DANISH EMISSION INVENTORY FOR SOLVENT USE IN INDUSTRIES AND HOUSEHOLDS

NERI Technical Report no. 768 2010

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Abstract: This report presents the Danish emission inventory for Non-Methane Volatile Organic Compounds (NMVOC), N_2O and CO_2 from the use of solvents in industries and households. The methodology, data sources, activity data, emission factors and emissions are presented for 1985 to 2007 and uncertainties, QA/QC and coming refinements are stated. Solvent use constitutes approximately one third of the total NMVOC emissions in Denmark, i.e. 27.940 tonnes in 2007 and represents 87.100 tonnes CO_2 equivalents, which constitutes 0.2 % of the total Danish CO_2 emissions. NMVOC emissions may be of small concern in relation to CO_2 emissions but they are fundamental in relation to many human and environmental health issues and to long-range transport of chemical active species. Use and emission patterns of NMVOCs are diverse and complex, as many chemicals are categorised as NMVOCs and are present in many different industrial activities and consumer products. Emissions are calculated based on detailed information on chemical use, mainly derived from Statistics Denmark and the Nordic database: Substances in Preparations in the Nordic Countries (SPIN) and from communication with industries and related institutions in Europe responsible for their respective national inventories. Refinements have been implemented in the 2007 calculations based on results from a joint Nordic project where data and methodological principles were shared and a coupling of the many existing source codes were suggested.

Keywords:	Emission, solvent use, Non-Methane VOC, CO_2, N_2O, greenhouse gas, activity data, emission factors
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Preface

The Danish National Environmental Research Institute (NERI) at Aarhus University prepares the Danish atmospheric air emission inventories and reports the results on an annual basis to the *United Nations Framework Convention on Climate Change (UNFCCC)* and to the *UNECE Convention on Long-Range Transboundary Air Pollution*. This report forms part of the documentation for the inventories and covers emissions of Non-Methane Volatile Organic Compounds (NMVOC), Nitrous oxide (N_2O) and Carbon dioxide (CO_2) from solvent use in industries and households, corresponding to source category 3A-D in the Danish National Inventory Report. Emissions are presented for 1985 to 2007.

The report was reviewed by senior executive officer Nina Holmengen, Statistics Norway, who is part of a team responsible for the Norwegian emission inventory for solvent use.

Summary

This report presents the Danish emission inventory for Non-Methane Volatile Organic Compounds (NMVOC), Nitrous oxide (N_2O) and Carbon dioxide (CO_2) from the use of solvents in industries and households, corresponding to source categories 3A to 3D in the Danish National Inventory Report (Nielsen et al., 2009). The methodology, data sources, activity data, emission factors and emissions are presented for 1985 to 2007 and uncertainties, QA/QC and coming refinements are stated.

Until 2002 the Danish solvent emission inventory was based on questionnaires, which were sent to selected industries and sectors requiring information on solvent use. In 2003 it was decided to implement a methodology that is more complete, consistent and transparent with respect to including the total amount of used solvent, attributing emissions to industrial sectors and households and establishing a reliable model that is easily updated on a yearly basis. The detailed method described in the United Nations Framework Convention on Climate Change (UNFCCC) Emission Inventory Guidebook (EMEP/CORINAIR, 2004) where all relevant solvents must be estimated, or at least those that together represent more than 90 % of the total NMVOC emission, was employed. Each chemical (NMVOC) is estimated separately or as groups of similar chemicals, e.g. glycolethers. The sum of emissions of all estimated NMVOCs used as solvents equals the NMVOC emission from solvent use.

Candidates for solvents are found from the criteria in the solvent directive (Directive 1999/13/EC) of the EU legislation: "Volatile organic compound shall mean any organic compound having at 293,15 K (Kelvin) a vapour pressure of 0,01 kPa (kilo pascal) or more, or having a corresponding volatility under the particular condition of use". This results in 28 specific chemicals, of which five are chemicals groups, each comprising several chemicals. These constitute more than 95 % of the total NMVOC emission from solvent use.

Solvent use constitutes approximately one third of the total NMVOC emissions in Denmark, i.e. 27 940 tonnes in 2007 and represents 87 100 tonnes CO_2 equivalents, which constitutes 0.2 % of the total Danish CO_2 emissions. NMVOC emissions from solvent use have decreased by 57 % in the period 1985 to 2007. From solvent use ethanol, turpentine (white spirit: stoddard solvent and solvent naphtha) and propylalcohol have the highest emissions.

NMVOC emissions may be of small concern in relation to CO_2 emissions but they are fundamental in relation to many human and environmental health issues and to long-range transport of chemically active species. Use and emission patterns of NMVOCs are diverse and complex as many chemicals are categorised as NMVOCs and are present in many different industrial activities and consumer products. Emissions are calculated based on detailed information on chemical use amounts. This information mainly derives from Statistics Denmark

(StatBank DK, 2008) and the Nordic database: Substances in Preparations in the Nordic Countries (SPIN) as well as from activity data and emission factors obtained from communication with industries and related institutions in Europe responsible for their respective national inventories and also the international guidebooks (EMEP/CORINAIR 2004 and IPCC 2000).

N_2O emissions were included in the solvent emission inventory in 2005. N_2O use related to the solvent sector is mainly as anaesthetic and to a smaller extent in the manufacture of electronics and as propellant. There are one producer and five distributors in Denmark. The produced amount is confidential. A reliable estimate of the total N_2O emissions is 119 tonnes in 2007.

In December 2008 a joint Nordic project where data and methodological principles were shared was concluded. This resulted in a refinement of emission factors for NMVOCs in household use of solvents, which have been implemented in the reporting of the 2007 emissions. Another outcome of the project was a scheme for coupling the many source codes that are used in the various reporting formats, i.e. SNAP/CORINAIR, CRF/NFR, RAINS/GAINS, NACE (industrial use) and Use Category (UCN). This will lead to a more exact allocation of activity data and emission factors for single chemicals. The scheme is presented in this report and it is planned to be implemented in the reporting of the 2008 emissions.

Sammendrag

Denne rapport beskriver den danske emissionsopgørelse for nonmethan flygtige organiske forbindelser (NMVOC), N_2O og CO_2 fra anvendelse af opløsningsmidler i industrier og husholdninger, hvilket repræsenterer kildekategorierne 3A til 3D i den danske National Inventory Report (Nielsen et al., 2009). Metode, datakilder, aktivitetsdata, emissionsfaktorer og emissioner er vist for perioden 1985 til 2007. Endvidere er usikkerheder, QA/QC og kommende forbedringer beskrevet.

Indtil 2002 var den danske opgørelse baseret på spørgeskemaer, der blev sendt ud til udvalgte industrier og sektorer, med forespørgsel om forbrug af opløsningsmidler. I 2003 blev en ny metode taget i brug. Metoden er mere komplet, konsistent og transparent i forhold til inkludering af totale forbrugsmængder, antal kemikalier, emissionsfaktorer ved anvendelse af husholdningsprodukter og i industriprocesser samt med hensyn til detaljeringsgraden af modellen. Som udgangspunkt anvendes den detaljerede model som er beskrevet i UNFCCC Emission Inventory Guidebook (EMEP/CORIN-AIR, 2004). Her skal alle kemikalier inkluderes, eller i det mindste dem der udgør mindst 90 % af de totale NMVOC-emissioner fra anvendelse af opløsningsmidler. Hvert kemikalie opgøres separat eller som en gruppe af ensartede kemikalier, f.eks. glykolethere. Summen af emissioner af hver enkelt NMVOC er lig med de totale NMVOC-emissioner.

Kemikalier der indgår i opgørelsen, skal opfylde kriterierne beskrevet i EU-lovgivningens Solvent Directive (Directive 1999/13/EC): En flygtig organisk forbindelse (VOC) er defineret som en organisk forbindelse med et damptryk på 0,01 kPa eller mere, målt ved 293,15 K eller ved specifikke anvendelsesforhold. Dette resulterer i 33 kemikalier, hvoraf fem er grupper der udgør mere end 95 % of de totale NMVOC-emissioner.

Anvendelse af opløsningsmidler bidrager til ca. en tredjedel af de totale NMVOC-emissioner i Danmark i 2007, dvs. 27.940 tons, og repræsenterer 87.100 tons CO_2-ækvivalenter, hvilket udgør 0.2 % af de totale danske CO_2-emissioner. NMVOC-emissioner fra anvendelse af opløsningsmidler er faldet med 57 % i perioden fra 1985 til 2007. Anvendelse af ethanol, terpentin og propylalkohol giver de største emissioner.

Anvendelse af NMVOC bidrager relativt lidt i relation til CO_2-emissioner, men i forbindelse med human sundhed og miljøspørgsmål som langtransport af persistente forbindelse er NMVOC-anvendelsen afgørende. Anvendelses- og emissionsmønstre er mangfoldige og komplekse, da NMVOC indgår i et utal af forbrugerprodukter og industriprocesser. Emissioner beregnes ud fra informationer om forbrugsmængder, hovedsagelig fra Danmarks Statistik (StatBank DK, 2008) og fra den nordiske database: Substances in Preparations in the Nordic Countries (SPIN). Aktivitetsdata og emissionsfaktorer er tillige fundet fra guidebogen (EMEP/CORINAIR 2004 og IPCC 2000) og fra kommunikation med industrier, brancheforeninger og relaterede institutioner i Europa.

N_2O-emissioner blev inkluderet i opgørelsen første gang i 2005. N_2O-anvendelse relateret til opløsningsmidler er primært til anaestesi og en mindre mængde anvendes i produktion af elektroniske komponenter og som drivgas. Der er en producent og fem distributører i Danmark. Den producerede mængde er fortrolig. Et pålideligt estimat for de totale N_2O-emissioner i Danmark i 2007 er 119 tons.

Et fælles nordisk projekt vedrørende udveksling og forbedring af data og metoder for emissionsopgørelsen for anvendelsen af opløsningsmidler blev afsluttet i december 2008. Et vigtigt resultat var forbedring af emissionsfaktorer for husholdningssektoren. Disse forbedringer er inkluderet i rapporteringen af 2007-emissionerne. Et andet væsentligt resultat var en kobling af de mange kodetyper, der bliver anvendt i de forskellige rapporteringer, dvs. SNAP/CORINAIR, CRF/NFR, RAINS-/GAINS, NACE (industrial use) og Use Category (UCN). En kodekobling vil give en mere eksakt allokering af aktivitetsdata og emissionsfaktorer for enkeltkemikalier og produkter. Kodekoblingen er præsenteret i denne rapport, og det er planen at implementere den i den kommende rapportering af 2008-emissionerne.

1 Introduction

Non-Methane Volatile Organic Compounds (NMVOC) emission inventories for solvent use are part of the Danish emission inventories, which are prepared and submitted by each member country to fulfil the national obligations to the United Nations Framework Convention on Climate Change (UNFCCC); the European Commission being party to the Climate Convention, the Kyoto Protocol, UNECE-Convention on Long-Range, Transboundary Air Pollution (CLRTAP). In the future, information on releases from diffusive sources (for example solvent use) shall be included in the reporting to UNECE-Aarhus Convention Protocol on Pollutant Release and Transfer Registers (PRTR). The NMVOC emission inventories from solvent use are included in the greenhouse gas (GHG) emission inventories, which are employed for fulfilling the National Emission Ceilings (NEC). The Danish National Environmental Research Institute (NERI), Aarhus University is responsible for preparing the inventories, which at present include the following pollutants relevant to solvent use: NMVOC, CO_2 and N_2O. Every five years the reporting includes a projection of emissions data and details of the activity data on which the inventories are based.

This report presents the Danish methodology used for calculating NMVOC, N_2O and CO_2 emissions from use of solvents in industrial processes and households that are related to the UNFCCC Common Reporting Format (CRF)-categories Paint application (CRF sector 3A), Degreasing and dry cleaning (CRF sector 3B), Chemical products, manufacture and processing (CRF sector 3C) and Other (CRF sector 3D).

Solvents are chemical compounds that are used on a global scale in industrial processes and as constituents in final products to dissolve e.g. paint, cosmetics, adhesives, ink, rubber, plastic, pesticides, aerosols or are used for cleaning purposes, i.e. degreasing. NMVOCs are main components in solvents - and solvent use in industries and households is typically the dominant source of anthropogenic NMVOC emissions (UNFCCC, 2008; Pärt, 2005; Karjalainen, 2005). In industrial processes where solvents are produced or used NMVOC emissions to air and as liquid can be recaptured and either used or destroyed. Solvent containing products are used indoor and outdoor and the majority of solvent sooner or later evaporate. A small fraction of the solvent ends up in waste or as emissions to water and may finally also contribute to air pollution by evaporation from these compartments.

Although NMVOCs are not considered direct greenhouse gases, their role as precursors in tropospheric ozone formation, which is a greenhouse gas, further justifies their inclusion in a greenhouse gas inventory. Furthermore, once emitted to the atmosphere NMVOCs react with reactive molecules, such as HO-radicals or UV-light, eventually resulting in the formation of CO_2 (e.g. Pedersen, 1992). Although the CO_2 contribution is relatively small compared to emissions from combustion of fossil fuels, waste and traffic, solvents are included in the national GHG emission inventories and are estimated to ensure the fulfilment of

NMVOC emissions ceilings (Directive 2001/81/EC). In relation to toxicity some NMVOCs may be harmful towards humans and/or the environment. In addition to high-volume NMVOCs, i.e. chemicals used in amounts over 1000 tonnes pr. year, also high frequency low dose exposure of low volume NMVOCs, as part of daily activities and use of consumer products, may show to be critical.

Emission inventories for solvents are based on model estimates, as direct and continuous emissions are only measured from a limited number of pollutants and sources, e.g. SO_2 and NOx from central power plants. For each source emission estimates are based on relationships between activity data and emission factors (emissions pr unit activity), often assuming a linear model by multiplying activity data with appropriate emission factors. Activity data are derived from various sources, e.g. StatBank DK (2008) or industrial sectors, and emission factors are either based on guideline default values, international recommendations or on knowledge from industrial processes and technologies in the various sectors. The method that is presented here allows for use of CO_2 conversion factors for specific chemicals, thus enabling a more exact calculation of the national CO_2 emissions.

2 Method and Data

Until 2002 the Danish solvent emission inventory was based on questionnaires, which were sent to selected industries and sectors requiring information on solvent use. In 2003 it was decided to implement a method that is more complete, accurate and transparent with respect to including the total amount of used solvent, attributing emissions to industrial sectors and households and establishing a reliable model that is readily updated on a yearly basis.

Emission modelling of solvents can basically be done in two ways: 1) By estimating the amount of (pure) solvents consumed, or 2) By estimating the amount of solvent containing products consumed, taking account of their solvent content (EMEP/CORINAIR, 2004).

In 1) all relevant solvents must be estimated, or at least those together representing more than 90 % of the total NMVOC emission, and in 2) all relevant source categories must be inventoried or at least those together contributing more than 90 % of the total NMVOC emission. A simple approach is to use a pr capita emission for each category, whereas a detailed approach is to get all relevant consumption data (EMEP/CORINAIR, 2004).

The detailed method 1) is used in the Danish emission inventory for solvent use, thus representing a chemicals approach, where each chemical (NMVOC) is estimated separately. The sum of emissions of all estimated NMVOCs used as solvents equals the NMVOC emission from solvent use. See Figure 1 for methodological overview.

2.1 Chemical list

Some of the chemical compounds that are stated for reporting to the Climate and CLRTAP Conventions are not relevant for use of solvents. NMVOC is the most important chemical group especially in relation to the CLRTAP. There is also some use of N_2O and due to the high greenhouse warming potential (GWP) of N_2O, yielding a CO_2-equivalent of 1 g N_2O = 310 g CO_2 (IPCC 2000), N_2O is important in relation to the Climate Convention. Only NMVOC, N_2O and CO_2 are considered in the present reporting to the Climate Convention, CLRTAP and the NEC Directive. However, minor emissions may apply to use of other chemicals and e.g. mercury, PAHs, dioxins and PCBs will be assessed in coming inventories.

The definitions of solvents and VOC that are used in the Danish inventory (Nielsen et al., 2009) are as defined in the solvent directive (Directive 1999/13/EC) of the EU legislation: "Organic solvent shall mean any VOC which is used alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials, or is used as a cleaning agent to dissolve contaminants, or as a dissolver, or as a dispersion medium, or as a viscosity adjuster, or as a surface tension adjuster, or a plasticiser, or as a

preservative". VOCs are defined as follows: "Volatile organic compound shall mean any organic compound having at 293,15 K a vapour pressure of 0,01 kPa or more, or having a corresponding volatility under the particular condition of use".

This implies that some chemicals, e.g. ethylenglycol, that have vapour pressures just around 0.01 kPa at 20 °C, may only be defined as VOCs at use conditions with higher temperature. However, use conditions under elevated temperature are typically found in industrial processes. Here the capture of solvent fumes is often efficient, thus resulting in small emissions (communication with industries).

The Danish list of chemicals comprises 33 chemicals or chemical groups representing more than 95 % of the total NMVOC emission from solvent use of the known NMVOCs, cf. Table 6. CO_2 conversion factors, where all C-molecules in a NMVOC molecule are converted to CO_2, are also listed in Table 6.

2.2 Activity data

For each chemical a mass balance is formulated:

$$\text{Consumption} = (\text{production} + \text{import}) - (\text{export} + \text{destruction/disposal} + \text{hold-up}) \quad \text{(Eq. 1)}$$

Data concerning production, import and export amounts of solvents and solvent containing products are collected from StatBank DK (2008) which contains detailed statistical information on the Danish society. Manufacturing and trading industries are committed to reporting production and trade figures to the Danish Customs & Tax Authorities in accordance with the Combined Nomenclature. Import and export figures are available on a monthly basis from 1995 to present and contain trade information from 272 countries world-wide. Production figures are reported quarterly as "industrial commodity statistics by commodity group and unit" from 1995 to present.

Destruction and disposal of solvents lower the NMVOC emissions. In principle this amount must be estimated for each NMVOC in all industrial activity and for all uses of NMVOC containing products. At present the solvent inventory only considers destruction and disposal for a limited number of NMVOCs. For some NMVOCs it is inherent in the emission factor, and for others the reduction is specifically calculated from information obtained from the industry or literature.

Hold-up is the difference in the amount in stock in the beginning and at the end of the year of the inventory. No information on solvents in stock has been obtained from industries. Furthermore, the inventory spans over several years so there will be an offset in the use and production, import and export balance over time.

In some industries the solvents are consumed in the process, e.g. in the graphics and plastic industry, whereas in the production of paints and lacquers the solvents are still present in the final product. These products can either be exported or used in the country. In order not to double count consumption amounts of NMVOCs it is important to keep

track of total solvent use, solvents not used in products and use of solvent containing products. Furthermore some chemicals may be represented as individual chemicals and also in chemical groups, e.g. "o-xylene", "mixture of xylenes" and "xylene". Some chemicals are better inventoried as a group of NMVOCs rather than individual NMVOCs, due to missing information on use or emission for the individual NMVOCs. The Danish inventory considers single NMVOCs, with a few exceptions.

Activity data for chemicals are thus primarily calculated from Equation 1 with input from StatBank DK (2008). When StatBank (2008) holds no information on production, import and export or when more reliable information is available from industries, scientific reports or expert judgements the data can be adjusted or even replaced.

2.3 Emission factors

For each chemical the emission is calculated by multiplying the consumption with the fraction emitted (emission factor), according to:

Emission = consumption * emission factor

The present Danish method uses emission factors that represent specific industrial activities, such as processing of polystyrene, dry cleaning etc. or that represent use categories, such as paints and detergents. Some chemicals have been assigned emission factors according to their water solubility. Higher hydrophobicity yields higher emission factors, since a lower amount ends in waste water, e.g. ethanol (hydrophilic) and turpentine (hydrophobic).

Emission factors are categorised in four groups in ascending order: (1) Lowest emission factors in the chemical industry, e.g. lacquer and paint manufacturing, due to emission reducing abatement techniques and destruction of solvent containing waste, (2) Other industrial processes, e.g. graphic industry, have higher emission factors, (3) Non-industrial use, e.g. auto repair and construction, have even higher emission factors, (4) Diffuse use of solvent containing products, e.g. painting, where practically all the NMVOC present in the products will be released during or after use.

For a given chemical the consumed amount can thus be attributed with two or more emission factors; one emission factor representing the emissions occurring at a production or processing plant and one emission factor representing the emissions during use of a solvent containing product. If the chemical is used in more processes and/or is present in several products more emission factors are assigned to the respective chemical amounts.

Emission factors can be defined from surveys of specific industrial activities or as aggregated factors from industrial branches or sectors. Furthermore, emission factors may be characteristic for the use pattern of certain products. The emission factors used in the Danish inventory also rely on the work done in the joint Nordic project (Fauser et al.

2009). Emission factors for the NMVOC chemicals distributed in SNAP and UCN categories for household use are shown in Table 2.

2.4 Source allocation

The Danish Working Environment Authority (WEA) is administrating the registrations of chemicals and products to the Danish product register. All manufacturers and importers of products for occupational and commercial use are obliged to register. The following products are comprised in the registration agreement:

- Chemicals and materials that are classified as dangerous according to the regulations set up by the Danish Environmental Protection Agency (EPA).
- Chemicals and materials that are listed with a limit value on the WEA "limit value list".
- Materials, containing 1 % or more of a chemical, which is listed on the WEA "limit value list".
- Materials, containing 1 % or more of a chemical, which are classified as hazardous to humans or the environment according to the EPA rules on classification.

There are the following important exceptions for products, which does not need to be registered:

- Products exclusively for private use.
- Pharmaceuticals ready for use.
- Cosmetic products.

The Danish product register does therefore not comprise a complete account of used chemicals. Source allocations of exceptions from the duty of declaration are done based on information from trade organisations, industries, scientific reports and information from the internet.

Registrations in the Danish product register are also entered in the database for Substances in Preparations in Nordic Countries (SPIN), which comprises information on chemical consumption in industrial categories and product use categories defined according to the Standard nomenclature for economic activities (NACE) system and Use Categories Nordic (UCN). SPIN is the main information source for allocating use amount of chemicals in the solvent sector. SPIN is bypassed when information is missing, e.g. due to confidentiality, or when expert judgement favours information from, e.g. contact with industries or scientific reports. This is the case for e.g. naphthalene where there are few producers and processing industries and for propane and butane used as propellant, where trade organisations hold reliable information that deviates from SPIN.

2.4.1 Code systems

Sometimes information is available in other coding formats, which are not directly comparable to SNAP, NACE or UCN. This can be the case, e.g., when information is exchanged between countries. To overcome this hurdle in collecting and comparing data and to handle the discrep-

ancies in coding systems the joint Nordic project "Improvement of Nordic Emission Models for Solvent Use" (Fauser et al., 2009) was performed in 2008. Here all the major codes associated with emission reporting and registration of chemical chemicals that are used and processed as solvents in the Nordic countries were collected and compared.

No existing linking of all codes has previously been agreed upon in an international context. In Table 1a-d a list linking SNAP/CO-RINAIR, CRF, NFR, RAINS/GAINS, NACE industrial use and UCN is suggested for the solvent use sector. The table has been agreed by the experts responsible for performing the emission inventories for solvent use in the five Nordic countries. The list is used to facilitate allocating use amounts of chemicals to activities in SNAP codes, which represent the IPCC reporting format. In the abbreviation paragraph the codes are described in more detail.

It is designed for an ideal situation, assuming that all codes are used and that there are no country specific limitations in data availability. The id is a running number, comprising all possible combinations of codes. The colouring of tables is for transparency to distinguish SNAP/CORINAIR categories 0601 to 0604.

Table 1a General linking of codes, SNAP 0601xx from Fauser et al. (2009).

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
1	**060101**	Manufacture of automobiles	3A	Industrial use of paints: Automobile production	**AUTO_P**	34	B2010, F25, I1010, M0500, M05000, M0505, M0515, M0520, M0530, M0560, M0570, M0599, M10, O1500, R2000, R20200, R2090	Paints and varnishes
2	**060102**	Car repairing	3A	Industrial use of paints: Vehicle refinishing	**VEHR_P**	50	B2010, F25, I1010, M0500, M05000, M0505, M0515, M0520, M0530, M0560, M0570, M0599, M10, O1500, R2000, R20200, R2090	Paints and varnishes
3	**060103**	Construction and buildings (except 060107)	3A	Non-industrial Use of paints: Architectural use of paints; Decorative paints	**DECO_P/ARCH_P**	45, 51	B2010, F25, G30, M0500, M05000, M0505, M0515, M0520, M0530, M0550, M0560, M0567, M0595, M0599, M10, O1500	Paints and varnishes
5	**060104**	Household use (except 060107)	3A	Non-industrial Use of paints: Household use of paints; Decorative paints	**DECO_P/DOM_P**	52, 95	B2010, F25, G30, M0500, M05000, M0505, M0515, M0520, M0530, M0550, M0560, M0567, M0595, M0599, M10, O1500	Paints and varnishes
6	**060104**	Household use (except 060107)	3A	Non-industrial Use of paints: Household use of paints; Decorative paints	**DECO_P/DOM_P**	Household use	D15	Paints and varnishes
7	**060105**	Coil coating	3A	Industrial use of paints: Other industrial use of paints; Coil coating (coating of aluminum and steel)	**COIL**	27	B2010, F25, G05, I1010, M0500, M05000, M0505, M0515, M0520, M0530, M0560, M0570, M0599, M10, O1500, R2000, R20200, R2090	Paints and varnishes
8	**060106**	Boat building	3A	Industrial use of paints: Other industrial use of paints		35.1	B2010, F25, I1010, M0500, M05000, M0505, M0510, M0515, M0520, M0530, M0540, M0550, M0560, M0570, M0590, M0599, M10, O1500, R2000, R20200, R2090	Paints and varnishes
9	**060107**	Wood	3A	Industrial use of paints: Other industrial use of paints; Wood coating	**WOOD_P**	20, 36.1	B2010, F25, G30, M0500, M05000, M0505, M0510, M0515, M0520, M0530, M0540, M0550, M0560, M0567, M0595, M0599, M10, O1500	Paints and varnishes
11	**060108**	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; General industry	**IND_P_OT**	All other combinations of NACE industrial use and use category codes, defined as SNAP 0601xx (paint), than stated for SNAP 060101 to 060107 and 060109	Use category codes defined as SNAP 0601xx (paint): B2010, B45, D15, F25, G05, G15, G30, I1010, M05, M10, O1500, R2000, R20200, R2090	Paints and varnishes
18	060108	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; General industry (continuous processes)	**IND_P_CNT**			Paints and varnishes
19	060108	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; Protective coating	**IND_P_PRC**			Paints and varnishes
20	060108	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; General industry (plastic parts)	**IND_P_PL**			Paints and varnishes
21	060108	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; Leather coating	**LEATHER**			Paints and varnishes
22	060108	Other industrial paint application	3A	Industrial use of paints: Other industrial use of paints; Winding wire coating	**WIRE**			Paints and varnishes
23	**060109**	Other non industrial paint application	3A			40-44, 46-49, 53-99	B2010, F25, G30, I1010, M0500, M05000, M0505, M0510, M0515, M0520, M0530, M0540, M0550, M0560, M0570, M0599, M10, O1500, R2000, R20200, R2090	Paints and varnishes

Table 1b General linking of codes *continued*, SNAP 0602xx.

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
26	060201	Metal degreasing	3B	Surface cleaning: Degreasing	DEGR	27, 28, 29.1, 29.2, 29.3, 29.4, 29.5, 29.6, 29.72, 37.1	R1010	Degreasers
27	060202	Dry cleaning	3B	Surface cleaning: Dry cleaning	DRY	93.1		Products that are likely to be used in dry cleaners used in NACE 93.01 (dry cleaners)
28	060203	Electronic components manufacturing	3B			29.70, 29.71, 30, 31.60, 31.62, 32	E07, R1010, R1020, R1095, R30400	Cleaning products except degreasers
29	060204	Other industrial cleaning	3B			All other combinations of NACE industrial use and use category codes, defined as SNAP 0602xx (degreasing and dry cleaning), than stated for SNAP 060201 to 060202 and 060203	Use category codes defined as SNAP 0602xx (degreasing and dry cleaning): E07, R1010, R1029, R1033, R30400	Cleaning products

Table 1c General linking of codes *continued*, SNAP 0603xx.

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
33	060301	Polyester processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals)	PNIS	24.16, 25.2		Raw materials and other products likely to be used as raw materials
34	060302	Polyvinylchloride processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals); Polyvinylchloride produceduction by suspension process	PVC_PR	24.16, 25.2	B35, H1540, R30800	As above
35	060303	Polyurethane foam processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals)	PNIS	24.16, 25.2		As above
36	060304	Polystyrene foam processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals); Polystyrene processing	PLSTYR_PR	24.16, 25.2		As above
37	060305	Rubber processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals); Synthetic rubber production	SYNTH_RUB	24.17, 25.10, 25.13	B35, R30300	As above
38	060305	Rubber processing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals); Tyre production	TYRE	25.11, 25.12		As above
39	060306	Pharmaceutical products manufacturing	3C	Solvent use in chemical industry: Pharmaceutical industry	PHARMA	24.4	R30600	As above
40	060307	Paints manufacturing	3C	Solvent use in chemical industry: Products incorporating solvents	PIS	24.12, 24.30	B35, F0510, F05110, F0520, F05250, F05400, F05990, H1530, M08, T20	As above
41	060308	Inks manufacturing	3C	Solvent use in chemical industry: Products incorporating solvents	PIS	24.12, 24.30	F0500, F10300, F10400, H1545	As above
42	060309	Glues manufacturing	3C	Solvent use in chemical industry: Products incorporating solvents	PIS	24.62	B35, H1520	As above
43	060310	Asphalt blowing	3C	Solvent use in chemical industry: Products incorporating solvents	PIS	26.8	R30990	
44	060311	Adhesive, magnetic tapes, films & photographs manufacturing	3C	Solvent use in chemical industry: Products incorporating solvents	PIS	24.64, 24.65	B35, F1020, F32, F3500, F3510	As above
45	060312	Textile finishing	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals)	PNIS	17	B25, I0530, R30990	As above

46	**060313**	Leather tanning	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals)	PNIS	18.1, 19.1, 19.2	G10, I0510	As above
47	**060314**	Other	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals); Manufacturing of shoes	**SHOE**	51		As above
48	**060314**	Other	3C	Solvent use in chemical industry: Products not incorporating solvents (excluding pharmaceuticals)	PNIS	All other combinations of NACE industrial use and use category codes, defined as SNAP 0603xx (chemical products), than stated for SNAP 060301 to 060313	Use category codes defined as SNAP 0603xx (chemical products): 1138, A10, A20, A25, A30, B25, B35, B40, B65, D05, E10, E15, E20, F05, F10, F32, F3500, F3510, F45, F50, G10, G12, G35, H15, I0510, I0530, K05, K15, K20, K25, L05, M08, O15000, O2510, O2520, O25200, O2530, O2540, O2550, O27, O40, P05, P15, R03, R05, R1005, R30000, R30100, R30200, R30300, R30500, R30600, R30700, R30800, R30900, R30990, S15, S42, S60, S8000, T20, V05, V10, V15, V20	As above

Table 1d General linking of codes *continued*, SNAP 0604xx.

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
49	060401	Glass wool enduction	3D	Other use of solvents in industry: Other industrial use of solvents	IND_OS	26.14, 26.8, 45.32	I1500, I1520, U0500	All products except adhesives, paints, varnishes and cleaning products
50	060402	Mineral wool enduction	3D	Other use of solvents in industry: Other industrial use of solvents	IND_OS	26.8, 45.32	I1500, I1520, U0500	As above
55	060403	Printing industry	3D	Printing industry; Heatset-Offset	PRINT_OFFS (PRT_OFFS)	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
56	060403	Printing industry	3D	Printing industry; Rotogravure in publication	PRINT_PUB (PRT_PUB)	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
57	060403	Printing industry	3D	Printing industry; Flexography in packaging	PRINT_PACK_FX (PRT_PACK)	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
58	060403	Printing industry	3D	Printing industry; Rotogravure in packaging	PRINT_PACK_RT (PRT_PACK)	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
59	060403	Printing industry	3D	Printing industry; Screen printing	PRINT_SCR (PRT_SCR)	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
60	060403	Printing industry	3D	Printing industry; Sheetfed-Offset	PRINT_SHEET	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above
61	060403	Printing industry	3D	Printing industry; Coldset	PRINT_COLD	22.1, 22.2	F30, F35200, F35300, F3540, R1020, R1095, S0720, S1010, S1060, T1000, T1090, T1500, T1530, T1540, T1550, T1570, T1580, T1590, S07, S10, T10, T15,	As above

Table 1d General linking of codes *continued*, SNAP 0604xx.

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
62	060404	Fat, edible and not edible oil extraction	3D	Other use of solvents in industry: Other industrial use of solvents	FATOIL	15.4	E05	Extraction agents
63	060405	Application of glues and adhesives	3D	Other use of solvents in industry: Application of glues and adhesives(use of high performance solvent based adhesives)	GLUE_INH	17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36	B20000, B2020, B2030, L10	Adhesives
64	060405	Application of glues and adhesives	3D	Other use of solvents in industry: Application of glues and adhesives (use of traditional solvent based adhesives)	GLUE_INT	17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36		Adhesives
65	060405	Application of glues and adhesives	3D	Other use of solvents in industry: Application of glues and adhesives (tape manufacturing)	ADH_TAPE	no NACE code for tape manufacturing		Adhesives
66	060405	Application of glues and adhesives	3D	Other use of solvents in industry: Application of glues and adhesives (other industrial use of adhesives, e.g., wood products)	ADH_OT_IND	17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36		Adhesives
67	060406	Preservation of wood	3D	Other use of solvents in industry: Preservation of wood (excluding creosote)	WOOD	20	B1543, I0540	Biocides, impregnation, raw materials and viscosity changers
68	060406	Preservation of wood	3D	Other use of solvents in industry: Preservation of wood (only creosote)	WOOD_CR	20		Biocides, impregnation, raw materials and viscosity changers
69	060407	Underseal treatment and conservation of vehicles	3D	Treatment of Vehicles	VEHTR	50.2, 50.4	M1550, R2010	Degreasers, rust inhibitors

Table 1d General linking of codes *continued*, SNAP 0604xx.

	SNAP/ CORINAIR		CRF/NFR	RAINS/GAINS		NACE (Industrial use)	Use Category (UCN)	
id	SNAP Code	Name of activity		Sector description	RAINS Code	NACE Code	UCN Code	Use category description
70	060408	Household solvent use (other than paint application)	3D	Household solvent use (excluding paints)	DOM_OS	DOM		All products except pharmaceuticals, paints and varnishes
71	060408	Household solvent use (other than paint application)	3D	Household solvent use (excluding paints)	DOM_OS	50.5	B60	All products except degreasers, rust inhibitors, pharmaceuticals, paints and varnishes
72	060408	Household solvent use (other than paint application)	3D	Household solvent use (excluding paints)	DOM_OS	52, 95	A0530, A40, B15000, B1530, B1541, B18100, B20000, B2020, B2030, B50, D2000, F30, H05, H20, I0500, I0550, I1500, I1520, K3010, K3025, K3030, K3500, K35000, K3510, K3590, K52, L10, M1540, O2500, O25000, P10, R1000, R10000, R10130, R1015, R1016, R1018, R1025, R1035, R1037, R1040, R1045, R1050, R1060, R1070, R1080, R1097, R10980, R1099, R10990, R2010, S0500, S0510, S25, U05000, U0510, U0520, U0530, U05340, U05350, U0540	All products except pharmaceuticals, paints and varnishes
75	060409	Vehicles dewaxing	3D	Treatment of Vehicles	VEHTR	50.1, 50.3	M1550, R2010	
76	060411	Household use of pharmaceutical products	3D	Household solvent use (excluding paints)	DOM_OS	52.3, 95	L20	Pharmaceuticals
78	060412	Other (preservation of seeds,....)	3D	Other use of solvents in industry: Other industrial use of solvents	IND_OS	All other combinations of NACE industrial use and use category codes, defined as SNAP 0604xx (other use), than stated for SNAP 060401 to 060411	Use category codes defined as SNAP 0604xx (other use): A05, A35, A40, A45, A50, A55, A60, B15, B16, B18, B2000, B2020, B2030, B30, B50, B55, B60, D20, D25, E03, E05, F12, F15, F20, F30, F35200, F35300, F3540, F40, G40, H05, H10, H20, I0500, I05200, I0540, I05450, I0550, I1020, I15, K30, K35, K40, K45, K52, K55, K60, L10, L15, L20, M15, O05, O10, O15100, O2500, O25000, O30, P01, P10, R1000, R10000, R10130, R1015, R1016, R1018, R1020, R1025, R10340, R1035, R1037, R1040, R1045, R1050, R1060, R1070, R1080, R1095, R1097, R10980, R1099, R10990, R15, R2010, S05, S07, S10, S25, S30, S35, S40, S45, S50, S65, S70, S75, S80100, T05, T10, T15, U05	All products except adhesives, paints, varnishes and cleaning products

Emissions of single chemicals must be attributed to industrial sectors and households. The SPIN database comprises information on chemical consumption in industrial categories and product use categories defined according to the NACE and UCN systems. The relative distribution on NACE and UCN categories are used to distribute the use amount retrieved, from primarily StatBank DK (2008), to SNAP codes, according to Table 1.

The reason for not using SPIN directly in assigning use amounts is that the database is not corrected for double counting, e.g. when a chemical is produced in Denmark and sold to a processing industry. This implies that the summed amount for a chemical across all categories may be higher than the amount found from StatBank DK (2008) (personal communication with SPIN). For some chemicals industry specific information on used amount is assumed to be more reliable than figures from StatBank DK (2008) and SPIN and can therefore be used.

2.4.2 Household use

An important source of solvent use is household use of solvents and solvent containing products. Due to the high number of solvent containing products and great variety of use practices, there is a high variability of release patterns of solvents to the atmosphere. Household use is diffuse, i.e. the emissions are wide-spread and are not controlled by collection of solvent vapours and remains. Accordingly the assignment of emission factors to solvent use and use of solvent containing products has a high potential uncertainty.

Although there is no obligation to register products exclusively used for private (household) use in Denmark, household use can be considered by assessing the UCN categories. The linking of UCN categories and household use can be seen in Table 2 for the following SNAP categories, which are attributed to household use:

- SNAP 060104 (Paint Application: Household Use except 060107) (id=5 and 6).
- SNAP 060408 (Other: Household Use other than paints) (id=70 to 74).
- SNAP 060411 (Other: Household Use of Pharmaceutical Products) (id=76 and 77).

The id numbers refer to the unique row number in Table 1. In Table 2 these household SNAP and UCN categories are linked with the chemicals that are found to comprise >95 % of the emissions for the 2007 solvent emission inventory. For each chemical the emission factors are stated.

Table 2 Emission factors for chemicals that comprise >95 % of the emissions for Danish 2007 solvent emission inventory. Only SNAP categories for household use are listed and combined with UCN categories. Empty cells mean that chemical use is not registered in the corresponding UCN category. The linking of SNAP and UCN categories are found from Table 1.

		propane, butane	Iso-propylalcohol	ethanol	formaldehyde	turpentine	methanol	methyl methacrylate	naphthalene	xylene	acetone	phenol	toluene	acyclic aldehydes
The following use categories (UCN) have been allocated to SNAP 060104 (Paint Application: Household Use except 060107) (id=5 and 6)														
B2010	Binding agents for paints, adhesives etc.													
D15	Propellants (for aerosols)	0.98												
F25	Thinners (for paints, lacquers, adhesives)													
G30	Flooring materials (Floor paints)			0.95	0.95	0.95		0.01		0.95		0.95	0.95	
M05	Paint, lacquers and varnishes		0.95	0.95	0.95	0.95	0.8	0.01	0.95	0.95	0.95	0.95	0.95	0.95
M10	Paint, lacquer and varnishes removers		0.95	0.95			0.8			0.95	0.95		0.95	
O15	Solvents		0.95	0.95	0.95	0.95	0.8	0.01	0.95	0.95	0.95	0.95	0.95	
The following use categories (UCN) have been allocated to SNAP 060408 (Other: Household Use other than paints) (id=70 to 74)														
A0530	Air cleaners and anti-odour agents													
A40	Anti-freezing agents		0.95	0.98										
B15	Pesticides for non agricultural uses		0.95	0.45	0.2	0.9	0.8	0.01	0.25	0.6		0.25	0.9	0.25
B18100	Car care products													
B20	Binding agents		0.95	0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	
B50	Fire extinguishing agents													
B60	Fuel additives		0.95	0.45		0.9	0.8		0.25	0.6			0.9	
D20	Odour agents (not cosmetic products)		0.95	0.45										
F30	Thinners (for other materials than paints, lacquers, adhesives etc.)													
H05	Skin care products (see also Cosmetics)													
H20	Hair shampoo													
I05	Impregnation/ proofing		0.95	0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	
I15	Insulating materials			0.45	0.2		0.8			0.6			0.9	
K30	Conserving agents (additives)													
K35	Construction materials (building materials)			0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	
K52	Cosmetics		0.95	0.45	0.2									
L10	Adhesives		0.95	0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	
M1540	Rust removers													
O25	Surface-active agents (surfactants, detergents)		0.95	0.45	0.2	0.9	0.8			0.6	0.9		0.9	
P10	Polishing agents		0.95	0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	
R10	Cleaning/washing agents		0.95	0.45	0.2	0.9	0.8	0.01		0.6	0.9	0.25	0.9	0.25
R2010	Underseal materials, incl. cavity seals													
S05	Sanitation agents		0.95	0.45			0.8							
S25	Rinsing agents		0.95	0.45										
U05	Filling materials		0.95	0.45	0.2	0.9	0.8	0.01	0.25	0.6	0.9	0.25	0.9	
The following use categories (UCN) have been allocated to SNAP 060411 (Other: Household Use of Pharmaceutical Products) (id=76 and 77)														
L20	Pharmaceuticals													

Table 2 (continued).

		cyclo-hexanone	1-butanol	cyanates	butanoles	butanones	Triethyl-amine	tetrachloro-ethylene	ethylen-glycol	propylen-glycol	glycol-ethers	styrene	pentane	acrylic acid
The following use categories (UCN) have been allocated to SNAP 060104 (Paint Application: Household Use except 060107) (id=5 and 6)														
B2010	Binding agents for paints, adhesives etc.													
D15	Propellants (for aerosols)													
F25	Thinners (for paints, lacquers, adhesives)													
G30	Flooring materials (Floor paints)	0.95		0.95		0.95			0.05	0.95	0.95	0.95		
M05	Paint, lacquers and varnishes	0.95	0.95	0.95	0.95	0.95	0.95		0.05	0.95	0.95	0.95		0.5
M10	Paint, lacquer and varnishes removers									0.95	0.95			0.5
O15	Solvents	0.95	0.95		0.95	0.95		0.8	0.05	0.95	0.95	0.95		0.5
The following use categories (UCN) have been allocated to SNAP 060408 (Other: Household Use other than paints) (id=70 to 74)														
A0530	Air cleaners and anti-odour agents													
A40	Anti-freezing agents					0.8			0.05	0.25		0.03		
B15	Pesticides for non agricultural uses	0.75	0.25			0.8			0.05	0.25	0.6			0.01
B18100	Car care products													
B20	Binding agents	0.75	0.25	0.5	0.25	0.8	0.5		0.05	0.25	0.6	0.03		0.01
B50	Fire extinguishing agents								0.05		0.6			
B60	Fuel additives													
D20	Odour agents (not cosmetic products)									0.25	0.6			
F30	Thinners (for other materials than paints, lacquers, adhesives etc.)													
H05	Skin care products (see also Cosmetics)													
H20	Hair shampoo													
I05	Impregnation/ proofing		0.25		0.25	0.8			0.05	0.25	0.6	0.03		0.01
I15	Insulating materials			0.5					0.05	0.25	0.6	0.03	0.98	
K30	Conserving agents (additives)													
K35	Construction materials (building materials)	0.75	0.25	0.5		0.8			0.05	0.25	0.6	0.03		
K52	Cosmetics									0.25		0.03		
L10	Adhesives	0.75	0.25	0.5		0.8			0.05	0.25	0.6	0.03	0.98	0.01
M1540	Rust removers													
O25	Surface-active agents (surfactants, deter-gents)	0.75	0.25						0.05	0.25	0.6	0.03		0.01
P10	Polishing agents		0.25			0.8			0.05	0.25	0.6	0.03	0.98	0.01
R10	Cleaning/washing agents	0.75	0.25		0.25	0.8		0.8	0.05	0.25	0.6	0.03	0.98	0.01
R2010	Underseal materials, incl. cavity seals													
S05	Sanitation agents									0.25	0.6			
S25	Rinsing agents									0.25				
U05	Filling materials	0.75	0.25	0.5		0.8	0.5		0.05	0.25	0.6	0.03		0.01
The following use categories (UCN) have been allocated to SNAP 060411 (Other: Household Use of Pharmaceutical Products) (id=76 and 77)														
L20	Pharmaceuticals													

2.5 Summary of method

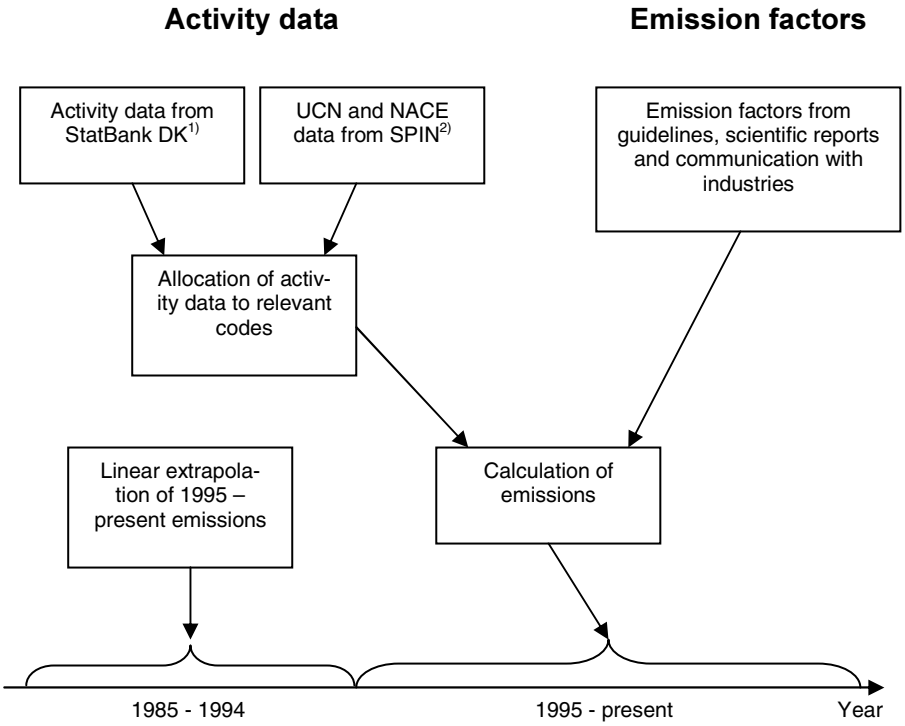

Figure 1 Outline of method for obtaining activity data and emission factors, allocating to source categories and calculating emissions.
1) Activity data from StatBank DK may be adjusted or replaced with activity data from reports and/or communication with e.g. industries.
2) UCN and NACE data from SPIN may be adjusted or replaced with data from reports and/or communication with e.g. industries.

3 Emission results

3.1 NMVOC

Table 3 and Figure 2 show the emissions of NMVOC from 1985 to 2007, where the used amounts of single chemicals have been assigned to specific products and CRF sectors. The link between CRF and SNAP categories can be seen in Table 1. The assignment of emission factors to chemicals in specific SNAP categories is shown in Table 2. The methodological approach for finding emissions in the period 1995-2007 is described in the previous section. A linear extrapolation is made for the period 1985–1994. A general decrease is seen throughout the sectors. Table 4 shows the used amounts of chemicals for the same period. Table 3 is derived from Table 4 by applying emission factors relevant to individual chemicals and production or use activities. Table 5 showing the used amount of products is derived from Table 4, by assessing the amount of chemicals that is comprised within products belonging to each of the four source categories. The CO_2 conversion factor for each chemical is shown in Table 6.

In Table 6 the emission for 2007 is split into individual chemicals. The most abundantly used NMVOC as solvent are ethanol, turpentine (white spirit defined as a mixture of stoddard solvent and solvent naphtha) and propylalcohol. Ethanol is used as solvent in the chemical industry and as windscreen washing agent. Turpentine is used as thinner for paints, lacquers and adhesives. Propylalcohol is used in cleaning agents in the manufacture of electrical equipment, flux agents for soldering, as solvent and thinner and as windscreen washing agent. Household emissions are dominated by propane and butane, which are used as aerosols in spray cans, primarily in cosmetics. As discussed previously higher emission factors are applicable for use of solvent containing products and lower emission factors are applicable for use in industrial processes.

Table 3 Emissions of NMVOC in Gg pr year.

Total emissions Gg pr year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Paint application (3A)	27.1	26.4	25.7	25.0	24.3	23.6	22.9	22.2	21.5	20.8	16.3	19.8
Degreasing and dry cleaning (3B)	11.2	11.0	10.7	10.4	10.1	9.87	9.60	9.33	9.06	8.78	6.96	8.77
Chemical products, manufacturing and processing (3C)	4.15	4.11	4.07	4.03	3.98	3.94	3.90	3.85	3.80	3.76	3.61	4.02
Other (3D)	23.4	22.7	22.1	21.4	20.8	20.1	19.5	18.9	18.2	17.6	18.3	17.0
Total NMVOC	65.9	64.2	62.5	60.9	59.2	57.6	55.9	54.2	52.6	50.9	45.2	49.5
Total CO_2 [a]	205	200	195	190	185	179	174	169	164	159	141	154

Continued	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Paint application (3A)	20.1	17.6	16.6	17.4	15.4	14.5	13.3	12.6	12.6	11.5	11.4
Degreasing and dry cleaning (3B)	7.78	7.00	7.77	7.42	6.20	6.70	6.33	5.60	5.25	4.78	4.84
Chemical products, manufacturing and processing (3C)	3.42	3.31	3.44	3.18	3.03	3.39	2.62	3.00	3.19	3.15	2.18
Other (3D)	13.5	13.3	12.9	12.6	11.5	12.3	11.0	10.6	10.8	10.2	9.52
Total NMVOC	44.7	41.2	40.7	40.6	36.1	36.9	33.3	31.8	31.9	29.5	27.9
Total CO_2 [a]	139	128	127	127	113	115	104	99.2	99.4	92.1	87.1

[a] 0.85*3.67*total NMVOC

Table 4 Used amounts of NMVOC as solvent in Gg pr year.

Used amounts of chemical Gg pr year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Paint application (3A)	38	40	41	43	45	47	48	50	51	52	52	56
Degreasing and dry cleaning (3B)	20	21	22	23	24	25	25	25	25	25	26	27
Chemical products, manufacturing and processing (3C)	61	64	66	69	71	76	78	81	84	86	95	93
Other (3D)	24	25	26	27	28	29	30	31	32	33	42	36
Total NMVOC	144	150	156	161	167	177	182	187	191	196	214	212

Continued	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Paint application (3A)	87	55	49	52	47	48	53	70	82	75	79
Degreasing and dry cleaning (3B)	26	23	26	26	24	25	24	26	26	28	36
Chemical products, manufacturing and processing (3C)	97	93	97	103	105	106	91	110	122	130	136
Other (3D)	38	33	33	35	36	35	35	44	46	52	51
Total NMVOC	248	203	204	216	211	213	203	250	277	284	302

Table 5 Used amounts of solvent containing products in Gg pr year.

Used amounts of products Gg pr year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Paint application (3A)	255	265	276	286	297	314	322	330	339	347	344	370
Degreasing and dry cleaning (3B)	40	42	44	45	47	50	50	50	50	50	52	53
Chemical products, manufacturing and processing (3C)	307	319	332	345	357	378	391	404	418	431	473	467
Other (3D)	119	124	129	134	139	147	152	156	160	165	211	182
Total products	722	751	781	811	841	888	914	941	967	993	1079	1072

Continued	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Paint application (3A)	579	364	324	345	315	317	351	469	544	499	529
Degreasing and dry cleaning (3B)	52	46	52	51	47	50	48	52	53	55	72
Chemical products, manufacturing and processing (3C)	487	463	484	513	523	529	455	549	612	651	678
Other (3D)	190	167	164	177	179	173	176	222	232	259	256
Total products	1308	1039	1024	1087	1064	1068	1030	1291	1441	1464	1534

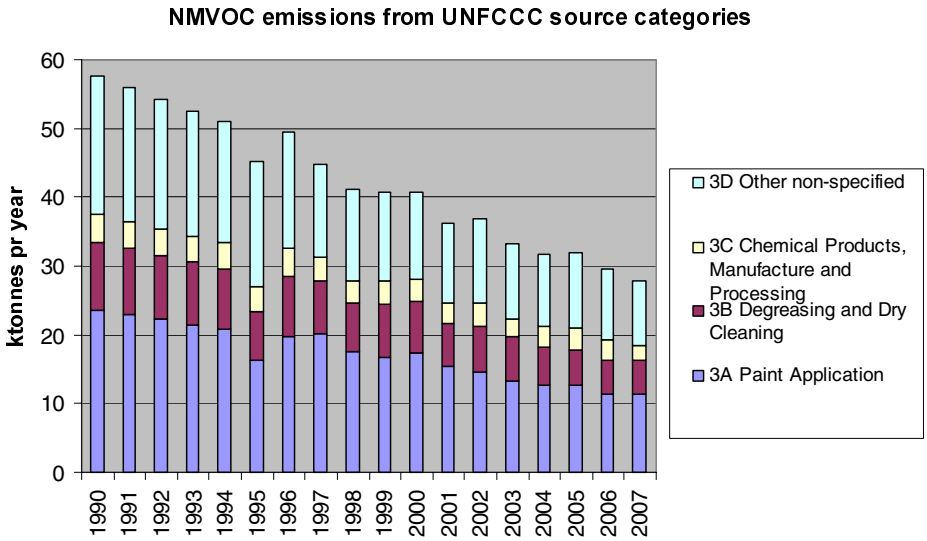

Figure 2 Emissions of NMVOC in ktonnes pr year (equal to Gg pr year). The methodological approach for finding emissions in the period 1995 – 2007 is described in the text, and a linear extrapolation is made for 1985 – 1994. Figures can be seen in Table 3.

Table 6 Chemicals with highest emissions 2007, and CO_2 conversion factors assuming that all carbon molecules in the NMVOC molecule are converted to $C0_2$.

Chemical	CAS no	Emissions 2007 (tonnes)	CO_2-conversion factor (g CO_2 pr g NMVOC)
ethanol	64-17-5	6311	1.91
turpentine (white spirit: stoddard solvent and solvent naphtha)	64742-88-7 8052-41-3	5186	2.79
propylalcohol	67-63-0	4537	2.20
pentane	109-66-0	2524	3.06
methanol	67-56-1	1499	1.38
acetone	67-64-1	1124	2.28
toluene	108-88-3	1118	3.35
xylene	1330-20-7 95-47-6 108-38-3 106-42-3	989	3.32
butanone	78-93-3	690	2.45
propane	74-98-6	667	2.86
butane	106-97-8	667	2.93
glycolethers	110-80-5 107-98-2 108-65-6 34590-94-8 112-34-5 and others	658	1.95
propylenglycol	57-55-6	565	1.74
formaldehyde	50-00-0	380	1.47
1-butanol	71-36-3	249	2.38
cyclohexanones	108-94-1	114	2.69
methyl methacrylate	80-62-6	105	2.20
phenol	108-95-2	98.0	2.81
butanoles	78-92-2 2517-43-3 and others	96.4	2.24
butylacetate	123-86-4	71.7	2.28
ethylenglycol	107-21-1	65.7	1.42
styrene	100-42-5	57.1	3.39
ethylacetate	141-78-6	49.4	2.00
tetrachloroethylene	127-18-4	41.9	0.531
acyclic aldehydes	78-84-2 111-30-8 and others	27.3	2.31
triethylamine	121-44-8	20.9	2.61
naphthalene	91-20-3	17.4	3.44
acyclic monoamines	75-31-0 and others	5.66	2.24
acrylic acid	79-10-7	4.55	1.83
Total 2007		27939	

3.2 Other use (N_2O)

Apart from NMVOC only N_2O is considered in this inventory. Five companies sell N_2O in Denmark and only one company produces N_2O. N_2O is primarily used in anaesthesia by dentists, veterinarians and in hospitals and in minor use as propellant in spray cans and in the production of electronics. Due to confidentiality no data on produced amount are available and thus the emissions related to N_2O production are unknown. An emission factor of 1 is assumed for all uses, which equals the sold amount to the emitted amount. Sold amounts are obtained from the respective companies and the produced amount is estimated from communication with the company.

Total sold and estimated produced N_2O for sale in Denmark, which equals the emissions, is:

2007: 0.12 Gg N_2O

4 Uncertainties, time-series consistency and QA/QC

4.1 QA/QC and verification

Table 7 External and internal data.

Description	AD or EF	Reference
Production, import and export data from Statistics Denmark (StatBank Denmark, 2008)	Activity data	Statistics Denmark (StatBank DK, 2008)
Calculations, emission factors, SPIN data. For industrial branches	Activity data and emission factors	Statistics Denmark (StatBank DK, 2008), SPIN, reports, personal communication
Calculations, emission factors, SPIN data. For CRF	Activity data and emission factors	Statistics Denmark (StatBank DK, 2008), SPIN, reports, personal communication
Emission factors for chemicals in SNAP codes and for household use for UCN codes. CO_2 conversion factors for chemicals	Emission factors and CO_2 conversion factors	Scientific reports and articles, personal communication

The QA/QC procedure is outlined in Nielsen et al. (2009). In general, Critical Control Points (CCP) has been defined as elements or actions, which need to be addressed in order to fulfil the quality objectives. The CCPs have to be based on clear measurable factors, expressed through a number of Points for Measuring (PM). The list of PMs is listed in Nielsen et al. (2009).

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every data set including the reasoning for the specific values

The sources of data described in the methodology section and in DS.1.2.1 and DS.1.3.1 are used in this inventory. It is the accuracy of these data that define the uncertainty of the inventory calculations. Any data value obtained from StatBank DK (2008) and SPIN are given as a single point estimate and no probability range or uncertainty is associated with this value. Information from reports is sometimes given in ranges. However, a Tier 2 (Monte Carlo) uncertainty assessment is currently being implemented in the Danish inventory, and a Tier 2 uncertainty estimate will be given for the solvent sector in the coming inventories. In the following list the current state of QA/QC and uncertainty assessment are stated.

Data Storage level 1	1. Accuracy	DS.1.1.2	Quantification of the uncertainty level of every single data value including the reasoning for the specific values.

No uncertainty levels are quantified for the external data.

Data Storage level 1	2. Comparability	DS.1.2.1	Comparability of the data values with similar data from other countries, which are comparable with Denmark and evaluation of the discrepancy.

1) Production and import/export data from StatBank DK (2008) for single chemicals can be directly compared with data from Eurostat (2008) for other countries. This has been done for a few chosen chemicals and countries. Furthermore, chosen Danish data from Eurostat (2008) have been validated with data from StatBank DK (2008) in order to check the consistency in data transfer from national to international databases.

2) Use categories for chemicals in products are found from the Nordic SPIN database. Data for all Nordic countries are available and reported uniformly. For chosen chemicals a comparison of chemical amounts and use has been made between countries.

3) A joint Nordic project funded by the Nordic Council of Ministers has been used on methodological issues and for emission factors.

Data Storage level 1	3.Completeness	DS.1.3.1	Documentation showing that all possible national data sources are included by setting up the reasoning for the selection of data sets

A number of external data sources form the basis for calculating emissions of single chemicals. The general methodology in the emission inventory is described above.

1) Statistics Denmark (StatBank DK 2008) is used as the main database for collecting data on production, import and export of single chemicals, chemical groups and for some products. In order to obtain a uniform and unique set of data it is important that the data for e.g. production of single chemicals is in the same reporting format and from the same source. The amount of data is very comprehensive and is linked with the data present in Eurostat. The database covers all sectors and is regarded as complete on a national level.

2) Nordic SPIN database provides data on the use of chemicals in Norway, Sweden, Denmark and Finland. It is financed by the Nordic Council of Ministers, Chemical group, and the data is supplied by the product registries of the contributing countries. The Danish product register (PROBAS) is a joint register for the WEA and the EPA and comprises a large number of chemicals and products. The information is obtained from registration according to the EPA rules and from scientific studies and surveys and other relevant sources. The product register is the most comprehensive collection of chemical data in products for Denmark and with the availability of data from the other Nordic countries it enables an inter-country comparison. For each chemical the data is reported in a uniform way, which enhances comparability, transparency and consistency.

3) Reports from and personal contacts with industrial branches. It is fundamental to have information from the industrial branches that have direct contact with the activities, i.e. chemicals and products of interest. The information can be in the form of personal communication, but also

reported surveys are of great importance. In contrast to the more generic approach of collecting information from large databases, the expert information from industrial branches may give valuable information on specific chemicals and/or products and industrial activities. By considering both sources a verification as well as optimum reliability and accuracy is obtained.

4) The present inventory procedure builds partly on information from the previous Danish solvent emission inventory, which is based on questionnaires to industrial branches. Furthermore a joint Nordic collaboration on solvent inventories has given important information on methods and data.

Data Storage level 1	4.Consistency	DS.1.4.1	The origin of external data has to be preserved whenever possible without explicit arguments (referring to other PM's)

Data are predominantly extracted from the internet (StatBank 2008 and SPIN). These are saved as original copies in their original form. Specific information from industries and experts are saved as e-mails and reports.

Data Storage level 1	6.Robustness	DS.1.6.1	Explicit agreements between the external institution of data delivery and NERI about the condition of delivery

As stated in DS.1.4.1 most data are obtained from the internet. No explicit agreements have been made with external institutions.

Data Storage level 1	7.Transparency	DS.1.7.1	Summary of each data set including the reasoning for selecting the specific data set

See DS.1.3.1.

Data Storage level 1	7.Transparency	DS.1.7.3	References for citation for any external data set have to be available for any single number in any data set.

See Table 7.

Data Storage level 1	7.Transparency	DS.1.7.4	Listing of external contacts to every data set

See Table 7.

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to type of variability (Distribution as: normal, log normal or other type of variability)

Tier1 assumes normal distribution of activity data and emission factors.

Data Processing level 1	1. Accuracy	DP.1.1.2	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to scale of variability (size of variation intervals)

In the Emission Inventory Guidebook uncertainty estimates for the final emission calculations are given for the associated SNAP codes.

Data Processing level 1	1. Accuracy	DP.1.1.3	Evaluation of the methodological approach using international guidelines

The methodological approach is based on the detailed methodology as outlined in the Emission Inventory Guidebook.

Data Processing level 1	1. Accuracy	DP.1.1.4	Verification of calculation results using guideline values

No guideline values are stated for Denmark in the Emission Inventory Guidebook.

Data Processing level 1	2.Comparability	DP.1.2.1	The inventory calculation has to follow the international guidelines suggested by UNFCCC and IPCC.

See DP.1.1.3 and DS.1.3.1.

Data Processing level 1	3.Completeness	DP.1.3.1	Assessment of the most important missing quantitative knowledge

In "Uncertainties and time-series consistency" important uncertainty issues related to missing quantitative knowledge is stated. To summarise; (i) identification and inclusion of all relevant chemicals (and products). (ii) Collection of data for quantifying production, import and export of single chemicals. (iii) Distribution of chemicals on products, activities, sectors and households. (iv) Emission factors for single chemicals, products and industrial and household activities.

Data Processing level 1	3.Completeness	DP.1.3.2	Assessment of the most important missing accessibility to critical data sources that could improve quantitative knowledge

The issues are referring to DP.1.3.1: (i) Identification of chemicals that qualify as NMVOCs. The definition in the solvent directive (Directive 1999/13/EC) is used. Here VOCs are defined as follows: "Volatile organic compound shall mean any organic compound having at 293,15 K a vapour pressure of 0,01 kPa or more, or having a corresponding volatility under the particular condition of use". A tentative list of 650 chemicals from the "National Atmospheric Emission Inventory" (NAI 2000) has been used, it is possible that relevant chemicals are not included. (ii) For some chemicals no data are available in StatBank DK (2008). This can be due to confidentiality or that the amount of chemicals must be derived from products wherein they are comprised. (iii) No direct link is available between the amounts of chemicals and products or activities. From the Nordic SPIN database it is possible to make a relative quantification of products and activities used in industry, and combined with estimates and expert judgement these products and activities are differentiated into sectors. More detailed information from the industrial sectors may still be required. (iv) For many industrial and household activities

involving solvent containing products no estimates on emission factors are available. Large variations occur between industry and product groups. And given the large number of chemicals more specific knowledge regarding industrial processes and consumption is needed.

Data Processing level 1	4.Consistency	DP.1.4.1	In order to keep consistency at a higher level an explicit description of the activities needs to accompany any change in the calculation procedure

Any changes in calculation procedures are noted for each year's inventory.

Data Processing level 1	5.Correctness	DP.1.5.1	Shows at least once by independent calculation the correctness of every data manipulation

Calculations performed by IIASA using RAINS codes, which are based on a different methodological approach gives total emission values that are similar to the emissions found in the present approach.

Data Processing level 1	5.Correctness	DP.1.5.2	Verification of calculation results using time-series

No detailed guidelines or calculations are accessible for time-series. These are therefore not used for verification.

Data Processing level 1	5.Correctness	DP.1.5.3	Verification of calculation results using other measures

No other measures are used for verification.

Data Processing level 1	5.Correctness	DP.1.5.4	Shows one to one correctness between external data sources and the data bases at Data Storage level 2

The transfer of emission data from level 1, storage and processing, to data storage level 2 is manually checked.

Data Processing level 1	7.Transparency	DP.1.7.1	The calculation principle and equations used must be described

See methodological approach previously described.

Data Processing level 1	7.Transparency	DP.1.7.2	The theoretical reasoning for all methods must be described

See methodological approach previously described.

Data Processing level 1	7.Transparency	DP.1.7.3	Explicit listing of assumptions behind all methods

See methodological approach previously described.

Data Processing level 1	7.Transparency	DP.1.7.4	Clear reference to data set at Data Storage level 1

See Table 7.

Data Processing level 1	7.Transparency	DP.1.7.5	A manual log to collect information about recalculations

Any changes in calculation procedures and methods are noted for each year's inventory.

Data Storage level 2	5.Correctness	DS.2.5.1	Documentation of a correct connection between all data type at level 2 to data at level 1

See DP.1.5.4.

Data Storage level 2	5.Correctness	DS.2.5.2	Check if a correct data import to level 2 has been made

See DP.1.5.4.

4.2 Uncertainties and time-series consistency

An estimate of the overall uncertainty in EMEP/CORINAIR of 165 % is used.

Important uncertainty issues related to the mass-balance approach are

(i) Identification of chemicals that qualify as NMVOCs. Although a tentative list of 650 chemicals from the NAI (2000) has been used, it is possible that relevant chemicals are not included, e.g. chemicals that are not listed with their name in StatBank DK (2008) but as a product.

(ii) Collection of data for quantifying production, import and export of single chemicals and products where the chemicals are comprised. For some chemicals no data are available in StatBank DK (2008). This can be due to confidentiality or that the amount of chemicals must be derived from products wherein they are comprised. For other chemicals the amount is the sum of the single chemicals *and* product(s) where they are included. The data available in StatBank DK (2008) are obtained from Danish Customs & Tax Authorities and they have not been verified in this assessment.

(iii) Distribution of chemicals on products, activities, sectors and households. The present approach is based on amounts of single chemicals. To differentiate the amounts into industrial sectors it is necessary to identify and quantify the associated products and activities and assign these to the industrial sectors and households. No direct link is available between the amounts of chemicals and products or activities. From the Nordic SPIN database it is possible to make a relative quantification of products

and activities used in the industry, and combined with estimates and expert judgement these products and activities are differentiated into sectors. The contribution from households is also based on estimates. If the household contribution is set too low, the emission from industrial sectors will be too high and vice versa. This is due to the fact that the total amount of chemicals is constant. A change in distribution of chemicals between industrial sectors and households will, however, affect the total emission as different emission factors are applied in industry and households, respectively.

A number of activities are assigned as "other", i.e. activities that can not be related to the comprised source categories. This assignment is based on expert judgement but it is possible that the assigned amount of chemicals may more correctly be included in other sectors. More detailed information from the industrial sectors is continuously being implemented.

(iv) Rough estimates and assumed emission factors are used for some chemicals. For some chemicals more reliable information has been obtained from the literature and from communication with industrial sectors. In some cases it is more appropriate to define emission factors for sector specific activities rather than for the individual chemicals.

A quantitative measure of the uncertainty has not been assessed. Single values have been used for emission factors and activity distribution ratios etc. A Tier2 (Monte Carlo) uncertainty assessment is currently being developed for the Danish inventory and will be implemented for the solvent sector in coming inventories.

5 Recalculations

The previous method was based on results from an agreement between the Confederation of Danish Industry (DI) and the EPA. The emissions from various industries were reported to the EPA. The reporting was not annual and linear interpolation was used between the reporting years. It is important to notice that not all use of solvents was included in this agreement and no activity data were available. It is not possible to perform direct comparison of methodologies or to make corrections to the previous method, due to the fundamental differences in structure. But an increase in total emissions was expected due to the more comprehensive list of chemicals.

Improvements and additions are continuously being implemented in the inventory due to the comprehensiveness and complexity of the use and application of solvents in industries and households. Important improvements by Fauser et al. (2009) and Schleicher et al. (2009) have been included. The main improvements in the 2007 reporting thus include revisions of the following:

- The following chemicals and groups have been removed compared to the 2006 inventory - due to vapour pressures below 0.01 kPa: aminooxygen groups, glycerol, toluendiisocyanate, dioctylphthalate, diethylenglycol.
- Emission factors (EFs) have been adjusted for all chemicals with most predominant effect for the following chemicals: ethanol, formaldehyde, turpentine, xylene, toluene and ethylenglycol.
- A differentiation of EFs in four different categories has been implemented: 1) chemical industry (lowest EF), 2) other industry, 3) non-industrial activities, 4) household and other diffuse use (highest EF). In previous inventories there was only a differentiation in two categories.
- More detailed and reliable information on use amounts and emission factors has been obtained from importers and producers for the following chemicals: methanol, ethanol in windscreen washing agent, naphthalene, propane and butane.
- Acrylic acid has been included in the inventory.

6 Planned improvements

Results from the Nordic project (Fauser et al., 2009) will lead to thorough improvements in the coming Danish solvent inventory regarding methodology, source allocation and emission factors and NMVOC to CO_2 conversion factors for chemicals.

Furthermore; inclusion of PAHs, heavy metals, PCBs and dioxins and chemicals that are listed in consumer products in StatBank DK (2008) and that are only partly included in the present inventory, is planned.

7 Conclusions

Non-Methane VOC, N_2O and CO_2 emissions from use of solvents in industries and households are presented for the period 1985 - 2007. The methodology for calculating emissions, finding activity data, emission factors and allocating use amounts of solvents to SNAP categories is described. The methodology is used for the period 1995 – 2007 and linear extrapolations are made for 1985 – 1994. Recent adjustments for improving the inventory are mentioned and uncertainty issues and QA/QC activities related to the methodology and data are discussed.

As many as 33 chemicals, of which five are chemicals groups, constitute more than 95 % of the total NMVOC emission from solvent use. In-depth investigation and evaluation of emissions, activity data, emission factors and source allocation are thus made for these chemicals and groups. Activity data and emissions of new chemicals and chemical containing products are continuously being assessed for inclusion in the inventory.

Solvent use constitutes approximately one third of the total NMVOC emissions in Denmark, i.e. 27.940 tonnes in 2007 and represents 87.100 tonnes CO_2-equivalents, which constitutes 0.2 % of the total Danish CO_2 emissions. NMVOC emissions from solvent use have decreased with 57 % in the period 1985 to 2007.

Emissions are derived for single chemicals used in specific industrial sectors and in household consumer products and a prioritised list of chemicals according to their emissions is shown. Ethanol, turpentine (white spirit: stoddard solvent and solvent naphtha) and propylalcohol have the highest emissions.

Furthermore, the results from the joint Nordic project, where all the major code systems associated with emission reporting and registration of chemicals that are used and processed as solvents in the Nordic countries are collected and linked, is presented.

Abbreviations and definitions

CAS: An identification number for substances described in the literature, assigned by Chemical Abstract Services, a division of the American Chemical Society (American Chemical Society 2007). Most CAS numbers refer to individual substances, but some are mixtures, such as petroleum solvents, e.g. naphtha.

CRF: The Common Reporting Format (CRF) is an integral part of the national emission inventory submission. It is designed to ensure that Parties included in Annex I to the Convention (Annex I Parties) report quantitative data in a standardised format, and to facilitate the comparison of inventory data across Annex I Parties. The information provided in the CRF is aimed at enhancing the comparability and transparency of inventories by facilitating, inter alia, activity data and emission factors cross-comparisons among Annex I Parties, and easy identification of possible mistakes, misunderstandings and omissions in the inventories (http://unfccc.int/files/meetings/cop_11/application/pdf/cop11_09_8_tables_of_the_common_reporting_format_for_luluc.pdf). CRF category classification should be used for reporting under the United Nations Framework Convention on Climate Change (UNFCCC) according to the Kyoto protocol.

NACE: "Nomenclature Generale des Activites Economiques dans I'Union Europeenne" (General Name for Economic Activities in the European Union) is a pan-European classification system that groups organisations according to their business activities. It assigns a unique 5 or 6 digit code to each industry sector. The NACE code system is the European standard for industry classifications and was introduced in 1970. In 1990 a revised version became applicable. The current version from 2008 is based on "International Standard Industrial Classification of all economic activities" (ISIC) of the United Nations. NACE industrial use codes are used by producers and manufacturers to register manufacture and preparation of chemicals to the product data bases in Finland, Norway, Sweden and Denmark (http://ec.europa.eu/environment/emas/pdf/general/nacecodes_en.pdf).

NMVOC: Non-methane volatile organic compound. The term "volatile organic compound" (VOC) refers to any organic compound having a vapour pressure of 0.01 kPa or more at 293.15 degrees K, or having a corresponding volatility under the particular conditions of use (Directive 1999/13/EC).

RAINS/GAINS: The Regional Air Pollution Information and Simulation (RAINS/GAINS) model developed by the International Institute for Applied Systems Analysis (IIASA) combines information on atmospheric emissions with a number of other economic, energy and environmental parameters. These air pollution related problems are considered in a multi-pollutant context, quantifying the contributions of, inter alia, NMVOCs. The source categories of the RAINS/GAINS model are not directly compatible with that of SNAP/CORINAIR or NFR. In several

cases, the relation between RAINS/GAINS sectors and the other sectoral classification schemes can be established only for a primary sector, e.g., the sum of all RAINS/GAINS categories for power and district heating plants can only be compared with the sum of several SNAP entries. RAINS/GAINS contain a feature to aggregate/display emissions into the SNAP/CORINAIR level 1 as well as NFR level 1 and 2 (http://www.iiasa.ac.at/~rains/voc_review/voc_ir-00-51.pdf).

SNAP and **NFR**: The CORINAIR (CORe INventory on AIR emissions) system is a European program for air emission inventories. CORINAIR includes methodology structure and software for inventories. The methodology is described in the EMEP/CORINAIR Emission Inventory Guidebook 3rd edition, 2007 update, prepared and maintained by the UNECE/EMEP Task Force on Emissions Inventories and Projections. The Task Force also maintains the air pollution source-category nomenclatures NFR (Nomenclature For Reporting) and SNAP (Selected Nomenclature for Air Pollution). NFR formats are in accordance with the EMEP 2002 Reporting Guidelines and cover seven groups; 1 Energy, 2 Industrial processes, 3 Solvent and other product use, 4 Agriculture, 5 Land-use change and forestry, 6 Waste, 7 Other. The SNAP nomenclature was originally developed for the 1985 EC CORINAIR emissions inventory (SNAP94) and has been revised a couple of times - latest in 1997 (SNAP97) to ensure compatibility between EMEP/CORINAIR and IPCC was recently revised (SNAP2007) (http://reports.eea.europa.eu-/EMEPCORINAIR5/en/page015.html. NFR category classification is used for reporting under the convention on Long-Range Transboundary Air Pollution (LRTAP) according to the Gothenburg protocol.

UCN: The set of technical functions, UCN (Use Categories Nordic), is a common list of use categories for the official product registers in Norway, Sweden and Denmark (in Denmark called the Product Registry). Notifying chemicals and materials (products) to the Product Registry involves stating information on the use of the chemicals, among others also what the product is used for (the technical function of the product). The list of use categories for product registers notifications consists of a list of five-character codes - each listed with an explanation text. The list has been created to meet the demands of the industry, primarily from the notifiers of paints, printing inks and adhesives, for correct use description of their products. It has also been designed to meet the demands of the new EU regulation of chemicals in which a distinction of biocides and agricultural pesticides has been introduced. Finally, it has been introduced as a common list of use categories in the Nordic countries in order to harmonise the registration of technical functions of the products in the product registers of Norway, Sweden and Denmark. The list can be seen at:
(http://www.arbejdstilsynet.dk/graphics/at/05-Information/04-Andre-informationsmaterialer/Produktregistret/Funktionskoder-alle.xls).

References

Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations, Brüssel, 1999

Directive 2001/81/EC Of The European Parliament And Of The Council of 23 October 2001 - on national emission ceilings for certain atmospheric pollutants. Official Journal of the European Communities

Directive 2004/42/EC of the European Parliament and Council on the Limitation of Emissions of Volatile Organic Compounds due to the Use of Organic Solvents in Certain Paints and Varnishes and Vehicle Refinishing Products and Amending Directive 1999/13/EC 30.04.2004, L 143/87

EMEP/CORINAIR, 2004: Emission Inventory Guidebook 3rd edition, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections, 2004 update. Available at: http://reports.eea.eu.int/EMEPCORINAIR4/en (15-04-2007)

Eurostat on the internet. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

Fauser, P., Saarinen, K., Harðardóttir, K., Kittilsen, M.O., Holmengen, N. & Skårman, T. 2009: Improvement of Nordic Emission Models for Solvent Use in Selected Sectors. TemaNord 2009:556. Nordic Council Of Ministers, Copenhagen.

IPCC, 2000: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Available at http://www.ipcc-nggip.iges.or.jp/public/gp/english/ (15-04-2007)

Karjalainen, T. 2005: Commission research in Action: tackling the hormone disrupting chemicals issue, EUR report 21941

NAI, 2000: British National Atmospheric Inventory performed by the National Environmental Technology Centre, June 2000, available at http://www.aeat.co.uk/netcen/airqual/naei/annreport/annrep99/app1_28.html (05-05-2006)

Nielsen, O.-K., Lyck, E., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Albrektsen, R., Hjelgaard, K., Vesterdal, L., Møller, I.S. & Baunbæk, L. 2009: Denmark's National Inventory Report 2009. Emission Inventories 1990-2007 - Submitted under the United Nations Framework Convention on Climate Change.National Environmental Research Institute, Aarhus University, 2009. 826 s. (NERI Technical Report; 724). IPCC, 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Available at http://www.ipcc-nggip.iges.or.jp/public/g-l/invs6.htm (15-04-2007).

Pedersen, T. 1992: Atmosfærekemi – En Introduktion. Kemisk Institut, Københavns Universitet. ISBN 87-87438-28-3

Pärt, P. (main author) 2005: Environment and health, EEA Report No 10/2005, Copenhagen

Schleicher, O., Fuglsang, K. & Boje, J. (Force Technology) 2009: Revision af beregninger af danske VOC emissioner fra opløsningsmidler og husholdninger. Arbejdsrapport fra Miljøstyrelsen Nr. 5. (in Danish)

SPIN on the Internet. Substances in Preparations in Nordic Countries, http://www.spin2000.net/spin.html

StatBank DK, 2008: Statistics Denmark, available at: http://www.statistikbanken.dk/statbank5a/default.asp?w=1024 (01-06-2007)

UNFCCC, 2008: Available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3929.php

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DANISH EMISSION INVENTORY FOR SOLVENT USE IN INDUSTRIES AND HOUSEHOLDS

This report presents the Danish emission inventory for Non-Methane Volatile Organic Compounds (NMVOC), N_2O and CO_2 from the use of solvents in industries and households. The methodology, data sources, activity data, emission factors and emissions are presented for 1985 to 2007 and uncertainties, QA/QC and coming refinements are stated. Solvent use constitutes approximately one third of the total NMVOC emissions in Denmark, i.e. 27.940 tonnes in 2007 and represents 87.100 tonnes CO_2 equivalents, which constitutes 0.2 % of the total Danish CO_2 emissions. NMVOC emissions may be of small concern in relation to CO_2 emissions but they are fundamental in relation to many human and environmental health issues and to long-range transport of chemical active species. Use and emission patterns of NMVOCs are diverse and complex, as many chemicals are categorised as NMVOCs and are present in many different industrial activities and consumer products. Emissions are calculated based on detailed information on chemical use, mainly derived from Statistics Denmark and the Nordic database: Substances in Preparations in the Nordic Countries (SPIN) and from communication with industries and related institutions in Europe responsible for their respective national inventories. Refinements have been implemented in the 2007 calculations based on results from a joint Nordic project where data and methodological principles were shared and a coupling of the many existing source codes were suggested.

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