Category		Title
NFR:	**1.A.2.f ii; 1.A.4.a.ii, 1.A.4.b ii; 1.A.4.c ii; 1.A.4.c iii; 1.A.5.b**	**Non-road mobile sources and machinery (land-based emissions)**
SNAP:	**0808 0809 0806 0807 0801**	**Other mobile sources and machinery — Industry Other mobile sources and machinery — Household and gardening Other mobile sources and machinery — Agriculture Other mobile sources and machinery — Forestry Other mobile sources and machinery — Military**
ISIC:		
Version	**Guidebook 2013**	

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Contents

1 Overview

This chapter provides a common tool for the estimation of combustion emissions from mobile sources. Categories excluded from this guidance are:

- aviation
- road transport
- railways
- and navigation (including small boats).

This chapter covers a mixture of 'other' equipment which is distributed across a wide range of industry sectors. However, despite this diversity there is the common theme that all the equipment covered uses reciprocating engines, fuelled with liquid hydrocarbon-based fuels. They comprise both diesel- (compression ignition), petrol- and LPG- (spark ignition) engined machinery.

More specifically, the types of equipment covered in this chapter are:

- 1.A.2.f ii mobile combustion in manufacturing industries and construction land-based mobile machinery;
- 1.A.4.a.ii commercial and institutional land-based mobile machinery;
- 1.A.4.b ii mobile combustion used in residential areas: household and gardening land-based mobile machinery;
- 1.A.4.c ii off-road vehicles and other machinery used in agriculture/forestry land-based mobile machinery (excluding fishing);
- 1.A.5.b other mobile including military land based mobile machinery.

For all these types of equipment, the emissions originate from the combustion of fuel to power the equipment.

In terms of relative size, the importance of these sectors varies from sector to sector and from nation to nation. In many cases it will be small, not a key source, but the contributions from some sectors to some nations' inventories may be moderately important.

The species for which it is the more important are SO_2, NO_x, CO_2 PM, CO and non-methane volatile organic compounds (NMVOCs) with the relative importance of the species depending on the type of engine, CI or SI, and the type of equipment. The emissions of CO_2 and SO_2 are predominantly fuel-based and independent of engine technology/type of equipment.

Furthermore, there is also the possibility that some double accounting could occur if the total amounts of petrol and diesel used by a nation are assumed to be combusted in road transport. Much of the equipment considered in this chapter is likely to be fuelled from the same sources, and therefore calculating and adding these emissions to the road transport emissions would double count the emissions from this fuel because of this non-road mobile machinery.

2 Description of sources

2.1 Process description

Exhaust emissions from 'other non-road mobile machinery' arise from the combustion of diesel, gasoline and LPG in non-road mobile machinery. In terms of the three most important sectors, this is shown in the flow diagram in Figure 2.1.

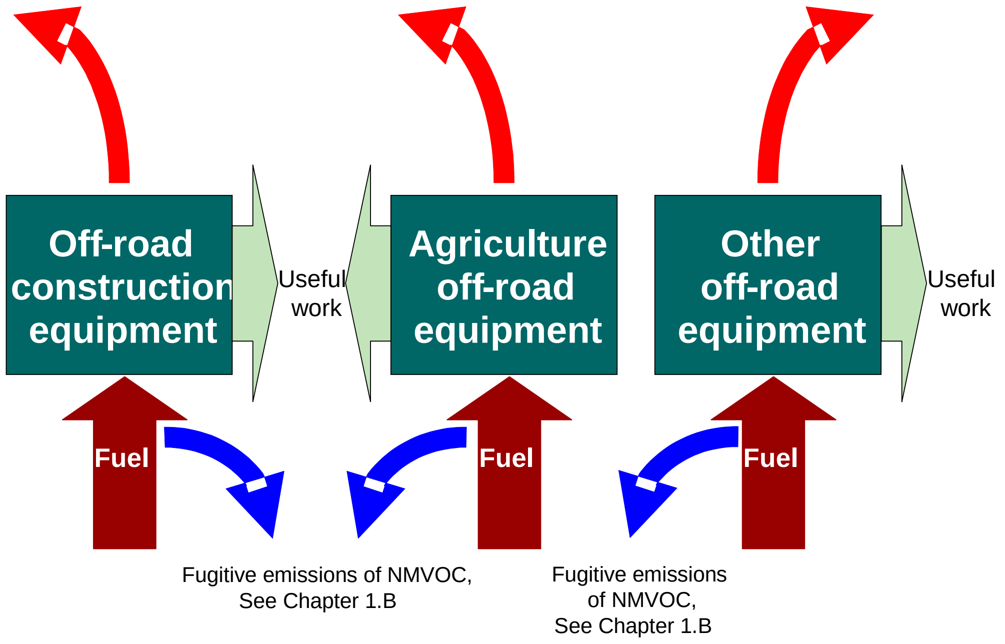

Figure 2-1 Flow diagram for the contribution from railways to mobile sources combustion emissions

2.2 Types of equipment used

The types of equipment used form a very broad list. Several inventorying systems have developed detailed lists of these. 0 provides an example of these, based on the SNAP nomenclature.

In some cases, there is a risk of overlapping with other sources, e.g. fire trucks, refuse collectors, sewage trucks, road tankers, etc. because it is not always clear whether or not these utility vehicles are part of national on-road vehicle inventories. It is good practice to count these as on-road vehicles. However, if this is not possible due to the available fuel statistics, they could be included in the Off-road source category. In such cases this needs to be clearly documented.

In addition, some of the vehicles have a second combustion engine in order to operate their special equipment. These additional machines should fall under 'off-road' machinery, if possible. If the fuel split between the first and second engines is not available, the emissions due to this second engine can be reported under the same source category as the emissions from the first engine.

In some other cases, machinery is mobile in principle, but actually stays at the same site for long periods, or is only mobile within a small radius, e.g., some excavators and cranes. In this case, it is proposed to consider these machines as ‘Other mobile sources and machinery’.

Moreover, there are large mobile generator sets, e.g. above 1 MW, which are mobile but in reality are not often moved. With regard to this equipment, there is a real risk of misallocation, because in many inventories such generator sets are most likely to fall into the categories of SNAP sectors 1, 2 or 3 under Stationary engines.

A further risk of misallocation occurs in the sector Airports, because many of the ground activities covered there are carried out by off-road machines and equipment, which fall into this source category. Therefore, there is a risk of double counting.

The reciprocating engines used in this mixture of other mobile sources comprise diesel, four-stroke and two-stroke petrol, and LPG engines. The diesel (CI) engines range from large diesel engines > 200 kW (installed in cranes, graders/scrapers, bulldozers, etc.) to small diesel engines, around 5 kW, fitted to household and gardening equipment (e.g. lawn and garden tractors, leaf blowers, etc). Petrol-fuelled engines are virtually all of smaller power, typically less than 10 kW, and are principally used in household and gardening equipment, with a small number being used in industry (e.g. to power fork-lift trucks or small electrical generator sets). The equipment used in each application is described in more detail.

2.3 Industry

In order to identify the vehicles and machinery dealt with, it is helpful to provide a brief description of the types of vehicles and machinery included in 0. A summary of the engine types used in off-road machinery is also given in 0.

Asphalt pavers/concrete pavers (SNAP 080801)

These wheeler crawler-type machines (road pavers, slurry seal pavers, chip spreaders, large pavement profilers, and pavement recyclers) are street finishers which use asphalt or concrete as paving material. They are equipped with three- to six-cylinder diesel engines with a power output between 15 and 160 kW. Larger engines are turbo charged.

Plate compactor/tampers/rammers (SNAP 080802)

Small compaction equipment is powered by two-stroke gasoline engines having about 1 to 3 kW output; medium-size and large-size compaction equipment is equipped either with four-stroke gasoline engines or with diesel engines of 2 to 21 kW. Tampers and rammers are tools for surface treatment operated by two-stroke petrol engines of about 1–3 kW power output. Large rammers fall under ‘Other construction equipment’.

Rollers (SNAP 080803)

These machines (e.g. smooth drum rollers, single drum rollers, tandem rollers, padfoot rollers), used for earth compaction, are all diesel engine equipped having a power output in the range of 2 to 390 kW.

Trenchers/mini excavators (SNAP 080804)

These crawler or wheel-type machines can be considered as a special type of a mini-excavator used for digging trenches. Some are equipped with special tools, e.g. cable plows. They are diesel engines equipped with a power output of 10 to 40 kW.

Excavators (wheel / crawler type) (SNAP 080805)

Excavators are mainly used for earth movement and loading work. Hydraulic and cable models are covered by this category. Some have special tools like fork arms, telescopic booms, rammers, etc. Excavators can be divided into three classes. Small ones used for digging work to put pipes or cables into the earth have a power output of about 10 to 40 kW. They are equipped with two- to four-cylinder diesel engines and fall under the sub-category ‘Trenchers’. Medium-size hydraulic and dragline excavators used for general earthmoving work have a power output of about 50 to 500 kW. The engines have 4 to 12 cylinders. Many of the engines are turbo charged. Above 500 kW starts the group of large excavators and crawler tractors used for heavy earthwork and raw material extraction. The power output can be as high as several thousand kW, having 8 to 16 cylinders. All engines are turbo charged.

Cement and mortar mixers (SNAP 080806)

Small concrete mixers run on electric power or four-stroke petrol engines of about 1 to 7.5 kW power output. Larger mixers run on diesel engines having a power output of 5 to 40 kW.

Cranes (SNAP 080807)

Cranes (e.g. crawler mobile cranes, carry cranes, tower cranes) are all either electricity (if they operate quasi-stationary) or diesel-engine powered, having an output of about 100 to 250 kW. Models with a special design can have a significantly higher power output. (Note: tower cranes are mainly driven by electrical engines.)

Graders/scrapers (SNAP 080808)

Graders (e.g. articulated steered or wheel-steered) are used to level surfaces. They have a power output of about 50 to 190 kW. Scrapers (e.g. wheel-steered tractor scrapers, articulated steered tractor scrapers) are used for earthwork. They have a power output of about 130–700 kW and are all diesel-engine powered.

Off-highway trucks (SNAP 080809)

These are large trucks (e.g. rigid frame dumpers, wheel-steered mine dumpers, articulated-steered mine dumpers, etc.) used for heavy goods transport on construction sites and quarries (but not on public roads), e.g., to transport sand, rocks, etc. They run on diesel engines of 300 to 500 kW power output, nearly all turbo charged.

Bulldozers (SNAP 080810)

This category includes wheel dozers, articulated-steered dozers, crawler dozers, crawler loaders, etc. They are mainly used for demolishing and earthmoving work and are all diesel engine equipped with a power output of about 30 to 250 kW. Large engines are turbo charged (some might have a significantly larger power output).

Tractors / loaders/backhoes (SNAP 080811)

Tractors are used for general transport work. They are all diesel engine equipped with a power output of 25 to 150 kW. Loaders (e.g. wheel loaders, articulated steered wheel loaders, landfill compactors) are used for earth work or can be equipped with special tools (e.g. with brush cutters, forearms, handling operation devices, snowthawers, etc.). Crawler loaders should be treated under ‘Bulldozers’. They are all diesel engine equipped. As is the case for excavators, loaders fall into three classes: ‘Minis’ have about 15 to 40 kW and are equipped with three- or four-cylinder diesel engines, with normal aspiration; medium-size loaders have a power output between 40 to 120 kW; large loaders go up to about 250 kW. The medium and large size engines are, in general, turbo charged. Backhoes are combinations of a wheel loader and a hydraulic excavator. They run on diesel engines with a power output of about 10 to 130 kW.

Skid steer loaders (SNAP 080812)

These are small wheel loaders which appeared on the market only a few years ago with great success. Some of them also have independent steering. They run on diesel engines having a power output between 15 to 60 kW.

Dumpers/tenders (SNAP 080813)

Small dumpers and tenders (e.g. wheel steered site dumpers, articulated steered site dumpers, crawler dumpers, etc.) are used for transport of goods at construction sites. Most of them run with diesel engines with a power output of about 5 to 50 kW some have four-stroke petrol engines with a power output between 5 to 10 kW.

Aerial lifts (SNAP 080814)

Small aerial lifts (< 2 kW) run mainly on electrical engines, while only some on small (mainly two-stroke) petrol engines with a power output of 3 to 10 kW. Large aerial lifts and work platforms are mounted on a truck chassis and are operated by separate engines with a power output of 5 to 25 kW or by a vehicle engine utilizing a pneumatic system. Attention must be paid to avoid double counting with the category ‘On-road vehicles’.

Fork lifts (SNAP 080815)

Forklift trucks, from small ones like pallet stacking trucks to large ones like stacking straddle carriers, are equipped with electrical or internal combustion engines. Electrical engines are mostly used for indoor material handling. The internal combustion engines run with petrol or LPG and/or diesel fuel. In general, they have a power output between 20 and 100 kW. The engine displacement is between 1.5 to 4 litres for four-stroke petrol/LPG engines and 2.5 to 6 litres for diesel engines.

Generator sets (SNAP 080816)

There are three main groups of power packs used. Small ones which can be carried by one or two persons. They have an output of 0.5 to 5 kW and are powered by four-stroke engines. Some of the very small sets still run with two-stroke engines. Medium ones which can be put on small one axle/two- or four-wheel trailer. They are three- or four-cylinder diesel-engine powered and have an output of about 5 to 100 kW. Larger engines are turbo charged. Larger power packs are actually small mobile power plants, put into a container and having a power output of 100 to about 1 000 kW. Nearly all engines are turbo charged. Generator sets above 1 000 kW are not classed as mobile machinery.

Pumps (SNAP 080817)

Mobile pumps are offered with a power range between 0.5 to 70 kW. Many of the pumps in use are operated with electric engines. If not, all types of fuels are used except LPG. However, above about 10 kW power output two-stroke and above 20 kW power output four-stroke petrol engines are not readily needed anymore.

Air/gas compressors (SNAP 080818)

Nearly all of the small compressors used for handicraft purposes run with electric engines. Large compressors used for construction works are equipped with diesel engines with a power output between 10 and 120 kW.

Welders (SNAP 080191)

Small mobile welders (< 10 kW) are also offered with four-stroke petrol engines, all larger ones are diesel-engine equipped and go up to about 40 kW.

Refrigerating units (SNAP 080820)

Diesel engines are used to operate refrigerators which are mounted on trucks and train wagons for cooling purposes. The power output of such units is in the range of 10 to 20 kW.

Other general industrial equipment (SNAP 080821)

These are sweepers, scrubbers, broomers, pressure washers, slope and brush cutters, swappers, piste machines, ice rink machines, blowers, vacuums, etc. not belonging to on-road vehicles. Petrol and diesel engines are used.

Other material handling equipment (SNAP 080822)

These are for example conveyors, tunnel locomotives, snow clearing machines, industrial tractors, pushing tractors. Mainly diesel engines are used.

Other construction equipment (SNAP 080823)

Under this heading falls paving and surfacing equipment, bore/drill rigs, crushing equipment, peat break machines, concrete breakers/saws, pipe layers, etc. Mainly diesel and two-stroke gasoline engines are used.

2.4 Agriculture and forestry

Two-Wheel Tractors (SNAP 080601)

Tractors are used in agriculture (and forestry) as universal working machines. Very small one axle/two wheels tractors only have a few kW power output (about 5 to 15 kW) and are equipped with two-stroke or four-stroke petrol or with diesel engines.

Agricultural tractors (SNAP 080602)

Two axles/four wheel tractors (there are also some articulated-wheel and crawler-type tractors which fall under this category) are nearly all exclusively diesel-engine powered and have a power output of between 20 and about 250 kW. The main power range used for agricultural purposes is 100 to 130 kW for the first tractor and 20 to 60 kW for the second one. For vineyards, somewhat smaller tractors are used, having a typical power output of 30 to 50 kW. (In forestry, the same tractors are used as in agriculture, having a power range of about 60 to 120 kW.) In general, over the last 30 years there has been a clear tendency towards higher power outputs and towards four-wheel drive. Larger four- and six-cylinder diesel engines are equipped with turbo charger.

Harvesters/combiners (SNAP 080603)

These machines are used mainly for harvesting grain (chaff, beet, etc.). They have a power output between 50 and 150 kW and all are diesel engine equipped.

Others (SNAP 080604)

Under this heading falls all other agricultural equipment, e.g. sprayers, manure distributors, mowers, balers, tillers, swatchers. They are mainly diesel engines, but two- and four-stroke gasoline engines are also used in these machines. The power output is in the range of 5 to 50 kW.

Professional chain saws/clearing saws (SNAP 080701)

These are chain saws for professional use; all are two-stroke petrol-engine driven with a power output of about 2 to 6 kW.

Forest tractors/harvesters/skidders (SNAP 080702)

These are vehicles (e.g. wheel forwarder, crawler forwarder, grapple skidder, cable skidder, etc.) used for general transport and harvesting work in forests. They are all diesel engine equipment with a power output of about 25 to 75 kW.

Others (SNAP 080703)

This heading covers machines such as tree processors, haulers, fellers, forestry cultivators, shredders and log cultivators. They are mainly diesel engine equipment; some use two-stroke engines.

2.5 Military, land based

In Military (SNAP 080100), no further split is provided. It is assumed that all equipment is diesel-engine powered.

2.6 Household and gardening

Trimmers/edgers/brush cutters (SNAP 080901)

This equipment is mainly two-stroke petrol engine equipped and has about 0.25 to 1.4 kW power output.

Lawn mowers (SNAP 080902)

Mowers are either two-stroke or four-stroke petrol-engine powered, having a power output between 0.5 and 5 kW. Some rear engine riding mowers are relatively powerful, used to treat large lawn surfaces. Mainly one- or two-cylinder diesel engines and four-stroke petrol engines are used, having a power output of about 5 to 15 kW. Front mowers are professional-like equipment for lawn cutting and mainly diesel or four-stroke petrol-engine powered. The power output ranges from 1.5 to 5 kW, displacements between 100 and 250 ccm.

Hobby chain saws (SNAP 080903)

Do-it-yourself motor saws are mainly equipped with two-stroke petrol engines (some have electric engines). Small (hobby) motor saws have a power output of about 1 to 2 kW (professionally-used motor saws of about 2 to 6 kW, cf. sector 'Forestry').

Snow mobiles/skidoos (SNAP 080904)

These are small 'moped-like' snow vehicles, equipped with two- and four-stroke gasoline engines with a power output of 10 to 50 kW.

Other household and gardening equipment (SNAP 080905)

Under this heading lawn and garden tractors, wood splitters, snow blowers, tillers, etc. are covered.

Other household and gardening vehicles (SNAP 080906)

This heading covers non-road vehicles like all-terrain vehicles, off-road motor cycles, golf carts, etc.

2.7 Emissions

The emissions originate from the combustion of fuel in CI or SI engines to power the machinery considered. The species for which it is the more important are CO_2 and SO_2 for the fuel-based emissions, with NO_x, PM, CO and NMVOCs as combustion by-products. Concentrations vary with diesel engines (fuel lean) producing more PM and NO_x, whilst petrol engines (fuel rich) produce more CO and NMVOCs. The emissions also differ between two-stroke and four-stroke gasoline engines, and the age of the equipment (see subsection 2.4, Controls, of the present chapter).

2.8 Contribution to total emissions

Typical contributions to total particulate emissions for the four NFR sectors within this chapter are all significant, ranging from 0.1 % to 10.7 %.

Table 2-1 Contribution to total particulate matter emissions from the 2004 EMEP database (WebDab)

NFR Sector	Data	PM_{10}	$PM_{2.5}$	TSP
1.A.3.d.ii — National navigation*	No of countries reporting	20	20	19
	Lowest value	0.0 %	0.0 %	0.0 %
	Typical contribution	0.5 %	0.7 %	0.4 %
	Highest value	1.7 %	2.2 %	1.2 %
1.A.4.c — Agriculture/Forestry/Fishing	No of countries reporting	23	23	23
	Lowest value	0.1 %	0.1 %	0.2 %
	Typical contribution	4.3 %	5.6 %	3.4 %
	Highest value	17.4 %	17.9 %	21.9 %
1.A.5.b — Other, Mobile (including military)	No of countries reporting	8	7	8
	Lowest value	0.0 %	0.0 %	0.0 %
	Typical contribution	5.6 %	1.8 %	10.7 %
	Highest value	31.3 %	11.6 %	68.3 %
* Includes contribution from chapter on shipping activities				

In total, and looking at the pollutants covered by the United Nations Economic Commission for Europe (UNECE) protocols only, it can be assumed that the sectors covered by this chapter contribute significantly to total NO_x and VOC emissions in most countries.

An indication of groups of major sub-sources, at least for Western European countries, can currently be obtained by analyzing the Environmental Protection Agency (EPA) data. Table 2-2 shows a first broad evaluation.

Table 2-2 Contribution of 'off-road' machinery to total emission [in percent], as estimated by US-EPA for different non-attainment areas

Pollutant	VOC	NO_x	CO	PM
Total over all areas[1)]	10.9	15.9	7.3	1.4
Total by areas	4–19	8–29	3–14	0.3–5.2
by category				
Agriculture	0.1–1.2	0.5–11	0.02–0.6	0.02–0.8
Airport service	0–0.25	0–3.5	0–0.8	0–0.2
Recreational marine	0–6.5	0–1.5	0–0.8	0–0.3
Construction	0.5–1.8	3–23	0.2–1.8	0.1–2.1
Industry	0.1–0.8	0.3–3.0	0.3–2.9	0.02–0.4
Lawn and garden	1.9–10.5	0.1–0.5	0.02–4.5	0.02–0.2
Light commercial	0.3–2.3	0.1–0.5	1.0–7.5	0.01–0.15
Forestry	0.02–0.16	0–0.1	0.02–0.35	0–0.3
Recreation	0.2–2.1	0–0.1	0.2–3.9	0–0.1

Note
[1)] Average of two different industries.

In the light of these results, the following sectors/sub-sectors seem of greatest importance for the different pollutants:

- for VOC: recreational marine (part of 'inland waterways')

  lawn and garden (part of 'household and gardening')
- for NO_x: agriculture

  construction (part of 'industry')
- for CO: light commercial (part of 'industry')

  lawn and garden (part of 'household and gardening')
- for PM: construction (part of 'industry')

This means that data collection for forestry and recreation (SNAP activity 080105 'Household and gardening') are of lower relevance for these pollutants. However, these sectors are of some relevance for emissions of heavy metals, in particular lead, due to the consumption of gasoline (see

Table 2-4). In any case, this assessment does not need to be true for all European countries.

When comparing emissions of PM_{10} to those of the more physiologically toxic $PM_{2.5}$, whilst the general patterns of importance remain, the significance of $PM_{2.5}$ from off-road machinery to the total emissions is higher than for total PM_{10}. This is because internal combustion engines produce PM with a much smaller mean size than, for example, many industrial processes.

2.9 Controls

Gaseous emissions can be controlled by two mechanisms: control of the combustion technology which can be combined with exhaust gas treatment and control of the fuel quality. Both these measures are used for non-road mobile machinery (NRMM).

A number of technical control technologies are available, including exhaust gas recirculation (EGR) and selective catalytic reduction (SCR) to control NO_x emissions, and diesel particulate filters (DPF) to control PM emissions. These technologies are better developed for the diesel engines used in road transport (particularly powering heavy-duty vehicles) and are currently only rarely used in conjunction with NRMM.

Within Europe emissions from NRMM are regulated by the non-road mobile machinery directives. The emission directives list specific emission limit values (g/kWh) for CO, VOC, NO_x (or VOC + NO_x) and TSP, depending on engine size (kW for diesel, ccm for gasoline) and date of implementation (referring to engine market date).

For diesel, Directives 97/68/EC and 2004/26/EC relate to non-road machinery other than agricultural and forestry tractors and the directives have different implementation dates for machinery operating under transient and constant loads. The latter directive also comprises emission limits for railway machinery. For tractors the relevant directives are 2000/25 and 2005/13. For gasoline, Directive 2002/88/EC distinguishes between hand-held (SH) and non hand-held (NS) types of machinery.

Table 2-3 Overview of EU emission directives relevant for diesel-fuelled non-road machinery

Stage/engine size [kW]	CO [g/kWh]	VOC	NO_x	$VOC+NO_x$	PM	Diesel machinery EU Directive	Diesel machinery Implement. date Transient	Diesel machinery Implement. date Constant	Tractors EU Directive	Tractors Implement. date
Stage I										
37<=P< 75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	1/7 2001
Stage II										
130<=P< 560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
75<=P< 130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
37<=P< 75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
18<=P< 37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA										
130<=P< 560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
75<=P< 130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
37<=P< 75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
19<=P< 37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB										
130<=P< 560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
75<=P< 130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
56<=P< 75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
37<=P< 56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV										
130<=P< 560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	1/1 2014
56<=P< 130	5	0.19	0.4	-	0.025		1/10 2014			1/10 2014

Table 2-4 Overview of the EU Emission Directive 2002/88/EC for gasoline-fuelled non-road machinery

	Category	Engine size [ccm]	CO [g/kWh]	HC [g/kWh]	NO_x [g/kWh]	$HC+NO_x$ [g/kWh]	Implementation date
	Stage I						
Handheld	SH1	S< 20	805	295	5.36	-	1/2 2005
	SH2	20=< S< 50	805	241	5.36	-	1/2 2005
	SH3	50=< S	603	161	5.36	-	1/2 2005
Non handheld	SN3	100=< S< 225	519	-	-	16.1	1/2 2005
	SN4	225=< S	519	-	-	13.4	1/2 2005
	Stage II						
Handheld	SH1	S< 20	805	-	-	50	1/2 2008
	SH2	20=< S< 50	805	-	-	50	1/2 2008
	SH3	50=< S	603	-	-	72	1/2 2009
Non handheld	SN1	S< 66	610	-	-	50	1/2 2005
	SN2	66=< S< 100	610	-	-	40	1/2 2005
	SN3	100=< S< 225	610	-	-	16.1	1/2 2008
	SN4	225=< S	610	-	-	12.1	1/2 2007

3 Methods

3.1 Choice of method

The method of choice will vary from source type to source type. In Figure 3-1 a procedure is presented to select the methods for estimating the emissions from NRMM. This decision tree is applicable to all nations. It basic concepts are:

- if detailed information is available then use as much as possible;
- if this source category is a key source, then a Tier 2 or Tier 3 method must be used for estimating the emissions.

For Tier 1, emissions are estimated using average emission factors for the broad NFR categories fuel type and broad engine type (two-stroke or four-stroke). For Tier 2, emissions are separated into more detailed classifications for the purposes of estimating emissions. This detailed level classifies the equipment into the fuel types and layers of engine technology. The latter layers are stratified according to the EU emission legislation stages, and three additional layers are added to cover the emissions from engines prior to the first EU legislation stages. Further disaggregation to the equipment level (including specific operational data and size of engine) is used for Tier 3.

For non-key sources a Tier 1 method is appropriate. Several methods to calculate emissions can be foreseen. In all cases, emission estimates have to be based on a mixture of (some) hard facts and a (large) number of assumptions. It is therefore important to define a method to be used for the estimation which builds upon as many hard facts as possible, reducing at the same time the number of assumptions. Therefore, the methodology proposed varies from source type to source type.

It is acknowledged that for these NFR codes there may be difficulties with activity data because of the number and diversity of the equipment types, locations and usage patterns associated with the different types of machinery. Furthermore, statistical data on fuel consumption by off-road vehicles are often not collected and published. In this case higher Tier methods will be needed to calculate emissions because these are more dependent on technology and operating conditions than the emission from road transport (the other principal consumer of the diesel and gasoline fuels).

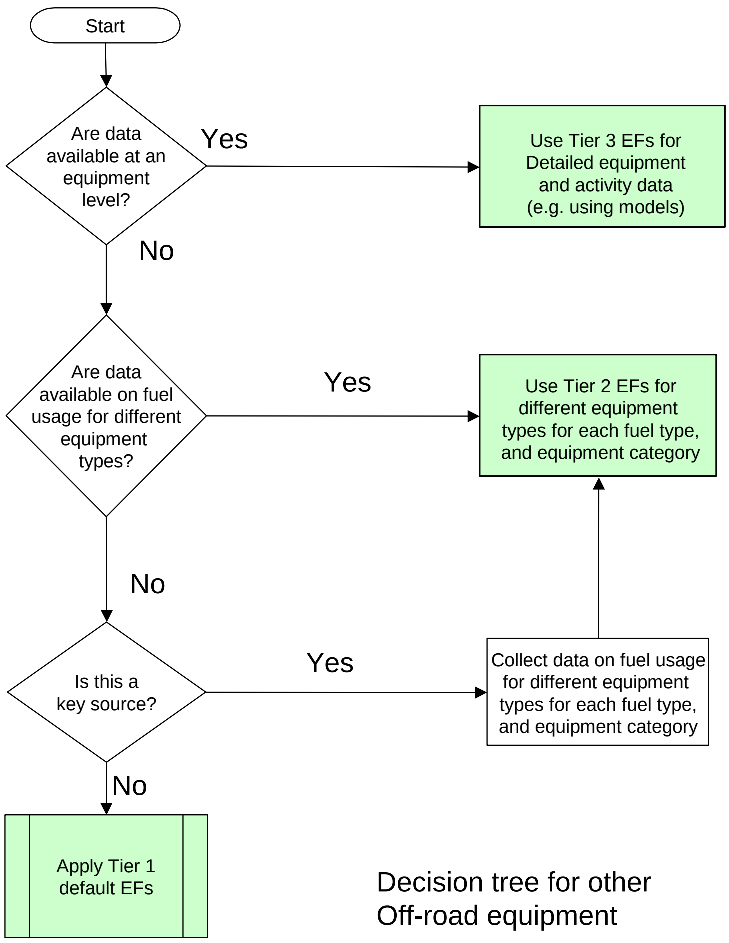

Figure 3-1 Decision tree for other off-road mobile machinery

3.2 Tier 1 default approach

3.3 Algorithm

For the Tier 1 approach emissions are estimated using the total fuel consumed in each of the source categories covered in this chapter. For each source category the algorithm is:

$$E_{pollutant} = \sum_{fuel\,type} FC_{fuel\,type} \times EF_{pollutant,\,fuel\,type} \qquad (1)$$

Where:

$E_{pollutant}$	=	the emission of the specified pollutant,
$FC_{fuel\ type}$	=	the fuel consumption for each fuel (diesel, LPG, four-stroke gasoline and two-stroke gasoline) for the source category,
$EF_{pollutant}$	=	the emission factor for this pollutant for each fuel type.

This equation is applied at the national level, using annual national fuel consumption for the off-road source categories included in this chapter.

Emission factors are provided for each type of fuel for each off-road source category.

3.4 Default emission factors

Table 3-1 presents the emission factors for Tier 1. The Tier 1 emission factors are based on data from the Danish Inventory; Winther & Nielsen (2006) with heavy metals and POPs taken from EMEP/Corinair 2006. The approach for deriving the Tier 1 and 2 emission factors for this Guidebook is outlined in 0.

For some pollutants (heavy metals, SO_2 and CO_2,) the emission factors are independent of the equipment technology, i.e. are simply fuel derived. For the various size fractions of particulate matter and emissions of POPs, whilst these emission factors do vary with equipment technology, they can be taken as a constant proportion of the PM_{10} or NMVOC emissions. Hence the key species, which do vary with differing equipment technologies, are PM_{10}, NO_x, NMVOC and CO.

Table 3-1 Tier 1 emission factors for off-road machinery

Tier 1 emission factors				
Fuel	NFR sector	Pollutant	Units	Emission factor
Diesel	1.A.4.c.ii-Agriculture	CH_4	g/tonnes fuel	55
		CO	g/tonnes fuel	10939
		CO_2	kg/tonnes fuel	3160
		N_2O	g/tonnes fuel	136
		NH_3	g/tonnes fuel	8
		NMVOC	g/tonnes fuel	3366
		NO_x	g/tonnes fuel	35043
		PM_{10}	g/tonnes fuel	1738
		$PM_{2.5}$	g/tonnes fuel	1738
		TSP	g/tonnes fuel	1738
	1.A.4.c.ii-Forestry	CH_4	g/tonnes fuel	33
		CO	g/tonnes fuel	7834
		CO_2	kg/tonnes fuel	3160
		N_2O	g/tonnes fuel	138
		NH_3	g/tonnes fuel	8
		NMVOC	g/tonnes fuel	2020
		NO_x	g/tonnes fuel	29093
		PM_{10}	g/tonnes fuel	976
		$PM_{2.5}$	g/tonnes fuel	976
		TSP	g/tonnes fuel	976
	1.A.2.f.ii and 1.A.4.a.ii	CH_4	g/tonnes fuel	55
		CO	g/tonnes fuel	10722
		CO_2	kg/tonnes fuel	3160
		N_2O	g/tonnes fuel	135
		NH_3	g/tonnes fuel	8
		NMVOC	g/tonnes fuel	3385
		NO_x	g/tonnes fuel	32792
		PM_{10}	g/tonnes fuel	2086
		$PM_{2.5}$	g/tonnes fuel	2086
		TSP	g/tonnes fuel	2086
	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	Cadmium	mg/kg fuel	0.010
		Copper	mg/ kg fuel	1.70
		Chromium	mg/ kg fuel	0.050
		Nickel	mg/ kg fuel	0.07
		Selenium	mg/ kg fuel	0.01
		Zinc	mg/ kg fuel	1.00
		Benz(a)anthracene	µg/kg fuel	80
		Benzo(b)fluoranthene	µg/kg fuel	50

Tier 1 emission factors				
Fuel	NFR sector	Pollutant	Units	Emission factor
		Dibenzo(a,h)anthracene	µg/kg fuel	10
		Benzo(a)pyrene	µg/kg fuel	30
		Chrysene	µg/kg fuel	200
		Fluoranthene	µg/kg fuel	450
		Phenanthene	µg/kg fuel	2500
LPG	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	CH_4	g/tonnes fuel	354
		CO	g/tonnes fuel	4823
		CO_2	kg/tonnes fuel	2990
		N_2O	g/tonnes fuel	161
		NH_3	g/tonnes fuel	10
		NMVOC	g/tonnes fuel	6720
		NO_x	g/tonnes fuel	61093
		PM_{10}	g/tonnes fuel	225
		$PM_{2.5}$	g/tonnes fuel	225
		TSP	g/tonnes fuel	225
Gasoline: four-stroke	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	CH_4	g/tonnes fuel	1956
		CO	g/tonnes fuel	770368
		CO_2	kg/tonnes fuel	3197
		N_2O	g/tonnes fuel	59
		NH_3	g/tonnes fuel	4
		NMVOC	g/tonnes fuel	17602
		NO_x	g/tonnes fuel	7117
		PM_{10}	g/tonnes fuel	157
		$PM_{2.5}$	g/tonnes fuel	157
		TSP	g/tonnes fuel	157
Gasoline: two-stroke	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	CH_4	g/tonnes fuel	2200
		CO	g/tonnes fuel	620793
		CO_2	kg/tonnes fuel	3197
		N_2O	g/tonnes fuel	17
		NH_3	g/tonnes fuel	3
		NMVOC	g/tonnes fuel	242197
		NO_x	g/tonnes fuel	2765
		PM_{10}	g/tonnes fuel	3762
		$PM_{2.5}$	g/tonnes fuel	3762
		TSP	g/tonnes fuel	3762

Gasoline	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	Cadmium	mg/kg fuel	0.01
		Copper	mg/kg fuel	1.70
		Chromium	mg/kg fuel	0.05
		Nickel	mg/kg fuel	0.07
		Selenium	mg/kg fuel	0.01
		Zinc	mg/kg fuel	1.00
		Benz(a)anthracene	µg/kg fuel	75
		Benzo(b)fluoranthene	µg/kg fuel	40
		Dibenzo(a,h)anthracene	µg/kg fuel	10
		Benzo(a)pyrene	µg/kg fuel	40
		Chrysene	µg/kg fuel	150
		Fluoranthene	µg/kg fuel	450
		Phenanthene	µg/kg fuel	1200

For land based military emissions, use emission factors for 1.A.2.f.ii as no other data are available.

Black carbon: For agriculture, forestry, industry and gasoline machinery, the following BC fractions of PM (f-BC) are proposed: 0.57, 0.65, 0.62 and 0.05, c.f. Appendix D.

SO_2: The emissions of SO_2 are estimated by assuming that all sulphur in the fuel is transformed completely into SO_2 using the formula:

$$E_{SO2} = 2 \sum_j \sum_l k_{S,l}\, b_{j,l}$$

where

$k_{S,l}$ = weight related sulphur content of fuel of type l [kg/kg],

$b_{j,l}$ = total annual consumption of fuel of type l in [kg] by source category j.

For the actual figure of $b_{j,l}$ the statistical fuel consumption should be taken, if available.

Lead: Emissions of lead are estimated by assuming that 75 % of lead contained in the fuel is emitted into air. The formula used is:

$$E_{Pb} = 0.75 \sum_{j} \sum_{l} k_{Pb,l}\, b_{j,l}$$

where

$k_{Pb,l}$ = weight-related lead content of fuel of type l in [kg/kg].

Since the simple methodology outlined above averages over different types of engines, using different types of fuels, it can provide only broad estimates at best.

3.5 Activity data

Activity data should be collected from national statistics. Where there is no explicit off-road machinery consumption statistics, it is good practice to use sample, survey or industry data to define an appropriate split for mobile and stationary combustion. Where no other data are available, it should be assumed that all gasoline and diesel-fuel consumption for the NFR categories in this chapter is for off-road machinery.

3.6 Tier 2 technology-dependent approach

3.7 Algorithm

The generic algorithm for calculating emissions for each category (industry, agriculture and forestry, military land-based and household and gardening) using the Tier 2 methodology is:

$$E_i = \sum_{j} \sum_{t} FC_{j,t} \times EF_{i,j,t}$$

where:

E_i = mass of emissions of pollutant i during the inventory period,

$FC_{j,t}$ = fuel consumption of fuel type j by equipment category c and of technology type t,

$EF_{i,j}$ = average emission factor for pollutant i for fuel type j for equipment category c and of technology type t,

i = pollutant type,

j = fuel type (diesel, four-stroke gasoline, LPG and two-stroke gasoline),

t = off-road equipment technology: < 1981, 1981–1990, 1991–Stage I, Stage I, Stage II, Stage IIIA).

In essence this involves sub-dividing the fuel consumption of fuel type j used by the NFR sectors into the different technology types such that the summation in the Tier 2 algorithm is equal to the single term in the Tier 1 algorithm, i.e.

$$\sum_{t} FC_{j,t} = FC_j$$

3.8 Emission factors

Table 3-2 presents the emission factors for Tier 2. The Tier 2 emission factors are based on data from the Danish Inventory; Winther & Nielsen (2006). For heavy metals and POPs, the emission factors for Tier 1 must be used (Table 3–1). The emission factors are grouped according to the EU emission legislation stages, and three additional layers are added to cover the emissions from engines prior to the first EU legislation stages. The approach for deriving the Tier 2 emission factors for this guidebook is outlined in 0.

For some pollutants (heavy metals, SO_2 and CO_2,) the emission factors are independent of the equipment technology, i.e. are simply fuel derived. The key species, which do vary with differing equipment technologies, are particulate matter, NO_x, NMVOC and CO.

Table 3-2 Tier 2 emission factors for off-road machinery

Tier 2 emission factors									
				Technology					
Fuel	NFR Sector	Pollutant	Units	< 1981	1981-1990	1991-Stage I	Stage I	Stage II	Stage IIIA
Diesel	1.A.4.c.ii: Agriculture	CH_4	g/tonnes fuel	116	96	67	25	19	13
		CO	g/tonnes fuel	17995	16103	13080	6035	5956	5964
		CO_2	kg/tonnes fuel	3160	3160	3160	3160	3160	3160
		N_2O	g/tonnes fuel	122	129	137	137	138	139
		NH_3	g/tonnes fuel	7	7	8	8	8	8
		NMVOC	g/tonnes fuel	7111	5917	4113	1561	1170	786
		NO_x	g/tonnes fuel	29900	37351	48674	30999	20610	13594
		PM_{10}	g/tonnes fuel	5137	3755	1644	832	627	581
		$PM_{2.5}$	g/tonnes fuel	5137	3755	1644	832	627	581
		TSP	g/tonnes fuel	5137	3755	1644	832	627	581
	1.A.4.c.ii: Forestry	CH_4	g/tonnes fuel	122	96	73	24	19	13
		CO	g/tonnes fuel	19014	16045	13553	5899	5940	5947
		CO_2	kg/tonnes fuel	3160	3160	3160	3160	3160	3160
		N_2O	g/tonnes fuel	123	131	137	138	139	139
		NH_3	g/tonnes fuel	7	7	8	8	8	8
		NMVOC	g/tonnes fuel	7484	5875	4465	1492	1169	780
		NO_x	g/tonnes fuel	33028	44030	49127	31571	20593	13494
		PM_{10}	g/tonnes fuel	5493	3731	2044	787	595	573
		$PM_{2.5}$	g/tonnes fuel	5493	3731	2044	787	595	573
		TSP	g/tonnes fuel	5493	3731	2044	787	595	573
	1.A.2.f.ii and 1.A.4.a.ii	CH_4	g/tonnes fuel	132	114	94	28	26	19

Tier 2 emission factors									
				Technology					
Fuel	**NFR Sector**	**Pollutant**	**Units**	**< 1981**	**1981-1990**	**1991-Stage I**	**Stage I**	**Stage II**	**Stage IIIA**
		CO	g/tonnes fuel	20690	18890	16018	6502	7061	6866
		CO_2	kg/tonnes fuel	3160	3160	3160	3160	3160	3160
		N_2O	g/tonnes fuel	121	128	135	136	136	136
		NH_3	g/tonnes fuel	7	7	8	8	8	8
		NMVOC	g/tonnes fuel	8143	7019	5766	1718	1588	1178
		NO_x	g/tonnes fuel	26552	33942	43624	31109	22087	16364
		PM_{10}	g/tonnes fuel	6207	4308	3551	967	1031	957
		$PM_{2.5}$	g/tonnes fuel	6207	4308	3551	967	1031	957
		TSP	g/tonnes fuel	6207	4308	3551	967	1031	957
Gasoline: two-stroke	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	CH_4	g/tonnes fuel	2891	3105	2222	2183	1095	
		CO	g/tonnes fuel	754523	701219	621083	620519	695237	
		CO_2	kg/tonnes fuel	3197	3197	3197	3197	3197	
		N_2O	g/tonnes fuel	12	13	16	18	20	
		NH_3	g/tonnes fuel	2	3	3	4	4	
		NMVOC	g/tonnes fuel	318295	341888	244692	240375	120580	
		NO_x	g/tonnes fuel	1050	1145	1852	3445	2495	
		PM_{10}	g/tonnes fuel	7037	6054	3869	3683	4299	
		$PM_{2.5}$	g/tonnes fuel	7037	6054	3869	3683	4299	
		TSP	g/tonnes fuel	7037	6054	3869	3683	4299	
Gasoline: four-stroke	1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii and 1.A.4.c.ii	CH_4	g/tonnes fuel	2059	3731	1975	1912	1677	
		CO	g/tonnes fuel	1218924	1135987	768445	774457	799828	
		CO_2	kg/tonnes fuel	3197	3197	3197	3197	3197	
		N_2O	g/tonnes fuel	56	50	59	59	60	
		NH_3	g/tonnes fuel	4	3	4	4	4	
		NMVOC	g/tonnes fuel	18534	33582	17779	17207	15093	
		NOx	g/tonnes fuel	2412	2985	7129	7088	6742	
		PM_{10}	g/tonnes fuel	148	133	157	159	159	
		$PM_{2.5}$	g/tonnes fuel	148	133	157	159	159	
		TSP	g/tonnes fuel	148	133	157	159	159	

Tier 2 emission factors									
				Technology					
Fuel	NFR Sector	Pollutant	Units	< 1981	1981-1990	1991-Stage I	Stage I	Stage II	Stage IIIA

Reference: Winther & Nielsen (2006) with Heavy Metals and POPs taken from EMEP/Corinair 2006.

Forestry and Agriculture emission factors have been separated as there are significant differences in emission factors. Where national statistics are combined an average of the two can be used.

For land-based military emissions use emission factors for 1.A.2.f.ii as no other data are available. However, be aware that these may underestimate emissions from military sources.

For estimation of emissions of SO_2, heavy metals and POPs, use Tier 1 emission factors in Table 3-1.

Black carbon: For information on BC fractions of PM (f-BC), please refer to Appendix D

3.9 Activity data

Basic national statistics will provide the fuel consumption data for the different NFR categories as used for Tier 1. To apply Tier 2 emission factors these fuel consumption statistics will need to be split by the relative proportion of engine technology (e.g. < 1981, 1981–1990, 1991–Stage I, Stage I, Stage II, Stage IIIA) in use in any particular inventory year. This can be done through country-specific studies (the preferable option) or by using expert judgement from experts in the field of the different off-road machinery categories from trade associations for manufacturers, engineers and distributors by either selecting a particular technology to represent a particular year or by building up year-specific age profiles. Basic data on the estimated life time of different machines is included in 0. This data — combined with industry knowledge to aggregate and weight the contribution of the detailed types to fuel consumption and data on the year of implementation of the different standards — can be used to build a picture of the age profiles for the different categories and technologies.

Alternatively, data derived from Winther & Nielsen (2006) given in the following Tables 3–3 to 3–9 can be used to split the total fuel consumption into engine technology layers for each inventory year.

In the Tables 3–3 and 3–4, the percentage split of total fuel consumption as a function of engine age are given for diesel machinery in 1.A.2.f.ii, 1.A.4.c.ii (Agriculture) and 1.A.4.c.ii (Forestry), and for gasoline two-stroke and four-stroke machinery.

The Tables 3–5 to 3–9 display the layer share of fuel consumption per engine age and inventory year for diesel-fuelled non-road machinery (Tables 3–5 to 3–7) and gasoline-fuelled non-road machinery (Tables 3–8 to 3–9). Only those inventory year/engine age combinations are listed for which fuel is consumed by more than one engine technology layer. For the remaining inventory year/engine age combinations, the engine technology layer which uses the fuel becomes self-explanatory.

See Appendix C for more description of the assumptions behind the aggregated fuel split data given in the Tables 3–3 to 3–9.

The following example explains how to combine the fuel shares per engine age from Table 3–3, with the inventory year specific fuel consumption shares disaggregated into engine ages and emission levels given in Table 3–5. For agricultural machinery, zero-year old engines use 8 % of the total fuel used in this sector. For the inventory year 2002, this 8 % share is further subdivided into fuel consumption shares for Stage 1 (8 %*64 % = 5.12 %) and Stage II (8 %*36 % = 2.88 %). For the inventory year 2001, fuel consumption shares of 8 %*80 % = 6.40 % and 8 %*20 % = 1.60 %) are calculated for the 1991–Stage I and Stage I emission levels, respectively. For the inventory year intervals 1981–1990 and 1991–1998, the fuel used by zero-year old engines refer to the emission levels 1981–1990 and 1991–Stage I, respectively.

Table 3-3 Split (%) of total fuel consumption per engine age (irrespective of inventory year) for diesel-fuelled non-road machinery (1.A.2.f.ii (Industry), 1.A.4.c.ii (Agriculture), 1.A.4.c.ii (Forestry))

Engine age	1.A.4.c.ii Agriculture	1.A.4.c.ii Forestry	1.A.2.f.ii Industry
0	8.00	12.00	8.80
1	7.60	12.00	8.80
2	7.20	12.00	8.80
3	6.79	12.00	8.80
4	6.39	12.00	8.80
5	5.99	12.00	8.80
6	5.59	8.67	8.80
7	5.18	5.33	8.80
8	4.78	2.00	8.80
9	4.38	2.00	6.53
10	3.98	2.00	4.27
11	3.57	2.00	2.00
12	3.17	2.00	1.78
13	2.77	2.00	1.56
14	2.37	2.00	1.33
15	1.97		1.11
16	1.90		0.89
17	1.83		0.67
18	1.76		0.44
19	1.69		0.22
20	1.62		
21	1.55		
22	1.48		
23	1.41		
24	1.34		
25	1.28		
26	1.21		
27	1.14		
28	1.07		
29	1.00		
	100.0	100.0	100.0

Table 3-4 Share of total fuel consumption per engine age (irrespective of inventory year) for gasoline-fuelled two-stroke and four-stroke non-road machinery (1.A.2.f.ii (Industry), 1.A.4.c.ii (Agriculture), 1.A.4.c.ii (Forestry), 1.A.4.b.ii (Residential)

Engine age	two-stroke	four-stroke
0	29.00	14.70
1	29.00	14.70
2	29.00	14.70
3	5.80	14.70
4	1.20	12.00
5	1.20	8.00
6	1.20	8.00
7	1.20	8.00
8	1.20	1.30
9	1.20	1.30
10		1.30
11		1.30
Total	100	100

Table 3-5 Layer share of fuel consumption per engine age and inventory year for diesel-fuelled agricultural non-road machinery (1.A.4.c.ii)

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
0	1991–Stage I	99	99	80	0	0	0	0	0	0	0	0	0
0	Stage I	1	1	20	64	8	0	0	0	0	0	0	0
0	Stage II	0	0	0	36	92	100	100	48	8	0	0	0
0	Stage IIIA	0	0	0	0	0	0	0	52	92	100	100	100
1	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
1	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
1	1991–Stage I	100	99	99	80	0	0	0	0	0	0	0	0
1	Stage I	0	1	1	20	64	8	0	0	0	0	0	0
1	Stage II	0	0	0	0	36	92	100	100	49	8	0	0
1	Stage IIIA	0	0	0	0	0	0	0	0	51	92	100	100
2	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
2	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
2	1991–Stage I	100	100	99	99	80	0	0	0	0	0	0	0
2	Stage I	0	0	1	1	20	64	8	0	0	0	0	0
2	Stage II	0	0	0	0	0	36	92	100	100	49	8	0
2	Stage IIIA	0	0	0	0	0	0	0	0	0	51	92	100
3	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
3	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
3	1991–Stage I	100	100	100	99	99	80	0	0	0	0	0	0
3	Stage I	0	0	0	1	1	20	64	8	0	0	0	0
3	Stage II	0	0	0	0	0	0	36	92	100	100	49	8
3	Stage IIIA	0	0	0	0	0	0	0	0	0	0	51	92
4	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
4	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
4	1991–Stage I	100	100	100	100	99	99	81	0	0	0	0	0

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
4	Stage I	0	0	0	0	1	1	19	66	9	0	0	0
4	Stage II	0	0	0	0	0	0	0	34	91	100	100	52
4	Stage IIIA	0	0	0	0	0	0	0	0	0	0	0	48
5	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
5	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
5	1991–Stage I	100	100	100	100	100	99	99	80	0	0	0	0
5	Stage I	0	0	0	0	0	1	1	20	66	9	0	0
5	Stage II	0	0	0	0	0	0	0	0	34	91	100	100
6	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
6	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
6	1991–Stage I	100	100	100	100	100	100	99	99	79	0	0	0
6	Stage I	0	0	0	0	0	0	1	1	21	70	9	0
6	Stage II	0	0	0	0	0	0	0	0	0	30	91	100
7	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
7	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
7	1991–Stage I	100	100	100	100	100	100	100	98	99	74	0	0
7	Stage I	0	0	0	0	0	0	0	2	1	26	64	12
7	Stage II	0	0	0	0	0	0	0	0	0	0	36	88
8	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
8	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
8	1991–Stage I	100	100	100	100	100	100	100	100	98	99	74	0
8	Stage I	0	0	0	0	0	0	0	0	2	1	26	63
8	Stage II	0	0	0	0	0	0	0	0	0	0	0	37
9	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
9	1981–1990	100	0	0	0	0	0	0	0	0	0	0	0
9	1991–Stage I	0	100	100	100	100	100	100	100	100	98	99	74
9	Stage I	0	0	0	0	0	0	0	0	0	2	1	26
10	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
10	1981–1990	100	100	0	0	0	0	0	0	0	0	0	0
10	1991–Stage I	0	0	100	100	100	100	100	100	100	100	98	99
10	Stage I	0	0	0	0	0	0	0	0	0	0	2	1
11	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
11	1981–1990	100	100	100	0	0	0	0	0	0	0	0	0
11	1991–Stage I	0	0	0	100	100	100	100	100	100	100	100	98
11	Stage I	0	0	0	0	0	0	0	0	0	0	0	2

Table 3-6 Layer share of fuel consumption per engine age and inventory year for diesel-fuelled forestry non-road machinery (1.A.4.c.ii)

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
0	1991–Stage I	77	77	59	2	2	2	2	2	0	0	0	0
0	Stage I	23	23	41	54	2	0	0	0	0	0	0	0
0	Stage II	0	0	0	43	96	98	98	50	2	2	2	2
0	Stage IIIA	0	0	0	0	0	0	0	48	98	98	98	98
1	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
1	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
1	1991–Stage I	100	77	78	60	2	2	2	2	2	0	0	0
1	Stage I	0	23	22	40	52	0	0	0	0	0	0	0
1	Stage II	0	0	0	0	46	98	98	98	50	2	2	2
1	Stage IIIA	0	0	0	0	0	0	0	0	48	98	98	98
2	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
2	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
2	1991–Stage I	100	100	78	79	61	2	2	2	2	2	0	0
2	Stage I	0	0	22	21	39	50	0	0	0	0	0	0
2	Stage II	0	0	0	0	0	48	98	98	98	50	2	2
2	Stage IIIA	0	0	0	0	0	0	0	0	0	48	98	98
3	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
3	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
3	1991–Stage I	100	100	100	79	80	63	2	2	2	2	2	0
3	Stage I	0	0	0	21	20	37	50	0	0	0	0	0
3	Stage II	0	0	0	0	0	0	48	98	98	98	50	2
3	Stage IIIA	0	0	0	0	0	0	0	0	0	0	48	98
4	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
4	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
4	1991–Stage I	100	100	100	100	80	81	63	2	2	2	2	2
4	Stage I	0	0	0	0	20	19	37	50	0	0	0	0
4	Stage II	0	0	0	0	0	0	0	48	98	98	98	50
4	Stage IIIA	0	0	0	0	0	0	0	0	0	0	0	48
5	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
5	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
5	1991–Stage I	100	100	100	100	100	81	81	63	2	2	2	2
5	Stage I	0	0	0	0	0	19	19	37	50	0	0	0
5	Stage II	0	0	0	0	0	0	0	0	48	98	98	98
6	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
6	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
6	1991–Stage I	100	100	100	100	100	100	62	62	62	5	5	5
6	Stage I	0	0	0	0	0	0	38	38	38	95	0	0
6	Stage II	0	0	0	0	0	0	0	0	0	0	95	95
7	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
7	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
7	1991–Stage I	100	100	100	100	100	100	100	62	62	62	5	5
7	Stage I	0	0	0	0	0	0	0	38	38	38	95	0
7	Stage II	0	0	0	0	0	0	0	0	0	0	0	95
8	< 1981	0	0	0	0	0	0	0	0	0	0	0	0

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
8	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
8	1991–Stage I	100	100	100	100	100	100	100	100	100	100	100	27
8	Stage I	0	0	0	0	0	0	0	0	0	0	0	73

Table 3-7 Layer share of fuel consumption per engine age and inventory year for diesel-fuelled industrial non-road machinery (1.A.2.f.ii)

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
0	1991–Stage I	35	36	18	14	14	14	13	12	4	4	4	4
0	Stage I	65	64	63	62	18	0	0	0	0	0	0	0
0	Stage II	0	0	18	24	68	86	87	84	25	8	8	8
0	Stage IIIA	0	0	0	0	0	0	0	4	71	88	88	88
1	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
1	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
1	1991–Stage I	100	36	37	18	14	14	14	12	12	4	4	4
1	Stage I	0	64	63	62	61	18	0	0	0	0	0	0
1	Stage II	0	0	0	20	25	68	86	88	84	25	8	8
1	Stage IIIA	0	0	0	0	0	0	0	0	4	71	88	88
2	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
2	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
2	1991–Stage I	100	100	37	38	18	14	13	12	12	12	4	4
2	Stage I	0	0	63	62	61	60	17	0	0	0	0	0
2	Stage II	0	0	0	0	21	26	69	88	88	84	25	8
2	Stage IIIA	0	0	0	0	0	0	0	0	0	4	71	88
3	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
3	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
3	1991–Stage I	100	100	100	39	40	18	13	12	12	12	12	4
3	Stage I	0	0	0	61	60	60	61	16	0	0	0	0
3	Stage II	0	0	0	0	0	23	26	71	88	88	84	25
3	Stage IIIA	0	0	0	0	0	0	0	0	0	0	4	71
4	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
4	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
4	1991–Stage I	100	100	100	100	40	41	17	12	12	12	12	12
4	Stage I	0	0	0	0	60	59	61	61	16	0	0	0
4	Stage II	0	0	0	0	0	0	22	27	71	88	88	84
4	Stage IIIA	0	0	0	0	0	0	0	0	0	0	0	4
5	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
5	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
5	1991–Stage I	100	100	100	100	100	41	40	16	12	12	12	12
5	Stage I	0	0	0	0	0	59	60	61	61	16	0	0
5	Stage II	0	0	0	0	0	0	0	23	27	71	88	88
6	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
6	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
6	1991–Stage I	100	100	100	100	100	100	38	38	14	10	10	10
6	Stage I	0	0	0	0	0	0	62	62	62	62	17	0

Age	Emission level	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	Stage II	0	0	0	0	0	0	0	0	24	28	73	90
7	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
7	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
7	1991–Stage I	100	100	100	100	100	100	100	38	38	14	9	9
7	Stage I	0	0	0	0	0	0	0	62	62	63	63	17
7	Stage II	0	0	0	0	0	0	0	0	0	24	28	74
8	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
8	1981–1990	0	0	0	0	0	0	0	0	0	0	0	0
8	1991–Stage I	100	100	100	100	100	100	100	100	38	38	14	9
8	Stage I	0	0	0	0	0	0	0	0	62	62	63	63
8	Stage II	0	0	0	0	0	0	0	0	0	0	24	28
9	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
9	1981–1990	100	0	0	0	0	0	0	0	0	0	0	0
9	1991–Stage I	0	100	100	100	100	100	100	100	100	38	38	14
9	Stage I	0	0	0	0	0	0	0	0	0	62	62	63
9	Stage II	0	0	0	0	0	0	0	0	0	0	0	24
10	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
10	1981–1990	100	100	0	0	0	0	0	0	0	0	0	0
10	1991–Stage I	0	0	100	100	100	100	100	100	100	100	76	75
10	Stage I	0	0	0	0	0	0	0	0	0	0	24	25
11	< 1981	0	0	0	0	0	0	0	0	0	0	0	0
11	1981–1990	100	100	100	0	0	0	0	0	0	0	0	0
11	1991–Stage I	0	0	0	100	100	100	100	100	100	100	100	76
11	Stage I	0	0	0	0	0	0	0	0	0	0	0	24

Table 3-8 Layer share of fuel consumption per engine age and inventory year for gasoline-fuelled two-stroke non-road machinery (1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii, 1.A.4.c.ii)

Age	Emission level	2007	2008	2009	2010
0	1981–1990	0	0	0	0
0	1991–Stage I	0	0	0	0
0	Stage I	99	85	0	0
0	Stage II	1	15	100	100
1	< 1981	0	0	0	0
1	1981–1990	0	0	0	0
1	1991–Stage I	0	0	0	0
1	Stage I	100	99	85	0
1	Stage II	0	1	15	100
2	< 1981	0	0	0	0
2	1981–1990	0	0	0	0
2	1991–Stage I	0	0	0	0
2	Stage I	100	100	99	85
2	Stage II	0	0	1	15
3	< 1981	0	0	0	0
3	1981–1990	0	0	0	0
3	1991–Stage I	100	0	0	0

Age	Emission level	2007	2008	2009	2010
3	Stage I	0	99	99	97
3	Stage II	0	1	1	3
4	< 1981	0	0	0	0
4	1981–1990	0	0	0	0
4	1991–Stage I	100	100	0	0
4	Stage I	0	0	92	92
4	Stage II	0	0	8	8
5	< 1981	0	0	0	0
5	1981–1990	0	0	0	0
5	1991–Stage I	100	100	100	0
5	Stage I	0	0	0	92
5	Stage II	0	0	0	8

Table 3-9 Layer share of fuel consumption per engine age and inventory year for gasoline-fuelled four-stroke non-road machinery (1.A.2.f.ii, 1.A.4.a.ii, 1.A.4.b.ii, 1.A.4.c.ii)

Age	Emission level	2007	2008	2009	2010
0	1981–1990	0	0	0	0
0	1991–Stage I	0	0	0	0
0	Stage I	42	4	0	0
0	Stage II	58	96	100	100
1	< 1981	0	0	0	0
1	1981–1990	0	0	0	0
1	1991–Stage I	0	0	0	0
1	Stage I	100	42	4	0
1	Stage II	0	58	96	100
2	< 1981		0	0	0
2	1981–1990	0	0	0	0
2	1991–Stage I	0	0	0	0
2	Stage I	100	100	42	4
2	Stage II	0	0	58	96
3	< 1981	0	0	0	0
3	1981–1990	0	0	0	0
3	1991–Stage I	100	0	0	0
3	Stage I	0	100	100	42
3	Stage II	0	0	0	58

3.10 Tier 3 equipment-specific and technology-stratified approach

The Tier 2 methods make use of fuel statistics, to be multiplied with bulk emission factors. Unfortunately, this method can be difficult to undertake because the statistical fuel consumption data are not available in the required detail.

Therefore, in the following, a more detailed Tier 3 methodology is described, which is mainly based on the US-EPA method for estimating off-road emissions (US-EPA 1991). The Tier 3 method presented here has not been updated with new data as has been the case for Tier 1 and 2, and hence a lack of consistency is expected between the Tier 1/Tier 2 results and the results obtained from Tier 3 calculations. An updated Tier 3 methodology is envisaged in the near future based on extensive measurements performed by the EU JRC (Joint Research Centre).

3.11 Algorithm

The basic algorithm used for the Tier 3 methodology is:

$$E = N \times HRS \times HP \times LF \times EF \qquad (5)$$

where:

E	=	mass of emissions of pollutant i during inventory period,
N	=	source population (units),
HRS	=	annual hours of use,
HP	=	average rated horsepower,
LF	=	typical load factor,
EF_i	=	average emissions of pollutant i per unit of use (e.g. [g/kWh]).

This approach has been complemented with data from emissions of construction work machinery in Switzerland (Infras 1993). In a first step, the methodology applied there has been simplified in order to reduce the data input requirements and then, in a second step, it has been extended to other types of machinery and, more importantly, engine types.

In this methodology, the parameters N, HRS, HP, LF, EF_i of the basic formula (5) mentioned above are split further by classification systems as follows:

- N: the machinery/vehicle population is split into different age and power ranges,
- HRS: the annual working hour is a function of the age of the equipment/vehicles; therefore, for each sub category, individual age dependent usage patterns can be defined,
- HP: the mean horsepower is a function of the power distribution of the vehicles/machinery; therefore, for each sub category an individual power distribution can be defined within given power ranges,

EF_i: the emission factor is, for each pollutant, a function of age and power output, and, for diesel engines, engine type mix; therefore, the emission factors are modified taking into account these dependencies.

In this advanced approach, in addition to exhaust emissions, evaporative emissions of gasoline engines are taken into account. In reality, evaporative emissions occur under all conditions, e.g. while the machine/vehicle is in operation or not in operation. However, the emissions of off-road machines and vehicles are not very well known. Therefore, only diurnal losses, based on US-EPA's methodology, are taken into account. That means that hot-soak, resting and running losses are not included.

The emissions are estimated using the formula:

$$E = N \times HRS \times EF_{eva} \quad (6)$$

The parameters N and HRS are identical to those used for the estimation of exhaust emissions. The emission factor EF_{eva} needs to be tabled.

In principle, elements of the above described approach are used in many national studies and by industry (Utredning 1989, Achten 1990, Barry 1993, Puranen et al. 1992, Danish Environmental Protection Agency 1992, Caterpillar 1992, ICOMIA 1993).

3.12 Tier 3 emission factors

In the Tier 3 approach the machinery/vehicle population is split into different types, ages and power ranges. The baseline emission factors for regulated diesel engines and machinery are taken as the EU type approval values (expressed in g/kWh). A feature of the regulations is their complexity with different types of machinery, and different power ranges having different implementation dates and limits, and in some cases being regulated by different directives.

Baseline emission factors for diesel machinery are presented in Table 3–10 for the uncontrolled case. In the Tables 3–11 to 3–15, emission factors based on the EU directive emission limits are given. For diesel machinery in general, the EU directives 97/68/EC and 2004/26/EC are relevant for Stage I, II and III emission legislation layers. For agricultural tractors, the EU directives 2000/25/EC and 2005/13/EC are relevant for Stage I, II and III emission legislation layers technology. For gasoline baseline emission factors are shown in the Tables 3–18 and 3–19 for the uncontrolled case. For LPG machinery, the baseline emission factors are given in Table 3–20. The diesel emission factors can be modified depending on the engine design parameters in accordance with Table 3-16. Moreover, in order to take into account the change of emissions with the age, degradation factors as shown in Table 3-17 (diesel machinery),

Table 3-21 (gasoline two-stroke) and Table 3-22 (gasoline four-stroke) are defined. The emission factors for SO_2 and CO_2, heavy metals and persistent organic pollutants have to be taken from the Tier 1 emission factor tables, or have to be calculated based on fuel composition and fuel-consumption data. Emission factors for persistent organic pollutants for LPG powered engines are not available. However, this source can be considered as irrelevant compared to other sources. Finally, Table 3-23 presents a set of emission factors for the calculation of evaporative losses from the gasoline powered engines.

Table 3-10 Baseline emission factors for uncontrolled diesel engines in [g/kWh]

Pollutant [g/kWh]	Power range in kW							
	0–20	20–37	37–75	75–130	130–300	300–560	560–1000	> 1000
NO_x	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
CH_4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CO	8.38	6.43	5.06	3.76	3.00	3.00	3.00	3.00
NMVOC	3.82	2.91	2.28	1.67	1.30	1.30	1.30	1.30
PM	2.22	1.81	1.51	1.23	1.10	1.10	1.10	1.10
$PM_{2.5}$	2.09	1.70	1.42	1.16	1.03	1.03	1.03	1.03
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	271	269	265	260	254	254	254	254

Note:
BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.55 and 0.5, respectively, c.f. Appendix D.

Equations used:

NO_x: 14.36, irrespective of power output

NMVOC: for P ≤ 130 kW: 12.0–6.5 · $P^{0,1}$; for P > 130 kW: 1.3

CO:for P ≤ 130 kW: 26.0–14 · $P^{0,1}$; for P > 130 kW: 3.0

PM:for P ≤ 130 kW: 6.0–3.0 · $P^{0,1}$; for P > 130 kW: 1.1

$PM_{2.5}$:for all engine powers, $PM_{2.5}$ = 94 % PM

N_2O:0.35, irrespective of power output and engine type

CH_4: 0.05, irrespective of power output and engine type

NH_3: 0.002, irrespective of power output and engine type

FC: for P ≤ 130 kW: 272–0.12 · P; for P > 130 kW: 254

P: max. power output

Table 3-11 Baseline emission factors for NRMM stage I (for 37 ≤ P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

Pollutant [g/kWh]	Power range in kW							
	0–20	20–37	37–75	75–130	130–300	300–560	560–1000	> 1000
Implementation date ([1])	N/A	N/A	1.7.98	1.7.98	1.7.98	1.7.98	N/A	N/A
NO_x	14.4	14.4	*9.20*	*9.20*	*9.20*	*9.20*	14.4	14.4
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
CH_4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CO	8.38	6.43	*6.50*	*5.00*	*5.00*	*5.00*	3.00	3.00
NMVOC	3.82	2.91	*1.30*	*1.30*	*1.30*	*1.30*	1.30	1.30
PM	2.22	1.81	*0.85*	*0.70*	*0.54*	*0.54*	1.10	1.10
$PM_{2.5}$	2.09	1.70	*0.80*	*0.66*	*0.51*	*0.51*	1.03	1.03
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	271	269	265	260	254	254	254	254

Notes:
The above table is produced on the basis of the emission factors for the uncontrolled case and replacing the emission standards proposed by the EC (European Commission 1993–1997) in the appropriate categories (numbers in italics). For CO, the emission standards proposed are in some cases higher than the emission factors of the uncontrolled engines. In this case it is proposed to use the 'uncontrolled' values.

BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.8 and 0.7, respectively, c.f. Appendix D.

Table 3-12 Baseline emission factors for NRMM stage II (for 20 ≤ P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

Pollutant [g/kWh]	Power range in kW							
	0–20 0–18	20–37 18–37	37–75	75–130	130–300	300–560	560–1000	> 1000
Implementation date (see footnote)	N/A	1.1. 2000	1.1. 2003	1.1. 2002	1.1.2001	1.1.2001	N/A	N/A
NO_x	14.4	*8.50*	*8.00*	*7.00*	*7.00*	*7.00*	14.4	14.4
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
CH_4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CO	8.38	*5.50*	*5.00*	*5.00*	*3.50*	*3.50*	3.00	3.00
NMVOC	3.82	*1.50*	*1.30*	*1.00*	*1.00*	*1.00*	1.30	1.30
PM	2.22	*0.80*	*0.40*	*0.30*	*0.20*	*0.20*	1.10	1.10
$PM_{2.5}$	2.09	0.75	*0.38*	*0.28*	*0.19*	*0.19*	1.03	1.03
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	271	269	265	260	254	254	254	254

([1]) Taken from EC Directive 97/68/EC, Article 9, (2) (on page 6 of PDF file).

Notes:
The above table is produced on the basis of the emission factors for the uncontrolled case and replacing the emission standards proposed by the EC (European Commission 1993–1997) in the appropriate categories (numbers in italics). For CO, the emission standards proposed are in some cases higher than the emission factors of the uncontrolled engines. In this case it is proposed to use the 'uncontrolled' values.
BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.8 and 0.7, respectively, c.f. Appendix D.

Table 3-13 Baseline emission factors for NRMM stage III (for 20 ≤ P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

Pollutant [g/kWh]	Power range in kW							
	0–20 0–18	20–37 18–37	37–75	75–130	130–300	300–560	560–1000	> 1000
Implementation date (see footnote)	N/A	1.1. 2006	1.1. 2007	1.1. 2006	1.7.2005	1.7.2005	N/A	N/A
NO_x*	14.4	*6.40*	*4.00*	*3.50*	*3.50*	*3.50*	14.4	14.4
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
CH_4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CO	8.38	*5.50*	*5.00*	*5.00*	*3.50*	*3.50*	3.00	3.00
NMVOC*	3.82	*1.10*	*0.70*	*0.50*	*0.50*	*0.50*	1.30	1.30
PM	2.22	*0.60*	*0.40*	*0.30*	*0.20*	*0.20*	1.10	1.10
$PM_{2.5}$	2.09	*0.56*	*0.38*	*0.28*	*0.19*	*0.19*	1.03	1.03
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	271	269	265	260	254	254	254	254

Notes:
1. The above table is produced on the basis of the emission factors for the uncontrolled case with values replaced by the emission standards specified in the European Commission Directive 2004/26/EC in the appropriate categories (the numbers in italics).
2. For this Directive it is actually the sum of the NO_x and NMVOC that is controlled, rather than the individual pollutants. The emission factors have been derived assuming vehicles produce the same NO_x/NMVOC ratio specified by their limit values in the Stage I and II directives.
3. BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.8 and 0.7, respectively, c.f. Appendix D.

Table 3-14 Baseline emission factors for agricultural tractors stages I and II (for 18 ≤ P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

Pollutant [g/kWh]	Power range in kW							
	0–19	19–37	37–75	75–130	130–300	300–560	560–1000	> 1000
Implementation date (see footnote)	N/A	1.1. 2001	1.1.2001 and 1.1.2003	1.1.2001 and 1.1.2002	1.7.2001	1.7.2001	N/A	N/A
NO_x	14.4	*8.50*	*9.20 & 8.00*	*9.20 & 7.00*	*7.00*	*7.00*	14.4	14.4
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
CH_4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CO	8.38	*5.50*	*6.50 & 5.00*	*5.00*	*3.50*	*3.50*	3.00	3.00
NMVOC	3.82	*1.50*	*1.30*	*1.00*	*1.00*	*1.00*	1.30	1.30

PM	2.22	*0.80*	*0.85 & 0.40*	*0.70 & 0.30*	*0.20*	*0.20*	1.10	1.10
$PM_{2.5}$	2.09	*0.75*	*0.80 & 0.38*	*0.66 & 0.28*	*0.19*	*0.19*	1.03	1.03
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	271	269	265	260	254	254	254	254

Notes:
The above table is produced on the basis of the emission factors for the uncontrolled case and replacing the emission standards specified by the European Commission Directive 2000/25/EC in the appropriate categories (numbers in italics). For two power ranges the standards were implemented in two stages. Where this led to progressive reductions in emission standards both values are given. Otherwise the single value given became applicable from the earlier date.
BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.8 and 0.7, respectively, c.f. Appendix D.

Table 3-15 Baseline emission factors for agricultural tractors stage III (for 18 ≤ P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

Pollutant	Power range in kW							
Implementation date (see footnote)	N/A	1.1. 2007	1.1. 2008	1.1. 2007	1.7.2006	1.7.2006	N/A	N/A
[g/kWh]	0–19	19–37	37–75	75–130	130–300	300–560	560–1000	> 1000
Pollutants, NO_x, N_2O, CH_4, CO, NMVOC, PM, NH_3, FC	For	limit	values	see	Table	8.5b		

Note:
BC: The BC fraction of PM for P < 130 kW and P >= 130 kW are 0.8 and 0.7, respectively, c.f. Appendix D.

Table 3-16 Pollutant weighing factors as a function of engine design parameters for uncontrolled diesel engines

Engine type	NO_x	$NMVOC/CH_4$	CO	PM	$FC/SO_2/CO_2$	N_2O/NH_3
NADI	1.0	0.8	0.8	0.9	0.95	1.0
TCDI/ITCDI	0.8	0.8	0.8	0.8	0.95	1.0
NAPC	0.8	1.0	1.0	1.2	1.1	1.0
TCPC	0.75	0.95	0.95	1.1	1.05	1.0
ITCPC	0.7	0.9	0.9	1.0	1.05	1.0

Note
NADI: Naturally Aspirated Direct Injection
NAPC: Naturally Aspirated Prechamber Injection
TCDI: Turbo-Charged Direct Injection
TCPC: Turbo-Charged Prechamber Injection
ITCDI: Intercooled Turbo-Charged Direct Injection
ITCPC: Intercooled Turbo-Charged Prechamber Injection

Table 3-17 Degradation factors of diesel engines for the different pollutants and fuel consumption

Pollutant	Degradation factor
CH_4/NMVOC:	1.5 % per year
CO	1.5 % per year
NO_x:	0 % per year
FC/SO_2/CO_2:	1 % per year
N_2O/NH_3:	0 % per year
PM:	3 % per year

Table 3-18 Baseline emission factors for uncontrolled two-stroke gasoline engines in [g/kWh]

Pollutant	Power range in kW							
[g/kWh]	0–2	2–5	5–10	10–18	18–37	37–75	75–130	130–300
NO_x	1.00	1.02	1.05	1.10	1.19	1.38	1.69	2.45
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CH_4	6.60	3.55	2.70	2.26	2.01	1.84	1.76	1.69
CO	1500	643	460	380	342	321	312	306
NMVOC	660	355	270	226	200	184	175	169
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	500	476	462	449	438	427	417	406

Note: BC: If country specific PM emission factors are available, it is proposed to use a BC fraction of PM of 0.05, c.f. Appendix D.

Equations used:

CO:	$300 + 1200/P$
NMVOC:	$160 + 500/P^{0.75}$
NO_x:	$6.73 \cdot 10^{-3} * P + 1$
CH_4:	$1.6 + 5/P^{0.75}$ (1 % of VOC)
N_2O:	0.01
NH_3:	0.002
FC:	$100 + 400/P^{0.05}$
P =	max. power output

Table 3-19 Baseline emission factors for uncontrolled four-stroke gasoline engines in [g/kWh]

Pollutant [g/kWh]	0–2	2–5	5–10	10–18	18–37	37–75	75–130	130–300
NO_x	4.00	4.00	4.02	4.04	4.08	4.15	4.28	4.58
N_2O	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
CH4	5.30	2.25	1.40	0.96	0.71	0.54	0.46	0.39
CO	2300	871	567	433	370	336	320	309
NMVOC	106	45.1	28.7	19.1	14.1	10.9	9.10	7.78
NH_3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
FC	430	409	396	386	376	366	358	348

Note: BC: If country specific PM emission factors are available, it is proposed to use a BC fraction of PM of 0.05, c.f. Appendix D.

Equations used:

CO: $300 + 2000/P$

NMVOC: $6 + 100/P^{0.75}$

NO_x: $2.7 \cdot 10^{-3} * P + 4.0$

CH_4: $0.3 + 5/P^{0.75}$ (5 % of VOC)

N_2O: 0.03

NH_3: 0.002

FC: $80 + 350/P^{0.05}$

P = max. power output

Table 3-20 Baseline emission factors for uncontrolled four-stroke LPG engines in [g/kWh]

Pollutant	Emission factor
NO_x	10, irrespective of power output
NMVOC	13.5, irrespective of power output
CO	15, irrespective of power output
NH_3	0.003, irrespective of power output
N_2O	0.05, irrespective of power output
CH_4	1.0, irrespective of power output
FC	350, irrespective of power output

Table 3-21 Degradation factors of two-stroke gasoline engines

Pollutant	Degradation factor
CH_4/NMVOC	1.4 % per year
CO	1.5 % per year
NO_x	- 2.2 % per year
FC/SO_2/CO_2	1 % per year
N_2O/NH_3	0 % per year

Table 3-22 Degradation factor of four-stroke gasoline and four-stroke LPG engines

Pollutant	Degradation factor
CH_4/NMVOC	1.4 % per year
CO	1.5 % per year
NO_x	- 2.2 % per year
FC/SO_2/CO_2	1 % per year
N_2O/NH_3	0 % per year

Table 3-23 Proposed emission factors for evaporative losses in g/h

SNAP	Code	Vehicle/machinery type	2SG	4SG
0802	01	Shunting locomotives		
	02	Rail-cars		
	03	Locomotives		
0803	01	Sailing boats with auxiliary engines	0.75	
	02	Motorboats/workboats	11.0	11.0
	03	Personal watercraft	0.75	
	04	Inland goods carrying vessels		
0806	01	Two-wheel tractors	0.30	0.30
	02	Agricultural tractors		
	03	Harvesters/combiners		
	04	Others (sprayers, manure distributors, etc.)	0.3	0.30
0807	01	Professional chain saws/clearing saws	0.03	
	02	Forest tractors/harvesters/skidders		
	03	Others (tree processors, haulers, forestry cultivators, etc.)	0.07	
0808	01	Asphalt/concrete pavers		
	02	Plate compactors/tampers /rammers	0.11	0.12
	03	Rollers		
	04	Trenchers/mini excavators		

SNAP	Code	Vehicle/machinery type	2SG	4SG
	05	Excavators (wheel/crawler type)		
	06	Cement and mortar mixers		1.20
	07	Cranes		
	08	Graders/scrapers		
	09	Off-highway trucks		
	10	Bulldozers (wheel/crawler type)		
	11	Tractors/loaders/backhoes		
	12	Skid steer tractors		
	13	Dumper/tenders		0.40
	14	Aerial lifts	2.30	
	15	Forklifts		2.25
	16	Generator sets	0.13	0.12
	17	Pumps	0.10	0.09
	18	Air/gas compressors		
	19	Welders		
	20	Refrigerating units		
	21	Other general industrial equipment (broomers, sweepers, etc.)	1.20	1.20
	22	Other material handling equipment (conveyors, etc.)		
	23	Other construction work equipment (paving/surfacing, etc.)	1.20	
0809	01	Trimmers/edgers/bush cutters	0.02	
	02	Lawn mowers	0.05	0.05
	03	Hobby chain saws	0.01	
	04	Snowmobiles/skidoos	1.00	1.00
	05	Other household and gardening equipment	0.05	0.05
	06	Other household and gardening vehicles	0.10	0.10

Notes
1. 2SG: two-stroke gasoline (fuel used: motor gasoline).
2. 4SG: four-stroke gasoline (fuel used: mixture of motor gasoline and lubrication oil).

The advanced approach can be considered as the one providing emission estimates of significantly better quality than the simple approach. It is also more transparent, because all major parameters influencing emissions are covered, e.g. the user of this approach has to report the assumptions made for selecting emission factors. Moreover, this approach allows one to take into account the legislative steps, which are currently in preparation at EU level. It can be assumed that the emission factors for persistent organic pollutants will not be affected by these measures.

3.13 Tier 3 activity data

Many of the input data required for the application of this approach (e.g. the usage and the population data) are not part of general statistical yearbooks. Therefore, special investigations have to be carried out and reasonable estimates can be made, based on general technical experiences.

Data on the numbers of different machines and their age (technologies) can sometimes be obtained from sales statistics either from national statistical organisations or trade associations for suppliers or users of equipment.

Trade associations for suppliers or users of equipment can also provide data on the power ratings, usage (time in use) and load factors for these off-road machines.

In the absence of national data, data from the Danish inventory can be used to provide assumptions on annual hours of use and fractions of different, engine size, ages and types of machines in use for different NFR codes as well as assumptions on load factors (Winther & Nielsen, 2006).

In the absence of country- specific load factors for the different categories any number of different typical load factors (LF) can be applied. Weightings for time in mode for Diesel and gasoline (> 20 kW) powered off-road industrial equipment (Cycle C), Generators and mobile power plant (Cycle D) and Utility, lawn and garden, typically < 20 kW (Cycle G), laid down in ISO DP 8178, and presented in Table 3-24 can be used. Weightings for time in mode for automotive, vehicle applications such as forestry and agricultural tractors can be taken from Table 3-25. However, it needs to be appreciated that the ISO DP 8178 standard, and the cycles for road vehicles, do change with time. For example, heavy-duty on-road vehicles are now tested to a different 13-mode cycle, and using a 30-minute duration transient cycle (the European Transient Cycle, ETC). It is proposed to add a new transient cycle (ISO 8178-11) to the suite of cycles for non-road mobile machinery. A full description of the Cycle classes A–G is provided in Table 3-26.

Table 3-24 Test points and weighting factors of ISO DP 8178 test cycles (2)

B-type mode number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Torque	**100**	**75**	**50**	**25**	**10**	**100**	**75**	**50**	**25**	**10**	**0**
Speed	**rated speed**					**intermediate speed**					**low idle**
Off-road vehicles											
Type C1	0.15	0.15	0.15		0.1	0.1	0.1	0.1			0.15
Type C2				0.06		0.02	0.05	0.32	0.30	0.10	0.15
Constant speed											
Type D1	0.3	0.5	0.2								
Type D2	0.05	0.25	0.3	0.3	0.1						
Locomotives (3)											
Type F	0.25							0.15			0.6
Utility, lawn and garden											
Type G1						0.09	0.2	0.29	0.3	0.07	0.05
Type G2	0.09	0.2	0.29	0.3	0.07						0.05
Type G3	0.9										0.1
Marine application											
Type E1	0.06 0.08	0.11					0.19	0.32			0.3
Type E2	0.2	0.5	0.15	0.15							
Marine application propeller law											
Mode number E3	1					2		3		4	
Power % of rated power	100					75		50		25	
Speed % of rated speed	100					91		80		63	
Weighting factor	0.2					0.5		0.15		0.15	
Mode number E4	1					2		3		4	5
Speed % of rated speed	100					80		60		40	idle
Torque % of rated torque	100					71.6		46.5		25.3	0
Weighting factor	0.06					0.14		0.15		0.25	0.4
Mode number E5	1					2		3		4	5
Power % of rated p.	100					75		50		25	0
Speed % of rated speed	100					91		80		63	idle
Weighting factor	0.08					0.13		0.17		0.32	0.3

(2) Values in table checked against currently used version of ISO DP 8178, as given by table at web address http://www.dieselnet.com/standards/cycles/iso8178.html The changes made in first table are corrections to errors rather than the adoption of a new test matrix.

(3) These conditions are up to date — see for example definition given in 1a(v). of Annex 1 (page 8 of PDF file) using test cycle defined in Specification B, para 3.7.1.2 of Annex 2, p. 19 of PDF file.

Table 3-25 Test cycle A (13 — mode cycle) used after July 2000 ([4])

Mode number cycle A	1	2	3	4	5	6	7	8	9	10	11	12	13
Speed	Low idle speed	A	B	B	A	A	A	B	B	C	C	C	C
% Torque	0	100	50	75	50	75	25	100	25	100	25	75	50
Weighting factor	0.15	0.08	0.10	0.10	0.05	0.05	0.05	0.09	0.10	0.08	0.05	0.05	0.05

Table 3-26 Test cycles of ISO DP 8178 for industrial engine applications with typical examples

Cycle A	**Automotive, vehicle applications**	
	Examples:	forestry and agricultural tractors, diesel and gas engines for on-road applications
Cycle B	**Universal**	
Cycle C	**Off-road vehicles and industrial equipment**	
	C1:	diesel-powered off-road industrial equipment
	Examples:	industrial drilling rigs, compressors, etc.; construction equipment including wheel loaders, bulldozers, crawler tractors, crawler loaders, truck-type loaders, off-highway trucks, etc.; agricultural equipment, rotary tillers; forestry equipment; self propelled agricultural vehicles; material handling equipment; fork lift trucks; hydraulic excavators; road maintenance equipment (motor graders, road rollers, asphalt finishers); snow plough equipment; airport supporting equipment; aerial lifts
	C2:	off-road vehicles with spark-ignited industrial engines > 20 kW
	Examples:	fork lift trucks; airport supporting equipment; material handling equipment; road maintenance equipment; agricultural equipment
Cycle D	**Constant speed**	
	D1:	power plants
	D2:	generating sets with intermittent load
	Examples:	gas compressors, refrigerating units, welding sets, generating sets on board of ships and trains, chippers, sweepers
	D3:	generating sets onboard ships (not for propulsion)
Cycle E	**Marine applications**	
	E1:	diesel engines for craft less than 24-m length (derived from test cycle B)
	E2:	heavy-duty constant speed engines for ship propulsion
	E3:	heavy-duty marine engines
	E4:	pleasure craft spark-ignited engines for craft less than 24-m length
	E5:	diesel engines for craft less than 24 m length (propeller law)
Cycle F	**Rail traction**	
	Examples:	locomotive, rail cars

([4]) Engine speed A < B < C. For their definitions see EC Directive 1999/96/EC Appendix 1 of Annex III.

Cycle G	**Utility, lawn and garden, typically < 20 kW**	
	G1:	non-handheld intermediate speed application
	Examples:	walk behind rotary or cylinder lawn mowers, front or rear engine riding lawn mowers, rotary tillers, edge trimmers, lawn sweepers, waste disposers, sprayers, snow removal equipment, golf carts
	G2:	non-handheld rated speed application
	Examples:	portable generators, pumps, welders, air compressors; rated speed application may also include lawn and garden equipment which operates at engine rated speed
	G3:	handheld rated speed applications
	Examples:	edge trimmers, string trimmers, blowers, vacuums, chain saws, portable saw mills

3.14 Speciation

Table 3-27, Table 3-28 and Table 3-29 provide information as used by Veldt et al. (1993), Derwent, and Loibl et al. (1993) in their work on emission estimates for the road transport sector.

Table 3-27 Composition of VOC emission of motor vehicles (data as provided by Veldt et al.)
A) Non-methane VOCs (composition in weight % of exhaust)

Species or group of species	Exhaust four-stroke (conventional)	Gasoline gases engine 3-way catalyst equipped	Evaporation	Diesel	LPG
Ethane	1.4	1.8		1	3
Propane	0.1	1	1	1	44
n-Butane	3.1	5.5	20	2	
i-Butane	1.2	1.5	10		
n-Pentane	2.1	3.2	15	2	
i-Pentane	4.3	7	25		
Hexane	7.1	6	15		
Heptane	4.6	5	2		
Octane	7.9	7			
Nonane	2.3	2			
Alkanes C> 10	0.9	3		30 (1)	
Ethylene	7.2	7		12	15
Acetylene	4.5	4.5		4	22
Propylene	3.8	2.5		3	10
Propadiene	0.2				
Methylacetylene	0.3	0.2			
1-Butene	1.7	1.5	1	)	
1,3 Butadiene	0.8	0.5		) 2	
2-Butene	0.6	0.5	2	)	

1-Pentene	0.7	0.5	2		
2-Pentene	1.1	1	3	1	
1-Hexene	0.6	0.4	)		
1,3 Hexene	0.6	0.4	) 1.5		
Alkanes C> 7	0.3	0.2	)	2 [(1)]	
Benzene	4.5	3.5	1	2	
Toluene	12.0	7	1	1.5	
o-Xylene	2.5	2		0.5	
M,p-Xylene	5.6	4	0.5	1.5	
Ethylbenzene	2.1	1.5		0.5	
Styrene	0.7	0.5			0.1
1,2,3-Trimethylbenzene	0.5	1			
1,2,4-Trimethylbenzene	2.6	4			
1,3,5-Trimethylbenzene	0.8	2			
Other aromatic compounds C9	3.8	3			
Aromatic compounds C> 10	4.5	6		20 [(1)]	
Formaldehyde	1.7	1.1		6	4
Acetaldehyde	0.3	0.5		2	2
Other Aldehydes C4	0.3	0.2		1.5	
Acrolein	0.2	0.2		1.5	
2-Butenal				1.0	
Benzaldehyde	0.4	0.3		0.5	
Acetone	0.1	1		1.5	
	100	100	100	100	100

[(1)] C13.

B) Methane (composition in weight % of exhaust)

Gasoline	
— conventional	5
— 3-way catalyst equipped	12
Diesel	4
LPG	3

Table 3-28 Composition of VOC-emissions (data as used by Derwent)

No	Species	Percentage by mass speciation by source category, w/w %		
		petrol engine exhaust	diesel exhaust	petrol evaporation vehicles
0	Methane	8.00	3.7	
1	Ethane	1.30	0.5	
2	Propane	1.20		
3	n-butane	1.95	2.5	19.990
4	i-butane	0.93	2.5	10.480
5	n-pentane	2.78	2.5	7.220

No	Species	Percentage by mass speciation by source category, w/w %		
		petrol engine exhaust	diesel exhaust	petrol evaporation vehicles
6	i-pentane	4.45	2.5	10.150
7	n-hexane	1.76	2.5	2.020
8	2-methylpentane	2.14	2.5	3.020
9	3-methylpentane	1.49	2.5	2.010
10	2,2-dimethylbutane	0.28	2.5	0.600
11	2,3-dimethylbutane	0.54	2.5	0.740
12	n-heptane	0.74	2.5	0.703
13	2-methylhexane	1.39	2.5	0.924
14	3-methylhexane	1.11	2.5	0.932
15	n-octane	0.37	2.5	0.270
16	Methylheptanes	3.90	2.5	0.674
17	n-nonane	0.18	2.5	
18	Methyloctanes	1.58	2.5	
19	n-decane	0.37	2.5	
20	Methylnonanes	0.84	2.5	
21	n-undecane	2.75	2.5	
22	n-duodecane	2.75	2.5	
23	Ethylene	7.90	11.0	
24	Propylene	3.60	3.4	
25	1-butene	1.40	0.5	1.490
26	2-butene	0.50		2.550
27	2-pentene	0.90		2.350
28	1-pentene	0.70	0.7	0.490
29	2-methyl-1-butene	0.70		0.670
30	3-methyl-1-butene	0.70	0.5	0.670
31	2-methyl-2-butene	1.40	0.5	1.310
32	Butylene	0.50		
33	Acetylene	6.30	3.2	
34	Benzene	3.20	2.6	2.340
35	Toluene	7.20	0.8	5.660
36	o-xylene	1.58	0.8	1.590
37	a-xylene	2.06	0.8	1.880
38	p-xylene	2.06	0.8	1.880
39	Ethylbenzene	1.20	0.8	1.320
40	n-propylbenzene	0.16	0.5	0.410
41	i-propylbenzene	0.13	0.5	0.120
42	1,2,3-trimethylbenzene	0.40	0.5	0.310
43	1,2,4-trimethylbenzene	1.60	0.5	1.600
44	1,3,5-trimethylbenzene	0.50	0.5	0.390
45	o-ethyltoluene	0.38	0.5	0.370
46	a-ethyltoluene	0.63	0.5	0.640
47	p-ethyltoluene	0.63	0.5	0.640

No	Species	Percentage by mass speciation by source category, w/w %		
		petrol engine exhaust	diesel exhaust	petrol evaporation vehicles
48	Formaldehyde	1.60	5.9	
49	Acetaldehyde	0.35	1.0	
50	Proprionaldehyde	0.57	1.0	
51	Butyraldehyde	0.07	1.0	
52	i-butyraldehyde		1.0	
53	Valeraldehyde	0.03		
54	Benzaldehyde	0.39		
55	Acetone	0.14	2.0	

Table 3-29 Composition of VOC emissions from traffic and mobile sources (Loibl et al. 1993)

	Exhaust — conventional cars	Exhaust —catalyst cars	Exhaust cold start (all cars)	2 stroke engines	Diesel engines	Evaporation losses
Non-reactive						
Ethane	2	3	1	1	-	-
Acetylene	8	3	4	2	-	-
Paraffins						
Propane	-	-	-	1	-	2
Higher paraffins	32	48	45	72	52	85
Olefins						
Ethene	11	7	6	3	6	-
Propene	5	4	2	1	3	-
Higher olefins (C4+)	6	9	7	9	3	10
Aromatics						
Benzene	5	1	4	2	-	1
Toluene	10	11	140	3	-	1
Higher aromatics (C8+)	21	6	21	6	12	1
Carbonyls						
Formaldehyde	-	8	-	-	13	-
Acetaldehyde	-	-	-	-	3	-
Higher aldehydes (C3+)					4	
Cetones					1	
Other NMVOC						
Alcohols, esters, ethers						
Acids						
Halogenated Compounds						
Other/undefined					3	

4 Data quality

4.1 Inventory quality assurance/quality control QA/QC

Estimation of the split of fuel consumption into the different technologies will require some assumptions about hours of use and age of vehicles. These assumptions still need to be transparent and should be cross- checked with industry experts (e.g. trade associations).

4.2 Completeness

For the Tier 3 method the estimates should be cross checked with total fuel consumption data to ensure that the bottom up theoretical calculations based on power rating and hours of use are valid, and can account for the fuel consumption data in national statistics. In addition, Tier 3 requires suitable application of degradation factors to ensure that emissions are not underestimated for machinery in use (the emission factors given are for type approval and not for in-use vehicles).

4.3 Avoiding double counting with other sectors

There is the possibility that some double accounting could occur if the total amounts of petrol and diesel used by a nation are assumed to be combusted in road transport. Much of the equipment considered in this chapter is likely to be fuelled from the same sources and therefore calculating and adding these emissions to the road transport emissions would double count the emissions from this fuel because of this non-road mobile machinery.

4.4 Verification

National experts should check the overall fuel balance, e.g. whether the calculated fuel consumption corresponds to the statistical fuel consumption if such statistical information is available. Moreover, they should carefully evaluate whether there are good reasons to deviate from the default values given in this note and the computer programme.

A central team should compare the main input parameters used by countries in order to identify major deviations. In cases where the following boundaries are exceeded, national experts should be contacted to check the correctness of the values and to learn about the reasons for their choice.

A) Tier 1 and Tier 2 methodologies

- The applied bulk emission factors for diesel, two-stroke gasoline, four-stroke gasoline, and LPG engines should not differ by more than 30 % for NOx and fuel consumption, more than 50 % for CO and NMVOC, and more than a factor of 2 for N2O, NH3, CH4 and diesel particulates from the all-country mean.

B) Tier 3 methodology

- The applied emission factors for the individual sub-categories should not differ by more than 30 % for NO_x and fuel consumption, more than 50 % for CO and NMVOC, and more than a factor of 2 for N_2O, NH_3, CH_4 and diesel particulates from the all-country mean.

- The applied average annual working hours should not differ by more than 50 % from the all-country mean.
- The applied average load factors should not differ by more than 25 % from the all-country mean.
- The applied average power output should not differ by more than 25 % from the all-country mean.

National statistical offices should check calculated energy consumption data in the greatest possible detail, or make available appropriate data for cross-checking. The (calculated) fuel consumed by categories should be incorporated in or cross-checked with the total national fuel balance.

4.5 Developing a consistent time series and recalculation

For Tier 2 it is important to establish an understanding of the different age and technology types of machines so that the appropriate emission factors can be applied.

4.6 Uncertainty assessment

For many subsectors, the estimation of emissions is still associated with quite large uncertainties due to the lack of information on vehicle and machinery population, emission factors, and conditions of use. Table 4-1 provides broad qualitative uncertainty estimates.

Table 4-1 Uncertainty estimates for input data required to apply the proposed methodologies

Sector	Subsector	Total fuel consump-tion	Parameter unit fuel consumption	Population	Load factor	Annual hours of use	Power range	Emission factor for the pollutants [1)]									Age distribution	Engine design distribution
								CO_2	CO	NMVOC	CH_4	NO_x	N_2O	NH_3	SO_2	PM		
Agriculture	02 Tractors	D	B	A	C	D	C	B	B	B	C	B	E	E	B	B	D	D
	03 Harvesters	D	B	C	D	C	B	B	B	B	C	B	E	E	B	B	D	D
	01/04 All others	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E
Forestry	02 Tractors	D	B	A	C	D	C	B	B	B	C	B	E	E	B	B	D	D
	01/03 All others	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E
Industry	01, 04, 05, 07 to 13, 15 (All types of construction equipment)	D	B	A	C	D	C	B	B	B	C	B	E	E	B	B	D	D
	02, 03, 06, 14, 16 to 22	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E

Military	All	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Household and gardening	All subsectors	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E

Note:
[1] As a rule, the emission factors to be used in the 'simple methodology' are one quality class worse.

Legend for Table 4-1

Emitting activity rates

Data quality A: very precise value, specifically known.

Data quality B: precise specific value.

Data quality C: approximate value, but sufficiently well estimated to be considered correctly representative.

Data quality D: approximate value, indicating good order of magnitude.

Data quality E: very approximate value, estimation of a possible order of magnitude.

Emission factors

Data quality A: data set based on a composite of several tests using analytical techniques and can be considered representative of the total population.

Data quality B: data set based on a composite of several tests using analytical techniques and can be considered representative of a large percentage of the total population.

Data quality C: data set based on a small number of tests using analytical techniques and can be considered reasonably representative of the total population.

Data quality D: data set based on a single source using analytical techniques or data set from a number of sources where data are based on engineering.

Data quality E: data set based on engineering calculations from one source; data set(s) based on engineering judgment; data set(s) with no documentation provided; may not be considered representative of the total population.

4.7 Gridding

The source categories covered by this chapter require to make use of somewhat different spatial allocation procedures:

- agricultural, forestry and military emissions should be disaggregated using land use data;
- industrial and household and gardening emissions should be disaggregated using general population density data;
- inland waterways should be allocated to the appropriate inland water surfaces.

Within each of the sectors further refinement is possible. However, since total emissions decrease with every further split, it is questionable whether the additional efforts are justified.

4.8 Reporting and documentation

Emissions for the categories in this chapter will need to be reported under a number of different NFR codes. Although agriculture and forestry have been split to help with the accuracy of calculations, these estimates will need to be combined for reporting.

4.9 Weakest aspects and priority areas for improvement in the current methodology

The Tier 3 methodologies proposed in this chapter generally require more input than is statistically available. Therefore, efforts should concentrate on data collection (actual fuel use in sectors and subsectors, machinery population, conditions of use). It would be very valuable to obtain in-use emission factors for this new equipment. (For road transport it was found that there were differences between on-road emissions and those predicted from new (Euro 3 and Euro III) regulations.)

Further typical information could be included to help derive appropriate Tier 2 and 3 activity data. Average data on % fuel consumption for different years and technologies could be provided.

Also, much equipment does use transient, rather than steady state cycles. The current methodology takes virtually no account of this, and consideration should be given to appropriately revising the methodology and including detailed in-use emission factors for machinery.

5 Temporal disaggregation criteria

There are no relevant reports available about the temporal disaggregation of emissions from the source categories covered. Therefore, only ‘common sense criteria’ can be applied. Table 5-1 provides a proposal for the ‘average’ European disaggregation of emissions. In practice, the temporal disaggregation might differ considerably among countries.

Table 5-1 Proposal of the average European temporal disaggregation of emissions. The figures indicate percentages of the disaggregation of total seasonal, weekly, and hourly emissions to seasons, days, and hours

		Seasonal disaggregation (in %)			
Sector	**Subsector**	**Winter**	**Spring**	**Summer**	**Fall**
Agriculture	All	10	20	50	20
Forestry	All	10	20	50	20
Industry	All	20	30	30	20
Military		20	30	30	20
Household and gardening	all but 04 04, snowmobiles	10 90	40 5	30 0	20 5

		Seasonal disaggregation (in %)							Hourly disaggregation (%)			
Sector	**Subsector**	**M**	**T**	**W**	**T**	**F**	**S**	**S**	**6-12**	**12-18**	**18-24**	**24-6**
Agriculture	All	18	18	18	18	18	5	5	45	45	8	2
Forestry	All	18	18	18	18	18	5	5	45	45	8	2
Industry	All	19	19	19	19	19	2.5	2.5	50	45	4	1
Military		19	19	19	19	19	2.5	2.5	35	35	15	15
Household & Gardening	all but 04 04, Snowmobiles	5 10	5 10	5 10	5 10	10 10	35 25	35 25	35 35	35 35	4 4	1 1

6 Glossary

CC	Cylinder Capacity of the engine
COPERT	COmputer Programme to calculate Emissions from Road Transport
Corinair	Corinair emission inventory
CORINE	COoRdination INformation Environmentale
EIG	Emission Inventory Guidebook
IPCC	Intergovernmental Panel on Climate Change
NAPFUE	Nomenclature of Fuels
NUTS	Nomenclature of Territorial Units for Statistics (0 to III). According to the EC definition, NUTS level 0 is the complete territory of the individual Member States
SNAP	Selected Nomenclature for Air Pollution
TU	Territorial Unit

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8 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection’s expert panel on Transport. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.

Appendix A Reference list of off-road machinery

Several source category sub-splits have been proposed and used elsewhere and provided the starting point for the category split (e.g. Achten 1990, US-EPA 1991). The sub-split needs to be well balanced since, due to the large number of other mobile sources and machinery, there is a risk of going into too great a detail. On the other hand, all main activities and consequently all major sources need to be well covered. Therefore, a compromise has to be found.

A similar sub-split could be used with NFR codes, for example forming equipment based codes, e.g. of the form 1.A.2.f.ii (812) where the first digit of the three-digit code is the fourth digit of the SNAP code (e.g. 8 for 'Other mobile sources and machinery — Industry) and the second and third digits are the two-digit code given in Table 2–1. Hence 812 would be the code for 'Skid-steer tractors'.

Proposal for a reference list of off-road machinery, which should be covered under SNAP codes 0801 to 0803 and 0806 to 0809

SNAP	Name		Machinery included
080100	Military		
080300	Inland waterways:	01	Sailing boats with auxiliary engines
		02	Motorboats/workboats
		03	Personal watercraft
		04	Inland goods carrying vessels
080600	Agriculture:	01	Two-wheel tractors
		02	Agricultural tractors
		03	Harvesters/combines
		04	Others (sprayers, manure distributors, agriculture mowers, balers, tillers, swatchers)
080700	Forestry:	01	Professional chain saws/clearing saws
		02	Forest tractors/harvesters/skidders
		03	Others (tree processors, haulers, forestry cultivators, fellers/bunchers, shredders, log loaders, pilling machines)
080800	Industry:	01	Asphalt/concrete pavers
		02	Plate compactors/tampers/rammers
		03	Rollers
		04	Trenchers/mini excavators
		05	Excavators (wheel/crawler type)
		06	Cement and mortar mixers
		07	Cranes

SNAP	Name		Machinery included
		08	Graders/scrapers
		09	Off-highway trucks
		10	Bull dozers (wheel/crawler type)
		11	Tractors/loaders/backhoes
		12	Skid-steer tractors
		13	Dumper/tenders
		14	Aerial lifts
		15	Forklifts
		16	Generator sets
		17	Pumps
		18	Air/gas compressors
		19	Welders
		20	Refrigerating units
		21	Other general industrial equipment (broomers, sweepers/ scrubbers, slope and brush cutters, pressure washers, pist machines, ice rink machines, scrapers, blowers, vacuums)
		22	Other material-handling equipment (conveyors, tunnel locs, snow-clearing machines, industrial tractors, pushing tractors)
		23	Other construction work equipment (paving/surfacing equipment, bore/drill rigs, crushing equipment, concrete breakers/saws, peat breaking machines, pipe layers, rod benchers/cutters)
080900	Household and gardening	01	Trimmers/edgers/bush cutters
		02	Lawn mowers
		03	Hobby chain saws
		04	Snowmobiles/skidoos
		05	Other household and gardening equipment (wood splitters, snow blowers, chippers/stump grinders, gardening tillers, leaf blowers/vacuums)
		06	Other household and gardening vehicles (lawn and garden tractors, all terrain vehicles, minibikes, off-road motorcycles, golf carts)

Appendix B Engine-types of off-road machinery

Engine-types of off-road machinery which should be covered under the Corinair 1990 SNAP codes 0801 to 0803

			Engine type			
SNAP	**Code**	**Vehicle/machinery type**	**D**	**2SG**	**4SG**	**LPG**
08 03	01	Sailing boats with auxiliary engines	x	x		
	02	Motorboats.workboats	x	x	x	
	03	Personal watercraft		x		
	04	Inland goods carrying vessels	x			
08 06	01	Two-wheel tractors	x	x	x	
	02	Agricultural tractors	x			
	03	Harvesters/combiners	x			
	04	Others (sprayers, manure distributors, etc.)	x	x	x	
08 07	01	Professional chain saws/clearing saws		x		
	02	Forest tractors/harvesters/skidders	x			
	03	Others (tree processors, haulers, forestry cultivators, etc.)	x	x		
08 08	01	Asphalt/concrete pavers	x			
	02	Plate compactors/tampers/rammers	x	x	x	
	03	Rollers	x			
	04	Trenchers/mini excavators	x			
	05	Excavators (wheel/crawler type)	x			
	06	Cement and mortar mixers	x		x	
	07	Cranes	x			
	08	Graders/scrapers	x			
	09	Off-highway trucks	x			
	10	Bull dozers (wheel/crawler type)	x			
	11	Tractors/loaders/backhoes	x			
	12	Skid-steer tractors	x			
	13	Dumper/tenders	x		x	
	14	Aerial lifts	x	x		
	15	Forklifts	x		x	x

			Engine type			
SNAP	**Code**	**Vehicle/machinery type**	**D**	**2SG**	**4SG**	**LPG**
	16	Generator sets	x	x	x	
	17	Pumps	x	x	x	
	18	Air/gas compressors	x			
	19	Welders	x			
	20	Refrigerating units	x			
	21	Other general industrial equipment (broomers, sweepers, etc.)	x	x	x	
	22	Other material handling equipment (conveyors, etc.)	x			
	23	Other construction work equipment (paving/surfacing, etc.)	x	x		
08 09	01	Trimmers/edgers/bush cutters		x		
	02	Lawn mowers	x	x	x	
	03	Hobby chain saws		x		
	04	Snowmobiles/skidoos		x	x	
	05	Other household and gardening equipment	x	x	x	
	06	Other household and gardening vehicles	x	x	x	

Legend:
D: diesel (fuel used: diesel oil for road transport)
2SG: two-stroke gasoline (fuel used: motor gasoline)
4SG: four-stroke gasoline (fuel used: mixture of motor gasoline and lubrication oil)
LPG: LPG (fuel used: liquefied petroleum gases)

Appendix C Background to Tier 1 and 2 emission factors for non-road machinery

1. Introduction

This note briefly explains the method used to calculate Tier 1 and Tier 2 emission factors for non-road machinery to be included in an updated version of the chapter in the EMEP/Corinair guidebook relating to non-road machinery.

The sectors agriculture, forestry, industry, residential and recreational craft are considered, as well as the fuel/machinery types diesel, two-stroke gasoline, four-stroke gasoline and LPG.

The calculation of the Tier 1 and 2 factors, rely on the Danish inventory explained by Winther & Nielsen (2006). The basis for fuel consumption and emission information is to a large extent taken from an extensive German survey made by Institut für Entsorgung und Umwelttechnik gGmbH (IFEU)2004).

The baseline emission factors used in the Danish inventory — and the IFEU (2004) study — are grouped into EU emission legislation categories. However, for engines older than directive first-level implementation dates, three additional emission level classes are added so that a complete matrix of fuel use and emission factors underpins the inventory.

In the following, a brief description is given of the baseline emission factors, and the approach to derive aggregated emission factors from the Danish fuel consumption and emission results.

2. Baseline emission factors

2.1 Diesel

For diesel engines the following technology levels are present in the emission factor basis: < 1981, 1981–1990, 1991–Stage I, Stage I, Stage II and Stage IIIA.

Actual measured factors of fuel consumption and NO_x, VOC, CO and TSP emissions, predominantly come from IFEU (2004). EMEP/Corinair (2003) is the source of N_2O and NH_3 emission factors, whereas the CH_4/NMVOC split of VOC is taken from USEPA (2004). The determination of emission factors for future machinery is based on own judgement, taking into account today's emission factors for new machinery and future EU emission legislation limits.

For diesel engines, actual fuel use and emission measurements of NO_x, VOC, CO and TSP are behind the fuel use and emission factors for Stage II engine levels (IFEU, 2004). For Stage IIIA, the emission factors are estimated using the following assumption: if the emission factor constructed as 90 % of the emission legislation value is higher than the Stage II value for a given component and emission stage, the Stage II value is used. Otherwise, the 90 % figure of the legislation value is used.

For Stage IIIA (all engine sizes), the emission legislation limits are given as the sum of NO_x and VOC. The constructed Stage IIIA emission factors for NO_x and VOC are calculated as 90 % of the product of the Stage IIIA (NO_x+VOC) emission limit and the NO_x/(NO_x+VOC) or the VOC/(NO_x+VOC) ratio for the corresponding Stage II emission limit. All baseline emission factors can be seen in Winther and Nielsen (2006).

2.2 Gasoline

For gasoline engines, the following technology levels are present in the emission factor basis: < 1981, 1981–1990, 1991–Stage I, Stage I and Stage II.

The fuel consumption and NO_x, VOC, CO and TSP (two-stroke only) emission factors are taken from IFEU (2004). For engines prior to stage I, the fuel use and emission factors are measured in various measurement programmes. For stage I and II engines, a large number of type approval test results are used. The emission factor source for four-stroke TSP is TNO (2001). All baseline emission factors can be seen in Winther and Nielsen (2006).

2.3 LPG

For LPG, the fuel use factor and the emission factors of CO, VOC, NO_x and TSP are taken from IFEU (2004). Due to lack of data, there is no distinction between technology levels.

2.4 Recreational craft

For recreational craft, the emission factors for the conventional technology levels are from IFEU (2004). For engines complying with Directive 2003/44/EC, the CO and VOC emission legislation limits rely on engine size, and are calculated by inserting the engine size value into the CO and VOC emission factor equations given in Directive 2003/44/EC.

The final emission factors for CO, VOC, NO_x and TSP are estimated using the assumption that if the emission factor constructed as 90 % of the emission legislation value is higher than the conventional emission factor, the latter value is used. Otherwise, the 90 % figure of the Directive 2003/44/EC legislation value is used.

3. Aggregated emission factors

The aggregated emission factors are derived from the Danish inventory results. The Danish inventory uses the detailed calculation approach, and fuel consumption and emissions are found as the product of the number of engines, annual working hours, average rated engine size, load factor, and fuel use/emission factors. The emission effects of engine deterioration and transient engine loads, and gasoline fuel evaporation is not included in the aggregated emission factors. For further details, please refer to Winther and Nielsen (2006).

For Tier 1, the results from the latest historical year, 2006, are behind the aggregated emission factors. For Tier 2, the overall principle has been to assess the technology relevant emission factors from the 2006 inventory year point of view. In many cases the aggregated emission factors for the same technology level are more or less the same regardless of the inventory year. However, in some cases, the same technology level can have some variation in the emission factors as a function of inventory year, due to the specific Danish rates of penetration of new technology. This appears from the submitted data spreadsheets. Bearing in mind the decision to regard the data from a 2006 inventory year point of view, the error made is within the acceptable range. One exception for diesel and gasoline engines occurs for the newest technology level. In this situation, data is taken for the forecast year 2010. Data for this year is regarded as more sound and reliable to use, since the stock data behind the 2006 results in the Danish inventory is too scarce.

3.1 Diesel

The Danish inventory basis for stock is regarded as detailed enough to distinguish between agriculture, forestry and industry machinery types. Table 1 show the machinery types which are behind the aggregated factors. In the submitted spreadsheets the emission factors are listed for Tier 1 and Tier 2.

Table 1

	Machinery type	Lifetime (yrs)
Agriculture	Self-propelled vehicles	15
Agriculture	Tractors	30
Agriculture	Harvesters	25
Agriculture	Tractors (machine pools)	7
Agriculture	Self-propelled vehicles (machine pools)	6
Agriculture	Harvesters (machine pools)	11
Forestry	Harvesters (forestry)	8
Forestry	Chippers	10
Forestry	Harvesters (forestry)	8
Forestry	Chippers	6
Forestry	Chippers	6
Forestry	Forwarders	8
Forestry	Forwarders	8
Forestry	Tractors (silvicultural)	6
Forestry	Tractors (silvicultural)	6
Forestry	Tractors (other)	15
Forestry	Tractors (other)	15
Industry	High pressure cleaners (diesel)	10
Industry	Motor graders	10
Industry	Airport GSE and other (light duty)	10
Industry	Asphalt pavers	10
Industry	Pumps (diesel)	15
Industry	Tractors (transport, industry)	30
Industry	Airport GSE and other (medium duty)	10
Industry	Generators (diesel)	15
Industry	Forklifts 2–3 tons (diesel)	20
Industry	Sweepers (diesel)	10
Industry	Aerial lifts (diesel)	10
Industry	Tampers/land rollers	14
Industry	Refrigerating units (long distance)	7
Industry	Refrigerating units (distribution)	6
Industry	Vibratory plates	10
Industry	Compressors (diesel)	13
Industry	Excavators/loaders	10
Industry	Track-type dozers	10
Industry	Track-type loaders	10
Industry	Wheel loaders (0–5 tons)	10
Industry	Wheel loaders (> 5,1 tons)	10
Industry	Wheel type excavators	10
Industry	Track type excavators (0–5 tons)	10
Industry	Refuse compressors	10
Industry	Telescopic loaders	14
Industry	Airport GSE and other (heavy duty)	10

	Machinery type	Lifetime (yrs)
Industry	Dump trucks	10
Industry	Mini loaders	14
Industry	Forklifts > 10 tons (diesel)	20
Industry	Forklifts 5–10 tons (diesel)	20
Industry	Forklifts 3–5 tons (diesel)	20
Industry	Forklifts 0–2 tons (diesel)	20
Industry	Track-type excavators (> 5,1 tons)	10

3.2 Gasoline

For gasoline engines the Danish stock and operational data available is for agriculture and forestry considered to be too scarce to underpin the calculation of sector wise emission factors, for two-stroke and four-stroke engines, respectively. Therefore, the decision has been to distinguish only between two-stroke and four-stroke engine-related factors. These factors are then repeated for all four land-based non-road sectors.

Tables 2 and 3 list the machinery types which are behind the aggregated factors. In the submitted spreadsheets, the emission factors are listed for Tier 1 and Tier 2.

Table 2

Sector	**Fuel type**	**Engine**	**Machinery types**	**Lifetime (yrs)**
Forestry	Gasoline	2-stroke	Chain saws (forestry)	3
Industry	Gasoline	2-stroke	Drills	10
Industry	Gasoline	2-stroke	Slicers	10
Industry	Gasoline	2-stroke	Rammers	10
Residential	Gasoline	2-stroke	Trimmers (professional)	4
Residential	Gasoline	2-stroke	Shrub clearers (private)	10
Residential	Gasoline	2-stroke	Shrub clearers (professional)	4
Residential	Gasoline	2-stroke	Hedge cutters (private)	10
Residential	Gasoline	2-stroke	Trimmers (private)	10
Residential	Gasoline	2-stroke	Other (gasoline)	10
Residential	Gasoline	2-stroke	Garden shredders	10
Residential	Gasoline	2-stroke	Suction machines	10
Residential	Gasoline	2-stroke	Chippers	10
Residential	Gasoline	2-stroke	Chain saws (private)	10
Residential	Gasoline	2-stroke	Chain saws (professional)	3
Residential	Gasoline	2-stroke	Hedge cutters (professional)	4

Table 3

Sector	Fuel Type	Engine	Machinery types	Lifetime (yrs)
Agriculture	Gasoline	4-stroke	Tractors (gasoline-certified)	31
Agriculture	Gasoline	4-stroke	Tractors (gasoline non-certified)	31
Agriculture	Gasoline	4-stroke	Fodder trucks	10
Agriculture	Gasoline	4-stroke	Scrapers	10
Agriculture	Gasoline	4-stroke	Other (gasoline)	10
Agriculture	Gasoline	4-stroke	Sweepers	10
Agriculture	Gasoline	4-stroke	Bedding machines	10
Industry	Gasoline	4-stroke	Pumps (gasoline)	5
Industry	Gasoline	4-stroke	Compressors (gasoline)	8
Industry	Gasoline	4-stroke	Aerial lifts (gasoline)	10
Industry	Gasoline	4-stroke	Vibratory plates (gasoline)	10
Industry	Gasoline	4-stroke	High pressure cleaners (gasoline)	10
Industry	Gasoline	4-stroke	Generators (gasoline)	10
Industry	Gasoline	4-stroke	Other (gasoline)	10
Industry	Gasoline	4-stroke	Sweepers (gasoline)	10
Industry	Gasoline	4-stroke	Cutters	10
Residential	Gasoline	4-stroke	Riders (professional)	5
Residential	Gasoline	4-stroke	Wood cutters	10
Residential	Gasoline	4-stroke	Lawn movers (private)	8
Residential	Gasoline	4-stroke	Lawn movers (professional)	4
Residential	Gasoline	4-stroke	Cultivators (private-large)	15
Residential	Gasoline	4-stroke	Cultivators (private-small)	5
Residential	Gasoline	4-stroke	Cultivators (professional)	8
Residential	Gasoline	4-stroke	Riders (private)	12

3.3 LPG

For LPG, the fuel use factor and the emission factors of CO, VOC, NO_x and TSP are taken from IFEU (2004). The only LPG machinery type using LPG in the Danish inventory is forklifts, and due to lack of data, there is no distinction between technology levels. In the submitted spreadsheets, the emission factors are listed for LPG machinery.

3.4 Recreational craft

For recreational craft, the distinction is given between diesel-fuelled engines, and two-stroke and four-stroke gasoline engines. For Tier 2, conventional technologies and engines complying with Directive 2003/44/EC are considered.

Table 4 lists the machinery types which are behind the aggregated factors. In the submitted spreadsheets, the emission factors are listed for Tier 1 and Tier 2.

Table 4

Fuel type	Boat type	Engine	Engine type	Lifetime
Gasoline	Other boats (< 20 ft)	Out-board engine	2-stroke	10
Gasoline	Yawls and cabin boats	Out-board engine	2-stroke	10
Gasoline	Sailing boats (< 26 ft)	Out-board engine	2-stroke	10
Gasoline	Speed boats	Out-board engine	2-stroke	10
Gasoline	Water scooters	Built in	2-stroke	10
Gasoline	Other boats (< 20 ft)	Out-board engine	4-stroke	10
Gasoline	Yawls and cabin boats	Out-board engine	4-stroke	10
Gasoline	Sailing boats (< 26 ft)	Out-board engine	4-stroke	10
Gasoline	Speed boats	In-board engine	4-stroke	10
Gasoline	Speed boats	Out-board engine	4-stroke	10
Gasoline	Water scooters	Built-in	4-stroke	10
Diesel	Motor boats (27–34 ft)	In-board engine		15
Diesel	Motor boats (> 34 ft)	In-board engine		15
Diesel	Motor boats (< 27 ft)	In-board engine		15
Diesel	Motor sailors	In-board engine		15
Diesel	Sailing boats (< 26 ft)	In-board engine		15

4. Fuel consumption split by engine age and engine technology layer for diesel machinery (agriculture, forestry, industry) and gasoline two-stroke/four-stroke machinery

In Tables 3–3 and 3–4, the percentage split of total fuel consumption as a function of engine age is given for diesel machinery in 1.A.2.f.ii, 1.A.4.c.ii (agriculture) and 1.A.4.c.ii (forestry), and for gasoline two-stroke and four-stroke machinery.

Tables 3–5 to 3–9 display the layer share of fuel consumption per engine age and inventory year for diesel-fuelled non-road machinery (Tables 3–5 to 3–7) and gasoline-fuelled non-road machinery (Tables 3–8 to 3–9). Only those inventory year/engine age combinations are listed for which fuel consumption for more than one engine technology layer is actually estimated. For the remaining inventory year/engine age combinations, the engine technology layer which uses the fuel becomes self-explanatory.

Gasoline agricultural tractors are excluded from the aggregated figures presented in the Tables 3–4, 3–8 and 3–9. Even though these machinery types may be an important part of a country's VOC and CO emission inventory for gasoline machinery in the 1980's (and to a smaller extent also in the 1990's), the data which are examined for the Danish situation in this case may become too uncertain to apply for other countries.

One major reason for leaving out gasoline tractors from the aggregated figures is that the life time for these machinery types is regarded as very long and hence the relative amount of the fuel consumption for Denmark may be very different from the situation in other countries. If gasoline agricultural tractors are regarded as a major source of fuel consumption and emissions, countries are encouraged to make a separate Tier 3 calculation of the fuel consumption for gasoline agricultural tractors. This latter fuel consumption estimate can then be subtracted from the total fuel consumption given in the statistics, in order to obtain a new total fuel consumption base which underpins the emission inventory for gasoline non-road machinery in general.

Furthermore, no attempt has been made to derive a fuel consumption split for gasoline two-stroke and four-stroke machinery based on the Danish inventory. It is regarded as very uncertain, if such a fuel consumption split found for Denmark can be used for other countries in general. Just as an indication, the Danish fuel consumption percentage split between two-stroke and four-stroke gasoline machinery is found to be roughly 25/75 (in all inventory years).

Specific issues

5.1 SO_2

The emission factors for SO_2 are constant and rely on the sulphur content used in the Danish inventory. If the sulphur content for a specific country deviates from this, the emission factors must be scaled accordingly.

5.2 CO_2

The emission factors for CO_2 are constant and rely on the figures proposed by the Danish Energy Authority (DEA). If the emission factors for a specific country deviate from this, the country is encouraged to use country-specific data.

5.3 N_2O and NH_3

The emission factors are constant in terms of g/kg fuel. As engine technology gradually becomes more and more modern, the specific fuel consumption goes down, and hence the g/GJ derived emission factors increase.

6. References

IFEU 2004: Entwicklung eines Modells zur Berechnung der Luftschadstoffemissionen und des Kraftstoffverbrauchs von Verbrennungsmotoren in mobilen Geräten und Maschinen - Endbericht, UFOPLAN Nr. 299 45 113, pp. 122, Heidelberg.

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Winther, M., Nielsen O. 2006: Fuel use and emissions from non-road machinery in Denmark from 1985-2004 - and projections from 2005-2030. Environmental Project 1092. The Danish Environmental Protection Agency. 238 pp. Available at: www.mst.dk/udgiv/Publications/2006/87-7052-085-2/pdf/87-7052-086-0.pdf.

Appendix D BC fractions of PM for non-road engines

In general the same diesel engine technologies are used by non-road working machinery and road transport vehicles, however, measurement data for BC and PM are scarce for non-road engines as such. Hence, for non-road diesel engines the decision is to use the f-BC fractions and +/- uncertainty ranges proposed for road transport engines, as the f-BC figures for these engines are derived from a comprehensive literature survey of EC and OC fractions of total exhaust PM made by Ntziachristos et al. (2007). This is also explained in Annex 3 in the guidebook chapter for road transport. The examined OC data from Ntziachristos et al. (2007) can be input for the further assessment of OC fractions of PM (f-OC).

For diesel engines < 130 kW f-BC fractions for diesel cars are used, and for diesel engines >= 130 kW f-BC fractions for heavy duty trucks are used (c.f. road transport Annex 3). In the case of gasoline 2-stroke and 4-stroke engines data from Kupiainen and Klimont (2004) is used. The same source is behind the average factor of 0.15 for LPG (+/- range = 50 %).

Table D.1 Proposed f-BC fractions as an input for aggregated Tier 1 and 2 f-BC fractions for non-road engines

Technology	Diesel < 130 kW		Diesel >= 130 kW		Gasoline (2/4 stroke)	
	f-BC	+/- (%)	f-BC	+/- (%)	f-BC	+/- (%)
<1981	0.55	10	0.5	20	0.05	50
1981-1990	0.55	10	0.5	20	0.05	50
1991-Stage I	0.55	10	0.5	20	0.05	50
Stage I	0.8	10	0.7	20	0.05	50
Stage II	0.8	10	0.7	20	0.05	50
Stage IIIA	0.8	10	0.7	20		
Stage IIIB, no DPF	0.8	50	0.7	20		
Stage IIIB, DPF	0.15	50	0.15	20		
Stage IV, no DPF	0.8	50	0.7	30		
Stage IV, DPF	0.15	50	0.15	30		

Tier 1

Using the proposed f-BC fractions from Table D.1, the Tier 1 f-BC fractions shown in Table D.2 are derived from the PM and BC Tier 3 non road emission calculations made for Denmark in 2006 (Winther, 2012).

Table D.2 Tier 1 BC fractions of PM for non road engines

Category	Fuel type/Engine type	f-BC
Agriculture	Diesel	0.57
Forestry	Diesel	0.65
Industry	Diesel	0.62
All	Gasoline 2-stroke	0.05
All	Gasoline 4-stroke	0.05

Tier 2

Using the proposed f-BC fractions from Table D.1 technology specific f-BC fractions for Tier 2 are derived from the PM and BC Tier 3 non road emission calculations made for Denmark in 2006 (Winther, 2012).

Table D.3 Tier 2 BC fractions of PM for non road engines

Category →	Agriculture	Forestry	Industry	All	All
Technology	Diesel	Diesel	Diesel	Gas. 2-stroke	Gas. 4-stroke
<1981	0.55	0.55	0.55	0.05	0.05
1981-1990	0.55	0.55	0.55	0.05	0.05
1991-Stage I	0.54	0.54	0.55	0.05	0.05
Stage I	0.79	0.78	0.80	0.05	0.05
Stage II	0.77	0.76	0.80	0.05	0.05
Stage IIIA	0.70	0.70	0.70		

Tier 3

The following Table D.4 contains the proposed f-BC fractions and +/- uncertainty ranges for the Tier 3 methodology described in the guidebook for non-road machinery. For diesel engines < 130 kW f-BC fractions for diesel cars are used, and for diesel engines >= 130 kW f-BC fractions for heavy duty trucks are used (c.f. road transport discussion note). In the case of gasoline 2-stroke and 4-stroke engines f-BC data from Kupiainen and Klimont (2004) are used. For gasoline, however, the use of f-BC data only becomes relevant, if country specific PM emission factors are available.

Table D.4 Proposed Tier 3 f-BC fractions for non-road engines

Table no.	Technology	Engine size	f-BC	+/- (%)
3-10	Uncontrolled diesel	< 130 kW	0.55	10
		>= 130 kW	0.5	20
3-11	Stage I diesel	< 130 kW	0.8	10
		>= 130 kW	0.7	20
3-12	Stage II diesel	< 130 kW	0.8	10
		>= 130 kW	0.7	20
3-13	Stage III diesel	< 130 kW	0.8	10
		>= 130 kW	0.7	20
3-14	Stage I-II diesel, agriculture	< 130 kW	0.8	10
		>= 130 kW	0.7	20
3-15	Stage III diesel, agriculture	< 130 kW	0.8	10
		>= 130 kW	0.7	20
3-18	2-stroke uncontrolled gasoline	-	0.05	50
3-19	4-stroke uncontrolled gasoline	-	0.05	50

References

Kupiainen, K. & Klimont, Z., 2004: Primary emissions of submicron and carbonaceous particles in Europe and the potential for their control. Interim Report IR-04-079. IIASA, Austria, 115pp.

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