Comparison of CO2 emission factors for fuels used in Greenhouse Gas Inventories and consequences for monitoring and reporting under the EC emissions trading scheme

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LIST OF ACRONYMS

CRF	Common Reporting Format
EC	European Community
EF	Emission factor
GHG	greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied Petroleum Gas
MS	Member States
NCV	Net calorific value
NIR	National Inventory Report
UNFCCC	United Nation's Framework Convention on Climate Change

1 Introduction and objective

Within the framework of the Guidelines for monitoring and reporting of emissions under the directive establishing a scheme for greenhouse gas emission allowance trading within the European Community, rules have to be established for the estimation of CO_2 emissions from fuel combustion for the installations included under the emissions trading scheme. In general there are the following methodologies that can be used to estimate greenhouse gas emissions for an installation:

1. CO_2 emissions from fuel combustions are estimated by multiplying the amount of fuel used with a fuel-specific CO_2 emission factor;
2. Direct measurement of CO_2 emissions;
3. Mass or carbon balance approaches for non-energy use of fuels or in specific other areas.

According to *IPCC Good Practice Guidance and Uncertainty Management of National Inventories*[1], continuous monitoring cannot be justified for CO_2 alone because of its comparatively high costs and because it does not improve accuracy for CO_2 estimation from fuel combustion.[2]. Therefore this paper in general concentrates on the use of the emission factor based method and its application for monitoring of CO_2 emissions under the EC emissions trading scheme. However, there may be some specific cases where continuous monitoring should be further considered.

2 Approach

The paper discusses different fuel types (solid, liquid and gaseous fuels) separately. For individual fuel types the following aspects are analysed:

1. the ranges of fuel-specific CO_2 emission factors within EU Member States;
2. the differences between country-specific emission factors and default IPCC CO_2 emission factors;
3. possible differences of country-specific emission factors and plant-specific emission factors;
4. the differences of fuel definitions used by Member States, IPCC, and Eurostat/ IEA.
5. the estimation problems in relation to non-energy use of fuels.

The information and data used in this paper is based on information contained

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1 Further referenced as *IPCC Good Practice Guidance*

2 *IPCC Good Practice Guidance*, p. 2.8

in GHG inventories (CRF and NIRs) from Parties under the UNFCCC, and more detailed information that was made available to the author by several EU Member States (the Netherlands, Germany, Finland and Sweden) as well as on data from Eurostat and IEA.

All CO_2 emission factors presented are based upon Net Calorific Values. The emission factors presented assume complete oxidation of carbon in the fuel during combustion. Unoxidised carbon is taken into account in the IPCC methodology by a separate correction factor. This approach is followed in this paper as well in order to obtain comparable values. However, in some cases country-specific information about the assumption in relation to complete or incomplete oxidation was not always available, thus in some cases where data was taken from NIRs, this assumption could not be confirmed. The values used to account for unoxidised carbon are not included in the analysis of this paper.

The annual inventory submission of Annex I Parties to the UNFCCC includes the CRF-Table 1.A(b) representing the reference approach which shows fuel-specific CO_2 emission factors used by Parties. Some Parties also provide fuel-specific emission factors in the national inventory reports (NIR) The following section intends to provide information where EU MS emission factors for specific fuel types differ from IPCC defaults.[3] Currently 9 (Denmark, Finland, Ireland, Italy, Germany, Netherlands, Spain, Sweden, UK) from the 14 Member States included in their report country-specific emission factors for fuels. All other MS use IPCC default EF in the reference approach table. However, this situation does not mean that county-specific EF for fuels are not available or will not be used in future years.[4] In some MS country-specific or plant-specific emission factors are available (e.g. in Greece, France, Austria) but not (yet?) reported in the CRF or NIR.

3 Comparison of European emission factors with IPCC default emission factors

In the following sections, comparative analysis in tables includes complete information on all fuel categories reported by Parties, however the analysis in the text focuses on fuel categories used in the energy or industry sector which are relevant under the European emissions trading scheme.

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3 The inventory data submitted in 2003 was used for the following comparisons for EU15 Member States. All MS except Luxemburg submitted the respective CRF tables, therefore these countries are not included in the following conclusions. Submissions from 2002 were used for accession countries and non-EU countries. Data for the year 2000 was used in the comparisons for all countries, except for Germany where only data for 1999 was submitted. In cases where certain fuel types were only used in years before 2000, data for earlier years was included.

4 For example Sweden indicates in the NIR that the energy contents of crude oil will be thoroughly examined together with the Swedish Petroleum Institute. The calorific values and specific weights of all petroleum products are also to be revised.

3.1 Liquid fuels

The ranges of specifications for secondary fuels are becoming more specific over time due to regulation within the EC. This is narrowing down the variation in oil products in general and their carbon content in particular, thus variations of CO_2 emission factors per fuel category should be generally small for liquid fuels. However, comparison of country-specific emission factors from EU Member States and accession countries sometimes shows considerable[5] differences between countries and with IPCC default EF.[6] Table 1 presents a detailed comparison of CO_2 emission factors for different fuels within European countries and with IPCC default emission factors.[7]

The CO_2 EF for ***crude oil*** potentially varies to a larger extent than for other liquid fuels as the properties and specification of the refinery input are less well defined and the carbon content is usually not measured. Few countries report country-specific values (Germany, Netherlands, Sweden, Poland, Slovakia). Those are sometimes considerably different than IPCC default values (Sweden). The IPCC describes a method to estimate the carbon content of crude oil based upon some properties of crude oil (API gravity, and sulphur content), that are generally measured and known parameters of traded crude oils. Based on their physical and chemical relationship with carbon content, these characteristics can be used to estimate the carbon content of a specific crude oil.

For ***LPG*** almost all country-specific CO_2 emission factors reported by EU member States and accession countries are higher than the IPCC default of 69.3 t C/TJ.[8] For the 14 Member States that reported information on fuel-specific emission factors, the difference between country specific and default emission factors is 3.1 %.[9] As the composition of secondary fuels are regulated within the EU there seems to be a systematic difference valid for all EU Member States. Within those EU Member States reporting country-specific EF for LPG the EF varies between 63.8 and 66.0 t CO_2 /TJ (by 3.8%). If installations would use IPCC default EF for LPG for reporting under the EC monitoring scheme, this would produce considerably differences to inventory estimates for CO_2 from

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5 As criteria for a “considerable” difference, a difference of 5 % to IPCC default EF was used for liquid fuels.

6 A CO2 emission factor as defined in terms of CO2 per TJ of fuel cannot be measured directly. What is measured or calculated from the chemical composition of the CO2 content (in weight %) The heating value (in terms of Net Calorific Value, NCV) is necessary to convert the amount of fuel in terms of energy instead of mass.

7 IPCC default emission factors as indicated in table 1-2, page 1.6 of the Workbook of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.

8 With the exception of Slovenia

9 If only those Member States with country-specific emission factor are compared with the IPCC default

EU Member States which use country-specific EF. If a default emission factors for LPG is specified under the EU emissions trading monitoring guidelines, an EU-specific or country-specific emission factor should be established.

For ***gas/diesel oil*** country-specific EF (average 73.9 t CO_2/TJ) are quite close to the IPCC default (74.1 t CO_2/TJ), but the range between European countries is larger from 72.3 to 75.5 t CO_2/TJ (4%) which may have considerable effects on emissions taking into account the large amounts of gas/diesel oil used in energy and industry sectors. Gas/diesel oil is a medium distillate oil primarily distilling between 180°C and 380°C. Several grades are available depending on uses:

- diesel oil for diesel compression ignition (cars, trucks, marine, etc.);
- light heating oil for industrial and commercial uses;
- other gas oil, including heavy gas oils which distil between 380°C and 540°C, and which are used as petrochemical feedstocks (= Destillate fuel oil)

Several countries report different emission factors for gas oil and diesel oil or specific emission factors for industrial uses. The EU emissions trading scheme will preferentially cover light heating oil for industrial use and heavy gas oils used as petrochemical feedstocks and it is desirable to establish separate emission factors for the grades that are used by industry, especially for light heating oils which is an important liquid fuel in the industrial energy consumption.

For ***residual fuel oil*** country-specific EF (77.1 t CO_2/TJ) are also close to the IPCC default (77.4 t CO_2/TJ), the range between European countries is somewhat smaller (76.0 – 78.8 t CO_2/TJ; 3.5%).

For ***other Kerosene***, the country-specific emission factors (72.1 t CO_2/TJ) are also close to the IPCC default (71.9 t CO_2/TJ) with a range of 3.2% between European countries (71.4 to 73.7 t CO_2/TJ).

For ***petroleum coke*** considerable variations occur between European countries and emission factors range from 79.8 t CO_2/TJ to 119 t CO_2/TJ (33 % difference). Petroleum coke is a black solid residue feedstock, obtained mainly by cracking and distillation of crude oil. The compositions of petroleum cokes highly depend on feedstocks and types of processes used. In general, petroleum cokes contain some portions of all the elements, which existed in the original feedstock. This means that emissions factors specific for the installation that take into account the feedstocks and processes used would be most appropriate. Default values at the European level could lead to considerable inconsistencies of CO_2 emission estimates and would increase uncertainties.

Some countries (Denmark, Finland, Germany, Ireland, Netherlands) provide information in their NIRs on the emission factor for ***refinery gas***. The difference between the country-specific average EF (58.6 t CO_2/TJ) and the IPCC default

(66.7 t CO_2/TJ is with 12 % considerable and all country-specific EF are lower than the IPCC default. The country-specific emission factors range from 46 to 65 t CO_2/TJ. Refinery gas includes a mixture of non-condensable gases mainly consisting of hydrogen, methane, ethane, and olefins obtained during distillation of crude oil or treatment of oil products (e.g. cracking) in refineries. Similar as for petroleum coke installation-specific emission factors would be most appropriate to reflect the processes. The use of European default EF would add high uncertainties to the estimation of CO_2 emissions. As the chemical composition of refinery gas is also variable from year to year, regular updates of emission factors are also necessary.

For the refinery products (***ethane, naphtha, bitumen, lubricants***) few country-specific data are available and most countries use IPCC default EF in the CRF reporting. There are large differences between country-specific emission factors for ***bitumen***, however only two countries provided information and it is difficult to assess if this difference is representative. However for these fuel categories, the separation of non-energy fuel use and fuel use may be more relevant with regard to the uncertainties of final CO_2 estimates than the emission factors used. The non-energy fuel use is discussed in section 5.

Table 1 Comparison of IPCC default CO_2 emission factors and country specific emission factors for liquid fuels for Europe [t CO_2/TJ, basis NCV]

Country	CO_2 emission factor [tCO_2/TJ]																	Source
	Primary fuels			Secondary Fuels / Products														
	Crude Oil	Orimulsion	Natural Gas Liquids	Gasoline	Jet Kerosene	Other Kerosene	Shale Oil	Gas / Diesel Oil	Residual Fuel Oil	LPG	Ethane	Naphtha	Bitumen	Lubricants	Petroleum Coke	Refinery Feed-stocks	refinery gas	Other oil	
IPCC default	***73.3***	***80.7***	***63.1***	***69.3***	***71.5***	***71.9***	***73.3***	***74.1***	***77.4***	***63.1***	***61.6***	***73.3***	***80.7***	***73.3***	***100.8***	***73.3***	***66.7***	***73.3***	
Austria	IPCC	NO	IPCC	IPCC	IPCC	IPCC	NO	IPCC	IPCC	IPCC	IE	IE	IPCC	IPCC	IE	IPCC		IPCC	CRF 2003
Belgium	IPCC			IPCC	IPCC			IPCC	IPCC	IPCC			IPCC	IPCC				IPCC	CRF 2003
Denmark	IPCC	80.0	NO	IPCC	72.0	NO	NO	74.0	78.0	65.0	NO	IPCC	IPCC	IPCC	92.0	IPCC	57.1	NO	NIR 2003
Finland	IPCC	NO	IPCC	72.7	IPCC	71.5	NO	73.6	IPCC	IPCC	IE	72.7	IPCC	IPCC	IPCC	IPCC	65.0	IPCC	NIR 2003
France	IPCC	NO	IPCC	IPCC	IPCC	IPCC	NO	IPCC	IPCC	IPCC	NO	IPCC	IPCC	IPCC	IPCC	IPCC		IPCC	CRF 2003 + 2002
Germany	73.4	NO	NA	74.7	74.8	IE	NO	74.5	78.8	63.8	NO	74.4	IPCC	IPCC	119.0	NA	60.0	IPCC	CRF 2003, UBA 2003
Greece	IPCC	IPCC	IPCC	IPCC	IPCC	IPCC		IPCC	IPCC	IPCC		IPCC	IPCC	IPCC	IPCC	IPCC		IPCC	CRF 2003
Ireland	IPCC		65.0	72.6	IPCC	71.4		73.3	76.0	63.7		IPCC			IPCC		65.0		CRF + NIR 2003
Italy	IPCC	IPCC	NO	IPCC	IPCC	71.5	NO	IPCC	77.6	65.6	NA	IPCC	NA	NA	IPCC	IPCC		85.3	CRF 2003
Netherlands	73.0		66.0	73.0	73.0	73.0		73.0	77.0	66.0		73.0	77.0	73.0			46.0	73.0	CRF + NIR 2003
Portugal	IPCC			IPCC	IPCC	IPCC		IPCC	IPCC	IPCC		IPCC	IPCC	IPCC	IPCC	IPCC		IPCC	CRF 2003
Spain	IPCC	NO	NO	72.0	73.7	73.7	NO	73.6	76.7	66.2	IE	72.4	IPCC	IPCC	97.5	IPCC		IPCC	CRF 2003
Sweden	77.0	NO	NO	72.6	73.1	NO	NO	75.3	76.2	65.1	NO	72.6	103.0	NO	103.0	75.3		75.3	CRF 2003
UK	IPCC	78.4	IPCC	70.9	72.5	72.5		73.6	76.7	65.0	IPCC	IPCC	IPCC	IPCC	79.8	IPCC		IPCC	CRF 2003
EU-14 average	***73.6***	***79.9***	***63.8***	***71.0***	***72.2***	***72.1***		***73.9***	***77.2***	***64.2***	***61.6***	***73.2***	***82.2***	***73.3***	***99.7***	***73.5***		***74.5***	
EU average only CS	***74.5***	***79.2***	***66.0***	***72.6***	***73.2***	***72.3***		***73.9***	***77.1***	***65.0***		***73.0***	***90.0***	***73.0***	***98.3***	***75.3***	***58.6***	***77.8***	
Diff. EU-14 average to IPCC default	***0.3%***	***-0.9%***	***1.1%***	***2.4%***	***1.0%***	***0.3%***		***-0.2%***	***-0.2%***	***1.8%***		***-0.2%***	***1.9%***	***0.0%***	***-1.2%***	***0.3%***		***1.5%***	
Diff. CS average to IPCC default	***1.6%***	***-1.8%***	***4.7%***	***4.8%***	***2.3%***	***0.6%***		***-0.3%***	***-0.3%***	***3.1%***		***-0.4%***	***11.6%***		***-2.6%***		***-12.2%***	***6.1%***	
Czech Republic	IPCC			IPCC	IPCC			IPCC	IPCC	IPCC		74.1	IPCC	IPCC				IPCC	CRF 2002
Estonia			IPCC	IPCC	IPCC	IPCC	77.4	IPCC	IPCC										CRF 2002
Hungary	IPCC		IPCC	IPCC	IPCC			IPCC	IPCC	IPCC			IPCC					IPCC	CRF 2002
Latvia				IPCC	IPCC	IPCC		IPCC	IPCC	IPCC			IPCC	IPCC				IPCC	CRF 2002
Poland	75.6			71.2	71.4	71.3		72.3	78.1	65.8						78.7			CRF 2003
Romania	IPCC			IPCC	IPCC	IPCC		IPCC	IPCC	IPCC	IPCC		IPCC	IPCC	IPCC	IPCC		IPCC	CRF 2003
Slovakia	75.1			72.3	73.4			74.4	76.7	64.4	IPCC	IPCC	IPCC	IPCC				IPCC	CRF 2002
Slovenia								73.3	76.6	62.4									NIR 2003
Average incl. access. countries	***74.1***		***63.6***	***70.5***	***71.8***	***72.0***	***77.4***	***73.9***	***77.2***	***64.0***	***61.6***	***73.3***	***81.8***	***73.3***	***98.3***	***73.9***		***74.4***	

Notes: IPCC = IPCC default EF used in CRF reference approach table 1.A.(b), NO = not occurring, IE = included elsewhere, NA = not applicable, blank = no value reported

Fuel categories shaded in grey: relevant in industry and energy sector in European countries, fuel categories highlighted in green: relevant in refineries

Emission factors highlighted in yellow: difference of more than 5% to IPCC default

3.2 Solid fuels

Eight from 14 EU MS report at least some country-specific EF for certain solid fuel types. Table 2 shows the CO_2 emission factors reported by Parties in the CRF reference approach table and the NIR..

Table 2 Comparison of IPCC default CO_2 emission factors and country specific emission factors for solid fuels for Europe [t CO_2/TJ, basis NCV]

Country	CO_2 emission factor [tCO_2/TJ]											Source
	Primary fuels							Sec. Fuels/ Products				
	Anthracite	Coking Coal	Other Bit. Coal	Sub-bit. Coal	Lignite	Oil Shale	Peat	BKB & Patent Fuel	Coke Oven / Gas Coke	coke oven gas	blast furnace gas	
IPCC default	***98.3***	***94.6***	***94.6***	***96.1***	***101.2***	***106.7***	***106.0***	***94.6***	***108.2***	***47.7***	***242.0***	
Austria	IE	IPCC	IPCC		IPCC	NO	IPCC	IPCC	IPCC			CRF 2003
Belgium		IPCC	IPCC	IPCC	IPCC			IPCC				CRF 2003
Denmark	NO	NO	95.0	NO	IPCC	NO	NO	NO	IPCC			CRF 2003
Finland			IPCC	NO	NO	NO	IPCC	IPCC	IPCC	40.5		CRF + NIR 2003
France	IE	IPCC	IPCC	NO	IPCC	NO	NO	IPCC	IPCC			CRF 2003 + 2002
Germany	IE	87.6	86.7	NO	111.1	NO	IE	93.3	108.3	44.0		CRF 2003, UBA 2003
Greece		IPCC	IPCC		124.7							CRF 2003
Ireland			IPCC				108.4	98.9				CRF 2003
Italy	NO	IPCC	97.5	94.6	IPCC	NO	NO	NO	IPCC			CRF 2003
Netherlands			96.7					94.0	103.0	44.0	200.0	CRF 2003
Portugal			IPCC					IPCC				CRF 2003
Spain	IE	96.4	99.8	99.6	117.4	NO		NO	106.5			CRF 2003
Sweden	NO	90.7	NO	NO	90.7	NO	107.0	NO	103.0			CRF 2003
UK	98.7	89.6	IPCC					111.6	106.2			CRF 2003
EU-14 average	***98.7***	***93.0***	***94.8***	***96.7***	***105.5***	***NO***	***106.8***	***97.0***	***106.8***			
EU average only CS	***98.7***	***91.1***	***95.1***	***97.1***	***111.0***		***107.7***	***99.4***	***105.4***	***42.8***		
Diff. EU-14 average to IPCC default	***0.4%***	***-1.7%***	***0.2%***	***0.7%***	***4.3%***		***0.8%***	***2.6%***	***-1.3%***			
Diff. CS average to IPCC default	***0.4%***	***-3.7%***	***0.6%***	***1.0%***	***9.7%***		***1.7%***	***5.1%***	***-2.6%***			
Czech Republic		IPCC	IPCC		IPCC				IPCC			CRF 2002
Estonia	IPCC					106.7	IPCC	IPCC	IPCC			CRF 2002
Hungary		IPCC	IPCC	IPCC	IPCC				IPCC			CRF 2002
Latvia			IPCC				IPCC		IPCC			CRF 2002
Poland		89.9	95.2		111.2				111.6			CRF 2003
Romania		IPCC	IPCC	IPCC	IPCC				IPCC			CRF 2003
Slovakia		94.8	93.8		100.4				106.8			CRF 2002
Slovenia	96.3		92.7	99.2	99.2				106.0			NIR 2003
Average incl. access. countries	***97.7***	***93.3***	***94.6***	***96.9***	***104.3***	***106.7***	***106.6***	***96.5***	***107.4***			

Notes: IPCC = IPCC default EF used in CRF reference approach table 1.A.(b), NO = not occurring, IE = included elsewhere, NA = not applicable, blank = no value reported
Fuel categories based on IPCC nomenclature, national energy balances may assign coke oven gas and blast furnace gas to gaseous fuels.

Lignite is the solid fuel where the country-specific EF in the EU vary most widely from 90.7 t CO_2/TJ to 124.7 t C/TJ (27% difference) and where the difference between country-specific emission factors and IPCC default is considerable (about 10 %).

For ***BKB and patent fuel***, the average country-specific EF from the reporting

EU countries is also considerable higher (99.4 t CO_2/TJ) than the IPCC default of 94.6 t CO_2/TJ. Within those EU Member States reporting country-specific EF for BKB and patent fuels the EF varies between 93.3 and 111.6 t CO_2/TJ (25 % difference).

Other Bituminous coal is the coal type most widely reported by almost all MS. Within those EU Member States reporting country-specific EF for other bituminous coal the EF varies between 86.7 and 99.8 t CO_2/TJ (13 % difference). However, the EU average EF is quite close to the IPCC default.

Within those European countries reporting country-specific EF for ***coking coal*** the EF varies between 87.6 and 96.4 t CO_2/TJ (9 % difference).

For ***coke oven/gas coke***, country specific EF reported by EU MS are mostly lower than the IPCC default and range from 103.0 to 111.6 t CO_2/TJ.

For ***peat*** considerable differences in the EF could be expected, which is not supported by the data provided. However, only few countries report country-specific emission factors for peat.

Certain fuel types are not very widely used by EU MS: ***Oil shale*** is only used in Estonia, whereas only UK reports a specific EF for ***anthracite*** which is included in other fuel categories for other MS (see also more detailed consideration of fuel categories in section 4).

For coal, CO_2 emissions per tonne vary considerably depending on the coal's composition of carbon, hydrogen, sulphur, ash, oxygen, and nitrogen. Especially if countries use coal from different regional proveniences, CO_2 emission factors will vary over a wide range. For Germany the differences for lignite vary from 103 t CO_2/TJ (central German provenience), 114 t CO2/TJ (Lausitz provenience) until 117 t CO_2/TJ (Rhine provenience). For hard coal the emission factors range from 93 t CO_2/TJ (German origin) to 95 t CO_2/TJ (imported coal from Poland) und 97 t CO_2/TJ (imported coal from Australia, South Africa and the USA)[10]. The composition of coal is usually available from importers and producers. Companies also usually have information about the coal proveniences used for fuel combustion.

For reporting in national energy balances and inventories, averaged emission factors and conversion factors are usually assigned to different sectors. In some countries the types of coal are being differentiated to types of consumers or to different sectors. E.g. in the Netherlands the main consumers of anthracite are the power companies and the iron and steel industry.[11] The NIR from United Kingdom also shows different emission factors for coal used for different

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[10] Ziesing, H.J., Matthes, F.C., Wittke F. (DIW und Öko-Institut) 2003: Harmonisierung der Energiedaten zur CO_2 –Berechnung. Eurostat-Vorhaben des Umweltbundesamtes.

[11] Van Harmelen A.K., Koch, W.W.R. 2002: CO_2 emission factors for fuels in the Netherlands, TNO report R 2002/174

consumers or sectors. However, for the aggregated data presented in the energy balances or the inventories some general assumptions are usually made for emission factors and the data does not directly reflect exact quantities of coal proveniences and corresponding emission factors in each sector.

3.3 Gaseous fossil fuels

The IPCC gaseous fuel category only includes natural gas, however different countries further distinguish gas types or proveniences of natural gas (see section 4). The comparison in this section only includes natural gas. Variations of CO_2 emission factors for natural gas should be generally smaller than for solid fuels. The CO_2 emission factor depends on the composition of the gas which, in its delivered state, is primarily methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons. Natural gas flared at the production site will usually be "wet", i.e., containing far larger amounts of non-methane hydrocarbons. The CO_2 emission factor will be correspondingly different. Table 3 compares the country-specific emission factors for CO_2 provided in the inventory submissions with the IPCC default emission factors.

Table 3 Comparison of IPCC default CO_2 emission factors and country specific emission factors for gaseous fuels for Europe [t CO_2/TJ, basis NCV]

Country	Natural gas (dry)	
	CO_2 emission factor [tCO_2/TJ]	Source
IPCC default	***56.1***	
Austria	IPCC	CRF 2003
Belgium	IPCC	CRF 2003
Denmark	57.3	CRF 2003
Finland	IPCC	CRF 2003
France	IPCC	CRF 2003 + CRF 2002
Germany	56.0	CRF 2003
Greece	IPCC	CRF 2003
Ireland	54.9	CRF 2003
Italy	55.8	CRF 2003
Netherlands	IPCC	CRF 2003
Portugal	IPCC	CRF 2003
Spain	56.6	CRF 2003
Sweden	56.5	CRF 2003
UK	58.3	CRF 2003
EU-14 average	***56.3***	
EU average only CS	***56.5***	
Diff. EU-14 average to IPCC default	***0.3%***	
Diff. CS average to IPCC default	***0.7%***	
Czech Republic	IPCC	CRF 2002
Estonia	IPCC	CRF 2002
Hungary	IPCC	CRF 2002
Latvia	63.1	CRF 2002
Poland	55.0	CRF 2003
Romania	IPCC	CRF 2003
Slovakia	58.9	CRF 2002
Slovenia	55.0	NIR 2003
average incl. accession countries	***56.6***	

Notes: IPCC = IPCC default EF used in CRF reference approach table 1.A.(b), NO = not occurring, IE = included elsewhere, NA = not applicable, blank = no value reported

The comparison shows that the average country-specific emission factor does not deviate much from the IPCC default EF, but that there occur considerable differences between countries. Some accession countries (Latvia and Slovakia) report high emission factors and the reported emission factors range from 54.9 to 63.1 t CO_2/TJ (13 % difference). However, small variations of the emission factors for natural gas can still have a large impact on CO_2 emissions as natural gas accounts for large quantities of emissions from energy and industry sector in some countries.

Gas qualities also vary depending the provenience. E.g. in Germany variations occur for gas from the North Sea, the Netherlands or Russia. For inventory purposes, most countries do not seem to distinguish different types of gas or gas provenience but base estimated on a country-specific average value, even if it is known that different gas types are used and they also use a standard Net Calorific Value.

In the past, it was often sufficient to request information on gas composition and properties from one single enterprise. With gas market liberalization, the number of gas vendors is increasing. When transactions take place at large scale it may become increasingly difficult to track back the actual origin and quality of gas as many trades may only be on paper on may not really signify that gases from different proveniences are mixed for the supply. In addition the quality of gas specified in contracts does not always and at every point in time match the quality of actually supplied gas.

Actual measurement of the gas quality by means of a representative sample of end-users seems to be the only really accurate option to estimate the CO_2 emission factor of gas in a completely liberalized market. In some countries companies have already started such measurements in order to control the quality of gas specified in the contracts with suppliers.

3.4 Recommendations

3.4.1 Liquid fuels

For some fuel categories (e.g. crude oil, petroleum coke, refinery gas) where emission factors can vary largely between installations because of the inputs or processes used, emission factors specific for an installation should be used. Power plants may also use oils with qualities which are different from those used in other industrial plants and they may also experiment with unusual fuels, for example, waste oils. This should also be reflected by the use of installation-specific emission factors. In all cases appropriate documentation on the establishment of the installation-specific emission factors should be provided.

If such installation-based information is not available, default emission factors should be used. The previous comparisons show that such default emission factors for CO_2 should be established in each country and they should be periodically updated. Such country-specific emission factors already exist in many countries and are in most cases used to calculate CO_2 emissions for the sectoral approach in the national greenhouse gas inventories. Countries should provide adequate documentation about the sources of their national emission factors and should follow established procedures for the measurements. For the implementation of the EU emissions trading scheme, it may be necessary that countries update their national emission factors in cooperation with suppliers of liquid fuels which will also be beneficial for the accuracy of greenhouse gas inventories.

3.4.2 Solid fuels

With regard to the monitoring and reporting of CO_2 emissions from coal combustion under the European emissions trading scheme, the most accurate results will be achieved by using CO_2 emission factors specific for the coal proveniences. This data should be collected from producers and importers and should be regularly updated and made available to the reporting installations. This could either be done in a coordinated European effort or by the national authorities. If not yet available, installations should request information on the coal provenience from the vendors.

The use of CO_2 emission factors specific for proveniences for the reporting under the EU emissions trading scheme may lead to some inconsistencies with national greenhouse gas inventories based on energy balances when emissions under the trading scheme are based on installation-specific information and when energy balances or inventories are using country-specific default values. For inventory preparation such disaggregated information on coal consumption is currently not usually available. This means monitoring and reporting under the EC emissions trading scheme could contribute to improve assumptions and estimations of national statistics and inventories.

3.4.3 Gaseous fuels

Where accurate information on measured CO_2 emission factors of natural gas and other specific properties are available based on reliable measurements at the level of installations, the specific emission factors should be used for reporting under the EU emissions trading scheme. However, in general it seems to be sufficient to base the estimation of CO_2 emissions from natural gas on country-specific default emission factors. When Member States use different emission factors in different sectors, they should establish sector-specific fuel emission factors.

4 Fuel categories

Many countries use fuel categories different from international definitions as provided by IPCC or IEA/Eurostat. Sometimes more disaggregated fuel types are specified, sometimes subcategories are aggregated to summarized categories. For international reporting national fuel definitions have to be mapped to definitions used in Eurostat/IEA questionnaires and to fuel categories used in IPCC reference approach reporting table. Mapping is fairly obvious for many fuels, however there are cases where this is not always straightforward and unambiguous (e.g. coal categories).

At the moment some countries report transparently the mapping of domestic fuel categories into international fuel categories through correspondance tables as part of their NIR, but such information is only available for few countries. International organizations rely on reporting from Parties and usually do not check if international definitions were really followed by the reporting countries. A detailed assessment of the appropriateness of definitions and mapping of national fuel categories into international categories for all European countries has so far not been conducted.

In some cases, large differences between country-specific emission factors and default emission factors for certain fuels in tables in section 3 may be a consequence of a different definition of the fuels in the respective categories.

Usually few energy experts in each countries are familiar with all definitions and problems related to the categorization of fuels at the national and international level. For the monitoring and reporting under the EU emissions trading scheme, a large number of individuals from companies will be involved in the reporting and a large number of verification experts will be involved in the verification of the reported data. E.g. it may not be easy for responsibles in companies to map slurry, solid smokeless fuels, tar, H.B.O. I, H.B.O. II or burning oil – only taking some country-specific fuel names available in English – into international definitions. Thus, there is a considerable potential of unintended reporting mistakes if the guidance related to the categorization of fuels is not easily applicable in practice. This problem highlights again the importance of country-specific default data and reporting requirements. Companies as well as verifiers will be more familiar with fuel definitions and categories used in their countries and in their respective languages as with international definitions. Thus, default values for international fuel categories may potentially lead to more reporting mistakes. Thus, fuel categories and related default emission factors should be established in each Member State. However, in order to be able to compare and verify country-specific data, it is essential that reporting is transparent with regard to the definition of fuel categories and the mapping to international categories. This means that reporting guidelines should to specify the explanatory information necessary for transparent and comparable reporting.

4.1 Fuel categories for biomass and waste fuels

The problem of fuel category definitions is most pronounced for waste fuel and biomass fuels where categories used by countries vary largely.

E.g for biomass fuels current reporting includes categories such as fuelwood, bark, wood chips, sawdust, other residues from wood production, malodorous gases from wood production industry, 0-fibres / biosludge, waste paper, poultry litter, meat and bone meal, straw etc. Waste categories can for example include municipal waste, construction & demolition waste, industrial waste, plastic waste, scrap tyres, landfill gas, sewage gas, waste oils, other wastes etc.

The biomass parts of wastes are considered as carbon-neutral and an emission factor of 0 is used in international reporting under the UNFCCC and the Kyoto Protocol. However, for the fossil fractions emissions have to be calculated. The key problem for waste fuels is the determination of the biogenic and fossil fractions of wastes and the related emission factors of the fossil parts as waste fuels are not standardized and could vary considerably with regard to different suppliers or over time. In certain industries, e.g. cement industry large amounts of waste fuels are used, and practical guidance is necessary how emissions from waste fuels should be determined, in particular how fossil fractions and corresponding emission factors are determined.

In this area frequently also information available at country-level is insufficient and uncertainties in energy balances and greenhouse gas inventories can be considerable because data on the consumption of waste fuels is not always available or reliable and the information on biogenic and fossil fractions could be based on expert judgement.

Different approaches are possible. E.g. guidelines could strictly require that for non-standardized fossil fuels, each installation is responsible for a reliable measurement of fossil fractions and emission factors. This would also require to establish methods for both areas that are considered as reliable and to establish required documentation for such cases (e.g. how often have fractions to be determined, how many samples are necessary etc.).

If the monitoring of composition of waste fuels with regard to biogenic and fossil carbon fractions is considered as too resource-demanding or if the biogenic fraction is very low, a conservative approach should be used, e.g. assuming 100% of fossil carbon for wastes when the composition is not determined. For important waste fuels - such as tyres or plastics - used in the energy or industry sector, this conservative assumption is a rather valid assumption. This would require establishment of additional default emission factors for these fuel types in some countries where such factors do not yet exist. This work should preferably be performed in each country as only this level allows the setting of default values for the relevant waste fuel types.

5 Non-energy use of fuels

About 5-10 % of fossil fuels are not used for combustion purposes, but for chemical conversion processes.[12]. In energy statistics this consumption is called non-energy use.

Table 4 Non-energy use of fossil fuels in selected European countries

Country	Total fuel consumption in 1999 [TJ]	Final non-energy consumption	Final non-energy consumption chemical industry	Final non-energy consumption, other sectors
Germany	11,835,536	8.6%	6.7%	1.9%
UK	8,120,704	5.7%	4.3%	1.4%
France	5,603,562	12.3%	9.2%	3.1%
Netherlands	2,804,000	13.2%	11.7%	1.5%
Denmark	729,087	1.7%	0%	1.7%
Austria	922,486	9.2%	3.4%	5.8%

Source: NEU-Network, homepage EuropeanUnionCountries 1995-2000.xls from June 2003

Non-energy use of fossil fuels for the production of chemicals and certain refinery products do not result in direct CO_2 emissions, but in during product use and during waste treatment. The non-energy use of fuels is still a source of considerable uncertainties in the energy sector of national greenhouse gas emission inventories since the quantities and the relationships are not well understood. With regard to monitoring of emissions from installations under the EC emissions trading scheme, emissions during the lifetime of products are not relevant for the emission estimation of the producing installation.

The petrochemical industry is characterized by co-production of energy and materials and integration of energy and material flows with the refining sector, which complicates CO_2 emission estimation and the correct assignment of emissions. Petrochemical industries are usually highly integrated complexes.

The key process in the petrochemical industry is currently steam cracking of either refinery products or natural gas fractions. The refinery products used include naphtha, gas oil, liquefied petroleum gas (LPG). The natural gas fractions include NGL and ethane. Steam cracking results in a broad array of intermediary chemical products (ethylene, propylene, butadiene, BTX) and by-products used for energy purposes (hydrogen, methane, pyrolysis gasoline). They are either used for heating within the petrochemical industry or recycled to the refineries. The intermediates serve as input for the production of a broad array of petrochemicals.

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12 Source: NEU-CO_2 Network at http://www.chem.uu.nl/nws/www/nenergy/

Some overlap exists between refineries and the petrochemical industry. For example, propylene, an important petrochemical product from steam cracking, can also be produced from refinery gas. The same applies to many aromatic compounds such as benzene and xylenes. Important quantities of so-called pyrolysis gasoline are recycled into the refining sector. Lubricants are still predominantly produced in refineries, but the production is gradually shifting into the petrochemical industry, which is able to produce superior quality lubricants. Different types of backflows occur from petrochemical industry to refineries.

5.1 Determination of boundaries

The first question that should be answered by the Monitoring Guidelines for emissions trading are boundary considerations with regard to the refineries included in Annex I of the directive. As chemical industries are not part of the EU emissions trading scheme it is essential to provide a clear boundary and distinction between refineries and petrochemical industry, including in those cases where in reality both parts are combined in integrated plants. This is only possible at the level of individual processes taking place at integrated petrochemical plants where guidelines should clearly separate the processes and respective products included in the refining production chain and those excluded under the trading scheme because it is seen as part of the chemical industry. Without clear guidance on these boundaries, installations will have to draw their own boundaries and allocation of processes and products (and assignment of associating emissions) or boundaries will depend on the way permits are provided to individual installations which could lead to considerable differences across Member States. As there is an implicit incentive under the EU emissions trading scheme to consider parts of an integrated production as part of the chemical industry instead of the refinery, ambiguity in guidance on boundaries may result in inaccurate allocations. Without clear guidance on boundaries, verifiers will not be able to detect and highlight such problems of wrong allocation.

Similar problems with the definitions of boundaries occur in the iron and steel sector related to the emissions from blast furnaces where carbon is used as fuel and reducing agent.

5.2 Fuel categories used

In the case of the petrochemical sector the national statistics of feedstock deliveries (non-energy use) are subject to large uncertainties. For most industries energy statistics cannot provide sufficient discrimination between the different uses of fossil fuel feedstock in enterprises to identify accurately the non-energy use. In particular, the definitions of deliveries for non-energy use within the petrochemical sector differ between countries.

With regard to the monitoring of greenhouse gas emissions under the EC emissions trading scheme, similar problems as for energy statistics or inventories should be avoided from the beginning by providing transparent definitions on the non-energy use of fuels in refineries or other relevant sectors (e.g. blast furnaces). Further analysis is necessary to assess if harmonized and comparable definitions are possible.

5.3 Estimation methodology

5.3.1 Carbon mass balance

A large number of individual combustion processes, flares and chemical oxidation processes occur in refineries that all lead to CO_2 emissions. If estimation of CO_2 emissions are based on individual processes it should also be ensured that the resulting aggregate CO_2 emissions match with the fuel inputs and the carbon stored in product outputs. Such verification step ensures that estimation of individual processes was complete.

With regard to the monitoring of greenhouse gas emissions under the EC monitoring scheme, a material flow analysis covering fossil energy carriers and synthetic organic materials should also be considered and a carbon mass balance could be applied. The carbon mass balance approach would completely account for the carbon flows entering the refineries with the energy consumption within the refinery and the carbon flows from the refineries in form of exported products (including energy carriers) and would have to consider storage and flaring. Appropriate tools (e.g. spreadsheet models) for this purpose should be developed to facilitate estimation and reporting.

The Non-energy fuel use (NEU) Network developed a spreadsheet model of the carbon flow through the many petrochemical processes and non-energy refinery products has been developed at the country-level called NEAT ("Non-Energy use Emission Accounting Tables", Gielen et al., 1999). However, the level addressed is the national level and further work would be necessary to develop a tool at the level of installations. However, taking into account the large number of processes and products involved, estimation will be a quite complex task. Verification of this estimation will be equally challenging therefore common estimation and reporting tools and a high level of transparency should be required.

5.3.2 Measurements

In order to avoid the complex detailed consideration and separation of energy and non-energy use of petroleum products in refineries as well as energy-related and process-related emissions, CO_2 emissions could be measured directly in the flue gases in refineries. This approach would require to continuously

- measure the flue gas quantities per time for all emission sources considered to be part of the refinery,

- measure the CO_2 concentration in flue gas and the oxidation factor,
- monitor the operation time of the plant,
- calculate CO_2 emissions from measurements.

The measurement approach may be simpler in the specific case of refineries, however further discussion will be needed with regard to the complexity of a carbon mass balance approach.

6 Conclusions and recommendations

This paper shows that the use of IPCC default emission factor across countries would not be appropriate for many fuels and that it is generally preferable to establish default values for fuel-specific emission factors at the level of Member States. Country-specific emission factors can also take into account more easily country-specific fuel categories. However, if default values are set by Member States, it may be necessary to establish certain general rules at EC level in order to achieve comparability, consistency, transparency and a defined level of accuracy. One important requirement for example is, that each Member State and each installation should report how the country-specific or installation-specific fuel categories are mapped to international fuel definitions and should provide adequate documentation on the establishment. This requirement is essential for reasons of transparency and comparability. A set of guidelines should accompany the set of CO_2 emission factors on the proper application of these factors.

Taking into account accuracy, default CO_2 emission factors should only be used when no more accurate specific emission factors based on measurements for the fuels used by an installation are available. Especially for fuel types that are used in large quantities at an installation, specific emission factors should be obtained either from vendors or by taking additional measurements.

A mandatory requirement to use fuel-specific emission factors may not create additional burdens for the companies covered by the EU emissions trading scheme, because they can require information about the carbon content of fuels from the fuel vendors where the information about the composition of specific fuels should already be available from quality control of fuel properties.