Continuation of the "International Network Non-energy Use and CO_2 Emissions ($NEU\text{-}CO_2$)" – Phase III

Executive Summary of Phase III of the NEU-CO_2 Project

- Publishable final activity report -

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1. Introduction

Fossil fuels are not only used for the generation of energy but also for non-energy purposes, i.e., as feedstock in the chemical industry and for the production of certain refinery products for non-energy purposes (e.g., lubricants and bitumen). The worldwide share of non-energy use on the total primary energy supply (TPES) has increased from around 4.3% in 1971 to 5.9% in the year 2003 (IEA, 2004). The fraction of fossil fuels consumed as non-energy use in Western Europe is, however, substantially higher, representing 11-12% of the total amount of fossil fuels used for final consumption. Non-energy use represents therefore an important potential source for CO_2 (carbon dioxide) emissions. Due to the complicated pathways of carbon in the chemical industry, non-energy use and associated CO_2 emissions have been and continue to be a major source of uncertainty in both energy balances and national greenhouse gas (GHG) emissions inventories.

The NEU-CO_2 network has been working on research topics related to non-energy use and resulting emissions since 1999 (three ENRICH projects in total). In Phase I and II of the NEU-CO_2 network, the NEAT model was developed, which is a tool based on mass balance and material flow analysis for estimating countrywide non-energy use, carbon storage and non-energy use CO_2 emissions independently from official energy statistics. Several network partners have applied NEAT for selected countries (i.e., the Netherlands, Italy, South Korea, and Germany). By analysing the carbon flows with the NEAT model, errors in both national energy balances and national GHG inventories were revealed (La Motta et al., 2005, Neelis et al., 2005a, Park, 2005, Weiss et al., forthcoming, a). The work during Phase I and II of the NEU-CO_2 network has furthermore contributed indirectly towards the international harmonisation of the definitions of non-energy use and to the revision of the 1996 IPCC (International Panel on Climate Change) guidelines for GHG inventories. In conclusion, our work during phase I and II of the NEU-CO_2 network proved to be very valuable not only for identifying weak points in official statistics but also to generate ideas for further data improvement and harmonization. Given the success of

the first two phases of the network, a third phase of the NEU-CO_2 project was financed by the European Commission, with duration of 24 months running from August 2004 to August 2006.

During phase III of the NEU-CO_2 network, we addressed seven work packages (WPs), each of which dealing with different aspects of non-energy use and related CO_2 emissions:

WP 1: Pooling and analysis of **information on materials with complicated pathways** in production, use, and waste management (e.g., non-specified by-products in the chemical industry, the use of solvents and lubricants).

WP 2: Development of a **Simplified** and less data intensive **Model Approach** based on the detailed NEAT model.

WP 3: Preparing an inventory of planned and implemented methods for **macro-validation of emissions to be monitored under the European Emission Trading Scheme (ETS)**.

WP 4: Assessing the success achieved by the NEU-CO_2 network in **harmonising data on non-energy use** as published in national and international energy balances.

WP 5: Contributing to the second **revision of the IPCC Guidelines** for National GHG emission inventories in order to improve terminology, remove ambiguity and contradictions, and to introduce improved estimation methods for non-energy use and related CO_2 emissions.

WP 6: **Organizing two workshops** in order to discuss the outcome achieved regarding work packages 1 to 5, to draw conclusions for further research steps to be taken, and to give recommendations to national and international bodies.

WP 7: **Disseminating network-results** via Internet, at conferences, and in reviewed scientific journals.

In the following section of the summary, we present the results for each work package individually.

2. Results of Individual Work Packages

2.1. WP 1: Pooling and Analysis of Information on Materials with Complicated Pathways

The task of pooling and analyzing information on materials with complicated pathways was coordinated by Vito (Vlaamse Instelling voor Technologisch Onderzoek) in Belgium and IIÖ (Institut für Industrielle Ökologie) in Austria. VITO studied the use of chemical by-products, i.e., recovered fuels and non-specified products as well as resulting non-fuel CO_2 emissions in the chemical industry. For this purpose, Vito developed a questionnaire, which was sent out to all project partners for collecting country-specific data. Furthermore, information already available from CRF (Common Reporting Format) tables of the NIR (National Inventory Reports) was studied. The response to the questionnaire was relatively poor, as publicly available country-specific information seems to be scarce. Rough estimates regarding by-products, carbon losses, and resulting CO_2 emissions from chemical processes were obtained from Neelis et al. (2006). Based on this source, process specific carbon emission factors were determined to account for losses, and the sum of non-fuel by-products of 36 chemical processes. With respect to by-products, the production of phenol, propylene oxide, caprolactam, adiponitrile, acrylonitrile, adipic acid, and ethylene oxide were identified as the most important chemical processes. The results of this research were incorporated in the detailed NEAT model, resulting in an improved model version, which accounts more accurately for carbon emissions .

Furthermore, the most important source of recovered fuels seems to be steam cracking, however the overall emissions from other chemical processes are not negligible (e.g., in Flanders about 2/3 of recovered fuel use in the chemical industry results from steam cracking, while 1/3 originates from other sources).

In the second part of this work package, IIÖ studied the consumption and fate of lubricants and solvents. For both product groups, questionnaires were developed, which where then sent to the project partners. The carbon storage fractions as chosen in the NIR for lubricants vary for individual countries, ranging between 0 for Netherlands and 1 for Austria and Italy. In many National GHG Inventories, still the very rough Marland and Rotty (1984) storage fractions of 50% are applied for lubricants. The carbon content values used for lubricants are quite similar for all countries studied, with values ranging from 18.5 t carbon/TJ for the USA and 21.3 t carbon/TJ for Germany. In general, detailed data beyond the National GHG Inventories on the actual fate of lubricants were scarcely available. We therefore highly recommend further research as emission estimates for lubricant use remain uncertain.

Regarding solvents, data were collected for 6 European countries. The use categories “Paint Application” and ”Others” are generally the most important source categories of emissions. The average emission factors were in the range from 30 % to 60 %, only France exceeds this range with 75 % due to very high emission factor in the dominating category “paint application”. Specific emissions due to solvent use are generally rather similar in the countries analyzed, with values around 10 kg of solvent/capita. This finding is in good consistency with reported GHG Inventory data.

2.2. WP 2: The NEAT Simplified Approach (NEAT-SIMP)

While the detailed NEAT model, as described by Neelis et al. (2005b), has several advantages, maybe its largest disadvantage is the large amount of data that is required to run it. Since this makes it practically impossible to apply the model for many developing countries, a simplified version of the detailed NEAT model (NEAT-SIMP) was developed. NEAT-SIMP enables the user to calculate total non-energy use and resulting emissions. In NEAT-SIMP, we calculate non-energy use as the sum of feedstock use and the production of refinery products used for non-energy purposes (i.e., lubricants and bitumen). We follow a *gross* definition of non-energy use, thereby

including the parts of hydrocarbon input, which are used for fuel purposes in industrial processes and steam crackers. We, however, exclude backflows from steam crackers to refineries from the non-energy use of fossil fuels. We furthermore distinguish industrial processes and product use as the two principal source categories for CO_2 emissions. Estimating *industrial process emissions* with the detailed NEAT model is relatively simple and requires only a limited amount of data. The spreadsheet model used in the detailed NEAT model for calculating industrial process emissions is therefore also applied in NEAT-SIMP. Contrary to the detailed NEAT model, we do not calculate emissions from the production of non-ferrous metals and ferroalloys based on production data of individual metals and alloys in NEAT-SIMP. In order to keep the data requirements low, we approximate instead the CO_2 emissions resulting from non-ferrous metals production solely on the basis of CO_2 emissions from aluminium production. Furthermore, in NEAT-SIMP we avoid the highly disaggregated and data-intensive NEAT analysis of product use emissions but instead we calculate CO_2 emissions with two independent methods, i.e., by applying a *top-down* approach and a *bottom-up* approach. We base the *top-down* approach on a comparison of product use emissions as stated in the National GHG inventories for the 33 Annex I countries and their respective per capita GDP in the period of 1990-2002. For calculating product use emissions with the *bottom-up* approach, we differentiate five principal sources, i.e., the consumption of pesticides, lubricants, solvents, surfactants, and waxes and paraffins. Emissions resulting from the consumption of solvents, surfactants, and waxes and paraffins are calculated based on population data and per capita emission estimates for individual product groups. Per capita emissions are derived from a detailed study of emissions from these sources in 15, mainly industrialized countries.

We applied NEAT-SIMP for the year 2000 to the 10 largest non-energy users, which are not included in Annex I under the UNFCCC (United Nations Framework Convention on Climate Change) and as cross-check to 3 selected Annex I countries, i.e., Germany, Italy, and the Netherlands. Among these countries, we identify China to be by far the largest consumer of fossil fuels for non-energy purposes (195 Mt CO_2

equivalents), followed by Korea (80 Mt CO_2) and India (56 Mt CO_2). Consequently, China is also the largest emitter of CO_2 from non-energy use among all countries studied (118 Mt CO_2) (Weiss et al, forthcoming, b). Our model results on total non-energy use deviate from official IEA (International Energy Association) data, mainly because the latter are inconsistent with regard to the system boundaries for non-energy use. Comparing NEAT-SIMP emission estimates with reference estimates for Annex I countries (i.e., Germany, Italy, and the Netherlands) reveals fairly good accordance but also shortcomings regarding completeness and accuracy of IPCC-SA (IPCC-Sectoral Approach) data in the respective GHG source categories. We therefore argue that applying NEAT-SIMP is suitable for obtaining first estimates on total non-energy use and related CO_2 emissions for developing and newly developed countries for which detailed estimates according to the IPCC guidelines are generally non-existent. The model has nevertheless its limitations regarding the accuracy of estimated product use emissions and for countries with unusual chemical feedstocks (e.g., as is the case for South Africa, where coal rather than oil-based hydrocarbons are used as feedstock in the chemical industry). Based on these findings, we conclude that, in spite of remaining uncertainties, NEAT-SIMP is a valuable, useful, and easily applicable tool to assess non-energy use and related CO_2 emissions for any country in the world.

2.3. WP 3: Methods for Macro-validation and Verification of Emissions Trading

As one of the most important policy measures for greenhouse gas emissions reduction, emissions trading was established within the EU and officially introduced by January 2005. In this work package we focus on two principal points, namely (i) the methods implemented by EU member states to validate and verify the *total* CO_2 emissions included in the emissions trading scheme (ETS) and (ii) the extent, to which emissions from the non-energy use of fossil fuels (e.g., resulting from steam crackers, ammonia plants) are covered by the ETS in the various EU member states. To gain a more detailed insight, we developed a questionnaire, which was sent to

organizations and individuals dealing with emissions trading in the EU. In parallel we also assessed the outcome of a questionnaire, sent by the EU Commission (DG Environment) to individual member states on the same issue. The result of our survey revealed that macro-validation mechanisms for emissions trading are or will be introduced by practically all EU member states. All countries plan to perform or already perform macro validation for the *total* CO_2 emissions included in the ETS, i.e., by comparing data from the ETS with the GHG inventory. Currently, Austria, Finland and Ireland perform such a crosscheck but provide little information on the actual procedure applied. Our questionnaire further revealed that in some countries (e.g., Germany) the chemical industry is excluded from the ETS, while in others it is included (e.g., the Netherlands). The Commission therefore regards the current situation as "highly unsatisfactory", especially because "a consistent interpretation and coverage of combustion installations across Member States in the second trading period is vital in order to avoid significant distortions of competition throughout the Internal Market" (EU, 2005). In this respect it seems to be of vital importance that the EU Commission outlines specifically, which industrial plants have to be included under the ETS because a clear distinction between combustion and process installation is not always straightforward due to legislation on the level of individual EU member states.

Furthermore, the EU questionnaire reveals some insight into the practices of data validation of emissions reported under the ETS. To ensure EU wide accuracy of emissions reporting under the ETS, guidance on the validation processes seems advisable. Major difficulties for crosschecking data from ETS and GHG inventories seem to be related to inter-institutional data sharing, which is in many cases complicated by confidential ETS data. Often system boundaries of ETS and GHG inventories are not consistent, which impedes direct data comparison. It might therefore be useful in the future to separately list also non-ETS emissions under the ETS (e.g., emissions resulting from fossil fuel use in installations <20 MW) in order to acquire complete overview of sector specific CO_2 emissions. Additional work also needs to be done in many EU member states linking and harmonizing data as

collected for national energy balances, emissions trading, and GHG inventories. This will ultimately allow more consistent and reliable estimation of CO_2 emissions in the European Union.

2.4. WP 4: Contribution to the harmonization of Data on Non-energy Use in Energy Balances

It is increasingly recognized that the definitions for non-energy use in national energy balances are incomparable. By the very nature of an energy balance this also implies inconsistencies or even errors for other sectors covered by the energy balance. While appreciation of this point by countries is growing, it continues to be very difficult to encourage them to address the underlying data collection issues, which would allow them to avoid omission or miss-classification of fuel use, provide more detail of non energy use, and follow more strictly the requirements on system boundaries as specified by IEA, EUROSTAT and UNECE (United Nations Economic Commission for Europe) in their joint energy balance questionnaire. In addition to alerting countries to the inconsistent definitions of non-energy use and the sizes of the fuel flows involved the network has made proposals for definition changes, which would permit consistent reporting although, with the generally weak data collection in this area, the proposals will not lead to the detailed statistics desired by analysts. Some countries are making an effort to improve their energy balance (e.g., the Netherlands) and/or their CO_2 emission inventory (e.g., Germany). These countries are aware of the importance of international harmonisation of system boundaries of non-energy use data. Possibly a higher economic valuation of CO_2 emissions will, in future, ultimately lead to the necessary incentives for internationally harmonized changes in this area and for a more important role of international organisations (e.g., the IEA) in this matter.

2.5 WP 5: Contribution to the second revision of the IPCC Guidelines

The NEU-CO_2 network contributed significantly to the revision of the new IPCC guidelines for GHG inventories in respect of the methodologies for calculating emissions from non-energy use. The revised Guidelines are published by the end of October 2006. For example, the NEAT model has provided material flow analyses and key process identifications, which form the bases of estimation methodologies in the revised Guidelines where none existed before. Equally, papers by network members have clarified and classified the different uses of fossil fuels for non-energy purposes and the classifications have been adopted within the revised Guidelines. This has been a valuable conceptual step. The NEU-CO_2 network has had important influence also in other respects, for example with regard to the completeness check of emission estimates. The new IPCC Guidelines are a compromise between detailed and accurate accounting on the one hand and limitations with regard to data availability and acceptable complexity on the other. It remains to be seen whether indeed a good compromise was found for the wide variety of countries preparing GHG inventories. In the first few years, some of the currently existing problems related to GHG emissions from non-energy use are unlikely to be resolved by applying the new guidelines. Remaining uncertainties regarding emission estimates for the non-energy use of fossil fuels will hence also depend on whether - as hoped - GHG inventory makers will take a critical, forward-thinking standpoint, thereby pointing out remaining problems and finding solutions to them. If followed, this would, inter alia, lead to the quest for improved and more complete production and consumption data for certain non-energy products and it would also support the striving for internationally harmonized energy balances.

2.6 WP 6: Organization of two Workshops

In the course of the third phase of the NEU-CO_2 network, we organized two workshops, the first in Amsterdam (June, 2005) and the second in Utrecht (February, 2006). The workshop proceedings are posted on the Internet (URL: http://www.chem.uu.nl/nws/www/nenergy/). While the focus during the first

workshop was mainly on questions related to NEAT model applications and the work package 1 and 4, we extensively discussed in the second workshop the NEAT-SIMP approach and the associated data collected by network participants as well as results regarding the work packages 3, 4, and 5.

2.7. WP 7: Dissemination of the Results

The homepage of the NEU-CO_2 network was constantly updated in the course of the third project phase (see, URL: http://www.chem.uu.nl/nws/www/nenergy/). All intermediate and final result of the network's activities can be found there. Apart from this, we plan to publish the most important results of our research activities in peer-reviewed journals. To date, we submitted one article on the revised IPCC 2006 Guidelines with special focus on the accounting of CO_2 emissions from the non-energy use of fossil fuels (corresponding author: Tim Simmons). For 2007 we plan to submit an article on the NEAT-SIMP and its application for selected non-Annex I countries (corresponding author: Martin Weiss).

3. Final Conclusions

Regarding research activities of the last two years during the third phase of the NEU-CO_2 network, we conclude that the project was very successful as our work not only contributed to an increasing awareness of inventory makers to the problems and uncertainties related to non-energy use and resulting CO_2 emissions but also to a deeper insight into specific problems related to the accounting of non-energy use in national energy balances and with the NEAT model approach. Key milestones achieved are the development and the application of a NEAT-Simplified Approach and our contributions the revision of the IPCC inventory guidelines. Further research is, however, necessary regarding non-specified by-products in the chemical industry and the fate and consumption of lubricants. Also further improvements of the energy balances are absolutely necessary. Given the higher degree of detail and – more generally – the higher ambition level regarding the estimation of CO_2 emissions from

non-energy use according to the new IPCC guidelines, these will hopefully create the required impetus to tackle and successfully resolve the remaining challenges on the way towards correct, transparent, and internationally comparable accounting of non-energy use and related emissions.

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