National Environmental Research Institute
University of Aarhus · Denmark

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# Verification of the Danish emission inventory data by national and international data comparisons

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# Data sheet


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| Abstract: | Danish emission intensity values, activity values and implied emission factors for identified key source categories are compared with corresponding values for the EU-15 countries (excluding Luxemburg). The emission values for all countries are based on national greenhouse gas inventories for the years 1990 (base year), 1997 and 2003 provided by the UNFCCC. The comparison is based on a proposed verification procedure that is designed for identifying emission indicators and evaluating data consistency and reliability for the energy and industry sectors. For all sectors the method gives good possibility for checking emission levels and consistency in time trends. |



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# Contents

# Preface

The Danish emissions of greenhouse gases are reported annually by the National Environmental Research Institute (NERI), University of Aarhus, on behalf of the Danish Ministry of Environment. NERI is responsible for the annual preparation and submission to the UNFCCC (and the EU) of the National Inventory Report and the GHG inventories in the Common Reporting Format in accordance with the UNFCCC Guidelines. NERI is also the designated entity with the overall responsibility for the national inventory under the Kyoto Protocol. The work concerning the annual greenhouse emission inventory is carried out at NERI 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 IPCC category, uncertainty estimates, explanations on recalculations, planned improvements and procedure for quality assurance and control.

The NIR and the CRF tables are available to the public on the National Environmental Research Institute's homepage:

http://www.dmu.dk/1_Viden/2_Miljoe-tilstand/3_luft/4_adaei/default_en.asp

The greenhouse gases reported under the Climate Convention are:

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

By signature of the Kyoto protocol several countries have committed to limit their greenhouse gas emissions. It is mandatory for the success of this protocol 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 IPCC report "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" different methods of verification of emission estimates are introduced.

This report represents the Danish contribution to the work on verification of emission estimates. The aim has been to suggest a methodology for testing verification priorities within each main sector and/or subcategory for optimal inter-country comparability. It can be used as a guide to select the best possible statistical data as indicators for comparing emission levels between countries, and for evaluating time trends between countries and on a national scale.

The method allows for identifying emission sources that may undergo a more thorough investigation concerning emission intensity values, emission factors and activity data.

# Summary

In Table 1 the results from the verification process of the Danish emission inventory data are summarised. The verification process has been tested on 21 Danish key source categories that have been identified from total emitted amounts and trend assessment. For each key source an indicator is chosen that will enable an inter-country comparison of emission density indicators, defined as the emissions/indicator ratio. The indicators are mainly taken from the Norwegian verification report (Holtskog et al., 2000). The verification process is performed for three years, 1990, 1997 and 2003.

**Table 1** Summary of verification of Danish Key Source Categories. Verification is based on 1) Agreement between calculated emission density indicator and reported implied emission factor (+ = good agreement, - = poor agreement, no = no reported emission factor), 2) Agreement between calculated emission density indicator and Danish value for $CO_2$ content in fuel (or other relevant factor) (+ = good agreement, - = poor agreement, no = no relevant factor), and 3) Consistency in time, explained decrease or increase (+ = good, - = poor, no = missing data). Comparable countries with respect to calculated emission density indicators are stated for each key source category.

| IPCC key category code (cf. Table 3) | Indicator | Verification quality | Comparable countries |
|---|---|---|---|
| 1A1a-coal | Energy use in "transformation" + "energy sector" (OECD) | 1) +<br>2) +<br>3) + | Netherlands<br>Portugal<br>Spain<br>UK |
| 1A2f-coal | Energy use in "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Netherlands<br>Portugal<br>Ireland<br>UK |
| 1A4b-coal | Energy use in "other sectors - residential" (OECD) | 1) +<br>2) +<br>3) - | Austria<br>Belgium<br>Netherlands<br>UK |
| 1A4c-coal | Energy use in "other sectors - agriculture" (OECD) | 1) +<br>2) +<br>3) + | Austria<br>Sweden<br>UK |
| 1A3b-gasoline | Energy use in "transport sector - road" (OECD) | 1) +<br>2) +<br>3) + | All countries |
| 1A3b-diesel | Energy use in "transport sector - road" (OECD) | 1) +<br>2) +<br>3) - | All countries except Austria, Spain, Sweden |
| 1A1-gas | Energy use in "transformation" + "energy sector" (OECD) | 1) +<br>2) +<br>3) + | Finland<br>Greece<br>Ireland<br>Netherlands<br>UK |
| 1A2-gas | Energy use in "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Italy<br>Spain<br>UK |
| 1A4-gas | Energy use in "other sectors" (OECD) | 1) +<br>2) +<br>3) + | All countries except Portugal and Sweden |
| 1A1-oil | Energy use in "transformation" + "energy sector" (OECD) | 1) -<br>2) -<br>3) - | Austria<br>Spain |
| 1A2-oil | Energy use in "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Finland<br>Greece<br>Ireland<br>Spain<br>Sweden |
| 1A4-oil | Energy use in "other sectors" (OECD) | 1) +<br>2) +<br>3) + | All countries |

(Table 1 continued)

| IPCC key category code (cf. Table 3) | Indicator | Verification quality | Comparable countries |
|---|---|---|---|
| 4D-direct | Agricultural area, land use (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland<br>Germany |
| 4A | Meat production from bovine + sheep + goat (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland, France, Germany, Spain, UK |
| 4D-indirect | Agricultural area, land use (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | no |
| 2A1 | Cement production (UN) | 1) +<br>2) +<br>3) + | Finland<br>Greece<br>Ireland<br>Spain<br>UK |
| 6A1 | Disposal of municipal waste on landfills (OECD) | 1) –<br>2) no<br>3) + | Austria |
| 4B-$CH_4$ | Meat production from bovine + sheep + goat + horse + pig + chicken + turkey (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland, Sweden, UK |
| 2B2 | No suitable indicator identified | 1) no<br>2) no<br>3) no | no |
| 4B-$N_2O$ | Meat production from bovine + sheep + goat + horse + pig + chicken + turkey (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Spain, UK |
| 1A | Energy use in "transformation" + “energy sector” + “industry sector” + “transport sector” + “other sectors" (OECD) | 1) +<br>2) no<br>3) - | no |

For each key source there are four verification parameters. First, the agreement between the calculated emission density indicator and the reported (if any) implied emission factor. Second, the agreement between the calculated emission density indicator and a theoretical value for the $CO_2$ content in fuel (or other relevant parameter). Third, an evaluation of the time trend of the calculated emission density indicator. And fourth, a comparison of emission density indicators between countries.

It is seen that there is good agreement for verification parameter 1 for the energy key source categories. This is probably due to a good correlation between the reported emission intensity values and the chosen indicators, implying good cause and effect relationship. Furthermore there is good agreement between the emission density indicator and the conversion factors for coal, oil and gas, respectively. There is good consistency in the time trends, and the inter country comparison shows good agreement between Denmark and Netherlands, Spain and UK.

For the agriculture key source categories there are no reported implied emission factors, which leave out the first verification parameter. For enteric fermentation there is a Danish emission value that is in good agreement with the emission density indicator. For the industry source category cement production there is a factor recommended by the IPCC that is in good agreement with the emission density indicator. There is an explained time trends for all agricultural and industrial key source categories. There are no countries that are consistently comparable.

For the waste key source category, there is poor agreement between the emission density indicator and the implied emission factor, good consistency in time trend (two years), and good comparability with Austria only.

In conclusion the used verification procedure is appropriate for evaluating data consistency and reliability for some sectors. For the energy sector the procedure has been appropriate. For agriculture the implied emission factors are not reported, which make part of the suggested verification procedure impossible. For all sectors the method gives good possibility for checking consistency in time trends. An important aspect is to identify appropriate indicators, which represent the key source category. Mainly for the energy sector there is cause effect relationship between the emission and the indicator, which gives a good basis for verification. For the other sectors there are more or less appropriate relationships, and similarities in geography, climate, industry structure and level of economic development may be necessary to include in order to obtain comparable emission density indicators. In these cases it is important to note that the verification 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).

# Sammenfatning

Resultater fra verifikation af den danske drivhusgas emissionsopgørelse er summeret i tabel 1. Verifikationen er udført for 21 hovedkategorier (key source categories), der er fundet ud fra total emitterede mængder og trend vurderinger. For hver hovedkategori er der valgt en indikator til anvendelse i en sammenligning af emissions densitets indikatorer mellem lande. En emissions densitets indikator er defineret som forholdet mellem emission og indikator. Indikatorer fra den norske verifikationsrapport (SFT, 2000) er anvendt for alle sektorer på nær landbrug. Verifikationen er udført for tre år, 1990, 1997 og 2003.

**Tabel 1** Opsummering af verifikation af danske hovedkategorier. Verifikationen er baseret på 1) Overensstemmelse mellem beregnet emissionsdensitetsindikator og rapporteret gennemsnitlig aggregeret emissionsfaktor (implied emission factor) (+ = god overensstemmelse, - = dårlig overensstemmelse, no = ingen rapporteret aggregeret emissionsfaktor), 2) Overensstemmelse mellem beregnet emissionsdensitetsindikator og dansk værdi for $CO_2$ (eller anden gas) indhold i brændstof (eller anden relevant parameter) (+ = god overensstemmelse, - = dårlig overensstemmelse, no = ingen rapporteret faktor), og 3) Konsistens i tids trends med forklaret fald eller stigning (+ = god overensstemmelse, - = dårlig overensstemmelse, no = ingen data). Sammenlignelige lande mht. beregnede emissionsdensitetsindikatorer er anført for hver hovedkategori.

| IPCC hovedkategori kode (se tabel 3) | Indikator | Verifikations kvalitet | Sammenlignelige lande |
|---|---|---|---|
| 1A1a-coal | Energi forbrug i "transformation" + "energy sector" (OECD) | 1) +<br>2) +<br>3) + | Holland<br>Portugal<br>Spanien<br>UK |
| 1A2f-coal | Energi forbrug i "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Holland<br>Portugal<br>Irland<br>UK |
| 1A4b-coal | Energi forbrug i "other sectors - residential" (OECD) | 1) +<br>2) +<br>3) - | Østrig<br>Belgien<br>Holland<br>UK |
| 1A4c-coal | Energi forbrug i "other sectors - agriculture" (OECD) | 1) +<br>2) +<br>3) + | Østrig<br>Sverige<br>UK |
| 1A3b-gasoline | Energi forbrug i "transport sector - road" (OECD) | 1) +<br>2) +<br>3) + | Alle lande |
| 1A3b-diesel | Energi forbrug i "transport sector - road" (OECD) | 1) +<br>2) +<br>3) - | Alle lande undtagen Østrig, Spanien, Sverige |
| 1A1-gas | Energi forbrug i "transformation" + "energy sector" (OECD) | 1) +<br>2) +<br>3) + | Finland<br>Grækenland<br>Irland<br>Holland<br>UK |
| 1A2-gas | Energi forbrug i "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Italien<br>Spanien<br>UK |
| 1A4-gas | Energi forbrug i "other sectors" (OECD) | 1) +<br>2) +<br>3) + | Alle lande undtagen Portugal og Sverige |
| 1A1-oil | Energi forbrug i "transformation" + "energy sector" (OECD) | 1) -<br>2) -<br>3) - | Østrig<br>Spanien |
| 1A2-oil | Energi forbrug i "industry sector" (OECD) | 1) +<br>2) +<br>3) + | Finland<br>Grækenland<br>Irland<br>Spanien<br>Sverige |
| 1A4-oil | Energi forbrug i "other sectors" (OECD) | 1) +<br>2) +<br>3) + | Alle lande |

(tabel 1 fortsat)

| IPCC hovedkategori kode (se tabel 3) | Indikator | Verifikations kvalitet | Sammenlignelige lande |
|---|---|---|---|
| 4D-direct | Landbrugsareal (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland<br>Tyskland |
| 4A | Kødproduktion fra kvæg + får + ged (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland, Frankrig, Tyskland, Spanien, UK |
| 4D-indirect | Landbrugsareal (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | no |
| 2A1 | Cement produktion (UN) | 1) +<br>2) +<br>3) + | Finland<br>Grækenland<br>Irland<br>Spanien<br>UK |
| 6A1 | Deponering af affald på lossepladser (OECD) | 1) –<br>2) no<br>3) + | Østrig |
| 4B-$CH_4$ | Kødproduktion fra kvæg + får + ged + heste + grise + kylling + kalkun (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Finland, Sverige, UK |
| 2B2 | Ingen passende indikator er fundet | 1) no<br>2) no<br>3) no | no |
| 4B-$N_2O$ | Kødproduktion fra kvæg + får + ged + heste + grise + kylling + kalkun (FAOstat Agriculture) | 1) no<br>2) no<br>3) + | Spanien, UK |
| 1A | Energi forbrug i "transformation" + “energy sector” + “industry sector” + “transport sector” + “other sectors" (OECD) | 1) +<br>2) no<br>3) - | no |

For hver hovedkategori er der fire verifikationsparametre. For det første er der overensstemmelsen mellem beregnet emissionsdensitetsindikator og rapporteret (hvis angivet) aggregeret emissionsfaktor. For det andet er der overensstemmelsen mellem beregnet emissionsdensitetsindikator og en teoretisk værdi for $CO_2$ (eller anden gas) indhold i brændstof (eller anden relevant parameter). For det tredje er der evalueringen af tids trends for beregnet emissionsdensitetsindikator, og endelig er der sammenligningen af emissionsdensitetsindikatorer mellem lande.

Af tabel 1 ses, at der er god overensstemmelse for verifikationsparameter 1 for energi hovedkategorier. Dette skyldes formentlig en god korrelation mellem rapporteret emission intensitet og valgt indikator, eller med andre ord en god årsag virkning beskrivelse. Desuden er der god overensstemmelse mellem emissionsdensitetsindikatorer og konverteringsfaktorer for henholdsvis kul, olie og gas. Der er god konsistens i tid trends og god overensstemmelse mellem emissionsdensitetsindikatorer for Danmark, Holland, Spanien og UK.

For landbrugets hovedkategorier er der ingen rapporterede aggregerede emissionsfaktorer, hvilket udelukker den første verifikationsparameter. For enterisk fermentering er der god overensstemmelse mellem en dansk emissionsværdi og den beregnede emissionsdensitetsindikator. For industriens hovedkategori, cement produktion, anbefaler IPCC en faktor, der er i god overensstemmelse med den beregnede emissionsdensitetsindikator. Der er forklarede tids trends for alle landbrugs og industri hovedkategorier. Der er ingen lande der konsistent er sammenlignelige.

For affalds hovedkategori er der dårlig overensstemmelse mellem emissionsdensitetsindikator og aggregeret emissionsfaktor, god konsistens i tidsudvikling (to år), og god sammenligning med Østrig.

Til opsummering, er den anvendte verifikationsprocedure passende til evaluering af data konsistens og pålidelighed for energisektoren. For landbrug og affald er aggregerede emissionsfaktorer ikke rapporteret, hvilket umuliggør en del af verifikationsproceduren. For alle sektorer giver metoden en god mulighed for at checke konsistens i tidsudvikling.

Et vigtigt aspekt er at identificere passende indikatorer som repræsenterer de pågældende hovedkategorier. Specielt for energisektoren er der en årsags-virknings sammenhæng mellem emissioner og indikatorer, som giver en god basis for verifikation. For de andre sektorer er der mere eller mindre anvendelige sammenhænge, og en sammenligning af geografi, klima, industrielle strukturer og niveauer af økonomisk udvikling kan være nødvendig for at sammenligne emissionsdensitetsindikatorer. I disse tilfælde er det vigtigt at bemærke, at verifikationen kun forholder sig til konsistens med hensyn til hvordan og hvad andre lande rapporterer. Det er ikke en verifikation af den videnskabelige værdi af emissions opgørelsens data (Holtskog et al., 2000).

# 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 (Sørensen et al., 2005). For each of the sectors: energy, industrial processes, agriculture and waste, verification is performed for key source 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, 2001). 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 source category; emission intensity 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 intensity 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 intensity 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 intensity to activity, comparisons based on implied emission factors should verify all three parameters.

Another way is to compare *emission density indicators* between countries, where the emission intensity value is divided with a chosen indicator 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 intensity value. As an example the $CO_2$ emission in the energy sector will be directly associated will energy 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 Authority, and the $CO_2$ emission from energy use is reported by the National Environmental Research Institute based on figures from the Danish Energy Authority. 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 intensity value.

Comparisons do not always represent verifications of the data themselves, but verification of the reliability and the consistency of data with respect to trends and inter- country comparisons. They will give an overview to focus on more specific cases of inconsistency for which a more in-depth data verification can be performed. This will enable a more resource-effective verification procedure.

The procedure within the Danish verification process will be to evaluate the Danish emission intensity values, activity values and implied emission factors for identified key source categories with corresponding values for the EU-15 countries (excluding Luxemburg where no sufficient data are found). The emission values for all countries are based on national greenhouse gas inventories for the years 1990 (base year), 1997 and 2003 provided by the UNFCCC.

Appropriate data for use as indicators have been found from a variety of sources but primarily OECD Energy Statistics of OECD Countries have been rendered suitable in association with $CO_2$ emissions from various sectors. It is a large task to identify and evaluate all indicators that may prove to be suitable for verification. In this report the indicators identified in the Norwegian verification inventory have been used, except for Agriculture, as it is assumed that the same conclusions on indicator suitability can be applied for Danish conditions.

# 2 Selection of verification priorities (key sources)

A key source analysis is performed according to the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2001) 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
6. Waste

The level of total emissions and level of total trends has been assessed for the source categories within these six sectors. The identified key source categories are to be included in the verification. The analysis corresponds to the standardised threshold procedure outlined in Rypdal & Flugsrud (2001). The ranking of the source categories in accordance to their contributions to the national total and total trends of greenhouse gases calculated in $CO_2$-equivalent units (Illerup et al., 2005), and an extract of the top of the list, covering 95% of the national total, is given in Table 2.

**Table 2** Danish key source categories covering 95% of the national total GHG emission and total trends. Key categories are identified by the secretariat's key category assessment for Danish 2003 figures. The secretariat's key category assessment does not cover the LULUCF sector.

| Danish key category | Gas | Level assessment | Level cumulative total | Trend assessment | Trend cumulative total |
|---|---|---|---|---|---|
| Stationary combustion - coal | $CO_2$ | 30,10% | | 14,10% | |
| Mobile combustion - road vehicles | $CO_2$ | 15,70% | 45,80% | 8,40% | 22,60% |
| Stationary combustion - gas | $CO_2$ | 14,80% | 60,60% | 29,30% | 51,80% |
| Stationary combustion - oil | $CO_2$ | 13,00% | 73,50% | 13,10% | 64,90% |
| Direct $N_2O$ emissions from agricultural soils | $N_2O$ | 3,80% | 77,40% | 7,00% | 72,00% |
| Enteric fermentation in domestic livestock | $CH_4$ | 3,60% | 81,00% | 2,60% | 74,60% |
| Indirect $N_2O$ from nitrogen used in agriculture | $N_2O$ | 3,20% | 84,10% | 7,50% | 82,10% |
| Other | $CO_2$ | 1,90% | 86,00% | | 82,10% |
| Cement production | $CO_2$ | 1,80% | 87,80% | 1,90% | 84,00% |
| Solid waste disposal sites | $CH_4$ | 1,50% | 89,40% | 1,20% | 85,20% |
| Manure management | $CH_4$ | 1,30% | 90,70% | 0,80% | 86,00% |
| Nitric acid production | $N_2O$ | 1,20% | 91,80% | 1,00% | 87,00% |
| ODS substitutes | HFCs, PFCs | 0,90% | 92,80% | 3,20% | 90,20% |
| Stationary combustion - other fuels | $CO_2$ | 0,90% | 93,70% | 1,20% | 91,40% |
| Mobile combustion - waterborne navigation | $CO_2$ | 0,70% | 94,40% | | 91,40% |
| Manure management | $N_2O$ | 0,70% | 95,10% | | 91,40% |
| Stationary combustion - gas | $CH_4$ | | | 1,70% | 93,10% |
| Mobile combustion - road vehicles | $N_2O$ | | | 1,20% | 94,30% |
| Fugitive emissions: oil and natural gas | $CO_2$ | | | 1,20% | 95,50% |

The Danish Key source categories do however not comply completely to the common reporting format. An analogue list of key source categories is shown in Table 3, which complies with the IPCC source categories. The IPPC source codes are given in the last column of Table 3 and will be referred to in the initial comparison analysis of emission intensities between countries.

**Table 3** Danish key source categories and corresponding IPCC source categories.

| Danish key category | IPCC source category | | | IPCC code |
|---|---|---|---|---|
| Stationary combustion - coal | 1.A.1 Energy Industries | a. Public Electricity and Heat Production | Solid Fuels | 1A1a-coal |
| Stationary combustion - coal | 1.A.2 Manufacturing Industries and Construction | f. Other | Solid Fuels | 1A2f-coal |
| Stationary combustion - coal | 1.A.4 Other Sectors | b. Residential | Solid Fuels | 1A4b-coal |
| Stationary combustion - coal | 1.A.4 Other Sectors | c. Agriculture/Forestry-/Fisheries | Solid Fuels | 1A4c-coal |
| Mobile combustion - road vehicles | 1.A.3 Transport | b. Road Transportation | Gasoline | 1A3b-gasoline |
| Mobile combustion - road vehicles | 1.A.3 Transport | b. Road Transportation | Diesel Oil | 1A3b-diesel |
| Stationary combustion - gas | 1.A.1 Energy Industries | Gaseous Fuels | | 1A1-gas |
| Stationary combustion - gas | 1.A.2 Manufacturing Industries and Construction | Gaseous Fuels | | 1A2-gas |
| Stationary combustion - gas | 1.A.4 Other Sectors | Gaseous Fuels | | 1A4-gas |
| Stationary combustion - oil | 1.A.1 Energy Industries | Liquid Fuels | | 1A1-oil |
| Stationary combustion - oil | 1.A.2 Manufacturing Industries and Construction | Liquid Fuels | | 1A2-oil |
| Stationary combustion - oil | 1.A.4 Other Sectors | Liquid Fuels | | 1A4-oil |
| Direct $N_2O$ emissions from agricultural soils | Direct Soil Emissions | | | 4D-direct |
| Enteric fermentation in domestic livestock | Total Agriculture | A. Enteric Fermentation | | 4A |
| Indirect $N_2O$ from nitrogen used in agriculture | Indirect Emissions | | | 4D-indirect |
| Cement production | Total Industrial Processes | A. Mineral Products | 1. Cement Production | 2A1 |
| Solid waste disposal sites | 1 Managed Waste Disposal on Land | | | 6A1 |
| Manure management | B. Manure Management | | | 4B-$CH_4$ |
| Nitric acid production | B. Chemical Industry | 2. Nitric Acid Production | | 2B2 |
| Manure management | B. Manure Management | | | 4B-$N_2O$ |
| Stationary combustion - gas | 1.A. Fuel Combustion | Gaseous Fuels | | 1A |

It can be seen from the Table 3 that some of the Danish source categories, such as stationary combustion – coal, constitute two or more IPCC source categories. Furthermore six Danish source categories have not been included in the analysis. The reason is that concordant sources have not been identified in the IPCC reporting schemes. These sources are however only small contributors to the level of total emissions and the level of total trends.

# 3 Indicator appraisal

To be able to compare emission intensity values, activity data and emission factors between countries the best possible statistical data (indicators) will be identified. For this purpose the Norwegian verification report (Holtskog et al., 2000) will be addressed. The conclusions from SFT (Holtskog et al., 2000) are summarised in Table 4. Except for Agriculture these indicators have been used in the Danish inventory. Further differentiation has been made in sub-categories for energy use.

**Table 4** Best indicators for inter-country comparison of source categories. Apart from the agriculture sector indicators for the Norwegian verification inventory (Holtskog et al., 2000), are applied for Danish conditions.

| IPCC key category code | Indicator Norwegian inventory | Indicator Danish inventory | Reference |
|---|---|---|---|
| 1A1a-coal | Energy use | Energy use in "transformation" + "energy sector" | Energy Statistic of OECD countries |
| 1A2f-coal | Energy use | Energy use in "industry sector" | Energy Statistic of OECD countries |
| 1A4b-coal | Energy use | Energy use in "other sectors - residential" | Energy Statistic of OECD countries |
| 1A4c-coal | Energy use | Energy use in "other sectors - agriculture" | Energy Statistic of OECD countries |
| 1A3b-gasoline | Energy use | Energy use in "transport sector - road" | Energy Statistic of OECD countries |
| 1A3b-diesel | Energy use | Energy use in "transport sector - road" | Energy Statistic of OECD countries |
| 1A1-gas | Energy use | Energy use in "transformation" + "energy sector" | Energy Statistic of OECD countries |
| 1A2-gas | Energy use | Energy use in "industry sector" | Energy Statistic of OECD countries |
| 1A4-gas | Energy use | Energy use in "other sectors" | Energy Statistic of OECD countries |
| 1A1-oil | Energy use | Energy use in "transformation" + "energy sector" | Energy Statistic of OECD countries |
| 1A2-oil | Energy use | Energy use in "industry sector" | Energy Statistic of OECD countries |
| 1A4-oil | Energy use | Energy use in "other sectors" | Energy Statistic of OECD countries |
| 4D-direct | Meat production | Agricultural area, land use | FAOstat Agriculture |
| 4A | Number of cattle | Meat production from bovine + sheep + goat | FAOstat Agriculture |
| 4D-indirect | Meat production (may be coincidental) | Agricultural area, land use | FAOstat Agriculture |
| 2A1 | Cement production | Cement production | UN Statistical yearbook |
| 6A1 | Amount disposal of waste | Disposal of municipal waste on landfills | OECD Environmental data |
| 4B-$CH_4$ | Animal output (not good) | Meat production from bovine + sheep + goat + horse + pig + chicken + turkey | FAOstat Agriculture |
| 2B2 | not assessed | No suitable indicator identified | - |
| 4B-$N_2O$ | not assessed | Meat production from bovine + sheep + goat + horse + pig + chicken + turkey | FAOstat Agriculture |
| 1A | Energy use | Energy use in "transformation" + "energy sector" + "industry sector" + "transport sector" + "other sectors" | Energy Statistic of OECD countries |

# 4 Verification procedure

For each key source category a comparison is made between Denmark and the EU-15 countries. This is done by comparing emission density indicators, defined as emission intensity value divided with a chosen indicator. The correlation between emissions and an independent indicator does not necessarily imply cause and effect, but in cases where the indicator is directly associated with the emission intensity value, such as for the energy sector, the emission density indicator is a measure of the implied emission factor and a direct comparison can be made. A qualitative verification of implied emission factors can furthermore be made when a measured or theoretical value of the $CO_2$ 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 purities and fuel combustion efficiencies. A comparison of national emission density indicators, analogous to the implied emission factors, will give valuable information on the quality and efficiency of the national energy sectors.

Furthermore the inter-country comparison of emission density indicators and comparison of theoretical values gives a methodological verification of the derivation of emission intensity values and of the correlation between emission intensity values and activity values.

When emissions are compared with non-dependent parameters similarities in geography, climate, industry structure and level of economic development may be necessary for obtaining similar emission density indicators.

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 inherent uncertainty with respect to absolute values of e.g. quantification of $CO_2$ emissions and with respect to methodological approaches in deriving emission intensity values. Thus a "good agreement" may be a relative statement for source categories with greatly different uncertainties. For agreement between calculated emission density indicators and reported implied emission factors or e.g. $CO_2$ content in fuel, the verification is quantitative and is reported as a percentage deviation. The evaluations "good agreement" and "poor agreement" are based on these deviations.

# 5 Energy

The UNFCCC reporting of emissions from energy use according to the IPPC Standard Reporting includes:

- 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

- $CO_2$ emissions from biomass combustion

- Fugitive emissions from solid fuels
    - Coal mining

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

Energy use in the energy sector is a suitable indicator, as it is directly related to oil, coal and natural gas combustion processes. Energy use is obtained from the OECD Energy Statistics of OECD Countries where energy use is reported as consumption in 1000 tonnes per year of coal and oil and in TJ for gas, respectively. The sectors and sub-sectors in OECD Energy Statistics that are used in this report are:

- Transformation
    - Electricity plants
    - Combined heat and power plants
    - Heat plants
    - Blast furnaces/gas works
    - Coke/patent fuel/BKB plants

- Petroleum refineries
- Petrochemical industry
- Liquefaction
- Other transformationsector

* Energy sector
    - Coal mines
    - Oil and gas extraction
    - Petroleum refineries
    - Electricity, CHP and heat plants
    - Pumped storage
    - Other energy sector

* Industry sector
    - Iron and steel industry
    - Chemical industry
    - Non-ferrous metals basic industries
    - Non-metallic mineral products
    - Transport equipment
    - Machinery
    - Mining
    - Food and tobacco
    - Paper, pulp and print
    - Wood and woos products
    - Construction
    - Textile and leather
    - Non-specified

* Transport sector
    - International civil aviation
    - Domestic air
    - Road
    - Rail
    - Pipeline transport
    - Internal navigation
    - Non-specified

* Other sectors
    - Agriculture
    - Commercial and public services
    - Residential
    - Non-specified

Coal types are coking coal, other bituminous coal, sub-bituminous coal, lignite, peat, oven and gas coke and pat. fuel and BKB (definitions in OECD/IEA Energy Statistics). The amounts are converted to TJ by using a Danish calorific value for 2003 of 25.5 TJ/1000 tonnes coal (Energistyrelsen, 2004). This is a mean value for all sorts of coal and for some countries, e.g. Germany, where lignite is a considerable energy source, the mean calorific value should be lower.

Oil is a diverse category comprising crude oil, refinery gas, motor gasoline, diesel and others. Oil is converted to TJ by using a Danish mean calorific value for 2004 of 42 TJ/1000 tonnes oil (Energistyrelsen, 2004).

The use of the same calorific values for coal and oil for all countries may be a source of error in the assessment.

For the energy sector the emission density indicator equals the emission intensity value divided by energy use from one or more sectors, including all respective sub-sectors, from OECD Energy Statistics (OECD, 1990-1991, 1997-1998 and 2002-2003). It is more precise to use values for entire sectors than for sub-sectors, as the reporting may be aggregated for some sectors. The emission density indicator has the unit ktonnes $CO_2$/PJ (tonnes $CH_4$ /PJ), which equals the implied emission factor. The $CO_2$ content for coal, oil and gas in unit ktonnes $CO_2$/PJ for Denmark is given in Energistyrelsen (2004). The implied emission factor can thus be verified quantitatively and the methodological approach in deriving the emission intensity value can be verified with respect to correlating the emission intensity value with the correct energy use. Conversely this means that the implied emission factor may not necessarily be erroneous if it does not equal the emission density indicator. It may just as well be a consequence of not correlating the most appropriate (or correct) energy use (OECD, 1990-1991, 1997-1998 and 2002-2003) with the emission intensity value.

## 5.1 Energy Industries – Public Energy and Heat Production – Solid Fuels (1A1a-coal)

Key source category: $CO_2$ emissions from “Energy Industries – Public Energy and Heat Production – Solid Fuels” (Gg $CO_2$).

Indicator: Energy use in "Transformation” and “Energy Sector" (ktonnes coal/year).

Conversion factor for coal (DK, mean value (Energistyrelsen, 2004)): 98 kg $CO_2$/GJ.

Calorific value for coal (DK, mean value (Energistyrelsen, 2004)): 25.5 TJ/ktonnes coal.

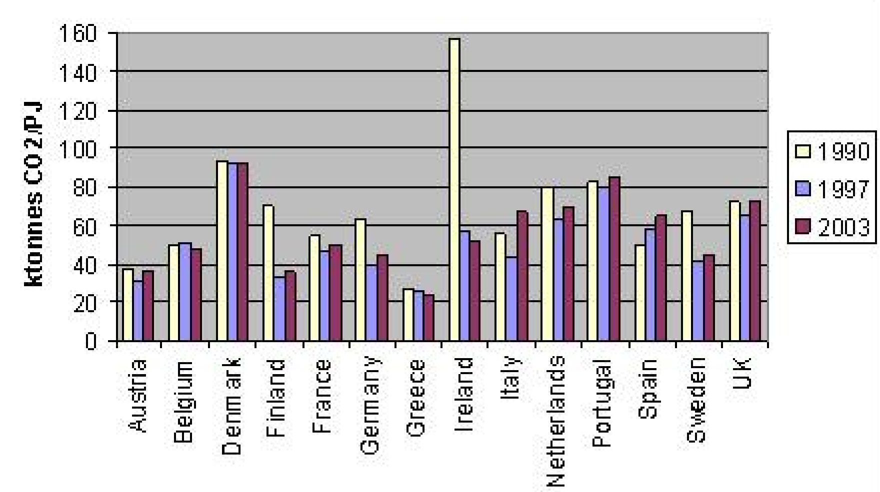


**Figure 1a** $CO_2$ emissions from "Energy Industries – Public Energy and Heat Production – Solid Fuels" (UNFCCC categories) relative to energy use in "Transformation" and "Energy Sector" - coal (OECD categories).

The emission density indicator (abscissa in Figure 1a) is analogous to the implied emission factor. A mean value for the $CO_2$ content in different coals is 98 ktonnes $CO_2$/PJ for Denmark (Energistyrelsen, 2004). Assuming that this factor is valid for all countries, the bars in Figure 1 should all have the value 98 ktonnes $CO_2$/PJ.

Denmark, Netherlands, Portugal, Spain and UK have lowest deviations from the theoretical value 98 ktonnes $CO_2$/PJ, and are thus comparable. As mentioned above; when the emission density indicator is based on $CO_2$ emissions from the energy sector and energy use in the same sector, all countries are in principle comparable. Deviations from this value arise from variations in coal purities and combustion efficiencies and from errors in correlating emission intensity values and energy use.

The Danish values are consistent between the three years, which indicates reliability in the estimates. For each country and each year the deviations between the emission density indicators, from Figure 1a, and the reported national implied emission factors are shown in Figure 1b.

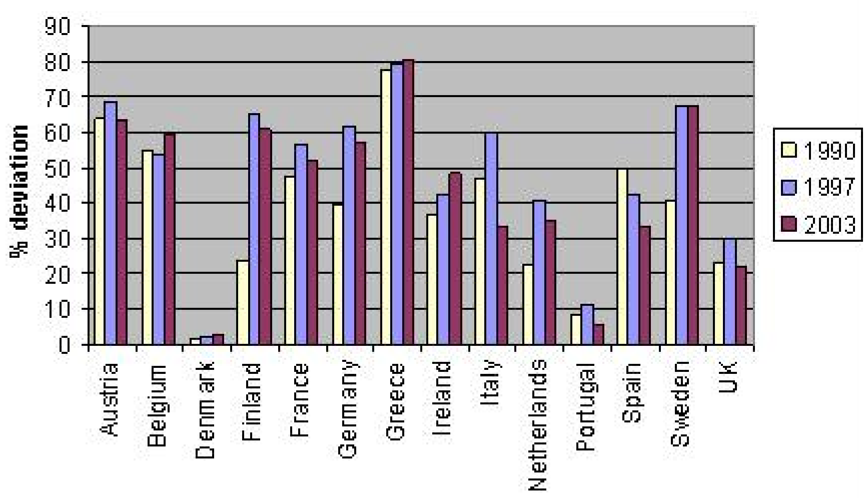


**Figure 1b** Deviations between the emission density indicators, from figure 1a, and the reported national implied emission factors (from UNFCCC).

The deviations in Figure 1b are lowest for Denmark and Portugal. This indicates good quality implied emission factors and a verification of the method, due to the concordance between emission intensity value and energy use. It should be mentioned that a Danish calorific value is used to convert tonnes of coal to TJ. For the other countries this may introduce an error, but the variations in calorific values between countries are small compared to the variations in reported national implied emission factors.

The absolute values of the reported national implied emission factors can not be seen directly from figures 1a or 1b. They range from 90.2 (Portugal, 2003) to 134 (Sweden, 2003), so the deviation from the Danish mean factor 98 ktonnes $CO_2$/PJ has a maximum of 37% (Sweden, 2003).

## 5.2 Manufacturing Industries and Construction – Other – Solid Fuels (1A2f-coal)

Key source category: $CO_2$ emissions from "Manufacturing Industries and Construction – Other – Solid Fuels" (Gg $CO_2$).

Indicator: Energy use in "Industry Sector" (ktonnes coal/year).

Conversion factor for coal (DK, mean value (Energistyrelsen, 2004)): 98 kg $CO_2$/GJ.

Calorific value for coal (DK, mean value (Energistyrelsen, 2004)): 25.5 TJ/ktonnes coal.

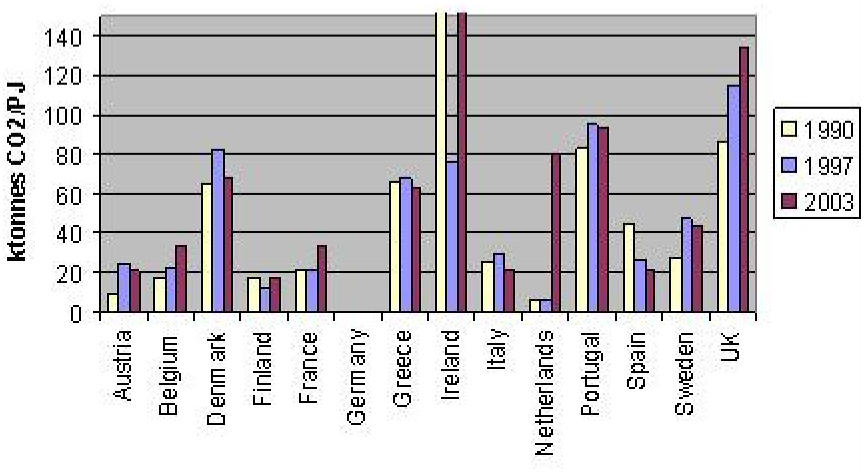


**Figure 2a** $CO_2$ emissions from "Manufacturing Industries and Construction – Other – Solid Fuels" (UNFCCC categories) relative to energy use in "Industry Sector" - coal (OECD categories). No emissions are reported for Germany.

The emission density indicator (abscissa in Figure 2a) corresponds to the implied emission factor, and can be compared with the mean Danish value for coal 98 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

Denmark, Netherlands (2003), Portugal, Ireland (1997) and UK have lowest deviations from this value and are comparable. The relatively high deviations can be explained by high energy use values. The energy use indicator is defined as the entire "Industry sector", and this may be an overestimation compared to the key source category “Manufacturing Industries and Construction – Other”. No sub-categories in the “Industry sector” have been found to represent the key source better.

There are low variations in the emission density indicator between years, which indicates reliability in the estimates.

For each country and each year the deviations between the emission density indicators, from Figure 2a, and the reported national implied emission factors are shown in Figure 2b.

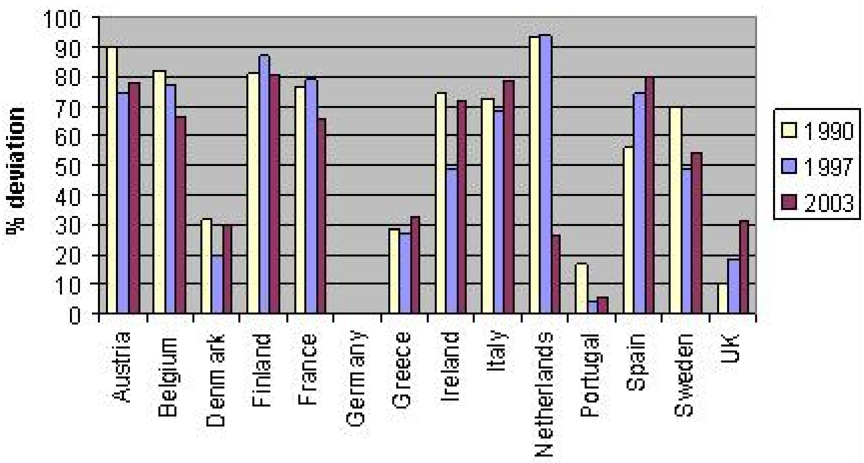


**Figure 2b** Deviations between the emission density indicators, from figure 2a, and the reported national implied emission factors (from UNFCCC).

The deviations in Figure 2b are lowest for Denmark, Greece, Portugal and UK. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute values of the Danish national implied emission factors range from 96 (1990) to 101 (1997).

## 5.3 Other Sectors – Residential – Solid Fuels (1A4b-coal)

Key source category: $CO_2$ emissions from “Other Sectors – Residential – Solid Fuels” (Gg $CO_2$).

Indicator: Energy use in "Other sectors - Residential" (ktonnes coal/year).

Conversion factor for coal (DK, mean value (Energistyrelsen, 2004)): 98 kg $CO_2$/GJ.

Calorific value for coal (DK, mean value (Energistyrelsen, 2004)): 25.5 TJ/ktonnes coal.

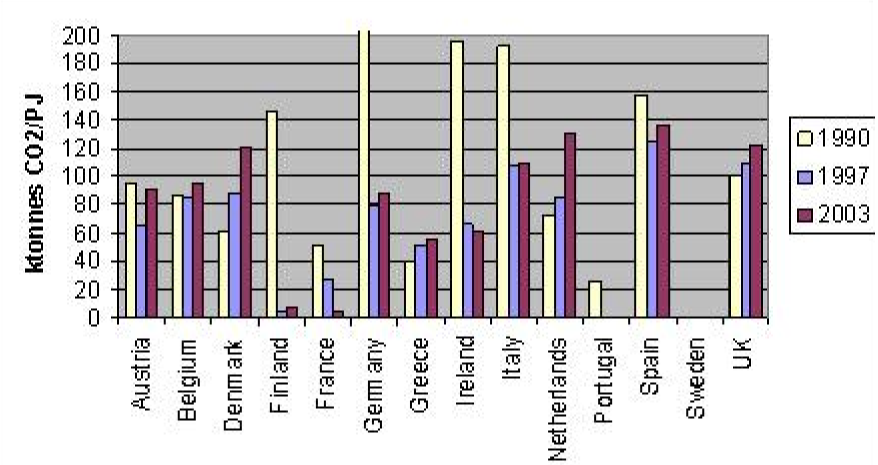


**Figure 3a** $CO_2$ emissions from "Other Sectors – Residential – Solid Fuels" (UNFCCC categories) relative to energy use in "Other sectors – Residential" - coal (OECD categories). No emissions are reported for Sweden and for Portugal (1997 and 2003).

Austria, Belgium, Denmark, Netherlands and UK have lowest deviations from the mean Danish value for coal 98 ktonnes $CO_2$/PJ. The relatively high variations can be explained by inconsistent energy use values. The energy use indicator is defined as the sub-category "Other Sectors - Residential", and according to OECD the figures for sub-categories are more uncertain than for aggregated categories.

The Danish emission density indicator shows a steady increase in the period, which can be traced to the decreasing activity value, which ranges from 746 TJ in 1990 to 29 TJ in 2003.

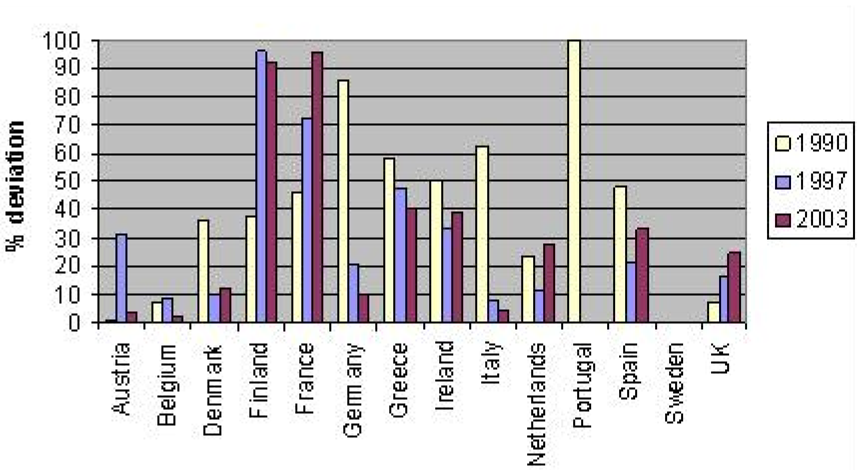


**Figure 3b** Deviations between the emission density indicators, from figure 3a, and the reported national implied emission factors. No emissions are reported for Sweden and for Portugal (1997 and 2003).

The deviations in Figure 3b are lowest for Austria, Belgium, Denmark, Netherlands and UK. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute values of the Danish national implied emission factors range from 97 (1990) to 106 (2003).

## 5.4 Other Sectors – Agriculture/Forestry/Fisheries – Solid Fuels (1A4c-coal)

Key source category: $CO_2$ emissions from "Other Sectors - Agriculture/Forestry/Fisheries – Solid Fuels" (Gg $CO_2$).

Indicator: Energy use in "Other sectors - Agriculture" (ktonnes coal/year).

Conversion factor for coal (DK, mean value (Energistyrelsen, 2004)): 98 kg $CO_2$/GJ.

Calorific value for coal (DK, mean value (Energistyrelsen, 2004)): 25.5 TJ/ktonnes coal.

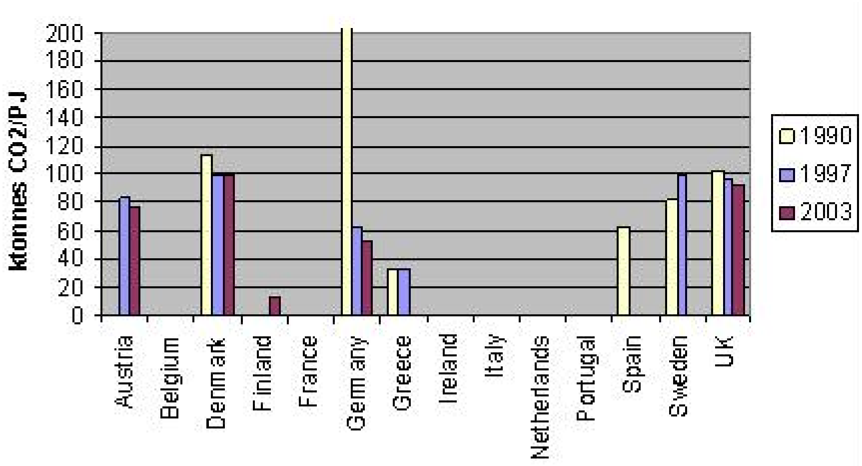


**Figure 4a** $CO_2$ emissions from "Other Sectors – Agriculture/Forestry/Fisheries – Solid Fuels" (UNFCCC categories) relative to energy use in "Other sectors – Agriculture" - coal (OECD categories). There are missing data for many countries.

Denmark, Austria, Sweden, and UK have lowest deviations from the mean Danish value for coal 98 ktonnes $CO_2$/PJ (Energistyrelsen, 2004). The many missing data are a consequence of the indicator, which is a sub-category of "Other Sectors". Relevant data may be reported as an "Other Sectors"-aggregate value.

The Danish emission density indicator is consistent in the time period.

For each country and each year the deviations between the emission density indicators, from Figure 4a, and the reported national implied emission factors (from UNFCCC) are shown in Figure 4b.

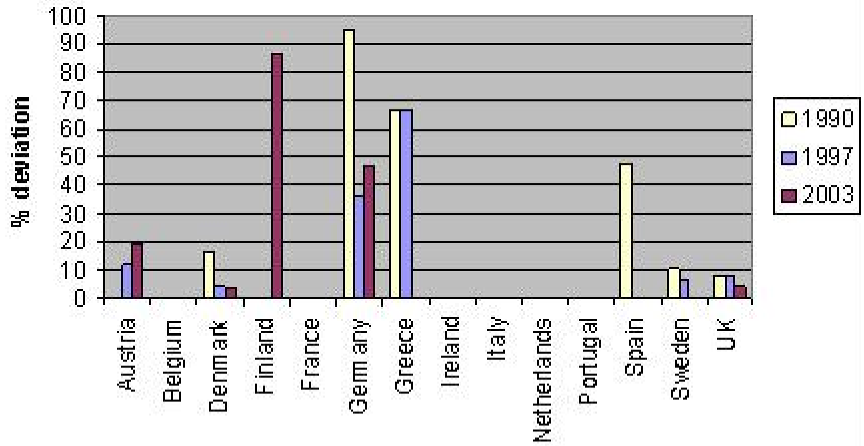


**Figure 4b** Deviations between the emission density indicators, from figure 4a, and the reported national implied emission factors (from UNFCCC). There are missing data for many countries.

The deviations in Figure 4b are lowest for Austria, Denmark, Sweden and UK. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factors is 95 ktonnes $CO_2$/PJ for all years.

## 5.5 Transport – Road Transportation – Gasoline (1A3b-gasoline)

Key source category: $CO_2$ emissions from "Transport – Road Transportation – Gasoline" (Gg $CO_2$).

Indicator: Energy use in "Transport Sector - Road" (ktonnes motor gasoline/year).

Conversion factor for motor gasoline (DK, Energistyrelsen, 2004): 73 kg $CO_2$/GJ.

Calorific value for motor gasoline (DK, Energistyrelsen, 2004): 43.8 TJ/ktonnes motor gasoline.

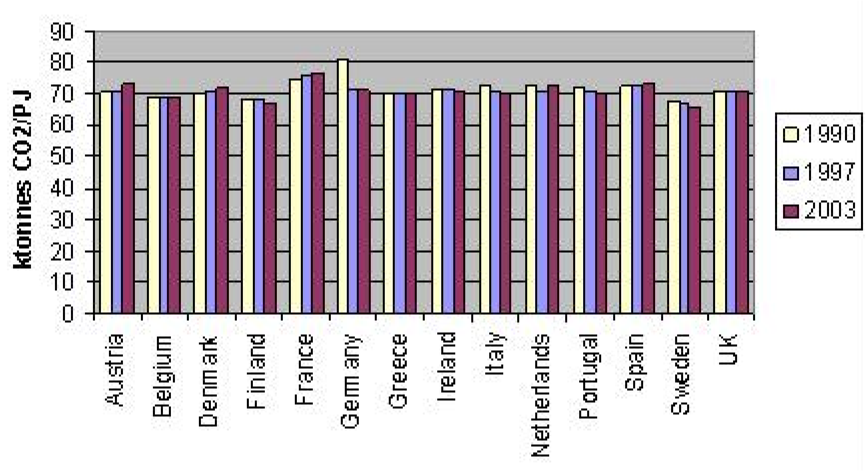


**Figure 5a** $CO_2$ emissions from "Transport – Road Transportation – Gasoline" (UNFCCC categories) relative to energy use in "Transport Sector - Road" – motor gasoline (OECD categories).

All countries are comparable with each other and the mean Danish value for motor gasoline 73 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

The Danish emission density indicator shows a slight increase for each time period.

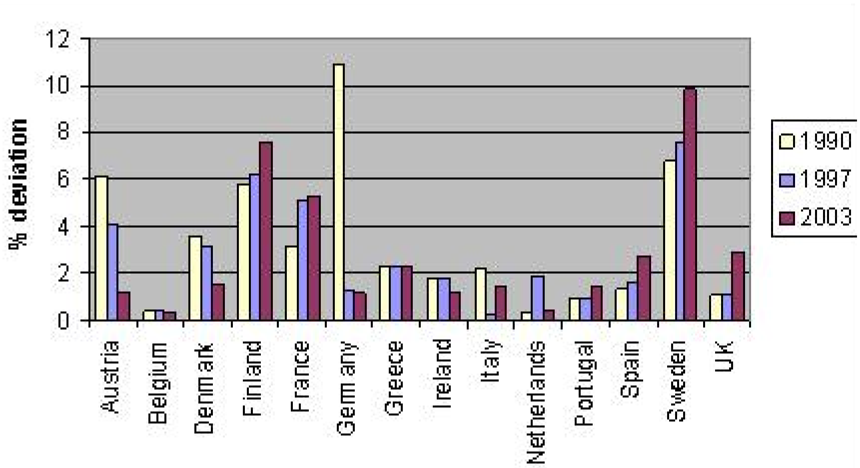


**Figure 5b** Deviations between the emission density indicators, from figure 5a, and the reported national implied emission factors (from UNFCCC).

The deviations between the emission density indicators, from Figure 5a, and the reported national implied emission factors (from UNFCCC) are low for all countries. The low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factor is 73 ktonnes $CO_2$/PJ for all years.

## 5.6 Transport – Road Transportation – Diesel Oil (1A3b-diesel)

Key source category: $CO_2$ emissions from "Transport – Road Transportation – Diesel Oil" (Gg $CO_2$).

Indicator: Energy use in "Transport Sector - Road" (ktonnes diesel/year).

Conversion factor for diesel (DK, Energistyrelsen, 2004): 74 kg $CO_2$/GJ.

Calorific value for diesel (DK, Energistyrelsen, 2004): 42.7 TJ/ktonnes diesel.

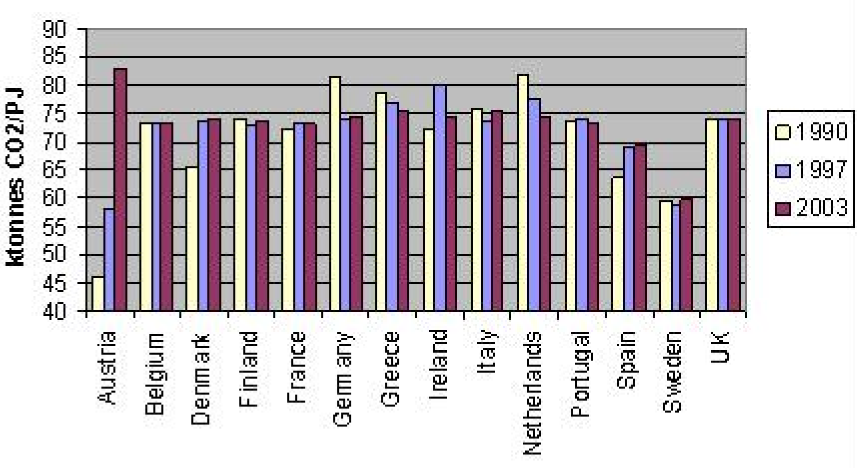


**Figure 6a** $CO_2$ emissions from "Transport – Road Transportation – Diesel Oil" (UNFCCC categories) relative to energy use in "Transport Sector - Road" – diesel (OECD categories).

All countries except Austria, Spain and Sweden are comparable with the Danish value for diesel of 74 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

The Danish emission density indicator for 1990 is low, and deviates with 11% compared to the reported implied emission factor, cf. Figure 6b. This reason for this deviation is a high indicator value reported to OECD.

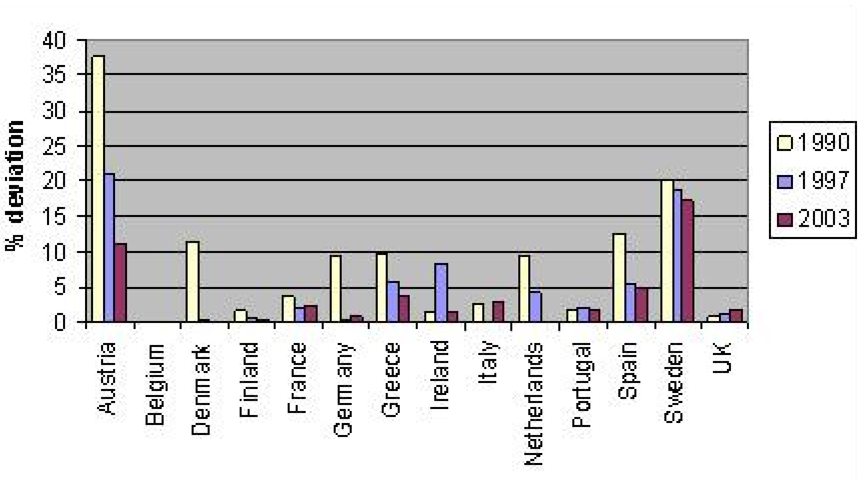


**Figure 6b** Deviations between the emission density indicators, from figure 6a, and the reported national implied emission factors (from UNFCCC).

The deviations in Figure 6b are low for all countries except Austria and Sweden. The low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factor is 74 ktonnes $CO_2$/PJ for all years.

## 5.7 Energy Industries – Gaseous Fuels (1A1-gas)

Key source category: $CO_2$ emissions from "Energy Industries – Gaseous Fuels" (Gg $CO_2$).

Indicator: Energy use in "Transformation" and "Energy Sector" - gas (TJ/year).

Conversion factor for refinery gas (DK, Energistyrelsen, 2004): 56.9 kg $CO_2$/GJ.

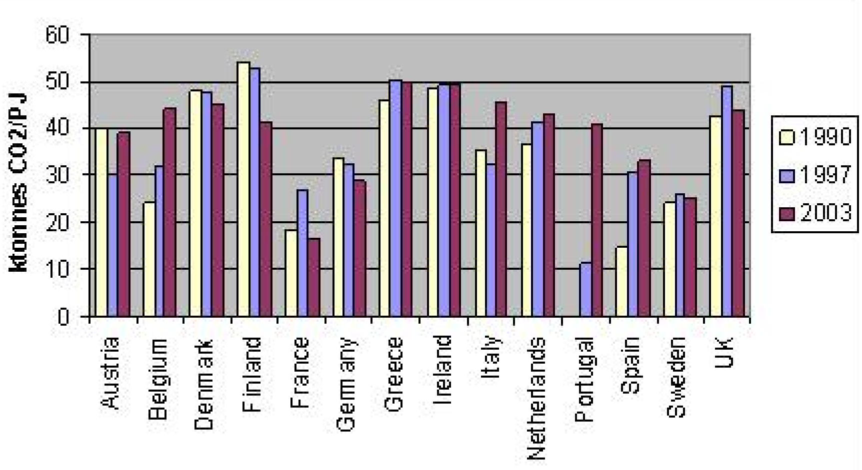


**Figure 7a** $CO_2$ emissions from "Energy Industries – Gaseous Fuels" (UNFCCC categories) relative to energy use in "Transformation" and "Energy Sector" - gas (OECD categories). No $CO_2$ emissions are reported for Portugal in 1990.

Denmark, Finland, Ireland, Greece, Netherlands and UK are comparable and have lowest deviations from the Danish value for refinery gas of 56.9 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

The Danish emission density indicator decreases slightly but is considered consistent between the years.

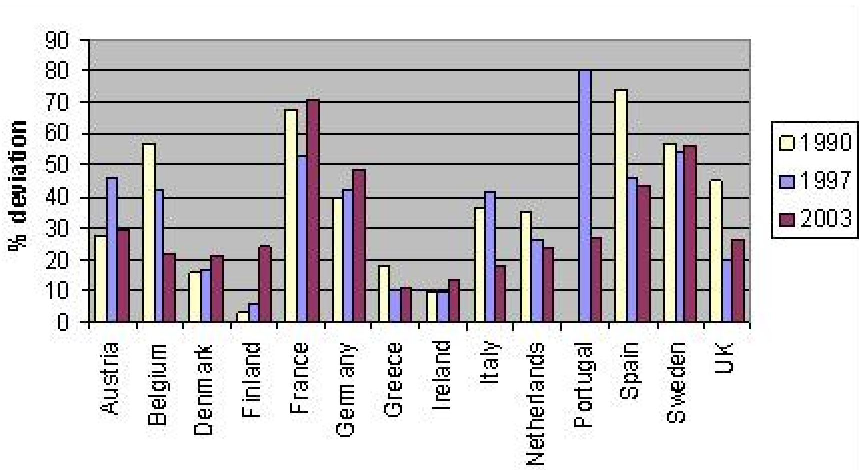


**Figure 7b** Deviations between the emission density indicators, from figure 7a, and the reported national implied emission factors (from UNFCCC). No $CO_2$ emissions are reported for Portugal in 1990.

The deviations in Figure 7b are lowest for most countries, including Denmark, Netherlands, Portugal and UK. The low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factor is 57 ktonnes $CO_2$/PJ for all years.

## 5.8 Manufacturing Industries and Construction – Gaseous Fuels (1A2-gas)

Key source category: $CO_2$ emissions from "Manufacturing Industries and Construction – Gaseous Fuels" (Gg $CO_2$).

Indicator: Energy use in "Industry Sector" - gas (TJ/year).

Conversion factor for refinery gas (DK, Energistyrelsen, 2004): 56.9 kg $CO_2$/GJ.

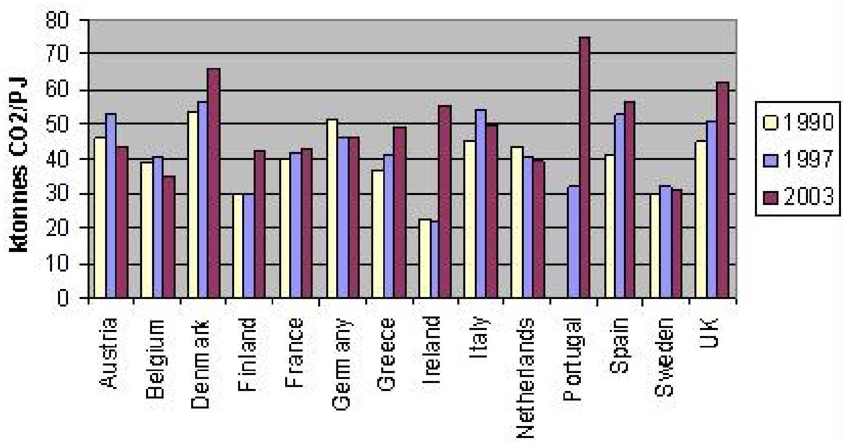


**Figure 8a** $CO_2$ emissions from "Manufacturing Industries and Construction – Gaseous Fuels" (UNFCCC categories) relative to energy use in "Industry Sector" - gas (OECD categories). No $CO_2$ emissions are reported for Portugal in 1990.

Denmark, Italy, Spain and UK are comparable and have lowest deviations from the Danish value for refinery gas of 56.9 ktonnes $CO_2$/PJ (Energistyrelsen, 2004). The energy use indicator is defined as the entire "Industry sector", and this may be an overestimation compared to the key source category "Manufacturing Industries and Construction". No sub-categories in the "Industry sector" have been found to represent the key source better.

The Danish emission density shows an increase between years, but is considered consistent.

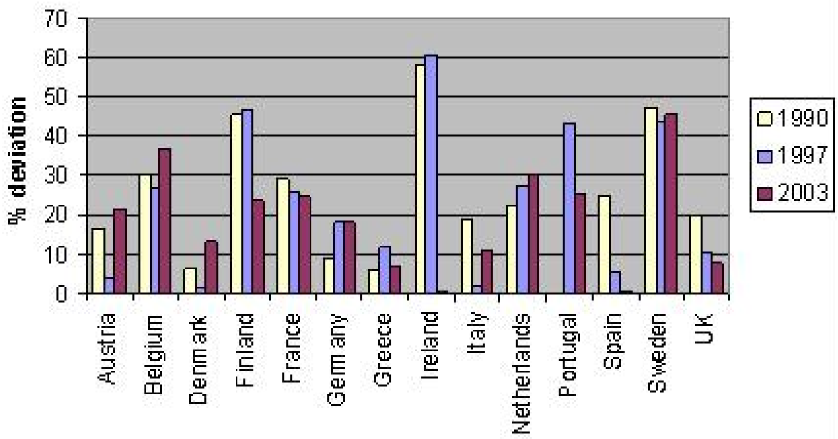


**Figure 8b** Deviations between the emission density indicators, from figure 8a, and the reported national implied emission factors (from UNFCCC). No $CO_2$ emissions are reported for Portugal in 1990.

The deviations in Figure 8b are lowest for Denmark, Greece, Italy, Spain and UK. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factor is 57 ktonnes $CO_2$/PJ for all years.

## 5.9 Other Sectors – Gaseous Fuels (1A4-gas)

Key source category: $CO_2$ emissions from "Other Sectors – Gaseous Fuels" (Gg $CO_2$).

Indicator: Energy use in "Other Sectors" - gas (TJ/year).

Conversion factor for refinery gas (DK, Energistyrelsen, 2004): 56.9 kg $CO_2$/GJ.

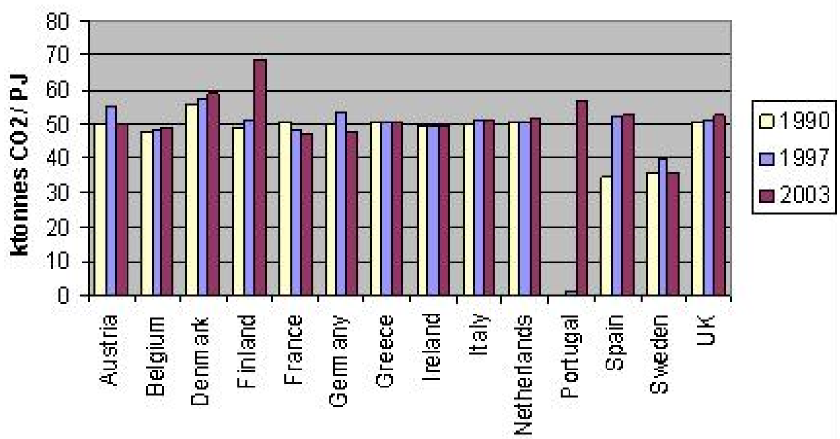


**Figure 9a** $CO_2$ emissions from "Other Sectors – Gaseous Fuels" (UNFCCC categories) relative to energy use in "Other Sectors" - gas (OECD categories). No $CO_2$ emissions are reported for Portugal in 1990.

All countries except Portugal and Sweden are comparable and are consistent with the Danish value for refinery gas of 56.9 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

The Danish emission density indicator is consistent between years, which indicate reliability in the estimates.

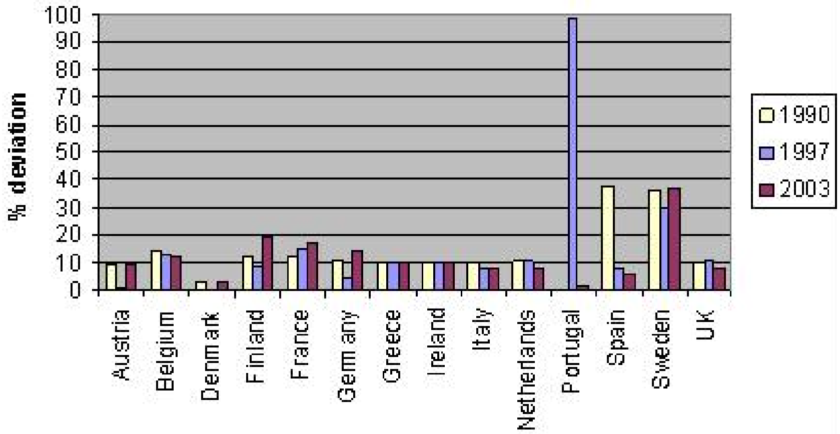


**Figure 9b** Deviations between the emission density indicators, from figure 9a, and the reported national implied emission factors (from UNFCCC). No $CO_2$ emissions are reported for Portugal in 1990.

The deviations in Figure 9b are low for all countries with a few exceptions. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute value of the Danish national implied emission factor is 57 ktonnes $CO_2$/PJ for all years.

## 5.10 Energy Industries – Liquid Fuels (1A1-oil)

(based on 2002-figures): $CO_2$ emissions from "Energy Industries – Liquid Fuels" (Gg $CO_2$).

Indicator: Energy use in "Transformation" and "Energy Sector" (ktonnes oil/year).

Conversion factor for oil (DK, mean value (Energistyrelsen, 2004)): 70 kg $CO_2$/GJ.

Calorific value for oil (DK, mean value (Energistyrelsen, 2004)): 42 TJ/ktonnes oil.

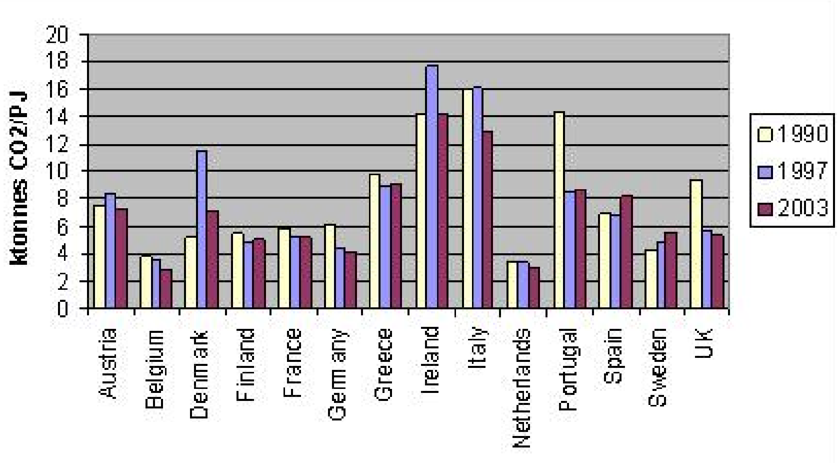


**Figure 10a** $CO_2$ emissions from "Energy Industries – Liquid Fuels" (UNFCCC categories) relative to energy use in "Transformation" and "Energy Sector" – oil (OECD categories).

Austria, Denmark and Spain have comparable emission density indicator. They are however not comparable with the mean Danish value for oil 70 ktonnes $CO_2$/PJ (Energistyrelsen, 2004). The high deviations for all countries can be explained by high energy use values defined as "Transformation" and "Energy Sector", which may be an overestimation, compared to the key source category "Energy Industries". No sub-categories have been assessed to represent the key source better.

The Danish emission density indicator peaks in 1997, which gives an inconsistency in the time trend. This is caused by high orimulsion consumption in 1997 compared to 2003. In 1990 there was no orimulsion consumption.

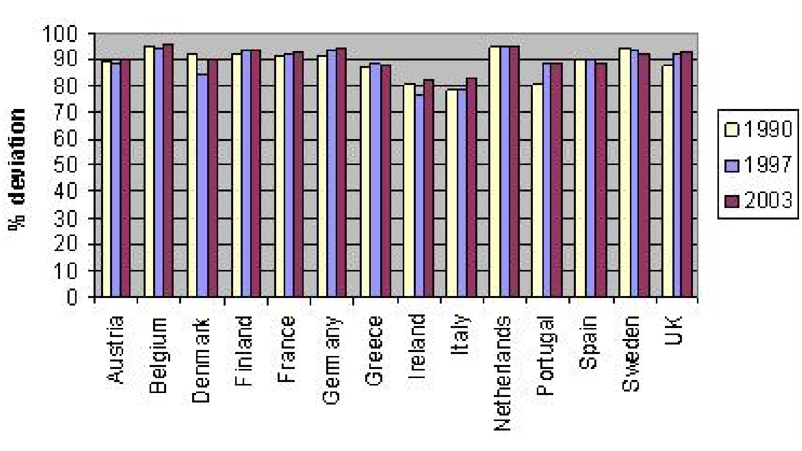


**Figure 10b** Deviations between the emission density indicators, from figure 10a, and the reported national implied emission factors (from UNFCCC).

High deviations are seen for all countries in Figure 10b. The absolute values of the Danish national implied emission factors range from 67 (1990) to 74 (1997).

## 5.11 Manufacturing Industries and Construction – Liquid Fuels (1A2-oil)

Key source category: $CO_2$ emissions from "Manufacturing Industries and Construction – Liquid Fuels" (Gg $CO_2$).

Indicator: Energy use in "Industry Sector" (ktonnes oil/year).

Conversion factor for oil (DK, mean value (Energistyrelsen, 2004)): 70 kg $CO_2$/GJ.

Calorific value for oil (DK, mean value (Energistyrelsen, 2004)): 42 TJ/ktonnes oil.

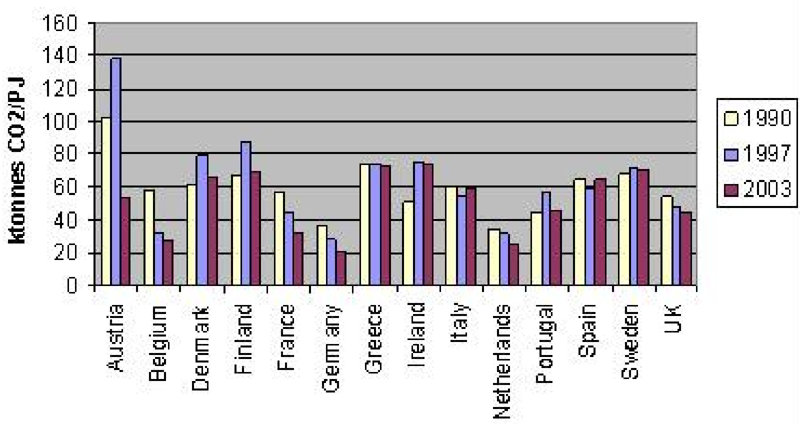


**Figure 11a** $CO_2$ emissions from "Manufacturing Industries and Construction – Liquid Fuels" (UNFCCC categories) relative to energy use in "Industry Sector" – oil (OECD categories).

Denmark, Finland, Greece, Ireland, Spain and Sweden are comparable and have lowest deviations from the Danish value for oil of 70 ktonnes $CO_2$/PJ (Energistyrelsen, 2004). The energy use indicator is defined as the entire "Industry sector", and this may be an overestimation compared to the key source category "Manufacturing Industries and Construction". No sub-categories in the "Industry sector" have been found to represent the key source better.

The Danish emission density indicator can be considered to be consistent in time.

For each country and each year the deviations between the emission density indicators, from Figure 11a, and the reported national implied emission factors are shown in Figure 11b.

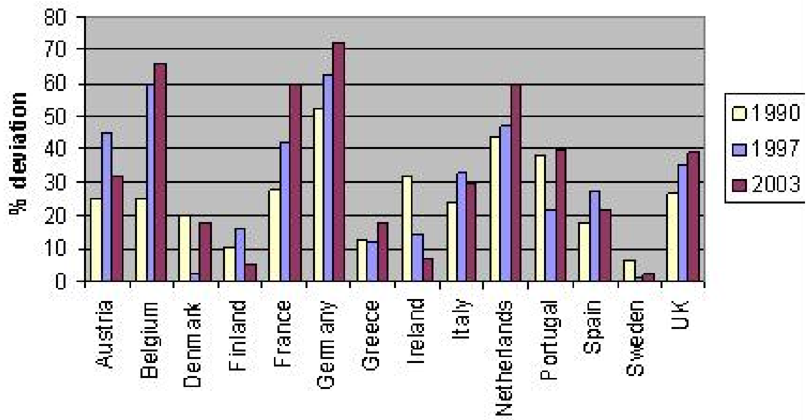


**Figure 11b** Deviations between the emission density indicators, from figure 11a, and the reported national implied emission factors (from UNFCCC).

The deviations in Figure 11b are lowest for Denmark, Finland, Greece and Sweden. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute values of the Danish national implied emission factors range from 77 (1990) to 79 (2003).

## 5.12 Other Sectors – Liquid Fuels (1A4-oil)

Key source category: $CO_2$ emissions from "Other Sectors – Liquid Fuels" (Gg $CO_2$).

Indicator: Energy use in "Other Sectors" (ktonnes oil/year).

Conversion factor for oil (DK, mean value (Energistyrelsen, 2004)): 70 kg $CO_2$/GJ.

Calorific value for oil (DK, mean value (Energistyrelsen, 2004)): 42 TJ/ktonnes oil.

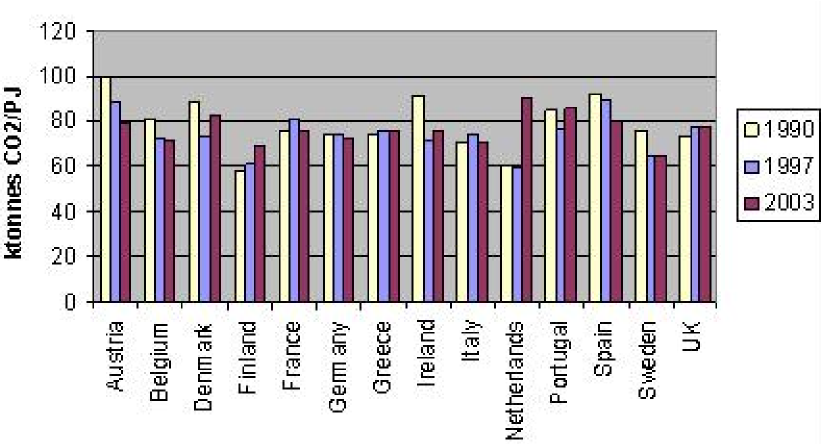


**Figure 12a** $CO_2$ emissions from "Other Sectors – Liquid Fuels" (UNFCCC categories) relative to energy use in "Other Sectors" – oil (OECD categories).

All countries are comparable and are consistent with the Danish value for oil of 70 ktonnes $CO_2$/PJ (Energistyrelsen, 2004).

The Danish emission density indicator is consistent between years, which indicate reliability in the estimates.

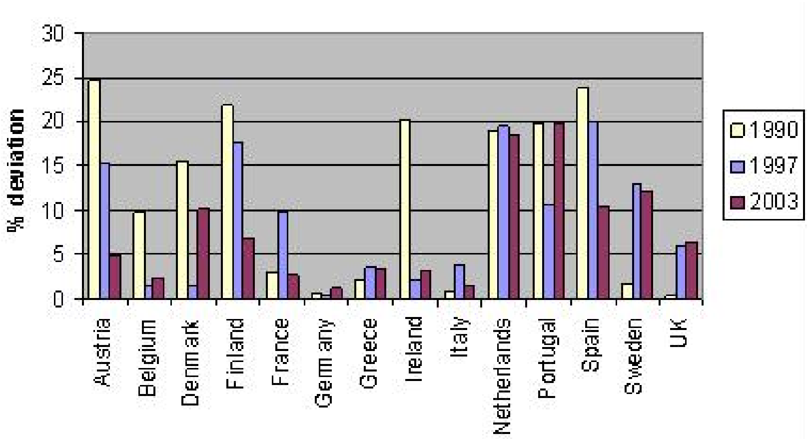


**Figure 12b** Deviations between the emission density indicators, from figure 12a, and the reported national implied emission factors (from UNFCCC).

The deviations in Figure 12b are lowest for Denmark, Belgium, France, Germany, Greece, Italy and UK. The relatively low deviation for Denmark indicates good quality implied emission factor, emission value and activity data. The absolute values of the Danish national implied emission factor are 74 kg $CO_2$/GJ for all years.

## 5.13 Fuel Combustion – Gaseous Fuels (1A)

Key source category: $CH_4$ emissions from "Fuel Combustion – Gaseous Fuels" (Gg $CH_4$)

Indicator: Energy use in "Transformation", "Energy Sector", "Industry Sector", "Transport Sector" and "Other Sectors" - gas (TJ/year)

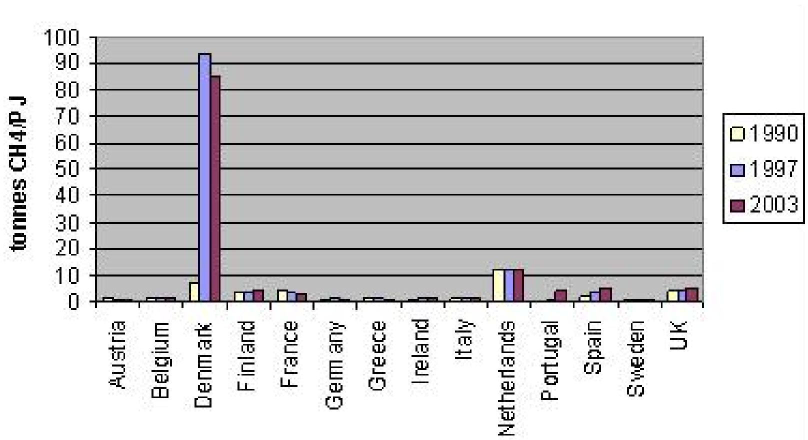


**Figure 13a** $CH_4$ emissions from "Fuel Combustion – Gaseous Fuels" (UNFCCC categories) relative to energy use in "Transformation", "Energy Sector", "Industry Sector", "Transport Sector" and "Other Sectors" - gas (OECD categories).

This key source is an aggregate of the UNFCCC sectors "Energy Industries", "Manufacturing and Construction", "Transport", "Other Sectors" and "Other". The actual $CH_4$ emissions (e.g. 18 Gg $CH_4$/year for 2003) are a factor 1000 higher than for Greece, Portugal and Sweden. The Danish emissions are together with Netherlands and UK the highest among the compared countries. The Danish emission trend goes from 0.6 in 1990 to 17 in 1997 and to 18 in 2003. The main reason for the increase in emission is an increasing emission factor for gas engines from 257 g/GJ in 1990 to 534 g/GJ in 1997 combined with an increasing consumption in gas engines from 0.83 PJ in 1990 to 28.8 PJ in 1997.

The Danish emission density indicators shown in Figure 13a vary strongly, but as can be seen from Figure 13b, they correspond well with the implied emissions factors for all years, since the deviation is low. This means there is a good correlation between $CH_4$ emissions and the energy use, but inconsistency in estimating the actual $CH_4$ emissions.

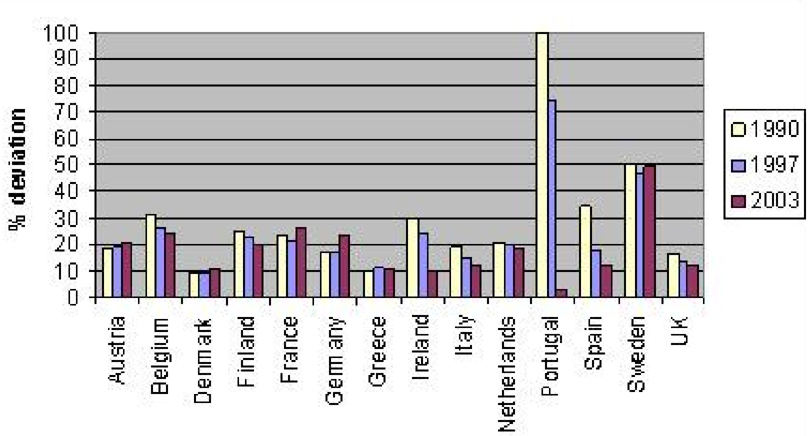


**Figure 13b** Deviations between the emission density indicators, from Figure 13a, and the reported national implied emission factors.

The deviations between the emission density indicators, from Figure 13a, and the reported national implied emission factors are shown in Figure 13b. The deviations are lowest for Denmark and Greece. The absolute values of the Danish national implied emission factors range from 8 (1990) to 102 (1997).

# 6 Agriculture

UNFCCC reporting according to the 1996 IPCC Guidelines for National Greenhouse Gas Inventories 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

Five Danish key source categories are comprised in the agricultural sector: Direct and indirect $N_2O$ emissions from agricultural soils, enteric fermentation and $N_2O$ and $CH_4$ emissions from manure management.

For the agricultural sector the indicators differ from the Norwegian verification report (SFT, 2000). Indicators have been chosen that describe a more direct cause-effect link to the emissions. The indicators are obtained from FAOstat Agriculture, 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.

Inter county comparisons of emission density indicators will be made and time trends will be considered.

## 6.1 Direct Soil Emissions (4D-direct)

Key source category: $N_2O$ emissions from "Direct Soil Emissions" (Gg $N_2O$)

Indicator: Agricultural area, land use (1000 Ha) (FAOstat Agriculture)

UNFCCC reporting of direct $N_2O$ emissions is from mineral fertilisers, Animal Wastes Applied to Soils, N-fixing Crops, Crop Residue and Cultivation of Histosols.

The agricultural area is used as indicator because both mineral fertilisers and animal manure are applied to the land. In Denmark each category contributes approximately with the same $N_2O$ emission. The indicator will then be a proxy of how intensive the agricultural land is managed.

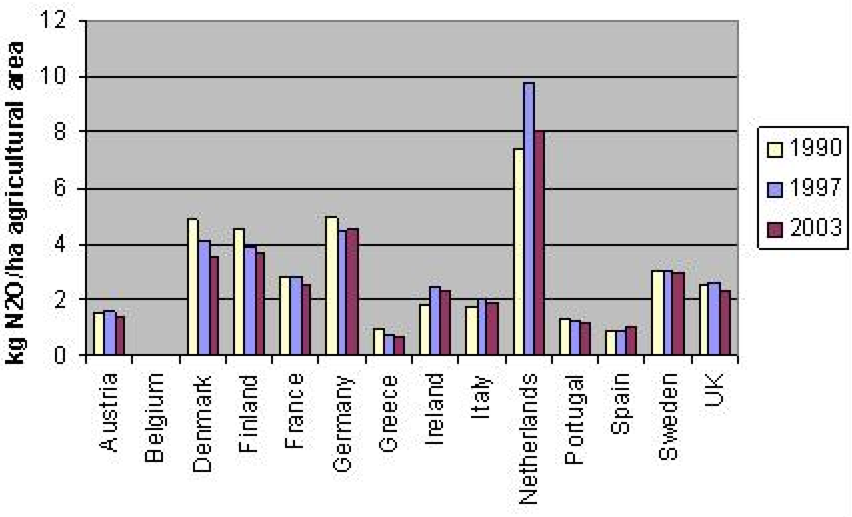


**Figure 14** $N_2O$ emissions from "Direct Soil Emissions" (UNFCCC categories) relative to Agricultural area (FAOstat Agriculture).

The Danish emission density indicator (abscissa in Figure 14) is comparable with the values from Finland and Germany. The Danish values are relatively high because of a high animal density and relative low input of mineral fertilisers. Countries with low animal stocking per hectare will most likely have a low emission density indicator value.

Nearly all countries show a decreasing trend, which may be explained by increasing environmental demands which force the farmers to reduce the nitrogen input. In general differences in the relative importance of animal and crop production will give diverging results. A reliable verification is only convenient for countries that have similar agricultural production.

The absolute values of the Danish $N_2O$ emissions range from 13 Gg $N_2O$/year (1990) to 9 Gg $N_2O$/year (2003).

## 6.2 Total Agriculture – Enteric Fermentation (4A)

Key source category: $CH_4$ emissions from "Total Agriculture – Enteric Fermentation" (Gg $CH_4$).

Indicator: Meat production from bovine (cattle and buffalo) + sheep + goat (1000 tonnes) (FAOstat Agriculture).

Enteric fermentation takes place in the digestive systems of animals (particularly ruminant animals such as cattle, buffalo, sheep, goats, and camels). Methane is produced in the "fore-stomach" or rumen by bacteria as a by-product of the fermentation process. The Danish figure for methane production is 127 kg/(head*year) for dairy cattle and lower for non-dairy cattle (males, heifers and calves). This value is among the highest reported due to the efficient Danish agriculture. The mean methane production from enteric fermentation from cattle is 67 kg $CH_4$/(head*year) for Denmark.

Because all ruminants add substantially to the $CH_4$ emission the meat production is chosen as indicator. This will make a comparison easier between countries having a major production of sheep and goats to those only having cattle.

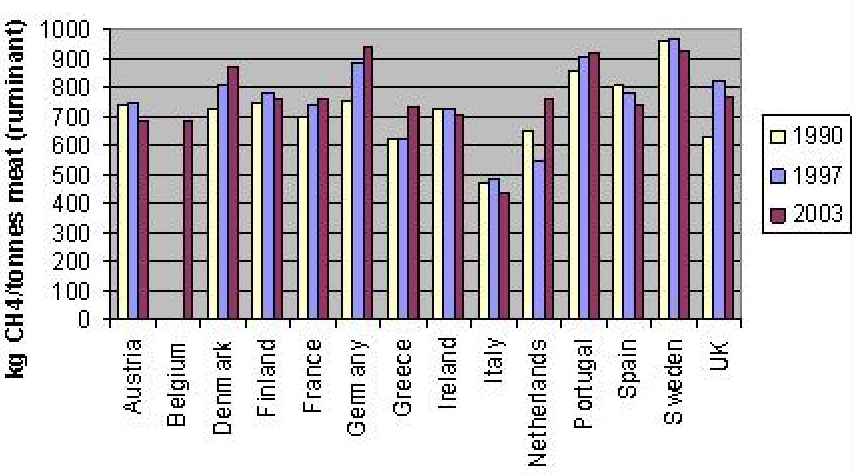


**Figure 15** $CH_4$ emissions from “Total Agriculture – Enteric Fermentation” (UNFCCC categories) relative to meat production of bovine (including cattle and buffalo) + sheep + goat (FAOstat Agriculture). For Belgium no production is reported for 1990 and 1997.

The Danish emission density indicator is comparable with the values from Finland, France, Germany, Spain and UK. The increase in methane emission from 1990 to 2003 in most countries can be explained with the EU milk quotas and the increasing milk production per dairy cow. The increasing milk production reduces the number of dairy cows and the number of offspring and subsequently the meat production. Countries having a large proportion of meat producing cattle or sheep and goats will most likely not show the same increase per tonnes meat compared to countries only having dairy cows like Denmark and Germany.

The absolute values of the Danish methane emissions range from 148 Gg $CH_4$/year (1990) to 130 Gg $CH_4$/year (2003).

## 6.3 Indirect Emissions (4D-indirect)

Key source category: $N_2O$ emissions from “Indirect Emissions” (Gg $N_2O$).

Indicator: Agricultural area, land use (1000 Ha) (FAOstat Agriculture).

UNFCCC reporting of indirect $N_2O$ emissions is from atmospheric deposition and nitrogen leaching and run-off. Nitrogen leaching and run-off contributes with the major part of the indirect emissions for Denmark. Indirect $N_2O$ emissions originates from both animal and crop production. Because of the close relationship between use of mineral fertilisers and nitrogen from manure management the agricultural area is seen as the most appropriate indicator.

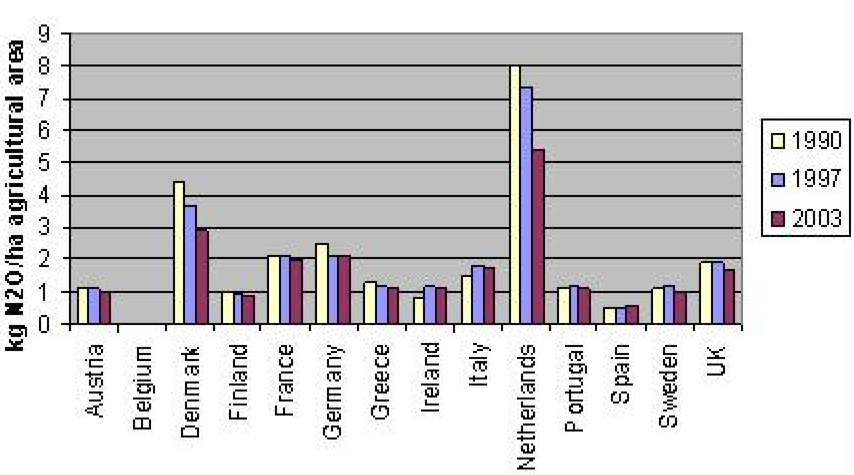


**Figure 16** $N_2O$ emissions from "Indirect Emissions" (UNFCCC categories) relative to Agricultural area, land use (FAOstat Agriculture).

The Danish emission density indicator is higher than most of the countries but lower than the Netherlands. The Danish values are relatively high because of medium to high agricultural nitrogen input with high losses of ammonia from manure handling and high leaching rates. Several countries have a lower emission factor for nitrogen leaching in their inventories than Denmark due to climatic conditions

Nearly all countries show a decreasing trend due to lower ammonia emission so they can comply with their National Emission Ceilings for acidifying and euthrofying substances under the NEC-directive and the consequences of the EU-nitrate directive which forces the farmers to reduce the nitrogen use in nitrate vulnerable zones.

The absolute values of the Danish $N_2O$ emissions range from 12 Gg $N_2O$/year (1990) to 8 Gg $N_2O$/year (2003).

## 6.4 Manure Management (4B-$CH_4$)

Key source category: $CH_4$ emissions from "Manure Management" (Gg $CH_4$)

Indicator: Total meat production from bovine (cattle and buffalo) + sheep + goat + horse + pig + chicken + turkey (1000 tonnes) (FAOstat Agriculture)

UNFCCC reporting of $CH_4$ emissions from manure management are from cattle (dairy cattle, non-dairy cattle), buffalo, sheep, goats, camels, llamas, horses, mules, asses, swine and poultry. The chosen indicator is therefore the total meat production.

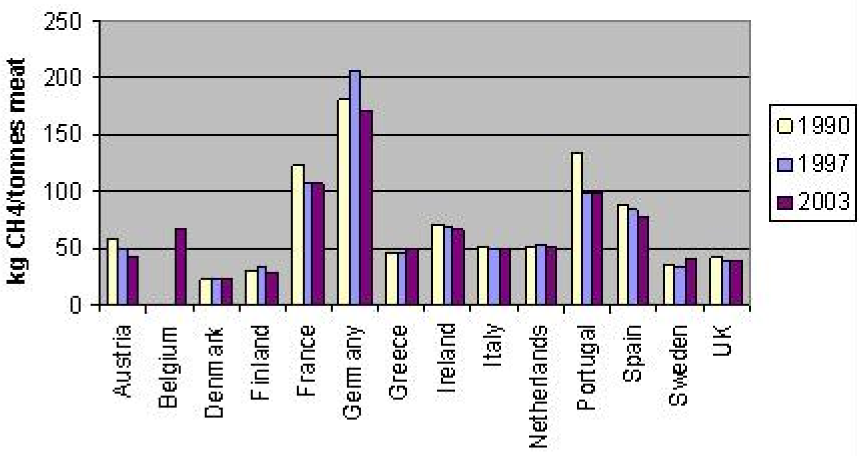


**Figure 17** $CH_4$ emissions from "Manure Management" (UNFCCC categories) relative to Total meat production from bovine (cattle and buffalo) + sheep + goat + horse + pig + chicken + turkey (FAOstat Agriculture).

The $CH_4$ from manure management is related to how manure is stored because the emission comes primarily from slurry tanks and the climatic conditions where warmer climates increase the $CH_4$ emission. The Danish emission density indicator is the lowest of all countries. This is due to a highly efficient agriculture with a low use of feed stuff per produced kg meat and use of a low emission factor for liquid manure (10% compared to the IPCC default of 39%). This low value is also used by Finland and Sweden. The highest values are found in countries with a high percentage of the manure handled as slurry combined with the use of the high emission factor of 39%. The emission factor of 39% is not found reliable under Nordic climatic conditions. Countries in more warm and dry climates than the Danish will normally have a higher proportion of all-year grassing, which yield lower $CH_4$, but if the 39% emission factor is used in these countries the effect in the indicator will be hidden. This may be an explanation of why the Mediterranean countries have higher values than the Nordic countries.

The trend for the Danish emission per kg produced meat is constant for the investigated years.

The absolute values of the Danish $CH_4$ emissions range from 35 Gg $CH_4$/year (1990) to 46 Gg $CH_4$/year (2003).

## 6.5 Manure Management (4B-$N_2O$)

Key source category: $N_2O$ emissions from "Manure Management" (Gg $N_2O$).

Indicator: Total meat production from bovine (cattle and buffalo) + sheep + goat + horse + pig + chicken + turkey (1000 tonnes) (FAOstat Agriculture).

UNFCCC reporting of $N_2O$ emissions from manure management are from anaerobic lagoons, liquid systems, solid storage, dry lot and other.

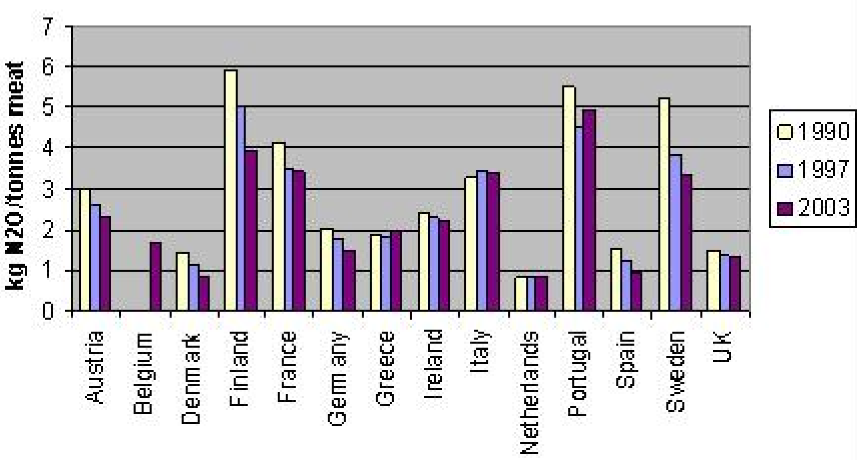


**Figure 18** $N_2O$ emissions from "Manure Management" (UNFCCC categories) relative to Total meat production from bovine (cattle and buffalo) + sheep + goat + horse + pig + chicken + turkey (FAOstat Agriculture).

The Danish emission density indicator is relatively low and comparable to the values from Spain and UK. $N_2O$ from manure management is mainly produced under aerobic conditions, but because a major part of the Danish manure is handled as slurry a low emission of $N_2O$ is estimated. Mediterranean countries with all year grassing will therefore produce more $N_2O$ per tonnes produced meat than the highly industrialised and specialised countries like Denmark and the Netherlands.

Denmark and most countries show a decreasing trend in the emission density indicator. This is explained with a lower proportion of the manure that is handled as solid manure yielding lower $N_2O$ emissions per tonnes meat.

The absolute values of the Danish $N_2O$ emissions range from 2.2 Gg $N_2O$/year (1990) to 1.8 Gg $N_2O$/year (2003).

# 7 Industrial Processes

## 7.1 Total Industrial Processes – Mineral Products – Cement Production (2A1)

Key source category: $CO_2$ emissions from "Total Industrial Processes – Mineral Products – Cement Production" (Gg $CO_2$).

Indicator: Cement production (ktonnes/year) (UN Statistical Yearbook, 2004).

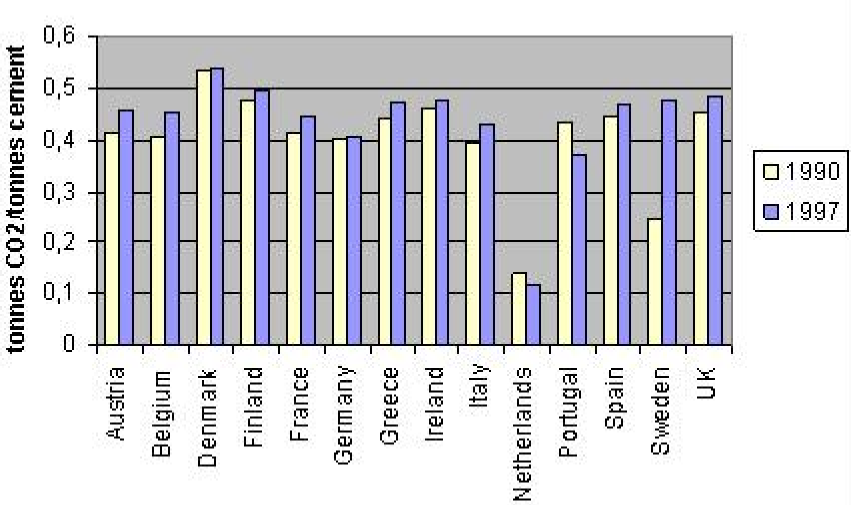


**Figure 19a** $CO_2$ emissions from "Total Industrial Processes – Mineral Products – Cement Production" (UNFCCC categories) relative to cement production (UN Statistical Yearbook). Data for 2003 could not be obtained for this report.

The emission density indicators for Denmark, Finland, Greece, Ireland, Spain and UK are comparable with the default emission factor of 0.4985 tonnes $CO_2$/tonnes cement, which is recommended by IPCC. The relative high values of the Danish values in Figure 19a compared to other countries can be explained by the high quality of the Danish products (i.e. grey and white cements) or other product mix in Denmark. Except for Netherlands the emission density indicators are in good agreement in an inter country comparison, and cement production can accordingly be considered to be a reliable indicator. There is consistency between the Danish 1990 and 1997 data.

The absolute values of the Danish $N_2O$ emissions range from 882 Gg $CO_2$/year (1990) to 1442 Gg $CO_2$/year (1997).

For each country and each year the deviations between the emission density indicators, from Figure 19a, and the reported national implied emission factors are shown in Figure 19b.

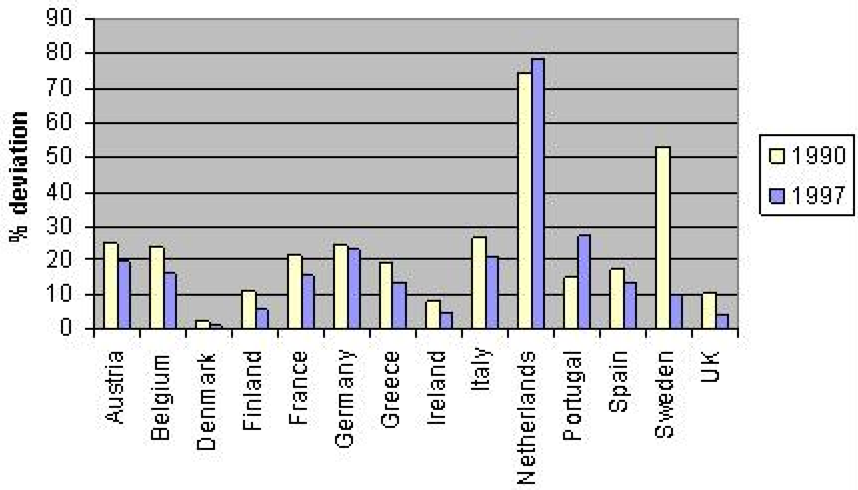


**Figure 19b** Deviations between the emission density indicators, from figure 19a, and the reported national implied emission factors (from UNFCCC). Data for 2003 could not be obtained for this report.

The absolute values of the Danish national implied emission factors range from 0.53 (1997) to 0.54 (1990), and show small deviations with the Danish emission density indicators in Figure 19a.

## 7.2 Chemical Industry – Nitric Acid Production (2B2)

Key source category: $N_2O$ emissions from "Chemical Industry – Nitric Acid Production" (Gg $N_2O$)

Indicator: No suitable indicator was found to represent this key source category

The nitric acid plant was closed in the middle of 2004 and therefore no attempts have been made to develop an indicator.

# 8 Waste

## 8.1 Managed Waste Disposal on Land (6A1)

Key source category: $CH_4$ emissions from "Managed Waste Disposal on Land" (Gg $CH_4$).

Indicator: Disposal of municipal waste on landfills (ktonnes) (OECD Environmental Data).

The UNFCCC reporting on Solid Waste Disposal covers Managed Waste Disposal on Land, Unmanaged Waste Disposal Sites (deep >5 m, shallow <5 m) and Other. In the Danish inventory only the category Managed Waste Disposal on Land is significant. $CH_4$ is emitted during biological decomposition of waste. Most of the emissions occur during the first years after disposal but $CH_4$ generation may take place for several decades.

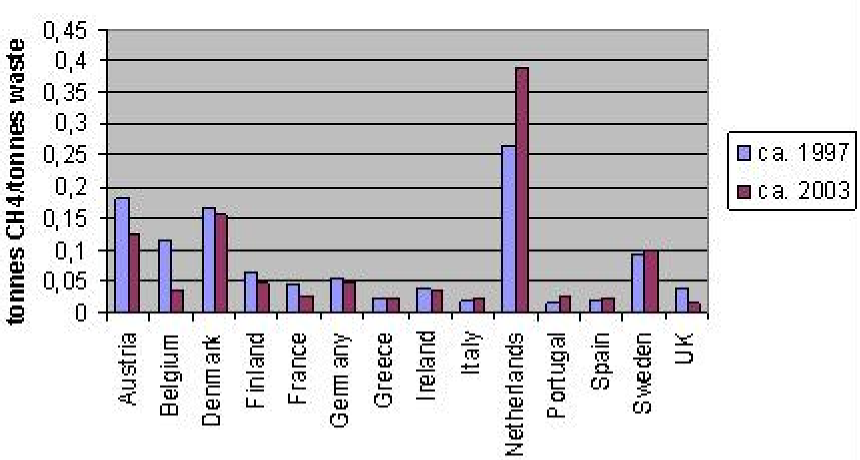


**Figure 20a** $CH_4$ emissions from "Managed Waste Disposal on Land" (UNFCCC categories) relative to Disposal of municipal waste on landfills (ktonnes) (OECD Environmental Data). Data for 1990 could not be obtained for this report.

The emission density indicator for Denmark and Austria are comparable. There are large variations in the emission density indicators between countries, which indicate a poor assessment of the emissions by the chosen indicator. However, there is reasonable consistency in the Danish emission density indicator between 1997 and 2003.

For each country and each year the deviations between the emission density indicators, from Figure 20a, and the reported national implied emission factors are shown in Figure 20b.

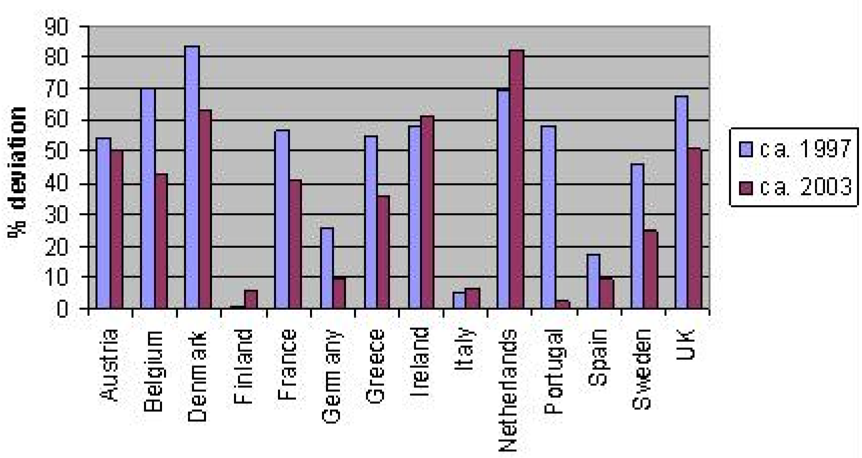


**Figure 20b** Deviations between the emission density indicators, from figure 20a, and the reported national implied emission factors (from UNFCCC). Data for 1990 could not be obtained for this report.

The deviations in Figure 20b are high for Denmark, which could be a result of poor correlation between reported emissions and the chosen indicator. The indicator from OECD is waste deposited on landfills. If waste used for composting and recycling is included a lower emission density indicator is obtained, which may be in better agreement with the reported implied emission factors. The absolute values of the Danish national implied emission factors range from 0.03 (1990) to 0.06 (1997).

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**NERI** **National Environmental Research Institute**

DMU Danmarks Miljøundersøgelser

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**627** Verification of the Danish emission inventory data by national and international data comparisons

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