STATISTICAL DEFINITIONS OF NON-ENERGY USE

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Abstract

This paper discusses data on the non-energy use of fossil fuels as published in energy balances. The international consistency of these data is important due to their use to estimate carbon storage according to the IPCC Reference Approach. The paper first gives an overview of the data sources and the possible definitions of non-energy use. Then a few datasets on non-energy use are compared and discussed. An attempt is made to use the relationship between feedstock consumption and ethylene production in the steam cracking process in order to determine the definitions chosen in the various countries. The paper ends with the conclusion that the non-energy use data published in national and international energy balances are very often inconsistent. Therefore, it is rather unlikely that the use of these data for the IPCC Reference Approach will yield reliable results. It is recommended to improve statistical data on non-energy use.

1. Introduction

According to current understanding, non-energy use data, as published in national energy balances, do not follow a common definition for all countries (Patel et al. 1999). This is an important issue since the data on non-energy use are used to estimate the amount of carbon stored in products the IPCC Reference Approach (IPCC/IEA/OECD/UNEP 1996). Therefore, it must be analysed whether the international data on non-energy use are indeed inconsistent. The two final goals of this analysis are to provide

- an overview of the various definitions of non-energy use by country and/or to identify the data gaps,
- recommendations how to standardise the data internationally.

These recommendations may consist of suggestions for changes in current survey questionnaires and for additional data sources and correction procedures.
These goals have not been reached so far. This paper provides preliminary results of the ongoing analyses.

2. Available statistics, terminology and system boundaries

The most important **statistical sources** containing data on the non-energy use of fossil fuels are:

- National energy balances (e.g. in Germany, the *Energiebilanz*, published by the Arbeitsgemeinschaft Energiebilanzen, var. editions)

- International energy statistics, i.e. energy balances published by EUROSTAT (var. editions) and the International Energy Agency (IEA, var. editions)
- Databases generated by the national associations of chemical/petrochemical industry, e.g. the VCI in Germany (VCI, var. editions)
- Databases generated by the regional associations of chemical/petrochemical industry, e.g. CEFIC, i.e. the European Chemical Industry Council.

EUROSTAT and the International Energy Agency (IEA) collect their data in a joint questionnaire (see below, Section 5 of this paper). These sources provide a dataset on non-energy use which has been balanced with the economies' total energy use and the part which is consumed in combustion processes.
The national associations of chemical industry collect and aggregate data of the companies' feedstock use. CEFIC then aggregates the national data to a dataset for Western Europe.

In this paper non-energy use is referred to as the use of fossil fuels both as feedstocks for the petrochemical industry plus certain products which mainly originate from the refinery sector and coke-oven plants, e.g. lubricants, bitumen, paraffins and pitch.
It should be noted that the various sources use different **terminologies** and that the **categories** distinguished also differ:

- EUROSTAT refers to non-energy use as "Final non-energy consumption" which is composed of the categories "Chemical Industry" and "Other sectors". The category "Chemical Industry" represents the feedstocks whereas lubricants, bitumen etc. are covered by the category "Other sectors".
- IEA statistics refer to petrochemical feedstocks as a subcategory called "Feedstocks" which is assigned to the chemical and petrochemical sector whereas the category "Non-energy use" only covers lubricants, bitumen etc. This category is split into three further categories, i.e. "Industry/Transf./Energy", "Transport" and "Other sectors".
- In national energy balances, further ways of presentation are chosen; these are usually combinations of the ways of presentation mentioned for EUROSTAT and IEA.
- According to current knowledge, national associations of chemical/petrochemical industry usually collect the total feedstock use. This is also the starting point for the data generated by CEFIC which however, make a correction for that part of non-energy use which is used as energy, i.e. to fuel the processes.

The point mentioned last is rather an issue of **system boundaries** which shall be discussed next. Figure 1 shows a general scheme of the energy flows for the processes used to produce bulk chemicals. All the entities are given in energy terms. Q_{TF} represents the total amount of chemical/petrochemical feedstocks excluding the process energy requirements provided from external sources $Q_{E,ext}$. A part of the input Q_{TF} is converted into the target products, i.e. basic chemicals with the energy content Q_C. The rest either ends up in energy

carriers which are used within basic chemical production or outside this system ($Q_{E,int}$ and Q_F) or it is lost due to leakages and material losses (Q_L).

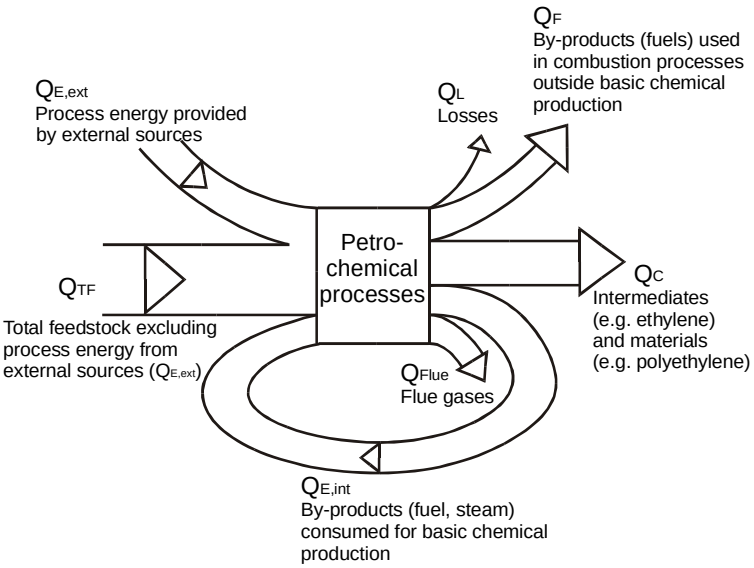


Figure 1 *Energy flows in the production of bulk chemicals*

According to an earlier analysis (Patel et al. 1999), three different definitions were used in the energy balances of the countries Netherlands (data for 1992), Italy (data for 1991) and Germany (data for 1989; old federal states only). The three definitions are given by (compare Figure 1):

- Netherlands (NL): $Q_{NEU, NL, i} = Q_{TF, i} - Q_{F, i} - Q_{E,int, i}$ Equation 1
- Italy (IT): $Q_{NEU, IT, i} = Q_{TF, i} - Q_{E,int, i}$ Equation 2
- Germany (FRG): $Q_{NEU, FRG, i} = Q_{TF, i} - Q_{F, i}$ Equation 3

3. Comparison of statistical data

In this section data provided by CEFIC is compared with data published by EUROSTAT and in national energy balances. The analysis focuses on Western Europe and gives special attention to Germany, the Netherlands and Italy.

Comparison of CEFIC and Eurostat data
Table 1 shows the comparison of the CEFIC data with the EUROSTAT data. CEFIC only makes a distinction between solid, liquid and gaseous fuels. Therefore the data published by EUROSTAT was aggregated to form these three categories. The EUROSTAT data listed represent the feedstock part of non-energy use (called "Chemical Industry", see above). As mentioned in the previous section the data given by CEFIC refer to feedstock plus a correction for that part of non-energy use which is used as a fuel. Table 1 also shows

modified CEFIC data which do not include this fuel correction. Using the acronyms given in Figure 1, the latter data are named CEFIC(Q_{TF})[1].

Table 1 also shows the ratio of the EUROSTAT values to the modified CEFIC values, i.e. "Eurostat/CEFIC(Q_{TF})". The appendix of this paper gives equivalents of Table 1 for Belgium and the Netherlands (combined dataset), France, Germany, Italy, United Kingdom and the United States.

The main findings are:

- For the total of the EU countries (EU12/E15), the EUROSTAT data are clearly smaller than the figures CEFIC(Q_{TF}). Except for UK, this is also true for the individual countries. This indicates that non-energy use in EUROSTAT is not defined as the total feedstock input (Q_{TF}) but that some correction has been made to account for the shares used as fuels ($Q_{E,int}$ and/or $Q_{E,ext}$). According to the joint IEA/UN/EUROSTAT questionnaire (IEA/UN/EUROSTAT 1995/1995) the EUROSTAT data should be corrected for the amounts used as fuels and the backflows to the refineries.
- The ratio "Eurostat/CEFIC(Q_{TF})" tends to increase over the years for all categories and nearly all countries (exceptions are NL&B and UK). This might be due to changes in the accounting method and/or in the processes (increased energy efficiency, reduced feedback flows or changes in external energy supply?).
- For liquid feedstocks, the share "Eurostat/CEFIC(Q_{TF})" for the total of the EU countries (EU12/EU15) is in the range of 65%-85%.
  - The figures for Germany lie within this range.
  - For France and United Kingdom, the fractions are clearly higher.
  - For Italy, they are much lower in early years, but higher in later years.
  - For the Netherlands and Belgium, they are clearly lower for all years.

  Naphtha accounts for about 80% of the total amount of liquid feedstocks (EUROSTAT var. eds.)[2]. Since naphtha is exclusively used in the steam cracking process, differences listed for the ratio "Eurostat/CEFIC(Q_{TF})" indicate that different accounting methods have been used. Since there is little scope for interpretation with regard to the feedstock use of a naphtha steam cracker, one could argue that the data CEFIC(Q_{TF}) are a very good approximation of the real amount of total feedstocks. In this case the conclusion would be that the differences in the EUROSTAT data reflect different accounting practices among the countries, and maybe even for one single country within the timeframe analysed (e.g. Italy).
- Most of the findings established for liquid feedstocks (previous bullet) are also true for the total of all kinds of feedstocks. A particular finding at this level is that United Kingdom is the only country where the Eurostat data are larger than the figures for CEFIC(Q_{TF}).

[1] The CEFIC data roughly account for the fact that a part of the feedstock is used as a fuel. This is done by only taking the fuel use in ammonia production into account. The data received by CEFIC from the associations in the Netherlands, Germany, France and Belgium already have undergone this correction. For the other countries, data are adjusted by CEFIC according to the following approximation: all gaseous fuels used as feedstock are assumed to be consumed for manufacturing ammonia; 30% of them are transferred to the category fuel and power (CEFIC 1999). This procedure was inverted for all countries to determine the values given for CEFIC(Q_{TF}) in Table 1. This results in some uncertainty for the data for the Netherlands, Germany, France and Belgium.

[2] The maximum ranges for the years listed in Table 1 are: 77-81% (EU12/15), 75-80% (D), 75-90% (F), 48-76% (Italy), 78-99% (NL&B), 79-83% (UK).

These findings indicate that there are considerable inconsistencies[3] which require further analysis.

Time series for naphtha consumption in Germany
Naphtha is an energy carrier which is exclusively used as a chemical raw material and not as a fuel for combustion processes. For this reason, data comparisons for naphtha may help to understand the problems related to the definition of non-energy use. Table 2 compares German naphtha consumption according to VCI (var. eds.) and the German energy balance (Arbeitsgem. Energiebilanzen var. eds.). For the period 1990-1995, the figures given by the Arbeitsgem. Energiebilanzen (var. eds.) are practically identical with the data published by EUROSTAT (var. eds.). It has been assumed in Table 2 that this is also the case for 1996. This assumption has been made since the German energy balance for 1996 has not been published to date. The discrepancy shown in Table 2 for the year 1996 indicates an inconsistency in the time series that might require further attention (see negative value in column D and percentage larger than 100% in column C). Column D, which lists the difference between the two statistics, shows a considerable fluctuation in early years and a strong decrease of values in recent years. The reason for this development should also be detected.

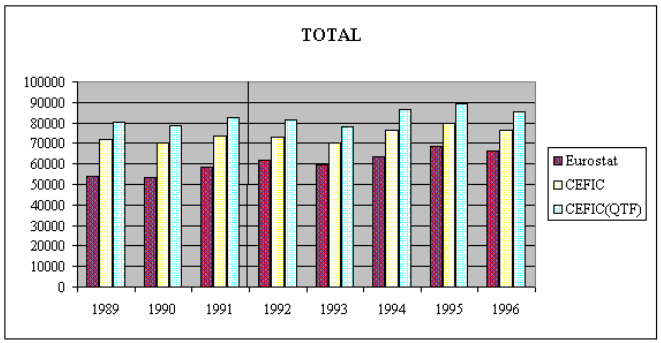
As discussed in Section 2, earlier analysis resulted in the understanding that non-energy used in German energy balances is equivalent to the total feedstock use, minus the energy by-products used in combustion processes outside the production of bulk chemicals (see equation 3). Since the VCI data can be assumed to represent reliable data for the *total* feedstock input (Q_{TF}) the difference compared to the German energy balance should represent the energy by-products Q_{Fi}. This difference is given in column D of Table 2. These data are expected to match reasonably with the values given in column E which lists bottom-up estimates for energy by-products; these data have been estimated using process data. Given a possible error margin of +/-25% for the data given in column E, an acceptable agreement is only found for the years 1989 and 1992.

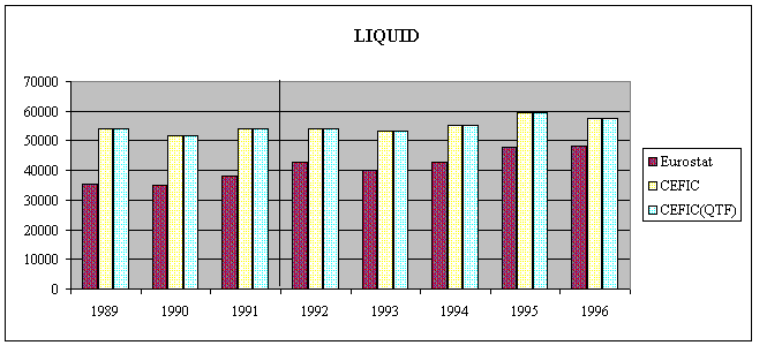
[3] A further small irregularity is that the EUROSTAT data do not show any use of natural gas in Germany in 1996 (EUROSTAT hardcopy 1998). However, a consumption of natural gas in the range of the values given in Table 3 (for 1995) should be reported.

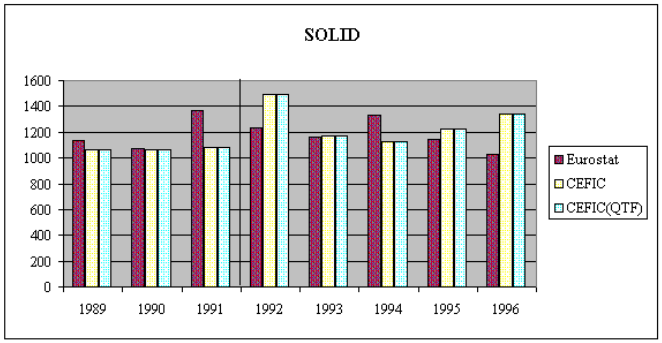
Table 1 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in the European Union (CEFIC 1999; EUROSTAT var. eds.)*

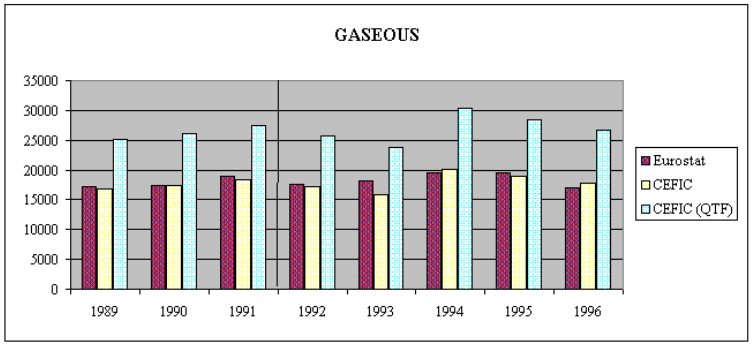
	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1989	53808	71899	80290	*67%*	1134.7883	1065	1065	*107%*	35435.212	54051	54051	*66%*	17238	16783	25174	*68%*
1990	53380	70120	78824	*68%*	1070.9464	1063	1063	*101%*	34911.054	51649	51649	*68%*	17398	17408	26112	*67%*
1991	58635	73329	82470	*71%*	1369.4222	1082	1082	*127%*	36255.578	53965	53965	*71%*	19010	18282	27423	*69%*
1992	61896	72768	81363	*76%*	1236.1939	1491	1491	*83%*	42970.806	54088	54088	*79%*	17683	17189	25783	*69%*
1993	59515	70262	78222	*76%*	1158.8341	1174	1174	*99%*	40118.166	53168	53168	*75%*	18233	15920	23880	*76%*
1994	63728	76599	86700	*74%*	1333.9266	1128	1128	*118%*	42877.073	55268	55268	*78%*	19513	20203	30304	*64%*
1995	68385	79659	89142	*77%*	1142.6076	1222	1222	*94%*	47743.392	59470	59470	*80%*	19493	18967	28450	*69%*
1996	66420	76647	85565	*78%*	1024.427	1341	1341	*76%*	48363.573	57469	57469	*84%*	17027	17836	26754	*64%*
1997	0	83429		*#DIV/0!*	0	1532		*#DIV/0!*	0	59923		*#DIV/0!*	0	21974		*#DIV/0!*

NOTE: 1989 - 1991 Eurostat EUR12 (1989/90 excl. former DDR), in contrast to CEFIC EUR15 (1989/90 excl. former DDR)









CEFIC kindly provided feedstock data to FhG-ISI. The partners of the NEU-CO_2 network are requested not to make further use of these data before consultation with CEFIC.

Table 2 *Comparison of German naphtha consumption according to VCI and the German energy balance*

Year	A Naphtha as feedstock acc. to VCI (var. eds.)	B Non-energy use of naphtha acc. to Arbeitsgem. Energiebilanzen (var. eds.)	C Ratio C = B/A	D Difference D = A - B	E Energy by-products*)
1985	n/a	6019	-	-	-
1989	8142	7249	89%	893	1160
1990	8310	7242	87%	1068	n/a
1991	8978	8375	93%	603	1320
1992	9600	8458	88%	1142	1430
1993	9706	8622	89%	1084	1462
1994	10000	9289	93%	711	1526
1995	9700	9536	98%	164	1500
1996	9470	10799 **)	114%	-1329	1464

Only Old Federal States (Alte Bundesländer) until 1990, including New Federal States from 1991 onwards.

*) Pyrolysis gasoline and fuel oil (fed back to refineries or used directly in combustion processes); the figures given in this column are bottom-up estimates using process data.

**) This figure has been taken from EUROSTAT (var. eds.). This is justified because for the period 1990-1995, the figures given by the Arbeitsgem. Energiebilanzen (var. eds.) are practically identical with the data published by EUROSTAT (var. eds.). The difference is largest for 1995, but even here it is still below 2%.

Non-energy use in Germany in 1995

Table 3 provides an overview of the non-energy use of fossil fuels in the chemical sector in Germany. The figures for naphtha have already been discussed in the context of Table 2. Table 3 shows a good agreement among the three sources for the fuel categories naphtha and LPG/Refinery gas. For natural gas the agreement is reasonable whereas there is a large difference between VCI and the other two sources for the category Gas/diesel oil/Residual fuel oil.

Table 3 *Non-energy use of selected fuels in the chemical sector in Germany, 1995*

All figures for 1995, in metric kilotonnes per year	Non-energy use in the chemical industry		
	(Eurostat 1998)	(Nat. energy bal. 1999)	(VCI 1997)
Naphtha	9694	9536	9700
Gas/diesel oil/Res. Fuel Oil	2840 (403+2437)	2840 (403+2437)	4199
of which: Steam cracker feed	*n/a*	*n/a*	*2573*
LPG, Refinery Gas	1824 (382+1442)	1824 (382+1442)	1824
of which: Steam cracker feed	*n/a*	*n/a*	*1460*
Natural gas*)	1748	1984	2139
Subtotal steam cracker feed**)	n/a	n/a	13733
Total Non-energy use in chemical industry for the selected fuels	16106	16184	17862
For comparison:			
Total Non-energy use, all fuels***)	22328	23227	n/a

*) Assumed density: 0.84 kg/m^3; assumed heating value (gross calorific value): 35.17 MJ/m^3

**) The amounts of naphtha reported are exclusively used as steamcracker feed and are therefore included in the "Subtotal steam cracker feed".

***) Including also products which are not used as chemical feedstocks (e.g. lubricants, bitumen, paraffins and pitch) and the so-called "other petroleum products" (which are used both as chemical feedstocks and for other non-energy purposes).

To some extent, the differences may be due to different definitions of the various fuel categories. The fact that the total non-energy in the chemical sector is highest according to the VCI is probably due to methodological differences. In that case it is, however, amazing that the figures for naphtha coincide.

Datasets for the Netherlands and Italy

Also for other countries, there seem to be inconsistencies in the datasets, as Table 4 and 5 show for the Netherlands and for Italy.

Table 4 *Non-energy use in the chemical sector in the Netherlands, 1992*

All figures for 1992, in metric kilotonnes per year	Selection of petroleum products used as chemical feedstocks		
	(Eurostat 1993)	Nat. energy balance 1993)	(Gielen et al. 1996)
Naphtha	2805	613	2790
Gas/diesel oil/Res. Fuel Oil	61	2345 *)	3800
LPG, Refinery Gas	1650	1615	1670
Total	4516	4573	8260

*) including 1680 kt aromatics, 600 kt other light oils, 5 kt petroleum, 55 kt gas/diesel oil, 5 kt heavy fuel oils

The data for Italy listed in Table 5 show that motor spirits, kerosenes and jet fuels are reported as non-energy use in the national energy balance in 1991 and 1996 and in the EUROSTAT data for 1996. In contrast, the EUROSTAT data for 1991 show smaller (kerosenes, jet fuels) or even negative figures (LPG, motor spirit), indicating a correction for the amount of energy used as a fuel outside the chemical sector. This presumption is supported

a) by the 1991 statistics of the Italian petrochemical industry which state an output of fuels from the petrochemical sector of 3693 kt (Bolletino Petrolifero 1991[4]); this is exactly the difference between the totals according to the national energy balance and EUROSTAT for 1991 according to Table 5.

b) by the time series given in Table A-4.

Table 5 *Italian data for the non-energy use in the chemical sector, petroleum pro-ducts only*

All figures in metric kilotonnes	1991		1996	
	EUROSTAT	Nat. energy balance (BEN)	EUROSTAT	Nat. energy balance (BEN)
Refinery Gas	201	230	208	208
LPG	-317	51	304	304
Motor spirit	-841	1089	1377	1377
Kerosenes, jet fuels	479	984	1083	1083
Naphtha	3451	3941	3936	3936
Gas / Diesel oil	1465	1648	1746	1746
Residual fuel oil	4	192	173	173
Total	4673	8366	9019	8827

[4] See page 104, "Lavorazione Impianti Petrolchimici", lower part ("Prodotti Ottenuti").

Further analysis is required to confirm that EUROSTAT has stopped correcting for the fuel use of non-energy origin since 1992. It is, however, for sure that Italian data on non-energy use as published in the national energy balance and in the EUROSTAT statistics since 1992 comprise fuels which are consumed in combustion processes outside the chemical/petrochemical sector (this explains the definition given in Equation 2 where $Q_{F,i}$ is *not* subtracted).

4. Data analyses for steam cracking

Steam cracking is by far the most important petrochemical process. It is applied for the production of olefins (mainly ethylene, propylene and butadiene) and aromatics (benzene, toluene and xylene). Steam cracking accounts for the entire non-energy use of naphtha, which, in turn, represents 80% of the total consumption of liquid hydrocarbon feedstocks in Western Europe; depending on the country, steam crackers also consume considerable amounts of gas oil and light hydrocarbons (originating from petroleum or natural gas sources). In Germany, the total amount of feedstocks consumed by all steam crackers accounts for about half of the total non-energy use. In the following, the attempt is made to use the relationship between feedstock consumption and ethylene production in the steam cracking process in order to determine the definitions for non-energy use chosen in the various countries.

The principle idea of the calculations is to combine feedstock data from statistics (i.e. data on non-energy use) with different ethylene coefficients which represent the specific ethylene yields, based on the various definitions of non-energy use. The combination results in calculated amounts for ethylene production (in absolute terms) which can be compared with the values reported in production statistics. Then, the most probable definition of non-energy use is the one where the two figures for ethylene production match best. Table A-7 in the appendix gives the example of the calculations for the Netherlands (based on the data given in Table 4, but excluding residual fuel oil).

Table 6 shows the results of the calculations. Due to the uncertainties involved, no firm statements can be made. Two definitions (i.e. $Q_{NEU} = Q_{TF} - Q_F$ and $Q_{NEU} = Q_{TF} - Q_{E,int}$) are reported in one group since the results are not accurate enough to make an assignment to one of the two.

The calculations are based on process data for Germany. In Germany, the so-called low severity process mode is generally applied. In other countries, e.g. Italy, the high severity mode is applied which results in a higher ratio of the two main products, ethylene to propylene. This has been taken into account in the calculations. In spite of this adjustment the process data used probably do not to reflect the situation in all countries very accurately. Apart from severity the question to which extent the energy requirements of the crackers are covered by the feedstock would have to be investigated country by country. There are further aspects adding to the uncertainty of the results:

- Due to lack of more detailed data, it had to be assumed that the entire non-energy use of gas oil, diesel oil, LPG and refinery gas is used in

steam crackers. Since some of these raw materials may be converted in other processes, the calculations overestimate ethylene production[5]
- The allocation of fuels to the various categories (e.g.: borderline between naphtha and gas oil) may differ from country to country.
- The analysis only covers the fuels naphtha, gas/diesel oil, LPG and refinery gas. Therefore, particularities for other fuels, which may also have an impact on the definition, are not taken into account (e.g. motor spirits, kerosenes and jet fuels in the Italian data, see above).

To summarise, the results given in Table 6 provide additional indication that the definition of non-energy use differs by countries. Table 6 supports – or at least does not contradict – the definitions determined in earlier work for the Netherlands, Italy and Germany (see Equations 1 to 3). Except for France, where there is a clear contradiction, Table 6 is also consistent with the outcome of the first NEU-CO_2 questionnaire (see Table A-8 in the appendix).

Two strategies can be followed to achieve more accurate results on the definitions:
- An in-depth analysis of the various sources used in the countries would provide additional insight.
- The method presented above could be refined by using results on material balances for feedstocks.

These issues are outside the scope of this paper. The information required to follow the second strategy may become available from material flow analyses, e.g. the NEAT model (once it has been calibrated for all countries).

Table 6 *Results of an attempt to determine the definitions used for non-energy use based on calculations for the steam cracking process*

[5] On the other hand this means that an underestimation of ethylene production in the case of the definition $Q_{TF,\,i} - Q_{F,\,i} - Q_{E,int,\,i}$ means that this definition is very likely to be correct; this is the case for the Dutch data and – with larger uncertainties – for the Belgian data (see Table A7).

Country	Definitions for non-energy use		
	$Q_{NEU} = Q_{TF}$	$Q_{NEU} = Q_{TF} - Q_F$ **or** $Q_{NEU} = Q_{TF} - Q_{E,int}$	$Q_{NEU} = Q_{TF} - Q_F - Q_{E,int}$
Belgium[1)]	least likely	possible	most likely
France[3)]	most likely	possible	very unlikely
Germany[3)]	all three are possible; possibly shift of definition towards QTF in recent years		very unlikely
India[2) 5)]	most likely (extremely large uncertainties)		least likely (extremely large uncertainties)
Italy[4)]	likely		very unlikely
Japan[2) 5)]	most likely (very large uncertainties)		least likely (very large uncertainties)
Korea[4)]	all three are possible		unlikely
Netherlands[4)]	unlikely		*very likely*
Russia[2)]	most likely (very large uncertainties)		least likely (very large uncertainties)
United Kingdom[2)]	most likely (extremely large uncertainties)		least likely (extremely large uncertainties)
United States[2)]	most likely	possible	unlikely

[1)] Low severity assumed; to be checked.
[2)] High severity assumed; to be checked.
[3)] Low severity
[4)] High severity
[5)] NGL included, to be checked.

5. Conclusions and recommendations

According to current understanding, the non-energy use data published in national and international energy balances are very often inconsistent. Therefore, it is rather unlikely that the use of these data for the IPCC Reference Approach will yield reliable results.

Incorrect accounting in the area of non-energy use may also affect the quality of the data on fuel use in combustion processes as published in energy balances. This is an additional incentive to achieve a better insight into the definitions chosen for non-energy use and the methods applied for data generation.

It is recommended to check whether the joint IEA/UN/EUROSTAT oil questionnaire (IEA/UN/EUROSTAT 1994/1995) unambiguously accounts for the fact that a part of the feedstock may be used as a fuel within the chemical/petrochemical industry. It may be necessary to explicitly ask for this information in the questionnaire[6] and to include warnings in the reporting instructions.

[6] E.g. by inserting extra lines in the Tables 3/1 and 3/3 of the joint IEA/UN/EUROSTAT questionnaire. Extra lines may be useful below the rows on chemical/petrochemical industry, explicitly asking for a) backflows, b) the amounts used as fuels within the sector and c) non-energy use. Alternatively, two additional memo items for the categories a) and b) could be added on page 3/6.
Similar action should be taken for the data on natural gas where a analogous problem might occur.

Further analysis within the NEU-CO_2 network may contribute to clarify the definitions used for non-energy use data and to provide suggestions how to overcome the inconsistencies.

6. References

Arbeitsgemeinschaft Energiebilanzen: Energiebilanz der Bundesrepublik Deutschland (German Energy Balance), various editions, Essen/Berlin, Germany

Bilancio Energetico Nazionale (BEN, Italian Energy Balance), various editions. Ministerio dell'Industria, Commercio e Artigianato, Direzione Generale delle Fonti di Energia ed Industrie di Base.

Bolletino Petrolifero (BP, statistics of the Italian petrochemical industry). Ministerio dell' Industria, del Commercio e Artigianato, Direzione Generale delle Fonti di Energia ed Industrie di Base, 1991.

CEFIC (European Chemical Industry Council): Personal communication with Mr. Vermeulen and data collection (brochure), 1999

Dutch national energy balance for 1992 (Tabel 3.1.5: Energie tragerbilans – Overige chemische Industrie). CBS, 1993

EUROSTAT: Energiebilanzen - Energy Balance Sheets - Bilans de l'Énergie. Office des publi-cations officielles des Communautés européennes, Luxembourg, various editions

Gielen, D.J., Vos, D., Van Dril, A.W.N. (1996): The petrochemical industry and its energy use. ECN, Petten, 1996

IEA (International Energy Agency): IEA Statistics – Energy statistics and balances of OECD countries. OECD, Paris, various editions

IEA/UN/EUROSTAT: Oil – Annual Questionnaire, Tables and reporting instructions. 1994 and 1995

IPCC/IEA/OECD/UNEP 1996: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1-3. IPCC WGI Technical Support Unit, Hadley Centre, Bracknell, UK, 1996

Patel, M.K., Jochem, E., Marscheider-Weidemann, F., Worrell, E. (1999): CO_2 emissions from non-energy use – Methodological aspects and a case study for Germany. Ambio, Vol. 28, No. 2, p. 175 – 181, 1999

Patel, M.K., Tosato, G. (1997): Understanding non-energy use and carbon storage in Italy in the context of the greenhouse gas issue. ENEA, Rome

VCI (Verband der Chemischen Industrie, German Association of the Chemical Industry): Primärchemikalienerhebung des VCI, Frankfurt, various editions

7. Acknowledgements

I would like to thank Joachim Schneidmadl for his help in data acquisition and analysis and Dr. Vermeulen, CEFIC for providing data on the use of feedstocks in Europe.

8. Appendix

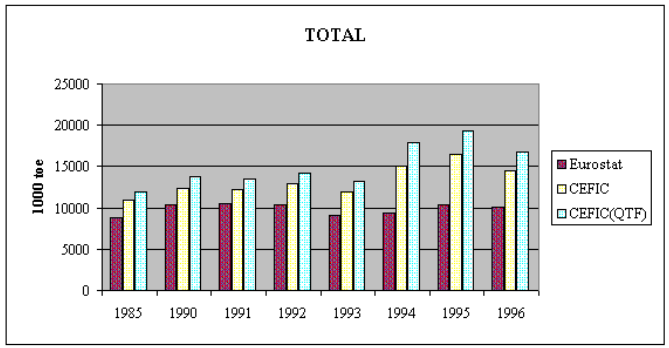
Note concerning Table A-1 to A-6 and Table 1:

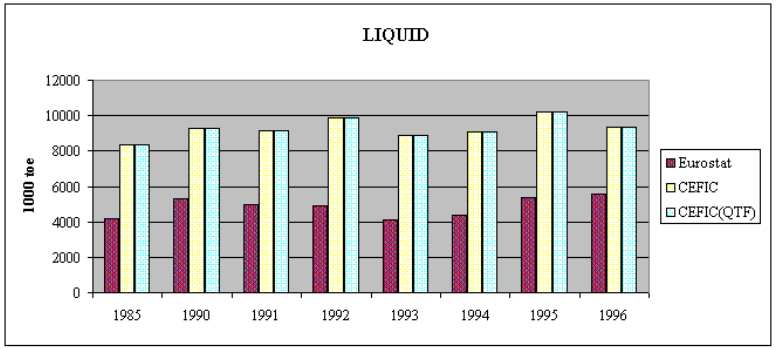
To allocate the fuels given in the EUROSTAT statistics to the three groups solid, liquid and gaseous the following estimates were made for the categories "tar and benzene" and "Other petroleum products" (the estimates are based on more detailed data for Germany). It was assumed that

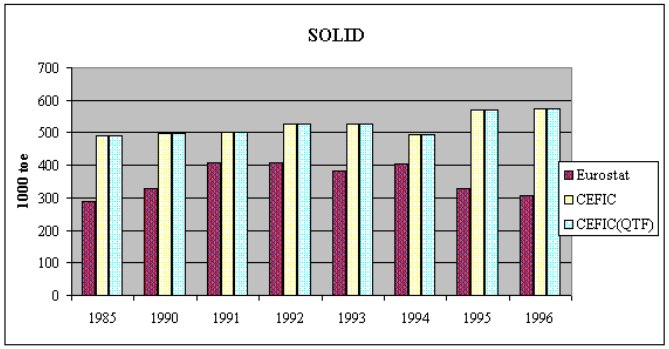
- two thirds of the category "tar and benzene" given in the EUROSTAT statistics are solid fuels while the rest is liquid
- one third of the category "Other petroleum products" represent solid fuels and two thirds are liquid.

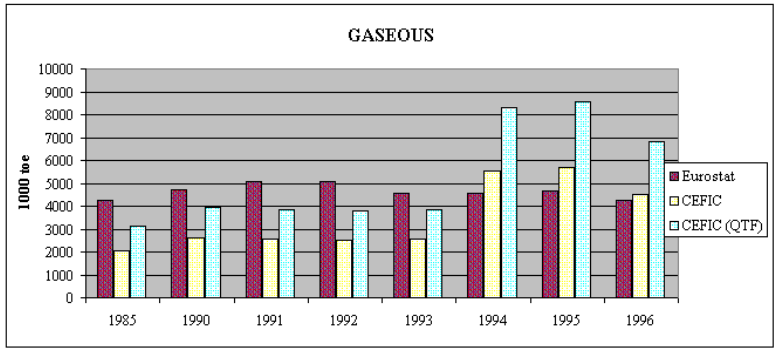
Table A-1 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in Belgium and the Netherlands (CEFIC 1999; EUROSTAT var. eds.)*

	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1985	8768	10942	11979	*73%*	289.57204	490	490	*59%*	4205.428	8378	8378	*50%*	4273	2074	3111	*137%*
1990	10311	12420	13730	*75%*	327.58145	497	497	*66%*	5279.4185	9303	9303	*57%*	4704	2620	3930	*120%*
1991	10507	12233	13513	*78%*	409.26531	500	500	*82%*	5004.7347	9174	9174	*55%*	5093	2559	3839	*133%*
1992	10438	12910	14168	*74%*	407.73572	527	527	*77%*	4934.2643	9867	9867	*50%*	5089	2516	3774	*135%*
1993	9063	11981	13264	*68%*	381.58726	528	528	*72%*	4116.4127	8888	8888	*46%*	4561	2565	3848	*119%*
1994	9380	15096	17864	*53%*	404.53972	495	495	*82%*	4386.4603	9065	9065	*48%*	4585	5536	8304	*55%*
1995	10383	16470	19329	*54%*	326.90623	569	569	*57%*	5379.0938	10184	10184	*53%*	4674	5717	8576	*55%*
1996	10144	14442	16711	*61%*	305.20139	575	575	*53%*	5567.7986	9329	9329	*60%*	4267	4538	6807	*63%*
1997	0	16898		*#DIV/0!*	0	880		*#DIV/0!*	0	8874		*#DIV/0!*	0	7144		*#DIV/0!*





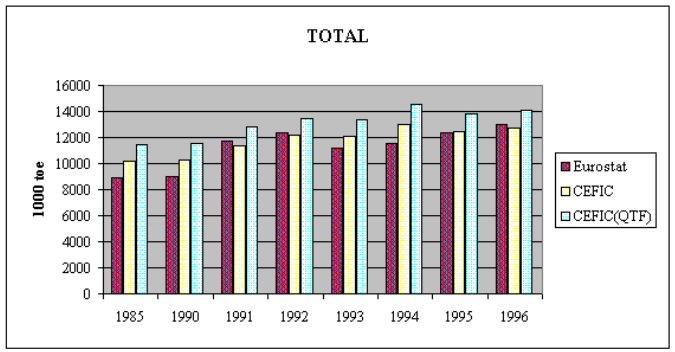


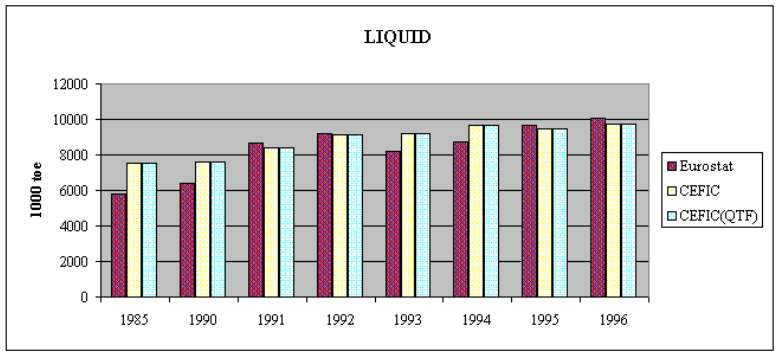


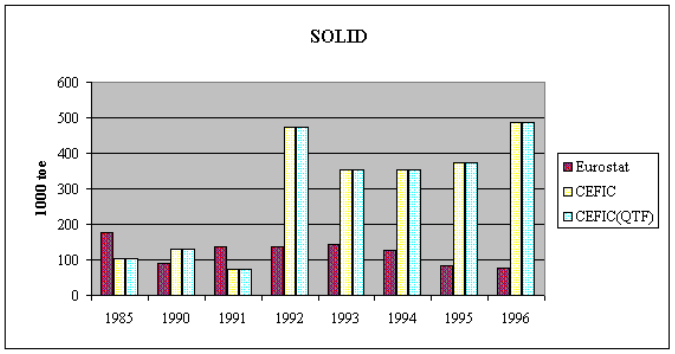
CEFIC kindly provided feedstock data to FhG-ISI. The partners of the NEU-CO_2 network are requested not to make further use of these data before consultation with CEFIC.

Table A-2 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in France (CEFIC 1999; EUROSTAT var. eds.)*

	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1985	8896	10195	11465	*78%*	176.96307	102	102	*173%*	5814.0369	7554	7554	*77%*	2905	2539	3809	*76%*
1990	8988	10285	11576	*78%*	91.057753	131	131	*70%*	6411.9422	7572	7572	*85%*	2485	2582	3873	*64%*
1991	11698	11361	12815	*91%*	136.58663	75	75	*182%*	8650.4134	8378	8378	*103%*	2911	2908	4362	*67%*
1992	12329	12150	13436	*92%*	136.58663	474	474	*29%*	9197.4134	9105	9105	*101%*	2991	2571	3857	*78%*
1993	11183	12133	13408	*83%*	142.27774	352	352	*40%*	8216.7223	9231	9231	*89%*	2821	2550	3825	*74%*
1994	11527	13045	14571	*79%*	126.4691	353	353	*36%*	8728.5309	9641	9641	*91%*	2668	3051	4577	*58%*
1995	12368	12473	13798	*90%*	82.204916	373	373	*22%*	9664.7951	9451	9451	*102%*	2618	2649	3974	*66%*
1996	12961	12769	14059	*92%*	76.513806	486	486	*16%*	10072.486	9704	9704	*104%*	2810	2579	3869	*73%*
1997	0	13883		*#DIV/0!*	0	372		*#DIV/0!*	0	10907		*#DIV/0!*	0	2604		*#DIV/0!*







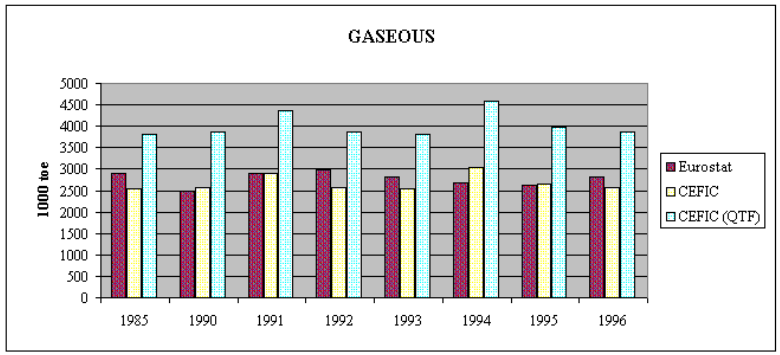


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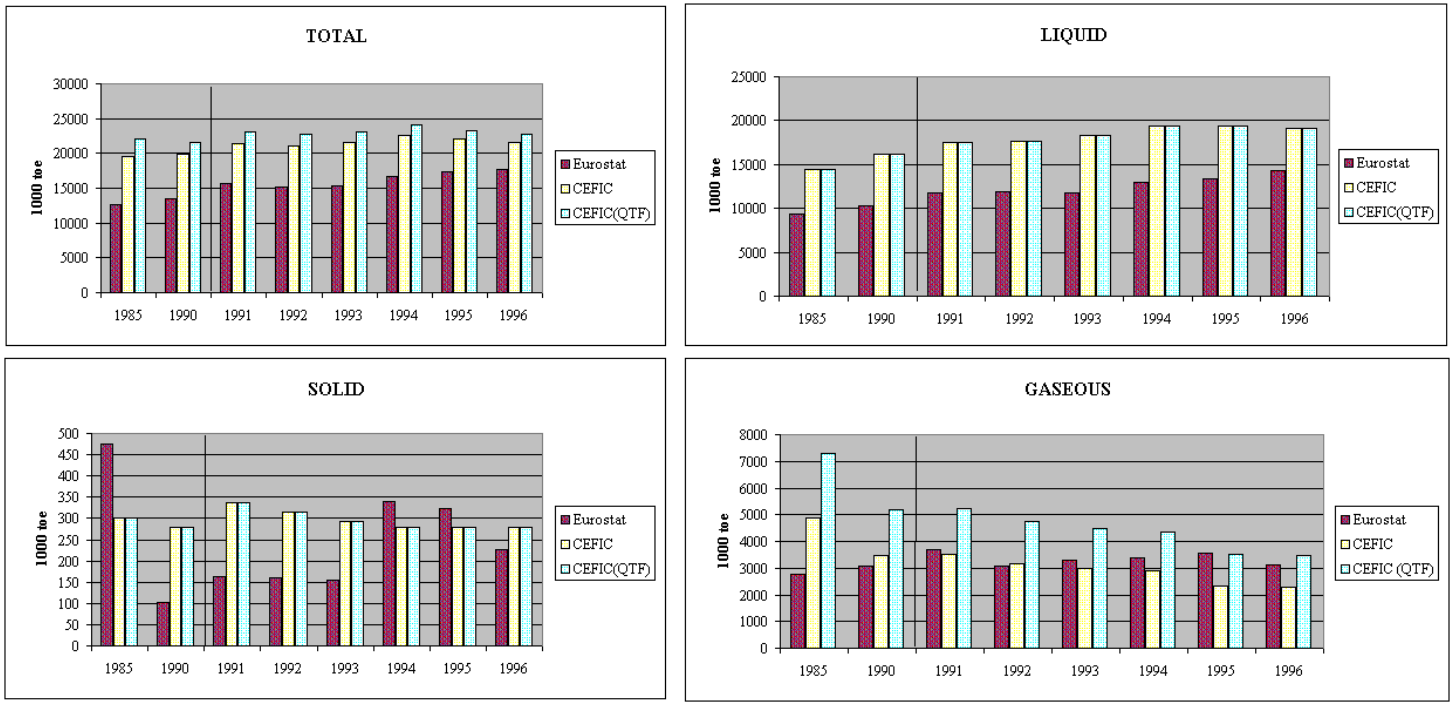
Table A-3 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in Germany (CEFIC 1999; EUROSTAT var. eds.)*

	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1985	12639	19629	22059	*57%*	475.0459	300	300	*158%*	9376.9541	14470	14470	*65%*	2787	4859	7289	*38%*
1990	13529	19923	21654	*62%*	101.17528	280	280	*36%*	10335.825	16181	16181	*64%*	3092	3462	5193	*60%*
1991	15659	21363	23112	*68%*	162.5128	336	336	*48%*	11808.487	17530	17530	*67%*	3688	3497	5246	*70%*
1992	15091	21118	22706	*66%*	159.35107	315	315	*51%*	11838.649	17628	17628	*67%*	3092	3175	4763	*65%*
1993	15253	21578	23077	*66%*	153.65996	294	294	*52%*	11800.34	18287	18287	*65%*	3297	2997	4496	*73%*
1994	16696	22600	24053	*69%*	338.90427	280	280	*121%*	12986.096	19414	19414	*67%*	3368	2906	4359	*77%*
1995	17348	22010	23183	*75%*	321.83954	280	280	*115%*	13411.16	19385	19385	*69%*	3577	2345	3518	*102%*
1996	17628	21646	22798	*77%*	227.55985	280	280	*81%*	14270.44	19062	19062	*75%*	3130	2304	3456	*91%*
1997	0	23500		*#DIV/0!*	0	280		*#DIV/0!*	0	20555		*#DIV/0!*	0	2665		*#DIV/0!*

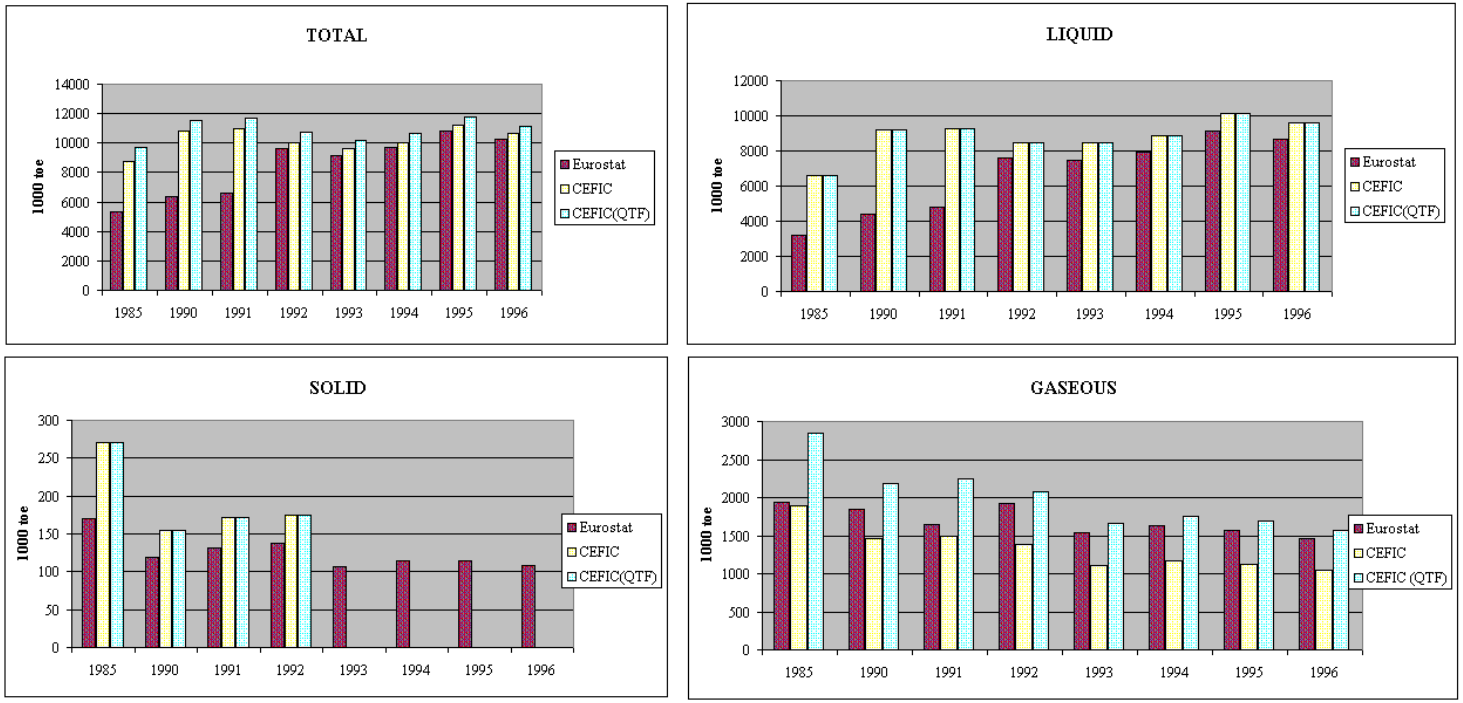
Note: 1985 + 1990 BRD, ABL



CEFIC kindly provided feedstock data to FhG-ISI. The partners of the NEU-CO_2 network are requested not to make further use of these data before consultation with CEFIC.

Table A-4 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in Italy (CEFIC 1999; EUROSTAT var. eds.)*

	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1985	5302	8776	9724	*55%*	170.10094	271	271	*63%*	3193.8991	6609	6609	*48%*	1938	1896	2844	*68%*
1990	6358	10836	11564	*55%*	118.88096	155	155	*77%*	4386.119	9225	9225	*48%*	1853	1456	2184	*85%*
1991	6569	10944	11693	*56%*	131.52787	171	171	*77%*	4795.4721	9276	9276	*52%*	1642	1497	2246	*73%*
1992	9632	10029	10721	*90%*	137.21897	175	175	*78%*	7569.781	8470	8470	*89%*	1921	1384	2076	*93%*
1993	9120	9603	10157	*90%*	106.86639	0	0	*#DIV/0!*	7472.1336	8494	8494	*88%*	1535	1109	1663	*92%*
1994	9707	10061	10643	*91%*	113.82219	0	0	*#DIV/0!*	7961.1778	8895	8895	*90%*	1628	1166	1748	*93%*
1995	10815	11226	11788	*92%*	113.82219	0	0	*#DIV/0!*	9123.1778	10101	10101	*90%*	1573	1125	1687	*93%*
1996	10259	10632	11154	*92%*	108.76343	0	0	*#DIV/0!*	8687.2366	9589	9589	*91%*	1461	1043	1565	*93%*
1997	0	11025		*#DIV/0!*	0	0		*#DIV/0!*	0	9859		*#DIV/0!*	0	1166		*#DIV/0!*

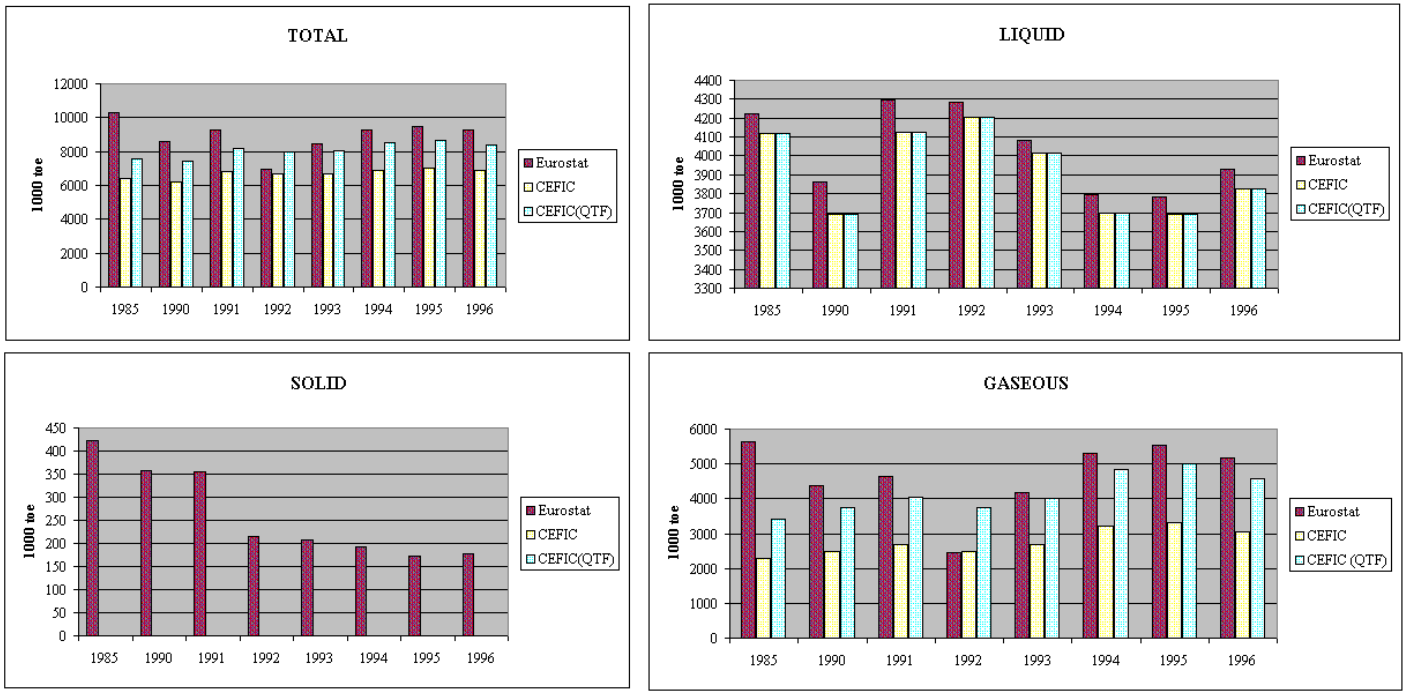


CEFIC kindly provided feedstock data to FhG-ISI. The partners of the NEU-CO_2 network are requested not to make further use of these data before consultation with CEFIC.

Table A-5 *Comparison of CEFIC and EUROSTAT data for chemical feedstocks in United Kingdom (CEFIC 1999; EUROSTAT var. eds.)*

	Total				Solid				Liquid				Gaseous			
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC(Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*	Eurostat	CEFIC	CEFIC (Q_{TF})	*Eurostat/ CEFIC(Q_{TF})*
1985	10266	6401	7543	*136%*	421.36454	0	0	*#DIV/0!*	4223.6355	4118	4118	*103%*	5621	2283	3425	*164%*
1990	8597	6186	7433	*116%*	356.8993	0	0	*#DIV/0!*	3861.1007	3691	3691	*105%*	4379	2495	3742	*117%*
1991	9281	6826	8177	*114%*	355.79696	0	0	*#DIV/0!*	4294.203	4125	4125	*104%*	4631	2701	4052	*114%*
1992	6958	6705	7956	*87%*	214.98901	0	0	*#DIV/0!*	4282.011	4202	4202	*102%*	2459	2503	3754	*66%*
1993	8462	6687	8022	*105%*	207.28124	0	0	*#DIV/0!*	4083.7188	4018	4018	*102%*	4168	2669	4004	*104%*
1994	9280	6920	8532	*109%*	192.21597	0	0	*#DIV/0!*	3792.784	3695	3695	*103%*	5292	3225	4837	*109%*
1995	9481	7020	8684	*109%*	173.26267	0	0	*#DIV/0!*	3784.7373	3691	3691	*103%*	5520	3329	4993	*111%*
1996	9289	6864	8384	*111%*	177.05674	0	0	*#DIV/0!*	3926.9433	3824	3824	*103%*	5182	3040	4560	*114%*
1997	0	6570		*#DIV/0!*	0	0		*#DIV/0!*	0	3512		*#DIV/0!*	0	3058		*#DIV/0!*

SEE CEFIC: no solid feedstocks



CEFIC kindly provided feedstock data to FhG-ISI. The partners of the NEU-CO_2 network are requested not to make further use of these data before consultation with CEFIC.

Table A-6 *CEFIC data for chemical feedstocks in the United States (CEFIC 1999)*

	Total			Solid			Liquid			Gaseous		
1000 TOE	Eurostat	CEFIC	CEFIC(Q_{TF})	Eurostat	CEFIC	CEFIC(Q_{TF})	Eurostat	CEFIC	CEFIC(Q_{TF})	Eurostat	CEFIC	CEFIC(Q_{TF})
1985	0	54676	71247	0	466	466	0	21069	21069	0	33142	49713
1990	0	62700	78584	0	538	538	0	30393	30393	0	31769	47653
1991	0	65767	82630	0	538	538	0	31502	31502	0	33727	50591
1992	0	67762	85714	0	634	634	0	31225	31225	0	35904	53855
1993	0	69053	87123	0	680	680	0	32233	32233	0	36140	54210
1994	0	73043	92431	0	751	751	0	33518	33518	0	38775	58162
1995	0	71892	91648	0	752	752	0	31628	31628	0	39512	59268
1996	0	76665	97992	0	769	769	0	33241	33241	0	42655	63983
1997	0	81863		0	797		0	38130		0	42936	

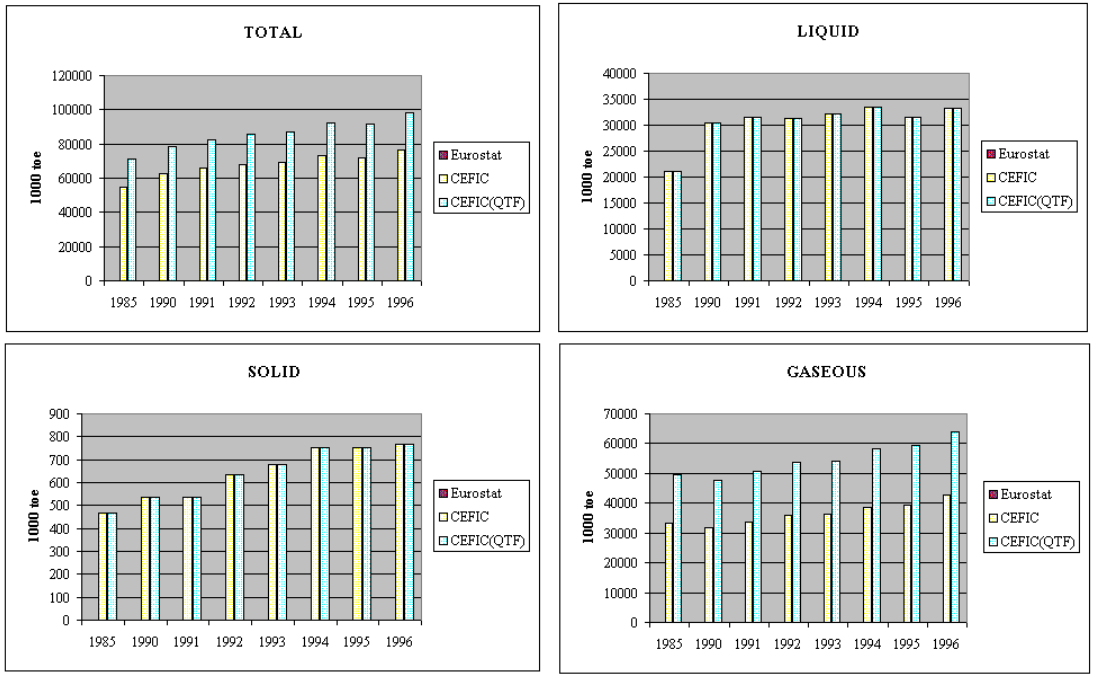


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Table A-7 *Spreadsheet calculation aiming to determine the definitions used for non-energy use in the various countries – Example chosen: the Netherlands, all figures for 1992*

Severity in the Netherlands: high (see Gielen et. al. 1996: rartio ethylene/propylene = 2.45/1.2)

Table a)

Assumed steamcracker feedstock (excl. Res. Fuel Oil)		$Q_{NEU} = Q_{TF}$	$Q_{NEU} = Q_{TF} - Q_F$	$Q_{NEU} = Q_{TF} - Q_{E,int}$	$Q_{NEU} = Q_{TF} - Q_F - Q_{E,int}$
All figures for 1992, in metric kilotonnes	**(Nat. energy balance 1993)**	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)
Naphtha	613	199	235	228	278
Gas / diesel oil	2345	569	754	669	942
LPG, Refinery Gas	1615	899	988	1083	1215
others					
Total Ethylene Production (calc.)		1667	1977	1981	2435
Real Ethylene Production (1992)		2450	2450	2450	2450
Difference (delta/real) in %		**-32**	**-19**	**-19**	**-1**

Table b)

Assumed steamcracker feedstock (excl. Res. Fuel Oil)		$Q_{NEU} = Q_{TF}$	$Q_{NEU} = Q_{TF} - Q_F$	$Q_{NEU} = Q_{TF} - Q_{E,int}$	$Q_{NEU} = Q_{TF} - Q_F - Q_{E,int}$
All figures for 1992, in metric kilotonnes	**(Eurostat 1993)**	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)
Naphtha	*2805*	910	1075	1045	1272
Gas / diesel oil	*55*	13	18	16	22
LPG, Refinery Gas	*1650*	918	1010	1106	1241
others					
Total Ethylene Production (calc.)		1842	2102	2167	2535
Real Ethylene Production (1992)		2450	2450	2450	2450
Difference (delta/real) in %		**-25**	**-14**	**-12**	**3**

Table c)

Assumed steamcracker feedstock (excl. Res. Fuel Oil)		$Q_{NEU} = Q_{TF}$	$Q_{NEU} = Q_{TF} - Q_F$	$Q_{NEU} = Q_{TF} - Q_{E,int}$	$Q_{NEU} = Q_{TF} - Q_F - Q_{E,int}$
All figures for 1992, in metric kilotonnes	**(Gielen et al. 1996)**	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)	Ethylene Output (calc.)
Naphtha	2790	905	1069	1040	1265
Gas / diesel oil	3800	922	1222	1085	1526
LPG, Refinery Gas	1670	930	1022	1120	1256
others					
Total Ethylene Production (calc.)		2756	3313	3244	4048
Real Ethylene Production (1992)		2450	2450	2450	2450
Difference (delta/real) in %		**12**	**35**	**32**	**65**

Conclusions

- The definition $Q_{NEU} = Q_{TF} - Q_F - Q_{E,int}$ is the most probable for the non-energy data published in the National energy balance (Table a) and in the EUROSTAT statistics (Table b).
- The definition $Q_{NEU} = Q_{TF}$ is the most probable for the non-energy data given in Gielen et al. 1996 (Table c).

Table A-8 *Results of the first NEU-CO_2 questionnaire on the definitions of non-energy use by countries*

	Austria	Denmark[1)]	France	Germany	India	Italy	Japan	Korea	Netherlands	Norway	Russia	UK	USA
Dutch definition: $Q_{NEU, NL, i} = Q_{TF, i} - Q_{F, i} - Q_{E,int, i}$	X	-	X						X				
Italian definition: $Q_{NEU, IT, i} = Q_{TF, i} - Q_{E,int, i}$		-				X							
German definition: $Q_{NEU, FRG, i} = Q_{TF, i} - Q_{F, i}$		-		X								X	
Further definitions		-						(X)[2)]					

[1)] There is no petrochemical industry in Denmark.

[2)] In the "National Communication of the ROK" 95% of naphtha is accounted for non-energy use. This may mean that neither $Q_{F, i}$ nor $Q_{E,int, i}$ is accounted for. If this is correct the definition for Korea is $Q_{NEU, Korea, i} = Q_{TF, i}$.