SNAP CODES: **(See below)**

SOURCE ACTIVITY TITLE: **COMBUSTION IN ENERGY & TRANSFORMATION INDUSTRIES**
Combustion Plants as Area Sources

The following activities are taken into account when combustion plants are treated collectively as area sources. Boilers, furnaces (except process furnaces), gas turbines and stationary engines which may also be considered individually as point sources are covered by this chapter as well as by chapter B111 on ”Combustion Plants as Point Sources”.

SNAP97 Codes	Combustion plants as area sources										
	NOSE CODE	NFR CODE	Boilers/furnaces							Gas turbines	Stationary engines
			Thermal capacity [MW]	Public power and cogeneration plants	District heating	Industrial combustion	Commercial and institutional combustion	Residential combustion	Agriculture forestry and fishing		
01 01 02	101.02	1 A 1 a	≥ 50	X							
01 02 02	101.02	1 A 1 a	and		X						
01.03.02	101.02	1 A 1 b				X					
01.04.02	101.02	1 A 1 c				X					
01.05.02	101.02	1 A 1 c				X					
02 01 02	101.02	1 A 4 a	< 300				X				
02 02 01	101.02	1 A 4 b i						X			
02 03 01	101.02	1 A 4 c i							X		
03 01 02	101.02	1 A 2 a-f				X					
01 01 03	101.03	1 A 1 a	< 50	X							
01 02 03	101.03	1 A 1 a			X						
01 03 02	101.03	1 A 1 b				X					
01 04 02	101.03	1 A 1 c				X					
01 05 02	101.03	1 A 1 c				X					
02 01 03	101.03	1 A 4 a					X				
02 02 02	101.03	1 A 4 b i						X			
02 03 02	101.03	1 A 4 c i							X		
03 01 03	101.03	1 A 2 a-f				X					
01 01 04	101.04	1 A 1 a	Not							X	
01 02 04	101.04	1 A 1 a	Rele							X	
02 01 04	101.04	1 A 4 a	-vant							X	
02 02 03	101.04	1 A 4 b i								X	
02 03 03	101.04	1 A 4 c i								X	
03 01 04	101.04	1 A 2 a-f								X	

SNAP97 Codes	Combustion plants as area sources										
	NOSE CODE	NFR CODE	Boilers/furnaces							Gas turbines	Stationary engines
			Thermal capacity [MW]	Public power and cogeneration plants	District heating	Industrial combustion	Commercial and institutional combustion	Residential combustion	Agriculture forestry and fishing		
01 01 05	101.05	1 A 1 a	Not								X
01 02 05	101.05	1 A 1 a	Relevant								X
02 01 05	101.05	1 A 4 a									X
02 02 04	101.05	1 A 4 b i									X
02 03 04	101.05	1 A 4 c i									X
03 01 05	101.05	1 A 2 a-									X

X : indicates relevant combination

1 ACTIVITIES INCLUDED

This chapter covers emissions from combustion plants treated collectively as area sources. However, e.g. if only a few units exist and thus only little data is available, the individual approach may be preferable also for small combustion plants.

The subdivision of the SNAP activities according to CORINAIR90 concerning combustion plants takes into account two criteria:

- the economic sector concerning the use of energy:
  - public power and co-generation,
  - district heating,
  - commercial, institutional and residential combustion,
  - industrial combustion,
    (Note: process furnaces are allocated separately.)
- the technical characteristics:
  - the installed thermal capacity,
    - $\geq$ 50 to < 300 MW,
    - < 50 MW,
  - other combustion technologies,
    - gas turbines,
    - stationary engines.

The emissions considered in this section are released by a controlled combustion process (boiler emissions, furnace emissions, emissions from gas turbines or stationary engines) and are mainly characterised by the types of fuels used. Furthermore, a technical characterisation of the combustion sources may be integrated according to the size and type of plants as well as on primary or secondary reduction measures.[1] Solid, liquid or gaseous fuels are used; whereby solid fuels comprise coal, coke, biomass and waste (as far as waste is used to generate heat or power). In addition a non-combustion process can be a source of ammonia emissions; namely the ammonia slip in connection with some NO_x abatement techniques.[1]

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution of area source emissions released by combustion plants to the total emissions in the countries of the CORINAIR90 inventory reported as areas sources is given as follows:

Table 1: Contributions of emissions from combustion plants as area sources to the total emissions of the CORINAIR90 inventory reported as area sources. See chapter ACOR for further information on CORINAIR 90 emissions for these SNAP activities taking point and area sources together

		Contribution to total emissions [%]							
Source category	SNAP code	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
≥ 300 MW	01 01 01 01 02 01 03 01 01	0	0	0	0	0	0	-	0
50-300 MW	01 01 02 01 02 02 02 01 02 02 02 01 02 03 01 03 01 02	12.1	10.0	1.0	0.1	2.3	9.3	3.3	0.5
< 50 MW	01 01 03 01 02 03 02 01 03 02 02 02 02 03 02 03 01 03	71.3	46.7	41.1	7.2	49.8	66.4	21.8	0.7
Gas turbines	01 01 04 01 02 04 02 01 04 02 02 03 02 03 03 03 01 04	0.1	2.0	0.03	0.03	0.1	1.0	0.2	-
Stationary engines	01 01 05 01 02 05 02 01 05 02 02 04 02 03 04 03 01 05	0.6	2.0	0.2	0.02	0.1	0.4	0.2	0

[1] Note: Small combustion installations are seldomly equipped with secondary measures.

- : no emissions are reported as area sources

0 : emissions are reported, but the exact amount is under the rounding limit

Plants with a thermal capacity < 50 MW are the major contributors. In particular, the contribution of small units in „Commercial, institutional and residential combustion“ with a thermal capacity < 50 MW (SNAP 020002) is significantly high: SO_x 37.0 %, NO_x 24.2 %, NMVOC 39.6 %, CH_4 6.9 %, CO 46.3 %, CO_2 44.4 %, N_2O 14.7 % and NH_3 0.6 % (related to total emissions of CORINAIR90 reported as area sources).
In the literature concerning heavy metal emissions in Europe, area source emissions are not reported separately. In order to show the relevance of the sector residential combustion, the share of the emissions of different heavy metals from this sector in the total emission in Germany is shown as an example in Table 2.

Table 2: Contribution of heavy metal emissions from residential combustion to national total emissions of former West Germany /1/

Pollutant	Contribution in [wt.-%]	
	1982	1990
As	5.8	15
Cd	3	4.4
Cr	n.d.	n.d.
Cu	4.2	6.4
Hg	1.9	2.8
Ni	4.5	7.7
Pb	0.2	0.4
Se	0.8	3.1
Zn	0.4	0.7

n.d. : no data are available

For Cd and Hg data are also available for Austria. The contribution to total emissions in 1992 was for Cd 38.4% and for Hg 27.8% /2/. The contribution of area sources, such as residential combustion, to total emissions has increased during recent years. This is caused by the fact that large emitters have been equipped with improved dust control facilities in Germany as well as in Austria, and hence the contribution from larger sources has been reduced.

For Particulate Matter:
Combustion Plants < 50 MW (boilers) are now covered in the new supplementary chapter Particulate emissions from smaller Combustion Plants (<50MWth) B111(S1).

Combustion Plants >= 50 and < 300 MW (boilers) are now covered in the new supplementary chapter Particulate emissions from large Combustion Plants (>50MWth) B111(S2).

Gas Turbines are now covered in the new supplementary chapter Particulate emissions from gas turbines and internal combustion engines B111(S3).

3 GENERAL

3.1 Description

The emissions considered in this chapter are generated in boilers or in gas turbines and stationary engines regardless of the allocation of combustion plants to SNAP activities. In addition, residential combustion is relevant for this chapter. Emissions from process furnaces and from waste incineration are excluded.

3.2 Definitions

Integrated Coal Gasification Combined Cycle Gas Turbine (IGCC)	gas turbine fuelled by gas which is a product of a coal gasification process.
Boiler	any technical apparatus in which fuels are oxidised in order to generate heat for locally separate use.
Co-generation plant	steam production in (a) boiler(s) for both power generation (in a steam turbine) and heat supply.
Combined Cycle Gas Turbine (CCGT)	gas turbine combined with a steam turbine. The boiler can also be fuelled separately.
Furnace	fireplace in which fuels are oxidised to heat the direct surroundings.
Plant	element of the collective of emission sources (e.g. residential combustion) treated as an area source.
Stationary engines	spark-ignition engines or compression-ignition engines.

3.3 Techniques

3.3.1 Medium-sized combustion plants - boilers, gas turbines, stationary engines - (thermal capacity ≥ 50 and < 300 MW)

For the combustion of solid, liquid and gaseous fuels in medium-sized combustion plants techniques are used which have already been described in Section 3.3 of chapter B111 on "Combustion Plants as Point Sources".

3.3.2 Small-sized combustion plants - boilers and furnaces - (thermal capacity < 50 MW)

Small sized combustion plants are divided here into industrial combustion and non-industrial combustion:

- Industrial combustion:
  The techniques used for the combustion of solid, liquid and gaseous fuels in industrial combustion plants have already been described in Section 3.3 of chapter B111 on

"Combustion Plants as Point Sources". The share of combustion techniques used is different: for the combustion of solid fuels mainly grate firing and stationary fluidised bed combustion are applied.

- Non-industrial combustion:
  Non-industrial combustion which includes other small consumers and residential combustion, is characterised by a great variety of combustion techniques.

  For the combustion of solid fuels e.g. mainly grate firing units are installed which can be distinguished by the type of stoking and the air supply. For example, in manually fed combustion units (such as single stoves) emissions mainly result from frequent start-ups/shut-downs; automatically fed combustion units are mainly emission relevant when the fuel is kept glowing. Normally, older combustion installations release more emissions than modern combustion installations. Furthermore, combustion installations which often operate with reduced load conditions are highly emission relevant: this operation mode occurs frequently in the case of over-dimensioned combustion units. /4, 5/

  For the combustion of liquid and gaseous fuels, in principle similar technologies are applied, such as those described in chapter B111 on "Combustion Plants as Point Sources" (Section 3.3).

3.4 Emissions

Relevant pollutants are sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), methane (CH_4) and heavy metals (arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) and in the case of heavy oil also vanadium (V)). Emissions of nitrous oxide (N_2O) and ammonia (NH_3) are normally of less importance.

The main influencing parameters which determine the emissions and species profiles of some pollutants are given in Sections 3.4 and 9 of chapter B111 on "Combustion Plants as Point Sources". In particular for small combustion installations (e.g. residential combustion) emissions of NMVOC and CO can occur in considerable amounts; these emissions are mostly released from inefficiently working stoves (e.g. wood-burning stoves). VOC emissions released from domestic wood-fired boilers (0.5 - 10 MW) can be significant. Emissions can be up to ten times higher at 20 % load than those at maximum load /29/.

The emissions are released through the stack. The relevance of fugitive emissions (from seals etc.) can be neglected for combustion installations. Due to the fact that most references do not clearly distinguish between SO_x and SO_2, for the following sections it can be assumed that SO_2 includes SO_3, if not stated otherwise.

3.5 Controls

3.5.1 Medium-sized combustion plants - boilers, gas turbines, stationary engines - (thermal capacity ≥ 50 and < 300 MW)

It can be assumed, that the smaller the combustion installation considered are, the lower is the probability to be equipped with secondary measures. For cases where abatement technologies for SO_2, NO_x or heavy metals (controlled as particulates) are installed, the corresponding technical details are given in Section 3.5 of chapter B111 on "Combustion Plants as Point Sources". For SO_2 abatement in Germany, larger boilers are mainly controlled by the limestone wet scrubbing process. In the case of smaller facilities dry sorption processes are preferred.

3.5.2 Small-sized combustion plants - boilers and furnaces - (thermal capacity < 50 MW)

Small-sized combustion plants have been split into industrial combustion and non-industrial combustion:

- Industrial combustion:
  For cases where abatement technologies for SO_2, NO_x or heavy metals are installed the corresponding technical details are given in Section 3.5 of chapter B111 on "Combustion Plants as Point Sources". If NO_x reduction measures are installed mostly primary reduction measures (e.g. low NO_x burner) are applied.
- Non-industrial combustion:
  For small consumers / residential combustion only primary emission control measures are relevant. Emission reduction is mainly achieved by optimised operation conditions (older installations) and improved combustion efficiencies (modern installations).

4 SIMPLER METHODOLOGY

For combustion plants treated as area sources only a simpler methodology is given; a detailed methodology is not applicable (see Section 5). Here "simpler methodology" refers to the calculation of emissions based on emission factors and activities and covers all relevant pollutants (SO_2, NO_x, NMVOC, CH_4, CO, CO_2, N_2O, heavy metals). Emissions of NH_3 are of less relevance (they are only released as ammonia slip in connection with secondary measures for NO_x abatement).

The annual emission E is determined by an activity A and an emission factor:

$$E_i = EF_i \cdot A \qquad (1)$$

E_i annual emission of pollutant i
EF_i emission factor of pollutant i
A annual activity rate

The activity rate A and the emission factor EF_i have to be determined on the same level of aggregation depending on the availability of data. The activity A should be determined within the considered territorial unit by using adequate statistics (see also Section 6). The activity should refer to the energy input of the emission sources considered (fuel consumption in [GJ]). Alternatively, secondary statistics (surrogate data) can be used for the determination of the fuel consumption [GJ]. The quality of surrogate data can be characterised by two criteria:

- level of correlation
  The surrogate data should be directly related to the required data (e.g. fuel consumption of households derived from heat demand of households).

- level of aggregation
  The surrogate data should be provided on the same level of aggregation (e.g. spatial, sectoral and seasonal resolution).

Examples for activity rate and surrogate data and origins of possible inaccuracies are listed in the following:

- annual fuel consumption (recommended activity rate):
  - Statistics concerning the annual fuel consumption are often not further specified for different economic branches, and emission source categories, respectively. Furthermore, no technical split can be provided.

- annual fuel production [Gg], e.g. production of hard coal, lignite, natural gas:
  - The specifications of the fuel used (e.g. different types of coal) are not given. For the conversion of the unit [Gg] into unit [GJ] only an average heating value can be used.

- density of population, number of households:
  - Population statistics correspond to a very high level of aggregation. Further information has to be used (e.g. percentages of fuel consumed) in order to determine the activity rate for small consumers (e.g. residential combustion). In particular for fuels which are distributed by pipelines (e.g. natural gas) this assessment leads to an uncertainty in the activity rate determined.

- number of enterprises, number of employees, turnover of enterprises [Mio ECU]:
  - The statistical data on enterprise level are often allocated to the economic sector (e.g. “Production and Distribution of Electric Power, Production and Distribution of Steam, Hot Water, Compressed Air, District Heating Plants” /EUROSTAT, see Section 6/). On the other hand, emission factors are specified with regard to the type of fuel and often also to the type of boiler used.

- heat consumption:
  - The specific heat consumption per capita (e.g. [J/employee], [J/inhabitant]) or related to the area heated (e.g. [J/building], [J/m²]) can be determined by using area and branch specific data (e.g. differentiation between branches, number of employees, number of inhabitants).

The emission factor EF_i should be calculated as a mean value of all combustion installations within the territorial unit considered. In practice, a limited number of installations are selected to determine a representative emission factor which is applied to the total population of the installations considered. Usually, such emission factors are only specified as a function of fuel characteristics. However, further parameters should be taken into account, in particular the technology distribution as well as the size and age distribution of the boilers. Furthermore, evidence has been given that emissions are significantly affected by the operating conditions (e.g. inefficiently working stoves).

The emission factor EF_i (see Equation (1)) takes into account abatement measures (primary and secondary). If not stated otherwise the emission factors presented refer to full load conditions.

In the following a calculation procedure for SO_2 emission factors is proposed according to Equation (2):

$$EF_{SO_2} = 2 \cdot \overline{C}_{S_{fuel}} \cdot (1 - \overline{\alpha}_s) \cdot \frac{1}{\overline{H}_u} \cdot 10^6 \qquad (2)$$

EF_{SO_2} emission factor for SO_2 [g/GJ]

$\overline{C}_{S_{fuel}}$ average sulphur content of fuel (in mass S/mass fuel [kg/kg])

$\overline{H}_u$ average lower heating value [Mg/kg]

$\overline{\alpha}_s$ average sulphur retention in ash [ ]

In cases where secondary reduction measures are installed, the reduction efficiency has to be integrated by applying one of the following assumptions:

- if the total population of combustion installations is equipped with secondary measures, a mean reduction efficiency of these measures should be used;
- if only few combustion installations are equipped with secondary measures, either these installations should be treated separately or the mean reduction efficiency should be calculated with regard to the total population.

Reduction efficiencies for different individual secondary measures are given in Tables 10 and 11 in chapter B111 on “Combustion Plants as Point Sources”.

Equation (2) can be used for all fuels, but for liquid and gaseous fuels the sulphur retention in ash α_s is not relevant. If certain input data of Equation (2) are not available, provided default values based on literature data can be used:

$\overline{C}_{S_{fuel}}$ sulphur contents of different fuels see Table 4[2] (in Section 8),

$\overline{\alpha}_S$ sulphur retention in ash of different types of boiler see Table 8[2] in chapter B111 on “Combustion Plants as Point Sources“,

$\overline{H}_u$ lower heating values of different types of fuels see Table 21[2] in chapter B111 on “Combustion Plants as Point Sources“.

For other pollutants, according to Equation (1) fuel and technology specific emission factors EF_i are given in Tables 5 - 12 based on literature data; for activity data see Section 6.

5 DETAILED METHODOLOGY

For combustion plants a detailed methodology means the determination of emissions based on measured data. This is not applicable to area sources as only few emission sources are monitored directly.

2 A mean value has to be calcutated with regard to the area concerned.

6 RELEVANT ACTIVITY STATISTICS

The following gives a list of available statistics on a national level for the determination of fuel consumption, installed capacities, socio-economic data, etc.:

- Office for Official Publication of the European Communities (ed.): Annual Statistics 1990; Luxembourg; 1992
- Statistical Office of the European Communities (EUROSTAT) (ed.): CRONOS Databank; 1993
- OECD (ed.): Environmental Data, Données OCDE sur l'environnement; Compendium; 1993
- Commission of the European Communities (ed.): Energy in Europe; 1993 - Annual Energy Review; Special Issue; Brussels; 1994
- EUROSTAT (ed.): Panorama of EU Industry'94; Office for official publications of the European Communities; Luxembourg; 1994

A brief discussion of potential surrogate data for the determination of the activity rate is given in Section 4.

7 POINT SOURCE CRITERIA

This section is not relevant since this chapter only covers area sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Medium-sized combustion plants (thermal capacity ≥ 50 and < 300 MW)

For medium combustion installations, emission factors for the pollutants NO_x, NMVOC, CH_4, CO, CO_2, N_2O and heavy metals are given in Tables 24 - 31 in chapter B111 on "Combustion Plants as Point Sources".

8.2 Small-sized combustion plants (thermal capacity < 50 MW)

Tables 4 - 12 contain emission factors for all pollutants except for SO_2 where sulphur contents of different fuels are given. All emission factor tables have been designed in a homogeneous structure: Table 3 provides a split of combustion techniques (types of boilers, etc.); this standard table has been used for all pollutants. The selection of fuels is based on the CORINAIR90 inventory.

For small-sized combustion installations, emission factors are given related to the type of fuel consumed and, if useful, related to technical specifications based on literature data. These emission factors normally refer to stationary operating conditions. Modifications are indicated as footnotes (instationary conditions e.g. due to manually fed boilers, etc.).

The sequence of the following emission factor tables is:

Table 3: Standard table for emission factors for different pollutants

Table 3: Standard table of emission factors for the relevant pollutants

						no technical specification	Technical specification									
							Industrial combustion							Non-industrial combustion		
Fuel category[1]				NAPFUE code[1]	P1[2]		no specification[10]	DBB[3]	WBB[4]	FBC[5]	GF[6]	GT[7]	Stat. E.[8]	no specification	Small consumers	Residential combustion[9]
s	coal		no specification	-												
s	coal	hc[11]		101 - 103												
s	coal	bc[11]		106												
...	...	...	...	...												
s	biomass		wood	111												
...	...		...	...												
s	waste		municipal	114												
...	...		...	...												
l	oil		no specification	-												
l	oil		residual	201												
...	...		...	...												
g	gas		no specification	-												
g	gas		natural	301												
...	...		...	...												

[1] the fuel category is based on the NAPFUE-code
[2] P1 = sulphur content of fuel
[3] DBB = Dry bottom boiler
[4] WBB = Wet bottom boiler
[5] FBC = Fluidised bed combustion
[6] GF = Grate firing; ST1, ST2 = Type of stoker
[7] GT = Gas turbine
[8] Stat. E. = Stationary engine
[9] A differentiation between old and modern techniques can be made for the ranges of emission factors given so that e.g. the smaller values relate to modern units.
[10] Here only related to combustion in boilers; gas turbines and stationary engines are excluded.
[11] hc = hard coal, bc = brown coal

Table 4: Sulphur contents of selected fuels

Fuel category				NAPFUE code	Sulphur content of fuel	
					range	unit
s	coal	hc	coking, steam, sub-bituminous	101 - 103	0.4 - 6.2	wt.-% (maf)
s	coal	bc	brown coal/lignite	105	0.4 - 6.2	wt.-% (maf)
s	coal	bc	briquettes	106		
s	coke	hc, bc	coke oven, petroleum	107, 108, 110	0.5 - 1 [1) 2)]	wt.-% (maf)
s	biomass		wood	111	< 0.03[1)]	wt.-% (maf)
s	biomass		peat	113		
s	waste		municipal	114		
s	waste		industrial	115		
l	oil		residual	203	0.3[3)] - 3.5[4)]	wt.-%
l	oil		gas	204	0.08 - 1.0	wt.-%
l	oil		diesel	205		
l	kerosene			206		
l	gasoline		motor	208	< 0.05[5)]	wt.-%
g	gas		natural	301		
g	gas		liquified petroleum gas	303		
g	gas		coke oven	304		
g	gas		blast furnace	305		
g	gas		refinery	308	<= 8[6)]	$g \cdot m^{-3}$
g	gas		gas works	311		

1) Marutzky 1989 /25/
2) Boelitz 1993 /24/
3) Personal communication Mr. Hietamäki (Finland)
4) Referring to NL-handbook 1988 /26/ the range is 2.0 - 3.5
5) $\alpha_S = 0$
6) NL-handbook 1988 /26/

Table 5: NO_x emission factors [g/GJ]

Fuel category				NAPFUE code	no technical specification	Technical specification: Industrial combustion: no specification	DBB	WBB	FBC	GF	GT	Stat. E.	Non-industrial combustion: no specification	Small consumers	Residential combustion
s	coal		no specification	-											60-232***
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	50 - 668[11]	155[13]							50[1,2]	150[9]	50[9]
s	coal	bc	brown coal/lignite	105	7.5 - 604[11]								12[2] - 100[1]		
s	coal	bc	briquettes	106	17 - 300[11]										100[9]
s	coke	hc,bc	coke oven, petroleum	107, 108, 110	13 - 323[11]								45	50[9,10]	50[9,10]
s	biomass		wood	111	130 - 968[11]	206[13]				100-300*, 30-120**			12 - 80[1]	75[9]	50[9], 147-200[4]
s	biomass		peat	113	130 - 240[11]								100[1]		
s	waste		municipal	114	140 - 280[11]										
s	waste		industrial	115	100 - 193[11]										
s	waste		wood	116	80 - 258[11]										
s	waste		agricultural	117	80 - 100[11]										
l	oil		no specification	-									50[2]		
l	oil		residual	203	98 - 520[11]	165[13]					350[12]	75 - 1,889[12]			
l	oil		gas	204	55 - 1,624[11]	70[13]					100 - 531[12]	80 - 1,493[12]	50[1], 51[4]	48[9]	47[9]
l	oil		diesel	205	300 - 373[11]						380[12]	840[12,13]			
l	kerosene			206	45 - 100[11]						120[12]	45 - 1,038[12]	50[1]		
l	gasoline		motor	208	80[11]							375[12]			
l	naphtha			210	24 - 1,085[11]										
g	gas		no specification	-									30[2]-50[3]		
g	gas		natural	301	32 - 307[11]	62[13]					81 - 360[12], 165[13,14]	75 - 1,200[12], 165[13]	50[1]	38[9]	30[8], 46[9]
g	gas		liquified petroleum gas	303	18 - 105[11]						120[12]		50[1],	57[9]	47[4], 69[9]
g	gas		coke oven	304	2 - 399[11]						250[12]		50[1]	38[9]	46[9]
g	gas		blast furnace	305	25 - 1,520[11]						250[12]				
g	gas		waste	307	52 - 238[11]										
g	gas		refinery	308	65 - 155[11]						55 - 357[12]				
g	gas		biogas	309	4 - 132[11]										
g	gas		from gas works	311	50 - 411[11]								50[1]		

[1] CORINAIR 1992 /8/
[2] LIS 1977 /15/
[3] UBA 1981 /21/, Kolar 1990 /14/
[4] Radian 1990 /18/, IPCC 1994 /12/
[5] spruce wood
[6] chip board, phenol bonded
[7] chip board, urea bonded
[8] LIS 1987 /16/
[9] UBA 1995 /23/
[10] coke from hard coal
[11] CORINAIR90 data of combustion plants as area sources
[12] CORINAIR90 data, area sources
[13] UBA 1995 /30/
[14] at 50 % load: 130 g/GJ

* 100[3,5], 120[3,6], 300[3,7] for underfeed stoker
** 30[3,5], 80[3,6], 120[3,7] for overfeed stoker
*** 60[8], 149[4], 232[4]

Table 6: NMVOC emission factors [g/GJ]

						Technical specification										
					no technical specification	Industrial combustion							Non-industrial combustion		
Fuel category				NAPFUE code		no specification	DBB	WBB	FBC	GF	GT	Stat. E.	no specification	Small consumers	Residential combustion
s	coal		no specification	-											
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	1-511[5]								400[1] - 600[2]		50[3]
s	coal	bc	brown coal/lignite	105	1-800[5]										
s	coal	bc	briquettes	106	1.5-700[5]								150[1,2]		225[3]
s		hc,bc	coke oven, petroleum	107,108, 110	0.5-700[5]								12[2]		225[3,4]
s	biomass		wood	111	7-1,000[5]								150[2] - 800[1]		480[3]
s	biomass		peat	113	3-600[5]								150[1]		
s	waste		municipal	114	9-70[5]										
s	waste		industrial	115	0.5-134[5]										
s	waste		wood	116	48-600[5]										
s	waste		agricultural	117	50-600[5]										
l	oil		no specification	-									15[2]		
l	oil		residual	203	2.1-34[5]						3 - 4[6]	1.4 - 103.7[6]			
l	oil		gas	204	1.5-116[5]						0.7 - 5[6]	1.5 - 250[6]	15[1]		1.5[3]
l	oil		diesel	205	1.5-2.5[5]						5[6]	3.5[6]			
l	kerosene			206	1-14[5]						1[6]	1.5 - 244[6]	15[1]		
l	gasoline		motor	208	2[5]							437[6]			
l	naphtha			210	1-5[5]										
g	gas		no specification	-									1.5[2]		
g	gas		natural	301	0.3-205[5]						0.1 - 5.7[6]	0.3 - 47[6]	10[1]		2.5[3]
g	gas		liquified petroleum gas	303	0.3-14[5]						1[6]				3.5[3]
g	gas		coke oven	304	0.3-12[5]						2[6]		25[1]		2.5[3]
g	gas		blast furnace	305	0.2-1.5[5]										
g	gas		waste	307	2-16[5]										
g	gas		refinery	308	0.3-2.5[5]						2[6]				
g	gas		biogas	309	2.4-10[5]										
g	gas		from gas works	311	0.6-10[5]								25[1]		

[1] CORINAIR 1992 /8/
[2] LIS 1977 /15/
[3] UBA 1995 /23/
[4] coke from hard coal
[5] CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW
[6] CORINAIR90 data, area sources

Table 7: CH_4 emission factors [g/GJ]

					no technical specification	Technical specification										
						Industrial combustion							Non-industrial Combustion		
Fuel category				NAPFUE code		no specification	DBB	WBB	FBC	GF	GT	Stat. E.	no specification	Small consumers	Residential combustion
s	coal		no specification	-											
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	2 - 511[4]										450[2]
s	coal	bc	brown coal/lignite	105	0.2 - 532[4]										
s	coal	bc	briquettes	106	1 - 350[4]										225[2]
s	coke	hc,bc	coke oven, petroleum	107, 108, 110	1.5 - 200[4]										225[2) 3]
s	biomass		wood	111	21 - 601[4]										74-200[1], 320[2]
s	biomass		peat	113	5 - 400[4]										
s	waste		municipal	114	6 - 32[4]										
s	waste		industrial	115	0.3 - 38[4]										
s	waste		wood	116	30 - 400[4]										
s	waste		agricultural	117	10 - 400[4]										
l	oil		no specification	-											
l	oil		residual	203	0.1 - 10[4]						1 - 3[5]	0,02 - 7,5[5]			
l	oil		gas	204	0.1 - 19[4]						1 - 20,9[5]	0,04 - 14[5]			3.5[2], 5[1]
l	oil		diesel	205	1.5 - 2.5[4]							3,5[5]			
l	kerosene			206	0.02 - 7[4]						1[5]	0,02 - 7,4[5]			
l	gasoline		motor	208	1							49[5]			
l	naphtha			210	0.02 - 5[4]										
g	gas		no specification	-									1[1]		
g	gas		natural	301	0.3 - 205[4]						0,3 - 22,5[5]	0,02 - 153[5]			2.5[2]
g	gas		liquified petroleum gas	303	0.02 - 6[4]						1[5]				1.1[1], 1.5[2]
g	gas		coke oven	304	0.02 - 12[4]						2[5]				2.5[2]
g	gas		blast furnace	305	0.02 - 4[4]										
g	gas		waste	307	0.4 - 2.5[4]										
g	gas		refinery	308	0.02 - 2.5[4]						2[5]				
g	gas		biogas	309	0.4 - 10[4]										
g	gas		from gas works	311	0.6 - 10[4]										

[1] Radian 1990 /18/, IPCC 1994 /12/
[2] UBA 1995 /23/
[3] coke from hard coal
[4] CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW
[5] CORINAIR90 data, area sources

Table 8: CO emission factors [g/GJ]

			Fuel category	NAPFUE code	no technical specification	Technical specification: Industrial combustion: no specification	DBB	WBB	FBC	GF	GT	Non-industrial Combustion: Stat. E.	no specification	Small consumers	Residential combustion
s	coal		no specification	-						178-196*, 100[2]-107[6]			185[5]		160-3,580**
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	9 - 5,000[11]	73[13]								500[9]	4,800[9]
s	coal	bc	brown coal/lignite	105	4 - 6,000[11]										
s	coal	bc	briquettes	106	11 - 5,200[11]								7,000[7]		4,300[9]
s	coke	hc,bc	coke oven, petroleum		2 - 5,500[11]									1,000[9] [10]	4,800[9] [10]
s	biomass		wood	111	82 - 10,000[11]	627[13]							7,000[7]	3,600[9]	5,790[9]
s	biomass		peat	113	65 - 10,000[11]										18-18,533***
s	waste		municipal	114	33 - 2,188[11]										
s	waste		industrial	115	15 - 510[11]										
s	waste		wood	116	61 - 8,500[11]										
s	waste		agricultural	117	200 - 8,500[11]										
l	oil		no specification	-									70[8]		
l	oil		residual	203	29 - 1,754[11]	10[13]					10 - 30.4[12]	11.7 - 438[12]	20[2]		13[4]
l	oil		gas	204	5.3 - 547[11]	10[13]					10 - 123[12]	12 - 691[12]		41[9]	43[9]
l	oil		diesel	205	12 - 547[11]						12[12]	190[12],[13]			
l	kerosene			206	3 - 151[11]						12[12]	3.4 - 669[12]			
l	gasoline		motor	208	12[11]										
l	naphtha			210	0.2 - 89[11]										
g	gas		no specification	-									70[8]		10[4]
g	gas		natural	301	2.4 - 500[11]	10[13]					8-123[12], 10[13][14]	2.4-335[12], 136[13]	252)	41[9]	25-250***
g	gas		liquified petroleum gas	303	3.3 - 250[11]									41[9]	10[4], 53[9]
g	gas		coke oven	304	3.3 - 279[11]						13[12]			41[9]	53[9]
g	gas		blast furnace	305	3 - 279[11]						13[12]				
g	gas		waste	307	8.8 - 27[11]										
g	gas		refinery	308	3.3 - 279[11]						2[12]				
g	gas		biogas	309	7.8 - 41[11]										
g	gas		from gas works	311	6.4 - 225[11]										

1) EPA 1987 /10/, CORINAIR 1992 /8/
2) CORINAIR 1992 /8/ for overfed stoker
3) OECD 1989 /31/, CORINAIR 1992 /8/
4) Radian 1990 /18/, IPCC 1994 /12/
5) EPA 1987 /10/, CORINAIR 1992 /8/
6) EPA 1985 /9/, CORINAIR 1992 /8/ for overfeed stoker
7) LIS 1987 /16/
8) LIS 1977 /15/
9) UBA 1995 /23/
10) coke from hard coal
11) CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW
12) CORINAIR90 data, area sources
13) UBA 1995 /30/
14) at 50 % load: 76 g/GJ

* 178[1], 190[2], 196[3] for underfeed stoker
**160[3], 484[4], 1,500[5], 1,607[6], 2,000[2], 3,400[3], 3,580[4]
*** 18[4], 53[9],4,949[4], 6,002[4], 18,533[4]
**** 25[2], 200[2], 250[2] (cooker)

Table 9: CO_2 emission factors [kg/GJ]

Fuel category				NAPFUE code	Emission factors value	range	remarks
s	coal		no specification	-			
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	94[6]	93 - 99[5], 55.9 - 106.8[2]	
s	coal	bc	brown coal/lignite	105		74 - 105.5[5], 67.5 - 116[2]	
s	coal	bc	briquettes	106	97[6]	97 - 113[3], 85.6 - 110.9[2]	
s	coke	hc,bc	coke oven, petroleum	107, 108, 110	105[6]	96 - 122[1][4], 85.6 - 151[2]	
s	biomass		wood	111		100 - 125[1][4], 83 - 322.6[2]	
s	biomass		peat	113		98 - 115[2]	
s	waste		municipal	114		109 - 141[1], 15 - 117[2]	
s	waste		industrial	115		20 - 153.3[2]	
s	waste		wood	116		83 - 92[2]	
s	waste		agricultural	117		69 - 100[2]	
l	oil		no specification	-			
l	oil		residual	203		76 - 78[3][4], 64 - 99[2]	
l	oil		gas	204	74[6]	73 - 74[5], 69 - 97[2]	
l	oil		diesel	205		73 - 74[2][4]	
l	kerosene			206	73[5]	67.7 - 78.6[2]	
l	gasoline		motor	208	71[2], 73[5]	71 - 74[1][3][4]	
l	naphtha			210	73[3]	72.1 - 74[2]	
g	gas		no specification	-			
g	gas		natural	301	56[6]	55 - 61[3][4][5], 52 - 72[2]	
g	gas		liquified petroleum gas	303	65[6]	55 - 75.5[2]	
g	gas		coke oven	304	44[6], 49[5]	44 - 192[2]	
g	gas		blast furnace	305		105 - 290[2]	
g	gas		waste	307		62.5 - 87.1[2]	
g	gas		refinery	308		55 - 66[2]	
g	gas		biogas	309		60 - 103.4[2]	
g	gas		from gas works	311		52 - 56[2]	

1) Schenkel 1990 /20/
2) CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW
3) IPCC 1993 /11/
4) Kamm 1993 /13/
5) BMU 1994 /7/
6) UBA 1995 /30/

Table 10: N_2O emission factors [g/GJ]

Fuel category				NAPFUE code	no technical specification	Technical specification									
						Industrial combustion							Non-industrial combustion		
						no specification	DBB	WBB	FBC	GF	GT	Stat. E.	no specification	Small consumers	Residential combustion
s	coal		no specification	-											
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	5 - 30[1]										
s	coal	bc	brown coal/lignite	105	1.4 - 18.2[1]										
s	coal	bc	briquettes	106	1.4 - 14[1]										
s	coke	hc,bc	coke oven, petroleum	107, 108, 110	1.4 - 14[1]										
s	biomass		wood	111	1.6 - 20[1]										
s	biomass		peat	113	2 - 14[1]										
s	waste		municipal	114	4[1]										
s	waste		industrial	115	2 - 5.9[1]										
s	waste		wood	116	4[1]										
s	waste		agricultural	117	1.4 - 4[1]										
l	oil		no specification	-											
l	oil		residual	203	0.8 - 46.5[1]						2.5 - 25[2]	1.1 - 2.1[2]			
l	oil		gas	204	0.6 - 17.8[1]						0.5 - 25[2]	0.6 - 14[2]			
l	oil		diesel	205	2 - 15.7[1]						15.7[2]	2 - 4[2]			
l	kerosene			206	2 - 14[1]						14[2]	2[2]			
l	gasoline		motor	208	14[1]							2[2]			
l	naphtha			210	12[1]										
g	gas		no specification	-											
g	gas		natural	301	0.1 - 14[1]						0.1-3[2]	0.1-3[2]			
g	gas		liquified petroleum gas	303	1 - 14[1]						14[2]				
g	gas		coke oven	304	1 - 12[1]						3[2]				
g	gas		blast furnace	305	0.8 - 34.6[1]						3[2]				
g	gas		waste	307	3.7 - 5[1]										
g	gas		refinery	308	1.5[1]						3[2]				
g	gas		biogas	309	1.5 - 3.7[1]										
g	gas		from gas works	311	2 - 3[1]										

[1] CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW
[2] CORINAIR90 data, area sources

Table 11: NH_3 emission factors [g/GJ]

Fuel category				NAPFUE code	no technical specification	Technical specification	
						Gas turbines	Stationary engines
s	coal		no specification	-			
s	coal	hc	coking, steam, sub-bituminous	101, 102, 103	0.14 - 0.48[1)]		
s	coal	bc	brown coal/lignite	105	0.01 - 0.86[1)]		
s	coal	bc	briquettes	106	0.01 - 0.86[1)]		
s	coke	hc,bc	coke oven, petroleum	107, 108, 110	0.01 - 0.86[1)]		
s	biomass		wood	111	5 - 9[1)]		
s	biomass		peat	113			
s	waste		municipal	114			
s	waste		industrial	115			
s	waste		wood	116			
s	waste		agricultural	117			
l	oil		no specification	-			
l	oil		residual	203	0.01[1)]		
l	oil		gas	204	0.01 - 2.68[1)]		0.1 - 0.2[1)]
l	oil		diesel	205			
l	kerosene			206			0.2[1)]
l	gasoline		motor	208			
l	naphtha			210			
g	gas		no specification	-			
g	gas		natural	301	0.15 - 1[1)]		
g	gas		liquified petroleum gas	303	0.01[1)]		
g	gas		coke oven	304	0.87[1)]		
g	gas		blast furnace	305			
g	gas		waste	307			
g	gas		refinery	308			
g	gas		biogas	309	15[1)]		
g	gas		from gas works	311			

[1)] CORINAIR90 data, combustion plants as area sources with a thermal capacity of > 300, 50 - 300, < 50 MW

Table 12: Heavy metal emission factors (mass pollutant/mass fuel [g/Mg])

Fuel category			NAPFUE code	Heavy metal element	no technical specification	Technical specification: Industrial combustion: no specification	DBB	WBB	FBC	GF	Non-industrial combustion: no specification	Small consumer	Residential combustion
s	coal	hc	101/102	Mercury		1.7 g/TJ[2]							0.3[1]
				Cadmium		0.1 g/TJ[2]							0.15[1]
				Lead		6.0 g/TJ[2]							2.5[1]
				Copper		3.1 g/TJ[2]							1.2[1]
				Zinc		10.5 g/TJ[2]							1[1]
				Arsenic		3.2 g/TJ[2]							1.2[1]
				Chromium		2.3 g/TJ[2]							0.9[1]
				Selen		0.5 g/TJ[2]							0.15[1]
				Nickel		4.4 g/TJ[2]							1.8[1]
s	coal	bc	105	Mercury		4.4 g/TJ[2]							0.1[2]
				Cadmium		0.4 g/TJ[2]							0. 04[2]
				Lead		3.9 g/TJ[2]							0.24[2]
				Copper		2.0 g/TJ[2]							
				Zinc		10.6 g/TJ[2]							0.14[2]
				Arsenic		4.2 g/TJ[2]							
				Chromium		3.1 g/TJ[2]							
				Selen									
				Nickel		3.9 g/TJ[2]							
l	oil, heavy fuel		203	Mercury		0.15-0.2[1]							
				Cadmium		0.1-1[1]							
				Lead		0.6-1.3[1]							
				Copper		0.05-1[1]							
				Zinc		0.02-0.2[1]							
				Arsenic		0.14-1[1]							
				Chromium		0.2-2.5[1]							
				Selen		0.003-1[1]							
				Nickel		17-35[1]							
g	gas		301	Mercury									

[1] Winiwarter 1995 /6/ [2] Jockel 1995 /1/

9 SPECIES PROFILES

For species profiles of selected pollutants see Section 9 in chapter B111 on "Combustion Plants as Point Sources".

10 UNCERTAINTY ESTIMATES

Uncertainties of emission data result from inappropriate emission factors and from missing statistical information on the emission generating activity. Those discussed here are related to emission factors. Usually uncertainties associated with emission factors can be assessed by comparing them with emission factors obtained by using measured data or other literature data. However, at this stage, the available emission factors based on literature data are often poorly documented without a specification concerning the area of application. A range of emission factors, depending on the parameters available (as given in chapter B111 on "Combustion Plants as Point Sources", Section 10), can therefore not be given here.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Weakest aspects discussed here are related to emission factors.

The average emission factor of a territorial unit should integrate the diversity of the combustion techniques installed within the territorial unit. Therefore, the number and diversity of the selected combustion installations for the calculation of the average emission factor should correspond with the number and diversity of the installations within the territorial unit (target population). Further work should be carried out to characterise territorial units with regard to the technologies in place (technology distribution, age distribution of combustion technique, etc.).

For all pollutants considered, neither qualitative nor quantitative load dependencies have yet been integrated into the emission factors. In particular for oil, coal and wood fired small stoves, increased emissions occur due to a high number of start-ups per year (e.g. up to 1,000 times a year) or due to load variations (e.g. manual furnace charging). Emissions from residential firing can be highly relevant (e.g. combustion of wood in the Nordic countries, in particular for VOC and CO emissions). Further work should be invested to clarify this influence with respect to the emission factors published.

For the weakest aspects related to the determination of activities based on surrogate data see Section 4. Uncertainty estimates of activity data should take into account the quality of available statistics. In particular, emissions from the combustion of wood in single stoves may increase as some national statistics have underestimated wood consumption to date /3/.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Spatial disaggregation of annual emission data (top-down approach) can be related
- for industrial combustion e.g. to the number of industrial employees in industrial areas and
- for residential combustion e.g. to the number of inhabitants in high density and low density areas and to the type of fuel.

In general the following disaggregation steps for emissions released from residential combustion can be used /cf. 27/:

- differentiation in spatial areas, e.g. administrative units (country, province, district, etc.), inhabited areas, settlement areas (divided in high and low density settlements),
- determination of regional emission factor per capita depending on the population density and the type of fuel used.

For emissions released from industrial combustion, spatial disaggregation takes into account the following steps:
- differentiation in spatial areas with regard to industrial areas,
- determination of emission factors related to the number of industrial employees.

13 TEMPORAL DISAGGREGATION CRITERIA

Temporal disaggregation of annual emission data (top-down approach) provides a split into monthly, weekly, daily and/or hourly emission data. For annual emissions released from combustion plants as area sources this data can be obtained for:

- industrial combustion by using in principle the disaggregation criteria and the procedure as described in Section 13 of chapter B111 on “Combustion Plants as Point Sources” by taking into account the number of plants in the area considered.
- non-industrial combustion (small consumer/residential combustion) by using a relation between the consumption of fuel and the heating degree-days.

The disaggregation of annual emissions released from non-industrial combustion (small consumers/residential combustion) has to take into account a split into:

- summer and winter time (heating periods),
- working days and holidays and
- daily fluctuations of load

for the main relevant fuels and, if possible, for the main relevant combustion techniques (manually fed stoves, etc.)

The procedure of disaggregation consists of the following step-by-step approach /cf. 28/:
- determination of the temporal variation of the heat consumption (based e.g. on user behaviour),

- determination of the fuel consumption e.g. by using statistics for district heat or consumption of gas, by using fuel balances for the estimation of coal and wood consumption (e.g. as given in /3/),
- correlation of the heating degree-days with the consumption of fuel (e.g. for gas, district heat). Typical heating degree-days are available in statistics. The correlation can be linear as given e.g. in /28/.
- determination of the relative activity (e.g. fuel consumption per hour per day) by using adequate statistics.

This approach makes it possible to determine annual, weekly and/or daily correction factors. For the determination of hourly emissions the following Equation (3) /cf. 28/ can be given as an example:

$$E_H(t) = \frac{E_A}{8,760[h]} \cdot f_a(t) \cdot f_w(t) \cdot f_d(t) \tag{3}$$

E_H	emission per hour(s) [Mg/h]
E_A	annual emission [Mg]
f_a	annual correction factor [ ]
f_w	weekly correction factor [ ]
f_d	daily correction factor [ ]
t	time

The constant (8,760 h) in Equation (3) represents the number of hours per year.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

As outlined in chapter B111 on ”Concepts for Emission Inventory Verification“ different verification procedures can be used. The aim of this section is to select those which are most adequate for emission data from combustion plants as area sources. Verification procedures considered here are principally based on the verification of emission data on a territorial unit level (national level).

The annual emissions related to a territorial unit can be compared to independently derived emission estimates. These independent emission estimates can be obtained by using econometric relations between annual emissions and exogenous variables, such as population equivalents, number of households, fossil fuel prices, etc.

Another possibility is to make emission density comparisons of e.g. emissions per capita or emissions per GDP between countries with comparable economic structures.

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19 RELEASE VERSION, DATE AND SOURCE

Version : 3.1

Date : December 1995

Source : Otto Rentz; Dagmar Oertel
University of Karlsruhe (TH)
Germany

Updated with particulate matter details by:
Mike Woodfield
AEA Technology
UK
December 2006

20 POINT OF ENQUIRY

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Annex 1: List of abbreviations

A_i	Activity rate of the emission source i
bc	Brown coal
CCGT	Combined Cycle Gas Turbine
CFBC	Circulating Fluidised Bed Combustion
DBB	Dry Bottom Boiler
E	Emission
EF_i	Emission factor of the emission source i, e.g. in [g/GJ]
f_a	Annual correction factor [ ]
f_d	Daily correction factor [ ]
f_w	Weekly correction factor [ ]
FBC	Fluidised Bed Combustion
g	Gaseous state of aggregation
GF	Grate Firing
GT	Gas Turbine
H	Lower heating value of fuel
hc	Hard coal
IGCC	Integrated Coal Gasification Combined Cycle Gas Turbine
l	Liquid state of aggregation
PFBC	Pressurised Fluidised Bed Combustion
s	Solid state of aggregation
S	Sulphur content of fuel
Stat. E.	Stationary Engine
t	Time
WBB	Wet Bottom Boiler