VERIFICATION OF THE DANISH 1990, 2000 AND 2010 EMISSION INVENTORY DATA

Scientific Report from DCE – Danish Centre for Environment and Energy No. 79 2013

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Data sheet

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Abstract: Danish emission values, implied emission factors and activity data for the national greenhouse gas inventory are assessed according to an updated verification procedure. Focus is on 25 identified key categories, represented by 29 verification categories, and 28 Annex II indicators covering energy, agriculture, industry and waste. The data are based on the national greenhouse gas inventories for the years 1990 (base year), 2000 and 2010, as reported in 2012, and provided by the UNFCCC and EU. Inter-country comparison and time series consistency check of emissions and implied emission factors is made for EU15 countries, excluding Luxemburg and including Norway and Switzerland and for some verification steps also including Australia, Canada, Japan, Russian Federation, USA and aggregated values for EU15 and EU27. National and inter-country verification and time trend consistency check of activity data is made with data for energy consumption (Eurostat), agricultural statistics (Eurostat), industrial processes (UN) and waste disposal (OECD). Verification in this approach is a combination of qualitative and quantitative assessments and can assist to identify sectors and categories that require more attention and thus facilitates the prioritisation of efforts that are required to obtain more accurate and reliable emission inventories in the future.

Keywords:	Emission inventory, UNFCCC, EU, greenhouse gases, verification procedure, IPCC, key category, indicators, activity data, implied emission factors, international comparison.
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Contents

Preface

The Danish emissions of greenhouse gases (GHG) are reported annually by DCE - the Danish Centre for Environment and Energy at Aarhus University (AU) on behalf of the Danish Ministry of Environment. DCE is responsible for the annual preparation and submission to the United Nations Framework Convention on Climate Change (UNFCCC) (and the European Union (EU)) of the National Inventory Report (NIR) and the GHG inventories in the Common Reporting Format (CRF) in accordance with the UNFCCC Guidelines. DCE is also the designated entity with the overall responsibility for the national inventory under the Kyoto Protocol (KP). The work concerning the annual greenhouse gas emission inventory is carried out at DCE in co-operation with other Danish ministries, research institutes, organisations and companies. The yearly emission inventory submissions includes trends in greenhouse gas emissions, description of each Intergovernmental Panel on Climate Change (IPCC) category, uncertainty estimates, explanations on recalculations, planned improvements and procedure for quality assurance and control.

Information on the emission inventory and the NIR and the CRF tables are available to the public at the website of the Department of Environmental Science (ENVS), Aarhus University (AU):

http://envs.au.dk/en/knowledge/air/emission-inventories/emissioninventory/

The greenhouse gases reported under the UNFCCC are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

By signature of the KP several countries are committed to limit their GHG emissions. Both high quality emission estimates are at the core of the UNFCCC process and also quality *improvements* are an essential part of the review process under KP. In this sense, verification activities help establish the reliability of the GHG inventory and may help to point to potential quality improvements in specific sectors/categories. It is mandatory for the success of the KP and its implementation mechanisms (e.g. emission trading) that the countries report high quality data. In this context the Danish NIR submission includes routines for quality control and by this report a procedure for verification will be added. As a part of the report "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" issued by the Intergovernmental Panel on Climate Change (IPCC, 2000) different methods of verification of emission estimates are introduced.

The verification is for 1990, 2000 and 2010 emissions reported in 2012 and includes only Denmark omitting Greenland and the Faroe Islands. Furthermore the sectors are included based on Tier 1 key category analysis.

This report represents the Danish contribution to the work on verification of emission estimates. The aim has been to suggest methodologies for testing verification priorities within each main sector and/or sub-category for optimal national level and inter-country comparability. On a national level emission inventory data are compared with independent data for some sectors and a selection of statistical data are suggested to use as indicators for comparing emission levels between countries, and for evaluating time trends between countries and on a national scale.

The work in this report has been performed by the team of Danish emission experts from the Department of Environmental Science/DCE, Aarhus University with contribution from external reviewer Ricardo Fernandez, European Environment Agency (EEA).

Summary

The verification report covers 1990, 2000 and 2010 emissions, reported in 2012, for 25 Danish key categories that have been identified from a Tier 1 analysis for total emitted amounts and trend assessment. Key categories comprise 14 energy, eight agriculture, two industry and one waste category. The 25 key categories cannot be directly derived from the Common Reporting Format (CRF) tables, therefore they are represented by 29 verification categories. See Table 2.1 and 2.2 for description of key categories and verification categories. Furthermore the seven priority, six additional and 15 supplementary Annex II indicators and results from the reference approach are covered.

Inter-country comparison is made for EU15 countries, Norway and Switzerland and for some verification steps also including Australia, Canada, Japan, the Russian Federation and the United States of America. Aggregated values for EU15 and EU27, respectively, are also included for some verification steps. The verification procedure comprises the following steps:

1) Inter-country comparison of 28 Annex II indicators covering energy and industry.

Verification criteria: Consistency in time trends, comparability between countries.

2) Inter-country comparison of implied emission factors (IEFs) for 29 verification categories.

Verification criteria: Consistency in time trends of Danish United Nations Framework Convention on Climate Change (UNFCCC) implied emission factors, comparability between countries.

3) National and inter-country comparison of activity data (AD) reported to the European Union (EU) and Eurostat (2013) for energy sector and agricultural sector, comparison of UNFCCC and United Nations (UN) (2013) activity data for industrial processes and comparison of UNFCCC and Organisation for Economic Co-operation and Development (OECD) (1997 and 2004) data for waste.

Verification criteria: Consistency in time trends of Danish EU and UNFCCC activity data, comparability with other activity data.

4) National verification with reference approach for energy sector.

Verification criteria: Comparability between national approach and reference approach.

In Table S.1 the results from verification of the 28 Annex II indicators are summarised. In Table S.2 and S.3 the results from verification of IEF and AD for the 29 verification categories, are summarised. For each indicator and verification category the verification criteria are stated.

Table S.1 Results of verification of Annex II indicators. P1 to P7 are priority, A1 to A6 are additional priority and S1 to S15 are supplementary indicators. Consistency in time trend for Denmark is expressed as %-change, decrease (-) or increase (+), from 1990 to 2000 and 2000 to 2010, respectively. Time series; "decrease" is defined as two consecutive decreases <-5%, "increase" as two consecutive increases >+5% and "constant" as two consecutive (absolute value of) changes <5%. A comparable country is when the mean deviation of indicators between Denmark and the country, for the years with available data, is below 10 %. Indicators for EU15, excluding Italy and Luxembourg, are used.

Indicator id	Nomenclature in Eurostat energy efficiency indicators	Indicator/description	Verification criteria	
			Consistency in indicator time trend	Comparable (level) countries
P1	MACRO	Total CO_2 intensity of GDP, t/M Euro	Decrease (-21%, -14%)	Austria, France
P2	MACRO B0	Energy related CO_2 intensity of GDP, t/M Euro	Decrease (-22%, -12%)	France
P3	TRANSPORT C0	CO_2 emissions from passenger cars, kt/Mkm	Constant (-4%, -3%)	France, Finland, Portugal, Spain, Sweden, UK
P4	INDUSTRY A1	Energy related CO_2 intensity of industry, t/M Euro	Decrease (-5%, -22%)	
P5	HOUSEHOLDS A1	Specific CO_2 emissions of households, t/dwelling	Decrease (-24%, -30%)	
P6	SERVICES A0	CO_2 intensity of the commercial and institutional sector, t/M Euro	No trend (-48%, -1%)	Greece
P7	TRANSFORMATION B0	Specific CO_2 emissions of public and auto-producer power plants, t/TJ	Decrease (-31%, -19%)	Netherlands
A1	TRANSPORT D0	CO_2 emissions from freight transport on road, kt /Mtkm	No trend (-6%, +3%)	
A2	INDUSTRY A1.1	Total CO_2 intensity - iron and steel industry, t/M Euro	Decrease (-7%, -23%)	
A3	INDUSTRY A1.2	Energy related CO_2 intensity - chemical industry, t/M Euro	Decrease (-53%, -67%)	
A4	INDUSTRY A1.3	Energy related CO_2 intensity - glass, pottery and building materials industry, t/M Euro	Increase (+17%, +35%)	
A5	INDUSTRY C0.1	Specific CO_2 emissions of iron and steel industry, t/t	No trend (+8%, -)	
A6	INDUSTRY C0.2	Specific energy related CO_2 emissions of cement industry, t/t	No trend (-17%, +14%)	Netherlands, Sweden
S1	TRANSPORT B0	Specific diesel related CO_2 emissions of passenger cars, g/100km	No trend (+5%, -8%)	Austria, Germany, Spain, Sweden, UK
S2	TRANSPORT B0	Specific petrol related CO_2 emissions of passenger cars, g/100km	Constant (-4%, +1%)	Greece, Netherlands, Portugal, Sweden, UK
S3	TRANSPORT C0	Specific CO_2 emissions of passenger cars, t/pkm	No trend (+6%, +2%)	Greece, Sweden
S4	TRANSPORT E1	Specific air-transport emissions, t/passenger	Decrease (-20%, -16%)	
S5	INDUSTRY A1.4	Energy related CO_2 intensity - food, drink and tobacco industry, t/M Euro	Decrease (-14%, -6%)	Belgium, Portugal
S6	INDUSTRY A1.5	Energy related CO_2 intensity - paper and printing industry, t/M Euro	No trend (-63%, +19%)	
S7	HOUSEHOLDS A0	Specific CO_2 emissions of households for space heating, t/m²	Decrease (-26%, -25%)	
S8	SERVICES B0	Specific CO_2 emissions of commercial and institutional sector for space heating, kg/m²	Decrease (-47%, -6%)	
S9	TRANSFORMATION D0	Specific CO_2 emissions of public power plants, t/TJ	Decrease (-28%, -16%)	Ireland

Continued				
S10	TRANSFORMATION E0	Specific CO_2 emissions of auto-producer plants, t/TJ	Decrease (-48%, -44%)	
S11	TRANSFORMATION	Carbon intensity of total power generation, t/TJ	Decrease (-35%, -23%)	
S12	TRANSPORT	Carbon intensity of transport, t/TJ	Constant (-0.4%, -0.5%)	Finland, France, Greece, Portugal, Spain, Sweden
S13	INDUSTRY C0.3	Specific energy related CO_2 emissions of paper industry, t/t	No trend (-, -)	
S14	INDUSTRY	CO_2 emissions related to total final energy consumption in the industry sector (kt/PJ)	No trend (+2%, -11%)	France, Germany, Greece, Spain
S15	HOUSEHOLDS	CO_2 emissions related to total energy consumption from households (kt/PJ)	Decrease (-23%, -36%)	

- = Missing data.

Table S.2 Results of verification of Implied Emission Factors (IEF) for 29 verification categories. In Table 2.1 and 2.2 the verification categories are explained. Consistency in time trend for Danish IEFs is expressed as %-change, decrease (-) or increase (+), from 1990 to 2000 and 2000 to 2010, respectively. Time series; "decrease" is defined as two consecutive decreases <-5%, "increase" as two consecutive increases >+5% and "constant" as two consecutive (absolute value of) changes <5%. A comparable country is when the mean deviation of IEF, between Denmark and the country, for the three years, is below 10 %. IEFs for EU15 countries (excluding Luxemburg), Norway, Switzerland, Australia, Canada, Japan, Russian Federation, USA and aggregated values for EU15 and EU27, are used.

	Verification criteria	
Verification category id	Consistency in Danish IEF time trend 1990 – 2000 & 2000 – 2010	Comparable (level) countries
1.A-liquid	Constant (0.7 %, -0.8 %)	All countries *except* USA
1.A-solid	Constant (0, -0.4 %)	Australia, Austria, Belgium, Canada, EU27, Finland, Ireland, Italy, Japan, Norway, Portugal, Spain, Switzerland, UK, USA
1.A-gaseous	Constant (+0.3 %, -0.6 %)	Austria, Belgium, Canada, EU15, EU27, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Russia, Spain, Sweden, Switzerland, UK
1.A-other	Constant (-0.2 %, 0.3 %)	Canada, EU15, EU27, France, Germany
1.A1.a-liquid	Constant (+3 %, -3 %)	All countries *except* Netherlands
1.A1.a-solid	Constant (0, -0.4 %)	Australia, Austria, Canada, EU15, EU27, Finland, Ireland, Italy, Japan, Norway, Portugal, Russia, Spain, UK, USA
1.A1.b-liquid	Constant (-0.2 %, -2 %)	Japan, Sweden, Switzerland
1.A1.c-gaseous	Constant (0, -0.3 %)	Austria, Canada, Germany, Greece, Italy, Netherlands, Norway, Spain
1.A3.b-gasoline	Constant (0, -0.5 %)	All countries e*xcept* Canada
1.A3.c-liquid	Constant (0, 0)	All countries
1.A3.d-residual oil	Constant (0, 0)	Australia, Canada, EU15, EU27, Finland, France, Greece, Italy, Norway, Portugal, Russia, Spain, Sweden, UK, USA
1.A4.b-liquid	Constant (-0.3 %, -0.3 %)	Austria, Belgium, Canada, EU15, EU27, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, UK
1.A4.c-liquid	Constant (-0.5 %, +0.2 %)	All countries *except* USA
2.A1	Decrease (-10 %, -9 %)	All countries *except* EU15, EU27, Finland, Japan, UK
4.A-cattle	Increase (+1 %, +18 %)	Austria, Canada, EU15, EU27, France, Germany, Greece, Italy, Netherlands, Norway, Portugal, Russia, Spain, Switzerland, USA
4.A-sheep	Constant (+3 %, -0.1 %)	Norway
4.A-swine	Constant (+2 %, -5 %)	Germany, Ireland, Japan
4.B-cattle	Increase (+32 %, +24 %)	
4.B-swine	Constant (+5%, -1 %)	Norway
4.B-liquid	Decrease (-9 %, -11 %)	France, Norway
4.B-solid	Constant (+0.2 %, +0.8 %)	Australia, Austria, Belgium, Canada, Greece, Ireland, Italy, Japan, Netherlands, Portugal, Russia, Spain, Sweden, Switzerland, UK
4.B-other	Increase (+17 %, +3 %)	
4.B-pasture	Constant (0, 0)	All countries *except* Australia, Japan, Netherlands, Spain, USA
4.D1.1	Constant (0, 0)	Austria, Belgium, EU15, EU27, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Switzerland
4.D1.2	Constant (0, 0)	Austria, Belgium, Canada, EU15, EU27, Finland, France, Germany, Greece, Ireland, Italy, Norway, Portugal, Russia, Switzerland
4.D1.4	Constant (0, 0)	All countries *except* Canada, Netherlands, USA
4.D3-deposition	Constant (0, 0)	All countries *except* UK, USA
4.D3-leaching	No trend (+7 %, -4 %)	
6.A	No trend (+87 %, -2 %)	

Table S.3 Results of verification of Activity Data (AD) for 29 verification categories. In Table 2.1 and 2.2 the verification categories are explained. Consistency in time trend for Danish AD is expressed as %-change, decrease (-) or increase (+), from 1990 to 2000 and 2000 to 2010, respectively. Time series; "decrease" is defined as two consecutive decreases <-5%, "increase" as two consecutive increases >+5% and "constant" as two consecutive (absolute value of) changes <5%. The other data source and mean deviation between Danish AD and other data for the three (or two) years is shown. Data for EU15, excluding Luxembourg, are used.

	Verification criteria	
Verification category id	Consistency in Danish AD time trend 1990 – 2000 and 2000 - 2010	Other data source Deviation between reported AD and other data (%)
1.A-liquid	No trend (5%, -13%)	Eurostat (UBA, 2013) Deviation: 0.9 %
1.A-solid	Decrease (-35%, -2%)	Eurostat (UBA, 2013) Deviation: 0.3 %
1.A-gaseous	No trend (+145%, +0.3%)	Eurostat (UBA, 2013) Deviation: 0.3 %
1.A-other	Increase (97%, 25%)	Eurostat (UBA, 2013) Deviation: 0.3 %
1.A1.a-liquid	No trend (+178%, -71%)	Eurostat (UBA, 2013) Deviation: 3 %
1.A1.a-solid	No trend (-35%, +3%)	Eurostat (UBA, 2013) Deviation: 0.1 %
1.A1.b-liquid	No trend (+10%, -13%)	Eurostat (UBA, 2013) Deviation: 14 %
1.A1.c-gaseous	No trend (167%, 3%)	Eurostat (UBA, 2013) Deviation: 0.4 %
1.A3.b-gasoline	Increase (+21%, +9)	Eurostat (UBA, 2013) Deviation: 4 %
1.A3.c-liquid	No trend (-23%, +6%)	Eurostat (UBA, 2013) Deviation: 0.6 %
1.A3.d-residual oil	No trend (-69%, +86%)	Eurostat (UBA, 2013) Deviation: 115 %
1.A4.b-liquid	Decrease (-38%, -45%)	Eurostat (UBA, 2013) Deviation: 9 %
1.A4.c-liquid	Constant (-5%, 0)	Eurostat (UBA, 2013) Deviation: 21 %
2.A1	No trend (+74%, -7%)	UN Statistical Yearbook: Cement production Deviation: 10 %
4.A-cattle	Decrease (-17%, -16%)	Eurostat: Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations Deviation: 2 %
4.A-sheep	No trend (+21%, -)	Eurostat: Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations Deviation: 11 %
4.A-swine	Increase (+26%, +11%)	Eurostat: Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations Deviation: 5 %
4.B-cattle	AD dependent on number of animals, which is included in 4.A-cattle	
4.B-swine	AD dependent on number of animals, which is included in 4.A-swine	
4.B-liquid	AD dependent on number of animals, which is included elsewhere	
4.B-solid	AD dependent on number of animals, which is included elsewhere	
4.B-other	AD dependent on number of animals, which is included elsewhere	

Continued		
4.B-pasture	AD dependent on number of animals, which is included elsewhere	
4.D1.1	Decrease (-37%, -25%)	Eurostat: Consumption estimate of manufactured fertilizers (Fertilizers Europe) Deviation: 1 %
4.D1.2	AD dependent on number of animals, which is included elsewhere	
4.D1.4		No independent comparable data
4.D3-deposition		No independent comparable data
4.D3-leaching		No independent comparable data
6.A	Decrease (-34%, -54%)	OECD Environmental Data: Disposal of municipal waste on landfills. Deviation: 73 %

- = Missing data.

For the 28 Annex II indicators and 29 verification categories there are three verification criteria; Consistency in time trends gives an indication of robustness and consistency in methodologies and data. Comparability between countries indicates accuracy and reliability in methods and data, and comparability with other (independent) data ensures accuracy in data.

Overall these criteria give lines of evidences that the inventory method and the associated data fulfil the demand for accuracy, reliability and transparency. However, specific conditions may prevail in activity data, e.g. variations in used fuel amount or industrial production, that give dips and jumps in calculated emissions, which challenges a direct time trend consistency check. In such cases it is important to investigate the reason for these anomalies and also an assessment of other (independent) data is important.

For Annex II indicators decrease is the predominant time trend for Denmark, i.e. for 15 indicators representing energy, industry, transport, households and services, cf. Table S.1. This suggests that the politically initiated change of applied fuels, the increasing power production based on wind and the increased energy efficiency in both production and consumption is reflected in the indicators. In general, the indicators for Denmark are not outliers. The inter-country comparison does not reveal consistently comparable countries. However, there is a tendency for the Danish indicators to be comparable with France, Greece, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

For 22 verification categories the IEFs show constant time series indicating consistent IEFs from 1990 to 2010, cf. Table S.2. This implies robustness in methodology and underlying data. Comparability of IEF between countries is found for energy, transport and industry (cement production). Most of the IEFs for the agricultural categories are comparable with other countries. A few categories, such as 4.A-sheep, 4.B-liquid, 4.B-other and 4.D3-leaching differ from other countries and the differences are identified and explained. In many countries the cattle and swine production are key sources and therefore due to the IPCC guidelines require use of national data, which leads to a larger variation of the IEF values. The Danish IEFs for cattle and swine are in line with other countries that have comparable agricultural conditions. IEF for solid waste disposal on land is not comparable between countries due to the fact that emissions arise as a result of decay of organic material in the deposited waste over time. This means that an IEF based on the emission in a given year and the amount of waste deposited in that year

will not be representative since the emission only to a very small degree is dependent on the amount of waste landfilled in the given year.

Activity data for verification categories generally reveal no time trend in the period 1990 to 2010, cf. Table S.3.

The energy sector has undergone large changes since 1990 including a politically initiated change of fuels towards fuels with less CO_2 emission, increased wind power production, liberalised electricity market and the construction of a natural gas grid. Electricity import/export cause fluctuations for fuel consumption in Danish power plants and thus fluctuations of the national CO_2 emission. A comparison of activity data from IEA energy statistics supplied to Eurostat (2013) and CRF data reported to EU, performed by Umweltbundesamt Gmbh (UBA, 2013) for the energy sector, shows good agreement with deviations 0.1-4 %. Exceptions are; petroleum refining (14 %), where Denmark includes combined heat and power plants in 1A1b and Eurostat does not include auto-producers under refineries, and residual oil use in navigation (115 %), where additional fuel consumption for sailing between Denmark and Greenland/Faroe Islands is not accounted for in the official Danish fuel statistics. Further exceptions are residential use of liquid fuels (9 %) and use of liquid fuels in agriculture/forestry/fisheries (21 %). The differences for liquid fuels applied in residential plants and plants in agriculture/forestry/fisheries are caused by reallocation of some liquid fuels in the Danish emission inventory. The Danish transport model represents better disaggregation data and part of the liquid fuel consumption is reallocated in the Danish inventory. The total consumption of liquid fuels has been verified with good agreement with deviations below 2 %. The data source for the IEA data is the international reporting from the Danish Energy Agency. The Danish Energy Agency also delivers data for the Danish emission inventory and thus data are not independent. However, the aggregation and data transfer differ and the verification with the IEA data will reveal errors in the data aggregation. For off-shore flaring no independent data are available.

For the agriculture sector activity data from Eurostat (2013) are used for verification, which yield high consistency and thus low deviations of 1-5 % and 11 % for number of cattle and sheep, respectively. No international independent data survey is available for crop residues, atmospheric deposition and nitrogen leaching.

Activity data for solid waste disposal on land is verified with OECD Environmental Data (OECD, 1997 and 2004): Disposal of municipal waste on landfills with a deviation of 73 %, which reflects the fraction of Municipal Solid Waste (MSW) in percentage of the total deposited waste; MSW being defined as "Municipal waste is waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities."(http://stats.oecd.org/).

Cement production is verified with UN Statistical Yearbook: Cement production with a deviation of 10 %. The deviation in cement production may be explained by a difference in activity data where the applied activity data

is "produced amount of clinker" whereas the activity in trade statistics probably is cement, and cement is milled clinker added, e.g. fly ash or other mineral compounds.

The sectoral approach for fuel combustion has been verified by the reference approach. The reference approach is based on data for fuel production, import, export and stock change whereas the sectoral approach is based on fuel consumption data. In 2010, the fuel consumption rates in the two approaches differ by 0.51 % and the CO_2 emission differs by 0.62 %. In the period 1990 to 2011, both the fuel consumption and the CO_2 emission differ by less than 2.0 %. The differences are below 1 % for all years except 1998 and 2009. According to IPCC Good Practice Guidance (IPCC, 2000) the difference should be within ±2 %.

In conclusion, the used verification procedure is appropriate for evaluating data consistency and accuracy. There are consistent time trends for Annex II indicators and for IEFs for verification categories identified based on the key category analysis. There is good agreement between reported and other activity data for verification categories for energy sectors and some agriculture sectors. Comparable countries can be identified for Annex II indicators and for verification categories comparability between countries is evident for energy and transport sectors.

It is a challenge to find suitable independent data, and in many cases the alternative datasets are to some extent based on the same raw data. However, these data can be used to some degree to assess the completeness and the correctness of the emission inventory. In situations when national data vary from EU mean values ± uncertainties it is often more correct to use national data instead of default values, as they represent specific national conditions.

The reasons for comparability and consistency are sometimes apparent, and in other cases identification of the underlying factors requires a more in-depth analysis. It is important to underline that a comparison between countries only considers consistency compared to how and what other countries report. It is not a verification of the scientific value of the inventory data themselves (Holtskog et al., 2000). When comparing Annex II indicators between countries it is important not to over-interpret the results; indicators are good for explaining emission trends but less so for establishing the reliability of the GHG inventory. Especially for the agricultural sector it is important to compare with countries that have comparable agricultural conditions. Comparability with countries with different conditions may show high deviations that do not necessarily indicate erroneous inventory data.

A quantitative verification of implied emission factors can furthermore be made when a measured or theoretical value of the carbon content in the respective fuel type (or other relevant parameter) is available. For the energy sector all countries are in principle comparable, and inter-country deviations arise from variations in fuel type applied in each of the fuel groups solid, liquid, gaseous or other fuels.

Verification in this approach is predominantly of qualitative nature. The terms "good agreement" and "poor agreement" are used for inter-country comparisons and time trends. Each source category has an in-herent uncertainty with respect to absolute values of e.g. quantification of CO_2 emissions and with respect to methodological approaches. Thus a "good agreement"

may be a relative statement for source categories with greatly different uncertainties. For agreement between reported data and other (independent) data, the verification is quantitative and is reported as a percentage deviation. The evaluations of agreement are based on these deviations.

An important outcome of a verification procedure is to support identification of sectors and categories that require more attention and thus a prioritisation of resources that are required to obtain more accurate and reliable emission inventories in the future.

Sammenfatning

Verifikationen dækker 2012-rapporteringen af 1990-, 2000- og 2010-emissionerne for 25 danske key-categories, fundet ved Tier 1-beregning af totale emitterede mængder og emissions trend-analyse. Key-categories består af 14 energi-, 8 landbrugs-, 2 industri- og 1 affaldskategori. De 25 key-categories kan ikke udtrækkes direkte fra Common Reporting Format(CRF)-tabellerne og er derfor repræsenteret ved 29 verifikationskategorier. Se tabel 2.1 og 2.2 for beskrivelse af key-categories og verifikationskategorier. Desuden dækker verifikationsprocessen syv priority, seks additional og 15 supplemental Annex II indikatorer, samt resultatet af referencemetoden.

Sammenligningen mellem lande er udført for EU15, Norge og Schweiz. For nogle verifikationstrin er også Australien, Canada, Japan, Rusland og USA inkluderet. Aggregerede værdier for EU15 og EU27 er inkluderet for nogle verifikationstrin. Verifikationsproceduren består af følgende trin:

1) Sammenligning mellem landes 28 Annex II-indikatorer, der dækker energi og industri.

Verifikationskriterier: Tidstrendkonsistens og sammenlignelighed mellem lande.

2) Sammenligning mellem lande af Implied Emission Factors (IEF) for 29 verifikationskategorier.

Verifikationskriterier: Tidstrend konsistens af danske UNFCCC (FN's konvention om klimaforandringer) IEF'ere og sammenlignelighed mellem lande.

3) Sammenligning nationalt og mellem lande af aktivitetsdata rapporteret til den Europæiske Union (EU) og Eurostat (2013) for energi- og landbrugssektor, sammenligning af UNFCCC og De Forenede Nationers (FN) (2013) aktivitetsdata for industrielle processer og sammenligning af UNFCCC og Organisationen for økonomisk samarbejde og udviklings (OECD) (1997 and 2004) data for affald.

Verifikationskriterier: Tidstrend konsistens af danske EU og UNFCCC aktivitetsdata og sammenlignelighed med andre aktivitetsdata.

4) National verifikation med referencemetoden for energisektor.

Verifikationskriterier: Sammenlignelighed mellem national metode og referencemetoden.

I Tabel S.1 (i Summary) er resultaterne fra verifikation af de 28 Annex II indikatorer summeret. I Tabel S.2 og S.3 (i Summary) er resultaterne for verifikation af IEF og aktivitetsdata for de 29 verifikationskategorier summeret. For hver indikator og verifikationskategori er verifikationskriterierne anført.

For de 28 Annex II-indikatorer og 29 verifikationskategorier er der tre verifikationskriterier; tidstrendkonsistens giver en indikation af robusthed og konsistens af metoder og data. Sammenlignelighed mellem lande indikerer

korrekthed og pålidelighed af metoder og data, og sammenlignelighed med andre (uafhængige) data sikrer korrekthed af data.

Samlet sandsynliggør disse kriterier at opgørelsesmetoden og de tilhørende data opfylder kravet om korrekthed, pålidelighed og gennemskuelighed. Imidlertid kan der være nogle omstændigheder vedrørende aktivitetsdata, f.eks. variationer i anvendt brændselsmængde eller industriel produktion, som giver udsving i beregnede emissioner, hvilket kan forhindre en direkte tidstrend analyse. I disse tilfælde, er det vigtigt at undersøge årsagen til udsvingene og samtidig er en vurdering af andre (uafhængige) data vigtig.

For Annex II-indikatorerne er et fald den mest forekommende tidstrend for Danmark; det ses for 15 indikatorer der repræsenterer henholdsvis energi, industri, transport, husholdninger og offentlig/privat service, se tabel S.1. Det viser, at de politisk initierede ændringer i brændselstyper, stigende vindbaseret elproduktion og øget energieffektivitet i både produktion og forbrug synes at være afspejlet i indikatorerne. Generelt er de danske indikatorværdier ikke outliers. Sammenligningen mellem landene indikerer ikke lande som Danmark er gennemgående sammenlignelige med. Der er dog en tendens til sammenlignelighed med Frankrig, Grækenland, Holland, Portugal, Spanien, Sverige og Storbritannien og Nordirland.

For de 22 verifikationskategorier viser IEF konstant tidstrend i perioden 1990 til 2010, se tabel S.2, hvilket antyder robuste metoder og underliggende data. Sammenlignelighed af IEF mellem landene forekommer for energi, transport og industri (cementproduktion). Sammenligningen af IEF for landbrug adskiller sig ikke væsentligt fra de øvrige lande. De største forskelle ses for landbrugskategorierne: CH_4 fra fordøjelse hos får, N_2O fra gyllebaserede staldsystemer, CH_4 fra gødningshåndtering fra dyrekategorien "øvrig" samt N_2O fra udvaskning. Forklaringen på forskellene er beskrevet i rapporten. Produktion af kvæg og svin er key-categories i mange lande og skal ifølge FN's klimapanels (IPCC) gudelines derfor anvende nationale data, hvilket betyder store variationer i IEF. De danske IEF'ere for kvæg og svin matcher fint andre lande som f.eks. Tyskland, Sverige og Holland, hvor de landbrugsmæssige produktionsforhold er sammenlignelige med danske.

IEF for deponier er ikke sammenlignelig med andre lande pga. at emissionerne skyldes nedbrydning af organisk materiale i deponeret affald over tid. Det betyder, at en IEF-baseret på emissionen i et givent år og mængden af affald deponeret samme år, ikke vil være repræsentativ, da emissionen kun i mindre grad er afhængig af mængde af affald deponeret det pågældende år.

Aktivitetsdata for verifikationskategorierne viser ikke nogen konsistent tidstrend i perioden 1990 til 2010, se tabel S.3.

Der er sket store ændringer i energisektoren siden 1990, med blandt andet politisk initierede ændringer i brændselstyper mod mindre CO_2-emissioner, øget mængde vindkraft, liberaliseret el-marked og udbygning af naturgas nettet. Import/eksport af el giver udsving i brændselsforbruget i danske kraftværker og således fluktuationer i de nationale CO_2-emissioner. En sammenligning af aktivitetsdata fra IEA-energistatistik rapporteret til Eurostat (2013) og CRF-data rapporteret til EU, udført af Umweltbundesamt Gmbh (UBA, 2013) for energisektoren, giver god overensstemmelse med afvigelser på 0.1-4 %. Undtagelser er raffinaderier (14 %), hvor Danmark inkluderer kraftvarmeproduktion i 1A1b, mens Eurostat ikke inkluderer den-

ne produktion under raffinaderier, samt anvendelse af fuelolie i søfart (115 %), hvor brændselsforbrug for sejlads mellem Danmark og Grønland/-Færøerne ikke er medregnet i den officielle danske energistatistik. Yderligere undtagelser er husholdningers anvendelse af flydende brændsel (9 %) og anvendelse af flydende brændsel i landbrug/skovbrug/fiskeri (21 %). Forskellene mht. flydende brændsel i husholdninger og anlæg i landbrug/skovbrug/fiskeri skyldes reallokering af nogle flydende brændsler i den danske emissionsopgørelse. Den danske transportmodel repræsenterer bedre disaggregerede data og en del af det flydende brændsel er re-allokeret i den danske opgørelse. Den totale anvendelse af flydende brændstof er verificeret med afvigelser på mindre end 2 %. Datakilden for IEA er den internationale rapportering fra Energistyrelsen. Energistyrelsen leverer også data til den danske emissionsopgørelse og derfor er der en vis afhængighed i data. Dataaggregering og -behandling er dog forskellig, og verifikationsprocessen vil derfor afsløre fejl i den samlede databehandling.

I landbrugssektoren er aktivitetsdata fra Eurostat (2013) anvendt til verifikation og viser god overensstemmelse med lave afvigelser på 1–6 % for kvæg og svin samt lidt større afvigelse for får på 11 %. Der findes ingen uafhængige internationale data tilgængelige for afgrøderester, atmosfærisk deposition og udvaskning af kvælstof.

Aktivitetsdata for deponier er verificeret med OECD Environmental Data (OECD, 1997 & 2004): *Disposal of municipal waste on landfills*, med en afvigelse på 73 %. Denne afvigelse afspejler fraktionen af husholdningsaffald (Municipal Solid Waste, MSW) i procent af den samlede mængde deponeret affald; hvor kommunalt husholdningsaffald (MSW) er defineret som "Affald der er indsamlet og behandlet af eller for kommunerne. Det dækker affald fra husholdninger, inklusive storskrald, lignende affald fra handel, kontorbygninger, institutioner og små virksomheder, parker og haver, opfejning fra veje samt indhold fra affaldsspande. Definitionen ekskluderer affald fra kommunale rensningsanlæg og affald fra konstruktion og nedrivning." (http://stats.oecd.org/).

Cementproduktion er verificeret med FN's statistiske årsbog: *Cement production* (UN, 2013) med en afvigelse på 10 %. Afvigelsen kan forklares med en forskel i aktivitetsdata, hvor de anvendte aktivitetsdata i den danske opgørelse er producerede mængde klinker, hvorimod aktivitetsdata fra handelsstatistikken sandsynligvis er cement, hvor cement er formalede klinker tilføjet f.eks. gips, flyveakse eller andre mineralske stoffer.

Sektormetoden for forbrug af brændsler er verificeret med referencemetoden. Referencemetoden er baseret på data for brændselsproduktion, import, eksport og ændringer i lager, hvor sektormetoden er baseret på brændselsforbrug. I 2010 er der en forskel i brændselsforbrug beregnet med de to metoder på 0.51 % og en forskel på 0.62 % i CO_2-emissionerne. I perioden fra 1990 til 2011 er der en forskel i brændselsforbrug og CO_2-emissioner på under 2 %. Forskellene er under 1 % for alle år - undtagen for 1998 og 2009. Ifølge IPCC Good Practice Guidance (IPCC, 2000) bør forskellen være indenfor ±2 %.

Som konklusion er den anvendte verifikationsprocedure egnet til at evaluere datakonsistens og korrekthed. Der er konsistente tidstrends for Annex II-indikatorer og for IEF for verifikationskategorierne, der er identificeret ved key category-analysen. Der er god overensstemmelse mellem rapporterede

og andre aktivitetsdata for verifikationskategorier for energisektoren og nogle landbrugssektorer. Der er sammenlignelige lande for Annex II-indikatorerne, og for verifikationskategorierne er der sammenlignelighed mellem lande for energi- og transportsektorerne.

Det er en udfordring at finde egnede uafhængige data, og i mange tilfælde er alternative data i nogen grad baseret på samme rådata. Disse alternative data kan dog anvendes til at vurdere datahåndtering og dermed komplethed og korrekthed af emissionsopgørelsen. I tilfælde hvor nationale data afviger fra EU-middelværdier ±usikkerheder, kan det være mere korrekt at anvende nationale data i stedet for defaultværdier, da de repræsenterer specifikke nationale forhold.

Baggrunden for sammenlignelighed og konsistens er i nogle tilfælde åbenlyse; i andre tilfælde kræver en identifikation af underliggende faktorer et mere indgående studie. Det er vigtigt at understrege, at en sammenligning mellem lande kun forholder sig til konsistens mht. hvor og hvad andre lande rapporterer. Det er ikke en verifikation af den specifikke værdi af en parameter (Holtskog et al., 2000). Specielt for landbrugssektoren er det vigtigt at sammenligne med lande der har sammenlignelige landbrugsforhold. Sammenligning med lande med afvigende forhold kan give høje afvigelser, der ikke nødvendigvis indikerer fejlagtige data.

En kvantitativ verifikation af IEF kan yderligere foretages, når målte eller teoretiske værdier af kulstofindholdet i det pågældende brændsel (eller en anden relevant parameter) er tilgængelig. For energisektoren er alle lande i princippet sammenlignelige, og en forskel mellem lande opstår fra variationer i brændselstype i grupperne fast, flydende, gas og anden brændsel.

Verifikationen i den anvendte tilgang er hovedsagelig kvalitativ. Benævnelserne ″good agreement″ og ″poor agreement″ er anvendt for sammenligning mellem lande og tidstrends. Hver kategori har iboende usikkerheder mht. absolut værdi af f.eks. beregning af CO_2-emissioner og beregningsmetoder. ″Good agreement″ kan derfor være et relativt udsagn for kategorier med store forskelle i usikkerheder. For overensstemmelse mellem rapporterede aktivitetsdata og andre (uafhængige) data er verifikationen kvantitativ og er rapporteret som procentafvigelse. Overensstemmelse er vurderet ud fra denne afvigelse.

Et vigtigt resultat af en verifikationsprocedure er at støtte identifikationen af sektorer og kategorier, der kræver større opmærksomhed og hermed at prioritere ressourcer, der kræves for at opnå mere korrekte og pålidelige emissionsopgørelser i fremtiden.

1 Introduction

This report covers the international and to some extent the national verification of the Danish greenhouse gas inventory. The national verification is inherent in the process of inventory preparation, and quality assurance/quality control (QA/QC) process (Nielsen et al., 2013). For each of the sectors: energy, industrial processes, agriculture and waste, verification is performed for key categories identified within the Danish inventory. The verification is founded on the principles outlined in the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). It is performed for single years as well as for time trends.

In principle each of the three following parameters must be verified for each key category; emission value, activity value and implied emission factor. This is done on a national scale by comparison with independent data and on an international scale by comparison with independent data and estimates from countries with similar source categories and sectors. The parameters are functionally related in the following way:

emission value = activity value * implied emission factor

The parameters are derived from methodologies that can be more or less complex and associated with simplifications and assumptions. So verification may include methodological as well as parametric aspects. For example implied emission factors for CO_2 related to coal combustion can be compared with empirical or theoretical CO_2 content per energy unit. Error in emission values may thus occur from parametric error in implied emission factors or activity values or from error in the methodological approach used for deriving them. Accordingly since implied emission factors are ratios of emission to activity, comparisons based on implied emission factors should verify all three parameters.

Another way is to compare emission density indicators, e.g. Annex II indicators, between countries, where the emission value is divided with a chosen denominator such as population, number of cars, energy use etc. This is a quick indirect check and verification of the order of magnitude of the emissions. The correlation between emissions and an independent parameter does not necessarily imply cause and effect, but it is an easy means to flag certain anomalies at country or sector level. The most appropriate indicator is one which directly is associated with the emission value. As an example the CO_2 emission in the fuel combustion sector will be directly associated with fossil fuel use in the energy sector. However, when evaluating the comparisons, it should be remembered that various data sources are not always completely independent of each other. In Denmark energy use is reported by the Danish Energy Agency, and the CO_2 emission from fuel combustion is reported by DCE based on figures from the Danish Energy Agency. In other countries there may not be such a link. An international comparison can therefore be made on the order of magnitude of emissions and also evaluate the methodological approach in finding the emission value.

Comparisons do not always represent verifications of the data themselves, but allows for a verification of the reliability and the consistency of data with respect to methodologies and trends.

2 Verification parameters (key categories)

A key category analysis is performed according to the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 1997 and 2000) as a part of the Danish annual NIR.

Six main sectors exist which are listed below:

1. Energy
2. Industrial Processes
3. Solvent and Other Product Use
4. Agriculture
5. Land-Use Change and Forestry (LULUCF)
6. Waste

The level of total emissions and level of total trends has been assessed for the source categories within these sectors, excluding LULUCF. The identified key categories are included in the verification. The analysis corresponds to the standardised threshold procedure outlined in Rypdal and Flugsrud (2001). The ranking of the key categories in accordance to their contributions to the national total of greenhouse gases calculated in CO_2 equivalent units (Nielsen et al., 2012), and an extract of the top of the list, covering 95 % of the national total, is given in Table 2.1.

In some cases the aggregation level in the key category analysis differs from the aggregation level in the Common Reporting Format (CRF). E.g. CO_2 emission from gas oil applied in stationary combustion is a key category (KC). This aggregation level is good practice for the key category analysis due to the fact that this aggregation level, which is also applied for uncertainty estimates, has to be statistically independent. In order to cover the key categories in the verification process the entire key category has been included when identical with a CRF category, and otherwise the most important related sectors have been chosen. Id's have been assigned to these verification categories, and these are stated in the column to the left in Table 2.1 and explained further in Table 2.2. It is these verification category id's that are used for verification throughout the report.

Table 2.1 Danish key categories covering 95 % of the national total GHG emission and total trends. Key categories are identified by tier 1 approach for Danish 2010 figures, excluding the LULUCF sector. Key categories are listed in descending order according to level assessment. Id's for source categories that will be applied for verification (verification categories) are stated in the left column.

Verification category id	IPCC key category		Gas	Level assessment, %	Level cumulative total, %	Trend assessment, %	Trend cumulative total, %
1.A-solid 1.A1.a-solid	Energy	Stationary Combustion, Coal	CO_2	25	25	21	44
1.A3.b-gasoline	Energy	Transport, Road transport	CO_2	20	45	13	57
1.A-gas 1.A1.c-gaseous	Energy	Stationary Combustion, Natural Gas	CO_2	17	62	24	24
4.A-cattle 4.A-sheep 4.A-swine	Agriculture	Enteric Fermentation	CH_4	4.7	67	Not key	Not key
1.A-liquid 1.A1.a-liquid 1.A4.b-liquid 1.A4.c-liquid	Energy	Stationary Combustion, Gas Oil	CO_2	2.6	69	8.5	66
4.D3-leaching	Agriculture	Leaching	N_2O	2.3	72	2.6	83
1.A-other	Energy	Stationary Combustion, Fossil Waste	CO_2	2.3	74	3.1	80
4.B-cattle 4.B-swine	Agriculture	Manure Management	CH_4	2.1	76	1.4	88
1.A-liquid	Energy	Transport, Agriculture	CO_2	2.1	78	0.5	93
4.D1.2	Agriculture	Animal waste applied to soils	N_2O	1.9	80	0.6	92
4.D1.1	Agriculture	Synthetic Fertilizer	N_2O	1.9	82	3.4	74
1)	Energy	Transport, Industry (Mobile)	CO_2	1.7	84	1.0	91
1.A-liquid 1.A1.a-liquid	Energy	Stationary Combustion, Residual Oil	CO_2	1.4	85	4.5	70
1.A1.b-liquid	Energy	Stationary Combustion, Refinery gas	CO_2	1.3	86	0.3	95
2)	Industrial Processes	Consumption of HFC	HFC	1.3	88	2.1	85
6.A	Waste	Solid Waste Disposal on Land	CH_4	1.3	89	2.0	87
2.A1	Industrial Processes	Cement production	CO_2	1.1	90	0.4	95
1.A-liquid	Energy	Transport, Fisheries	CO_2	0.9	91	Not key	Not key
1.A-liquid 1.A3.d-residual oil	Energy	Transport, Navigation (large vessels)	CO_2	0.8	92	0.6	92
1.A-liquid	Energy	Stationary Combustion, Petroleum Coke	CO_2	0.8	93	0.4	94
4.B-liquid 4.B-solid 4.B-other 4.B-pasture	Agriculture	Manure Management	N_2O	0.7	93	0.4	94
3)	Energy	Flaring Off-shore	CO_2	0.5	94	Not key	Not key
4.D1.4	Agriculture	Crop Residue	N_2O	0.5	94	Not key	Not key
4.D3-deposition	Agriculture	Atmospheric Deposition	N_2O	0.5	95	0.4	93
1.A-liquid 1.A3.c-liquid	Energy	Transport, Railways, Oil	CO_2	0.4	95	Not key	Not key

1) Not included as other countries do not have data for this specific category at this differentiated level.

2) Many different compounds and uses, and due to data complexity the key category is not considered.

3) Not included due to differing and not specified units in implied emission factors and activity data.

Table 2.2 29 verification categories that cover the Danish key categories and are included in the verification procedure.

id	CRF category description			
1.A-liquid	1.A. Fuel combustion	Liquid Fuels		CO_2
1.A-solid	1.A. Fuel combustion	Solid Fuels		CO_2
1.A-gaseous	1.A. Fuel combustion	Gaseous Fuels		CO_2
1.A-other	1.A. Fuel combustion	Other Fuels		CO_2
1.A1.a-liquid	1.A.1. Energy Industries	a. Public Electricity and Heat Production	Liquid Fuels	CO_2
1.A1.a-solid	1.A.1. Energy Industries	a. Public Electricity and Heat Production	Solid Fuels	CO_2
1.A1.b-liquid	1.A.1. Energy Industries	b. Petroleum Refining	Liquid Fuels	CO_2
1.A1.c-gaseous	1.A.1. Energy Industries	c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	CO_2
1.A3.b-gasoline	1.A.3. Transport	b. Road Transportation	Gasoline and LPG	CO_2
1.A3.c-liquid	1.A.3. Transport	c. Railways	Liquid Fuels	CO_2
1.A3.d-residual oil	1.A.3. Transport	d. Navigation	Residual Oil (Residual Fuel Oil)	CO_2
1.A4.b-liquid	1.A.4. Other Sectors	b. Residential	Liquid Fuels	CO_2
1.A4.c-liquid	1.A.4. Other Sectors	c. Agriculture/Forestry/Fisheries	Liquid Fuels	CO_2
2.A1	Total Industrial Processes	A. Mineral Products	1. Cement Production	CO_2
4.A-cattle	Total Agriculture	A. Enteric Fermentation	Cattle	CH_4
4.A-sheep	Total Agriculture	A. Enteric Fermentation	Sheep	CH_4
4.A-swine	Total Agriculture	A. Enteric Fermentation	Swine	CH_4
4.B-cattle	Agriculture	CH_4 Emissions from Manure Management	1. Cattle	CH_4
4.B-swine	Agriculture	CH_4 Emissions from Manure Management	8. Swine	CH_4
4.B-liquid	Agriculture	N_2O Emissions from Manure Management	Liquid System	N_2O
4.B-solid	Agriculture	N_2O Emissions from Manure Management	Solid Storage and Dry Lot	N_2O
4.B-other	Agriculture	N_2O Emissions from Manure Management	Other	N_2O
4.B-pasture	Agricultural Soils	2. Pasture, Range and Paddock Manure		N_2O
4.D1.1	Agricultural Soils	1. Direct Soil Emissions	1. Synthetic Fertilizers	N_2O
4.D1.2	Agricultural Soils	1. Direct Soil Emissions	2. Animal Manure Applied To Soils	N_2O
4.D1.4	Agricultural Soils	1. Direct Soil Emissions	4. Crop Residue	N_2O
4.D3-deposition	Agricultural Soils	3. Indirect Emissions	1. Atmospheric Deposition	N_2O
4.D3-leaching	Agricultural Soils	3. Indirect Emissions	2. Nitrogen Leaching and Run-Off	N_2O
6.A	Solid Waste Disposal	1 Managed Waste Disposal on Land		CH_4

3 Verification procedure

The IPCC good practice guidance (IPCC, 2000) provides guidance on verification procedures stating 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. The comparison can be made for different greenhouse gases at national, sectoral, source category, and sub-source category levels. The verification techniques include internal quality checks, inventory intercomparison, comparison of intensity indicators, comparison with atmospheric concentrations, and source measurements and modelling studies.

Specifically, the following activities are described in IPCC (2000). Their implementation and application in the present Danish verification procedure are explained:

3.1 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 therefore there is no possibility to compare with independent national emission estimates.

3.2 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. No such comparison is referred to in this report.

3.3 Bottom-up, top-down comparisons

Checks are done annually as part of the mandatory reporting requirements for the comparison between the reference and sectoral approaches for CO_2 emissions from fuel combustion. The result is reported annually in the NIR and any major differences are investigated and explained. The results are presented in this report as "National verification with reference approach for energy sector".

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

An available global emission database is 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). Furthermore 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, comparisons with these databases 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 this activity has not been prioritized for the Danish verification activities.

3.5 Comparisons of activity data with independently compiled datasets

National and inter-country verification of activity data for 14 energy, 8 agriculture, 2 industry and 1 waste key category, represented by 29 verification categories, for 1990, 2000 and 2010 emissions, reported in 2012, is performed in this report.

Activity data reported in the CRF tables to the UNFCCC are compared with data for energy consumption reported to Eurostat (2013) for 2005 and 2010 data (UBA, 2013). The data for fuel consumption have been extracted from the Eurostat database and aggregated into solid fuels, liquid fuels, gaseous fuels and biomass to be comparable with the IPCC fuel categories. The extracted fuel consumption data are then compared to the data reported by Member States in the CRF tables. The comparison is available for both the reference approach and the sectoral approach. The comparison is being done annually in connection with the internal EU QC checks and circulated to the Member States for commenting. The comparison is carried out by the European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM) as part on the work on compiling the greenhouse gas emission inventory for the European Union.

Eurostat (2013) is also used for agricultural statistics for number of livestock and consumption of manufactured fertilizer, UN (2013) data are used for industrial processes and OECD (1997 and 2004) are used for solid waste disposal. Inter-country comparison is made for EU15 countries excluding Luxemburg and including Switzerland.

Verification criteria are consistency in time trends of Danish activity data, and comparability between Danish activity data and independent data.

Only small deviations are anticipated as the activity data used in the Danish inventory are based on the official statistics also reported to international organisations, e.g. IEA, Food and Agriculture Organization FAOstat (2013) and Eurostat (2013). The verification is accordingly mainly dealing with methodology in handling of the comprehensive data sets.

3.6 Comparisons of implied emission factors between countries

Inter-country comparison of implied emission factors for 14 energy, 8 agriculture, 2 industry and 1 waste key category, represented by 29 verification categories, for 1990, 2000 and 2010 emissions, reported in the CRF tables to the UNFCCC in 2012, is performed in this report.

The inter-country comparison is made for EU15 countries (excluding Luxemburg), Norway, Switzerland, Australia, Canada, Japan, Russian Federation, USA and aggregated values for EU15 and EU27, are used.

Verification criteria are consistency in time trends of Danish UNFCCC implied emission factors, and comparability between countries UNFCCC implied emission factors.

3.7 Comparisons based on estimated uncertainties

Compilation and comparison of uncertainties associated with specific emission factors for other countries has not been made in this report.

3.8 Comparisons of emission intensity indicators between countries

As a consequence of EU decisions no. 280/2004/EC and 2005/166/EC, the EU member states have been obligated since 2005 to annually report indicators to the Commission. The reporting is to occur in parallel with the obligations to report greenhouse gases according to the decisions mentioned.

The verification procedure comprises an inter-country comparison of these 28 Annex II Indicators covering energy and industry. Available reported indicator values for EU15 countries, excluding Italy and Luxembourg, are used for verification.

Verification criteria are consistency in time trends and comparability between countries.

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

IPCC (2000) 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 and high uncertainties.

Inverse modelling, to estimate emissions based on atmospheric measurements, was performed in a study by Manning (2007) where official reporting to the UNFCCC was compared with the emission results of inverse modelling. The comparison was made for the United Kingdom and for northwestern 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.

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

No comparisons have been made with global or regional emission budgets.

4 Energy

The UNFCCC reporting of emissions from the energy sector, according to the CRF format, covers the following categories:

- Energy industries:
  - Public electricity and heat production
  - Petroleum refining
  - Manufacture of solid fuels and other energy industries

- Manufacturing industries and construction:
  - Iron and steel
  - Non-ferrous metals
  - Chemicals
  - Pulp, paper and print
  - Food processing, beverages and tobacco
  - Other (oil drilling, construction, all other manufacture)

- Transport:
  - Civil aviation
  - Road transportation
  - Railways
  - Navigation
  - Other

- Other sectors:
  - Commercial/institutional
  - Residential
  - Agriculture/forestry/fishing

- Fugitive emissions from solid fuels:
  - Coal mining

- Fugitive emissions from oil and natural gas:
  - Oil
  - Natural gas.

Fuel use in the energy sector is a suitable indicator, as CO_2 emission is directly related to fuel combustion processes. For verification fuel use is obtained from Eurostat (2013) and compared to the reported, allowing for national calorific values for the respective fuels (UBA, 2013).

For each energy key subcategory the verification comprises:

- Inter-country comparison of UNFCCC implied emission factors and consistency in time trends of Danish UNFCCC implied emission factors. A comparable country is when the mean deviation of IEF, between Denmark and the country, for the three years, is below 10 %. IEF for EU15 countries (excluding Luxemburg), Norway, Switzerland, Australia, Canada, Japan, the Russian Federation, the United States of America and aggregated values for EU15 and EU27, are used. Results for IEF verification are summarised in Table S.2.

- National and inter-country comparison of CRF activity data reported to EU with fuel consumption data from Eurostat (UBA, 2013) and consistency in time trends of Danish EU activity data. In the analysis by UBA (2013) fuel consumption for the different countries is converted to TJ by using national calorific values for the respective fuels. Results for verification of activity data, i.e. including countries with a mean deviation between EU CRF and Eurostat activity data lower than 5 %, are stated in Table S.3.
- National verification with reference approach, see Chapter 8.
- Furthermore Annex II indicators are compared between countries and time trends are assessed, see Chapter 9.

Consistency in time trend for Danish EU and UNFCCC data is expressed as %-change, decrease (-) or increase (+), from 1990 to 2000 and 2000 to 2010, respectively. Time series; "decrease" is defined as two consecutive decreases <-5 %, "increase" as two consecutive increases >+5 % and "constant" as two consecutive (absolute value of) changes <5 %.

4.1 1.A-liquid

Verification category: CO_2 emissions from "1.A. Fuel Combustion – Liquid Fuels".

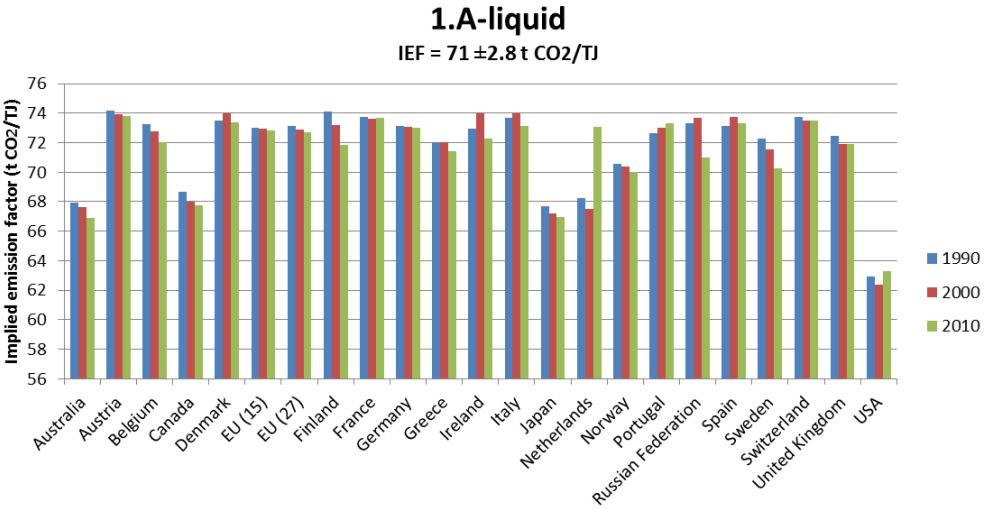


Figure 4.1a Comparison of implied emission factors reported to UNFCCC.

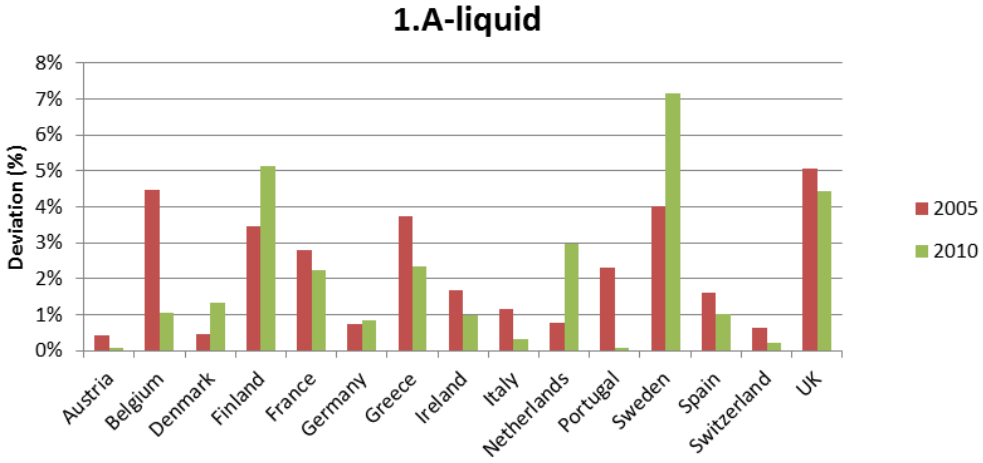


Figure 4.1b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.1a. Deviations in IEFs between countries arise from variations in applied liquid fuel types. The Danish IEF is comparable to the IEF for all countries except USA.

The Danish IEFs are consistent between the three years, which indicates reliability in the estimates. The Danish IEF was higher in year 2000 than in 1990 and 2010 mainly due to consumption of orimulsion in a power plant unit this year. The CO_2 emission factor for orimulsion is higher than for other liquid fuels[1].

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.1b. The deviations are below 5 % for all countries and years, except for Finland 2010, Sweden 2010 and UK 2005.

For Denmark, the deviation is 0.5 % in 2005 and 1.3 % in 2010. The main reason for this deviation is that the data reported to Eurostat does not include the fuel consumption for transport between Denmark and Greenland/Faroe Island as domestic transport. The Danish reporting of CO_2 emissions includes this fuel consumption in domestic transport. The CO_2 emission from Denmark is reported for Denmark (EU), Denmark+Greenland (Kyoto Protocol) and Denmark+Greenland+Faroe Island (UNFCCC). Denmark considers the fuel consumption domestic for all three reports.

These are lines of evidences indicating good quality implied emission factors and reliable methodologies, and accordingly verification of the Danish emission inventory for liquid fuels.

4.2 1.A-solid

Verification category: CO_2 emissions from "1.A Fuel Combustion – Solid Fuels".

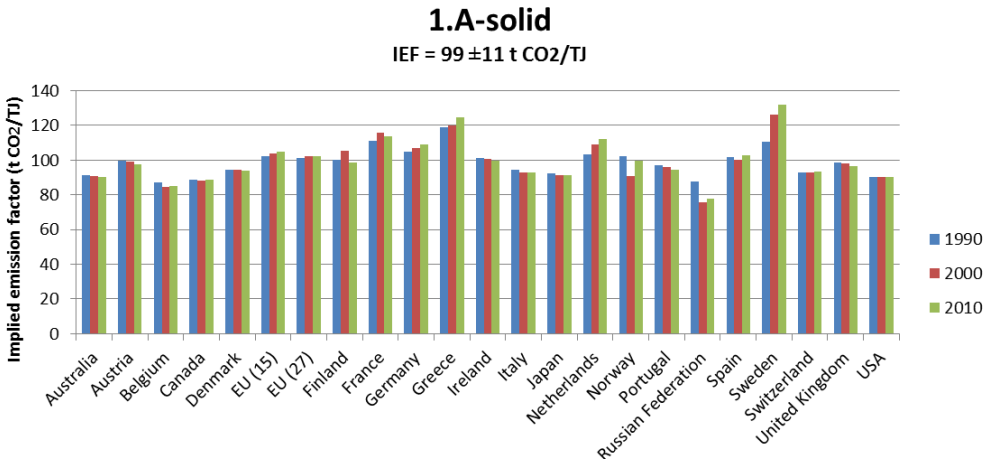


Figure 4.2a Comparison of implied emission factors reported to UNFCCC.

[1] Except petroleum coke.

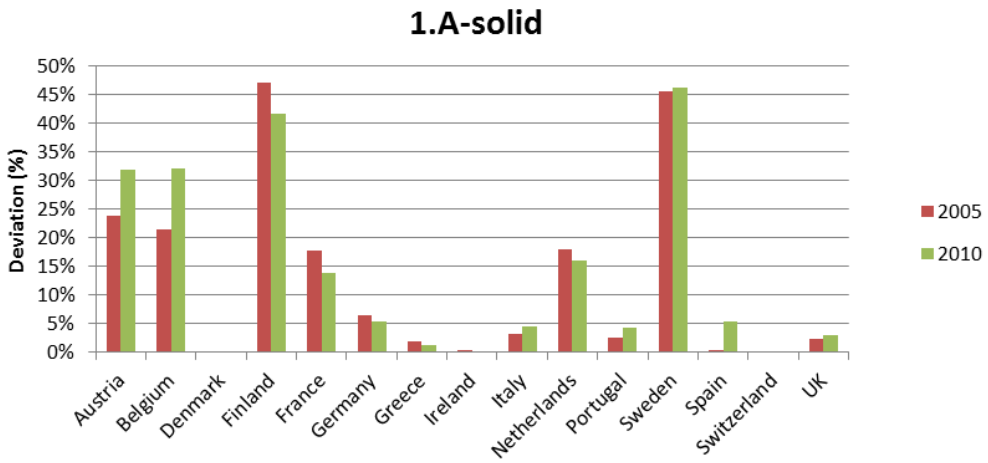


Figure 4.2b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.2a. Deviations in IEFs between countries arise from variations in applied solid fuel types. The Danish IEF is comparable to IEFs for Australia, Austria, Italy, Japan, Portugal, Switzerland, UK and USA. Bituminous coal is applied in Denmark whereas some countries apply coal types with higher CO_2 emission factors.

The Danish IEFs are consistent between the three years, which indicates reliability in the estimates.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.2b. For Denmark, the deviation between Eurostat data and CRF data reported to EU is -0.2 % in 2005 and -0.3 % in 2010. Furthermore the deviations are below 5 % for Greece, Ireland, Italy, Portugal, Spain 2005 and UK.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of solid fuels has been verified.

4.3 1.A-gaseous

Verification category: CO_2 emissions from "1.A Fuel Combustion – Gaseous Fuels".

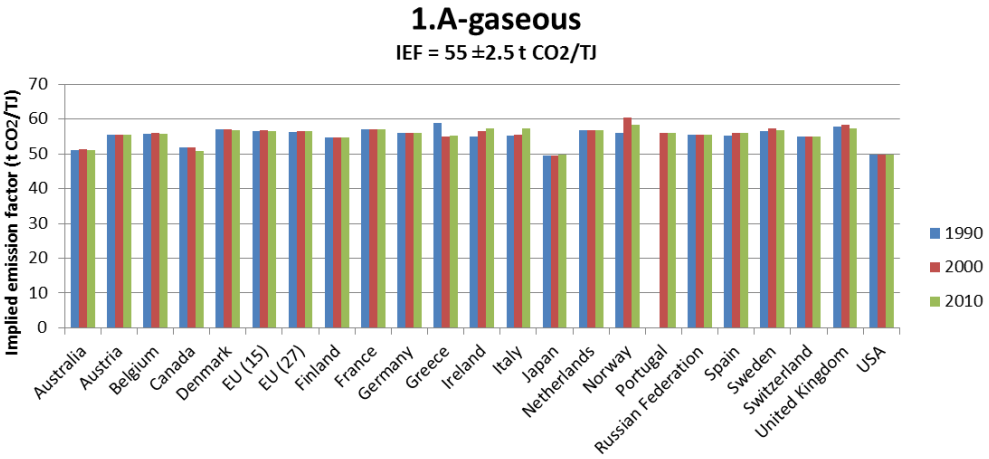


Figure 4.3a Comparison of implied emission factors reported to UNFCCC.

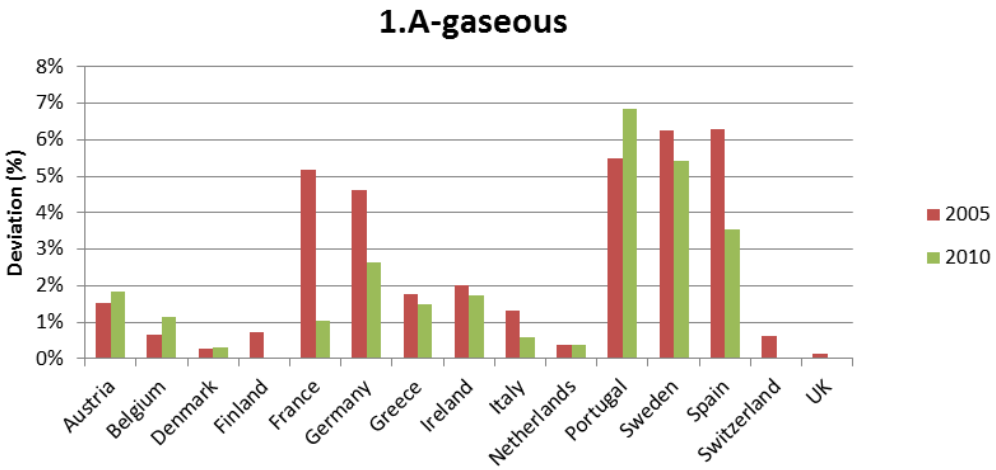


Figure 4.3b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.3a. Deviations in IEFs between countries arise from variations in gas quality. The Danish IEF is comparable to the IEF for most European countries including EU15 and EU27[2].

The Danish IEFs are consistent between the three years, which indicates reliability in the estimates and a relatively constant gas quality.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.3b. For Denmark, the deviation is 0.3 % in both 2005 and 2010.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of gaseous fuels has been verified.

4.4 1.A-other

Verification category: CO_2 emissions from "1.A Fuel Combustion – Other Fuels".

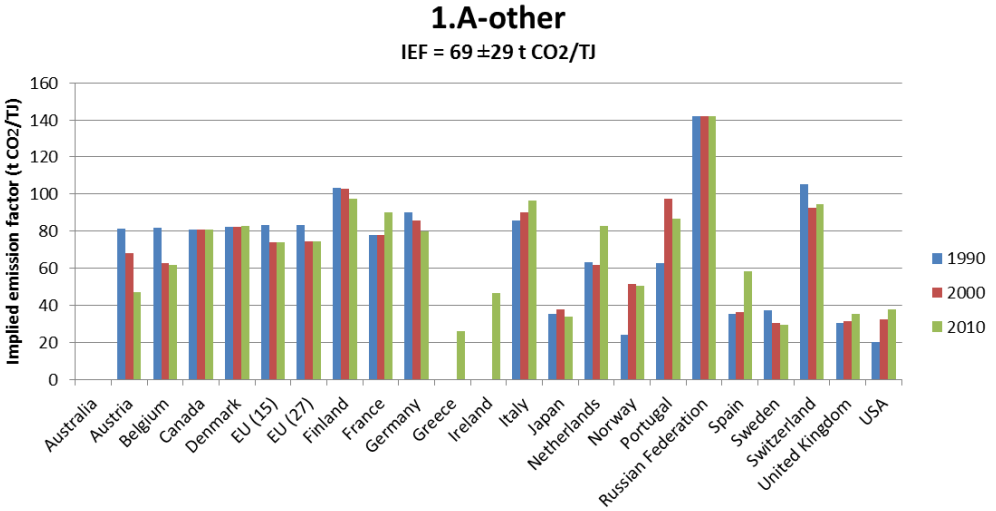


Figure 4.4a Comparison of implied emission factors reported to UNFCCC.

[2] Detailed list is shown in Table 2.

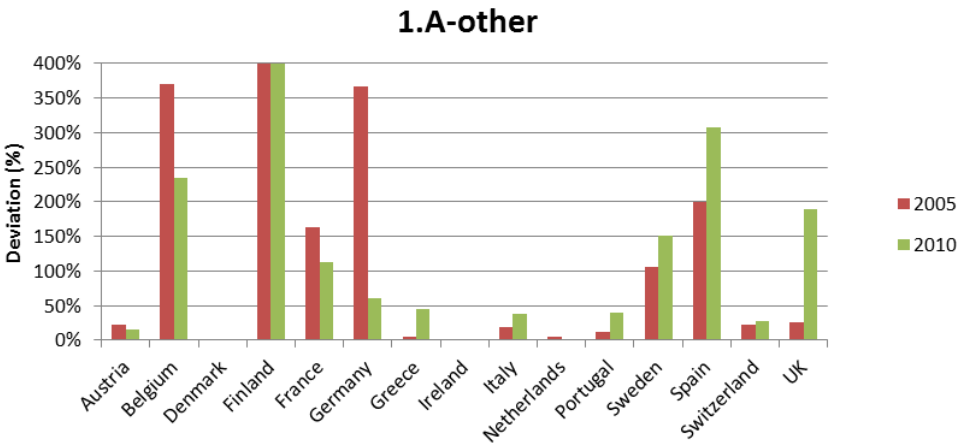


Figure 4.4b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

For Denmark, the fuel category "Other Fuels" is equal to the fossil waste fraction. For other countries, the fuel category may include other fuels and this is the reason for the large variation of data in this category.

IEFs for different countries are shown in Figure 4.4a. Deviations in IEFs between countries are a result of variations in fuel types included in the category Other Fuels. Denmark includes fossil waste in this fuel category. The Danish IEF is comparable to the IEF for EU15, EU27, France, Germany, Italy and Canada.

The Danish IEFs are consistent between the three years, which indicates reliability in the estimates. However, the emission factor has been assumed constant in the Danish inventory due to lack of historic data for biogenic content of the incinerated waste.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.4b. The fuel mapping results in comparable data for Denmark, but for some other countries, this is not the case. This is the reason for the large deviation for some countries, e.g. Finland. For Denmark, the deviation is low: 0.3 % in 2005 and -0.2 % in 2010.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of fossil waste has been verified.

4.5 1.A1.a-liquid

Verification category: CO_2 emissions from "1.A.1. Energy Industries – a. Public Electricity and Heat Production – Liquid Fuels".

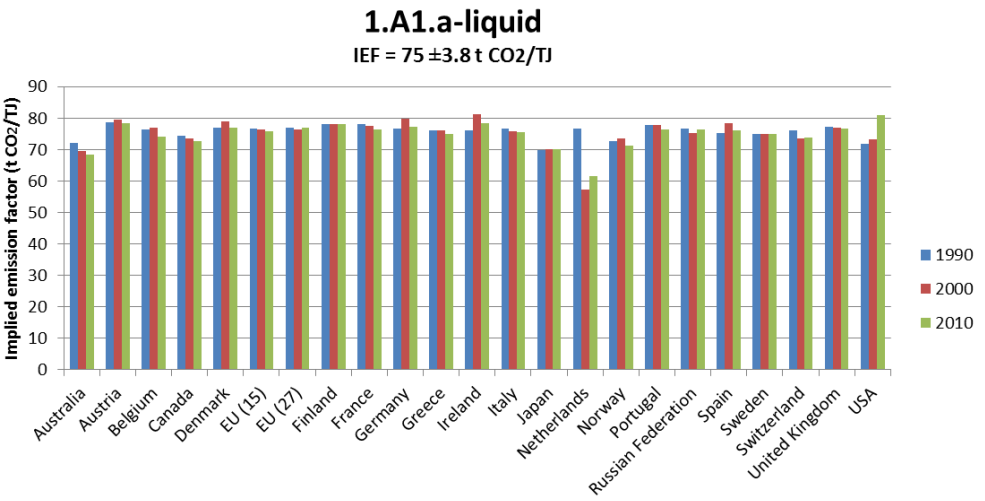


Figure 4.5a Comparison of implied emission factors reported to UNFCCC.

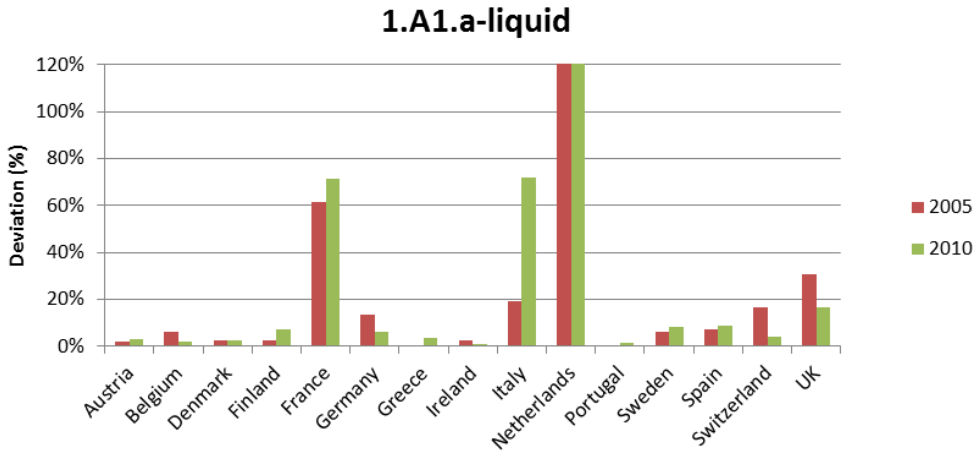


Figure 4.5b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for different countries are shown in Figure 4.5a. Deviations in IEFs between countries arise from variations in applied liquid fuel types. The Danish IEF is comparable to the IEF for most European countries including EU15 and EU27[3].

The Danish values are consistent between the three years, which indicates reliability in the estimates. The Danish IEF was higher in year 2000 than in 1990 and 2010 mainly due to consumption of orimulsion in a power plant unit this year. The CO_2 emission factor for orimulsion is higher than for other liquid fuels[4].

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.5b. For Denmark, the deviation is 2.6 % in both 2005 and 2010. The main reason for this deviation is that in the Eurostat mapping all fuel consumption in auto-producer plants is included in the industry sector whereas the Danish inventory includes auto-producer plants in the transformation sector if it is a privately owned plant producing power/district heating only for public power and district heating.

[3] A detailed list is shown in Table S.2
[4] Except petroleum coke.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of liquid fuels in public electricity and heat production plants has been verified.

4.6 1.A1.a-solid

Verification category: CO_2 emissions from "1.A.1. Energy Industries – a. Public Electricity and Heat Production – Solid Fuels".

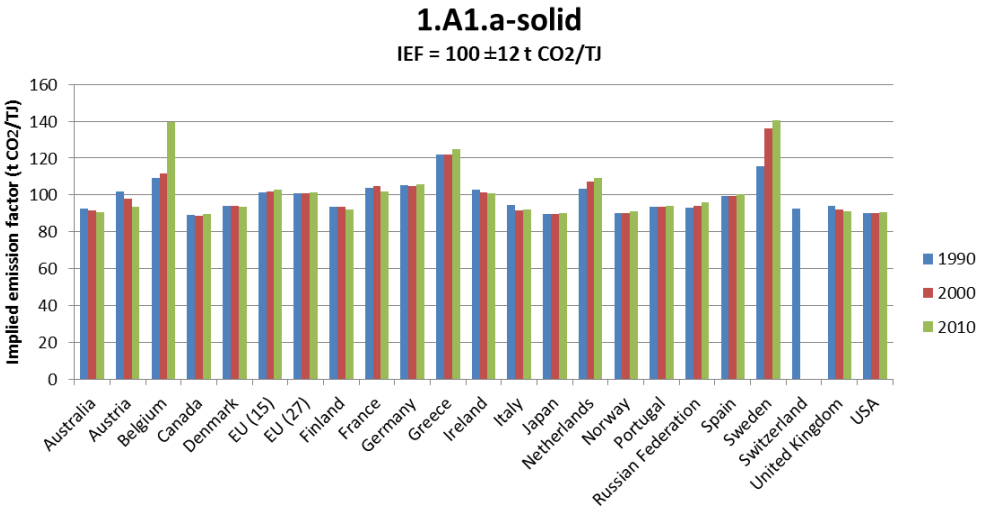


Figure 4.6a Comparison of implied emission factors reported to UNFCCC.

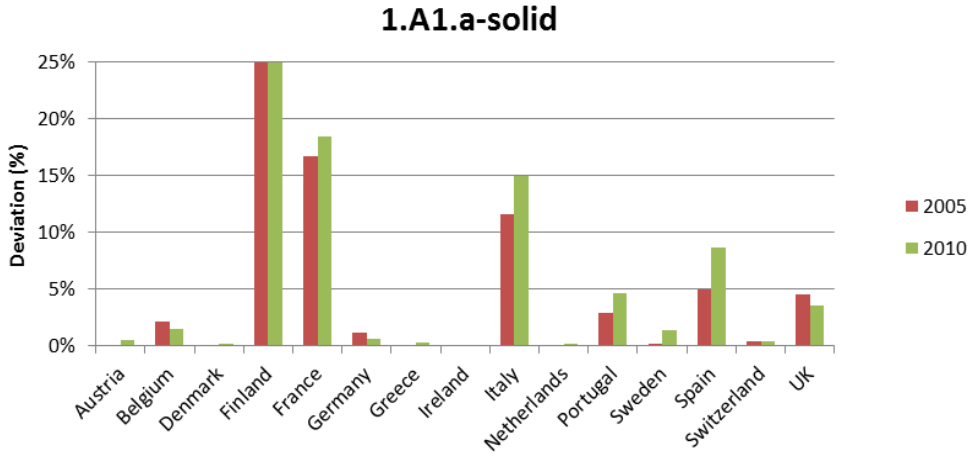


Figure 4.6b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.6a. Deviations in IEFs between countries are a result of variations in applied solid fuel types. The Danish IEF is comparable to the IEF for Australia, Austria, Canada, Finland, Italy, Japan, Norway, Portugal, Russia, the United Kingdom and the United States of America. Bituminous coal is applied in Denmark whereas some countries apply coal types with higher CO_2 emission factors.

The Danish IEFs are consistent between the three years.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.6b. For Denmark, the deviation between Eurostat data and CRF data reported to EU is -0.0 % in 2005 and -0.2 % in 2010.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of solid fuels in public electricity and heat production has been verified.

4.7 1.A1.b-liquid

Verification category: CO_2 emissions from "1.A.1 Energy Industries – b. Petroleum Refining – Liquid Fuels".

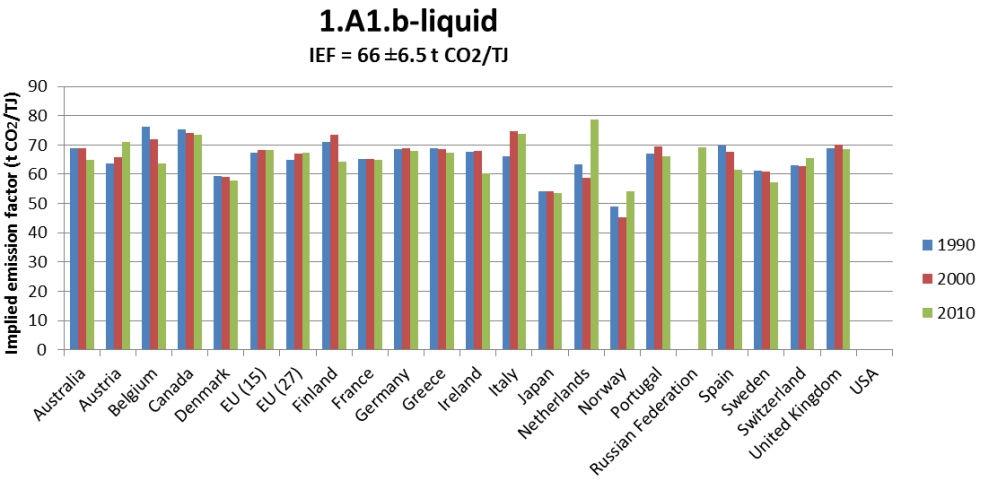


Figure 4.7a Comparison of implied emission factors reported to UNFCCC.

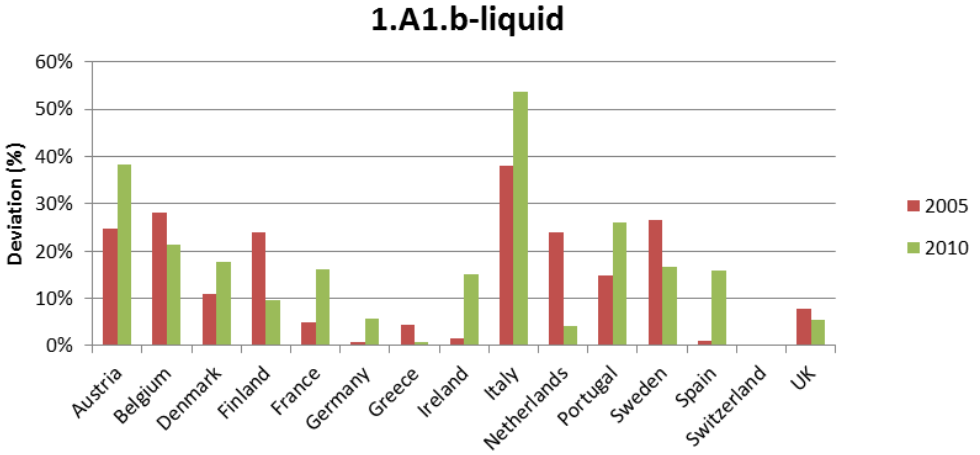


Figure 4.7b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for different countries are shown in Figure 4.7a. Deviations in IEFs between countries arise from variations in applied liquid fuel types. The Danish IEF is comparable to the IEFs for Japan, Sweden and Switzerland. The Danish IEF values are consistent between the three years, which indicates reliability in the estimates.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.7b. For Denmark, the deviation is 11 % in 2005 and 18 % in 2010. The main reason for this deviation is that in the CRF data the fuel consumption for a gas turbine installed in a refinery is included in the category refineries whereas the consumption is included elsewhere in the Eurostat data.

The IEF and fuel consumption data indicates good quality of the Danish inventory for combustion of liquid fuels in petroleum refining.

4.8 1.A1.c-gaseous

Verification category: CO_2 emissions from "1.A.1 Energy Industries – c. Manufactures of Solid Fuels and Other Energy Industries – Gaseous Fuels".

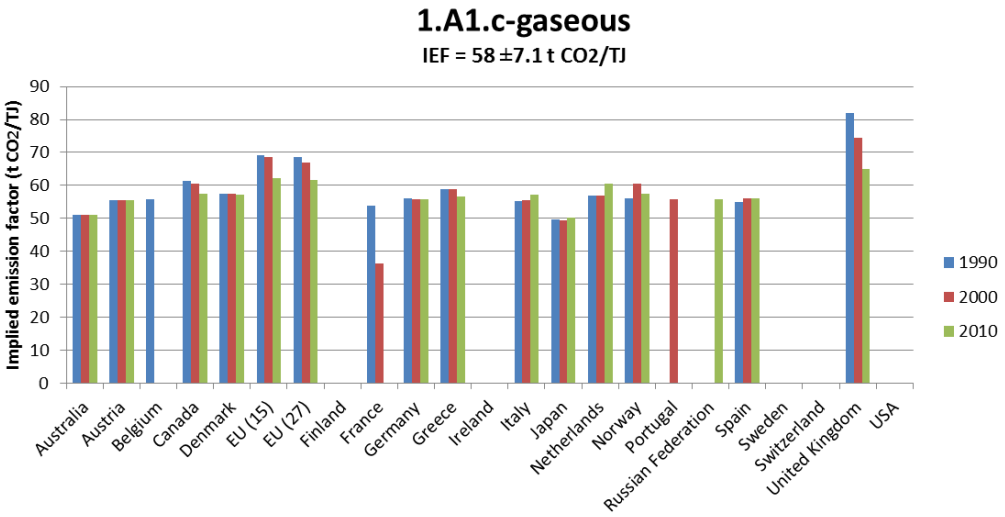


Figure 4.8a Comparison of implied emission factors reported to UNFCCC.

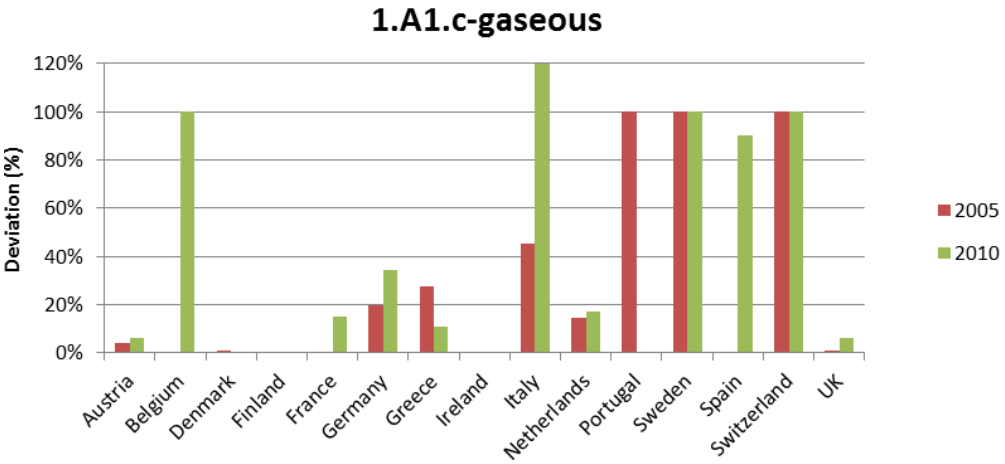


Figure 4.8b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

The emission source category covers off-shore gas turbines.

IEFs for all countries are shown in Figure 4.8a. Deviations in IEFs between countries arise from variations in gas quality. The Danish IEF is comparable to the IEFs for Austria, Canada, Germany, Greece, Italy, Netherlands, Norway and Spain.

The Danish IEFs are consistent between the three years, which indicates reliability in the estimates and a relatively constant gas quality.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.8b. For Denmark, the deviation is 0.8 % in 2005 and 0 % in 2010.

The IEF and fuel consumption data indicates good quality of the Danish inventory. Thus, the Danish emission inventory for combustion of gaseous fuels in the sector has been verified.

4.9 1.A3.b-gasoline

Verification category: CO_2 emissions from "1.A.3 Transport – b. Road Transportation – Gasoline and LPG".

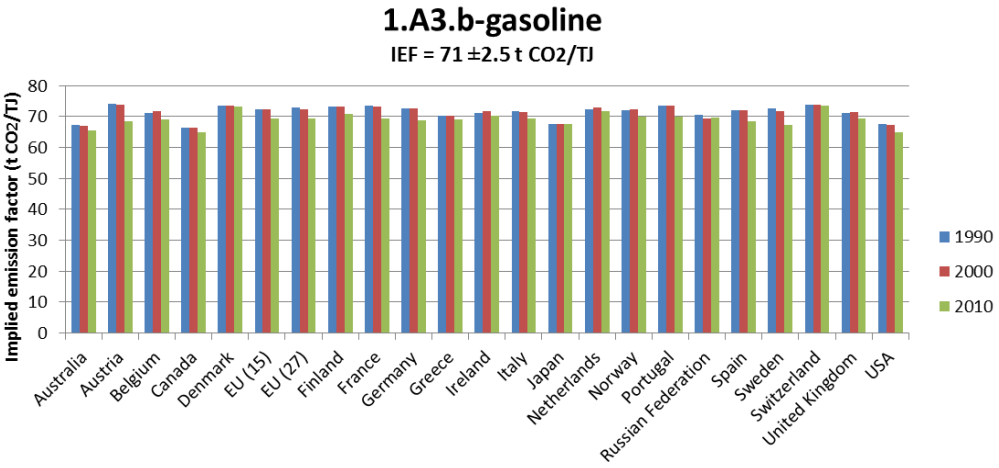


Figure 4.9a Comparison of implied emission factors reported to UNFCCC.

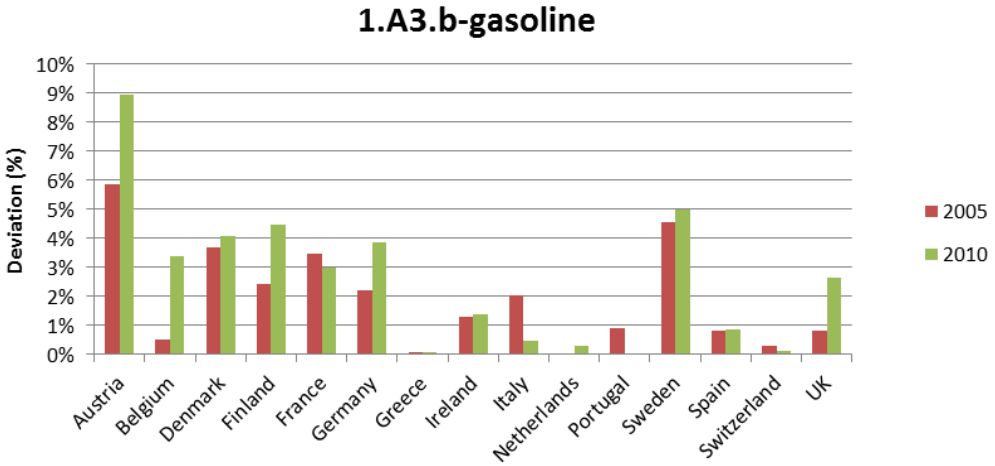


Figure 4.9b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

In Figure 4.9a the Danish IEFs decrease slightly from 2000 to 2010 due to the small amount of E5 (5 % ethanol + 95 % gasoline) fuels being sold at Danish gas filling stations as a replacement for neat gasoline. Ethanol is by definition CO_2 neutral as a fuel for vehicular combustion.

In Figure 4.9b the difference between Danish activity data reported to EU and Eurostat for road transport is due to the amount of gasoline used by gardening equipment, reported as road transport fuel by Eurostat, but being transferred to the 1.A4b sector (residential) in the EU report.

4.10 1.A3.c-liquid

Verification category: CO_2 emissions from "1.A3 Transport – c. Railways – Liquid Fuels".

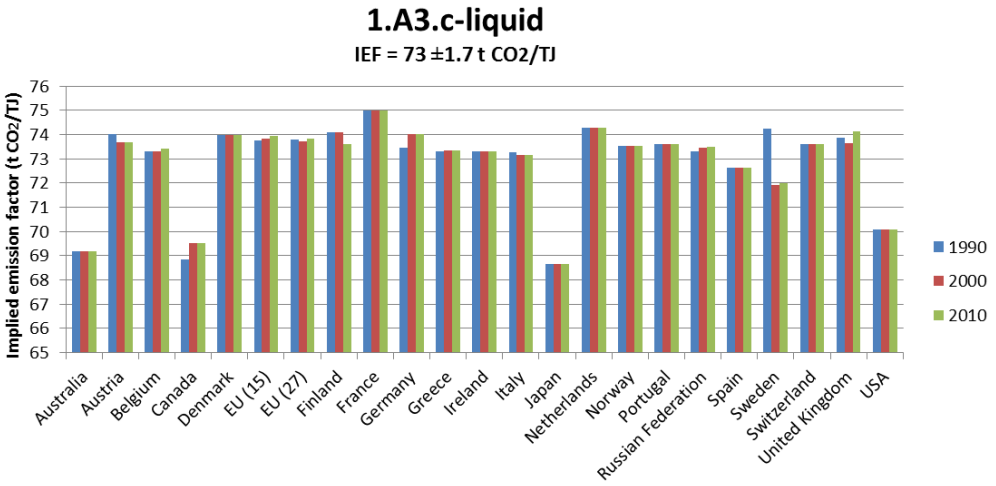


Figure 4.10a Comparison of implied emission factors reported to UNFCCC.

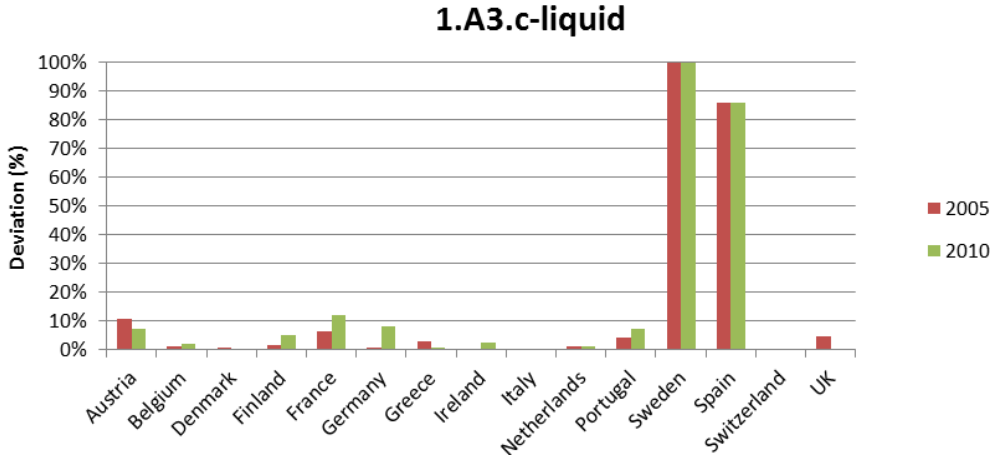


Figure 4.10b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

4.11 1.A3.d-residual oil

Verification category: CO_2 emissions from "1.A.3 Transport – d. Navigation –Residual Oil (Residual Fuel Oil)".

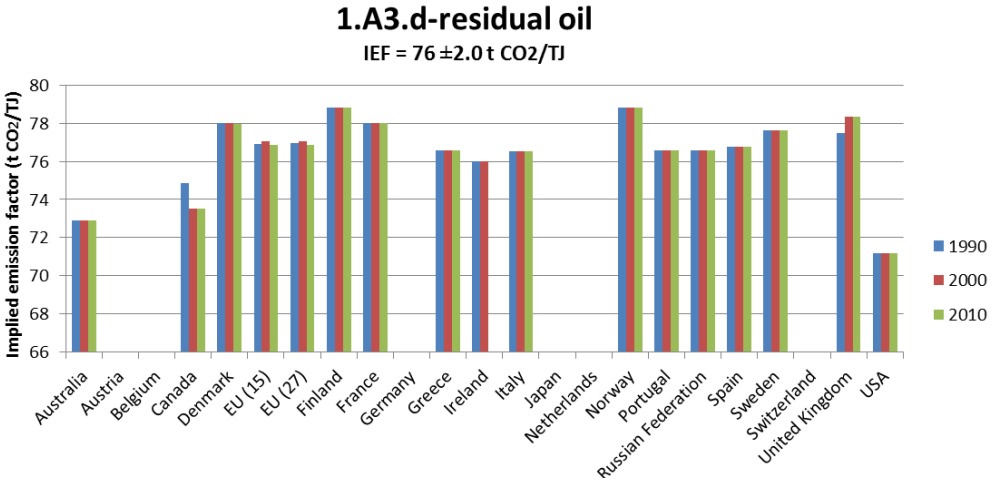


Figure 4.11a Comparison of implied emission factors reported to UNFCCC.

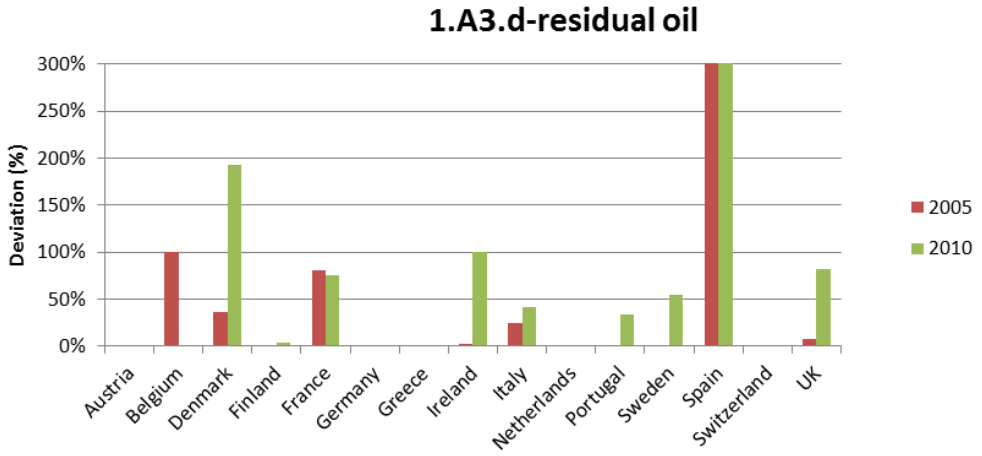


Figure 4.11b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

The reason for the large difference in Figure 4.11b between Danish activity data reported to EU and Eurostat for residual oil in Danish navigation is due to fuel transferal between the Danish energy statistics source categories when these are used as an input for the Danish EU inventories.

The Danish reported EU fuel consumption is an estimated figure based on fleet/activity bottom-up model calculations for ships sailing between Danish ports, and ship transport between Denmark, Greenland and the Faroe Islands. Hence, these estimated figures are not the same as the statistical values reported by oil companies to the Danish Energy Agency.

For ships sailing between Danish ports a fuel transferal is made between the energy statistics input values for domestic navigation and stationary sources in the industry sector to account for the fuel differences. For ship transport between Denmark, Greenland and the Faroe Islands fuel is taken from the DEA statistical sector international navigation in order to account for this fuel amount not being reported in the statistics as domestic fuel consumption for navigation.

4.12 1.A4.b-liquid

Verification category: CO_2 emissions from "1.A.4 Other Sectors – b. Residential – Liquid Fuels".

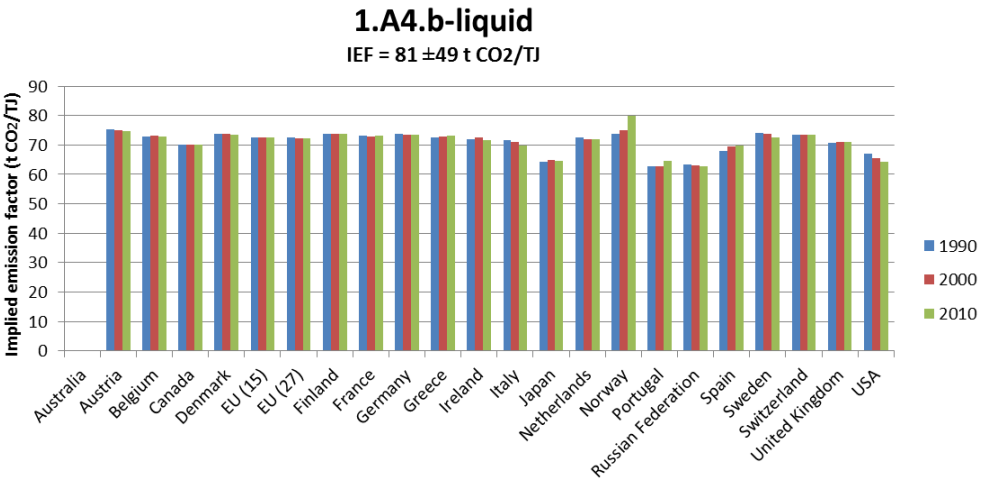


Figure 4.12a Comparison of implied emission factors reported to UNFCCC.

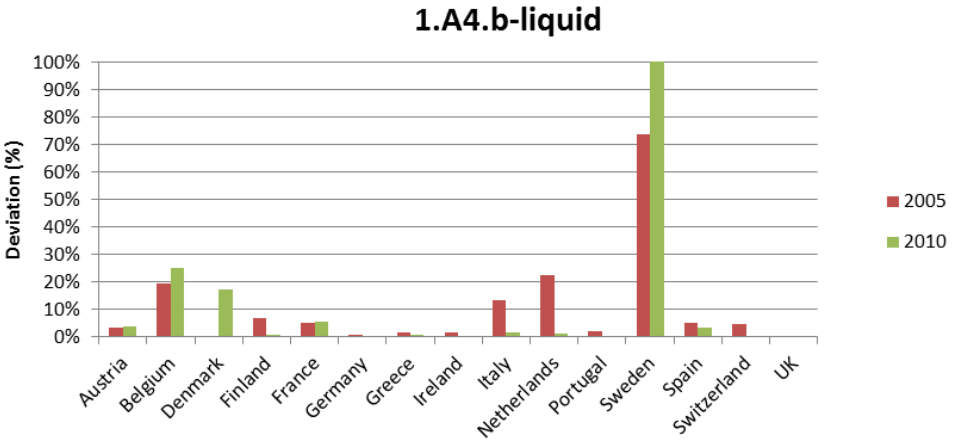


Figure 4.12b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.12a. Deviations in IEFs are a result of different liquid fuel types applied in the different countries. The Danish IEF is comparable to the IEFs for most European countries including EU15 and EU27[5].

The Danish IEF are consistent between the three years, which indicates reliability in the estimates.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.12b. For Denmark, the deviation is 0.2 % in 2005 and 17 % in 2010. The main reason for this deviation is that the Danish transport model shows a higher consumption of gas/diesel oil in the transport sector than included in the energy statistics. In the Danish emission inventory for 2010, 3.4 PJ gas/diesel oil have been reallocated from residential plants to other mobile sources.

The IEF indicates good quality of the Danish inventory. The difference in activity data has been explained and the total consumption of liquid fuels has been verified in section 4.1. Thus, the Danish emission inventory for combustion of liquid fuels in residential plants has been verified.

4.13 1.A4.c-liquid

Verification category: CO_2 emissions from "1.A.4 Other Sectors – c. Agriculture/Forestry/Fisheries – Liquid Fuels".

[5] See detailed list in Table S.2.

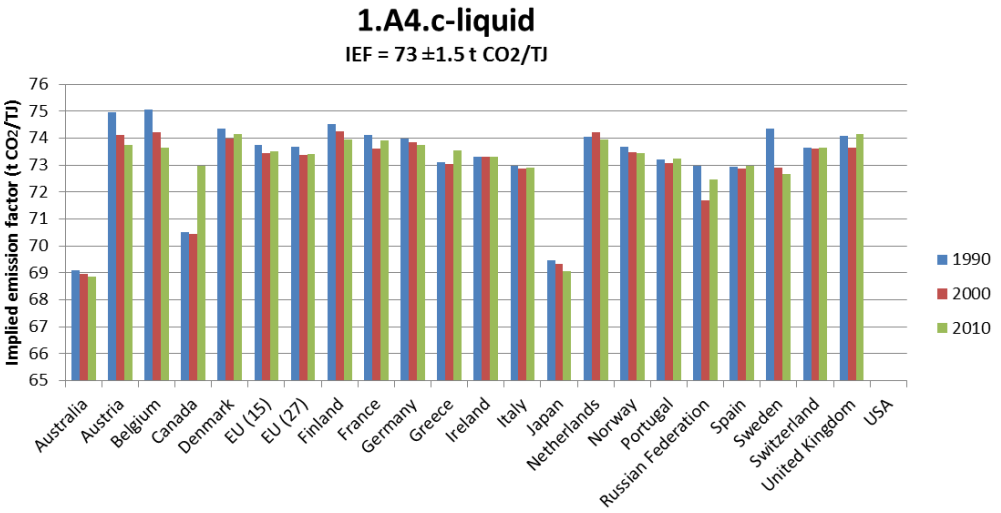


Figure 4.13a Comparison of implied emission factors reported to UNFCCC.

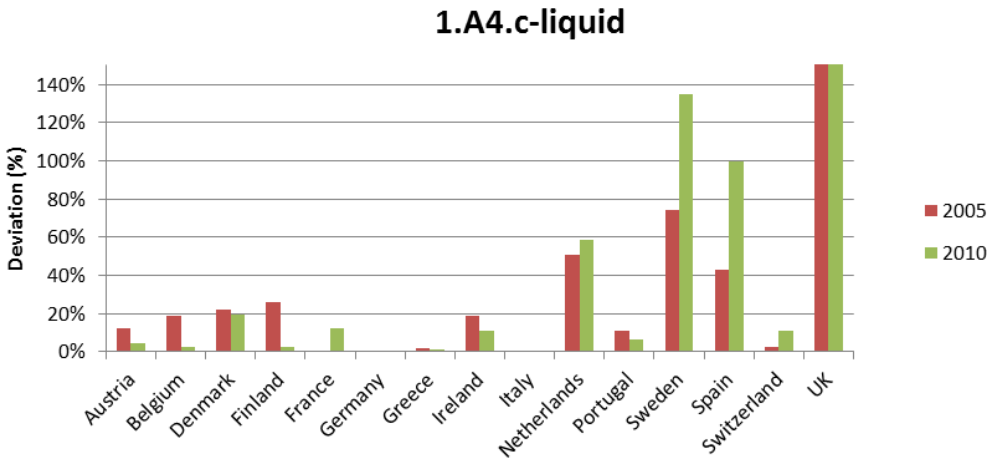


Figure 4.13b Deviation between activity data reported to EU and Eurostat (UBA, 2013).

IEFs for all countries are shown in Figure 4.13a. Deviations in IEFs are a result of different liquid fuel types applied in the different countries. The Danish IEF is comparable to the IEFs for most European countries including EU15 and EU27[6]. The Danish IEF is highest in 1990 and lowest in 2000. The difference is however below 0.5 %.

Activity data reported to Eurostat and to EU have been compared for 2005 and 2010 (UBA 2013). The deviations between the two activity data sets are shown in Figure 4.13b. For Denmark, the deviation is 22 % in 2005 and 20 % in 2010. The main reason for this deviation is that the Danish transport model shows a higher consumption of gas/diesel oil in agriculture/forestry/-fishery than included in the Danish energy statistics of these categories. To fill the fuel gap in the Danish emission inventory, a certain amount of gas/diesel oil has been transferred from industrial plants in the Danish energy statistics.

The IEF data indicates good quality of the Danish inventory. The difference in activity data has been explained and the total consumption of liquid fuels has been verified in section 4.1. Thus, the Danish emission inventory for combustion of liquid fuels in agriculture/forestry/fisheries has been verified.

[6] Se detailed list in Table S.2.

5 Agriculture

UNFCCC reporting according to the 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) national greenhouse gases from agriculture are divided into four sources:

- Domestic livestock; enteric fermentation and manure management
- Rice cultivation
- Agricultural soils
- Agricultural burning; prescribed savannah burning and burning of agricultural residues

Emissions from rice production do not occur in Denmark. Field burning of agricultural residues may only take place in connection with fields with continuously cultivation of seed grass or in cases where weather conditions result in surplus of straw in the form of wet or broken bales. Thus, the greenhouse gas emission from field burning only contributes with less than 1 % of the total agricultural emissions.

The Danish agricultural emission includes emissions from enteric fermentation, manure management and agricultural soils. The main part of the emission is related to the production of cattle and swine.

The Danish agricultural sector comprises 14 key categories, and for each agricultural verification category, see Table 2.1 and 2.2, the verification comprises:

- Inter-country comparison of UNFCCC implied emission factors (IEFs) and consistency in time trends of Danish UNFCCC implied emission factors. A comparable country is when the mean deviation of IEF, between Denmark and the country, for the three years, is below 10 %. IEF for EU15 countries (excluding Luxemburg), Norway, Switzerland, Australia, Canada, Japan, Russian Federation, USA and aggregated values for EU15 and EU27, are used. The results on IEFs are derived in this section and are summarised in Table S.2.
- National and inter-country verification of UNFCCC activity data with independent activity data and assessment of consistency in time trends of Danish UNFCCC activity data. The results on activity data are elaborated in this section and are summarised in Table S.3.

The activity data are obtained from Eurostat (2013) and FAOstat (2013), where data is predominantly supplied by the national governments. FAO also collaborates with various agencies in order to achieve conformity in the presentation of international figures.

Consistency in time trend for Danish UNFCCC data is expressed as %-change, decrease (-) or increase (+), from 1990 to 2000 and 2000 to 2010, respectively. Time series; "decrease" is defined as two consecutive decreases <-5 %, "increase" as two consecutive increases >+5 % and "constant" as two consecutive (absolute value of) changes <5 %.

5.1 4.A-cattle

Verification category: CH_4 emissions from "Total Agriculture – Enteric Fermentation - Cattle" (thousand heads).

Independent activity data: "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Bovine Animals" (thousand heads) (Eurostat, 2013).

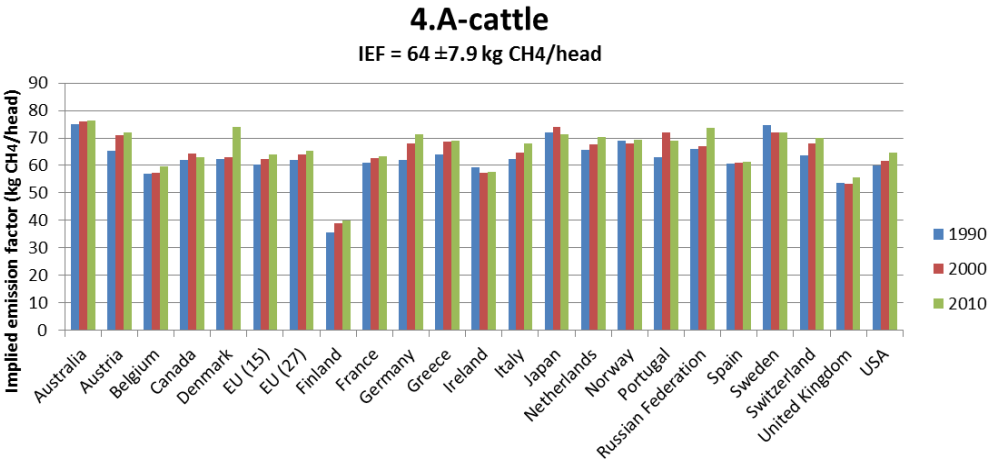


Figure 5.1a Comparison of implied emission factors reported to UNFCCC.

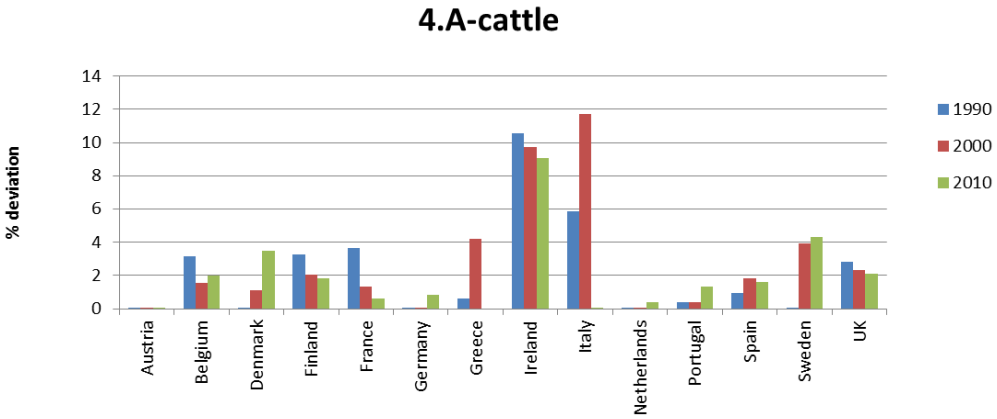


Figure 5.1b Deviation between activity data reported to UNFCCC and "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Bovine Animals" (thousand heads) (Eurostat, 2013).

The Danish implied emission factor (IEF) for cattle is based on national values and correlates well with the level of most other countries. The IEF depends on milk yield and feed intake. A strong increase of the Danish IEF has taken place from 2000 to 2010, which is a consequence of a significant rise in milk yield. As shown in Figure 5.1a many other countries follow the same trend of increasing milk yield but with slower increasing rate.

The Danish inventory for the production of cattle is in good agreement with the number estimated in Eurostat and the deviation is estimated to less than 4 %, cf. Figure 5.1b.

5.2 4.A-sheep

Verification category: CH_4 emissions from "Total Agriculture – Enteric Fermentation - Sheep" (thousand heads).

Independent activity data: "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Sheep" (thousand heads) (Eurostat, 2013).

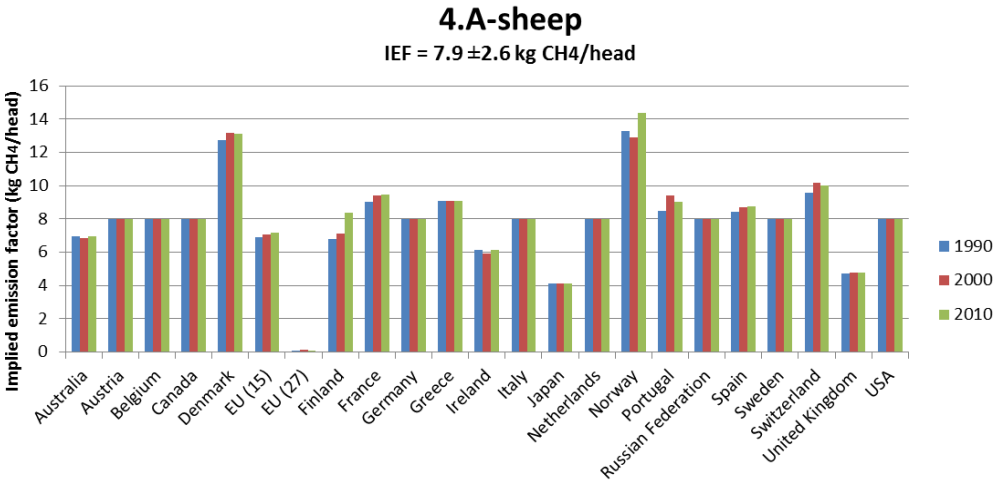


Figure 5.2a Comparison of implied emission factors reported to UNFCCC.

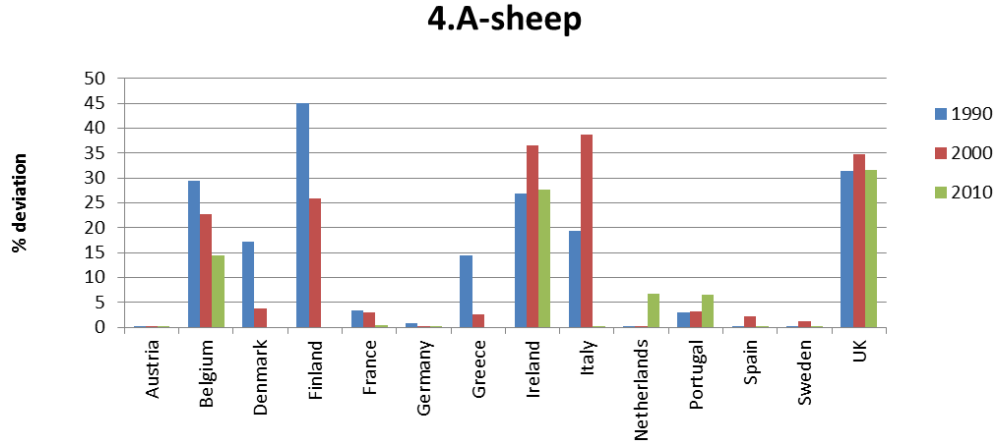


Figure 5.2b Deviation between activity data reported to EU and "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Sheep" (thousand heads) (Eurostat, 2013).

The UNFCCC default emission factor for sheep is 8 kg CH_4 per sheep per year which is used in many countries as shown in Figure 5.2a. The Danish IEF is considerable higher because the factor includes emissions from mother sheep and lambs. The feed intake is based on the Danish normative data administrated by the Danish Centre for Food and Agriculture at Aarhus University and the normative data includes feed both for the mother sheep and lamb.

Figure 5.2b shows a difference in sheep production compared to Eurostat (2013) of 17 % in 1990 and 4 % in 2000. No activity data in Eurostat are reported for 2010. The uncertainty for number of sheep was higher in 1990. At present each sheep is registered with an ear tap and are regularly reported to the Central Husbandry Register administrated by the Ministry of Food, Agriculture and Fisheries.

5.3 4.A-swine

Verification category: CH_4 emissions from "Total Agriculture – Enteric Fermentation - Swine" (thousand heads).

Independent activity data: "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Swine, Domestic Species" (thousand heads) (Eurostat, 2013).

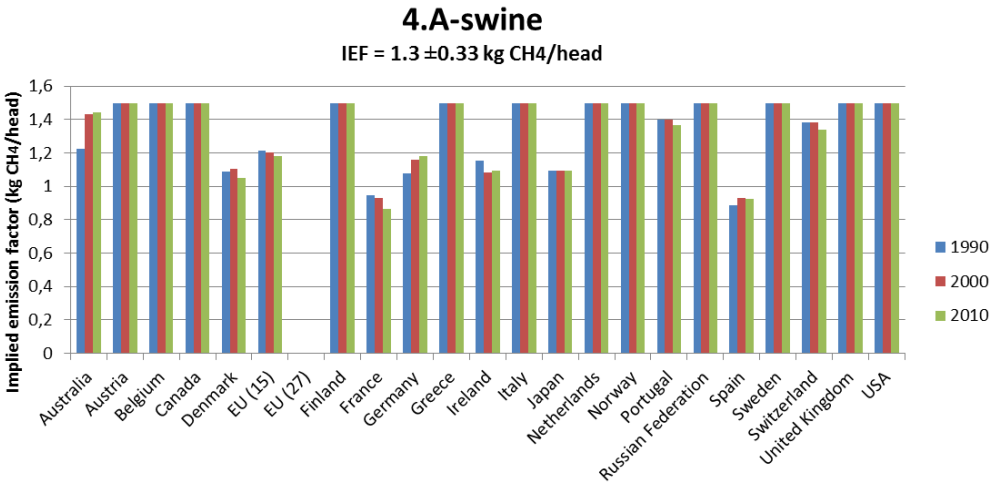


Figure 5.3a Comparison of implied emission factors reported to UNFCCC.

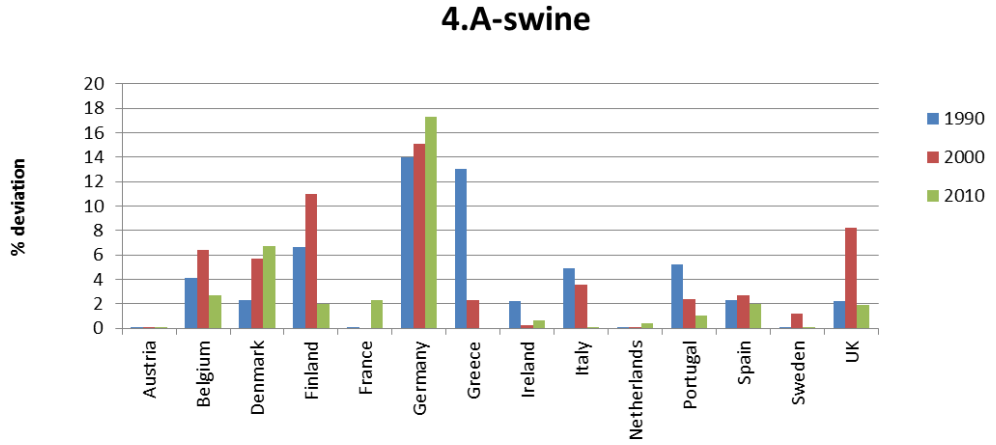


Figure 5.3b Deviation between activity data reported to UNFCCC and "Agriculture, forestry & fisheries - Agriculture - Regional agriculture statistics - Animal populations – Live Swine, Domestic Species" (thousand heads) (Eurostat, 2013).

The UNFCCC default IEF is 1.5 kg CH_4 per head per year and the Danish IEF is particularly lower at 1.1 kg CH_4 per head. The IEF depend on the amount of feed, feed composition and the digestibility. Due to the large export of swine and the farmers need for economic optimization there is a continuous focus on possibilities to optimize feed intake and to increase feed efficiency. This leads to a lower IEF compared to the conservative IEF in the IPCC (1997) guidelines. This is also the case for other European countries, which use national IEF and have comparable agricultural conditions to Denmark, e.g. France and Germany.

The number of swine compared with Eurostat (2013), cf. Figure 5.3b, shows a difference up to 6 % in 2000 and 2010. The difference is caused by the time of the year for counting the animal production. The population given in the inventory is based on Statistics Denmark which survey is provided in June and the population in Eurostat reflects the production in December.

5.4 4.B-cattle

Verification category: CH_4 emissions from "CH_4 Emissions from Manure Management - Cattle" (thousand heads).

Independent activity data: Number of animals is included in 4.A-cattle.

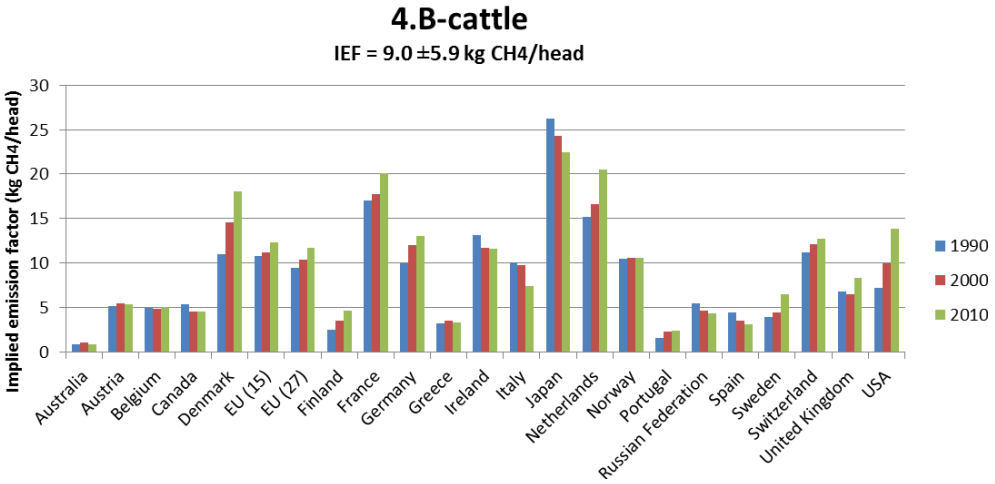


Figure 5.4 Comparison of implied emission factors reported to UNFCCC.

The IEFs for manure management from cattle show large variations between countries. The IEF depends on the type of manure, which again depends on housing type. Structural change in Denmark has resulted in a large number of large farms with slurry based housing systems, which have a high emission factor compared with other types of manure. This explains the increase of IEF from 1990 to 2010. Same development is seen for other EU countries as e.g. France, Germany, Netherlands, UK, Switzerland and Sweden.

The Danish IEF is relatively high compared with other countries, but a direct comparison cannot be made by only looking at the IEF. More information on especially distribution of housing type and use of values for the methane conversion factor (MCF) is needed. IEF for Denmark is at the same level as France and the Netherlands. France use a very high MCF value for slurry compared to DK, which is due to the temperate and warm climate zones, but has relatively few cattle placed in slurry based housing system. The Netherlands have more or less the same distribution of animal manure waste system as Denmark but use a higher MCF for slurry. Based on these comparisons the Danish IEFs are reasonable.

5.5 4.B-swine

Verification category: CH_4 emissions from "CH_4 Emissions from Manure Management - Cattle" (thousand heads).

Independent activity data: Number of animals is included in 4.A-swine.

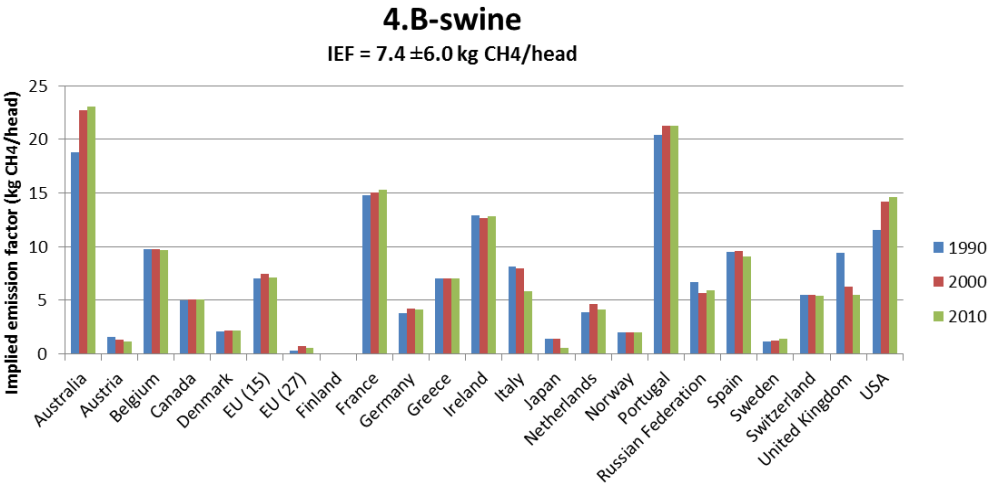


Figure 5.5 Comparison of implied emission factors reported to UNFCCC.

Figure 5.5 shows large variations in IEF for manure management for swine. The Danish level is notably lower compared to many other countries, which is mainly due to two conditions; Firstly, Denmark have a relatively large part of weaners and fattening pigs, which have lower emission factor and secondly, Denmark are defined as a cool climate region. The IEFs for Norway and Sweden are at the same level as Denmark.

5.6 4.B-liquid

Verification category: N_2O emissions from "Manure Management - Liquid System" (kg N/yr).

Independent activity data: Data dependent on number of animals and nitrogen-excretion for each livestock category.

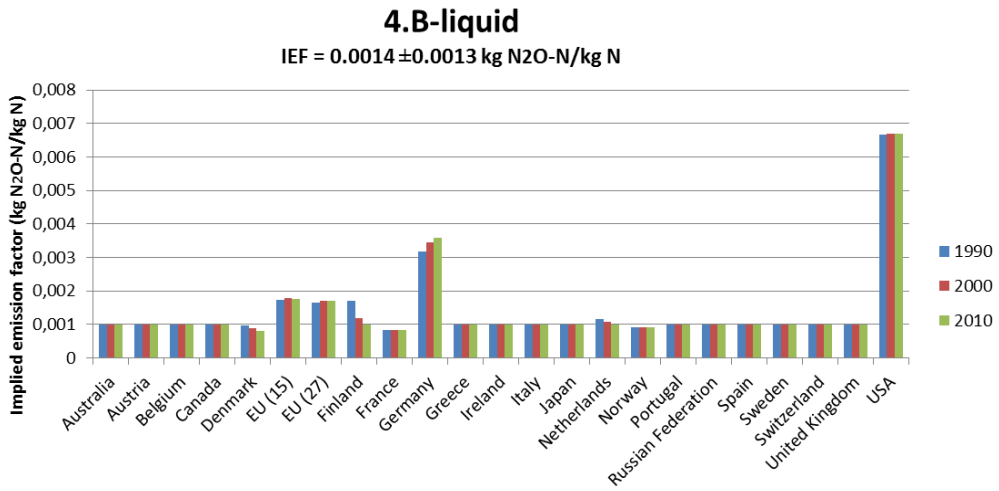


Figure 5.6 Comparison of implied emission factors reported to UNFCCC.

Almost all countries use the same IEF for liquid manure at 0.1 %, which indicates use of the IPCC (1997) default value. The slightly lower IEF for Denmark is caused by biogas treated slurry, which reduces the emission of CH_4 and N_2O. The amount of biogas treated slurry has increased from 1990 to 2010.

5.7 4.B-solid

Verification category: N_2O emissions from "Manure Management - Solid Storage and Dry Lot" (kg N/yr).

Independent activity data: Data dependent on number of animals and nitrogen-excretion for each livestock category.

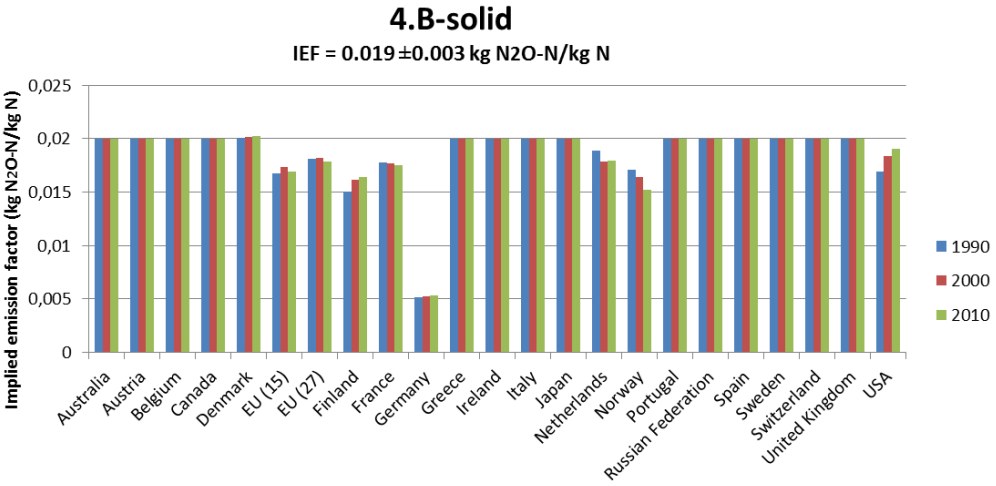


Figure 5.7 Comparison of implied emission factors reported to UNFCCC.

In Denmark the IPCC (1997) default value of 2 % is used to estimate N_2O from solid manure, which is the same procedure as in many other countries. Some other European countries use national IEFs, e.g. Finland, France, Germany, Netherlands and Norway.

5.8 4.B-other

Verification category: N_2O emissions from "Manure Management - Other" (kg N/yr).

Independent activity data: Data dependent on number of animals and nitrogen-excretion for each livestock category.

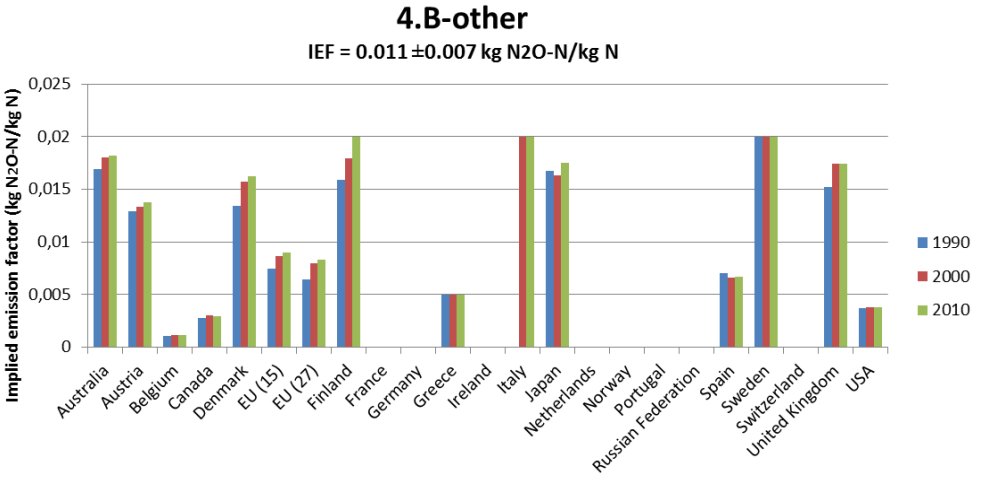


Figure 5.8 Comparison of implied emission factors reported to UNFCCC.

Large variations in IEFs are seen for N_2O emissions from animal manure waste systems categorised as "Other". This is due to that other systems than anaerob lagoon, liquid or solid storage/dry lot are included. A comparison with other countries is therefore not necessarily a useful method to verify the Danish IEF.

5.9 4.B-pasture

Verification category: N_2O emissions from "Agricultural Soils – Pasture, Range and Paddock Manure" (kg N/yr).

Independent activity data: No independent data on N-excretion rate.

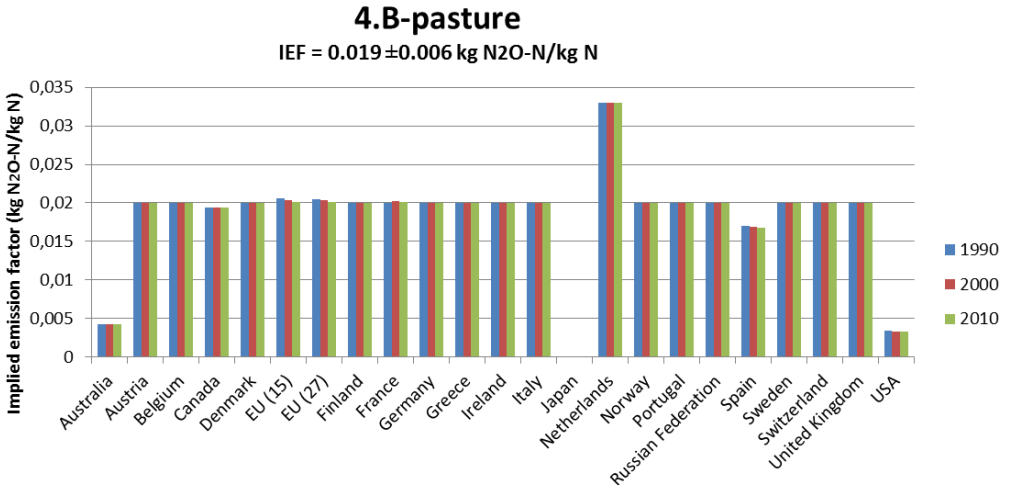


Figure 5.9 Comparison of implied emission factors reported to UNFCCC.

Denmark uses the IPCC (1997) default value in calculating the N_2O emission from animal manure deposit by grazing animals, which also the case for most other countries.

5.10 4.D1.1

Verification category: N_2O emissions from "Agricultural Soils – Direct Soil Emissions – Synthetic Fertilizers" (kg N/year).

Independent activity data: "Consumption Estimate of Manufactured Fertilizers" (kg N) (Eurostat, 2013).

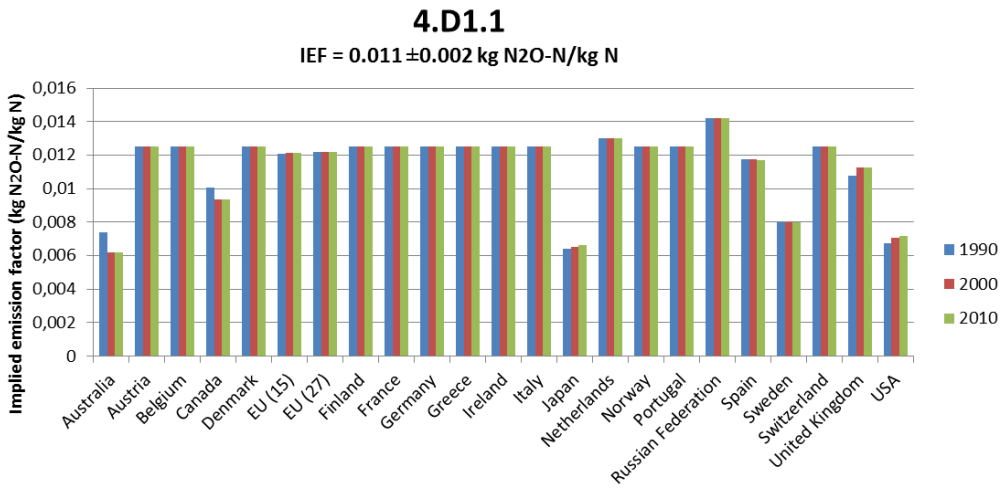


Figure 5.10a Comparison of implied emission factors reported to UNFCCC.

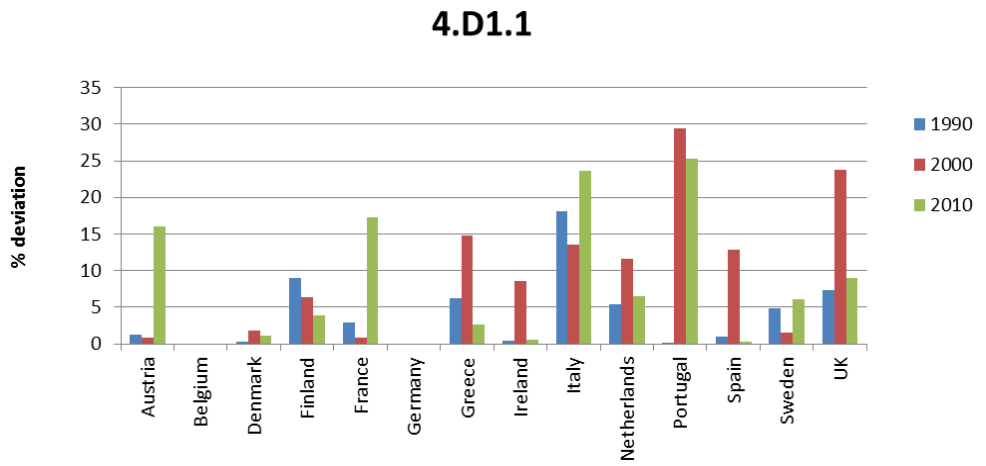


Figure 5.10b Deviation between activity data reported to UNFCCC and "Consumption Estimate of Manufactured Fertilizers" (kg N) (Eurostat, 2013).

Denmark uses the IPCC (1997) default value to estimate the N_2O emission from use of synthetic fertilizer and thus do not differ from most other countries. A few other European countries, such as Spain, Sweden and UK have provided national IEFs, which are lower than the default value.

The consumption of synthetic fertilizer is in accordance with Eurostat (2013) for all years 1990, 2000 and 2010, cf. Figure 5.10b.

5.11 4.D1.2

Verification category: N_2O emissions from "Agricultural Soils – Direct Soil Emissions – Animal Manure Applied to Soils" (kg N/yr).

Independent activity data: Data dependent on N-excretion and the number of animals. Animal production for the main categories is included in 4.A-cattle, 4.A-sheep and 4.A-swine.

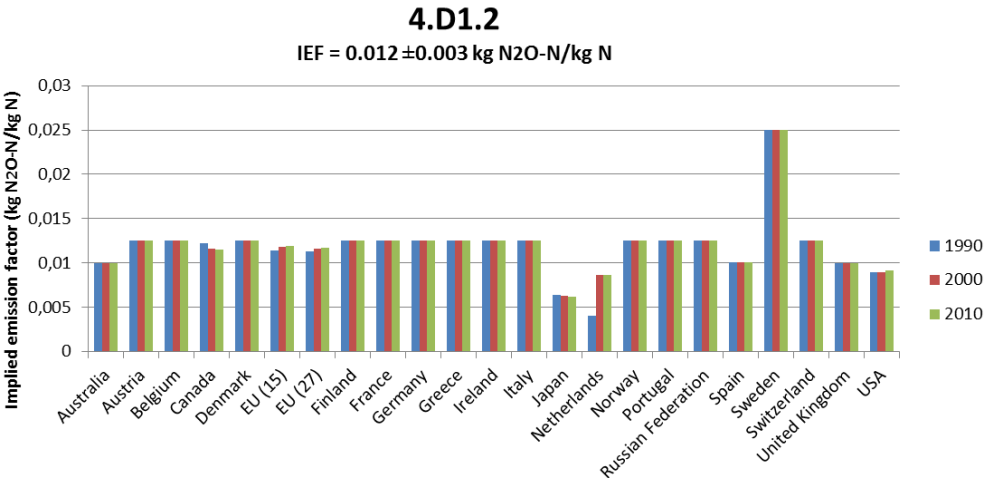


Figure 5.11 Comparison of implied emission factors reported to UNFCCC.

The IPCC default value at 1.25 % is used in the Danish inventory. A few other European countries use lower IEFs, i.e. Austria, Netherlands, Spain and UK. If a national Danish IEF should be estimated, these countries documentation and calculation methodology could be investigated.

5.12 4.D1.4

Verification category: N_2O emissions from "Agricultural Soils – Direct Soil Emissions – Crop Residue" (kg N/yr).

Independent activity data: No independent data on rate of nitrogen in crop residues returned to soil.

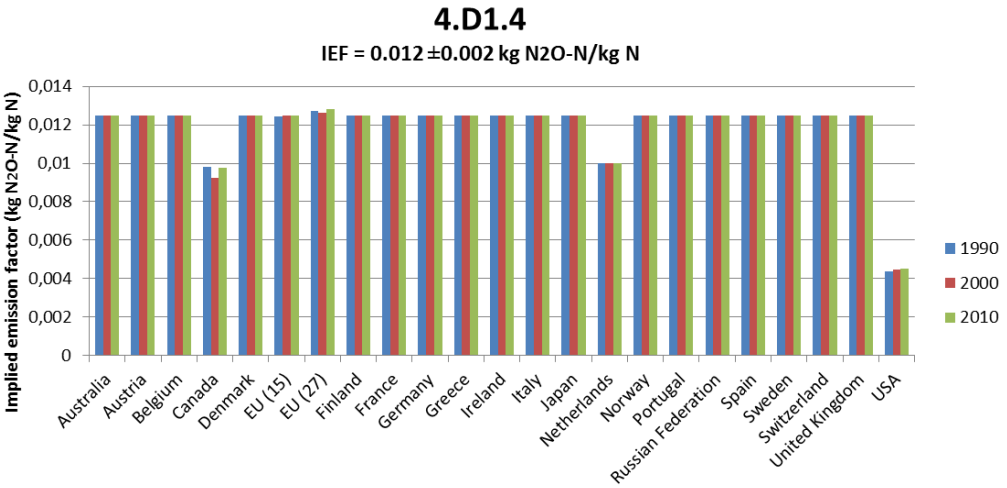


Figure 5.12 Comparison of implied emission factors reported to UNFCCC.

The IPCC (1997) default value at 1.25 % is used by most countries.

5.13 4.D3-deposition

Verification category: N_2O emissions from "Agricultural Soils – Indirect Emissions – Atmospheric Deposition" (kg N/yr).

Independent activity data: No independent data on rate of volatilized N from fertilizers, animal manures and other NH_3 emission sources.

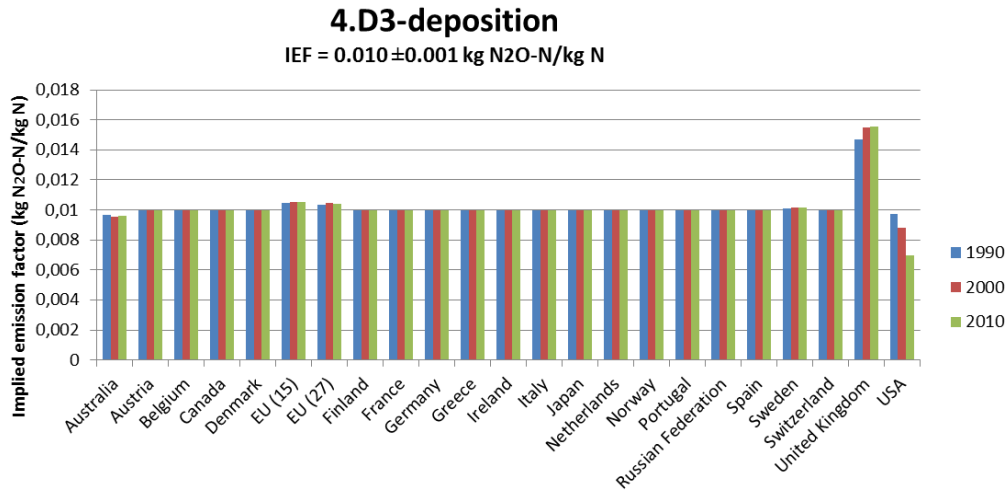


Figure 5.13 Comparison of implied emission factors reported to UNFCCC.

The IPCC (1997) default value at 1 % is used by most countries.

5.14 4.D3-leaching

Verification category: N_2O emissions from "Agricultural Soils – Indirect Emissions – Nitrogen Leaching and Run-Off" (kg N/yr).

Independent activity data: Data dependent on the amount of nitrogen applied on soil e.g. as the amount of nitrogen in animal manure, the use of synthetic fertilizer and the sewage sludge applied on the fields.

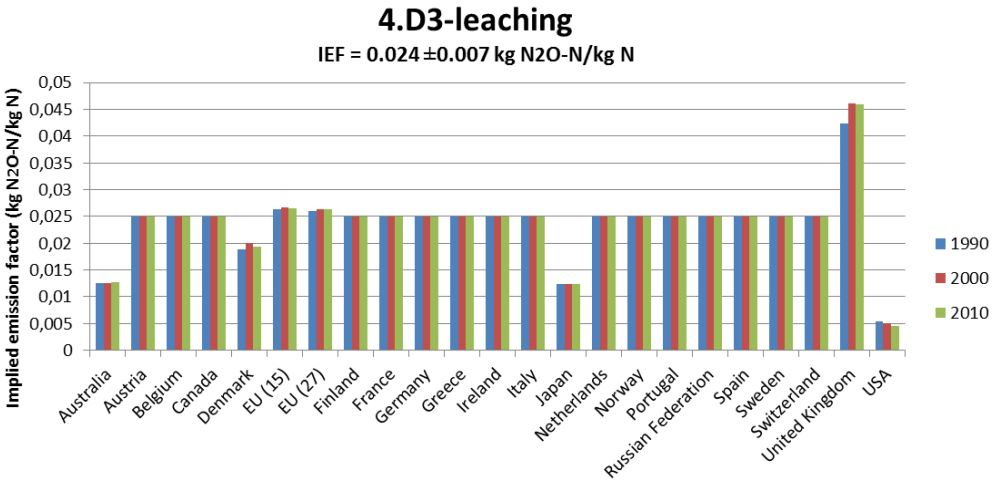


Figure 5.14 Comparison of implied emission factors reported to UNFCCC.

The Danish IEF for nitrogen leaching and run-off is 2.0 %, which is lower than most other countries. The IPCC recommends an N_2O emission factor of 0.025, of which 0.015 is for leaching to groundwater, 0.0075 for transport to watercourses and 0.0025 for transport out to sea. Because of the Action Plans for the Aquatic Environment, the nitrogen leaching to groundwater, watercourses and the sea has been estimated in the National Monitoring program of the Water Environment and Nature (NOVANA). Based on the results from this program it is possible to estimate the emission from categories; N flow to groundwater, N flow to watercourses and N flow to the sea. This explains the lower IEF used in the Danish inventory.

5.15 Summary of verification of agricultural categories

The agricultural sector accounts for eight key categories represented by 14 verification categories, cf. Table 2.1 and 2.2. For some verification categories Denmark use the IEF default values recommended by the IPCC and for others national IEF are used. A summary of the IEF verification is shown in Table 5.1.

The majority of the countries use default value for verification categories that cover the emission of N_2O from agricultural soils (4.D). An exception is N-leaching (4.D3-leaching) where the Danish IEF is lower compared to many other countries, which is due to the availability of more detailed data in Denmark, cf. section 5.14.

For 4.B-liquid, 4.B-solid and 4.B-pasture, that include N_2O emission from manure management, most countries use default IEFs from IPCC (1997). However, the Danish IEF for 4.B-liquid is slightly lower compared to other countries, which is due to emission reduction as a consequence of biogas treated slurry. 4.B-other comprises different housing systems in each country and therefore large variations in IEFs are seen between countries, cf. section 5.8.

The verification categories 4.A and 4.B from animals cover the CH_4 emission from enteric fermentation and manure management, respectively. IEFs for cattle and swine are at the same level as other countries with comparable ag-

ricultural conditions. An exception is 4.A-sheep, where the IEF for Denmark is higher than other countries, due to inclusion of emission from both mother sheep and lamb. Other countries only include emissions from mother sheep.

Table 5.1 Summary of verification of IEFs for agricultural sector.

	Same level as the majority of other countries	Denmark differ from other countries
Denmark use IPCC default values	4.D1.1	4.D3-leaching
	4.D1.2	4.B-liquid
	4.D1.4	4.B-other
	4.D3-deposition	
	4.B-solid	
	4.B-pasture	
	Same level as other comparable countries	Denmark differ from other countries
Denmark use national values	4.A-cattle	4.A-sheep
	4.A-swine	
	4.B-cattle	
	4.B-swine	

Verification of the activity data is performed with data from Eurostat (2013) and indicates low deviations ranging from 1 % to 6 %. However, a larger deviation of 11 % is seen for sheep, which is due to lower accuracy in number of sheep in 1990.

Based on these assessments and comparisons the IEF and activity data implemented in the Danish emission inventory are considered acceptable.

6 Industrial Processes

6.1 2.A1

Key subcategory: CO_2 emissions from "Total Industrial Processes – Mineral Products – Cement Production" (ktonnes).

Independent activity data: "Cement Production" (ktonnes) (UN, 2013).

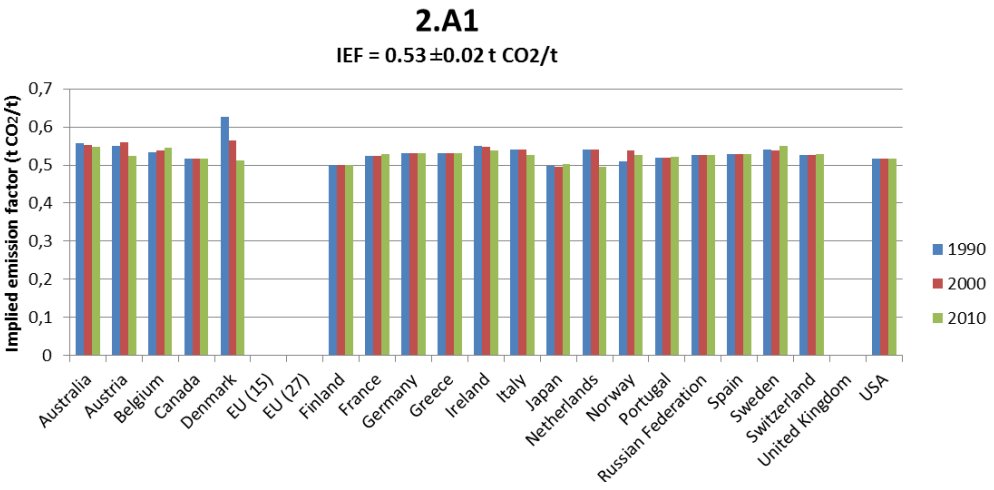


Figure 6.1a Comparison of implied emission factors reported to UNFCCC.

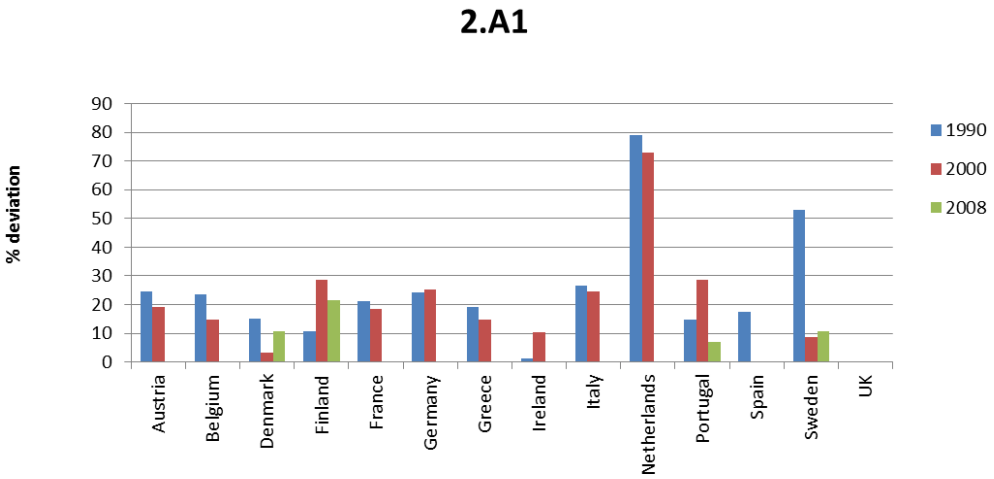


Figure 6.1b Deviation between activity data reported to UNFCCC and "Cement Production" (ktonnes) (UN, 2013).

Deviations in IEFs between countries, in Figure 6.1a, may probably arise from variations in product mix. The Danish producer has for 1990 stated the EF for three different types of clinker for grey cement to be 0.459, 0.477 and 0.669 t CO_2/t meaning that the average IEF depends on the actual product mix. In addition to clinkers for grey cement, production of white cement does have a similar high EF (>0.6 t CO_2/t).

Figure 6.1b shows the deviations between the applied activity data in national inventories and the activity reported to UN Statistical yearbook (UN, 2013). The deviation seen for Denmark may be explained by difference in activity data. The applied activity data is produced amount of clinker whereas the activity in the trade statistics probably is cement. Cement is milled clinker added e.g. fly ash or other mineral compounds.

These lines of evidence indicate good quality in implied emission factors, activity data, and reliable methodologies.

7 Waste

7.1 6.A

Key subcategory: CH_4 emissions from "Solid Waste Disposal - Managed Waste Disposal on Land" (ktonnes).

Independent activity data: "Disposal of Municipal Waste on Landfills" (ktonnes) (OECD, 1997 and 2004).

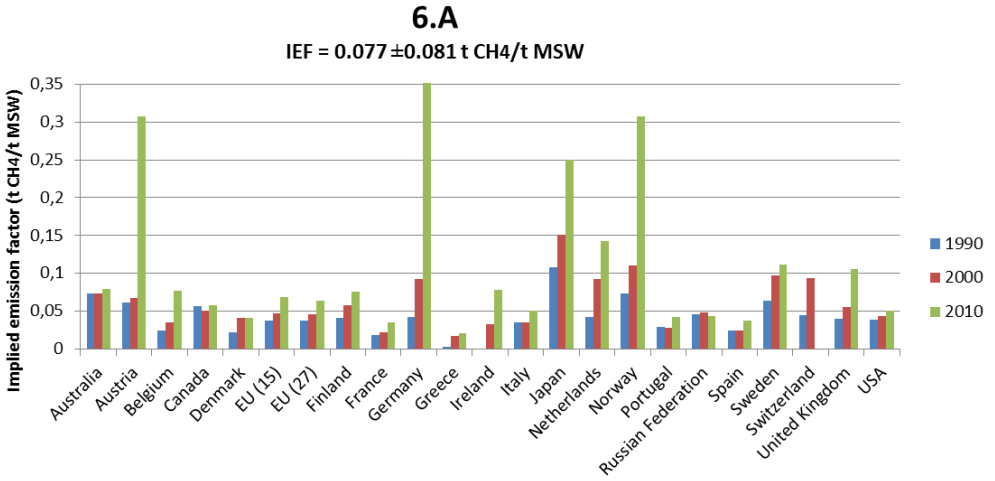


Figure 7.1a Comparison of implied emission factors reported to UNFCCC.

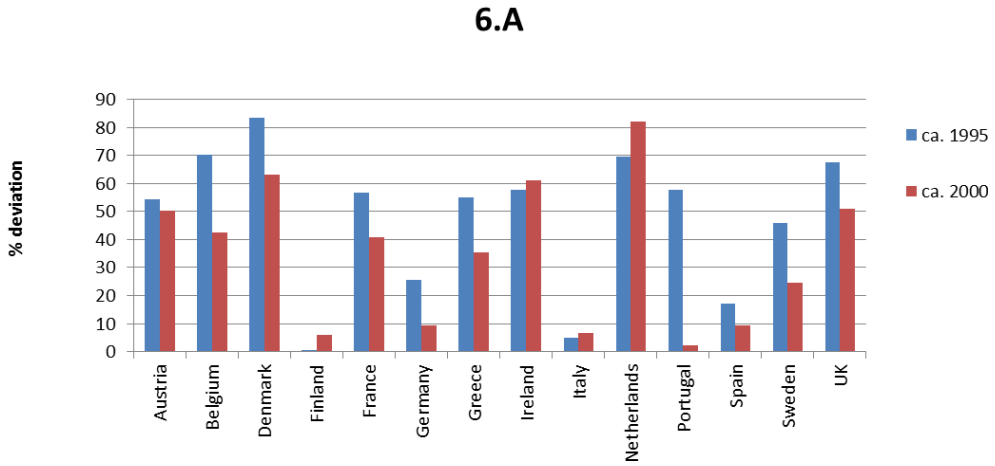


Figure 7.1b Deviation between activity data reported to UNFCCC and "Disposal of Municipal Waste on Landfills" (ktonnes) (OECD, 1997 and 2004).

As can be observed from Figure 7.1a, some countries show a high increase in the IEF for 2010 compared to 1990 and 2000. The increase may partly be explained by the fact that 1) the implied emission factors reported to UNFCCC are based on cumulative emissions resulting from decay of organic material in the deposited waste over time (historical waste) and 2) the total amount of deposited waste per year is decreasing, due to a significant development in directing MSW away from landfilling towards increased recycling. Recycling rates in Europe are highest in Austria, Germany, Belgium, the Netherlands and Switzerland (EEA, 2013), which may explain the steep increase in IEF for these countries.

Regarding Figure 7.1b, the high discrepancy between AD data reported to the UNFCCC and the OECD is due to the fact that OECD only covers part of the total solid waste deposited at landfills. According to OECD (http://stats.oecd.org), MSW constitutes waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste. This definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities, which are included in the Danish SWDS AD. The combination of 1) major initiatives to increase recycling of MSW in Denmark were taken before 2001, i.e. landfill ban, landfill and incineration tax and separate collection schemes and 2) high methane recovery rates from managed SWDS may explain the low IEFs for DK. The overall treatment of MSW in DK is characterized by low amounts of landfilling (4 %) and high amounts of incineration (54 %) in 2010 (Kjær, 2013).

8 National verification with reference approach for energy sector

In addition to the sector specific CO_2 emission inventories (the national approach), the CO_2 emission is also estimated using the reference approach described in the IPCC Reference Manual (IPCC, 1997). The reference approach is based on data for fuel production, import, export and stock change. The CO_2 emission inventory based on the reference approach is reported to the Climate Convention and used for verification of the official data in the national approach.

Data for import, export and stock change used in the reference approach originate from the annual "basic data" table prepared by the Danish Energy Agency (DEA) and published on their home page (DEA 2013). The fraction of carbon oxidised has been assumed to be 1.00. The carbon emission factors are default factors originating from the IPCC Reference Manual (IPCC, 1997). The country-specific emission factors are not used in the reference approach, the approach being for the purposes of verification. The emission factor for fossil waste is, however, based on the emission factor applied in the national approach.

The Climate Convention reporting tables include a comparison of the national approach and the reference approach estimates. To make results comparable, the incineration of fossil waste and the corresponding CO_2 emission have been added in the reference approach. Furthermore, consumption for non-energy purposes is subtracted in the reference approach, because non-energy use of fuels is included in other sectors (Industrial processes and Solvent use) in the Danish national approach.

Three fuels are used for non-energy purposes: lubricants, bitumen and white spirit. The total consumption for non-energy purposes is relatively low – 12.4 PJ in 2011.

The CO_2 emission from lube oil was 33 Gg in 2011 corresponding to 21 % of the CO_2 emission from lube oil consumption assuming full oxidation. This is in agreement with the IPCC Guideline methodology for lube oil emissions. Methodology and emission data for lube oil is shown in NIR chapter 4.8.

The CO_2 emission from white spirit was 17 Gg in 2011 corresponding to 61 % of the CO_2 emission from white spirit assuming full oxidation. The CO_2 emission data for white spirit is shown in NIR chapter 5, Table 5.4.

The CO_2 emission from bitumen is included as part of the emission from the source sectors *2A5 Asphalt roofing* and *2A6 Road paving with asphalt*.

According to IPCC Good Practice Guidance (IPCC, 2000) the difference should be within 2 %. A comparison of the national approach and the reference approach is illustrated in Figure 8.1.

In 2011, the fuel consumption rates in the two approaches differ by 0.58 % and the CO_2 emission differs by 0.52 %. In 2010, the fuel consumption rates in the two approaches differ by 0.51 % and the CO_2 emission differs by 62 %. In the period 1990-2011, both the fuel consumption and the CO_2 emission

differ by less than 2.0 %. The differences are below 1 % for all years except 1998 and 2009.

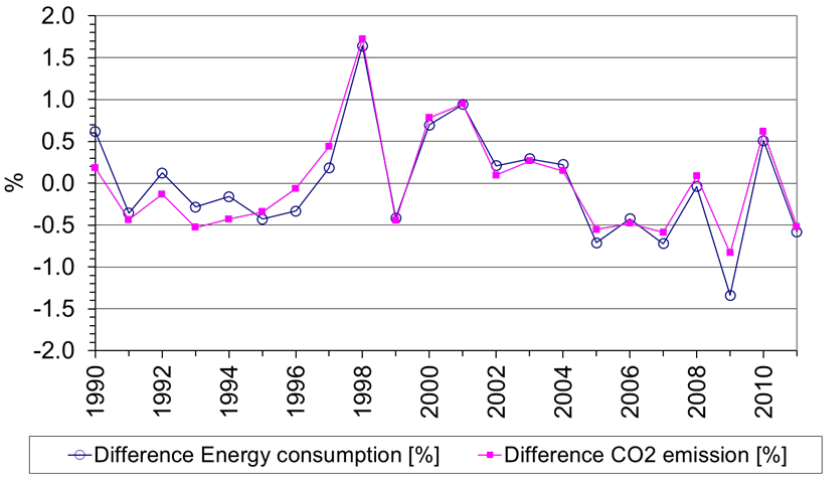


Figure 8.1 Comparison of the reference approach and the national approach.

The large differences in certain years, e.g. 1998 are due to high statistical differences in the Danish energy statistics in these years. This is illustrated in Figure 8.2.

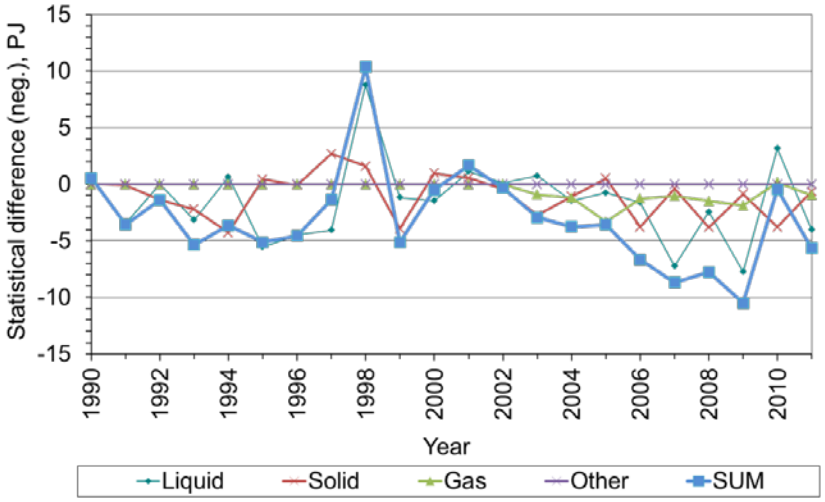


Figure 8.2 Statistical differences in the Danish energy statistics (DEA, 2013).

9 Inter-country comparison of 28 Annex II indicators covering energy and industry

As a consequence of EU decisions no. 280/2004/EC and 2005/166/EC, the EU member states have been obligated to report indicators annually to the Commission since 2005. The reporting is to occur in parallel with the obligations to report greenhouse gases according to the decisions mentioned.

The verification procedure comprises an inter-country comparison of these 28 Annex II Priority indicators, Additional indicators and Supplementary indicators, covering energy and industry. Available reported indicator values for EU15 countries, excluding Italy and Luxembourg, are used for verification.

Data for the Danish indicators have been derived directly from the CRF format if data are included there. In addition, input data to the Danish inventory have been applied. Finally, some additional data sources have been applied for the indicators; for the economic data, the source is Eurostat (2013) and building data are from Statistics Denmark (2013). The data for the transport sector are supported by data from the Danish Road Directorate and Statistics Denmark.

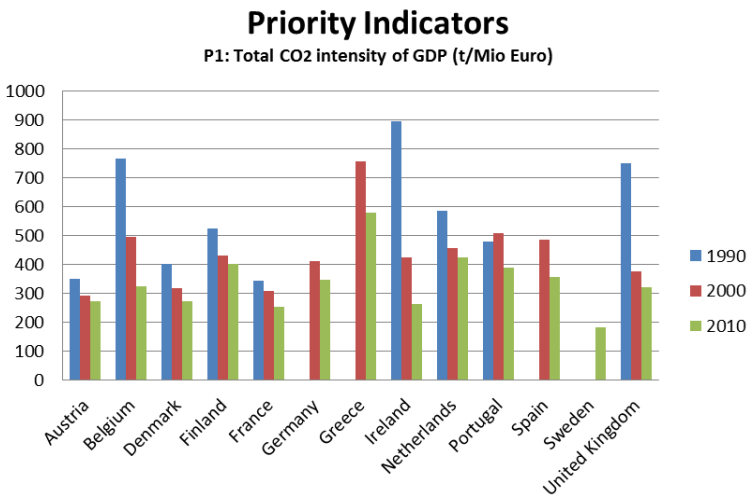
Verification criteria are consistency in time trends and comparability between countries.

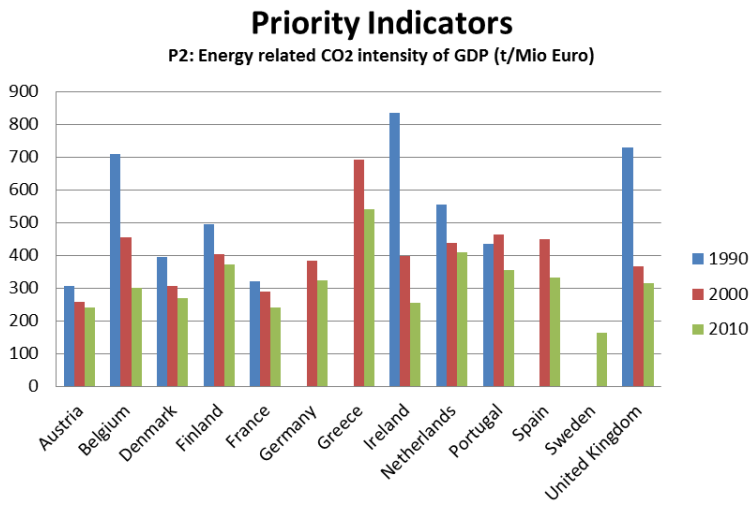
9.1 Priority Indicators

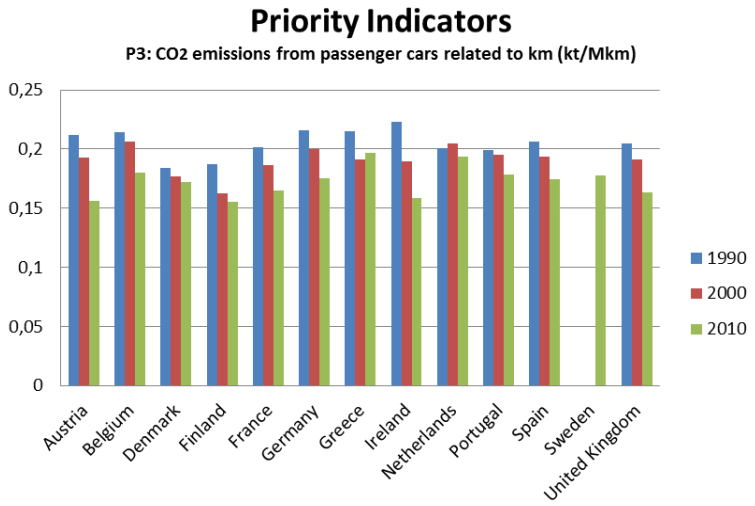
Table 9.1 Annex II priority indicators; definitions, data sources, comments for Danish indicators, mean ± standard deviation for 1990, 2000, 2010 for EU15 excluding Italy and Luxemburg. Danish value is stated and marked in italics when outside mean ± st.dev. interval.

No	Nomenclature in Eurostat energy efficiency indicators	Indicator/description	Guidance and definitions of numerator and denominator.	Comments for Danish indicators	Mean values ± standard deviation (units in third column)
P1	MACRO	Total CO_2 intensity of GDP, t/M Euro	Total CO_2 emissions (kt) (excluding LUCF) from CRF.		1990: 565 ±198 (DK 393) 2000: 438 ±125 (DK 309) 2010: 337 ±100 (DK 266)
			Gross Domestic Product (GDP) at constant 1995 prices (Source: National Accounts).		
P2	MACRO B0	Energy related CO_2 intensity of GDP, t/M Euro	CO_2 emissions from combustion of fossil fuels (IPCC source category 1A, sectoral approach).		1990: 529 ±190 (DK 381) 2000: 407 ±113 (DK 295) 2010: 316 ±94 (DK 259)
			GDP at constant 1995 prices (Source: National Accounts).		
P3	TRANSPORT C0	CO_2 emissions from passenger cars, kt/Mkm	CO_2 emissions from the combustion of fossil fuels for all transport activity with passenger cars (automobiles designated primarily for transport of persons and having capacity of 12 persons or fewer; gross vehicle weight rating of 3900 kg or less - IPCC source category 1A3bi).	The reference to 1A3bi suggests CO_2 from gasoline only. However, for the number of vehicles km it is stated that activity data should be consistent with emission data. Since the number of vehicles km relate to all passenger cars, CO_2 emissions from both gasoline and diesel driven passenger cars have been included (1A3b).	1990: 0.205 ±0.012 (DK *0.184*) 2000: 0.191 ±0.012 (DK *0.177*) 2010: 0.173 ±0.013 (DK 0.172)
			Number of vehicle kilometres by passenger cars. (Source: transport statistics). Note: Activity data should be consistent with the emission data, if possible.		
P4	INDUSTRY A1	Energy related CO_2 intensity of industry, t/M Euro	CO_2 emissions from combustion of fossil fuels in manufacturing industries, construction and mining and quarrying (except coal mines and oil and gas extraction) including combustion for the generation of electricity and heat (IPCC source category 1A2). Energy used for transport by industry should not be included here but in		1990: 377 ±120 (DK *194*) 2000: 337 ±126 (DK *185*)

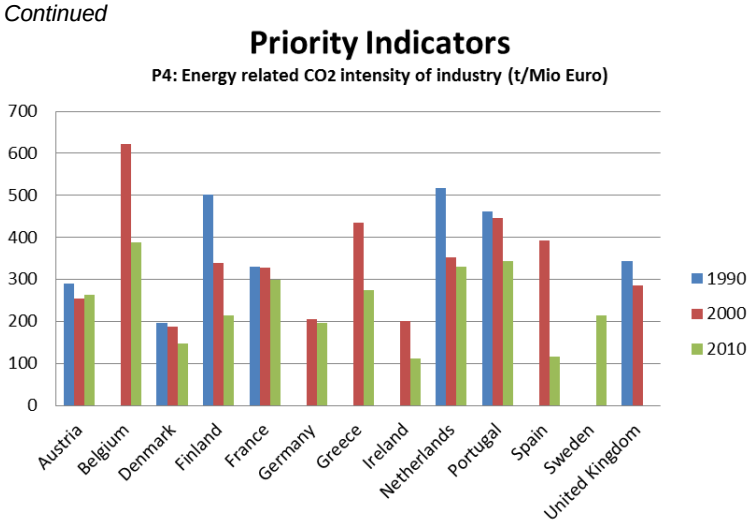
			the transport indicators. Emissions arising from off-road and other mobile machinery in industry should be included in this sector.		2010: 253 ±96 (DK *144*)
			Gross value added at constant 1995 prices in manufacturing industries (NACE 15-22, 24-37), construction (NACE 45) and mining and quarrying (except coal mines and oil and gas extraction) (NACE 13-14) (Source: National Accounts).		
P5	HOUSEHOLDS A1	Specific CO_2 emissions of households, t/dwelling	CO_2 emissions from fossil fuel combustion in households (IPCC source category 1A4b).	Including non-stationary sources in source category 1A4b.	1990: 3.19 ±1.86 (DK 2.09) 2000: 2.41 ±1.28 (DK 1.59) 2010: 2.31 ±1.61 (DK 1.11)
			Stock of permanently occupied dwellings.		
P6	SERVICES A0	CO_2 intensity of the commercial and institutional sector, t/M Euro	CO_2 emissions from fossil fuel combustion in commercial and institutional buildings in the public and private sectors (IPCC source category 1A4a). Energy used for transport by services should not be included here but in the transport indicators.		1990: 31.7 ±12.0 (DK *18.2*) 2000: 29.5 ±15.8 (DK *9.38*) 2010: 20.2 ±11.4 (DK 9.31)
			Gross value added at constant 1995 prices in services (NACE 41, 50, 51, 52, 55, 63, 64, 65, 66, 67, 70, 71, 72, 73, 74, 75, 80, 85, 90, 91, 92, 93, 99) (Source: National Accounts)		
P7	TRANSFORMATION B0	Specific CO_2 emissions of public and auto-producer power plants, t/TJ	CO_2 emissions from all fossil fuel combustion for gross electricity and heat production by public and auto-producer thermal power and combined heat and power plants. Emissions from heat only plants are not included.	Data do not include CO_2 from CHP auto-producers that relate to own energy consumption (end use not included). Same data as in supplementary indicator S9.	1990: 217 ±75 (DK 160) 2000: 167 ±63 (DK 110) 2010: 126 ±62 (DK 90)
			Gross electricity produced and any heat sold to third parties (combined heat and power plants - CHP) by public and auto-producer thermal power and combined heat and power plants. Output from heat only plants is not included. Public thermal plants generate electricity (and heat) for sale to third parties, as their primary activity. They may be privately or publicly owned. Auto-producer thermal power stations generate electricity (and heat) wholly or partly for their use as an activity, which supports their primary activity. The gross electricity generation is measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers is included. (Source: energy balance).	Data do not include output from CHP auto-producers that relate to own energy consumption (own end use not included).	

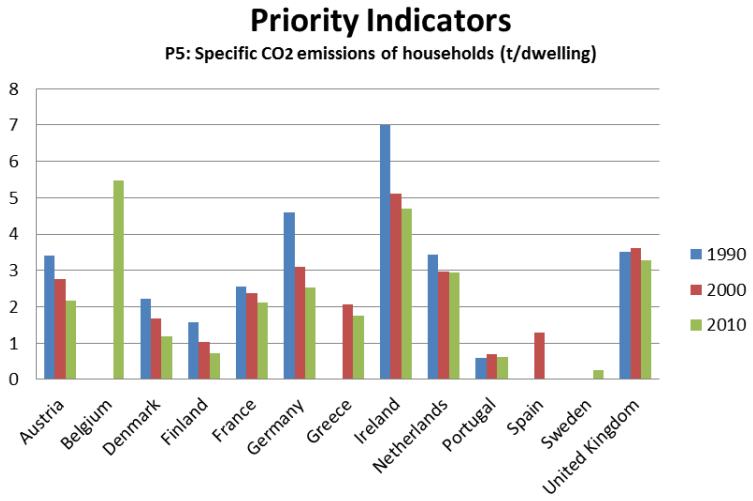

Priority Indicators
P1: Total CO2 intensity of GDP (t/Mio Euro)
1000
900
800
700
600
500
400
300
200
100
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

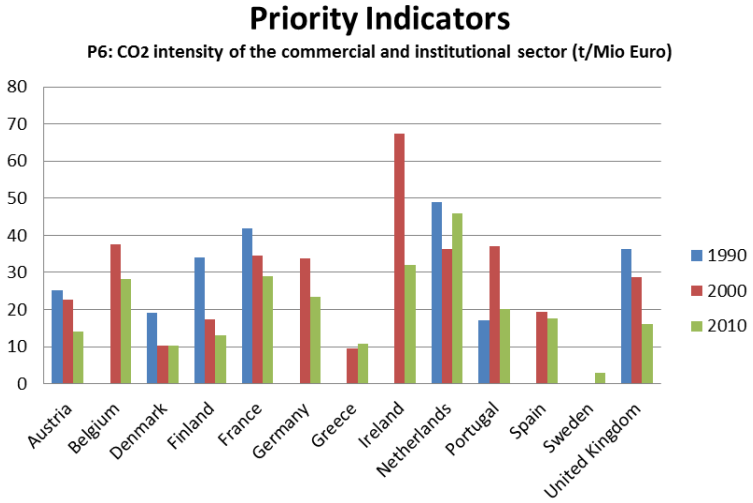

Priority Indicators
P2: Energy related CO2 intensity of GDP (t/Mio Euro)
900
800
700
600
500
400
300
200
100
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Priority Indicators
P3: CO2 emissions from passenger cars related to km (kt/Mkm)
0,25
0,2
0,15
0,1
0,05
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

Continued


Priority Indicators
P4: Energy related CO2 intensity of industry (t/Mio Euro)
700
600
500
400
300
200
100
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Priority Indicators
P5: Specific CO2 emissions of households (t/dwelling)
8
7
6
5
4
3
2
1
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Priority Indicators
P6: CO2 intensity of the commercial and institutional sector (t/Mio Euro)
80
70
60
50
40
30
20
10
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

Continued

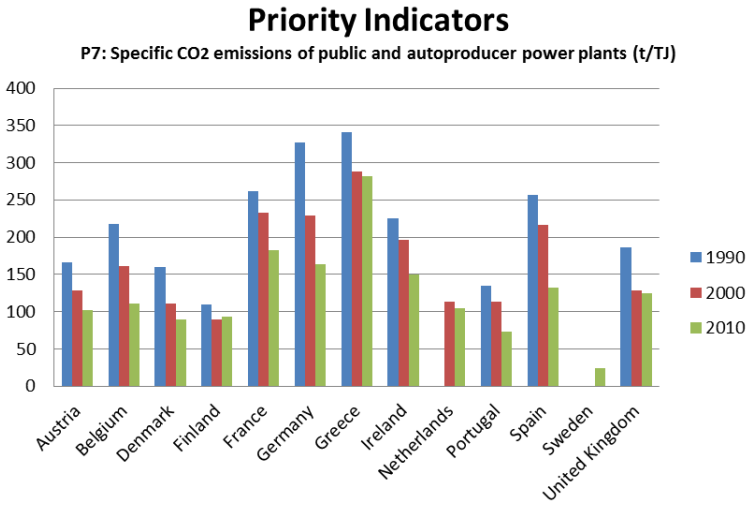


Figure 9.1 Annex II priority indicators (P1 to P7), for 1990, 2000 and 2010, for EU15 excluding Italy and Luxembourg.

See Table S.1 for summary of time trend consistency and comparable countries. For Denmark, all indicators have been decreasing due to improved energy efficiency and a change of applied fuels and increased wind power production. The levels of the Danish indicators are in general similar to the level reported by other EU countries. Three indicators are however below the confidence interval shown in Table 9.1.

9.1.1 P1 and P2: Total and Energy related CO_2 intensity of GDP

The decrease of both indicators is a result of a fluctuating but decreasing CO_2 emission and a GDP that was steadily increasing until 2007. The indicators both decreased 33 % since 1990. The fluctuations are a result of electricity trade that results in fluctuating fuel consumption – and CO_2 emission - in power producing plants.

The overall decrease of the indicators is mainly a result of:

- More efficient electricity and heat production
- Improved energy efficiency in energy consumption
- A gradual shift to less CO_2 emitting fuels, e.g. from coal to gas, and an increased use of biomass fuels
- Increased wind power production

It should be noticed that CO_2 emissions from international sea and air transport is not included in spite of the fact that these activities are included in GDP data. This is, however, in agreement with the Monitoring Mechanism definition of the indicator.

The indicator values for Denmark are within the estimated confidence interval for other countries, shown in Table 9.1.

9.1.2 P3: CO_2 emission from passenger cars related to km

The decrease in the CO_2 emission factor for Danish passenger cars until 2010 is mainly due to the phasing in of more fuel efficient diesel passenger cars in the Danish vehicle fleet, replacing older, mainly gasoline fuelled, vehicles.

The Danish indicator for the years 1990 and 2000 are below the estimated confidence interval for other countries, shown in Table 9.1. A possible ex-

planation is that other countries for this indicator only base the calculations on gasoline passenger cars, which on average are less fuel efficient than the diesel ones.

9.1.3 P4: Energy related CO_2 intensity of industry

The energy related CO_2 intensity of industry has decreased since 1990, mainly from 1996 onwards. Gross value added of industry was higher in 2011 than in 1990 whereas the CO_2 emission has decreased since 1990. The decrease of CO_2 intensity is a result of both change of fuels towards less CO_2 emitting fuels and the changes in industry structure towards less energy demanding industry.

The indicator has decreased 20 % since 1990.

The indicator for Denmark is below the estimated confidence interval for other countries, shown in Table 9.1. This is a result of the low prevalence of industries with high energy demand.

9.1.4 P5: Specific CO_2 emissions of households

The main part of the CO_2 emission from households is related to room heating and thus fluctuations are a result of year to year temperature variations. The decrease of CO_2 emission per dwelling is a result of an increased number of dwellings connected to district heating as well as an increased consumption of biomass and natural gas whereas consumption of gas oil has decreased. The consumption of electricity in households has increased 5 % since 1990. The number of dwellings has increased slightly.

The indicator has decreased 59 % since 1990.

The indicator value for Denmark is within the estimated confidence interval for other countries, shown in Table 9.1.

9.1.5 P6: The CO_2 intensity of the commercial and institutional sector

The indicator has decreased. The applied fuels have changed towards less CO_2 emitting fuels and the energy consumption efficiency has increased. In addition, the consumption of district heating has increased, and the CO_2 emission related to district heating is not included in the indicator.

The indicator for Denmark is below the estimated confidence interval for other countries in the years 1990 and 2000, see Table 9.1. A large part of the energy consumption is district heating and the emission from production of this district heating is not to be included in the indicator. Thus, it is expected that the indicator is low for Denmark.

9.1.6 P7 and S11: CO_2 intensity of power generation

Two of the indicators show carbon intensity of power generation:

- Specific CO_2 emissions of public and auto-producer power plants (P7)
- Carbon intensity of total power generation (S11)

The two indicators are closely related, but the indicator for total power generation includes the increasing electricity from wind turbines (and hydropower/solar power).

Both indicators decrease as a result of a decreasing consumption of coal and oil for power production and an increased power production based on natural gas (with lower CO_2 emission factor than coal and oil), biomass and wind turbines. Furthermore, the efficiency of power producing plants has increased. The increasing gap between the two indicators is a result of the large increase of electricity production based on biomass and wind turbines. The fluctuations follows the electricity import/export as increased production of power in export years is mainly based on coal fuelled power plants.

The indicator for public and auto-producer plants has decreased 42 % since 1990 and the indicator for total power generation has decreased 47 % since 1990.

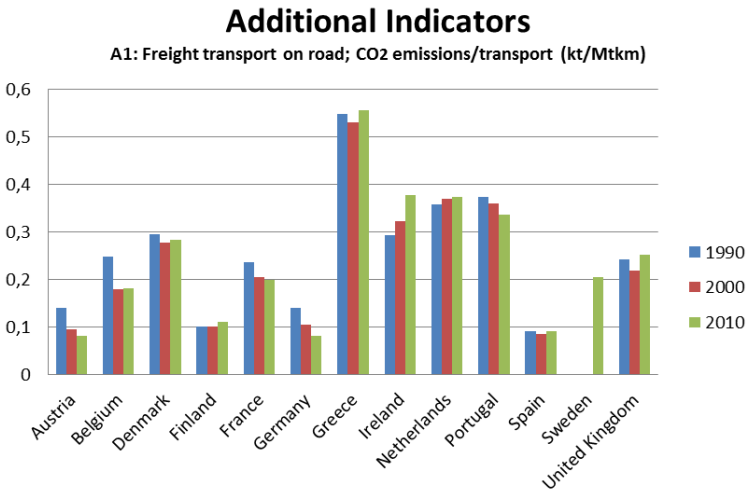
The indicator values for Denmark are within the estimated confidence interval for other countries, shown in Table 9.1.

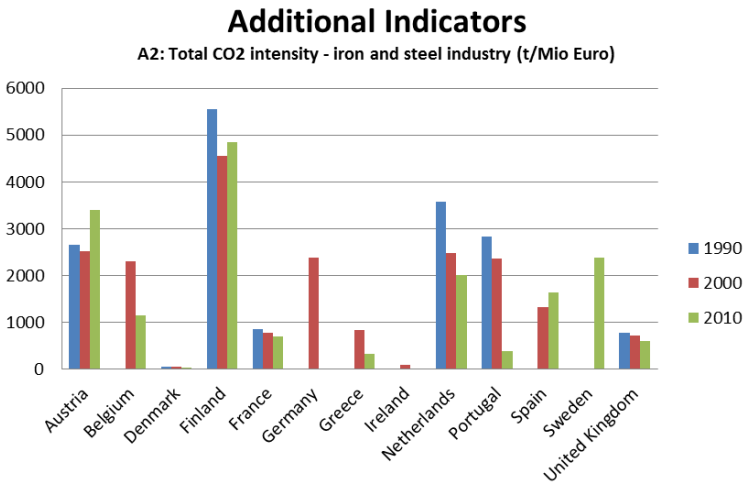
9.2 Additional Indicators

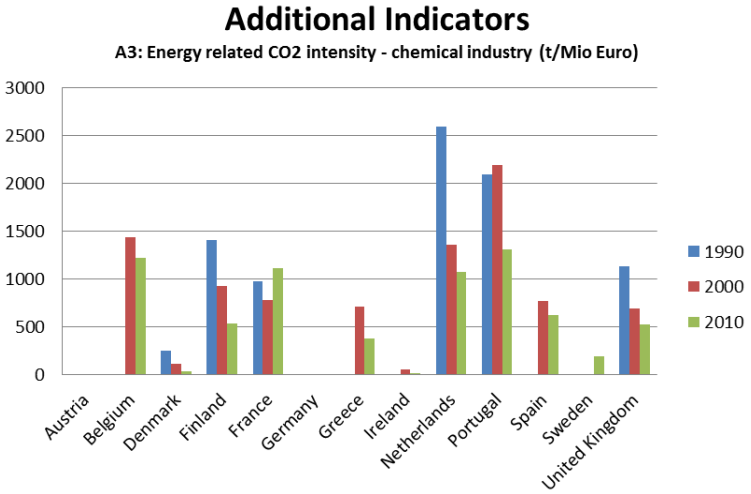
Table 9.2 Annex II additional indicators; definitions, data sources, comments for Danish indicators, mean ± standard deviation for 1990, 2000, 2010 for EU15 excluding Italy and Luxemburg. Danish value is stated and marked in italics when outside mean ± st.dev. interval.

No	Nomenclature in Eurostat energy efficiency indicators	Indicator/description	Guidance and definitions of numerator and denominator	Comments for Danish indicators	Mean values ± standard deviation (units in third column)
A1	TRANSPORT D0	CO_2 emissions from freight transport on road, kt /Mtkm	CO_2 emissions from the combustion of fossil fuel for all transport activity with light duty trucks (vehicles with a gross vehicle weight of 3900 kg or less designated primarily for transportation of light-weight cargo or which are equipped with special features such as four-wheel drive for off-road operation - IPCC source category 1A3bii) and heavy duty trucks (any vehicle rated at more than 3900 kg gross vehicle weight designated primarily for transportation of heavy-weight cargo - IPCC source category 1A3biii excluding buses).		1990: 0.256 ±0.131 (DK 0.295) 2000: 0.237 ±0.138 (DK 0.277) 2010: 0.240 ±0.142 (DK 0.284)
			Number of tonne-kilometres transported in light and heavy duty trucks on road; one tonne-kilometre represents the transport of one tonne by road over one kilometre. (source: transport statistics). Note: Activity data should be consistent with the emission data, if possible.		
A2	INDUSTRY A1.1	Total CO_2 intensity - iron and steel industry, t/M Euro	CO_2 emissions from combustion of fossil fuels in manufacture of iron and steel including combustion for the generation of electricity and heat (IPCC source category 1A2a), from the iron and steel production process (IPCC source category 2C1) and from ferroalloys production process (IPCC source category 2C2).		1990: 2330 ±1912 (DK *63*) 2000: 1704 ±1302 (DK *58*) 2010: 1489 ±1460 (DK 45)
			Gross value added at constant 1995 prices in manufacture of basic iron and steel and of ferro-alloys (NACE 27.1), manufacture of tubes (NACE 27.2), other first processing of iron and steel (NACE (27.3), casting of iron (NACE 27.51) and casting of steel (NACE 27.52). (source: National Accounts).	The level of disaggregation of activity may include additional activities compared to the requested.	
A3	INDUSTRY A1.2	Energy related CO_2 intensity - chemical industry, t/M Euro	CO_2 emissions from combustion of fossil fuels in manufacture of chemicals and chemical products including combustion for the generation of electricity and heat (IPCC source category 1A2c).		1990: 1207 ±928 (DK *249*) 2000: 821 ±658 (DK *116*) 2010: 588 ±487 (DK *38*)
			Gross value added at constant 1995 prices in manufacture of chemicals and chemical products (NACE 24) (source: National Accounts).		
A4	INDUSTRY A1.3	Energy related CO_2 intensity - glass, pottery and building materials industry,	CO_2 emissions from combustion of fossil fuels in manufacture of non-metallic mineral products (NACE 26) including combustion for the generation of electricity and heat.	The energy related CO_2 emission is only related to consumption of fossil fuels at the production site.	1990: 1652 ±671 (DK 1384) 2000: 1400 ±753 (DK 1617)

		t/M Euro	Gross value added at constant 1995 prices in manufacture of non-metallic mineral products (NACE 26) (source: National Accounts).		2010: 1586 ±831 (DK 2178)
A5	INDUSTRY C0.1	Specific CO_2 emissions of iron and steel industry, t/t	CO_2 emissions from combustion of fossil fuels in manufacture of iron and steel including combustion for the generation of electricity and heat (IPCC source category 1A2a), from the iron and steel production process (IPCC source category 2C1) and from ferroalloys production process (IPCC source category 2C2).	The definition of this numerator is identical to the numerator for additional priority indicator 2. However, to ensure that the numerator and the denominator refer to the same activity CO_2 emission data related to production of oxygen steel has been calculated.	1990: 1.45 ±0.74 (excl. Portugal) (DK *0.22*) 2000: 1.37 ±0.81 (excl. Portugal) (DK *0.24*) 2010: 1.44 ±0.69 (excl. Portugal) (DK -)
			Production of oxygen steel (NACE 27) (source: production statistics).	Production of EAF (electric arc furnace) steel. No production of steel billets and slabs from scrap at the electro steelwork 2002-2004.	
A6	INDUSTRY C0.2	Specific energy related CO_2 emissions of cement industry, t/t	CO_2 emissions from combustion of fossil fuels in manufacture of non-metallic mineral products (NACE 26) including combustion for the generation of electricity and heat.	Based on the indicator definition Specific energy related CO_2 emissions of cement industry and the definition of the denominator Cement production it has been decided to include only the CO_2 emissions from production of cement. Thus, data are not identical to the CO_2 emission data for additional priority indicator 2.	1990: 0.907 ±0.907 (DK 0.60) 2000: 0.511 ±0.156 (DK 0.50) 2010: 0.527 ±0.168 (DK 0.57)
			Cement production (NACE 26) (source: production statistics).	The produced amount is obtained from the environmental report of the cement production company. Data are reported in TCE (total cement equivalents) and this value has been used in the inventory.	


Additional Indicators
A1: Freight transport on road; CO2 emissions/transport (kt/Mtkm)
0,6
0,5
0,4
0,3
0,2
0,1
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Additional Indicators
A2: Total CO2 intensity - iron and steel industry (t/Mio Euro)
6000
5000
4000
3000
2000
1000
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Additional Indicators
A3: Energy related CO2 intensity - chemical industry (t/Mio Euro)
3000
2500
2000
1500
1000
500
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

Continued

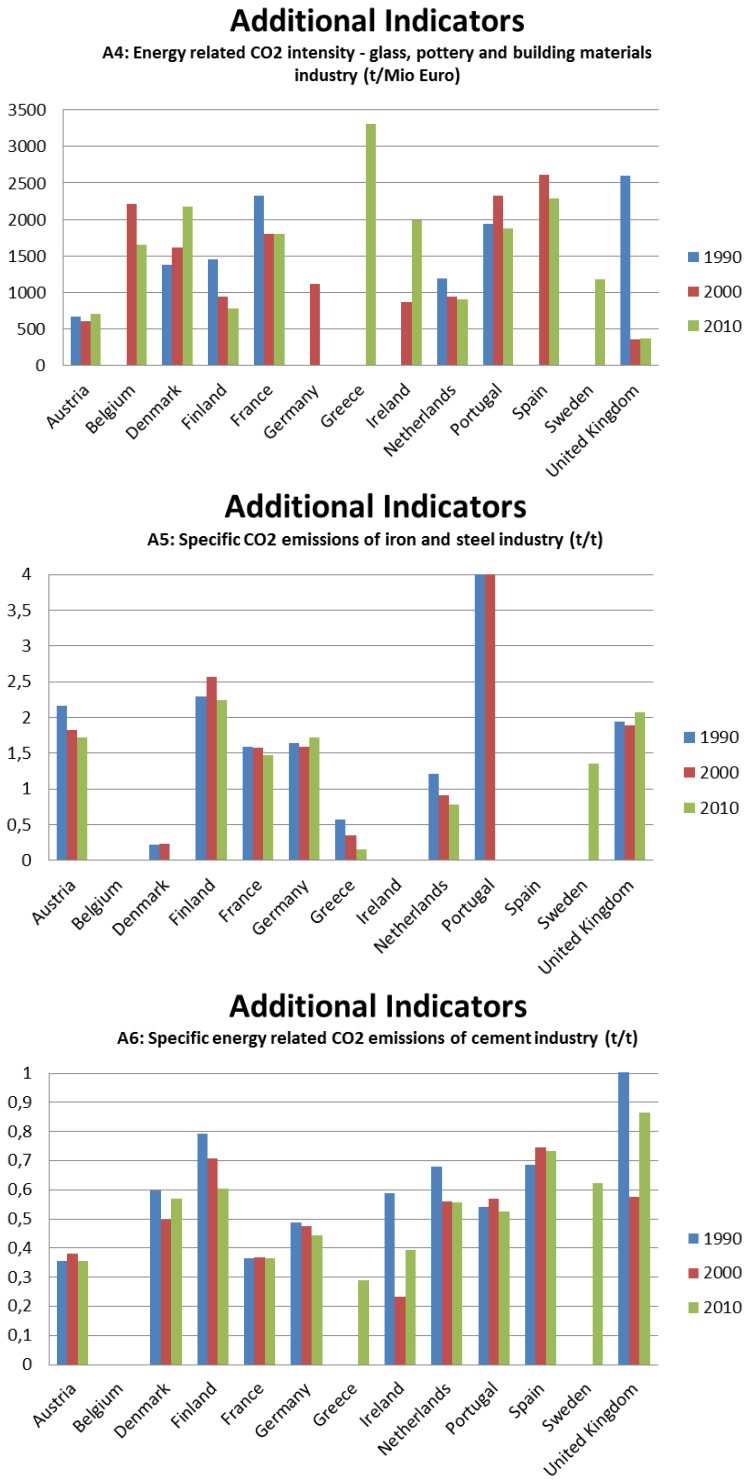


Figure 9.2 Annex II additional indicators (A1 to A6), for 1990, 2000 and 2010, for EU15 excluding Italy and Luxembourg.

See Table S.1 for summary of time trend consistency and comparable countries. Three of the indicators are below the estimated confidence interval for all countries.

A2 Total CO_2 intensity - iron and steel industry, t/M Euro and

A3 Energy related CO_2 intensity - chemical industry, t/M Euro

The Danish indicators A2 and A3 are below the average indicators and the explanation may be that the Danish companies use external produced heat and power. The CO_2 emissions related to heat and power are therefore not included in the emissions accounted for in CRF category 1A2a.

A5 Specific CO_2 emissions of iron and steel industry, t/t

The low Danish indicator may be explained by lack of basic iron and steel production, e.g. as an integrated iron and steel plant. Denmark have only had an Electric Arc Furnace (EAF) for melting of iron scrap, however, this plant was closed in 2005.

9.3 Supplementary Indicators

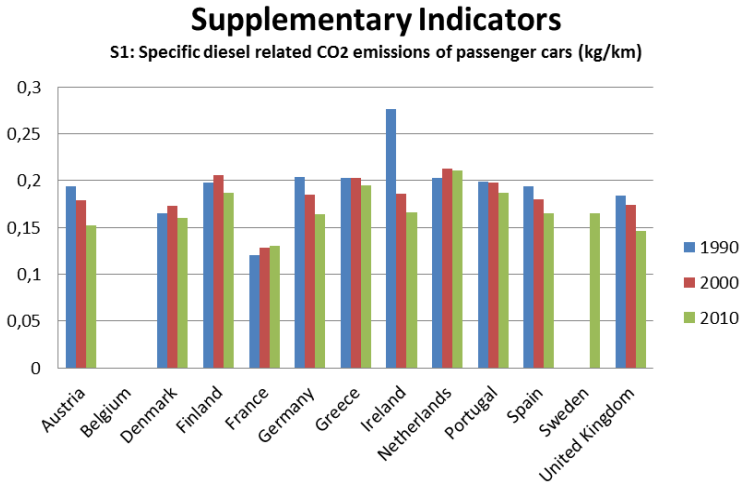
Table 9.3 Annex II supplementary indicators; definitions, data sources, comments for Danish indicators, mean ± standard deviation for 1990, 2000, 2010 for EU15 excluding Italy and Luxemburg. Danish value is stated and marked in italics when outside mean ± st.dev. interval.

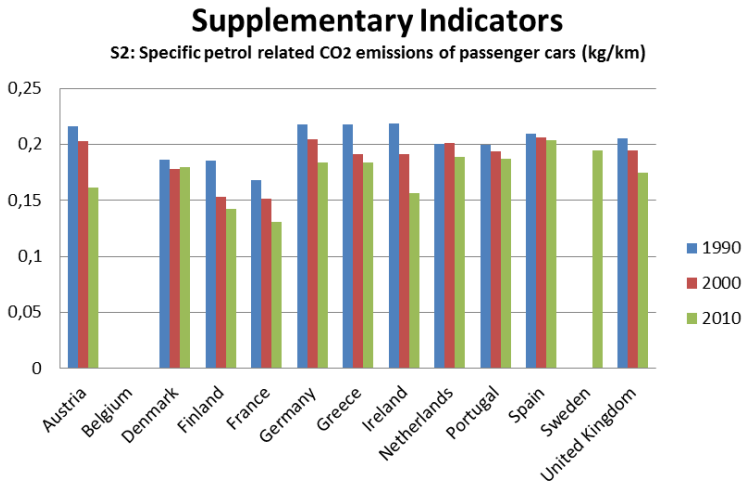
No	Nomenclature in Eurostat energy efficiency indicators	Indicator/description	Guidance and definitions of numerator and denominator	Comments for Danish indicators	Mean values ± standard deviation (units in third column)
S1	TRANSPORT B0	Specific diesel related CO_2 emissions of passenger cars, kg/km	CO_2 emissions from the combustion of diesel for all transport activity with passenger cars (automobiles designated primarily for transport of persons and having capacity of 12 persons or fewer; gross vehicle weight rating of 3900 kg or less - IPCC source category 1A3bi only diesel).		1990: 0.194 ±0.036 (DK 0.165) 2000: 0.184 ±0.023 (DK 0.173) 2010: 0.169 ±0.022 (DK 0.160)
			Number of vehicle kilometres of total diesel-driven passenger cars licensed to use roads open to public traffic. (source: transport statistics).		
S2	TRANSPORT B0	Specific petrol related CO_2 emissions of passenger cars, kg/km	CO_2 emissions from the combustion of petrol for all transport activity with passenger cars (automobiles designated primarily for transport of persons and having capacity of 12 persons or fewer; gross vehicle weight rating of 3900 kg or less – IPCC source category 1A3bi only petrol).		1990: 0.202 ±0.016 (DK 0.186) 2000: 0.188 ±0.019 (DK 0.178) 2010: 0.174 ±0.022 (DK 0.180)
			Number of vehicle kilometres of total petrol-driven passenger cars licensed to use roads open to public traffic. (source: transport statistics).		
S3	TRANSPORT C0	Specific CO_2 emissions of passenger cars, kg/pkm	CO_2 emissions from the combustion of fossil fuels for all transport activity with passenger cars (automobiles designated primarily for transport of persons and having capacity of 12 persons or fewer; gross vehicle weight rating of 3900 kg or less - IPCC source category 1A3bi).	The reference to 1A3bi suggests CO_2 from gasoline only. However, data should be consistent with emission data. Since Number of passenger-kilometres travelled in passenger cars relate to all passenger cars, CO_2 emissions from both gasoline and diesel driven passenger cars have been included (1A3b).	1990: 0.130 ±0.019 (DK *0.104*) 2000: 0.126 ±0.020 (DK 0.110) 2010: 0.118 ±0.016 (DK 0.112)
			Number of passenger-kilometres travelled in passenger cars; one passenger-kilometre is the transport of one passenger over one kilometre. (source: transport statistics) Note: Activity data should be consistent with the emission data, if possible.		
S4	TRANSPORT E1	Specific air-transport emissions, kg/passenger	CO_2 emissions from domestic air transport (commercial, private, agricultural, etc.), including take-offs and landings (IPCC source category 1A3aii). Exclude use of fuel at airports for ground transport. Also exclude fuel for stationary combustion at airports.		1990: 136 ±59 (DK 97) 2000: 114 ±44 (DK 78)

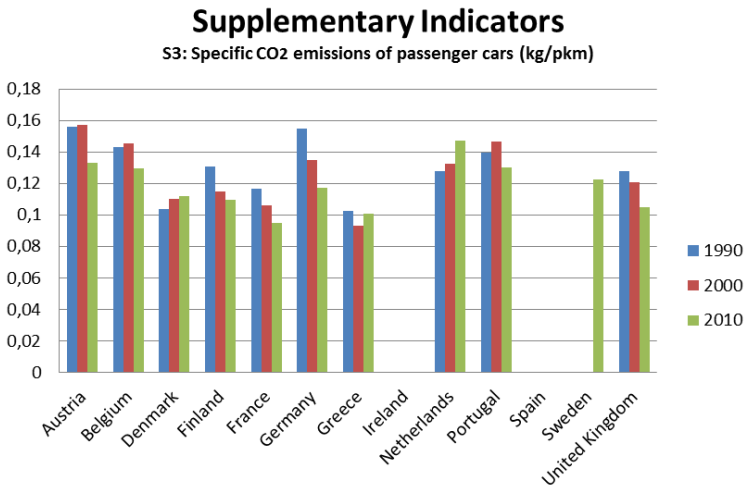
			Number of persons, excluding on-duty members of the flight and cabin crews, making a journey by air (domestic aviation only) (source: transport statistics). Note: Activity data should be consistent with the emission data, if possible.		2010: 96 ±39 (DK 66)
S5	INDUSTRY A1.4	Energy related CO_2 intensity - food, drink and tobacco industry, t/M Euro	CO_2 emissions from combustion of fossil fuels in manufacture of food products and beverages and tobacco products including combustion for the generation of electricity and heat (IPCC source category 1A2e).		1990: 388 ±123 (DK 401) 2000: 294 ±122 (DK 346) 2010: 235 ±106 (DK 326)
			Gross value added at constant 1995 prices in manufacture of food products and beverages (NACE 15) and tobacco products (NACE 16) (source: National Accounts).		
S6	INDUSTRY A1.5	Energy related CO_2 intensity - paper and printing industry, t/M Euro	CO_2 emissions from combustion of fossil fuels in manufacture of pulp, paper and paper products and publishing, printing and reproduction of recorded media including emissions from combustion for the generation of electricity and heat (IPCC source category 1A2d).		1990: 549 ±383 (DK *138*) 2000: 367 ±255 (DK *51*) 2010: 307 ±221 (DK *61*)
			Gross value added at constant 1995 prices in manufacture of pulp, paper and paper products (NACE 21) and publishing, printing and reproduction of recorded media (NACE 22) (source: National Accounts).		
S7	HOUSEHOLDS A0	Specific CO_2 emissions of households for space heating, t/m²	CO_2 emissions from fossil fuel combustion for space heating in households.	CO_2 from biofuels not included.	1990: 24 ±16 (DK 16) 2000: 18 ±9.5 (DK 12) 2010: 14 ±9.4 (DK 8.9)
			Total surface area of permanently occupied dwellings.		
S8	SERVICES B0	Specific CO_2 emissions of commercial and institutional sector for space heating, kg/m²	CO_2 emissions from fossil fuel combustion for space heating in commercial and institutional buildings in the public and private sectors.		1990: 23 ±13 (DK *8.2*) 2000: 15 ±12 (DK 4.4) 2010: 13 ±10 (DK 4.1)
			Total surface area of services buildings (NACE 41, 50, 51, 52, 55, 63, 64, 65, 66, 67, 70, 71, 72, 73, 74, 75, 80, 85, 90, 91, 92, 93, 99).	Definition according to Danish BBR.	
S9	TRANSFORMATION D0	Specific CO_2 emissions of public power plants, t/TJ	CO_2 emissions from all fossil fuel combustion for gross electricity and heat production by public thermal power and combined heat and power plants (IPCC source categories 1A1ai and 1A1aii). Emissions from heat only plants are not included.	CO_2 from gaseous fossil fuels (1A1aiii) in Public Electricity and Heat Production included. Auto-producers not included. Heat only plants not included.	1990: 206 ±86 (DK 160) 2000: 184 ±73 (DK 115) 2010: 139 ±83 (DK 96)
			Gross electricity produced and any heat sold to third parties (combined heat and power plants - CHP) by public thermal power and combined heat and power plants. Output from heat only plants is not included. Public thermal plants gener-	Auto-producers not included. Gross electricity production and net district heating production.	

			ate electricity (and heat) for sale to third parties, as their primary activity. They may be privately or publicly owned. The gross electricity generation is measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers is included (source: energy balance).		
S10	TRANSFORMATION E0	Specific CO_2 emissions of auto-producer plants, t/TJ	CO_2 emissions from all fossil fuel combustion for gross electricity and heat production by auto-producer thermal power and combined heat and power plants.	Auto-producers power plants and CHP plants.	1990: 172 ±109 (DK 120) 2000: 118 ±71 (DK 63) 2010: 82 ±34 (DK *35*)
			Gross electricity produced and any heat sold to third parties (combined heat and power - CHP) by auto-producer thermal power and combined heat and power plants. Auto-producer thermal power stations generate electricity (and heat) wholly or partly for their use as an activity, which supports their primary activity. The gross electricity generation is measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers is included (source: energy balance).	Auto-producers power plants and CHP. Gross electricity production and net district heating production.	
S11	TRANSFORMATION	Carbon intensity of total power generation, t/TJ	CO_2 emissions from all fossil fuel combustion for gross electricity and heat production by public thermal power and combined heat and power plants and by auto-producer thermal power and combined heat and power plants. Emissions from heat only plants are not included.	Data do not include CO_2 from CHP auto-producers that relate to own energy consumption (end use not included).	1990: 165 ±91 (DK 157) 2000: 134 ±75 (DK 103) 2010: 98 ±65 (DK 80)
			Gross electricity produced and any heat sold to third parties (combined heat and power - CHP) by public and auto-producer power and combined heat and power plants. Includes electricity production from renewable sources and nuclear power. (source: energy balance).	Thermal plants included as well as Wind turbines and hydro power.	
S12	TRANSPORT	Carbon intensity of transport, t/TJ	CO_2 emissions from fossil fuels for all transport activity (IPCC source category 1A3).		1990: 68 ±6.5 (DK 73) 2000: 68 ±6.6 (DK 73) 2010: 65 ±7.4 (DK *73*)
			Includes total final energy consumption of transport from all energy sources (including biomass and electricity consumption) (source: energy balance).	Including biomass and electricity consumption.	
S13	INDUSTRY C0.3	Specific energy related CO_2 emissions of paper industry, t/t	CO_2 emissions from combustion of fossil fuels in manufacture of pulp, paper and paper products and publishing, printing and reproduction of recorded media including emissions from combustion for the generation of electricity and heat (IPCC source category 1A2d).		1990: 0.577 ±0.299 (DK -) 2000: 0.485 ±0.298 (DK -) 2010: 0.327 ±0.204 (DK -)
			Physical output of paper (NACE 21) (source: production statistics).	The indicator has not been included due to the fact that there is no production of virgin paper pulp in Denmark; however, there is a production of recycled paper	

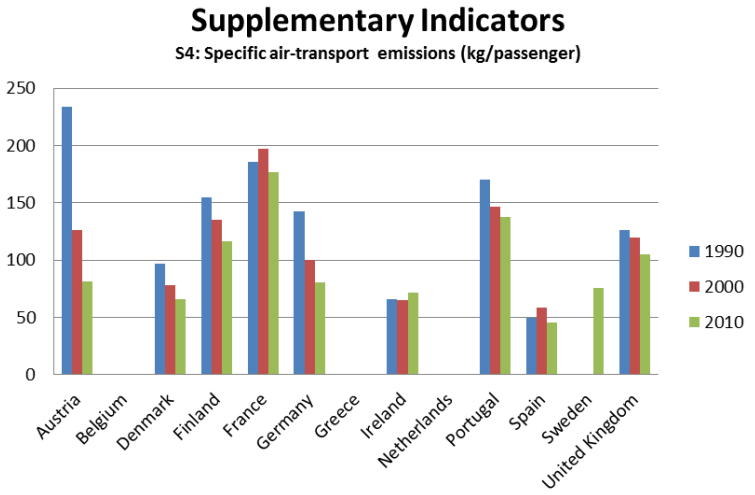
				pulp. Production of semi-chemical pulp in Denmark ceased in 1997.	
S14	INDUSTRY	CO_2 emissions related to total final energy consumption in the industry sector (kt/PJ)	Emissions from combustion of fossil fuels in manufacturing industries, construction and mining and quarrying (except coal mines and oil and gas extraction) including combustion for the generation of electricity and heat (IPCC source category 1A2). Energy used for transport by industry should not be included here but in the transport indicators. Emissions arising from off-road and other mobile machinery in industry should be included in this sector.		1990: 54 ±8.0 (DK 47) 2000: 49 ±9.4 (DK 48) 2010: 42 ±12 (DK 43)
			Includes total final energy consumption of industry from all energy sources (including biomass and electricity consumption) (source: energy balance).	Manufacturing industry and Construction. Includes consumption of electricity and district heating. Fuel consumption for auto-producer CHP not included if the produced energy is sold (only end use is included).	
S15	HOUSEHOLDS	CO_2 emissions related to total energy consumption from households (kt/PJ)	CO_2 emissions from fossil fuel combustion in households (IPCC source category 1A4b).		1990: 37 ±12 (DK 30) 2000: 35 ±12 (DK 23) 2010: 29 ±15 (DK 14)
			Includes total final energy consumption of households from all energy sources (including biomass and electricity consumption) (source: energy balance).	Includes consumption of biomass, electricity and district heating.	

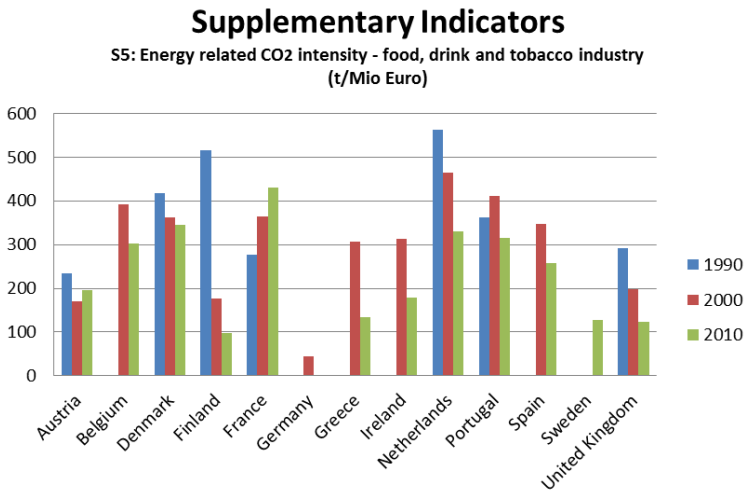

Supplementary Indicators
S1: Specific diesel related CO2 emissions of passenger cars (kg/km)
0,3
0,25
0,2
0,15
0,1
0,05
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

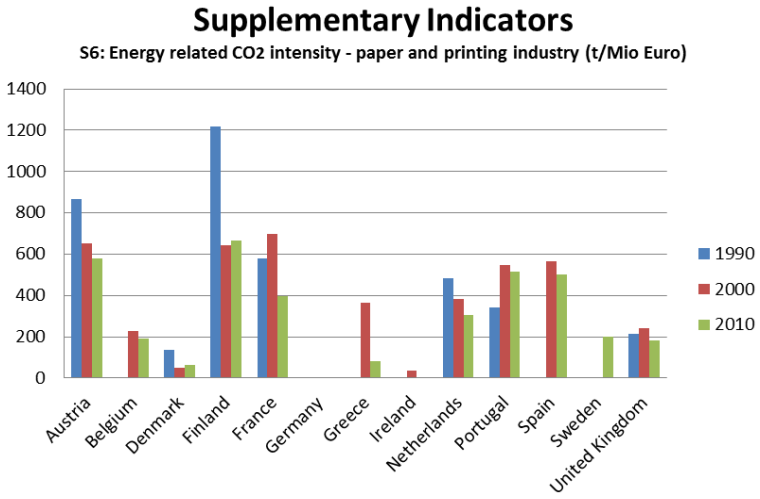

Supplementary Indicators
S2: Specific petrol related CO2 emissions of passenger cars (kg/km)
0,25
0,2
0,15
0,1
0,05
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Supplementary Indicators
S3: Specific CO2 emissions of passenger cars (kg/pkm)
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

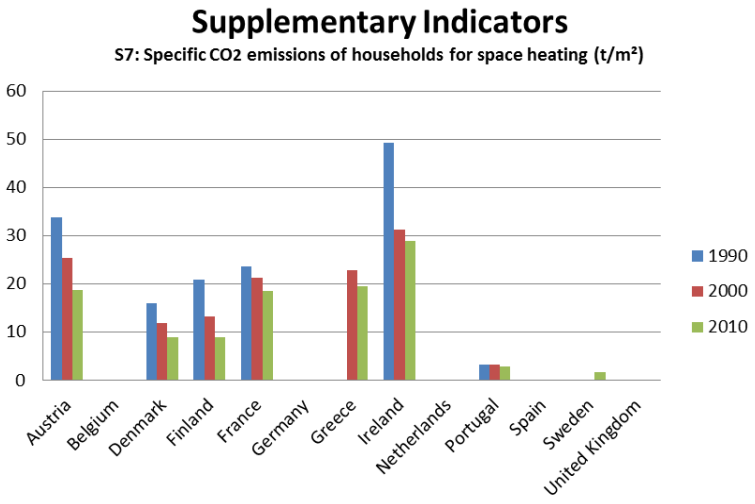
Continued

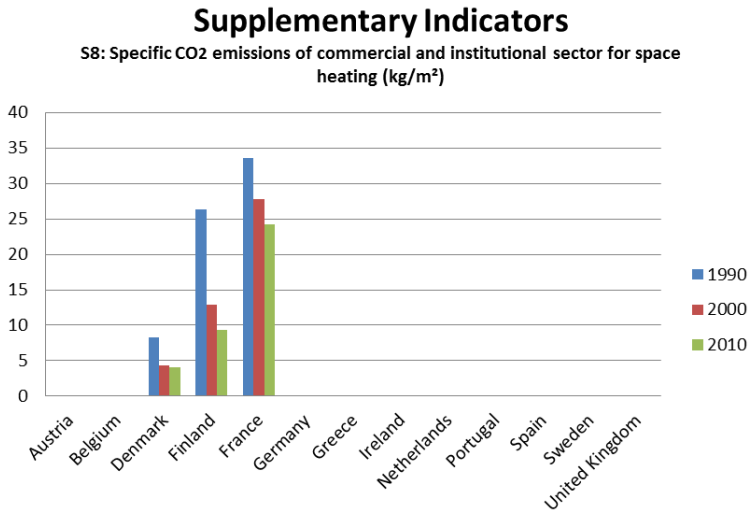

Supplementary Indicators
S4: Specific air-transport emissions (kg/passenger)
250
200
150
100
50
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

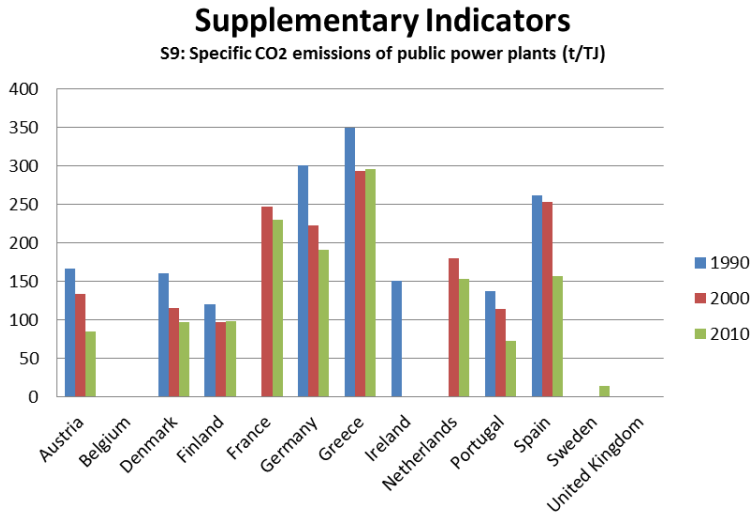

Supplementary Indicators
S5: Energy related CO2 intensity - food, drink and tobacco industry (t/Mio Euro)
600
500
400
300
200
100
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Supplementary Indicators
S6: Energy related CO2 intensity - paper and printing industry (t/Mio Euro)
1400
1200
1000
800
600
400
200
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

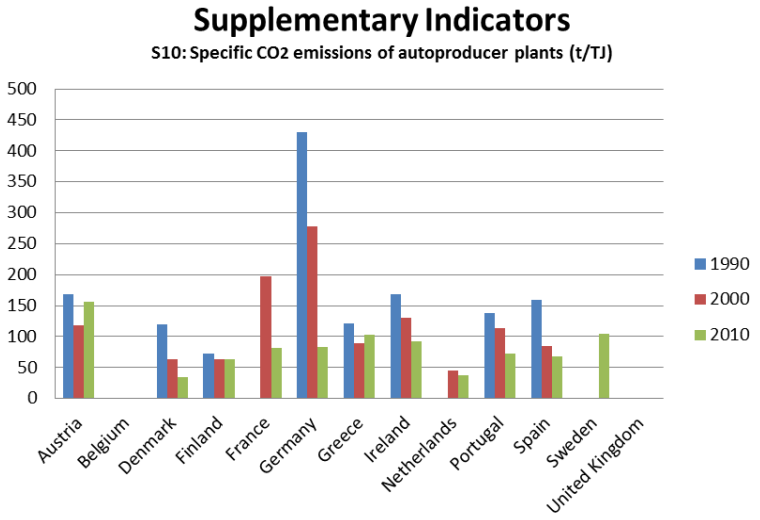
Continued

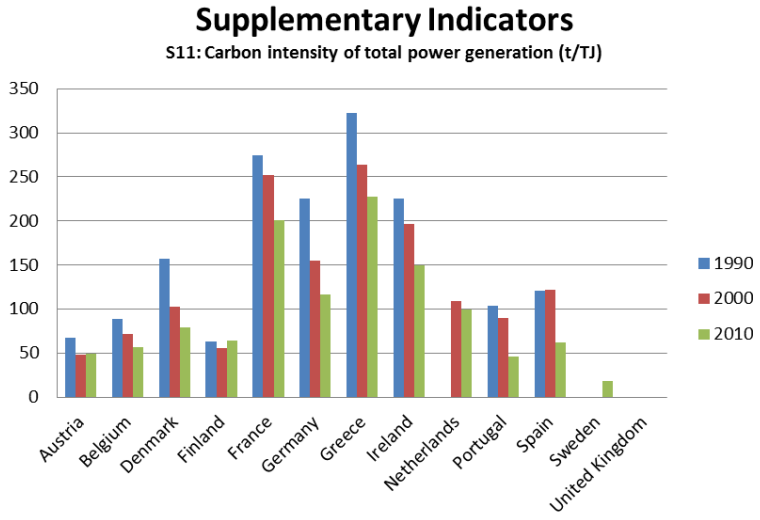

Supplementary Indicators
S7: Specific CO2 emissions of households for space heating (t/m²)
60
50
40
30
20
10
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

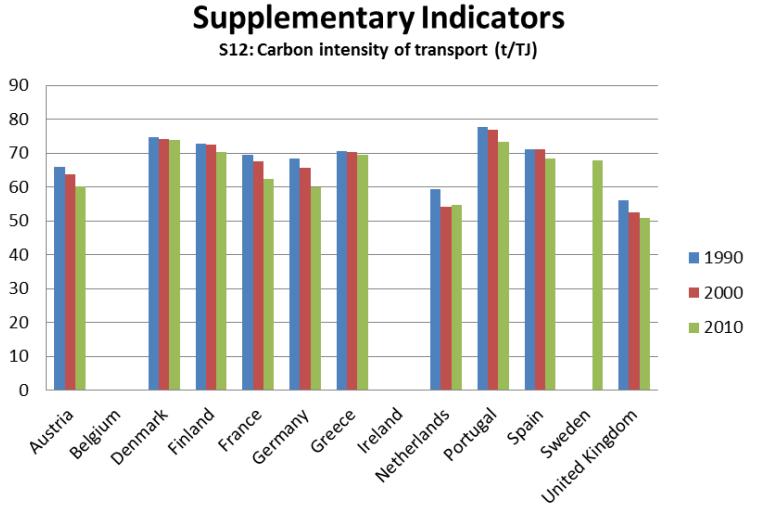

Supplementary Indicators
S8: Specific CO2 emissions of commercial and institutional sector for space heating (kg/m²)
40
35
30
25
20
15
10
5
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Supplementary Indicators
S9: Specific CO2 emissions of public power plants (t/TJ)
400
350
300
250
200
150
100
50
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

Continued


Supplementary Indicators
S10: Specific CO2 emissions of autoproducer plants (t/TJ)
500
450
400
350
300
250
200
150
100
50
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Supplementary Indicators
S11: Carbon intensity of total power generation (t/TJ)
350
300
250
200
150
100
50
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010


Supplementary Indicators
S12: Carbon intensity of transport (t/TJ)
90
80
70
60
50
40
30
20
10
0
Austria
Belgium
Denmark
Finland
France
Germany
Greece
Ireland
Netherlands
Portugal
Spain
Sweden
United Kingdom
1990
2000
2010

Continued

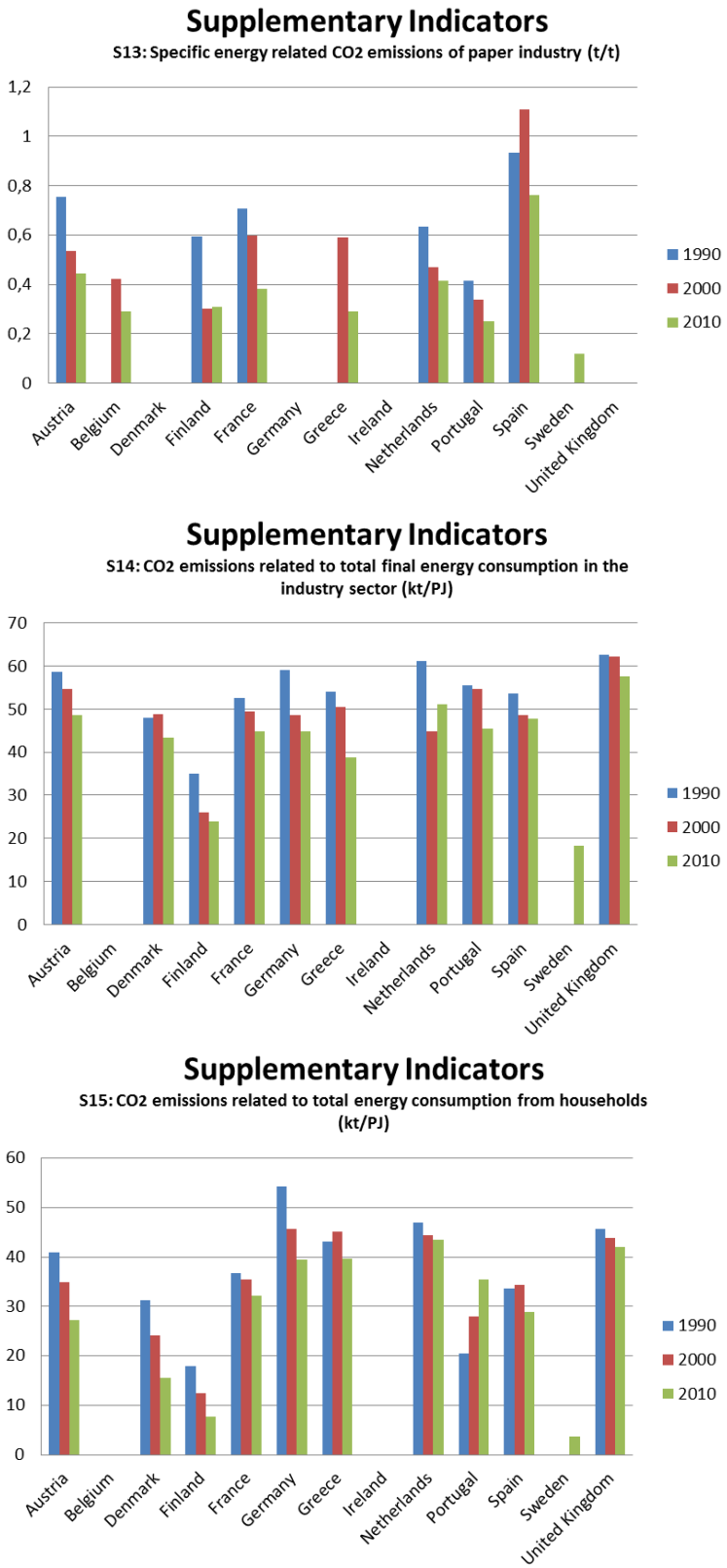


Figure 9.3 Annex II supplementary indicators (S1 to S15), for 1990, 2000 and 2010, for EU15 excluding Italy and Luxembourg.

See Table S.1 for summary of time trend consistency and comparable countries. Four indicators are below the confidence interval estimated for all countries and one indicator is above.

9.3.1 S3 Specific CO_2 emissions of passenger cars, t/pkm

Although the km related CO_2 emission factors for passenger cars (indicator P3) has decreased from 1990 to 2010, the passenger load factor (number of passengers per vehicle km) has decreased from 1.77 to 1.54 in the same period. This has resulted in an increase in the specific CO_2 emissions per passenger km driven from 1990 to 2010.

The Danish indicator value for 1990 is below the confidence interval estimated on the basis of all country indicators. As explained in the above text, in 1990 the Danish passenger load factor was relatively high, and consequently the specific CO_2 emissions per passenger km driven became relatively low.

9.3.2 S6 Energy related CO_2 intensity - paper and printing industry, t/M Euro

The Danish indicator S6 is below the average indicators and the explanation may be that the Danish companies use external produced heat and power. The CO_2 emissions related to heat and power is therefore not included in the emissions accounted for in 1A2d.

9.3.3 S7 Specific CO_2 emissions of households for space heating, t/m²

The indicator has decreased 44 % since 1990. The decrease is a result of the increase use of district heating, improved insulation of buildings and increased use of biomass and natural gas whereas consumption of gas oil has decreased. The indicator for Denmark is within the estimated confidence interval for all countries.

9.3.4 S8 Specific CO_2 emissions of commercial and institutional sector for space heating, kg/m²

Only Denmark, Finland and France have reported this indicator. The Danish indicator value for 1990 is below the confidence interval estimated for all three countries. The low indicator value is a result of the use of district heating. The emission from production of district heating is not included in the indicator.

9.3.5 S9 Specific CO_2 emissions of public power plants, t/TJ

The indicator has decreased 40 % for Denmark. Improved total efficiency of the plants and change of applied fuels have contributed to the decrease. The indicator for Denmark is within the estimated confidence interval for all countries.

9.3.6 S10 Specific CO_2 emissions of auto-producer plants, t/TJ

In Denmark, a large and increasing part of the auto-producer plants are based on biomass or waste incineration. The high total efficiency of the Danish plants that is possible due to the use of district heating. District heating also contributes to the relatively low indicator for Denmark. In 2010, the indicator is below the confidence interval estimated for all countries.

9.3.7 S11 Carbon intensity of total power generation, t/TJ

See Priority Indicator 7 (P7) above.

9.3.8 S12 Carbon intensity of transport, t/TJ

The variations in carbon intensity of transport between countries are the result of the consumption of different fossil fuel types (diesel, gasoline, residual oil, LPG being the most prominent), biodiesel, bio ethanol and the consumption of electricity by railways.

9.3.9 S13 Specific energy related CO_2 emissions of paper industry, t/t

The indicator has not been included due to the fact that there is no production of virgin paper pulp in Denmark; however, there is a production of recycled paper pulp. Production of semi-chemical pulp in Denmark ceased in 1997.

References

DEA, 2013: Energistyrelsen – Danish Energy Agency. Energy Statistics 2011. Available at: http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Aarsstatistik/Sider/Forside.aspx (08/02-2013).

EEA, 2013: EEA Report No 2/2013. Managing municipal solid waste — a review of achievements in 32 European countries. Available at: http://www.eea.europa.eu/publications/managing-municipal-solid-waste

Eurostat, 2013: European Commission. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (09/01-2013).

FAOstat, 2013: Food and Agriculture Organization of the United Nations. Available at: http://faostat3.fao.org/home/index.html#DOWNLOAD (12/01-2013).

Holtskog, S., Haakonsen, G., Kvingedal, E., Rypdal, K. & Tornsjø, B., 2000: Verification of the Norwegian emission inventory – Comparing emission intensity values with similar countries. The Norwegian Pollution Control Authority in cooperation with Statistics Norway. SFT report 1736/2000.

IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual, 1996. Available at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm (12-11-2012).

IPCC, 2000: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC, May 2000. Available at: http://www.ipcc-nggip.iges.or.jp/public/gp/english (12-11-2012).

Kjær, B., 2013: Municipal waste management in Denmark. Waste topic center report prepared for the EEA.

Nielsen, O.-K., Plejdrup, M.S., Winther, M., Gyldenkærne, S., Thomsen, M., Fauser, P., Nielsen, M., Mikkelsen, M.H., Albrektsen, R., Hjelgaard, K., Hoffmann, L. & Bruun, H.G., 2013: Quality manual for the Danish greenhouse gas inventory: Version 2, 44 pp.

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G., 2012: Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, Aarhus University, DCE - Danish Centre for Environment and Energy. 1168 s. (Scientific Report from DCE – Danish Centre for Environment and Energy; Nr. 19).

OECD, 1997 and 2004: Environmental Data, compendium 1997 and 2004. Organisation for Economic Co-operation and Development, Paris.

Rypdal, K. & Flugsrud, K., 2001: Sensitivity analysis as a tool for systematic reductions in greenhouse gas inventory uncertainties. Environmental Science & Policy 4 (2001) 117-135.

Statistics Denmark, 2013: Danmarks Statistik, Statistikbanken. Available at: http://www.statistikbanken.dk/statbank5a/default.asp?w=1280 (12/12-2012).

UBA, 2013: Excel spreadsheet with results from a comparison of activity data from IEA energy statistics supplied to Eurostat and CRF data reported to EU, performed by Umweltbundesamt Gmbh for the energy sector.

UN, 2013: United Nations Statistical Yearbook 2010 – fifty fifth issue. United Nations, New York. Available at:
http://unstats.un.org/unsd/syb/default.htm (12/10-2012).

Manning, A., 2007: Baseline trends and top-down estimates of UK and NW European GHG emissions. In: Atmospheric monitoring and inverse modelling for verification of national and EU bottom-up GHG inventories. Editor: P. Bergamaschi.

VERIFICATION OF THE DNISH 1990, 2000 AND 2010 EMISSION INVENTORY DATA

Danish emission values, implied emission factors and activity data for the national greenhouse gas inventory are assessed according to an updated verification procedure. Focus is on 25 identified key categories, represented by 29 verification categories, and 28 Annex II indicators covering energy, agriculture, industry and waste. The data are based on the national greenhouse gas inventories for the years 1990 (base year), 2000 and 2010, as reported in 2012, and provided by the UNFCCC and EU. Inter-country comparison and time series consistency check of emissions and implied emission factors is made for EU15 countries, excluding Luxemburg and including Norway and Switzerland and for some verification steps also including Australia, Canada, Japan, Russian Federation, USA and aggregated values for EU15 and EU27. National and inter-country verification and time trend consistency check of activity data is made with data for energy consumption (Eurostat), agricultural statistics (Eurostat), industrial processes (UN) and waste disposal (OECD). Verification in this approach is a combination of qualitative and quantitative assessments and can assist to identify sectors and categories that require more attention and thus facilitates the prioritisation of efforts that are required to obtain more accurate and reliable emission inventories in the future.

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