# The main findings achieved by the network and perspectives for further work

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## 1. Introduction

The IPCC has introduced two different approaches for reporting on the $CO_2$ emissions released by a country, the so-called **"Reference Approach" (RA) and the "Sectoral Approach" (SA)** (IPCC/IEA/OECD/UNEP 1996). The RA is a simple method to estimate carbon flows based on the supply data for fuels as published in energy balances. On the other hand, the SA follows a more disaggregated approach to determine $CO_2$ emissions, starting at the sectoral level and partly even from the processes in the various sectors. Hence, the SA provides information on the relative importance of the source categories and on the types of products. The RA can play an important role in checking the calculations from the SA. In addition, the RA is the reporting method applied by the non-Annex-1 countries, since it has the advantage of requiring less data than the SA.

## 2. Methodological options

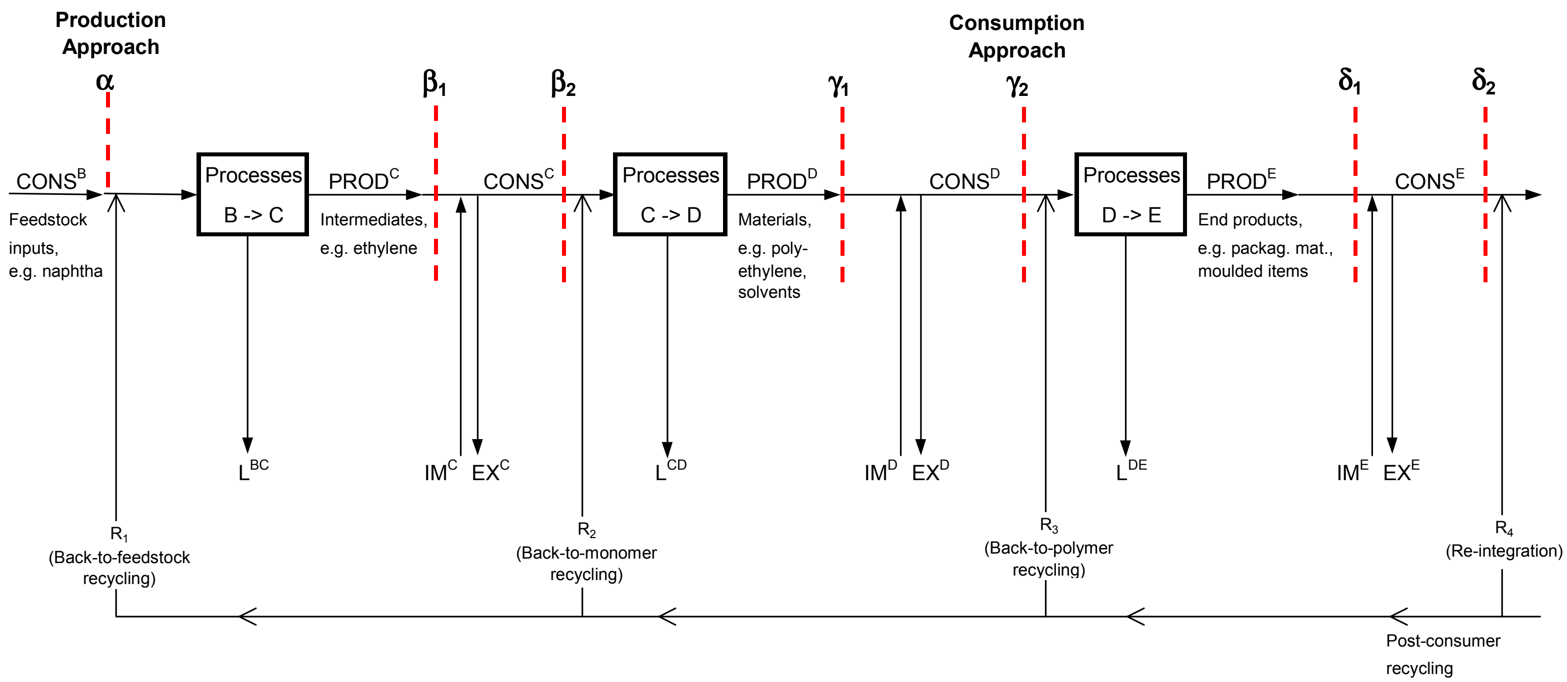
One of the main reasons why the NEU-$CO_2$ network was set up was that the Guidelines on the RA leaves **large scope for interpretation**. For example, no clear statement is made whether carbon storage should refer to all synthetic organic products or only to the subgroup of long-lived products, e.g. plastics. Moreover, it is left open whether the determination of emissions should focus exclusively on the "raw material side" ("upstream perspective") or whether it should be complemented by a "downstream or consumption-oriented" perspective. Consequently, the analyst does not get any guidance whether imports and exports of chemical products should be taken into account and if yes, how this should be done. Given these uncertainties, the default carbon storage factors provided by the IPCC Guidelines (IPCC/IEA/OECD/UNEP 1996) seem void. In addition, they are very unlikely to represent a good approximation of the situation in any country given the structural differences in the chemical/petrochemical sector.

In the **early phase of the network, a consensus** grew about how to deal with these points. The joint foundation can be described as follows:

- It was decided that, instead of using default values, carbon storage should be determined on the basis of **material flow analyses** for the chemical/petro-chemical industry in several countries.
- "**Carbon storage**" was considered to be a synonym for carbon inherent in long-lived materials (e.g. plastics).
- In contrast, "**carbon release**" was considered to cover the amounts of carbon inherent in short-lived materials (e.g. solvents), process emissions originating from the feedstock and that share of the feedstock which is used as fuels.
- It was agreed upon that the importance of **foreign trade** for the final results should be analysed.

The discussions within the network revealed the importance of the question whether an "**upstream perspective**" or a "**downstream perspective**" should be taken. In other words, a decision had to made at which level in the process chain the carbon flow should be measured. The options are given in Figure 1 by the levels $\alpha$, $\beta_1$, $\beta_2$, $\gamma_1$, $\gamma_2$, $\delta_1$ and $\delta_2$. The total carbon flow can differ decisively depending on this choice. For example, for countries with large net imports of intermediates (C), materials (D) and end products (E), the amount feedstock inputs ($CONS^B$) is clearly smaller than their total consumption of end products ($CONS^E$; see Figure 1).

For level $\gamma_1$, $\gamma_2$, $\delta_1$ and $\delta_{2,}$ the total carbon flow can easily be split into the categories of **long-lived products** (carbon storage) and **short-lived products** (carbon release): products made of plastics and other durable materials are ascribed to the category "carbon storage" whereas all products which are oxidised or biodegraded easily are assigned to "carbon release". In contrast, a more sophisticated solution must be found in order to split the total carbon flow at level $\alpha$, $\beta_1$ and $\beta_2$ since most of these products are liquid and are more or less susceptible to destruction. In these cases, the allocation is done by determining which share of the carbon flow studied ($\alpha$, $\beta_1$ or $\beta_2$) finally ends up in long-lived versus short-lived *materials* (i.e. $\gamma_1$ represents the reference level). This method has already been applied in Gielen (1997) and Patel et al. (1999).




Carbon flows (in kt of $CO_2$ equivalents):

| | |
|---|---|
| $CONS^i$ | = domestic consumption of commodity i |
| $PROD^i$ | = total production of commodity i |
| $IM^i$ | = imports of commodity i |
| $EX^i$ | = exports of commodity i |
| $L^j$ | = losses & leakages from processes j |

Indices:

| | |
|---|---|
| i | = commodity, e.g. i = B = feedstock inputs, i = C = intermediates, i = D = materials and intermediates, i = E = final products |
| j | = group of processes, e.g. j = BC for the conversion of feedstock inputs B to basic chemicals C |

Figure 1: A country's carbon flows connected with the production of synthetic organic materials

## 3. Models developed in the first phase of the NEU-$CO_2$ network

In its first year, the NEU-$CO_2$ network developed two models, i.e.

- the **NEAT model** (Gielen et al. 1999) and
- the **Shortcut Method** (Patel 1999b).

In the following, the methodological choices made in the two models are described.

### 3.1 Methodology of the NEAT model

NEAT is a detailed material flow model. Based on material balances, it traces the carbon flows throughout the process chain.

When developing the NEAT model the following decisions were made:

- To study the impact of foreign trade, the model takes both an "upstream perspective" or a "downstream perspective".
- For the upstream perspective, level $\alpha$ was chosen (see Figure 1). In the following, this approach will be referred to as the "production approach".
- For the downstream perspective, level $\gamma_2$ was chosen (see Figure 1). In the following, this approach will be referred to as the "consumption approach". It is important to note that this choice was mainly made for pragmatic reasons. For example, level $\delta_2$ is much closer to final consumption than level $\gamma_2$ and therefore, might have been be a more valuable metric. However, it turned out to be practically unfeasible to trace the carbon flows down to the *end products* (D) due to the enormous number of these products, the danger of double counting and – to some extent – the insufficient availability of data (e.g. there are no subcategories for plastics products in the current PRODCOM classification).

When applying the "production approach" NEAT acts as a **bottom-up model**. This means that detailed production and trade data at the levels $\gamma_1$ (production) and $\beta$ (trade) are used to calculate the equivalent carbon flow at level $\alpha$. If we use the abbreviations shown in Figure 1 we can say that NEAT provides an estimate of the total feedstock inputs ($CONS^B_{NEAT}$) which can be compared to the respective figure from statistics ($CONS^B_{STATISTICS}$). Moreover, NEAT allows the calculation of various components of $CONS^B$, e.g. the amount of carbon stored in short-lived versus long-lived products.

### 3.2 Methodology of the Shortcut Method

The main characteristics of the Shortcut Method are:

- The Shortcut Method exclusively takes the "upstream perspective". Just as in the NEAT model level $\alpha$ was chosen (see Figure 1), i.e. the model follows the so-called "**production approach**".
- Using factors derived from material balances of the chemical/petrochemical sector, the purpose of the Shortcut Method is to divide the total amount of

carbon input into the parts which end up **in short-lived versus long-lived products**.

- The Shortcut Method relies on feedstock data ($CONS^B$), i.e. it does not allow to generate an independent estimate from other sources (as NEAT does).

## 4. First conclusions drawn from the analyses

The NEAT model was applied to several countries and showed that specific trade and production aspects can have a strong impact on the results. Consequently, a country-specific procedure should be taken which is in contrast to the method suggested by the current RA where default carbon storage factors are used. Due to the complexity of the issue, it is unlikely that each country generates and applies country-specific factors for carbon storage when calculating $CO_2$ emissions according to the RA. The generation of such factors would require a complex model of its own – probably something similar to the NEAT model.

On the other hand, the experience made when applying NEAT revealed problems which are partly related to the unclear scope or lack of production and trade data, partly due to uncertainties of endogenic data (e.g. on specific process emissions) and partly due to necessary simplification of the interlinkages between the material flows. However, the parallel application of the model to several countries has proven to be very valuable to detect problems and develop improvements.

Independent of this model work, the statistical definitions of non-energy use were studied for various countries (Patel, 1999a). These analyses confirmed the earlier presumption that the non-energy use data published in national and international energy balances are very often inconsistent. Therefore, it is practically impossible that the direct use of these data for the RA will yield reliable results. The conclusions are that

- a **model approach is required** which is independent of these data and that
- there is a strong need to **improve statistical data** on non-energy use.

## 5. Impacts of the new CRF

In September 1999, *Subsidiary Body for Scientific and Technological Advice* (SBSTA) published the new Common Reporting Format (SBSTA 1999). This brings about important changes which are relevant for the NEU-$CO_2$ network:

The new Common Reporting Format (CRF) has reduced considerably the scope of interpretation with regard to the RA. According to the decisions made by SBSTA, it is the future objective of the RA to determine $CO_2$ emissions from **fuel combustion** (see § 23 of SBSTA 1999). The results according to the RA are supposed to be used for verification purposes of the inventories determined using the SA (SBSTA 1999).[1] As a consequence, the category **"Carbon stored"** in the

1 See also Table 1.A(c) of the CRF: The $CO_2$ emissions according to the Reference Approach in Table 1.A(c) are taken from the column "Actual $CO_2$ emissions" in Table 1.A(b) and they are compared to the $CO_2$ emissions according to the SA, which is also referred to as "National Approach".

RA must represent all carbon that is not combusted, i.e. **the total amount of carbon stored in *all* chemical products**[2]. This includes both short-lived and long-lived synthetic organic materials and hence, is in contrast to the decision made in the early phase of the network when "carbon storage" was considered to be a synonym for carbon inherent in long-lived products only (see Chapter 2). As a further consequence of the new CRF, **"carbon storage" according to the RA** (or Table 1.A(b) of the CRF) must refer to production level $\alpha$, i.e. only **NEAT's "production approach"** provides a consistent figure, not NEAT's "consumption approach"[3].

Moreover, the **Shortcut Method is totally incompatible** with the requirements according to the new CRF because the main purpose of the Shortcut Method, i.e. the distinction between carbon inherent in short-lived and long-lived products, has become irrelevant.

Apart from determining **carbon storage** the model also provides a bottom-up estimate of **total non-energy use in various definitions** (see other papers presented at this workshop). The comparison with the figures published in energy balances ("coverage") indicates to which extent data harmonisation is required for the country studied.

Since the NEAT model accounts for the production and trade structure of the country studied the results are expected to be more reliable than those generated with the help of the default factors. It is therefore suggested that **countries should be asked to use the NEAT model results** when entering the data in the column "Carbon stored" of the CRF's Table 1.A(b). This will ensure that the final result of Table 1.A(b), i.e. the so-called as "Actual $CO_2$ emissions", will be a **more reliable check for the SA** (also referred to as "National Approach"; see Table 1.A(c) of the CRF).

Moreover, the countries should be asked to **report both carbon storage according to the NEAT model and the results of the RA** (based on default storage factors). The differences should also be explained. It is expected that this will act as an **incentive** for these countries to improve the data on non-energy use in future statistics.

**NEAT calculates the data for three definitions of Carbon Storage, i.e. $CS_I$, $CS_{II}$ and $CS_{III}$.** All of these definitions refer to the carbon storage in long-lived plus short-lived materials, however they differ with regard to process emissions and fuels used in steam crackers. The definitions are given in Figure 2 which also shows the impacts on the so-called "Actual emissions" determined by the RA:

- According to paragraph 23 of the CRF (SBSTA 1999) the "Actual emissions" of the RA should be usable to verify $CO_2$ emissions from fuel combustion according to the SA. The NEAT carbon storage indicator $CS_{III}$ gets closest to

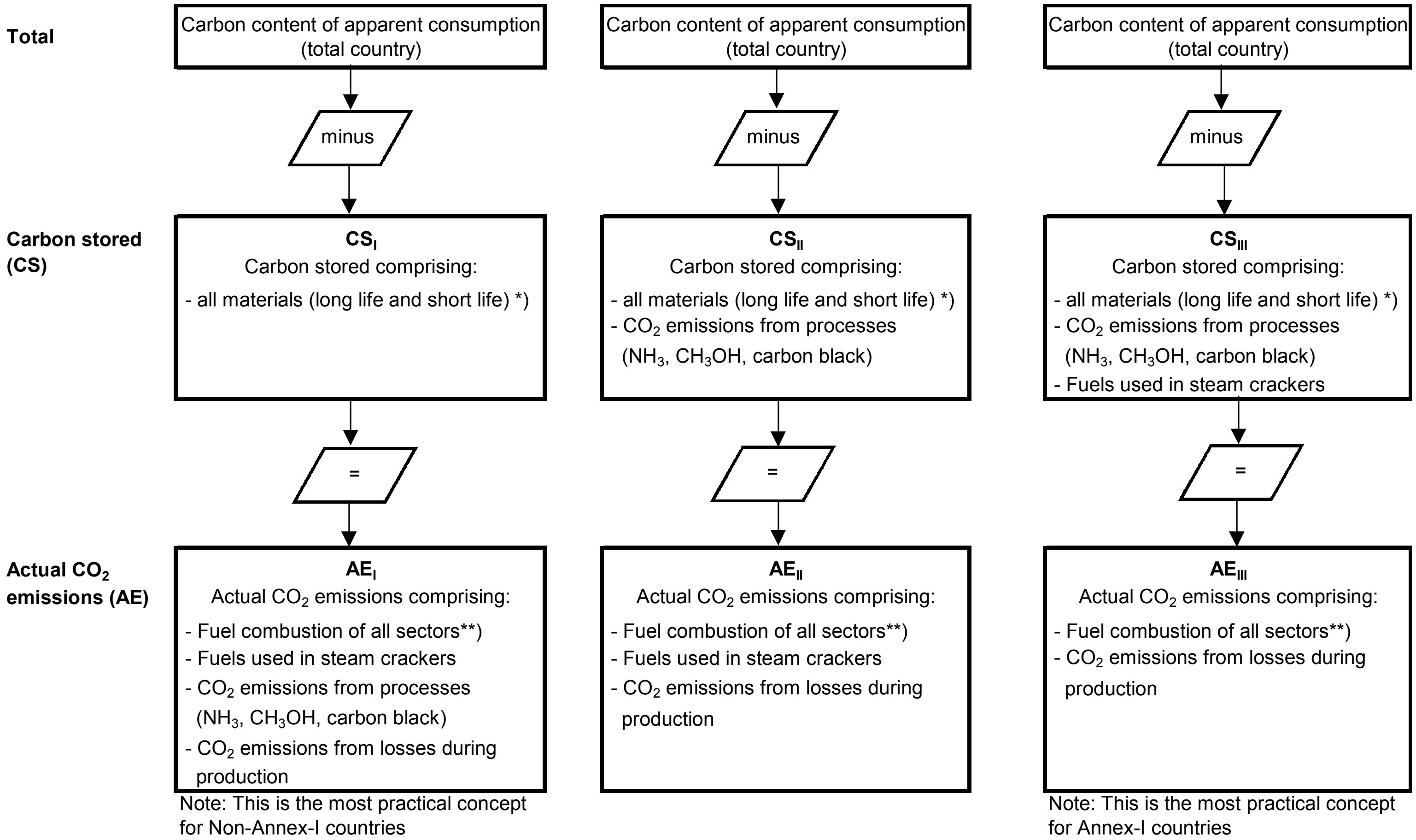
2 To be precise, the assumption that the total amount of carbon which is not combusted is identical with the total amount of carbon stored in all chemical products is again an approximation. In reality, there will be a difference between the two which is caused to a large extent by carbon oxidation during the production of ammonia, methanol and carbon black. This will be dealt with later on in this chapter.

3 Annex 1 tries to explain this statement using an example.

this requirement (see Figure 2). It therefore seems to be the most practical concept for Annex-I-countries since these are required to apply the SA.

- On the other hand, carbon storage indicator $CS_I$ allows the calculation of "Actual emissions" ($AE_I$) comprising $CO_2$ from all major oxidation processes in the country, i.e. all types of fuel combustion, $CO_2$ emissions from processes and $CO_2$ from losses during production. Due to the comprehensiveness of indicator $AE_I$, carbon storage indicator $CS_I$ seems the appropriate approach for those countries which do not apply the SA, i.e. for Non-Annex-I-countries.

Apart from the general problems of NEAT mentioned in Chapter 4, the fuel use of steam crackers has more complicated implications than presented in Figure 2. Figure 2 and the NEAT model calculations assume that steam crackers are self sufficient in energy terms, i.e. that their fuel use is completely covered by suitable outputs of the steam cracker itself. However, this is not necessarily the case. As a consequence indicator $CS_{III}$ might overestimate the real carbon storage and therefore, lead to too low figures for "Actual $CO_2$ emissions" ($AE_{III}$).
A similar problem occurs for those countries which do not account for the steam crackers' fuel use in the category "Non-energy use" but include these amounts in the sectoral energy data. In this case $AE_{III}$ also underestimates the results of the SA.




*) Always referring to "Production Approach", i.e. following the "upstream perspective".
**) Referring to IPCC's Sectoral Approach (SA)

Figure 2: Different concepts of "Carbon Storage" and "Actual Emissions" suggested the IPCC Reference Approach (RA)

Finally, for reasons of completeness, it must be mentioned that NEAT only covers the chemical/petrochemical sector and therefore, does not include $CO_2$ emissions from limestone production ($CO_2$ of mineral origin) and coke use in the iron and steel industry.

## 6. Extension of the CRF, IPCC Guidelines and EMEP/CORINAIR Guidebook

Data analysis in the NEU-$CO_2$ Network has shown that the $CO_2$ emission factors for the production of ammonia, olefins, methanol and carbon black are often missing or are incomplete in the IPPC 1996 Revised Guidelines (IPCC/IEA/OECD/ UNEP 1996), the CRF (SBSTA 1999) and EMEP/CORINAIR's Atmospheric Emission Guidebook (EMEP/CORINAIR 1999). Table 1 compares the information published in these sources with preliminary data generated by the NEU-$CO_2$ network.

Table 1: Specific $CO_2$ emissions for the production of selected bulk chemicals

| | EMEP/ CORINAIR | IPCC Guidelines | CRF | NEU-$CO_2$ *) |
|---|---|---|---|---|
| Ammonia | No methodology prepared | 1.5 kg $CO_2$/kg ammonia | Mentioned but no data | kg $CO_2$ / kg ammonia<br>- from natural gas: 1.6<br>- from oil: 2.4 |
| Olefins (ethyene, propylene) | Data on the contribution to a country's total $CO_2$ emissions | Not mentioned | Mentioned but no data | kg $CO_2$ / kg ethylene<br>- from naphtha: 1.3<br>- from middle dest.: 1.8<br>- from LPG: 0.9 |
| Methanol | Not mentioned | Not mentioned | Mentioned but $CO_2$ considered negligible | kg $CO_2$ / kg methanol<br>- from natural gas: 0.4<br>- from oil: 1.3<br>- from soft coal: 2.1 |
| Carbon black | No methodology prepared | Not mentioned | Mentioned but $CO_2$ considered negligible | kg $CO_2$ / kg carbon black<br>- from oil: 1.6 |

*) Preliminary values

EMEP/CORINAIR's Atmospheric Emission Guidebook does not contain a methodology for ammonia, urea and carbon black because the contribution to total national emissions is considered "to be currently insignificant, i.e. less than 1% of national emissions of any pollutant". In fact, the contribution of ammonia production to the total national $CO_2$ emissions are estimated at 0.97% in Germany, 0.55% in Italy and 0.48% in the U.S. (own calculations). These are indeed small percentages. However, ammonia production contributes substantially to the $CO_2$ emissions of the petrochemical/chemical sector and they should therefore not be neglected at this level. IPCC's emission factor for ammonia production is practically identical with NEU-$CO_2$ network's estimate for ammonia production from natural gas which is the dominating type of feedstock for this product worldwide (see Table 1). According to the NEU-$CO_2$ Network's knowledge, the SA/CRF wrongly assume that $CO_2$ emissions from methanol and carbon black are negligible and they only refer to $CH_4$ emissions from these production processes. The CRF/SA do not provide default $CO_2$ emission factors for any of the products listed in Table 1. for this reason, **the NEU-$CO_2$ network suggests that consolidated data of the type listed in the right column of Table 1 shall be included in IPCC's Sectoral Approach**.

To account for diverse accounting practices for the fuel use of steam crackers, the SA should only cover the emissions from this source for those countries which include these fuels in the category "non-energy use" and do not list them under the energy use of the chemical/petrochemical sector. This means that the emission factors for olefins listed in Table 1 can be used when preparing the emission inventories under the SA e.g. for Germany, but they are irrelevant for the Netherlands.

## 7. Conclusions for further work within the current project

The current project started on January 1, 1999 and will run until June 30, 2000. It is suggested to use the remaining time to conduct the following analyses for as many countries as possible:

- Application of the updated NEAT model to determine total non-energy use in various definitions and comparison with statistical data
- Calculation of carbon storage using the updated NEAT model
- Comparison with the results according to the RA using default storage factors
- Calculation of $CO_2$ emissions related to the production of ammonia, olefins, methanol and carbon black; for urea correction for $CO_2$ fixed in polymers; for all data comparison with SA if reported there.

Further activities will be required to provide IPCC and SBSTA with recommendations (see Chapter 8).

## 8. First recommendations to the IPCC and SBSTA

The ultimate goal of the current project is to make recommendations how the IPCC Guidelines could be improved. The recommendations shall also include the identification of further research requirements. Given the release of the new CRF, recommendations should also be provided to the SBSTA, if relevant.

The following first recommendations can be given:

- Those parts in the **IPCC Guidelines** which refer to the RA should be **streamlined** by removing or re-writing those parts which are in contradiction to the new CRF. The project team will make general suggestions whereas suggestion for wording in detail would have to be dealt with in a separate activity.
- There is some scope to **improve the terminology chosen in the CRF**, thereby making it easier to comprehend[4]. The project team will give examples for

[4] For example, given the new role of the RA, it might be helpful to rename the column "Actual $CO_2$ emissions" in Table 1.A(b) of the CRF into "$CO_2$ from fuel combustion".

improved wording whereas a thorough screening of the CRF would have to be dealt with in a separate activity.

- It is recommended to ask **countries to use the NEAT model results** when entering the data in the column "Carbon stored" of the CRF's Table 1.A(b). Moreover, the countries should be asked to **report both carbon storage according to the NEAT model and the results of the RA** (based on default storage factors). The differences should also be explained.
- It is recommended that IPCC and/or SBSTA develop **a concept how non-energy use should be defined** in energy balances and that they support the improvement of data on non-energy use in future statistics.

## 9. Topics for further acquisition

Apart from further work which is directly related to the issues addressed in Chapter 8, there is scope for further activities for the NEU-$CO_2$ network in the following areas:

- Offer services as peer reviewers of inventories (RA, SA, CRF)
- Collection of detailed data for the products listed in Table 1 and generation of consolidated values for the specific $CO_2$ emission related to their production[5]
- Estimates of $CO_2$ emissions from solvents and other short-lived materials (these estimates could serve as an input to the SA; they could be made by use of NEAT and other sources and in co-operation with associations and consultants)
- Fine-tuned calibration of NEAT for selected countries[6]
- Estimation of carbon losses due to incomplete conversion in the chemical/petro-chemical industry.
- Extension of NEAT by non-energy processes outside the chemical/petro-chemical sector, e.g. limestone production and electrode use in steel/aluminium production.
- Other modelling activities, e.g. dealing with the potential of $CO_2$ mitigation by increased recycling of synthetic organic materials.

## 9. References

EMEP/CORINAIR's Atmospheric Emission Inventory Guidebook (Volume 1-3). Second Edition. Prepared by EMEP (Co-operative Programme for Monitoring and Evaluation of the long Range Transmission of Air Pollutants in Europe) and CORINAIR (The Core Inventory of Air Emissions in Europe). European Environment Agency (EEA). Edited by Stephen Richardson. Copenhagen, September 1999

5 The following factors will have to be taken into account: autothermal/non-autothermal operation of steam crackers; feedstocks by type and quantity (possibly in cooperation with local associations and consultants); operation mode (severity) etc.

6 This will require further in-depth analyses of selected processes (e.g. share of DMT and TPA in PET production) and of statistical data (e.g. inclusion of MTBE, stryrene etc. in non-energy use data).

Gielen, D. J.: Potential $CO_2$ emissions in the Netherlands due to carbon storage in materials and products. Ambio 26, 101-106. 1997.

Gielen et al.: The NEAT model – Non-energy use GHG Emission Accounting Table. Paper presented at the 1st NEU-$CO_2$ Workshop in Paris, 23-24 September 1999. Workshop proceedings, December 1999

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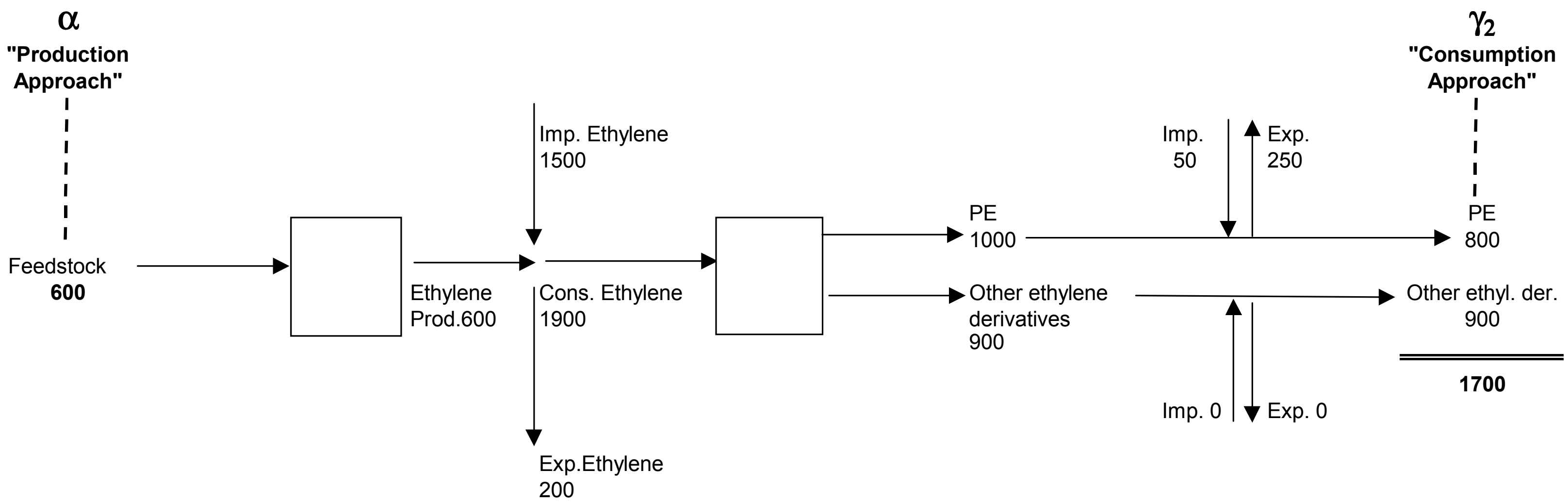
Subsidiary Body for Scientific and Technological Advice (SBSTA): Report of the Subsidiary Body for Scientific and Technological Advice on its Tenth Session, Addendum: Draft Decision on Guidelines for the Preparation of National Communications by Parties Included in Annex I to the Convention. Part I: UNFCCC Reporting Guidelines on Annual Inventories. Bonn, 31 May – 11 June 1999

*Note: The Common Reporting Format (CRF) is available on NEU-$CO_2$ 's webpage (http://www.eu.fhg.de/NENERGY/)*

- *as a printout (pdf file) plus explanations: Please click "SBSTA Meeting 31 May– 11 June 1999"*
- *as an Excel file: Please click "Common Reporting Format Tool V1.01"*

## Annex 1 Use of the NEAT results ($\alpha$, $\gamma_2$) for carbon storage in the RA




Note: NEAT calculates the carbon flow according to the "Production Approach" ($\alpha$) using downstream data:

= 1000 + 900 + 200 - 1500
= 600

| **National Energy Balance** | | **Use of NEAT results, Level $\alpha$** | | **Use of NEAT results, Level $\gamma_2$** | |
|---|---|---|---|---|---|
| Fuel use, total economy | 5000 | Fuel use, total economy | 5000 | Fuel use, total economy | 5000 |
| of which: Non-energy use | 800 | of which: Carbon storage, $\alpha$ | 600 | of which: Carbon storage, $\gamma_2$ | 1700 |
| Fuel combustion | 4200 | Fuel combustion | 4400 | Fuel combustion | 3300 |