CHAPTER 5

NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE

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5 NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE

5.1 INTRODUCTION

This section provides methods for estimating emissions from the first use of fossil fuels as a product for primary purposes other than i) combustion for energy purposes and ii) use as feedstock or reducing agent. Emissions from the latter two uses are accounted for by methods described in the chemical industry (Chapter 3) and in metal industry (Chapter 4).

The products covered here comprise lubricants, paraffin waxes, bitumen/asphalt, and solvents. Emissions from further uses or disposal of the products after first use (i.e., the combustion of waste oils such as used lubricants) are to be estimated and reported in the Waste Sector when incinerated or in the Energy Sector when energy recovery takes place.

Generally, the methods for calculating carbon dioxide (CO_2) emissions from non-energy product uses follow a basic formula, in which the emission factor is composed of a carbon content factor and a factor that represents the fraction of fossil fuel carbon that is *Oxidised During Use* (ODU), e.g., actual co-combustion of the fraction of lubricants that slips into the combustion chamber of an engine). This concept is applied to oxidation during first use only of lubricants and paraffin waxes and not to subsequent uses (e.g., energy recovery):

EQUATION 5.1
BASIC FORMULA FOR CALCULATING CO_2 EMISSIONS FROM NON-ENERGY PRODUCT USES

$$CO_2\ Emissions = \sum_i \left(NEU_i \bullet CC_i \bullet ODU_i\right) \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from non-energy product uses, tonne CO_2

NEU_i = non-energy use of fuel *i*, TJ

CC_i = specific carbon content of fuel *i*, tonne C/TJ (=kg C/GJ)

ODU_i = ODU factor for fuel *i*, fraction

44/12 = mass ratio of CO_2/C

The production and use of asphalt for road paving and roofing and the use of solvents derived from petroleum and coal are either not sources or are negligible sources of direct greenhouse gas emissions. They are, however, included in this chapter since they are sometimes substantial sources of non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) emissions which eventually oxidise to CO_2 in the atmosphere. The resulting CO_2 input can be estimated from the emissions of these non-CO_2 gases (see Section 7.2.1.5 of Volume 1). While almost negligible for asphalt, for solvent use this may have some significance. Emissions from any other non-energy product of fossil fuels not described here should be reported under the subcategory 2D4 'Other'.

There may be a risk that some of the CO_2 emissions calculated for this source category could be partly accounted for elsewhere. Cases where this may occur are clearly indicated in the subsequent sections and should be cross-checked to avoid double counting.

Methane (CH_4) emissions from the activities covered in this chapter are expected to be minor or not to occur at all. Although some CH_4 emissions occur from asphalt production and use for road paving, no method to estimate CH_4 emissions is provided since these emissions are expected to be very negligible.

Section 1.4 of Chapter 1 of this volume provides guidance for assessing consistency and completeness of carbon emissions from non-energy and feedstock use of fuels by (a) checking that non-energy use/feedstock requirements of processes included in the inventory are in balance with the non-energy use/feedstock supply as recorded in national energy statistics, (b) checking that total reported bottom-up calculated CO_2 emissions from non-energy use/feedstock sources at different subcategory levels are complete and consistent, (c) documenting and reporting how these emissions are allocated in the inventory. The sources described in this chapter are part of the verification of completeness of fossil CO_2 from non-energy sources and reporting of their allocation.

TABLE 5.1
NON-ENERGY PRODUCT USES OF FUELS AND OTHER CHEMICAL PRODUCTS

Types of fuels used	Examples of non-energy uses	Gases covered in this chapter	
		CO_2	NMVOC, CO
Lubricants	Lubricants used in transportation and industry; Section 5.2	X	
Paraffin waxes	Candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging; Section 5.3	X	
Bitumen; road oil and other petroleum diluents	Used in asphalt production for road paving and e.g., in roofing; Section 5.4		X
White spirit[1], kerosene[2], some aromatics	As solvent e.g. for surface coating (paint), dry cleaning; Section 5.5		X

5.2 LUBRICANT USE

5.2.1 Introduction

Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be subdivided into (a) motor oils and industrial oils, and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate.

5.2.2 Methodological issues

The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector. However, in the case of 2-stroke engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the Energy Sector (see Volume 2).

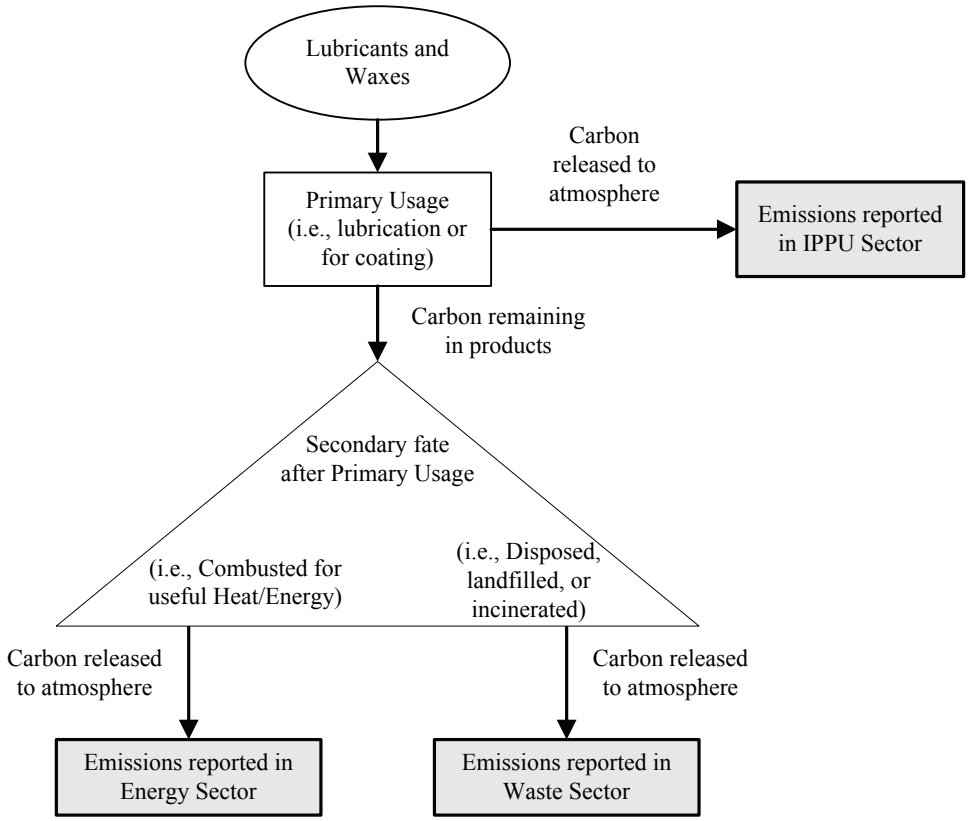
It is difficult to determine which fraction of the lubricant consumed in machinery and in vehicles is actually combusted and thus directly results in CO_2 emissions, and the fraction not fully oxidised that results firstly in NMVOC and CO emissions (except for the use in 2-stroke engines, which is excluded here). For this reason, these NMVOC and CO emissions are very seldom reported by countries in the emission inventories. Therefore, for calculating CO_2 emissions the total amount of lubricants lost during their use is assumed to be fully combusted and these emissions are directly reported as CO_2 emissions.

Regulations and policies for the disposal of used oil in most OECD countries often restrict landfilling and dumping, and encourage the separate collection of used oil. A small proportion of lubricants oxidises during use, but the main contribution to emissions is when the waste lubricants are collected at the end of their use, in accordance with country-specific regulations, and subsequently combusted. These waste oil handling emissions, however, are to be reported in the Waste Sector (or in the Energy Sector when energy recovery takes place). Figure 5.1 illustrates this.

[1] Also known as mineral turpentine, petroleum spirits, industrial spirit ('SBP').

[2] Also known as paraffin or paraffin oils (UK, South Africa).

Figure 5.1 Sectoral allocation of emissions from lubricants and waxes



Since CH_4 and N_2O emissions are very small in comparison to CO_2, these can be neglected for the greenhouse gas calculation.

5.2.2.1 CHOICE OF METHOD

There are two methodological tiers for determining emissions from the use of lubricants. Both Tier 1 and Tier 2 rely on essentially the same analytical approach, which is to apply emission factors to activity data on the amount of lubricant consumption in a country (in energy units, e.g., TJ). The Tier 2 method requires data on the quantities of different types of lubricants, excluding the amount used in 2-stroke engines, in combination with type-specific *Oxidised During Use* (ODU) factors to activity data, preferably country-specific, while the Tier 1 method relies on applying one default ODU factor to total lubricant activity data (see decision tree, Figure 5.2). Since the default ODU factor is four times smaller for greases than for lubricating oils, using a higher tier method will primarily capture the impact of using actual fractions of oils and greases in the emission calculation. It is considered *good practice* to use the Tier 2 method when this is a *key category*.

Tier 1: CO_2 emissions are calculated according to Equation 5.2 with aggregated default data for the limited parameters available and the ODU factor based on a default composition of oil and greases in total lubricant figures (in TJ units):

EQUATION 5.2
LUBRICANTS – TIER 1 METHOD

$$CO_2\ Emissions = LC \bullet CC_{Lubricant} \bullet ODU_{Lubricant} \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from lubricants, tonne CO_2

LC = total lubricant consumption, TJ

$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ)

$ODU_{Lubricant}$ = ODU factor (based on default composition of oil and grease), fraction

44/12 = mass ratio of CO_2/C

Tier 2: The Tier 2 method for lubricants relies on a similar equation, however detailed data on the quantities consumed per type of lubricants use (in energy units, e.g., TJ) and, preferably, country-specific emission factors should be used. The emission factors are composed of fuel type specific carbon content and the ODU factor:

EQUATION 5.3
LUBRICANTS – TIER 2 METHOD

$$CO_2\ Emissions = \sum_i \left(LC_i \bullet CC_i \bullet ODU_i\right) \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from lubricants, tonne CO_2

LC_i = consumption of lubricant type *i*, TJ

CC_i = carbon content of lubricant type *i*, tonne C/TJ (= kg C/GJ)

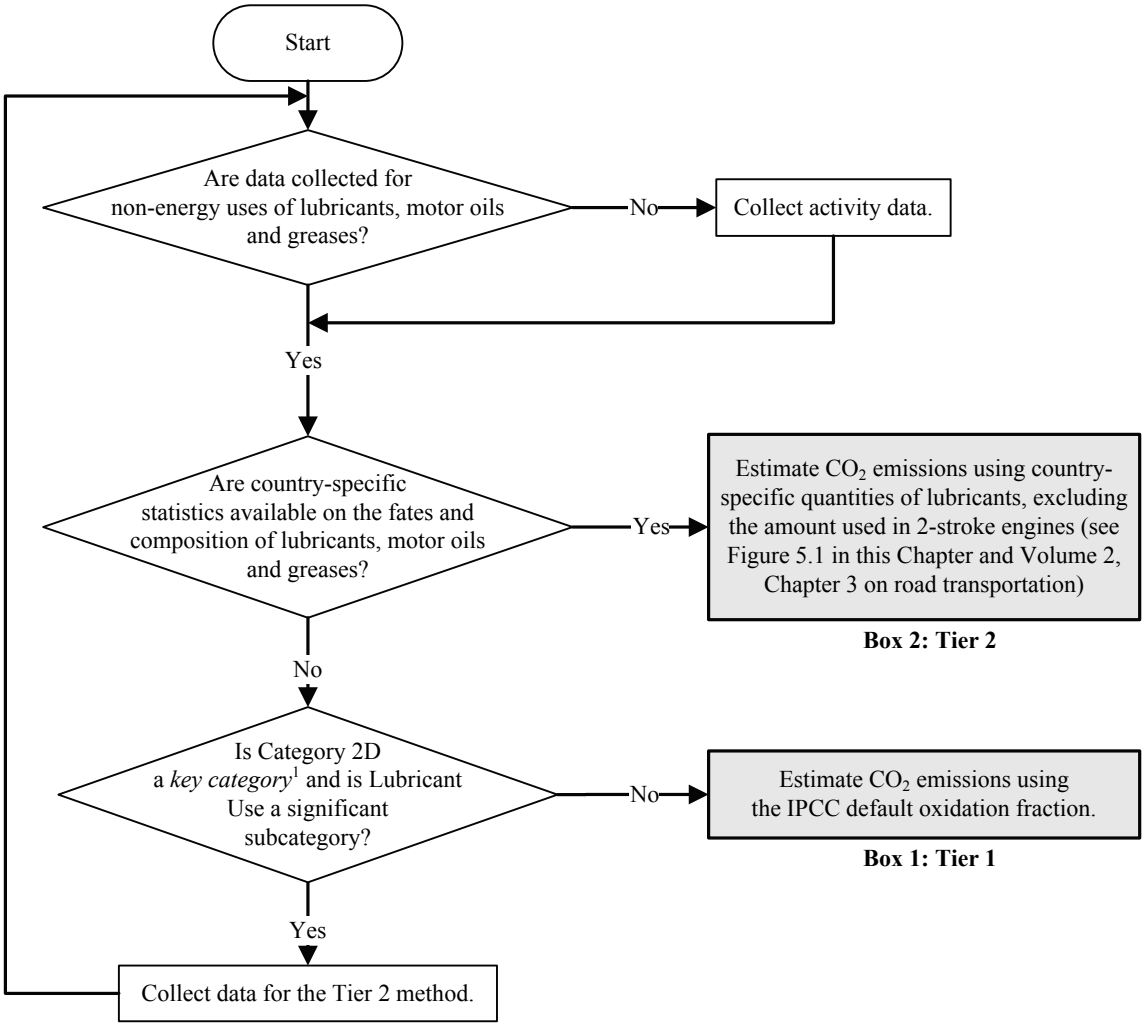
ODU_i = ODU factor for lubricant type *i*, fraction

44/12 = mass ratio of CO_2/C

Lubricant *i* refers to motor oils/industrial oils and greases separately, excluding the amount used in 2-stroke engines.

In both tiers the carbon contents may be the default value for lubricants described in Volume 2 (Chapter 1, Table 1.3), or a country-specific value, if available.

Figure 5.2 Decision tree for CO_2 from non-energy uses of lubricants



Note:
1. See Volume 1 Chapter 4, Methodological Choice and Identification of Key Categories (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.

5.2.2.2 CHOICE OF EMISSION FACTORS

The emission factor is composed of a specific carbon content factor (tonne C/TJ) multiplied by the ODU factor. A further multiplication by 44/12 (the mass ratio of CO_2/C) yields the emission factor (expressed as tonne CO_2/TJ). For lubricants the default carbon contents factor is 20.0 kg C/GJ on a Lower Heating Value basis. (See Table 1.3 in Chapter 1 of Volume 2. Note that kg C/GJ is identical to tonne C/TJ.) It is assumed that use is combustion resulting in 100 percent oxidation to CO_2, with no long-term storage of carbon in the form of ash or post-combustion residue. A small fraction of lubricating oils is oxidised during use (see Table 5.2). An even smaller fraction of greases are oxidised during use. Default ODU factors for oils (20 percent) and greases (5 percent) are based on limited available data (Table 5.2).

Tier 1: Having only total consumption data for all lubricants (i.e., no separate data for oil and grease), the weighted average ODU factor for lubricants as a whole is used as default value in the Tier 1 method. Assuming that 90 percent of the mass of lubricants is oil and 10 percent is grease, applying these weights to the ODU factors for oils and greases yields an overall (rounded) ODU factor of 0.2 (Table 5.2). This ODU factor can then be applied to an overall carbon content factor, which may be country-specific or the default value for lubricants to determine national emission levels from this source when activity data on the consumption of lubricants is known (Equation 5.2).

Tier 2: Those countries with specific details on the specific quantities of lubricants used as motor oils/industrial oils and as greases can apply different ODU factors, either the default values of 0.2 and 0.05, respectively, or their own ODU factors for lubricants and greases based on national knowledge. These default or country-specific ODU factors can then be multiplied with the country-specific carbon content factors or the single default IPCC carbon content factor for lubricants to determine national emission levels (Equation 5.3).

TABLE 5.2
DEFAULT OXIDATION FRACTIONS FOR LUBRICATING OILS, GREASE AND LUBRICANTS IN GENERAL

Lubricant / type of use	Default fraction in total lubricant [a] (%)	ODU factor
Lubricating oil (motor oil /industrial oils)	90	0.2
Grease	10	0.05
IPCC Default for total lubricants [b]		**0.2**

[a] Excluding the use in 2-stroke engines.

[b] Assuming 90 percent lubricating oil consumption and 10 percent grease consumption and rounded to one significant digit.

Source: Rinehart (2000).

5.2.2.3 CHOICE OF ACTIVITY DATA

Data on the non-energy use of lubricants are required to estimate emissions, with activity data expressed in energy units (TJ). To convert consumption data in physical units, e.g., in tonnes, into common energy units, e.g., in TJ (on a Lower Heating Value basis), calorific values are required (for specific guidance see Section 1.4.1.2 of Chapter 1 of Volume 2 on Energy). Basic data on non-energy products used in a country may be available from production, import and export data and on the energy/non-energy use split in national energy statistics. Additional information may need to be collected to determine the amount of lubricants being used in 2-stroke engines, which should be excluded from the Tier 2 calculation in this source category. For the Tier 2 method, the individual quantities applied as motor oil/industrial oils and as greases need to be separately known. For specific guidance on the data collection for lubricants used for 2-stroke engines, see Chapter 3 on Road Transport of Volume 2: Energy.

5.2.2.4 COMPLETENESS

Emissions from the use of lubricants in 2-stroke engines should be accounted for in the Energy Sector. Any emissions that occur due to oxidation from post-use combustion or degradation after disposal should be accounted for separately in the Waste Sector (or Energy Sector, if combustion is used for energy recovery). To avoid double counting and to ensure completeness, the proper allocation of those emissions not related to the non-combustion usage of lubricants in the Energy and Waste Sectors should be cross-checked.

5.2.2.5 DEVELOPING A CONSISTENT TIME SERIES

Emissions from lubricants should be calculated using the same method and data sets for every year in the time series.

5.2.3 Uncertainty assessment

5.2.3.1 EMISSION FACTOR UNCERTAINTIES

The default ODU factors developed are very uncertain, as they are based on limited knowledge of typical *lubricant* oxidation rates. Expert judgment suggests using a default uncertainty of 50 percent.

The carbon content coefficients are based on two studies of the carbon content and heating value of lubricants, from which an uncertainty range of about ±3 percent is estimated (U.S.EPA, 2004).

5.2.3.2 ACTIVITY DATA UNCERTAINTIES

Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used in individual countries, for which a default of 5 percent may be used in countries with well developed energy statistics and 10-20 percent in other countries, based on expert judgement of the accuracy of energy statistics. If the amount of lubricants used in 2-stroke engines, which is to be subtracted from the total consumption used here, is not known, the uncertainty in the activity data will be higher and biased (too high). In countries where a large fraction of the use is in 2-stroke engines, the uncertainty range in the activity data in this section is much higher at the lower end, and can be estimated from the estimated share of 2-stroke engines in the national consumption total.

5.2.4 Quality Assurance and Quality Control (QA/QC), Reporting and Documentation

5.2.4.1 QUALITY ASSURANCE AND QUALITY CONTROL

It is *good practice* to check the consistency of the total annual consumption figure with the production, import and export data. In addition, it is recommended to compare the amounts discarded, recovered and combusted and the amount used in 2-stroke engines, if available, with total consumption figures in the calculation to check the internal consistency of activity data and ODU factors used in the calculation of different source categories across sectors.

5.2.4.2 REPORTING AND DOCUMENTATION

It is *good practice* to report and document:

- The total amount of lubricants produced, imported, exported, consumed, and discarded are to be reported when available. In addition, the amount used for 2-stroke engines and subtracted should be reported. If the latter information is not available or not used in the emission calculation this should be reported.
- When using the Tier 2 method, the consumption data should be reported per type of lubricant used in the calculation.
- If the default ODU factor is used, this should be noted in the reporting documentation.
- If a country-specific emission factor for lubricants was developed, in other words, if a country-specific ODU factor and/or country-specific carbon contents fraction is used, the corresponding data should be provided with an explanation of how this was measured.
- The allocation of CO_2 emissions from lubricants in Table 1.6 on the allocation of CO_2 from non-energy use of fossil fuels (see Chapter 1 of this volume).

5.3 PARAFFIN WAX USE

5.3.1 Introduction

The category, as defined here, includes such products as petroleum jelly, paraffin waxes and other waxes, including ozokerite (mixtures of saturated hydrocarbons, solid at ambient temperature). Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. Paraffin waxes are categorised by oil content and the amount of refinement.

5.3.2 Methodological issues

Waxes are used in a number of different applications. Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants). In the cases of incineration and wastewater treatment the emissions should be reported in the Energy or Waste Sectors, respectively (see Figure 5.1).

5.3.2.1 CHOICE OF METHOD

There are two methodological tiers for determining emissions and storage from paraffin waxes. Both Tier 1 and Tier 2 rely on essentially the same analytical approach, which is to apply emission factors to activity data on the amount of paraffin waxes consumed in a country (in energy units, e.g., TJ). The Tier 2 method relies on determining the actual use of paraffin waxes and applying a country-specific ODU factor to activity data, while the Tier 1 method relies on applying default emission factors to activity data (see decision tree, Figure 5.3).

Tier1: CO_2 emissions are calculated according to Equation 5.4 with aggregated default data for the limited parameters available:

EQUATION 5.4
WAXES – TIER 1 METHOD

$$CO_2\ Emissions = PW \bullet CC_{Wax} \bullet ODU_{Wax} \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from waxes, tonne CO_2

PW = total wax consumption, TJ

CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ)

ODU_{Wax} = ODU factor for paraffin wax, fraction

44/12 = mass ratio of CO_2/C

Tier 2: The Tier 2 method for paraffin waxes relies on a similar equation, however detailed data on the quantities (possibly also on the types) of paraffin waxes produced (in energy units) and their respective use as well as country-specific emission factors should be used:

EQUATION 5.5
WAXES – TIER 2 METHOD

$$CO_2\ Emissions = \sum_i \left(PW_i \bullet CC_i \bullet ODU_i\right) \bullet 44/12$$

Where:

CO_2 Emissions = CO_2 emissions from waxes, tonne CO_2

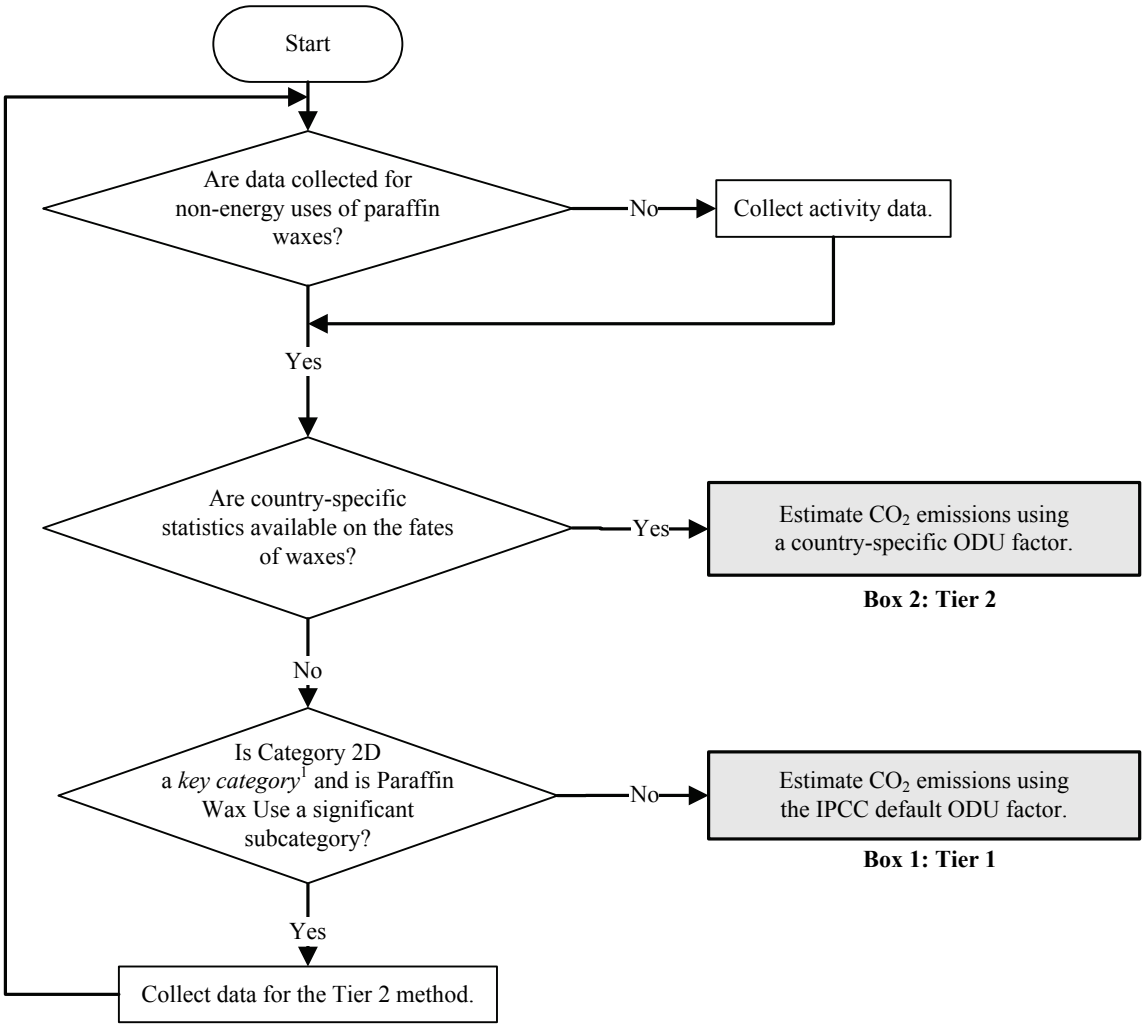
PW_i = consumption of was type *i*, TJ

CC_i = carbon content of wax type *i*, tonne C/TJ (= kg C/GJ)

ODU_i = ODU factor for wax type *i*, fraction

44/12 = mass ratio of CO_2/C

Figure 5.3 Decision tree for CO_2 from non-energy uses of paraffin waxes



Note:
1. See Volume 1 Chapter 4, Methodological Choice and Identification of Key Categories (noting Section 4.1.2 on limited resources), for discussion of *key categories* and use of decision trees.

5.3.2.2 CHOICE OF EMISSION FACTORS

A country-specific carbon content or default carbon content of 20.0 kg C/GJ (on a Lower Heating Value basis) should be applied. (See Table 1.3 in Chapter 1 of Volume 2. Note that kg C/GJ is identical to tonne C/TJ.) This default value is based on a combustion emission factor of 73.3 kg CO_2/GJ (API, 2004).

Tier 1: It can be assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2 (Equation 5.4).

Tier 2: Those countries with specific details on the uses of paraffin waxes in the country can determine their own country-specific ODU factors for waxes based on national knowledge of the combustion (Equation 5.5). These factors can be combined with either the default carbon contents listed above or a country-specific carbon contents if any are available.

5.3.2.3 CHOICE OF ACTIVITY DATA

Data on the use of paraffin waxes are required to estimate emissions, with activity data expressed in energy units (TJ). To convert consumption data in physical units, e.g., in tonnes, into common energy units, e.g., in TJ (on a Lower Heating Value basis), calorific values are required (for specific guidance see Section 1.4.1.2 of Chapter 1 of Volume 2 on Energy). Basic data on non-energy products used in a country may be available from production, import and export data and on the energy/non-energy use split in national energy statistics. If the reported national statistics do not contain this as a separate fuel category but instead only show this as part of an

aggregated 'other oil products' category, the national statistical agency should be contacted, since the oil product statistics are often collected at a more detailed level.

5.3.2.4 COMPLETENESS

Emissions from incineration (without heat recovery) of wax coated boxes fall under the Waste Sector. Any emissions from paraffin waxes that are produced due to energy recovery should be reported in the Energy Sector.

5.3.2.5 DEVELOPING A CONSISTENT TIME SERIES

Emissions from paraffin waxes should be calculated using the same method and data sets for every year in the time series. If a country-specific ODU factor is used, inventory compilers are encouraged to check whether the mix of applications with emissive and storage fates changes significantly over time. If that is the case, the ODU factors used per year should preferably reflect this change.

5.3.3 Uncertainty assessment

5.3.3.1 EMISSION FACTOR UNCERTAINTIES

The default emission factors are highly uncertain, because knowledge of national circumstances of paraffin wax fates is limited. Ideally, a Tier 2 method would be employed in which national data on the use and fates of waxes can be used as a surrogate to determine the quantities destined for an emissive fate versus storage fate. The default carbon content coefficient is subject to an uncertainty range of ±5 percent (U.S.EPA, 2004). However, the ODU factor is highly dependent on specific-country conditions and policies and the default value of 0.2 exhibits an uncertainty of about 100 percent.

5.3.3.2 ACTIVITY DATA UNCERTAINTIES

Much of the uncertainty in emission estimates is related to the difficulty in determining the quantity of non-energy products used and discarded in individual countries, for which a default of 5 percent may be used in countries with well developed energy statistics and 10-20 percent in other countries, based on expert judgement of the accuracy of energy statistics.

5.3.4 Quality Assurance and Quality Control (QA/QC), Reporting and Documentation

5.3.4.1 QUALITY ASSURANCE AND QUALITY CONTROL

It is *good practice* to check the consistency of the total annual consumption figure with the production, import and export data. In addition, the amounts discarded, recovered and combusted, if available, may be compared with total consumption figures in the calculation to check the internal consistency of activity data and ODU factors used in the calculation of different source categories across sectors.

5.3.4.2 REPORTING AND DOCUMENTATION

It is *good practice* to report and document country-specific emission factors, if these are used.

- If a country-specific emission factor for waxes was developed, in other words, if a country-specific ODU factor and/or country-specific carbon content fraction is used, the local value(s) with an explanation of their derivation should be provided .
- If the default ODU factor is used, this should be noted in the reporting documentation.

5.4 ASPHALT PRODUCTION AND USE

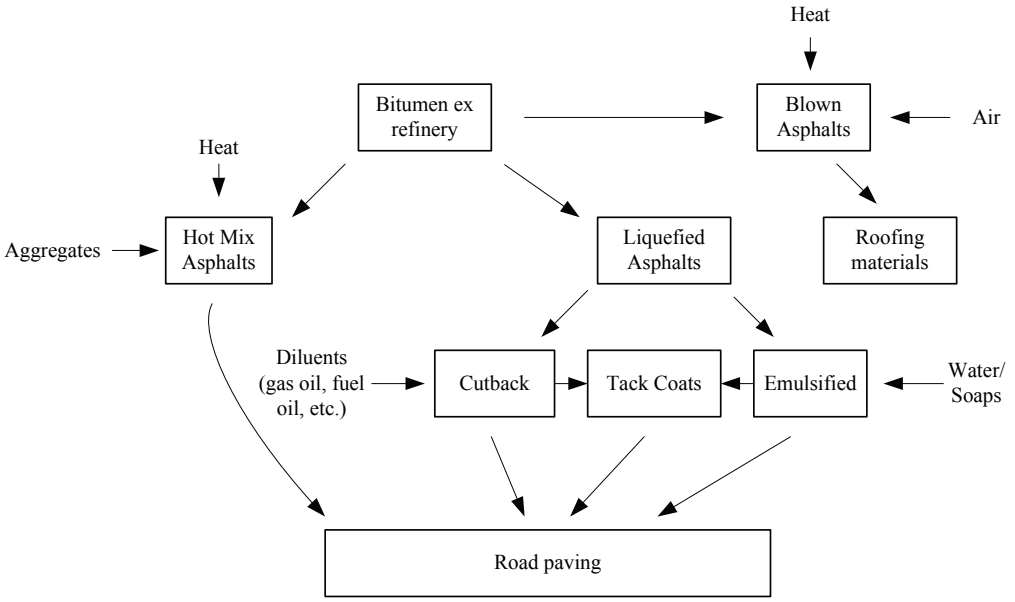
5.4.1 Introduction

This source category comprises the non-combustion emissions from the production of asphalt in asphalt plants other than refineries and its application (such as paving and roofing operations as well as subsequent releases from the surfaces). It includes asphalt blowing for roofing. The production and use of asphalt results mainly in emissions of NMVOC, CO, SO_2 and particulate matter, while the fate of the remaining hydrocarbons are stored in the product (much less than one per cent of the carbon is emitted). Emissions from the installation of roofing materials are assumed negligible. Emissions from the combustion of fuels needed to supply heat to the asphalt processes (production or heating of the asphalt mix) are covered under the Energy Sector.

Asphalt is commonly referred to as bitumen, asphalt cement, or asphalt concrete or road oil and is mainly produced in petroleum refineries. In some countries the laid mixed product is also referred to as 'asphalt' but it also known as 'macadam'. In view of the ambiguities created by differing nomenclatures, a single set of terms will be adopted here and applied uniformly in the text without implying any preferences for the terms used (see Box 5.1).

BOX 5.1
ASPHALT PRODUCTION AND USE

The heavy black and very viscous organic liquid mainly produced from refineries and used as a feedstock for the road paving and roofing materials will be termed bitumen, to distinguish it from the products made from it. This also conforms to the terminology used in international energy statistics, which may provide some of the data required for emissions estimation. At normal temperatures bitumen is in a semi-solid state. It is processed and used as illustrated in the figure below.



The diagram shows that bitumen may be heated and mixed with aggregate of various sizes, diluted with petroleum oils or water/soap emulsions, or heated and blown with air to polymerise/stabilise it and make it suitable for e.g., the treatment of roofing materials. These will be termed 'asphalt processes' and their products will be referred to as 'asphalt products'

Bitumen and aggregates are mixed in either a fixed or mobile plant, usually within 30 to 50 km of the road surface paving site (EAPA, 2003). In industrialised countries typically 80 to 90 percent of bitumen is used for the manufacture of road surface paving (U.S.EPA, 2004). However, in developing countries with rapid infrastructural growth, the amount of bitumen used for roofing products may be of the same order of magnitude

as those used for road paving (UNFCCC, 2004). Other uses of asphalt products are as binder or sealant in the production of roofing material, as a foundation sealant, and other industrial uses such as pipe coating.

Direct greenhouse gas emissions, e.g., CO_2 or CH_4, associated with the production and use of asphalt are negligible since the majority of the light hydrocarbon compounds were extracted during the refining process to produce commercial fuels. From the EMEP/CORINAIR guidebook it can be concluded that CH_4 emissions from hot mix asphalt and cutback asphalt and from the asphalt roofing industry are negligible (EEA, 2005). Greenhouse gas emissions from the use of recycled asphalt pavements as aggregate for new road paving are also negligible.

5.4.2 Methodological issues

Emission methodologies and default emission factors for NMVOC and CO are presented in the Road Paving (SNAP code 040610), Roofing Materials (SNAP code 040611) and Asphalt Blowing (SNAP code 060310) sections of the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2005). It is recommended that users refer to the guidebook when developing detailed NMVOC and CO estimates. (See also Volume 1, Chapter 7 of these *Guidelines*.) Note that in EMEP/CORINAIR the emissions from asphalt blowing for roofing are separately accounted for (under miscellaneous chemical product manufacture with SNAP code 060310).

Limestone may be used as part of the aggregate in the asphalt. However, no CO_2 is assumed to be released in the heating process (see Section 2.5, Other Process Uses of Carbonates, under Chapter 2 of this volume).

PRODUCTION AND USE OF ASPHALT FOR ROAD PAVING

Asphalt paving consist of a mix of aggregate, sand, filler, bitumen and occasionally a number of additives. Asphalt road surfaces are, thus, composed of compacted aggregate and bitumen binder. Hot Mix Asphalt (HMA) is by far the most widely used, generally over 80 percent, and produces very few emissions (EAPA, 2003). Other types of road paving include cutback asphalt and emulsified asphalt, which are both liquefied asphalts (EEA, 2005). Cutback asphalts are liquefied by blending with petroleum solvents (diluents such as heavy residual oils, kerosene or naphtha solvents) and therefore show a relatively high level of emissions of CO and NMVOC due to the evaporation of the diluent. Therefore most emissions from road paving will arise from the use of cutback asphalts. Depending on the evaporation rate, three types are distinguished: Rapid-Cure (RC), using a naphtha or gasoline-type diluent of high volatility, Medium-Cure (MC) using a diluent of medium volatility and Slow-Cure (SC) cutback asphalt which use oils of low volatility. This is in contrast to so-called emulsified asphalt that contains mostly water and little or no solvent. The amount of diluent used is usually lower in warm countries than in the cooler climates, and hence lower emission factors may be expected in warm countries.

Activity data for hot mix asphalt and production of cold mixes or 'modified asphalt' can be obtained for most European and several other industrialised countries from the European Asphalt Pavement Association (EAPA) or national paving and roofing associations such as the Asphalt Institute (EAPA, 2003; Asphalt Institute, 2004). Hot mix asphalt typically contains about 8 percent asphalt cement (bitumen) (EEA, 2005), but this may differ between countries (a figure of 5 percent has also been reported). For most industrialised countries the fraction of cutback asphalt is a few per cent, however several show shares of 5 percent to 12 percent, and exceptional shares up to 20 percent, or have none (EAPA, 2002; EAPA 2003; U.S. EPA, 2004). If the quantity of asphalt paved is not known but rather the area paved, a conversion factor of 100 kg asphalt/m^2 road surface may be used to calculate the mass of asphalt produced.

Gases are emitted from the asphalt plant (hot mix, cutback or emulsified), the road surfacing operations and subsequently by the road surface. The EMEP/CORINAIR Emission Inventory Guidebook provided process-specific uncontrolled emission factors for the different asphalt plants.

ASPHALT ROOFING

The asphalt roofing industry produces saturated felt, roofing and siding shingles, roll roofing and sidings: asphalt shingles, smooth surfaced organic and asbestos felt roll roofing, mineral surfaced organic and asbestos felt roll roofing and sidings, asphalt saturated organic and asbestos felts, asphalt saturated and/or coated sheeting and asphalt compound. Most of these products are used in roofing and other building applications. Asphalt felt, roofing and shingle manufacture involves the saturation or coating of felt. Key steps in the total process include asphalt storage, asphalt blowing, felt saturation, coating and mineral surfacing, of which asphalt blowing is included here. Direct greenhouse gas emissions from asphalt roofing products are negligible compared to emissions such as NMVOC, CO and particulate matter.

Asphalt blowing is the process of polymerising and stabilising asphalt to improve its weathering characteristics. Air blown asphalts are used in the production of asphalt roofing products. Blowing may take place in an asphalt

processing plant or an asphalt roofing plant (or in a refinery)[3]. Asphalt blowing leads to the highest emissions of NMVOC and CO, more than the other process steps. All asphalt used for non-paving applications has been blown (EEA, 2005).

5.4.3 Completeness

If no emissions are (explicitly) available for this source category, it should be checked whether they are already included elsewhere (e.g., in refinery emissions).

5.4.4 Uncertainty assessment

Although results from the use of more sophisticated methods are considered as the most accurate, the uncertainty for NMVOC and CO emissions from road paving and asphalt roofing may be in the range of ±25 percent and larger if the calculation was not based on detailed activity and control technology data (from −100 percent to +25 percent).

The emission factors for NMVOC and CO for batch mix and drum mix HMA production have an uncertainty range of about ±50 percent, while the default factors for total HMA production and for cutback asphalt production and use will be about ±100 percent uncertain (i.e., between -50 percent and +100 percent). When country-specific emission factors are used for cutback asphalt production and paving, the uncertainty in the emission factors may be considerably smaller, e.g. in the range of ±50 percent.

Production data for HMA and cutback asphalt may be as accurate as ±10 percent, when based on data compiled by the asphalt production or construction industry. However, when activity data on cutback asphalt needs to be extrapolated, the uncertainties are very large, since it has been observed for a number of countries that the amount of cutback asphalt used can vary substantially from year to year; factors of two or more are not rare (EAPA, 2002; EAPA 2003; U.S. EPA, 2004). Also data on the mix of HMA production plant types and control technology applied as well as on the mix of cutback asphalt types (RC, MC, SC) will generally be less accurate than total production data. The uncertainty in production statistics of asphalt roofing material may be as accurate as ±10 percent if accounting is complete. If that is not the case, the uncertainty at the high end of the range could be as high as 100 percent or more.

The default fossil carbon content fraction of NMVOC from asphalt production and use for road paving varies between 40 to 50 percent by mass and is about 80 percent for NMVOC from asphalt roofing (calculated from the NMVOC speciation provided in the EMEP/CORINAIR Emission Inventory Guidebook).

5.4.5 Reporting and Documentation

The relatively small emissions from production and use of asphalt, including asphalt blowing, should be reported under the subcategory 2D4 ‘Other’ of this source category 2D ‘Non-Energy Products from Fuels and Solvent Use’.

5.5 SOLVENT USE

5.5.1 Introduction

The use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various non-methane volatile organic compounds (NMVOC), which are subsequently further oxidised in the atmosphere. Fossil fuels used as solvent are notably white spirit and kerosene (paraffin oil). White spirit is used as an extraction solvent, as a cleaning solvent, as a degreasing solvent and as a solvent in aerosols, paints, wood preservatives, lacquers, varnishes and asphalt products. In Western Europe about 60 percent of the total white spirit consumption is used in paints, lacquers and varnishes. White spirit is the most widely used solvent in the paint industry.

[3] In UNECE inventories related emissions are accounted for under miscellaneous chemical product manufacture (separately for asphalt roofing manufacture/application and for asphalt blowing, SNAP codes 040610 and 060310) or under fugitive emissions from refineries (see EMEP/CORINAIR Emission Inventory Guidebook), but in the greenhouse gas inventory all emissions, including the precursor emissions, should be reported under the subcategory 2D4 ‘Other’.

Methodologies for estimating these NMVOC emissions can be found in the EMEP/CORINAIR Emission Inventory Guidebook (EEA, 2005). This source category 'solvent use' is treated as a separate category because the nature of this source requires a somewhat different approach to emissions estimation than that used for calculating other emission categories. For this reason the *2006 IPCC Guidelines* treats this also as a separate subcategory. In the EMEP/CORINAIR guidebook the subcategory 'solvent and other product use' group 6 of the Selected Nomenclature for sources of Air Pollution (SNAP) and is subdivided into five subcategories. Excluding the fifth: 'other product use' that refers to F-gases, N_2O and ammonia, which are covered elsewhere in the IPPU Volume these are:

- SNAP 0601: Paint application;
- SNAP 0602: Degreasing, dry cleaning and electronics;
- SNAP 0603: Chemical products manufacturing or processing. Including the processing of polyester, PVC, foams and rubber, manufacture of paints, inks, glues and adhesives and the finishing of textile
- SNAP 0604: Other use of solvents and related activities. Including such activities as 'enduction' (i.e., coating) of glass wool and mineral wool, printing industry, fat and oil extraction, uses of glues and adhesives, wood preservation, domestic solvent use (other than paint application) and vehicle underseal treatment and vehicle dewaxing.

Apart from emissions from road transport and, when occurring, production and handling of oil and biofuel combustion, this source category is often the largest source of national NMVOC emissions and its share may vary between 5 percent and 30 percent, with a global average of about 15 percent (Olivier and Berdowski, 2001).

5.5.2 Completeness

Emissions from this source category can be estimated using either a production-based or consumption-based approach. If total domestic sales figures of paints etc. are not available, apparent national consumption can be inferred from production, imports and exports. However, if trade statistics are not complete, this may introduce a significant uncertainty in the activity data. Thus, it is recommended that inventory compilers try to ensure that all significant evaporative uses of solvent and other product use are addressed by NMVOC emission estimates.

5.5.3 Developing a consistent time series

Usually for this source category only small annual changes are expected. However, when environmental policies are implemented to replace more toxic volatile compounds in solvents (e.g., with water,) both NMVOC emissions and the fossil carbon content of the NMVOC emissions may change over time.

5.5.4 Uncertainty assessment

The uncertainty of the NMVOC emissions will generally be quite large, e.g., about ±50 percent, except for countries that have developed a detailed inventory for these sources, in which case the uncertainty may be of the order of 25 percent. The default fossil carbon content fraction of NMVOC is 60 percent by mass, based on limited published national analyses of the speciation profile (U.S. EPA, 2002; Austria, 2004; Hungary, 2004; Klein Goldewijk *et al*., 2005). It may vary between 50 and 70 percent carbon by mass, so having an uncertainty of about ±10 percent. Country-specific fractions should have a lower uncertainty, e.g., ±5 percent.

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