> Non-road energy consumption and pollutant emissions

Study for the period from 1980 to 2050

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Authors
Benedikt Notter, Martin Schmied

In-house consultant
Giovanni d'Urbano, Felix Reutimann, Harald Jenk
Air Pollution Control and Chemicals Division

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Translation
Keith Hewlett, Zug

Design
Karin Nöthiger, 5443 Niederrohrdorf

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> Abstracts

This report quantifies non-road pollutant emissions and fuel consumption in Switzerland. This source encompasses all mobile machines and appliances that are equipped with a combustion engine and are not intended to transport passengers and goods by road. The calculations were made for eight different machine and appliance categories, and cover the period from 1980 to 2050, with 2010 as the reference year. The report thus provides an overview of the situation in the non-road segment and can also serve as a technical basis for assessing potential measures aimed at reducing air pollution.

Keywords:
Exhaust emissions from machines and appliances, Emissions of air pollutants, Non-road segment

Der Bericht quantifiziert die Luftschadstoffemissionen und den Energieverbrauch des Non-road-Sektors in der Schweiz. Diese Quellengruppe umfasst alle mit einem Verbrennungsmotor ausgerüsteten mobilen Maschinen und Geräte, die nicht zur Beförderung von Personen und Gütern auf der Strasse bestimmt sind. Die Berechnungen wurden für acht einzelne Maschinen- resp. Gerätegattungen durchgeführt. Sie decken den Zeitraum von 1980 bis 2050 ab, mit einem Schwerpunkt für das Jahr 2010. Der Bericht gibt damit einen Überblick über den Non-road-Sektor und kann zugleich als fachliche Grundlage für die Beurteilung von möglichen Massnahmen zur Verminderung der Luftverschmutzung dienen.

Stichwörter:
Abgas Maschinen und Geräte, Luftschadstoffemissionen, Non-road-Sektor

Ce rapport quantifie les émissions polluantes et la consommation de l'énergie du secteur non routier en Suisse. Cette source comprend l'ensemble des machines et appareils qui sont mobiles et équipés d'un moteur à combustion interne, mais ne sont pas destinés au transport routier de personnes et de biens. Les calculs ont été effectués pour huit catégories différentes de machines et appareils. Ils couvrent la période de 1980 à 2050, en mettant l'accent sur l'année 2010. Ce rapport donne une vue d'ensemble du secteur non routier et sert en même temps de base technique pour évaluer quelles mesures permettraient de diminuer la pollution atmosphérique.

Mots-clés:
gaz d'échappement de machines et appareils, émissions de polluants atmosphériques, secteur non routier

Il presente rapporto quantifica le emissioni inquinanti e il consumo di energia del settore non-stradale in Svizzera. Detto settore comprende le macchine mobili e gli apparecchi di lavoro equipaggiati con un motore a combustione interna non destinati al trasporto di persone e di merci sulla strada. I calcoli, che riguardano otto categorie di macchine e apparecchi, sono stati effettuati per il periodo dal 1980 al 2050, con particolare accento sul 2010. Il rapporto offre una panoramica del settore non-stradale e, al contempo, funge da base tecnica per valutare possibili misure di riduzione dell'inquinamento atmosferico.

Parole chiave:
gas di scarico, macchine e apparecchi, emissioni di inquinanti atmosferici, settore non-stradale

> Foreword

It is not only road traffic that continues to produce considerable quantities of air pollutants today, but also the non-road sector, i.e. mobile machines and appliances that are not intended to transport passengers and goods by road. These include construction, agricultural and forestry machinery, as well as a broad range of garden-care and hobby appliances, etc.

With respect to exhaust regulations and emission measurements, the non-road sector was for many years a neglected area of air pollution control. In 2008, the Federal Office for the Environment (FOEN) published a comprehensive report on fuel consumption and pollutant emissions in the non-road sector. In the meantime, significant developments have taken place in the area of exhaust regulations, as well as with regard to engine technology and various technological innovations. This report takes account of these developments and represents an update of the previously published data. It therefore forms an updated basis for assessing the relevance of specific source groups, calculating the anticipated chronological development of emissions and estimating the impacts of potential reduction measures.

This updated non-road report has been compiled on the basis of a significant volume of data that has been collected and processed by a large number of participants. Although the figures reflect the current status of knowledge, they can of course change as the results of new developments and findings are published. The FOEN is therefore always grateful to receive information about new developments so that it can constantly improve this dataset and keep it up to date.

Dr. Martin Schiess
Head of Air Pollution Control and Chemicals
Swiss Federal Office for the Environment (FOEN)

> Summary

Considerable quantities of various air pollutants are produced not only from road traffic, but also by a broad variety of other mobile motors that are mostly operated in the non-road segment. Accurate and up-to-date data relating to non-road emissions in Switzerland are required for a variety of purposes, including the preparation of the annual climate gas stock, which Switzerland is obliged to produce within the scope of the Kyoto Protocol, or as the basis for planning air pollution control measures. The FOEN thus decided to use this study for the purpose of updating the non-road emissions database that was created in 2008 (FOEN 2008).

Emission sources

The non-road segment encompasses all mobile machines and appliances that are equipped with a combustion engine and are not intended to transport passengers and goods by road. For calculation purposes, the various machines and appliances were divided into the following categories:

- Construction machinery
- Industrial machinery
- Agricultural machinery
- Forestry machinery
- Garden-care/hobby appliances
- Navigation machinery
- Railway machinery
- Military machinery

For various reasons, in this version the term “non-road” has been used instead of the term “off-road” that was used in previous versions. Firstly, the term “off-road” implies that the corresponding emissions originate exclusively off the road, but some non-road vehicles such as tractors and construction machines also travel on roads from time to time and thus also display licence plates. Secondly, “non-road” is now the designation for the sector that is widely used at the international level. And finally, by using the term “non-road” it is possible to avoid an incorrect association with off-road motor vehicles, i.e. all-terrain motor cars.

Traditionally speaking, mobile machines and appliances with an electric motor are not allocated to the non-road sector. However, in view of the fact that in recent years combustion engines have gradually been substituted with electric motors in some appliance categories as a result of improved battery technology and health considerations, this updated study now encompasses the corresponding electric machines and appliances. This ensures that, as before, the stock encompasses the energy consumption of all the various categories. No pollutant emissions are recorded for electric machines

and appliances because this report focuses on direct emissions and does not take account of emissions arising from electricity and fuel production.

In addition to electric machines and appliances, this stock now includes the following new machine categories that were not yet included in the previous version (FOEN 2008):

- Generators in trade and industry
- Vehicles and mobile machines for use on airport aprons (airside sector)
- Cargo ships on the Rhine

Air pollutants

In this report, the emission levels of the four "classical" air pollutants (plus one greenhouse gas) have been calculated and in each case expressed in tonnes per annum:

- Carbon monoxide (CO)
- Hydrocarbons (HC)
- Nitrogen oxides (NO_x)
- Particulate matter (PM)
- Carbon dioxide (CO_2)

Emissions of the following non-regulated pollutants have been added in this revised version:

- Components of hydrocarbons:
- Methane (CH_4)
- Non-methane hydrocarbons (NMHC), correspond to the difference between HC and CH_4)
- Benzene (C_6H_6)
- Nitrous oxide (N_2O)

Calculation methodology

Emissions were mainly calculated on the basis of the following criteria:

- Stock, no. of operating hours and nominal capacity of non-road machines and appliances
- Load, emission and adjustment factors for these machines and appliances

For each type of machine and each pollutant, the total emissions are calculated by multiplying the number of operating hours by the corresponding emission factors, and subsequently adding them together.

Here the emission factors for the four classical pollutants depend to a very great extent on the type of machine and its method of operation. By contrast, CO_2 emissions are a direct consequence of the consumption of fuel, and are directly coupled to this using fixed conversion factors.

Stock, operating hours and fuel consumption of non-road machines and appliances in 2010

Tab. 1 shows that the category with the greatest number of number of machines is garden-care/hobby appliances, with a proportion of 80% of the total stock in 2010, followed by agricultural machines (11%).

In terms of fuel consumption, however, the picture is completely different: due to the lengthy operating times per machine and the high nominal capacities, construction machinery accounts for 33% of total energy consumption. Despite the much greater number of machines, the corresponding figure for the garden-care/hobby appliances category is only 3%. Agricultural machinery also accounts for a high proportion of energy consumption (29%).

Tab. 1 > Non-road stock and operating hours in 2010

Stock and operating hours of non-road source groups (2010) Figures rounded up or down.

Machine category	Stock [-]	Operating hours [million hrs p.a.]	Operating hours per machine [hrs p.a.]
Construction machinery	57,100	23.8	420
Industrial machinery	69,800	47.5	680
Agricultural machinery	319,000	33.0	100
Forestry machinery	11,900	2.3	190
Garden-care / hobby appliances	2,320,000	149.7	60
Navigation machinery	95,100	3.4	40
Railway machinery	700	0.5	780
Military machinery	13,100	0.9	70
Total (non-road sector)	**2,890,000**	**261.1**	**90**

Tab. 2 > Energy consumption in the non-road sector in 2010

Stock and operating hours, non-road source groups (2010) Figures rounded up or down.

Machine category	Fuel consumption [tonnes p.a.]			Electricity consumption [GJ]	Total energy consumption [PJ]
	Diesel[1]	Petrol	Gas		
Construction machinery	135,800	2,561	-	-	5.92
Industrial machinery	57,200	2,610	5,840	799	3.57
Agricultural machinery	106,700	14,390	-	-	5.18
Forestry machinery	7,460	1,770	-	-	0.39
Garden-care / hobby appliances	-	10,560	-	122	0.57
Navigation machinery	24,010	12,586	-	-	1.56
Railway machinery	11,500	-	-	-	0.49
Military machinery	5,990	426	-	-	0.27
Total (non-road sector)	**348,700**	**44,900**	**5,840**	**921**	**18.0**

Non-road pollutant emissions in 2010

Fig. 1 shows the proportions of the various emission categories to non-road emissions for the four classical pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM). Different machine/appliance categories account for the highest emission levels, depending on the pollutant.

With respect to carbon monoxide and hydrocarbons, by far the highest emission levels come from agricultural machinery (41 and 37% respectively, cf. Tab. 3). This is primarily attributable to the use of single-axle mowers that have a relatively high nominal capacity as well as very high load factors. However, appliances used for garden care and in forestry also make a decisive contribution towards CO and HC emissions (garden appliances, 28% of CO and 24% of HC emissions; forestry machinery, 5% of CO and 8% of HC emissions), mainly because a very large number of them are petrol-driven.

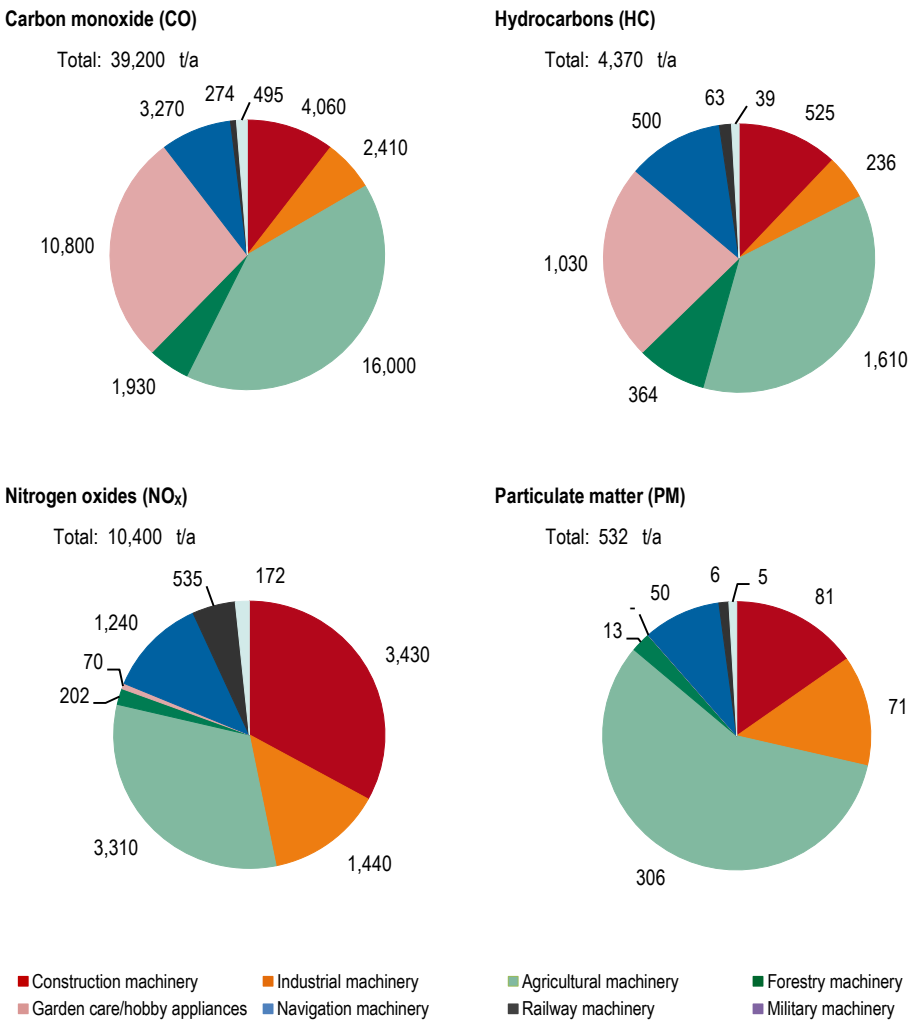
With respect to nitrogen oxides (NO_x), by far the greatest sources of emissions are construction machinery (33% of non-road emissions) and agricultural machinery (32%), but industrial machinery (14%) and ships (12%) – and to a lesser extent, railway machinery (5%) – also make a significant contribution towards non-road emissions of NO_x.

Agriculture is by far the largest source of particulate matter emissions today, with a proportion of 58% of the total emissions in the non-road sector. In 2005, the emissions of particulate matter from construction machines was similar to the level produced from agricultural machinery (FOEN 2008). Thanks largely to the obligation stipulated in the Ordinance on Air Pollution Control to equip construction machines with particle filters with effect from 2009, the level of PM emissions from these machines fell to

[1] Including heating oil for steamships

around a quarter of those from agricultural machinery in 2010, despite the fact that emissions in the agriculture sector also fell by 19% in the same period thanks to the increased use of new technologies.

Fig. 1 > Emissions of regulated pollutants in the non-road sector in 2010



Numerical values, cf. Tab. 3.

Tab. 3 > Emissions of regulated pollutants in the non-road sector in 2010

Figures rounded up or down.

Machine category	Carbon monoxide (CO) [tonnes p.a.]	Hydrocarbons (HC) [tonnes p.a.]	Nitrogen oxides (NO_X) [tonnes p.a.]	Particulate matter (PM) [tonnes p.a.]	Carbon dioxide (CO_2) [tonnes p.a.]
Construction machinery	4,060	525	3,430	81	435,800
Industrial machinery	2,410	236	1,440	71	203,200
Agricultural machinery	16,000	1,610	3,310	306	381,300
Forestry machinery	1,930	364	202	13	29,000
Garden-care / hobby appliances	10,800	1,030	70	-	33,200
Navigation machinery	3,270	500	1,240	50	115,000
Railway machinery	274	63	535	6	36,200
Military machinery	495	39	172	5	20,200
Total (non-road sector)	**39,200**	**4,370**	**10,400**	**532**	**1,254,000**

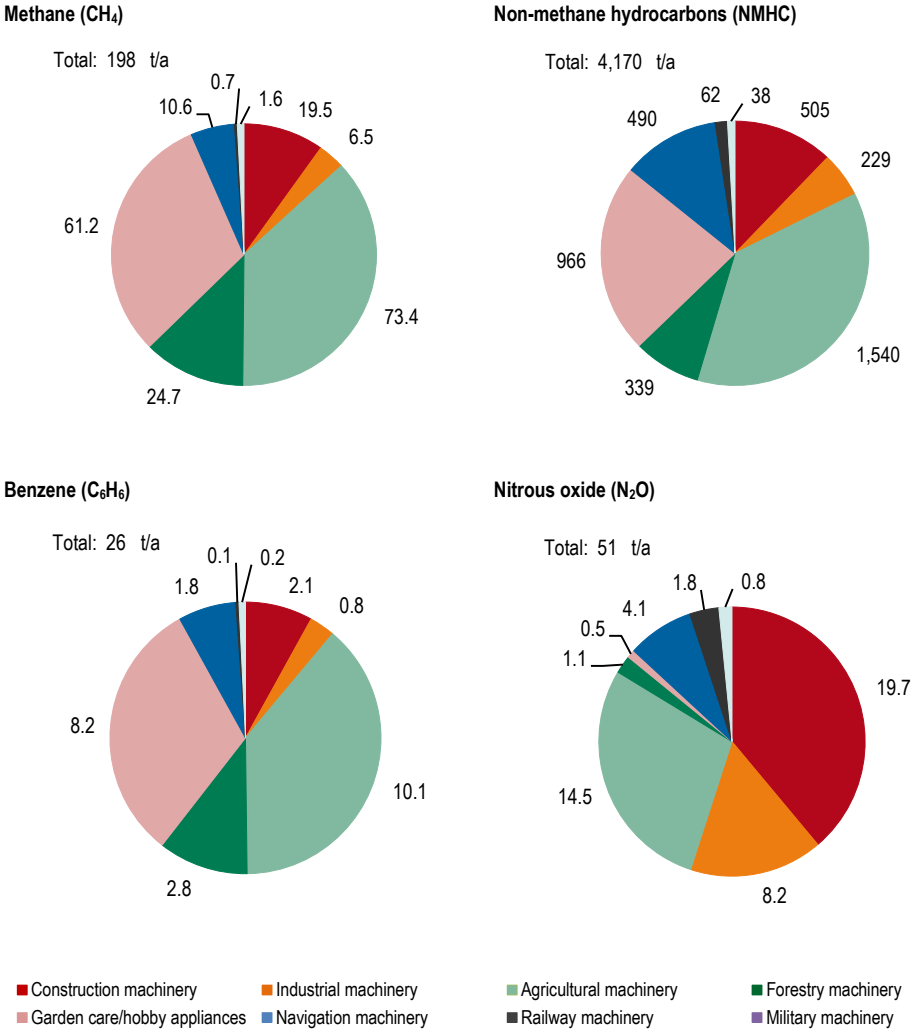
Fig. 2 (below) depicts the proportions of the various emission groups to emissions of non-regulated pollutants in the non-road sector: methane (CH_4), non-methane hydrocarbons (NMHC) and benzene (C_6H_6), plus nitrous oxide (N_2O), ammonia (NH_3) and particle number (PN).

With respect to the hydrocarbon components, by nature the proportion of the individual emission groups to the total is similar to that of total hydrocarbons. It varies slightly from component to component, however, since the proportion of individual components to total hydrocarbons varies according to type of fuel and engine technology. For example, garden appliances contribute more towards total methane emissions than to total hydrocarbons (methane, 31% compared with total hydrocarbons, 24%). This is because a large number of garden appliances are equipped with 2-stroke engines, which produce higher concentrations of methane in total hydrocarbon emissions (7%) than 4-stroke petrol and diesel engines (3.4 and 2.4% respectively). The opposite effect occurs with regard to non-methane hydrocarbons.

With respect to benzene, the contribution by garden appliances, agricultural and forestry machines towards total emissions is higher than that to total hydrocarbons, because in these categories a large number of petrol engines are generally used, and with a 0.8% proportion of total hydrocarbons, even after the introduction in 2000 of the lower limit level for benzene in petrol these engines still produce much higher specific benzene emissions than diesel engines with a 0.15 proportion of total hydrocarbons. Here the use of benzene-free alkylate petrol, primarily in the forestry sector, but to an increasing extent in other areas too, has not been taken into account.

As far as nitrous oxide is concerned, the largest emitters are construction machines, followed by agricultural and industrial machinery. The reason for this is that specific emissions from diesel and 4-stroke petrol engines, which are the most widely used in these categories, are around three times higher than those from 2-stroke engines.

Fig. 2 > Emissions of non-regulated air pollutants in the non-road sector in 2010



Numerical values, cf. Tab. 4.

Tab. 4 > Emissions of non-regulated pollutants in the non-road sector in 2010

Figures rounded up or down.

Machine category	Methane (CH_4) [t/a]	Non-methane hydrocarbons (NMHC) [tonnes p.a.]	Benzene (C_6H_6) [tonnes p.a.]	Nitrous oxide (N_2O) [tonnes p.a.]
Construction machinery	20	505	2	20
Industrial machinery	7	229	1	8
Agricultural machinery	73	1,540	10	14
Forestry machinery	25	339	3	1
Garden-care / hobby appliances	61	966	8	–
Navigation machinery	11	490	2	4
Railway machinery	1	62	–	2
Military machinery	2	38	–	1
Total (non-road sector)	**198**	**4,170**	**26**	**51**

Development of non-road emissions (1980–2050)

The chronological development of overall non-road emissions is depicted in Fig. 3. Here we can see that emission levels of almost all pollutants considered in this report increased until 1995. Benzene emissions fell sharply thanks to the introduction in 2000 of the lower limit level for benzene in petrol. Then from 2002, i.e. when the first EU regulations governing maximum emission levels entered into effect, emission levels of all pollutants (except carbon dioxide and nitrous oxide) began to decrease significantly. The sharpest decline concerns particulate matter, which has fallen by around 50%.

A further reduction is expected for the majority of pollutants in the future as a result of the specification of lower limit levels and improvements in engine technology. A further increase (though at a slower pace) is only to be anticipated for the greenhouse gases CO_2 and N_2O. The level of PM emissions is expected to fall the most sharply: here a reduction by 12% is predicted by 2030, and a drop to 5% of the level recorded in 2010 is anticipated by 2050. This reduction is attributable to cleaner engines as well as to the assumed market penetration of particle filters. It should be noted here that forecasts are generally less reliable over longer timeframes.

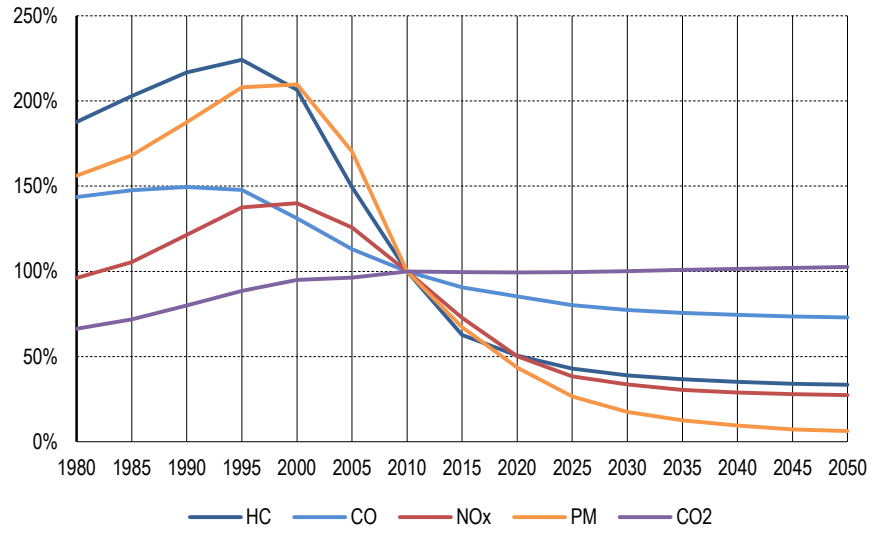
Fig. 3 > Relative development of pollutant emissions in the non-road sector compared with figures from 2010

a) Relative development of regulated air pollutants and CO_2
b) Relative development of non-regulated air pollutants

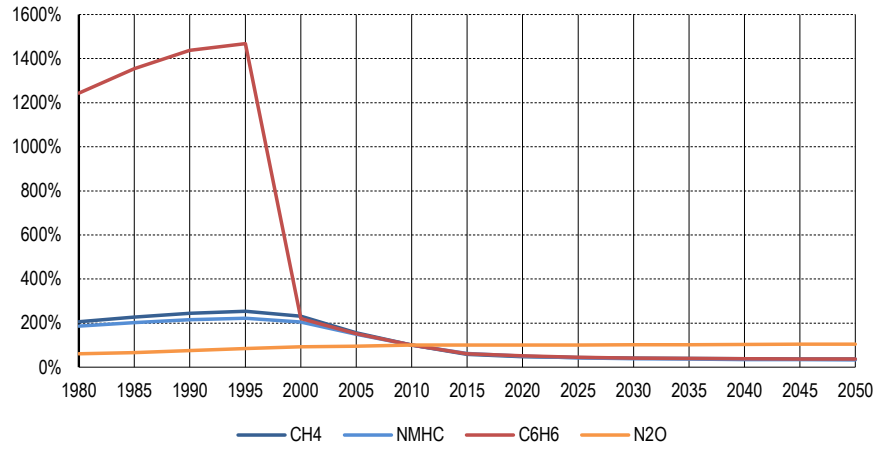
The reference year for the development of pollutant emissions is 2010.

The trend in particle emissions (PM) is based on the development of the stock of machines that are equipped with particle filters (Fig. 23).

a)



b)



Numerical values, see table Tab. 54 on page 186

Comparison with road traffic fuel consumption and emissions

Tab. 5 shows a direct comparison between non-road and road traffic fuel consumption and emissions in 2005. Non-road emissions of carbon dioxide, hydrocarbons, nitrogen oxides and particulate matter are disproportionately high in comparison with those attributable to road traffic. Although only 9% of fuel is consumed by non-road machines and appliances, the non-road segment's proportion of overall emissions (i.e. non-road + road) is between 20% (carbon monoxide) and 32% (particulate matter).

Tab. 5 > Comparison between the non-road sector and road traffic (2010)

Figures rounded up or down.

	Non-road sector [tonnes p.a.]	Road traffic [tonnes p.a.]	Proportion of non-road sector to overall level (road + non-road)
Consumption			
Diesel	348,700	1,726,600	17 %
Petrol	44,900	2,807,100	2 %
Energy	18 PJ	193 PJ	9 %
Carbon monoxide (CO)			
Carbon monoxide (CO)	39,200	124,200	24 %
Hydrocarbons (HC)	4,370	17,100	20 %
Nitrogen oxides (NO_x)	10,400	39,300	21 %
Particulate matter (PM)	532	1,135	32 %
Carbon dioxide (CO_2)	1,254,000	14,373,100	8 %

Source: Road Traffic Statistics. FOEN 2010

Outlook

The emission data presented in this report indicate that additional major efforts aimed at reducing air pollution will be required in the next few years in the non-road segment. It is possible, for example, to greatly reduce emissions of diesel soot with the aid of particle filter systems. It is becoming apparent that compliance with the European exhaust regulations EU IIIB and EU IV is possible with the aid not only of particle filters, but also with the application of alternative technologies such as selective catalytic reduction; however, the introduction of regulations at the EU V level in 2019 will require all diesel machines with an output between 19 and 560 kW to be equipped with particle filters. In Switzerland, the majority of construction machines used on building sites have had to be equipped with particle filters since the entry into force of the Ordinance on Air Pollution Control in 2009. As far as other types of machinery are concerned for which a retrofitting requirement does not apply, a reduction will only be possible at a considerably later date.

1 > Current situation

Despite increasingly stringent legislation, the level of air pollutants remains too high. The majority of these emissions are attributable to motorised road traffic, but the non-road segment also makes a sizeable contribution. This segment encompasses all mobile machines and appliances that are equipped with a combustion engine and are not intended to transport passengers and goods by road. According to the standard definition, the non-road sector only encompasses machines and appliances equipped with a combustion engine. However, in view of the fact that combustion engines are gradually being replaced by electric motors in some machine categories, this study also includes the corresponding electric machines and appliances.

In an effort to improve air quality, the FOEN and various cantons and municipalities are implementing or proposing guidelines and measures for reducing levels of non-road emissions. Until now, report UW-0828 of the Federal Office for the Environment dated 2008 (FOEN 2008) was used as the basis for calculating pollutant emissions and fuel consumption in the non-road sector, but since the information contained in this report is now out of date, it was necessary to compile a new data set.

2 > Objectives

The main purpose of this report is to present up-to-date calculations of non-road air pollutant emissions and fuel consumption in Switzerland.

The calculations were made for eight different categories of machines and appliances: construction machinery, industrial machinery, agricultural machinery, forestry machinery, garden-care/hobby appliances, ships, railway machinery, military machinery.

In recent years, combustion engines have gradually been substituted with electric motors in some appliance categories as a result of improved battery technology and health considerations. This updated study now encompasses the corresponding electric machines and appliances. The aim here is to ensure that, as before, the stock encompasses the energy consumption of all the various categories. No pollutant emissions are recorded for electric machines and appliances because this report focuses on direct emissions and does not take account of those arising from electricity and fuel production.

The report covers the period from 1980 and includes forecasts up to 2050, with 2010 serving as reference year. The objective is for the report to provide an overview of the situation in the non-road segment and to serve as a technical basis for assessing potential measures aimed at reducing air pollution.

3 > Procedure

The previously existing data relating to the non-road sector were compiled in 2008 in Report UW-0828 of the Federal Office for the Environment (FOEN 2008) 49 (SAEFL 1996a), which in turn updated the initial calculations carried out in 1996 (SAEFL 1996). The criteria for calculation were updated within the scope of the studies carried out for this new report, which included updating the stock of machines and appliances and their operating hours, reviewing the criteria for emission factors, and improving and refining the calculation methodology.

The stock and operating hours had to be reviewed and modified as necessary on the basis of new statistical material and estimates by specialists. Appendix A2 (page 141) contains an overview of the applied definitions and datasets.

The revision of emission criteria was necessary due to the introduction in 2008 of European exhaust regulations for new non-road engines. These new regulations call for a constant improvement of new non-road engines in terms of emissions of specific pollutants, and this development had to be taken into account for calculating emission factors.

The calculation methodology was improved versus the one used for Report UW-0828, so that new findings could be incorporated into the present report (e.g. influence of particle filters on emissions from new engines).

4 > Methodology

4.1 Basic principles

Non-road emissions are primarily calculated on the basis of the following criteria:

- Stock and operating hours of machines in the various categories, engine type, capacity and year of manufacture.
- Emission factors: Emission factors are allocated to machines, according to engine type and year of manufacture, which indicate emission levels in grams per kilowatt hour. Emission factors are classified into categories that encompass the period (by year of manufacture) for which certain emission factors are characteristic for the various types of machines. For new machines, the emission categories correspond to the period from which certain maximum levels are legally binding for the type of machine concerned.

These two data sets (stock/hours of operation and emission factors) are used for calculating the emissions for each type of machine (i.e. machines in the same category, of the same type and capacity, and similar year of manufacture, to which the same emission can be allocated) in accordance with the following formula (cf. Appendix A1 on page 138):

$$Em = N \cdot H \cdot P \cdot \lambda \cdot \varepsilon \cdot CF_1 \cdot CF_2 \cdot CF_3$$

Key

Em	= emission per machine type, pollutant, emission category (in grams or tonnes p.a.)
N	= no. of machines/appliances (stock)
H	= hours of operation (hrs p.a.)
P	= mean nominal capacity (kW)
λ	= effective load factor (dimensionless))
ε	= emission factor (g per kWh)
CF_1	= correction factor for deviation of effective load from standard load in the cycle on which the emission factor is based (dimensionless)
CF_2	= correction factor for dynamic utilisation of the machine (dimensionless)
CF_3	= correction factor for wear and tear of the machine (dimensionless)

The total non-road emissions per annum can be determined by adding together the data for all machine types per reference year.

The calculation methodology outlined above refers to the four classical pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulate

matter (PM). The applied emission factors are machine-related and dependent on its operation.

By contrast, CO_2 emissions are directly dependent on fuel consumption. The corresponding conversion factors are indicated in Tab. 44 on page 172.

Emissions of non-regulated air pollutants are calculated as follows:

- Components of hydrocarbons (methane, non-methane hydrocarbons, benzene: these are calculated as differentiated proportions to hydrocarbons HC) according to type of fuel and engine technology. For benzene, a differentiation is made between the periods before and after 2000, since in that year the limit level of 1% for benzene content entered into force. The applied conversion factors for hydrocarbons to their components are indicated in Appendix A4 (pages 154 ff) in the footnotes to the respective emission factor tables.
- Nitrous oxide (N_2O): here, differentiated emission factors in grams per kWh are applied, depending on the engine technology. These factors are also indicated in Appendix A4 (pages 154 ff).

4.2 Stock model

4.2.1 Structure

The stock of non-road machines and appliances was compiled in collaboration with various expert groups (cf. Appendix A14, page 228). For calculation purposes, the various machines and appliances were divided into the following eight categories in accordance with the CORINAIR definitions[2]:

- Construction machinery
- Industrial machinery
- Agricultural machinery
- Forestry machinery
- Garden-care/hobby appliances
- Navigation machinery
- Railway machinery
- Military machinery

The eight categories are divided into sub-categories by engine type and engine power class (Fig. 4). Some power class levels are based on engine type and category. The resulting sub-categories are referred to as segments. In addition, in the non-road database an age distribution dataset has been compiled for each category, and this can be used for determining which machines and appliances are to be allocated to which emission level.

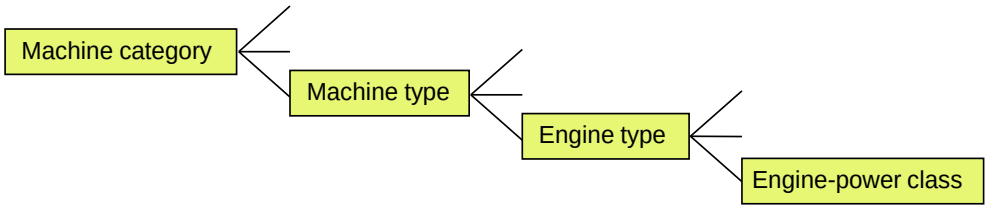
[2] CORINAIR (**COR**e **IN**ventory of **AIR** emissions) is a joint project of the European Topic Centre on Air Emissions and the European Environmental Agency (EEA). The objective here is to collect, manage and publish data relating to air emissions with the aid of a European air emissions inventory and database system.

Appendix A2 (page 141) contains a list of all machine categories and types.

In addition to electric machines and appliances that have been included in the non-road inventory in view of the increasing substitution of combustion engines with electric motors (cf. chapter 2, page 21), this updated inventory contains the following new machine categories that were not included in the previous version (FOEN 2008):

- Generators in trade and industry (previously, only generators used in the agriculture sector were included
- Airport apron vehicles and mobile machines (airside), excluding aircraft
- Cargo ships on the Rhine

Fig. 4 > Example of classification structure of non-road database based on composition of a machine/ appliance segment



4.2.2 Collection of data

For the development of stock and operating hours from 1980 until 2000, reference was made to the previous non-road database (FOEN 2008, stock and operating hours based on EWI 2005). Stock or operating hours were only retrospectively adjusted if more recent information was available that rendered a correction necessary.

A variety of methods were used for collecting the required data. Questionnaires were mailed to manufacturers, importers and operators. Where available, use was made of existing statistics in Switzerland and abroad, e.g. the database of the Swiss Federal Motor Vehicle Inspection Office. (MOFIS), the basic inventory data of the Swiss Master Builders Association (SBV 2013), the periodical agricultural census and the federal government's import/export statistics (Swiss-Impex, EZV 2014). Market studies (Off-Highway Research 2005, 2008, 2012) were an important source for the development of the stock of construction machinery and tractors. In addition, the websites of various manufacturers were consulted, questionnaires were distributed to importers and operators, and applications for refunds of oil tax, as well as applications for the use of heating oil, submitted to the Federal Customs Administration, were evaluated. Special workgroups were formed for the purpose of collecting data relating to specific types of machines and appliances. Due to the relatively modest volume of statistics available in existing data sets, the various data collection groups estimated stock and operating hours based on the evaluation of questionnaires and the experience of the involved specialists. In the majority of cases, the age distribution was taken from EWI (2005) and was only adjusted in a few cases.

The forecasts up to 2050 are based on various key data:

- Construction sector, industry: Forecasts regarding gross value added in the involved sectors up to 2030 (VÖV 2012), and forward projection of this trend, taking account of the predicted population growth (medium scenario of the Federal Statistical Office, BFS 2014). With respect to construction machinery, the development of overall activity (in kWh) resulting from the forward trend projection for individual machine categories closely corresponds to the predicted development of gross value added. In the industry category, however, the trend in stock and operating hours is well below the development of gross value added. The reason for this is that the latter depicts the development for the entire industry sector, whereas the non-road inventory is limited to mobile machines and appliances, of which fork lift and snow groomers account for a high proportion. The activities of fork lifts are currently declining slightly, while those of snow groomers are increasing at a slower pace than the gross value added of the industry sector.
- Agriculture: Development of agricultural land and forward projection of the trend
- Military and railway machinery: Information provided by the Army Logistics Basis (LBA), Swiss Federal Railways and the Bern-Lötschberg-Simplon (BLS) railway operator up to the planning horizon, thereafter forward trend projection with increasing flattening of the curve
- Other sectors: Forward projection of previous trends, with flattening from 2020

The above listing shows that the further forecasts reach into the future, the less reliable they become. In view of this, the figures in this report relating to stock and emissions should be interpreted with increasing caution the further in the future the years lie for which they apply.

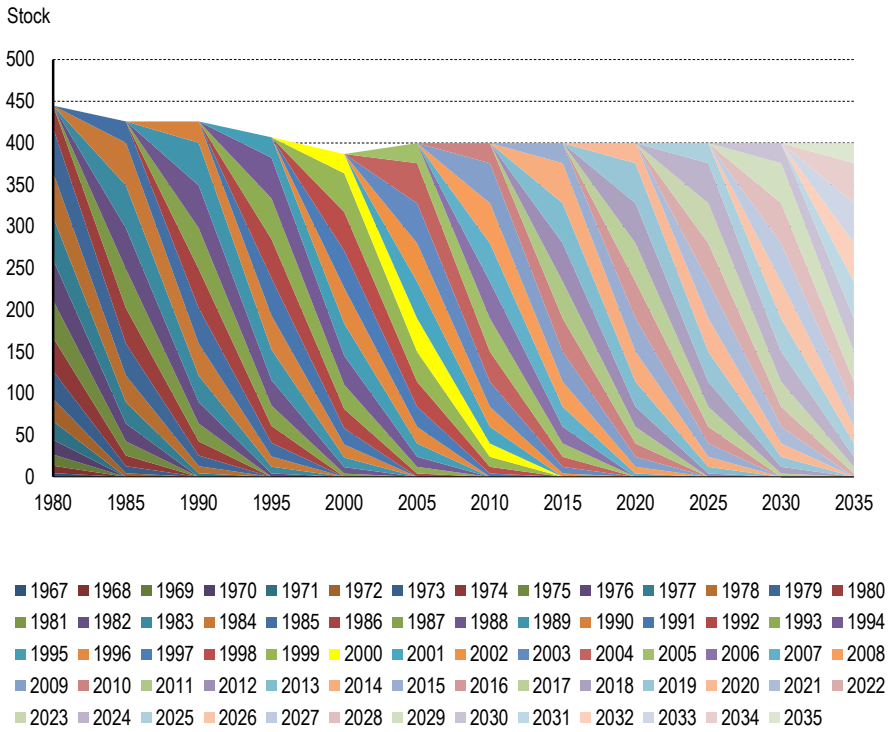
Appendix A2 (pages 141 ff) contains a summary of the definitions and bases of the datasets per machine category.

4.2.3 Stock model

For the period concerned, age distribution and stock data can be used as the basis for calculating segment-specific stock models for the various machine and appliance categories. In the stock model, the machines and appliances for each segment are depicted by age or year of manufacture.

Fig. 5 > Stock model based on the example of road asphalt finishers ("Construction machinery" category)

Distribution by year of manufacture in a given reference year. The stock model was calculated in accordance with the data from the new non-road database in 5-year intervals. This explains the angular nature of the curves.



In the above model, the stock of road asphalt finishers brought into circulation in 2000 (yellow curve) has been taken into account as follows (cf. Fig. 7 for age distribution): in 2000 itself, half the new machines put into operation that year (23 vehicles) have been taken into account, because on average half the new machines are available if these are put into operation in equal distribution over the period concerned. From 46 new machines that were brought into circulation in 2000, 40 were still in use in 2005, and this number had fallen to 16 in 2010. In 2015, none of the road asphalt finishers that were brought into circulation in 2000 were still in service.

4.2.4 Operating hours

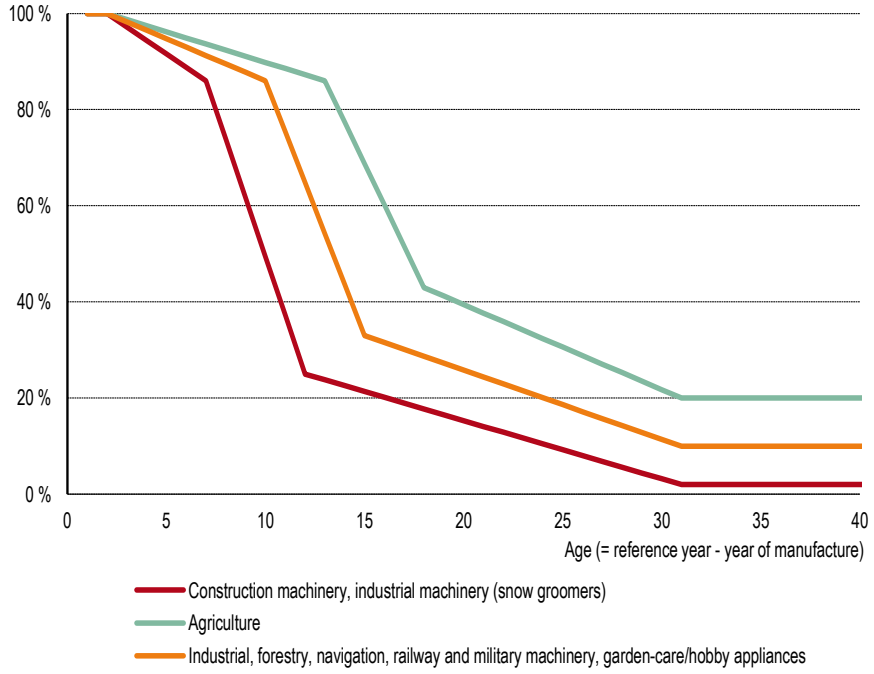
For each machine category, the number of operating hours was entered specific to the corresponding capacity. In addition, assumptions were made regarding the development of operating hours of the machines and appliances in each capacity range over the period under observation. For this purpose it was assumed that the useful life of a machine increases in proportion to its capacity. This assumption was based on information taken from EWI (2005) and the inventory datasets of the Swiss Master Builders Association (SBV 2013), findings of experts in the various expert groups (Appendix A14, page 228) and data obtained from other reference sources (IFEU 2004).

4.2.5 Dependency of operating hours on age

Newer machines are used more intensively than older ones, and this fact is reflected in the model through a function for the dependency of operating hours on the age of the machine. Here, a greater age dependency was assumed for construction machines than for all others. The functions for age dependency are depicted in Fig. 6.

Fig. 6 > Reduction of annual operating hours of a machine depending on age

Age dependency of operating hours in accordance with SAEFL 1994.

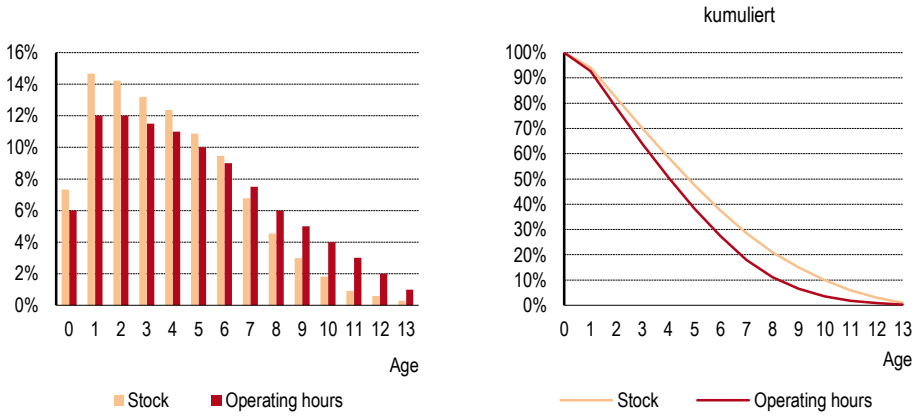


4.2.6 Age distribution of stock and operating hours

Fig. 7 depicts the age distribution of stock and operating hours for dump trucks (construction machinery). Age distribution varies according to machine type and engine power class. Due to the age dependency of operating hours (see Fig. 6), the age distribution of the latter differs from that of the stock.

Fig. 7 > Age distribution of stock and operating hours for dump trucks

Reference year 2010.



Left: 12% of the stock and 14% of the operating hours are attributable to machines that are more than 8 years old.
Right: 20% of the stock and 10% of the operating hours are attributable to machines that are more than 8 years old.

4.3 Emission fundamentals

4.3.1 Emission limit values

Emission fundamentals (emission limit values, emission stages, emission and consumption factors, other influencing factors) vary according to machine type and engine type. Here the following groups have been defined:

- Diesel machines (excluding navigation and railway machinery)
- Small petrol-driven appliances
- Navigation machinery
- Railway machinery

This grouping is based on the construction of the engine on the one hand, and on the distinction in legislation governing emissions on the other hand. In the EU legislation governing emissions, diesel-powered construction, industrial, agricultural, forestry and military machinery are all grouped together. Navigation and railway diesel engines are subject to separate exhaust limit values in the EU within the scope of the same EU Directive 97/68/EC (EU 1997), and for this reason they are treated differently in terms of exhaust requirements.

In Switzerland, only certain categories of non-road machines and appliances are subject to emission legislation. For example, construction machines are governed by the Ordinance on Air Pollution Control (Amendment dated 19 September 2008). However, in this report it is assumed that, in view of the limited size of the market, all machines and appliances that are put into operation in Switzerland meet the corresponding EU regulations.

Diesel machines (excluding ships and railway machinery)

Diesel engines are of particularly high importance in terms of non-road emissions. By contrast with road traffic, legislation aimed at limiting emissions from non-road diesel engines only entered into force in 2001 in the EU. Since then, non-road machines that are put into operation in the EU have been required to meet the emission limit values stipulated by EU Directive 97/68/EC (EU 1997). The EU emission limit values are divided into categories (EU I to EU V), with the aim of reducing emissions on a step-by-step basis. Tab. 6 presents a selection of emission thresholds.

With respect to the entry into effect of maximum emission levels for the individual categories, a distinction was made between construction, industrial and military machinery on the one hand, and agricultural and forestry machinery on the other. Tab. 7 lists the years in which the respective emission limit values were (or are to be) introduced. The levels and their time of introduction for EU V are proposals by the Commission and have not yet entered into force.

Tab. 6 > EU emission limit values for non-road diesel machines (in grams per kWh)

Figures in parentheses refer to maximum total emission levels of hydrocarbons and nitrogen oxides (HC + NO_x): the maximum emission levels for carbon monoxide (CO), hydrocarbons (HC), for ships/boats, railway machinery and petrol-driven appliances are listed in Appendix A3 on page 146.

engine power class	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Nitrogen oxides (NO_x)						
<18 kW[3]	-	-	-	-	-	(7.5)
18–37 kW	-	8.0	(7.5)	-	-	(4.7)
37–56 kW	9.2	7.0	(4.7)	(4.7)	-	(4.7)
56–75 kW	9.2	7.0	(4.7)	3.3	0.4	0.4
75–130 kW	9.2	6.0	(4.0)	3.3	0.4	0.4
130–560 kW	9.2	6.0	(4.0)	2.0	0.4	0.4
>560 kW	-	-	-	-	-	3.5
Particulate matter (PM)						
<18 kW	-	-	-	-	-	0.4
18–37 kW	-	0.8	0.6	-	-	0.015
37–56 kW	0.85	0.4	0.4	0.025	-	0.015
56–75 kW	0.85	0.4	0.4	0.025	0.025	0.015
75–130 kW	0.7	0.3	0.3	0.025	0.025	0.015
130–560 kW	0.54	0.2	0.2	0.025	0.025	0.015
>560 kW	-	-	-	-	-	0.045

Sources: EC 1997; EC 2014

[3] In some EU emission categories, the emission power limit is 19 kW

Tab. 7 > Year of entry into effect of EU limit values for diesel engines

Figures have been rounded up/down to the respective year.

Capacity range	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Construction, industrial and military machinery						
<18 kW	-	-	-	-	-	2019
18–37 kW	-	2002	2007	-	-	2019
37–56 kW	2002	2004	2008	2013	-	2019
56–75 kW	2002	2004	2008	2012	2014	2020
75–130 kW	2002	2003	2007	2012	2014	2020
130–560 kW	2002	2002	2006	2011	2014	2019
>560 kW	-	-	-	-	-	2019
Agricultural and forestry machinery						
<18 kW	-	-	-	-	-	2019
18–37 kW	-	2003	2007	-	-	2019
37–56 kW	2003	2004	2008	2013	-	2019
56–75 kW	2003	2004	2008	2012	2014	2020
75–130 kW	2003	2004	2007	2012	2014	2020
130–560 kW	-	2003	2006	2011	2014	2019
>560 kW	-	-	-	-	-	2019

Sources: EC, 1997; EC, 2014

Small petrol-driven appliances

With respect to emission criteria for small petrol-driven appliances (chainsaws, lawn mowers, rammers, vibrators, etc.), a distinction has to be made between appliances with 4-stroke and 2-stroke engines. The relevant legislation distinguishes between small hand-held appliances and larger non-hand-held machines. In this report, this distinction is equated with 2-stroke and 4-stroke engines.

The first EU emission limit values entered into effect in 2004 for most small appliances (Tab. 32 and Tab. 34, pages 159 and 161 respectively). Here the main aim was to reduce emission levels of hydrocarbons. From EU II onwards, similar emission limit values apply to both 2-stroke (hand-held) and 4-stroke (non-hand-held) appliances. Exceptions for certain appliance categories have not been taken into account.

Navigation machinery

Emission regulations distinguish between two groups:

- Navigation machinery
- Recreational craft and sports boats

Due to their size, ships are powered exclusively with diesel engines. Boats can be equipped with diesel or petrol engines.

Emission limit values were already specified for both ships and boats in 1993 following the adoption of an ordinance governing shipping on Lake Constance. These maxi-

mum emission levels were incorporated into the exhaust regulations for navigation engines (SAV) and have been binding since 1995 for all bodies of water in Switzerland. In 1996, more stringent exhaust regulations were specified for Lake Constance, though these were never incorporated into the SAV and are therefore not binding for other bodies of water in Switzerland.

The SAV was subsequently revised in 2007 within the scope of the co-ordination of exhaust regulations throughout Europe, and this meant that recreational craft, sports boats, etc., could now be used on Switzerland's bodies of water if they meet the requirements of EU Directive 2003/44/EC. In this Directive, the emission limit values for boats equipped with petrol engines are less stringent than those in the previously valid SAV I, but as before, in Switzerland the applicable emission limit values for boats with 2-stroke engines are the same as those for 4-stroke engines.

Ships with an engine power >37 kW that are used for commercial purposes (i.e. passenger ships, ferries and cargo ships/barges) have to comply with the emission limit values stipulated in the ordinance governing shipping on the Rhine, the first level of which has been binding since 2003. A second level was implemented in July 2007.

Since 2007, ships operated for commercial purposes can be used in accordance with EU Directive 97/68/EC class IIIA.

Railway machinery

For railway machinery, the International Railway Union (UIC) has been recommending emission limit values since the 1980s, but these are not legally binding. In the EU, the exhaust regulations specified in Directive 97/68/EC have applied to railway machinery since 2005. For emission limit values a distinction is made between locomotives and motorised coaches, but for the capacity ranges under consideration in this report they are identical.

4.3.2 Emission stages

The emission calculation model takes account of emission regulations and the ongoing improvement of engines in terms of reducing harmful exhaust emissions by means of emission stages. Here the stock and operating hours are differentiated further so that the machines are characterised not only by category, machine type, engine type and engine power class, but also by year of manufacture. In this way the relevant maximum emission levels can be allocated in accordance with the corresponding legislation, or in view of their age they belong to the group of machines that are not yet subject to emission regulations.

Diesel machines (excluding navigation and railway machinery)

Emission factors for diesel machines are differentiated in the calculation model through emission stages (EU I to EU V) in accordance with EU emission directives (e.g. EU 1997) (see also Tab. 28, page 154). Older machines are allocated to two different stages. In this way it is possible to take into account the fact that a reduction of emissions has already been attained before the introduction of emission thresholds, thanks to improved engine technology (e.g. change from aspirating to turbo engines).

Small petrol-driven appliances

Emission categories for small petrol-driven appliances are based on the two stages of EU emission legislation. Emission categories I and II entered into effect in 2004 and 2008 respectively. No new limit values were specified for small appliances in emission stages III and IV; the limit values specified for emission category II therefore apply until the introduction of emission stage V in 2019. Older appliances that are not yet subject to emission regulations are allocated to three emission categories (Pre-EU) according to their age. The allocation of older appliances to three emission categories is now becoming a necessity due to the late introduction of emission limit values for small appliances.

Navigation machinery

For ship and boat engines, emission stages for the period from 1995 to 2003 are based on the SAV exhaust regulations. Category II of the ordinance governing shipping on Lake Constance has not been reflected in the model as a separate emission stage.

Older ship engines that are not subject to exhaust regulations have been allocated to a single emission category (Pre-SAV). For commercially operated ships (passenger ships, ferries, cargo ships/barges), engines manufactured after 2003 have to meet the requirements of the two emission stages of the ordinance governing shipping on the Rhine, and engines manufactured between 2007 and 2009 have to comply with EU IIIA (Directive 97/68/EC). In 2019, emission stage V will also enter in effect for navigation machinery; categories IIIB and IV will be skipped.

Recreational craft, sports boats, etc., were subject to the requirements of SAV I up to and including 2006. Since 2007 they have to comply with stage I of the EU Recreational Craft Directive (2003/44/EC). In Switzerland, however, 2-stroke engines have to meet the more stringent exhaust requirements for 4-stroke petrol engines. Emission stage II of the ordinance governing shipping on Lake Constance has not been explicitly taken into account for the emission model, since this stage is only binding for Lake Constance and is only complied with by a very small number of boats[4].

Railway machinery

The International Union of Railways (UIC) has been issuing recommendations for limit values for railway diesel engines since the 1980s. For 2008 models it recommends three emission categories (UIC I to UIC III). In this report, UIC I and UIC II have been used for emission calculations, while UIC III is not relevant since EU emission limit values have been in effect for railway diesel engines since 2006 (IIIA and IIIB). Emission category V will also enter into effect in 2019 for railway machinery, and stage IV will be skipped. Older railway diesel engines have been allocated to a separate category (Pre-EU).

4.3.3 Emission factors

The emission factors of the various machine types for limited pollutants are listed in Appendix A4 (pages 154 ff). The pollutants are: carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_X) and particulate matter (PM). Each emission factor is shown on a coloured background that indicates its origin.

[4] According to the Bavarian Ministry of Economics, Transport and Technology, vesels with old engines were kept in operation for significantly longer periods of time in order to avoid the expensive retrofitting of new engines for emission stage II (www.bootsport.info).

Emission factors for non-regulated pollutants are also listed in Appendix A4 (pages 154 ff).

A description of the basic procedure, assumptions and criteria for calculating these factors is provided below.

Diesel machines

Machines subject to non-regulated emissions (older engines)

For older and small machines that are not subject to any regulations, the emission factors are based on evaluations by engine specialists (FOEN 2008), who rely on three different sources for their information. For diesel engines these are:

- Data in Non-road Report 49 (SAEFL 1996), though only measurement data obtained from ISO cycle C1 were taken into account.
- Information published in the EPA[5] study dated 2004 (EPA 2004).
- Emission levels for particulate matter obtained by engine experts under the guidance of the Swiss Federal Laboratories for Materials Testing and Research from black exhaust measurements carried out by Agroscope ART and IVECO. The measurements obtained by Agroscope ART were carried out on around 400 tractors between 1979 and 2006. Since the conversion of black exhaust measurements into particulate matter is associated with various uncertainties,[6] these figures primarily serve to confirm the plausibility of the emission factors.

On the basis of the data obtained from these three sources, older and smaller engines (i.e. those manufactured prior to the introduction of EU I) are classified into two emission stages: one for engines manufactured before 1996 (Pre-EU A) and those manufactured between 1996 and the introduction of EU I (Pre-EU B). In this way the fact can be taken into account that specific pollutant emissions were already reduced before the introduction of EU I as the result of improved engine technology (turbo engines).

Between Pre-EU A and Pre-EU B, for emission factors for particulate matter and nitrogen oxides a reduction rate is assumed that (based on circumstances in Switzerland) corresponds to those of the black exhaust measurements carried out by Agroscope ART and IVECO. The mean values of emission factors in these two pre-EU stages were chosen so that they correspond to the EPA tier 0 levels. The resulting emission factors for the first stage (prior to 1996) correspond fairly closely to the measurement readings for ISO cycle 8178 C1 contained in Report 49 (SAEFL 1996).

Tab. 8 shows a comparison between the readings for the three data sources and the emission factors for particulate matter specified by the engine experts.

[5] Environmental Protection Agency (USA).

[6] International exhaust emissions stipulate that particulate matter must be determined gravimetrically. For approval purposes, conversions from black exhaust measurements are not recognised, but they are nonetheless frequently used by engine manufacturers for development purposes.

Tab. 8 > Comparison between data from the three sources and the emission factors specified by engine specialists (PM emission levels only)

The figures only concern engines that are not subject to any EU emission regulations. The data from the evaluation of black exhaust measurements primarily serve the purpose of verifying the plausibility of the emission factors.

Engine power class	Dataset from SAEFL 49 (ISO cycles C1 measurements only)[6]	EPA	derived from black smoke measurements ART/IVECO/EMPA	Selected emission factors
Power range	**Engines manufactured <1996**	**Tier 0**	**Engines manufactured <1996**	**Pre-EU A**
<18 kW	2.62 g/kWh	1.34 g/kWh	0.91 g/kWh	1.50 g/kWh
18–37 kW	1.40 g/kWh	1.07 g/kWh	0.76 g/kWh	1.20 g/kWh
37–75 kW	1.17 g/kWh	0.97 g/kWh	0.69 g/kWh	1.09 g/kWh
75–130 kW	0.72 g/kWh	0.54 g/kWh	0.63 g/kWh	0.61 g/kWh
130–220 kW	0.26 g/kWh	0.54 g/kWh	-	0.61 g/kWh
Power range			**Engines manufactured ≥1996**	**Pre-EU B**
<18 kW			-	1.18 g/kWh
18–37 kW			0.58 g/kWh	0.94 g/kWh
37–75 kW			0.60 g/kWh	0.85 g/kWh
75–130 kW			0.49 g/kWh	0.47 g/kWh
130–220 kW			-	0.47 g/kWh

The influence of sulphur content in fuel, which has meanwhile lessened significantly, has not been taken into consideration. With older engines without exhaust treatment, sulphur-related particle emissions are of secondary importance.

With respect to carbon monoxide and hydrocarbons, the same levels are used for both stages (Pre-EU A and Pre-EU B), namely those of the EPA study for Tier 0. The EPA criterion is applied for machines <18 kW. Where this is implausible in the opinion of the engine specialists, the latter have made estimates based on the three cited sources (SAEFL Report 49, EPA study and evaluation of black exhaust measurements).

Emission factors of petrol engines are assumed in accordance with the data contained in Report 49 (SAEFL 1996).

Machines subject to emission regulations (newer engines)

Emission factors of newer engines for carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM) are based on the European emission limit values described in chapter 4.3.1 (EU 1997). For emission calculations, the limit values are applied after deduction of a tolerance of 10%. Hydrocarbons and nitrogen oxides in emission stages EU-IIIA are a special case: in EU IIIA, only a total limit level from specific nitrogen oxide and hydrocarbon emissions (HC + NO_X). is applicable. The emission factor in EU IIIA was calculated on the basis of emission factors in EU I and EU III, based on the assumption that the reduction rate from EU II to EU IIIA is identical to that from EU I to EU II. The emission factor for nitrogen oxides in EU IIIA is then obtained from the 10% lower limit value for HC + NO_X, minus the previously calculated emission factor for hydrocarbons.

From EU IIIB, the emission factors were derived from the limit levels on the basis of the following rules:

- Where total limit levels from nitrogen oxide and hydrocarbons (HC + NO_X) apply, 90% of these were allocated to NO_X and 10% to HC (in accordance with IFEU 2009)
- For nitrogen oxides (NO_X) and particulate matter (PM), the limit levels were applied without deduction, since machine manufacturers can hardly keep below the stringent limit values applicable from EU IIIB any longer.
- For hydrocarbons (HC), the limit values are applied with a deduction of a 30% tolerance (cf. IFEU 2009).
- For carbon monoxide (CO), the deductions already applied in EU IIIA are also applied to the limit levels in EU IIIB to EU V.
- In the event that, in accordance with these rules an emission factor in a given emission category is higher than in a previous emission factor for the same machine group and size category, the emission factor that entered into effect later is reduced to the level of the previous one if the latter is supported through measurements, otherwise the previous emission factor is increased to the level of the later one.

If the readings obtained for approval purposes are well below the corresponding thresholds, either the mean level of these readings and the thresholds, or the mean level of these readings plus a manufacturing tolerance of 20%, is used instead of the threshold. Here, examples include the emission factor for particulate matter (PM) in emission category EU V for power ranges 18 to 560 kW, and for machines in emission categories EU IIIB and EU IV that are equipped with a particle filter (cf. Tab. 28, page 154).

In Fig. 8 (NO_X) and Fig. 9 (PM) the emission limit values and the emission factors used in the calculation model are depicted above one another so that they can be readily compared.

The emission factors for diesel engines (those subject to emission regulations as well as those not subject to such regulations), and the origin of each individual value, are shown in Tab. 28 and Tab. 29 (pages 154 and 156).

Fig. 8 > Comparison of emission limit values and emission factors: nitrogen oxides (NO_x)

Emission limit values and emission factors correspond to the figures in Tab. 6, page 31 and Tab. 28, page 154
For EU IIIA, the figures are total limit levels for NO_X and HC emissions.

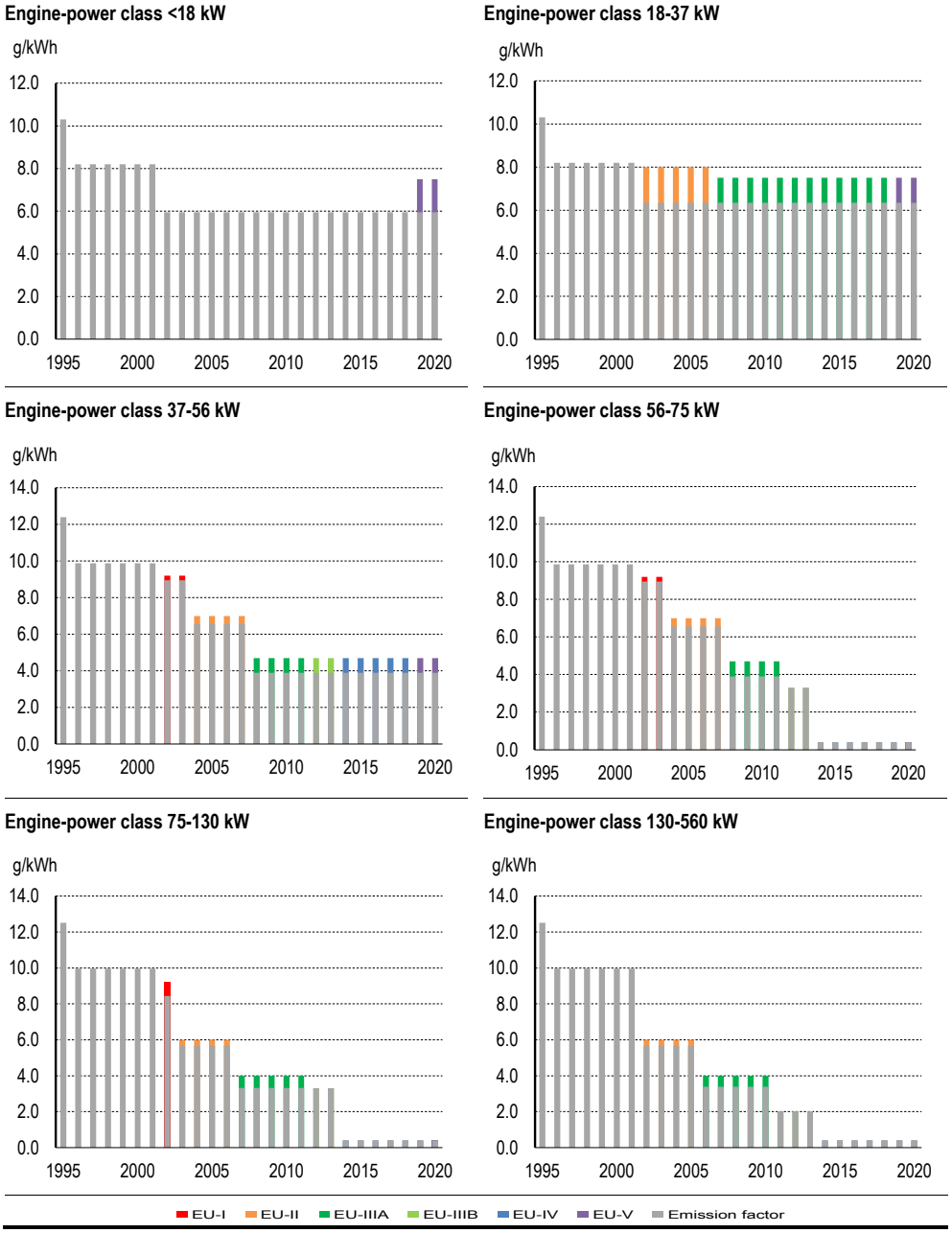


Fig. 9 > Comparison of emission limit values and emission factors: particulate matter (PM)

The emission limit values and emission factors correspond to the figures in Tab. 6, page 31 and Tab. 28, page 154.

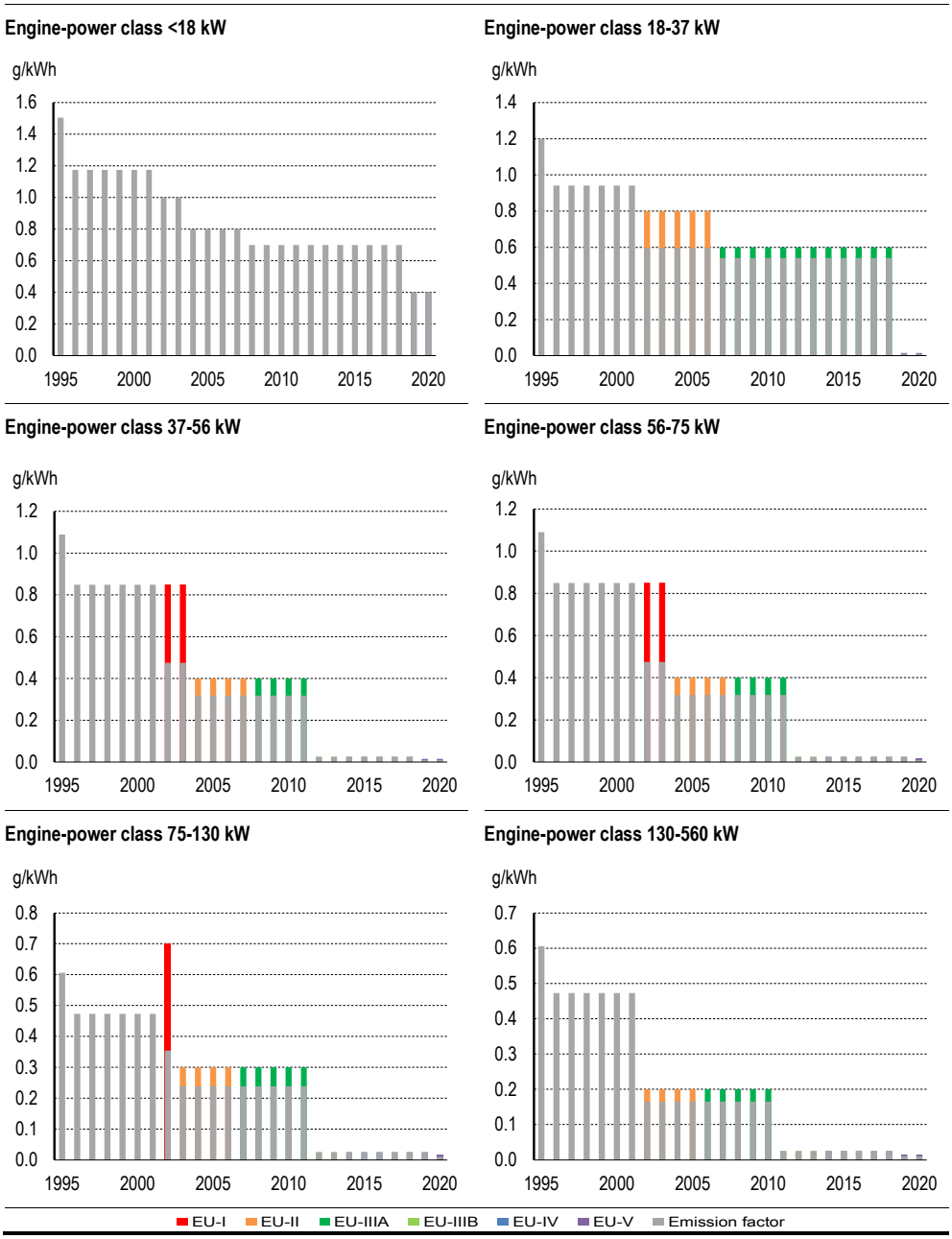
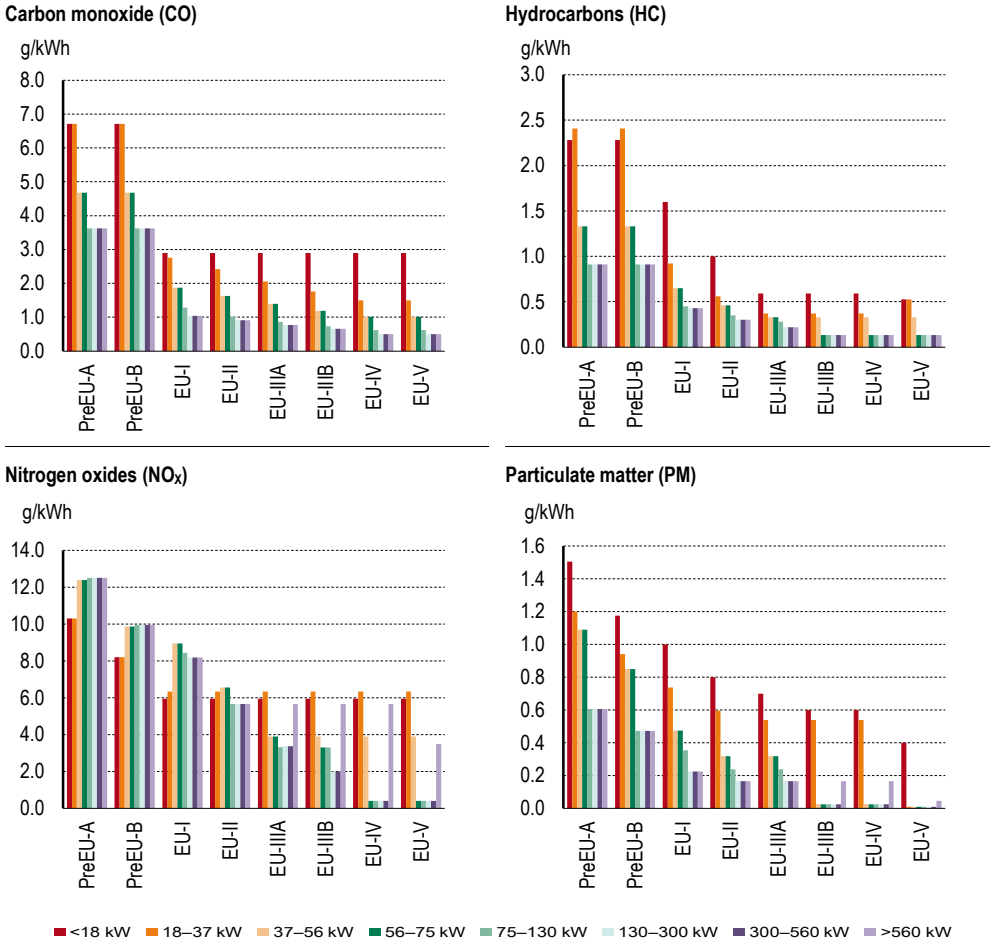


Fig. 10 > Emission factors for diesel engines, by emission stage



Numerical values, cf. Tab. 28, page 154

Small petrol-driven appliances

The emission factors for small appliances (2-stroke and 4-stroke engines) in emission stage EU I manufactured after 2004 were obtained from the limit values after deduction of a manufacturing tolerance of 10%. Exceptions for 2-stroke engines are the EU I and EU II CO thresholds, and the EU I HC limit values, which are well above recorded measurement levels[7].

The emission factors for older engines (manufactured prior to 2004) that are not subject to emission regulations (= Pre-EU) are based on assumptions deduced from measurement levels (INFRAS 2008) and figures reported in similar studies (IFEU 2004). The assumptions were also made in collaboration with representatives of Euromot.

Navigation machinery

The emission factors for ships/boats are largely based on the applicable limit values specified since 1995 in the SAV. Emission limit values up to emission category EU IIIA are in principle adopted less a manufacturing tolerance of 10%; for emission

[7] According to the results of measurements carried out by BNM Research (BNM, 2000), small 2-stroke appliances emit around 450 g per kWh of CO. The threshold for CO is 805 g per kWh.

category Euro V, the manufacturing tolerance of 10% is only applied for HC and CO, and for NO_x and PM the emission limit levels are applied without deduction. For boats, the Swiss Federal Laboratories for Materials Testing and Research has produced detailed information on threshold utilisation, which forms the basis for specifying the corresponding emission factors. The emission factors for ships/boats that are not subject to emission regulations (i.e. those manufactured before 1995 or equipped with small engines) are based on assumptions, in some cases taking levels for other machine types.

Railway machinery

The emission factors for machines not subject to emission regulations correspond to the emission limit recommendations of the UIC. The emission factors for much older engines (year of manufacture prior to 1982) are additionally based on the factors for diesel machines with the same year of manufacture. The emission factors for engines manufactured after 2006 correspond to the EU limit values from EU IIIA, less a tolerance of 10%. For emission stage Euro V the manufacturing tolerance of 10% is only applied for HC and CO, and for NO_x and PM the limit levels are applied without deduction.

Tab. 9 lists the emission levels of two types of railway machinery that are widely used by Swiss Federal Railways (SBB). The figures in parentheses represent the corresponding emission factors according to the UIC. Only the figures for nitrogen oxides are fairly similar. With respect to HC and CO emissions, locomotive type Am 843 has a significantly lower level than the UIC figure (and is also well below the EU emission limits, which have only been applicable since 2006). Since corresponding data do not exist for all other types of railway machinery, the emission calculations are nonetheless based on the UIC emission factors, particularly since evaluations of vehicles operated by German Railways (DB) (IFEU 2003) show that levels for the various vehicles vary considerably.

Tab. 9 > Emission levels of two railway machines widely used by Swiss Federal Railways

Type of vehicle	Category	Nominal output	Emission category	Quantity	Emission factors (g/kWh)			
					HC	CO	NO_X	PM
Tm 234	Rail tractor	550 kW	UIC-I	98	1.1 (0.8)	4.0 (3.0)	7.0 (12.0)	0.15 (0.5)
Am 843	Locomotive	1,500 kW	UIC-II	73	0.2 (0.8)	0.7 (3.0)	8.9 (9.5)	0.1 (0.25)

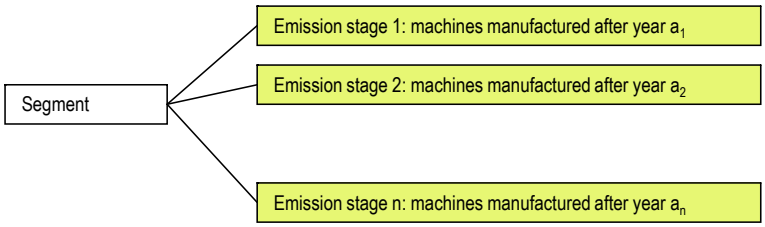
Figures in parentheses represent the UIC emission factors (as per Tab. 41, page 169)

4.3.4 Sub-segments

For the purpose of allocating machines to emission categories, the main segments (machines distinguished by category, engine type and capacity) are divided into sub-segments that comprise machines in the same emission stage. The sub-segments thus cover machines of all years of manufacture in which a certain emission category applied.

Fig. 11 > Derivation of a sub-segment from a main segment and emission stage

In accordance with this simplified diagram, emission stage i is binding for all machines with effect from year a_i. Based on the provisions governing sell-off periods and the flexibility scheme, the introduction of a new emission category is delayed for a certain percentage of the machines, which is also depicted in the model.



The precise specification of which emission stage applies from which year is based on the times of entry into effect of the legally binding emission limit values for a given category. The assumed years of entry into effect are shown in Appendix A4 (pages 154 ff), together with the emission factors. For the period after 2014 the year of introduction of additional emission levels is still uncertain.

Based on the provisions governing sell-off period and the flexibility scheme in the EU Directives (EC, 1997; EC 2014), not all new machines put into circulation after the time of introduction of a new emission category have to comply with the requirements of that emission stage:

- The sell-off period allows machine manufacturers to sell machines during a period of up to two years after the time of introduction of the emission stage that were manufactured prior to the time of introduction. This rule applies without the specification of a limit in terms of quantity.
- The flexibility scheme permits the bringing into circulation (upon application) of a limited number of machines from the previous emission category. The applicable limit is 20% of the sold machines until the introduction of the next emission stage. For emission stage III B (introduced in the period from 2011 to 2013), the limit was increased to 37.5%, and the limit for agricultural tractors was raise to 40%.

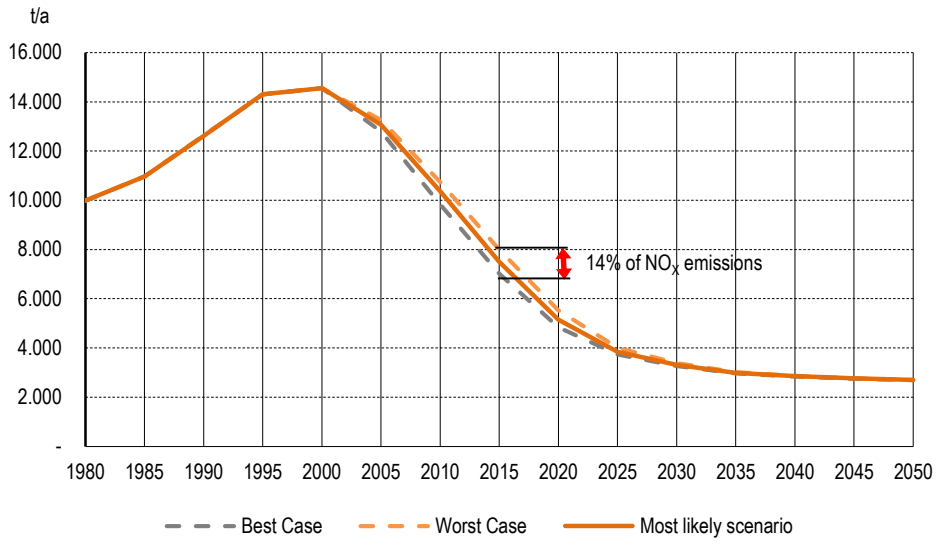
In theory it is thus possible that, on the basis of the sell-off period, before the introduction of a new emission stage machines can be manufactured in advance, and that, during the first two years following the entry into effect of a new emission stage, exclusively machines belonging to the previous emission stage can be sold. Subsequently, the flexibility scheme can also be fully exploited until the next emission category enters into effect. This means that the introduction of machines belonging to a new emission stage can be delayed by several years.

In practical terms, the extent to which the introduction of new emission stages is delayed is not yet known. For this reason a sensitivity analysis was carried out in which a best case, worst case and probable scenario were defined (Fig. 12). In the best case scenario, all new machines in the current emission stage comply with the new emission stage from the date of its introduction. In the worst case scenario, the sell-off period

and flexibility scheme are fully exploited, i.e. the first machines in the current stage are only brought onto the market after a delay of two years, and until the introduction of the next emission stage, as many old machines as possible in accordance with the flexibility scheme are put into circulation before the introduction of the next emission stage. The probable scenario is based on information provided by machine manufacturers and assumes a proportion of 25% of new machines in the first year of a new emission stage, 50% in the second year and 100% with effect from the third year. The delay is somewhat longer with respect to the introduction of emission stage IIIB, though emission stage IV will be introduced more quickly (the fact that many machine manufacturers were not ready for emission category IIIB is also the reason why the flexibility scheme limit in terms of quantity was increased for this stage). The sensitivity analysis shows that the difference in NO_X emissions between the best case and the worst case scenarios is around 14% in the period between 2015 and 2020. Emissions in the probable scenario are around 7% higher than those in the best case scenario, and are thus almost exactly in the middle of the two extremes.

Fig. 12 > Sensitivity of NO_X emissions to the delayed introduction of emission stages

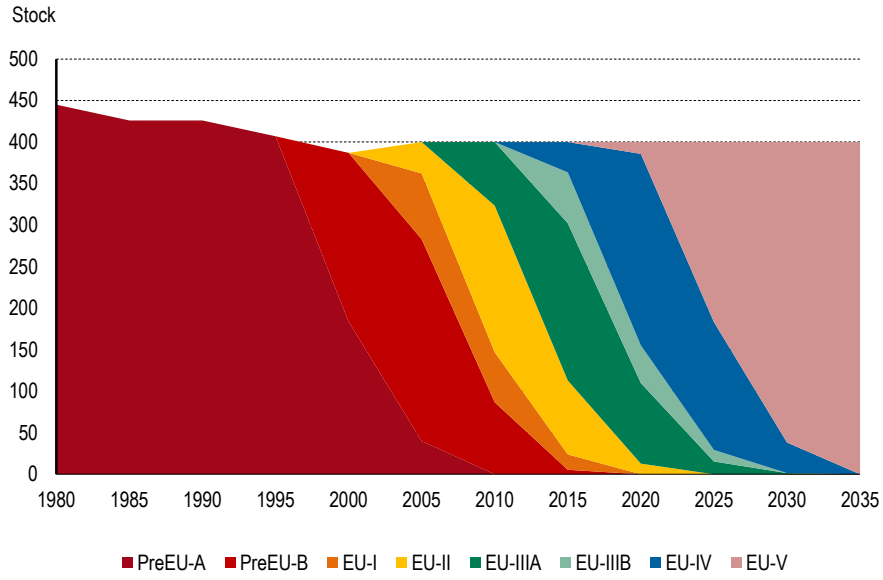
In the best case scenario, all new machines in the current emission stage comply with new emission stages as of their date of introduction. In the worst case scenario, the sell-off period and flexibility scheme are utilised to the full. The probable scenario is based on information provided by machine manufacturers, and attempts to reflect reality as closely as possible.



How quickly engines that meet the corresponding limits pervade the machine stock depends on the respective age distributions. Fig. 13 depicts the situation for asphalt finishers as an example.

Fig. 13 > Depiction of emission stages for asphalt finishers (construction machinery)

All asphalt finishers that have been in use in the EU since 2001, and which it is assumed are also used in Switzerland, meet at least the requirements of EU I. It is assumed that older machines will be taken out of circulation by 2015 at the latest. The stock model was calculated in accordance with the data from the new non-road database in 5-year intervals, hence the angled curves.



4.3.5 Fuel consumption

Non-road fuel consumption is calculated using the same methodology as for pollutant emissions. The fuel consumption factors of the various machine types are listed in Appendix A4 (pages 154 ff).

Diesel-powered machines

The consumption factors applied to diesel machines are based on the data of the Environmental Protection Agency (USA) (EPA 2004). In line with the method used by the EPA (EPA 2004) and IFEU (2013), no chronological distinction of consumption factors is made according to emission categories.

Petrol-driven appliances

The consumption factors of petrol-driven appliances are based on data in test reports carried out by the German Agricultural Society (Deutsche Landwirtschsafts-Gesellschaft) (DLG 2008). The reduction of consumption in dependency on emission categories was chosen so that it runs parallel to hydrocarbon emissions.

Navigation machinery

The consumption factors of ships/boats were adopted in accordance with the data contained in Report 49 (SAEFL 1996). Due to the lower level of efficiency, the consumption factors of steamships are significantly higher than those for motor vessels.

Railway machinery

The consumption factors for railway vehicles are based on the measurements of the IFEU (IFEU 2003) and manufacturers of locomotives used by Swiss Federal Railways (SBB).

4.3.6 Electricity consumption

The electricity consumption of electric machines and appliances is calculated on the basis of the same methodology applied for the calculation of fuel consumption and pollutant emissions. However, the reciprocal of the efficiency level is used instead of an emission factor in grams per kWh. The assumed efficiency levels are listed in Tab. 42 on page 170.

Efficiency rates increase over the course of time thanks to advances in technology and the introduction of more stringent efficiency standards. The overall level of efficiency is the result of the efficiency of the motor, battery and charger.

Electric motors in industry

Electric non-road machines used in industry (mostly forklifts) are battery-operated. According to de Haan and Zah (2013), the efficiency of a 100 kW motor was estimated to be around 85% in 2010, and an improvement by 0.67% every 10 years is assumed. The efficiency of smaller motors is lower; the reductions for lower output ranges is based on efficiency tables for electric motors depending on output (Nipkow 1989; Dolder 2014). The majority of batteries used in fork lifts today are lead accumulators with a low efficiency rate (according to the relevant Swiss association, swisslifter, approx. 70%). However, it is assumed that lithium-ion batteries with an efficiency rate of 96% (de Haan and Zah 2013) will be widely used in forklifts by 2050. The efficiency of chargers – again citing de Haan and Zah (2013) – is expected to constantly increase from 87% in 1980 to 95% by 2050.

Electric motors in small appliances

Electric motors used in small garden-care/hobby appliances can be both cable and battery operated. The efficiency of cable-operated appliances is higher because losses attributable to batteries and chargers do not apply. Depending on the appliance category and operator (professional/hobby users), assumptions vary with respect to the mix of cable and battery operated appliances:

- In the professional garden-care segment it is assumed that electric appliances in use are battery-operated.
- In the hobby segment, a mix between cable and battery operated appliances is assumed: here the proportion of battery operated appliances in this segment to the overall quantity of electric machines was around 33% in 2010 and is expected to increase over time – from 3% in 1980 to 75% by 2050 (Dieterich 2012; TASPO 2013).
- It is assumed that primarily stationary appliances such as shredders and log splitters are cable-operated (in both the professional and the hobby segment).
- Lawn mowing robotics are exclusively battery-operated.

The efficiency of batteries was estimated at 70% in 1980 and 90% in 2010, and is expected to increase to 95% by 2050. For chargers, the same assumptions apply as those for electric appliances in industry.

4.3.7 Influencing factors

Emission levels and the fuel consumption of machines can be influenced by a variety of factors, as a result of which the effective emission and consumption levels may deviate from the underlying values. Where such influences can be identified, they are adjusted with the aid of correction factors (CF).

Load (CF_1)

As a rule, machines are operated at partial load. This means that, for calculation of emissions the engine rated power has to be reduced by a load factor to the effective engine power. Load factors vary according to type and age of the machine[8]. Appendix A5 on page 154 contains a list of the load factors for the various machine categories and types.

In the case of diesel machines, the emission and consumption factors refer to use at 48% of full load. This corresponds to the mean load of the ISO 8178 C1 non-road measurement cycle. In practice, however, certain machines are operated at a different mean load (for example, diesel railway vehicles in Switzerland are primarily used for shunting operations at low engine load), and this means that the standard load factor for these machine categories has to be adjusted in accordance with the ISO measurement cycle. The load factors effectively attributed to the various machine categories and types are listed in Appendix A5 on page 154.

Since the specific consumption in particular greatly depends on the load, for diesel machines that are operated at a mean load that deviates from the ISO measurement cycle, an adjustment of the consumption factor has to be made via the load factor. This adjustment is calculated on the basis of the following formula:

$$CF_1 = 2.0095 - 2.1981 \cdot \Delta_{LF} + 1.886 \cdot \Delta_{LF}^{\ 2}$$

mit: CF_1 = correction factor for consumption if the effective load deviates from the standard load in accordance with ISO cycle 8178 C1

Δ_{LF} = ratio of effective load to standard load in accordance with ISO cycle 8178 C1

The effect of this adjustment is that the specific consumption at an effective load factor of 20% is around 30% higher than at the ISO load factor of 48%.

Due to a lack of background data, this adjustment takes account of consumption, but not emissions.

Dynamic use (CF_2)

Emission factors are obtained from stationary measurements (ISO 8178 C1 measurement cycle). But if in practice a machine is operated very dynamically (frequently changing load), this has an influence on its emissions, and this is taken into account when calculating the emission levels by applying suitable dynamic operation factors

[8] A dependency of the load factor on the age of the machine only applies to agricultural tractors, since unlike other machine types, old tractors continue to be used for many more years, but are often only required to perform less demanding tasks with correspondingly low engine loads.

for the various machine categories and types. Appendix A6 on page 178 contains a list of machine categories and types with dynamic pollutant emissions. The applied dynamic operation factors are based on data produced by the EPA (EPA 2004), and are differentiated by emission category, since depending on the engine technology concerned the influence of dynamic operation may be higher, lower or negligible (aspiration engines). Dynamic operation factors for carbon monoxide and particulate matter are only applied for diesel machines in certain categories depending on emission stage, size and applied load factors for carbon monoxide, particulate matter and nitrogen oxides (Tab. 10). Dynamic factors >1.00 for all machines with an output between 56 and 560 kW are applied for nitrogen oxides (NO_X) from emission category IV because selective catalytic reduction technology is used in these machines and this results in higher NO_X emissions in the low partial load range.

Tab. 10 > Applied dynamic operation factors for certain machine types

Dynamic use (CF_2).

Emission stage	CO	HC	NO_X	PM
Pre-EU A (before 1995, aspiration engines)	1.53	1.00	1.00	1.00
From 1996 to EU II	1.53	1.00	1.00	1.23
EU IIIA	1.53	1.00	1.00	1.47
EU IIIB	1.00	1.00	1.00	1.00
From EU IV	1.00	1.00	power range between 56 and 560 kW: 1.20 for load factors >0.35 1.50 for load factors <=0.35 power range <56 and >560 kW: 1.00 for all load factors	1.00

Wear and tear (CF_3)

he level of an engine's fuel consumption and pollutant emissions depends on its age, and in the emissions model this is taken into account using a deterioration (wear and tear) factor. Different assumptions relating to wear and tear are made, depending on the pollutant. The influence of wear and tear is calculated using the deterioration factors indicated in Tab. 11. From emission category EU IIIA, engine manufacturers are responsible for ensuring long-term stability of emissions and have to provide evidence of this in the form of continuous operation tests (EC 1997). Thus from emission stage EU IIIA, $CF_3 = 1.0$.

Tab. 11 > Deterioration factors (up to emission stage EU IIIA)

Wear and tear (CF_3).

Engine type	Period of deterioration (P_h)	CO		HC		NO_X		PM		Consumption	
			Max.		Max.		Max.		Max.		Max.
2-stroke petrol	100 h	1.1	1.1	1.3	1.3	1.0	1.0			1.2	1.2
4-stroke petrol	500 h	1.1	1.1	1.5	1.5	1.0	1.0			1.2	1.2
Diesel	2,000 h	1.1	1.2	1.15	1.3	1.0	1.0	1.1	1.2	1.0	1.0

The correction factor for the wear and tear of a machine can be calculated using the deterioration factors and the number of operating hours to date. In the case of diesel engines, for example, the PM emission factor increases by 10% every 2,000 hours, the maximum increase is 20%, i.e. even after the number of operating hours surpasses 4,000 the emission factor is only increased by 20%.

$$CF_3(Age) = factor^{wear\,and\,tear}\left(\frac{\sum_{n=Age}^{refyear} H(n)}{P_h}\right)$$

Key

CF_3 = correction factor for wear and tear (dimensionless)
H = hours of operation at a certain age of the machine (hrs p.a.)
P_h = period of deterioration (hrs)

In the model, in the case of diesel engines the maximum correction factor for the wear and tear of a machine is attained after approximately 3,800 hours of operation, after which it is assumed that no further deterioration occurs.

4.3.8 Particle filters

he purpose of particle filters is to efficiently reduce emissions of particulate matter from diesel engines. Contrary to earlier expectations (cf. FOEN 2008), from emission category EU IIIB it is in fact possible to meet particulate matter emission limit values without the use of particle filters. Nonetheless, some manufacturers are now installing particle filters ex works in machines from emission stage EU IIIB (Integer 2013). In order for engines to meet the requirements of emission stage EU V, it is assumed that they will need to be fitted with particle filters, because with the introduction of this emission category, a limit value will enter into effect not only for particulate matter, but also for particle number. In accordance with the Ordinance on Air Pollution Control, construction machines >18 kW already have to be operated with particle filters now, though transition periods are applicable. This Swiss requirement means that machines that are not fitted with a particle filter ex works have to be retrofitted with a

particle filter system (FOEN 2009). This is taken especially into account in the emission calculation model:

- In the case of diesel engines, for stock for each segment the proportion of machines retrofitted with a particle filter is indicated or estimated (cf. chapter 5.5, page 58).
- Since it is above all more recent machines that are retrofitted with particle filter systems[9], the calculations for the model are based on the assumption that in each case the newest models in the stock of retrofittable machines have in fact been retrofitted.
- The particle emissions and fuel consumption of machines that have been retrofitted with particle filters are adjusted to the corresponding emission levels (particulate matter, –90%; particle count, –95%, fuel consumption +3%) using a correction factor. The correction factors are +3% for fuel consumption and -99% for particle number; for particulate matter they depend on the emission factor without a particle filter, and thus from the emission stage and engine power range; these correction factors are listed in Tab. 45 (page 173)t.

[9] For both economic and technical reasons, generally speaking it is only more recent machines that are retrofitted with particle filter systems. With older machines, there is a greater risk of technical complications due to increased smoke emissions. Furthermore, the remaining service life of an older machine is shorter, which means that retrofitting is less economically viable.

5 > Stock and operating hours

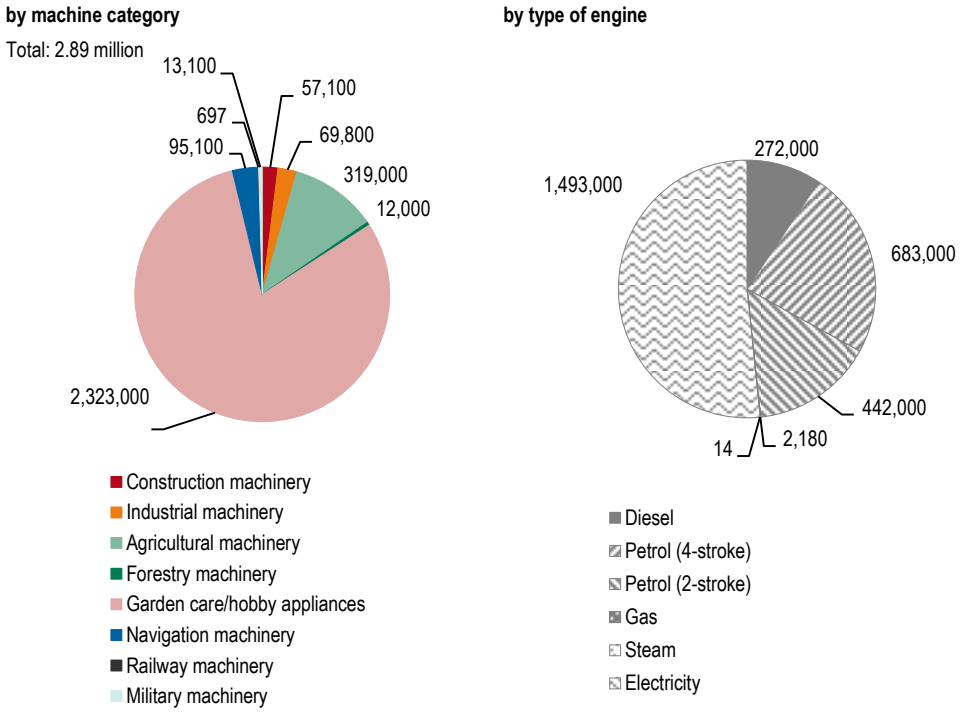
5.1 Stock in 2010

Fig. 14 shows the distribution of stock (no. of non-road machines and appliances) for 2010. 80% of the approximately 2.89 million machines and appliances belong to the garden-care/hobbies category, while the second-largest category is agricultural machinery. Construction machinery only accounts for 2% of the overall stock. It is thus apparent that, in terms of quantity, the stock in the non-road sector is dominated by small machines and appliances with an output of a few kilowatts, although they only account for a relatively low proportion of energy consumption and pollutant emissions. More than half of them are electric appliances that do not directly produce any emissions of air pollutants.

The conventional non-road sector, i.e. comprising machines and appliances equipped with a combustion engine, is dominated by petrol engines, with slightly more 4-stroke than smaller 2-stroke engines. The majority of both 2-stroke and 4-stroke petrol engines have a low output (<18 kW, mostly 1 to 5 kW). By contrast, diesel engines are typically larger and significantly more powerful.

There is also a small number of gas-operated machines (above all, forklifts) and steam-powered ships. For the latter, the steam is exclusively generated using extra-light heating oil. For the purpose of calculating fuel consumption, this is added to the figure for diesel consumption unless it is reported separately.

Fig. 14 > Stock in 2010 by machine category and type of engine 2010



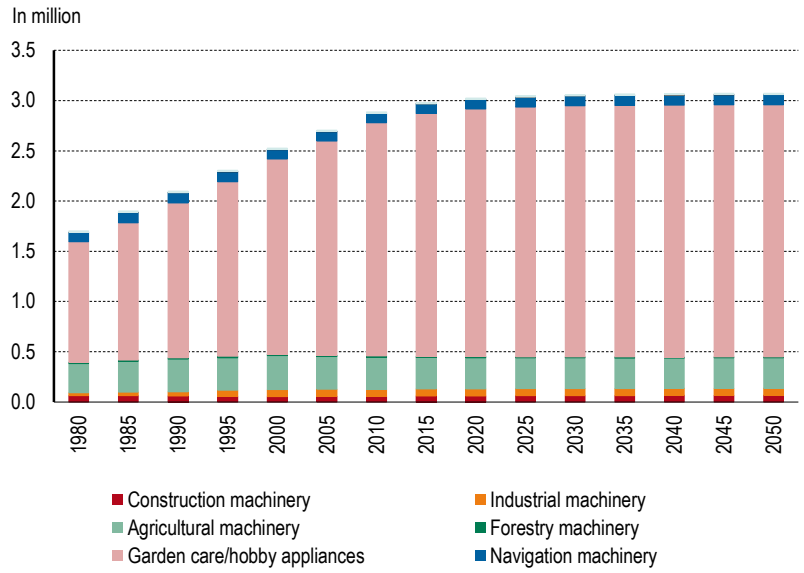
Numerical values, cf. tab. 12 on page 56

5.2 Chronological development of stock

Over the past few years, the total number of non-road machines has increased due to the trend in the garden-care/hobby appliances and construction machinery categories. This trend is expected to persist, though not quite so strongly. Here it should be noted that forecasts are less reliable, the longer they reach into the future (cf. chapter 4.2.2). The main reason why the reduction in the number of agricultural machines is not more pronounced despite the sharp decline in agricultural operations[10] is that, on the one hand, old agricultural machines do not have to be disposed of as quickly as other machines (the registration costs for a tractor are very low, and there is therefore no incentive to cancel the registration of an old tractor). Another reason for the relatively slow reduction of the fleet of agricultural machines is that, despite the decline in the number of farms, the total area of land used for agricultural purposes has only reduced very slightly (by around 2% since 1990), and this has given rise to an increase in the average size of farms by 55%.

[10] The number of agricultural businesses fell by 36 % in the period from 1990 to 2010 (Swiss Federal Statistical Office 2012).

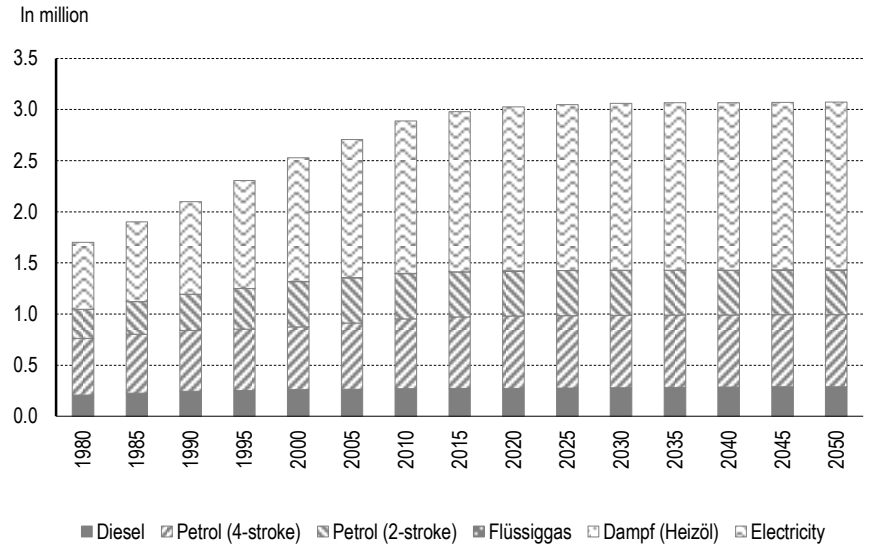
Fig. 15 > Development of stock by machine category (1980 to 2050)



Numerical values, cf. Tab. 48 on page 179

If we take a look at the stock by engine type (Fig. 16) we can see that the greatest increase is in the number of electric machines and appliances. This is attributable to, for example, the rapidly increasing popularity of lawn mowing robotics, but also to the increasing substitution of 2-stroke or 4-stroke petrol-driven appliances with battery-operated electric appliances as a result of the improvements that have been made in battery technology in recent years. With respect to combustion engines, the most pronounced increase is in the 4-stroke petrol-engine segment, followed by diesel machines. This trend is expected to persist, though to a lesser extent. By contrast, the distribution of 2-stroke engines has stagnated in the past few years, and is in fact expected to decrease slightly in the future.

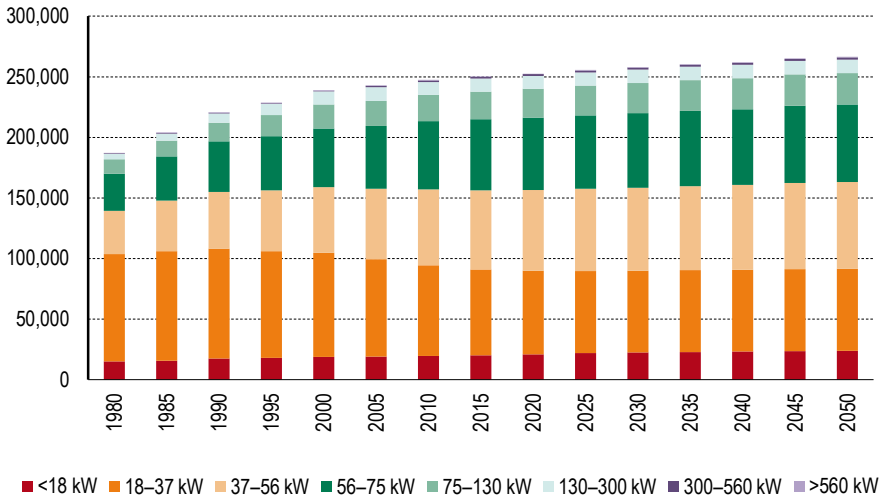
Fig. 16 > Development of stock by engine type (1980 to 2050)



A look at the development of stock of diesel machines by engine capacity shows that the number with large engines is increasing, while the number with smaller engines is tending to decrease (Fig. 17). This trend applies especially to machines with a power range between 300 and 560 kW, the number of which almost tripled between 1980 and 2010 and is expected to increase to four times the figure recorded in 1980.

Contrary to this general trend towards larger machines, however, the stock of machines in the lowest output category, namely those with a capacity below 18 kW, is increasing. This is primarily attributable to the growing popularity of mini-excavators, which have been used to an ever increasing extent in the construction sector, as well as in the landscape gardening segment, in the past few years.

Fig. 17 > Development of stock of machines with diesel engines by capacity (1980 to 2050, excluding navigation machinery and road vehicles used on airport aprons)

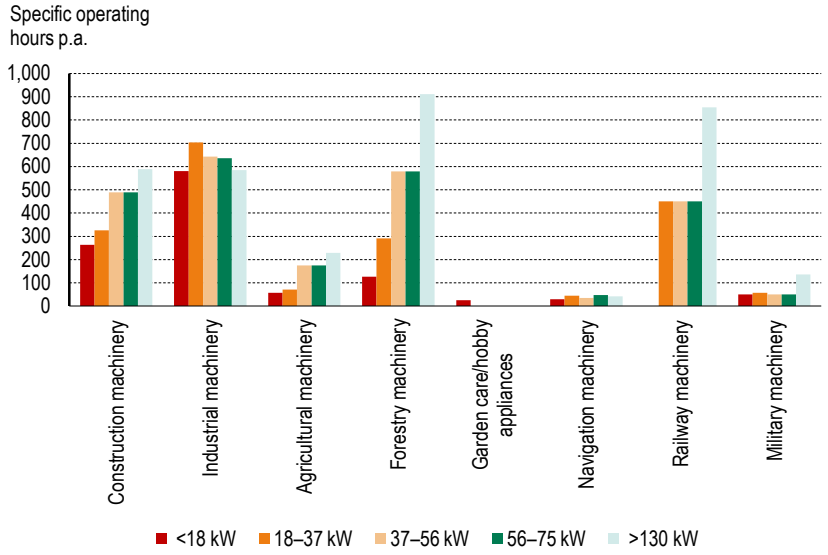


5.3 Operating hours in 2010

The picture with respect to operating hours is quite different from that for stock, since the specific operating hours vary considerably from category to category (Fig. 18) The specific operating hours of industrial machines, for example, are very high, whereas gardening/hobby appliances are only used sporadically. In the reference year (2010), the specific operating hours of construction machines (i.e. operating hours per machine and year) were around 6 times higher than those of garden-care/hobby appliances. As a comparison between Fig. 19 (left) and Fig. 14 (left) shows, construction machinery accounts for a much higher proportion of the total operating hours than of the total stock. And as we can see from Fig. 19 (right) and Fig. 14 (right), petrol engines account for a much lower proportion of the total operating hours than of the total stock.

In the previous study (FOEN 2008), the difference between the average operating hours of garden-care appliances and construction and industrial machinery was more pronounced than it is now. However, the average operating hours of garden-care appliances have doubled in the meantime from 30 to around 60 hours p.a. (cf. Tab. 12). This is primarily attributable to the sharp increase in the use of lawn mowing robotics, which have a low output and correspondingly low specific energy consumption, but during the summer months are almost constantly in operation and thus accumulate around 1,200 operating hours per appliance and year. This is why their proportion of the overall operating hours of this appliance category is 70%, even though they only accounted for 4% of the stock of garden-care appliances in 2010.

Fig. 18 > Average operating hours per machine/appliance per annum

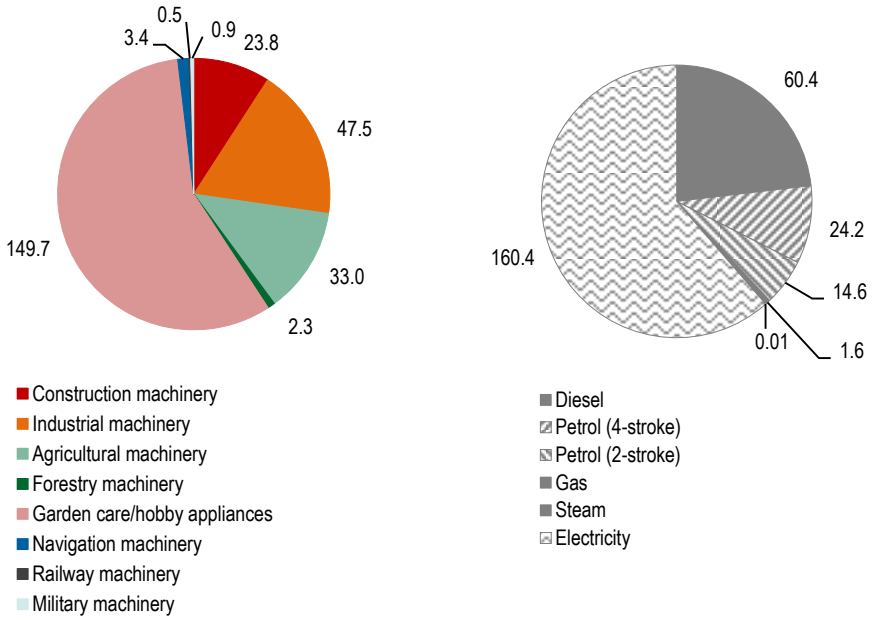


Numerical values, cf. Tab. 12 on page 56

Fig. 19 > Total operating hours by machine category and engine type in 2010

by machine category **by type of engine**

Total: 261.14 million hours p.a.



Numerical values, cf. Tab. 12

Tab. 12 > Non-road stock and operating hours, 2010

Reference year, 2010; figures rounded up or down.

Category	Stock	Operating hours (million hrs p.a.)	Specific operating hours				
			<18 kW	18–37 kW	37–56 kW	56–75 kW	>130 kW
Construction machines	57,100	23.8	330	330	490	490	590
Industrial machinery	69,800	47.5	690	700	640	640	580
Agricultural machinery	319,000	33.0	60	70	180	180	230
Forestry machinery	11,900	2.3	130	290	580	580	910
Garden-care/hobby machines	2,323,000	149.7	60	-	-	-	-
Navigation machinery	95,100	3.4	30	40	40	50	40
Railway machinery	697	0.5	-	450	450	450	850
Military machinery	13,100	0.9	50	60	50	50	140
Total	**2,890,000**	**261.1**					

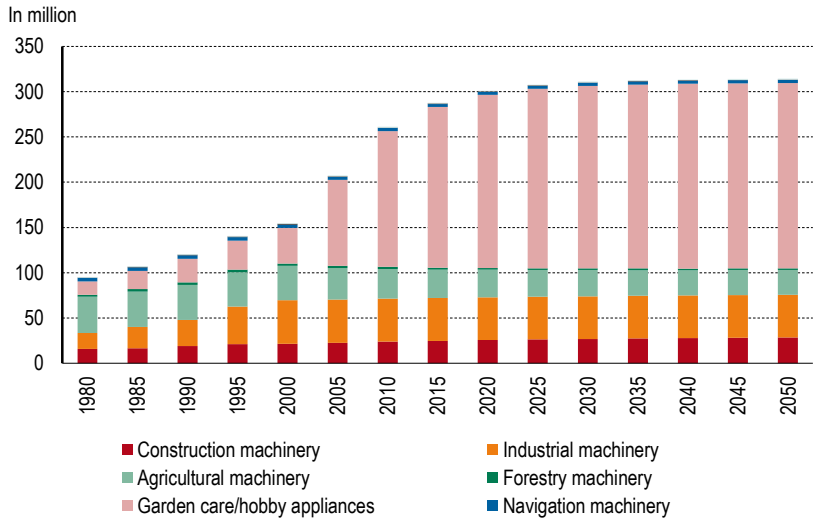
5.4 Chronological development of operating hours from 1980 to 2050

The chronological development of operating hours of non-road machines and appliances shows a marked increase in all categories, especially with respect to industrial machines and garden-care/hobby appliances (Fig. 20).

Between 2000 and 2010 there was a sharp increase in operating hours, which was primarily attributable to the increased use of lawn mower robotics that are in operation for long periods of time at very low output (cf. previous chapter). The operating hours of construction machines are also continuing to increase, while in the other categories they have been decreasing slightly since 2000.

This trend is expected to persist in the future, even though the pace of the increase in the operating hours of lawn mower robotics and construction machines is likely to slow down.

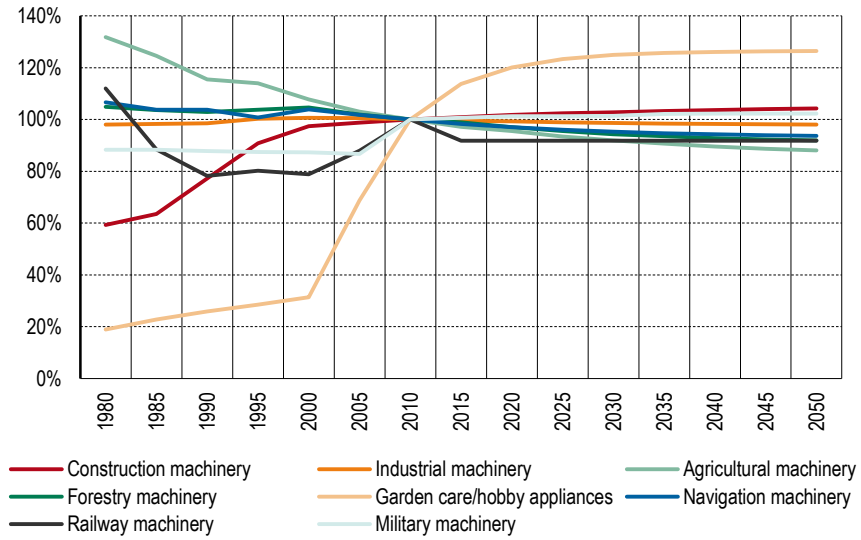
Fig. 20 > Development of overall operating hours by machine category (1980 to 2050)



Numerical values, cf. Tab. 49 on page 179

Fig. 21 > Development of specific operating hours per machine/appliance and year (1980 to 2050)

Relative change versus reference year 2010



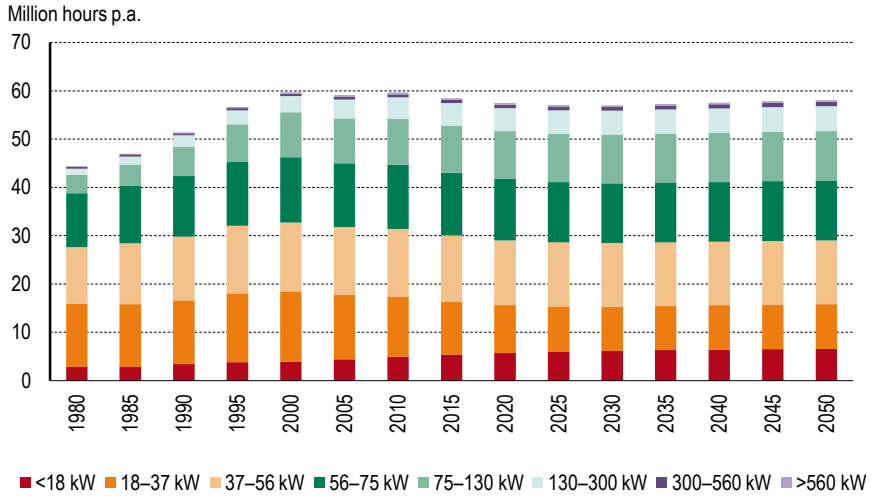
Numerical values, cf. Tab. 50 on page 179

With respect to the development of specific operating hours (i.e. per machine/appliance and year, see Fig. 21), the graph shows a sharp increase (76%) for construction machines, from 240 hrs p.a. in 1980 to 430 in 2050. By contrast, a reduction in average operating hours by 33% is anticipated for agricultural machinery, from 140 hrs p.a. in 1980 to 90 in 2050. The most notable change in specific operating hours is in the garden-care/hobby sector (+570%, from approx. 12 hrs p.a. in 1980 to 80 in 2050),

with a sharp increase from 2000 triggered by the boom in lawn mower robotics, which is however expected to slow down in the future.

Fig. 22 shows the development of operating hours by capacity for diesel-powered non-road machines (excluding navigation machinery and road vehicles used on airport aprons). The picture is similar to that for the development of stock by capacity (Fig. 17), even though the overall operating hours of diesel machines are expected to decrease in the future. The structural changes (trend towards more powerful machines) are also apparent. Like the stock, the operating hours of small machines (<18 kW) also increase, which is primarily attributable to the increased use of mini-excavators.

Fig. 22 > Development of overall operating hours of diesel machines by engine power class (1980 to 2050, excluding navigation machinery and road vehicles used on airport aprons)



5.5 Development of stock of machines equipped with a particle filter system

The stock of machines with diesel engines that have been retrofitted with a particle filter has increased sharply in the past few years (Fig. 23). In accordance with the Ordinance on Air Pollution Control, since 2010 construction machines manufactured in and before that year and used on building sites have had to be fitted with particle filters (except machines <18 kW). Periods of grace apply to construction machines with an engine power >37 kW, regardless of their year of manufacture. From 1 May 2015, all machines >37 kW have to be equipped with a particle filter (cf. FOEN 2009). It should be noted, however, that not all construction machines are used on building sites – applications in industry, agriculture and forestry are exempted from these provisions to date. For this reason, the proportion of agricultural, forestry and navigation machinery equipped with particle filters is still relatively low. The proportion of diesel railway machines fitted with particle filters was around 67% in 2010. The proportion of military construction and navigation machinery equipped with a particle filter is similar to the figure for their civil counterparts; as a rule, caterpillar vehicles are normally not

fitted with particle filters. The figures up to 2010 are estimates based on the time of introduction of the Ordinance on Air Pollution Control, data provided by manufacturers relating to sales of particle filter systems, data cited in the consultation procedure on the revision of the ordinance on exhaust emissions from ships, and information provided by railway operators (BLS, 2012; SBB 2012) and the Army Logistics Basis (LBA).

The development for the period from 2010 to 2020 was estimated (except for construction machines on building sites, because here the requirement of the use of particle filters is stipulated in the Ordinance on Air Pollution Control) on the basis of the emission reduction strategies of machine manufacturers for emission categories EU IIIB and EU IV (Integer 2013, cf. Tab. 13), and their market shares in Switzerland in 2010 (Off-Highway Research, 2005, 2012). Particle limit levels for these categories can be met with or without particle filters, and for this reason manufacturers adopt different strategies (Table 13). But emissions are lower when particle filters are used (cf. Tab. 45, page 173). For emission category EU V it is assumed that it will only be possible to meet the respective particle count limit values with the aid of particle filters. Thus the proportion of machines in all categories fitted with a particle filter will increase at a faster pace from 2019 – the longer the average service life of the respective machines, the slower the pace.

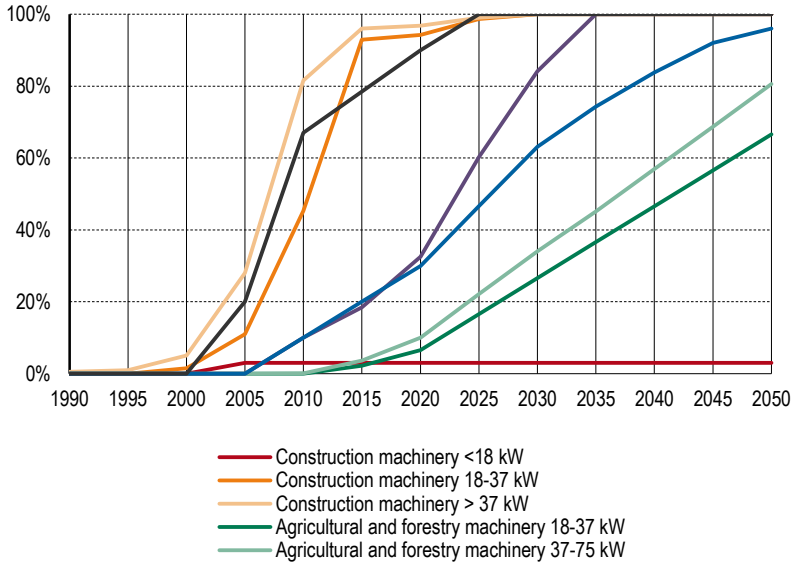
Tab. 13 > Planned installation of particle filters in engines larger than 18 kW in emission stages EU IIIB and EU IV, by manufacturer

Source: Integer, 2013 ("Partially" indicates that in most cases, higher-power range engines are to be fitted with particle filters.

Manufacturer	EU IIIB / US Tier 4 Interim	EU IV / US Tier 4 Final
AGCO	No	No
Caterpillar	Partially	Yes
CNH	No	No
Cummins	Partially	Partially
Deutz	Partially	Yes
IHI	No	No
Isuzu	Partially	No
John Deere	Partially	Yes
Komatsu	Partially	Partially
Kubota	Partially	Yes
Liebherr	Partially	No
Takeuchi	No	No
Volvo CE	Partially	Not yet known
Volvo Penta	No	No
Weichai	No	No

Fig. 23 > Development of stock of diesel machines equipped or retrofitted with particle filters

The development up to 2010 corresponds to sales figures for particle filter systems in Switzerland. For the period from 2010 to 2020, the estimates are based on the emission reduction strategies of machine manufacturers for EU IIIB and EU IV (Integer 2013) and their respective market shares in Switzerland in 2010 (Off-Highway Research, 2005, 2012). For the period after 2020 it is assumed that, based on the particle limit values specified in EU V, all new machines with an output higher than 18 kW will have to be equipped with a particle filter.



6 > Stock and operating hours of the individual machine categories

6.1 Construction machines

The division of construction machines into sub-categories is largely based on the classification system used by CORINAIR. The stock was estimated on the basis of information in the MOFIS database (with the aid of correction factors for non-registered machines, cf. FOEN 2008), market studies (Off-Highway Research, 2005, 2008, 2012) and data provided by the members of the group of experts. The division by engine power range was made on the basis of the previous study (FOEN 2008), information provided by machine manufacturers concerning the trend in the distribution of engine power ranges, and sales by specific engine power range in the cited market studies. The estimate of specific operating hours of the individual machines was also based on the previous study, as well as on the findings of members of the group of experts and basic inventory data of the Swiss Master Builders Association (SBV 2013). For their chronological development it was assumed that construction machines are utilised to a greater or a lesser extent, depending on the market situation.

6.1.1 Stock

Fig. 24 shows the stock of construction machines by machine type (top left: only types with an stock >1,000 machines) and capacity (top right). The largest group is rammers/vibrators (10,500[11]), followed by compressors (7,650) and mini-excavators (i.e. hydraulic excavators) (7,400). 80% of construction machines are operated with diesel engines, while it is only rammers/vibrators and emergency power generators that primarily use petrol engines. In terms of capacity, the distribution of construction machines is fairly even among all capacity ranges up to 300 kW (only very few have an engine power range of up to 560 kW).

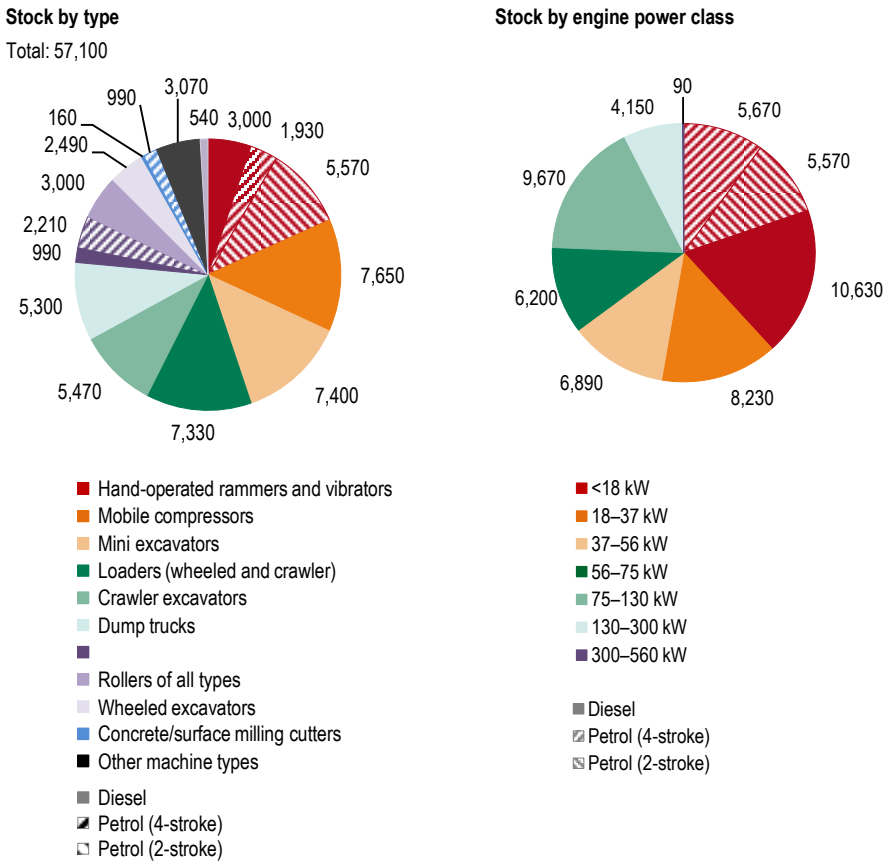
6.1.2 Operating hours and their chronological development (1980 to 2050)

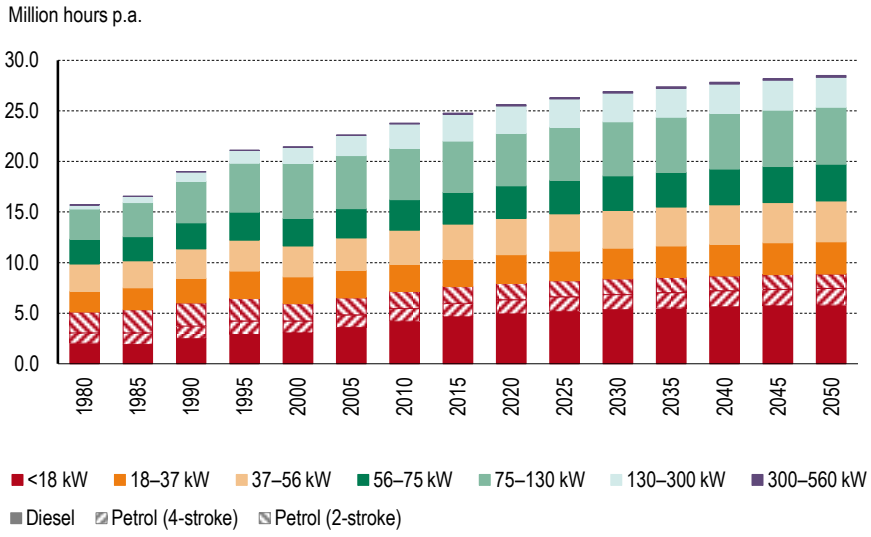
The development of operating hours of construction machines by size and engine type is depicted in the lower half of Fig. 24. Here we can see that the use of construction machines increased further in the period from 2000 to 2010; a further, though less rapid, increase is to be anticipated in the future. At the same time, a shift from small, petrol-operated machines to large diesel-powered ones took place between 1980 and 2010. However, from 2000 a slowdown in the previously observed stable trend towards larger machines is apparent, and for this reason an even distribution of engine power ranges has been assumed from 2015.

[11] 10,500 = 5,570 +1 ,930 + 3,000 (2-stroke and 4-stroke petrol, diesel)

Fig. 24 > Construction machines: stock in 2010 and development of operating hours (1980 to 2050)

Top left: only categories with an stock >1,000 machines.
Reference year for stock: 2010.





The colours indicate the machine category and engine power range, and the shading indicates the type of engine.
Numerical values, cf. Tab. 51 on page 180

6.2 Industrial machinery

The stock and operating hours of mobile industrial machines are based on the MOFIS database, information provided by industry associations swisslifter (Swiss forklifts association), SIK (Swiss association of municipal machinery and appliance manufacturers and dealers), and SBS (Swiss cable railways association, for snowgroomers), as well as on applications submitted by operators of emergency and other generators and information provided by Zurich and Geneva airports.

In the category of industrial machinery, only relatively large machines have been listed. Smaller appliances such as drills and milling machines have been categorised under garden-care/hobby appliances. Since the previous report (FOEN 2008), in addition to electric appliances, mobile machines used on airport aprons (airside) and generators used in trade, industry and the public sector have been added to the industrial machinery category. To distinguish mobile generators from stationary motors, all diesel-powered generators are classified as mobile models, and are thus included in the non-road inventory, while those operated with heating oil are regarded as stationary models. This is a simplified assumption, but it nonetheless roughly corresponds to reality.

6.2.1 Stock

As we can see from Fig. 25 (top left), this category is dominated by forklifts. Those used indoors are normally operated with electricity or gas (mostly propane). This applies to 79% of all forklifts. In most cases, the engine power range is below 75 kW.

Much more powerful machines (up to 340 kW) are used for runway services. The stock of snowgroomers is much higher than in the previous study (FOEN 2008) because for the first time an extract from the MOFIS database for the winter was available that also included vehicles exmatriculated during the summer months (the standard MOFIS extracts are available as of the end of September each year).

6.2.2 Operating hours and their chronological development from 1980 to 2050

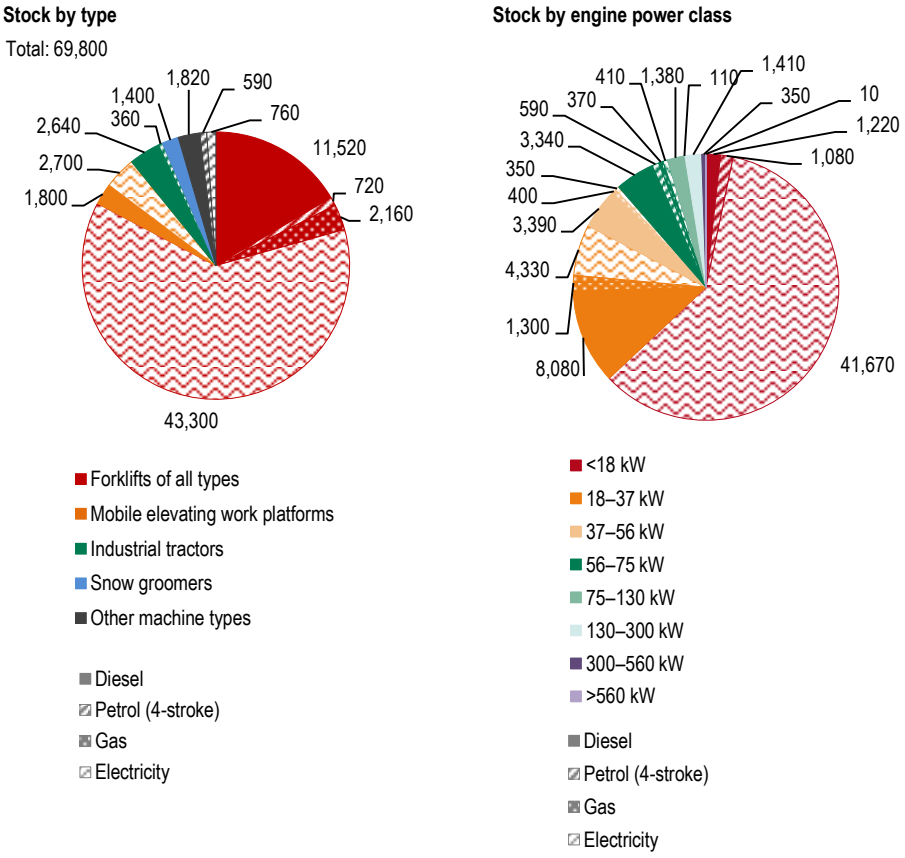
According to data provided by swisslifter, the stock of forklifts decreased by 4% between 2000 and 2010 as a result of automation in the logistics sector. A general stabilisation of the stock is anticipated in the future. This trend can be seen from the development of operating hours depicted in the lower half of Fig. 25.

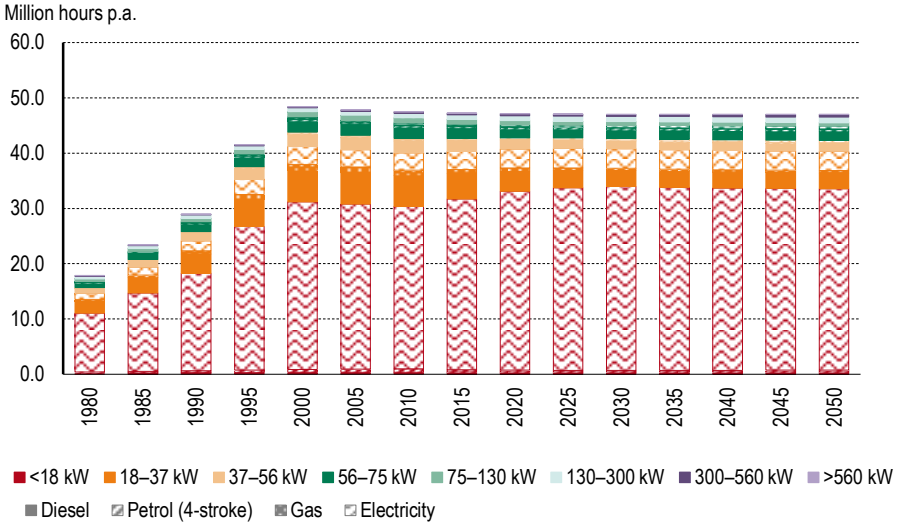
Due to the high level of specific operating hours for many machine categories (in some cases, 700 to 1,200 hours p.a.), the total operating hours for industrial machinery amounted to 47.5 million in 2005.[12]

[12] By way of comparison, construction machinery was in operation for a total of 23.8 million hours in 2010.

Fig. 25 > Industrial machinery: stock in 2010 and development of operation hours (1980 to 2050)

Top left: only categories with an stock >1,000 machines.
Reference year for stock: 2010.





The colours indicate the machine category and engine power classes, shading indicates the engine type.
Numerical values, cf. Tab. 51 on page 180

6.3 Agricultural machinery

The stock and operating hours for agricultural machines were primarily projected on the basis of the figures obtained from the 1996, 2003, 2005 and 2010 censuses of agricultural businesses. The information in the MOFIS database was included, but could only be used to a limited extent, partly because only some machines are registered (particularly small machines such as single-axle mowers and single-axle tractors), but also because some registered tractors are not used for agricultural purposes. This primarily concerns older models, but also tractors used in forestry and for the care of public areas such as woodlands and parks. The latter are included under "forestry" in the "cable and grapple skidders" sub-category, while old models of tractors are listed under "hobby tractors".

6.3.1 Stock

Fig. 26 (top left) shows that almost half the agricultural machines are petrol-driven. This primarily concerns chainsaws (90,100) and single-axle mowers (55,700). Tractors account for 62% of the stock of diesel-powered machines (107,750 in 2010). The majority of tractors (60%) have a nominal capacity between 37 and 75 kW (average for all vehicles: 52 kW). The distribution by engine power class is continuing to move in the direction of larger tractors, though at a very slow pace due to the lengthy service life of these vehicles.

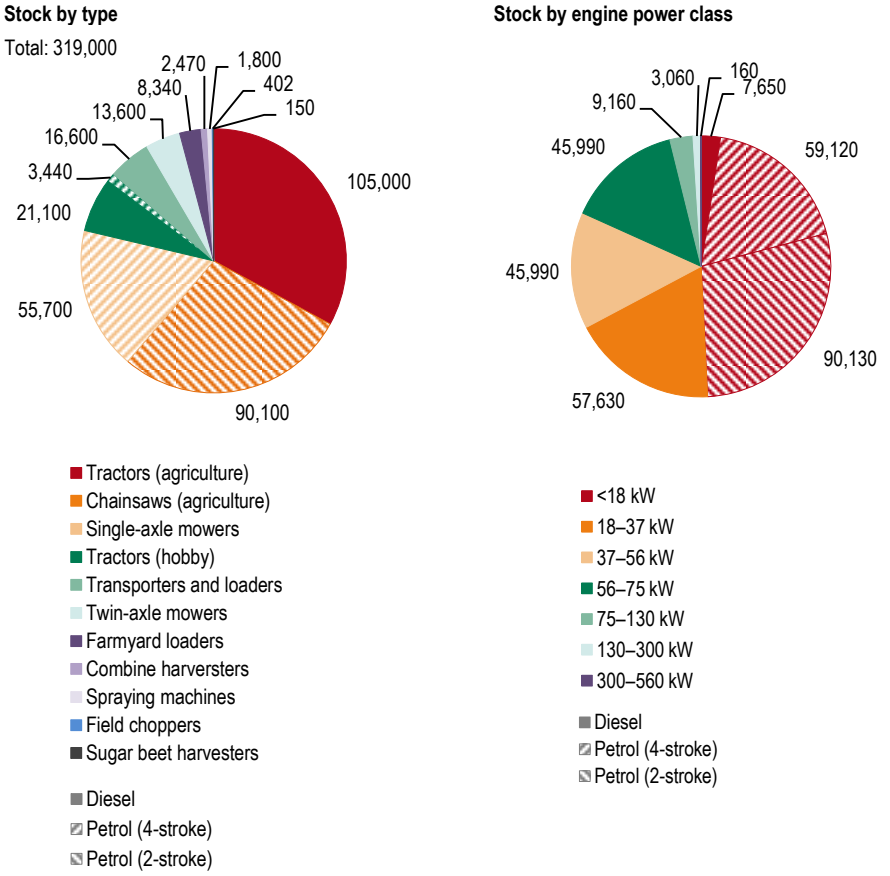
6.3.2 Operating hours and their development from 1980 to 2050

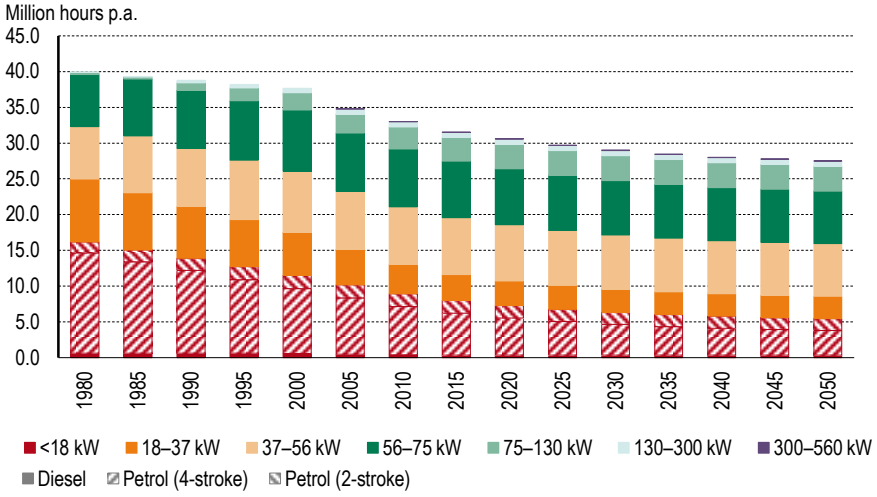
Based on the usage of agricultural tractors with regard to the management of agricultural land (Ammann, 2007), Agroscope cites the average annual duration of operation of tractors at 200 hours (cf. FOEN 2008). This figure represents an average for the overall fleet of tractors, and also takes account of the large number of old tractors with a very low number of operating hours.

A decline in the number of operating hours of agricultural machines can be observed over the course of time. The probable main reasons for this are the increasing trend towards wage labour and thus the use of larger machines, plus the more efficient use of machines. The total area of agricultural land is continually decreasing (2% decline between 1990 and 2012, FSO 2012), which is also contributing towards the decline in activity. By contrast, in 2006 the proportion of land under minimum cultivation amounted to only 1.1% of the total area of agricultural land, respectively 3% of the area of arable land (Ledermann & Schneider, 2008), and thus only has a minor influence on the use of agricultural machines.

Fig. 26 > Agricultural machinery: stock in 2010 and development of operating hours (1980 to 2050)

Reference year for stock: 2010.





The colours indicate the machine category and engine power class, and the shading indicates the type of engine.
Numerical values, cf. Tab. 51 on page 180

6.4 Forestry machinery

The figures for stock and operating hours recorded by the Swiss Federal Statistical Office (FSO) and contained in the MOFIS database include very little information relating to the stock of forestry machinery. For this reason, the inventory is mainly based on estimates by members of the group of experts, and information provided by manufacturers. For larger machine categories, sales figures for Switzerland are available from 2009 in the statistics kept by the German KWF (Kuratorium für Waldarbeit und Forsttechnik e.V.) (KWF 2012). In this inventory, tractors are listed as "cable and grapple skidders".

6.4.1 Stock

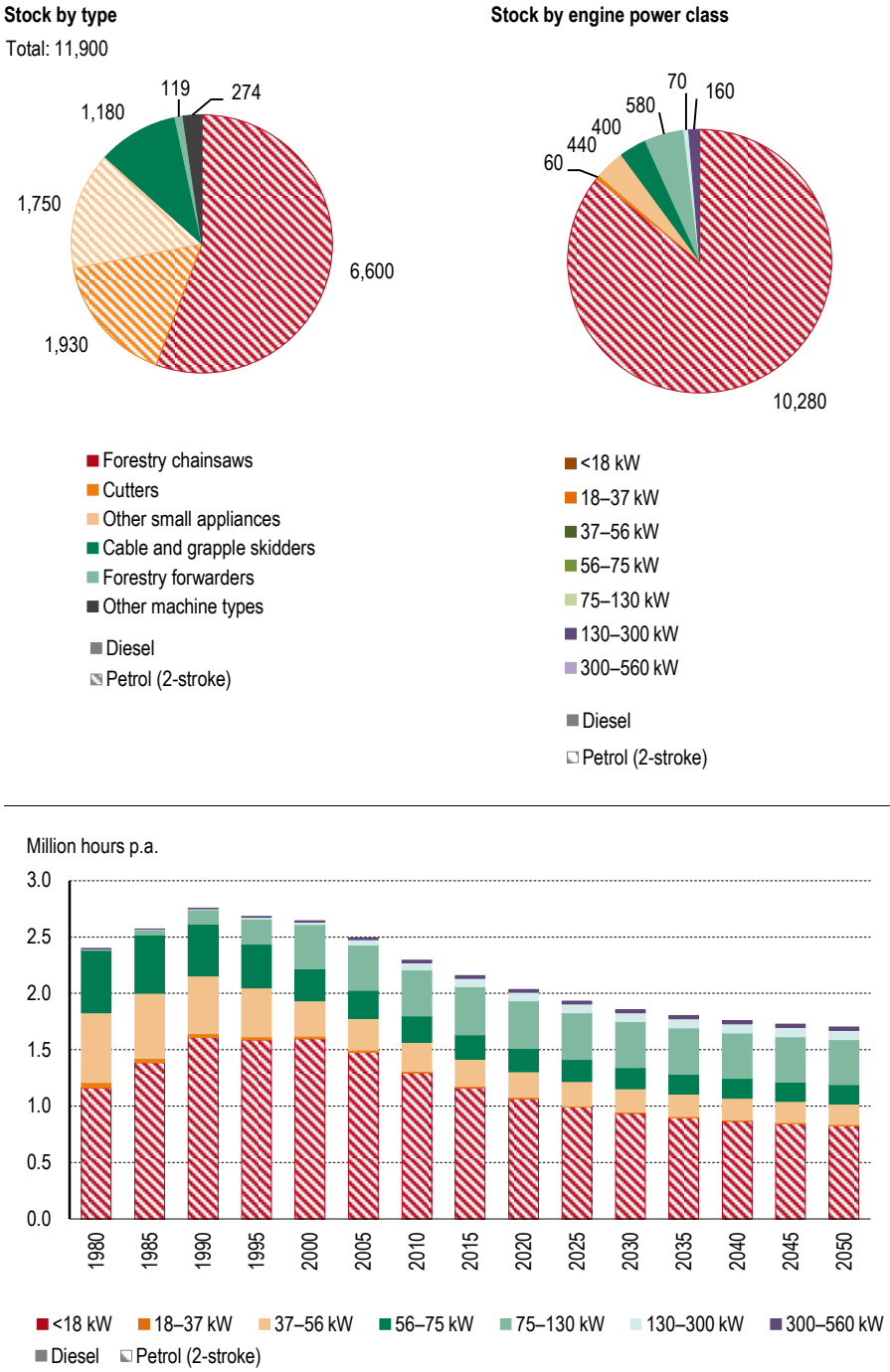
As we can see from Fig. 27 (top left: only types with an stock >100 machines), the majority of machines used in the forestry sector are hand-held petrol-driven appliances (primarily chainsaws and cutters). Most of the diesel-powered equipment takes the form of tractors (i.e. cable and grapple skidders).

6.4.2 Operating hours and their chronological development from 1980 to 2050

Thanks to efficiency measures, the total number of operating hours of machines in the forestry sector has fallen sharply since 1990, though the proportion of machines with high-power range engines is increasing (Fig. 27, bottom).). Another noted trend is the increasing processing of wood as an energy source, though this is not so much reflected in the operating hours as in the demand for energy (cf. chapter 8.4).

Fig. 27 > Forestry machinery: stock in 2010 and development of operating hours (1980 to 2050)

Top left: only categories with an stock >100 machines.
Reference year for stock: 2010.



The colours indicate the machine category and engine power class, and the shading indicates the type of engine.
Numerical values, cf. Tab. 51 on page 180

6.5 Garden-care/hobby appliances

This category covers all small appliances that are used by professionals and by private households. In addition to garden-care equipment, these include golf carts, motor sleds, snow blowers, cleaning appliances, grinders and drills.

Here the inventory was made on the basis of information provided by manufacturers and importers, and estimates by members of the group of experts. The average stock was calculated by taking the estimated sales figures and the average service life of the appliances. The figures for the operating hours were mainly taken from the previous study (FOEN 2008) and verified together with the members of the group of experts.

The division of stock by engine type (primarily petrol-driven appliances) and engine power class was made by distinguishing between hand-held and other appliances. Here it was assumed that hand-held appliances are equipped with 2-stroke petrol engines, while non-hand-held appliances are operated with 4-stroke petrol engines. This was based on technical specifications provided by manufacturers and importers.

6.5.1 Stock

Fig. 28 (top left: only types with an stock >50,000 machines) shows that a very large majority of small appliances with a combustion engine are used for garden-care purposes by private households (lawn mowers, motor scythes, etc.).

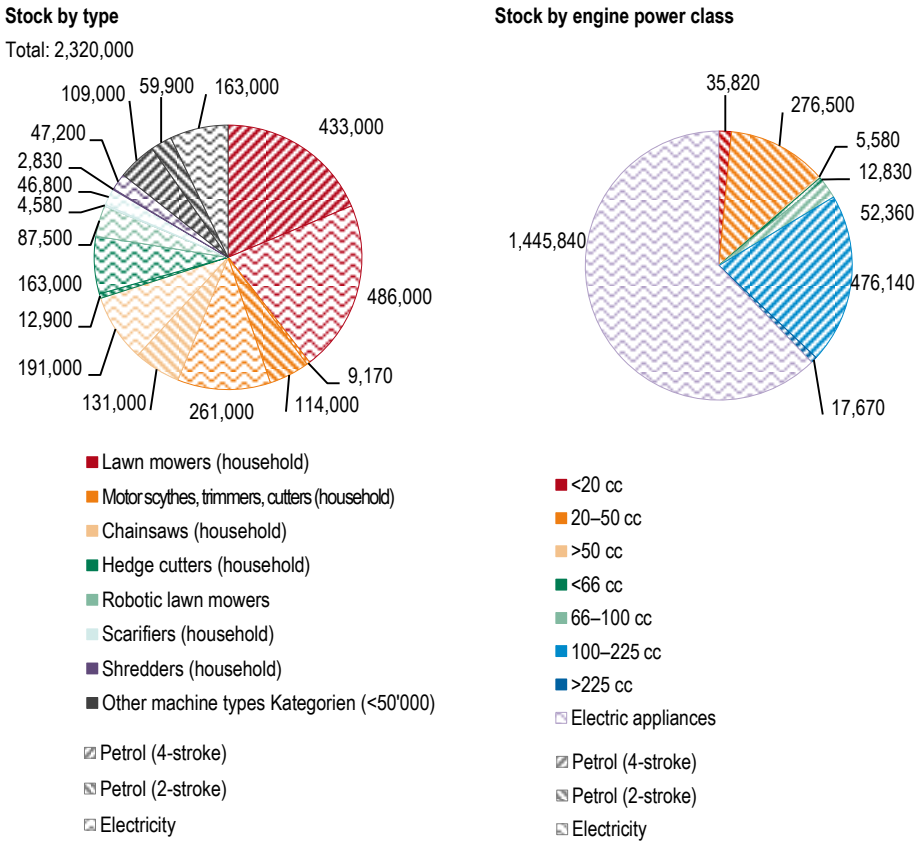
The various appliances use very small engines with an engine power less than 10 kWh or 20 to 50 cc (2-stroke engines) and 50 to 225 cc (4-stroke engines) – see Fig. 28, top right. Approximately 60% of the appliances were operated electrically. Roughly two-thirds of the appliances in the stock with a combustion engine were 4-stroke, and one-third were 2-stroke petrol engines.

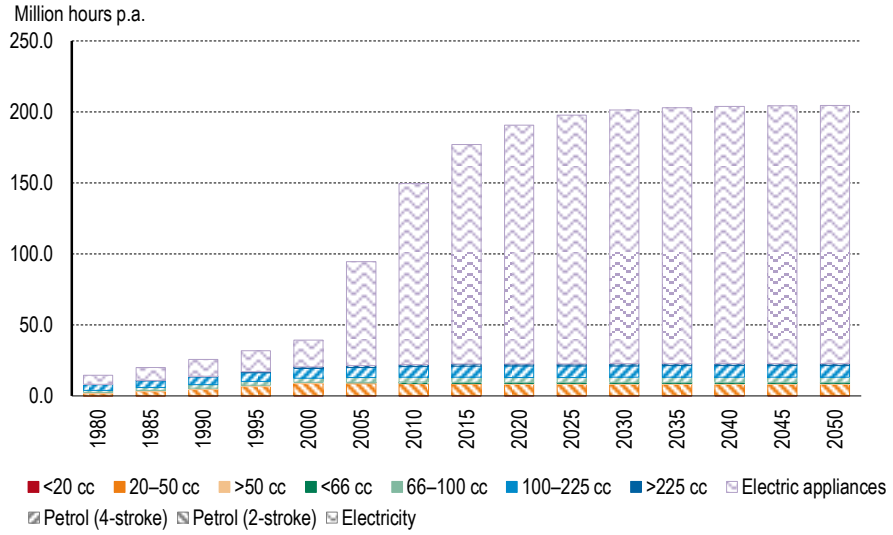
6.5.2 Operating hours and their chronological development from 1980 to 2050

The development of the stock and operating hours is based on estimates by the members of the group of experts. Here it was assumed that the stock increased significantly in the period from 1980 to 2000. This increase slowed down in the period from 2000 to 2010. The specific operating hours of the appliances have hardly changed. However, the boom in lawn mower robotics, for which the levels of operating hours are very high, commenced in 2000, and this caused the total number of operating hours to increase sharply (Fig. 28, bottom). It is anticipated that, as the consequence of health considerations and tighter regulations governing maximum emission levels, there will be a further shift in stock shares towards battery-operated electric appliances, especially in the professional segment. While the increase in battery-operated appliances in the professional segment will take place at the cost of petrol motors, in the hobby segment cable-operated electric appliances have been in widespread use for some time already; here there is likely to be a shift from cable-operated to battery-operated appliances.

Fig. 28 > Garden-care/hobby appliances: stock in 2010 and development of operating hours (1980 to 2050)

Top left: only categories with an stock >50,000 machines.
Reference year for stock: 2010.





The colours indicate the machine category and engine power classes, and the shading indicates the engine type.
Numerical values, cf. Tab. 51 on page 180

6.6 Navigation machinery

The stock of ships and boats in Switzerland is well documented thanks to the data recorded by the Swiss Federal Statistical Office, the relevant cantonal authorities and the province of Vorarlberg. The statistics kept by the latter record the stock of ships and boats in the region of Lake Constance, differentiated by engine power classes. Since no corresponding statistics exist for Switzerland's lakes, the size distribution for Lake Constance was assumed to be representative for Switzerland's bodies of water. The distribution of passenger ships, ferries and cargo vessels/barges by size was made on the basis of information provided by navigation transport operators. The fact that many vessels are equipped with more than one engine was taken into account via the distribution by engine power class. However, with respect to cargo ships on the Rhine (included in the non-road inventory for the first time in this updated report), a distinction is made between main and auxiliary engines by allocating them to separate machine categories. The data relating to cargo ships on the Rhine are based on a study of their emissions (INFRAS 2012).

The operating hours were estimated by the members of the group of experts. The utilisation of passenger ships was based on information provided by operators, while the corresponding figures for cargo vessels/barges were based on information provided by the two Basel cantons and INFRAS 2012.

6.6.1 Stock

Fig. 29 (top left) shows that the stock of navigation machinery is dominated by rental and privately owned boats, and yachts (85%). There were also 146 passenger ships, 8 ferries and 244 cargo ships (excluding those operated on the Rhine) in operation in 2010, plus around 1000 professional fishing boats. Military vessels are not included in this machine category, since these are allocated to military machinery (cf. chapter 6.8). With respect to cargo ships in operation on the Rhine, only the number of trips can be calculated, but not the number of ships themselves (cf. INFRAS 2012). Here the two figures are treated as equal, which almost certainly results in an overestimation of the stock, but not of the ultimately relevant total number of operating hours.

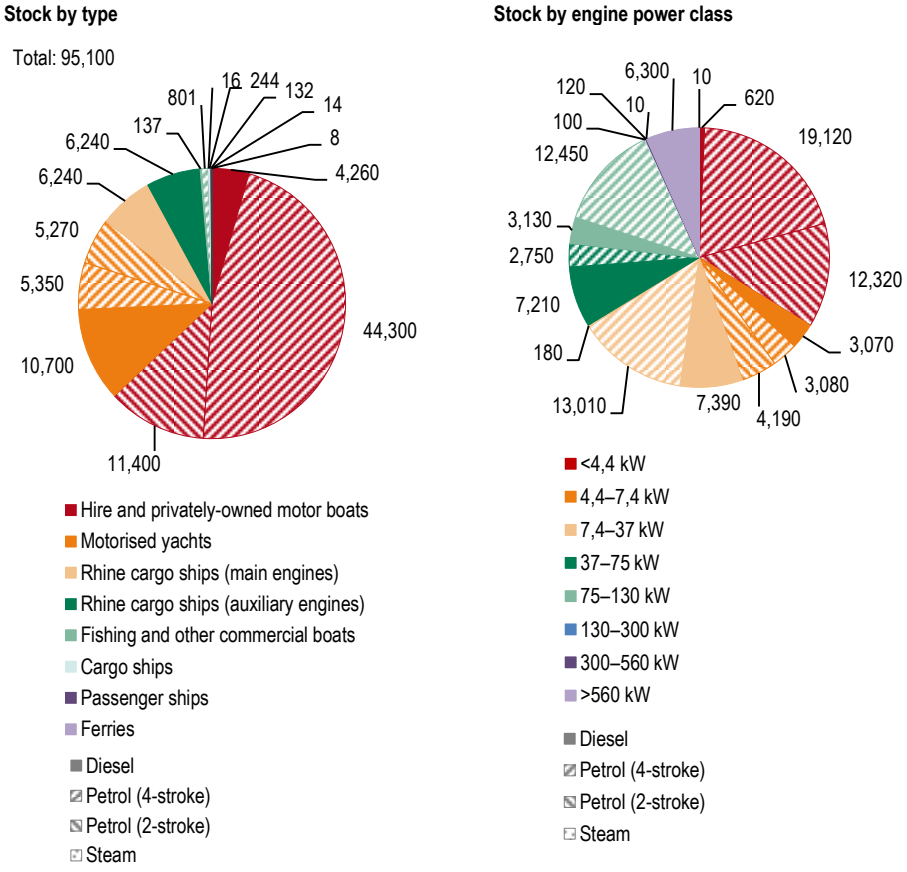
6.6.2 Operating hours and their chronological development from 1980 to 2050

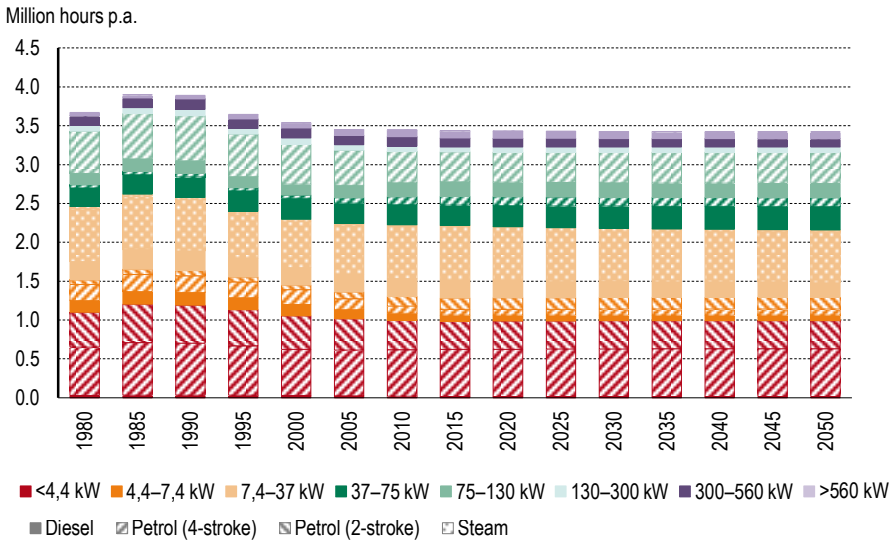
In this category, the average annual operating hours vary enormously. While recreational craft (yachts, hired and privately-owned motor boats) are only used sporadically (average = 30 hrs p.a.), the average operating hours of ships and boats used for professional purposes are very high: 500 hrs p.a. for fishing boats, cargo vessels/barges, etc., 1200 hrs p.a. for passenger ships, 3500 hrs p.a. for ferries For the main engines of cargo ships on the Rhine, a journey time of 1.5 hours is assumed on the Swiss section of the river. However, the auxiliary engines also remain in operation as generators during docking, and are used for approximately 33 hours per journey (numerical values, cf. Tab. 51 on page 180).

As we can see from the bottom half of Fig. 29, the proportion of vessels equipped with a petrol engine has fallen slightly. No significant changes are anticipated with respect to the stock of ships and boats.

Fig. 29 > Navigation machinery: stock in 2010 and development of operating hours (1980 to 2050)

Reference year for stock: 2010.





The colours indicate the machine category and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 51 on page 180

6.7 Railway machinery

Most of the railway vehicles in Switzerland that are equipped with a combustion engine take the form of shunting locomotives, railway tractors and dual-system tractors (the latter can be operated with diesel as well as electricity). The stock and operating hours figures are based on annual reports (BLS 2012; SBB 2012) and other BLS and SBB sources.

In the statistics of the railway operating companies, the service vehicles listed in the previous inventory (FOEN 2008) are no longer shown separately, and have been included under rail tractors.

6.7.1 Stock

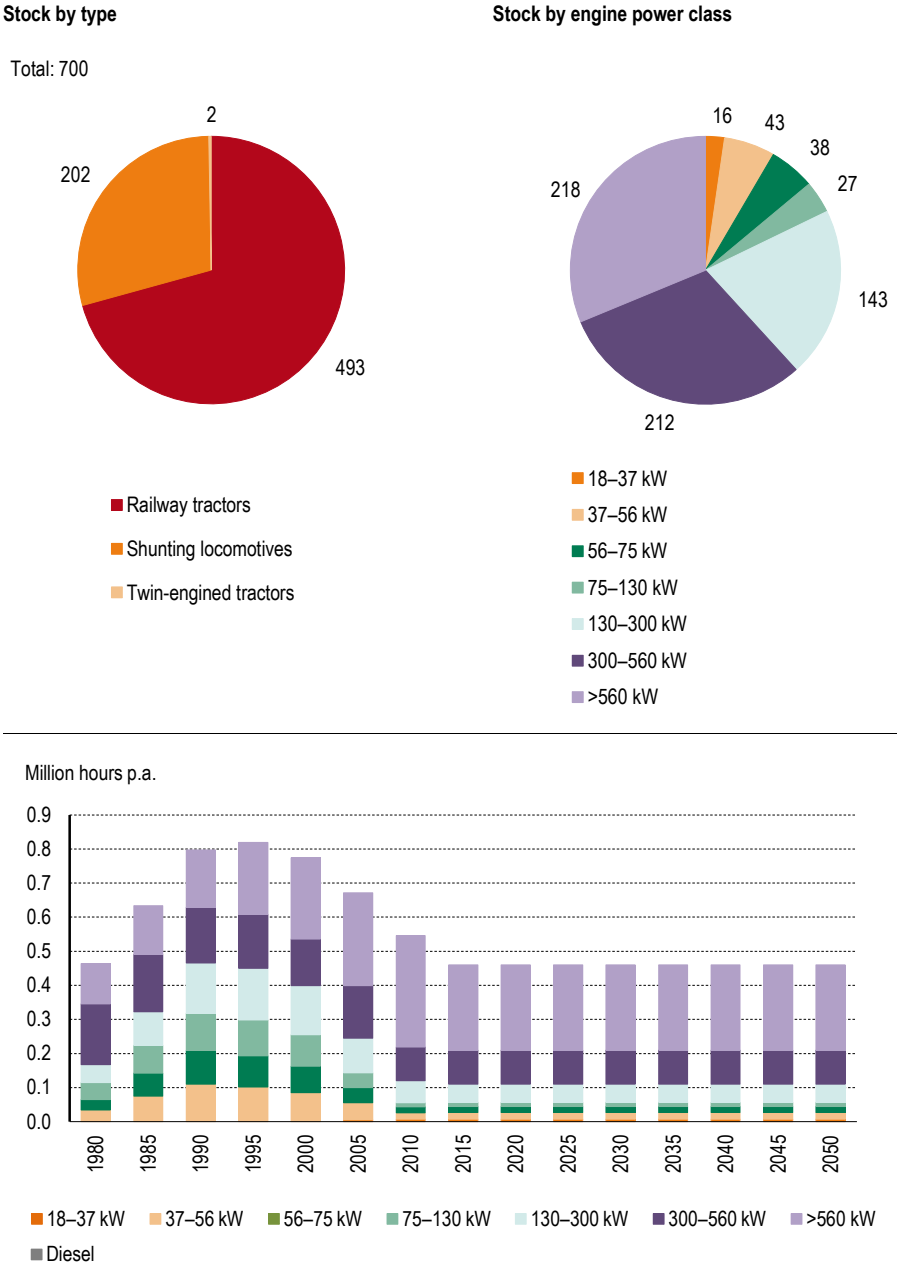
Fig. 30 (top left) shows that the majority of the railway vehicles in Switzerland that are equipped with a combustion engine take the form of railway tractors. The number of diesel locomotives is comparatively low, but by comparison with diesel machines in other categories, the engine power of diesel railway vehicles is relatively high.

6.7.2 Operating hours and their chronological development from 1980 to 2050

According to data provided by the operators, the stock and specific operating hours of diesel railway vehicles have decreased sharply over the past few years. These have been replaced by more powerful vehicles, as can be deduced from the distribution of diesel railway vehicles by size (Fig. 30, bottom).

Fig. 30 > Railway machinery: stock in 2010 and development of operating hours (1980 to 2050)

Reference year for stock: 2010.



The colours indicate the machine category and engine power classes, and the shading indicates the engine type.
Numerical values, cf. Tab. 51 on page 180

6.8 Military machinery

The stock and operating hours of military machinery are based on recent data provided by the military authorities (Army Basic Logistics, LBA). The figures cited in this report correspond to the entire stock of the Swiss Federal Department of Defence (VBS), Civil Protection and Sport; the specific operating hours correspond to the average of all (used and unused) vehicles and appliances. The figures relating to operating hours and stock are several times higher in comparison with the previous inventory (FOEN 2008), especially for tanks and construction machines, and have also been adjusted retrospectively for the period prior to 2000. The reasons for the discrepancies are unknown, but the LBA has confirmed that the latest figures are correct.

By contrast with the previous non-road stock (FOEN 2008), military generators have now been included. In addition, a number of machine categories (45m support bridges, use of pumps, water transport) have been added to the current inventory, through their numbers are very low.

6.8.1 Stock

As we can see from Fig. 31 (top left), generators head the stock of military machines, followed by armoured vehicles which have very high engine capacities (in some cases >560 kW). With the exception of around 80% of generators and a few boats, almost all machines are equipped with diesel engines.

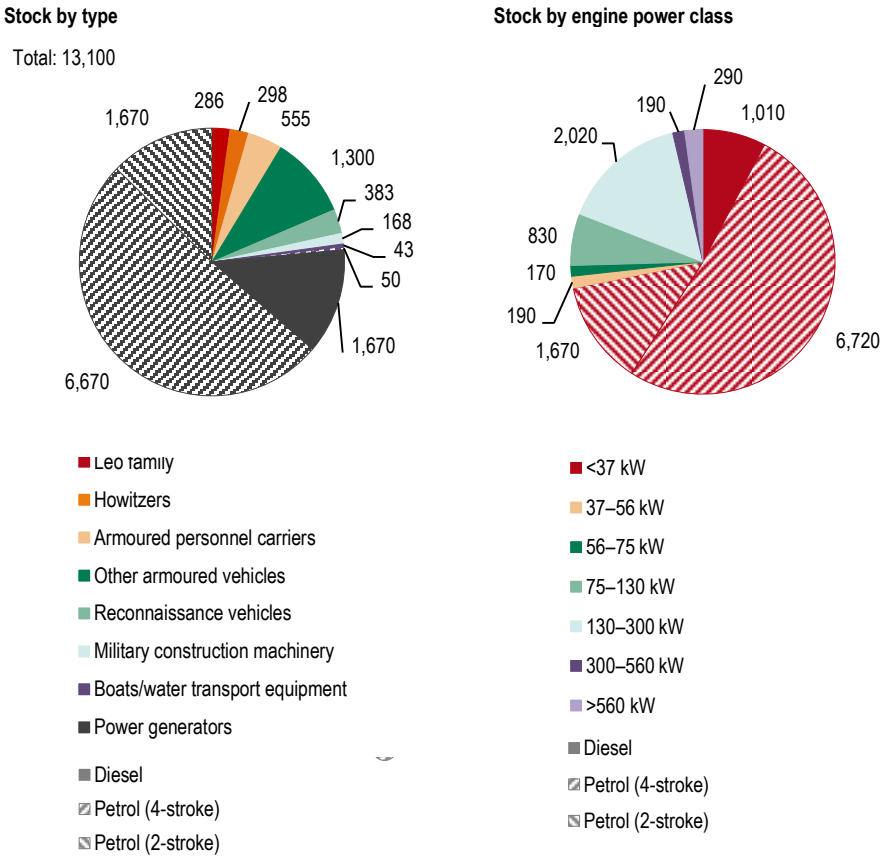
6.8.2 Operating hours and their chronological development from 1980 to 2050

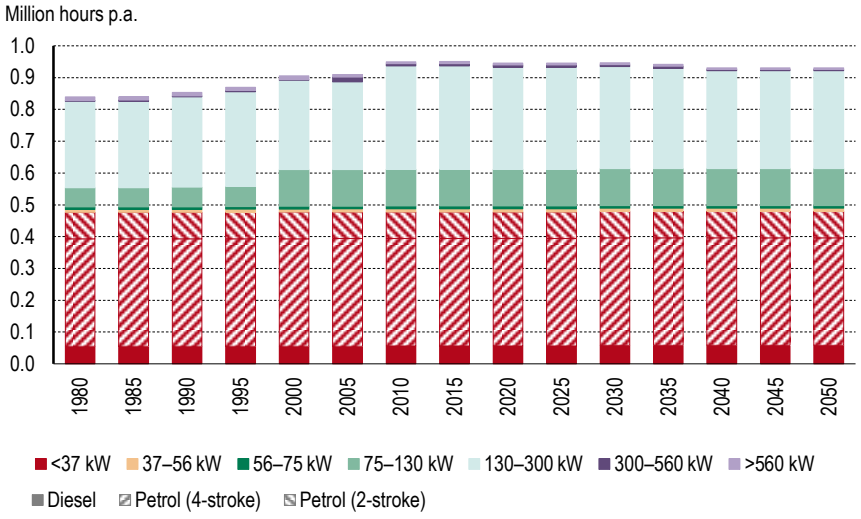
Generators are also predominant in terms of operating hours of military machinery, followed by armoured vehicles. With respect to the latter, in the past ten years, almost all armoured personnel carriers have been replaced by various types of light wheeled tanks. And various models of Eagle reconnaissance vehicles have been added since 2000.

According to information provided by the Swiss Federal Department of Defence, Civil Protection and Sport, a slight reduction in the use of military machines is to be expected in the future.

Fig. 31 > Military machinery: stock in 2010 and development of operating hours (1980 to 2050)

Top left: combined categories of construction machines and boats/appliances for water transport.
Reference year for stock: 2010.





The colours indicate the machine category and engine capacity, and the shading indicates the engine type.
Numerical values, cf. Tab. 51 on page 180

7 > Energy consumption and pollutant emissions

7.1 Energy consumption in 2010

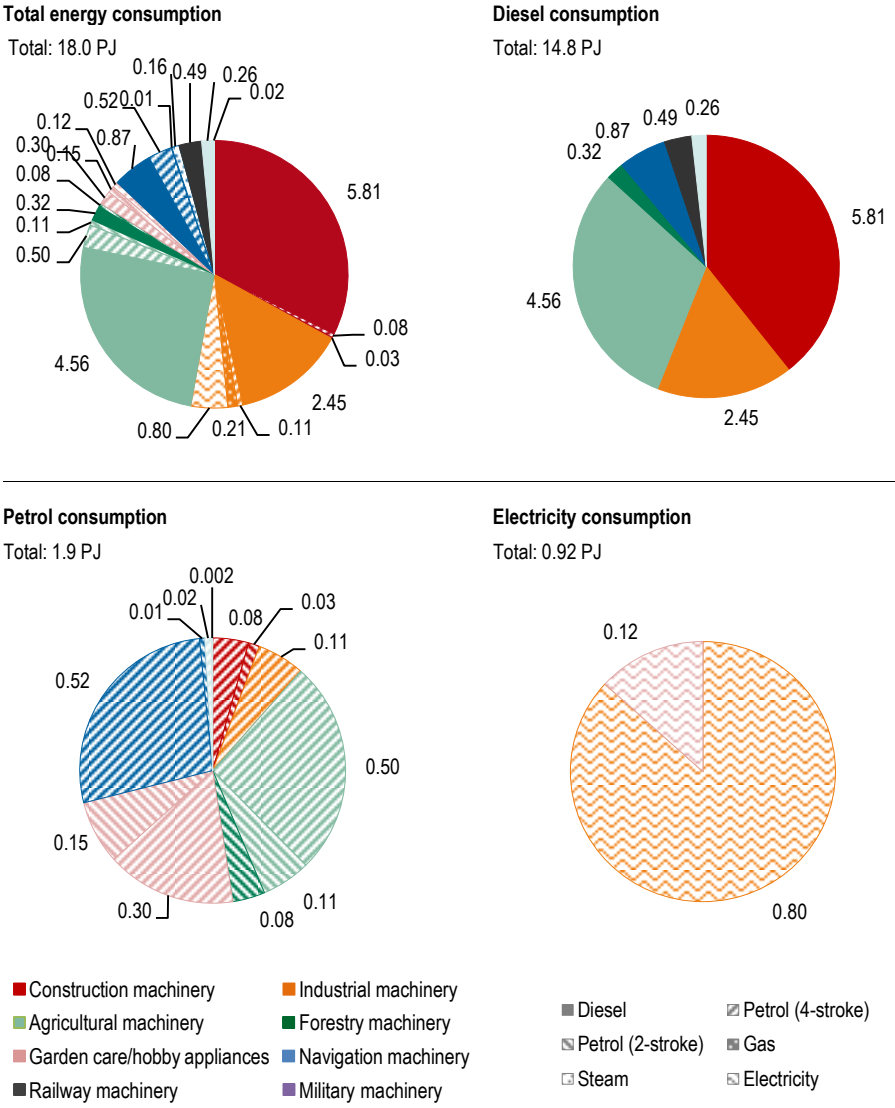
Fig. 32 shows the non-road consumption of fuel and electricity in 2010 based on the calculation model. We can see that diesel is the dominant fuel in the non-road sector (14.8 PJ in 2010). The consumption of diesel is more than 7 times higher than the consumption of petrol. Thus, based on the overall Swiss energy statistics, the non-road sector accounts for around 15% of the total sales of diesel in Switzerland (97.8 PJ; FOE 2011). Road traffic accounts for most of the remaining 83 PJ (1.4 million tonnes, FOEN 2010).

Despite the high stock and operating hours, with a level of 0.92 PJ p.a., electric appliances only account for around 5% of the total energy consumed in the non-road sector. The main reason for this is that the majority of electric appliances used in the garden-care segment are small and have a low engine power range. The other non-road electric motors, namely large electric forklifts and lifting platforms, account for around 87% of the electricity consumed in the non-road sector, despite the much lower stock and number of operating hours.

Within the non-road sector, the largest proportion of energy is consumed by construction and agricultural machinery (33% and 29% respectively of overall non-road energy consumption). In this respect, construction machinery has therefore surpassed agricultural machinery since the last update of the inventory (FOEN 2008).

Fig. 32 > Energy consumption in the non-road sector in 2010 in PJ p.a.

Reference year: 2010.



The colours indicate the machine category, shading indicates the engine type. Numerical values, cf. Table Tab. 14 on page 79

Tab. 14 > Energy consumption in the non-road sector (2010)

Stock and operating hours of non-road source groups in 2010.
Figures rounded up or down.

Machine category	Fuel consumption [tonnes p.a.]			Electricity consumption [GJ]	Total energy consumption [PJ]
	Diesel[13]	Petrol	Gas		
Construction machines	135,800	2,561	-	-	5.92
Industrial machinery	57,200	2,610	5,840	799	3.57
Agricultural machinery	106,700	14,390	-	-	5.18
Forestry machinery	7,460	1,770	-	-	0.39
Garden-care/hobby appliances	-	10,560	-	122	0.57
Navigation machinery	24,010	12,586	-	-	1.56
Railway machinery	11,500	-	-	-	0.49
Military machinery	5,990	426	-	-	0.27
Total non-road-sector	**348,700**	**44,900**	**5,840**	**921**	**18.0**

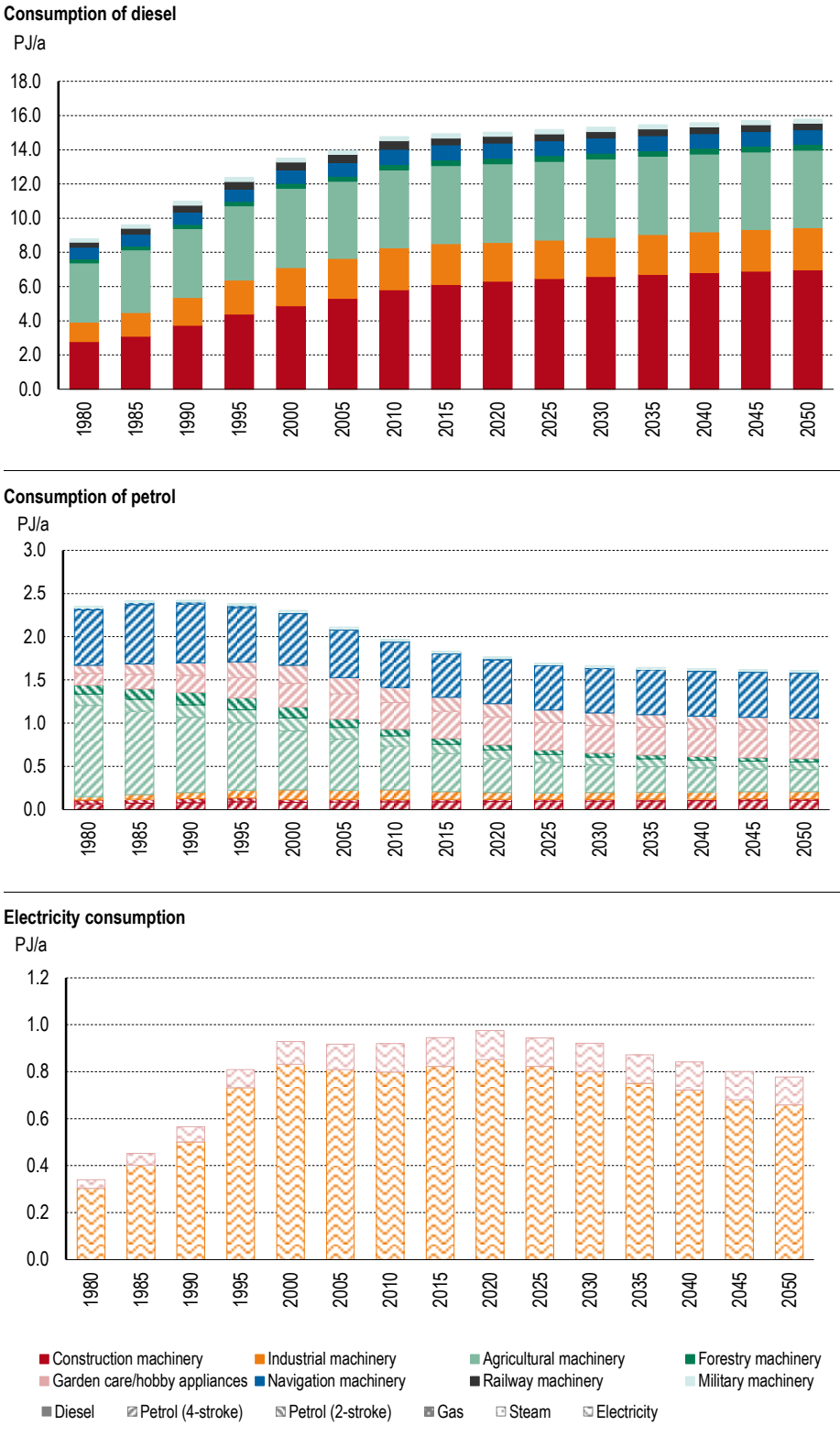
7.2 Development of energy consumption (1980 to 2050)

Fig. 33 shows the development of diesel, petrol and electricity consumption according to the calculation model. As we can see, the non-road consumption of diesel increased sharply between 1980 and 2010. A further increase, though at a slower pace, is anticipated in the next few years. The consumption of petrol is expected to continue to decline, particularly because fewer petrol-driven machines will be in use in the agricultural sector and petrol engines in small appliances are being increasingly replaced by electric motors. It should be noted that the reliability of forecasts decreases the further they reach into the future (cf. chapter 4.2.2).

The development of electricity consumption depends to some extent on the development with respect to forklifts, since these account for a major proportion of electricity consumption in the non-road sector. Here, three different developments play a role: firstly, the stock of forklifts has been declining slightly since 2000 – a trend that is expected to persist in the future due to increasing automation in the area of logistics. Secondly, at the same time the number of electric motors used in forklifts is increasing. And thirdly, an improvement in the degree of efficiency is anticipated thanks to technological developments (cf. Tab. 42 on page 170). The combination of these three trends has given rise to the prediction of a slight decrease in the electricity consumption of forklifts by 2050. With respect to electric garden-care appliances a sharp increase in electricity consumption can be observed – this trend will persist in the future, though at a slower pace; from 2020, the assumption here, too, is that an improvement in efficiency will outweigh the slowing activity and result in a slight decrease in consumption. On balance, a decrease in electricity consumption in the non-road sector is to be expected from approximately 2020.

[13] Including heating oil for steamships

Fig. 33 > Development of energy consumption in the non-road sector



The colours indicate the machine category, and the shading indicates the engine type. Numerical values, cf. Tab. 53 on page 185

7.3 Emissions in 2010

Fig. 34 shows the proportions of the various pollutant groups to non-road emissions for the four regulated pollutants (carbon monoxide [CO], hydrocarbons [HC], nitrogen oxides [NO_x] and particulate matter [PM]). Different machines and appliances are the main sources of emissions, according to pollutant.

In the case of carbon monoxide (CO) and hydrocarbons (HC), agricultural machines account for by far the highest proportion of emissions. This is mainly attributable to the fact that the single-axle mowers used in this sector have a relatively high nominal engine rated power as well as very high load factors. Appliances used in the garden-care/hobby sector also account for a significant proportion of non-road CO and HC emissions, primarily as a consequence of the widespread use of petrol engines in these categories.

As far as nitrogen oxides (NO_x) are concerned, construction and agricultural machinery account for by far the highest proportion of emissions. However, mobile industrial and navigation machinery, and to a lesser extent railway machinery, also account for a relevant share of NO_X emissions in the non-road sector.

Agriculture is by far the largest source of particulate matter emissions today. In 2005, construction and agricultural machinery accounted for more or less equal levels of PM emissions (FOEN 2008). Thanks to the particle filter requirement that entered into force in 2009 in accordance with the Ordinance on Air Pollution Control, the level of particulate matter emitted by construction machines in 2010 was only around a quarter of that emitted by agricultural machinery.

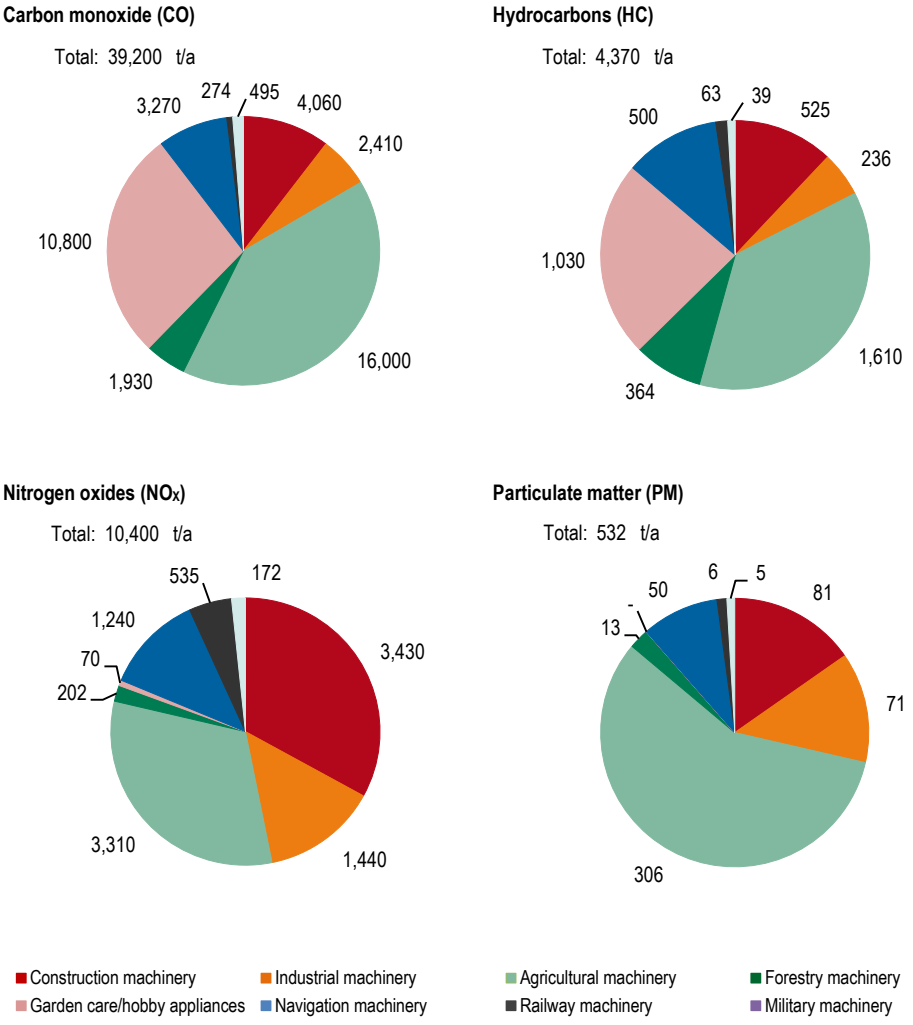
Fig. 35 depicts the proportions of the various emission groups to the emissions in the non-road sector for non-regulated pollutants: the components of the hydrocarbons methane (CH^4), non-methane hydrocarbons (NMHC) and benzene (C^6H^6) and nitrous oxide (N^2O), ammonia (NH^3) and particle number (PN).

Among the components of hydrocarbons, the proportion of the individual emission groups to the total is by nature similar to that for total hydrocarbons. However, it differs slightly by component, since the proportion of individual components to total hydrocarbons varies according to the type of fuel and engine technology. For example, garden appliances contribute more towards total methane emissions than to total hydrocarbons because 2-stroke petrol engines are widely used in garden appliances, and these have higher methane concentrations in total hydrocarbon emissions (7%) than 4-stroke petrol and diesel engines (3.4% and 2.4% respectively). The opposite effects occurs among non-methane hydrocarbons.

With respect to benzene, garden appliances and agricultural machinery thus contribute a higher proportion to total emissions than to total hydrocarbons, because in these categories numerous petrol engines are used, and with a share of 0.8% of total hydrocarbons, these indicate much higher specific emissions of benzene than diesel engines with 0.15% of total hydrocarbons, even after the introduction of the lower benzene limit level.

As far as nitrous oxide is concerned, construction machines are the biggest emitters, followed by agricultural and industrial machinery. The reason for this is that diesel and 4-stroke petrol engines, which are the most widely used in these categories, and their specific emissions are around three times higher than those of 2-stroke petrol engines.

Fig. 34 > Emissions of regulated air pollutants in the non-road sector in 2010



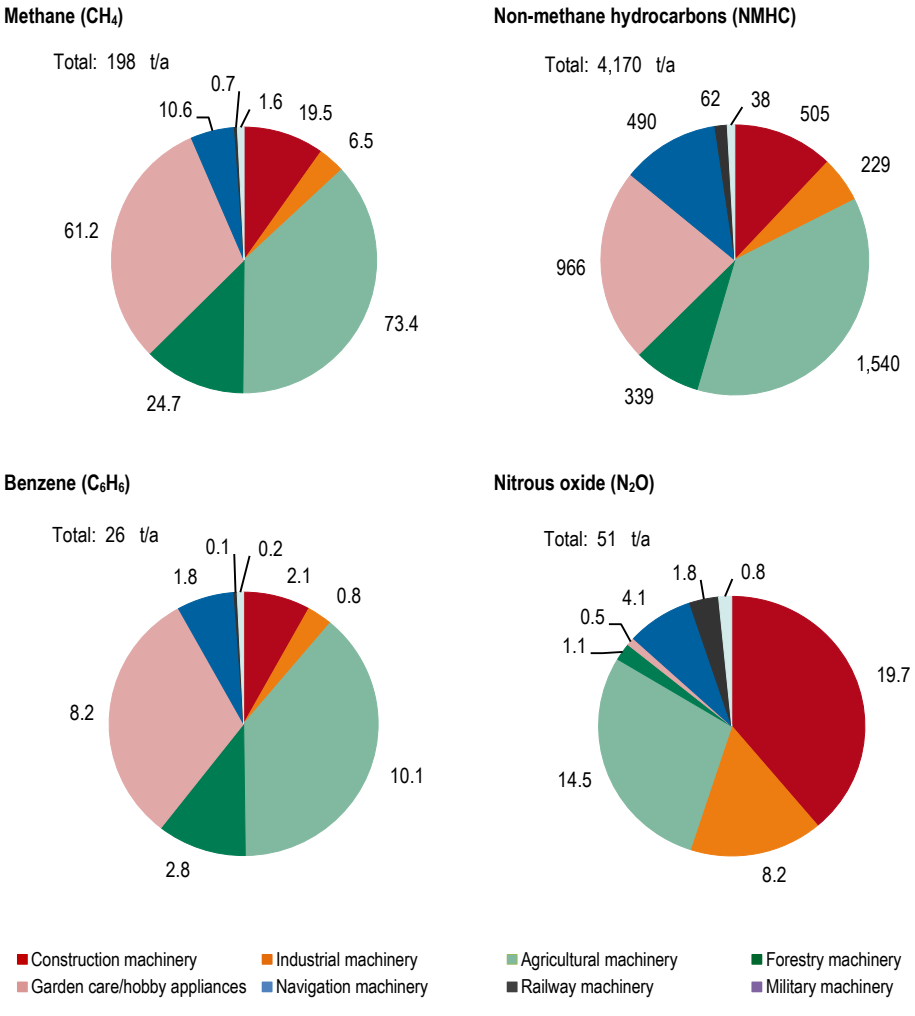
Numerical values, cf. Tab. 15

Tab. 15 > Emissions of regulated air pollutants in the non-road sector in 2010

Figures rounded up or down.

Category	Carbon monoxide (CO) [tonnes p.a.]	Hydrocarbons (HC) [tonnes p.a.]	Nitrogen oxides (NO_X) [tonnes p.a.]	Particulate matter (PM) [tonnes p.a.]	Carbon dioxide (CO_2) [tonnes p.a.]
Construction machinery	4,060	525	3,430	81	435,800
Industrial machinery	2,410	236	1,440	71	203,200
Agricultural machinery	16,000	1,610	3,310	306	381,300
Forestry machinery	1,930	364	202	13	29,000
Garden-care/hobby appliances	10,800	1,030	70	-	33,200
Navigation machinery	3,270	500	1,240	50	115,000
Railway machinery	274	63	535	6	36,200
Military machinery	495	39	172	5	20,200
Total non-road sector	**39,200**	**4,370**	**10,400**	**532**	**1,254,000**

Fig. 35 > Emissions of non-regulated air pollutants in the non-road sector in 2010



Numerical values, cf. Table Tab. 16.

Tab. 16 > Emissions of non-regulated air pollutants in the non-road sector in 2010

Figures rounded up or down.

Category	Methane (CH_4) [tonnes p.a.]	Non-methane hydrocarbons (NMHC) [tonnes p.a.]	Benzene (C_6H_6) [tonnes p.a.]	Nitrous oxide (N_2O) [tonnes p.a.]
Construction machinery	20	505	2	20
Industrial machinery	7	229	1	8
Agricultural machinery	73	1,540	10	14
Agricultural machinery	25	339	3	1
Garden-care/hobby appliances	61	966	8	–
Navigation machinery	11	490	2	4
Railway machinery	1	62	–	2
Military machinery	2	38	–	1
Total non-road sector	**198**	**4,170**	**26**	**51**

7.4 Development of emissions

7.4.1 Relative development

Fig. 36 shows the development of total non-road emissions for all machine categories. As we can see, almost all emissions covered by this report increased until 1995. Benzene emissions fell sharply from 2002 onwards due to the introduction of the limit level for benzene in petrol. From 2002 onwards, i.e. after the first EU regulations governing emission levels entered into effect (cf. Appendix A3, pages 146 ff), emissions of all pollutants except carbon dioxide and nitrous oxide began to fall sharply, especially those of particulate matter, for which a reduction to 12% of the present-day level is anticipated by 2030, and to 5% of the present-day level by 2050. The reduction in emissions of particulate matter can be attributed to the introduction of cleaner engines as well as to the anticipated stronger market penetration of particle filters (assumptions as per Fig. 23).

By contrast with other pollutant emissions, the development of carbon dioxide emissions is less dynamic. Generally speaking, it is in line with the development of operating hours of non-road machines (see Fig. 20).

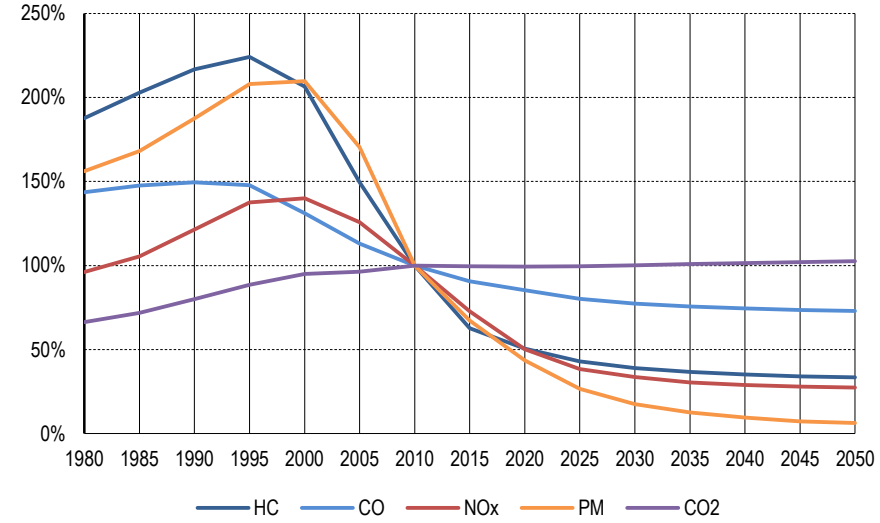
Fig. 36 > Relative development of pollutant emissions in the non-road sector compared with 2010 levels

a) Relative development of regulated air pollutants and CO_2
b) Relative development of non-regulated air pollutants

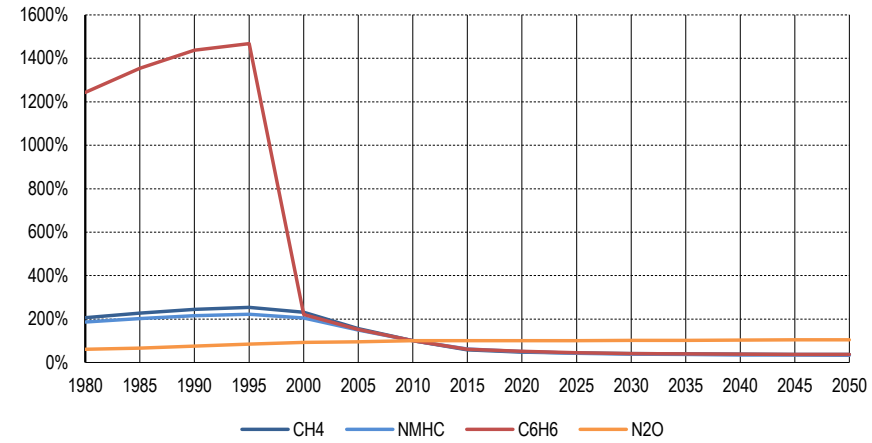
The development of pollutant emissions is indexed to 2010.

The trend in emissions of particulate matter (PM) represents the development of the stock of machines retrofitted with a particle filter (see Fig. 23).

a)



b)



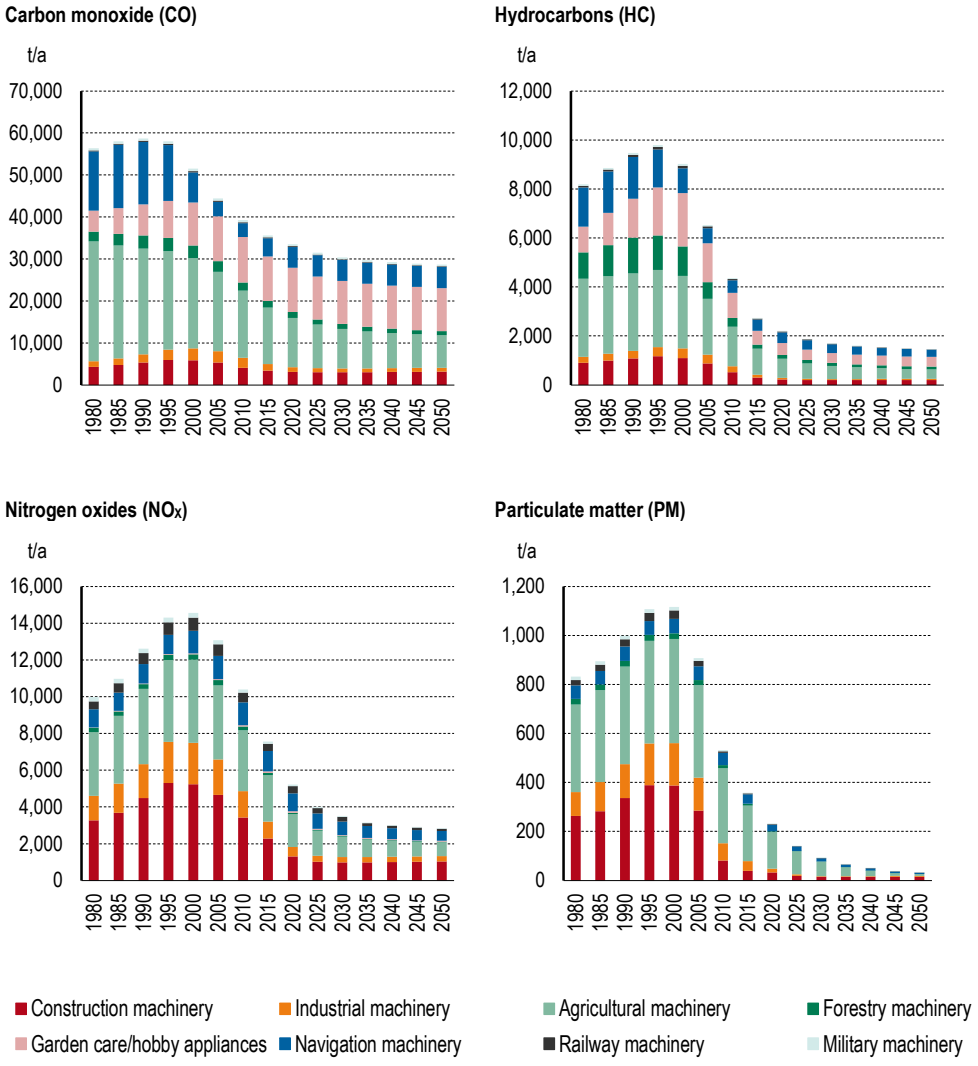
Numerical values, cf. Tab. 54 on page 186

7.4.2 Development of emissions by machine category

Fig. 37 shows the development of emissions of the four classical pollutants (CO, HC, NO_x and PM10) by machine category (source).

Fig. 37 > Development of pollutant emissions

Development of emissions of regulated pollutants (1980 to 2050).



Numerical values, cf. Tab. 54 on page 186

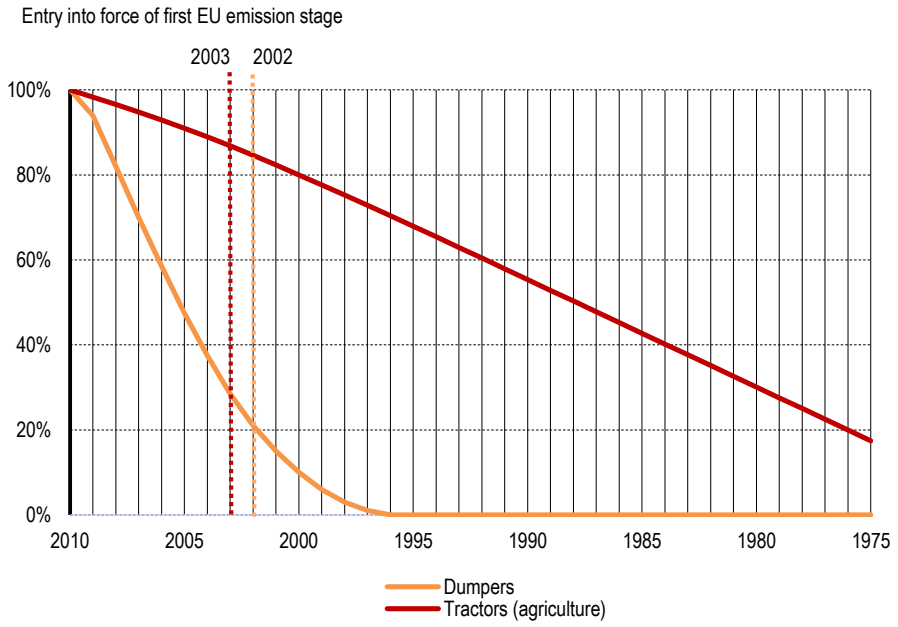
Basically we can anticipate a reduction in emissions of all listed pollutants during the next few years, but the reduction of carbon monoxide emissions is expected to be lower than that of the other pollutants. In addition, it is apparent that the degree of reduction in individual pollutant emissions varies among the different machine/appliance categories. For example, the reduction of particle emissions from construction machinery is more pronounced than from agricultural machinery. This means that, despite an abso-

lute reduction, the relative proportion of PM emissions from agricultural machinery will increase. There are three reasons for this:

- Based on the provisions of the Ordinance on Air Pollution Control (FOEN 2009), numerous construction machines were already retrofitted with particle filter systems in 2010 (82% of machines >37 kW, cf. Fig. 23), whereas only a negligible number of agricultural machines have been retrofitted to date. The degree of retrofitting of agricultural machinery is likely to remain low in the future, too, since there are as yet no signs of an introduction of a retrofitting requirement in this category.
- Compared with agricultural machinery, the construction machines currently in use are newer, as we can see from Fig. 38. This means that there is a higher proportion of newer, and thus "cleaner", machines in use in the construction industry than in the agricultural sector.
- For construction machinery, the first set of EU regulations governing maximum emission levels entered into effect earlier than the regulations governing agricultural machinery. This, combined with the fact that the fleet of construction machines is newer than that of agricultural machines, resulted in a situation in which 40% of most construction machinery categories met the EU emission requirements in 2005, compared with only 8% of tractors (Fig. 38).

Fig. 38 > Age distribution of construction and agricultural machinery

The curves represent the respective age distribution, while the vertical dotted lines indicate the year in which the first EU regulations governing maximum emission levels entered into effect (1 year earlier for construction machines than for agricultural equipment). NB: the vertical dotted lines indicating the years in which the regulations entered into effect represent a delay of one year (e.g. from 2003 → 2002) since all machines have to meet the specified requirement in the year of entry into effect.



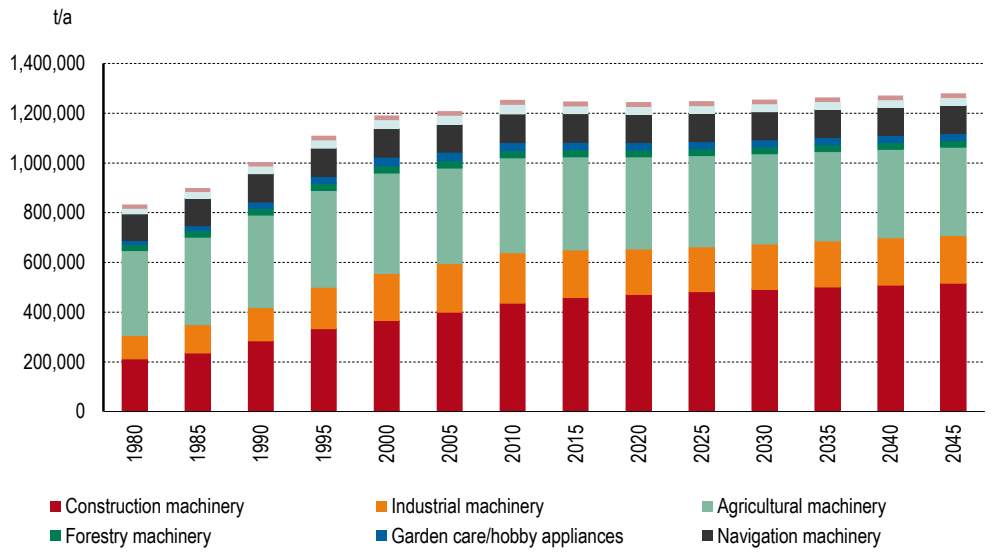
In 2010, 80% of excavators/dump trucks complied with EU I (since 80% of these machines were less than 9 years old and were thus brought into circulation after the introduction of EU I)

7.4.3 Development of CO_2 emissions

CO_2 emissions are a direct consequence of, and are immediately related to, fuel consumption. The corresponding conversion factors are indicated in Tab. 44 on page 172.

In 2010, non-road emissions of carbon dioxide (CO_2) amounted to a total of 1.3 million tonnes, which is equivalent to 2.7% of Switzerland's total annual CO_2 emissions (45.9 million tonnes p.a.; FOEN 2014). In the period from 1990 to 2010, non-road CO_2 emissions increased by 25%. Only a slight increase is expected in the period up to 2050, though in contrast to road vehicles there is also no recognisable trend towards more fuel-efficient machines (FOEN 2010).

Fig. 39 > Development of non-road CO_2 emissions



Numerical values, cf. Tab. 54 on page 186

8 > Energy consumption and pollutant emissions by machine category

8.1 Construction machinery

8.1.1 Energy consumption

In contrast to the composition of the construction machinery stock, with respect to fuel consumption it is crawler excavators and wheeled and caterpillar loaders that head the list, accounting for 54% of consumption (Fig. 40, top). Together, the various excavator types (mini-excavators, i.e. below 37 kW, plus larger caterpillar and wheeled excavators) account for around 42% of the energy consumption of mobile machines. Petrol-driven engines only play a minor role in the construction sector in terms of fuel consumption.

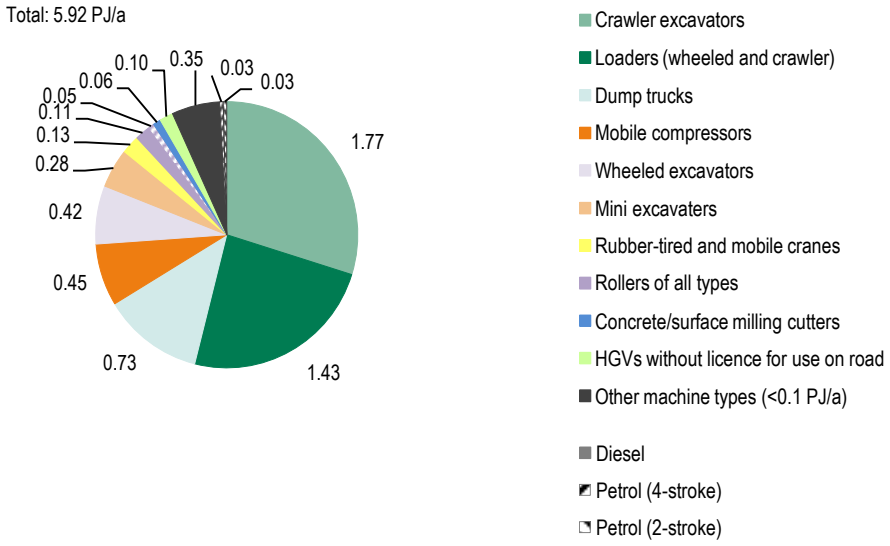
8.1.2 Development of energy consumption from 1980 to 2050

In terms of energy consumption, Fig. 40 (bottom) shows a sharp increase in the role played by large machines with a engine power greater than 130 kW. In the period from 1980 to 2010, their proportion of overall consumption almost trebled, and it is expected to increase by a further 20% by 2050.

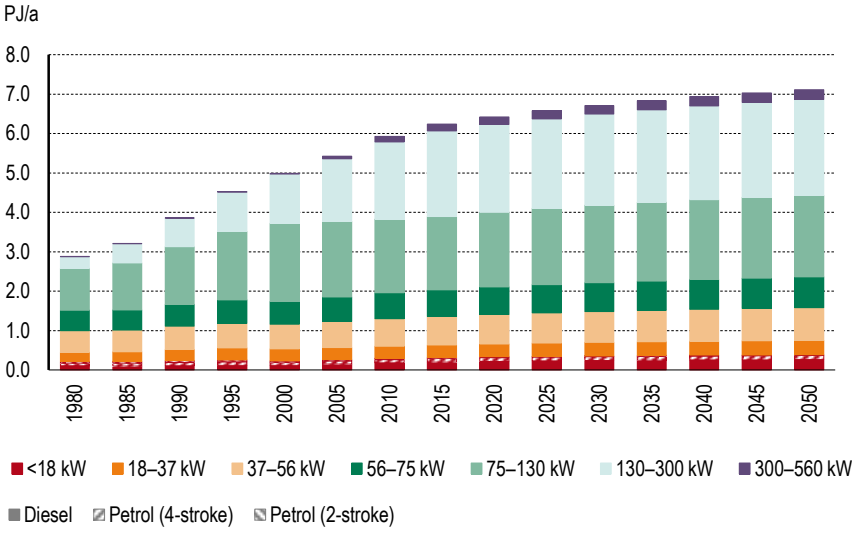
Fig. 40 > Construction machinery: energy consumption in 2010 and chronological development (1980 to 2050)

Top: only categories with energy consumption ≥0.1 PJ, 2010.

Energy consumption (2010)



Development of energy consumption



The colours indicate the machine category and engine power classes, and the shading indicates the engine type.
Numerical values, cf. Tab. 55 on page 188

8.1.3 Emissions

Here, too, in terms of nitrogen oxide emissions (Fig. 41, top left) it is crawler excavators and wheeled and caterpillar loaders that predominate. In terms of PM emissions, however, crawler excavators are only in third place, behind loaders and mini-excavators. This is because the particle filter requirement as stipulated in the Ordinance on Air Pollution Control is more stringent for larger machines (introduction for machines with an engine power between 18 and 37 kW only in 2010, no particle filter requirement for machines <18 kW, cf. FOEN 2009); the EU particulate matter limit levels are higher for smaller machines (cf. Tab. 28 on page 154).

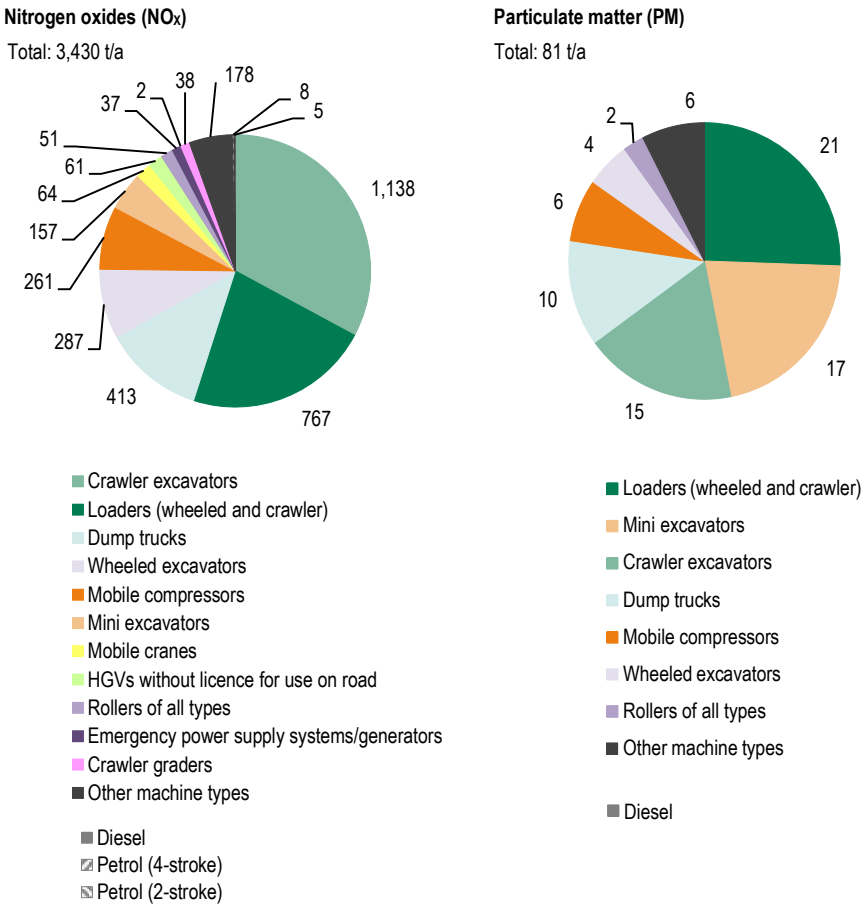
8.1.4 Development of pollutant emissions from 1980 to 2050

Nitrogen oxide emissions have fallen sharply in the past few years thanks to the applicable European exhaust regulations and the entry into force of the Ordinance on Air Pollution Control (Fig. 41, bottom left). In 2050, nitrogen oxide emissions should only be around a quarter of the present-day level. Above all, large machines (>75 kW) will be subject to more stringent maximum emission levels with effect from 2014 following the introduction of EU IV.

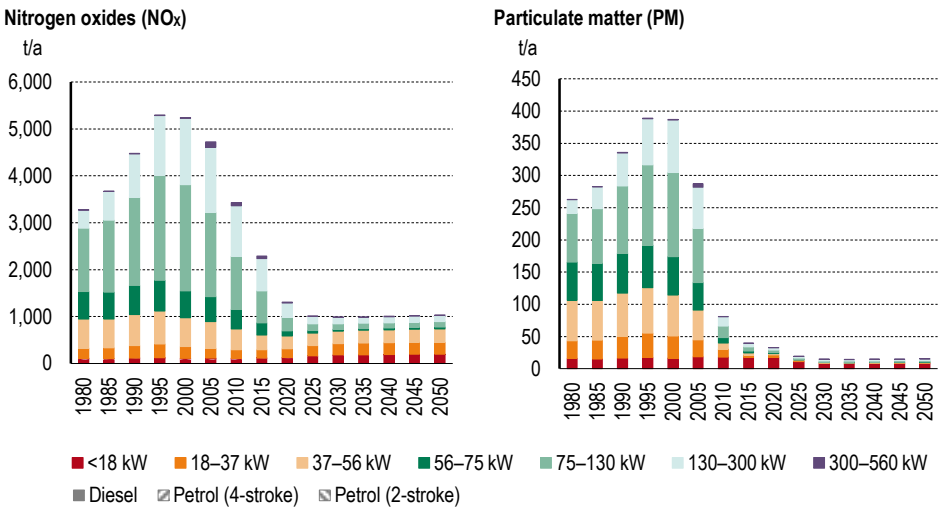
The forecast concerning the development of PM emissions is even more positive (Fig. 41, bottom right). These have already fallen sharply thanks to the introduction of the Ordinance on Air Pollution Control (by 28% in the period from 2005 to 2010 alone). By 2050, the quantity of PM emissions should only be around one-fifth of the present-day level. During the period of applicability of EU IIIB and EU IV, many manufacturers equipped their machines (primarily the larger models) with particle filters, and in 2019/2020 EU V is to enter into force, which will mean that all machines with an engine power class of between 18 and 560 kW will have to be equipped with particle filters.

Fig. 41 > Construction machinery: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with NO_x-emissions ≥35 t, 2010.
Top right: only categories with PM emissions ≥1 t, 2010.



Development of emissions



The colours indicate the machine category and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 63 on page 194

8.2 Industrial machinery

8.2.1 Energy consumption

Fork lifts account for more than half the energy consumption in this category (Fig. 42, top). These appliances are powered by electricity, diesel and petrol, but some are also powered by gas (mostly propane gas). Due to their large size, runway vehicles account for a high level of energy consumption (1.02 PJ p.a. or 29% of the energy consumption in the industrial machinery category), even though they only represent 4% of the stock.

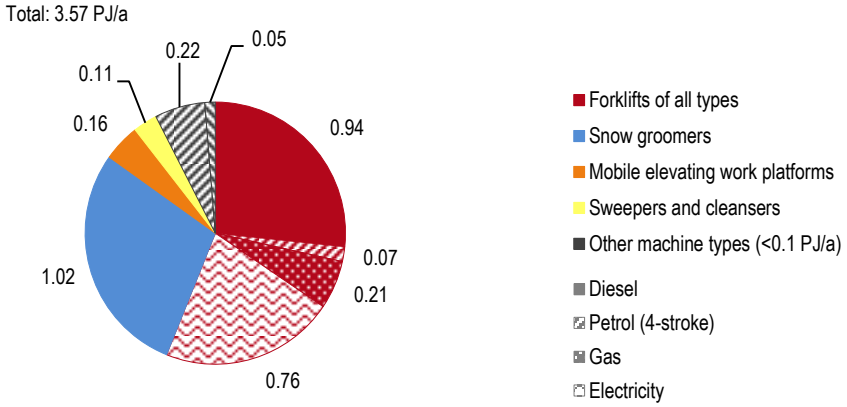
8.2.2 Development of fuel consumption from 1980 to 2020

The fuel consumption of industrial machinery more than doubled in the period from 1980 to 2000 (Fig. 42, bottom). Since 2000, energy consumption has been falling due to the reduction in the stock and operating hours of forklifts. This trend is expected to stabilise in the future. An increase in the energy consumption of runway vehicles, machines and appliances used on airport aprons, and generators is expected, mainly due to an increase in categories above 130 kW (see Fig. 42, bottom).

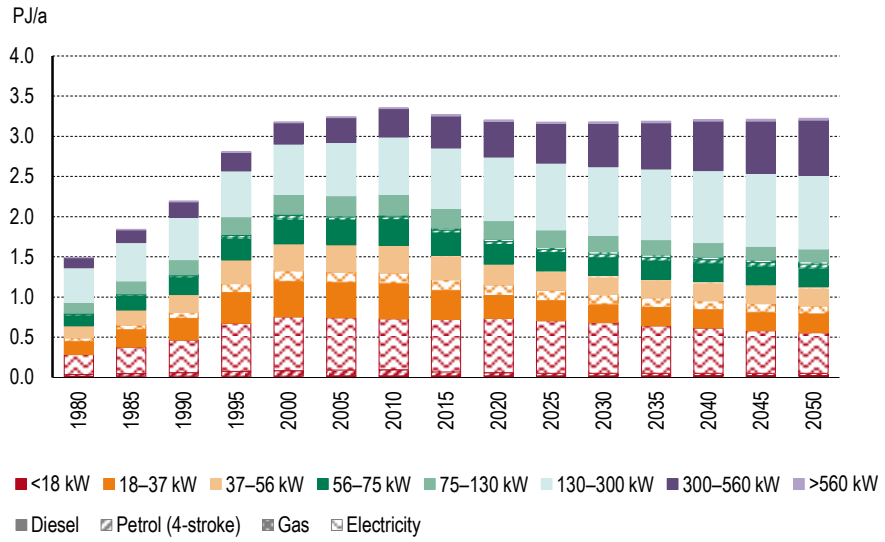
Fig. 42 > Industrial machinery: energy consumption in 2010 and chronological development (1980 to 2050)

Top: only categories with energy consumption ≥0.1 PJ, 2010.

Energy consumption (2010)



Development of energy consumption



The colours indicate the machine category and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 56 on page 189

8.2.3 Emissions

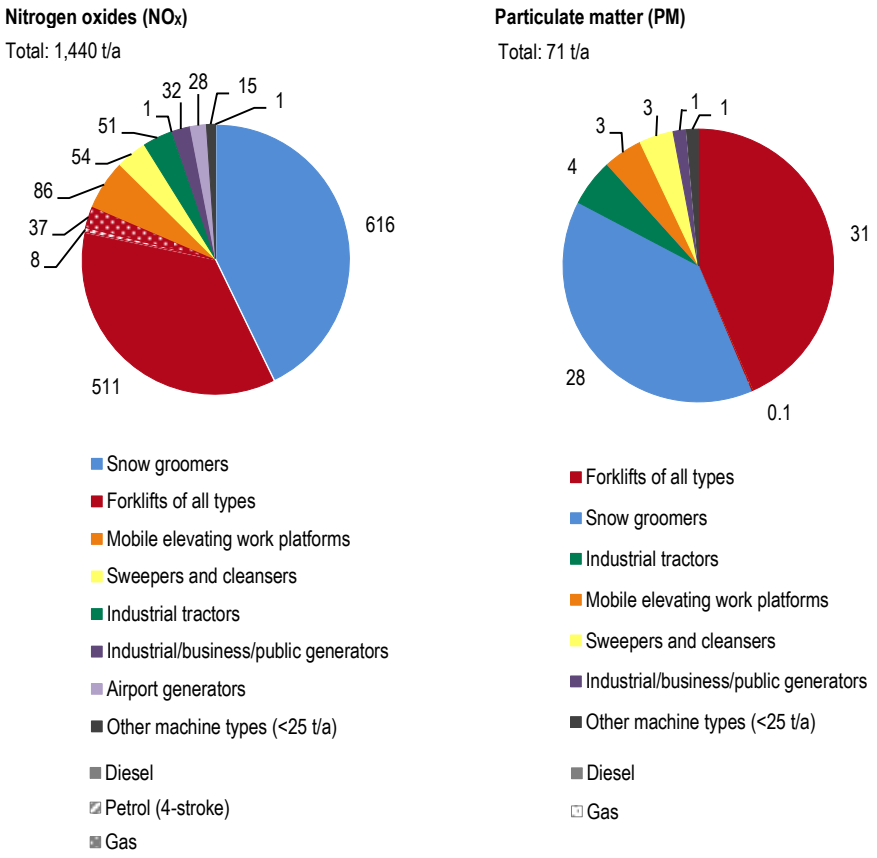
Pollutant emissions are depicted in Fig. 43 (top) by machine type. Here we can see that forklifts account for higher PM emissions than for nitrogen oxide emissions. There are two reasons for this: the average age of forklifts is relatively high (9 years, compared with 7 years for runway vehicles), and the engines in forklifts are relatively small, which means that specific PM emissions are correspondingly high, since by contrast with specific nitrogen oxide emissions, PM emissions are significantly higher from small engines than from large engines. In addition, it was assumed in the calculation model that around 60% of larger machines were already retrofitted with particle filter systems in 2010 (here the proportion is assumed on the basis of the figures for construction machinery. The only exception concerns runway vehicles, of which only around 2% were equipped with particle filters as of 2010 (based on the MOFIS database and SBS 2014).

8.2.4 Development of pollutant emissions from 1980 to 2020)

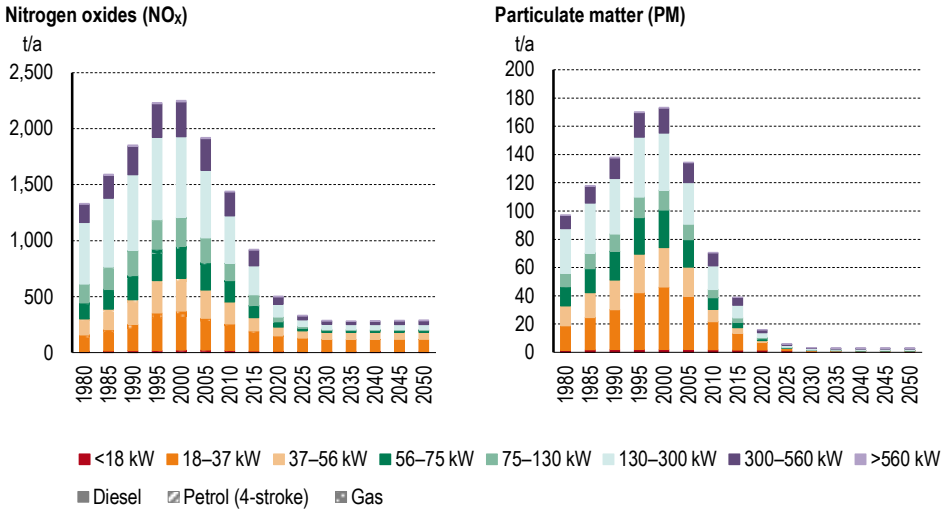
The development of pollutant emissions from industrial machinery is similar to that for construction machinery (Fig. 43, bottom), though the reduction in the next few years is slightly more pronounced, since the activities and energy consumption will not increase (as is the case with construction machinery), but will also fall slightly overall.

Fig. 43 > Industrial machinery: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with NO_X emissions ≥25 t, 2010.
Top right: only categories with PM emissions ≥1 t, 2010.



Development of emissions



The colours indicate the machine category and engine power class, while the shading indicates the engine type.
Numerical values, cf. Tab. 64 on page 200

8.3 Agricultural machinery

8.3.1 Energy consumption

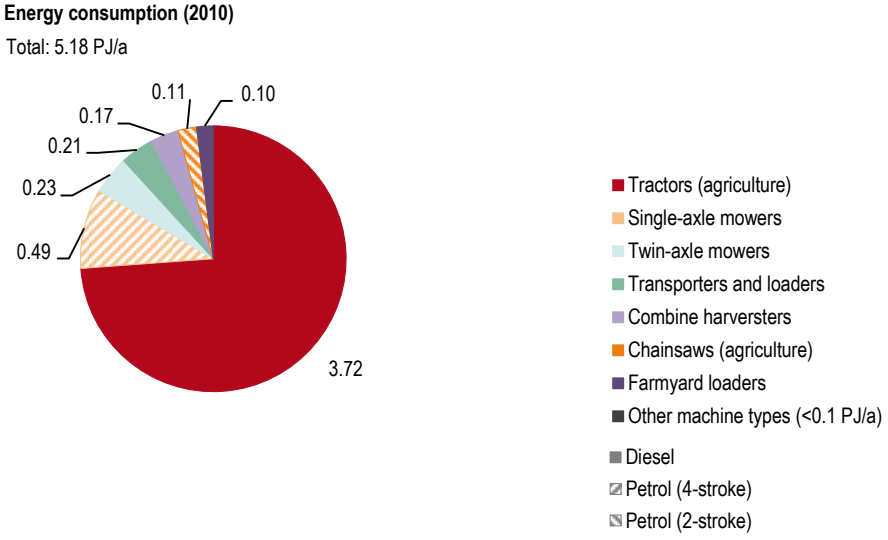
The energy consumption of agricultural machinery amounted to around 5.19 PJ p.a. in 2010, with tractors accounting for 72% of this figure (Fig. 44, top). Diesel engines account for 88% of the energy consumption. 4-stroke petrol engines (primarily single-axle mowers) account for around 10% and 2-stroke petrol engines (chainsaws) for around 2% of the energy consumption.

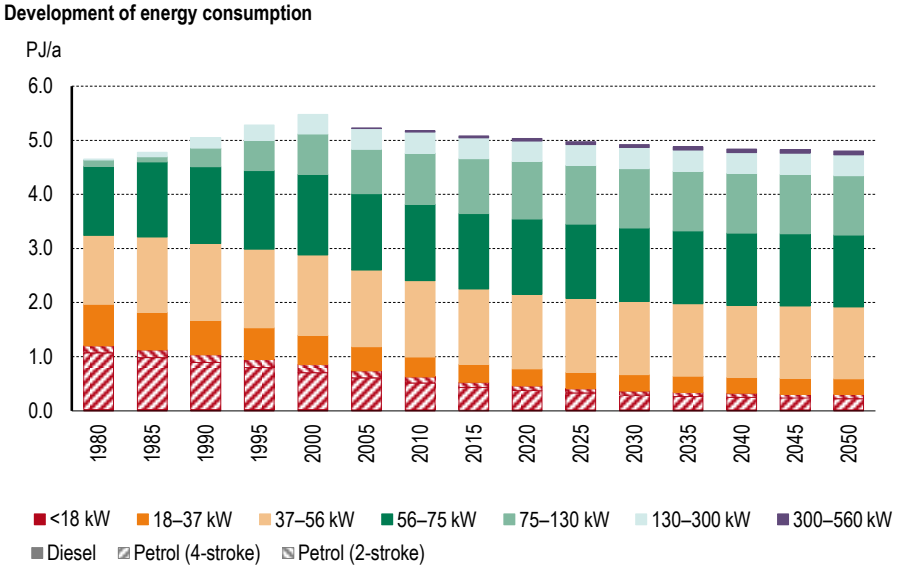
8.3.2 Development of energy consumption from 1980 to 2050

Energy consumption increased until 2000, and has been falling since then (Fig. 44, bottom). This trend is expected to continue in the future thanks to efficiency increases and a further decline in the area of agricultural land. The consumption of diesel continued to increase until 2000, while petrol consumption has been falling since 1980.

Fig. 44 > Agricultural machinery: energy consumption in 2010 and chronological development (1980 to 2050)

Top: only categories with energy consumption ≥0.1 PJ, 2010.





The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 57 on page 190

8.3.3 Emissions

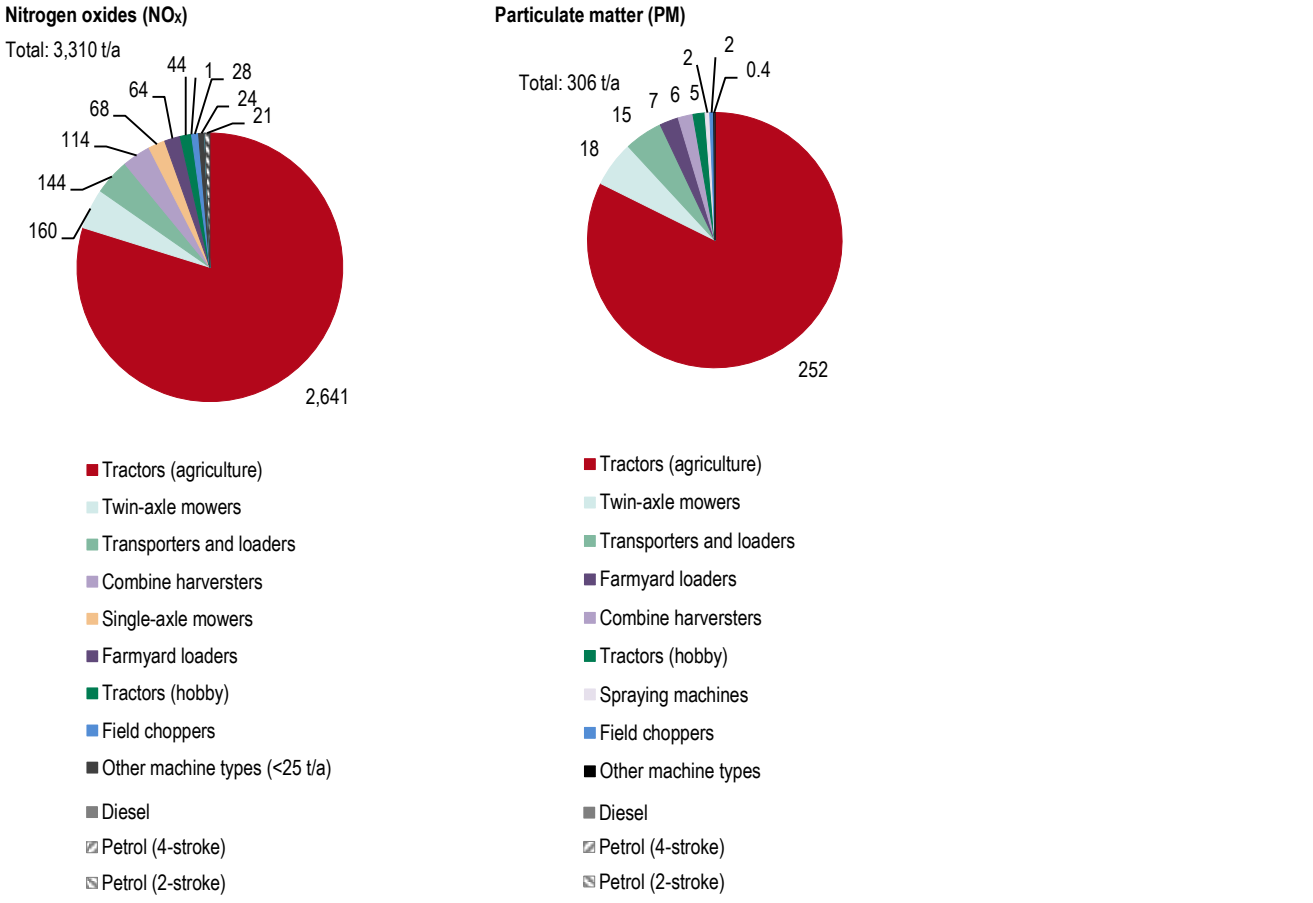
In 2010, particle emissions from agricultural machinery amounted to almost 300 tonnes (Fig. 45, top right). This is more than four times higher than the figure for construction machinery, although the consumption of diesel by agricultural machinery is only 79% of that for construction machinery. This discrepancy is due to the high average age of agricultural machines, the later introduction of exhaust regulations for agricultural machinery, and the fact that agricultural machinery has not been retrofitted with particle filters to date.

8.3.4 Development of pollutant emissions from 1980 to 2050

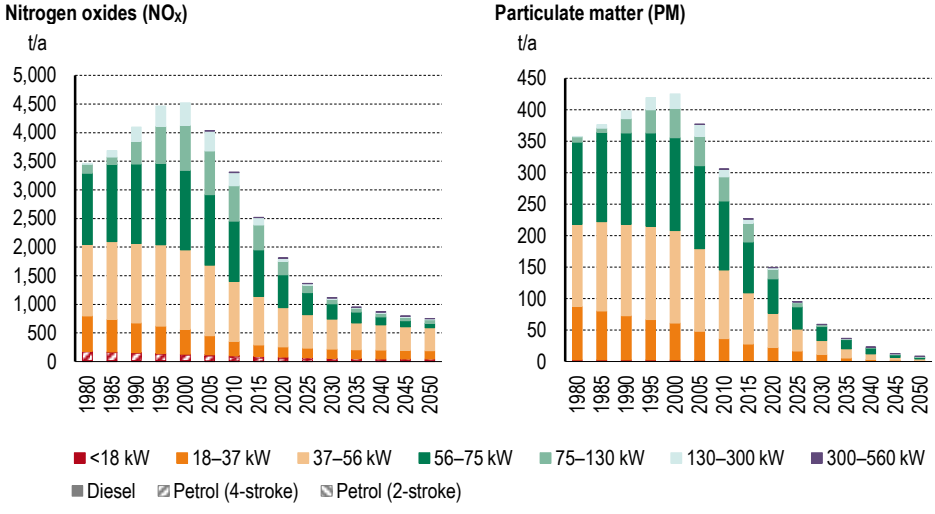
For the reasons cited above, pollutant emissions from agricultural machinery will not decrease to the same extent over the next few years as those from other machine categories. Nonetheless, we can expect emissions to be halved in the period from 2010 to 2020 thanks to the European exhaust regulations (Fig. 45, bottom).

Fig. 45 > Agricultural machinery: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with NO_X emissions ≥35 tonnes, 2010.
Top right: only categories with PM emissions ≥1 tonnes, 2010.



Development of emissions



The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 65 on page 204

8.4 Forestry machinery

8.4.1 Energy consumption

In 2010, the energy consumption of forestry machinery amounted to 0.39 PJ, of which petrol accounted for one-fifth (Fig. 46, top). The most important machine type in terms of energy consumption is cable and grapple skidders (i.e. tractors used in the forestry sector), with 0.16 PJ p.a. of diesel, followed by chainsaws with 0.06 PJ p.a. of petrol.

8.4.2 Development of energy consumption from 1980 to 2050

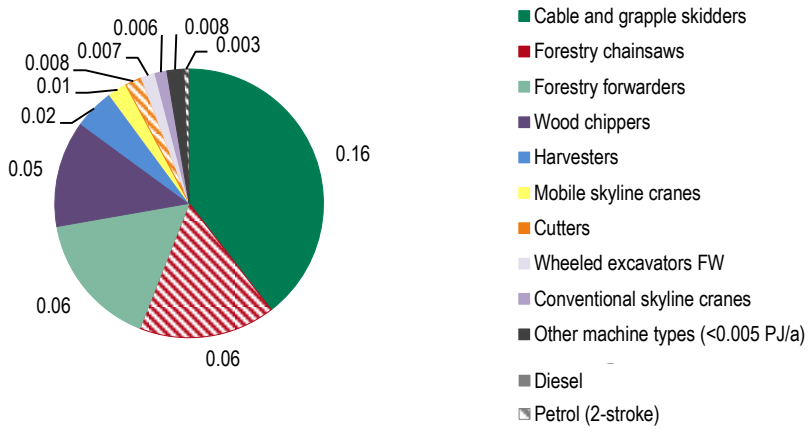
The development of energy consumption (Fig. 46, bottom) shows a slight decline since 2000 and a clear shift from small engines to those with a higher engine power. The trend towards increasing processing of wood as an energy source should be noted here: this is apparent from the energy consumption of wood chippers, which is making a significant contribution to total energy consumption in the forestry machinery category (Fig. 46, top and engine power classes 75 to 560 kW, bottom).

Fig. 46 > Forestry machinery: energy consumption in 2010 and chronological development (1980 to 2050)

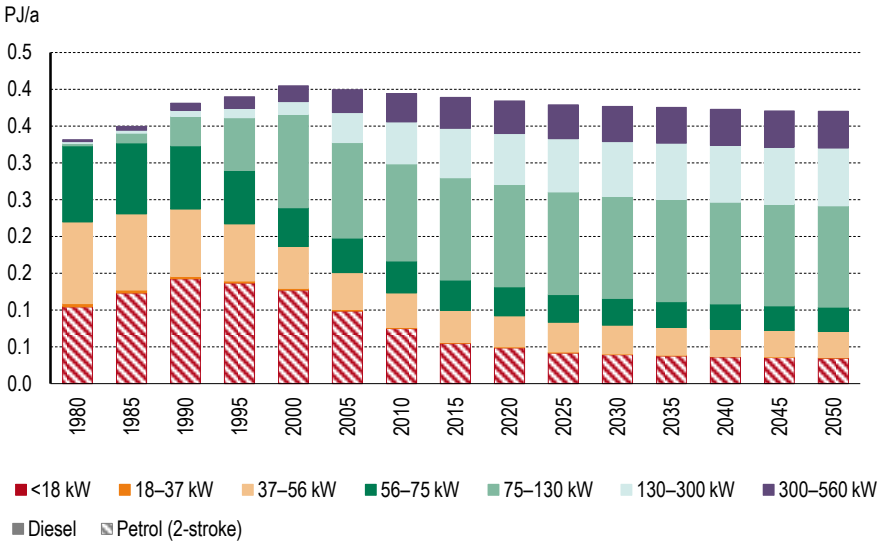
Top: only categories with energy consumption ≥0.005 PJ, 2010.

Energy consumption (2010)

Total: 0.39 PJ/a



Development of energy consumption



The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type. Numerical values, cf. Tab. 58 on page 190

8.4.3 Emissions

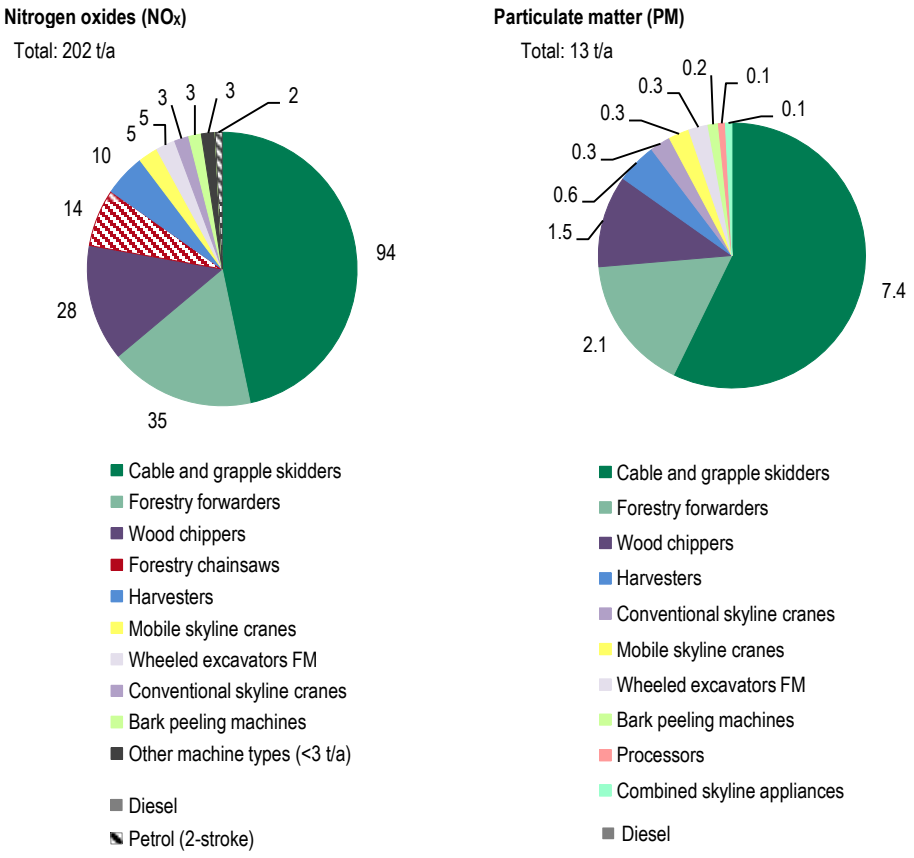
Nitrogen oxide and PM emissions from forestry machines in 2010 are shown in Fig. 47 (top). These are primarily caused by machines equipped with diesel engines. Hydrocarbon emissions, which are disproportionately high (364 tonnes p.a.) in the forestry sector due to the large number of appliances equipped with 2-stroke engines, are not shown here. At 2% of energy consumption, forestry machinery thus accounts for around 9% of total non-road HC emissions.

8.4.4 Development of pollutant emissions from 1980 to 2050

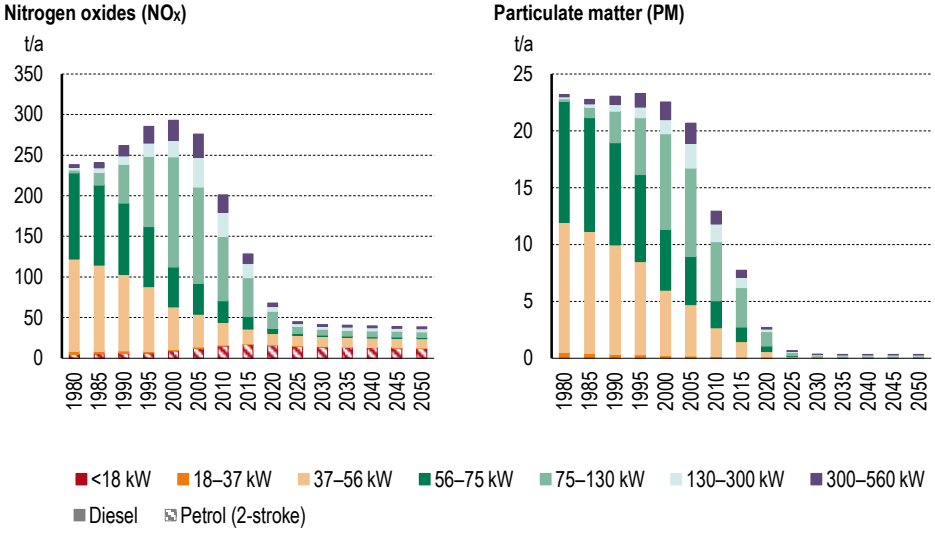
The shift towards larger machines is having a positive impact on the development of pollutant emissions from forestry machinery, since larger engines are subject to more stringent maximum emission levels. We can therefore expect emissions of nitrogen oxides and particulate matter to decrease significantly over the next few years (Fig. 47, bottom).

Fig. 47 > Agricultural machinery: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with NO_X emissions ≥3 t, 2010.
Top right: only categories with PM emissions ≥1 t, 2010.



Development of emissions



The colour coding distinguishes the machine type and engine power class, while the shading indicates the engine type.
Numerical values, cf. Tab. 66 on page 207

8.5 Garden-care/hobby appliances

8.5.1 Energy consumption

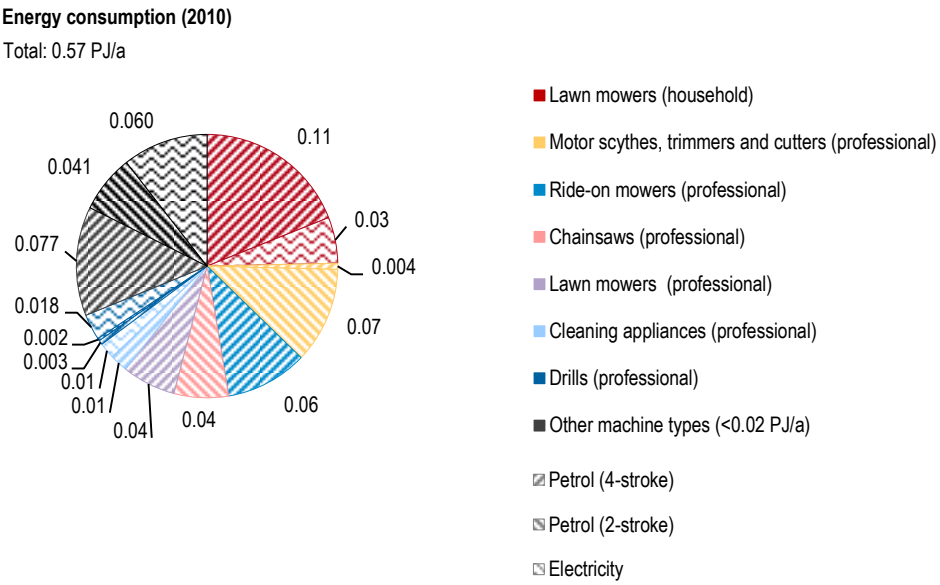
This category only concerns electric and petrol-driven appliances. Despite their predominance in the stock, electric appliances only account for 20% of the energy consumption in this category. In a comparison between machine categories, the most important appliances in terms of consumption are household lawn mowers and motor scythes used for professional purposes, followed by appliances used for professional garden-care (Fig. 48, top) – in contrast to the stock, where hobby appliances predominate (cf. chapter 6.5.1).

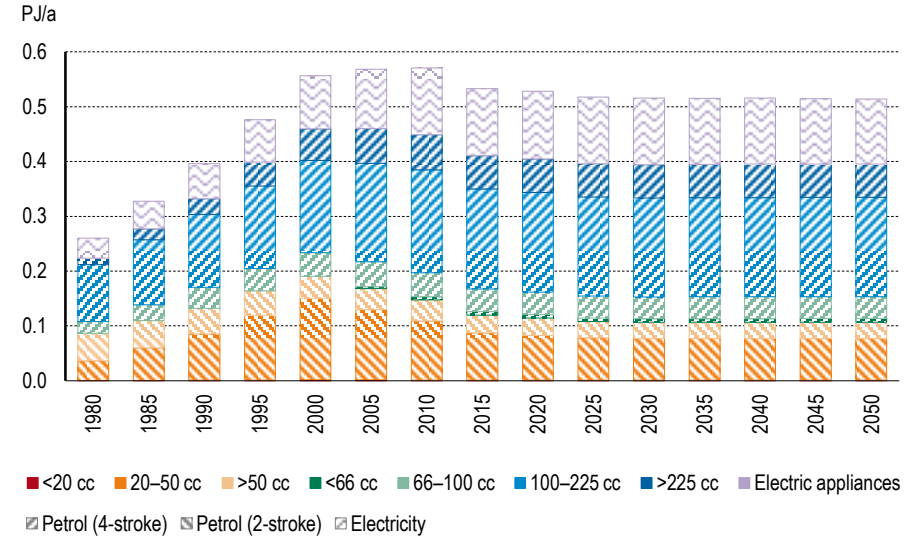
8.5.2 Development of energy consumption from 1980 to 2050

With respect to the development of energy consumption (Fig. 48, bottom), in contrast to the development of operating hours (Fig. 28, bottom) there has been a clear slowdown in the increase from 2000 onwards. The increase in operating hours is primarily attributable to the boom in robotic lawn mowers with very lengthy periods of operation. But since the power range of these appliances is very low (around 25 W), this is not reflected in the energy consumption. In addition, the substitution of petrol-driven appliances with battery-powered models in the professional segment is resulting in a slower increase in energy demand, since electric appliances tend to have a lower output and a higher degree of efficiency. Among petrol-driven appliances, the use of 2-stroke engines is continuing to decline.

Fig. 48 > Garden-care/hobby appliances: energy consumption in 2010 and chronological development (1980 to 2050)

Top: only categories with energy consumption ≥0.02 PJ, 2010.





The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 59 on page 191

8.5.3 Emissions

Petrol engines produce high levels of pollutant emissions, especially carbon monoxide and hydrocarbons (Fig. 49, top). 2-stroke engines account for 71% of HC emissions, despite the fact that they only account for 26% of the energy consumption of appliances with combustion engines. Thus motor scythes and chainsaws, which are primarily operated with 2-stroke engines, head the list in terms of hydrocarbon emissions, followed by lawn mowers with 4-stroke engines, which cause the most carbon monoxide emissions.

8.5.4 Development of pollutant emissions from 1980 to 2050

A pronounced decrease in hydrocarbon emissions is to be anticipated over the next few years, since the more stringent EU exhaust regulations will mean that new engines will emit lower levels (Fig. 49, bottom right). This tightening of maximum emission limit values, which applies within the EU, also means that 4-stroke engines will increasingly replace 2-stroke engines, so that the stock of the latter will decrease. With respect to carbon monoxide, a slight increase is to be anticipated until the introduction of EU V. Emissions will only fall slightly after EU V is introduced in 2019/2020 (Fig. 49, bottom left).

8.5.5 Benzene emissions and the influence of alkylate based petrol

When they are operated with conventional petrol, small appliances in the garden-care/hobby category emit relatively high quantities of benzene, a toxic and carcinogenic air pollutant. The level of benzene emissions in this category amounted to around 8 tonnes p.a. in 2010. These emissions can be significantly reduced, however, through the use of alkylate petrol, which is also known as appliance petrol (FOEN, 1997; FOEN 1999). According to a study commissioned by the Federal Office for the Environment (INFRAS 2008), alkylate petrol reduces benzene emissions by an estimated 96%.

If around 80% of professional operators of small appliances (including in the agriculture and forestry sectors), were to use alkylate petrol in 2-stroke petrol appliances (which account for the highest benzene emissions), it would be possible to avoid 11.2 tonnes of benzene emissions, which is equivalent to 43% of the total non-road benzene emissions (cf. Tab. 4).

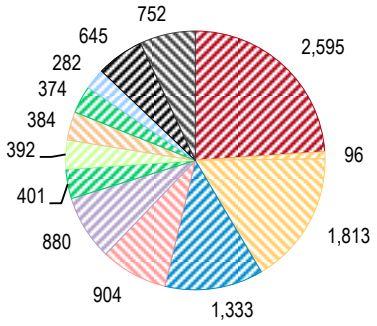
In the hobby segment, the reduction potential is lower due to lower fuel consumption: if it were possible to persuade 50% of hobby users of small appliances to use alkylate petrol in their 2-stroke machines, this would lead to a reduction equivalent of around 0.5 tonnes, or 1.9% of the total non-road benzene emissions.

Fig. 49 > Garden-care/hobby appliances: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with CO emissions ≥250 tonnes, 2010.
Top right: only categories with HC emissions ≥32 tonnes, 2010.

Carbon monoxide (CO)

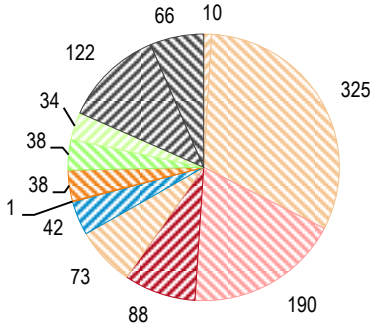
Total: 10,800 t/a



- Lawn mowers (household)
- Motor scythes, trimmers and cutters (professional)
- Ride-on mowers (professional)
- Chainsaws (professional)
- Lawn mowers (professional)
- Mill cutters/chopping machines (professional)
- Snow blowers (household)
- Chainsaws (household)
- Scarifiers (professional)
- Cleaning appliances (professional)
- Other machine types (<250 t/a)
- Petrol (4-stroke)
- Petrol (2-stroke)

Hydrocarbons (HC)

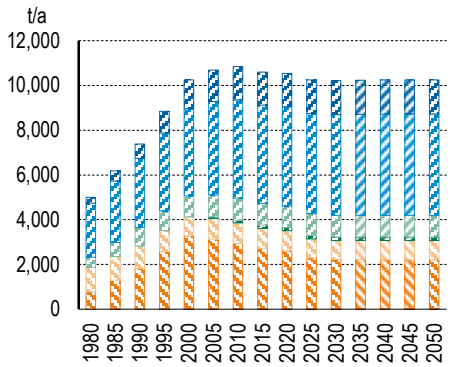
Total: 1,030 t/a



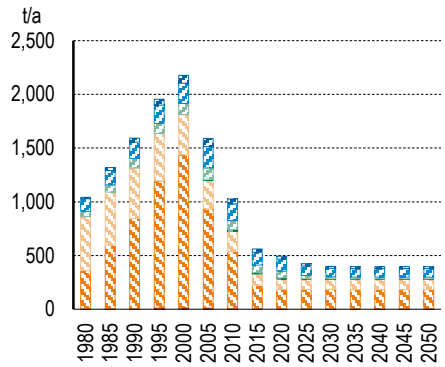
- Motor scythes, trimmers and cutters (professional)
- Chainsaws (professional)
- Lawn mowers (household)
- Chainsaws (household)
- Ride-on mowers (professional)
- Motor scythes, trimmers and cutters (household)
- Hedge cutters (professional)
- Snow blowers (household)
- Other machine types (<32 t/a)
- Petrol (4-stroke)
- Petrol (2-stroke)

Development of emissions

Carbon monoxide (CO)



Hydrocarbons (HC)



- <20 cc
- 20–50 cc
- >50 cc
- <66 cc
- 66–100 cc
- 100–225 cc
- >225 cc
- Petrol (4-stroke)
- Petrol (2-stroke)

The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 67 on page 210

8.6 Navigation machinery

8.6.1 Energy consumption

In 2010, the energy consumption of ships and boats amounted to 1.56 PJ p.a., with diesel accounting for 56% and petrol for 34% (Fig. 50, top). Commercial operations generate the highest proportion of diesel and heating oil consumption, which largely corresponds to the consumption data provided by major operators for 2010.

The fuel consumption of steamships is high compared to their proportion of the overall passenger capacity. This is because the specific consumption of these vessels is several times higher than that of conventional passenger boats.

The level of petrol consumption is 0.53 PJ, 84% of which is attributable to privately operated boats, while fishing and other commercial boats account for the remaining 16%. The proportion of boats equipped with 2-stroke engines is very low (1%).

8.6.2 Development of fuel consumption from 1980 to 2050

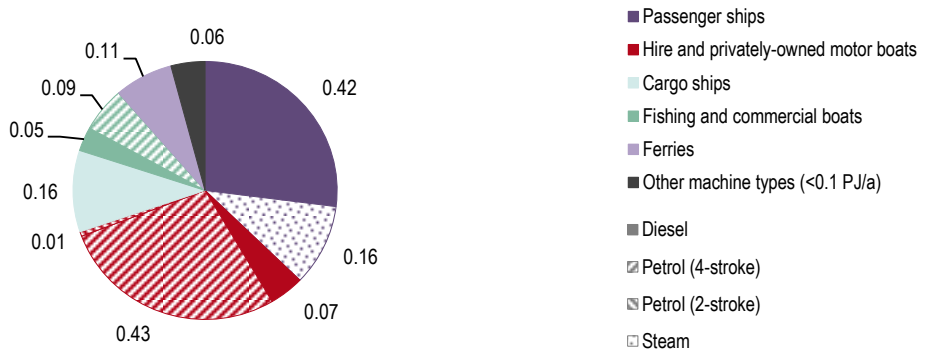
In the period under review, the fuel consumption of ships and boats only changed very slightly, and we can expect the figure 15 years from now to be similar to the present-day level (Fig. 50, bottom).

Fig. 50 > Navigation machinery: energy consumption in 2010 and chronological development (1980 to 2050)

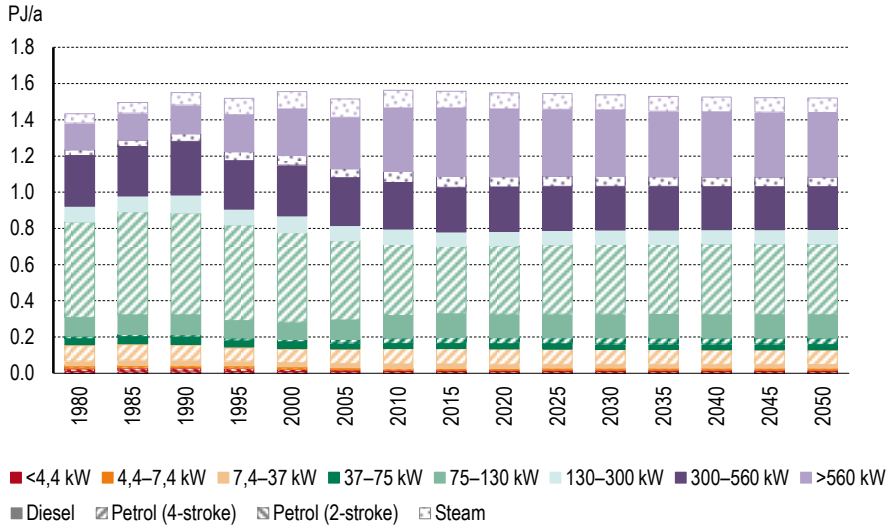
Top: only categories with energy consumption ≥0.1 PJ, 2010.

Energy consumption (2010)

Total: 1.56 PJ/a



Development of energy consumption



The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.

Numerical values, cf. Tab. 60 on page 192

8.6.3 Emissions

Pollutant emissions from ships and boats have a negative impact on the quality of both air and water. A significant proportion of emitted hydrocarbons enters into the water, where they interfere with the normal biological functions of fish and represent a threat to the quality of drinking water (EMPA 2006). In view of this, special importance has to be attached to hydrocarbon emissions from ships and boats.

Nitrogen oxide emissions of navigation machinery are mainly attributable to passenger ships and hired or privately owned motor boats (Fig. 51, top). According to the assumptions used for the calculation model, only about 10% of vessels have been retrofitted with particle filters to date, and this means that PM emissions from passenger ships and cargo vessels/barges are correspondingly high. Pollutant emissions from steamships are comparatively low (0.02 tonnes p.a.).

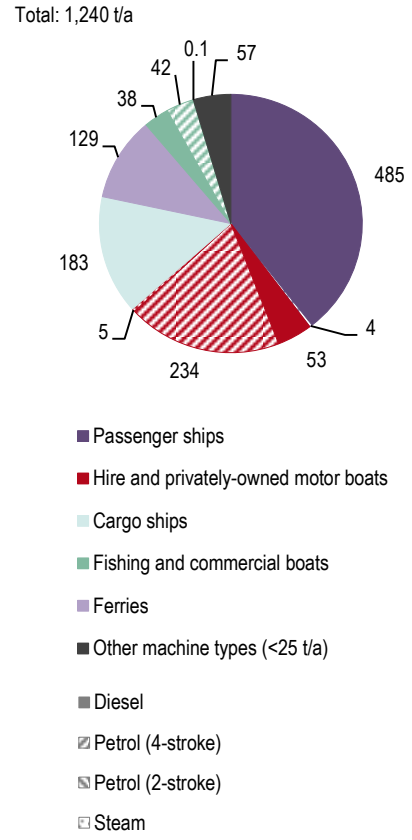
8.6.4 Development of pollutant emissions from 1980 to 2050

Nitrogen oxide emissions from ships have barely decreased in recent years. The EU exhaust regulations (EU I) were less stringent than the SAV exhaust standards that entered into effect in the mid-1990s (Fig. 51, bottom). Lower limit levels only apply since the introduction of EU II in 2008. PM emissions have already decreased more sharply since 2000; they should also be reduced in the course of the next few years providing that ships are retrofitted with particle filter systems (see Fig. 23 on page 60).

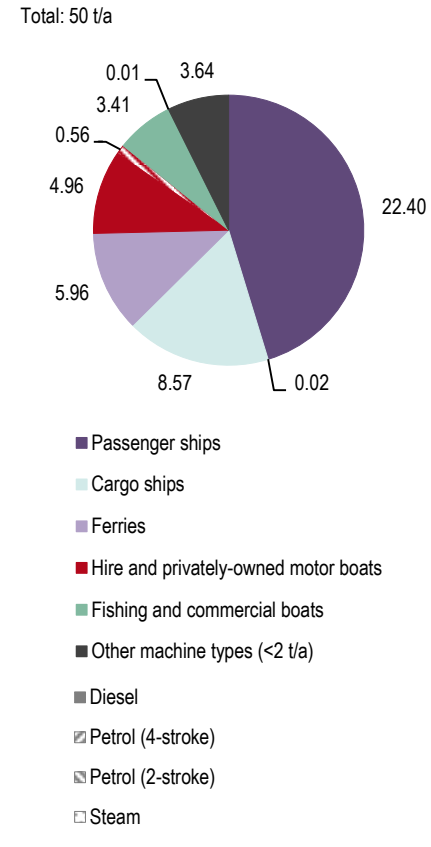
Fig. 51 > Navigation machinery: emissions in 2010 and chronological development (1980 to 2050)

Top left: only categories with NO_X emissions ≥25 t, 2010.
Top right: only categories with PM emissions ≥2 t, 2010.

Nitrogen oxides (NO_X)

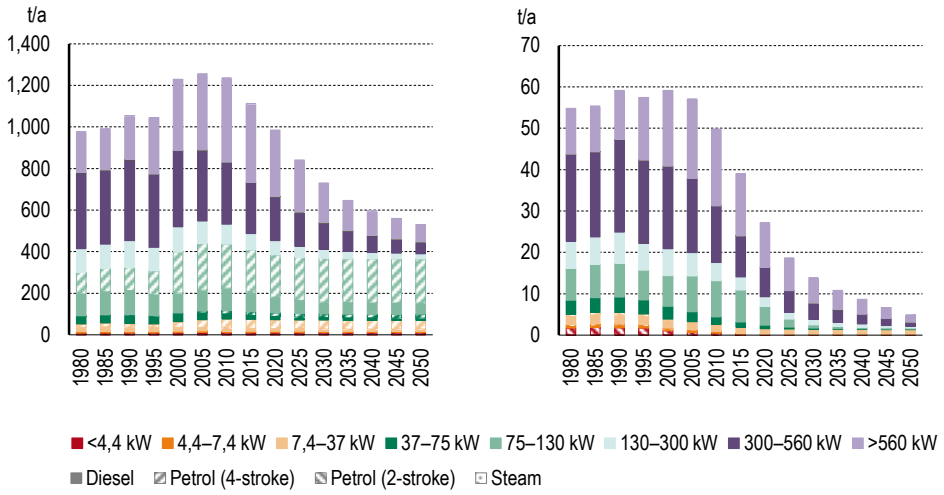


Particulate matter (PM)



Development of emissions

Nitrogen oxides (NO_X)



Particulate matter (PM)

The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 68 on page 218

8.7 Railway machinery

8.7.1 Energy consumption

Only diesel-powered machinery is taken into account, mainly in the form of shunting locomotives. In 2010, the overall consumption of diesel amounted to 0.49 PJ (Fig. 52, top). According to the 2012 annual report of Swiss Federal Railways (SBB), 12,603 tonnes of diesel were consumed in 2010 for traction purposes (SBB 2012). Since all other variables are either known or can be estimated, the operating hours of diesel railway machinery were calibrated so that the model calculation yields almost exactly this fuel consumption.

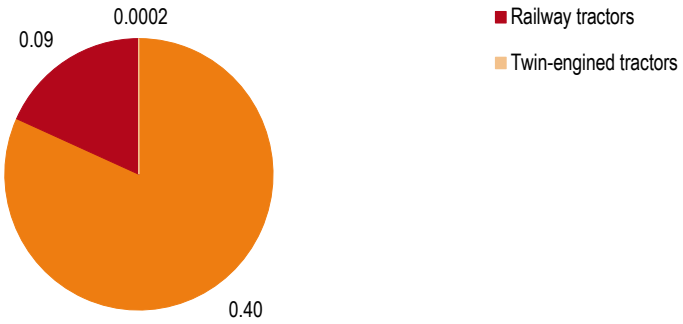
8.7.2 Development of energy consumption from 1980 to 2050

Diesel consumption by railway machinery will decrease by 20% between 2010 and 2015, since operator BLS has taken 48 shunting locomotives out of service during this period. It is difficult to forecast the future development because various trends point to both an increase and a decrease in diesel consumption: an increase is anticipated in both the passenger and the freight segment, but this does not necessarily mean an increase in shunting activity, because the railway operators are endeavouring to make this as efficient as possible. Smaller shunting terminals are to be closed down. The use of goods locomotives with diesel generators, which can cover the (mostly not electrified) final stretch, is currently being discussed, and this could result in an increase in diesel consumption. But on the other hand, precisely this development could give rise to a decrease in shunting activity. In view of this, a stable trend is assumed for non-road energy consumption in the railway machinery category.

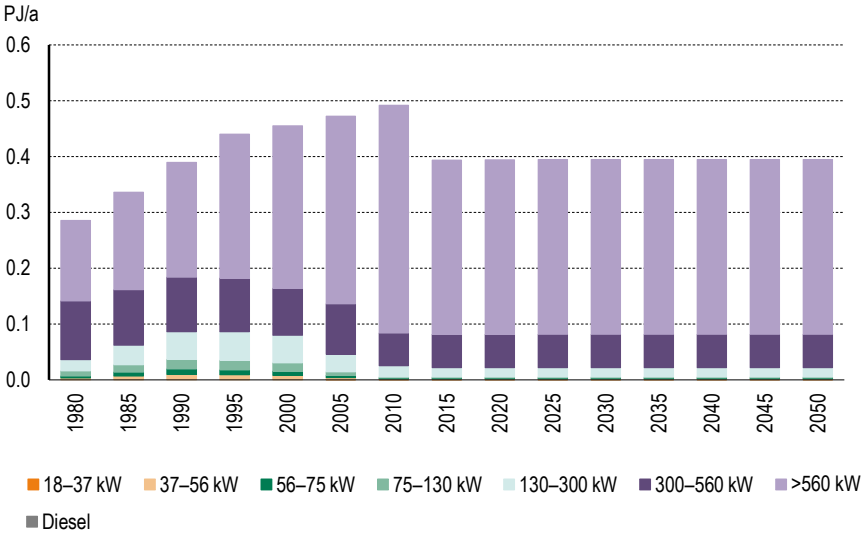
Fig. 52 > Railway machinery: energy consumption in 2010 and chronological development (1980 to 2050)

Energy consumption (2010)

Total: 0.49 PJ/a (diesel motors only)



Development of energy consumption



The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 61 on page 193.

8.7.3 Emissions

Railway vehicles have a relatively lengthy service life, and their average age is therefore fairly high. This means that the specific emissions of diesel locomotives are disproportionately high. Railway vehicles produce comparatively high levels of nitrogen oxides (535 tonnes p.a., Fig. 53, top left).

The calculation model assumed that a fairly high proportion of railway vehicles have been retrofitted with particle filters (67% of the vehicles; BLS 2012; SBB 2012). The level of PM emissions (6 tonnes p.a.) is comparatively low (Fig. 53, top right).

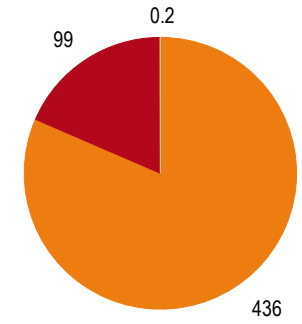
8.7.4 Development of pollutant emissions from 1980 to 2050

The level of PM emissions has already decreased by 82% since 2000 and will continue to fall in the next few years thanks to the ongoing retrofitting of older machines with particle filters (to around half the 2010 level by 2020, Fig. 53, bottom right). The decrease in nitrogen oxides is significantly lower than that of PM: emissions will fall by around a quarter from 2010 to 2020 (Fig. 53, bottom left).

Fig. 53 > Railway machinery: emissions in 2010 and chronological development (1980 to 2050)

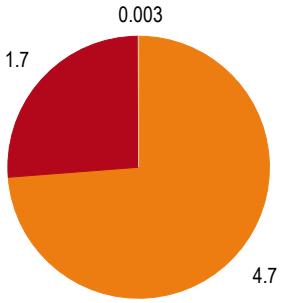
Nitrogen oxides (NO_x)

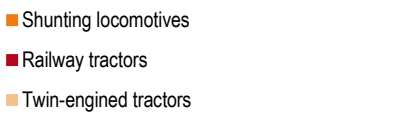
Total: 535 t/a

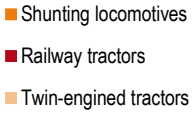


Particulate matter (PM)

Total: 6 t/a

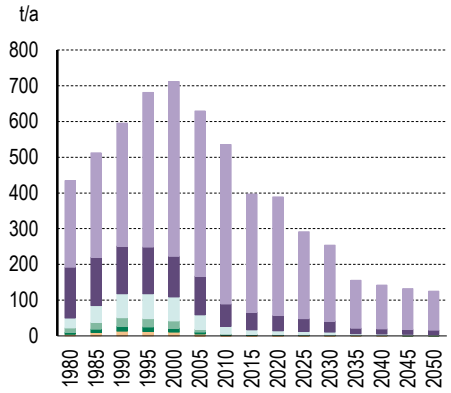




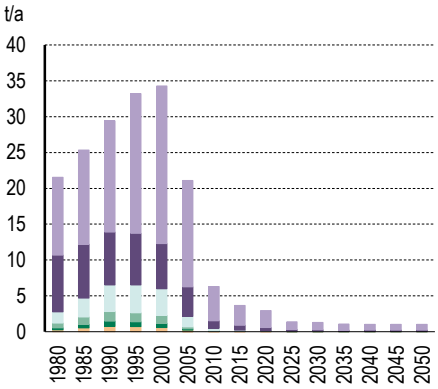


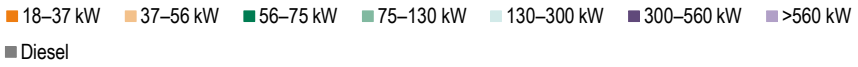
Development of emissions

Nitrogen oxides (NO_x)



Particulate matter (PM)





The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.

Numerical values, cf. Tab. 69 on page 222

8.8 Military machinery

8.8.1 Energy consumption

In 2010, the energy consumption of machines used for military purposes amounted to 0.27 PJ (Fig. 54, top). The proportion of petrol was very low (7%), since this fuel is only used for certain types of boats. Tanks account for the highest proportion (73%) of the overall fuel consumption (Fig. 54, top), while military construction machinery only accounts for 7%.

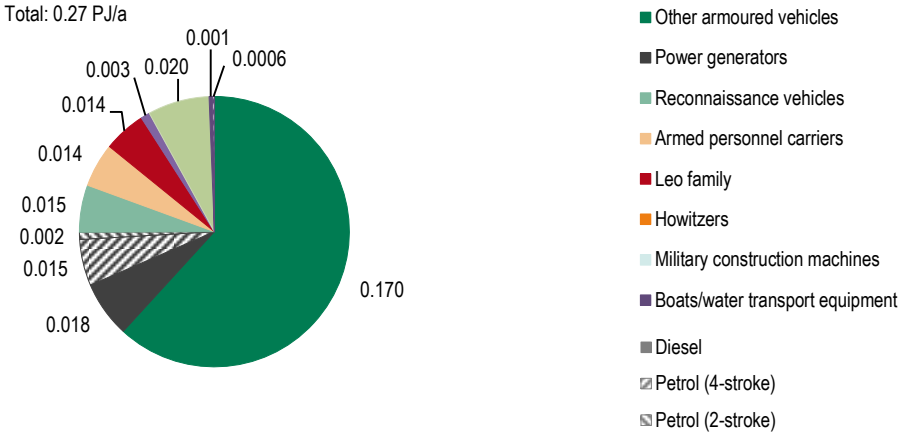
8.8.2 Development of fuel consumption from 1980 to 2050

Fuel consumption for military purposes has increased slightly in the past, but is expected to decrease slightly over the next few years (Fig. 54, bottom).

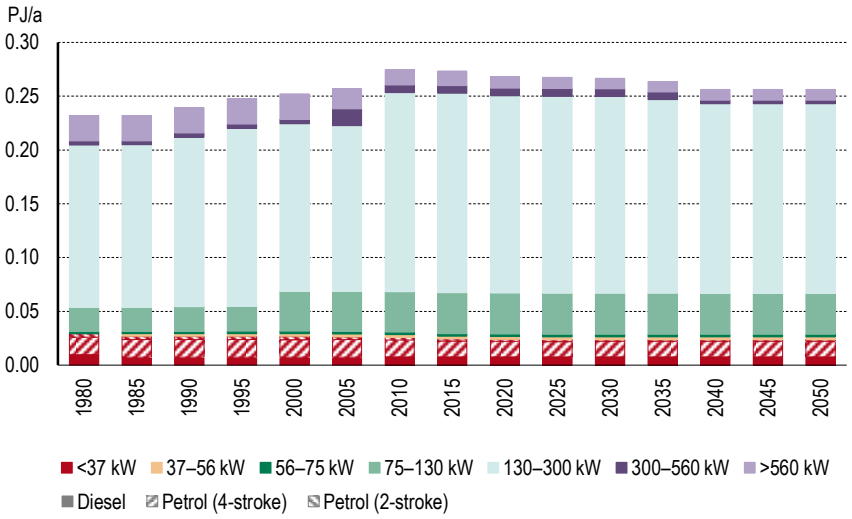
Fig. 54 > Military machinery: energy consumption in 2010 and chronological development (1980 to 2050)

Top left: combined figures for construction machines and water transport categories.

Energy consumption (2010)



Development of energy consumption



The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 62 on page 193

8.8.3 Emissions

In 2010, machines used for military purposes emitted 172 tonnes of nitrogen oxides and 5 tonnes of particulate matter (Fig. 55, top). For both pollutants, the predominant machine type is “other tanks” (mostly wheeled models).

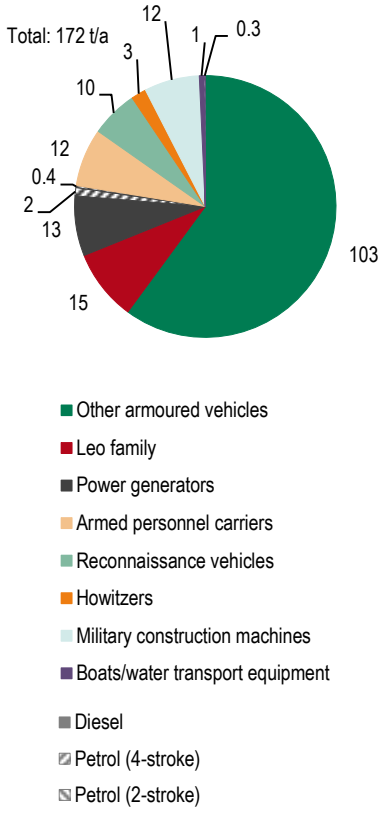
8.8.4 Development of pollutant emissions from 1980 to 2050

The proportion of military machines (except caterpillar vehicles, which are not equipped with particle filters) retrofitted with particle filter systems is similar to that for construction machinery. The level of PM emissions from military machinery is therefore expected to decrease significantly over the next few years (Fig. 55, bottom right). The situation with respect to the development of nitrogen oxides is also similar to that for construction machinery (Fig. 55, bottom left).

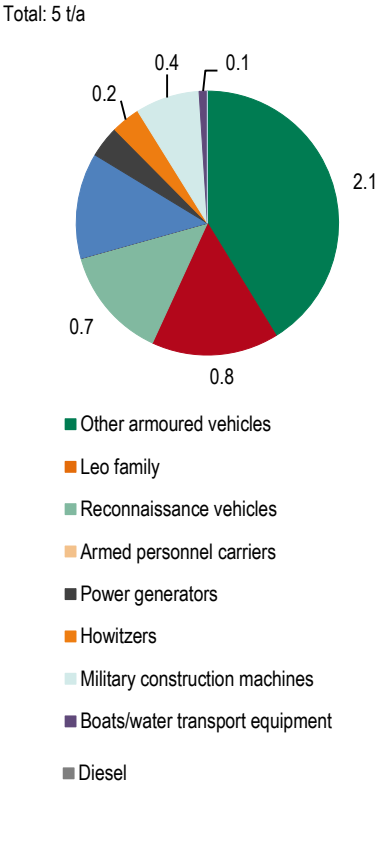
Fig. 55 > Military machinery: emissions in 2010 and chronological development (1980 to 2050)

Top: combined figures for construction machinery and water transport categories.

Nitrogen oxides (NO_x)

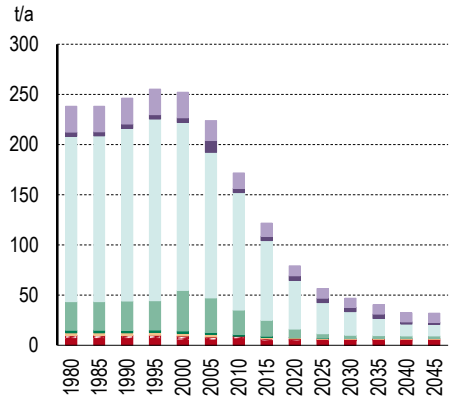


Particulate matter (PM)

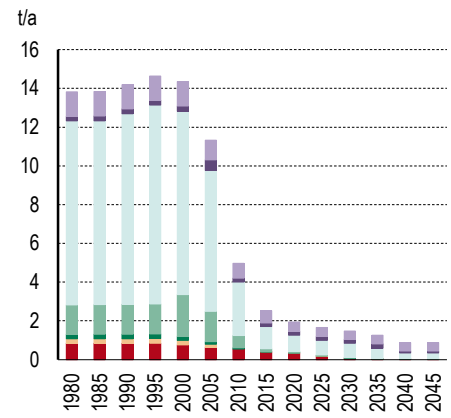


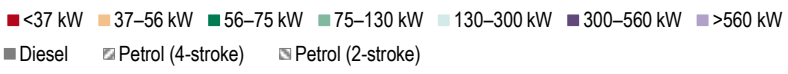
Development of emissions

Nitrogen oxides (NO_x)



Particulate matter (PM)





The colour coding distinguishes the machine type and engine power class, and the shading indicates the engine type.
Numerical values, cf. Tab. 70 on page 223

9 > Supplementary observations

9.1 Comparison with emissions from road vehicles

Non-road pollutant emissions estimated with the aid of the calculation model can only be compared with emissions from road vehicles to a limited extent (FOEN 2010). This is partly because the available statistical material for use in the non-road calculation model is not as detailed as the data set for road vehicles, but also because the non-road calculation model itself is not as detailed as that for road vehicles. Nonetheless, it is possible to make comparisons of an indicative nature.

Tab. 17 shows a comparison of energy and fuel consumption and pollutant emissions for non-road machinery and road vehicles. As we can see, non-road machinery accounts for a higher proportion of overall emissions than of overall fuel consumption. Emissions of particulate matter and hydrocarbons are especially high.

As far as hydrocarbon emissions are concerned, the high level is attributable to the high proportion of non-road appliances equipped with a 2-stroke engine. For example, with an emission level of 1,200 tonnes in 2010, chainsaws account for around a quarter of the total non-road hydrocarbon emissions. These appliances are used in the agriculture and forestry sectors, as well as for garden-care purposes, and represent the most important category of machines equipped with a 2-stroke engine. In the same year, hydrocarbon emissions from road traffic amounted to almost 17,000 tonnes.

The fact that non-road machines account for a high level of particle emissions is partly due to the very high number of diesel engines in use, especially on construction sites and in the agriculture and forestry sectors. But another factor is the specific pollutant emissions from non-road machines, which are relatively high due to the later introduction of maximum emission levels for such machines.[14] As a consequence, the annual level of particle emissions from agricultural machinery alone is approximately the same as the level for heavy goods vehicles (the latter, around 220 tonnes p.a. in 2010, non-road agricultural machinery around 310 tonnes p.a.), even though the number of operating hours for heavy goods vehicles is considerably higher than is the case with agricultural machines[15].

[14] The first emission limit values for nonroad machines entered into effect in 2001, whereas limit levels for diesel vehicles already entered into effect in 1987.

[15] In 2010, heavy goods vehicles covered an accumulated distance of 2,304 million kilometres. At an average speed of 50 km/h, this is equivalent to around 46 million hours p.a. By way of comparison: agricultural machines equipped with a diesel engine were in use for an accumulated total of 25 million hours in 2010.

Tab. 17 > Comparison between the non-road sector and road vehicles for 2010

Figures rounded up or down.

	Non-road-sector [tonnes p.a.]	Road vehicles [tonnes p.a.]	Proportion of non-road sector to total (road + non-road)
Consumption			
Diesel	348,900	1,726,600	17 %
Petrol	46,300	2,807,100	2 %
Energy	18.0 PJ	193 PJ	9 %
Pollutant emissions			
Carbon monoxide (CO)	39,200	124,200	24 %
Hydrocarbons (HC)	4,370	17,100	20 %
Nitrogen oxides (NO_x)	10,400	39,300	21 %
Particulate matter (PM)	532	1,135	32 %
Carbon dioxide (CO_2)	1,254,000	14,373,100	8 %

Source (road transport): FOEN 2010

This correlation also becomes apparent when we compare pollutant emissions and fuel consumption. Tab. 18 shows average specific pollutant emissions (emissions per level of fuel consumption in g per kg) from non-road machines and road vehicles and directly compares them with one another. As we can see, on average the emission factors for non-road machines are several times higher than those for road vehicles. The differences are especially pronounced in the case of petrol engines, mainly because of the high proportion of 2-stroke engines used in non-road petrol-driven appliances (around 21% of non-road petrol consumption is attributable to 2-stroke engines, and the figure for road vehicles only around 0.5%. In the non-road sector, the specific emissions of diesel vehicles (nitrogen oxides and PM) are around 2 to 3 time higher than in the road transport sector. This underscores the fact that in the non-road segment there is still considerable potential in terms of reduction of air pollution, which needs to be exploited over the next few years with the aid of suitable regulations governing maximum exhaust emissions.

Tab. 18 > Comparison of specific pollutant emissions from non-road machines and road vehicles in 2010

Expressed as pollutant emissions in relation to fuel consumption [g/kg].

Pollutant	Non-road sector [g/kg]	Road vehicles [g/kg]	Ratio of emission factors between non-road machines and road vehicles
Petrol engines			
Carbon monoxide (CO)	758	42	18:1
Hydrocarbons (HC)	67	6	13:1
Diesel engines			
Nitrogen oxides (NO_X)	29	16	2:1
Particulate matter (PM)	1.5	0.5	3:1

Source (road transport): FOEN 2010

9.2 Impacts of retrofitting with particle filters

Fig. 56 (left) shows the past and future development of PM emissions caused by construction machinery, compared with the bandwidth of emissions that can be influenced by legislation in Switzerland (as long as it is only emissions that are limited, and not the actual use of the machine). The lower segment of the bandwidth corresponds to the emissions that would arise if all machines were equipped with particle filters. The upper segment corresponds to the emissions that arise if the machines comply with the EU limit values.

Construction machinery

With respect to construction machinery it is apparent that the effective development of PM emissions prior to 2000 took place at the upper limit of the bandwidth, since until then very little effort had been made to reduce emissions. At that time also in the EU were no applicable emission limit values in force. From 2000, the first impacts of voluntary retrofitting can be observed, namely decreasing emissions. It was not long before the EU emission stages were introduced, resulting in a lowering of the upper limit of the influencable bandwidth. Then around 2010 the development of emissions approached the lower limit of the influencable bandwidth following the step-by-step entry into force of the Ordinance on Air Pollution Control (cf. FOEN 2009) At the same time, some machine manufacturers began equipping engines in EU IIIB and EU IV stages with particle filters (cf. Tab. 13 in chapter 48). Between 2020 and 2025, emissions should attain the level that is possible when all machines are equipped with particle filters.

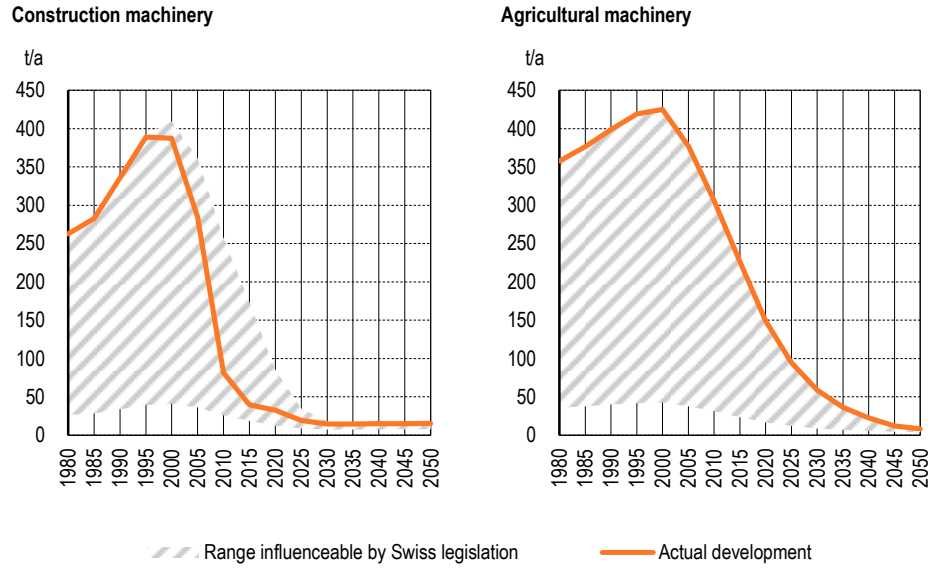
Agricultural machinery

Fig. 56 (right) shows the same development for agricultural machinery. Here it is apparent that the effective emissions to date have been in line with the upper limits specified by EU legislation, since Switzerland does not possess any legislation for agricultural machinery that goes beyond the EU provisions. The upper range of the emissions bandwidth specified by EU legislation is also falling at a slower pace than is the case with construction machinery, since agricultural machines remain in operation for longer and older machines are thus not so quickly replaced. For this reason, a

retrofitting requirement for new machines would only have a minor impact (FOEN 2008). Emissions from agricultural machinery will only fall between 2045 and 2050 to the attainable level when all machines have been equipped with particle filters.

Fig. 56 > Construction and agricultural machinery: effective development of PM emissions and range that can be influenced by Swiss legislation

The influencable range is based on a scenario in which all machines are equipped with particle filters (lower level of the shaded area) and a scenario in which the EU limit values are complied with (upper segment). The effective development corresponds to the emissions with the present-day and anticipated extent of equipping of machines with particle filters.



Equipment with particle filters as per data in chapter 4.3.8 (page 48)

9.3 Comparison with UW-0808

9.3.1 Methodology

The methodology applied in the previous study (UW-0828; FOEN 2008) has been largely adhered to here. Due to new developments relating to dealing with the more stringent limit values, however, a few minor adjustments have been made:

- Dynamic factors (CF_2, see chapter 4.3.7): In the previous study, the dynamic factors were differentiated by machine category, emissions concept and pollutant. In view of the differing dynamic factors for NO_X for various stage IV machines, the model was adapted so that dynamic factors differentiated by size can be applied (cf. Tab. 10 on page 47).
- Wear and tear factors (CF_3, see chapter 4.3.7.): In the previous study, these were treated as constant per pollutant and engine technology, but since these no longer apply from EU IIIA (or are factor 1), they can now be differentiated by emission stage in the model.
- Consideration of delayed introduction of emission stages: For the previous report it was assumed that, following the introduction of a new emissions stage, all new machines would meet the corresponding requirements. But the introduction was delayed due to the inclusion of sell-off periods and the flexibility scheme in the EU legislation (cf. chapter 4.3.4). This situation has been taken into account in this report in that, in the two years following the introduction of a new emissions stage, realistic estimates have been made concerning the proportions of new machines that still comply with the previous emissions stage ("probable introduction scenario, cf. Fig. 12 on page 43).
- Consideration of particle filters: In the previous study, constant correction factors for the use of particle filters were applied per pollutant. In specific terms, the PM emissions were reduced by 90% and fuel consumption was increased by 3%. These adjustments were only applied for machines retrofitted with particle filters – it was assumed that particle filters would be used in all machines following the introduction of a certain emissions stage (EU IIIB) because it would otherwise not be possible to comply with the respective limit level, and thus no adjustment of the emissions factor determined by the low limit value was necessary. As a result of the step-by-step tightening of PM limit values in accordance with EU legislation, and the different responses to these by machine manufacturers (cf. Tab. 13 in chapter 4.3.8), it was now necessary to differentiate the correction factors by emission stage and size, since the influence of a particle filter varies according to the limit value. In addition, the correction factors are no longer applied solely to retrofitted machines, but rather to all machines equipped with a particle filter.

9.3.2 Stock and operating hours

For the purpose of comparing the figures for the new non-road inventory with the data previously used by the FOEN from UW-0828 (FOEN 2008), 2010 was chosen as reference year. The figures in UW-0828 were collected in a separate study (EWI 2005).

Fig. 57 compares the stock, operating hours (specific, i.e. per appliance, as well as total) and energy requirement in accordance with the previous and current figures. The biggest differences arise for construction, industrial, garden-care and military machinery. The energy requirement is the figure obtained from stock, operating hours, the respective mean nominal engine power per machine and the load factors. Since the load factors for some machines were adjusted, this adaptation is described below first since it concerns several machine categories.

Load factors

New studies (e.g. Fridell et al 2014) show that the previously applied load factors of the US EPA (2004) are too high for the typical use of construction machinery in Europe. For this reason, the effective load factors of some machine categories and their counterparts in the forestry and military sectors were adjusted (Tab. 19). In most cases, these adjustments concern a reduction by 27 to 37%. However, the load factors in machines used for military purposes were previously lower, so these were adjusted upwards by between 4 and 67%. For 2010, the adjustment of load factors results in a reduction of energy consumption by around 6% for the entire non-road sector – this figure includes the increase in specific energy consumption levels based on the higher load correction factor (CF_1, cf. chapter 4.3.7). The reduction in energy consumption for construction machines on their own amounts to 15% in 2010, since the load factors for excavators – the most important type of machine in this category – were reduced. By contrast, the adjustment of load factors in the military machinery category results in an increase in energy consumption by 1%.

Tab. 19 > Comparison of load factors with the figures in UW-0828

Expressed in pollutant emissions in relation to fuel consumption in [g/kg].

Category	Type of machine	Size	Effective load factor		Change
			UW-0828	Current	
Construction machinery	Cable excavators	(All)	0.48	0.35	-27 %
	Mobile cranes	(All)	0.48	0.3	-37 %
	Loaders	(All)	0.48	0.35	-27 %
	Dump trucks	(All)	0.48	0.35	-27 %
	Drills	(All)	0.48	0.35	-27 %
	Mini-excavators	<18 kW	0.48	0.3	-37 %
	Mini-excavators	18–75 kW	0.48	0.35	-27 %
	Crawler excavators	75–300 kW	0.48	0.48	0 %
	Wheel excavators	37–75 kW	0.48	0.33	-31 %
Forestry machinery	Wheel excavators	(All)	0.48	0.4	-17 %
Military machinery	Crawler excavators	(All)	0.288	0.35	22 %
	Loading shovels	(All)	0.288	0.35	22 %
	Crawler excavators	(All)	0.288	0.48	67 %
	Bulldozers/crawler tractors (crawler tractors)	(All)	0.288	0.48	67 %
	Mobile cranes	(All)	0.288	0.3	4 %

Construction machinery

Stock and operating hours for construction machinery are higher than in the previous inventory. This is primarily attributable to the fact that, at the time the figures were collected for the previous inventory in the early 2000s, the construction industry passed through a phase of falling gross value-added (cf. FSO 2012) and thus a tendency towards a decline in building activity was assumed. In the meantime it has become apparent that gross value-added in the construction industry increased by around 19% between 2000 and 2010, which means that the use of construction machinery also increased. The reduction of load factors also reduces the energy requirement of construction machines (cf. section above and Tab. 19), but the net change in energy requirement versus the previous inventory is nonetheless clearly positive at 11%.

Industrial machinery

In the mobile industrial machines segment, too – which in the non-road inventory also includes machinery used by traders and municipal utilities – the stock and operating hours are higher than in the previous report. This is primarily attributable to the stock of runway vehicles, which was previously underestimated because a large number of these were not contained in the extract of the standard MOFIS database as of the end of September. Based on the extract as of the end of January, the stock is almost twice as high (cf. chapter 6.2.1 on page 63). By contrast, the stock of forklifts has decreased slightly versus the previous figure. Furthermore, in the current stock generators used in trade, industry and public administration, as well as machines and vehicles used on airport aprons, have been added, though this only explains a minor proportion of the increase.

Agricultural machinery

A slight reduction in the activities of agricultural machines was already assumed in the previous inventory, but this decrease has turned out to be greater than expected. In addition, in the current inventory the results by size based on the census of agricultural companies in the past few years were also taken into account, and these reveal that the proportion of larger machines was overestimated in the previous inventory. In view of this, the distribution by size was adjusted retrospectively, which led to a further reduction in the energy requirement. In 2010, the latter was around 18% lower than in the previous study.

Forestry machinery

In the forestry machinery category too, the current activities are slightly below the level for 2010 assumed in the previous study. With respect to total energy demand, the reduction of the load factor for wheeled excavators also plays a role, which results in a 12% lower energy requirement versus the previous study.

Garden-care/hobby appliances

In absolute terms, the stock and operating hours in this category have indicated the greatest increase versus the previous study. This is primarily attributable to the fact that electric appliances have been included for the first time. The 2010 stock is consequently 210% higher than the previous one. Excluding electric appliances, it would be 17% higher. The number of operating hours is currently seven times higher than in the previous study, mainly because of the lengthy operating hours of robotic lawn mowers. Due to the low power range of electric appliances, the energy requirement is "only" 130% higher than in the previous inventory.

Navigation machinery

The current stock is 15% higher than in the previous study, which is mainly attributable to increases in the number of motor boats and cargo and passenger ships, though cargo ships on the Rhine were also included for the first time. With respect to the latter, the fact that the number of journeys per year is known, but not the number of journeys travelled by the same ship, is problematic. This does not have an effect on total activity, but the fact that for inventory purposes the assumption that the number of journeys equals the number of ships, means that the figure is likely to be overestimated. The total number of operating hours is only 4% higher than in the previous inventory, and the total energy requirement has only changed marginally (+0.3%) due to shifts in the distribution by size towards smaller motor boats and yachts.

Railway machinery

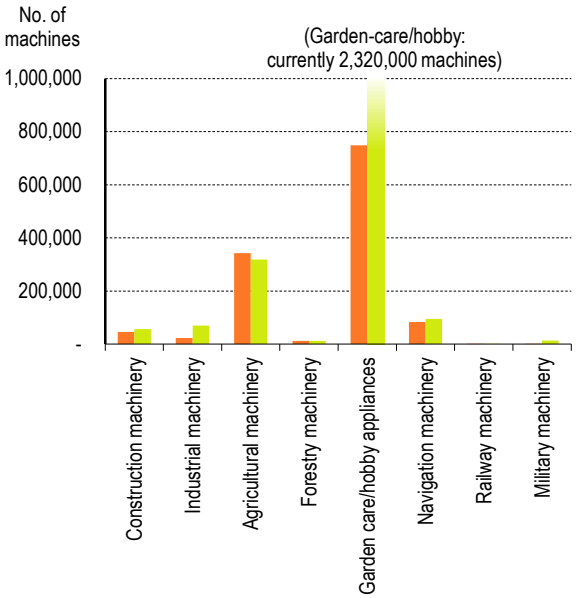
In the current inventory, the total energy demand for 2010 is 4% lower than in the previous one. This is attributable to declining numbers of railway tractors and the simultaneously increasing mean nominal power range of shunting locomotives.

Military machinery

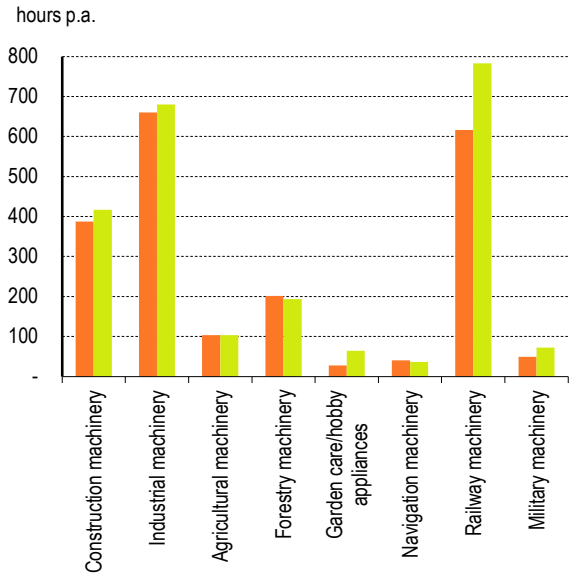
In relative terms, of all machine categories, military machinery activities have increased to the greatest extent (increase in energy requirement by 480%). This is mainly attributable to a significant underestimate of the operating hours of military construction machinery, and the stock and operating hours of armoured personnel carriers, in the previous study. The data were examined and confirmed by the Army Logistics Base, and were corrected retrospectively. We were unable to identify the reasons for the underestimate in EWI (2005). But since military activities only account for a proportion of 1.5% of total energy consumption in the non-road sector, this adjustment only has a minor impact on the overall picture.

Fig. 57 > Comparison of current data with the figures in UW-0828

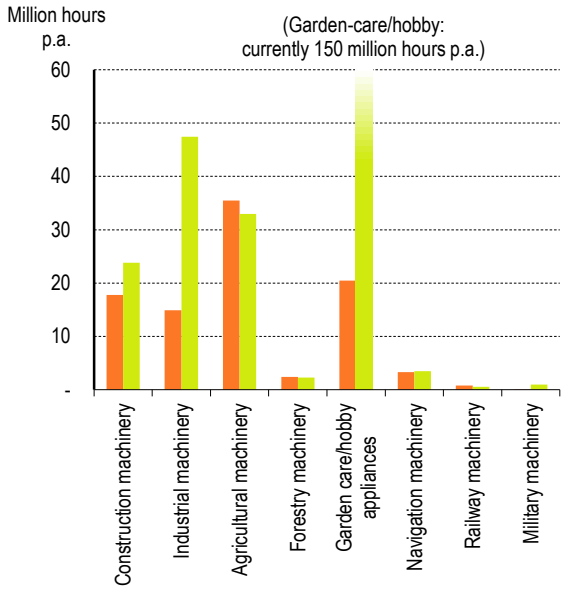
Stock



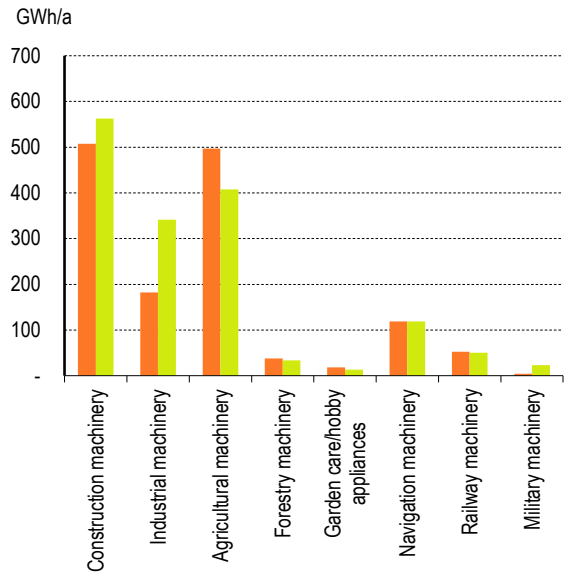
Specific operating hours



Total operating hours



Energy requirement



UW-0828 Updated study

Numerical values, cf. Tab. 48 – Tab. 49 on page 179, Tab. 53 on page 185 and FOEN 2008

9.3.3 Emission factors

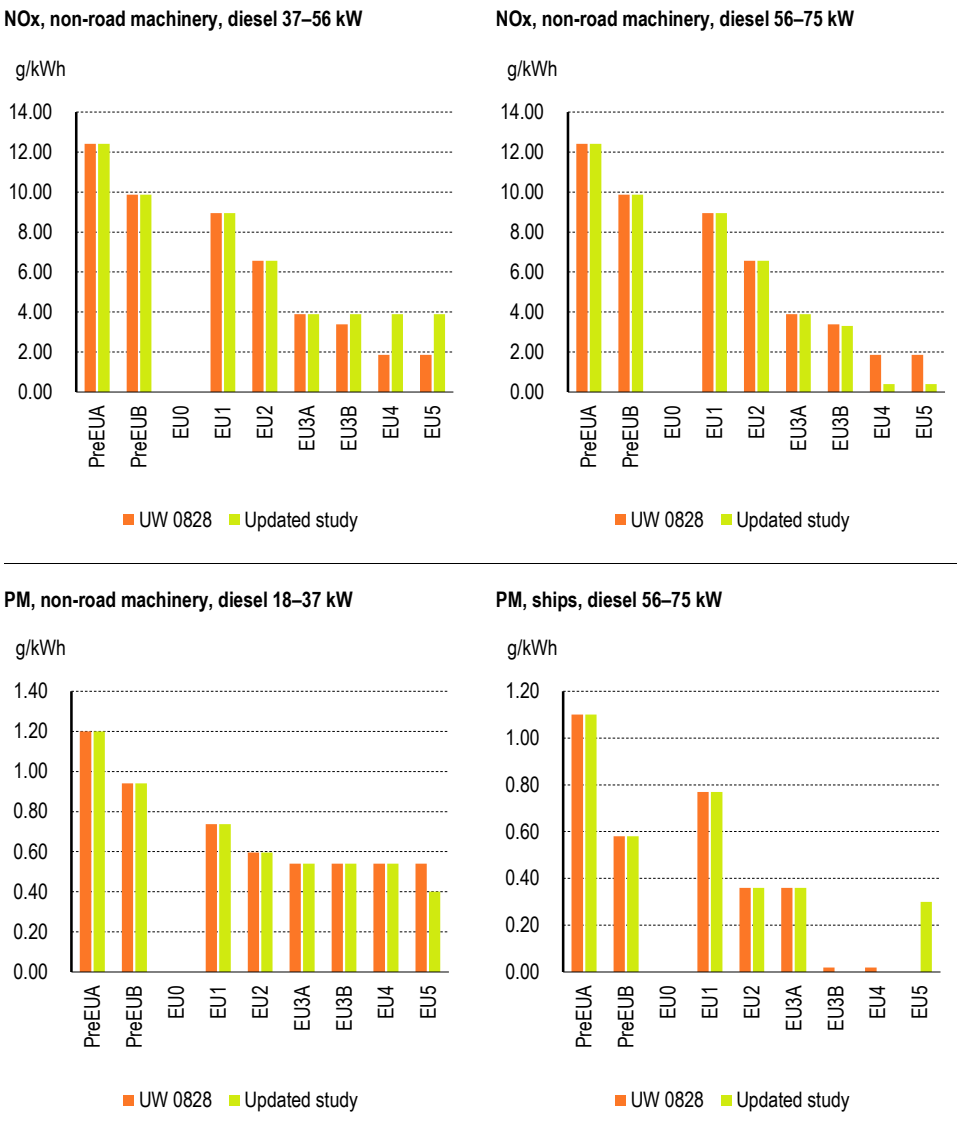
In this updated report, most of the emission factors up to the time at which the respective EU emission stages had entered into effect – EU IIIA for diesel machines, EU II for small petrol-driven appliances – were adopted for the current report from the previous study (FOEN 2008) (cf. chapter 4.3.3). For the emission categories that only entered into effect at a later date, assumptions were made in the previous study regarding the development of the emission factors; in the meantime more detailed information is available, and this means that the current emission factors differ from those applied in the earlier study.

Diesel machines

For nitrogen oxides (NO_x), the current emission factors from EU IIIB are partly below and partly above those cited in the previous study (Fig. 58, top), depending on the machine size. Overall, emissions are slightly higher throughout the entire non-road sector due to the adjustment of the basic emission factors. This effect is further enhanced due to the higher dynamic factors from EU IV (cf. chapter 4.3.7) and because the delayed introduction of the various emission categories (cf. chapter 4.3.4) has been taken into account.

With respect to PM, the adjustments of the emission factors for construction machines and agricultural and forestry machinery result in a decrease of emissions versus the previous study. This is primarily attributable to the more stringent limit value specified in EU V for smaller machines (Fig. 58, bottom left). By contrast, for navigation and railway machinery, EU IIIB and EU IV (for railway machinery, only EU IV) did not enter into effect as expected. The limit values in EU IIIA for navigation machinery and EU IIIB for railway machinery are to remain in effect until the introduction of EU V in 2019/2020 (Fig. 58, bottom right). Thus the emission factors in the current study are higher than the assumptions made in the previous study, and the modelled total emissions for navigation and railway machinery are therefore also higher. Overall, however, PM emissions in the non-road sector (including the discontinuation of ageing factors with effect from EU IIIA and taking the delayed introduction into account) are slightly lower than those which would result with the current data, but with the application of the previous methodology.

Fig. 58 > Diesel machines: comparison with the emission factors in UW-0828



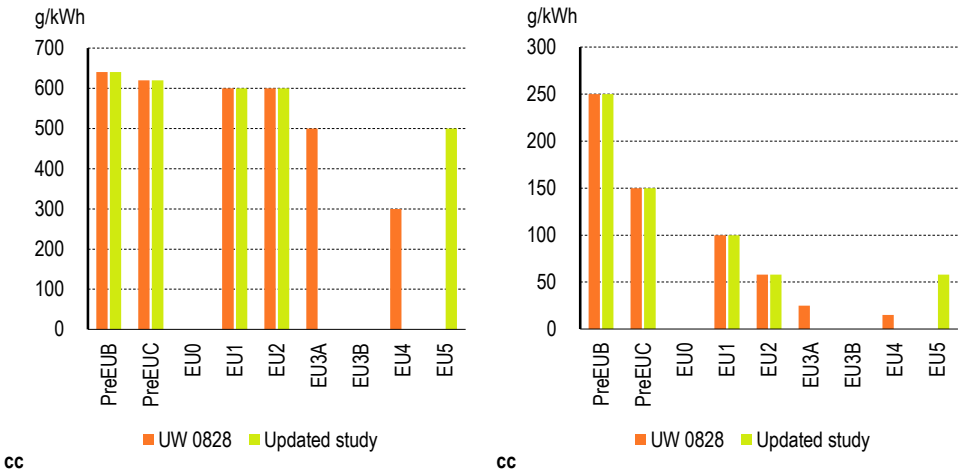
Numerical values, cf. Tab. 28 on page 154, and FOEN 2008

Small petrol-driven appliances

From 2015, carbon monoxide (CO) emissions, which are largely influenced by petrol-driven appliances, will reduce to a significantly lower extent than in the previous study. The reason for this is that the CO limit value for EU V (which is scheduled to enter into effect in 2019/2020) is significantly higher than the emission factors that were assumed in the previous study. But these emission stages are now to be skipped, which means that the limit values for EU II will apply until 2019 or 2020 (Fig. 59, left).

The same effect applies to hydrocarbon (HC) emissions, which are also largely influenced by petrol engines (Fig. 59, right).

Fig. 59 > Petrol-driven appliances: comparison with emission factors in UW-0828

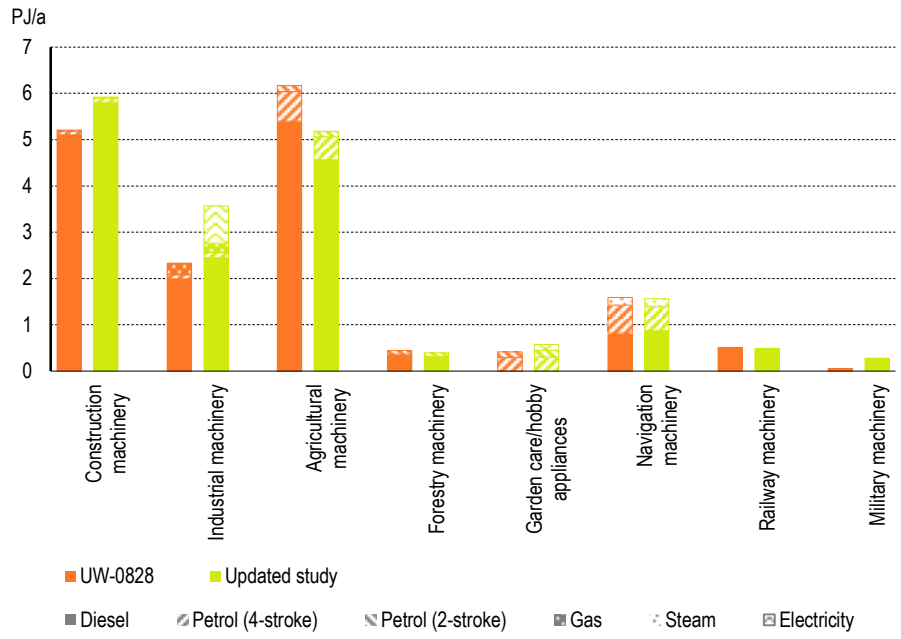


Numerical values, cf. Tab. 34 on page 161 and FOEN 2008

9.3.4 Energy consumption

In the reference year (2010), the energy consumption in the current report (Fig. 60) and in UW-0828 developed similarly to that of the energy requirement (cf. chapter 9.3.2, Fig. 57, bottom right), because the consumption factors were not changed. Slight differences in the relative changes to Fig. 57 (bottom right) can be explained by the differing proportions of the various types of drive and their varying energy content (calorific values) and degrees of efficiency.

Fig. 60 > Comparison of energy consumption in 2010 with values predicted in UW-0828, by machine category



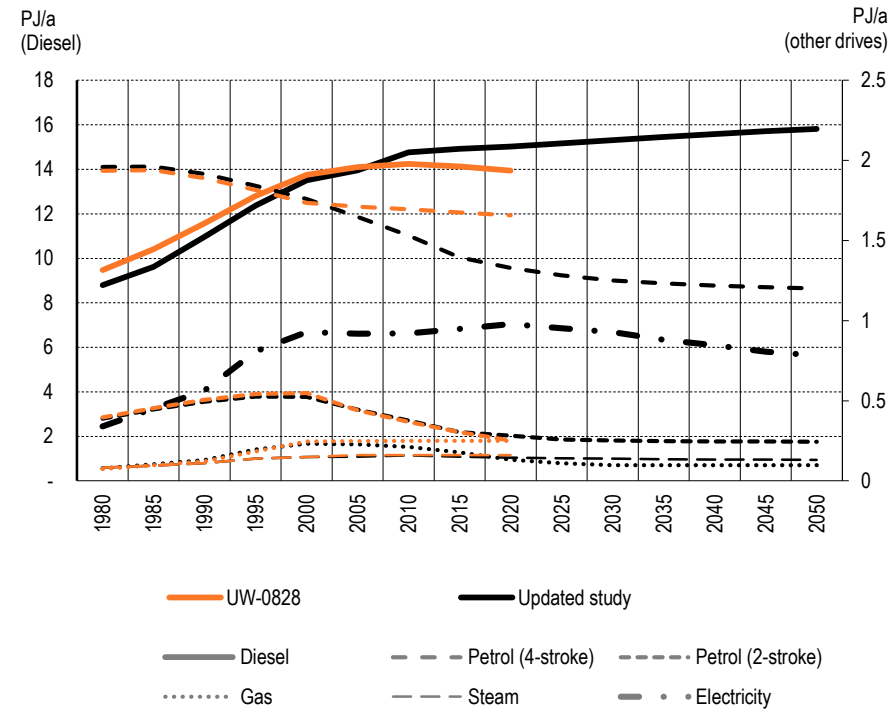
The colour coding indicates the study, while the shading indicates the type of drive.
Numerical values, cf. Tab. 53 on page 185 and FOEN 2008

The comparison of chronological developments (Fig. 61) shows that in UW-0828 a tendency towards lower consumption by diesel and 2-stroke petrol machines was assumed from 2000 than in the current inventory. With respect to diesel, this is above all associated with the more pessimistic expectations that were felt at that time regarding the development of the construction sector, which, as has now become clear, picked up sharply in the period from 2000 to 2010. Until 2005, however, diesel consumption as per UW-0828 was still slightly above the current level in absolute terms. This is attributable to the downward adjustment of the load factors of the most important construction machine types in the current report (cf. chapter 9.3.2, Tab. 19). With regard to 2-stroke petrol appliances, both reports show a reduction from 2000, but this was less pronounced than was anticipated in UW-0828.

With respect to 4-stroke petrol engines and gas-powered machines, the forecasts contained in UW-0828 are above the current levels. For 4-stroke petrol engines, the difference is primarily attributable to the stock of single-axle mowers in the agriculture sector, which decreased more strongly than expected. For gas-powered machines, the difference is attributable to the reduction in the use of forklifts.

No notable changes have taken place with regard to heating oil used in steam ships. Electricity consumption was not taken into account in UW-0828.

Fig. 61 > Comparison of the development of energy consumption with UW-0828



The colour coding indicates the study, while the broken lines indicate the type of drive
Numerical values, cf. Tab. 52 on page 184 and FOEN 2008

9.3.5 Emissions

The differences in emissions between the current study and UW-0828 (Fig. 62) can for the most part be explained in the same way as the differences in stock and energy requirement, since the emission factors for 2010 were not modified. An almost negligible additional reduction in emissions arises from the fact that, in the current study, no wear and tear factors were applied from emission category IIIA (cf. chapters 4.3.7 and 9.3.1).

In the current report, new emission factors were only applied from EU IIIB, and together with the changes in stock and operating hours, these influence the development from 2015 onwards (Fig. 63). Since the forecasts in UW-0828 only extend to 2020 and the most significant differences will only begin to take effect with the introduction of EU V (2019/2020), no notable differences are visible in Fig. 63.

Carbon monoxide (CO)

Up to 2010, the figures from UW-0828 are around 0.7 to 3.5% above the current data. This is partly due to lower load factors in the current study, and partly to the fact that, from 2000, the current inventory records a lower number of single-axle mowers, which are petrol-driven, have high nominal power ranges and load factors, and thus have a strong influence on CO emissions. Between 2015 and 2020, the emissions as per UW-0828 decrease more rapidly so that they almost reach the level in the current report by 2020. This is attributable to the fact that, for UW-0828, lower CO limit values for petrol engines were expected with EU III and EU IV, which were never implemented (cf. chapter 9.3.3).

Hydrocarbons (HC)

The current emissions and those recorded in UW-0828 are similar to those for carbon monoxide (CO), for the same reasons: some lower load factors and higher emission factors from 2015 in the current inventory.

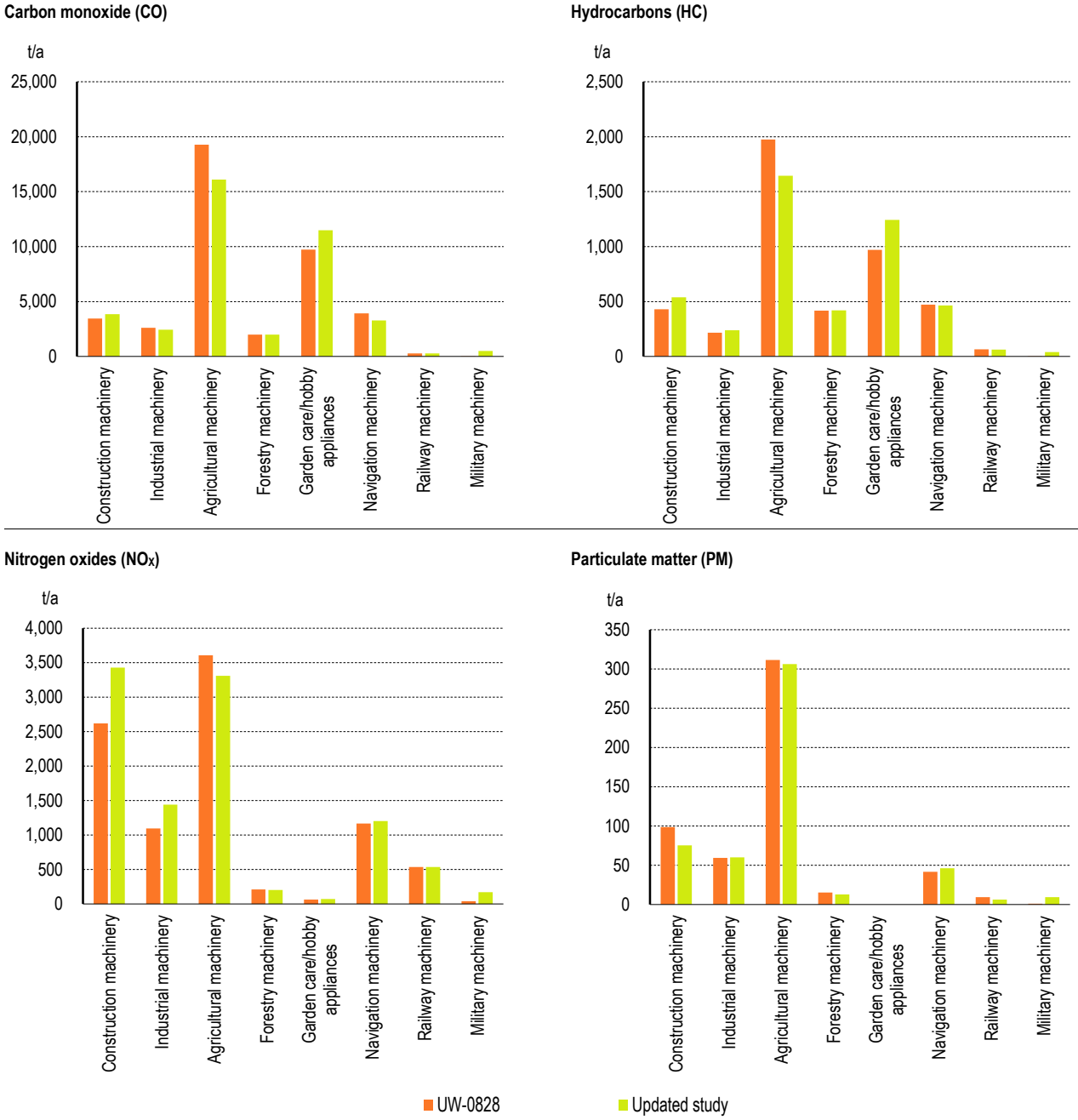
Nitrogen oxides (NO_x)

The differences with regard to nitrogen oxides can be largely explained by the same effects as those that apply to the differences in diesel consumption: lower load factors for construction machines, but generally higher stock and operating hours for diesel machines in the current study. In addition, higher basic emission factors and dynamic factors (CF_2), combined with the delayed introduction of new emission stages, result in higher emissions in the period from 2010 to 2015.

Particulate matter (PM)

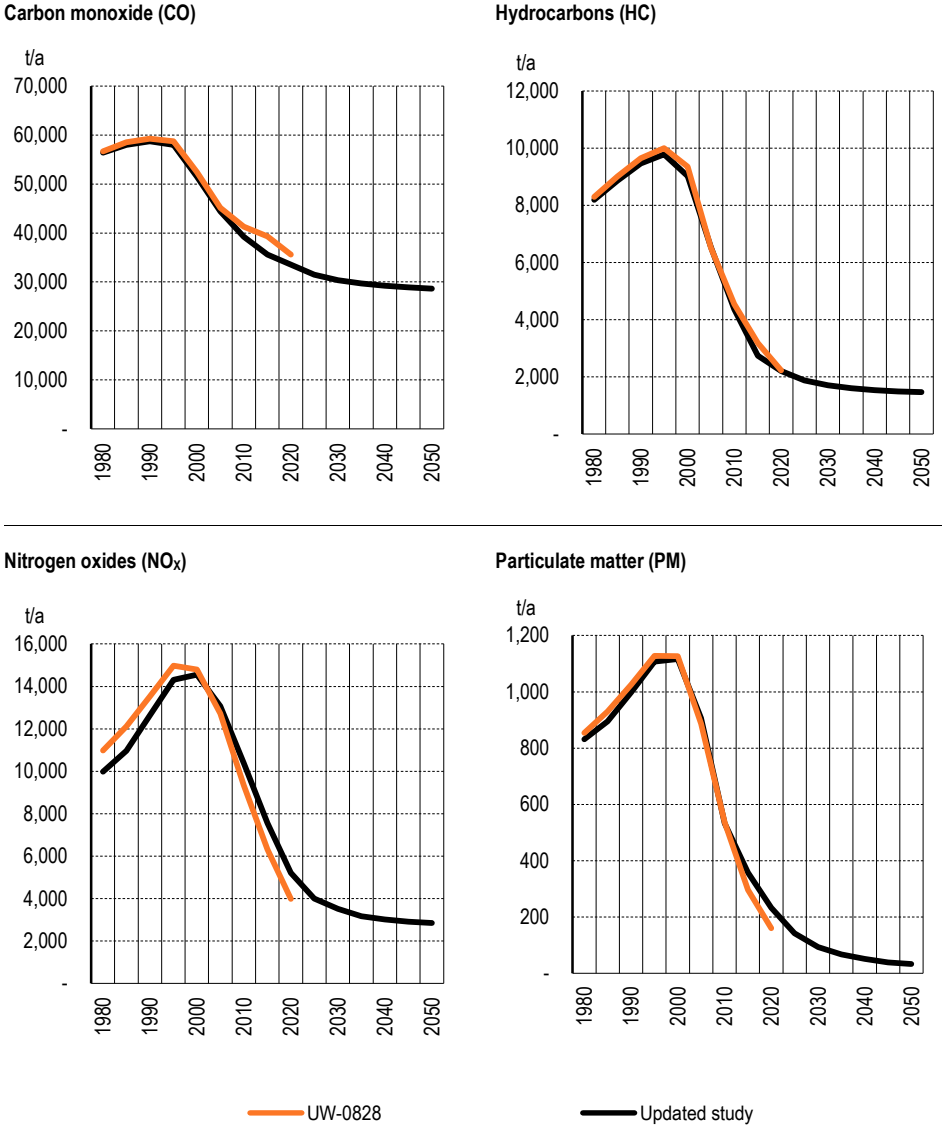
In the case of PM too, the lower load factors, but higher stock and operating hours from 2000, are primarily responsible for the fact that the emissions in accordance with UW-0828 are initially higher than the current level. This situation only reverses after 2010, since the modifications of the basic emission factors and influencing factors, together with the more widespread distribution of particle filters, result in lower specific emissions in the current inventory.

Fig. 62 > Comparison of emissions in 2010 with the predicted values in UW-0828, by machine category



The colour coding indicates the study, while the shading indicates the type of drive.
Numerical values, cf. Tab. 54 on page 186 and FOEN 2008

Fig. 63 > Comparison of the development of emissions of regulated pollutants with those recorded in UW-0828



Numerical values, cf. UW-0828; FOEN 2008; current data; Table Tab. 54 on page 186

> Appendix

A1 Calculation methodology

This appendix contains a detailed description of the methodology for calculating emissions, which involves 4 steps:

- > Calculation of stock for each machine segment and year of manufacture
- > Calculation of operating hours for each machine segment and year of manufacture
- > Differentiation of stock/operating hours by emission stages
- > Calculation of pollutant emissions

All required input criteria are shown against a grey background.

Step 1: Calculation of stock for each machine segment and year of manufacture

1a: Calculation of stock for each segment. Segments are divided into machine type ***(Mtyp),*** engine type ***(Etyp)*** and size ***(Sclass).***

$$N_{Seg} = N_{Mtyp,\,Etyp,\,Sclass} = N_{Mtyp} \cdot \beta_{Mtyp,\,Etyp,\,Sclass}$$

Key: N_{Seg} = no. of machines per segment

N_{Mtyp} = no. of machines per machine type

β_{Seg} = distribution of engine types and size classes for a given machine type

1b: Differentiation of stock/operating hours by year of manufacture with the aid of age distribution

$$N_{Seg,\,year} = N_{Seg} \cdot \varpi_{Seg}$$

Key: $N_{Seg,\,year}$ = no. of machines per segment ***Seg*** and year of manufacture ***year***

ϖ_{Seg} = age distribution in stock differentiated by segment ***Seg***

Step 2: Calculation of operating hours

2a: Calculation of operating hours per machine category

$$H_{Mtyp} = N_{Mtyp} \cdot h_{Mtyp}$$

Key: H_{Mtyp} = operating hours per machine category ***Mtyp*** [hrs p.a.]

h_{Mtyp} = specific operating hours per machine category ***Mtyp*** [hrs p.a.]

2b: Calculation of operating hours per segment (non-adjusted)

$$\tilde{H}_{Seg,\ year} = N_{Seg,\ year} \cdot h_{Seg}$$

Key: $\tilde{H}_{Seg,\ year}$ = operating hours per segment ***Seg*** and year of manufacture ***year*** [hrs p.a.]

$\boldsymbol{h}_{Seg}$ = specific operating hours per segment ***Seg*** [hrs p.a.]

2c: Adjustment of operating hours per segment so that the target level is attained for specific operating hours per machine category as per 2a.

$$H_{Seg,\ year} = \tilde{H}_{Seg,\ year} \cdot \frac{N_{Mtyp} \cdot h_{Mtyp}}{\sum_{Seg} \tilde{H}_{Seg,\ year}}$$

Key: h_{Mtyp} = specific operating hours per machine category ***Mtyp*** [hrs p.a.]

Step 3: Differentiation of stock/operating hours by emission levels

This concerns the calculation of stock and operating hours per sub-segment while taking account of the age dependency of the operating hours. Segments differentiated by emission concepts are referred to as sub-segments.

$$N_{Sub} = \sum_{Emstage} N_{Seg,\ year}$$

$$H_{Sub} = \sum_{EmStage} H_{Seg,\ year} \cdot \alpha\ (Age)$$

Key: $\boldsymbol{N}_{Sub}$ = machine stock per sub-segment ***Sub***

$\boldsymbol{H}_{Sub}$ = operating hours per sub-segment ***Sub*** [hrs p.a.]

$\alpha\ (Age)$ = age dependency of operating hours

Step 4: Calculation of pollutant emissions

4a: Calculation of energy consumption per sub-segment

$$W_{Sub} = H_{Sub} \cdot P_{Sclass}^{Nompower} \cdot \gamma_{Mtyp}^{Norm} \cdot Cor_{Mtyp,\,Etyp}^{LF}(Age)$$

Key: W_{Sub} = energy consumption per sub-segment [kWh p.a.]

$P_{Sclass}^{Nompower}$
= nominal rated power per segment [kW]

λ_{Mtyp}^{Norm}
= standard load factor as per ISO cycle per machine type relating to machine age

$Cor_{Mtyp,\,Etyp}^{LF}$ (Age)
= adjustment factor in case of deviation of effective load from standard load as per ISO cycle C1

4b: Calculation of emissions per pollutant and sub-segment, with differentiation of emission factors by pollutant, machine category (construction machinery, agricultural machinery, etc.) and emission level

$$Em_{Sub,\,pollutant} = W_{Sub} \quad CF_1(Cor_{Mtyp,Etyp}^{LF}) \quad CF_{2\ pollutant,Mtyp}$$

$$CF_{3\ Etyp}(Age) \quad \varepsilon_{pollutant,Mcat,Emstage}$$

Key: $Em_{Sub,\,pollutant}$
= pollutant emissions per sub-segment [grams p.a.]

$CF_1(Cor_{Mtyp,\,Eyp}^{LF})$
= adjustment factor for specific consumption in the case of deviation of load factor from standard load as per ISO cycle

$CF_{2\ pollutant\ Mtyp}$
= dynamic factor by pollutant and machine category

$CF_{3\ pollutant\ Etyp}(\sum H_{Sub})$
= deterioration rate by pollutant and engine type in dependence on accumulated operating hours
at a given machine age

$\varepsilon_{pollutant\ Mtyp,\,Emstage}$
= emission factor by pollutant, machine type and emission stage [g per kWh]

A2 Machine categories and types

Tab. 20 > Categories and types of non-road machines

Unless stated to the contrary in the last column, the MOFIS database entries have been limited as follows:

a) Construction and industrial machinery: entries with type of vehicle, "production machine", "production cart" or "motor cart" (FAZ = 50, 51 or 80).

b) Agricultural machinery: entries with type of vehicle "agricultural production cart" or "agricultural motor cart" (FAZ = 52 or 81).

Category	Type of machine	Delimitation/definition in data sources
Construction machinery	Asphalt finishers	MOFIS: body type 204 (Strassenfertiger) Off-Highway Research: asphalt finishers
Construction machinery	Hydraulic rammers of all types	MOFIS: body type 282 (Ramme)
Construction machinery	Rollers of all types	MOFIS: body type 229 (Walze) or 250 (Pneu-walze)
Construction machinery	Mechanical vibrators	Stock estimated on basis of FOEN 2008; expert group
Construction machinery	Hand-operated rammers, vibrators	
Construction machinery	Cable dredgers	
Construction machinery	Rubber-tyred and mobile cranes	MOFIS: body type 156 (Kran), 179 (Pneukran) or 311 (Kranwagen) Off-Highway Research: mobile cranes
Construction machinery	Graders	MOFIS: body type 140 (Planiermaschine) Off-Highway Research: motor graders
Construction machinery	HGV's without licence for use on road	Stock estimated on basis of FOEN, 2008; expert group
Construction machinery	Crawler tractors	Off-Highway Research: crawler dozers
Construction machinery	Loaders (rubber-tyred and crawler) of all types	MOFIS: body type 158 (Ladeschaufel), 259 (Ladeschaufel/Bagger) or 277 (Ladeschau-fel/Heckbagger) Off-Highway Research: crawl-er/backhoe/wheeled/skid-steer loaders
Construction machinery	Dump trucks	MOFIS: body type 152 (Kippmulde), 153 (Kippkasten) or 231 (Wechselladekipper) Off-Highway Research: rigid/articulated dump trucks
Construction machinery	Emergency power supply systems/generators	Stock estimated on basis of FOEN, 2008; expert group, applications to Fed. Customs Admin. for refund of oil tax with sector description "construc-tion", "railway line construction", "tunnel construc-tion""
Construction machinery	Pumps of all types	MOFIS: body type 110 (concrete pump) or 169 (motor pump)
Construction machinery	Mobile compressors	MOFIS: body type 155 (compressor) Off-Highway Research: mobile compressors
Construction machinery	Mobile elevating work platforms	Stock estimated on basis of FOEN 2008; expert group
Construction machinery	Tunnel locomotives	

Category	Type of machine	Delimitation/definition in data sources
Construction machinery	Concrete/surface milling cutters	MOFIS: body type 112 (Bodenfräse) or 346 (Belagfräse)
Construction machinery	Trench cutters	MOFIS: body type 248 (Grabenfräse)
Construction machinery	Drilling machines of all types (esp. civil engineering)	Stock estimated on basis of FOEN, 2008; expert group
Construction machinery	Mini-excavators	MOFIS: body type 245 (excavator); capacity <37 kW Off-Highway Research: mini excavators
Construction machinery	Crawles excavators	MOFIS: body type 245 (excavator); capacity >37 kW Off-Highway Research: hydraulic excavator – crawler
Construction machinery	Wheeled excavators	MOFIS: body type 245 (excavator); capacity >37 kW Off-Highway Research: hydraulic excavator – wheeled
Industrial machinery	Forklifts of all types	MOFIS: body type 133 (forklift), 168 (Seitenga-belstapler) or 198 (Teleskopstapler)
Industrial machinery	Sweepers and cleansers	MOFIS: body type 205 (Kehrmaschine) or 320 (Reinigungsmaschine)
Industrial machinery	Mobile elevating work platforms	Stock estimated on basis of FOEN, 2008; expert group
Industrial machinery	Industrial tractors	MOFIS: vehicle type 42 (tractor), or 82 (Motorkar-ren) AND body type 251 (small tractor)
Industrial machinery	Runway vehicles	MOFIS: body type 281 (runway vehicle)
Industrial machinery	Air side passenger cars	Stock in airside segment according to information provided by Zurich and Geneva airports
Industrial machinery	Air side light duty vehicles	
Industrial machinery	Air side Heavy duty vehicles/buses	
Industrial machinery	Air side generators	
Industrial machinery	Air side tractors	
Industrial machinery	Air side dispatch appliances	
Industrial machinery	Industrial machi-nery/business/public	Diesel generators in accordance with applications to Fed. Customs Admin. for oil tax refunds, excluding sector descriptions “construction”, “railway line construction”, “tunnel construction”, “airports”
Agricultural machinery	Single-axle mowers	LBZ: motor mowers, single-axle tractors MOFIS: body type 83 (agricultural single-axle tractor)
Agricultural machinery	Tractors (agriculture)	LBZ: tractors MOFIS: vehicle type 43 (agricultural tractor) Difference MOFIS-LBZ allocated to “hobby tractors”. Reasons: a) Old tractors kept in use but not entered in LBZ; b) Some other types of machines (e.g. transport-ers, dual-axle mowers registered in MOFIS as tractors (approx. 3,000 to 4,000; cf. entries in corresponding categories)
Agricultural machinery	Combine harvesters	LBZ: Mähdrescher MOFIS: body type 164 (Mähdrescher) and J69

Category	Type of machine	Delimitation/definition in data sources
Agricultural machinery	Spraying machines	LBZ: Pflanzenschutzspritzen MOFIS: body type 171 (Motorspritze) or 318 (Mehrzweckspritze)
Agricultural machinery	Field choppers	LBZ: Feldhäcksler MOFIS: body type 326 (Häcksler)
Agricultural machinery	Twin-axle mowers	LBZ: dual-axle mowers MOFIS: vehicle type 52 (Landwirtschaftlicher Arbeitskarren) or 81 (Landwirtschaftlicher Motorkarren) with body type 327 (mower), or vehicle type 43 (tractor) with body type 269 (Geräteträger)
Agricultural machinery	Transporters and loaders	LBZ: Transporter MOFIS: vehicle type 43 (Traktor) with body types 108 (Brücke), 151 (Kippbrücke), 220 (Transporter/Wechselaufbauten), 226 (Wechselaufbau), 238 (Brücke mit Ladekran), 255 (Wechselabrollaufbau Haken), 278 (Ladewagen), 330 (Mistzettler)
Agricultural machinery	Farmyard loaders	LBZ: Hoflader, Kompakt-, Teleskop-Lader
Agricultural machinery	Chainsaws (agriculture)	Stock estimated on basis of FOEN, 2008; expert group
Agricultural machinery	Tractors (hobby)	Vehicle type 43 (agricultural tractor) minus tractors in accordance with LBZ + dual-axle mowers and transporters erroneously registered as tractors, cf. corresponding categories
Agricultural machinery	Beet harvesting machine	Sales of beet harvesting machine according to SLV (Schweiz. Landmaschinenverband)
Forestry machinery	Chainsaws (forestry)	Stock estimated on basis of FOEN 2008; expert group
Forestry machinery	Cutters	
Forestry machinery	Other small appliances	
Forestry machinery	Cable and grapple skidders	
Forestry machinery	Harvesters	KWF statistics: harvesters
Forestry machinery	Processors	Stock estimated on basis of FOEN 2008; expert group
Forestry machinery	Wood chippers	
Forestry machinery	Bark peeling machines	
Forestry machinery	Wheeled excavators FM	
Forestry machinery	Forestry forwarders	KWF statistics: Forstschlepper
Forestry machinery	Conventional skyline cranes	Stock estimated on basis of FOEN 2008; expert group
Forestry machinery	Mobile skyline cranes	
Forestry machinery	Combined skyline appliances	
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Stock estimated on basis of FOEN 2008; expert group; proportion of professional use based on estimate by expert group and Jardin Suisse (2012)
Garden-care/hobby appliances	Hedge cutters (professional)	
Garden-care/hobby appliances	Blowers (professional)	
Garden-care/hobby appliances	Lawn mowers (professional)	
Garden-care/hobby appliances	Ride-on mowers (professional)	
Garden-care/hobby appliances	Chainsaws (professional)	

Category	Type of machine	Delimitation/definition in data sources
Garden-care/hobby appliances	Scarifiers (professional)	
Garden-care/hobby appliances	Mill cutters/shredders (professional)	
Garden-care/hobby appliances	Shredders (professional)	
Garden-care/hobby appliances	Snow blowers (professional)	
Garden-care/hobby appliances	Cleaning appliances (professional)	
Garden-care/hobby appliances	Abrasive grinders (professional)	
Garden-care/hobby appliances	Drills (professional)	
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Stock estimated on basis of FOEN 2008; expert group, sales according to survey of large-scale distributors
Garden-care/hobby appliances	Hedge cutters (household)	
Garden-care/hobby appliances	Blowers (household)	
Garden-care/hobby appliances	Lawn mowers (household)	
Garden-care/hobby appliances	Ride-on mowers (household)	
Garden-care/hobby appliances	Chainsaws (household)	
Garden-care/hobby appliances	Motor sleds (household)	
Garden-care/hobby appliances	Scarifiers (household)	
Garden-care/hobby appliances	Mill cutters/shredders (household)	
Garden-care/hobby appliances	Shredders (household)	
Garden-care/hobby appliances	Snow blowers (household)	
Garden-care/hobby appliances	Cleaning appliances (household)	
Garden-care/hobby appliances	Lawn moving robotics	
Garden-care/hobby appliances	Wood splitter (professional)	
Garden-care/hobby appliances	Wood splitter (Household)	
Navigation machinery	Motorised yachts	VKS statistics: motor yachts
Navigation machinery	Fishing & other commercial boats	FOEN professional fishing statistics (FOEN 2010): assumption of 3.15 boats per business (based on FOEN 2008)
Navigation machinery	Hire and privately owned motor boats	FSO statistics (FSO 2012): motor boats, minus number of professional fishing and workboats
Navigation machinery	Passenger ships	VSSU (Verband schweiz. Schifffahrtsunternehmen) survey
Navigation machinery	Cargo ships/barges	FSO statistics (FSO 2012): cargo ships, tugs
Navigation machinery	Ferries	VSSU (Verband schweiz. Schifffahrtsunternehmen) survey
Navigation machinery	Cargo ships Rhine, main engines	INFRAS, 2012
Navigation machinery	Cargo ships Rhine, auxiliary engines	
Railway machinery	Shunting locomotives	Information from SBB, BLS: diesel-powered shunting locomotives
Railway machinery	Twin-engined tractors	Information from SBB, BLS: railway tractors with hybrid drive
Railway machinery	Railway tractors	Information from SBB, BLS: railway tractors (incl. diesel-powered service vehicles)
Military machinery	Pz 68 family	Information from LBA

Category	Type of machine	Delimitation/definition in data sources
Military machinery	Leo 87	
Military machinery	Howitzers	
Military machinery	Armoured personnel carriers	Information from LBA: Spz 2000 and M113
Military machinery	Other armoured vehicles	Information from LBA: Piranha I, II, IIIC, Duro IIIP
Military machinery	Reconnaissance vehicles	Information from LBA: Eagle family
Military machinery	Caterpillar loaders/crawler Loaders	Information from LBA
Military machinery	Rubber-wheeled loading shovels/wheel	
Military machinery	Crawler excavators Mil	
Military machinery	Walking excavators Mil	
Military machinery	Bulldozers/crawler tractors	
Military machinery	Pile drivers/piling rigs	
Military machinery	Crane trucks	
Military machinery	Patrol boats	
Military machinery	Other boats	
Military machinery	Assortment Lenz use	
Military machinery	Power generating appliances	
Military machinery	Support bridge46m	
Military machinery	Assortment water pipe	

A3 Maximum emission limit values

A3-1 Diesel machines excluding ships/boats and railway vehicles

Tab. 21 > EU emission limit values for non-road diesel machines[16] (in g per kWh)

Figures in brackets are limit values for the total of hydrocarbon and nitrogen oxide emissions ($HC+NO_X$).

Engine power class	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Carbon monoxide (CO)						
<18 kW	-	-	-	-	-	8.0
18–37 kW	-	5.5	5.5	-	-	6.6
37–56 kW	6.5	5.0	5.0	5.0	-	5.0
56–75 kW	6.5	5.0	5.0	5.0	5.0	5.0
75–130 kW	5.0	5.0	5.0	5.0	5.0	5.0
130–300 kW	5.0	3.5	3.5	3.5	3.5	3.5
300–560 kW	5.0	3.5	3.5	3.5	3.5	3.5
>560 kW	-	-	-	-	-	3.5
Hydrocarbons (HC)						
<18 kW	-	-	-	-	-	(7.5)
18–37 kW	-	1.5	(7.5)	-	-	(7.5)
37–56 kW	1.3	1.3	(4.7)	(4.7)	-	(4.7)
56–75 kW	1.3	1.3	(4.7)	0.19	0.19	0.19
75–130 kW	1.3	1.0	(4.0)	0.19	0.19	0.19
130–300 kW	1.3	1.0	(4.0)	0.19	0.19	0.19
300–560 kW	1.3	1.0	(4.0)	0.19	0.19	0.19
>560 kW	-	-	-	-	-	0.19
Nitrogen oxides (NO_X)						
<18 kW	-	-	-	-	-	(7.5)
18–37 kW	-	8.0	(7.5)	-	-	(7.5)
37–56 kW	9.2	7.0	(4.7)	(4.7)	-	(4.7)
56–75 kW	9.2	7.0	(4.7)	3.3	0.4	0.4
75–130 kW	9.2	6.0	(4.0)	3.3	0.4	0.4
130–300 kW	9.2	6.0	(4.0)	2.0	0.4	0.4
300–560 kW	9.2	6.0	(4.0)	2.0	0.4	0.4
>560 kW	-	-	-	-	-	3.5

[16] Separate emission limit valuesapply to ships/boats and railway vehicles (see tables on page 155).

Engine power class	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Particulate matter (PM)						
<18 kW	-	-	-	-	-	0.4
18–37 kW	-	0.8	0.6	-	-	0.015
37–56 kW	0.85	0.4	0.4	0.025	-	0.015
56–75 kW	0.85	0.4	0.4	0.025	0.025	0.015
75–130 kW	0.7	0.3	0.3	0.025	0.025	0.015
130–300 kW	0.54	0.2	0.2	0.025	0.025	0.015
300–560 kW	0.54	0.2	0.2	0.025	0.025	0.015
>560 kW	-	-	-	-	-	0.045

Sources: EC 1997; 2014

Tab. 22 > Year of introduction for non-road diesel machines

Figures have been rounded up or down for each year.

Engine power class	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Construction, industrial and military machinery						
<18 kW	-	-	-	-	-	2019
18–37 kW	-	2002	2007	-	-	2019
37–56 kW	2002	2004	2008	2013	-	2019
56–75 kW	2002	2004	2008	2012	2014	2020
75–130 kW	2002	2003	2007	2012	2014	2020
>130 kW	2002	2002	2006	2011	2014	2019
Agricultural and forestry machinery						
<18 kW	-	-	-	-	-	2019
18–37 kW	-	2003	2007	-	-	2019
37–56 kW	2003	2004	2008	2013		2019
56–75 kW	2003	2004	2008	2012	2014	2020
75–130 kW	2003	2004	2007	2012	2014	2020
>130 kW	-	2003	2006	2011	2014	2019

Sources: EC 1997, 2014

A3-2

Small petrol-fuelled appliances

Tab. 23 > EU emission limit levels for small petrol-fuelled appliances (in g/kWh)

Figures in parentheses are total maximum limit values for hydrocarbon and nitrogen oxide emissions (HC + NO_x).

Engine power class	EU I	EU II	EU V		Capacity	EU I	EU II	EU V
Carbon monoxide (CO)								
<20 cc	805	805	805		<66 cc	519	610	610
20–50 cc	805	805	805		66–100 cc	519	610	610
>50 cc	603	603	603		100–225 cc	519	610	610
-	-	-	-		>225 cc	519	610	610
Hydrocarbons (HC)								
<20 cc	295	(50)	(50)		<66 cc	(50)	(50)	(10)
20–50 cc	241	(50)	(50)		66–100 cc	(40)	(40)	(10)
>50 cc	161	(72)	(72)		100–225 cc	(16.1)	(16.1)	(10)
-	-	-	-		>225 cc	(13.4)	(12.1)	(8)
Nitrogen oxides (NO_x)								
<20 cc	5.36	(50)	(50)		<66 cc	(50)	(50)	(10)
20–50 cc	5.36	(50)	(50)		66–100 cc	(40)	(40)	(10)
>50 cc	5.36	(72)	(72)		100–225 cc	(16.1)	(16.1)	(10)
-	-	-	-		>225 cc	(13.4)	(12.1)	(8)
Assumptions with respect to introduction of emission categories								
<20 cc	2004	2008	2019		<66 cc	2004	2005	2019
20–50 cc	2004	2008	2019		66–100 cc	2004	2005	2019
>50 cc	2004	2009	2019		100–225 cc	2004	2005	2019
-	-	-	-		>225 cc	2004	2007	2019

Source: EC 1997

A3-3

Navigation machinery

Tab. 24 > Emission limit values for diesel ships (in g/kWh)

The emission limit values for the SAV emission categories were calculated on the basis of mean capacities.

The figures in brackets are limit values for the total of hydrocarbon and nitrogen oxide emissions ($HC+NO_X$).

Engine power class	SAV I	SAV II[17]	EU I	EU II	EU IIIa	EU V
Carbon monoxide (CO)						
<18 kW	-	-	-	-	-	-
18–37 kW	100	45	-	-	-	-
37–75 kW	80	30	6.5	5.0	5.0	5
75–130 kW	60	20	5.0	5.0	5.0	5
130–300 kW	60	20	5.0	5.0	5.0	3.5
300–560 kW	60	20	5.0	5.0	5.0	3.5
560–1,000 kW	60	20	5.0	5.0	5.0	3.5
>1,000 kW	60	20	5.0	5.0	5.0	3.5
Hydrocarbons (HC)						
<18 kW	-	-	-	-	-	-
18–37 kW	8.0	3.4	-	-	-	-
37–75 kW	6.0	2.2	1.3	1.3	(7.5)	(4.7)
75–130 kW	4.5	1.6	1.3	1.0	(7.2)	(5.4)
130–300 kW	4.0	1.3	1.3	1.0	(7.2)	1
300–560 kW	3.5	1.2	1.3	1.0	(7.2)	0.19
560–1,000 kW	3.1	1.0	1.3	1.0	(7.2)	0.19
>1,000 kW	3.1	1.0	1.3	1.0	(7.2)	0.19
Nitrogen oxides (NO_X)						
<18 kW	-	-	-	-	-	-
18–37 kW	15	10	-	-	-	-
37–75 kW	15	10	9.2	7.0	(7.5)	(4.7)
75–130 kW	15	10	9.2	6.0	(7.2)	(5.4)
130–300 kW	15	10	9.2	6.0	(7.2)	2.1
300–560 kW	15	10	9.2	6.0	(7.2)	1.2
560–1,000 kW	15	10	9.2	6.0	(7.2)	1.2
>1,000 kW	15	10	9.2	6.0	(7.2)	0.4

Legal bases for emission limit values:
SAV (2007), paragraph 7.2.1,
SAV (2007), paragraph 7.2.2,
SAV (2007), paragraph 3.1.5,
SAV (2007), paragraph 3.1.5,
SAV (2007), paragraph 7.2.2 and Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.2.3,
Maximum PM emission values are indicated in the ordinance as smoke degree.
According to EC (2014)

[17] For ship engines, SAV II is only binding for vessels operated on Lake Constance.

Engine power class	SAV I	SAV II[17]	EU I	EU II	EU IIIa	EU V
Particulate matter (PM)						
<18 kW	4.0/3.0*	3.5/2.5*	-	-	-	-
18–37 kW	4.0/3.0*	3.5/2.5*	-	-	-	-
37–75 kW	4.0/3.0*	3.5/2.5*	0.85	0.40	0.40	0.30
75–130 kW	4.0/3.0*	3.5/2.5*	0.70	0.30	0.30	0.14
130–300 kW	4.0/3.0*	3.5/2.5*	0.54	0.20	0.20	0.11
300–560 kW	4.0/3.0*	3.5/2.5*	0.54	0.20	0.20	0.02
560–1,000 kW	4.0/3.0*	3.5/2.5*	0.54	0.20	0.20	0.02
>1,000 kW	4.0/3.0*	3.5/2.5*	0.54	0.20	0.20	0.01
Assumptions regarding the introduction of the emission stages						
All classes	1995	1996	2003	2008	2009	2019

Tab. 25 > Emission limit values for diesel boats (in g/kWh)

The limit values for the SAV emission stages were calculated on the basis of mean capacities.

Engine power class	SAV I	SAV II[18]	EU I	EU II
Carbon monoxide (CO)				
<4.4 kW	350	200	5	5
4.4–7.4 kW	250	125	5	5
7.4–37 kW	130	50	5	5
37–74 kW	80	30	5	5
74–100 kW	65	22	5	5
>100 kW	60	20	5	5
Hydrocarbons (HC)				
<4.4 kW	25	15	2.7	2.7
4.4–7.4 kW	17	9	2.3	2.3
7.4–37 kW	9	4	1.9	1.9
37–74 kW	6	2.2	1.8	(4.7)
74–100 kW	5	1.6	1.7	(5.8)
>100 kW	4	1.4	1.7	(5.8)
Nitrogen oxides (NO_X)				
<4.4 kW	15	10	9.8	9.8
4.4–7.4 kW	15	10	9.8	9.8
7.4–37 kW	15	10	9.8	9.8
37–74 kW	15	10	9.8	(4.7)
74–100 kW	15	10	9.8	(5.8)
>100 kW	15	10	9.8	(5.8)
Particulate matter (PM)				
<4.4 kW	4.0/3.0*	3.5/2.5*	1.0	0.30
4.4–7.4 kW	4.0/3.0*	3.5/2.5*	1.0	0.30
7.4–37 kW	4.0/3.0*	3.5/2.5*	1.0	0.30
37–74 kW	4.0/3.0*	3.5/2.5*	1.0	0.15
74–100 kW	4.0/3.0*	3.5/2.5*	1.0	0.15
>100 kW	4.0/3.0*	3.5/2.5*	1.0	0.15
Assumptions regarding the introduction of emission stages				
All power classes	1995	1996	2007	2015

Legal bases for emission limit values:
SAV (2007), paragraph 7.2.1 and Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.2.1,
SAV (2007), paragraph 7.2.2 and Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.2.3,
*Maximum PM emission levels are indicated in the ordinance as smoke degree,
Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.3.1.2,
SAV (2007), paragraph 3.1.1.

[18] For boat engines, SAV II is only binding for vessels operated on Lake Constance.

Tab. 26 > Emission limit values for petrol-fuelled boats (in g/kWh)

The limit values for the SAV emission stages were calculated on the basis of mean capacities.

Engine power class	2-stroke petrol engines			4-stroke petrol engines		
	SAV I	SAV II	SAV/EU[19]	SAV I	SAV II[20]	EU I
Carbon monoxide (CO)						
<4.4 kW	350	200	350	350	200	350
4.4–7.4 kW	250	125	250	250	125	250
7.4–37 kW	130	54	180	130	54	180
37–74 kW	80	30	160	80	30	160
74–100 kW	65	22	157	65	22	157
>100 kW	60	20	155	60	20	155
Hydrocarbons (HC)						
<4.4 kW	25	15	28	25	15	28
4.4–7.4 kW	17	9.4	19	17	9.4	19
7.4–37 kW	9	4.0	11	9	4.0	11
37–74 kW	6	2.2	8.5	6	2.2	8.5
74–100 kW	5	1.6	7.8	5	1.6	7.8
>100 kW	4	1.4	7.3	4	1.4	7.3
Nitrogen oxides (NO_x)						
<4.4 kW	15	8.5	15	15	8.5	15
4.4–7.4 kW	15	7.6	15	15	7.6	15
7.4–37 kW	15	6.3	15	15	6.3	15
37–74 kW	15	5.5	15	15	5.5	15
74–100 kW	15	5.1	15	15	5.1	15
>100 kW	15	5.0	15	15	5.0	15
Assumptions regarding the introduction of EU emission stages						
All power classes	1995	1996	2007	1993	1996	2007

Legal bases for emission limit values: SAV (2007), paragraph 7.2.1 and Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.2.1, Lake Constance shipping ordinance (2005), Appendix C, paragraph 3.3.1.1, SAV (2007), paragraph 3.1.1, SAV (2007), paragraph 7.3, identical to figure for 4-stroke engines.

[19] In accordance with the SAV, the same levels apply to both 2-stroke and 4-stroke engines.

[20] For boat engines, SAV II is only binding for vessels operated on Lake Constance, and (since 2006) only for petrol engines with a power range >74 kW.

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Railway vehicles

Tab. 27 > Emission limit values for railway vehicles[21] (in g/kWh)

he figures are non-binding recommendations. The figures in brackets are emission limit values for the total of hydrocarbon and nitrogen oxide emissions ($HC+NO_X$).

Engine power class	UIC IA	UIC IB	UIC IC	UIC II	UIC III	EU IIIa	EU IIIb	EU V
Carbon monoxide (CO)								
<560 kW	8.0	4.0	3.0	2.5	2.0	3.5	3.5	3.5
>560 kW	8.0	4.0	3.0	3.0	2.0	3.5	3.5	3.5
Hydrocarbons (HC)								
<560 kW	2.4	1.6	0.8	0.6	0.5	(4.0)	(4.0)	(4.0)
>560 kW	2.4	1.6	0.8	0.8	0.5	0.5	0.4	0.4
Nitrogen oxides (NO_X)								
<560 kW	20.0	16.0	12.0	6.0	4.5	(4.0)	(4.0)	(4.0)
>560 kW	20.0	16.0	12.0	9.5	6.0	6.0	3.6	0.4
Particulate matter (PM)								
<560 kW	2.5	2.0	1.6	0.25	0.15	0.2	0.025	0.025
>560 kW	2.5	2.0	1.6	0.25	0.20	0.2	0.025	0.025
Assumptions regarding the introduction of emission stages								
<560 kW	1982	1993	1997	2003	2008	2007	2012	2019
>560 kW	1982	1993	1997	2003	2008	2009	2012	2019

Sources: IFEU 2003; EU emission stages: EC 2004

[21] In EU Directive 97/68/EC, locomotives and railcars are dealt with separately, but for the engine power classes concerned here the limit valuesare identical.

A4 Emission and energy consumption factor

A4-1 Diesel machines excluding ships/boats and railway vehicles

Tab. 28 > Emission factors for diesel machines (in g/kWh) – regulated pollutants

Figures rounded up or down to 2 decimal places. Figures in italics: assumptions regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Carbon monoxide (CO)								
<18 kW	6.71	6.71	2.90	2.90	2.90	2.90	2.90	*2.90*
18–37 kW	6.71	6.71	2.76	2.42	2.06	1.76	1.50	*→ 1.50*
37–56 kW	4.68	4.68	1.87	1.63	1.39	1.19	1.01	*→ 1.01*
56–75 kW	4.68	4.68	1.87	1.63	1.39	1.19	1.01	*→ 1.01*
75–130 kW	3.62	3.62	1.28	1.01	0.86	0.73	0.62	*→ 0.62*
130–560 kW	3.62	3.62	1.04	0.91	0.77	0.66	0.50	*→ 0.50*
>560 kW	3.62	3.62	1.04	0.91	0.77	0.66	0.50	*→ 0.50*
Hydrocarbons (HC)								
<18 kW	2.28	2.28	1.60	1.00	0.59	0.59	0.59	*0.53*
18–37 kW	2.41	2.41	0.92	0.56	0.37	0.37	0.37	*0.37*
37–56 kW	1.33	1.33	0.65	0.46	0.33	0.33	0.33	*0.33*
56–75 kW	1.33	1.33	0.65	0.46	0.33	0.13	0.13	*0.13*
75–130 kW	0.91	0.91	0.45	0.35	0.28	0.17	0.17	*0.13*
130–560 kW	0.91	0.91	0.43	0.30	0.22	0.17	0.17	*0.13*
>560 kW	0.91	0.91	0.43	0.30	0.22	0.17	0.17	*0.13*
Nitrogen oxides (NO_x)								
<18 kW	10.31	8.20	5.95	5.95	5.95	5.95	5.95	*5.95*
18–37 kW	↑ 10.31	↑ 8.20	6.34	6.34	6.34	6.34	6.34	*6.34*
37–56 kW	12.40	9.87	8.95	6.56	3.90	→ 3.90	→ 3.90	*→ 3.90*
56–75 kW	12.40	9.87	8.95	6.56	3.90	3.30	0.40	*0.40*
75–130 kW	12.52	9.96	8.44	5.67	3.32	3.30	0.40	*0.40*
130–560 kW	12.52	9.96	8.19	5.66	3.38	2.00	0.40	*0.40*
>560 kW	12.52	9.96	8.19	5.66	→ 5.66	→ 5.66	→ 5.66	*3.50*
Particulate matter (PM)								
<18 kW	1.51	1.18	1.00	0.80	0.70	0.60	0.60	*0.40*
18–37 kW	1.20	0.94	0.74[22]	0.60	0.54	→ 0.54	→ 0.54	*0.01*
37–56 kW	1.09	0.85	0.47	0.32	→ 0.32	0.03	0.03	*0.01*
56–75 kW	1.09	0.85	0.47	0.32	→ 0.32	0.03	0.03	*0.01*
75–130 kW	0.61	0.47	0.35	0.24	→ 0.24	0.03	0.03	*0.01*
130–560 kW	0.61	0.47	0.22	0.16	→ 0.16	0.03	0.03	*0.01*
>560 kW	0.61	0.47	0.22	0.16	→ 0.16	→ 0.16	→ 0.16	*0.05*

Sources of emission and consumption factors:

EPA data,

EPA data with reduction rate equivalent to that for black exhaust measurement data,

Homologation level plus manufacturing tolerance,

Average of homologation and limit value,

Division of limit value for total of HC + NO_x, less 10 %,

Maximum level less 30 %,

Maximum level less 10 %,

Emission limit value

Assumption or adoption of figure from another emission stage (arrow).

[22] Level based on evaluations of black exhaust measurement data.

Engine power class	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	EU V
Fuel consumption								
<18 kW	248	248	248	248	248	248	248	248
18–37 kW	248	248	248	248	248	248	248	248
37–75 kW	248	248	248	248	248	248	248	248
75–130 kW	223	223	223	223	223	223	223	223
>130 kW	223	223	223	223	223	223	223	223

Tab. 29 > Emission factors for diesel machines (in g/kWh) – non-regulated pollutants

Figures in italics: assumption regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	*EU V*
Methane (CH_4)[23]								
<18 kW	0.0547	0.0547	0.0384	0.0240	0.0142	0.0142	0.0142	*0.0089*
18–37 kW	0.0578	0.0578	0.0221	0.0134	0.0089	0.0089	0.0089	*0.0089*
37–56 kW	0.0319	0.0319	0.0156	0.0110	0.0079	0.0055	0.0058	*0.0055*
56–75 kW	0.0319	0.0319	0.0156	0.0110	0.0079	0.0031	0.0031	*0.0031*
75–130 kW	0.0218	0.0218	0.0108	0.0084	0.0067	0.0031	0.0031	*0.0031*
130–560 kW	0.0218	0.0218	0.0103	0.0072	0.0053	0.0031	0.0031	*0.0031*
>560 kW	0.0218	0.0218	0.0103	0.0072	0.0053	0.0031	0.0031	*0.0031*
Non-methane hydrocarbons (NMHC)[24]								
<18 kW	2.23	2.23	1.56	0.98	0.58	0.58	0.58	*0.52*
18–37 kW	2.35	2.35	0.90	0.55	0.36	0.36	0.36	*0.36*
37–56 kW	1.30	1.30	0.63	0.45	0.32	0.32	0.32	*0.32*
56–75 kW	1.30	1.30	0.63	0.45	0.32	0.13	0.13	*0.13*
75–130 kW	0.89	0.89	0.44	0.34	0.27	0.13	0.13	*0.13*
130–560 kW	0.89	0.89	0.42	0.29	0.21	0.13	0.13	*0.13*
>560 kW	0.89	0.89	0.42	0.29	0.21	0.13	0.13	*0.13*
Nitrous oxide (N_2O)								
0–3,000 kW	0.035	0.035	0.035	0.035	0.035	0.035	0.035	*0.035*
Benzene (C_6H_6)[25]								
<18 kW	0.0034	0.0034	0.0024	0.0015	0.0009	0.0009	0.0009	*0.0008*
18–37 kW	0.0036	0.0036	0.0014	0.0008	0.0006	0.0006	0.0006	*0.0006*
37–56 kW	0.0020	0.0020	0.0010	0.0007	0.0005	0.0005	0.0005	*0.0005*
56–75 kW	0.0020	0.0020	0.0010	0.0007	0.0005	0.0002	0.0002	*0.0002*
75–130 kW	0.0014	0.0014	0.0007	0.0005	0.0004	0.0002	0.0002	*0.0002*
130–560 kW	0.0014	0.0014	0.0006	0.0005	0.0003	0.0002	0.0002	*0.0002*
>560 kW	0.0014	0.0014	0.0006	0.0005	0.0003	0.0002	0.0002	*0.0002*

Sources: IFEU 2009; INFRAS 2008

[23] 2.4 % of hydrocarbons (IFEU 2009)
[24] 97.6 % of hydrocarbons (IFEU 2009)
[25] 0.15 % of hydrocarbons (INFRAS 2008)

Tab. 30 > Assumptions regarding the introduction of emission stages

The first machines in the respective emission stages are to be put into operation from the year indicated in the table. See chapter 4.3.4 for assumptions regarding the delayed introduction of emission stages.

For emission categories in which the emission factors are based on assumptions instead of limit values(cf. chapter 4.3.3), the year of introduction is placed in parentheses.

Figures in italics: assumptions regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	*EU V*
Construction, industrial and military machinery								
<18 kW	(<1996)	(1996)	(2002)	(2004)	(2008)	(2012)	-	*2019*
18–37 kW	(<1996)	(1996)	-	2002	2007	(2012)	-	*2019*
37–56 kW	(<1996)	(1996)	2002	2004	2008	(2012)	(2014)	*2019*
56–75 kW	(<1996)	(1996)	2002	2004	2008	2012	2014	*2020*
75–130 kW	(<1996)	(1996)	2002	2003	2007	2012	2014	*2020*
>130 kW	(<1996)	(1996)	2002	2002	2006	2011	2014	*2019*
Agricultural and forestry machinery								
<18 kW	(<1996)	(1996)	(2003)	(2004)	(2004)	(2012)	-	*2019*
18–37 kW	(<1996)	(1996)	-	2003	2007	(2012)	-	*2019*
37–56 kW	(<1996)	(1996)	2003	2004	2008	(2012)	(2014)	*2019*
56–75 kW	(<1996)	(1996)	2003	2004	2008	2012	2014	*2020*
75–130 kW	(<1996)	(1996)	2003	2004	2007	2012	2014	*2020*
>130 kW	(<1996)	(1996)	-	2003	2006	2011	2014	*2019*

Sources: EC 1997, 2014

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Gas-fuelled machines

Tab. 31 > Emission factors for gas-fuelled machines (in g/kWh)

For gas-fuelled machines, emission factors are based on measurements of engines with different degrees of retrofitting (with or without a catalyser) instead of on emission limit values.

Pollutant	Without after-treatment	With oxidation catalysers	50% with 3-way catalysers	100% with 3-way catalysers
CO	10	0.2	0.2	0.2
HC	8	0.5	0.5	0.5
NO_X	10	10	6	2
PM	0.02	0.01	0.01	0.01
FC	450	450	455	460
CH_4[26]	0.552	0.035	0.035	0.035
NMHC[27]	7.448	0.466	0.466	0.466
N_2O	0.05	0.05	0.05	0.05
C_6H_6	0	0	0	0

Assumptions regarding introduction of emission stages

All capacities		1980	1994	2000

Sources of emission and consumption factors: Mayer 2005; EEA 2013

[26] 6.9 % of HC emissions (EEA 2013)
[27] 93.1 % of HC emissions (EEA 2013)

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Petrol-fuelled appliances

Tab. 32 > Emission factors for appliances with 4-stroke petrol engines (in g/kWh) – regulated pollutants

For appliances brought into circulation before 2004, the emission factors are based on the corresponding assumptions (Pre-EU) instead of on emission limit values. The year of introduction is shown in parentheses. Figures in italics: assumption regarding the future development of emission factors.

Capacity range	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	*EU V*
Carbon monoxide (CO)						
<66 cc	470	470	470	467	→ 467	*→ 467*
66–100 cc	470	470	470	467	→ 467	*→ 467*
100–225 cc	470	470	470	467	→ 467	*→ 467*
>225 cc	470	470	470	467	→ 467	*→ 467*
Hydrocarbons (HC)						
<66 cc	60	60	60	41	41	*8*
66–100 cc	40	40	40	32	32	*8*
100–225 cc	20	20	20	12	12	*8*
>225 cc	20	20	20	10	9	*6*
Nitrogen oxides (NO_X)						
<66 cc	1.5	2	3	4.5	4.5	*0.9*
66–100 cc	1.5	2	3	3.6	3.6	*0.9*
100–225 cc	3.5	3.5	3.5	2.8	2.8	*0.9*
>225 cc	3.5	3.5	3.5	2.2	1.9	*0.72*
Fuel consumption (FC)						
<66 cc	500	500	500	480	480	*460*
66–100 cc	480	480	480	470	470	*460*
100–225 cc	460	460	460	450	450	*450*
>225 cc	460	460	460	450	450	*450*
Assumptions regarding introduction of emission stages						
<66 cc	(<1996)	(1996)	(2000)	2004	2005	*2019*
66–100 cc	(<1996)	(1996)	(2000)	2004	2005	*2019*
100–225 cc	(<1996)	(1996)	(2000)	2004	2009	*2019*
>225 cc	(<1996)	(1996)	(2000)	2004	2007	*2019*

Sources of emission and consumption factors:

Division of maximum level for total of HC + NO_X, less 10 %,

Reduction parallel to HC emissions

Limit value less 10 %,

Maximum limit value

Assumptions or adopted level from another emission category or capacity (arrow).

Tab. 33 > Emission factors for appliances with 4-stroke petrol engines (in g/kWh) – non-regulated pollutants, except benzene[28]

Figures in italics: assumption regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	*EU V*
Methane (CH_4)[29]						
<66 cc	2.04	2.04	2.04	1.394	1.394	*0.272*
66–100 cc	1.36	1.36	1.36	1.088	1.088	*0.272*
100–225 cc	0.68	0.68	0.68	0.408	0.408	*0.272*
>225 cc	0.68	0.68	0.68	0.34	0.306	*0.204*
Non-methane hydrocarbons (NMHC)[30]						
<66 cc	58.0	58.0	58.0	39.6	39.6	*7.7*
66–100 cc	38.6	38.6	38.6	30.9	30.9	*7.7*
100–225 cc	19.3	19.3	19.3	11.6	11.6	*7.7*
>225 cc	19.3	19.3	19.3	9.7	8.7	*5.8*
Nitrous oxide (N_2O)						
0–3,000 cc	0.03	0.03	0.03	0.03	0.03	*0.03*

Sources: INFRAS 2008; IFEU 2009; EEA 2013

[28] Benzene emission factors, cf. Tab. 43 on page 173
[29] 3.4 % of hydrocarbons (IFEU 2009)
[30] 96.6 % of hydrocarbons (IFEU 2009)

Tab. 34 > Emission factors for appliances with 2-stroke petrol engines (in g/kWh) – regulated pollutants

For appliances brought into circulation before 2004, the emission factors are based on the corresponding assumptions (Pre-EU) instead of on emission limit values. The year of introduction is shown in parentheses. Figures in italics: assumption regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	*EU V*
Carbon monoxide (CO)						
<20 cc	650	640	620	→ 600	→ 600	*500*
20–50 cc	650	640	620	→ 600	→ 600	*500*
>50 cc	650	640	620	540	540	*500*
Hydrocarbons (HC)						
<20 cc	260	250	150	100	41	*41*
20–50 cc	260	250	150	100	41	*41*
>50 cc	260	250	150	100	58	*58*
Nitrogen oxides (NO_X)						
<20 cc	1.5	2	3	4.8	4.5	*4.5*
20–50 cc	1.5	2	3	4.8	4.5	*4.5*
>50 cc	1.5	2	3	4.8	6.3	*6.3*
Fuel consumption						
<20 cc	660	650	550	500	440	*410*
20–50 cc	660	650	550	500	440	*410*
>50 cc	660	650	550	500	460	*410*
Assumptions regarding the introduction of emission stages						
<20 cc	(<1996)	(1996)	(2000)	2004	2009	*2019*
20–50 cc	(<1996)	(1996)	(2000)	2004	2009	*2019*
>50 cc	(<1996)	(1996)	(2000)	2004	2011	*2019*

Source: SAEFL 1996

Sources of emission and consumption factors:

Division of maximum level for the total of HC + NO_X, less 10 %,

Reduction parallel to reduction of HC emissions

Limit value less 10 %,

Assumption or adopted level from another emission category/capacity (arrow).

Tab. 35 > Emission factors for appliances with 2-stroke petrol engines (in g/kWh) – non-regulated pollutants, except benzene[31]

Figures in italics: assumption regarding the future development of emission factors.

Engine power class	Pre-EU A	Pre-EU B	Pre-EU C	EU I	EU II	*EU V*
Methane (CH_4)[32]						
<20 cc	18.2	17.5	10.5	7	2.87	*2.87*
20–50 cc	18.2	17.5	10.5	7	2.87	*2.87*
>50 cc	18.2	17.5	10.5	7	4.06	*4.06*
Non-methane hydrocarbons (NMHC)[33]						
<20 cc	242	233	140	93	38	*38*
20–50 cc	242	233	140	93	38	*38*
>50 cc	242	233	140	93	54	*54*
Nitrous oxide (N_2O)						
0–3,000 cc	0.01	0.01	0.01	0.01	0.01	*0.01*

Sources: INFRAS 2008; IFEU 2009; EEA 2013

[31] Benzene emission factors, cf. Tab. 43 on page 173
[32] 7 % of hydrocarbons (IFEU 2009)
[33] 93 % of hydrocarbons (IFEU 2009)

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Navigation machinery

Tab. 36 > Emission factors for diesel ships (in g/kWh)

Figures in italics: assumption regarding the future development of emission factors.
Non-regulated pollutants: same emission factors as for the other diesel machines (Tab. 28).

Engine power class	Pre-SAV	SAV	EU I	EU II	EU IIIa	*EU V*
Carbon monoxide (CO)						
<18 kW	6.7	6.7	6.7	6.7	6.7	*6.7*
18–37 kW	6.7	6.7	6.7	6.7	6.7	*6.7*
37–75 kW	5.9	5.9	5.9	4.5	4.5	*4.5*
75–130 kW	5	5	4.5	4.5	4.5	*4.5*
130–300 kW	5	5	4.5	4.5	4.5	*3.15*
300–560 kW	5	5	4.5	4.5	4.5	*3.15*
>560 kW	5	5	4.5	4.5	4.5	*3.15*
Hydrocarbons (HC)						
<18 kW	10	7.2	5.0	3.0	2.0	*2.0*
18–37 kW	10	7.2	5.0	3.0	2.0	*2.0*
37–75 kW	10	5.4	1.2	1.2	1.1	*0.42*
75–130 kW	10	4.1	1.2	0.9	0.8	*0.49*
130–300 kW	5	3.6	1.2	0.9	0.8	*→ 0.8*
300–560 kW	5	3.2	1.2	0.9	0.8	*0.17*
>560 kW	5	2.8	1.2	0.9	0.8	*0.17*
Nitrogen oxides (NO_X)						
<18 kW	10.3	10.3	10.3	10.3	10.3	*10.3*
18–37 kW	10.3	10.3	10.3	10.3	10.3	*10.3*
37–75 kW	12.4	12.4	8.3	6.3	5.7	*4.23*
75–130 kW	12.5	12.5	8.3	6.3	5.7	*4.86*
130–300 kW	12.5	12.5	8.3	6.3	5.7	*2.1*
300–1,000 kW	12.5	12.5	8.3	6.3	5.7	*1.2*
>1,000 kW	12.5	12.5	8.3	6.3	5.7	*0.4*
Particulate matter (PM)						
<18 kW	1.5	1.2	1.0	0.80	0.70	*→ 0.70*
18–37 kW	1.2	0.9	0.74	0.60	0.54	*→ 0.54*
37–75 kW	1.1	0.58	0.77	0.36	0.36	*0.3*
75–130 kW	0.6	0.47	0.63	0.27	0.27	*0.14*
130–300 kW	0.6	0.47	0.49	0.18	0.18	*0.11*
300–1,000 kW	0.6	0.47	0.49	0.18	0.18	*0.02*
>1,000 kW	0.6	0.47	0.49	0.18	0.18	*0.01*

Sources for emission and consumption factors:

Same figure as for diesel engines (Tab. 28),

Division of maximum level for the total of HC + NO_X, less 10 %,

Maximum level, less 10 %,

Maximum level,

Division of maximum level for the total of HC + NO_X

Assumption or adopted level from another emission category/capacity (arrow)

Engine power class	Pre-SAV	SAV	EU I	EU II	EU IIIa	*EU V*
Fuel consumption						
<18 kW	248	248	248	248	248	*248*
18–37 kW	248	248	248	248	248	*248*
37–75 kW	248	248	248	248	248	*248*
75–130 kW	223	223	223	223	223	*223*
>130 kW	223	223	223	223	223	*223*
Assumptions regarding introduction of emission stages						
All capacities	(<1995)	1995	2003	2008	2009	*2019*

Source for consumption factors: SAEFL 1996

Tab. 37 > Emission factors for boats with diesel engines (in g/kWh)

Figures in italics: assumption regarding the future development of emission factors.
Non-regulated pollutants: same emission factors as for the other diesel machines (Tab. 28).

Engine power class	Pre-SAV	SAV	EU I	*EU II*
Carbon monoxide (CO)				
<4.4 kW	6.7	6.7	4.5	*4.5*
4.4–7.4 kW	6.7	6.7	4.5	*4.5*
7.4–37 kW	6.7	6.7	4.5	*4.5*
37–74 kW	5.9	5.9	4.5	*4.5*
74–100 kW	5.0	5.0	4.5	*4.5*
>100 kW	5.0	3.6 (6%)	→ 3.6	→ 3.6
Hydrocarbons (HC)				
<4.4 kW	10	10	2.4	*2.4*
4.4–7.4 kW	10	10	2.1	*2.1*
7.4–37 kW	10	2.0 (23%)	1.7	*1.7*
37–74 kW	10	1.4 (23%)	→ 1.4	*0.42*
74–100 kW	10	1.2 (23%)	→ 1.2	*0.52*
>100 kW	5	1.2 (30%)	→ 1.2	*0.52*
Nitrogen oxides (NO_x)				
<4.4 kW	13	11	8.8	*8.8*
4.4–7.4 kW	13	11 (71 %)	8.8	*8.8*
7.4–37 kW	13	11 (71 %)	8.8	*8.8*
37–74 kW	13	11 (71 %)	8.8	*4.23*
74–100 kW	13	11 (71 %)	8.8	*5.22*
>100 kW	13	11 (73 %)	8.8	*5.22*

Sources of emission and consumption factors:

Same figure as for diesel engines (Tab. 28),

Division of maximum level for the total of HC + NO_x, less 10%,

Limit value, taking account of utilisation of limit values (figure in parentheses) according to EMPA 2006,

Limit value, less 10 %,

Limit value,

Division of limit value for the total of HC + NO_x

Assumption or adopted level from another emission stage/power class (arrow).

Engine power class	Pre-SAV	SAV	EU I	*EU II*
Particulate matter (PM)				
<4.4 kW	1.5	1.2	0.9	*0.9*
4.4–7.4 kW	1.5	1.2	0.9	*0.9*
7.4–37 kW	1.2	1.1	0.9	*0.9*
37–74 kW	1.1	1.0	0.9	*0.3*
74–100 kW	0.9	0.9	0.9	*0.15*
>100 kW	0.9	0.9	0.9	*0.15*
Fuel consumption				
<4.4 kW	400	400	400	*400*
4.4–7.4 kW	400	400	400	*400*
7.4–37 kW	400	380	380	*380*
37–74 kW	380	350	350	*350*
74–100 kW	400	330	330	*330*
>100 kW	300	300	300	*300*
Assumptions regarding the introduction of emission stages				
All power classes	(<1995)	1995	2007	*2015*

Source for consumption factors: SAEFL 1996

Tab. 38 > Emission factors for boats with petrol engines (in g/kWh) – regulated pollutants

Engine power class	2-stroke petrol engines			4-stroke petrol engines		
	Pre-SAV	SAV	SAV/EU	Pre-SAV	SAV	EU
Carbon monoxide (CO)						
<4.4 kW	645	315	315	350	315	315
4.4–7.4 kW	645	200 (79 %)	225	350	200 (79 %)	225
7.4–37 kW	645	100 (79 %)	162	350	100 (79 %)	162
37–74 kW	645	65 (79 %)	144	350	65 (79 %)	144
74–100 kW	645	55 (79 %)	141	350	55 (79 %)	141
>100 kW	645	45 (73 %)	139	350	45 (73 %)	139
Hydrocarbons (HC)						
<4.4 kW	260	22	25	25	22	25
4.4–7.4 kW	260	12 (66%)	13	20	12 (66%)	13
7.4–37 kW	260	6.0 (66%)	8	20	6.0 (66%)	8
37–74 kW	260	4.0 (66%)	6	20	4.0 (66%)	6
74–100 kW	260	3.3 (66%)	5	20	3.3 (66%)	5
>100 kW	260	2.1 (52%)	5	20	2.1 (52%)	5
Nitrogen oxides (NO_x)						
<4.4 kW	15	13	13	3.5	13	13
4.4–7.4 kW	15	9.3 (62%)	→ 9.3	3.5	9.3 (62%)	→ 9.3
7.4–37 kW	15	9.3 (62%)	→ 9.3	3.5	9.3 (62%)	→ 9.3
37–74 kW	15	9.3 (62%)	→ 9.3	3.5	9.3 (62%)	→ 9.3
74–100 kW	15	9.3 (62%)	→ 9.3	3.5	9.3 (62%)	→ 9.3
>100 kW	15	9.6 (64%)	→ 9.6	3.5	9.6 (64%)	→ 9.6
Fuel consumption						
<4.4 kW	700	400	400	400	400	400
4.4–7.4 kW	700	400	400	400	400	400
7.4–37 kW	650	380	380	380	380	380
37–74 kW	650	380	380	380	380	380
74–100 kW	650	380	380	380	380	380
>100 kW	650	380	380	380	380	380
Assumptions regarding the introduction of emission stages						
All capacities	(<1995)	1995	2007	(<1995)	1995	2007

Source of consumption factors: SAEFL 1996a

Sources of emission and consumption factors:

Same figure as for petrol engines (Tab. 32, Tab. 34),

Limit value, less 10 %,

Limit value, less 30% due to requirement to comply with limit value for 1 more year,

Limit value, taking account of utilisation of limit value (figure in parentheses) according to EMPA 2006,

Assumption or adopted level from another emission stage/power class (arrow).

Tab. 39 > Emission factors for boats with petrol engines (in g/kWh) – non-regulated pollutants, except benzene[34]

Engine power class	2-stroke petrol engines			4-stroke petrol engines		
	Pre-SAV	SAV	SAV/EU	Pre-SAV	SAV	EU
Methane (CH_4)[35]						
<4.4 kW	18.20	1.54	1.75	1.25	1.10	1.25
4.4–7.4 kW	18.20	0.84	0.91	1.00	0.60	0.65
7.4–37 kW	18.20	0.42	0.56	1.00	0.30	0.40
37–74 kW	18.20	0.42	0.56	1.00	0.20	0.30
74–100 kW	18.20	0.42	0.56	1.00	0.17	0.25
>100 kW	18.20	0.42	0.56	1.00	0.10	0.25
Non-methane hydrocarbons (NMHC)[36]						
<4.4 kW	241.8	20.5	23.3	23.8	20.9	23.8
4.4–7.4 kW	241.8	11.2	12.1	19.0	11.4	12.4
7.4–37 kW	241.8	5.6	7.4	19.0	5.7	7.6
37–74 kW	241.8	5.6	7.4	19.0	3.8	5.7
74–100 kW	241.8	5.6	7.4	19.0	3.1	4.8
>100 kW	241.8	5.6	7.4	19.0	2.0	4.8
Nitrous oxide (N_2O)						
0–300 kW	0.01	0.01	0.01	0.03	0.03	0.03

Sources: INFRAS 2008; IFEU 2009; EEA 2013

[34] Benzene emission factors, cf. Tab. 43 on page 173

[35] 4-stroke engines: 5 % of hydrocarbons; 2-stroke engines: 7 % of hydrocarbons (IFEU 2009)

[36] 4-stroke engines: 95 % of hydrocarbons; 2-stroke engines: 93 % of hydrocarbons (IFEU 2009)

Tab. 40 > Emission factors for ships powered with steam (in g/kWh)

Pollutant	Steam 1	Steam 2	Steam 3	Steam 4	Steam 5	Steam 6	Steam 7
CO	0.3	0.3	0.3	0.09	0.09	0.09	0.09
HC	0.449	0.449	0.449	0.33	0.33	0.33	0.33
NO_X	2.336	2.336	2.336	1.77	1.558	1.257	1.027
PM	0.033	0.024	0.015	0.009	0.006	0.006	0.006
Fuel consumption	1406	1115	1115	1115	1115	1115	1115
CH_4	0.0218	0.0218	0.0218	0.0218	0.0218	0.0103	0.0072
NMHC	0.89	0.89	0.89	0.89	0.89	0.42	0,29
N_2O	0.035	0.035	0.035	0.035	0.035	0.035	0.035
C_6H_6	0.0014	0.0014	0.0014	0.0014	0.0014	0.0006	0.0005

Assumptions regarding the date of introduction of improvements of steamships

All classes	<1950	1950	1980	1990	1995	2000	2005

The emission and consumption factors for steamships are not based on emission limit values.

Source: SAEFL 1996a, S. 218,

Assumption based on consumption data provided by shipping companies,

Adoption of figures from the respective other diesel machines

A4-5

Railway vehicles

Tab. 41 > Emission factors for railway vehicles (in g/kWh)

Figures in italics: assumption regarding the future development of emission factors.
Non-regulated pollutants: same emission factors as for the other diesel machines (Tab. 28).

Engine power class	Pre-EU	UIC I	UIC II	EU IIIa	EU IIIb	EU V
Carbon monoxide (CO)						
<560 kW	4.0	3.0	2.5	→ 2.5	→ 2.5	→ 2.5
>560 kW	4.0	3.0	3.0	→ 3.0	→ 3.0	→ 3.0
Hydrocarbons (HC)						
<560 kW	1.6	0.8	0.6	0.4	0.17	→ 0.17
>560 kW	1.6	0.8	0.8	0.5	0.4	0.36
Nitrogen oxides (NO_X)						
<560 kW	13	12	6.0	3.2	1.8	→ 1.8
>560 kW	16	12	9.5	5.4	3.2	→ 3.2
Particulate matter (PM)						
<560 kW	0.6	0.5	0.25	0.18	0.025	*0.025*
>560 kW	0.6	0.5	0.25	0.18	0.025	*0.025*
Fuel consumption						
<560 kW	223	223	223	223	223	223
>560 kW	223	223	223	223	223	223
Assumptions regarding the introduction of EU emission stages						
<560 kW		2000	2003	2006	2012	2020
>560 kW		2000	2003	2009	2012	2020

Sources for emission and consumption factors:

Figures as for diesel engines,

Figures as for diesel engines, recommendation UIC limit value stage UIC I-II,

Limit value,

Assumption INFRAS,

Assumption or adopted level from another emission category/engine power class (arrow).

A4-6

Electric machines and appliances

Tab. 42 > Efficiency of electric machines and appliances

The figures correspond to the overall level of efficiency of motors, batteries and chargers. Since cable-operated appliances are also used in the garden-care/hobby appliances category, a distinction is made there between those operated solely by battery (roboticic lawn mowers and types intended for professional use), those operated solely by cable (wood shredders and choppers) and those with mixed operation (all other appliances). In the latter group, the proportion of battery-operated appliances will increase over time (cf. bottom row).

Engine power class	1980	1990	2000	2010	2020	2030	2040	2050
Industry (all battery-operated)								
<18 kW	47 %	47 %	48 %	50 %	55 %	62 %	68 %	74 %
18–37 kW	48 %	49 %	49 %	51 %	57 %	63 %	70 %	77 %
37–56 kW	49 %	50 %	50 %	52 %	58 %	65 %	71 %	78 %
56–75 kW	50 %	50 %	50 %	53 %	59 %	65 %	72 %	78 %
Garden-care/hobby								
<18 kW, battery	40 %	44 %	52 %	60 %	64 %	66 %	68 %	70 %
<18 kW, cable	73 %	73 %	76 %	79 %	81 %	81 %	81 %	81 %
<18 kW, mixed operation	65 %	65 %	68 %	70 %	71 %	71 %	71 %	72 %
Proportion of appliances with batteries in mixed group	3 %	5 %	10 %	33 %	50 %	58 %	67 %	75 %

Sources: de Haan & Zah 2013; Nipkow 1989; expert groups; own assumptions

A4-7

Benzene emissions of petrol engines, by year

Tab. 43 > Benzene emissions of petrol engines, by year

Since a limit value of 1% has applied for benzene in petrol since 2000, it is not possible to list the benzene emission factors for petrol engines by power class and emission stage. In view of this, the table below shows the average emission factors by engine type and capacity in 10-year intervals. The benzene emissions for petrol engines are calculated as 5% of the hydrocarbons until 1999 and 0.8% from 2000 (cf. Infras 2008). The average emission factors listed below are slightly higher than the indicated figures indicated in Tab. 32 to Tab. 39 for hydrocarbons multiplied with the indicated factors, since here the wear and tear factors (CF_3, see chapter 4.3.7) are already included.

Engine power class	1980	1990	2000	2010	2020	2030	2040	2050
Small appliances with 4-stroke engines								
<66 cc	3.00	3.00	0.66	0.50	0.43	0.09	0.09	0.09
66–100 cc	2.56	2.69	0.44	0.38	0.33	0.10	0.09	0.09
100–225 cc	1.17	1.18	0.19	0.14	0.11	0.08	0.08	0.08
>225 cc	1.45	1.45	0.23	0.14	0.10	0.07	0.07	0.07
Small appliances with 2-stroke engines								
<20 cc	14.5	14.5	2.20	1.06	0.39	0.36	0.36	0.36
20–50 cc	15.8	16.3	2.46	1.06	0.42	0.41	0.41	0.41
>50 cc	16.6	16.8	2.47	1.08	0.60	0.60	0.60	0.60
Petrol-fuelled boats with 4-stroke engines								
<4.4 kW	1.54	1.54	0.23	0.22	0.24	0.25	0.25	0.25
4.4–7.4 kW	1.27	1.26	0.16	0.12	0.13	0.13	0.13	0.13
7.4–37 kW	1.41	1.40	0.13	0.07	0.08	0.08	0.08	0.08
37–74 kW	1.26	1.25	0.11	0.05	0.06	0.06	0.06	0.06
74–100 kW	1.22	1.22	0.11	0.04	0.05	0.05	0.05	0.05
>100 kW	1.26	1.25	0.10	0.03	0.05	0.05	0.05	0.05
Petrol-fuelled boats with 2-stroke engines								
<4.4 kW	16.9	16.9	1.26	0.25	0.26	0.26	0.26	0.26
4.4–7.4 kW	16.9	16.9	1.20	0.14	0.13	0.14	0.14	0.14
7.4–37 kW	16.9	16.9	1.16	0.08	0.08	0.08	0.08	0.08

A4-8

Conversion factors for carbon dioxide emissions

Tab. 44 > Conversion factors for calculating CO_2 emissions

Grams of CO_2 per gram of fuel[37].

Fuel	Conversion factor
Diesel	3,150 g/g
Petrol	3,141 g/g
Heating oil	3,140 g/g
Gas	2,558 g/g

[37] CO_2 emissions are determined independently of the engine type with the aid of these conversion factors. As a result, carbon dioxide emissions from appliances with 2-stroke engines tend to be overestimated, since with these engines a significant proportion of carbon is emitted in the form of hydrocarbon and carbon monoxide.

A4-9

Correction factors for calculating PM emissions (PM) with fitted particle filters

Tab. 45 > Correction factors for calculating PM emissions (PM) with fitted particle filters

Engine power class	Pre-EU A	Pre-EU B	EU I	EU II	EU IIIA	EU IIIB	EU IV	*EU V*
Diesel engines (excluding navigation machinery and railway vehicles)								
<18 kW	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15
18–37 kW	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0
37–56 kW	0.1	0.1	0.1	0.1	0.1	0.4	0.4	1.0
56–75 kW	0.1	0.1	0.1	0.1	0.1	0.4	0.4	1.0
75–130 kW	0.1	0.1	0.1	0.1	0.1	0.4	0.4	1.0
130–560 kW	0.1	0.1	0.1	0.1	0.1	0.4	0.4	1.0
>560 kW	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.37
Navigation machinery								
<18 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.1
18–37 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.1
37–56 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.01
56–75 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.01
75–130 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.01
130–560 kW	0.1	0.1	0.1	0.1	0.1	–	–	0.01
>560 kW	0.1	0.1	0.1	0.1	0.1	–	–	1
Railway vehicles								
<18 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
18–37 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
37–56 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
56–75 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
75–130 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
130–560 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6
>560 kW	0.1	0.1	0.1	0.1	0.1	0.6	–	0.6

A5 Nominal capacities and load factors

Tab. 46 > Engine rated power, standard load factors and effective load factors for the individual machine types

Machine catagory	Machine type	Engine type	Engine rated power kW	Lastfaktor		
				Standard	Deviation	Effective
Construction machinery	Asphalt finishers	Diesel	71	0.48	0.42	0.20
Construction machinery	Hydraulic rammers of all types	Diesel	95	0.48	0.42	0.20
Construction machinery	Rollers of all types	Diesel	42	0.48	0.42	0.20
Construction machinery	Mechanical vibrators	Diesel	72	0.48	0.42	0.20
Construction machinery	Hand-operated rammers, vibrators	Diesel	5	0.48	0.42	0.20
Construction machinery	Hand-operated rammers, vibrators	Petrol (4-str)	4	0.20	1.00	0.20
Construction machinery	Hand-operated rammers, vibrators	Petrol (2-str)	3	0.20	1.00	0.20
Construction machinery	Cable dredgers	Diesel	103	0.48	0.73	0.35
Construction machinery	Rubber-tyred and mobile cranes	Diesel	153	0.48	0.63	0.30
Construction machinery	Graders	Diesel	130	0.48	1.00	0.48
Construction machinery	HGV's without licence for use on road	Diesel	200	0.48	1.00	0.48
Construction machinery	Crawler tractors	Diesel	129	0.48	1.00	0.48
Construction machinery	Loaders (rubber-tyred and crawler) of all types	Diesel	107	0.48	0.73	0.35
Construction machinery	Dump trucks	Diesel	74	0.48	0.73	0.35
Construction machinery	Emergency power supply systems/generators	Diesel	125	0.47	0.98	0.46
Construction machinery	Emergency power supply systems/generators	Petrol (4-str)	8	0.47	1.00	0.47
Construction machinery	Pumps of all types	Diesel	15	0.77	1.00	0.77
Construction machinery	Pumps of all types	Petrol (4-str)	5	0.20	1.00	0.20
Construction machinery	Mobile compressors	Diesel	62	0.47	0.98	0.46
Construction machinery	Mobile elevating work platforms	Diesel	72	0.48	0.42	0.20
Construction machinery	Tunnel locomotives	Diesel	193	0.48	0.60	0.29
Construction machinery	Concrete/surface milling cutters	Diesel	133	0.48	1.00	0.48
Construction machinery	Concrete/surface milling cutters	Petrol (4-str)	12	0.48	1.00	0.48
Construction machinery	Trench cutters	Diesel	22	0.48	1.00	0.48
Construction machinery	Drilling machines of all types (esp. civil engineering)	Diesel	96	0.48	0.73	0.35
Construction machinery	Mini-excavators	Diesel	19	0.48	0.66	0.32
Construction machinery	Crawler excavators	Diesel	98	0.48	0.87	0.42
Construction machinery	Wheeled excavators	Diesel	68	0.33	1.00	0.33
Industrial machinery	Forklifts of all types	Diesel	41	0.48	0.42	0.20
Industrial machinery	Forklifts of all types	Petrol (4-str)	28	0.20	1.00	0.20
Industrial machinery	Forklifts of all types	LPG	41	0.20	1.00	0.20
Industrial machinery	Forklifts of all types	Electricity	16	0.48	0.42	0.20
Industrial machinery	Sweepers and cleansers	Diesel	59	0.48	0.42	0.20
Industrial machinery	Mobile elevating work platforms	Diesel	67	0.48	0.42	0.20
Industrial machinery	Mobile elevating work platforms	Electricity	-	0.48	0.42	0.20
Industrial machinery	Industral tractors	Diesel	35	0.48	0.52	0.25
Industrial machinery	Industral tractors	Petrol (4-str)	20	0.48	0.52	0.25

Machine catagory	Machine type	Engine type	Engine rated power kW	Lastfaktor		
				Standard	Deviation	Effective
Industrial machinery	Runway vehicles	Diesel	226	0.48	1.00	0.48
Industrial machinery	Air side passenger cars	Diesel	65	0.20	1.00	0.20
Industrial machinery	Air side passenger cars	Petrol (4-str)	65	0.20	1.00	0.20
Industrial machinery	Air side passenger cars	LPG	65	0.20	1.00	0.20
Industrial machinery	Air side passenger cars	Electricity	65	0.20	1.00	0.20
Industrial machinery	Air side light duty vehicles	Diesel	70	0.20	1.00	0.20
Industrial machinery	Air side light duty vehicles	Petrol (4-str)	70	0.20	1.00	0.20
Industrial machinery	Air side Heavy duty vehicles/buses	Diesel	130	0.20	1.00	0.20
Industrial machinery	Air side generators	Diesel	150	0.47	0.98	0.46
Industrial machinery	Air side tractors	Electricity	70	0.20	1.00	0.20
Industrial machinery	Air side dispatch appliances	Diesel	50	0.20	1.00	0.20
Industrial machinery	Air side dispatch appliances	Electricity	50	0.20	1.00	0.20
Industrial machinery	Industrial generators/business/publicGenerators industrial/business/public	Diesel	174	0.47	0.98	0.46
Agricultural machinery	Single-axle mowers	Petrol (4-str)	8	0.48	0.83	0.40
Agricultural machinery	Tractors (agriculture)	Diesel	62	0.48	0.63	0.30
Agricultural machinery	Combine harvesters	Diesel	163	0.48	0.83	0.40
Agricultural machinery	Spraying machines	Diesel	25	0.48	0.63	0.30
Agricultural machinery	Field choppers	Diesel	193	0.48	0.83	0.40
Agricultural machinery	Twin-axle mowers	Diesel	40	0.48	0.63	0.30
Agricultural machinery	Transporters and loaders	Diesel	45	0.48	0.63	0.30
Agricultural machinery	Farmyard loaders	Diesel	35	0.48	0.63	0.30
Agricultural machinery	Chainsaws (agriculture)	Petrol (2-str)	3	0.50	1.70	0.85
Agricultural machinery	Tractors (hobby)Tractorsa (hobby)	Diesel	43	0.48	0.42	0.20
Agricultural machinery	Tractors (hobby)Tractorsa (hobby)	Petrol (4-str)	35	0.48	0.42	0.20
Agricultural machinery	Beet harvesting machine	Diesel	380	0.48	0.63	0.30
Forestry machinery	FMChainsaws (forestry)	Petrol (2-str)	4	0.50	1.70	0.85
Forestry machinery	Cutters	Petrol (2-str)	3	0.28	1.79	0.50
Forestry machinery	Other small appliances	Petrol (2-str)	4	0.28	1.00	0.28
Forestry machinery	Cable and grapple skidders	Diesel	69	0.48	0.63	0.30
Forestry machinery	Pick-up loaders	Diesel	117	0.48	1.00	0.48
Forestry machinery	Processors	Diesel	55	0.48	1.00	0.48
Forestry machinery	Wood chippers	Diesel	284	0.48	1.00	0.48
Forestry machinery	Bark peeling machinesBark peeling machines	Diesel	272	0.48	1.00	0.48
Forestry machinery	Wheeled excavators FM	Diesel	95	0.48	0.83	0.40
Forestry machinery	Forestry forwarders	Diesel	124	0.48	1.00	0.48
Forestry machinery	Conventional skyline cranes	Diesel	62	0.48	0.42	0.20
Forestry machinery	Mobile skyline cranes	Diesel	91	0.48	0.42	0.20
Forestry machinery	Combined skyline appliances	Diesel	125	0.48	0.42	0.20
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Hedge cutters (professional)	Petrol (2-str)	1	0.28	1.79	0.50

Machine catagory	Machine type	Engine type	Engine rated power kW	Lastfaktor		
				Standard	Deviation	Effective
Garden-care/hobby appliances	Hedge cutters (professional)	Electricity	1	0.28	1.79	0.50
Garden-care/hobby appliances	Blowers (professional)	Petrol (4-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Blowers (professional)	Petrol (2-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Lawn mowers (professional)	Petrol (4-str)	4	0.28	1.00	0.28
Garden-care/hobby appliances	Ride-on mowers (professional)	Petrol (4-str)	8	0.28	1.00	0.28
Garden-care/hobby appliances	Chainsaws (professional)	Petrol (2-str)	3	0.50	1.70	0.85
Garden-care/hobby appliances	Scarifiers (professional)	Petrol (4-str)	4	0.28	1.00	0.28
Garden-care/hobby appliances	Mill cutters/shredders (professional)	Petrol (4-str)	4	0.50	1.00	0.50
Garden-care/hobby appliances	Shredders (professional)	Petrol (4-str)	2	0.48	1.00	0.48
Garden-care/hobby appliances	Snow blowers (professional)	Petrol (4-str)	2	0.48	1.00	0.48
Garden-care/hobby appliances	Cleaning appliances (professional)	Petrol (4-str)	2	0.28	1.00	0.28
Garden-care/hobby appliances	Cleaning appliances (professional)	Electricity	2	0.28	1.00	0.28
Garden-care/hobby appliances	Abrasive grinders (professional)	Petrol (2-str)	2	0.48	1.04	0.50
Garden-care/hobby appliances	Abrasive grinders (professional)	Electricity	2	0.48	1.04	0.50
Garden-care/hobby appliances	Drills (professional)	Petrol (4-str)	2	0.48	1.04	0.50
Garden-care/hobby appliances	Drills (professional)	Petrol (2-str)	2	0.48	1.04	0.50
Garden-care/hobby appliances	Drills (professional)	Electricity	2	0.48	1.04	0.50
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Electricity	1	0.28	1.79	0.50
Garden-care/hobby appliances	Hedge cutters (household)	Petrol (2-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Hedge cutters (household)	Electricity	1	0.28	1.79	0.50
Garden-care/hobby appliances	Blowers (household)	Petrol (4-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Blowers (household)	Petrol (2-str)	1	0.28	1.79	0.50
Garden-care/hobby appliances	Blowers (household)	Electricity	1	0.28	1.79	0.50
Garden-care/hobby appliances	Lawn mowers (household)	Petrol (4-str)	4	0.28	1.00	0.28
Garden-care/hobby appliances	Lawn mowers (household)	Electricity	4	0.28	1.00	0.28
Garden-care/hobby appliances	Ride-on mowers (household)	Petrol (4-str)	8	0.28	1.00	0.28
Garden-care/hobby appliances	Chainsaws (household)	Petrol (2-str)	2	0.50	1.00	0.50
Garden-care/hobby appliances	Chainsaws (household)	Electricity	2	0.50	1.00	0.50
Garden-care/hobby appliances	Motor sleds (household)	Petrol (4-str)	4	0.48	1.00	0.48
Garden-care/hobby appliances	Scarifiers (household)	Petrol (4-str)	2	0.28	1.00	0.28
Garden-care/hobby appliances	Scarifiers (household)	Electricity	2	0.28	1.00	0.28
Garden-care/hobby appliances	Mill cutters/shredders (household)	Petrol (4-str)	4	0.50	1.00	0.50
Garden-care/hobby appliances	Mill cutters/shredders (household)	Electricity	4	0.50	1.00	0.50
Garden-care/hobby appliances	Shredders (household)	Petrol (4-str)	4	0.48	1.00	0.48
Garden-care/hobby appliances	Shredders (household)	Electricity	4	0.48	1.00	0.48
Garden-care/hobby appliances	Snow blowers (household)	Petrol (4-str)	2	0.48	1.00	0.48
Garden-care/hobby appliances	Snow blowers (household)	Electricity	2	0.48	1.00	0.48
Garden-care/hobby appliances	Cleaning appliances (household)	Petrol (4-str)	2	0.28	1.00	0.28
Garden-care/hobby appliances	Cleaning appliances (household)	Electricity	2	0.28	1.00	0.28
Garden-care/hobby appliances	Lawn moving robotics	Electricity	0	1.00	1.00	1.00

Machine catagory	Machine type	Engine type	Engine rated power kW	Lastfaktor		
				Standard	Deviation	Effective
Garden-care/hobby appliances	Wood splitter (professional)	Petrol (4-str)	5	0.50	1.00	0.50
Garden-care/hobby appliances	Wood splitter (Household)	Electricity	5	0.50	1.00	0.50
Navigation machinery	Motorised yachts	Diesel	17	0.48	0.63	0.30
Navigation machinery	Motorised yachts	Petrol (4-str)	4	0.30	1.00	0.30
Navigation machinery	Motorised yachts	Petrol (2-str)	3	0.30	1.00	0.30
Navigation machinery	Fishing & other commercial boats	Diesel	175	0.48	0.63	0.30
Navigation machinery	Fishing & other commercial boats	Petrol (4-str)	37	0.30	1.00	0.30
Navigation machinery	Fishing & other commercial boats	Petrol (2-str)	3	0.30	1.00	0.30
Navigation machinery	Hire and privately owned motor boats	Diesel	131	0.48	0.63	0.30
Navigation machinery	Hire and privately owned motor boats	Petrol (4-str)	62	0.30	1.00	0.30
Navigation machinery	Hire and privately owned motor boats	Petrol (2-str)	4	0.30	1.00	0.30
Navigation machinery	Passenger ships	Diesel	449	0.62	1.00	0.62
Navigation machinery	Passenger ships	Steam	489	0.62	1.00	0.62
Navigation machinery	Cargo ships/barges	Diesel	218	0.62	1.00	0.62
Navigation machinery	Ferries	Diesel	670	0.62	1.00	0.62
Navigation machinery	Cargo ships Rhine, main engines	Diesel	1,300	0.48	0.42	0.20
Navigation machinery	Cargo ships Rhine, auxiliary engines	Diesel	40	0.40	0.42	0.17
Railway machinery	Shunting locomotives	Diesel	794	0.33	0.48	0.16
Railway machinery	Twin-engined tractors	Diesel	200	0.33	0.48	0.16
Railway machinery	Railway tractors	Diesel	259	0.33	0.48	0.16
Military machinery	Leo 87	Diesel	800	0.48	0.50	0.24
Military machinery	Howitzers	Diesel	200	0.48	0.50	0.24
Military machinery	Armoured personnel carriers	Diesel	261	0.48	0.50	0.24
Military machinery	Other armoured vehicles	Diesel	200	0.48	0.50	0.24
Military machinery	Reconnaissance vehicles	Diesel	95	0.48	0.50	0.24
Military machinery	Caterpillar loaders/crawler Loaders	Diesel	200	0.48	0.73	0.35
Military machinery	Rubber-wheeled loading shovels/wheel loaders	Diesel	95	0.48	0.73	0.35
Military machinery	Crawler excavators Mil	Diesel	95	0.48	1.00	0.48
Military machinery	Walking excavators Mil	Diesel	95	0.48	0.60	0.29
Military machinery	Pile drivers/piling rigs	Diesel	55	0.48	0.60	0.29
Military machinery	Crane trucks	Diesel	204	0.48	0.63	0.30
Military machinery	Patrol boats	Diesel	22	0.48	0.63	0.30
Military machinery	Other boats	Petrol (4-str)	22	0.30	1.00	0.30
Military machinery	Power generating appliances	Diesel	47	0.47	0.98	0.46
Military machinery	Power generating appliances	Petrol (4-str)	5	0.47	0.98	0.46
Military machinery	Power generating appliances	Petrol (2-str)	2	0.47	0.98	0.46
Military machinery	Assortment water pipe	Diesel	95	0.48	0.60	0.29

A6 Machine types with dynamic pollutant emissions

Tab. 47 > Machine types with dynamic pollutant emissions

The table below lists machine types with dynamic emissions of PM and carbon monoxide (CO). The dynamic factors for NO_X from stage IV (cf. Tab. 10)are applied for all diesel engines with an engine power between 56 and 560 kW.

Machine catagory	Machine type
Construction machinery	Asphalt finishers
Construction machinery	Rollers of all types
Construction machinery	Crawler excavators
Construction machinery	Wheeled excavators
Construction machinery	Mini-excavators
Construction machinery	Cable dredgers
Construction machinery	Rubber-tyred and mobile cranes
Construction machinery	Graders
Construction machinery	HGV's without licence for use on road
Construction machinery	Crawler tractors
Construction machinery	Loaders (rubber-tyred and crawler) of all types
Construction machinery	Dump trucks
Construction machinery	Tunnel locomotives
Construction machinery	Concrete/surface milling cutters
Construction machinery	Trench cutters
Industrial machinery	Forklifts of all types
Industrial machinery	Sweepers and cleansers
Industrial machinery	Tractors(Ind.)
Agricultural machinery	Tractors (agriculture)
Agricultural machinery	Combine harvesters
Agricultural machinery	Spraying machines
Agricultural machinery	Field choppers
Agricultural machinery	Twin-axle mowers
Agricultural machinery	Transporters and loaders
Agricultural machinery	Farmyard loaders
Agricultural machinery	Beet harvesting machine

Machine catagory	Machine type
Forestry machinery	Vollernter
Forestry machinery	Processors
Forestry machinery	Wood chippers
Forestry machinery	Bark peeling machines
Forestry machinery	Wheeled excavators
Forestry machinery	Forestry forwarders
Forestry machinery	Conventional skyline cranes
Forestry machinery	Mobile skyline cranes
Navigation machinery	Hire and privately owned motor boats
Railway machinery	Shunting locomotives
Military machinery	Pz 68 family
Military machinery	Leo 87
Military machinery	Howitzers
Military machinery	Armoured personnel carriers
Military machinery	Other armoured vehicles
Military machinery	Reconnaissance vehicles
Military machinery	Caterpillar loaders/crawler Loaders
Military machinery	Rubber-wheeled loading shovels/wheel loaders
Military machinery	Crawler excavators
Military machinery	Walking excavators
Military machinery	Bulldozers/crawler tractors
Military machinery	Crane trucks
Military machinery	Patrol boats

A7 Stock and operating hours by machine category

Tab. 48 > Stock

Category	1980	1990	2000	2010	2020	2030	2040	2050
Construction machines	63,364	58,816	52,729	57,102	60,384	62,726	64,370	65,520
Industrial machinery	26,714	43,244	70,671	69,786	69,757	70,083	70,314	70,451
Agricultural machinery	292,773	324,567	337,869	318,876	309,825	305,235	302,413	302,336
Forestry machinery	11,815	13,844	13,055	11,857	10,831	10,170	9,787	9,559
Garden-care/hobby appliances	1,198,841	1,539,624	1,944,373	2,322,737	2,464,323	2,499,627	2,508,448	2,510,652
Navigation machinery	94,866	103,383	93,912	95,055	97,522	99,104	100,040	100,595
Railway machinery	529	1,300	1,255	697	640	640	640	640
Military machinery	13,092	13,373	14,272	13,083	12,853	12,856	12,537	12,537
Total	**1,701,994**	**2,098,151**	**2,528,136**	**2,889,193**	**3,026,135**	**3,060,441**	**3,068,549**	**3,072,290**

Tab. 49 > Total operating hours (in million hrs p.a.)

Category	1980	1990	2000	2010	2020	2030	2040	2050
Construction machines	15.7	19.0	21.4	23.8	25.6	26.9	27.8	28.5
Industrial machinery	17.8	29.0	48.4	47.5	47.1	47.0	47.0	47.0
Agricultural machinery	39.9	38.8	37.7	33.0	30.6	29.0	28.0	27.5
Forestry machinery	2.4	2.8	2.6	2.3	2.0	1.9	1.8	1.7
Garden-care/hobby appliances	14.6	25.7	39.3	149.7	190.8	201.3	203.9	204.5
Navigation machinery	3.7	3.9	3.5	3.4	3.4	3.4	3.4	3.4
Railway machinery	0.5	0.8	0.8	0.5	0.5	0.5	0.5	0.5
Military machinery	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total	**95**	**121**	**155**	**261**	**301**	**311**	**313**	**314**

Tab. 50 > Specific operating hours (in hrs p.a.)

Category	1980	1990	2000	2010	2020	2030	2040	2050
Construction machines	247	322	406	417	424	429	432	435
Industrial machinery	666	670	684	680	675	671	668	667
Agricultural machinery	136	119	112	103	99	95	93	91
Forestry machinery	203	199	203	193	188	182	180	178
Garden-care/hobby appliances	12	17	20	64	77	81	81	81
Navigation machinery	39	38	38	36	35	35	34	34
Railway machinery	877	613	617	783	719	719	719	719
Category	64	64	63	73	74	74	74	74

A8 Stock and operating hours of individual machine types

Tab. 51 > Stock and operating hours by machine category

Reference year, 2010.

Machine catagory	Machine type	Engine type	Stock	Operating hours	Specific operating hours p.a.	Service life [yrs]
Construction machinery	Asphalt finishers	Diesel	400	120,000	300	4.7
Construction machinery	Hydraulic rammers of all types	Diesel	60	18,000	300	4.7
Construction machinery	Rollers of all types	Diesel	3,000	900,000	300	4.7
Construction machinery	Mechanical vibrators	Diesel	85	25,641	302	4.7
Construction machinery	Hand-operated rammers, vibrators	Diesel	3,000	1,049,950	350	4.7
Construction machinery	Hand-operated rammers, vibrators	Petrol (4-str)	1,932	579,601	300	3.6
Construction machinery	Hand-operated rammers, vibrators	Petrol (2-str)	5,568	1,670,449	300	3.6
Construction machinery	Cable dredgers	Diesel	120	24,000	200	7.2
Construction machinery	Rubber-tyred and mobile cranes	Diesel	850	267,827	315	4.7
Construction machinery	Graders	Diesel	189	94,500	500	5.9
Construction machinery	HGV's without licence for use on road	Diesel	150	105,000	700	8.8
Construction machinery	Crawler tractors	Diesel	325	113,750	350	4.7
Construction machinery	Loaders (rubber-tyred and crawler) of all types	Diesel	7,333	3,707,198	506	4.7
Construction machinery	Dump trucks	Diesel	5,300	2,650,000	500	4.7
Construction machinery	Emergency power supply systems/generators	Diesel	992	106,515	107	7.2
Construction machinery	Emergency power supply systems/generators	Petrol (4-str)	2,208	175,085	79	3.6
Construction machinery	Pumps of all types	Diesel	162	23,613	146	4.7
Construction machinery	Pumps of all types	Petrol (4-str)	538	78,695	146	3.6
Construction machinery	Mobile compressors	Diesel	7,650	1,530,000	200	4.7
Construction machinery	Mobile elevating work platforms	Diesel	340	104,202	306	4.7
Construction machinery	Tunnel locomotives	Diesel	110	55,000	500	4.7
Construction machinery	Concrete/surface milling cutters	Diesel	161	76,133	473	4.7
Construction machinery	Concrete/surface milling cutters	Petrol (4-str)	989	458,176	463	3.6
Construction machinery	Trench cutters	Diesel	50	15,000	300	4.7
Construction machinery	Drilling machines of all types (esp. civil engineering)	Diesel	230	139,000	604	4.7
Construction machinery	Mini-excavators	Diesel	7,400	3,922,000	530	4.7
Construction machinery	Crawler excavators	Diesel	5,470	4,016,716	734	8.8
Construction machinery	Wheeled excavators	Diesel	2,490	1,782,955	716	8.8
Industrial machinery	Forklifts of all types	Diesel	11,520	8,294,400	720	8.8
Industrial machinery	Forklifts of all types	Petrol (4-str)	720	518,400	720	8.8
Industrial machinery	Forklifts of all types	LPG	2,160	1,555,200	720	8.8
Industrial machinery	Forklifts of all types	Electricity	43,300	31,176,000	720	8.8
Industrial machinery	Sweepers and cleansers	Diesel	670	670,000	1,000	5.9
Industrial machinery	Mobile elevating work platforms	Diesel	1,801	900,400	500	7.2
Industrial machinery	Mobile elevating work platforms	Electricity	2,701	1,350,600	500	7.2
Industrial machinery	TractorsIndustral tractors	Diesel	2,640	792,000	300	7.2

Machine catagory	Machine type	Engine type	Stock	Operating hours	Specific operating hours p.a.	Service life [yrs]
Industrial machinery	TractorsIndustral tractors	Petrol (4-str)	360	108,000	300	7.2
Industrial machinery	Runway vehicles	Diesel	1,400	980,000	700	7.2
Industrial machinery	Air side passenger cars	Diesel	213	102,125	480	3.5
Industrial machinery	Air side passenger cars	Petrol (4-str)	536	257,203	480	3.5
Industrial machinery	Air side passenger cars	LPG	16	7,565	480	3.5
Industrial machinery	Air side passenger cars	Electricity	24	11,347	480	3.5
Industrial machinery	Air side light duty vehicles	Diesel	258	98,154	380	3.8
Industrial machinery	Air side light duty vehicles	Petrol (4-str)	57	21,546	380	3.8
Industrial machinery	Air side Heavy duty vehicles/buses	Diesel	332	33,200	100	4.3
Industrial machinery	Air side generators	Diesel	79	71,100	900	7.2
Industrial machinery	Air side tractors	Electricity	272	136,000	500	7.2
Industrial machinery	Air side dispatch appliances	Diesel	51	30,780	600	7.2
Industrial machinery	Air side dispatch appliances	Electricity	462	277,020	600	7.2
Industrial machinery	generators Industrial machinery/business/public	Diesel	215	66,005	307	7.2
Agricultural machinery	Single-axle mowers	Petrol (4-str)	55,674	6,680,880	120	18.8
Agricultural machinery	TractorsTractors (agriculture)	Diesel	106,504	20,208,297	190	20.7
Agricultural machinery	Combine harvesters	Diesel	2,499	274,890	110	6.7
Agricultural machinery	Spraying machines	Diesel	1,850	239,760	130	11.1
Agricultural machinery	Field choppers	Diesel	409	48,942	120	8.9
Agricultural machinery	Twin-axle mowers	Diesel	13,907	1,702,159	122	9.6
Agricultural machinery	Transporters and loaders	Diesel	17,105	1,368,341	80	10.4
Agricultural machinery	Farmyard loaders	Diesel	8,455	845,500	100	7.8
Agricultural machinery	Chainsaws (agriculture)	Petrol (2-str)	90,132	1,802,640	20	3.6
Agricultural machinery	TractorsTractors (hobby)Tractorsa (hobby)	Diesel	21,146	440,382	21	36.3
Agricultural machinery	TractorsTractors (hobby)Tractorsa (hobby)	Petrol (4-str)	3,442	51,378	15	31.7
Agricultural machinery	Beet harvesting machine	Diesel	150	21,000	140	2.4
Forestry machinery	FMChainsaws (forestry)	Petrol (2-str)	6,600	900,000	136	1.1
Forestry machinery	Cutters	Petrol (2-str)	1,933	289,950	150	1.1
Forestry machinery	Other small appliances	Petrol (2-str)	1,750	105,000	60	2.4
Forestry machinery	Cable and grapple skidders	Diesel	1,250	750,000	600	5.9
Forestry machinery	Pick up loaders	Diesel	40	36,000	900	3.2
Forestry machinery	Processors	Diesel	10	7,250	725	4.4
Forestry machinery	Wood chippers	Diesel	43	38,700	900	3.8
Forestry machinery	Bark peeling machines	Diesel	4	3,200	800	6.5
Forestry machinery	Wheeled excavators FM	Diesel	39	19,500	500	5.9
Forestry machinery	Forestry forwarders	Diesel	125	115,000	920	3.6
Forestry machinery	Conventional skyline cranes	Diesel	73	36,500	500	8.0
Forestry machinery	Mobile skyline cranes	Diesel	70	40,600	580	5.4
Forestry machinery	Combined skyline appliances	Diesel	15	13,500	900	5.4
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	2,000	400,000	200	2.9
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	28,000	5,600,000	200	2.9

Machine catagory	Machine type	Engine type	Stock	Operating hours	Specific operating hours p.a.	Service life [yrs]
Garden-care/hobby appliances	Hedge cutters (professional)	Petrol (2-str)	4,126	618,959	150	3.6
Garden-care/hobby appliances	Hedge cutters (professional)	Electricity	15,000	2,249,941	150	3.6
Garden-care/hobby appliances	Blowers (professional)	Petrol (4-str)	826	92,557	112	3.0
Garden-care/hobby appliances	Blowers (professional)	Petrol (2-str)	3,098	347,088	112	4.2
Garden-care/hobby appliances	Lawn mowers (professional)	Petrol (4-str)	15,720	1,572,000	100	2.9
Garden-care/hobby appliances	Ride-on mowers (professional)	Petrol (4-str)	6,000	1,200,000	200	3.6
Garden-care/hobby appliances	Chainsaws (professional)	Petrol (2-str)	5,502	550,200	100	2.4
Garden-care/hobby appliances	Scarifiers (professional)	Petrol (4-str)	1,310	655,000	500	3.6
Garden-care/hobby appliances	Mill cutters/shredders (professional)	Petrol (4-str)	2,620	393,000	150	3.6
Garden-care/hobby appliances	Shredders (professional)	Petrol (4-str)	1,965	157,200	80	3.6
Garden-care/hobby appliances	Snow blowers (professional)	Petrol (4-str)	8,000	440,000	55	4.7
Garden-care/hobby appliances	Cleaning appliances (professional)	Petrol (4-str)	4,585	1,375,500	300	4.7
Garden-care/hobby appliances	Cleaning appliances (professional)	Electricity	13,000	3,900,000	300	4.7
Garden-care/hobby appliances	Abrasive grinders (professional)	Petrol (2-str)	5,556	333,346	60	3.0
Garden-care/hobby appliances	Abrasive grinders (professional)	Electricity	25,000	1,500,014	60	3.0
Garden-care/hobby appliances	Drills (professional)	Petrol (4-str)	1,395	209,268	150	1.1
Garden-care/hobby appliances	Drills (professional)	Petrol (2-str)	632	94,807	150	1.1
Garden-care/hobby appliances	Drills (professional)	Electricity	24,014	3,602,076	150	1.1
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	9,167	57,292	6	4.7
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	114,167	713,542	6	4.7
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Electricity	261,300	1,633,122	6	3.0
Garden-care/hobby appliances	Hedge cutters (household)	Petrol (2-str)	12,933	81,598	6	4.7
Garden-care/hobby appliances	Hedge cutters (household)	Electricity	163,338	1,030,515	6	3.0
Garden-care/hobby appliances	Blowers (household)	Petrol (4-str)	833	5,208	6	4.7
Garden-care/hobby appliances	Blowers (household)	Petrol (2-str)	13,000	81,250	6	4.7
Garden-care/hobby appliances	Blowers (household)	Electricity	23,056	144,098	6	3.0
Garden-care/hobby appliances	Lawn mowers (household)	Petrol (4-str)	433,421	4,875,986	11	5.9
Garden-care/hobby appliances	Lawn mowers (household)	Electricity	485,898	5,466,352	11	5.9
Garden-care/hobby appliances	Ride-on mowers (household)	Petrol (4-str)	11,667	145,838	13	5.9
Garden-care/hobby appliances	Chainsaws (household)	Petrol (2-str)	130,895	818,095	6	4.7
Garden-care/hobby appliances	Chainsaws (household)	Electricity	191,088	1,194,299	6	5.9
Garden-care/hobby appliances	Motor sleds (household)	Petrol (4-str)	1,500	15,000	10	5.9
Garden-care/hobby appliances	Scarifiers (household)	Petrol (4-str)	4,583	13,750	3	5.9
Garden-care/hobby appliances	Scarifiers (household)	Electricity	46,769	140,306	3	5.9
Garden-care/hobby appliances	Mill cutters/shredders (household)	Petrol (4-str)	18,333	114,583	6	4.7
Garden-care/hobby appliances	Mill cutters/shredders (household)	Electricity	15,278	95,486	6	5.9
Garden-care/hobby appliances	Shredders (household)	Petrol (4-str)	2,833	7,650	3	5.9
Garden-care/hobby appliances	Shredders (household)	Electricity	47,223	127,501	3	5.9
Garden-care/hobby appliances	Snow blowers (household)	Petrol (4-str)	24,833	1,117,487	45	5.9
Garden-care/hobby appliances	Snow blowers (household)	Electricity	2,980	134,098	45	5.9
Garden-care/hobby appliances	Cleaning appliances (household)	Petrol (4-str)	7,000	140,000	20	5.9

Machine catagory	Machine type	Engine type	Stock	Operating hours	Specific operating hours p.a.	Service life [yrs]
Garden-care/hobby appliances	Cleaning appliances (household)	Electricity	10,000	200,000	20	5.9
Garden-care/hobby appliances	Lawn moving robotics	Electricity	87,500	105,000,000	1,200	4.2
Garden-care/hobby appliances	Wood splitter (professional)	Petrol (4-str)	400	12,000	30	5.9
Garden-care/hobby appliances	Wood splitter (Household)	Electricity	34,394	1,031,820	30	5.9
Navigation machinery	Motorised yachts	Diesel	10,669	320,499	30	8.8
Navigation machinery	Motorised yachts	Petrol (4-str)	5,350	160,714	30	5.9
Navigation machinery	Motorised yachts	Petrol (2-str)	5,274	158,417	30	5.9
Navigation machinery	Fishing & other commercial boats	Diesel	137	70,221	511	8.8
Navigation machinery	Fishing & other commercial boats	Petrol (4-str)	801	409,157	511	5.9
Navigation machinery	Fishing & other commercial boats	Petrol (2-str)	16	8,122	511	5.9
Navigation machinery	Hire and privately owned motor boats	Diesel	4,263	127,948	30	8.8
Navigation machinery	Hire and privately owned motor boats	Petrol (4-str)	44,259	1,328,425	30	5.9
Navigation machinery	Hire and privately owned motor boats	Petrol (2-str)	11,404	342,277	30	5.9
Navigation machinery	Passenger ships	Diesel	132	157,989	1,197	25.5
Navigation machinery	Passenger ships	Steam	14	11,061	790	9.9
Navigation machinery	Cargo ships/barges	Diesel	244	122,000	500	25.5
Navigation machinery	Ferries	Diesel	8	28,000	3,500	25.5
Navigation machinery	Carg ships Rhine, main engines	Diesel	6,243	9,159	1	25.5
Navigation machinery	Carg ships Rhine, auxiliary engines	Diesel	6,243	207,725	33	7.2
Railway machinery	Shunting locomotives	Diesel	202	323,200	1,600	17.7
Railway machinery	Twin-engined tractors	Diesel	2	600	300	20.9
Railway machinery	Railway tractors	Diesel	493	221,850	450	23.8
Military machinery	Leo 87	Diesel	286	6,292	22	21.0
Military machinery	Howitzers	Diesel	298	5,364	18	32.5
Military machinery	Armoured personnel carriers	Diesel	555	19,980	36	31.4
Military machinery	Other armoured vehicles	Diesel	1,300	299,000	230	11.9
Military machinery	Reconnaissance vehicles	Diesel	383	57,450	150	11.9
Military machinery	Caterpillar loaders/crawler loaders	Diesel	10	5,000	500	4.7
Military machinery	Rubber-wheeled loading shovels/wheel loaders	Diesel	47	23,500	500	4.7
Military machinery	Crawler excavators Mil	Diesel	25	12,500	500	4.7
Military machinery	Walking excavators Mil	Diesel	7	3,500	500	4.7
Military machinery	Pile drivers/piling rigs	Diesel	36	2,088	58	4.7
Military machinery	Crane trucks	Diesel	43	2,795	65	4.7
Military machinery	Patrol boats	Diesel	11	6,336	576	4.7
Military machinery	Other boats	Petrol (4-str)	50	4,500	90	4.7
Military machinery	Power generating appliances	Diesel	1,667	83,333	50	7.2
Military machinery	Power generating appliances	Petrol (4-str)	6,667	333,333	50	3.6
Military machinery	Power generating appliances	Petrol (2-str)	1,667	83,333	50	3.6
Military machinery	Assortment water pipe	Diesel	32	1,600	50	20.0

A9

Energy consumption and pollutant emissions

Tab. 52 > Non-road energy consumption and pollutant emissions

	1980	1990	2000	2010	2020	2030	2040	2050
Energy consumption (in PJ p.a.)								
Diesel	8.80	10.98	13.52	14.76	15.03	15.31	15.58	15.81
Petrol (4-stroke)	1.96	1.91	1.76	1.53	1.33	1.25	1.22	1.20
Petrol (2-stroke)	0.39	0.49	0.52	0.38	0.28	0.25	0.25	0.24
Gas	0.08	0.13	0.23	0.21	0.13	0.10	0.10	0.10
Heating oil (for steamships)	0.08	0.11	0.15	0.16	0.15	0.14	0.13	0.13
Electricity	0.34	0.57	0.93	0.92	0.98	0.93	0.85	0.78
Pollutant emissions (in tonnes p.a.)								
HC	8,195	9,470	9,019	4,367	2,205	1,705	1,540	1,465
CO	56,403	58,725	51,492	39,270	33,517	30,359	29,230	28,657
NO_X	9,986	12,623	14,557	10,395	5,214	3,509	3,016	2,845
PM	831	998	1,116	532	232	94	51	33
CO_2	833,004	1,003,198	1,190,692	1,253,924	1,245,064	1,255,347	1,271,652	1,287,251
CH_4	408	485	458	198	95	81	76	74
NMHC	7,787	8,985	8,560	4,170	2,110	1,624	1,464	1,391
N_2O	31	38	47	51	51	52	52	53
Benzene	326	376	58	26	13	11	10	10

A10 Energy consumption by machine category

Tab. 53 > Energy consumption by machine category (in PJ/a)

Category	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Construction machines	Diesel	2.78	3.73	4.88	5.81	6.31	6.59	6.82	6.99
Construction machines	Petrol (4-stroke)	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09
Construction machines	Petrol (2-sroke)	0.04	0.05	0.03	0.03	0.02	0.02	0.02	0.01
Industrial machinery	Diesel	1.15	1.62	2.24	2.45	2.27	2.30	2.40	2.48
Industrial machinery	Petrol (4-stroke)	0.04	0.07	0.11	0.11	0.07	0.07	0.08	0.08
Industrial machinery	Gas	0.08	0.13	0.23	0.21	0.13	0.10	0.10	0.10
Industrial machinery	Electricity	0.30	0.50	0.83	0.80	0.85	0.81	0.73	0.66
Agricultural machinery	Diesel	3.47	4.03	4.65	4.56	4.59	4.57	4.53	4.51
Agricultural machinery	Petrol (4-stroke)	1.05	0.87	0.68	0.50	0.36	0.28	0.23	0.21
Agricultural machinery	Petrol (2-stroke)	0.13	0.15	0.15	0.11	0.09	0.08	0.07	0.07
Forestry machinery	Diesel	0.23	0.24	0.28	0.32	0.34	0.34	0.34	0.34
Forestry machinery	Petrol (2-stroke)	0.10	0.14	0.13	0.08	0.05	0.04	0.04	0.03
Garden-care/hobby appliances	Petrol (4-stroke)	0.14	0.20	0.27	0.30	0.29	0.29	0.29	0.29
Garden-care/hobby appliances	Petrol (2-stroke)	0.09	0.13	0.19	0.15	0.11	0.11	0.11	0.11
Garden-care/hobby appliances	Electricity	0.04	0.06	0.10	0.12	0.12	0.12	0.12	0.12
Navigation machinery	Diesel	0.68	0.74	0.79	0.87	0.88	0.87	0.86	0.86
Navigation machinery	Petrol (4-stroke)	0.64	0.68	0.60	0.52	0.51	0.52	0.52	0.52
Navigation machinery	Petrol (2-stroke)	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01
Navigation machinery	Steam (heating oil)	0.08	0.11	0.15	0.16	0.15	0.14	0.13	0.13
Railway machinery	Diesel	0.29	0.39	0.46	0.49	0.39	0.39	0.39	0.39
Military machinery	Diesel	0.21	0.22	0.23	0.26	0.25	0.25	0.24	0.24
Military machinery	Petrol (4-stroke)	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Military machinery	Petrol (2-stroke)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

A11 Emissions by machine category

Tab. 54 > Emissions by machine category (in tonnes p.a.)

Pollutant	Catagory	1980	1990	2000	2010	2020	2030	2040	2050
HC	Construction machines	900	1,084	1,089	525	222	194	196	198
HC	Industrial machinery	246	305	405	236	68	47	47	48
HC	Agricultural machinery	3,189	3,161	2,957	1,614	782	535	436	392
HC	Forestry machinery	1,080	1,463	1,204	364	150	132	122	117
HC	Garden-care/hobby appliances	1,043	1,591	2,177	1,027	492	399	397	397
HC	Navigation machinery	1,602	1,708	1,016	500	425	354	312	285
HC	Railway machinery	62	85	99	63	46	30	16	14
HC	Military machinery	73	73	72	39	19	15	14	14
CO	Construction machines	4,317	5,335	5,872	4,063	3,108	3,016	3,102	3,171
CO	Industrial machinery	1,300	1,918	2,810	2,407	1,144	902	902	906
CO	Agricultural machinery	28,542	25,178	21,521	15,976	11,736	9,455	8,346	7,747
CO	Forestry machinery	2,376	3,190	2,973	1,933	1,404	1,150	1,065	1,016
CO	Garden-care/hobby appliances	5,000	7,388	10,251	10,850	10,546	10,211	10,240	10,247
CO	Navigation machinery	14,101	14,882	7,184	3,273	4,935	5,038	5,035	5,037
CO	Railway machinery	208	270	319	274	210	168	128	120
CO	Military machinery	559	563	562	495	433	419	412	412
NO_X	Construction machines	3,276	4,479	5,243	3,428	1,309	992	1,007	1,033
NO_X	Industrial machinery	1,333	1,855	2,252	1,441	505	289	287	292
NO_X	Agricultural machinery	3,464	4,096	4,524	3,311	1,809	1,111	867	752
NO_X	Forestry machinery	238	262	293	202	68	41	40	39
NO_X	Garden-care/hobby appliances	24	35	52	70	70	45	44	44
NO_X	Navigation machinery	977	1,055	1,230	1,236	985	730	597	531
NO_X	Railway machinery	435	596	711	535	389	254	142	125
NO_X	Military machinery	238	246	252	172	79	47	33	30
PM	Construction machines	263	336	387	81	32	15	15	15
PM	Industrial machinery	97	138	173	71	16	3	3	3
PM	Agricultural machinery	358	399	425	306	149	59	23	8
PM	Forestry machinery	23	23	23	13	3	0	0	0
PM	Garden-care/hobby appliances	0	0	0	0	0	0	0	0
PM	Navigation machinery	55	59	59	50	27	14	9	5
PM	Railway machinery	22	29	34	6	3	1	1	1
PM	Military machinery	14	14	14	5	2	1	1	1
CO_2	Construction machines	212,343	284,303	367,394	435,819	471,337	492,608	509,197	522,170
CO_2	Industrial machinery	93,188	133,828	189,098	203,195	182,203	181,542	189,517	195,309
CO_2	Agricultural machinery	342,748	371,824	403,637	381,271	370,628	362,499	356,162	353,407
CO_2	Forestry machinery	24,444	28,092	29,848	29,043	28,308	27,760	27,456	27,266
CO_2	Garden-care/hobby appliances	16,512	24,570	33,962	33,176	29,893	29,128	29,202	29,224
CO_2	Navigation machinery	105,661	114,274	114,672	114,996	113,934	113,115	112,192	111,949
CO_2	Railway machinery	21,032	28,688	33,519	36,222	29,017	29,058	29,058	29,058

Pollutant	Catagory	1980	1990	2000	2010	2020	2030	2040	2050
CO_2	Military machinery	17,076	17,618	18,562	20,203	19,744	19,637	18,868	18,868
CH_4	Construction machines	42	48	42	20	8	7	7	7
CH_4	Industrial machinery	8	9	11	7	2	1	1	1
CH_4	Agricultural machinery	150	154	147	73	34	26	23	21
CH_4	Forestry machinery	74	101	83	25	10	9	8	8
CH_4	Garden-care/hobby appliances	67	101	139	61	27	24	24	24
CH_4	Navigation machinery	64	67	32	11	13	13	13	12
CH_4	Railway machinery	1	1	1	1	1	0	0	0
CH_4	Military machinery	3	3	3	2	1	1	1	1
NMHC	Construction machines	859	1,035	1,047	505	214	187	189	191
NMHC	Industrial machinery	238	296	395	229	66	46	46	47
NMHC	Agricultural machinery	3,039	3,007	2,811	1,541	748	509	414	371
NMHC	Forestry machinery	1,006	1,362	1,121	339	140	123	114	109
NMHC	Garden-care/hobby appliances	976	1,490	2,037	966	466	375	373	373
NMHC	Navigation machinery	1,538	1,641	984	490	413	341	299	273
NMHC	Railway machinery	61	84	97	62	46	29	16	14
NMHC	Military machinery	69	70	68	38	18	15	14	13
N_2O	Construction machines	9	13	17	20	21	22	23	24
N_2O	Industrial machinery	4	6	8	8	8	8	8	8
N_2O	Agricultural machinery	11	13	14	14	14	14	13	13
N_2O	Forestry machinery	1	1	1	1	1	1	1	1
N_2O	Garden-care/hobby appliances	0	0	0	0	1	1	1	1
N_2O	Navigation machinery	4	4	4	4	4	4	4	4
N_2O	Railway machinery	1	1	2	2	1	1	1	1
N_2O	Military machinery	1	1	1	1	1	1	1	1
Benzene	Construction machines	26	29	4	2	1	1	1	1
Benzene	Industrial machinery	2	3	1	1	0	0	0	0
Benzene	Agricultural machinery	133	129	20	10	5	3	3	3
Benzene	Forestry machinery	53	72	9	3	1	1	1	1
Benzene	Garden-care/hobby appliances	52	80	17	8	4	3	3	3
Benzene	Navigation machinery	58	61	5	2	2	2	2	2
Benzene	Railway machinery	0	0	0	0	0	0	0	0
Benzene	Military machinery	3	3	0	0	0	0	0	0

A12 Energy consumption by machine type

Tab. 55 > Construction machines: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Construction machinery	Asphalt finishers	Diesel	0.012	0.016	0.019	0.023	0.023	0.023	0.023	0.023
Construction machinery	Hydraulic rammers of all types	Diesel	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Construction machinery	Rollers of all types	Diesel	0.064	0.081	0.081	0.106	0.124	0.137	0.148	0.157
Construction machinery	Mechanical vibrators	Diesel	0.009	0.008	0.007	0.005	0.004	0.003	0.002	0.002
Construction machinery	Hand-operated rammers, vibrators	Diesel	-	0.006	0.014	0.015	0.015	0.015	0.015	0.015
Construction machinery	Hand-operated rammers, vibrators	Petrol (4-str)	0.009	0.012	0.011	0.011	0.011	0.011	0.012	0.013
Construction machinery	Hand-operated rammers, vibrators	Petrol (2-str)	0.042	0.046	0.034	0.026	0.019	0.016	0.016	0.015
Construction machinery	Cable dredgers	Diesel	0.005	0.007	0.008	0.009	0.009	0.009	0.009	0.009
Construction machinery	Rubber-tyred and mobile cranes	Diesel	0.074	0.094	0.120	0.133	0.135	0.129	0.125	0.121
Construction machinery	Graders	Diesel	0.041	0.051	0.060	0.058	0.053	0.048	0.044	0.041
Construction machinery	HGV,s without licence for use on road	Diesel	0.073	0.087	0.096	0.099	0.099	0.099	0.099	0.099
Construction machinery	Crawler tractors	Diesel	0.048	0.061	0.071	0.069	0.065	0.061	0.058	0.056
Construction machinery	Loaders (rubber-tyred and crawler) of all types	Diesel	0.747	1.000	1.225	1.427	1.528	1.589	1.638	1.677
Construction machinery	Dump trucks	Diesel	0.248	0.337	0.423	0.733	0.936	1.067	1.174	1.260
Construction machinery	Emergency power supply systems/generators	Diesel	0.001	0.001	0.015	0.060	0.077	0.082	0.084	0.085
Construction machinery	Emergency power supply systems/generators	Petrol (4-str)	0.011	0.014	0.012	0.014	0.014	0.014	0.015	0.015
Construction machinery	Pumps of all types	Diesel	0.001	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Construction machinery	Pumps of all types	Petrol (4-str)	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.002
Construction machinery	Mobile compressors	Diesel	0.320	0.446	0.463	0.448	0.412	0.377	0.349	0.326
Construction machinery	Mobile elevating work platforms	Diesel	0.005	0.010	0.016	0.020	0.023	0.025	0.026	0.027
Construction machinery	Tunnel locomotives	Diesel	0.018	0.024	0.029	0.034	0.037	0.039	0.041	0.042
Construction machinery	Concrete/surface milling cutters	Diesel	0.016	0.026	0.039	0.048	0.052	0.055	0.057	0.059
Construction machinery	Concrete/surface milling cutters	Petrol (4-str)	0.046	0.054	0.058	0.057	0.053	0.055	0.058	0.060
Construction machinery	Trench cutters	Diesel	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Construction machinery	Drilling machines of all types (esp. civil engineering)	Diesel	0.028	0.038	0.046	0.049	0.050	0.050	0.050	0.050
Construction machinery	Mini-excavators	Diesel	0.122	0.153	0.209	0.282	0.337	0.374	0.396	0.408
Construction machinery	Crawler excavators	Diesel	0.660	0.939	1.450	1.767	1.937	2.044	2.131	2.202
Construction machinery	Wheeled excavators	Diesel	0.279	0.343	0.477	0.419	0.382	0.358	0.338	0.323

Tab. 56 > Industrial machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Industrial machinery	Forklifts of all types	Diesel	0.327	0.545	0.963	0.941	0.554	0.411	0.407	0.404
Industrial machinery	Forklifts of all types	Petrol (4-str)	0.019	0.032	0.057	0.065	0.027	0.019	0.019	0.018
Industrial machinery	Forklifts of all types	LPG	0.078	0.131	0.232	0.211	0.132	0.098	0.097	0.096
Industrial machinery	Forklifts of all types	Electricity	0.275	0.458	0.802	0.765	0.811	0.756	0.674	0.610
Industrial machinery	Sweepers and cleansers	Diesel	0.048	0.073	0.078	0.106	0.125	0.137	0.143	0.147
Industrial machinery	Mobile elevating work platforms	Diesel	0.087	0.132	0.141	0.162	0.176	0.183	0.188	0.190
Industrial machinery	Mobile elevating work platforms	Electricity	0.017	0.026	-	-	-	-	-	-
Industrial machinery	Industral tractors	Diesel	0.048	0.072	0.077	0.087	0.094	0.098	0.100	0.101
Industrial machinery	Industral tractors	Petrol (4-str)	0.007	0.011	0.011	0.012	0.011	0.011	0.011	0.012
Industrial machinery	Runway vehicles	Diesel	0.586	0.721	0.867	1.016	1.149	1.251	1.320	1.378
Industrial machinery	Air side passenger cars	Diesel	0.000	0.001	0.001	0.010	0.013	0.016	0.018	0.019
Industrial machinery	Air side passenger cars	Petrol (4-str)	0.015	0.024	0.040	0.031	0.033	0.039	0.042	0.041
Industrial machinery	Air side passenger cars	LPG	-	-	-	0.001	0.001	0.001	0.001	0.001
Industrial machinery	Air side passenger cars	Electricity	-	-	-	0.001	0.002	0.004	0.005	0.007
Industrial machinery	Air side light duty vehicles	Diesel	0.004	0.006	0.010	0.011	0.014	0.018	0.020	0.021
Industrial machinery	Air side light duty vehicles	Petrol (4-str)	0.001	0.002	0.003	0.003	0.004	0.004	0.005	0.005
Industrial machinery	Air side Heavy duty vehicles/buses	Diesel	0.004	0.006	0.010	0.011	0.014	0.017	0.019	0.020
Industrial machinery	Air side generators	Diesel	0.015	0.024	0.041	0.048	0.063	0.079	0.088	0.094
Industrial machinery	Air side tractors	Electricity	0.005	0.007	0.012	0.014	0.017	0.019	0.019	0.019
Industrial machinery	Air side dispatch appliances	Diesel	0.001	0.002	0.003	0.003	0.004	0.005	0.006	0.007
Industrial machinery	Air side dispatch appliances	Electricity	0.007	0.011	0.018	0.020	0.025	0.028	0.028	0.028
Industrial machinery	Industrial generators/business/public	Diesel	0.028	0.042	0.045	0.051	0.068	0.085	0.095	0.102

Tab. 57 > Forestry machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Agricultural machinery	Single-axle mowers	Petrol (4-str)	1.054	0.865	0.673	0.490	0.351	0.266	0.222	0.200
Agricultural machinery	Tractors (agriculture)	Diesel	3.059	3.431	3.870	3.719	3.689	3.631	3.568	3.539
Agricultural machinery	Combine harvesters	Diesel	0.152	0.207	0.228	0.171	0.131	0.136	0.136	0.136
Agricultural machinery	Spraying machines	Diesel	0.034	0.029	0.023	0.020	0.018	0.015	0.014	0.013
Agricultural machinery	Field choppers	Diesel	0.019	0.025	0.031	0.036	0.040	0.043	0.044	0.044
Agricultural machinery	Twin-axle mowers	Diesel	0.006	0.082	0.170	0.234	0.281	0.300	0.310	0.317
Agricultural machinery	Transporters and loaders	Diesel	0.190	0.220	0.249	0.206	0.179	0.155	0.140	0.132
Agricultural machinery	Farmyard loaders	Diesel	0.009	0.032	0.055	0.102	0.137	0.155	0.167	0.174
Agricultural machinery	Chainsaws (agriculture)	Petrol (2-str)	0.130	0.145	0.153	0.115	0.086	0.075	0.074	0.074
Agricultural machinery	Tractors (hobby)	Diesel	-	0.004	0.020	0.052	0.069	0.081	0.089	0.095
Agricultural machinery	Tractors (hobby)	Petrol (4-str)	-	0.007	0.009	0.008	0.011	0.012	0.013	0.012
Agricultural machinery	Beet harvesting machine	Diesel	-	-	-	0.025	0.043	0.054	0.060	0.064

Tab. 58 > Forestry machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Forestry machinery	FMChainsaws (forestry)	Petrol (2-str)	0.098	0.131	0.112	0.065	0.042	0.033	0.031	0.030
Forestry machinery	Cutters	Petrol (2-str)	0.001	0.007	0.012	0.008	0.005	0.004	0.004	0.004
Forestry machinery	Other small appliances	Petrol (2-str)	0.005	0.004	0.004	0.003	0.002	0.002	0.001	0.001
Forestry machinery	Cable and grapple skidders	Diesel	0.215	0.192	0.174	0.155	0.146	0.134	0.126	0.121
Forestry machinery	Pick-up loaders	Diesel	-	0.001	0.014	0.019	0.018	0.018	0.018	0.018
Forestry machinery	Processors	Diesel	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Forestry machinery	Wood chippers	Diesel	0.004	0.013	0.031	0.050	0.058	0.064	0.066	0.068
Forestry machinery	Bark peeling machines	Diesel	0.001	0.004	0.005	0.004	0.003	0.002	0.001	0.001
Forestry machinery	Wheeled excavators FM	Diesel	0.000	0.002	0.004	0.007	0.009	0.010	0.011	0.011
Forestry machinery	Forestry forwarders	Diesel	-	0.012	0.032	0.064	0.081	0.089	0.093	0.095
Forestry machinery	Conventional skyline cranes	Diesel	0.006	0.007	0.006	0.006	0.005	0.004	0.003	0.003
Forestry machinery	Mobile skyline cranes	Diesel	0.001	0.006	0.009	0.009	0.007	0.006	0.006	0.006
Forestry machinery	Combined skyline appliances	Diesel	-	-	-	0.004	0.007	0.009	0.009	0.010

Tab. 59 > Garden-care/hobby appliances: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	0.004	0.006	0.006	0.006	0.006
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	0.010	0.050	0.098	0.067	0.051	0.047	0.047	0.047
Garden-care/hobby appliances	Hedge cutters (professional)	Petrol (2-str)	0.001	0.004	0.008	0.008	0.006	0.006	0.006	0.006
Garden-care/hobby appliances	Hedge cutters (professional)	Electricity	0.001	0.003	0.006	0.008	0.008	0.007	0.007	0.007
Garden-care/hobby appliances	Blowers (professional)	Petrol (4-str)	-	-	-	0.001	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Blowers (professional)	Petrol (2-str)	-	0.001	0.010	0.004	0.001	0.000	0.000	0.000
Garden-care/hobby appliances	Lawn mowers (professional)	Petrol (4-str)	0.024	0.027	0.030	0.038	0.037	0.037	0.037	0.037
Garden-care/hobby appliances	Lawn mowers (professional)	Petrol (2-str)	0.009	0.005	-	-	-	-	-	-
Garden-care/hobby appliances	Ride-on mowers (professional)	Petrol (4-str)	0.011	0.026	0.052	0.058	0.055	0.054	0.054	0.054
Garden-care/hobby appliances	Chainsaws (professional)	Petrol (2-str)	0.033	0.036	0.038	0.038	0.032	0.029	0.030	0.030
Garden-care/hobby appliances	Scarifiers (professional)	Petrol (4-str)	-	0.004	0.013	0.017	0.015	0.015	0.015	0.015
Garden-care/hobby appliances	Mill cutters/shredders (professional)	Petrol (4-str)	0.010	0.012	0.014	0.018	0.016	0.016	0.016	0.016
Garden-care/hobby appliances	Shredders (professional)	Petrol (4-str)	-	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Garden-care/hobby appliances	Snow blowers (professional)	Petrol (4-str)	0.007	0.009	0.007	0.007	0.006	0.006	0.006	0.006
Garden-care/hobby appliances	Cleaning appliances (professional)	Petrol (4-str)	-	0.007	0.011	0.013	0.013	0.012	0.012	0.012
Garden-care/hobby appliances	Cleaning appliances (professional)	Petrol (2-str)	-	0.001	-	-	-	-	-	-
Garden-care/hobby appliances	Cleaning appliances (professional)	Electricity	-	0.008	0.010	0.011	0.011	0.010	0.010	0.010
Garden-care/hobby appliances	Abrasive grinders (professional)	Petrol (2-str)	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005
Garden-care/hobby appliances	Abrasive grinders (professional)	Electricity	0.008	0.008	0.007	0.008	0.007	0.007	0.007	0.007
Garden-care/hobby appliances	Drills (professional)	Petrol (4-str)	-	-	0.002	0.003	0.004	0.004	0.004	0.004
Garden-care/hobby appliances	Drills (professional)	Petrol (2-str)	-	-	0.003	0.002	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Drills (professional)	Electricity	-	-	0.017	0.018	0.017	0.016	0.016	0.016
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	0.001	0.006	0.012	0.007	0.005	0.005	0.005	0.005
Garden-care/hobby appliances	Motor scythes, trimmers, cutters (household)	Electricity	0.000	0.002	0.005	0.004	0.003	0.003	0.003	0.003
Garden-care/hobby appliances	Hedge cutters (household)	Petrol (2-str)	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Hedge cutters (household)	Electricity	0.000	0.001	0.001	0.002	0.003	0.003	0.003	0.003
Garden-care/hobby appliances	Blowers (household)	Petrol (4-str)	-	-	-	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Blowers (household)	Petrol (2-str)	-	0.000	0.000	0.001	0.001	0.000	0.001	0.001
Garden-care/hobby appliances	Blowers (household)	Electricity	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Lawn mowers (household)	Petrol (4-str)	0.066	0.085	0.105	0.108	0.108	0.107	0.107	0.107
Garden-care/hobby appliances	Lawn mowers (household)	Petrol (2-str)	0.012	0.007	-	-	-	-	-	-
Garden-care/hobby appliances	Lawn mowers (household)	Electricity	0.022	0.027	0.032	0.032	0.033	0.033	0.033	0.032
Garden-care/hobby appliances	Ride-on mowers (household)	Petrol (4-str)	0.001	0.003	0.006	0.006	0.007	0.007	0.007	0.007
Garden-care/hobby appliances	Chainsaws (household)	Petrol (2-str)	0.014	0.014	0.014	0.014	0.012	0.012	0.012	0.012
Garden-care/hobby appliances	Chainsaws (household)	Electricity	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005
Garden-care/hobby appliances	Motor sleds (household)	Petrol (4-str)	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Garden-care/hobby appliances	Scarifiers (household)	Petrol (4-str)	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Scarifiers (household)	Electricity	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Mill cutters/shredders (household)	Petrol (4-str)	0.003	0.004	0.005	0.004	0.004	0.004	0.004	0.004
Garden-care/hobby appliances	Mill cutters/shredders (household)	Electricity	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Shredders (household)	Petrol (4-str)	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Shredders (household)	Electricity	-	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Snow blowers (household)	Petrol (4-str)	0.014	0.020	0.020	0.017	0.014	0.014	0.014	0.014
Garden-care/hobby appliances	Snow blowers (household)	Electricity	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Cleaning appliances (household)	Petrol (4-str)	-	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Cleaning appliances (household)	Petrol (2-str)	-	0.000	-	-	-	-	-	-
Garden-care/hobby appliances	Cleaning appliances (household)	Electricity	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Garden-care/hobby appliances	Lawn moving robotics	Electricity	-	-	-	0.018	0.021	0.021	0.021	0.021
Garden-care/hobby appliances	Wood splitter (professionalWood splitter (professionel	Petrol (4-str)	-	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Garden-care/hobby appliances	Wood splitter (Household)	Electricity	-	0.008	0.012	0.012	0.012	0.012	0.012	0.012

Tab. 60 > Navigation machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Navigation machinery	Motorised yachts	Diesel	0.028	0.030	0.026	0.027	0.026	0.025	0.024	0.023
Navigation machinery	Motorised yachts	Petrol (4-str)	0.005	0.005	0.005	0.004	0.003	0.003	0.003	0.003
Navigation machinery	Motorised yachts	Petrol (2-str)	0.006	0.007	0.004	0.003	0.003	0.003	0.003	0.003
Navigation machinery	Fishing & other commercial boats	Diesel	0.053	0.049	0.044	0.047	0.043	0.039	0.037	0.035
Navigation machinery	Fishing & other commercial boats	Petrol (4-str)	0.129	0.118	0.108	0.087	0.073	0.066	0.061	0.059
Navigation machinery	Fishing & other commercial boats	Petrol (2-str)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Navigation machinery	Hire and privately owned motor boats	Diesel	0.057	0.062	0.054	0.066	0.073	0.077	0.078	0.079
Navigation machinery	Hire and privately owned motor boats	Petrol (4-str)	0.508	0.552	0.487	0.431	0.433	0.447	0.454	0.459
Navigation machinery	Hire and privately owned motor boats	Petrol (2-str)	0.017	0.018	0.012	0.009	0.009	0.009	0.009	0.010
Navigation machinery	Passenger ships	Diesel	0.347	0.327	0.386	0.420	0.414	0.395	0.381	0.376
Navigation machinery	Passenger ships	Dampf	0.084	0.111	0.148	0.159	0.146	0.139	0.133	0.131
Navigation machinery	Cargo ships/barges	Diesel	0.119	0.186	0.153	0.159	0.168	0.173	0.176	0.178
Navigation machinery	Ferries	Diesel	0.056	0.056	0.097	0.112	0.113	0.114	0.114	0.114
Navigation machinery	Carg ships Rhine, main engines	Diesel	0.013	0.016	0.019	0.023	0.027	0.029	0.030	0.031
Navigation machinery	Carg ships Rhine, auxiliary engines	Diesel	0.010	0.012	0.013	0.015	0.016	0.018	0.018	0.019

Tab. 61 > Railway machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Railway machinery	Shunting locomotives	Diesel	0.243	0.277	0.340	0.402	0.306	0.307	0.307	0.307
Railway machinery	Twin-engined tractors	Diesel	0.003	0.011	0.010	0.000	0.003	0.003	0.003	0.003
Railway machinery	TractorsRailway tractors	Diesel	0.040	0.102	0.105	0.090	0.085	0.085	0.085	0.085

Tab. 62 > Military machinery: energy consumption (in PJ p.a.)

Category	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Military machinery	Pz 68 family	Diesel	0.004	0.004	0.004	-	-	-	-	-
Military machinery	Leo 87	Diesel	0.024	0.024	0.024	0.014	0.008	0.007	0.007	0.007
Military machinery	Howitzers	Diesel	0.004	0.004	0.004	0.003	0.002	0.002	0.001	0.001
Military machinery	Armoured personnel carriers	Diesel	0.142	0.142	0.122	0.014	0.014	0.014	0.004	0.004
Military machinery	Other armoured vehicles	Diesel	-	0.007	0.025	0.170	0.170	0.170	0.170	0.170
Military machinery	Reconnaissance vehicles	Diesel	0.001	0.001	0.015	0.015	0.016	0.016	0.016	0.016
Military machinery	Caterpillar loaders/crawler Loaders	Diesel	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004
Military machinery	Rubber-wheeled loading shovels/ wheel loaders	Diesel	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Military machinery	Crawler excavators Mil	Diesel	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006
Military machinery	Walking excavators Mil	Diesel	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Military machinery	Bulldozers/crawler tractors	Diesel	0.000	0.000	0.000	-	-	-	-	-
Military machinery	Pile drivers/piling rigs	Diesel	-	-	0.000	0.000	0.000	0.000	0.000	0.000
Military machinery	Crane trucks	Diesel	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000
Military machinery	Patrol boats	Diesel	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Military machinery	Other boats	Petrol (4-str)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Military machinery	Assortment Lenz use	Diesel	-	-	-	-	0.000	0.000	0.000	0.000
Military machinery	Power generating appliances	Diesel	0.018	0.018	0.018	0.018	0.019	0.019	0.019	0.019
Military machinery	Power generating appliances	Petrol (4-str)	0.016	0.016	0.016	0.015	0.014	0.014	0.014	0.014
Military machinery	Power generating appliances	Petrol (2-str)	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.002
Military machinery	Support bridge 46m	Diesel	-	-	-	-	0.003	0.003	0.003	0.003
Military machinery	Assortment water pipe	Diesel	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000

A13 Emissions by machine type

Tab. 63 > Construction machines: emissions (in tonnes p.a.)

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Asphalt finishers	Diesel	1	2	2	1	0	0	0	0
HC	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
HC	Rollers of all types	Diesel	9	11	11	5	3	3	3	3
HC	Mechanical vibrators	Diesel	1	1	1	0	0	0	0	0
HC	Hand-operated rammers, vibrators	Diesel	-	1	3	1	1	1	1	1
HC	Hand-operated rammers, vibrators	Petrol (4-str)	12	15	13	8	5	4	4	5
HC	Hand-operated rammers, vibrators	Petrol (2-str)	418	463	327	137	57	54	52	50
HC	Cable dredgers	Diesel	1	1	1	0	0	0	0	0
HC	Rubber-tyred and mobile cranes	Diesel	8	10	12	5	2	2	2	2
HC	Graders	Diesel	5	6	7	3	1	1	1	1
HC	HGV's without licence for use on road	Diesel	9	11	12	5	2	1	1	1
HC	Crawler tractors	Diesel	5	6	8	3	1	1	1	1
HC	Loaders (rubber-tyred and crawler) of all types	Diesel	95	121	145	64	24	22	23	24
HC	Dump trucks	Diesel	39	50	61	39	17	18	20	22
HC	Emergency power supply systems/generators	Diesel	0	0	2	3	1	1	1	1
HC	Emergency power supply systems/generators	Petrol (4-str)	12	18	15	10	6	5	5	5
HC	Pumps of all types	Diesel	0	1	1	0	0	0	0	0
HC	Pumps of all types	Petrol (4-str)	1	2	2	1	1	1	1	1
HC	Mobile compressors	Diesel	48	67	69	23	9	7	7	6
HC	Mobile elevating work platforms	Diesel	1	1	2	1	0	0	0	0
HC	Tunnel locomotives	Diesel	2	3	3	1	0	0	0	1
HC	Concrete/surface milling cutters	Diesel	2	3	5	2	1	1	1	1
HC	Concrete/surface milling cutters	Petrol (4-str)	59	68	74	42	24	18	18	19
HC	Trench cutters	Diesel	0	0	0	0	0	0	0	0
HC	Drilling machines of all types (esp. civil engineering)	Diesel	4	5	6	2	1	1	1	1
HC	Mini-excavators	Diesel	31	40	53	28	14	15	15	16
HC	Crawles excavators	Diesel	95	128	190	108	42	32	32	34
HC	Wheeled excavators	Diesel	42	50	66	31	10	7	6	6
CO	Asphalt finishers	Diesel	7	9	10	5	2	1	1	1
CO	Hydraulic rammers of all types	Diesel	1	1	1	0	0	0	0	0
CO	Rollers of all types	Diesel	42	52	51	28	15	12	13	13
CO	Mechanical vibrators	Diesel	3	3	2	1	0	0	0	0
CO	Hand-operated rammers, vibrators	Diesel	-	3	8	4	3	3	3	3
CO	Hand-operated rammers, vibrators	Petrol (4-str)	203	266	233	252	258	283	309	335
CO	Hand-operated rammers, vibrators	Petrol (2-str)	884	980	728	609	521	467	448	429
CO	Cable dredgers	Diesel	3	4	5	2	1	1	1	1
CO	Rubber-tyred and mobile cranes	Diesel	44	55	70	23	8	6	6	6
CO	Graders	Diesel	26	34	40	13	4	3	3	2

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CO	HGV's without licence for use on road	Diesel	51	61	67	25	8	5	5	5
CO	Crawler tractors	Diesel	30	38	45	14	4	4	3	3
CO	Loaders (rubber-tyred and crawler) of all types	Diesel	513	665	805	303	111	95	98	100
CO	Dump trucks	Diesel	189	251	311	189	86	79	86	93
CO	Emergency power supply systems/generators	Diesel	0	1	7	10	6	5	5	5
CO	Emergency power supply systems/generators	Petrol (4-str)	244	323	283	324	335	356	366	366
CO	Pumps of all types	Diesel	1	2	2	1	1	1	1	1
CO	Pumps of all types	Petrol (4-str)	25	27	34	37	35	36	37	38
CO	Mobile compressors	Diesel	156	218	225	77	40	31	29	27
CO	Mobile elevating work platforms	Diesel	2	4	5	3	1	1	2	2
CO	Tunnel locomotives	Diesel	11	14	17	6	2	2	2	2
CO	Concrete/surface milling cutters	Diesel	11	18	26	10	4	3	3	3
CO	Concrete/surface milling cutters	Petrol (4-str)	1,020	1,180	1,269	1,309	1,307	1,380	1,439	1,486
CO	Trench cutters	Diesel	1	2	2	1	1	0	0	0
CO	Drilling machines of all types (esp. civil engineering)	Diesel	13	17	20	7	3	3	3	3
CO	Mini-excavators	Diesel	129	163	217	129	108	73	76	78
CO	Crawles excavators	Diesel	493	684	1,034	532	196	134	135	140
CO	Wheeled excavators	Diesel	216	260	352	152	49	30	27	26
NO_X	Asphalt finishers	Diesel	10	14	15	11	4	3	3	3
NO_X	Hydraulic rammers of all types	Diesel	3	4	4	2	0	0	0	0
NO_X	Rollers of all types	Diesel	54	69	62	51	30	30	32	34
NO_X	Mechanical vibrators	Diesel	9	8	6	2	1	0	0	0
NO_X	Hand-operated rammers, vibrators	Diesel	-	5	9	7	6	6	6	6
NO_X	Hand-operated rammers, vibrators	Petrol (4-str)	1	2	2	1	1	0	1	1
NO_X	Hand-operated rammers, vibrators	Petrol (2-str)	2	2	2	5	6	6	6	5
NO_X	Cable dredgers	Diesel	6	8	9	5	2	1	1	1
NO_X	Rubber-tyred and mobile cranes	Diesel	86	110	124	64	15	8	8	8
NO_X	Graders	Diesel	53	67	69	34	7	2	2	2
NO_X	HGV's without licence for use on road	Diesel	96	114	114	61	17	6	5	5
NO_X	Crawler tractors	Diesel	63	79	81	38	7	3	3	3
NO_X	Loaders (rubber-tyred and crawler) of all types	Diesel	912	1,230	1,323	767	209	129	133	136
NO_X	Dump trucks	Diesel	275	380	424	413	172	147	162	173
NO_X	Emergency power supply systems/generators	Diesel	1	2	17	37	13	6	6	6
NO_X	Emergency power supply systems/generators	Petrol (4-str)	2	2	2	2	1	1	1	1
NO_X	Pumps of all types	Diesel	1	3	2	2	2	2	2	2
NO_X	Pumps of all types	Petrol (4-str)	0	0	0	0	0	0	0	0
NO_X	Mobile compressors	Diesel	375	528	483	261	101	76	70	66
NO_X	Mobile elevating work platforms	Diesel	4	9	13	9	3	2	3	3
NO_X	Tunnel locomotives	Diesel	21	28	29	16	4	2	2	2
NO_X	Concrete/surface milling cutters	Diesel	20	34	44	25	6	4	4	4
NO_X	Concrete/surface milling cutters	Petrol (4-str)	7	8	9	6	5	2	2	2
NO_X	Trench cutters	Diesel	1	1	1	1	1	1	1	1

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
NO_X	Drilling machines of all types (esp. civil engineering)	Diesel	33	45	49	27	8	5	5	5
NO_X	Mini-excavators	Diesel	110	139	167	157	187	297	316	327
NO_X	Crawles excavators	Diesel	791	1,164	1,650	1,138	400	195	183	189
NO_X	Wheeled excavators	Diesel	337	423	536	287	101	57	51	49
PM	Asphalt finishers	Diesel	1	1	1	0	0	0	0	0
PM	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
PM	Rollers of all types	Diesel	6	7	7	2	1	0	0	0
PM	Mechanical vibrators	Diesel	1	1	0	0	0	0	0	0
PM	Hand-operated rammers, vibrators	Diesel	-	1	2	1	1	0	0	0
PM	Hand-operated rammers, vibrators	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Hand-operated rammers, vibrators	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Cable dredgers	Diesel	0	0	1	0	0	0	0	0
PM	Rubber-tyred and mobile cranes	Diesel	5	6	7	1	0	0	0	0
PM	Graders	Diesel	3	4	4	0	0	0	0	0
PM	HGV's without licence for use on road	Diesel	6	7	7	1	0	0	0	0
PM	Crawler tractors	Diesel	3	4	5	1	0	0	0	0
PM	Loaders (rubber-tyred and crawler) of all types	Diesel	61	78	87	17	4	2	2	2
PM	Dump trucks	Diesel	26	35	40	10	3	2	2	2
PM	Emergency power supply systems/generators	Diesel	0	0	1	1	0	0	0	0
PM	Emergency power supply systems/generators	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Pumps of all types	Diesel	0	0	0	0	0	0	0	0
PM	Pumps of all types	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Mobile compressors	Diesel	30	41	35	6	1	0	0	0
PM	Mobile elevating work platforms	Diesel	0	1	1	0	0	0	0	0
PM	Tunnel locomotives	Diesel	1	2	2	0	0	0	0	0
PM	Concrete/surface milling cutters	Diesel	1	2	3	0	0	0	0	0
PM	Concrete/surface milling cutters	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Trench cutters	Diesel	0	0	0	0	0	0	0	0
PM	Drilling machines of all types (esp. civil engineering)	Diesel	3	3	3	0	0	0	0	0
PM	Mini-excavators	Diesel	17	21	27	21	17	7	7	7
PM	Crawles excavators	Diesel	67	86	113	15	4	2	2	2
PM	Wheeled excavators	Diesel	30	35	41	4	1	0	0	0
CO_2	Asphalt finishers	Diesel	867	1,145	1,386	1,688	1,712	1,712	1,712	1,712
CO_2	Hydraulic rammers of all types	Diesel	238	283	313	321	322	322	322	322
CO_2	Rollers of all types	Diesel	4,725	5,936	5,997	7,819	9,106	10,106	10,917	11,573
CO_2	Mechanical vibrators	Diesel	695	598	491	359	259	199	165	148
CO_2	Hand-operated rammers, vibrators	Diesel	-	458	1,065	1,067	1,067	1,067	1,067	1,067
CO_2	Hand-operated rammers, vibrators	Petrol (4-str)	680	893	779	814	778	839	915	991
CO_2	Hand-operated rammers, vibrators	Petrol (2-str)	3,077	3,409	2,503	1,888	1,392	1,203	1,154	1,106
CO_2	Cable dredgers	Diesel	372	485	604	650	673	673	673	673
CO_2	Rubber-tyred and mobile cranes	Diesel	5,428	6,899	8,851	9,790	9,943	9,524	9,179	8,896
CO_2	Graders	Diesel	3,005	3,781	4,400	4,267	3,892	3,549	3,274	3,045

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CO_2	HGV's without licence for use on road	Diesel	5,393	6,410	7,098	7,285	7,293	7,293	7,293	7,293
CO_2	Crawler tractors	Diesel	3,538	4,455	5,197	5,074	4,786	4,505	4,284	4,111
CO_2	Loaders (rubber-tyred and crawler) of all types	Diesel	54,994	73,577	90,168	105,007	112,487	116,983	120,535	123,400
CO_2	Dump trucks	Diesel	18,274	24,775	31,152	53,967	68,866	78,549	86,381	92,729
CO_2	Emergency power supply systems/generators	Diesel	65	107	1,094	4,447	5,687	6,053	6,215	6,221
CO_2	Emergency power supply systems/generators	Petrol (4-str)	788	1,062	922	1,032	1,010	1,054	1,082	1,083
CO_2	Pumps of all types	Diesel	109	225	198	213	219	225	232	238
CO_2	Pumps of all types	Petrol (4-str)	79	92	113	118	107	108	111	114
CO_2	Mobile compressors	Diesel	23,575	32,825	34,089	32,963	30,323	27,747	25,658	23,967
CO_2	Mobile elevating work platforms	Diesel	335	729	1,155	1,473	1,686	1,812	1,912	1,997
CO_2	Tunnel locomotives	Diesel	1,337	1,755	2,109	2,483	2,719	2,856	2,993	3,107
CO_2	Concrete/surface milling cutters	Diesel	1,148	1,931	2,853	3,512	3,822	4,035	4,209	4,348
CO_2	Concrete/surface milling cutters	Petrol (4-str)	3,420	3,958	4,257	4,202	3,946	4,083	4,258	4,398
CO_2	Trench cutters	Diesel	92	109	121	122	123	123	123	123
CO_2	Drilling machines of all types (esp. civil engineering)	Diesel	2,059	2,764	3,374	3,610	3,655	3,655	3,655	3,655
CO_2	Mini-excavators	Diesel	8,944	11,271	15,348	20,781	24,833	27,543	29,118	30,052
CO_2	Crawles excavators	Diesel	48,609	69,108	106,685	130,032	142,533	150,449	156,858	162,053
CO_2	Wheeled excavators	Diesel	20,498	25,262	35,073	30,835	28,095	26,339	24,903	23,748
CH_4	Asphalt finishers	Diesel	0	0	0	0	0	0	0	0
CH_4	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
CH_4	Rollers of all types	Diesel	0	0	0	0	0	0	0	0
CH_4	Mechanical vibrators	Diesel	0	0	0	0	0	0	0	0
CH_4	Hand-operated rammers, vibrators	Diesel	-	0	0	0	0	0	0	0
CH_4	Hand-operated rammers, vibrators	Petrol (4-str)	0	1	0	0	0	0	0	0
CH_4	Hand-operated rammers, vibrators	Petrol (2-str)	29	32	23	10	4	4	4	3
CH_4	Cable dredgers	Diesel	0	0	0	0	0	0	0	0
CH_4	Rubber-tyred and mobile cranes	Diesel	0	0	0	0	0	0	0	0
CH_4	Graders	Diesel	0	0	0	0	0	0	0	0
CH_4	HGV's without licence for use on road	Diesel	0	0	0	0	0	0	0	0
CH_4	Crawler tractors	Diesel	0	0	0	0	0	0	0	0
CH_4	Loaders (rubber-tyred and crawler) of all types	Diesel	2	3	3	2	1	1	1	1
CH_4	Dump trucks	Diesel	1	1	1	1	0	0	0	0
CH_4	Emergency power supply systems/generators	Diesel	0	0	0	0	0	0	0	0
CH_4	Emergency power supply systems/generators	Petrol (4-str)	0	1	1	0	0	0	0	0
CH_4	Pumps of all types	Diesel	0	0	0	0	0	0	0	0
CH_4	Pumps of all types	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Mobile compressors	Diesel	1	2	2	1	0	0	0	0
CH_4	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
CH_4	Tunnel locomotives	Diesel	0	0	0	0	0	0	0	0
CH_4	Concrete/surface milling cutters	Diesel	0	0	0	0	0	0	0	0
CH_4	Concrete/surface milling cutters	Petrol (4-str)	2	2	3	1	1	1	1	1
CH_4	Trench cutters	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CH_4	Drilling machines of all types (esp. civil engineering)	Diesel	0	0	0	0	0	0	0	0
CH_4	Mini-excavators	Diesel	1	1	1	1	0	0	0	0
CH_4	Crawles excavators	Diesel	2	3	5	3	1	1	1	1
CH_4	Wheeled excavators	Diesel	1	1	2	1	0	0	0	0
NMHC	Asphalt finishers	Diesel	1	2	2	1	0	0	0	0
NMHC	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
NMHC	Rollers of all types	Diesel	9	11	10	5	2	3	3	3
NMHC	Mechanical vibrators	Diesel	1	1	1	0	0	0	0	0
NMHC	Hand-operated rammers, vibrators	Diesel	-	1	3	1	1	1	1	1
NMHC	Hand-operated rammers, vibrators	Petrol (4-str)	11	15	13	8	5	4	4	4
NMHC	Hand-operated rammers, vibrators	Petrol (2-str)	389	431	304	128	53	50	48	46
NMHC	Cable dredgers	Diesel	1	1	1	0	0	0	0	0
NMHC	Rubber-tyred and mobile cranes	Diesel	8	9	12	5	2	2	2	2
NMHC	Graders	Diesel	4	6	7	3	1	1	1	1
NMHC	HGV's without licence for use on road	Diesel	9	11	12	5	2	1	1	1
NMHC	Crawler tractors	Diesel	5	6	8	3	1	1	1	1
NMHC	Loaders (rubber-tyred and crawler) of all types	Diesel	93	118	141	62	23	22	23	23
NMHC	Dump trucks	Diesel	38	49	60	38	17	18	20	21
NMHC	Emergency power supply systems/generators	Diesel	0	0	2	3	1	1	1	1
NMHC	Emergency power supply systems/generators	Petrol (4-str)	12	17	14	10	6	4	5	5
NMHC	Pumps of all types	Diesel	0	1	1	0	0	0	0	0
NMHC	Pumps of all types	Petrol (4-str)	1	2	2	1	1	0	1	1
NMHC	Mobile compressors	Diesel	47	65	67	22	8	7	7	6
NMHC	Mobile elevating work platforms	Diesel	1	1	2	1	0	0	0	0
NMHC	Tunnel locomotives	Diesel	2	2	3	1	0	0	0	1
NMHC	Concrete/surface milling cutters	Diesel	2	3	5	2	1	1	1	1
NMHC	Concrete/surface milling cutters	Petrol (4-str)	57	66	71	40	24	17	18	18
NMHC	Trench cutters	Diesel	0	0	0	0	0	0	0	0
NMHC	Drilling machines of all types (esp. civil engineering)	Diesel	4	5	6	2	1	1	1	1
NMHC	Mini-excavators	Diesel	31	39	52	27	14	14	15	16
NMHC	Crawles excavators	Diesel	93	125	185	105	41	31	32	33
NMHC	Wheeled excavators	Diesel	41	49	65	30	10	7	6	6
N_2O	Asphalt finishers	Diesel	0	0	0	0	0	0	0	0
N_2O	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
N_2O	Rollers of all types	Diesel	0	0	0	0	0	0	0	0
N_2O	Mechanical vibrators	Diesel	0	0	0	0	0	0	0	0
N_2O	Hand-operated rammers, vibrators	Diesel	-	0	0	0	0	0	0	0
N_2O	Hand-operated rammers, vibrators	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Hand-operated rammers, vibrators	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Cable dredgers	Diesel	0	0	0	0	0	0	0	0
N_2O	Rubber-tyred and mobile cranes	Diesel	0	0	0	0	0	0	0	0
N_2O	Graders	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
N_2O	HGV's without licence for use on road	Diesel	0	0	0	0	0	0	0	0
N_2O	Crawler tractors	Diesel	0	0	0	0	0	0	0	0
N_2O	Loaders (rubber-tyred and crawler) of all types	Diesel	3	3	4	5	5	5	6	6
N_2O	Dump trucks	Diesel	1	1	1	2	3	4	4	4
N_2O	Emergency power supply systems/generators	Diesel	0	0	0	0	0	0	0	0
N_2O	Emergency power supply systems/generators	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Pumps of all types	Diesel	0	0	0	0	0	0	0	0
N_2O	Pumps of all types	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Mobile compressors	Diesel	1	2	2	2	1	1	1	1
N_2O	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
N_2O	Tunnel locomotives	Diesel	0	0	0	0	0	0	0	0
N_2O	Concrete/surface milling cutters	Diesel	0	0	0	0	0	0	0	0
N_2O	Concrete/surface milling cutters	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Trench cutters	Diesel	0	0	0	0	0	0	0	0
N_2O	Drilling machines of all types (esp. civil engineering)	Diesel	0	0	0	0	0	0	0	0
N_2O	Mini-excavators	Diesel	0	0	1	1	1	1	1	1
N_2O	Crawles excavators	Diesel	2	3	5	6	7	7	7	8
N_2O	Wheeled excavators	Diesel	1	1	2	1	1	1	1	1
Benzol	Asphalt finishers	Diesel	0	0	0	0	0	0	0	0
Benzol	Hydraulic rammers of all types	Diesel	0	0	0	0	0	0	0	0
Benzol	Rollers of all types	Diesel	0	0	0	0	0	0	0	0
Benzol	Mechanical vibrators	Diesel	0	0	0	0	0	0	0	0
Benzol	Hand-operated rammers, vibrators	Diesel	-	0	0	0	0	0	0	0
Benzol	Hand-operated rammers, vibrators	Petrol (4-str)	1	1	0	0	0	0	0	0
Benzol	Hand-operated rammers, vibrators	Petrol (2-str)	21	23	3	1	0	0	0	0
Benzol	Cable dredgers	Diesel	0	0	0	0	0	0	0	0
Benzol	Rubber-tyred and mobile cranes	Diesel	0	0	0	0	0	0	0	0
Benzol	Graders	Diesel	0	0	0	0	0	0	0	0
Benzol	HGV's without licence for use on road	Diesel	0	0	0	0	0	0	0	0
Benzol	Crawler tractors	Diesel	0	0	0	0	0	0	0	0
Benzol	Loaders (rubber-tyred and crawler) of all types	Diesel	0	0	0	0	0	0	0	0
Benzol	Dump trucks	Diesel	0	0	0	0	0	0	0	0
Benzol	Emergency power supply systems/generators	Diesel	0	0	0	0	0	0	0	0
Benzol	Emergency power supply systems/generators	Petrol (4-str)	1	1	0	0	0	0	0	0
Benzol	Pumps of all types	Diesel	0	0	0	0	0	0	0	0
Benzol	Pumps of all types	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Mobile compressors	Diesel	0	0	0	0	0	0	0	0
Benzol	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
Benzol	Tunnel locomotives	Diesel	0	0	0	0	0	0	0	0
Benzol	Concrete/surface milling cutters	Diesel	0	0	0	0	0	0	0	0
Benzol	Concrete/surface milling cutters	Petrol (4-str)	3	3	1	0	0	0	0	0
Benzol	Trench cutters	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Benzol	Drilling machines of all types (esp. civil engineering)	Diesel	0	0	0	0	0	0	0	0
Benzol	Mini-excavators	Diesel	0	0	0	0	0	0	0	0
Benzol	Crawles excavators	Diesel	0	0	0	0	0	0	0	0
Benzol	Wheeled excavators	Diesel	0	0	0	0	0	0	0	0

Tab. 64 > Industrial machinery: emission (in tonnes p.a.)

Pollutant	Machine type	Engine tape	1980	1990	2000	2010	2020	2030	2040	2050
HC	Forklifts of all types	Diesel	54	90	155	78	16	8	8	8
HC	Forklifts of all types	Petrol (4-str)	25	41	73	63	14	7	6	6
HC	Forklifts of all types	LPG	46	16	4	3	2	1	1	1
HC	Sweepers and cleansers	Diesel	6	10	10	6	2	2	2	2
HC	Mobile elevating work platforms	Diesel	11	16	17	10	3	3	3	3
HC	TractorsIndustral tractors	Diesel	7	11	12	8	3	2	2	2
HC	TractorsIndustral tractors	Petrol (4-str)	9	14	14	11	6	4	4	4
HC	Runway vehicles	Diesel	74	91	107	51	19	17	18	19
HC	Air side passenger cars	Diesel	0	0	0	0	0	0	0	0
HC	Air side passenger cars	Petrol (4-str)	7	6	2	0	0	0	0	0
HC	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
HC	Air side light duty vehicles	Diesel	0	1	0	0	0	0	0	0
HC	Air side light duty vehicles	Petrol (4-str)	1	1	0	0	0	0	0	0
HC	Air side Heavy duty vehicles/buses	Diesel	0	1	1	0	0	0	0	0
HC	Air side generators	Diesel	2	3	5	2	1	1	1	1
HC	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
HC	generators Industrial machinery/ Business/public	Diesel	3	5	5	3	1	1	1	1
CO	Forklifts of all types	Diesel	237	396	688	375	96	39	34	34
CO	Forklifts of all types	Petrol (4-str)	425	709	1,251	1,468	642	469	464	461
CO	Forklifts of all types	LPG	37	15	8	6	4	3	3	3
CO	Sweepers and cleansers	Diesel	31	47	49	31	13	9	10	10
CO	Mobile elevating work platforms	Diesel	35	53	55	32	14	12	12	12
CO	Industral tractors	Diesel	35	52	55	36	17	11	11	11
CO	Industral tractors	Petrol (4-str)	156	235	251	272	271	279	285	289
CO	Runway vehicles	Diesel	270	331	392	162	73	65	68	70
CO	Air side passenger cars	Diesel	0	0	0	0	0	0	0	0
CO	Air side passenger cars	Petrol (4-str)	43	37	15	4	3	4	4	4
CO	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
CO	Air side light duty vehicles	Diesel	2	3	2	0	0	0	0	0
CO	Air side light duty vehicles	Petrol (4-str)	8	8	3	1	1	1	1	1
CO	Air side Heavy duty vehicles/buses	Diesel	1	2	2	2	1	0	0	0

Pollutant	Machine type	Engine tape	1980	1990	2000	2010	2020	2030	2040	2050
CO	Air side generators	Diesel	7	11	19	7	4	4	5	5
CO	Air side dispatch appliances	Diesel	1	1	1	1	0	1	1	1
CO	Generators Industrial machinery/ Business/public	Diesel	12	18	19	8	5	5	6	6
NO_X	Forklifts of all types	Diesel	277	462	747	511	184	112	109	108
NO_X	Forklifts of all types	Petrol (4-str)	3	5	8	8	3	1	1	1
NO_X	Forklifts of all types	LPG	48	80	107	37	16	12	12	12
NO_X	Sweepers and cleansers	Diesel	44	66	64	54	28	23	24	25
NO_X	Mobile elevating work platforms	Diesel	81	123	120	86	39	27	27	27
NO_X	Industral tractors	Diesel	45	69	67	51	30	25	26	26
NO_X	Industral tractors	Petrol (4-str)	1	2	2	1	1	1	0	0
NO_X	Runway vehicles	Diesel	763	942	1,012	616	170	66	64	67
NO_X	Air side passenger cars	Diesel	0	0	0	2	2	2	2	2
NO_X	Air side passenger cars	Petrol (4-str)	5	7	6	1	0	0	1	0
NO_X	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
NO_X	Air side light duty vehicles	Diesel	2	3	4	3	2	1	2	2
NO_X	Air side light duty vehicles	Petrol (4-str)	1	1	1	0	0	0	0	0
NO_X	Air side Heavy duty vehicles/buses	Diesel	5	8	10	7	1	1	1	1
NO_X	Air side generators	Diesel	20	32	49	28	9	4	4	5
NO_X	Air side dispatch appliances	Diesel	1	2	3	2	1	1	1	2
NO_X	Generators Industrial machinery/ Business/public	Diesel	36	54	52	32	18	12	13	14
PM	Forklifts of all types	Diesel	31	52	85	31	6	0	0	0
PM	Forklifts of all types	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Forklifts of all types	LPG	0	0	0	0	0	0	0	0
PM	Sweepers and cleansers	Diesel	4	6	6	3	1	0	0	0
PM	Mobile elevating work platforms	Diesel	7	10	9	3	1	0	0	0
PM	Industral tractors	Diesel	5	7	7	4	2	1	1	1
PM	Industral tractors	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Runway vehicles	Diesel	46	56	59	28	6	1	1	1
PM	Air side passenger cars	Diesel	0	0	0	0	0	0	0	0
PM	Air side passenger cars	Petrol (4-str)	0	0	0	0	0	0	0	0
PM	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
PM	Air side light duty vehicles	Diesel	1	1	1	0	0	0	0	0
PM	Air side light duty vehicles	Petrol (4-str)	0	0	0	0	0	0	0	0
PM	Air side Heavy duty vehicles/buses	Diesel	0	0	0	0	0	0	0	0
PM	Air side generators	Diesel	1	2	3	1	0	0	0	0
PM	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
PM	Generators Industrial machinery/ Business/public	Diesel	2	3	3	1	0	0	0	0
CO_2	Forklifts of all types	Diesel	24,058	40,099	70,861	69,279	40,761	30,222	29,922	29,745
CO_2	Forklifts of all types	Petrol (4-str)	1,426	2,377	4,194	4,812	1,967	1,394	1,373	1,364
CO_2	Forklifts of all types	LPG	5,523	9,205	16,351	14,907	9,320	6,885	6,817	6,777

Pollutant	Machine type	Engine tape	1980	1990	2000	2010	2020	2030	2040	2050
CO_2	Sweepers and cleansers	Diesel	3,537	5,369	5,732	7,819	9,236	10,068	10,552	10,834
CO_2	Mobile elevating work platforms	Diesel	6,429	9,748	10,408	11,940	12,932	13,504	13,822	14,012
CO_2	Industral tractors	Diesel	3,529	5,331	5,699	6,429	6,900	7,178	7,331	7,424
CO_2	Industral tractors	Petrol (4-str)	522	788	839	890	826	829	843	854
CO_2	Runway vehicles	Diesel	43,127	53,082	63,776	74,750	84,553	92,058	97,132	101,455
CO_2	Air side passenger cars	Diesel	32	50	109	725	965	1,191	1,340	1,428
CO_2	Air side passenger cars	Petrol (4-str)	1,138	1,794	2,975	2,278	2,453	2,873	3,125	3,044
CO_2	Air side passenger cars	LPG	-	-	-	39	51	64	72	77
CO_2	Air side light duty vehicles	Diesel	276	435	722	793	1,039	1,289	1,452	1,547
CO_2	Air side light duty vehicles	Petrol (4-str)	75	118	188	205	262	324	365	389
CO_2	Air side Heavy duty vehicles/buses	Diesel	279	439	702	797	997	1,236	1,391	1,483
CO_2	Air side generators	Diesel	1,131	1,784	3,052	3,523	4,613	5,780	6,497	6,900
CO_2	Air side dispatch appliances	Diesel	79	125	212	246	324	404	454	484
CO_2	Generators Industrial machinery/ Business/public	Diesel	2,027	3,084	3,277	3,762	5,004	6,242	7,027	7,491
CH_4	Forklifts of all types	Diesel	1	2	4	2	0	0	0	0
CH_4	Forklifts of all types	Petrol (4-str)	1	1	2	2	0	0	0	0
CH_4	Forklifts of all types	LPG	3	1	0	0	0	0	0	0
CH_4	Sweepers and cleansers	Diesel	0	0	0	0	0	0	0	0
CH_4	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
CH_4	Industral tractors	Diesel	0	0	0	0	0	0	0	0
CH_4	Industral tractors	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Runway vehicles	Diesel	2	2	3	1	0	0	0	0
CH_4	Air side passenger cars	Diesel	0	0	0	0	0	0	0	0
CH_4	Air side passenger cars	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
CH_4	Air side light duty vehicles	Diesel	0	0	0	0	0	0	0	0
CH_4	Air side light duty vehicles	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Air side Heavy duty vehicles/buses	Diesel	0	0	0	0	0	0	0	0
CH_4	Air side generators	Diesel	0	0	0	0	0	0	0	0
CH_4	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
CH_4	Generators Industrial machinery/ Business/public	Diesel	0	0	0	0	0	0	0	0
NMHC	Forklifts of all types	Diesel	52	87	151	76	15	8	8	8
NMHC	Forklifts of all types	Petrol (4-str)	24	40	70	61	14	6	6	6
NMHC	Forklifts of all types	LPG	43	15	4	2	1	1	1	1
NMHC	Sweepers and cleansers	Diesel	6	9	10	6	2	2	2	2
NMHC	Mobile elevating work platforms	Diesel	11	16	16	10	3	3	3	3
NMHC	Industral tractors	Diesel	7	11	11	7	3	2	2	2
NMHC	Industral tractors	Petrol (4-str)	9	13	14	11	5	4	4	4
NMHC	Runway vehicles	Diesel	73	89	104	49	19	17	17	18
NMHC	Air side passenger cars	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine tape	1980	1990	2000	2010	2020	2030	2040	2050
NMHC	Air side passenger cars	Petrol (4-str)	6	5	2	0	0	0	0	0
NMHC	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
NMHC	Air side light duty vehicles	Diesel	0	1	0	0	0	0	0	0
NMHC	Air side light duty vehicles	Petrol (4-str)	1	1	0	0	0	0	0	0
NMHC	Air side Heavy duty vehicles/buses	Diesel	0	1	1	0	0	0	0	0
NMHC	Air side generators	Diesel	2	3	5	2	1	1	1	1
NMHC	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
NMHC	Generators Industrial machinery/ Business/public	Diesel	3	5	5	3	1	1	1	1
N_2O	Forklifts of all types	Diesel	1	1	2	2	1	1	1	1
N_2O	Forklifts of all types	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Forklifts of all types	LPG	0	0	1	1	0	0	0	0
N_2O	Sweepers and cleansers	Diesel	0	0	0	0	0	0	0	0
N_2O	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
N_2O	Industral tractors	Diesel	0	0	0	0	0	0	0	0
N_2O	Industral tractors	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Runway vehicles	Diesel	2	3	3	4	4	4	5	5
N_2O	Air side passenger cars	Diesel	-	0	0	0	0	0	0	0
N_2O	Air side passenger cars	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Air side passenger cars	LPG	-	-	-	0	0	0	0	0
N_2O	Air side light duty vehicles	Diesel	-	0	0	0	0	0	0	0
N_2O	Air side light duty vehicles	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Air side Heavy duty vehicles/buses	Diesel	0	0	0	0	0	0	0	0
N_2O	Air side generators	Diesel	0	0	0	0	0	0	0	0
N_2O	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
N_2O	Generators Industrial machinery/ Business/public	Diesel	0	0	0	0	0	0	0	0
Benzol	Forklifts of all types	Diesel	0	0	0	0	0	0	0	0
Benzol	Forklifts of all types	Petrol (4-str)	1	2	1	1	0	0	0	0
Benzol	Sweepers and cleansers	Diesel	0	0	0	0	0	0	0	0
Benzol	Mobile elevating work platforms	Diesel	0	0	0	0	0	0	0	0
Benzol	Industral tractors	Diesel	0	0	0	0	0	0	0	0
Benzol	Industral tractors	Petrol (4-str)	0	1	0	0	0	0	0	0
Benzol	Runway vehicles	Diesel	0	0	0	0	0	0	0	0
Benzol	Air side generators	Diesel	0	0	0	0	0	0	0	0
Benzol	Air side dispatch appliances	Diesel	0	0	0	0	0	0	0	0
Benzol	Generators Industrial machinery/ Business/public	Diesel	0	0	0	0	0	0	0	0

Tab. 65 > Agricultural machinery: emissions (in tonnes p.a.)

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Single-axle mowers	Petrol (4-str)	1,348	1,106	858	555	304	145	83	66
HC	TractorsTractors (agriculture)	Diesel	477	502	513	350	172	101	70	56
HC	Combine harvesters	Diesel	19	22	23	9	2	2	2	2
HC	Spraying machines	Diesel	7	6	4	3	1	0	0	0
HC	Field choppers	Diesel	2	3	3	2	1	1	1	1
HC	Twin-axle mowers	Diesel	1	16	32	26	10	7	7	7
HC	Transporters and loaders	Diesel	38	39	40	21	6	3	3	3
HC	Farmyard loaders	Diesel	2	6	11	10	5	4	4	4
HC	Chainsaws (agriculture)	Petrol (2-str)	1,295	1,452	1,459	621	259	251	248	246
HC		Diesel	-	1	3	7	9	9	8	2
HC	Tractors (hobby)	Petrol (4-str)	-	9	11	10	12	11	10	5
HC	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	1	1	1	1	1
CO	Single-axle mowers	Petrol (4-str)	23,228	19,059	14,862	10,929	8,094	6,412	5,489	4,992
CO	Tractors (agriculture)	Diesel	2,223	2,408	2,559	1,726	848	481	321	252
CO	Combine harvesters	Diesel	105	130	137	47	10	7	7	7
CO	Spraying machines	Diesel	30	25	19	13	5	3	2	2
CO	Field choppers	Diesel	12	15	19	14	4	2	2	2
CO	Twin-axle mowers	Diesel	5	69	140	122	55	35	30	31
CO	Transporters and loaders	Diesel	163	176	189	103	34	18	13	12
CO	Farmyard loaders	Diesel	7	27	46	48	29	20	18	19
CO	Chainsaws (agriculture)	Petrol (2-str)	2,770	3,105	3,342	2,767	2,378	2,165	2,134	2,117
CO		Diesel	-	2	8	21	28	27	25	9
CO		Petrol (4-str)	-	163	199	184	249	283	301	301
CO	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	2	2	2	3	3
NO_X	Single-axle mowers	Petrol (4-str)	157	129	101	68	42	22	12	8
NO_X	Tractors (agriculture)	Diesel	2,862	3,307	3,631	2,641	1,412	805	585	490
NO_X	Combine harvesters	Diesel	192	269	271	114	22	7	7	7
NO_X	Spraying machines	Diesel	31	28	21	14	8	6	5	5
NO_X	Field choppers	Diesel	25	32	38	28	10	2	2	2
NO_X	Twin-axle mowers	Diesel	5	78	154	160	107	85	86	88
NO_X	Transporters and loaders	Diesel	177	213	233	144	65	41	36	33
NO_X	Farmyard loaders	Diesel	8	30	47	64	56	57	61	63
NO_X	Chainsaws (agriculture)	Petrol (2-str)	6	7	9	21	28	27	27	27
NO_X	Tractors (hobby)	Diesel	-	3	17	44	56	54	41	25
NO_X	Tractors (hobby)	Petrol (4-str)	-	1	1	1	2	1	1	1
NO_X	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	10	3	3	3	4
PM	Single-axle mowers	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	TractorsTractors (agriculture)	Diesel	318	343	355	252	122	47	19	6

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
PM	Combine harvesters	Diesel	13	15	15	6	1	0	0	0
PM	Spraying machines	Diesel	4	3	3	2	1	0	0	0
PM	Field choppers	Diesel	1	2	2	2	1	0	0	0
PM	Twin-axle mowers	Diesel	1	9	18	18	9	3	0	0
PM	Transporters and loaders	Diesel	20	23	25	15	5	2	0	0
PM	Farmyard loaders	Diesel	1	3	6	7	5	2	0	0
PM	Chainsaws (agriculture)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Tractors (hobby)	Diesel	-	0	2	5	5	4	3	1
PM	Tractors (hobby)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	0	0	0	0	0
CO_2	Single-axle mowers	Petrol (4-str)	77,893	63,912	49,760	36,226	25,917	19,646	16,388	14,788
CO_2	TractorsTractors (agriculture)	Diesel	225,159	252,544	284,805	273,706	271,475	267,208	262,590	260,443
CO_2	Combine harvesters	Diesel	11,208	15,267	16,781	12,604	9,629	9,981	10,025	10,035
CO_2	Spraying machines	Diesel	2,480	2,147	1,706	1,466	1,300	1,139	1,028	963
CO_2	Field choppers	Diesel	1,385	1,824	2,281	2,656	2,948	3,134	3,210	3,258
CO_2	Twin-axle mowers	Diesel	409	6,030	12,524	17,203	20,683	22,092	22,841	23,363
CO_2	Transporters and loaders	Diesel	13,989	16,192	18,312	15,179	13,157	11,413	10,334	9,714
CO_2	Farmyard loaders	Diesel	646	2,340	4,035	7,501	10,050	11,444	12,284	12,825
CO_2	Chainsaws (agriculture)	Petrol (2-str)	9,579	10,738	11,296	8,462	6,351	5,578	5,497	5,452
CO_2	Tractors (hobby)	Diesel	-	284	1,474	3,803	5,105	5,982	6,581	6,967
CO_2	Tractors (hobby)	Petrol (4-str)	-	546	663	610	819	907	951	899
CO_2	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	1,855	3,193	3,976	4,433	4,700
CH_4	Single-axle mowers	Petrol (4-str)	46	38	29	19	10	5	3	2
CH_4	Tractors (agriculture)	Diesel	11	12	12	9	4	2	2	1
CH_4	Combine harvesters	Diesel	0	1	1	0	0	0	0	0
CH_4	Spraying machines	Diesel	0	0	0	0	0	0	0	0
CH_4	Field choppers	Diesel	0	0	0	0	0	0	0	0
CH_4	Twin-axle mowers	Diesel	0	0	1	1	0	0	0	0
CH_4	Transporters and loaders	Diesel	1	1	1	1	0	0	0	0
CH_4	Farmyard loaders	Diesel	0	0	0	0	0	0	0	0
CH_4	Chainsaws (agriculture)	Petrol (2-str)	91	102	102	43	18	18	17	17
CH_4	Tractors (hobby)	Diesel	-	0	0	0	0	0	0	0
CH_4	TractorsTractors (hobby)	Petrol (4-str)	-	0	0	0	0	0	0	0
CH_4	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	0	0	0	0	0
NMHC	Single-axle mowers	Petrol (4-str)	1,302	1,068	829	536	294	140	80	63
NMHC	Tractors (agriculture)	Diesel	466	490	500	341	168	98	68	55
NMHC	Combine harvesters	Diesel	19	22	22	9	2	2	2	2
NMHC	Spraying machines	Diesel	7	6	4	3	1	0	0	0
NMHC	Field choppers	Diesel	2	3	3	2	1	1	1	1
NMHC	Twin-axle mowers	Diesel	1	15	31	25	9	7	7	7

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
NMHC	Transporters and loaders	Diesel	37	38	40	21	6	3	3	3
NMHC	Farmyard loaders	Diesel	2	6	10	10	4	4	4	4
NMHC	Chainsaws (agriculture)	Petrol (2-str)	1,204	1,350	1,357	577	241	233	230	228
NMHC	TractorsTractors (hobby)	Diesel	-	1	3	7	9	9	8	2
NMHC	TractorsTractors (hobby)	Petrol (4-str)	-	9	11	9	12	11	10	5
NMHC	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	1	1	1	1	1
N_2O	Single-axle mowers	Petrol (4-str)	1	1	1	1	0	0	0	0
N_2O	TractorsTractors (agriculture)	Diesel	8	10	11	11	11	10	10	10
N_2O	Combine harvesters	Diesel	1	1	1	1	0	0	0	0
N_2O	Spraying machines	Diesel	0	0	0	0	0	0	0	0
N_2O	Field choppers	Diesel	0	0	0	0	0	0	0	0
N_2O	Twin-axle mowers	Diesel	0	0	1	1	1	1	1	1
N_2O	Transporters and loaders	Diesel	1	1	1	1	1	0	0	0
N_2O	Farmyard loaders	Diesel	0	0	0	0	0	0	0	1
N_2O	Chainsaws (agriculture)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	TractorsTractors (hobby)	Diesel	-	0	0	0	0	0	0	0
N_2O	TractorsTractors (hobby)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	0	0	0	0	0
Benzol	Single-axle mowers	Petrol (4-str)	67	55	7	4	2	1	1	1
Benzol	TractorsTractors (agriculture)	Diesel	1	1	1	1	0	0	0	0
Benzol	Combine harvesters	Diesel	0	0	0	0	0	0	0	0
Benzol	Spraying machines	Diesel	0	0	0	0	0	0	0	0
Benzol	Field choppers	Diesel	0	0	0	0	0	0	0	0
Benzol	Twin-axle mowers	Diesel	0	0	0	0	0	0	0	0
Benzol	Transporters and loaders	Diesel	0	0	0	0	0	0	0	0
Benzol	Farmyard loaders	Diesel	0	0	0	0	0	0	0	0
Benzol	Chainsaws (agriculture)	Petrol (2-str)	65	73	12	5	2	2	2	2
Benzol	TractorsTractors (hobby)	Diesel	-	0	0	0	0	0	0	0
Benzol	TractorsTractors (hobby)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Pick-up loaders Beet harvesting machine	Diesel	-	-	-	0	0	0	0	0

Tab. 66 > Forestry machinery: emissions (in tonnes p.a.)

Pollutant	Machne type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	FMChainsaws (forestry)	Petrol (2-str)	987	1,316	1,024	303	127	111	103	98
HC	Cutters	Petrol (2-str)	13	70	110	30	12	10	9	9
HC	Other small appliances	Petrol (2-str)	50	45	36	13	5	5	5	5
HC	Cable and grapple skidders	Diesel	29	26	21	10	3	2	2	2
HC	Pick-up loaders	Diesel	-	0	2	1	0	0	0	0
HC	Processors	Diesel	0	0	0	0	0	0	0	0
HC	Wood chippers	Diesel	1	2	4	2	1	1	1	1
HC	Bark peeling machines	Diesel	0	0	1	0	0	0	0	0
HC	Wheeled excavators FM	Diesel	0	0	1	0	0	0	0	0
HC	Forestry forwarders	Diesel	-	1	4	3	1	1	1	1
HC	Conventional skyline cranes	Diesel	1	1	1	0	0	0	0	0
HC	Mobile skyline cranes	Diesel	0	1	1	0	0	0	0	0
HC	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0
CO	Chainsaws (forestry)	Petrol (2-str)	2,088	2,785	2,448	1,557	1,158	959	887	847
CO	Cutters	Petrol (2-str)	27	147	262	228	170	127	115	108
CO	Other small appliances	Petrol (2-str)	105	95	82	61	50	43	42	41
CO	Cable and grapple skidders	Diesel	147	132	112	51	14	9	9	8
CO	Pick-up loaders	Diesel	-	1	10	4	1	1	1	1
CO	Processors	Diesel	0	1	1	1	0	0	0	0
CO	Wood chippers	Diesel	3	9	21	10	3	3	3	3
CO	Bark peeling machines	Diesel	1	3	3	1	0	0	0	0
CO	Wheeled excavators FM	Diesel	0	2	3	2	1	1	1	1
CO	Forestry forwarders	Diesel	-	8	22	13	5	5	5	5
CO	Conventional skyline cranes	Diesel	4	5	4	2	1	0	0	0
CO	Mobile skyline cranes	Diesel	0	3	5	2	0	0	0	0
CO	Combined skyline appliances	Diesel	-	-	-	1	0	0	0	0
NO_X	Chainsaws (forestry)	Petrol (2-str)	4	6	8	14	14	12	11	11
NO_X	Cutters	Petrol (2-str)	0	0	1	2	1	1	1	1
NO_X	Other small appliances	Petrol (2-str)	0	0	0	1	1	1	1	1
NO_X	Cable and grapple skidders	Diesel	220	199	169	94	30	16	15	15
NO_X	Pick-up loaders	Diesel	-	2	16	10	2	1	1	1
NO_X	Processors	Diesel	0	1	2	1	1	0	0	0
NO_X	Wood chippers	Diesel	6	17	36	28	6	3	3	3
NO_X	Bark peeling machines	Diesel	1	5	6	3	1	0	0	0
NO_X	Wheeled excavators FM	Diesel	1	3	5	5	2	0	1	1
NO_X	Forestry forwarders	Diesel	-	15	37	35	8	5	5	5
NO_X	Conventional skyline cranes	Diesel	5	7	6	3	1	0	0	0
NO_X	Mobile skyline cranes	Diesel	1	6	8	5	1	0	0	0
NO_X	Combined skyline appliances	Diesel	-	-	-	2	1	0	0	0
PM	Chainsaws (forestry)	Petrol (2-str)	-	-	-	-	-	-	-	-

Pollutant	Machne type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
PM	Cutters	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Other small appliances	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Cable and grapple skidders	Diesel	22	19	15	7	2	0	0	0
PM	Pick-up loaders	Diesel	-	0	1	1	0	0	0	0
PM	Processors	Diesel	0	0	0	0	0	0	0	0
PM	Wood chippers	Diesel	0	1	2	1	0	0	0	0
PM	Bark peeling machines	Diesel	0	0	0	0	0	0	0	0
PM	Wheeled excavators FM	Diesel	0	0	0	0	0	0	0	0
PM	Forestry forwarders	Diesel	-	1	2	2	0	0	0	0
PM	Conventional skyline cranes	Diesel	1	1	1	0	0	0	0	0
PM	Mobile skyline cranes	Diesel	0	0	1	0	0	0	0	0
PM	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0
CO_2	Chainsaws (forestry)	Petrol (2-str)	7,266	9,688	8,254	4,771	3,073	2,471	2,285	2,183
CO_2	Cutters	Petrol (2-str)	93	513	883	587	400	327	296	278
CO_2	Other small appliances	Petrol (2-str)	366	329	281	190	132	112	108	105
CO_2	Cable and grapple skidders	Diesel	15,789	14,099	12,773	11,419	10,740	9,893	9,298	8,935
CO_2	Pick-up loaders	Diesel	-	108	1,033	1,400	1,317	1,337	1,337	1,337
CO_2	Processors	Diesel	10	59	134	138	161	170	173	175
CO_2	Wood chippers	Diesel	330	979	2,285	3,703	4,284	4,703	4,884	4,975
CO_2	Bark peeling machines	Diesel	73	293	367	294	224	151	76	76
CO_2	Wheeled excavators FM	Diesel	32	182	321	491	660	748	808	841
CO_2	Forestry forwarders	Diesel	-	865	2,381	4,695	5,936	6,525	6,858	7,024
CO_2	Conventional skyline cranes	Diesel	446	547	472	416	353	275	221	185
CO_2	Mobile skyline cranes	Diesel	38	431	664	655	508	412	412	412
CO_2	Combined skyline appliances	Diesel	-	-	-	284	520	635	698	741
CH_4	Chainsaws (forestry)	Petrol (2-str)	69	92	72	21	9	8	7	7
CH_4	Cutters	Petrol (2-str)	1	5	8	2	1	1	1	1
CH_4	Other small appliances	Petrol (2-str)	3	3	3	1	0	0	0	0
CH_4	Cable and grapple skidders	Diesel	1	1	1	0	0	0	0	0
CH_4	Pick-up loaders	Diesel	-	0	0	0	0	0	0	0
CH_4	Processors	Diesel	0	0	0	0	0	0	0	0
CH_4	Wood chippers	Diesel	0	0	0	0	0	0	0	0
CH_4	Bark peeling machines	Diesel	0	0	0	0	0	0	0	0
CH_4	Wheeled excavators FM	Diesel	0	0	0	0	0	0	0	0
CH_4	Forestry forwarders	Diesel	-	0	0	0	0	0	0	0
CH_4	Conventional skyline cranes	Diesel	0	0	0	0	0	0	0	0
CH_4	Mobile skyline cranes	Diesel	0	0	0	0	0	0	0	0
CH_4	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0
NMHC	Chainsaws (forestry)	Petrol (2-str)	918	1,224	953	282	118	103	96	91
NMHC	Cutters	Petrol (2-str)	12	65	102	28	11	10	9	8
NMHC	Other small appliances	Petrol (2-str)	46	42	34	12	5	5	5	4
NMHC	Cable and grapple skidders	Diesel	29	25	21	10	3	2	2	2

Pollutant	Machne type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
NMHC	Pick-up loaders	Diesel	-	0	2	1	0	0	0	0
NMHC	Processors	Diesel	0	0	0	0	0	0	0	0
NMHC	Wood chippers	Diesel	1	2	4	2	1	1	1	1
NMHC	Bark peeling machines	Diesel	0	0	1	0	0	0	0	0
NMHC	Wheeled excavators FM	Diesel	0	0	0	0	0	0	0	0
NMHC	Forestry forwarders	Diesel	-	1	4	3	1	1	1	1
NMHC	Conventional skyline cranes	Diesel	1	1	1	0	0	0	0	0
NMHC	Mobile skyline cranes	Diesel	0	1	1	0	0	0	0	0
NMHC	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0
N_2O	Chainsaws (forestry)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Cutters	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Other small appliances	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Cable and grapple skidders	Diesel	1	1	1	1	0	0	0	0
N_2O	Pick-up loaders	Diesel	-	0	0	0	0	0	0	0
N_2O	Processors	Diesel	0	0	0	0	0	0	0	0
N_2O	Wood chippers	Diesel	0	0	0	0	0	0	0	0
N_2O	Bark peeling machines	Diesel	0	0	0	0	0	0	0	0
N_2O	Wheeled excavators FM	Diesel	0	0	0	0	0	0	0	0
N_2O	Forestry forwarders	Diesel	-	0	0	0	0	0	0	0
N_2O	Conventional skyline cranes	Diesel	0	0	0	0	0	0	0	0
N_2O	Mobile skyline cranes	Diesel	0	0	0	0	0	0	0	0
N_2O	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0
Benzol	Chainsaws (forestry)	Petrol (2-str)	49	66	8	2	1	1	1	1
Benzol	Cutters	Petrol (2-str)	1	3	1	0	0	0	0	0
Benzol	Other small appliances	Petrol (2-str)	2	2	0	0	0	0	0	0
Benzol	Cable and grapple skidders	Diesel	0	0	0	0	0	0	0	0
Benzol	Pick-up loaders	Diesel	-	0	0	0	0	0	0	0
Benzol	Processors	Diesel	0	0	0	0	0	0	0	0
Benzol	Wood chippers	Diesel	0	0	0	0	0	0	0	0
Benzol	Bark peeling machines	Diesel	0	0	0	0	0	0	0	0
Benzol	Wheeled excavators FM	Diesel	0	0	0	0	0	0	0	0
Benzol	Forestry forwarders	Diesel	-	0	0	0	0	0	0	0
Benzol	Conventional skyline cranes	Diesel	0	0	0	0	0	0	0	0
Benzol	Mobile skyline cranes	Diesel	0	0	0	0	0	0	0	0
Benzol	Combined skyline appliances	Diesel	-	-	-	0	0	0	0	0

Tab. 67 > Garden-care/hobby appliances: emissions (in tonnes p.a.)

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	10	10	2	2	2
HC	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	101	507	941	325	112	111	111	111
HC	Hedge cutters (professional)	Petrol (2-str)	8	40	75	38	14	14	14	14
HC	Blowers (professional)	Petrol (4-str)	-	-	-	2	0	0	0	0
HC	Blowers (professional)	Petrol (2-str)	-	9	97	21	1	1	1	1
HC	Lawn mowers (professional)	Petrol (4-str)	30	34	36	31	22	16	16	16
HC	Lawn mowers (professional)	Petrol (2-str)	91	45	-	-	-	-	-	-
HC	Ride-on mowers (professional)	Petrol (4-str)	13	34	66	42	25	17	17	17
HC	Chainsaws (professional)	Petrol (2-str)	335	364	358	190	95	97	98	98
HC	Scarifiers (professional)	Petrol (4-str)	-	5	17	15	9	7	7	7
HC	Mill cutters/shredders (professional)	Petrol (4-str)	13	15	18	16	10	7	7	7
HC	Shredders (professional)	Petrol (4-str)	-	3	5	4	4	1	1	1
HC	Snow blowers (professional)	Petrol (4-str)	17	20	17	13	10	3	3	3
HC	Cleaning appliances (professional)	Petrol (4-str)	-	17	26	24	19	6	5	5
HC	Cleaning appliances (professional)	Petrol (2-str)	-	10	-	-	-	-	-	-
HC	Abrasive grinders (professional)	Petrol (2-str)	65	65	60	29	11	11	11	11
HC	Drills (professional)	Petrol (4-str)	-	-	5	5	5	2	2	2
HC	Drills (professional)	Petrol (2-str)	-	-	28	8	3	3	3	3
HC	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	1	1	0	0	0
HC	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	12	61	115	38	12	11	11	11
HC	Hedge cutters (household)	Petrol (2-str)	1	3	6	4	2	2	2	2
HC	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
HC	Blowers (household)	Petrol (2-str)	-	0	4	3	1	1	1	1
HC	Lawn mowers (household)	Petrol (4-str)	70	91	113	88	67	47	46	46
HC	Lawn mowers (household)	Petrol (2-str)	114	72	-	-	-	-	-	-
HC	Ride-on mowers (household)	Petrol (4-str)	1	3	6	5	3	2	2	2
HC	Chainsaws (household)	Petrol (2-str)	137	137	129	73	28	28	28	28
HC	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
HC	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
HC	Mill cutters/shredders (household)	Petrol (4-str)	4	4	5	3	3	2	2	2
HC	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
HC	Snow blowers (household)	Petrol (4-str)	31	47	46	34	22	7	6	6
HC	Cleaning appliances (household)	Petrol (4-str)	-	2	3	2	2	1	0	0
HC	Cleaning appliances (household)	Petrol (2-str)	-	1	-	-	-	-	-	-
HC	Wood splitter (professional)	Petrol (4-str)	-	0	1	1	0	0	0	0
CO	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	96	128	137	139	140
CO	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	214	1,072	2,112	1,813	1,606	1,353	1,351	1,350
CO	Hedge cutters (professional)	Petrol (2-str)	17	84	167	202	196	168	169	169
CO	Blowers (professional)	Petrol (4-str)	-	-	-	21	5	6	6	6
CO	Blowers (professional)	Petrol (2-str)	-	20	215	108	17	14	14	14

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CO	Lawn mowers (professional)	Petrol (4-str)	546	614	676	880	895	913	918	919
CO	Lawn mowers (professional)	Petrol (2-str)	192	96	-	-	-	-	-	-
CO	Ride-on mowers (professional)	Petrol (4-str)	232	579	1,153	1,333	1,334	1,353	1,358	1,359
CO	Chainsaws (professional)	Petrol (2-str)	708	769	815	904	888	844	849	849
CO	Scarifiers (professional)	Petrol (4-str)	-	87	290	374	373	381	383	383
CO	Mill cutters/shredders (professional)	Petrol (4-str)	217	264	308	401	400	408	410	410
CO	Shredders (professional)	Petrol (4-str)	-	31	43	55	58	59	59	59
CO	Snow blowers (professional)	Petrol (4-str)	159	191	158	154	148	148	148	148
CO	Cleaning appliances (professional)	Petrol (4-str)	-	144	228	282	294	300	301	302
CO	Cleaning appliances (professional)	Petrol (2-str)	-	22	-	-	-	-	-	-
CO	Abrasive grinders (professional)	Petrol (2-str)	136	136	134	162	160	139	140	140
CO	Drills (professional)	Petrol (4-str)	-	-	44	73	87	90	91	92
CO	Drills (professional)	Petrol (2-str)	-	-	66	41	32	28	28	28
CO	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	12	16	17	17	17
CO	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	28	142	281	201	169	139	137	137
CO	Hedge cutters (household)	Petrol (2-str)	1	7	14	23	25	21	21	21
CO	Blowers (household)	Petrol (4-str)	-	-	-	1	1	1	1	1
CO	Blowers (household)	Petrol (2-str)	-	1	10	15	16	14	14	14
CO	Lawn mowers (household)	Petrol (4-str)	1,557	2,002	2,481	2,595	2,634	2,663	2,672	2,674
CO	Lawn mowers (household)	Petrol (2-str)	252	155	-	-	-	-	-	-
CO	Ride-on mowers (household)	Petrol (4-str)	27	67	134	155	161	163	163	163
CO	Chainsaws (household)	Petrol (2-str)	318	318	313	384	396	342	342	342
CO	Motor sleds (household)	Petrol (4-str)	11	11	11	14	14	14	14	14
CO	Scarifiers (household)	Petrol (4-str)	-	1	2	3	3	3	3	3
CO	Mill cutters/shredders (household)	Petrol (4-str)	83	101	118	108	103	102	102	102
CO	Shredders (household)	Petrol (4-str)	-	3	5	7	7	7	7	7
CO	Snow blowers (household)	Petrol (4-str)	300	442	433	392	339	339	340	340
CO	Cleaning appliances (household)	Petrol (4-str)	-	18	28	28	27	27	27	27
CO	Cleaning appliances (household)	Petrol (2-str)	-	3	-	-	-	-	-	-
CO	Wood splitter (professional)	Petrol (4-str)	-	8	11	15	15	16	16	16
NO_X	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	1	1	0	0	0
NO_X	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	0	2	6	13	12	12	12	12
NO_X	Hedge cutters (professional)	Petrol (2-str)	0	0	0	1	1	2	2	2
NO_X	Blowers (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
NO_X	Blowers (professional)	Petrol (2-str)	-	0	1	1	0	0	0	0
NO_X	Lawn mowers (professional)	Petrol (4-str)	4	4	5	5	5	2	2	2
NO_X	Lawn mowers (professional)	Petrol (2-str)	0	0	-	-	-	-	-	-
NO_X	Ride-on mowers (professional)	Petrol (4-str)	2	4	8	6	5	2	2	2
NO_X	Chainsaws (professional)	Petrol (2-str)	1	2	2	7	10	11	11	11
NO_X	Scarifiers (professional)	Petrol (4-str)	-	1	2	2	2	1	1	1
NO_X	Mill cutters/shredders (professional)	Petrol (4-str)	1	2	2	2	2	1	1	1
NO_X	Shredders (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
NO_X	Snow blowers (professional)	Petrol (4-str)	0	1	1	1	1	0	0	0
NO_X	Cleaning appliances (professional)	Petrol (4-str)	-	0	1	2	2	1	1	1
NO_X	Cleaning appliances (professional)	Petrol (2-str)	-	0	-	-	-	-	-	-
NO_X	Abrasive grinders (professional)	Petrol (2-str)	0	0	0	1	1	1	1	1
NO_X	Drills (professional)	Petrol (4-str)	-	-	0	1	1	0	0	0
NO_X	Drills (professional)	Petrol (2-str)	-	-	0	0	0	0	0	0
NO_X	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
NO_X	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	0	0	1	1	1	1	1	1
NO_X	Hedge cutters (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
NO_X	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
NO_X	Blowers (household)	Petrol (2-str)	-	0	0	0	0	0	0	0
NO_X	Lawn mowers (household)	Petrol (4-str)	11	15	18	17	15	6	5	5
NO_X	Lawn mowers (household)	Petrol (2-str)	1	0	-	-	-	-	-	-
NO_X	Ride-on mowers (household)	Petrol (4-str)	0	0	1	1	1	0	0	0
NO_X	Chainsaws (household)	Petrol (2-str)	1	1	1	3	3	3	3	3
NO_X	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
NO_X	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
NO_X	Mill cutters/shredders (household)	Petrol (4-str)	1	1	1	1	1	0	0	0
NO_X	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
NO_X	Snow blowers (household)	Petrol (4-str)	1	1	2	3	2	1	1	1
NO_X	Cleaning appliances (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
NO_X	Cleaning appliances (household)	Petrol (2-str)	-	0	-	-	-	-	-	-
NO_X	Wood splitter (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
PM	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Hedge cutters (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Blowers (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Blowers (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Lawn mowers (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Lawn mowers (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Ride-on mowers (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Chainsaws (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Scarifiers (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Mill cutters/shredders (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Shredders (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Snow blowers (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Cleaning appliances (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Cleaning appliances (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Abrasive grinders (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Drills (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Drills (professional)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	-	-	-	-	-

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
PM	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Hedge cutters (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Blowers (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Blowers (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Lawn mowers (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Lawn mowers (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Ride-on mowers (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Chainsaws (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Motor sleds (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Scarifiers (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Mill cutters/shredders (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Shredders (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Snow blowers (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Cleaning appliances (household)	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Cleaning appliances (household)	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Wood splitter (professional)	Petrol (4-str)	-	-	-	-	-	-	-	-
CO_2	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	318	412	415	422	423
CO_2	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	746	3,731	7,252	4,984	3,738	3,485	3,479	3,477
CO_2	Hedge cutters (professional)	Petrol (2-str)	59	294	573	560	455	433	435	435
CO_2	Blowers (professional)	Petrol (4-str)	-	-	-	70	17	17	17	17
CO_2	Blowers (professional)	Petrol (2-str)	-	68	742	302	39	36	36	36
CO_2	Lawn mowers (professional)	Petrol (4-str)	1,804	2,029	2,217	2,843	2,703	2,703	2,716	2,720
CO_2	Lawn mowers (professional)	Petrol (2-str)	669	334	-	-	-	-	-	-
CO_2	Ride-on mowers (professional)	Petrol (4-str)	777	1,942	3,850	4,280	4,028	4,005	4,019	4,023
CO_2	Chainsaws (professional)	Petrol (2-str)	2,464	2,675	2,788	2,793	2,354	2,174	2,185	2,188
CO_2	Scarifiers (professional)	Petrol (4-str)	-	291	971	1,231	1,127	1,126	1,132	1,133
CO_2	Mill cutters/shredders (professional)	Petrol (4-str)	728	884	1,030	1,319	1,207	1,207	1,213	1,214
CO_2	Shredders (professional)	Petrol (4-str)	-	105	148	178	181	178	179	179
CO_2	Snow blowers (professional)	Petrol (4-str)	544	652	539	506	466	448	448	448
CO_2	Cleaning appliances (professional)	Petrol (4-str)	-	503	795	929	926	908	912	913
CO_2	Cleaning appliances (professional)	Petrol (2-str)	-	77	-	-	-	-	-	-
CO_2	Abrasive grinders (professional)	Petrol (2-str)	475	475	459	445	373	358	359	360
CO_2	Drills (professional)	Petrol (4-str)	-	-	148	232	271	273	276	277
CO_2	Drills (professional)	Petrol (2-str)	-	-	222	127	85	73	72	71
CO_2	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	40	51	50	51	51
CO_2	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	94	472	919	545	393	356	353	352
CO_2	Hedge cutters (household)	Petrol (2-str)	5	24	47	62	57	55	55	55
CO_2	Blowers (household)	Petrol (4-str)	-	-	-	2	3	4	4	4
CO_2	Blowers (household)	Petrol (2-str)	-	3	33	41	38	37	37	37
CO_2	Lawn mowers (household)	Petrol (4-str)	4,852	6,255	7,758	8,015	7,972	7,891	7,906	7,912
CO_2	Lawn mowers (household)	Petrol (2-str)	857	534	-	-	-	-	-	-
CO_2	Ride-on mowers (household)	Petrol (4-str)	84	210	419	479	487	482	483	484

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CO_2	Chainsaws (household)	Petrol (2-str)	1,052	1,052	1,025	1,042	921	878	881	882
CO_2	Motor sleds (household)	Petrol (4-str)	34	34	34	42	43	43	42	42
CO_2	Scarifiers (household)	Petrol (4-str)	-	2	6	9	10	10	10	10
CO_2	Mill cutters/shredders (household)	Petrol (4-str)	257	312	366	331	313	303	303	302
CO_2	Shredders (household)	Petrol (4-str)	-	11	17	21	20	21	21	21
CO_2	Snow blowers (household)	Petrol (4-str)	1,012	1,506	1,478	1,293	1,068	1,029	1,028	1,028
CO_2	Cleaning appliances (household)	Petrol (4-str)	-	59	94	91	87	83	83	83
CO_2	Cleaning appliances (household)	Petrol (2-str)	-	10	-	-	-	-	-	-
CO_2	Wood splitter (professional)	Petrol (4-str)	-	25	36	46	46	46	46	46
CH_4	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
CH_4	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	7	35	66	23	8	8	8	8
CH_4	Hedge cutters (professional)	Petrol (2-str)	1	3	5	3	1	1	1	1
CH_4	Blowers (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
CH_4	Blowers (professional)	Petrol (2-str)	-	1	7	1	0	0	0	0
CH_4	Lawn mowers (professional)	Petrol (4-str)	1	1	1	1	1	1	1	1
CH_4	Lawn mowers (professional)	Petrol (2-str)	6	3	-	-	-	-	-	-
CH_4	Ride-on mowers (professional)	Petrol (4-str)	0	1	2	1	1	1	1	1
CH_4	Chainsaws (professional)	Petrol (2-str)	23	25	25	13	7	7	7	7
CH_4	Scarifiers (professional)	Petrol (4-str)	-	0	1	0	0	0	0	0
CH_4	Mill cutters/shredders (professional)	Petrol (4-str)	0	1	1	1	0	0	0	0
CH_4	Shredders (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
CH_4	Snow blowers (professional)	Petrol (4-str)	1	1	1	0	0	0	0	0
CH_4	Cleaning appliances (professional)	Petrol (4-str)	-	1	1	1	1	0	0	0
CH_4	Cleaning appliances (professional)	Petrol (2-str)	-	1	-	-	-	-	-	-
CH_4	Abrasive grinders (professional)	Petrol (2-str)	5	5	4	2	1	1	1	1
CH_4	Drills (professional)	Petrol (4-str)	-	-	0	0	0	0	0	0
CH_4	Drills (professional)	Petrol (2-str)	-	-	2	1	0	0	0	0
CH_4	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
CH_4	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	1	4	8	3	1	1	1	1
CH_4	Hedge cutters (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
CH_4	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
CH_4	Blowers (household)	Petrol (2-str)	-	0	0	0	0	0	0	0
CH_4	Lawn mowers (household)	Petrol (4-str)	2	3	4	3	2	2	2	2
CH_4	Lawn mowers (household)	Petrol (2-str)	8	5	-	-	-	-	-	-
CH_4	Ride-on mowers (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Chainsaws (household)	Petrol (2-str)	10	10	9	5	2	2	2	2
CH_4	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
CH_4	Mill cutters/shredders (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
CH_4	Snow blowers (household)	Petrol (4-str)	1	2	2	1	1	0	0	0
CH_4	Cleaning appliances (household)	Petrol (4-str)	-	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CH_4	Cleaning appliances (household)	Petrol (2-str)	-	0	-	-	-	-	-	-
CH_4	Wood splitter (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
NMHC	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	9	10	2	2	2
NMHC	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	94	472	875	302	104	103	103	103
NMHC	Hedge cutters (professional)	Petrol (2-str)	7	37	70	36	13	13	13	13
NMHC	Blowers (professional)	Petrol (4-str)	-	-	-	2	0	0	0	0
NMHC	Blowers (professional)	Petrol (2-str)	-	9	90	20	1	1	1	1
NMHC	Lawn mowers (professional)	Petrol (4-str)	29	33	35	30	21	15	15	15
NMHC	Lawn mowers (professional)	Petrol (2-str)	84	42	-	-	-	-	-	-
NMHC	Ride-on mowers (professional)	Petrol (4-str)	13	32	64	41	24	17	17	17
NMHC	Chainsaws (professional)	Petrol (2-str)	311	338	333	176	88	90	91	91
NMHC	Scarifiers (professional)	Petrol (4-str)	-	5	16	14	9	6	6	6
NMHC	Mill cutters/shredders (professional)	Petrol (4-str)	12	15	17	15	10	7	7	7
NMHC	Shredders (professional)	Petrol (4-str)	-	3	4	4	4	1	1	1
NMHC	Snow blowers (professional)	Petrol (4-str)	16	20	16	13	9	3	2	2
NMHC	Cleaning appliances (professional)	Petrol (4-str)	-	16	25	23	18	5	5	5
NMHC	Cleaning appliances (professional)	Petrol (2-str)	-	10	-	-	-	-	-	-
NMHC	Abrasive grinders (professional)	Petrol (2-str)	60	60	55	27	10	11	11	11
NMHC	Drills (professional)	Petrol (4-str)	-	-	4	5	5	1	2	2
NMHC	Drills (professional)	Petrol (2-str)	-	-	26	7	3	3	3	3
NMHC	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	1	1	0	0	0
NMHC	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	11	57	107	35	11	11	10	10
NMHC	Hedge cutters (household)	Petrol (2-str)	1	3	5	4	2	2	2	2
NMHC	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
NMHC	Blowers (household)	Petrol (2-str)	-	0	4	3	1	1	1	1
NMHC	Lawn mowers (household)	Petrol (4-str)	68	88	109	85	65	45	44	44
NMHC	Lawn mowers (household)	Petrol (2-str)	106	67	-	-	-	-	-	-
NMHC	Ride-on mowers (household)	Petrol (4-str)	1	3	6	5	3	2	2	2
NMHC	Chainsaws (household)	Petrol (2-str)	127	127	120	68	26	26	26	26
NMHC	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
NMHC	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
NMHC	Mill cutters/shredders (household)	Petrol (4-str)	4	4	5	3	3	2	2	2
NMHC	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
NMHC	Snow blowers (household)	Petrol (4-str)	30	45	45	33	21	7	6	6
NMHC	Cleaning appliances (household)	Petrol (4-str)	-	2	3	2	2	1	0	0
NMHC	Cleaning appliances (household)	Petrol (2-str)	-	1	-	-	-	-	-	-
NMHC	Wood splitter (professional)	Petrol (4-str)	-	0	1	1	0	0	0	0
N_2O	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
N_2O	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Hedge cutters (professional)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Blowers (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
N_2O	Blowers (professional)	Petrol (2-str)	-	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
N_2O	Lawn mowers (professional)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Lawn mowers (professional)	Petrol (2-str)	0	0	-	-	-	-	-	-
N_2O	Ride-on mowers (professional)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Chainsaws (professional)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Scarifiers (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Mill cutters/shredders (professional)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Shredders (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Snow blowers (professional)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Cleaning appliances (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Cleaning appliances (professional)	Petrol (2-str)	-	0	-	-	-	-	-	-
N_2O	Abrasive grinders (professional)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Drills (professional)	Petrol (4-str)	-	-	0	0	0	0	0	0
N_2O	Drills (professional)	Petrol (2-str)	-	-	0	0	0	0	0	0
N_2O	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
N_2O	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Hedge cutters (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
N_2O	Blowers (household)	Petrol (2-str)	-	0	0	0	0	0	0	0
N_2O	Lawn mowers (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Lawn mowers (household)	Petrol (2-str)	0	0	-	-	-	-	-	-
N_2O	Ride-on mowers (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Chainsaws (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Mill cutters/shredders (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Snow blowers (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Cleaning appliances (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
N_2O	Cleaning appliances (household)	Petrol (2-str)	-	0	-	-	-	-	-	-
N_2O	Wood splitter (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Motor scythes, trimmers, cutters (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
Benzol	Motor scythes, trimmers, cutters (professional)	Petrol (2-str)	5	25	8	3	1	1	1	1
Benzol	Hedge cutters (professional)	Petrol (2-str)	0	2	1	0	0	0	0	0
Benzol	Blowers (professional)	Petrol (4-str)	-	-	-	0	0	0	0	0
Benzol	Blowers (professional)	Petrol (2-str)	-	0	1	0	0	0	0	0
Benzol	Lawn mowers (professional)	Petrol (4-str)	2	2	0	0	0	0	0	0
Benzol	Lawn mowers (professional)	Petrol (2-str)	5	2	-	-	-	-	-	-
Benzol	Ride-on mowers (professional)	Petrol (4-str)	1	2	1	0	0	0	0	0
Benzol	Chainsaws (professional)	Petrol (2-str)	17	18	3	2	1	1	1	1
Benzol	Scarifiers (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Mill cutters/shredders (professional)	Petrol (4-str)	1	1	0	0	0	0	0	0
Benzol	Shredders (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Benzol	Snow blowers (professional)	Petrol (4-str)	1	1	0	0	0	0	0	0
Benzol	Cleaning appliances (professional)	Petrol (4-str)	-	1	0	0	0	0	0	0
Benzol	Cleaning appliances (professional)	Petrol (2-str)	-	1	-	-	-	-	-	-
Benzol	Abrasive grinders (professional)	Petrol (2-str)	3	3	0	0	0	0	0	0
Benzol	Drills (professional)	Petrol (4-str)	-	-	0	0	0	0	0	0
Benzol	Drills (professional)	Petrol (2-str)	-	-	0	0	0	0	0	0
Benzol	Motor scythes, trimmers, cutters (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
Benzol	Motor scythes, trimmers, cutters (household)	Petrol (2-str)	1	3	1	0	0	0	0	0
Benzol	Hedge cutters (household)	Petrol (2-str)	0	0	0	0	0	0	0	0
Benzol	Blowers (household)	Petrol (4-str)	-	-	-	0	0	0	0	0
Benzol	Blowers (household)	Petrol (2-str)	-	0	0	0	0	0	0	0
Benzol	Lawn mowers (household)	Petrol (4-str)	3	5	1	1	1	0	0	0
Benzol	Lawn mowers (household)	Petrol (2-str)	6	4	-	-	-	-	-	-
Benzol	Ride-on mowers (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Chainsaws (household)	Petrol (2-str)	7	7	1	1	0	0	0	0
Benzol	Motor sleds (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Scarifiers (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Mill cutters/shredders (household)	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Shredders (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Snow blowers (household)	Petrol (4-str)	2	2	0	0	0	0	0	0
Benzol	Cleaning appliances (household)	Petrol (4-str)	-	0	0	0	0	0	0	0
Benzol	Cleaning appliances (household)	Petrol (2-str)	-	0	-	-	-	-	-	-
Benzol	Wood splitter (professional)	Petrol (4-str)	-	0	0	0	0	0	0	0

Tab. 68 > Navigation machinery: emissions (in tonnes p.a.)

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Motorised yachts	Diesel	17	18	11	5	3	3	2	2
HC	Motorised yachts	Petrol (4-str)	7	8	6	4	4	4	4	4
HC	Motorised yachts	Petrol (2-str)	59	64	26	5	4	4	4	4
HC	Fishing & other commercial boats	Diesel	31	28	16	7	3	2	2	2
HC	Fishing & other commercial boats	Petrol (4-str)	200	183	89	33	37	34	32	30
HC	Fishing & other commercial boats	Petrol (2-str)	4	3	1	0	0	0	0	0
HC	Hire and privately owned motor boats	Diesel	27	29	16	8	5	3	3	3
HC	Hire and privately owned motor boats	Petrol (4-str)	708	769	358	113	169	179	182	184
HC	Hire and privately owned motor boats	Petrol (2-str)	164	178	71	10	11	11	11	11
HC	Passenger ships	Diesel	239	225	239	181	107	61	37	22
HC	Passenger ships	Dampf	1	1	0	0	0	0	0	0
HC	Cargo ships/barges	Diesel	92	144	106	76	47	31	21	14
HC	Ferries	Diesel	38	38	59	47	29	17	10	6
HC	Cargo ships Rhine, main engines	Diesel	7	9	9	7	5	3	2	1
HC	Cargo ships Rhine, auxiliary engines	Diesel	10	11	10	4	2	1	1	1
CO	Motorised yachts	Diesel	11	12	11	10	8	7	7	7
CO	Motorised yachts	Petrol (4-str)	95	103	73	54	52	50	48	47
CO	Motorised yachts	Petrol (2-str)	123	134	82	51	48	45	44	43
CO	Fishing & other commercial boats	Diesel	25	23	18	16	14	13	12	12
CO	Fishing & other commercial boats	Petrol (4-str)	2,563	2,348	1,146	471	613	563	527	506
CO	Fishing & other commercial boats	Petrol (2-str)	7	7	4	2	2	2	2	2
CO	Hire and privately owned motor boats	Diesel	33	36	29	31	32	33	34	34
CO	Hire and privately owned motor boats	Petrol (4-str)	10,558	11,471	5,199	2,078	3,646	3,853	3,917	3,955
CO	Hire and privately owned motor boats	Petrol (2-str)	344	374	205	121	130	134	136	137
CO	Passenger ships	Diesel	218	205	243	254	221	183	163	153
CO	Passenger ships	Steam	1	1	1	1	1	1	1	1
CO	Cargo ships/barges	Diesel	75	117	96	96	89	82	78	76
CO	Ferries	Diesel	35	35	61	68	60	53	49	47
CO	Cargo ships Rhine, main engines	Diesel	7	9	10	12	13	12	11	11
CO	Cargo ships Rhine, auxiliary engines	Diesel	6	7	7	8	7	7	8	8
NO_X	Motorised yachts	Diesel	21	23	19	18	14	13	12	12
NO_X	Motorised yachts	Petrol (4-str)	1	1	2	2	2	2	2	2
NO_X	Motorised yachts	Petrol (2-str)	3	3	2	2	2	2	2	2
NO_X	Fishing & other commercial boats	Diesel	51	47	39	38	23	16	15	14
NO_X	Fishing & other commercial boats	Petrol (4-str)	23	21	39	42	35	32	30	29
NO_X	Fishing & other commercial boats	Petrol (2-str)	0	0	0	0	0	0	0	0
NO_X	Hire and privately owned motor boats	Diesel	54	58	48	53	38	30	30	30
NO_X	Hire and privately owned motor boats	Petrol (4-str)	101	110	196	234	237	243	247	250
NO_X	Hire and privately owned motor boats	Petrol (2-str)	7	8	6	5	5	5	5	5
NO_X	Passenger ships	Diesel	454	427	505	485	355	208	130	92

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
NO_X	Passenger ships	Dampf	4	5	6	4	4	4	4	3
NO_X	Cargo ships/barges	Diesel	155	243	199	183	143	96	68	53
NO_X	Ferries	Diesel	73	73	127	129	97	59	38	27
NO_X	Cargo ships Rhine, main engines	Diesel	17	21	25	26	22	13	8	5
NO_X	Cargo ships Rhine, auxiliary engines	Diesel	12	14	15	13	9	7	7	7
PM	Motorised yachts	Diesel	2	2	2	2	1	1	1	1
PM	Motorised yachts	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Motorised yachts	Petrol (2-str)	1	1	0	0	0	-	-	-
PM	Fishing & other commercial boats	Diesel	4	4	4	3	2	0	0	0
PM	Fishing & other commercial boats	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Fishing & other commercial boats	Petrol (2-str)	0	0	0	0	0	-	-	-
PM	Hire and privately owned motor boats	Diesel	4	4	4	5	3	0	0	0
PM	Hire and privately owned motor boats	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Hire and privately owned motor boats	Petrol (2-str)	2	2	1	1	0	-	-	-
PM	Passenger ships	Diesel	26	25	28	22	12	7	4	2
PM	Passenger ships	Dampf	0	0	0	0	0	0	0	0
PM	Cargo ships/barges	Diesel	9	14	11	9	5	3	2	1
PM	Ferries	Diesel	4	4	7	6	3	2	1	1
PM	Cargo ships Rhine, main engines	Diesel	1	1	1	1	1	0	0	0
PM	Cargo ships Rhine, auxiliary engines	Diesel	1	1	1	1	0	0	0	0
CO_2	Motorised yachts	Diesel	2,050	2,227	1,929	1,999	1,899	1,804	1,747	1,713
CO_2	Motorised yachts	Petrol (4-str)	351	381	336	286	258	246	238	233
CO_2	Motorised yachts	Petrol (2-str)	459	499	331	238	223	211	205	201
CO_2	Fishing & other commercial boats	Diesel	3,937	3,607	3,251	3,449	3,150	2,889	2,706	2,595
CO_2	Fishing & other commercial boats	Petrol (4-str)	9,540	8,740	7,948	6,426	5,373	4,844	4,533	4,348
CO_2	Fishing & other commercial boats	Petrol (2-str)	27	25	17	11	9	8	8	7
CO_2	Hire and privately owned motor boats	Diesel	4,213	4,578	3,981	4,893	5,388	5,636	5,734	5,789
CO_2	Hire and privately owned motor boats	Petrol (4-str)	37,570	40,822	35,953	31,827	31,965	33,016	33,564	33,889
CO_2	Hire and privately owned motor boats	Petrol (2-str)	1,250	1,359	904	650	670	689	701	707
CO_2	Passenger ships	Diesel	25,560	24,040	28,393	30,883	30,464	29,100	28,072	27,700
CO_2	Passenger ships	Dampf	6,119	8,140	10,847	11,650	10,693	10,155	9,768	9,615
CO_2	Cargo ships/barges	Diesel	8,760	13,712	11,236	11,691	12,354	12,717	12,951	13,080
CO_2	Ferries	Diesel	4,085	4,085	7,149	8,222	8,313	8,361	8,386	8,407
CO_2	Cargo ships Rhine, main engines	Diesel	982	1,194	1,425	1,683	1,973	2,148	2,239	2,291
CO_2	Cargo ships Rhine, auxiliary engines	Diesel	757	865	974	1,086	1,203	1,290	1,342	1,373
CH_4	Motorised yachts	Diesel	0	0	0	0	0	0	0	0
CH_4	Motorised yachts	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Motorised yachts	Petrol (2-str)	4	4	2	0	0	0	0	0
CH_4	Fishing & other commercial boats	Diesel	0	0	0	0	0	0	0	0
CH_4	Fishing & other commercial boats	Petrol (4-str)	10	9	4	2	2	2	2	2
CH_4	Fishing & other commercial boats	Petrol (2-str)	0	0	0	0	0	0	0	0
CH_4	Hire and privately owned motor boats	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CH_4	Hire and privately owned motor boats	Petrol (4-str)	35	38	18	6	8	9	9	9
CH_4	Hire and privately owned motor boats	Petrol (2-str)	11	12	5	1	1	1	1	1
CH_4	Passenger ships	Diesel	1	1	1	1	1	0	0	0
CH_4	Passenger ships	Dampf	0	0	0	0	0	0	0	0
CH_4	Cargo ships/barges	Diesel	0	1	0	0	0	0	0	0
CH_4	Ferries	Diesel	0	0	0	0	0	0	0	0
CH_4	Cargo ships Rhine, main engines	Diesel	0	0	0	0	0	0	0	0
CH_4	Cargo ships Rhine, auxiliary engines	Diesel	0	0	0	0	0	0	0	0
NMHC	Motorised yachts	Diesel	17	18	11	5	3	3	2	2
NMHC	Motorised yachts	Petrol (4-str)	7	7	5	4	4	4	4	4
NMHC	Motorised yachts	Petrol (2-str)	55	59	24	4	4	4	4	4
NMHC	Fishing & other commercial boats	Diesel	31	28	16	6	3	2	2	2
NMHC	Fishing & other commercial boats	Petrol (4-str)	190	174	84	31	35	32	30	29
NMHC	Fishing & other commercial boats	Petrol (2-str)	3	3	1	0	0	0	0	0
NMHC	Hire and privately owned motor boats	Diesel	27	29	16	8	4	3	3	3
NMHC	Hire and privately owned motor boats	Petrol (4-str)	673	731	340	107	160	170	173	174
NMHC	Hire and privately owned motor boats	Petrol (2-str)	152	166	66	10	10	10	10	11
NMHC	Passenger ships	Diesel	238	224	238	180	106	61	37	22
NMHC	Passenger ships	Dampf	0	1	0	0	0	0	0	0
NMHC	Cargo ships/barges	Diesel	92	144	106	76	47	31	21	14
NMHC	Ferries	Diesel	38	38	58	47	28	17	10	6
NMHC	Cargo ships Rhine, main engines	Diesel	7	8	9	7	5	3	2	1
NMHC	Cargo ships Rhine, auxiliary engines	Diesel	10	11	10	4	2	1	1	1
N_2O	Motorised yachts	Diesel	0	0	0	0	0	0	0	0
N_2O	Motorised yachts	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Motorised yachts	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Fishing & other commercial boats	Diesel	0	0	0	0	0	0	0	0
N_2O	Fishing & other commercial boats	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Fishing & other commercial boats	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Hire and privately owned motor boats	Diesel	0	0	0	0	0	0	0	0
N_2O	Hire and privately owned motor boats	Petrol (4-str)	1	1	1	1	1	1	1	1
N_2O	Hire and privately owned motor boats	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Passenger ships	Diesel	1	1	1	2	1	1	1	1
N_2O	Passenger ships	Dampf	0	0	0	0	0	0	0	0
N_2O	Cargo ships/barges	Diesel	0	1	1	1	1	1	1	1
N_2O	Ferries	Diesel	0	0	0	0	0	0	0	0
N_2O	Cargo ships Rhine, main engines	Diesel	0	0	0	0	0	0	0	0
N_2O	Cargo ships Rhine, auxiliary engines	Diesel	0	0	0	0	0	0	0	0
Benzol	Motorised yachts	Diesel	0	0	0	0	0	0	0	0
Benzol	Motorised yachts	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Motorised yachts	Petrol (2-str)	3	3	0	0	0	0	0	0
Benzol	Fishing & other commercial boats	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
Benzol	Fishing & other commercial boats	Petrol (4-str)	10	9	1	0	0	0	0	0
Benzol	Fishing & other commercial boats	Petrol (2-str)	0	0	0	0	0	0	0	0
Benzol	Hire and privately owned motor boats	Diesel	0	0	0	0	0	0	0	0
Benzol	Hire and privately owned motor boats	Petrol (4-str)	35	38	3	1	1	1	1	1
Benzol	Hire and privately owned motor boats	Petrol (2-str)	8	9	1	0	0	0	0	0
Benzol	Passenger ships	Diesel	0	0	0	0	0	0	0	0
Benzol	Passenger ships	Dampf	0	0	0	0	0	0	0	0
Benzol	Cargo ships/barges	Diesel	0	0	0	0	0	0	0	0
Benzol	Ferries	Diesel	0	0	0	0	0	0	0	0
Benzol	Cargo ships Rhine, main engines	Diesel	0	0	0	0	0	0	0	0
Benzol	Cargo ships Rhine, auxiliary engines	Diesel	0	0	0	0	0	0	0	-

Tab. 69 > Railway machinery: emissions (in tonnes p.a.)

Poluttant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Shunting locomotives	Diesel	53	60	74	50	38	24	14	12
HC	Twin-engined tractors	Diesel	1	2	2	0	0	0	0	0
HC	Railway tractors	Diesel	9	22	22	13	8	6	2	2
CO	Shunting locomotives	Diesel	187	213	262	239	181	141	104	97
CO	Twin-engined tractors	Diesel	1	5	5	0	1	1	1	1
CO	Railway tractors	Diesel	20	51	52	36	29	26	23	22
NO_X	Shunting locomotives	Diesel	376	442	555	436	325	208	120	106
NO_X	Twin-engined tractors	Diesel	4	14	14	0	1	1	1	1
NO_X	Railway tractors	Diesel	55	139	143	99	63	45	21	18
PM	Shunting locomotives	Diesel	18	21	26	5	2	1	1	1
PM	Twin-engined tractors	Diesel	0	1	1	0	0	0	0	0
PM	Railway tractors	Diesel	3	8	8	2	1	0	0	0
CO_2	Shunting locomotives	Diesel	17,865	20,421	25,025	29,600	22,558	22,590	22,590	22,590
CO_2	Twin-engined tractors	Diesel	194	778	754	14	222	222	222	222
CO_2	Railway tractors	Diesel	2,973	7,490	7,740	6,607	6,237	6,246	6,246	6,246
CH_4	Shunting locomotives	Diesel	1	1	1	1	0	0	0	0
CH_4	Twin-engined tractors	Diesel	0	0	0	0	0	0	0	0
CH_4	Railway tractors	Diesel	0	0	0	0	0	0	0	0
NMHC	Shunting locomotives	Diesel	52	60	73	49	38	24	13	12
NMHC	Twin-engined tractors	Diesel	1	2	2	0	0	0	0	0
NMHC	Railway tractors	Diesel	9	22	22	12	8	6	2	2
N_2O	Shunting locomotives	Diesel	1	1	1	1	1	1	1	1
N_2O	Twin-engined tractors	Diesel	0	0	0	0	0	0	0	0
N_2O	Railway tractors	Diesel	0	0	0	0	0	0	0	0
Benzol	Shunting locomotives	Diesel	0	0	0	0	0	0	0	0
Benzol	Twin-engined tractors	Diesel	0	0	0	0	0	0	0	0
Benzol	Railway tractors	Diesel	0	0	0	0	0	0	0	0

Tab. 70 > Military machinery (in tonnes p.a.)

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
HC	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
HC	Leo 87	Diesel	2	2	2	1	1	1	1	1
HC	Howitzers	Diesel	0	0	0	0	0	0	0	0
HC	Armoured personnel carriers	Diesel	15	15	12	1	1	1	0	0
HC	Other armoured vehicles	Diesel	-	1	2	9	4	2	2	2
HC	Reconnaissance vehicles	Diesel	0	0	1	1	0	0	0	0
HC	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
HC	Rubber-wheeled loading shovels/ wheel loaders	Diesel	1	1	1	0	0	0	0	0
HC	Crawles excavators Mil	Diesel	1	1	1	0	0	0	0	0
HC	Walking excavatorsMil	Diesel	0	0	0	0	0	0	0	0
HC	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
HC	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
HC	Crane trucks	Diesel	0	0	0	0	0	0	0	0
HC	Patrol boats	Diesel	0	0	0	0	0	0	0	0
HC	Other boats	Petrol (4-str)	1	1	1	0	0	0	0	0
HC	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
HC	Power generating appliances	Diesel	3	3	3	1	1	0	0	0
HC	Power generating appliances	Petrol (4-str)	18	18	18	11	6	4	4	4
HC	Power generating appliances	Petrol (2-str)	31	31	29	13	5	5	5	5
HC	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
HC	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
CO	Pz 68 family	Diesel	2	2	2	-	-	-	-	-
CO	Leo 87	Diesel	12	11	12	7	4	4	4	4
CO	Howitzers	Diesel	2	2	2	2	1	1	1	1
CO	Armoured personnel carriers	Diesel	82	82	70	6	6	6	1	1
CO	Other armoured vehicles	Diesel	-	3	12	48	17	9	7	7
CO	Reconnaissance vehicles	Diesel	1	1	8	5	2	1	1	1
CO	Caterpillar loaders/crawler Loaders	Diesel	2	2	2	1	0	0	0	0
CO	Rubber-wheeled loading shovels/ wheel loaders	Diesel	5	5	5	2	1	0	0	0
CO	Crawles excavators Mil	Diesel	4	4	4	1	0	0	0	0
CO	Walking excavatorsMil	Diesel	1	1	1	0	0	0	0	0
CO	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
CO	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
CO	Crane trucks	Diesel	1	1	1	0	0	0	0	0
CO	Patrol boats	Diesel	0	0	0	0	0	0	0	0
CO	Other boats	Petrol (4-str)	11	12	7	4	5	5	5	5
CO	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
CO	Power generating appliances	Diesel	9	9	9	5	2	2	2	2
CO	Power generating appliances	Petrol (4-str)	362	362	362	357	344	344	344	344

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CO	Power generating appliances	Petrol (2-str)	66	66	65	56	49	46	46	46
CO	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
CO	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
NO_X	Pz 68 family	Diesel	4	4	4	-	-	-	-	-
NO_X	Leo 87	Diesel	26	26	26	15	9	8	8	6
NO_X	Howitzers	Diesel	4	4	4	3	2	2	1	1
NO_X	Armoured personnel carriers	Diesel	154	154	132	12	12	12	3	3
NO_X	Other armoured vehicles	Diesel	-	7	25	103	38	14	9	9
NO_X	Reconnaissance vehicles	Diesel	1	1	15	10	4	1	1	1
NO_X	Caterpillar loaders/crawler Loaders	Diesel	4	4	4	2	0	0	0	0
NO_X	Rubber-wheeled loading shovels/ wheel loaders	Diesel	10	10	9	5	1	0	0	0
NO_X	Crawles excavators Mil	Diesel	7	7	6	3	1	0	0	0
NO_X	Walking excavatorsMil	Diesel	1	1	1	1	0	0	0	0
NO_X	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
NO_X	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
NO_X	Crane trucks	Diesel	2	2	2	1	0	0	0	0
NO_X	Patrol boats	Diesel	0	0	0	0	0	1	1	1
NO_X	Other boats	Petrol (4-str)	0	0	0	0	0	0	0	0
NO_X	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
NO_X	Power generating appliances	Diesel	21	21	19	13	7	5	5	5
NO_X	Power generating appliances	Petrol (4-str)	3	3	3	2	1	1	1	1
NO_X	Power generating appliances	Petrol (2-str)	0	0	0	0	1	1	1	1
NO_X	Support bridge 46m	Diesel	-	-	-	-	1	1	1	1
NO_X	Assortment water pipe	Diesel	-	1	1	1	1	1	1	0
PM	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
PM	Leo 87	Diesel	1	1	1	1	0	0	0	0
PM	Howitzers	Diesel	0	0	0	0	0	0	0	0
PM	Armoured personnel carriers	Diesel	9	9	8	1	1	1	0	0
PM	Other armoured vehicles	Diesel	-	0	1	2	0	0	0	0
PM	Reconnaissance vehicles	Diesel	0	0	1	0	0	0	0	0
PM	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
PM	Rubber-wheeled loading shovels/ wheel loaders	Diesel	1	1	1	0	0	0	0	0
PM	Crawles excavators Mil	Diesel	0	0	0	0	0	0	0	0
PM	Walking excavatorsMil	Diesel	0	0	0	0	0	0	0	0
PM	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
PM	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
PM	Crane trucks	Diesel	0	0	0	0	0	0	0	0
PM	Patrol boats	Diesel	0	0	0	0	0	0	0	0
PM	Other boats	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
PM	Power generating appliances	Diesel	2	2	2	1	0	0	0	0
PM	Power generating appliances	Petrol (4-str)	-	-	-	-	-	-	-	-
PM	Power generating appliances	Petrol (2-str)	-	-	-	-	-	-	-	-
PM	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
PM	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
CO_2	Pz 68 family	Diesel	268	283	298	-	-	-	-	-
CO_2	Leo 87	Diesel	1,733	1,733	1,733	1,025	590	525	525	525
CO_2	Howitzers	Diesel	289	289	289	218	125	125	94	94
CO_2	Armoured personnel carriers	Diesel	10,424	10,424	8,958	1,063	1,063	1,063	325	325
CO_2	Other armoured vehicles	Diesel	-	482	1,829	12,483	12,540	12,540	12,540	12,540
CO_2	Reconnaissance vehicles	Diesel	88	93	1,114	1,139	1,144	1,144	1,144	1,144
CO_2	Caterpillar loaders/crawler Loaders	Diesel	255	255	256	260	263	263	263	263
CO_2	Rubber-wheeled loading shovels/ wheel loaders	Diesel	570	570	571	581	587	587	587	587
CO_2	Crawles excavators Mil	Diesel	400	400	401	408	412	412	412	412
CO_2	Walking excavatorsMil	Diesel	75	75	75	77	77	77	77	77
CO_2	Bulldozers/crawler tractors	Diesel	23	26	29	-	-	-	-	-
CO_2	Pile drivers/piling rigs	Diesel	-	-	29	29	27	27	27	27
CO_2	Crane trucks	Diesel	132	132	132	135	28	6	6	6
CO_2	Patrol boats	Diesel	44	44	43	51	56	71	71	71
CO_2	Other boats	Petrol (4-str)	43	45	46	41	37	38	38	38
CO_2	Assortment Lenz use	Diesel	-	-	-	-	16	16	16	16
CO_2	Power generating appliances	Diesel	1,340	1,341	1,342	1,359	1,366	1,366	1,366	1,366
CO_2	Power generating appliances	Petrol (4-str)	1,163	1,163	1,161	1,124	1,039	1,018	1,018	1,018
CO_2	Power generating appliances	Petrol (2-str)	229	229	222	174	132	119	119	119
CO_2	Support bridge 46m	Diesel	-	-	-	-	206	206	206	206
CO_2	Assortment water pipe	Diesel	-	34	34	35	35	35	35	35
CH_4	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
CH_4	Leo 87	Diesel	0	0	0	0	0	0	0	0
CH_4	Howitzers	Diesel	0	0	0	0	0	0	0	0
CH_4	Armoured personnel carriers	Diesel	0	0	0	0	0	0	0	0
CH_4	Other armoured vehicles	Diesel	-	0	0	0	0	0	0	0
CH_4	Reconnaissance vehicles	Diesel	0	0	0	0	0	0	0	0
CH_4	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
CH_4	Rubber-wheeled loading shovels/ wheel loaders	Diesel	0	0	0	0	0	0	0	0
CH_4	Crawles excavators Mil	Diesel	0	0	0	0	0	0	0	0
CH_4	Walking excavatorsMil	Diesel	0	0	0	0	0	0	0	0
CH_4	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
CH_4	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
CH_4	Crane trucks	Diesel	0	0	0	0	0	0	0	0
CH_4	Patrol boats	Diesel	0	0	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
CH_4	Other boats	Petrol (4-str)	0	0	0	0	0	0	0	0
CH_4	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
CH_4	Power generating appliances	Diesel	0	0	0	0	0	0	0	0
CH_4	Power generating appliances	Petrol (4-str)	1	1	1	0	0	0	0	0
CH_4	Power generating appliances	Petrol (2-str)	2	2	2	1	0	0	0	0
CH_4	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
CH_4	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
NMHC	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
NMHC	Leo 87	Diesel	2	2	2	1	1	1	1	1
NMHC	Howitzers	Diesel	0	0	0	0	0	0	0	0
NMHC	Armoured personnel carriers	Diesel	14	14	12	1	1	1	0	0
NMHC	Other armoured vehicles	Diesel	-	1	2	9	4	2	2	2
NMHC	Reconnaissance vehicles	Diesel	0	0	1	1	0	0	0	0
NMHC	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
NMHC	Rubber-wheeled loading shovels/ wheel loaders	Diesel	1	1	1	0	0	0	0	0
NMHC	Crawles excavators Mil	Diesel	1	1	1	0	0	0	0	0
NMHC	Walking excavatorsMil	Diesel	0	0	0	0	0	0	0	0
NMHC	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
NMHC	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
NMHC	Crane trucks	Diesel	0	0	0	0	0	0	0	0
NMHC	Patrol boats	Diesel	0	0	0	0	0	0	0	0
NMHC	Other boats	Petrol (4-str)	1	1	0	0	0	0	0	0
NMHC	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
NMHC	Power generating appliances	Diesel	3	3	3	1	1	0	0	0
NMHC	Power generating appliances	Petrol (4-str)	18	18	17	11	6	4	4	4
NMHC	Power generating appliances	Petrol (2-str)	29	29	27	12	5	5	5	5
NMHC	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
NMHC	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
N_2O	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
N_2O	Leo 87	Diesel	0	0	0	0	0	0	0	0
N_2O	Howitzers	Diesel	0	0	0	0	0	0	0	0
N_2O	Armoured personnel carriers	Diesel	0	0	0	0	0	0	0	0
N_2O	Other armoured vehicles	Diesel	-	0	0	1	1	1	1	1
N_2O	Reconnaissance vehicles	Diesel	0	0	0	0	0	0	0	0
N_2O	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
N_2O	Rubber-wheeled loading shovels/ wheel loaders	Diesel	0	0	0	0	0	0	0	0
N_2O	Crawles excavators Mil	Diesel	0	0	0	0	0	0	0	0
N_2O	Walking excavators Mil	Diesel	0	0	0	0	0	0	0	0
N_2O	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
N_2O	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0

Pollutant	Machine type	Engine type	1980	1990	2000	2010	2020	2030	2040	2050
N_2O	Crane trucks	Diesel	0	0	0	0	0	0	0	0
N_2O	Patrol boats	Diesel	0	0	0	0	0	0	0	0
N_2O	Other boats	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
N_2O	Power generating appliances	Diesel	0	0	0	0	0	0	0	0
N_2O	Power generating appliances	Petrol (4-str)	0	0	0	0	0	0	0	0
N_2O	Power generating appliances	Petrol (2-str)	0	0	0	0	0	0	0	0
N_2O	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
N_2O	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0
Benzol	Pz 68 family	Diesel	0	0	0	-	-	-	-	-
Benzol	Leo 87	Diesel	0	0	0	0	0	0	0	0
Benzol	Howitzers	Diesel	0	0	0	0	0	0	0	0
Benzol	Armoured personnel carriers	Diesel	0	0	0	0	0	0	0	0
Benzol	Other armoured vehicles	Diesel	-	0	0	0	0	0	0	0
Benzol	Reconnaissance vehicles	Diesel	0	0	0	0	0	0	0	0
Benzol	Caterpillar loaders/crawler Loaders	Diesel	0	0	0	0	0	0	0	0
Benzol	Rubber-wheeled loading shovels/ wheel loaders	Diesel	0	0	0	0	0	0	0	0
Benzol	Crawles excavators Mil	Diesel	0	0	0	0	0	0	0	0
Benzol	Walking excavators Mil	Diesel	0	0	0	0	0	0	0	0
Benzol	Bulldozers/crawler tractors	Diesel	0	0	0	-	-	-	-	-
Benzol	Pile drivers/piling rigs	Diesel	-	-	0	0	0	0	0	0
Benzol	Crane trucks	Diesel	0	0	0	0	0	0	0	0
Benzol	Patrol boats	Diesel	0	0	0	0	0	0	0	0
Benzol	Other boats	Petrol (4-str)	0	0	0	0	0	0	0	0
Benzol	Assortment Lenz use	Diesel	-	-	-	-	0	0	0	0
Benzol	Power generating appliances	Diesel	0	0	0	0	0	0	0	0
Benzol	Power generating appliances	Petrol (4-str)	1	1	0	0	0	0	0	0
Benzol	Power generating appliances	Petrol (2-str)	2	2	0	0	0	0	0	0
Benzol	Support bridge 46m	Diesel	-	-	-	-	0	0	0	0
Benzol	Assortment water pipe	Diesel	-	0	0	0	0	0	0	0

A14 Workgroups and their composition

A14-1 Construction/industrial machinery

Name	Company/organisation	Association
Roger Widmer	Probst Maveg AG	VSBM (Verband der schweiz. Baumaschinenwirtschaft)
Nicole Loichat	Schweizerischer Baumeisterverband	SBV (Schweiz. Baumeisterverband)
Urs Ritter	Linde MH Schweiz	swisslifter (Schweiz. Hubstaplerverband)
Fulvio Sartori	Seilbahnen Schweiz	SBS (Seilbahnen Schweiz)
René Boschung	Marcel Boschung AG	SIK (Schweiz. Interessensgemeinschaft der Fabrikanten und Händler von Kommunal-Maschinen und Geräten)
François Jaussi	Liebherr Machines Bulle SA	–

A14-2 Agricultural/forestry machinery

Name	Company/organisation	Association
Marco Landis	Forschungsanstalt Agroscope Reckenholz-Tänikon	–
Willi von Atzigen	Schweiz. Verband für Landtechnik	SVLT (Schweiz. Verband für Landtechnik)
Daniel Bernhard	Matra	SLV (Schweiz. Landmaschinen-Verband)
Pius Wiss	Wiss AG	FUS (Verband Forstunternehmer Schweiz)
Dr. Oliver Thees	Eidg. Forschungsanstalt WSL	–

A14-3 Small appliances

Name	Company/organisation
Hugo Helbling	Husqvarna Schweiz AG
Martin Buser	Husqvarna Schweiz AG
Eric Krebs	Honda Motor Europe Ltd
Arthur Lörli	Walker Vertriebs AG

A14-4 Engine specialists

Name	Companz/organisation
François Jaussi	Liebherr Machines Bulle SA
Marco Landis	Forschungsanstalt Agroscope Reckenholz-Tänikon

> Abbreviations, figures and tables

Glossary

Stock and operating hours
Describes the quantitative composition of an object or process by indicating a quantity for each component.
In this report, it encompasses two components: stock (= number of machines) and number of operating hours, differentiated by machine category, engine type, engine power range and year of manufacture.

Machine category
In this report, non-road machines and appliances have been divided into eight main categories: construction machinery, industrial machinery, agricultural machinery, forestry machinery, garden-care/hobby appliances, navigation machinery, railway machinery, military machinery (cf. Appendix 2).

Machine segment
Sub-division within a machine type (e.g. hydraulic excavators with diesel engines with an engine power greater than 37 kW).

Machine sub-segment
Sub-division of a machine segment, encompassing machines with a similar year of manufacture (according to emission stages).

Machine type
Type of machine within a category (e.g. construction machinery is divided into hydraulic excavators, wheeled/mobile cranes, loaders, dump trucks, trenching machines, pumps, etc.) (cf. Appendix 2).

Non-road sector
Refers to all mobile machines and appliances equipped with a combustion engine and which are not intended for the purpose of transporting passengers and goods by road.
(NB: here the term “non-road” does not include heavy passenger vehicles, which are often referred to as off-roaders or all-terrain vehicles).

Abréviations

ALB
Army Logistics Basis

ART
Agroscope Reckenholz-Tänikon research group

CO
Carbon monoxide

CO_2
Carbon dioxide

CORINAIR
Core Stock of Air Emissions

DB
Deutsche Bahn (German Railways)

EEA
European Environment Agency

EFKO
Swiss Federal Vehicle Inspection Office

EMPA
Swiss Federal Laboratories for Materials Testing and Research, Dübendorf

EPA
Environmental Protection Agency (USA)

EU
European Union

Euro 1/I. 2/II, 3/III, 4/IV, 5/V
European exhaust standards for light and heavy motor vehicles

FAT
Swiss Federal Research Station for Agricultural Economics and Engineering, Tänikon

FOEN
Swiss Federal Office for the Environment (renamed at the beginning of 2006 – formerly Swiss Agency for the Environment, Forests and Landscape (SAEFL)

FSO
Swiss Federal Statistical Office

FUS
Swiss Association of Forestry Contractors

HC
Hydrocarbons

HGV
Heavy goods vehicle

IFEU
Institute for Energy and Environment Research, Heidelberg (Germany)

KWF
Kuratorium für Wald- und Forstwirtschaft e.V. (Deutschland) (German Forestry Management Board)

LBZ
Agricultural business census

MOFIS
Motor Vehicle Information System, database of the Swiss Federal Vehicle Inspection Office (EFKO)

NO_x
Nitrogen oxides

OZD
Federal Customs Administration

PM
Particulate matter

SAEFL
Swiss Agency for the Environment, Forests and Landscape (now FOEN – name was changed at the end of 2005)

SAV
Ordinance on exhaust emissions from ship and boat engines on Switzerland's bodies of water

SBB
Swiss Federal Railways

SBV
Swiss Association of Master Builders

FOE
Federal Office of Energy

SIK
Swiss association of municipal machinery and appliance manufacturers and dealers

SLV
Swiss Agricultural Machinery Association

SVLT
Swiss Association for Agricultural Technology

UIC
Union Internationale des Chemins de Fer (International Railway Union)

VBS
Swiss Federal Department of Defence, Civil Protection and Sport

VKS
Association of (cantonal) Navigation Services

VSBM
Swiss Association of Construction Machinery

VSSU
Swiss Association of navigation contractors

Figures

Tables

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