SNAP CODES: **080100**
080200
080300
080600
080700
080800
080900
081000

SOURCE SECTOR TITLES: **OTHER MOBILE SOURCES & MACHINERY**
Military
Railways
Inland Waterways
Agriculture
Forestry
Industry
Household and Gardening
Other off-road

NOSE CODE: **202.01**
202.02
202.03
202.06
202.07
202.08
202.09
202.10

NFR CODE: **1 A 5 b**
1 A 3 c
1 A 3 d ii
1 A 4 c ii
1 A 2 a-f
1 A 4 b ii
1 A 3 e ii

1 ACTIVITIES INCLUDED

The aim of this chapter is to provide a common tool concerning the estimation of emissions of several sub-sectors of SNAP sector 8, including remarks concerning the collection, evaluation and assessment of relevant information, of other mobile sources and machinery:

- Off-Road Vehicles and Machines (SNAP 0806, 0807, 0808, 0809)
- Railways (SNAP 0802)
- Inland Waterways (SNAP 0803) only.

Apart from the 'on-road' vehicles (passenger cars, light duty vehicles, heavy duty vehicles, buses, two wheelers), which are covered by SNAP sector 7, internal combustion engines are used in many other modes of application. In the light of the large number of machinery types to be considered, the work to be carried out requires definition of the source category in more detail.

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.

Table 1-1 provides an overview of the proposed sub-split of the source categories to be considered, which has been based on the experiences so far.

In some cases, there is a risk of overlapping with other SNAP sectors, 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 proposed to count these as on-road vehicles. 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. In some other cases, machinery is mobile in principle, but actually stays at the same site for long periods, or only is mobile within a small radius, e.g., some excavators and cranes. In this case, it is proposed to consider these machines here as 'Other Mobile Sources and Machinery'. Moreover, there are large mobile generator sets, e.g. above 1 MW, which are mobile but quite often not moved in reality. With regard to this equipment, there is a real risk of misallocation, because in many inventories such generator sets most likely fall into the categories of SNAP sectors 1, 2 or 3 under the item '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 the category 0801. Therefore, there is a risk of double counting.

Table 1-1: Proposal for a Reference List of 'Off-road' machinery which should be covered under SNAP codes 0801 to 0803 and 0806 to 0809

080100	Military		
080200	Railways:	01	Shunting locs
		02	Rail-cars
		03	Locomotives
080300	Inland Waterways:	01	Sailing Boats with auxiliary engines
		02	Motorboats / Workboats
		03	Personal Watercraft
		04	Inland Goods Carrying Vessels
080600	Agriculture:	01	2-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/crowler type)
		06	Cement and Mortar Mixers
		07	Cranes
		08	Graders / Scrapers
		09	Off-Highway Trucks
		10	Bull Dosers (wheel/crowler 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 & Gardening	01	Trimmers/Edgers/Bush Cutters
		02	Lawn Mowers
		03	Hobby Chain Saws
		04	Snowmobiles/Skidoos
		05	Other household and gardening equipment (wood splitters, snowblowers, 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, golfcarts)

2 CONTRIBUTION TO TOTAL EMISSIONS

There are indications that the activities covered by this note consume a significant proportion of diesel fuel (Table 2-1).

Table 2-1: Consumption of diesel/gas-oil and motor spirit by selected source categories in EC 12 in 1000 tonnes in 1990 (EUROSTAT 1992)

Source Category	diesel/gas-oil [kt]	motor spirit [kt]
[1] Road Transport	79.620	103.226
[2] Industry	9.620	82
[3] Agriculture	9.763	222
[4] Inland navigation	5.061	387
[5] Railways	2.144	-
[1]-•[2]..[5]*100 / [1]	67	99.3

Remark: The figures given should be considered as an indication of the potential consumption of fuels in the sectors listed only, because it is unclear whether the full amount given for sectors [2] to [4] is actually used in internal combustion engines.

In total, and looking at the pollutants covered by the UN-ECE protocols only, it can be assumed that the sectors covered by this guidebook contribute significantly to total NOx and VOC emissions in most countries.

However, figures are only available for some countries. Moreover, due to the lack of a common systematic approach, these figures are not fully comparable among each other, because the machinery covered still differs somewhat among countries. Table 2-2 shows some of the data for VOC, NOx and SO_2 currently available. In some countries, the sector might also be a major source of some of the other pollutants covered by CORINAIR, e.g. CO, and of some pollutants currently not covered by international emission inventory activities, e.g. diesel particulates, heavy metals and persistent organic compounds (UNECE 1994,a,b). Further details on the CORINAIR90 results are presented in chapter ACOR.

An indication of groups of major sub-sources, at least for Western European countries, can currently be obtained by analyzing the EPA data. Table 2-3 shows a first broad evaluation. In the light of these results, the following sectors seem of greatest importance for the different pollutants:

For VOC: Recreational marine (Subpart of 'Inland Waterways')
Lawn and Garden (Subpart of 'Household and Gardening')

For NO_X: Agriculture
Construction (Subpart of 'Industry')

For CO: Light Commercial (Subpart of 'Industry')
Lawn and Garden (Subpart of 'Household and Gardening')

For PM: Construction (Subpart of 'Industry')

Table 2-2: Estimates of national emissions of VOC, NOx and SO_2 from parts of the CORINAIR sector 08 'Other Mobile Sources and Machinery' in selected countries (Please note: the figures are not fully comparable among each other because the individual subsectors covered by the estimates differ)

Country	Off - road source categories covered	Annual emissions of source category in kt (and % of total national emissions for the pollutants)		
		VOC	NO_x	SO_2
Norway	Agriculture Forestry Industry Military Railways	1.5 (1.0)	12.8 (5.8)	0.7 (0.7)
Denmark	Agriculture Forestry Industry Airport machinery	5.5 (2.6)	36.5 (11.9)	2.5 (0.9)
Finland	Agriculture Forestry Industry Household and Gardening	11.0 (5)	41.0 (15)	2.7 (n.a.)
Sweden	Agriculture Forestry Industry Household and Gardening	7.3 (1.6)	70.5 (6.5)	5.1 (2.6)
Switzerland	Industry	1.1 (0.4)	6.8 (4.2)	0.3 (0.5)
Netherlands	Industry	22..56 (5..12)	53..125 (9..19)	4..10 (1..3)

This means that data collection for the sectors forestry and recreation (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.

Table 2-3: Contribution of 'Off-road' machinery to total emission [in percent], as estimated by US-EPA for different non-attainment areas

Pollutant	**VOC**	**NOx**	**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

1) Average of two different industries

Table 2-4: Trace element emissions in Europe in [tonnes/year] (UNECE 1994b)

No.	Category	As (1982)	Cd (1982)[1)]	Hg (1987)	Pb (1985)[2)]	Zn (1982)
1	Fuel combustion in utility boilers	330	125	189	1300	1510
2	Fuel combustion in industrial,	380	145	216	1600	1780
3	Gasoline combustion	-	-	-	64000	-
4	Non-ferrous metal industry	3660	730	29	13040	26700
5	Iron and steel production	230	53	2	3900	9410
6	Waste incineration	10	37	35	540	650
7	Other sources	360	30	255	112	4540
	Total	4970	1120	726	85500	44590

1) The 1990 emissions of Cd in Europe was estimated between 270 and 1950 tonnes (678 tonnes as average value)
2) The 1990 emissions of Pb in Europe was estimated between 32200 and 54150 tonnes.

Industrial associations also published some emission data. EUROMOT has provided emission estimates for the sector off-road machinery using a somewhat different methodology than that proposed in this guidebook in order to overcome the problem of estimating the equipment population and the annual hours of equipment use (EUROMOT 1992). The EUROMOT methodology assumes that the 'annual sales' times the 'equipment life time' is equal to the 'number of equipment in use' times the 'annual hour of equipment usage'. This assumption is valid only if there is no growth in engine population over the lifetime. Moreover, the estimate is not made for a specific year but for a period corresponding to the lifetime of equipment (which may vary from about 5 to 15 years). In the light of the uncertainties associated with the equipment population and the usage, the EUROMOT method seems to be a good way to overcome the problem.[1)] Moreover, ICOMIA very recently provided emission data for the sector 'Inland Waterways'. Table 2-5 shows some of the results of these two publications, related to the estimated 1985 emissions of the European Union.

Table 2-5: Emission estimates of EUROMOT and ICOMIA

Country	Off - road source categories covered	Annual emissions of source category in kt (and % of total national emissions for the pollutants)		
		VOC	NO_x	SO_2
EUROMOT	Agriculture Forestry Inland Waterways	500 (4.8)	2450 (23.5)	650 (-)
ICOMIA	Inland Waterways (Inland goods carrying vessels most likely not fully covered)	41.8 (0.004)	12.4 (0.001)	112 (-)

It is, therefore, proposed to aim at estimating emissions of all pollutants covered by CORINAIR 90, except NH_3 if too difficult, and to add diesel particulates and other relevant pollutants which are of priority for the PARCOM/ATMOS work, in particular Cd, Cu, Pb and Zn as far as heavy metals are concerned, and polyaromatic hydrocarbons (benzo(a)anthracene, benzo(b)fluoranthene, diebenzo(a,h)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthene) as far as persistent organic compounds are concerned.

3 GENERAL

3.1 Brief description of machinery

In order to identify the vehicles and machinery dealt with, it is helpful to provide a brief description (see also Table 3-1).

3.1.1 SNAP 080100 Military

There is no further split provided. It is assumed that all equipment is diesel engine powered.

1) However, it needs to be checked whether the inherent assumption made that the lifetime of equipment depends on its power output and not on its purpose is correct, e.g., is the lifetime of a 20 kW engine used for marine propulsion equal to a 20 kW engine used in a trencher?

3.1.2 SNAP 0802xx Railways

01Shunting Locomotives

These locomotives are used for shunting wagons. They are equipped with diesel engines having a power output of about 200 to 2000 kW.

02Railcars

Railcars are mainly used for short distance rail traction, e.g., urban/suburban traffic. They are equipped with diesel engines having a power output of about 150 to 1000 kW.

03Locomotives

Diesel locomotives are used for long distance rail traction. They are equipped with diesel engines having a power output of about 400 to 4000 kW.

3.1.3 SNAP 0803xx Inland Waterways

01Sailing Boats with auxiliary engines

One can distinguish small sailing boats with a length of up to about 6 metres which are partly equipped with outboard engines and larger sailing ships which, in general, have inboard engines. The small engines used for small sailing boats have a power output between about 2 and 8 kW and are all 2 stroke petrol engines. For larger sailing boats mainly diesel engines are used having a power output between 5 and about 500 kW. Four-stroke petrol engines with a power output between about 100 and 200 kW are also on offer but rarely used. The average 8 to 10 metre sailing boat is equipped with an engine of 10 to 40 kW power output.

02Motor Boats / Workboats

A large number of 2-stroke petrol engines is on offer for recreational motor boats with a length of about 3 to 15 metres. They have a power output between 1 and 200 kW. There are also 4-stroke engines on offer having a power output between 5 to 400 kW. For larger motor boats generally diesel engines are used which are identical to those used for large sailing boats.
There is a large number of different workboats in use, e.g., for inland passenger transport, in harbours for ship towing and other commercial purposes (e.g., swimming cranes and excavators), for police and custom purposes. These boats have a power output of about 20 to 400 kW and are all diesel engine equipped.

03Personal Watercrafts

These are 'moped' type crafts, all equipped with two-stroke engines.

04Inland Goods Carrying Vessels

They are all equipped with slow diesel engines having a power output between 200 and 800 kW with an average of about 500 kW. Since not all vehicles/machinery listed above make use of all types of engines, the methodology can be concentrated on those engines mainly used. Table 3-1 provides an overview on the engine types taken into account.

3.1.4 SNAP 0806xx Agriculture

01Two-Wheel Tractors

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.

02Agricultural Tractors

Two axles/four wheel tractors (there are also some articulated wheel and crawler type tractors which fall under this category) are nearly 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 4- and 6 cylinder diesel engines are equipped with turbo charger.

03Harvesters/Combiners

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

04Others

Under this heading falls all other agricultural equipment, e.g. sprayers, manure distributors, mowers, balers, tillers, swatchers. Mainly diesel engines, but also 2- and 4-stroke gasoline engines are used in these machines. The power output is in the range of 5 to 50 kW.

3.1.5 SNAP 0807xx Forestry

01Professional Chain Saws / Clearing Saws

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

02Forest Tractors / Harvesters / Skidders

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.

03Others

Under this heading are covered machines such as tree processors, haulers, fellers, forestry cultivators, shredders, and log cultivators. They are mainly diesel engine equipment; some use 2-stroke engines.

3.1.6 SNAP 0808xx Industry

01Asphalt Pavers / Concrete Pavers

These wheeler crawler type machines (road pavers, slurry seal pavers, chip spreaders, large pavement profilers, pavement recyclers) are street finishers which use asphalt or concrete as paving material. They are equipped with 3- to 6-cylinder diesel engines with a power output between 15 and 160 kW. Larger engines are turbo charged.

02Plate Compactor / Tampers / Rammers

Small compaction equipment is powered by 2-stroke gasoline engines having about 1 to 3 kW output; medium size and large size compaction equipment are equipped either with 4-stroke gasoline engines or with diesel engines of 2 to 21 kW. Tampers and rammers are tools for surface treatment operated by 2-stroke petrol engines of about 1 - 3 kW power output. Large rammers fall under 'Other Construction Equipment'.

03Rollers

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.

04Trenchers / Mini Excavators

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.

05Excavators (wheel / crawler type)

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 distinguished 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 2- to 4-cylinder diesel engines and fall under the sub-category 'Trenchers'. Medium size hydraulic and dragline ones used for general earth moving 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.

06Cement and Mortar Mixers

Small concrete mixers run on electric power or 4-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.

07Cranes

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.)

08Graders / Scrapers

Graders (e.g. articulated steered or wheel steered ones) 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.

09Off-Highway Trucks

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.

10Bulldozers

This category includes wheel dozers, articulated steered dozers, crawler dozers, crawler loaders etc. They are mainly used for demolishing and earth moving 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.)

11Tractors / Loaders / Backhoes

Tractors are used for general transport word. 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 it is the case for excavators, loaders fall into three classes: 'Minis' have about 15 to 40 kW and are equipped with 3 or 4 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.

12Skid Steer Loaders

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

13Dumpers / Tenders

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 4-stroke petrol engines with a power output between 5 to 10 kW.

14Aerial Lifts

Small aerial lifts (< 2 kW) run mainly on electrical engines, only some on small mainly 2-stroke petrol engines with a power output of 3 to 10 kW. Large aerial lifts and work platforms are mounted on truck chassis and are operated by separate engines with a power output of 5 to

25 kW or by the vehicle engine utilizing a pneumatic system. Attention must be paid to avoid double counting with the category 'On road vehicles'.

15Fork Lifts

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 4-stroke petrol/LPG engines and 2.5 to 6 litres for diesel engines.

16Generator Sets

There are three main groups of power packs used. Small ones which can be carried by 1 or 2 persons. They have an output of 0.5 to 5 kW and are powered by 4-stroke engines. Some of the very small sets still run with 2-stroke engines. Medium ones which can be put on small one axle / two or four wheel trailer. They are 3 or 4 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 1000 kW. Nearly all engines are turbo charged. Generator sets above 1000 kW are not considered as mobile machinery.

17Pumps

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 2-stroke and above 20 kW power output 4-stroke petrol engines are not readily need anymore.

18Air / Gas Compressors

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.

19Welders

Small mobile welders (< 10 kW) are also offered with 4-stroke petrol engines, all larger ones are diesel engine equipped and go up to about 40 kW.

20Refrigerating Units

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.

21Other General Industrial Equipment

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.

22Other Material Handling Equipment

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

23Other Construction Equipment

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 2-stroke gasoline engines are used.

3.1.7 SNAP 0809xx Household and Gardening

01Trimmers / Edgers / Brush Cutters

This equipment is mainly 2-stroke petrol engine equipped and has about 0.25 to 1.4 kW power output.

02Lawn Mowers

Mowers are either 2-stroke or 4-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 1- or 2-cylinder diesel engines and 4-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 4-stroke petrol engine powered. The power output ranges from 1,5 to 5 kW, displacements between 100 and 250 ccm.

03Hobby Chain Saws

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

04Snow Mobiles / Skidoos

These are small 'moped-like' snow vehicles, equipped with 2- and 4-stroke gasoline engines with a power output of 10 to 50 kW.

05Other Household and Gardening Equipment

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

06Other Household and Gardening Vehicles

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

Table 3-1: Engine-types of 'Off-road' machinery which should be covered under the CORINAIR 1990 SNAP codes 0801 to 0803

SNAP	Code	Vehicle / Machinery Type	Engine Type D	2SG	4SG	LPG
08 02	01	Shunting locs	x			
	02	Rail-cars	x			
	03	Locomotives	x			
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	2-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/crowler type)	x			
	06	Cement and Mortar Mixers	x		x	
	07	Cranes	x			
	08	Graders / Scrapers	x			
	09	Off-Highway Trucks	x			
	10	Bull Dosers (wheel/crowler 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
	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	

<u>Legend:</u>

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

4 SIMPLER METHODOLOGY

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 work which builds upon as many hard facts as possible, reducing at the same time the number of assumptions. However, when searching for such a compromise method, one always has to keep in mind the objective of the work, i.e. the final data usage which determines to a large extent the source category split requirements.

A simple methodology for estimating emissions is based on total fuel consumption data which then have to be multiplied by appropriate bulk emission factors (Eggleston et al. 1993). Therefore, the formula to be applied in this case is:

$$E_i = FC \cdot Ef_i \qquad (1)$$

with

E_i = mass of emissions of pollutant i during inventory period

FC = fuel consumption

EF_i = average emissions of pollutant i per unit of fuel used

With regard to emissions of CO_2, SO_2 and emissions of lead, it is proposed to use the following equations:

Ultimate CO_2 emissions are estimated on the basis of fuel consumption only, assuming that the carbon content of the fuel is fully oxidised to CO_2**.** The following formula is applied:

$$\text{mass of } CO_2 = 44.011 \text{ (mass of fuel}/(12.011 + 1.008 \cdot r_{H/C})) \qquad (2)$$

with

$r_{H/C}$ = the ratio of hydrogen to carbon atoms in the fuel (~1.8 for gasoline and ~2.0 for diesel)

If **end-of-pipe CO_2** emissions are to be calculated, then other emissions of C atoms in the form of CO, VOC and particulate emissions have to be taken into account. Then the following formula is applied :

$$\begin{aligned}\text{mass of } CO_2 = 44.011 \text{ (mass of fuel}/(12.011 + 1.008 \cdot r_{H/C}))\\ - \text{mass of CO}/28.011 - \text{mass of VOC}/13.85\\ - \text{mass of particulates}/12.011) \qquad (2a)\end{aligned}$$

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

$$E_{SO2} = 2 \sum_j \sum_l k_{S,l}\, b_{j,l} \qquad (3)$$

with

$k_{S,l}$ = 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.

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

$$E_{Pb} = 0.75 \sum_j \sum_l k_{Pb,l}\, b_{j,l} \qquad (4)$$

with

$k_{Pb,l}$ = 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 its best.

5 DETAILED METHODOLOGY

The simple methodology outlined under section 4 makes use of fuel statistics, to be multiplied with bulk emission factors accordingly expressed. In fact, at first glance it seems to be an easy way to estimate (by order of magnitude) the emissions of off-road machinery and equipment taking estimated average emission factors (see, for example, OECD 1991) and to multiply them by the statistical fuel consumption. Unfortunately, this is quite often not feasible, because the statistical fuel consumption data are not available in the required detail. For most countries, only for the sector 'Railways' and the sub-part 'Goods Carrying Vessels', which is part of the sector 'Inland Waterways', fuel consumption data seem to be specific enough to be used for an order of magnitude estimate.

Therefore, in the following, a more detailed methodology is described, which is mainly based on the US-EPA method for estimating off-road emissions (US-EPA 1991).
The following basic formula is used to calculate emissions:

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

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 based on a recently published report on emissions of construction work machinery in Switzerland (Infras 1993). In a first step, the methodology applied there has been somewhat 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 horse power 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.

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 year-books. Therefore, special investigations have to be carried out and reasonable estimates can be made, based on general technical experiences.

With regard to the typical load factor, it is proposed to apply, as far as possible, the weighting factors laid down in ISO DP 8178. Tables 5.2-1 and 5.2-2 provide examples of the kind of vehicles and mobile machinery which fall under the different test cycles.

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:

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

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).

Table 5.2-1: Test points and weighting factors of ISO DP 8178 test cycles

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			
Type C2				0.06		0.02	0.05	0.32	0.30	0.10	
Constant speed											
Type D1	0.3	0.5	0.2								
Type D2	0.05	0.25	0.3	0.3	0.1						
Locomotives											
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	0.11					0.19	0.32			0.3
Type E2	0.2	0.5	0.15	0.15							

Marine application propeller					
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

Test cycle **A** (13 - mode cycle)

Mode number cycle A	1	2	3	4	5	6	7	8	9	10	11	12	13
Speed	Low idle speed	Intermediate speed					Low idle speed	Rated speed					Low idle speed
% Torque	0	10	25	50	75	100	0	100	75	50	25	10	0
Weighting factor	0.25/3	0.08	0.08	0.08	0.08	0.25	0.25/3	0.1	0.02	0.02	0.02	0.02	0.25/3

Table 5.2-2: 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 plow 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 Application**	
	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
Cycle G	**Utility, Lawn and Garden, typically < 20 kW**	
	G1:	non hand held 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 hand held 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:	hand held rated speed applications
	Examples:	edge trimmers, string trimmers, blowers, vacuums, chain saws, portable saw mills

6 RELEVANT ACTIVITY STATISTICS

The following types of fuels are used in the sectors:

- for diesel engines: Diesel oil for road transport (NAPFUE code 205),
- for 2-stroke gasoline engines: Mixture of motor gasoline (NAPFUE code 208) and lubrication oil, mixing rate is about 25:1,
- for 4-stroke gasoline engines: Motor gasoline (NAPFUE code 208),
- for LPG engines: Liquefied petroleum gas (NAPFUE code 303).

7 POINT SOURCE CRITERIA

There are no relevant point sources which fall under the source categories dealt with in this chapter.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

With regard to the simple methodology, Table 8-1 shows the emission factors proposed for diesel engines and Table 8-2 shows the bulk emission factors for gasoline engines. No emission factors for CO_2, SO_2 and lead are given because these emissions depend fully on actual fuel composition and fuel consumption. For heavy metals and persistent organic compounds, the emission factors given in Tables 8-1 and 8-2 should be applied.

With regard to the advanced approach, Tables 8-3 to 8-8 provide the baseline emission factors. For diesel engines, these baseline emission factors are modified depending on the engine design parameters in accordance with Table 8-9. Moreover, in order to take into account the change of emissions with the age, degradation factors as shown in Tables 8-10 to 8-12 are defined. It should be noted that the emission factors calculated by the advanced approach differ somewhat from those proposed to be used in the basic approach. Emission factors for SO_2, CO_2, heavy metals and persistent organic pollutants have to be taken from Tables 8-1 and 8-2, 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 8-13 presents a set of emission factors for the calculation of evaporative losses from the gasoline powered engines.

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.

It should be mentioned that, apart from smoke emission of agricultural tractors (CEC 1977) there are no emission limiting regulations in force in Europe for the sectors covered by this note. However, currently there is legislation in preparation for parts of the sector, e.g. diesel engines used in construction works (European Commission 1993).

Table 8-1: Bulk emission factors for 'Other Mobile Sources and Machinery', part 1: Diesel engines

Diesel Engines [g/kg fuel]	NOx	NM-VOC	CH_4	CO	NH_3	N_2O	PM
Agriculture	50.3	7.27	0.17	16.0	0.007	1.29	5.87
Forestry	50.3	6.50	0.17	14.5	0.007	1.32	5.31
Industry	48.8	7.08	0.17	15.8	0.007	1.30	5.73
Household	48.2	10.4	0.17	22.9	0.007	1.23	7.65
Railways	39.6	4.65	0.18	10.7	0.007	1.24	4.58
Inland waterways	42.5	4.72	0.18	10.9	0.007	1.29	4.48

Heavy Metal Emission Factors for all Categories in mg/kg fuel

Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
0.01	1.7	0.05	0.07	0.01	1

Persistent Organic Pollutants Emission Factors for all Categories in mg/kg fuel

Diesel engines	[µg/kg fuel] irrespective of sector
Benz(a)anthracene	80
Benzo(b)fluoranthene	50
Dibenzo(a,h)anthracene	10
Benzo(a)pyrene	30
Chrysene	200
Fluoranthene	450
Phenanthene	2500

Remark: Emission factors are still quite uncertain and may need revision as soon as more information becomes available

Table 8-2: Bulk emission factors for 'Other Mobile Sources and Machinery', part 2: gasoline engines

Gasoline 4-stroke [g/kg fuel]	NOx	NMVOC	CH_4	CO	NH_3	N_2O
Agriculture	7.56	73.6	3.68	1486	0.005	0.07
Forestry	-	-	-	-	-	-
Industry	9.61	43.4	2.17	1193	0.005	0.08
Household	8.00	110	5.50	2193	0.005	0.07
Railways	-	-	-	-	-	-
Inland waterways	9.70	34.4	1.72	1022	0.005	0.08

Persistent Organic Pollutants Emission Factors for all Categories in mg/kg fuel

Gasoline 4-stroke	[µg/kg fuel] irrespective of sector
Benz(a)anthracene	75
Benzo(b)fluoranthene	40
Dibenzo(a,h)anthracene	10
Benzo(a)pyrene	40
Chrysene	150
Fluoranthene	450
Phenanthene	1200

Gasoline 2-stroke [g/kg fuel]	NOx	NMVOC	CH_4	CO	NH_3	N_2O
Agriculture	1.70	617	6.17	1070	0.004	0.02
Forestry	1.55	762	7.67	1407	0.004	0.02
Industry	2.10	602	6.00	1103	0.004	0.02
Household	1.77	813	8.13	1572	0.004	0.02
Railways	-	-	-	-	-	-
Inland waterways	2.67	505	5.06	892	0.004	0.02

Heavy Metal Emission Factors for all Categories in mg/kg fuel

Cadmium	Copper	Chromium	Nickel	Selenium	Zinc
0.01	1.7	0.05	0.07	0.01	1

Remark:
- POP emission factors for gasoline 2-stroke engines are not available
- Emission factors are still quite uncertain and may need revision as soon as more information becomes available

Table 8-3: Baseline emission factors for uncontrolled diesel engines in [g/kWh]

POLLUTANT	**Power Range in kW**							
[g/kWh]	**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	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
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
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

Equations used:

NOx: 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
N_20: 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 8-4: Baseline emission factors for stage I (for 37 • P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

POLLUTANT	**Power Range in kW**							
[g/kWh]	**0-20**	**20-37**	**37-75**	**75-130**	**130-300**	**300-560**	**560-1000**	**>1000**
NO_x	14.4	14.4	*9.20*	*9.20*	*9.20*	*9.20*	14.4	14.4
N_2O	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
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
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: 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) 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 cases it is proposed to use the “uncontrolled” values.

Table 8-5: Baseline emission factors for stage II (for 20 • P < 560 kW) controlled diesel engines in [g/kWh], irrespective of engine type

POLLUTANT	**Power Range in kW**							
[g/kWh]	**0-20**	**20-37**	**37-75**	**75-130**	**130-300**	**300-560**	**560-1000**	**>1000**
NO_x	14.4	*8.50*	*8.00*	*7.00*	*7.00*	*7.00*	14.4	14.4
N_2O	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
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
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: 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) 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 cases it is proposed to use the “uncontrolled” values.

Table 8-6: Baseline emission factors for uncontrolled 2-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

Equations used:

CO: $300 + 1200/P$
NMVOC: $160 + 500/P^{0.75}$
NOx: $6{,}73 \cdot 10^{-3} * P + 1$
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 8-7: Baseline emission factors for uncontrolled 4-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

Equations used:

CO: $300 + 2000/P$
NMVOC: $6 + 100/P^{0.75}$
NOx: $2,7 \cdot 10^{-3} * P + 4.0$
CH_4: $0,3 + 5/P^{0.75}$ (5% of VOC)
N_2O: 0.03
NH_3: 0.003
FC: $80 + 350/P^{0.05}$
P = Max. Power output

Table 8-8: Baseline emission factors for uncontrolled 4-stroke LPG engines in [g/kWh]

NOx:	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_20:	0.05, irrespective of power output
CH_4:	1.0, irrespective of power output
FC:	350, irrespective of power output

Table 8-9: 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

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

Table 8-10: Degradation factors of diesel engines for the different pollutants and fuel consumption

CH_4/NMVOC:	1.5% per year
CO:	1.5% per year
NOx:	0% per year
FC/SO_2/CO_2:	1% per year
N_2O/NH_3:	0% per year
PM:	3% per year

Table 8-11: Degradation factors of 2-stroke gasoline engines

CH_4/NMVOC:	1.4% per year
CO:	1.5% per year
NOx:	- 2.2% per year
FC/SO_2/CO_2:	1% per year
N_2O/NH_3:	0% per year

Table 8-12: Degradation factor of 4-stroke gasoline and 4-stroke LPG engines

CH_4/NMVOC:	1.4% per year
CO:	1.5% per year
NOx:	- 2.2% per year
FC/SO_2/CO_2:	1% per year
N_2O/NH_3:	0% per year

Table 8-13: Proposed emission factors for evaporative losses in g/h

SNAP	Code	Vehicle / Machinery Type	2SG	4SG
0802	01	Shunting locs		
	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	2-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	

SNAP	Code	Vehicle / Machinery Type	2SG	4SG
0808	01	Asphalt/Concrete Pavers		
	02	Plate compactors / Tampers / Rammers	0.11	0.12
	03	Rollers		
	04	Trenchers / Mini Excavators		
	05	Excavators (wheel/crowler type)		
	06	Cement and Mortar Mixers		1.20
	07	Cranes		
	08	Graders / Scrapers		
	09	Off-Highway Trucks		
	10	Bull Dosers (wheel/crowler 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

Legend:
2SG: 2-stroke gasoline (fuel used: motor gasoline)
4SG: 4-stroke gasoline (fuel used: mixture of motor gasoline and lubrication oil)

9 SPECIES PROFILES

There is still no systematic approach concerning the evaluation and the reporting of species profiles, e.g. it is not clear whether individual compounds, chemical groups or reactivity classes should be reported.

With regard to VOC profiles, Tables 9-1, 9-2 and 9-3 provide information as used by Veldt, Derwent and Loibl et al. in their work on emission estimates for the road transport sector. In principle, the composition given there can also be used for the sectors covered by this guidebook.

10 UNCERTAINTY ESTIMATES

For many sub-sectors, 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 10-1 provides broad qualitative uncertainty estimates.

11 WEAKEST ASPECTS AND PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The detailed methodologies proposed in this chapter need no improvements in the short term because already they 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) and on emission factors for N_2O in general, and all pollutants as far as two-stroke gasoline powered machinery is concerned.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

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
- Railway emissions should be disaggregated as a line source along tracks, in the way it will be done for on road emissions, or they could be treated as area source taking into account the railway track distribution
- 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.

Table 9-1: 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	Gasoline			Diesel	LPG
	Exhaust gases		Evaporation		
	4-stroke engine				
	(conventional)	3-way catalyst equipped			
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

Table 9-1: continued

B) Methane (composition in weight % of exhaust)

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

Table 9-2: Composition of VOC-emissions (data as used by Derwent)

No.	Species	Percentage by mass speciation by source category, w/w %		
		petrol engines 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
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

No.	Species	Percentage by mass speciation by source category, w/w %		
		petrol engines exhaust	diesel exhaust	petrol evaporation vehicles
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
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 9-3: 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	

Table 10-1: Uncertainty estimates for input data required to apply the proposed methodologies

Sector	Subsector	Total Fuel Consumption	Parameter Unit Fuel Consumption	Population	Load Factor	Annual Hours of use	Power Range	Emission factor for the pollutants [1)] CO_2	CO	NM VOC	CH_4	NO_x	N_2O	NH_3	SO_2	PM	Age Distri-bution	Engine Design Distributio
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 con- struction 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 & Gardening	all subsectors	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E
Railways	all subsectors	B	B	A	B	B	B	B	B	B	C	B	E	E	B	B	B	B
Inland Waterways	01 Sailing boats, Motor boats, Personal watercraft	D	C	E	D	D	D	E	E	E	E	E	E	E	E	E	E	E
	04 Inland Goods Carrying Vessels	D	B	A	C	D	C	B	B	B	C	B	E	E	B	B	D	D

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

Table 10-1: Legend

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.

13 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 13-1 provides a proposal for the 'average' European disaggregation of emissions. In practice, the temporal disaggregation might differ considerably among countries.

Table 13-1: 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
Inland Waterways	all but 04	5	10	75	10
	04, Inland Goods Carrying Vessels	20	30	30	20
Agriculture	all	10	20	50	20
Forestry	all	10	20	50	20
Industry	all	20	30	30	20
Military		20	30	30	20
Household & Gardening	all but 04	10	40	30	20
	04, Snowmobiles	90	5	0	5
Railways	all	25	25	25	25

		Seasonal Disaggregation (in %)							Hourly Disaggregation (in			
Sector	Subsector	M	T	W	T	F	S	S	6-12	12-18	18-24	24-6
Inland Waterways	all but 04	5	5	5	5	10	35	35	35	35	4	1
	04, Inland Goods Carrying Vessels	18	18	18	18	18	5	5	35	35	4	1
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	5	5	5	5	10	35	35	35	35	4	1
	04, Snowmobiles	10	10	10	10	10	25	25	35	35	4	1
Railways	all	15	15	15	15	20	10	10	35	25	35	5

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

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 the national experts should be contacted in order to check the correctness of the values and to learn about the reasons for their choice.

A) Simple methodology

- The applied bulk emission factors for diesel, two-stroke gasoline, four-stroke gasoline, and LPG engines 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.

B) Advanced 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.

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

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List of ABBREVIATIONS USED

CH_4	:	Methane
CO	:	Carbon monoxide
CO_2	:	Carbon dioxide
Cd	:	Cadmium
Cu	:	Copper
FC	:	Fuel Consumption
HM	:	Heavy Metals
NH_3	:	Ammonia
NMVOC	:	Non-methane volatile organic compounds
NO_x	:	Nitrogen oxides
NO_2	:	Nitrogen
N_2O	:	Nitrous oxide
Pb	:	Lead
PM	:	Particulate matter
POP	:	Persistent organic pollutants
SO_2	:	Sulphur dioxide
VOC	:	Volatile organic compounds
Zn	:	Zinc
CC	:	Cylinder Capacity of the Engine
CORINE	:	COoRdination INformation Environmentale
CORINAIR	:	CORINeAIR emission inventory
COPERT	:	COmputer Programme to calculate Emissions from Road Transport
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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19 RELEASE VERSION, DATE AND SOURCE

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