PART B: Methodology Chapters

CORINAIR NOMENCLATURES

A detailed nomenclature called NAPSEA (Nomenclature for Air Pollution Socio-Economic Activities) was developed for the CORINAIR 1985 Project. NAPACT consisted of three daughter nomenclatures : NAPACT : Nomenclature for Air Pollution ACTivities, NAPTEC : Nomenclature for Air Pollution TEChniques, NAPFUE : Nomenclature for Air Pollution Fuels.

From these nomenclatures, a selected sub-set was established as the basis for the prototype CORINAIR 1985 inventory: *SNAP* P, *Selected Nomenclature for sources of Air Pollution* Prototype. SNAP P links directly to the various components of NAPSEA.

In 1990/91, when preparations were being made for a CORINAIR 1990 inventory, discussions were held with experts from EMEP and OECD to develop a common nomenclature for CORINAIR and for reporting under the LRTAP Convention. SNAP90 emerged from these discussions but the detailed link to NAPACT and NAPFUE was not made.

In 1995, the European Topic Centre on Air Emissions (ETC/AE) developed the CORINAIR nomenclature further resulting in SNAP94 as presented in the first edition of the Guidebook.

In 1998 ETC/AE developed the nomenclature still further, resulting in SNAP97 as presented in the second edition of the Guidebook. SNAP97 covers additional activities that are sources of the heavy metals and persistent organics and is fully consistent with the IPCC nomenclature *(1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories, WMO/IPCC, 1997)* developed for reporting under the UN Framework Climate Change Convention (see also the sections on correspondence between SNAP97 and IPCCC1996). In 1999 UNFCCC developed the Common Reporting Format (CRF), which is in line with the 1996 IPCC Guidelines, and is described in the UNFCCC Reporting guidelines (http://www.unfccc.int/resource/docs/cop5/07.pdf). The CRF is used by countries for reporting of greenhouse gas inventories since 2000.

Eurostat has also initiated a project to develop process-oriented source nomenclatures such as SNAP to be more consistent with the NACE socio-economic nomenclatures and to include processes of emissions to water and describing waste generation. This resulted in the *NOSE Manual (NOmenclature for Sources of Emissions), version 1.0, May 1998.* The manual contains a list of processes, NOSE-P, which consists for air emissions mainly of SNAP97 and in addition some preliminary codes for emissions to water. NOSE-P was further developed and tested since 1999 by Eurostat, in co-operation with EEA. In this Guidebook NOSE-P codes have been incorporated in all chapters.

In 2001 the UN/ECE TFEIP developed the NFR (*Nomenclature For Reporting)* source sector classification system for the Reporting Guidelines. In the development of NFR a correlation was established between the SNAP, NFR and CRF/IPCC reporting source categories. Following experiences from the 2001 reporting round the system has been revised in 2002 according to the final draft CLRTAP/EMEP 2002 Reporting Guidelines (described in eb.air.ge.1.2002.7.pdf). This correlation is included in the contents/index for the current version of the Guidebook (AIND) and codes are also included in the Guidebook's technical chapters. National reporters of emission inventories will be using this format for the first time to report emissions in the 2002 reporting round (due 31 January 2003).

CORRESPONDENCE BETWEEN SNAP97 AND IPCC 1996 SOURCE CATEGORIES

This document provides the corresponding allocation of all SNAP 97 items in IPCC 1996 source categories. It is to be noticed that each SNAP item corresponds to only one IPCC source category as defined in standard data tables.

All codes used in this document refer to :
- CORINAIR / SNAP 97 version 1.0 dated 20/03/1998
- IPCC / Greenhouse Gas Inventory / Reporting Instructions / Revised 1996 Guidelines for National Greenhouse Gas Inventories (Volume 1)

	CORINAIR / SNAP classification		IPCC classification
01	**COMBUSTION IN ENERGY AND TRANSFORMATION INDUSTRIES**		
01 01	**Public power**		
	Items 01.01.01 to 01.01.05	1A1a	Electricity and heat production
01 02	**District heating plants**		
	Items 01.02.01 to 01.02.05	1A1a	Electricity and heat production
01 03	**Petroleum refining plants**		
	Items 01.03.01 to 01.03.06	1A1b	Petroleum refining
01 04	**Solid fuel transformation plants**		
	Items 01.04.01 to 01.04.07	1A1c	Manufacture of Solid Fuels and Other Energy Industries
01 05	**Coal mining, oil / gas extraction, pipeline compressors**		
	Items 01.05.01 to 01.05.05	1A1c	Manufacture of Solid Fuels and Other Energy Industries
01 05 06	Pipeline compressors	1A3e	Transport-Other transportation
02	**NON-INDUSTRIAL COMBUSTION PLANTS**		
02 01	**Commercial and institutional plants**	1A5a	(*)
	Items 02.01.01 to 02.01.06	1A4a	Other Sectors-Commercial/Institutional
02 02	**Residential plants**		
	Items 02.02.01 to 02.02.05	1A4b	Other Sectors-Residential
02 03	**Plants in agriculture, forestry and aquaculture**		
	Items 02.03.01 to 02.03.05	1A4c	Other Sectors-Agriculture/Forestry/Fishing
03	**COMBUSTION IN MANUFACTURING INDUSTRY**		
03 01	**Combustion in boilers, gas turbines and stationary engines**	1A2	Industry
	Items 03.01.01 to 03.01.06		When relevant economic sector split data are available in CORINAIR, data can be allocated to sub-categories a to f.
03 02	**Process furnaces without contact**		
03 02 03	Blast furnace cowpers	1A2a	Industry-Iron and steel
03 02 04	Plaster furnaces	1A2f	Industry-Other
03 02 05	Other furnaces	1A2f	Industry-Other by default

(*) stationary military sources are not differenciated in SNAP 02 01. This item cannot be allocated twice; miltary emissions representing generally minor contributions within this category, figures are allocated to IPCC 1A4a only to avoid double counting.

CORINAIR / SNAP classification		IPCC classification	
03 03	**Processes with contact**		
	Items 03.03.01 to 03.03.03	1A2a	Industry-Iron and steel
	Items 03.03.04 to 03.03.10 and 03.03.22 to 03.03.24	1A2b	Industry-Non-ferrous metals
	SF6 emission for 03.03.10	2C4	Industrial Processes-Metal Production-SF6 Used
	Items 03.03.11 to 03.03.20 and 03.03.25 and 03.03.26	1A2f	Industry-Other
03 03 21	Paper-mill industry (drying processes)	1A2d	Industry-Pulp, Paper and Print
04	**PRODUCTION PROCESSES**		
04 01	**Processes in petroleum industries**		
	Items 04.01.01 to 04.01.05	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
04 02	**Processes in iron and steel industries and collieries**		
	Items 04.02.01 and 04.02.04	1B1b	Fugitive emissions from fuels-Solid fuels/Transformation
	Items 04.02.02 , 04.02.03 and 04.02.05 to 04.02.10	2C1	Industrial Processes-Metal Production-Iron and steel
04 03	**Processes in non-ferrous metal industries**		
04 03 01	Aluminium production (electrolysis)	2C3	Industrial Processes-Metal Production-Aluminium
04 03 02	Ferro alloys	2C2	Industrial Processes-Metal Production-Ferroalloys
	SF6 emission from 03.03.10, 04.03.01 and 04.03.04	2C4	Industrial Processes-Metal Production-SF6 Used
	Items 04.03.03 to 04.03.09	2C5	Industrial Processes-Metal Production-Other
04 04	**Processes in inorganic chemical industries**		
04 04 01	Sulphuric Acid	2B5	Industrial Processes-Chemical Industry/Other
04 04 02	Nitric acid	2B2	Industrial Processes-Chemical Industry-Nitric Acid
04 04 03	Ammonia	2B1	Industrial Processes-Chemical Industry-Ammonia
	Items 04.04.04 to 04.04.11 and 04.04.13 to 04.04.16	2B5	Industrial Processes-Chemical Industry/Other
04 04 12	Calcium Carbide production	2B4	Industrial Processes-Chemical Industry-Carbide
04 05	**Processes in organic chemical industries (bulk production)**		
	Items 04.05.01 to 04.05.20 and 04.05.22 to 04.05.26	2B5	Industrial Processes-Chemical Industry-Other
04 05 21	Adipic acid	2B3	Industrial Processes-Chemical Industry-Adipic Acid
04 05 27	Other	2B5	Industrial Processes-Chemical Industry-Other
04 06	**Proc. in wood, paper pulp, food, drink and other industries**		
	Items 04.06.01 to 04.06.04	2D1	Industrial processes-Other Production-Pulp and Paper
	Items 04.06.05 to 04.06.08	2D2	Industrial processes-Other Production-Food and Drink
04 06 10	Roof covering with Asphalt Materials	2A5	Industrial processes-Mineral Products-Asphalt Roofing
04 06 11	Road paving with Asphalt	2A6	Industrial proc.-Mineral Products-Road Paving with Asphalt
04 06 12	Cement (decarbonizing)	2A1	Industrial processes-Mineral Products-Cement
04 06 14	Lime (decarbonizing)	2A2	Industrial processes-Mineral products/Lime
	Items 04.06.13 and 04.06.15 to 04.06.17 and 04.06.20	2A7	Industrial processes-Mineral Products-Other
04 06 18	Limestone and Dolomite use	2A3	Industrial processes-Limestone and Dolomite use
04 06 19	Soda Ash production and use	2A4	Industrial processes-Soda Ash production and use
04 08	**Production of halocarbons and sulphur hexafluoride**		
04 08 01	Halogenated hydrocarbons production - By-products	2E1	Indust. Processes.-Production of HFC and SF6-By-products
04 08 02	Halogenated hydrocarbons production - Fugitive	2E2	Industrial Processes.-Production of HFC and SF6-Fugitive
04 08 03	Halogenated hydrocarbons production - Other	2E3	Industrial Processes.-Production of HFC and SF6-Other
04 08 04	Sulphur hexafluoride production - By-products	2E1	Indust. Processes.-Production of HFC and SF6-By-products
04 08 05	Sulphur hexafluoride production - Fugitive	2E2	Industrial Processes.-Production of HFC and SF6-Fugitive
04 08 06	Sulphur hexafluoride production - Other	2E3	Industrial Processes.-Production of HFC and SF6-Other

CORINAIR / SNAP classification		IPCC classification	
05	**EXTRACTION AND DISTRIBUTION OF FOSSIL FUELS AND GEOTHERMAL ENERGY**		
05 01	**Extraction and 1st treatment of solid fossil fuels**		
	Items 05.01.01 to 05.01.03	1B1a	Fugitive emissions from fuels-Solid fuels/Coal mining
05 02	**Extraction, 1st treatment and loading of liquid fossil fuels**		
	Items 05.02.01 to 05.02.02	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 03	**Extraction, 1st treat. and loading of gaseous fossil fuels**		
	Items 05.03.01 to 05.03.03	1B2b	Fugitive emissions from fuels-Oil and natural gas/Natural gas
05 04	**Liquid fuel distribution (except gasoline distribution)**		
	Items 05.04.01 to 05.04.02	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 05	**Gasoline distribution**		
	Items 05.05.01 to 05.05.03	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 06	**Gas distribution networks**		
	Items 05.06.01 to 05.06.02	1B2b	Fugitive emissions from fuels-Oil and natural gas/Natural gas
05 07	**Geothermal energy extraction**	7	Other
06	**SOLVENT AND OTHER PRODUCT USE**		
06 01	**Paint application**		
	Items 06.01.01 to 06.01.09	3A	Solvent and other product use-Paint application
06 02	**Degreasing, dry cleaning and electronics**		
	Items 06.02.01 to 06.02.04 except SF6, PFC and HFC	3B	Solvent and other product use-Degreasing and dry cleaning
	PFC and HFC emissions	2F5	Indust. proc.-Consumption of halocarbons and SF6-Solvents
	SF6 emissions	2F6	Indust. proc.-Consumption of halocarbons and SF6-Other
06 03	**Chemical products manufacturing or processing**		
	Items 06.03.01 to 06.03.14	3C	Solvent and other product use-Chemical products
	PFC and HFC emissions	2F5	Indust. proc.-Consumption of halocarbons and SF6-Solvents
06 04	**Other use of solvents and related activities**		
	Items 06.04.01 to 06.04.12	3D	Solvent and other product use-Other
	SF6, PFC and HFC emissions for 06.04.01 and 06.04.02	2F6	Indust. proc.-Consumption of halocarbons and SF6-Other
06 05	**Use of HFC, N2O, NH3, PFC and SF6**		
06 05 01	Anaesthesia	3D	Solvent and other product use-Other
06 05 02	Refrigeration and air conditioning equipments using halocarbons	2F1	Refrigeration and air conditioning equipments
06 05 03	Refrigeration and air conditioning equipments using other products than halocarbons	2G	Industrial processes-Other
06 05 04	Foam Blowing (except 060304)	2F2	Industrial processes-Foam Blowing
06 05 05	Fire extinguishers	2F3	Industrial processes-Fire extinguishers
06 05 06	Aerosol cans	2F4	Industrial processes-Aerosols
06 05 07	Electrical equipment	2F6	Industrial proc.-Consumption of halocarbons and SF6-Other
06 05 08	Other	2F6	Industrial proc.-Consumption of halocarbons and SF6-Other
		3D	Solvent and other product use-Other (except halocarbons and sulphur hexafluoride)

	CORINAIR / SNAP classification		IPCC classification
07	**ROAD TRANSPORT**		
07 01	**Passenger cars**		
	Items 07.01.01 to 07.01.03	1A3b	Transport-Road (1-Cars)
07 02	**Light duty vehicles < 3.5 t**		
	Items 07.02.01 to 07.02.03	1A3b	Transport-Road (2-Light duty trucks)
07 03	**Heavy duty vehicles > 3.5 t and buses**		
	Items 07.03.01 to 07.03.03	1A3b	Transport-Road (3-Heavy duty trucks and buses)
07 04	**Mopeds and Motorcycles < 50 cm3**	1A3b	Transport-Road (4-Motorcycles)
07 05	**Motorcycles > 50 cm3**		
	Items 07.05.01 to 07.05.03	1A3b	Transport-Road (4-Motorcycles)
07 06	**Gasoline evaporation from vehicles**	1A3b	Transport-Road
07 07	**Automobile tyre and brake wear**	-	Not allocated
08	**OTHER MOBILE SOURCES AND MACHINERY**		
08 01	**Military**	1A5	Other
08 02	**Railways**		
	Items 08.02.01 to 08.02.03	1A3c	Transport-Railways
08 03	**Inland waterways**		
	Items 08.03.01 to 08.03.04	1A3d	Transport-Navigation
08 04	**Maritime activities**		
08 04 02	National sea traffic within EMEP area	1A3d	Transport-Navigation / 2-National navigation
08 04 03	National fishing	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 04 04	International sea traffic (international bunkers)	1A3d	Transport-Navigation / 1-International marine(bunkers)
08 05	**Air traffic**		
08 05 01	Domestic airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 02	International airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (1-International)
08 05 03	National cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 04	International cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (1-International)
08 06	**Agriculture**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 07	**Forestry**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 08	**Industry**	1A2f	Industry-Other by default
08 09	**Household and gardening**	1A4b	Small combustion-Residential
08 10	**Other off-road**	1A3e	Transport-Other

	CORINAIR / SNAP classification		IPCC classification
09	**WASTE TREATMENT AND DISPOSAL**		
09 02	**Waste incineration**		
	Items 09.02.01 and 09.02.02	6C	Waste-Incineration
	Items 09.02.03 and 09.02.06	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring
	Items 09.02.04 to 09.02.05 and 09.02.07 to 09.02.08	6C	Waste-Incineration
09 04	**Solid Waste Disposal on Land**		
09 04 01	Managed Waste Disposal on Land	6A1	Waste-Solid waste disposal on land-Managed Disposal
09 04 02	Unmanaged Waste Disposal Sites	6A2	Waste-Solid waste disposal on land-Unmanaged Sites
09 04 03	Other	6A3	Waste-Solid waste disposal on land-Other
09 07	**Open burning of agricultural wastes (except 10.03)**	6C	Waste-Incineration
09 09	**Cremation**		
	Items 09.09.01 to 09.09.02	6C	Waste-Incineration
09 10	**Other waste treatment**		
09 10 01	Waste water treatment in industry	6B1	Waste-Wastewater treatment/Industrial
09 10 02	Waste water treatment in residential and commercial sect.	6B2	Waste-Wastewater treatment/Domestic and commercial
09 10 03	Sludge spreading	6D	Waste-Other
09 10 05	Compost production	6D	Waste-Other
09 10 06	Biogas production	6D	Waste-Other
09 10 07	Latrines	6B2	Waste-Wastewater treatment
09 10 08	Other production of fuel (refuse derived fuel,...)	6C	Waste-Incineration
10	**AGRICULTURE**		
10 01	**Cultures with fertilizers**		
	Items 10.01.01 to 10.01.02 and 10.01.04 to 10.01.06	4D	Agriculture-Agricultural soils
10 01 03	Rice field	4C	Agriculture-Rice cultivation
10 02	**Cultures without fertilizers**		
	Items 10.02.01 to 10.02.02 and 10.02.04 to 10.02.06	4D	Agriculture-Agricultural soils
10 02 03	Rice field	4C	Agriculture-Rice cultivation
10 03	**On-field burning of stubble, straw,...**		Agriculture-Field burning of agricultural wastes
10 03 01	Cereals	4F1	Agriculture-Field burning of agricultural wastes-Cereals
10 03 02	Pulse	4F2	Agriculture-Field burning of agricultural wastes-Pulse
10 03 03	Tuber and Root	4F3	Agriculture-Field burning of agric. wastes-Tuber and Root
10 03 04	Sugar Cane	4F4	Agriculture-Field burning of agric. wastes-Sugar Cane
10 03 05	Other	4F5	Agriculture-Field burning of agricultural wastes-Other
10 04	**Enteric fermentation**		
10 04 01	Dairy cows	4A1a	Agriculture-Enteric fermentation/Cattle/Dairy
10 04 02	Other cattle	4A1b	Agriculture-Enteric fermentation/Cattle/Non-dairy
10 04 03	Ovines	4A3	Agriculture-Enteric fermentation/Sheep
	Items 10.04.04 and 10.04.12	4A8	Agriculture-Enteric fermentation/Swine
10 04 05	Horses	4A6	Agriculture-Enteric fermentation/Horses
10 04 06	Mules and asses	4A7	Agriculture-Enteric fermentation/Mules and asses
10 04 07	Goats	4A4	Agriculture-Enteric fermentation/Goats
	Items 10.04.08 to 10.04.10	4A9	Agriculture-Enteric fermentation/Poultry
	Items 10.04.11 and 10.04.15	4A10	Agriculture-Enteric fermentation/Other
10 04 13	Camels	4A5	Agriculture-Enteric fermentation/Camels and llamas
10 04 14	Buffalos	4A2	Agriculture-Enteric fermentation/Buffalos

CORINAIR / SNAP classification			IPCC classification
10 05	**Manure management regarding Organic compounds**		
10 05 01	Dairy cows	4B1a	Agriculture-Manure management/Cattle/Dairy
10 05 02	Other cattle	4B1b	Agriculture-Manure management/Cattle/Non-dairy
	Items 10.05.03 and 10.05.04	4B8	Agriculture-Manure management/Swine
10 05 05	Sheep	4B3	Agriculture-Manure management/Sheep
10 05 06	Horses	4B6	Agriculture-Manure management/Horses
	Items 10.05.07 to 10.05.09	4B9	Agriculture-Manure management/Poultry
	Items 10.05.10 and 10.05.15	4B13	Agriculture-Manure management/Other
10 05 11	Goats	4B4	Agriculture-Manure management/Goats
10 05 12	Mules and asses	4B7	Agriculture-Manure management/Mules and asses
10 05 13	Camels	4B5	Agriculture-Enteric fermentation/Camels and llamas
10 05 14	Buffalos	4B2	Agriculture-Enteric fermentation/Buffalos
10 06	**Use of pesticides and Limestone**		
	Items 10.06.01 to 10.06.04 (CO2 from liming only)	5D	CO2 Emissions and removals from soil
10 09	**Manure management regarding Nitrogen compounds**		
10 09 01	Anaerobic	4B10	Agriculture-Manure management-Anaerobic
10 09 02	Liquid Systems	4B11	Agriculture-Manure management-Liquid Systems
10 09 03	Solid Storage an dry lot	4B12	Agriculture-Manure management-Solid Storage
10 09 04	Other	4B13	Agriculture-Manure management-Other
11	**OTHER SOURCES AND SINKS**		
11 01	**Non-managed broadleaf forests**	-	Not allocated
11 02	**Non-managed coniferous forests**	-	Not allocated
11 03	**Forest and other vegetation fires**	-	Not allocated
11 04	**Natural grassland and other vegetation**	-	Not allocated
11 05	**Wetlands (marshes - swamps)**	4D	N2O from Leakage of N into Waters
11 06	**Waters**	4D	N2O from Leakage of N into Waters
11 07	**Animals**	-	Not allocated
11 08	**Volcanoes**	-	Not allocated
11 09	**Gas seeps**	-	Not allocated
11 10	**Lightning**	-	Not allocated

CORINAIR / SNAP classification		IPCC classification	
11 11	**Managed broadleaf forests**		
	Items 11.11.04 to 11.11.11 and 11.11.15 to 11.11.17	5E	Land Use Change and Forestry-Other
11 12	**Managed coniferous forests**		
	Items 11.12.04 and 11.12.12 and 11.12.15 to 11.12.16	5E	Land Use Change and Forestry-Other
11 21	**Changes in forest and other woody biomass stock**		
11 21 01	Tropical forests	5A1	Changes in forest and other woody biomass stocks/Tropical
11 21 02	Temperate forests	5A2	Changes in forest and other woody biomass stocks/Temperate
11 21 03	Boreal forests	5A3	Changes in forest and other woody biomass stocks/Boreal
11 21 04	Grassland/tundra	5A4	Changes in forest and other woody biomass stocks/Grassland
11 21 05	Other	5A5	Changes in forest and other woody biomass stocks/Other
11 22	**Forest and grassland conversion**		
11 22 01	Tropical forests	5B1	Forest and grassland conversion/Tropical
11 22 02	Temperate forests	5B2	Forest and grassland conversion/Temperate
11 22 03	Boreal forests	5B3	Forest and grassland conversion/Boreal
11 22 04	Grassland	5B4	Forest and grassland conversion/Grassland
11 22 05	Other	5B5	Forest and grassland conversion/Other
11 23	**Abandonment of Managed Land**		
11 23 01	Tropical forests	5C1	Abandonment of managed lands/Tropical
11 23 02	Temperate forests	5C2	Abandonment of managed lands/Temperate
11 23 03	Boreal forests	5C3	Abandonment of managed lands/Boreal
11 23 04	Grassland	5C4	Abandonment of managed lands/Grassland
11 23 05	Other	5C5	Abandonment of managed lands/Other
11 24	**CO2 Emissions and removals from soil (except 10.06)**	5D	CO2 Emissions and removals from soil
11 25	**Other**	5E	Other

CORRESPONDENCE BETWEEN 1996 IPCC SOURCE CATEGORIES AND SNAP 97

This document provides the corresponding allocation of 1996 IPCC source categories into SNAP 97 items.

All codes used in this document refer to :
- CORINAIR / SNAP 97 version 1.0 dated 20/03/1998
- IPCC / Greenhouse Gas Inventory / Reporting Instructions / Revised 1996 Guidelines for National Greenhouse Gas Inventories (Volume 1)

IPCC classification	CORINAIR / SNAP classification

1 ENERGY

1 A FUEL COMBUSTION ACTIVITIES

1 A 1	**Energy Industries**		
1 A 1 a	Public Electricity and Heat Production	01 01	Public power (01.01.01 to 01.01.05)
		01 02	District heating plants (01.02.01 to 01.02.05)
1 A 1 b	Petroleum refining	01 03	Petroleum refining plants (01.03.01 to 01.03.06)
1 A 1 c	Manufacture of Solid fuels and Other Energy Industries	01 04	Solid fuel transformation plants (01.04.01 to 01.04.07)
		01 05	Coal mining, oil / gas extraction, pipeline compressors (01.05.01 to 01.05.05)

1 A 2	**Manufacturing Industries and Construction**		
1 A 2 a	Iron and Steel	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
		03 02 03	Blast furnace cowpers
		03 03 01	Sinter and pelletizing plants
		03 03 02	Reheating furnaces steel and iron
		03 03 03	Gray iron foundries
1 A 2 b	Non-ferrous Metals	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
		03 03 04 to 03 03 09	Primary and secondary Pb/Zn/Cu production
		03 03 10	Secondary Aluminium production
		03 03 22 to 03 03 24	Alumina, Magnesium and Nickel production
1 A 2 c	Chemicals	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
1 A 2 d	Pulp, Paper and Print	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
		03 03 21	Paper-mill industry (drying processes)
1 A 2 e	Food Processing, Beverages and Tobacco	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
1 A 2 f	Other	03 01 (b)	Manuf. indus. combust. in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
		03 02 04	Plaster furnaces
		03 02 05	Other furnaces
		03 03 11 to 03 03 20	Cement, Lime, Asphalt concrete, Glass, Mineral wool, Bricks and Tiles, Fine Ceramic materials
		03 03 25	Enamel production
		03 03 26	Other process with contact
		08 08	Other mobile and machinery/Industry

(b) When relevant economic sector split data are available in CORINAIR/NAD module, data can be allocated to sub-categories a to f.

IPCC classification	CORINAIR / SNAP classification	
1 A 3 Transport		
1 A 3 a Civil Aviation		
i International (c)	08 05 02	Internat. airport traffic (LTO cycles - <1000 m)
	08 05 04	International cruise traffic (>1000 m)
ii Domestic	08 05 01	Domestic airport traffic (LTO cycles - <1000 m)
	08 05 03	National cruise traffic (>1000 m)
1 A 3 b Road Transportation	07 01	Passenger cars (07.01.01 to 07.01.03)
	07 02	Light duty vehicles < 3.5 t (07.02.01 to 07.02.03)
	07 03	Heavy duty vehicles > 3.5 t and buses (07.03.01 to 07.03.03)
	07 04	Mopeds and Motorcycles < 50 cm3
	07 05	Motorcycles > 50 cm3 (07.05.01 to 07.05.03)
	07 06	Gasoline evaporation
1 A 3 c Railways	08 02	Railways (08.02.01 to 08.02.03)
1 A 3 d Navigation		
i International Marine (c)	08 04 04	International sea traffic (internat. bunkers)
ii National navigation	08 04 02	National sea traffic within EMEP area
	08 03 01 to 08 03 04	Inland waterways
1 A 3 e Other	08 10	Other mobile sources and machinery
	01 05 06	Pipeline compressors
1 A 4 Other Sectors		
1 A 4 a Commercial / Institutional	02 01	Commercial and institutional plants (02.01.01 to 02.01.06)
1 A 4 b Residential	02 02	Residential plants (02.02.01 to 02.02.05)
	08 09	Household and gardening
1 A 4 c Agriculture / Forestry / Fishing	02 03	Plants in agriculture, forestry and aquaculture (02.03.01 to 02.03.05)
	08 04 03	National fishing
	08 06	Agriculture
	08 07	Forestry
1 A 5 Other		
1 A 5 a Stationary	02 01	Commercial and institutional plants (02.01.01 to 02.01.06) (military only)
1 A 5 b Mobile	08 01	Military

1 B FUGITIVE EMISSIONS FROM FUELS

1 B 1 Solid fuels		
1 B 1 a Coal Mining	05 01	Extraction and 1st treatment of solid fossil fuels (05.01.01 to 05.01.03)
1 B 1 b Solid fuel transformation	04.02.01	Coke oven (door leakage and extinction)
	04 02 04	Solid smokeless fuel
1 B 1 c Other		
1 B 2 Oil and natural gas		
1 B 2 a Oil	04 01	Processes in petrol. indust. (04.01.01 to 04.01.05)
	05 02	Extraction, 1st treatment and loading of liquid fossil fuels (05.02.01 to 05.02.02)
	05 04	Liquid fuel distribution (except gasoline distribution) (05.04.01 to 05.04.02)
	05 05	Gasoline distribution (05.05.01 to 05.05.03)
1 B 2 b Natural gas	05 03	Extraction, 1st treat. and loading of gaseous gaseous fossil fuels (05.03.01 to 05.03.03)
	05 06	Gas distribution networks (05.06.01 to 05.06.02)
1 B 2 c Venting and flaring	09.02.03	Flaring in oil refinery
	09.02.06	Flaring in oil and gas extraction

(c) not to be included in national total, but to be reported separately

IPCC classification	CORINAIR / SNAP classification

2 INDUSTRIAL PROCESSES

2 A MINERAL PRODUCTS

2 A 1	**Cement Production**	04 06 12	Cement (decarbonizing)
2 A 2	**Lime Production**	04 06 14	Lime (decarbonizing)
2 A 3	**Limestone and Dolomite Use**	04 06 18	Limestone and Dolomite Use
2 A 4	**Soda Ash Production and use**	04 06 19	Soda Ash Production and Use
2 A 5	**Asphalt Roofing**	04 06 10	Roof covering with asphalt materials
2 A 6	**Road Paving with Asphalt**	04 06 11	Road paving with asphalt
2 A 7	**Other**	04 06 13	Glass (decarbonizing)
		04 06 15	Batteries manufacturing
		04 06 16	Extraction of mineral ores
		04 06 17	Other (includ. asbestos products manufacturing)

2 B CHEMICAL INDUSTRY

2 B 1	**Ammonia Production**	04 04 03	Ammonia
2 B 2	**Nitric Acid Production**	04 04 02	Nitric acid
2 B 3	**Adipic Acid Production**	04 05 21	Adipic acid
2 B 4	**Carbide Production**	04 04 12	Calcium carbide production
2 B 5	**Other**	04 04 01	Sulfuric acid
		04 04 04 to 04 04 06	Ammonium sulphate / nitrate / phosphate
		04 04 07 and 04 04 08	NPK fertikisers, Urea
		04 04 09 to 04 04 11	Carbon black, Titanium dioxide, Graphite
		04 04 14	Phosphate fertilisers
		04 04 15	Storage and handling of inorganic products
		04 04 16	Other process in inorganic chemical industry
		04 05	Processes in organic chemical industry except adipic acid (04.05.01 to 04.05.20, 04.05.22 to 04.05.26 and 04.05.34)

2 C METAL PRODUCTION

2 C 1	**Iron and Steel Production**	04 02 02	Blast furnace charging
		04 02 03	Pig iron tapping
		04 02 05 to 04 02 10	Furnace steel plant, Rolling mills, Sinter and pelletizing plants (except combustion), Other
2 C 2	**Ferroalloys Production**	04 03 02	Ferro alloys
2 C 3	**Aluminium production**	04 03 01	Aluminium production (electrolysis)-except SF6
2 C 4	**SF6 Used in Aluminium and Magnesium Foundries**	03 03 10	Secondary aluminium production
		04 03 01	Aluminium production (electrolysis)-SF6 only
		04 03 04	Magnesium production - SF6 only
2 C 5	**Other**	04 03 03 to 04 03 05	Silicium, Magnesium, Nickel production
		04 03 06	Allied metal manufacturing
		04 03 07	Galvanizing
		04 03 08	Electroplating
		04 03 09	Other processes in non-ferrous industries

2 D OTHER PRODUCTION

2 D 1	**Pulp and Paper**	04 06 01	Chipboard
		04 06 02 to 04 06 04	Paper pulp
2 D 2	**Food and Drink**	04 06 05 to 04 06 08	Bread, Wine, Beer and spirits

IPCC classification	CORINAIR / SNAP classification	

2 E PRODUCTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE

2 E 1 By-Product Emissions	04 08 01 04 08 04	Halogenated hydrocarbons production - By-products Sulphur hexafluoride production - By-products
2 E 2 Fugitive Emissions	04 08 02 04 08 05	Halogenated hydrocarbons production - Fugitive Sulphur hexafluoride production - Fugitive
2 E 3 Other	04 08 03 04 08 06	Halogenated hydrocarbons production - Other Sulphur hexafluoride production - Other

2 F CONSUMPTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE

2 F 1 Refrigeration and Air Conditioning Equipment	06 05 02	Refrigeration and air conditioning equipment using halocarbons
2 F 2 Foam Blowing	06 05 04	Foam Blowing
2 F 3 Fire Extinguishers	06 05 05	Fire Extinguishers
2 F 4 Aerosols	06 05 06	Aerosol cans
2 F 5 Solvents	06 01 to 06 04	Solvents concerning halocarbons
2 F 6 Other	06 01 to 06 04	Sources concerning SF6
	06 05 07	Electrical equipment
	06 05 08	Other

2 G OTHER

	06 05 03	Refrigeration and air conditioning equipment using other products

3 SOLVENT AND OTHER PRODUCT USE

3 A PAINT APPLICATION

	06 01	Paint application (06.01.01 to 06.01.09)

3 B DEGREASING AND DRY CLEANING

	06 02	Degreasing, dry cleaning and electronics (06.02.01 to 06.02.04)

3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING

	06 03	Chemical products manufacturing or processing (06.03.01 to 06.03.14)

3 D OTHER

	06 04	Other use of solvents and related activities (06.04.01 to 06.04.12)
	06 05 01	Anaesthesia
	06 05 08	Other except for halocarbons and SF6

4 AGRICULTURE

4 A ENTERIC FERMENTATION

4 A 1 Cattle		
4 A 1 a Dairy	10 04 01	Dairy cows
4 A 1 b Non-Dairy	10 04 02	Other cattle
4 A 2 Buffalo	10 04 14	Buffalos
4 A 3 Sheep	10 04 03	Ovines
4 A 4 Goats	10 04 07	Goats
4 A 5 Camels and Llamas	10 04 13	Camels
4 A 6 Horses	10 04 05	Horses
4 A 7 Mules and Asses	10 04 06	Mules and asses
4 A 8 Swine	10 04 04 and 10 04 12	Fattening pigs, Sows
4 A 9 Poultry	10 04 08 to 10 04 10	Laying hens, Broilers, Other poultry
4 A 10 Other	10 04 11 and 10 04 15	Fur animals, Other animals

IPCC classification	CORINAIR / SNAP classification	

4 B MANURE MANAGEMENT

4 B 1 Cattle		
4 B 1 a Dairy	10 05 01	Manure management of organic compounds - Dairy cows
4 B 1 b Non-Dairy	10 05 02	Manure management of organic compounds - Other cattle
4 B 2 Buffalo	10 05 14	Manure management of organic compounds - Buffalos
4 B 3 Sheep	10 05 05	Manure management of organic compounds - Sheep
4 B 4 Goats	10 05 11	Manure management of organic compounds - Goats
4 B 5 Camels and Llamas	10 05 13	Manure management of organic compounds - Camels
4 B 6 Horses	10 05 06	Manure management of organic compounds - Horses
4 B 7 Mules and Asses	10 05 12	Manure management of organic compounds - Mules and asses
4 B 8 Swine	10 05 03 and 10 05 04	Manure management of organic compounds - Fattening pigs, Sows
4 B 9 Poultry	10 05 07 to 10 05 09	Manure management of organic compounds - Laying hens,Broilers,Other
4 B 10 Anaerobic	10 09 01	Manure management of nitrogen compounds - Anaerobic
4 B 11 Liquid Systems	10 09 02	Manure management of nitrogen compounds - Liquid Systems
4 B 12 Solid Storage and Dry Lot	10 09 03	Manure management of nitrogen compounds - Solid Storage and Dry Lot
4 B 13 Other	10 09 04	Manure management of nitrogen compounds - Other Management
	10 05 10 and 10 05 15	Manure management of nitrogen compounds - Fur animals, Other animals

4 C RICE CULTIVATION

4 C 1 Irrigated	10 01 03 and 10 02 03	Rice field with/without fertilisers (e)
4 C 2 Rainfed	10 01 03 and 10 02 03	Rice field with/without fertilisers (e)
4 C 3 Deep Water	10 01 03 and 10 02 03	Rice field with/without fertilisers (e)
4 C 4 Other	10 01 03 and 10 02 03	Rice field with/without fertilisers (e)

(e) Low emissions are expected for European countries and deals mainly with continuously flooded process.

4 D AGRICULTURAL SOILS

	10 01 except 10 01 03	Cultures with fertilizers (10.01.01, 10.01.02 and 10.01.04 to 10.01.06)
	10 02 except 10 02 03	Cultures without fertilizers (10.02.01, 10.02.02 and 10.02.04 to 10.02.06)
	11 05	N2O from leakage of N into Wetlands
	11 06	N2O from leakage of N into Waters

4 E PRESCRIBED BURNING OF SAVANNAS

	No item allocated here (not relevant for Europe)

IPCC classification		CORINAIR / SNAP classification	

4 F FIELD BURNING OF AGRICULTURAL WASTES

4 F 1	**Cereals**	10 03 01	Cereals
4 F 2	**Pulse**	10 03 02	Pulse
4 F 3	**Tuber and Root**	10 03 03	Tuber and Root
4 F 4	**Sugar Cane**	10 03 04	Sugar Cane
4 F 5	**Other**	10 03 05	Other

4 G OTHER

		10 06 01 to 10 06 04	Use of pesticides and limestone (except CO2)

5 LAND USE CHANGE AND FORESTRY

5 A CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS

5 A 1	**Tropical Forests**	11 21 01	Tropical Forests
5 A 2	**Temperate Forests**	11 21 02	Temperate Forests
5 A 3	**Boreal Forests**	11 21 03	Boreal Forests
5 A 4	**Grasslands/Tundra**	11 21 04	Grasslands/Tundra
5 A 5	**Other**	11 21 05	Other

5 B FOREST AND GRASSLAND CONVERSION

5 B 1	**Tropical Forests**	11 22 01	Tropical Forests
5 B 2	**Temperate Forests**	11 22 02	Temperate Forests
5 B 3	**Boreal Forests**	11 22 03	Boreal Forests
5 B 4	**Grasslands/Tundra**	11 22 04	Grasslands/Tundra
5 B 5	**Other**	11 22 05	Other

5 C ABANDONMENT OF MANAGED LANDS

5 C 1	**Tropical Forests**	11 23 01	Tropical Forests
5 C 2	**Temperate Forests**	11 23 02	Temperate Forests
5 C 3	**Boreal Forests**	11 23 03	Boreal Forests
5 C 4	**Grasslands/Tundra**	11 23 04	Grasslands/Tundra
5 C 5	**Other**	11 23 05	Other

5 D CO2 Emissions and Removals from Soil

		10 06 01 to 10 06 04	Use of pesticides and limestone (CO2 only)
		11 24	CO2 Emissions from / or removals into soils (except 10.06)

5 E OTHER

		11 11 04 to 11 11 17	Managed broadleaf forests
		11 12 04 to 11 12 16	Managed coniferous forests
		11 25	Other

6 WASTE

6 A SOLID WASTE DISPOSAL ON LAND

6 A 1	**Managed Waste disposal**	09 04 01	Managed Waste disposal
6 A2	**Unmanaged Waste Disposal**	09 04 02	Unmanaged Waste Disposal
6 A3	**Other**	09 04 03	Other

6 B WASTEWATER HANDLING

6 B 1	**Industrial Wastewater**	09 10 01	Waste water treatment in industry
6 B 2	**Domestic and Commercial Wastewater**	09 10 02	Waste water treatment in residential and commercial sectors
		09 10 07	Latrines
6 B 3	**Other**		

IPCC classification	CORINAIR / SNAP classification

6 C WASTE INCINERATION

	09 02 01 and 09 02 02	Incineration of municipal/industrial wastes
	09 02 04	Flaring in chemical industry
	09 02 05	Incineration of sludges from wastewater
	09 02 07	Incineration of hospital wastes
	09 02 08	Incineration of waste oil
	09 07	Open burning of agricultural wastes (not on field)
	09 09	Cremation (09.09.01 to 09.09.02)

6 D OTHER WASTE

	09 10 03	Sludge spreading
	09 10 05	Compost production from waste
	09 10 06	Biogas production
	09 10 08	Other production of fuel (refuse derived fuel,...)

7 OTHER

	05 07	Geothermal energy extraction

SNAP ITEMS NOT ALLOCATED IN IPCC

07 07	Automobile tyre and brake wear
04 04 13	Chlorine
11 01	Non-managed broadleaf forests (11.01.04 to 11.01.11 and 11.01.15 to 11.01.17)
11 02	Non-managed coniferous forests (11.02.04 to 11.02.12 and 11.02.15 to 11.02.16)
11 03	Forest fires (11.03.01 and 11.03.02)
11 04	Natural grassland (11.04.01 to 11.04.05)
11 05	Wetlands (marshes - swamps) (11.05.01 to 11.05.06) except for N2O from leakage of N into wetlands
11 06	Waters (11.06.01 to 11.06.07) except for N2O from leakage of N into waters
11 07	Animals (11.07.01 to 11.07.03)
11 08	Volcanoes
11 09	Gas seeps
11 10	Lightning

CORINAIR 1990 SUMMARY OF EMISSIONS

This section presents a summary of the emissions reported for each SNAP activity (SNAP90 nomenclature) and the eight main pollutants in the CORINAIR 1990 inventory.

The tables present:

- A main summary for the 28 countries presenting total emissions and percent contributions from the 11 main source groups for each pollutant, then
- On the left hand pages, the total emissions from 28 European countries per activity and pollutant and
- On the right hand pages, the percent contribution of each activity to the overall totals for each pollutant.

The 28 countries included are as follows: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom; Norway, Switzerland; Bulgaria, Czech Republic, Estonia, Hungary, Latvia Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

These summary tables have been prepared in September 1995. More detailed data and additional background information is available in 3 EEA (ETC/AE) Topic reports:

- CORINAIR 90 : Summary Report no 1 (Sectors), *Topic Report 7 (1996);*
- CORINAIR 90 : Summary Report no 2 (Sub-sectors) , *Topic Report 8 (1996);*
- CORINAIR 90 : Summary Report no 3 (Large Point Sources), *Topic Report no. 20 (1996)*

It should be noted that the results presented here are for activities as listed under SNAP90 codes. The guidebook is presented on the basis of SNAP97 codes and some differences occur (see also the section on CORINAIR nomenclatures in this Guidebook).

The emission estimates provided here have in various cases been revised afterwards reflecting improved methodologies or activity statistics (e.g. energy statistics). However for comparisons between countries and between detailed source sectors the 1990 inventories (dated 1995) are still useful and have therefore been incorporated, unchanged from the tables in the first edition of the guidebook. The results presented here have also been incorporated in various chapters of the guidebook.

Emission estimates for more recent years are available in: the section on CORINAIR96 in this Guidebook, the EEA *Topic Report no. 8 (1997)* “Corinair94 inventory” and on the following Internet sites, also including time series of emission estimates:

- EEA Internet site (http://www.eea.eu.int), under EEA Data Warehouse
- European Topic Centre on Air Emissions (ETC/AE) (http://etc-ae.eionet.eu.int/etc-ae/index.htm)
- EMEP (http://www.emep.int/index.html)

CORINAIR90 summary (Feb. 1995)

Europe (28 countries)	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
1 public power, cogeneration and district heating	14947500	3758590	55023	42999	807111	1332194000	96939	1405
2 commercial, institutional and residential combustion	3045695	753956	989439	618669	9946611	849641000	44921	2491
3 industrial combustion	6967997	2438689	154014	92168	8200489	1140657000	53809	1357
4 production processes	922703	391759	1220294	75893	3187774	179916000	355672	172331
5 extraction and distribution of fossil fuels	45111	82174	1376403	10408375	62851	27048000	83	0
6 solvent use	301	900	4920258	20	960	379000	0	107
7 road transport	718230	7846112	6765744	200037	38919349	695497000	29886	13351
8 other mobile sources and machinery	565032	2309640	676573	25287	2223182	138733000	6269	225
9 waste treatment and disposal	86557	241094	506961	8752435	4426583	83173000	13366	127851
10 agriculture	1402	49621	758756	14793437	579196	22450000	726021	5266873
11 nature	573037	50013	4347357	10405808	1358327	294778000	552718	114992
Total in tonnes	**27873565**	**17922548**	**21770822**	**45415128**	**69712433**	**4764466000**	**1879684**	**5700983**
Total (excluding nature), kg per capita	**56**	**37**	**36**	**72**	**140**	**9166**	**3**	**11**

Percentages

Europe (28 countries)	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
1 public power, cogeneration and district heating	54	21	0	0	1	28	5	0
2 commercial, institutional and residential combustion	11	4	5	1	14	18	2	0
3 industrial combustion	25	14	1	0	12	24	3	0
4 production processes	3	2	6	0	5	4	19	3
5 extraction and distribution of fossil fuels	0	0	6	23	0	1	0	0
6 solvent use	0	0	23	0	0	0	0	0
7 road transport	3	44	31	0	56	15	2	0
8 other mobile sources and machinery	2	13	3	0	3	3	0	0
9 waste treatment and disposal	0	1	2	19	6	2	1	2
10 agriculture	0	0	3	33	1	0	39	92
11 nature	2	0	20	23	2	6	29	2

Emissions in kilotonnes, except CO2 in megatonnes

Snap90 Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 1	PUBLIC POWER, COGENERATION AND DISTRICT HEATING								
10100	Public power and cogeneration plants								
10101	Combustion plants > = 300 mw	13691	3316	41	33	650	1160	84	1
10102	Combustion plants > = 50 and < 300 mw	385	161	2	2	25	58	5	
10103	Combustion plants < 50 mw	110	29	1	1	8	19	2	
10104	Gas turbines	8	38			11	10		
10105	Stationary engines	25	28	1		6	1		
10200	District heating plants								
10201	Combustion plants > = 300 mw	129	46	1	1	6	19	2	
10202	Combustion plants > = 50 mw and < 300 mw	326	67	2	2	23	27	3	
10203	Combustion plants < 50 mw	272	69	5	4	80	36	2	
10204	Gas turbines		2			1	1		
10205	Stationary engines		2						
GROUP 2	COMMERCIAL, INSTITUTIONAL & RESIDENTIAL COMBUSTION								
	(now further subdivided)								
20001	Combustion plants > = 50 mw	163	44	15	3	20	19	2	1
20002	Combustion plants < 50 mw	2865	708	973	615	9916	829	43	1
20003	Gas turbines								
20004	Stationary engines	18	2	1	1	11	2		
GROUP 3	INDUSTRIAL COMBUSTION								
30100	Ind. Combus. In boilers, gas turbines & station. Engines	19	23	3	1	6	8	1	
30101	Plants > = 300 mw	1782	431	5	5	214	179	11	
30102	Plants > = 50 mw and < 300 mw	1236	274	9	7	586	180	6	
30103	Plants < 50 mw	2309	571	31	23	654	358	18	
30104	Gas turbines	1	35	1	3	13	14		
30105	Stationary engines	14	31	3		10	5		
30200	Process furnaces without contact	12	4			1	1		
30201	Refinery processes furnaces (now 10306)	380	89	40	4	44	47	4	
30202	Coke oven furnaces (now 10406)	130	53	5	3	155	50		
30203	Blast furnaces cowpers	14	37	1	3	1136	62	1	
30204	Plaster furnaces	6	1			3	1	2	

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 1	PUBLIC POWER, COGENERATION AND DISTRICT HEATING								
10100	Public power and cogeneration plants								
10101	Combustion plants > = 300 mw	**49.1**	**18.5**	0.2	0.1	0.9	**24.3**	4.5	
10102	Combustion plants > = 50 and < 300 mw	1.4	0.9				1.2	0.3	
10103	Combustion plants < 50 mw	0.4	0.2				0.4	0.1	
10104	Gas turbines		0.2				0.2		
10105	Stationary engines	0.1	0.2						
10200	District heating plants								
10201	Combustion plants > = 300 mw	0.5	0.3				0.4	0.1	
10202	Combustion plants > = 50 mw and < 300 mw	1.2	0.4				0.6	0.2	
10203	Combustion plants < 50 mw	1.0	0.4			0.1	0.8	0.1	
10204	Gas turbines								
10205	Stationary engines								
GROUP 2	COMMERCIAL, INSTITUTIONAL & RESIDENTIAL COMBUSTION								
	(now further subdivided)								
20001	Combustion plants > = 50 mw	0.6	0.2	0.1			0.4	0.1	
20002	Combustion plants < 50 mw	**10.2**	4.0	4.4	1.3	**14.0**	**17.6**	2.3	
20003	Gas turbines								
20004	Stationary engines	0.1							
GROUP 3	INDUSTRIAL COMBUSTION								
30100	Ind. Combus. In boilers, gas turbines & station. Engines	0.1	0.1				0.2	0.1	
30101	Plants > = 300 mw	6.4	2.4			0.3	3.8	0.6	
30102	Plants > = 50 mw and < 300 mw	4.4	1.5			0.8	3.8	0.3	
30103	Plants < 50 mw	8.3	3.2	0.1	0.1	0.9	7.5	1.0	
30104	Gas turbines		0.2				0.3		
30105	Stationary engines	0.1	0.2				0.1		
30200	Process furnaces without contact								
30201	Refinery processes furnaces (now 10306)	1.4	0.5	0.2		0.1	1.0	0.2	
30202	Coke oven furnaces (now 10406)	0.5	0.3			0.2	1.0		
30203	Blast furnaces cowpers	0.1	0.2			1.6	1.3	0.1	
30204	Plaster furnaces							0.1	

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
30300	Industrial combustion - processes with contact								
30301	Sinter plant	356	177	19	30	3383	20		
30302	Reheating furnaces steel and iron	76	50	4	2	124	30	1	
30303	Gray iron foundries	13	7	8	1	987	7		
30304	Primary lead production	47	3			2	1		
30305	Primary zink production	24				2			
30306	Primary copper production	33	1			118	1		
30307	Secondary lead production	10							
30308	Secondary zink production					1			
30309	Secondary copper production	3		1		1			
30310	Secondary aluminium production	1	1	3					
30311	Cement	211	413	5	5	110	100	5	
30312	Lime	28	28	1	1	219	15		
30313	Asphalt concrete plants	14	2	1		2	3		
30314	Flat glass	28	59	1		2	6		
30315	Container glass	40	44	1		1	5		
30316	Glass wool	1	2						
30317	Other glass	7	26			1	1		
30318	Mineral wool	8	1			3	1		
30319	Bricks and tiles	81	49	5	3	225	27	1	
30320	Fine ceramics materials	52	14			182	13	1	
30321	Paper mill industry (drying proces.)	18	8	5		17	3	1	
30322	Alumina production	12	2						
GROUP 4	INDUSTRIAL PROCESSES								
40100	Production processes - petrolium industries (introduction)			1		6			
40101	Petrolium products processing	130	26	150	9	10	10	1	
40102	Fluid catalytic cracking - co boiler	115	23	4		28	4		
40103	Sulphur recovery plants	89		1		2			
40104	Storage &handl. Of products in refinery			93				1	
40200	Production proc. - iron & steel industries & colleries	7	4	2		211			
40201	Coke oven	30	9	38	30	333	4		5
40202	Blast furnace charging	8	1	3	16	475	5		
40203	Pig iron tapping	5	2		2	1			
40204	Solid smokeless fuel			1	1				
40205	Open hearth furnace steel plant	9	10	1	1	3			
40206	Basic oxygen furnace	48	7	1		1019	1		
40207	Electric furnace steel plant	2	13	4		435			
40208	Rolling mills	3	3	8		2	1		

% of total emissions

Snap Code	**Description**	**So2**	**NO_X as NO_2**	**Nmvoc**	**Ch4**	**Co**	**Co2**	**N20**	**Nh3**
30300	Industrial combustion - processes with contact								
30301	Sinter plant	1.3	1.0	0.1	0.1	4.9	0.4		
30302	Reheating furnaces steel and iron	0.3	0.3			0.2	0.6	0.1	
30303	Gray iron foundries					1.4	0.1		
30304	Primary lead production	0.2							
30305	Primary zink production	0.1							
30306	Primary copper production	0.1				0.2			
30307	Secondary lead production								
30308	Secondary zink production								
30309	Secondary copper production								
30310	Secondary aluminium production								
30311	Cement	0.8	2.3			0.2	2.1	0.3	
30312	Lime	0.1	0.2			0.3	0.3		
30313	Asphalt concrete plants	0.1					0.1		
30314	Flat glass	0.1	0.3				0.1		
30315	Container glass	0.1	0.2				0.1		
30316	Glass wool								
30317	Other glass		0.1						
30318	Mineral wool								
30319	Bricks and tiles	0.3	0.3			0.3	0.6	0.1	
30320	Fine ceramics materials	0.2	0.1			0.3	0.3	0.1	
30321	Paper mill industry (drying proces.)	0.1					0.1	0.1	
30322	Alumina production								
GROUP 4	INDUSTRIAL PROCESSES								
40100	Production processes - petrolium industries (introduction)								
40101	Petrolium products processing	0.5	0.1	0.7			0.2	0.1	
40102	Fluid catalytic cracking - co boiler	0.4	0.1				0.1		
40103	Sulphur recovery plants	0.3							
40104	Storage &handl. Of products in refinery			0.4				0.1	
40200	Production proc. - iron & steel industries & colleries					0.3			
40201	Coke oven	0.1	0.1	0.2	0.1	0.5	0.1		0.1
40202	Blast furnace charging					0.7	0.1		
40203	Pig iron tapping								
40204	Solid smokeless fuel								
40205	Open hearth furnace steel plant		0.1						
40206	Basic oxygen furnace	0.2				1.5			
40207	Electric furnace steel plant		0.1			0.6			
40208	Rolling mills								

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
40300	Production proc. - non ferrous metal industry	2				10			1
40301	Aluminium production (electrolysis)	34	4	1		276	5		
40302	Ferro alloys	22	6	2	1	246	4		
40303	Silicium production					1			
40304						26			
40400	Production proc. - inorganic chemical industry	9	3			7		1	5
40401	Sulfuric acid	201	7	1		13	1		
40402	Nitric acid		111	17		3		101	7
40403	Ammonia	1	28	19	1	7	16	18	30
40404	Ammonium sulphate	3	1	1		1			8
40405	Ammonium nitrate		5						13
40406	Ammonium phosphate								3
40407	Npk fertilisers	26	48	38					65
40408	Urea					1			29
40409	Carbon black	13			6	4			
40410	Titanium dioxide	11		41					
40411	Graphite	1							
40412	Calcium carbide production	1					2		
40500	Production proc. - organic chemical industry			14		5			
40501	Ethylene	1	6	60	4	8	6	2	
40502	Propylene			41					
40503	1,2 dichoroethane (ecxept 040505)			8					
40504	Vinylchloride (ecxept 040505)			10		1			
40505	1,2 dichloroeth. + vinylchl.(balanced proc)			5					
40506	Polyethylene low density			34					
40507	Polyethelene high density			20					
40508	Polyvinylchloride			12					
40509	Polypropylene			25					
40510	Styrene			1					
40511	Polystyrene			4					
40512	Styrene butadiene			36					
40513	Styrene-butadiene latex			2					
40514	Styrene-butadiene rubber (sbr)			5					
40515	Acrylonit. Butadiene styrene (abs) resins			7					
40516	Ethylene oxyde			5					
40517	Formaldehyde			11		6			
40518	Ethylbenzene			2					
40519	Phtalic anhydride	1		18		21			
40520	Acrylonitrile			3					
40521	Adipic acid		1					233	
40522	Storage & handling of chemical products			78					

% of total emissions

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
40300	Production proc. - non ferrous metal industry								
40301	Aluminium production (electrolysis)	0.1				0.4	0.1		
40302	Ferro alloys	0.1				0.4	0.1		
40303	Silicium production								
40304									
40400	Production proc. - inorganic chemical industry							0.1	0.1
40401	Sulfuric acid	0.7							
40402	Nitric acid		0.6	0.1				5.4	0.1
40403	Ammonia		0.2	0.1			0.3	1.0	0.5
40404	Ammonium sulphate								0.1
40405	Ammonium nitrate								0.2
40406	Ammonium phosphate								0.1
40407	Npk fertilisers	0.1	0.3	0.2					1.1
40408	Urea								0.5
40409	Carbon black								
40410	Titanium dioxide			0.2					
40411	Graphite								
40412	Calcium carbide production								
40500	Production proc. - organic chemical industry			0.1					
40501	Ethylene			0.3			0.1	0.1	
40502	Propylene			0.2					
40503	1,2 dichoroethane (ecxept 040505)								
40504	Vinylchloride (ecxept 040505)								
40505	1,2 dichloroeth. + vinylchl.(balanced proc)								
40506	Polyethylene low density			0.2					
40507	Polyethelene high density			0.1					
40508	Polyvinylchloride			0.1					
40509	Polypropylene			0.1					
40510	Styrene								
40511	Polystyrene								
40512	Styrene butadiene			0.2					
40513	Styrene-butadiene latex								
40514	Styrene-butadiene rubber (sbr)								
40515	Acrylonit. Butadiene styrene (abs) resins								
40516	Ethylene oxyde								
40517	Formaldehyde			0.1					
40518	Ethylbenzene								
40519	Phtalic anhydride			0.1					
40520	Acrylonitrile								
40521	Adipic acid							**12.4**	
40522	Storage & handling of chemical products			0.4					

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
40600	Production proc. - wood,paper pulp,food,drink & other ind.	2	2	4		1			
40601	Chipboard	5	7	27	2	6	1		
40602	Paper pulp (kraft process)	27	11	32		5			
40603	Paper pulp (acid sulfite process)	52	2	17					
40604	Paper pulp (neutral sulphite semi-chimi.)	14							
40605	Bread			157			2		
40606	Wine			10			18		
40607	Beer			55					
40608	Spirits			56					
40609	Bark gasifierb								
40610	Asphalt roofing materials	1		11		5			
40611	Road paving with asphalt			23					
40612	Cement	31	34			5	82		
40613	Glass	18	13				4		
40614	Lime	3	1	1		4	11		
40700	Production proc. - cooling plants								4
GROUP 5	EXTRACTION & DISTRIBUTION OF FOSSIL FUELS								
50100	Extraction and 1st treatment of solid fuels			3					
50101	Open cast mining		1		2396				
50102	Undergroung mining				4546				
50103	Storage				563	33			
50200	Extraction, 1st treatment and loading of liquid fuels				30				
50201	Land-based			2	3				
50202	Off-shore		51	346	100	1	6		
50300	Extract., 1st treatment and loading of gaseous fuels			12	10				
50301	Desulfura.	44	1						
50302	Other land-based	1	13	119	28	1	18		
50303	Off-shore		4	5	33	1	1		
50400	Liquid fuel distribution (except gasoline)			2					
50401	Marine terminals (tankers, handl., Stor.)			137	1				
50402	Other handling and storage			32					
50500	Gasoline distribution			6					
50501	Refinery despatch station			41					
50502	Transp. And depots (exc. Serv. Station)			154					
50503	Service stations			396					

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
40600	Production proc. - wood,paper pulp,food,drink & other ind.								
40601	Chipboard			0.1					
40602	Paper pulp (kraft process)	0.1	0.1	0.1					
40603	Paper pulp (acid sulfite process)	0.2		0.1					
40604	Paper pulp (neutral sulphite semi-chimi.)	0.1							
40605	Bread			0.7					
40606	Wine						0.4		
40607	Beer			0.3					
40608	Spirits			0.3					
40609	Bark gasifierb								
40610	Asphalt roofing materials			0.1					
40611	Road paving with asphalt			0.1					
40612	Cement	0.1	0.2				1.7		
40613	Glass	0.1	0.1				0.1		
40614	Lime						0.2		
40700	Production proc. - cooling plants								0.1
GROUP 5	EXTRACTION & DISTRIBUTION OF FOSSIL FUELS								
50100	Extraction and 1st treatment of solid fuels								
50101	Open cast mining				5.3				
50102	Undergroung mining				**10.0**				
50103	Storage				1.2				
50200	Extraction, 1st treatment and oading of liquid fuels				0.1				
50201	Land-based								
50202	Off-shore		0.3	1.6	0.2		0.1		
50300	Extract., 1st treatment and loading of gaseous fuels			0.1					
50301	Desulfura.	0.2							
50302	Other land-based		0.1	0.5	0.1		0.4		
50303	Off-shore				0.1				
50400	Liquid fuel distribution (except gasoline)								
50401	Marine terminals (tankers, handl., Stor.)			0.6					
50402	Other handling and storage			0.1					
50500	Gasoline distribution								
50501	Refinery despatch station			0.2					
50502	Transp. And depots (exc. Serv. Station)			0.7					
50503	Service stations			1.8					

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
50600	Gas distribution networks			29	361				
50601	Pipelines			2	128				
50602	Pipeline compressor stations (now 81000)		12	7	125	3	2		
50603	Distribution networks			83	2084	23			
GROUP 6	SOLVENT USE								
60000	Solvent use (introduction)								
60100	Solvent use - paint application			510					
60101	Manufacture of automobiles			131		1			
60102	Other indus. Application			719					
60103	Construction and buildings			365					
60104	Domestic use			199					
60200	Solvent use - degreasing and dry cleaning								
60201	Metal degreasing			400					
60202	Dry cleaning			125					
60300	Solvent use - chemicals products manufacturing/proc.			138					
60301	Polyester processing			10					
60302	Polyvinylchloride processing			76					
60303	Polyurethane processing			18					
60304	Polystyrene foam process.			24					
60305	Rubber processing			79					
60306	Pharmaceutical prod. Manu.			116					
60307	Paints manufacturing			75					
60308	Inks manufacturing			4					
60309	Glues manufacturing			80					
60310	Asphalt blowing			29					
60311	Adhesive tapes manufact.			24					
60400	Solvent use - other use of solvents and related activities			457					
60401	Glass wool enduction			86					
60402	Mineral wool enduction			1					
60403	Printing industry			278					
60404	Fat edible and not edible oil extraction			88					
60405	Application of glues and adhesives			186					
60406	Preservation of wood			136					
60407	Underseal treatment of vehicles			31					
60408	Domestic solvent use (other than paint appl.)			492					
60409	Vehicles dewaxing			43					

% of total emissions

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
50600	Gas distribution networks			0.1	0.8				
50601	Pipelines				0.3				
50602	Pipeline compressor stations (now 81000)		0.1		0.3				
50603	Distribution networks			0.4	4.6				
GROUP 6	SOLVENT USE								
60000	Solvent use (introduction)								
60100	Solvent use - paint application			2.3					
60101	Manufacture of automobiles			0.6					
60102	Other indus. Application			3.3					
60103	Construction and buildings			1.7					
60104	Domestic use			0.9					
60200	Solvent use - degreasing and dry cleaning								
60201	Metal degreasing			1.8					
60202	Dry cleaning			0.6					
60300	Solvent use - chemicals products manufacturing/proc.			0.6					
60301	Polyester processing								
60302	Polyvinylchloride processing			0.3					
60303	Polyurethane processing			0.1					
60304	Polystyrene foam process.			0.1					
60305	Rubber processing			0.4					
60306	Pharmaceutical prod. Manu.			0.5					
60307	Paints manufacturing			0.3					
60308	Inks manufacturing								
60309	Glues manufacturing			0.4					
60310	Asphalt blowing			0.1					
60311	Adhesive tapes manufact.			0.1					
60400	Solvent use - other use of solvents and related activities			2.1					
60401	Glass wool enduction			0.4					
60402	Miniral wool enduction								
60403	Printing industry			1.3					
60404	Fat edible and not edible oil extraction			0.4					
60405	Application of glues and adhesives			0.9					
60406	Preservation of wood			0.6					
60407	Underseal treatment of vehicles			0.1					
60408	Domestic solvent use (other than paint appl.)			2.3					
60409	Vehicles dewaxing			0.2					

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 7	ROAD TRANSPORT								
70100	Road transport - passenger cars	2	161	138	12	1182	17		
70101	Highway driving	36	1007	340	22	3536	71	4	3
70102	Rural driving	93	1704	1014	38	8187	135	7	5
70103	Urban driving	115	1198	1965	78	18521	180	6	4
70200	Road transport - light duty vehicles < 3.5 t		14	12	1	71	1		
70201	Highway driving	11	93	35	1	231	9	1	
70202	Rural driving	31	204	108	3	914	22	1	
70203	Urban driving	57	240	228	7	2111	42	1	
70300	Road transport - heavy duty vehicles > 3.5 t	7	166	22	2	53	9	1	
70301	Highway driving	91	1006	169	6	480	62	3	
70302	Rural driving	174	1360	229	7	1085	86	3	
70303	Urban driving	96	678	245	6	1028	49	2	
70400	Road transport - mopeds and motorcycles < 50 cm3	2	3	318	6	492	3		
70500	Road transport - motorcycles > 50 cm3			7		19			
70501	Highway driving		2	55	2	138	1		
70502	Rural driving	2	6	158	6	377	3		
70503	Urban driving	2	6	163	5	494	3		
70600	Road transport - gasoline evaporation from vehicles			1550					
GROUP 8	OTHER MOBILE SOURCES AND MACHINERY								
80100	Other mob. Sources - off road vehicles and machines	7	100	23	2	72	6		
80101	Agriculture (now 80600)	115	733	210	7	1000	46	1	
80102	Forestry (now 80700)	1	13	13	1	33	1		
80103	Industry (now 80800)	27	258	73	2	131	16	2	
80104	Military (now 80100)	3	41	19	1	101	3		
80105	Households / gardening (now 80900)		3	79	1	351	1		
80200	Other mob. Sources -railways	40	199	33	1	83	14		
80300	Other mob. Sources - inland waterways	12	71	29		33	5		

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 7	ROAD TRANSPORT								
70100	Road transport - passenger cars		0.9	0.6		1.7	0.4		
70101	Highway driving	0.1	5.6	1.6		5.1	1.5	0.2	0.1
70102	Rural driving	0.3	9.5	4.7	0.1	**11.7**	2.8	0.4	0.1
70103	Urban driving	0.4	6.7	9.0	0.2	**26.6**	3.8	0.3	0.1
70200	Road transport - light duty vehicles < 3.5 t		0.1	0.1		0.1			
70201	Highway driving		0.5	0.2		0.3	0.2	0.1	
70202	Rural driving	0.1	1.1	0.5		1.3	0.5	0.1	
70203	Urban driving	0.2	1.3	1.0		3.0	0.9	0.1	
70300	Road transport - heavy duty vehicles > 3.5 t		0.9	0.1		0.1	0.2	0.1	
70301	Highway driving	0.3	5.6	0.8		0.7	1.3	0.2	
70302	Rural driving	0.6	7.6	1.1		1.6	1.8	0.2	
70303	Urban driving	0.3	3.8	1.1		1.5	1.0	0.1	
70400	Road transport - mopeds and motorcycles < 50 cm3			1.5		0.7	0.1		
70500	Road transport - motorcycles > 50 cm3								
70501	Highway driving			0.3		0.2			
70502	Rural driving			0.7		0.5	0.1		
70503	Urban driving			0.7		0.7	0.1		
70600	Road transport - gasoline evaporation from vehicles			7.1					
GROUP 8	OTHER MOBILE SOURCES AND MACHINERY								
80100	Other mob. Sources - off road vehicles and machines		0.6	0.1		0.1	0.1		
80101	Agriculture (now 80600)	0.4	4.1	1.0		1.4	1.0	0.1	
80102	Forestry (now 80700)		0.1	0.1					
80103	Industry (now 80800)	0.1	1.4	0.3		0.2	0.3	0.1	
80104	Military (now 80100)		0.2	0.1		0.1	0.1		
80105	Households / gardening (now 80900)			0.4		0.5			
80200	Other mob. Sources -railways	0.1	1.1	0.2		0.1	0.3		
80300	Other mob. Sources - inland waterways		0.4	0.1			0.1		

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	Description	SO_2	NO_X as NO_2	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
80400	Other mob. Sources - marine activities	5	21	14	2	40	1		
80401	Harbours (now deleted)	59	82	10	1	19	5		
80402	National sea traffic	249	468	94	3	166	15	1	
80403	National fishing	25	143	7	1	17	8		
80500	Other mob. Sources - airports (lto cycles and ground act.)	20	179	71	4	174	18	1	
GROUP 9	WASTE TREATMENT AND DISPOSAL ACTIVITIES								
90100	Waste water treatment (now 91001/2)	2	1	32	211			8	10
90200	Waste incineration		1						
90201	Incineration of dom/municipal wastes	29	43	4	9	114	17		
90202	Incineration of industrial wastes	14	4	5	1	14	2		
90203	Flaring in oil industry	35	10	1		3	2		
90204	Flaring in chemical industries	1				14	1		
90205	Incineration of sludges from water treatment	1	1			1			
90206	Flaring in oil and gas production								
(new)									
90300	Sludge spreading (now 91003)			16	155				7
90400	Landfills (now 91004)	5	29	45	7932	267	19		74
90500	Compost prodn from waste (now 91005)				27		27		
90600	Biogas production (now 91006)				40				
90700	Open burning of agricl wastes (except 100300)		153	401	358	4014	15	5	
90800	Latrines (now 91007)				18				37

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
80400	Other mob. Sources - marine activities		0.1	0.1		0.1			
80401	Harbours (now deleted)	0.2	0.5				0.1		
80402	National sea traffic	0.9	2.6	0.4		0.2	0.3	0.1	
80403	National fishing	0.1	0.8				0.2		
80500	Other mob. Sources - airports (lto cycles and ground act.)	0.1	1.0	0.3		0.2	0.4	0.1	
GROUP 9	WASTE TREATMENT AND DISPOSAL ACTIVITIES								
90100	Waste water treatment (now 91001/2)			0.1	0.5			0.4	0.2
90200	Waste incineration								
90201	Incineration of dom/municipal wastes	0.1	0.2			0.2	0.4		
90202	Incineration of industrial wastes	0.1							
90203	Flaring in oil industry	0.1	0.1						
90204	Flaring in chemical industries								
90205	Incineration of sludges from water treatment								
90206	Flaring in oil and gas production								
(new)									
90300	Sludge spreading (now 91003)			0.1	0.3				0.1
90400	Landfills (now 91004)		0.2	0.2	**17.5**	0.4	0.4		1.3
90500	Compost prodn from waste (now 91005)				0.1		0.6		
90600	Biogas production (now 91006)				0.1				
90700	Open burning of agricl wastes (except 100300)		0.9	1.8	0.8	5.8	0.3	0.3	
90800	Latrines (now 91007)								0.6

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 10	AGRICULTURE ACTIVITIES								
100100	Cultures with fertilizers (except animal manure)			46	468			179	226
100101	Permanent crops	1	16	50	38	7	1	42	59
100102	Arable land crops			61	244			322	693
100103	Rice field			3	47			1	7
100104	Market gardening		7	6	24	1	6	8	54
100105	Grassland		4	101	195			84	56
100106	Fallows				1			1	
100200	Cultures without fertilizers								
100201	Permanent crops			24	15			9	
100202	Arable land crops			10	10			17	
100203	Rice field				84			1	
100204	Market gardening			1	1			1	
100205	Grassland			42	16			33	3
100206	Fallows				8			13	
100300	Stubble burning		21	34	35	571	4		
100400	Animal breeding (enteric fermentation)								
100401	Dairy cows				3895				12
100402	Other cattle				4149				11
100403	Ovines				975				6
100404	Pigs				215				
100405	Horses				80				
100406	Asses				5				
100407	Goats				66				1
100500	Animal breeding (excretions)				150				21
100501	Dairy cows			31	850		2	4	1430
100502	Other cattle			12	1092		2	7	1225
100503	Fattening pigs			289	1353		1	3	607
100504	Sows			26	259		4		195
100505	Sheep			3	216		2	1	316
100506	Horses			2	80				56
100507	Laying hens			5	115				140
100508	Boilers			9	70				101
100509	Other poultry			3	33				36
100510	Fur animals				2				10

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 10	AGRICULTURE ACTIVITIES								
100100	Cultures with fertilizers (except animal manure)			0.2	1.0			9.5	4.0
100101	Permanent crops		0.1	0.2	0.1			2.2	1.0
100102	Arable land crops			0.3	0.5			**17.1**	**12.2**
100103	Rice field				0.1			0.1	0.1
100104	Market gardening				0.1		0.1	0.4	0.9
100105	Grassland			0.5	0.4			4.5	1.0
100106	Fallows							0.1	
100200	Cultures without fertilizers								
100201	Permanent crops			0.1				0.5	
100202	Arable land crops							0.9	
100203	Rice field				0.2			0.1	
100204	Market gardening							0.1	
100205	Grassland			0.2				1.8	0.1
100206	Fallows							0.7	
100300	Stubble burning		0.1	0.2	0.1	0.8	0.1		
100400	Animal breeding (enteric fermentation)								
100401	Dairy cows				8.6				0.2
100402	Other cattle				9.1				0.2
100403	Ovines				2.1				0.1
100404	Pigs				0.5				
100405	Horses				0.2				
100406	Asses								
100407	Goats				0.1				
100500	Animal breeding (excretions)				0.3				0.4
100501	Dairy cows			0.1	1.9			0.2	**25.1**
100502	Other cattle			0.1	2.4			0.4	**21.5**
100503	Fattening pigs			1.3	3.0			0.2	**10.6**
100504	Sows			0.1	0.6		0.1		3.4
100505	Sheep				0.5			0.1	5.5
100506	Horses				0.2				1.0
100507	Laying hens				0.3				2.5
100508	Boilers				0.2				1.8
100509	Other poultry				0.1				0.6
100510	Fur animals								0.2

Emissions in kilotonnes, except CO2 in megatonnes

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
GROUP 11	NATURE								
110100	Nature - deciduous forests		15	188	83	23		19	19
110101	High isoprene emitters			910	354			39	
110102	Low isoprene emitters			91	10	1		1	
110103	Non isoprene emitters			578	257			24	
110200	Nature - coniferous forests			2342	1259	2		184	27
110300	Nature - forest fires	3	35	105	83	1332	56	1	
110400	Nature - natural grassland			135	192			54	19
110500	Nature - humid zones				68			1	
110501	Undrained and brackish marshes				2444			16	
110502	Drained marshes				25			3	
110503	Raised bogs				238			1	
110600	Nature - waters				10			7	
110601	Lakes				4716			15	
110602	Shallow saltwaters				363			13	
110603	Ground waters				6				
110604	Drainage waters				1			3	
110605	Rivers				32			1	
110606	Ditches and canals				33			2	
110607	Open sea (> 6m)				3			167	
110700	Nature - animals								
110701	Termittes								
110702	Mammals				99		171		19
110800	Nature - volcanos	570							
110900	Nature - near surface deposits				120				
111000	Nature - humans (now deleted)				8		68		30
	Total	27873	17923	21770	45415	69712	4764	1880	5701

% of total emissions

Snap Code	**Description**	**SO_2**	**NO_X as NO_2**	**NMVOC**	**CH_4**	**CO**	**CO_2**	**N_2O**	**NH_3**
Group 11	Nature								
110100	Nature - deciduous forests		0.1	0.9	0.2			1.0	0.3
110101	High isoprene emitters			4.2	0.8			2.1	
110102	Low isoprene emitters			0.4				0.1	
110103	Non isoprene emitters			2.7	0.6			1.3	
110200	Nature - coniferous forests			**10.8**	2.8			9.8	0.5
110300	Nature - forest fires		0.2	0.5	0.2	1.9	1.2	0.1	
110400	Nature - natural grassland			0.6	0.4			2.9	0.3
110500	Nature - humid zones				0.1			0.1	
110501	Undrained and brackish marshes				5.4			0.9	
110502	Drained marshes				0.1			0.2	
110503	Raised bogs				0.5			0.1	
110600	Nature - waters							0.4	
110601	Lakes				**10.4**			0.8	
110602	Shallow saltwaters				0.8			0.7	
110603	Ground waters								
110604	Drainage waters							0.2	
110605	Rivers				0.1			0.1	
110606	Ditches and canals				0.1			0.1	
110607	Open sea (> 6m)							8.9	
110700	Nature - animals								
110701	Termittes								
110702	Mammals				0.2		3.6		0.3
110800	Nature - volcanos	2.0							
110900	Nature - near surface deposits				0.3				
111000	Nature - humans (now deleted)						1.4		0.5

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

SULPHUR DIOXIDE

The following overviews provide by pollutant the 30 highest emitting activities for Europe from the CORINAIR90 database (Sept. 1995). Activities are classified by SNAP90. The chapter numbers have been updated where possible to be in line with SNAP97.

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Public power and cogeneration - combustion plants > =300 MW	13,691,291	B111
Commercial, institutional and residential - combustion plants < 50MW	2,864,830	B111/2
Industrial combustion - plants < 50 MW	2,309,207	B111/2
Industrial combustion - plants = 300 MW	1,781,768	B111/2
Industrial combustion - plants > = 50 MW and > 300 MW	1,236,293	B111
Nature - volcanoes	569,584	B1108
Public power and cogeneration - combustion - plants >= 50 and < 300 MW	385,432	B111/2
Industrial combustion - refinery processes furnaces	380,253	B136
Industrial combustion - sinter plant	356,859	B331
District heating - combustion plants > = 50 MW and < 300 MW	326,419	B111/2
District heating - combustion plants < 50 MW	272,089	B111/2
Other mobile sources - maritime activities: national sea traffic	249,193	B842
Industrial combustion - cement	210,915	B3311
Production processes - sulphuric acid	201,576	B441
Road transport - heavy duty vehicles and buses: rural driving	173,698	B710
Commercial, institutional and residential - combustion plants > = 50 MW	163,245	B111/2
Industrial combustion - coke oven furnaces	130,181	B146
Production processes - petroleum products processing	130,078	B411
District heating - combustion plants > = 300 MW	128,502	B111
Production processes - fluid catalytic cracking - co boiler	114,967	B411
Road transport - passenger cars: urban driving	114,800	B710
Other mobile sources - off road vehicles and machines: agriculture	114,531	B810
Public power and cogeneration - combustion plants < 50 MW	110,368	B111/2
Road transport - heavy duty vehicles and buses: urban driving	95,908	B710
Road transport - passenger cars: rural driving	92,747	B710
Road transport - heavy duty vehicles and buses: highway driving	90,551	B710
Production processes - sulphur recovery plants	89,039	B413
Industrial combustion - bricks and tiles	81,399	B3319
Industrial combustion - reheating furnaces steel and iron	76,268	B332
Other mobile sources - maritime activities: harbours	59,443	B842

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

NITROGEN OXIDES

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Public power and cogeneration - combustion plants > = 300MW	3,316,424	B111
Road transport - passenger cars: rural driving	1,704,195	B710
Road transport - heavy duty vehicles and buses: rural driving	1,359,636	B710
Road transport - passenger cars: urban driving	1,197,845	B710
Road transport - passenger cars: highway driving	1,006,586	B710
Road transport - heavy duty vehicles and buses: highway driving	1,006364	B710
Other mobile sources - off road vehicles and machines: agriculture	732,756	B810
Commercial, institutional and residential - combustion plants < 50 MW	708,312	B111/2
Road transport - heavy duty vehicles and buses: urban driving	677,639	B710
Industrial combustion - plants < 50 MW	572,610	B111/2
Other mobile sources - maritime activities: national sea traffic	467,936	B842
Industrial - plants > = 300 MW	430,562	B111
Industrial combustion - cement	413,004	B3311
Industrial combustion - plants > 50 MW and < 300MW	273,985	B111/2
Other mobile sources - off road vehicles and machines: industry	258,391	B810
Road transport - light duty vehicles < 3.5 t: urban driving	240,235	B710
Road transport - light duty vehicles < 3.5 t: rural driving	204,077	B710
Other mobile sources - railways	198,581	B810
Other mobile sources - airports (LTO cycles and ground activities)	179,314	B851
Industrial combustion - sinter plant	176,964	B331
Road transport - heavy duty vehicles > 3.5 t and buses	165,587	B710
Public power and cogeneration - combustion plants > = 50 and < 300 MW	160,575	B111/2
Road transport - passenger cars	160,502	B710
Waste treatment and disposal - open burning of agricultural wastes (except 10.3)	153,174	B970
Other mobile sources - maritime activities: national fishing	143,096	B842
Production processes - nitric acid	111,264	B442
Other mobile sources - off road vehicles and machines	99,538	B810
Road transport - light duty vehicles < 3.5 t: highway driving	92,845	B710
Industrial combustion - refinery processes furnaces	89,013	B136
Other mobile sources - maritime activities: harbours	82,145	B842

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

NON-METHANE VOLATILE ORGANIC COMPOUNDS

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Nature - coniferous forests	2,342,106	B1101
Road transport - passenger cars: urban driving	1,965,227	B710
Road transport - gasoline evaporation from vehicles	1,549,946	B760
Road transport - passenger cars: rural driving	1,014,220	B710
Commercial, institutional and residential - combustion plants < 50 MW	973,489	B111/2
Nature - deciduous forests: high isoprene emitters	909,742	B1101
Solvent use - paint application: other industrial application	719,192	B610
Nature - deciduous forests: non isoprene emitters	577,876	B1101
Solvent use - paint application	509,636	B610
Solvent use - domestic solvent use (other than paint application)	492,206	B610
Solvent use - other use of solvents and related activities	456,658	B641
Waste treatment and disposal - open burning of agricultural wastes (except 100300)	401,380	B970
Solvent use - metal degreasing	399,998	B621
Gasoline distribution - service stations (incl. refuelling)	396,021	B551
Solvent use - paint application: construction and buildings	364,887	B610
Road transport - passenger cars: highway driving	350,078	B710
Extraction, 1st treatment and loading of liquid fossil fuels - off-shore	345,707	B521
Road transport - mopeds and motorcycles < 50 CM3	317,543	B710
Agriculture - animal breeding (excretions): fattening pigs	289,279	B1050
Solvent use - printing industry	278,098	B643
Road transport - heavy duty vehicles and buses: urban driving	245,212	B710
Road transport - heavy duty vehicles and buses: rural driving	229,168	B710
Road transport - light duty vehicles < 3.5 t: urban driving	227,684	B710
Other mobile sources - off road vehicles and machines: agriculture	210,494	B810
Solvent use - paint application: domestic use	199,250	B610
Nature - deciduous forests	187,552	B1101
Solvent use - application of glues and adhesives	186,469	B641
Road transport - heavy duty vehicles and buses: highway driving	169,288	B710
Road transport - motorcycles < 50 CM3: urban driving	163,621	B710
Road transport - motorcycles < 50 CM3: road driving	157,745	B710

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

AMMONIA

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Agriculture - animal breeding (excretions): dairy cows	1,430,200	B1050
Agriculture - animal breeding (excretions): other cattle	1,225,113	B1050
Agriculture - cultures with fertilizers: arable land crops	693,248	B1050
Agriculture - animal breeding (excretions): fattening pigs	607,266	B1050
Agriculture - animal breeding (excretions): sheep	315,755	B1050
Agriculture - cultures with fertilizers: except animal manure	226,848	B1050
Agriculture - animal breeding (excretions): sows	194,725	B1050
Agriculture - animal breeding (excretions): laying hens	140,003	B1050
Agriculture - animal breeding (excretions): broilers	100,502	B1050
Waste treatment and disposal - land filling	73,675	B940
Production processes - NPKrtilisers	64,827	B443
Agriculture - cultures with fertilizers: permanent crops	59,319	B1010
Agriculture - animal breeding (excretions): horses	56,439	B1050
Agriculture - cultures with fertilizers: grassland	55,515	B1010
Agriculture - cultures with fertilizers: market gardening	53,987	B1010
Waste treatment and disposal - latrines	37,496	B9107
Agriculture - animal breeding (excretions): other poultry	35,989	B1050
Nature - humans	29,991	
Production processes - ammonia	29,655	B443
Production processes - urea	29,082	B443
Nature - coniferous forests	27,315	B1101
Agriculture - animal breeding (excretions)	21,200	B1050
Nature - deciduous forests	19,316	B1101
Nature - animals: mammals	19,242	B1107
Nature - natural grassland	19,026	B1104
Production processes - ammonium nitrate	13,265	B443
Agriculture - animal breeding (excretions): dairy cows	11,615	B1040
Agriculture - animal breeding (enteric fermentation): other cattle	10,872	B1040
Agriculture - animal breeding (excretions): fur animals	10,118	B100408
Waste treatment and disposal - waste water treatment	9,565	B9101

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

NITROUS OXIDE

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Agriculture - cultures with fertilizers: arable crops	321,601	B1010
Production processes - adipic acid	232,608	B4521
Nature - coniferous forests	184,477	B1101
Agriculture - cultures with fertilizers except animal manure	178,600	B1010
Nature - open sea (>6m)	166,995	
Production processes - nitric acid	100,890	B442
Public power and cogeneration - combustion plants > = 300 MW	83,986	B111
Agriculture - cultures with fertilizers: grassland	83,716	B1010
Nature - natural grassland	53,902	B1104
Commercial, institutional and residential - combustion plants < 50 MW	43,093	B111/2
Agriculture -cultures with fertilizers: permanent crops	41,893	B1010
Nature - deciduous forests: high isoprene emitters	39,400	B1101
Agriculture - cultures without fertilizers: grassland	33,385	B1020
Nature - deciduous forests: non isoprene emitters	24,355	B1101
Nature - deciduous forests	18,508	B1101
Industrial combustion - plants < 50 MW	17,963	B111/2
Production processes - ammonia	17,784	B443
Agriculture - cultures without fertilizers: arable land crops	17,119	B1020
Nature - humid zones: undrained and brackish marshes	16,259	B1105
Nature - lakes	14,534	
Nature - shallow saltwaters	13,153	
Agriculture - cultures without fertilizers: fallows	12,997	B1020
Industrial combustion - plants > = 300 MW	11,153	B111
Agriculture - cultures without fertilizers: permanent crops	9,234	B1020
Agriculture - cultures with fertilizers: market gardening	8,405	B1010
Waste treatment and disposal - waste water treatment	7,989	B9101
Nature - waters	7,432	B1106
Road transport - passenger cars: rural driving	6,800	B710
Agriculture - animal breeding (excretions): other cattle	6,790	B1050
Road transport - passenger cars: urban driving	6,419	B710

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

CARBON DIOXIDE

ACTIVITY	EMISSIONS, KILOTONNES	CHAPTER
Public power and cogeneration - combustion plants > = 300MW	1,160,276	B111
Commercial, institutional and residential - combustion plants < 50 MW	829,163	B111/2
Industrial combustion - plants < 50 MW	358,119	B111/2
Road transport - passenger cars: urban driving	180,267	B710
Industrial combustion - plants > = 50 MW and < 300 MW	179,725	B111/2
Industrial combustion - plants > = 300 MW	178,940	B111
Nature - animals: mammals	170,594	B1107
Road transport - passenger cars: rural driving	135,402	B710
Industrial combustion - cement	100,336	B3311
Road transport - heavy duty vehicles and buses: rural driving	86,923	B710
Production processes - cement	82,297	B3311
Road transport - passenger cars: highway driving	71,408	B710
Nature - humans	67,709	
Road transport - heavy duty vehicles and buses: highway driving	62,145	B710
Industrial combustion - blast furnaces cowpers	61,991	B323
Public power and cogeneration - combustion plants > = 50 and < 300 MW	57,906	B111/2
Nature - forest fires	56,468	B1103
Industrial combustion - coke oven furnaces	49,661	B146
Road transport - heavy duty vehicles and buses: urban driving	49,011	B710
Industrial combustion - refinery processes furnaces	46,967	B136
Other mobile sources - off road vehicles and machines: agriculture	46,620	B810
Road transport - light duty vehicles < 3.5 t: urban driving	42,145	B710
District heating - combustion plants < 50 MW	36,365	B111/2
Industrial combustion - reheating furnaces steel and iron	30,368	B332
District heating - combustion plants > = 50 MW and < 300 MW	27,424	B111/2
Industrial combustion - bricks and tiles	26,920	B3319
Waste treatment and disposal - compost production from waste	26,790	B9105
Road transport light duty vehicles < 3.5 t: rural driving	22,433	B710
Industrial combustion - sinter plant	20,220	B331
Public power and cogeneration - combustion plants < 50 MW	19,310	B111/2

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

CARBON MONOXIDE

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Road transport - passenger cars: urban driving	18,520,778	B710
Commercial, institutional and residential - combustion plants < 50 MW	9,916,245	B111/2
Road transport - passenger cars: rural driving	8,187,460	B710
W.T.D. - open burning of agricultural wastes (except 100300)	4,013,882	B970
Road transport -passenger cars: highway driving	3,535,644	B710
Industrial combustion - sinter plant	3,382,958	B331
Road transport - light duty vehicles < 3.5 t: urban driving	2,110,908	B710
Nature - forest fires	1,332,324	B1103
Road transport - passenger cars	1,181,522	B710
Industrial combustion - blast furnaces cowpers	1,135,531	B323
Road transport - heavy duty vehicles and buses: rural driving	1,085,091	B710
Road transport - heavy duty vehicles and buses: urban driving	1,027,815	B710
Production processes - basic oxygen furnace steel plant	1,019,295	B426
Other mobile sources - off road vehicles and machines: agriculture	1,000,351	B810
Industrial combustion grey iron foundries	987,210	B333
Road transport - light duty vehicles < 3.5 t: rural driving	914,069	B710
Industrial combustion - plants < 50 MW	654,004	B111/2
Public power and cogeneration - combustion plants > = 300 MW	649,705	B111
Industrial combustion - plants > = 50 MW and < 300 MW	586,384	B111/2
Agriculture - stubble burning	571,397	B1030
Road transport - motorcycles > 50 CM3: urban driving	493,857	B710
Road transport - mopeds and motorcycles < 50 CM3	492,280	B710
Road transport - heavy duty vehicles and buses: highway driving	480,072	B710
Production processes - blast furnace charging	474,744	B422
Production processes - electric furnace steel plant	434,884	B427
Road transport - motorcycles > 50 CM3: road driving	377,154	B710
Other mobile sources - household / gardening	351,126	B810
Production processes - coke oven	332,718	B146
Production processes - aluminium production (electrolysis)	275,668	B431
Waste treatment and disposal - land filling	267,235	B940

CORINAIR 90 - TOP 30 ACTIVITIES (28 COUNTRIES)

METHANE

ACTIVITY	EMISSIONS, TONNES	CHAPTER
Waste treatment and disposal - land filling	7,932,129	B940
Nature - lakes	4,715,539	
Extraction and 1st treatment of solid fossil fuels -underground mining	4,545,789	B511
Agriculture - animal breeding (enteric fermentation): other cattle	4,148,720	B1040
Agriculture - animal breeding (enteric fermentation): dairy cows	3,895,439	B1040
Nature - humid zones: undrained and brackish marshes	2,444,432	B1105
Extraction and 1st treatment of solid fossil fuels - open cast mining	2,396,352	B511
Gas distribution networks - distribution networks	2,083,998	B561
Agriculture - animal breeding (excretions): fattening pigs	1,353,113	B1050
Nature - coniferous forests	1,259,173	B1101
Agriculture - animal breeding (excretions): other cattle	1,092,047	B1050
Agriculture - animal breeding (enteric fermentation): ovines	975,100	B1040
Agriculture - animal breeding (excretions): dairy cows	850,195	B1050
Commercial, institutional and residential - combustion plants < 50 MW	614,872	B111/2
Extraction and 1st treatment of solid fossil fuels - storage	563,349	B511
Agriculture - cultures with fertilizers except animal manure	468,000	B1010
Nature - shallow saltwaters	362,631	
Gas distribution networks	360,693	B561
W.T.D - open burning of agricultural wastes (except 100300)	358,234	B970
Nature - deciduous forests: high isoprene emitters	353,525	B1101
Agriculture - animal breeding (excretions): sows	259,424	B1050
Nature - deciduous forests: non isoprene emitters	256,742	B1101
Agriculture - cultures with fertilizers: arable land crops	244,320	B1010
Nature - humid zones: raised bogs	237,733	B1105
Agriculture - animal breeding (excretions): sheep	215,746	B1050
Agriculture - animal breeding (enteric fermentation): pigs	214,996	B1040
Waste treatment and disposal - waste water treatment	211,916	B9101
Agriculture - cultures with fertilizers: grassland	195,492	B1010
Nature - natural grassland	192,093	B1104
Waste treatment and disposal - sludge spreading	155,484	B9103

CORINAIR 1996 - SUMMARY BY ACTIVITY FOR FOUR COUNTRIES

This section presents a summary of emissions for the year 1996 for four countries - Austria, Denmark, France and the Netherlands - at SNAP97 level 2.

The tables provide:
- emissions of the SNAP97 level 2 activity as percentage (%) of the national total, as an average of the four countries;
- emissions of the SNAP97 level 2 activity for each of the four countries.

SNAP level 2 in percentage (%) of National Totals 1996

Austria, Denmark, France, Netherlands

sector	name	SO_2	NO_X	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
1	**Combustion in energy and transformation industries**	**43.2**	**12.4**	**0.2**	**0.1**	**0.4**	**24.0**	**1.0**	**0.0**
101	Public power	26.0	9.6	0.1	0.0	0.2	18.6	0.7	0.0
102	District heating plants	3.4	0.8	0.0	0.0	0.1	2.0	0.1	0.0
103	Petroleum refining plants	12.2	1.2	0.0	0.0	0.0	3.8	0.2	0.0
104	Solid fuel transformation plants	1.2	0.3	0.0	0.0	0.0	0.7	0.0	0.0
105	Coal mining, oil/gas extraction, pipeline compressors	0.4	0.5	0.0	0.0	0.0	0.4	0.0	0.0
2	**Non-industrial combustion plants**	**9.0**	**6.8**	**8.2**	**3.6**	**23.3**	**24.8**	**1.3**	**0.1**
201	Commercial and institutional plants	3.0	2.2	0.2	0.1	1.5	7.2	0.4	0.0
202	Residential plants	5.3	4.1	7.8	3.4	21.6	15.6	1.0	0.1
203	Plants in agriculture, forestry and aquaculture	0.7	0.6	0.2	0.1	0.3	2.0	0.0	0.0
3	**Combustion in manufacturing industry**	**24.4**	**9.0**	**0.6**	**0.3**	**5.9**	**19.1**	**1.2**	**0.0**
301	Comb. manu. ind.- comb. in boiler/gas turb./station. engine	17.2	5.7	0.4	0.2	1.1	14.7	0.6	0.0
302	Comb. manu. ind.- process furnaces without contact	0.1	0.2	0.0	0.0	0.0	1.0	0.0	0.0
303	Comb. manu. ind.- processes with contact	7.0	3.2	0.2	0.1	4.8	3.4	0.5	0.0
4	**Production processes**	**8.7**	**2.0**	**5.6**	**0.2**	**9.4**	**7.6**	**27.9**	**2.8**
401	Processes in petroleum industries	5.0	0.4	1.0	0.0	0.0	1.0	0.0	0.0
402	Processes in iron and steel industries and collieries	1.0	0.5	0.2	0.0	8.0	2.0	0.0	0.0
403	Processes in non-ferrous metal industries	0.6	0.0	0.0	0.0	0.8	0.2	0.0	0.0
404	Processes in inorganic chemical industries	1.6	0.7	0.8	0.1	0.3	1.2	10.5	2.7
405	Processes in organic chemical industries (bulk production)	0.1	0.0	1.1	0.1	0.1	0.1	17.4	0.1
406	Processes in wood, paper pulp, food, drink and other industries	0.5	0.3	2.4	0.0	0.2	3.1	0.0	0.1
408	Production of halocarbons and sulphur hexafluoride	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5 Extraction and distribution of fossil fuels / geothermal energy	**1.2**	**0.0**	**4.1**	**8.7**	**0.4**	**0.1**	**0.0**	**0.0**
501 Extraction and 1st treatment of solid fossil fuels	0.0	0.0	0.0	3.0	0.4	0.0	0.0	0.0
502 Extraction, 1st treat. and loading of liquid fossil fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
503 Extraction, 1st treat. and loading of gaseous fossil fuels	1.2	0.0	0.3	2.0	0.0	0.1	0.0	0.0
504 Liquid fuel distribution (except gasoline distrib. in 0505)	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
505 Gasoline distribution	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
506 Gas distribution networks	0.0	0.0	0.4	3.6	0.0	0.0	0.0	0.0
507 Geothermal energy extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 Solvent and other product use	**0.0**	**0.0**	**25.0**	**0.0**	**0.0**	**0.3**	**0.8**	**0.1**
601 Paint application	0.0	0.0	9.3	0.0	0.0	0.1	0.0	0.0
602 Degreasing, dry cleaning and electronics	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
603 Chemicals products manufacturing or processing	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0
604 Other use of solvents and related activities	0.0	0.0	11.0	0.0	0.0	0.2	0.0	0.1
605 Use of HFC, N2O, NH3, PFC and SF6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
7 Road transport	**9.0**	**47.9**	**33.5**	**0.5**	**52.3**	**26.3**	**4.1**	**0.9**
701 Passenger cars	4.3	26.4	15.5	0.4	41.4	15.4	2.9	0.9
702 Light duty vehicles < 3.5 t	1.9	4.8	2.1	0.0	5.4	4.4	0.4	0.0
703 Heavy duty vehicles > 3.5 t and buses	2.7	16.6	1.9	0.1	1.1	6.1	0.7	0.0
704 Mopeds and motorcycles < 50 cm3	0.0	0.0	2.9	0.0	1.5	0.1	0.0	0.0
705 Motorcycles > 50 cm3	0.1	0.1	1.7	0.0	2.8	0.2	0.0	0.0
706 Gasoline evaporation from vehicles	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0
707 Automobile tyre and brake wear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 Other mobile sources and machinery	**3.1**	**19.8**	**5.0**	**0.0**	**4.9**	**4.0**	**0.4**	**0.0**
801 Other mobile & mach.- military	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
802 Other mobile & mach.- railways	0.1	0.6	0.1	0.0	0.0	0.2	0.0	0.0
803 Other mobile & mach.- inland waterways	0.2	1.4	0.2	0.0	0.1	0.3	0.1	0.0
804 Other mobile & mach.- maritime activities	1.7	3.2	0.6	0.0	0.1	0.7	0.1	0.0
805 Other mobile & mach.- air traffic	0.1	0.4	0.8	0.0	0.5	1.0	0.0	0.0
806 Other mobile & mach.- agriculture	0.7	9.3	2.3	0.0	2.8	1.3	0.1	0.0
807 Other mobile & mach.- forestry	0.0	0.4	0.1	0.0	0.1	0.1	0.0	0.0
808 Other mobile & mach.- industry	0.2	3.9	0.4	0.0	0.6	0.4	0.0	0.0
809 Other mobile & mach.- household and gardening	0.0	0.0	0.3	0.0	0.4	0.0	0.0	0.0
810 Other mobile & mach.- other off-road	0.1	0.5	0.1	0.0	0.1	0.1	0.0	0.0
9 Waste treatment and disposal	**1.3**	**1.0**	**1.0**	**24.7**	**2.3**	**1.4**	**1.0**	**0.3**
902 Waste incineration	1.3	0.9	0.2	0.2	0.2	1.0	0.3	0.0
904 Solid waste disposal on land	0.0	0.0	0.2	23.2	0.0	0.0	0.0	0.0
907 Open burning of agricultural wastes (except on field 1003)	0.0	0.1	0.2	0.1	2.1	0.0	0.0	0.0
909 Cremation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
910 Other waste treatment	0.0	0.0	0.4	1.2	0.0	0.3	0.6	0.3
10 Agriculture	**0.0**	**0.8**	**0.7**	**47.3**	**0.2**	**0.0**	**51.9**	**95.1**
1001 Cultures with fertilizers (except animal manure)	0.0	0.8	0.7	1.9	0.2	0.0	47.9	15.6

1002 Cultures without fertilizers	0.0	0.0	0.0	0.2	0.0	0.0	1.3	0.0
1003 On-field burning of stubble, straw, ...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1004 Enteric fermentation	0.0	0.0	0.0	36.7	0.0	0.0	0.0	0.0
1005 Manure management regarding organic compounds	0.0	0.0	0.0	8.5	0.0	0.0	0.2	79.5
1006 Use of pesticides and limestone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1009 Manure management regarding nitrogen compounds	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0
11 Other sources and sinks	**0.0**	**0.2**	**16.1**	**14.6**	**1.0**	**-7.6**	**10.4**	**0.6**
1101 Non-managed broadleaf forests	0.0	0.0	0.5	0.2	0.0	0.0	0.2	0.0
1102 Non-managed coniferous forests	0.0	0.0	1.2	0.8	0.0	0.0	0.3	0.0
1103 Forest and other vegetation fires	0.0	0.1	0.1	0.1	0.5	0.0	0.0	0.0
1104 Natural grassland and other vegetation	0.0	0.0	0.4	0.4	0.1	0.0	2.2	0.0
1105 Wetlands (marshes-swamps)	0.0	0.0	0.0	4.7	0.0	0.0	0.1	0.0
1106 Waters	0.0	0.0	0.0	2.1	0.0	0.0	2.3	0.0
1107 Animals	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.6
1108 Volcanoes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1109 Gas seeps	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0
1110 Lightning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1111 Managed broadleaf forests	0.0	0.0	8.8	1.3	0.0	0.0	3.0	0.0
1112 Managed coniferous forests	0.0	0.0	5.1	2.7	0.0	0.0	2.2	0.0
1121 Changes in forest and other woody biomass stocks	0.0	0.0	0.0	0.0	0.0	-8.5	0.0	0.0
1122 Forest and grassland conversion	0.0	0.0	0.0	0.1	0.4	0.9	0.0	0.0
1123 Abandonment of managed lands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1124 CO2 emissions from/or removals into soils (except 1006)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1125 Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Comparable National Total (excluding all emissions from sector 11 and for NMVOC and CO2 also emissions from sector 10)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

AUSTRIA

CORINAIR EMISSIONS 1996

EMISSION ESTIMATES (Kilotonnes; for CO2: Megatonnes)

sector	name	SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
0	**National Total**	**51,903**	**162,862**	**425,159**	**630,551**	**1,021,197**	**50,273**	**10,791**	**76,975**
1	**Combustion in energy and transformation industries**	**8,358**	**9,809**	**196**	**104**	**1,154**	**12,179**	**125**	**181**
101	Public power	4,454	5,872	92	47	540	9,155	67	100
102	District heating plants	3,904	3,922	104	57	612	3,003	57	80
103	Petroleum refining plants	0	0	0	0	0	0	0	0
104	Solid fuel transformation plants	0	0	0	0	0	0	0	0
105	Coal mining, oil/gas extraction, pipeline compressors	0	15	0	1	2	21	0	0
2	**Non-industrial combustion plants**	**16,193**	**20,220**	**41,430**	**14,034**	**433,444**	**14,148**	**604**	**911**
201	Commercial and institutional plants	4,123	8,472	3,867	1,287	137,269	3,682	208	362
202	Residential plants	12,066	11,747	37,557	12,744	296,090	10,466	396	549
203	Plants in agriculture, forestry and aquaculture	4	1	7	2	85	0	0	0
3	**Combustion in manufacturing industry**	**9,417**	**15,020**	**525**	**298**	**5,503**	**7,755**	**171**	**303**
301	Comb. manu. ind.- comb. in boiler/gas turb./station. engine	6,249	9,093	334	165	3,332	3,377	139	211
302	Comb. manu. ind.- process furnaces without contact	1,350	1,844	85	58	428	1,634	8	34
303	Comb. manu. ind.- processes with contact	1,817	4,083	106	74	1,742	2,744	24	57
4	**Production processes**	**13,471**	**19,362**	**22,506**	**114**	**264,000**	**13,528**	**547**	**205**
401	Processes in petroleum industries	3,488	3,479	1,500	0	435	2,590	0	0
402	Processes in iron and steel industries and collieries	4,485	4,367	317	9	232,290	7,393	0	0
403	Processes in non-ferrous metal industries	406	17	219	0	342	339	0	0
404	Processes in inorganic chemical industries	3,188	4,400	0	64	11,064	430	547	205
405	Processes in organic chemical industries (bulk production)	0	0	12,337	0	0	0	0	0
406	Processes in wood, paper pulp, food, drink and other industries	1,905	7,099	8,132	41	19,868	2,777	0	0
408	Production of halocarbons and sulphur hexafluoride	0	0	0	0	0	0	0	0
5	**Extraction and distribution of fossil fuels / geothermal energy**	**1,200**	**0**	**4,041**	**5,570**	**0**	**95**	**0**	**0**
501	Extraction and 1st treatment of solid fossil fuels	0	0	0	8	0	0	0	0
502	Extraction, 1st treat. and loading of liquid fossil fuels	0	0	0	0	0	0	0	0
503	Extraction, 1st treat. and loading of gaseous fossil fuels	1,200	0	0	0	0	71	0	0
504	Liquid fuel distribution (except gasoline distrib. in 0505)	0	0	0	0	0	0	0	0
505	Gasoline distribution	0	0	3,884	0	0	0	0	0
506	Gas distribution networks	0	0	157	5,562	0	24	0	0
507	Geothermal energy extraction	0	0	0	0	0	0	0	0

6	**Solvent and other product use**	**0**	**0**	**133,737**	**0**	**0**	**417**	**750**	**2**
601	Paint application	0	0	15,162	0	0	47	0	0
602	Degreasing, dry cleaning and electronics	0	0	0	0	0	0	0	0
603	Chemicals products manufacturing or processing	0	0	17,513	0	0	55	0	0
604	Other use of solvents and related activities	0	0	101,062	0	0	315	0	0
605	Use of HFC, N2O, NH3, PFC and SF6	0	0	0	0	0	0	750	2
7	**Road transport**	**2,765**	**84,066**	**52,270**	**2,152**	**303,849**	**15,059**	**1,792**	**2,412**
701	Passenger cars	1,078	31,909	24,236	1,640	262,257	9,123	1,547	2,318
702	Light duty vehicles < 3.5 t	382	6,132	1,592	54	14,089	1,451	74	29
703	Heavy duty vehicles > 3.5 t and buses	1,299	45,784	6,397	159	12,494	4,385	170	46
704	Mopeds and motorcycles < 50 cm3	2	13	2,408	228	4,711	30	0	17
705	Motorcycles > 50 cm3	4	228	1,356	71	10,298	69	1	3
706	Gasoline evaporation from vehicles	0	0	16,280	0	0	0	0	0
707	Automobile tyre and brake wear	0	0	0	0	0	0	0	0
8	**Other mobile sources and machinery**	**444**	**7,059**	**2,893**	**142**	**7,325**	**727**	**34**	**36**
801	Other mobile & mach.- military	11	427	107	4	560	41	2	1
802	Other mobile & mach.- railways	82	1,503	310	29	1,043	149	6	2
803	Other mobile & mach.- inland waterways	13	453	736	52	1,297	49	2	2
804	Other mobile & mach.- maritime activities	0	0	0	0	0	0	0	0
805	Other mobile & mach.- air traffic	224	677	507	1	1,995	100	10	25
806	Other mobile & mach.- agriculture	91	3,182	571	14	1,113	304	12	4
807	Other mobile & mach.- forestry	23	814	164	5	444	78	3	1
808	Other mobile & mach.- industry	0	0	0	0	0	0	0	0
809	Other mobile & mach.- household and gardening	0	2	497	37	873	5	0	1
810	Other mobile & mach.- other off-road	0	0	0	0	0	0	0	0
9	**Waste treatment and disposal**	**52**	**157**	**668**	**218,182**	**4,422**	**119**	**13**	**54**
902	Waste incineration	45	138	205	64	77	116	8	2
904	Solid waste disposal on land	0	0	0	183,648	0	0	0	0
907	Open burning of agricultural wastes (except on field 1003)	7	15	463	157	4,340	0	4	52
909	Cremation	0	4	0	0	5	2	0	0
910	Other waste treatment	0	0	0	34,313	0	0	0	0

10	**Agriculture**	**2**	**6,083**	**2,343**	**205,975**	**1,500**	**0**	**3,267**	**72,337**
1001	Cultures with fertilizers (except animal manure)	0	5,782	1,971	26,060	0	0	3,052	4,500
1002	Cultures without fertilizers	0	296	211	8,866	0	0	211	253
1003	On-field burning of stubble, straw, ...	2	5	161	53	1,500	0	4	18
1004	Enteric fermentation	0	0	0	144,186	0	0	0	0
1005	Manure management regarding organic compounds	0	0	0	26,809	0	0	0	67,566
1006	Use of pesticides and limestone	0	0	0	0	0	0	0	0
1009	Manure management regarding nitrogen compounds	0	0	0	0	0	0	0	0
11	**Other sources and sinks**	**0**	**1,086**	**164,551**	**183,980**	**0**	**-13,753**	**3,489**	**535**
1101	Non-managed broadleaf forests	0	50	4,180	3,590	0	0	162	0
1102	Non-managed coniferous forests	0	217	36,835	38,676	0	0	696	0
1103	Forest and other vegetation fires	0	0	0	0	0	0	0	0
1104	Natural grassland and other vegetation	0	0	0	0	0	0	0	0
1105	Wetlands (marshes-swamps)	0	0	0	178	0	0	0	0
1106	Waters	0	0	0	3,996	0	0	0	0
1107	Animals	0	0	0	10,700	0	0	0	535
1108	Volcanoes	0	0	0	0	0	0	0	0
1109	Gas seeps	0	0	0	0	0	0	0	0
1110	Lightning	0	0	0	0	0	0	0	0
1111	Managed broadleaf forests	0	181	15,021	12,902	0	0	581	0
1112	Managed coniferous forests	0	638	108,516	113,939	0	0	2,051	0
1121	Changes in forest and other woody biomass stocks	0	0	0	0	0	-13,753	0	0
1122	Forest and grassland conversion	0	0	0	0	0	0	0	0
1123	Abandonment of managed lands	0	0	0	0	0	0	0	0
1124	CO2 emissions from/or removals into soils (except 1006)	0	0	0	0	0	0	0	0
1125	Other	0	0	0	0	0	0	0	0
	Comparable National Total (excluding all emissions from sector 11 and for NMVOC and CO2 also emissions from sector 10)	**51,903**	**161,776**	**258,265**	**446,570**	**1,021,197**	**64,026**	**7,302**	**76,440**
	other mobile & mach. - dom. airport traffic (LTO cycles<1000m)	12	138	60	1	585	44	1	1
	other mobile & mach. - domestic cruise traffic (> 1000 m)	18	87	15	0	57	56	0	2
	other mobile & mach. - intern. airport traf. (LTO cycles<1000m)	212	539	448	0	1,410	660	10	24
	other mobile & mach. - international cruise traffic (> 1000 m)	255	7,168	538	0	1,096	793	0	29
	other mobile & mach. - international sea traffic (in.bunkers)	0	0	0	0	0	0	0	0

DENMARK

CORINAIR EMISSIONS 1996

EMISSION ESTIMATES (Kilotonnes; for CO2: Megatonnes)

sector	name	SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
0	**National Total**	**180,010**	**288,438**	**136,374**	**779,369**	**597,981**	**78,286**	**17,021**	**99,268**
1	**Combustion in energy and transformation industries**	**144,868**	**129,051**	**1,829**	**1,615**	**10,769**	**48,116**	**1,431**	**0**
101	Public power	140,943	118,835	1,179	1,134	6,988	43,056	1,300	0
102	District heating plants	2,790	3,982	549	380	3,255	2,725	89	0
103	Petroleum refining plants	1,130	2,483	35	35	312	1,396	26	0
104	Solid fuel transformation plants	0	124	5	5	15	71	1	0
105	Coal mining, oil/gas extraction, pipeline compressors	5	3,628	61	61	198	868	15	0
2	**Non-industrial combustion plants**	**12,062**	**7,685**	**11,443**	**7,514**	**120,653**	**9,493**	**235**	**0**
201	Commercial and institutional plants	1,388	1,488	433	350	5,928	1,702	39	0
202	Residential plants	5,859	4,971	9,156	6,398	107,120	6,905	174	0
203	Plants in agriculture, forestry and aquaculture	4,815	1,226	1,854	767	7,606	886	22	0
3	**Combustion in manufacturing industry**	**11,516**	**14,066**	**1,104**	**587**	**6,477**	**6,177**	**159**	**0**
301	Comb. manu. ind.- comb. in boiler/gas turb./station. engine	11,504	8,427	985	469	5,283	4,861	120	0
302	Comb. manu. ind.- process furnaces without contact	0	0	0	0	0	0	0	0
303	Comb. manu. ind.- processes with contact	12	5,639	119	119	1,194	1,316	40	0
4	**Production processes**	**2,691**	**504**	**10,884**	**202**	**0**	**1,388**	**0**	**0**
401	Processes in petroleum industries	2,614	0	10,824	112	0	0	0	0
402	Processes in iron and steel industries and collieries	0	0	0	0	0	0	0	0
403	Processes in non-ferrous metal industries	0	0	0	0	0	0	0	0
404	Processes in inorganic chemical industries	77	504	0	0	0	0	0	0
405	Processes in organic chemical industries (bulk production)	0	0	0	0	0	0	0	0
406	Processes in wood, paper pulp, food, drink and other industries	0	0	60	90	0	1,388	0	0
408	Production of halocarbons and sulphur hexafluoride	0	0	0	0	0	0	0	0
5	**Extraction and distribution of fossil fuels / geothermal energy**	**0**	**0**	**6,875**	**16,353**	**43,867**	**0**	**0**	**0**
501	Extraction and 1st treatment of solid fossil fuels	0	0	0	6,269	43,867	0	0	0
502	Extraction, 1st treat. and loading of liquid fossil fuels	0	0	0	0	0	0	0	0
503	Extraction, 1st treat. and loading of gaseous fossil fuels	0	0	350	1,633	0	0	0	0
504	Liquid fuel distribution (except gasoline distrib. in 0505)	0	0	0	0	0	0	0	0
505	Gasoline distribution	0	0	3,211	0	0	0	0	0
506	Gas distribution networks	0	0	3,314	8,451	0	0	0	0
507	Geothermal energy extraction	0	0	0	0	0	0	0	0

6	**Solvent and other product use**	**0**	**0**	**20,590**	**0**	**0**	**0**	**0**	**0**
601	Paint application	0	0	7,103	0	0	0	0	0
602	Degreasing, dry cleaning and electronics	0	0	0	0	0	0	0	0
603	Chemicals products manufacturing or processing	0	0	2,020	0	0	0	0	0
604	Other use of solvents and related activities	0	0	11,467	0	0	0	0	0
605	Use of HFC, N2O, NH3, PFC and SF6	0	0	0	0	0	0	0	0
7	**Road transport**	**1,776**	**79,334**	**60,925**	**2,795**	**354,846**	**10,142**	**1,008**	**1,277**
701	Passenger cars	457	44,201	31,395	2,212	307,959	5,699	786	1,257
702	Light duty vehicles < 3.5 t	560	7,758	3,398	182	23,393	1,979	126	9
703	Heavy duty vehicles > 3.5 t and buses	754	27,278	3,269	278	7,926	2,389	95	10
704	Mopeds and motorcycles < 50 cm3	2	12	3,524	40	5,940	32	0	0
705	Motorcycles > 50 cm3	3	85	1,011	84	9,627	43	1	1
706	Gasoline evaporation from vehicles	0	0	18,328	0	0	0	0	0
707	Automobile tyre and brake wear	0	0	0	0	0	0	0	0
8	**Other mobile sources and machinery**	**6,823**	**55,843**	**11,924**	**675**	**60,120**	**3,573**	**168**	**6**
801	Other mobile & mach.- military	68	1,039	148	4	492	53	2	0
802	Other mobile & mach.- railways	95	3,010	308	25	736	301	12	1
803	Other mobile & mach.- inland waterways	8	409	1,831	177	5,103	50	2	0
804	Other mobile & mach.- maritime activities	6,159	22,625	936	30	2,948	1,255	80	0
805	Other mobile & mach.- air traffic	17	1,178	322	16	1,843	235	8	0
806	Other mobile & mach.- agriculture	306	16,678	2,862	75	15,193	993	41	3
807	Other mobile & mach.- forestry	1	8	1,042	104	1,615	7	0	0
808	Other mobile & mach.- industry	165	10,710	2,049	78	6,277	613	22	1
809	Other mobile & mach.- household and gardening	4	186	2,424	166	25,912	64	1	0
810	Other mobile & mach.- other off-road	0	0	0	0	0	0	0	0
9	**Waste treatment and disposal**	**274**	**1,954**	**543**	**74,208**	**1,250**	**378**	**7**	**0**
902	Waste incineration	274	1,954	543	1,008	1,250	378	7	0
904	Solid waste disposal on land	0	0	0	71,599	0	0	0	0
907	Open burning of agricultural wastes (except on field 1003)	0	0	0	0	0	0	0	0
909	Cremation	0	0	0	0	0	0	0	0
910	Other waste treatment	0	0	0	1,600	0	0	0	0

10	**Agriculture**	**0**	**0**	**1,311**	**321,182**	**0**	**0**	**7,892**	**97,984**
1001	Cultures with fertilizers (except animal manure)	0	0	1,303	0	0	0	7,888	22,102
1002	Cultures without fertilizers	0	0	8	0	0	0	3	57
1003	On-field burning of stubble, straw, ...	0	0	0	0	0	0	0	0
1004	Enteric fermentation	0	0	0	153,841	0	0	0	0
1005	Manure management regarding organic compounds	0	0	0	167,341	0	0	0	75,825
1006	Use of pesticides and limestone	0	0	0	0	0	0	0	0
1009	Manure management regarding nitrogen compounds	0	0	0	0	0	0	0	0
11	**Other sources and sinks**	**0**	**0**	**8,946**	**354,237**	**0**	**-981**	**6,121**	**0**
1101	Non-managed broadleaf forests	0	0	0	0	0	0	0	0
1102	Non-managed coniferous forests	0	0	0	0	0	0	0	0
1103	Forest and other vegetation fires	0	0	0	0	0	0	0	0
1104	Natural grassland and other vegetation	0	0	0	0	0	0	0	0
1105	Wetlands (marshes-swamps)	0	0	0	201,899	0	0	267	0
1106	Waters	0	0	0	32,338	0	0	5,208	0
1107	Animals	0	0	0	0	0	0	0	0
1108	Volcanoes	0	0	0	0	0	0	0	0
1109	Gas seeps	0	0	0	120,000	0	0	0	0
1110	Lightning	0	0	0	0	0	0	0	0
1111	Managed broadleaf forests	0	0	1,557	0	0	0	225	0
1112	Managed coniferous forests	0	0	7,388	0	0	0	421	0
1121	Changes in forest and other woody biomass stocks	0	0	0	0	0	-981	0	0
1122	Forest and grassland conversion	0	0	0	0	0	0	0	0
1123	Abandonment of managed lands	0	0	0	0	0	0	0	0
1124	CO2 emissions from/or removals into soils (except 1006)	0	0	0	0	0	0	0	0
1125	Other	0	0	0	0	0	0	0	0
	(excluding all emissions from sector 11 and for NMVOC and CO2 also emissions from sector 10)	**180,010**	**288,438**	**126,117**	**425,132**	**597,981**	**79,267**	**10,900**	**99,268**
	other mobile & mach. - dom. airport traffic (LTO cycles<1000m)	5	341	200	4	1,233	75	2	0
	other mobile & mach. - domestic cruise traffic (> 1000 m)	10	487	14	2	82	160	4	0
	other mobile & mach. - intern. airport traf. (LTO cycles<1000m)	13	837	122	12	611	198	6	0
	other mobile & mach. - international cruise traffic (> 1000 m)	125	8,179	735	78	527	1,954	54	0
	other mobile & mach. - international sea traffic (in.bunkers)	70,752	131,907	3,528	111	11,219	4,818	304	0

FRANCE

CORINAIR EMISSIONS 1996

EMISSION ESTIMATES (Kilotonnes; for CO2: Megatonnes)

sector	name	SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
0	**National Total**	**926,116**	**1,705,156**	**2,485,348**	**2,754,926**	**8,238,691**	**360,173**	**303,800**	**807,717**
1	**Combustion in energy and transformation industries**	**357,323**	**126,789**	**3,508**	**1,979**	**15,473**	**57,600**	**2,050**	**0**
101	Public power	175,287	82,927	1,416	193	4,746	30,416	1,149	0
102	District heating plants	37,601	11,588	434	267	3,560	6,759	221	0
103	Petroleum refining plants	124,460	17,107	615	607	3,403	14,996	560	0
104	Solid fuel transformation plants	14,760	6,665	146	108	1,803	4,337	73	0
105	Coal mining, oil/gas extraction, pipeline compressors	5,215	8,502	897	804	1,961	1,093	47	0
2	**Non-industrial combustion plants**	**85,997**	**106,720**	**215,180**	**148,419**	**1,854,044**	**95,016**	**4,502**	**0**
201	Commercial and institutional plants	31,929	38,257	1,619	2,617	17,995	31,187	1,170	0
202	Residential plants	49,944	65,293	210,626	143,837	1,818,346	61,749	3,239	0
203	Plants in agriculture, forestry and aquaculture	4,124	3,170	2,935	1,965	17,703	2,080	93	0
3	**Combustion in manufacturing industry**	**263,204**	**156,189**	**11,142**	**8,245**	**555,617**	**76,950**	**4,206**	**0**
301	Comb. manu. ind.- comb. in boiler/gas turb./station. engine	176,489	79,012	4,630	3,690	40,916	53,541	2,157	0
302	Comb. manu. ind.- process furnaces without contact	496	3,318	36	14	418	5,219	53	0
303	Comb. manu. ind.- processes with contact	86,219	73,859	6,476	4,541	514,283	18,190	1,996	0
4	**Production processes**	**72,880**	**16,788**	**86,060**	**4,800**	**579,135**	**20,053**	**81,118**	**27,773**
401	Processes in petroleum industries	49,758	5,322	10,210	309	685	2,972	73	0
402	Processes in iron and steel industries and collieries	410	2,934	3,163	2,031	527,596	2,742	0	0
403	Processes in non-ferrous metal industries	5,564	335	283	0	50,854	502	0	0
404	Processes in inorganic chemical industries	12,844	7,753	23,057	2,460	0	2,443	14,158	27,773
405	Processes in organic chemical industries (bulk production)	0	444	14,732	0	0	0	66,887	0
406	Processes in wood, paper pulp, food, drink and other industries	4,304	0	34,615	0	0	11,395	0	0
408	Production of halocarbons and sulphur hexafluoride	0	0	0	0	0	0	0	0
5	**Extraction and distribution of fossil fuels / geothermal energy**	**13,924**	**0**	**100,485**	**260,527**	**0**	**694**	**0**	**0**
501	Extraction and 1st treatment of solid fossil fuels	0	0	0	158,854	0	0	0	0
502	Extraction, 1st treat. and loading of liquid fossil fuels	0	0	211	0	0	0	0	0
503	Extraction, 1st treat. and loading of gaseous fossil fuels	13,924	0	741	552	0	694	0	0
504	Liquid fuel distribution (except gasoline distrib. in 0505)	0	0	45,210	0	0	0	0	0
505	Gasoline distribution	0	0	51,524	0	0	0	0	0
506	Gas distribution networks	0	0	2,799	101,121	0	0	0	0
507	Geothermal energy extraction	0	0	0	0	0	0	0	0

6	**Solvent and other product use**	**0**	**0**	**611,035**	**0**	**0**	**1,904**	**1,979**	**420**
601	Paint application	0	0	252,866	0	0	788	0	0
602	Degreasing, dry cleaning and electronics	0	0	51,165	0	0	159	0	0
603	Chemicals products manufacturing or processing	0	0	81,240	0	0	253	0	0
604	Other use of solvents and related activities	0	0	225,764	0	0	704	0	0
605	Use of HFC, N2O, NH3, PFC and SF6	0	0	0	0	0	0	1,979	420
7	**Road transport**	**100,321**	**899,430**	**894,115**	**18,483**	**4,484,604**	**123,271**	**7,746**	**6,562**
701	Passenger cars	49,933	521,601	418,475	11,724	3,498,388	71,447	5,654	6,343
702	Light duty vehicles < 3.5 t	21,598	100,951	61,352	1,890	519,989	23,160	1,179	100
703	Heavy duty vehicles > 3.5 t and buses	27,689	274,709	33,802	2,000	73,892	26,758	882	88
704	Mopeds and motorcycles < 50 cm3	438	286	85,745	953	142,908	758	10	10
705	Motorcycles > 50 cm3	663	1,883	47,012	1,916	249,427	1,148	21	21
706	Gasoline evaporation from vehicles	0	0	247,729	0	0	0	0	0
707	Automobile tyre and brake wear	0	0	0	0	0	0	0	0
8	**Other mobile sources and machinery**	**16,101**	**372,433**	**142,940**	**55**	**422,593**	**16,961**	**388**	**0**
801	Other mobile & mach.- military	0	0	0	0	0	0	0	0
802	Other mobile & mach.- railways	795	9,866	1,161	45	2,668	785	26	0
803	Other mobile & mach.- inland waterways	176	2,338	259	10	601	173	6	0
804	Other mobile & mach.- maritime activities	4,003	42,652	19,519	0	578	2,152	72	0
805	Other mobile & mach.- air traffic	736	7,359	26,435	0	47,495	5,349	0	0
806	Other mobile & mach.- agriculture	7,808	208,499	71,176	0	277,588	6,220	207	0
807	Other mobile & mach.- forestry	339	9,514	3,299	0	12,853	271	9	0
808	Other mobile & mach.- industry	2,132	91,681	13,028	0	60,317	1,791	60	0
809	Other mobile & mach.- household and gardening	112	524	8,063	0	20,493	221	8	0
810	Other mobile & mach.- other off-road	0	0	0	0	0	0	0	0
9	**Waste treatment and disposal**	**15,978**	**23,289**	**27,939**	**580,452**	**231,998**	**4,168**	**3,519**	**3,596**
902	Waste incineration	15,978	19,798	1,574	8,362	8,794	2,729	1,296	0
904	Solid waste disposal on land	0	0	5,359	535,941	0	0	0	0
907	Open burning of agricultural wastes (except on field 1003)	0	3,480	7,800	7,800	223,200	0	120	0
909	Cremation	0	11	1	5	4	0	1	0
910	Other waste treatment	0	0	13,205	28,344	0	1,440	2,102	3,596

10	**Agriculture**	**0**	**0**	**17,678**	**1,543,831**	**0**	**0**	**171,865**	**768,978**
1001	Cultures with fertilizers (except animal manure)	0	0	17,678	29,475	0	0	160,518	140,780
1002	Cultures without fertilizers	0	0	0	1,293	0	0	1,293	0
1003	On-field burning of stubble, straw, ...	0	0	0	0	0	0	0	0
1004	Enteric fermentation	0	0	0	1,341,607	0	0	0	0
1005	Manure management regarding organic compounds	0	0	0	171,456	0	0	0	628,198
1006	Use of pesticides and limestone	0	0	0	0	0	0	0	0
1009	Manure management regarding nitrogen compounds	0	0	0	0	0	0	10,054	0
11	**Other sources and sinks**	**388**	**3,518**	**375,266**	**188,135**	**95,227**	**-36,444**	**26,427**	**388**
1101	Non-managed broadleaf forests	0	0	12,998	2,606	0	0	521	0
1102	Non-managed coniferous forests	0	0	2,697	1,501	0	0	300	0
1103	Forest and other vegetation fires	388	1,721	4,526	3,226	49,533	0	57	388
1104	Natural grassland and other vegetation	0	0	14,017	7,135	0	0	7,135	0
1105	Wetlands (marshes-swamps)	0	0	0	56,394	0	0	75	0
1106	Waters	0	0	0	22,803	0	0	453	0
1107	Animals	0	0	0	0	0	0	0	0
1108	Volcanoes	0	0	0	0	0	0	0	0
1109	Gas seeps	0	0	0	0	0	0	0	0
1110	Lightning	0	499	0	0	0	0	0	0
1111	Managed broadleaf forests	0	0	282,421	56,630	0	0	11,326	0
1112	Managed coniferous forests	0	0	58,607	32,618	0	0	6,524	0
1121	Changes in forest and other woody biomass stocks	0	0	0	0	0	-42,390	0	0
1122	Forest and grassland conversion	0	1,298	0	5,222	45,694	5,984	36	0
1123	Abandonment of managed lands	0	0	0	0	0	0	0	0
1124	CO2 emissions from/or removals into soils (except 1006)	0	0	0	0	0	-38	0	0
1125	Other	0	0	0	0	0	0	0	0
	Comparable National Total (excluding all emissions from sector 11 and for NMVOC and CO2 also emissions from sector 10)	**925,728**	**1,701,638**	**2,092,404**	**2,566,791**	**8,143,464**	**396,617**	**277,373**	**807,329**
	other mobile & mach. - dom. airport traffic (LTO cycles<1000m)	494	4,372	19,089	0	35,768	1,557	0	0
	other mobile & mach. - domestic cruise traffic (> 1000 m)	1,204	18,241	1,711	0	5,354	3,792	0	0
	other mobile & mach. - intern. airport traf. (LTO cycles<1000m)	242	2,987	7,346	0	11,727	763	0	0
	other mobile & mach. - international cruise traffic (> 1000 m)	2,950	76,502	3,548	0	10,884	9,292	0	0
	other mobile & mach. - international sea traffic (in.bunkers)	130,615	141,504	64,756	0	1,919	7,435	240	0

THE NETHERLANDS

CORINAIR EMISSIONS 1996

sector	name	SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
		EMISSION ESTIMATES (Kilotonnes; for CO2: Megatonnes)							
0	**National Total**	**134,983**	**502,610**	**361,938**	**1,302,267**	**911,828**	**181,348**	**74,253**	**151,826**
1	**Combustion in energy and transformation industries**	**48,408**	**64,068**	**1,740**	**2,183**	**18,390**	**43,073**	**386**	**3**
101	Public power	16,100	48,200	813	1,120	14,000	41,700	332	0
102	District heating plants	1	1,330	36	54	589	873	1	0
103	Petroleum refining plants	32,100	13,400	409	311	1,520	8,990	52	0
104	Solid fuel transformation plants	204	279	17	0	111	106	0	3
105	Coal mining, oil/gas extraction, pipeline compressors	3	859	466	698	2,170	394	1	0
2	**Non-industrial combustion plants**	**2,608**	**47,500**	**12,140**	**24,610**	**104,740**	**47,500**	**112**	**275**
201	Commercial and institutional plants	1,660	10,300	1,000	1,410	3,350	11,500	25	0
202	Residential plants	667	26,900	9,270	20,400	99,800	25,700	70	275
203	Plants in agriculture, forestry and aquaculture	281	10,300	1,870	2,800	1,590	10,300	17	0
3	**Combustion in manufacturing industry**	**31,120**	**54,910**	**7,613**	**5,649**	**65,280**	**37,380**	**132**	**259**
301	Comb. manu. ind.- comb. in boiler/gas turb./station. engine	28,700	53,800	7,250	5,530	64,100	36,600	132	1
302	Comb. manu. ind.- process furnaces without contact	0	0	0	0	0	0	0	0
303	Comb. manu. ind.- processes with contact	2,420	1,110	363	119	1,180	780	0	258
4	**Production processes**	**24,010**	**15,938**	**70,768**	**5,589**	**167,260**	**15,771**	**31,701**	**3,663**
401	Processes in petroleum industries	8,740	1,620	12,600	337	2,110	963	50	8
402	Processes in iron and steel industries and collieries	7,390	6,380	2,960	317	99,800	3,220	0	18
403	Processes in non-ferrous metal industries	2,270	926	287	0	32,700	401	0	4
404	Processes in inorganic chemical industries	4,200	5,980	3,780	966	17,800	5,040	27,800	2,430
405	Processes in organic chemical industries (bulk production)	733	562	10,800	3,360	13,600	607	3,850	613
406	Processes in wood, paper pulp, food, drink and other industries	677	470	40,000	609	1,250	5,540	1	590
408	Production of halocarbons and sulphur hexafluoride	0	0	341	0	0	0	0	0
5	**Extraction and distribution of fossil fuels / geothermal energy**	**2**	**0**	**28,008**	**191,007**	**1**	**3**	**0**	**0**
501	Extraction and 1st treatment of solid fossil fuels	0	0	0	0	0	0	0	0
502	Extraction, 1st treat. and loading of liquid fossil fuels	0	0	176	7	0	0	0	0
503	Extraction, 1st treat. and loading of gaseous fossil fuels	0	0	10,600	107,000	0	0	0	0
504	Liquid fuel distribution (except gasoline distrib. in 0505)	2	0	572	0	1	0	0	0
505	Gasoline distribution	0	0	8,790	0	0	0	0	0
506	Gas distribution networks	0	0	7,870	84,000	0	3	0	0
507	Geothermal energy extraction	0	0	0	0	0	0	0	0

6	**Solvent and other product use**	**0**	**0**	**85,710**	**289**	**0**	**0**	**470**	**1,046**
601	Paint application	0	0	42,900	24	0	0	0	0
602	Degreasing, dry cleaning and electronics	0	0	1,640	0	0	0	0	0
603	Chemicals products manufacturing or processing	0	0	4,130	264	0	0	0	6
604	Other use of solvents and related activities	0	0	35,800	1	0	0	0	1,040
605	Use of HFC, N2O, NH3, PFC and SF6	0	0	1,240	0	0	0	470	0
7	**Road transport**	**11,063**	**211,268**	**133,930**	**5,514**	**486,000**	**27,538**	**6,031**	**0**
701	Passenger cars	4,020	104,000	55,300	3,670	387,000	17,200	3,860	0
702	Light duty vehicles < 3.5 t	1,710	12,900	5,260	256	25,200	2,700	289	0
703	Heavy duty vehicles > 3.5 t and buses	5,290	93,900	20,500	853	28,800	7,340	1,880	0
704	Mopeds and motorcycles < 50 cm3	10	61	6,900	363	12,100	72	0	0
705	Motorcycles > 50 cm3	33	407	7,070	372	32,900	226	2	0
706	Gasoline evaporation from vehicles	0	0	38,900	0	0	0	0	0
707	Automobile tyre and brake wear	0	0	0	0	0	0	0	0
8	**Other mobile sources and machinery**	**16,863**	**90,544**	**12,206**	**570**	**36,815**	**5,631**	**1,161**	**0**
801	Other mobile & mach.- military	0	0	0	0	0	0	0	0
802	Other mobile & mach.- railways	99	1,640	75	3	267	91	20	0
803	Other mobile & mach.- inland waterways	1,960	34,000	3,220	148	9,000	1,830	412	0
804	Other mobile & mach.- maritime activities	12,400	20,600	847	35	2,610	1,040	228	0
805	Other mobile & mach.- air traffic	224	2,700	1,240	113	5,750	694	46	0
806	Other mobile & mach.- agriculture	1,280	18,700	3,600	150	11,200	1,170	259	0
807	Other mobile & mach.- forestry	0	0	0	0	0	0	0	0
808	Other mobile & mach.- industry	0	0	0	0	0	0	0	0
809	Other mobile & mach.- household and gardening	19	4	754	17	258	0	19	0
810	Other mobile & mach.- other off-road	881	12,900	2,470	103	7,730	806	178	0
9	**Waste treatment and disposal**	**908**	**2,048**	**6,433**	**478,186**	**8,287**	**4,452**	**563**	**200**
902	Waste incineration	280	1,640	4,440	599	6,720	3,550	1	1
904	Solid waste disposal on land	22	333	1,030	477,000	1,360	331	74	0
907	Open burning of agricultural wastes (except on field 1003)	0	0	0	0	0	0	0	0
909	Cremation	0	0	0	0	0	0	0	0
910	Other waste treatment	606	75	963	587	207	571	488	199

10	**Agriculture**	**0**	**15,200**	**3,060**	**515,000**	**17,000**	**0**	**27,500**	**140,460**
1001	Cultures with fertilizers (except animal manure)	0	15,200	3,060	50,000	17,000	0	23,100	9,460
1002	Cultures without fertilizers	0	0	0	0	0	0	3,700	0
1003	On-field burning of stubble, straw, ...	0	0	0	0	0	0	0	0
1004	Enteric fermentation	0	0	0	366,000	0	0	0	0
1005	Manure management regarding organic compounds	0	0	0	99,000	0	0	700	131,000
1006	Use of pesticides and limestone	0	0	0	0	0	0	0	0
1009	Manure management regarding nitrogen compounds	0	0	0	0	0	0	0	0
11	**Other sources and sinks**	**0**	**1,135**	**330**	**73,670**	**8,055**	**0**	**6,197**	**5,920**
1101	Non-managed broadleaf forests	0	129	44	2,270	1,100	0	273	0
1102	Non-managed coniferous forests	0	191	0	3,370	1,630	0	404	0
1103	Forest and other vegetation fires	0	0	0	0	0	0	0	0
1104	Natural grassland and other vegetation	0	758	286	13,400	6,470	0	1,600	0
1105	Wetlands (marshes-swamps)	0	57	0	1,000	485	0	120	0
1106	Waters	0	0	0	57,000	0	0	3,800	0
1107	Animals	0	0	0	0	0	0	0	5,920
1108	Volcanoes	0	0	0	0	0	0	0	0
1109	Gas seeps	0	0	0	0	0	0	0	0
1110	Lightning	0	0	0	0	0	0	0	0
1111	Managed broadleaf forests	0	0	0	0	0	0	0	0
1112	Managed coniferous forests	0	0	0	0	0	0	0	0
1121	Changes in forest and other woody biomass stocks	0	0	0	0	0	0	0	0
1122	Forest and grassland conversion	0	0	0	0	0	0	0	0
1123	Abandonment of managed lands	0	0	0	0	0	0	0	0
1124	CO2 emissions from/or removals into soils (except 1006)	0	0	0	0	0	0	0	0
1125	Other	0	0	0	0	0	0	0	0
	Comparable National Total (excluding all emissions from sector 11 and for NMVOC and CO2 also emissions from sector 10)	**134,983**	**501,475**	**358,548**	**1,228,597**	**903,773**	**181,348**	**68,056**	**145,906**
	other mobile & mach. - dom. airport traffic (LTO cycles<1000m)	0	0	0	0	0	0	0	0
	other mobile & mach. - domestic cruise traffic (> 1000 m)	0	0	0	0	0	0	0	0
	other mobile & mach. - intern. airport traf. (LTO cycles<1000m)	0	0	0	0	0	0	0	0
	other mobile & mach. - international cruise traffic (> 1000 m)	0	0	0	0	0	0	0	0
	other mobile & mach. - international sea traffic (in.bunkers)	0	0	0	0	0	0	0	0

EMISSION PROJECTIONS

CONTENTS

1 GENERAL

1.1 Introduction

Emission projections form an important tool to design and assess emission reduction strategies, which aim at achieving given emission reduction targets in the future. Projections of emissions of air pollutants help to evaluate alternative abatement options to achieve these targets within given scenarios of societal trends (developments of population, land use, GDP, transport and economic sectors such as agriculture, energy, industry etc.). More specifically, within emission reduction strategies emission abatement measures are to be allocated in a temporal and spatial frame and the future efficiency of a large variety of measures to be taken today and tomorrow has to be assessed.

In the case of air pollution, the most important problems currently being addressed are:

- climate change (greenhouse gases);
- stratospheric ozone depletion (ozone depleting substances);
- tropospheric ozone (summer smog: ozone precursors);
- acidification (acidifying gases) and eutrophication (nitrogen compounds);
- air quality (winter smog, particulates, heavy metals (HM), persistent organic pollutants (POP)).

In order to reduce these problems, international activities are aiming at a consistent and internationally harmonised approach for preparing air emission projections. The most relevant international activities are the UN/ECE Convention on Long-range Transboundary Air Pollution (CLRTAP), regarding emissions of acidifying pollutants (SO_2, NO_x, NH_3), ozone precursors (CO, NO_x and NMVOC) and since 1997 also heavy metals and POPs, and the UN Framework Convention on Climate Change (UNFCCC), regarding emissions of greenhouse gases (CO_2, N_2O, CH_4 and since 1997 also various other compounds: PFC, HFC, SF_6).

This chapter provides guidance on the preparation of projections of emissions of pollutants into the air for the gases relevant for UN/ECE-CLRTAP. However, the methodology described here is applicable as well for other pollutants, for example greenhouse gases. Where appropriate, further information is supplied in this chapter.

In 1989, the Executive Body of the Convention of the UN/ECE recommended, that economic growth scenarios as used in emission projections should be clearly defined. As far as possible, they should be based upon on three standard economic growth scenarios: base (medium), strong and weak growth. As a first consequence, the UN/ECE Task Force on Emission Projections was established in 1991. In 1993, the Task Force became a panel of the UN/ECE Task Force on Emission Inventories (Expert Panel on Emission Projections, EPEP). The respective activities of these bodies resulted in a chapter on emission projections in the first edition of the Guidebook (February 1996). This new chapter was prepared by participants of EPEP and is making use of the first version of the chapter with a number of extensions, in particular containing more sectoral information.

This chapter highlights the differences and similarities between emission projections and emission inventories and in general aims at improving the links between projections and inventories, thus improving the assessment of emission reduction strategies. Information on the nature and magnitude of historic emissions and the related sources is obtained from emission inventories (e.g. CORINAIR). In order to establish consistency between historic and projected emissions, emission inventories and emission projections should be based on the same structure. In Europe the joint EMEP-CORINAIR approach, as described in this Guidebook, is the most relevant. Starting from such an inventory, priorities for emission reduction measures can be derived in appropriate sectoral, substance related, spatial and temporal resolution. To a large extent, emissions from large sources have already been reduced. Therefore, an approach for preparing emission projections should be able to cover the wide range of all sources, small and large, with the corresponding large number of available technologies.

Thus, an emission projection can be considered as an emission inventory for tomorrow with a set of assumptions and simplifications of the future situation replacing knowledge of the historic situation. Emission projections can be considered estimates of future emissions, based on assumptions of the most important factors that determine these emissions: socio-economic scenario's and future emission factors. It is important to realise that emission projections cannot give a picture of tomorrow's reality, but represent an evaluation of the future effect of emission control options that are in place or are proposed. Emission projections are mainly meant to inform about the likely effect of different emission control options.

1.2 Projections: current reduction plans and baseline scenarios

It is important that the various terms used regarding the preparation and use of emission projections are unambiguously defined. An overview of some the most important terms is given in Annex 1.

The terminology used here is mainly derived from the experience in UN/ECE-CLRTAP-EMEP. It is useful to note the difference between:

- Current Reduction Plans (CRP);
- Current Legislation (CLE);
- Policies "in the pipeline"
- (Future) societal trends
- Baseline scenario

Current Reduction Plans can be defined as the politically determined intention to reach specific national emission reduction targets (or "emission ceilings"), as defined in the various Protocols of the UN/ECE-CLRTAP. Such a plan cannot be modelled (e.g. as an emission projection) but is the result of political decisions and may result from the examination of a range of different emission projection scenarios.

Current legislation (CLE) can be defined as the national (and/or EU wide) legal and regulatory provisions in place at a certain agreed date. In UN/ECE-CLRTAP, usually 31 December of the previous year is used as a criterion for determining current legislation.

Policies “in the pipeline” are those proposed national and international legal and regulatory measures that are expected to be adopted within a short period. This differs from CLE in that regulations that are not yet in place are included. Any such projection needs to be accompanied by a clear description of the assumed future regulations.

Future societal trends are the expected future trends of the most important and relevant activities that influence the magnitude of emissions for a specific source sector and pollutant. These are the main activity assumed to be the driving force behind the emission of a specific sector, for example the energy consumption of a sector, the production of steel, the number of cows etc. A configuration of such trends is also often called “scenario” (e.g. energy scenario) and therefore, in this chapter the terms “future societal trend” and “scenario” are used as synonyms.

Baseline (emission) scenarios can be defined as a combination of assumptions of future societal trends and current legislation. Because the baseline scenario usually is the framework and starting point of any emission projection, it is important that the following assumptions and simplifications are made clear and explicit in case of preparation of an emission projection:

- Future societal trends: which (official) scenario has been used (e.g. regarding energy one of the EU scenarios like “Conventional Wisdom” or “pre-Kyoto” will often be used)?
- Current legislation: What is the date for which legislation and regulations are in force? For each regulation a projection also needs to know:
    - the year of entry into force of the specific measure(s)
    - the lifetime of the emission reduction installation/measure
    - the emission reduction that can be achieved for each specific measure

There can be only one baseline case. The LRTAP convention requests a baseline case and two other scenarios, high and low growth. The baseline case is the one against which other scenarios are compared and it is important that it is clearly defined, for example regarding the assumptions used for the development of GDP and other socio-economic activity data.

1.3 UN/ECE-CLRTAP expert panel on projections

The (new) Expert Panel on Emission Projections (EPEP), as part of the Task Force on Emission Inventories (TFEI), had its first meeting on 10-11 March 1997 (Roskilde, Denmark). Some of the main conclusions are summarised here.

The design of any methodology and instruments to carry out emission projections should account for relevant requirements of possible users. Some key users are:

- parties of the CLRTAP requiring guidelines for the submission of emission projections;
- policy makers, e.g. in the UN/ECE Working Group on Strategies (harmonisation and standardisation of submitted emission projections; review of officially submitted projections);
- the UN/ECE Task Force on Integrated Assessment Modelling (harmonisation of data input for scenarios, especially with respect to societal projected trends).

Current reporting on emission projections within CLRTAP is hampered by unclear guidelines and definitions. In this respect, apart from the so-called current reduction plans, which are the politically determined emission reduction targets, the Expert Panel on Emission Projections should thus focus its work on improving the reporting on baseline scenarios, which include current legislation and thus, as a long term aim, on harmonisation and standardisation in reporting on baseline scenarios.

Baseline emission projections should explicitly comprise the assumptions made with regard to:

- projected economic activity and other societal data for the main source categories,
- projected emission factors, including effectiveness of abatement measures,
- penetration of abatement measures (changes in behaviour),
- clear representation of underlying relevant legislation in the country and how this is reflected in the baseline, current reduction scenario.

Furthermore, the Expert Panel proposed to TFEI and TFIAM that the Guidelines for reporting of emission projections within the framework of UN/ECE-CLRTAP should be revised as follows :

(a) The baseline scenario should be covered by the reports. This scenario (in other terms the current legislation scenario) reflects the state of action (regulations or other binding measures) in place as of 31 December of the year prior to the reporting deadline;

(b) Reports should include information on the following general assumptions used (the so-called key features of the scenario used) for the preparation of the emission projection: (growth in) Gross Domestic Product (GDP) in constant prices, (growth in) population and (growth in) world oil price in constant prices.

(c) Apart from information on these general assumptions, reports should also include information on the following key (sectoral) scenarios (or future societal trends) assumed for emission projections: primary energy consumption (including fuel split), livestock (numbers of cattle, poultry and pigs), road transport (mileage of passenger cars and tonkm of freight transport; including fuel split). Reports should also mention major policy changes affecting the future development of total energy consumption, fuels, electricity import, transport and agriculture.

(d) Reports should include SO_x, NO_x, NH_3 and non-methane volatile organic compounds (NMVOC) according to the reporting guidelines. For consistency purposes, attempts should be made to cover CH_4, CO_2 and CO.

(e) The years 2000, 2005 and 2010 should be covered (information required under b and c should also be reported for the year 1990);

(f) Emission projections should be reported using the updated source category split (SNAP 97), also employed for emission inventories. If this sectoral breakdown is not feasible, Parties may use a more aggregated split (energy, industry, solvent use, transport, others), e.g. SNAP level 1 according to the CORINAIR structure.

The proposal has been discussed in the EMEP Steering Body in September 1997 and the Executive Body in December 1997 and was subsequently incorporated into the “Procedures for estimating and reporting emission data under the CLRTAP” (EB.AIR/GE.1/1997/5, 30 June 1997). See for more information on CLRTAP TFIAM the Internet site http://www.unece.org/env/tfiam/Welcome.html and on IIASA (RAINS model) http://www.iiasa.ac.at/~rains/.

2 GENERAL APPROACH FOR EMISSION PROJECTIONS

2.1 Main existing approaches

The main approaches used for preparing emission projections can be divided into two classes:

- socio-economic,
- technology based.

The former correlate emissions with socio-economic time series, such as GDP development, without accounting in detail for technological change. Technological change on the other hand is explicitly considered in technology based approaches such as the emission factor approach. This latter approach is nowadays widely used, mainly due to the fact that technological change became a prevailing parameter, for example in the power plant sector resulting in increased electricity production and decreasing NO_x-emissions. However, the emission factor (technology based) approach can be rather detailed and preparing an emission projection with such a detailed method may be time consuming. Therefore, it is important to select the appropriate level of aggregation, for which guidance is given in this chapter.

The relation between (economic) scenarios, environmental policies (technical measures and non-technical or “volume measures”) and emission projections is shown in Figure 1.

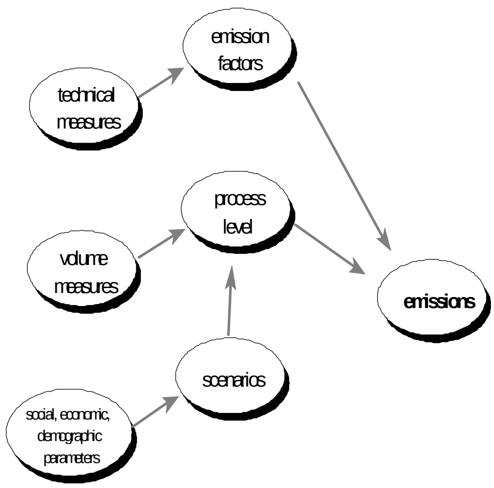

Figure 1 From economic scenarios and environmental policy to emission projections

Within a technology based approach, influences of socio-economic (population, energy prices, indicators for economic growth and trade, etc.) and technological boundary conditions (specific emissions of modern technologies) can be separately represented by:

- activity rates;
- emission factors;
- technology implementation (or “penetration”) schemes (changes in behaviour).

Projections for these parameters can be carried out independently from each other. Such an approach is useful because emission policies and measures do not only apply to the technology level in terms of prescribed emission limit values (the emission factor), but in some cases also the activity level is addressed, e.g. in terms of restricted traffic in certain regions (sometimes called “volume measures”). Such measures can be taken into account by this approach on an appropriate level of aggregation. Parameters in terms of emission factors, activity data and implementation shares of technologies have consequently to be determined for past, present and future.

As regards the assessment of emission factors, considerable progress has already been made as e.g. documented in the other sections of this Atmospheric Emission Inventory Guidebook.

Concerning (future) activity data, available statistics provide data on many aggregation levels, in different dimensions and different completeness. Here, compatibility between activity data for emission inventories (with the required level of aggregation e.g. the CORINAIR SNAP sector structure) and future activity data for emission projections is one of the main problems to solved and for which guidance is given in this chapter.

Furthermore, different technologies, which are installed in a certain sector have to be assessed in terms of activity shares or rates of penetration. Here, the respective environmental legislation (emission limit values or even phasing out of certain technologies) must be taken into account. Within this frame, autonomous technological change takes place, which can be assessed by technology lifetime modelling.

2.2 The basic formula (emission factor approach)

The general basic formula for the widely used “emission factor” approach, described in this guidebook can be described as follows. The time series of national annual emission projections, and also in many cases for emission inventories, for a given emitting sector is:

$$E_{i,j} = A_{i,j} \cdot FS_{i,j} \qquad (1)$$

E:	emission time series	[Mg/year]
A:	activity rate time series	[var] [1)]
FS:	sectoral emission factor time series	[var.]
i:	sector	
j:	pollutant	

[1)] Varying units, to match emission factor and activity rate.

In this formula, a technical relationship is assumed to exist between the (future projected) activity rate (A) and the emission (E). The formula implies that if the activity rate increases with for example 20 % the emission also increases with 20 % (if the emission factor is kept constant). On the level of individual plants this relation is not always valid, but for calculations on a national level the formula is accurate enough. Sectors can be defined on different levels of detail and aggregation, for example “total road transport” or “road transport of petrol driven passenger cars”. The activity rate is in general the result of scenarios relevant for a specific sector or depending on the level of aggregation; this can be a general economic scenario (e.g. GDP). The emission factor (FS) is a technological parameter, which can on the most detailed level be obtained from the sector specific chapters of this Guidebook or, if the calculation is performed on a higher aggregated level, FS has to be redefined (including implementation shares/penetration rates of the respective technologies on such a level).

It is often necessary to model the (future) introduction of abatement technologies. If all those details of the various technologies and processes are known, then the sectoral emission factor can be described as follows. The time series of sectoral emission factors FS (annual, national) is composed of the weighted emission factors of relevant technologies within a considered sector.

$$FS_{i,j} = \sum_k \sum_l P_{i,j,k,l} \cdot F_{i,j,k,l} \qquad (2)$$

P: activity share or penetration rate of a technology within a sector [ ]
F: process level emission factor [var.]
k: technology type
l: type of input material (e.g. ores) and/or fuel

This formula is also shown in a wider context in figure 2, which has a clear link with figure 1 presented above. It can be stated that the activity rate A is the economic factor, the emission factor F is the technological factor and P is a weighting factor or the penetration rate of a certain technology (e.g. an abatement technology) in the sector. P represents the behaviour factors of the sectors in which the processes/technologies occur, in fact the behaviour of people, of course within technical, economical and political boundaries. It comprises a mixture of various aspects: legislative requirements, market shares in different sectors, dynamic behaviour of public technology acceptance, etc. In practice, P varies from year to year for example because new technologies enter the market place.

The emission factors F are given for a wide range of technologies, processes, fuels, etc. in the sector specific chapters of this Guidebook.

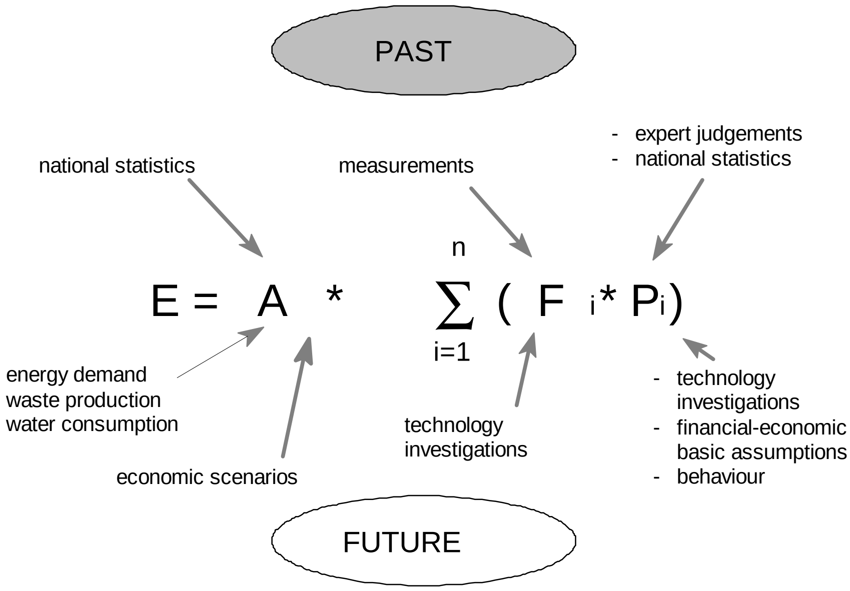

Figure 2 The fundamental formula for emission calculations and its application in inventories and projections

In the next sections of this chapter, the basic formula and the simplifications and assumptions used in practice are discussed.

2.3 The link between inventories and projections

The formula (2) (also in figure 2) is not only applied for projections, in many cases emissions in a base year are calculated in the same way. The main difference is that Ai and Pi are not the result of economic scenarios or expected behaviour, but they are facts, actual developments and so in practice often given by statistics. This means that the main difference between an emission inventory and a projection is the time reference.

Consistency between inventories and projections is important and may be enhanced by using the same type of activity rate, by taking the Pi in a base year as a starting point for projections and by using the same emission factors in case the technology is the same.

This implies that emission factors presented in this guidebook for emission inventories can be applied for projections as well. However, it should be realised that abatement technologies and process improvement normally reduce these emission factors and that different countries are at different stages in the introduction of cleaner technologies. To be able to use available emission factors, it is important to relate them to a well-defined technical situation/process, mentioning the abatement technology, the process itself, and the 'best available technology' in a certain year.

Each emission projection must be based on an existing emission inventory as a starting point, since compatibility of past and future emission data is an important criterion for the applicability of any projection. In order to establish the required compatibility between emission inventories and projections it is recommended to use the emission inventories based on the CORINAIR methodology. Moreover, since emission inventories are needed within very short time periods, it may be necessary, when data are not yet available, to use preliminarily projected emission data in order to fill gaps. Thus, emission projections may also serve to support emission inventories. However, for projections sometimes a higher aggregated level is required than for inventories, so such projected emissions data will have to be validated by means of more detailed emission inventories when these become available.

2.4 Scenarios (future trends of activity rates)

2.4.1 Introduction

The future activity levels (A) are one of the main (economic) parameters in the emission calculation. A scenario (or "future societal trend") comprises future trends of activity rates and is based on economic theories and relations, including many assumptions. The aim of an emission projection is to show the consequences of such a scenario in terms of emissions. Therefore, different scenarios are interesting for many purposes. For the purpose of this Guidebook scenarios are assumed to be available for the preparation of emission projections. The Guidebook aims at giving guidance regarding the use of such scenarios (e.g. the optimal level of aggregation). Scenarios or future societal trends are usually prepared to show possible future developments in a consistent way at a rather high level of aggregation of sectors. At a (very) detailed level the uncertainty tends to be larger. Another general remark on the use of socio-economic scenarios for emission projections is that possible changes in the economic structure (feedback) due to investments in environmental measures are not taken into account. The following levels of detail/aggregation of scenarios might be distinguished.

General scenarios for international development

A country is not a closed system. For many countries, assumptions on developments in the rest of the world, specifically countries with strong international trading relationships, are important as a general framework. These interrelationships are not fixed, so different scenarios could be worked out. Another important parameter, which is internationally determined, is the energy price. More over, exchange rates or trade patterns may influence relevant conditions outside a country.

National economic scenarios

Based on possible international developments, national economic scenarios can be designed. The impact of national population growth on economic activity is an important factor. For short-term scenarios (say less than 10 years) the actual detailed structure of the economy is the base for the estimated developments. Longer term scenarios are generally presented in monetary terms, on a high level of aggregation (say 10 to 40 sectors).

Scenarios on a process level (CORINAIR SNAP level 3)

In some cases, further details are necessary for the preparation of emission projections, especially if emissions are related to a limited number of processes (heavy metals, POP, VOC). Here with processes CORINAIR SNAP level 3 type activities are meant. This fine-tuning can be realised in two different ways.

The first option is to distinguish more processes than is generally done in economic scenarios. The number of processes could be several hundreds, including many consumption processes. The macro-economic approach could be supplemented with micro-economic information, i. e. about plants, which will be closed or started up. This can be called a detailed "bottom-up" approach, using the basic formula as mentioned before. This is the approach that is described further in the sectoral chapters. To do this for all the different sectors would be very time consuming and may well be impracticable especially where a range of scenarios are to be evaluated. However, there is a simpler approach on a higher level of aggregation.

For any pollutant, there are 10-40 sectors that jointly emit 80-90% of the emissions. Pollutants like SO2 have a well defined set of sources that emit most of the emissions. Even NMVOC, which are emitted from a much wider range of sources have a restricted set of large source categories. In order to produce an emission projection, effort should be concentrated on these 10-40 source categories. These can be projected in detail. The remaining source categories should only be estimated as a group with average factors, activities and abatement measures. If time and resources allow, then some of the smaller source categories could be refined. If the impact of a very specific source category and its abatement options is to be determined, then emissions from that source category are projected alone and compared with the national projection estimated in the more general approach as indicated above.

The second option is the identification of the physical developments (like production figures) that correspond to the development of monetary data. From a technological (and environmental) point of view, physical activity data are more suitable. If only monetary data are available (e.g. future production figures of a certain sector) then it would be an option to transform these monetary data into physical activity data. This asks for information about the flows of materials and products through society and its relation with processes. This transformation could be developed with the help of (macro-economic) input-output matrices. Such an approach can be regarded as a socio-economic based "top-down" approach, in which the emission factor is redefined in a way that it can be correlated with (macro-)economic scenarios. This approach will be referred to in the following sections as (macro-economic) "top-down" approach, but in general this will not be described in further detail.

The approach described in this Guidebook can be regarded as a "bottom-up" approach, aiming at finding the optimal balance between the level of detail in the projected activity rate and the level of detail of the (projected) emission factors, in combination with the penetration rates. This will be explained in more detail in the sectoral chapters, showing examples.

Generally, scenarios of activities as used for emission projections should be in line with overall country specific forecasts of energy demand, GDP development, crude oil prices, etc. Consistency is of special importance when different countries are compared. Therefore, comparable boundary conditions are required or, at least differing assumptions should be documented explicitly.

2.4.2 General socio-economic factors

General socio-economic factors represent overall dynamic boundary conditions, that have a strong influence on sectoral activity rates. Some effects are obvious, others less. Such socio-economic factors are important in most (macro-)economic models. For information purposes some examples are listed here :

- the world oil price. This may influence the fuel consumption behaviour of industry as well as of private consumers. A high oil price can lead for example to reduced consumption of fuels, to a switch towards alternative fuels or to alternative means of passenger transportation. The world oil price may also influence the price of organic solvents and thus influence the competitiveness of alternative products.
- the electricity price in a country. Low electricity costs by using hydropower, may influence fuel consumption. For example residential heating could be based to a larger extent on this cheap electricity.
- the dynamic structure of the electricity producing sectors. In some countries, there is an ongoing trend towards nuclear power, whereas on the other hand the share of renewable energy sources is estimated to take over a large part of today's conventional thermal capacity in the future.
- the dynamic structure of the transport sector. The continuing growth of the share of trucks in goods transportation may lead to stringent measures forcing transport companies to use the railway to a larger extent, as for instance in Switzerland for transit transport. Moreover, the growth of high speed railway systems as well as the ongoing growth of air traffic may change the transport behaviour of the population.

General socio-economic factors can be regarded as the “driving forces” behind pressures on the environment (like air emissions). Socio-economic factors, which are of major influence on many sectoral activity data are, for instance: number of population, land use, GDP overall or industry volume, number of households and dwellings. For these factors, projections are available from several sources, thus, sectoral activity projections can be linked to these overall projections according to appropriate assumptions for the linking (e.g. by correlation procedures, saturation functions, etc. (Holtmann et al. 1995)). See also the basic formula in this Guidebook (figure 2).

In Table 1, selected examples are given of available past and future data for some socio-economic factors, several of the references are annually published with respective actualisation. Thus, country experts may find relevant data in these publications, if no projections are available within the country itself.

Table 1 Available projections for general socio-economic factors

Category of socio-economic factors	Sources
Total population numbers (historic and future)	EUROSTAT 1993a; EUROSTAT 1993b; EUROSTAT 1995
Population projections (future)	EUROSTAT 1990, Bulatao et al. 1990 (UN projections)
Gross domestic product(historic and future)	OECD 1993 (annually published)
National account SEA-GDP-volume (historic and future)	EUROSTAT 1995
National account-GDP-industry volume (historic and future)	EUROSTAT 1995
Index of industrial production (historic and future)	EU-Commission 1992
Construction of new dwellings (historic and future)	EU-Commission 1994
Number of households (historic and future)	EU-Commission 1994
Industrial products-electricity (historic and future)	EUROSTAT 1993a
Industrial products-electricity; conventional thermal production (historic and future)	EUROSTAT 1993a

Table 2: Available projections of activity data for aggregated source categories, 1990=100 (RAINS model, IIASA)

Industry name	1990	1995	2000	2005	2010
Cement and lime	100	88	89	91	93
Coke plants	100	80	84	87	90
Nitric acid plants	100	90	91	93	95
Non ferrous metals melters	100	92	94	97	100
Oil refineries	100	87	91	97	100
Pig iron, blast furnaces	100	84	87	89	91
Pulp and paper	100	97	100	103	106
Sinter - agglomerate	100	86	88	90	93
Sulphuric acid plants	100	83	86	89	91

References as given in Table 1 and 2 are intended to give some guidance for information and data sources, if own projections of such parameters are not available.

2.4.3 Energy and waste scenarios

Energy as one of the main resources (energy, labour, capital) of any industrial activity is one of the main influencing parameters of used for specific the emission performance of processes, sectors and branches. Energy and waste scenarios are projections with regard to energy and waste, but also when focusing on emissions into air, they are of high importance.

Energy scenarios strongly influence emissions of certain pollutants (SOx, NOx, CO2, etc.) which are mainly emitted from combustion processes. The energy demand can be regarded as the main activity rate (GJ/year with emission factors correspondingly in g/GJ).

Energy efficiency measures can reduce these emissions without further abatement measures. This has occurred in the past and will continue. If a higher energy efficiency is assumed for the future, this may lead to a lower energy use than that assumed in the economic forecast. Ideally, the adoption of energy conservation as an abatement option should be fed back into the economic model to adjust its predictions.

Energy demand can be dealt with on macro- and micro-scales. The latter approach is based on knowledge of the energy demand of production and consumption processes, using energy factors the same way as emission factors can be used. Energy conservation measures can be translated into new energy factors. For this approach, activity rates on the process level must be available. On the other hand, the national energy demand can be related to macro-economical parameters like production, energy price, investments, employment rate, etc. This can be done on a sectoral level. In this approach, general assumptions on energy conservation are included.

In both approaches, the driving forces behind energy conservation must be quantified. One of the driving forces is the energy price, but other production factors are also important. Expensive labour costs may be replaced by energy consumption due to automation and investments may save energy. A specific energy conservation policy can play an important role. Energy in the form of electricity or heat can be produced in several ways. So the second step is to divide the total energy demand into several energy conversion processes, for which emission factors are known. In short-term projections, this division will not be very different from the present situation, but in long-term projections, a quite different situation is possible. In the chapter on the energy sector these aspects are described in more detail.

Waste is the result of production and consumption processes with a range of preventive options. These processes have specific emission factors. Similar to energy scenarios, waste scenarios are important for the determination of sectoral activity rates and emissions, here especially for air and soil pollution resulting from waste treatment (incineration, landfills). For integrated inventories or projections such scenarios are even more relevant.

2.5 Environmental policies

Environmental policies impose certain emission reduction requirements per technology, per sector or for a whole country. Thus, a framework of possible future emission developments is given, accounting for current and planned legislation. This gives the framework, in which all other developments (e.g. autonomous technological change) will take place.

Respective relevant international obligations are for instance EU-legislation and UN/ECE protocols. Within UN/ECE protocols, overall reduction rates for the respective countries are fixed ("emission ceilings"), which have to be transformed into national legislation, then addressing certain sectors or technologies. EU-Directives focus directly on certain sectors and technologies, imposing certain emission limit values.

Additionally, national or regional regulations may in many cases go beyond these limits. Moreover, also voluntary agreements between companies and local administration may result in further reduced emission rates.

Thus, for the near future the development of emission factors is more or less clear. However, a general aspect which should be explicitly mentioned, is the compliance of real installations with these international and national emission reduction requirements. During the preparation of an emission projection it is therefore important to make use of the experience and results of existing and new initiatives within international conventions, like for example the planned new institution within UN/ECE-CLRTAP which will deal specifically with the verification of compliance.

In view of the wide range of cheap reduction measures already implemented, especially end of pipe measures, further reduction requirements may become increasingly costly. Thus, the consideration of economic aspects of new policies may become an integral part of the assessment of possible options to improve policies. This is especially relevant when addressing the large number of small emission sources.

2.6 Emission factors

2.6.1 Quality of emission factors

The uncertainty and quality of emission factors is discussed in the appropriate chapters of this Guidebook. In forecasts it is important to remember that the further into the future a projection goes, the more uncertainties will be associated with each individual emission factor. Often emission factors are derived from measurements at a typical current plant, in the future these may no more be typical. Abatement efficiencies and emission factors for future technologies may be assumptions in such cases. For more information on quality aspects for emission factors, please refer to the respective chapter of this Guidebook.

2.6.2 Aggregation Level of Sources

A central aspect of emission inventories as well as of projections is the aggregation level (e.g. technology, sector or country level) or source category resolution. Insufficient specification in this respect will lead to compatibility problems for inventories and projections. For different structures of emission inventories, correspondence tables may be used if available in order to allocate certain sectors to higher aggregated categories or vice versa as for instance described in this Guidebook for the CORINAIR and the IPCC sector structure. However, gaps and overlaps may arise nevertheless.

2.6.3 Emission factors on technology level

If an individual source sector (for example CORINAIR SNAP level 3) is treated on its own, then a specific emission factor and activity rate are needed. In other cases, many sectors are combined at a “higher level”. Generalised emission factors are needed and the activity rate used may be some economic data which would not be used for any of the individual sectors. In this case, the uncertainties are likely to be higher but if the sectors all emit only a small part of the national total the impact of the overall projected emission is likely to be small.

Emission factors on process or technology level (below SNAP level 3) are available from a large number of technology specific or general publications and comprehensive compendia such as this Atmospheric Emission Inventory Guidebook, and in many other publications, addressing specific pollutants, technologies, etc. (e.g. US-EPA AP 42 handbook, Dutch SPIN-report, German VDI-guidelines, etc.). The emission factor is usually related to a very specific activity. The applicability of given emission factors on a certain case has to be checked and adaptation may be necessary, e.g. for different fuel properties. Emission factors should be defined in terms of specific pollutants, development state of a technology, used fuels, other input material, abatement measures, age of facilities, operating conditions and times, etc.

As regards dimensions and units of emission factors, they should be compatible with the given overall source category structure (e.g. CORINAIR SNAP). For specified fuels or other parameters, emission factors can as well be calculated, e.g. by deriving SO_2 emissions from the fuels' sulphur content.

Emission factors on technology level undergo external influences e.g. by environmental legislation requiring compliance with certain emission limit values. Consequences are retrofitting of existing technologies, improved performance of new technologies and phasing out of old technologies. These effects have to be accounted for by adapted emission factors and adapted technology implementation shares.

Examples of these process/technology related emission factors are:

- EF for a specific type of car, built in 1990, driving with an average speed of 80 km/h steadily on a motorway, equipped with a catalyst; the activity rate is in km driven with that type of car at this speed.
- EF for well-defined modern stables (including specific measures) with cows; the activity rate is the number of cows.
- EF for the application of a certain type of paint on houses; the activity rate is the amount of paint used.
- EF for the production of styrene in a well-defined plant (including pollution control measures); the activity rate is the production volume of styrene.

2.6.4 Emission factors on sectoral level

In practice, emission factors are often used on a higher aggregated (sectoral) level (for example CORINAIR SNAP level 1 or 2), e.g. because of lack of data on the detailed process level. For the purpose of projections on an aggregated level, consistent procedures have to be applied in order to derive aggregated emission factors corresponding to the aggregation level of the respective activities within the considered sectors. Emission factors can be determined on sectoral level, provided that all emission relevant technologies applied in a sector are specified by their emission factors and their respective activity shares.

For certain time steps, the technology configuration within a sector is to be expressed in terms of its contribution to the sectoral activity, thus indicating the respective contribution of technologies to sectoral emissions.

In practice, there are several ways of adjustments used because of lack of data on the detailed level, of which two are explained here:

a. assumptions on the penetration rate P are included in the EF;

b. the EF is related to another A (or activity rate a) than the best one from a technological point of view.

It should be noted that statistics are necessary for quantifying P and A in emission inventories. However, in emission projections they are the result of economic scenarios and assumptions about the behaviour of people and of sectors. But also in these cases such simplifications might be useful.

Assumptions on the penetration rate P

For every of the examples mentioned above, in practice simplifications may be necessary, leading to the following EF used in practice in some cases:

- EF for all cars on gasoline under all circumstances in a specific country, in which the penetration of the catalyst is included;
- EF for cows in all kinds of stables, which means an average for modern and old stables including a penetration rate;
- EF for paint application on houses in general, including assumptions on the types of paint used;
- an average EF for styrene production in the world, also used for a specific country.

Relate EF to another activity rate (A)

The ideal situation is to be able to make projections for each activity rate (A), which has a good technical relation with the emission E. In almost all cases, these activity rates should be defined in physical terms. However, it would be an impossible job to make all these detailed projections. That is why other activity rates are often used, in many cases based on economic scenarios and in monetary terms, even if the relation with the emission E is less clear.

Also the EF should be adjusted and defined in another way as is shown in the following examples:

- EF for cars related to the number of inhabitants;
- EF for cows in general related to the 'added value' of this part of agriculture;
- EF for paint application related to the number of houses (or inhabitants);
- EF for styrene production related to the 'added value' of the chemical industry.

In case of styrene production, the emission in the base year itself could be used as the EF related to an index, which is 1 in the base year and represents the growth of the chemical industry. A further simplification is not to distinguish processes within the chemical industry for projections. In that case, the total emission for the chemical industry can be related to the relative growth of this sector as can be done for other sectors as well.

It is clear that these simplifications (prior aggregations rather than post aggregations) also imply a devaluation of principally available information. Because emission projections are based on economic scenarios and penetration of technologies, which are both the result of many assumptions, this can be acceptable in some cases. However, the acceptability depends on the goal of these projections and too much aggregation makes the result useless. In case the question is: 'what result could be achieved with full penetration of catalysts in cars?', it is better to make the calculations explicitly for the penetration of the catalyst and use EF for cars with and without catalysts.

2.7 Penetration of technologies or changes in behaviour

The third parameter in the basic formula deals with a projected penetration of technologies. The penetration of technologies in certain sectors is on one hand strongly influenced by environmental legislation, leading to improved emission performance of installations, and existing investment programs. However, also other effects may have to be taken into account, since the availability of new technologies or products may modify behaviour. This will influence penetration rates between different technologies or sectors. For instance, the introduction of certain new technologies may cause a switch to other capacity classes within a sector, thus modifying the technology partition and subsequently the emission performance within this sector. The enforced penetration of technologies by environmental legislation may even cause the disappearance of certain technologies, leading to modifications in the activity structure as well.

Moreover, when considering specific policy measures as currently applied in several countries, such as taxes on fuels and products and other economic instruments, these are directly addressing the behaviour of consumers, thus giving incentives to make use of less pollution creating technologies and products. Such influences have to be considered as well, however, specific socio-economic approaches are required beyond current engineering or technology related approaches. Here, scenarios with regard to consumers behaviour and reaction on such instruments have to be established. Uncertainty of results will be higher than for imposed legislative regulations, which are normally fixed in terms of emission limit values and transition periods.

Examples of the issues mentioned are:

- What is the potential emission reduction of certain technologies?

  For example the technology can be assumed to penetrate up to 100%, unless this is technically impossible. In this case, the technical measures to be taken are clear, but this kind of projection of penetration also shows the result of the policy with the assumption every actor actually follows this policy.

- What will be the effect of financial and other policy instruments on emissions (penetration)?

  Environmental taxes or energy taxes could be examples. They will have effect on the decisions of different consumers to invest in energy conservation or pollution reduction. If some criteria can be developed (i. e. for the rate of return) the actual penetration might be calculated.

- What will be the emissions in a future year based on the actual policy, supported by a certain budget for inspection (compliance)?

  This scenario can only be calculated, if the efficiency of inspection and its dependency on a budget can be quantified. This can be translated in the penetration of technologies.

Because of a lack of knowledge about the real driving forces for the penetration of technologies, in general quite simple assumptions are used. However, it is important to make these assumptions explicit to be able to compare different emission projections.

2.8 Other aspects

The spatial resolution of current emission projection approaches is mainly the country level. However, for the requirements of atmospheric modelling, finer resolutions may be necessary. Then, emission sources have to be assessed in the appropriate spatial resolution (e.g. below NUTS level 0). In the framework of the CORINAIR emission inventorying activities, data for large point sources are already being collected with respective indication of location.

This spatial resolution of emission projections should be done in the same way as for historic inventories. The historic spatial distributions can thus be modified by the projected emission totals on a sector by sector

2.9 Future perspectives

2.9.1 Sources of emissions

One of the major challenges regarding current emission inventories and emission projections is to achieve a harmonised, consistent nomenclature for sources of emissions and time series of emission estimates according to these. For inventories of air emissions within EMEP/CORINAIR, use is made of the SNAP source classification system, which is continuously being updated as new sources are identified and especially when new pollutants are added. One of the problems is that often the activity rates needed for emission projections are lacking. This problem with regard to missing activity data in physical dimensions on sector level may be overcome by current activities at EUROSTAT, in co-operation with EEA, aiming at providing such data for emission balancing purposes (cf. NOSE = Nomenclature for Sources of Emissions). Moreover, with complete time series of past activity data being available, authorised sectoral activity projections coming from the considered countries would be very helpful. In terms of technology shares, a consistent documentation of emission limit values and of technologies suitable to realise them is required (cf. activities of current UN/ECE Task Forces on NOx and VOC abatement options/techniques). An improved consideration of compliance with legal requirements may result from the newly established compliance group within the UN/ECE, thus supporting a more realistic picture of technology implementation within countries and sectors and thus improving estimates of emissions.

2.9.2 Integrated Approach

The current section of the Guidebook only deals with emissions into air. However, side effects are more and more taken into account in terms of emissions into water and generation of waste and emission transfers from one environmental medium to another. Another aspect is replacing e.g. NMVOC emissions by NOx- and CO2-emissions in the case of incineration (cf. current activities of the current UN/ECE VOC and NOx Task Forces). Moreover, several pollutants contribute to specific atmospheric problems, such as the precursors of ground level ozone (VOC and NOx). In this respect, activities in the development of emission projections are more and more oriented towards an integrated approach looking at various air pollution related problems simultaneously (in the case of the second NOx protocol of UN/ECE-CLRTAP: acidification, eutrophication, tropospheric ozone).

The integrated approach is important for several reasons (see also Figure 3):

- it leads to consistency on the technical level; most of the available abatement measures will reduce emissions of more than one pollutant and thus correspondingly several emission factors.
- it helps to realise consistency in different scenarios by relating the emissions to water, air and soil, energy use and waste production to the same activity rate (A); however, for some processes the best A might not be the best Waste Explaining Variable or Energy Explaining Variable, but in practice these differences may only appear on a detailed level and in a few cases.
- it is important that environmental costs and environmental benefits (like emission reductions) are related, which means for projections that they are based on the same assumptions about technologies, their penetration and the development of the activity level of processes.

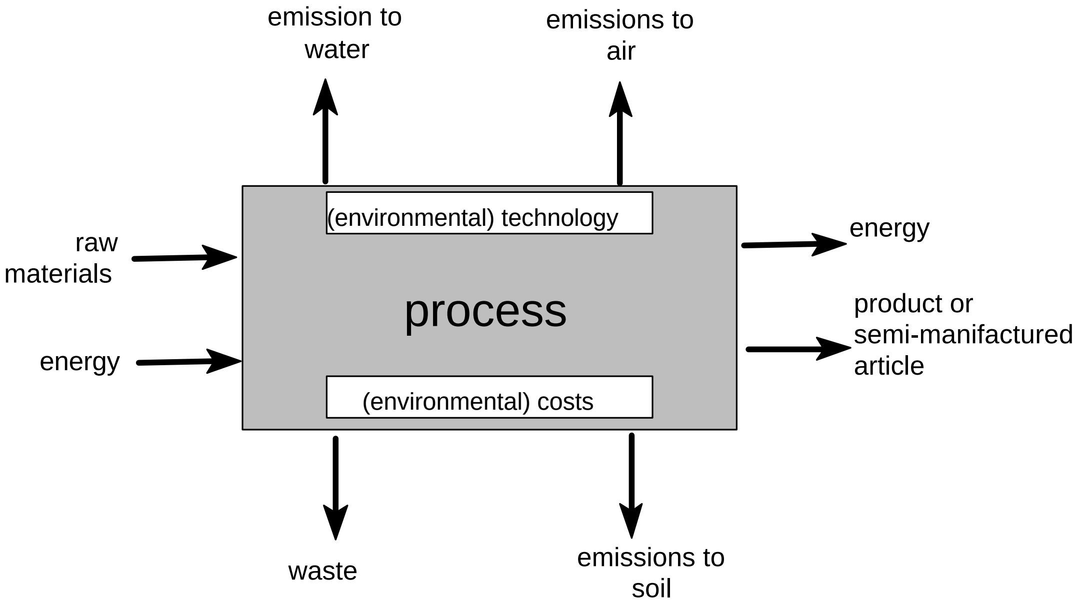

Figure 3 A schematic approach for production (and consumption) processes

The feasibility of moving towards an integrated approach regarding inventories is currently being investigated in several fora, e.g. the proposed PER (Polluting Emissions Register of the EU IPPC Directive, only focusing on large installations), the work on PRTR (Polluting Release and Transfer Registers) of OECD and the activities of EEA on an IEI (Integrated Emission Inventory). Extending the inventories to other media will lead to the requirement for projections of not only emissions to air but also of generated waste, emissions to water and consumption of energy and raw materials. Several methodological difficulties remain to be solved, e.g. in order to avoid double counting of emissions and to make sure that for a certain pollutant, all relevant sources are included.

Here, once more the emission factor approach can easily be applied, combining different pollutant and media specific emission factors with one sector specific activity rate and technology implementation share.

2.10 Physical growth and monetary growth

National and supranational production statistics are mainly based on the input-output-approach, which links different economic sectors by economic flows in monetary terms. Thus, a comparable dimension leads to a consistent representation of an economy. However, since for emission inventories and projections data are mainly required in physical terms, it is difficult to derive the respective physical flows from the monetary flows. Relations are very dynamic and include rather different economic trends, thus, further uncertainty is induced.

Thus, a detailed methodology is required in order to derive activity rates in physical dimensions from data in economic dimensions. In this respect, the support of experts on statistics is very important.

2.11 Release version, data and source

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3 INTRODUCTION TO SECTORAL PROJECTIONS

Sectoral projections in the framework of the Atmospheric Emission Inventory Guidebook mean projections of air pollutant emissions on various levels. These sectoral projections can be subdivided into two broad categories with different levels of aggregation:

- “aggregated” sectoral emission projections: SNAP level 1 (or 2),
- “detailed” sectoral emissions projections: SNAP level 2 (or 3).

In all cases, the previously described emission factor approach (“the basic formula”) is used, but on different levels of aggregating both the activity rates and the emission factors, as explained below.

In the following sections, (production) processes are distinguished, which comprise a variety of technologies, fuels and other input material. For the preparation of emission projections, the three types of data required according to the basic formula are: future activity rates, emission factors and technology shares (penetration rates).

For emission inventorying purposes, activity data for the past are required, which are to a large extent available from existing statistics. Thus, problems to be solved for emission inventories are mainly: sectors not covered by statistics, compatibility problems in terms of definition, dimension and units, and required accuracy.

Emission projections require appropriate future activity data. These are available as “externally authorised” scenarios only in a few cases, like for example the Conventional Wisdom energy scenario developed by the Commission (DGXVII) (EC, 1996) used for various studies within EU (acidification strategy) and UN/ECE-CLRTAP. For example for many of the assessments prepared by IIASA for the Task Force on Integrated Assessment Modelling (TFIAM) in the framework of the second NO_x Protocol (or “multi-pollutant, multi-effect”) use is made of these consistent energy scenarios for individual EU member states. It is important to start preparation of baseline emission projections using such authorised scenarios to increase consistency and credibility of the results. IIASA makes use of an aggregated sector definition, which is to a large extent based on the SNAP system , see for more details the IIASA Internet site http://www.iiasa.ac.at/~rains/.

If more detailed sectoral scenarios are required (e.g. on SNAP level 2 and/or 3), then these could be derived from the past development in a sector. Detailed expert knowledge with regard to possible future developments is then needed, since trends may undergo structural changes in the future, which however may already be foreseeable to a certain extent (for example phasing out of leaded petrol). As mentioned before, with missing activity forecasts on the sectoral level, forecasts on an aggregated level may be helpful. For instance, cement production rates could be related to projected numbers of dwellings, households or total population of a country.

It should be noted that, when moving away from the technology level, emission factors need to be aggregated as well, which should be done in a consistent and transparent way.

Available information on emission factors on a detailed level (SNAP level 2 or 3) is given in the sector specific chapters of this Atmospheric Emission Inventory Guidebook, and is therefore not repeated here.

Technology shares or penetration rates have to be derived from knowledge of the technology structure within a certain sector of a country. These data are therefore rather country specific and to a large extent determined by environmental legislation, but also by behaviour.

The above mentioned subdivision regarding the level of detail in the identified source sectors is worked out in each sections by means of a “simple” and a “detailed” approach. In the simple approach, projections are carried out on a more aggregated level (SNAP level 1 or 2; e.g. iron and steel production), whereas in the detailed approach, projections on the detailed sectoral level are covered (SNAP level 3; e.g. electric furnace steel plant), based on separate activity and emission factor projections and accounting for detailed properties of processes.

A sectoral emission projection according to the CORINAIR 90 structure (incl. some appropriate subdivisions) may lead to more than 300 single sectors to be balanced and provided with data (cf. Holtmann et al. 1995), which could require much effort. When only a set of already given default data is to be modified, the resulting effort will be much less. The choice of any approach (“simple” or “detailed”) depends on several aspects:

- the availability of appropriate data (in particular future activity rates);
- the level of detail required;
- the available time for performing projections.

It should be noted that the required level of detail depends on how the way various scenarios are being prepared to reflect possible policies and measures and simultaneously reflect possible trends in the societal trends. Using the basic formula this means that on a sectoral level the level of detail should be such that it is possible make the following adjustments:

- change in activity rate (this can be the result of policies, but often it is determined by various other driving forces);
- change in the emission factors and penetration rates (technology shares), on the level that the policies are (expected) to influence these.

Finally, in general there should be a balance between the required detail in the result (projected emissions), the level of detail of available data on future activity rates and the level of detail in emission factors (and the penetration rate of technologies).

4 COMBUSTION PROCESSES (SNAP 01, 02, 03, 07, 08)

SNAP CODES: **01, 02, 03, 07, 08**

SOURCE ACTIVITY TITLE **Combustion of (fossil) fuels (SNAP 01, 02, 03, 07, 08)**

4.1 Activities included

This chapter covers emissions related to energy use:

SNAP sector	Description
1	Combustion in Energy and Transformation Industries
2	Non-industrial Combustion Plants
3	Combustion in Manufacturing Industry
7	Road Transport
8	Other Mobile Sources and Machinery

The SNAP sectors road transport (07) and other mobile source and machinery (08) are described in more detail in a separate chapter. For specific cases such a more detailed method is advisable. It depends on the purposes of the use of the emission projections whether the more simple/general approach of this chapter can be used or whether the more detailed method, separately described, should be used.

4.2 General description

Emissions caused by the combustion of fossil and other fuels comprise a large part of the emissions of the pollutants involved in climate change and acidification. When no technological developments are considered, the projected emissions can be derived in a rather straight way from projected energy consumption (see also par. 2.4.3).

4.3 Simple methodology

4.3.1 Assumptions

A full emission inventory is available for a certain base year by at least SNAP main sector and fuel.

Energy use per fuel and per sector for the base year is available for instance for the year 1995 as in table 4.1 for all Parties to the UNECE/CLRTAP Convention in Europe.

Energy projections, for example the RAINS OEP (official energy pathways, UNECE) scenario are available. An example of such a projection for the year 2010 is summarised in table 4.2.

The emission projection should be made using the basic equation

$$E_{pollutant} = \sum_{activities} A_{activity} \times (\sum_{technology} F_{technology,pollutant} \times (P_{technology}))$$

with	$E_{pollutant}$	Emission of the pollutant under study
	$A_{activity}$	Activity rate for each activity
	$F_{technology, pollutant}$	Emission factor for the activity and the pollutant
	$P_{technology}$	Penetration of the technology, with $\sum_{technologies} P_{technology} = 1$

4.3.2 Projected activity rate changes (energy scenarios)

In the simple approach for energy related emissions, the activity can be interpreted as the per sector and per fuel energy use in the inventory and in the projected year. The above formula then reads:

$$E_{pollutant} = \sum_{\substack{activities\\fuels}} A_{\substack{activity\\fuels}} \times (\sum_{technology} F_{technology,pollutant} \times (P_{technology}))$$

To use the simple method in a first step thus a combination should be made of:

1. the sectors discerned in the projection table (of future energy consumption per sector) and the technology split available in the inventory and of
2. the fuels as used in the projection and in the inventory.

In most cases such a transformation table is not difficult to make. The exact form of it will depend on national peculiarities, but from the definitions of both activity and fuel splits in the energy balance for the most recent (current situation) and in the inventory it can relatively easily be derived.

To compile the projection all activity rates *A* (fuel uses) should be replaced by the expected future values in the projected year.

4.3.3 Technological development: emission factors

It is expected that in most projections some assumptions on technological development and the introduction of new technologies must be assessed. In the above formula this means that the emission factors should be modified according to the technological assumptions in the projection. Again such assumptions will depend on national peculiarities. Some examples might be:

1. Lower sulphur levels in all or certain fuels: multiply all SO_2 emission factors by the expected decrease;
2. The introduction of un-leaded gasolines: replace all Pb emission factors for road traffic by zero’s;

3. Introduction of abatement technologies at certain activities and fuels:
   - BAT: assume the penetration rate $P_{technology}$ = 1 for the technology where the emission factor is lowest for each of the activities and $P_{technology}$ = 0 for all others;
   - De-NO_x add on technology in power plants: replace all NO_x emission factors for power plants with new lower values, incorporating the NO_x removal efficiencies.

4.3.4 Policy development: penetration

The third aspect in the above formula is the policy induced or autonomous penetration of new technologies into the economic system. This is mainly relevant when a projected time series of emissions is to be produced. Such projections can be made on the basis of assumptions on the replacement of existing technologies and plants by newer ones, by deriving time series of expected penetrations Ptechnology. Such time series need to be dependent on economic model outputs like investments. However in most cases a projection which assumes a high penetration rate of 1 (in case of BAT), as described above.

Table 0-1 Energy use in EU 15 for the year 1995 (PJ) in the Official Energy Pathway scenario as defined in the RAINS model[1]

	Bro high grade	Brown coal/lignite, low grade	Derived coal (coke, briquettes)	Hard coal, high quality	Hard coal, low quality	Hard coal, medium quality	Heavy fuel oil	Light fractions (gasoline,kerosen, naphta,LPG)	Medium distillates (diesel,light fuel oil)	Natural gas (incl_ other gases)	Nuclear	Other solid-high S (incl_ high S waste)	Other solid-low S (biomass, waste, wood)
Fuel production and Conversion - Combustion	13	0	6	57	0	0	560	735	0	388		0	21
Fuel production and Conversion - Losses	0	0	3	135	0	0	203	6	0	159		0	1
Households and other	102	0	162	227	0	0	69	526	3,365	4,812		0	374
Industry - Combustion in boilers	17	0	0	0	14	10	28	0	136	548		106	51
Industry - Other combustion total	53	0	1,211	561	2	2	1,214	315	445	2,973		0	337
Non-energy use	6	0	34	18	0	0	1,393	1,669	45	418		0	0
Power Plants & distr. heat plants - Ex. other	2,203	0	0	3,232	55	0	1,451	18	1	1,393		8	201
Power Plants & distr. heat plants - Ex. wet bottom	0	0	0	736	0	0	0	0	0	0		0	0
Power Plants & distr. heat plants - New	160	0	0	476	8	21	565	5	35	1,221		10	164
Power Plants & distr. heat plants - total (calc)	0	0	0	0	0	0	0	0	0	0	7,370	0	0
Transport - Other	0	0	0	0	0	0	46	70	1,093	1		0	0
Transport - Road : Cars and Heavy duty trucks	0	0	0	0	0	0	0	5,486	3,790	10		0	0
Total	2,554	0	1,415	5,443	80	32	5,529	8,829	8,911	11,923	7,370	124	1,148

[1] The 'Official Energy Pathway', i.e., projections of energy consumption as reported by governments to UN/ECE and published in the UN/ECE Energy Data Base (UN/ECE, 1995a). Where necessary, missing forecast data have been constructed by IIASA based on a simple energy projection model.

Table 0-1 Energy projection for EU 15 in 2010 (PJ) in the Official Energy Pathway scenario as defined in the RAINS model[2]

Sector name	Brown coal/lignite, high grade	Brown coal/lignite, low grade	Derived coal (coke, briquettes)	Hard coal, high quality	Hard coal, low quality	Hard coal, medium quality	Heavy fuel oil	Hydro	Light fractions (gasoline,kerosen, naphta,LPG)	Medium distillates (diesel,light fuel oil)	Natural gas (incl_ other gases)	Nuclear	Other solid-high S (incl_ high S waste)
Fuel production and Conversion - Combustion	13	0	6	65	0	0	598		692	5	485		0
Fuel production and Conversion - Losses	0	0	3	99	0	0	188		5	0	274		0
Households and other	37	1	46	44	0	0	60		535	3,126	5,886		0
Industry - Combustion in boilers	31	0	0	20	12	8	43		0	123	588		146
Industry - Other combustion total	75	0	1,027	502	3	2	1,134		350	548	3,702		0
Non-energy use	10	0	5	32	0	0	1,357		1,710	67	443		0
Power Plants & distr. heat plants - Ex. other	538	0	0	1,763	14	0	682	0	11	18	687		9
Power Plants & distr. heat plants - Ex. wet bottom	0	0	0	321	0	0	0	0	0	0	0		0
Power Plants & distr. heat plants - New	1,533	0	0	3,339	44	89	1,176	0	26	63	4,474		22
Power Plants & distr. heat plants - total (calc)	0	0	0	0	0	0	0	3,092	0	0	0	8,019	0
Transport - Other	0	0	0	0	0	0	44		69	1,059	2		0
Transport - Road : Cars and Heavy duty trucks	0	0	0	0	0	0	0		5,979	4,866	44		0
Total	**2,237**	**1**	**1,086**	**6,184**	**73**	**99**	**5,282**	**3,092**	**9,377**	**9,875**	**16,585**	**8,019**	**177**

2 The 'Official Energy Pathway', i.e., projections of energy consumption as reported by governments to UN/ECE and published in the UN/ECE Energy Data Base (UN/ECE, 1995a). Where necessary, missing forecast data have been constructed by IIASA based on a simple energy projection model.

4.4 Detailed methodology

Not yet developed.

4.5 Weakest aspects/priority areas for improvements in current methodology

Consistency in the use of methodologies and definitions (of sectors) for energy scenarios can be improved between countries. It is furthermore important that emission projections from stationary fuel combustion (the “energy sector”) are consistent and compatible with emission projections from transport. This means energy scenarios and scenarios for future transport (future passenger and freight kilometres) should be as far as possible made consistent.

4.6 Additional comments

No additional comments are given.

4.7 Verification procedures

Since current and future energy related emissions form a substantial part of total emissions it is important to compare national estimates (compiled with national models/methods) with “central” alternative estimates, such as in particular the energy scenarios, and related emissions, as prepared regularly by the Commission (DGXVII). Furthermore consistency should be checked between energy and transport scenarios.

4.8 References

See general references (paragraph 10).

4.9 Bibliography

See also general bibliography (paragraph 11).

4.10 Release version, data and source

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5 INDUSTRIAL PROCESSES (SNAP 04 and 05)

SNAP CODE **04-05**

SOURCE ACTIVITY TITLE **Production processes (SNAP 04) and extraction and distribution of fossil fuels and geothermal energy (SNAP 05)**

5.1 Activities included

Activities included in this category comprise production processes (SNAP 04) and extraction and distribution of fossil fuels and geothermal energy (SNAP 05). In more detail, concerned processes are:

- processes in petroleum industries, iron and steel industries and collieries, non-ferrous metal industries, inorganic and organic chemical industries, and wood, paper pulp, food, drink and other industries and cooling plants (SNAP 04).
- extraction and distribution of fossil fuels and geothermal energy, covering mainly production, treatment and distribution of solid, liquid, and gaseous fossil fuels (CORINAIR SNAP code 05).

No combustion processes are included in this section, these are covered by the CORINAIR SNAP source categories 03 (see chapter 4).

5.2 General description

For the sectors and pollutants considered here, mainly process performance and properties of input material are relevant for emissions. The dimension of any emission factor used must be compatible to the activity dimension, either both according to the CORINAIR structure or to any other approach. General parameters may influence the emission performance of relevant processes, such as input material, process design, available primary and secondary measures, etc. With regard to projections, specific assumptions are required for these parameters.

With regard to future activity rates for the concerned sectors, external scenarios are normally not available. However, for certain countries projected production rates for specific products, e.g. for PVC production, may exist, which can be used for sectoral activity projections.

The frame of the development of technology shares is given by environmental legislation for industrial processes in the respective countries. In such a given framework, autonomous technological change in terms of technology application takes place. In this respect, lifetime models can be applied, requiring data on average technology lifetime and age distribution of the collective of technologies considered within a sector.

5.3 Simple methodology

The simple methodology covers emission projections on higher levels than the sectoral (SNAP level 3) or technology level. Here for instance, the petroleum industries are being addressed, comprising transport and storage of petroleum products, service stations and other.

Activity data on these higher levels are given by statistics in terms of production indices (e.g. setting 1985 = 100), mineral oil consumption, in monetary terms, etc.

The determination of appropriate aggregated emission factors on such aggregated levels may turn out to be difficult, since rather different sectors have to be lumped together and weighted according to their contribution to a certain activity rate, which remains to be defined.

The frame of the development of technology shares is given by environmental legislation for industrial processes in the respective countries. In such a given framework, autonomous technological change in terms of technology application has to be accounted for on the required level of aggregation.

5.4 Detailed methodology

The detailed methodology enables for performing emission projections on SNAP level 3, thus activity data are needed on this level in terms of mainly physical output or throughput for the respective processes for a whole country. Very detailed data are available from statistics for many of these sectors, e.g. in terms of produced amounts, etc. However, for some sectors no activity data are available at all on the required detailed level and they may be derived from some overall indices.

Emission factors for many air pollutants on process level are available from a large variety of sources, such as this Atmospheric Emission Inventory Guidebook, and many other publications (see SPIN 1995, VDI-guidelines, US-EPA AP 42, etc.). Generally, it has to be stated that for industrial processes (SNAP 04), data are available to a very large extent, whereas for fossil fuel treatment (SNAP 05), emission factors are scarcely available for some sub-sectors in the required level of detail.

The assessment of the respective technology implementation shares requires a detailed consideration of relevant environmental legislation (especially regulations with regard to VOC emissions). Moreover, in this imposed framework, the autonomous technology change has to be accounted for e.g. by lifetime models. Therefore, some more technology properties are to be defined, such as average installation lifetime, age distribution, etc.

5.5 Weakest aspects/priority areas for improvements in current methodology

More research is necessary for sectors for which data are scarcely available, e.g. in terms of emission factors for the fossil fuel treatment sectors and for geothermal energy.

With regard to technology implementation shares, for the detailed methodology data are required in terms of average technological lifetime for specific processes. However, such data are scarcely available in the necessary detail. Here, some more research is required.

5.6 Additional comments

No additional comments are given here.

5.7 Verification procedures

Verification of activity data only seems possible to a limited extent, since external projections are scarce if not missing at all on the required level of detail. Here, reference to some projected overall production indices may be the only option, such as energy consumption or coal mining projections. Moreover, the future shares of renewable energy sources may strongly influence activity rates of SNAP 05 (if for example a 50 % share for solar electricity production for the year 2015 is estimated). Available emission factors have to be checked whether they fit to the considered case out of a wide range of processes with many possible modifications. Moreover, the respective technology implementation shares in the countries may not simply be in line with legislative requirements. They may not meet or even exceed them due to local agreements between authorities and companies. Thus, the real technological background is to be verified in several respects.

5.8 References

See general references (par. 10).

5.9 Bibliography

See general bibliography (par. 11).

5.10 Release version, data and source

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6 SOLVENT AND OTHER PRODUCT USE (SNAP 06)

SNAP CODE: **06**

SOURCE ACTIVITY TITLE **Solvent and other product use (SNAP 06)**

6.1 Activities included

With regard to industrial development and increasing emission regulation, this source category is of major importance. It generally comprises besides some few large installations especially many small sources releasing NMVOC-emissions. Here, in most sectors a large number of different technologies and substances have to be addressed. For instance these are different paint application processes in automobile production and repair, different printing processes (such as heatset offset, publication rotogravure, etc.), degreasing and cleaning of various substrates, the manufacture and processing of a large variety of chemical products, and others and as well the various substances used e.g. as solvents.

6.2 General description

For the sectors considered here, mainly the respective process performance is relevant for the emissions of the considered pollutants. The dimension of any emission factor used must be compatible to the activity dimension, either both according to the CORINAIR SNAP structure or to any other approach. Moreover, further parameters may influence the emission performance of relevant processes, such as input material, process design, available primary and secondary measures, etc. With regard to projections, specific assumptions are required for these parameters.

6.3 Simple methodology

Activity data are available in terms of overall solvent consumption or production indices for the solvent using branches.

Appropriate aggregated emission factors can be defined on the basis of general solvent consumption data including general assumptions for the overall abatement status in this source category. In practice, it is difficult to account for all existing technologies and their respective emission performance and to consider activity contributions of all of them. This is mainly due to the large number of small emission sources with rather different emission behaviour. In this respect, it may be case dependent how to integrate modifications within one sector into any aggregated parameter.

The frame of the development of technology shares is given by environmental legislation for industrial processes in the respective countries, whereby especially NMVOC emissions or solvent usage are reglemented. In such a given framework, autonomous technological change in terms of technology application has to be accounted for.

6.4 Detailed methodology

The detailed methodology aims at covering each individual sector (SNAP level 3) comprising a large number of solvent using technologies and related substances. Moreover, several subdivisions may be necessary (e.g. car painting subdivided into passenger cars, truck bodies, truck cabins and buses) in order to account for detailed technological properties and legislative reglementations.

The availability of statistical data for this source category is relatively good, however, for some sectors they remain to be derived from aggregated statistical data.

Emission factors are available to a large extent, since many recent activities and projects have focused on this NMVOC emission relevant source category. Extensive information is given e.g. in this Atmospheric Emission Inventory Guidebook, in publications of the US-EPA, of the Dutch KWS 2000 project, and many other publications (cf. Holtmann et al. 1995, Vol. III).

Due to the large number of small sources to be considered, it is difficult to assess the implementation status of abatement techniques and primary measures. Moreover, due to the small size of installations, they are very often not directly addressed by respective environmental legislation and hence not covered by respective statistics. Here, statistical approaches may be helpful to determine the required implementation shares.

6.5 Weakest aspects/priority areas for improvements in current methodology

For some sectors, availability of activity data on the required level of detail is still weak for the large variety of small sources. Appropriate data may for the time being be derived from aggregated statistical data, if no other source is available, such as production indices for the organic chemical industry.

With regard to technology implementation shares, for the detailed methodology data are required in terms of average technological lifetime for specific processes. However, such data are scarcely available in the necessary detail. Here, some more research is required.

6.6 Additional comments

No additional comments are given here.

6.7 Verification procedures

Verification of activity data only seems possible to a limited extent, since external projections are scarce if not missing at all. Here, reference to some projected overall solvent consumption indices may be the only option. Available emission factors have to be checked whether they fit to the considered case out of a wide range of processes with many possible modifications. Moreover, the respective technology implementation shares in the countries may not simply be in line with legislative requirements. Moreover, very often most of the small sources are not being addressed at all by national environmental legislation and thus only estimates are possible with regard to implementation shares of advanced technologies.

6.8 References

See general references (par. 10).

6.9 Bibliography

See general bibliography (par. 11).

6.10 Release version, data and source

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7 TRANSPORT (SNAP 07 and 08)

SNAP CODE **07-08**

SOURCE ACTIVITY TITLE **Road transport (SNAP 07) and other mobile sources and machinery (SNAP 08)**

7.1 Activities included

This section covers all mobile sources (SNAP 7 and 8). It includes road, rail, air and water transport as well as a range of off-road sources. It covers both passengers and freight transport. See the chapters on SNAP07 and SNAP08 in this handbook for more details.

7.2 General description

The detail of estimating emissions from these sources for the historic inventories is given in chapters on SNAP07 and SNAP08. These should be the basis for estimating emission projections for these sources.

Generally, projections of transport use are available in many countries and can form the basis of projections. However it is important to check how these projections are related to any other economic projections that may be being used. Transport activity projections may be directly related to assumptions about GDP growth and demographic developments, they may include assumptions about saturation and capacity of the transport network or they may be a demand model matching demand to supply without clear links to economic models. This is important where total national emissions are being projected and it the transport projections have to be added to other projections to give a total. Clearly they have to be compatible.

Changes in technologies are very important for projecting transport emissions. There have been substantial changes in the vehicle technologies used. The introduction of three-way catalysts on petrol-engined motor cars has reduced the emissions from new vehicles so much that emissions of NOx, CO, and NMVOC are currently falling in many countries while the use of these vehicles is rising. Therefore it is particularly important that the changes in engine and vehicle technologies are modelled correctly when considering transport emissions.

Legislation has been a driving force in the introduction of cleaner technologies for motor vehicles. This cannot be modelled from economic assumptions but needs to entered into a projection explicitly. It is important, therefore, to ensure that all legislation likely to effect emissions from transport sources is identified and its impact assessed.

7.2.1 Road Transport

Road transport (passenger and freight) is usually the largest transport source in a country. This Guidebook describes a detailed technological method of estimating emissions. One important feature is that the vehicle fleet is made up of a mix of vehicles built to meet differing regulations. The fleet receives new vehicles compiling with the latest emission regulations while older vehicles were built to meet lower standards. A projection of emissions from such a vehicle fleet should be based on the base year estimate with as few changes as possible. It should be assumed that current behaviour of homogeneous population groups in the same circumstances does not change unless there is a clear reason for this (e.g. modal choice; driving behaviour). But population characteristics may change (e.g. higher incomes, an increase in average age, smaller households) and circumstances may change (e.g. more or better infrastructure, higher fuel prices, other land-use patterns), resulting in other behaviour. Both influences can result in changes in e.g. average vehicle and trip lengths. There are a number of factors that need to be considered. These are described below.

- **Vehicle Standards**. New vehicles have to meet emission standards. These are being laid down for the future (but the proposed 2001 in the EU are not yet agreed). At this stage it is impossible to be precise about the way vehicles will meet future regulations. This is usually handled by assuming that future vehicles will just meet the future legislation. This has been a reasonable assumption in the past. It is possible to assume that a specific technology is used with specific emission rates, however its introduction cannot be guaranteed.

- **Fuel Quality**. A number of improvements can be made by changing fuel quality. Reductions in fuel volatility (measured as reed vapour pressure, RVP) will reduce evaporative emissions. Reductions is the sulphur content of fuel lead to improved catalyst longevity and reduce particulate emissions. However reducing the sulphur content of diesel fuel will, for example, reduce the particulate emissions of current vehicles but future vehicles will be designed to meet the vehicle standards legislation with the available fuel so projected emissions may not fall below that required by the vehicle standards regulation.

- **Inspection and Maintenance Programmes (I&M)**. These have been proposed as a way of improving the emission performance of the existing in-service fleet. It is possible that a large proportion of the emissions come from a relatively small fraction of the vehicle fleet. However the interpretation of this in emission projections needs some care. It is not clear that the emission factors used actually include the highest emitters. Similarly the efficacy of I&M programmes is unclear. When making these kind of assumptions it must be stated explicitly exactly what is being assumed.

- **Retirement Programmes**. Incentives can be offered to encourage vehicle owners to retire old. High emitting, vehicles and but newer ones. This increased the fleet turnover and accelerates the introduction of new lower emitting vehicles.

- **Traffic Management**. Here measures are taken to encourage vehicle users not to use the vehicles as much; to use public transport for example. The types of measures should be considered. If only small areas are effected then there may be little effect nationally as vehicles are displaced onto other roads. The impact of changing speeds is also unclear. While traffic may be slower it may also include more acceleration and decelleration and so emissions may even rise in some situations.

- **Other policy measures.** The government can take other measures that influence passenger and freight transport, for example measures regarding fuel prices, land-use planning, parking facilities and parking prices.

7.2.2 Aircraft

Aircraft use is expected to rise and projections of this are available across Europe. Emission rates from the latest aircraft are available and, given the long lifetime of aircraft this should give a good indication of the future.

It is important to remember what is being included in the inventory. Landing and take off cycles (LTO) are only part of the flight. In addition recent discussion on differences between airports has shown that there can be large differences in the LTO emissions between airports that are caused by distance travelled on the ground and airport operation. Increased congestion at airports may also effect this in the future.

7.2.3 Shipping

Ships typically have long lifetimes and so the introduction of any new technologies into the shipping fleets will be a slow process unless retrofitting is enforced. However changes to fuel quality will have an immediate effect. This is being currently discussed at the IMO (International Maritime Organisation).

The impact of fuel regulations, particularly sulphur contents will need to be modelled. Restrictions may only apply to certain areas and this will need to be considered as well.

7.2.4 Other Sources

These are a wide range of sources including railways, domestic machines such as lawn mowers, industrial compressors and forestry equipment such as chain saws and construction machinery such as earth movers. In general very little is known about these sources and even less about their future development. Therefore it is proposed that only simple approaches are used. Activity rates are assumed to grow in the same way as the appropriate sectoral economic growth unless more specific data is available.

7.3 Simple methodology

The simple method should be used where this was used in the historic inventory, the simple methods within the chapters in this Guidebook on SNAP07 and SNAP08. Activity rates in terms of transport mode demand are required. Future emission factors are determined by the appropriate legislation. Simple fleet turnover models may be needed to estimate the proportion of the fleet with new technology engines or abatement. The impact of fuel quality regulation should be included where appropriate as a general reduction in the emission factor. (For example, a 10% reduction in the fuel sulphur content would lead to a 10% reduction in emissions.).

The activity statistics that are needed are:
GDP growth by sector (for the off-road sources)

> GDP growth gives an indication of the assumed growth (scenarios) in this area. If more refined estimates are needed it is recommended that effort is focused on those sources with significant emissions.

Future population size, number of households and income per capita or household

These factors play an important role by the development of future passenger transport.

Future fuel prices

The development of fuel prices strongly depends on the development of the oil price (world market) and the taxes and levies raised by the government (possibly as part of the environmental policy); see also section 2.4.3 ‘Energy scenarios’.

With these statistics calculations can be made of transport volumes:

Future Vehicle Kilometres by Car, LGV, HGV, Buses and Motorcycles.

Ideally these should be by type of vehicle and road type (urban, rural, Motorway etc.). This is unlikely to be the case. However even a single general growth estimate will give a useful estimate.

Future Aircraft movements

Numbers of aircraft are needed together with their types. However, if growth in passenger numbers and cargo are given aircraft numbers can be estimated (remembering that aircraft capacities are growing).

Future Shipping movements

This is similar to aircraft movements.

Future Rail transport (passengers and freight)

Also similar to aircraft (and shipping) movements.

Future emission factors are determined simply from legislation. Shares of technologies can be estimated using a simple fleet model if nothing else is available. Fleet statistics are available except for off-road sources. In any one year the fleet changes as some vehicles are scrapped and new one enter the fleet. This can be modelled by

$N_y = (\Sigma n_{y-1,i} (1-s_i)) + E_y$ where

$N_y =$ Number of vehicles in the fleet in year y

$n_{y-1,i} =$ Number of vehicles in fleet in year y-1 of age i

$s_i =$ Fraction of vehicles of age I scrapped

$E_y =$ Number of new vehicles entering fleet in year y

7.4 Detailed methodology

If the more detailed approach was used in the base year then it should be used for the projections as well.

The more detailed methods described in the Guidebook chapters on SNAP07 and SNAP08 are used for emission projections as well. The more detailed activity rates have to be input or assumed from more general data. Where changes in some of the sub-sector splits are unknown (e.g. fraction of engines > 2 l) the current years data should be used.

Clearly not all the activity rate data needed will be available. However the increased quality off the results in reflecting the actual fleet composition and driver behaviour make the detailed approach worthwhile.

A few of the other mobile sources may give most of the emissions from SNAP 0806- 0809 (the “off-road” sources). Where this is the case these should be given more attention.

The activity statistics that are needed are:

GDP growth by sector (for the off-road sources)

GDP growth gives an indication of the assumed growth (scenarios) in this area. If more refined estimates are needed it is recommended that effort is focused on those sources with significant emissions.

Future population size, number of households and income per capita or household

These factors play an important role by the development of future passenger transport.

Future fuel prices

The development of fuel prices strongly depends on the development of the oil price (world market) and the taxes and levies raised by the government (possibly as part of the environmental policy); see also section 2.4.3 ‘Energy scenarios’.

With these statistics calculations can be made of transport volumes:

Future Vehicle Kilometres by Car, LGV, HGV, Buses and Motorcycles.

Ideally these should be by type of vehicle and road type (urban, rural, Motorway etc.). This is unlikely to be the case. However even a single general growth estimate will give a useful estimate.

Future Aircraft movements

Numbers of aircraft are needed together with their types. However, if growth in passenger numbers and cargo are given aircraft numbers can be estimated (remembering that aircraft capacities are growing).

Future Shipping movements

This is similar to aircraft movements.

Future Rail transport (passengers and freight)

Also similar to aircraft (and shipping) movements.

For emission factors, see the simple methodology as a starting point. Where extra data beyond basis growth in demand is required and is not readily available it should be assumed that the data in the historic inventory can be used. Thus age distributions, splits between road types and modes etc. Can all be assumed to be unchanged into the future.

7.5 Weakest aspects/priority areas for improvements in current methodology

The limitations of the current procedures are that they do not adequately reflect the detail of these emission sources. For example it is very difficult to capture changes in road transport between urban and rural areas. Projections will be limited to the detail of the traffic projections on which they are based.

Inter-modal shifts, from cars to trains or aeroplanes are modelled in some transport models but these often are not compatible with economic models and so it is difficult to have a projection that couples increasing wealth and travel in a totally satisfactory way.

On the other hand the approach does give a reasonable projection of the impact of legislation and other controls on emission.

Care must be taken by the user of this manual that they are aware of the limitations of their input data and that it is compatible with data used to project other SNAP codes, in particular energy scenarios (SNAP 01, 02, 03).

7.6 Additional comments

No additional comments are given here.

7.7 Verification procedures

Since current and future transport related emissions form a substantial part of total emissions it is important to compare national estimates (compiled with national models/methods) with “central” alternative estimates, such as the transport baseline emissions as prepared by the Commission within the Auto Oil 1 programme (1996) and the Auto Oil 2 programme (1999).

Furthermore consistency should be checked between energy and transport scenarios.

7.8 References

See general references (par. 10).

7.9 Bibliography

See general bibliography (par. 11).

7.10 Release version, data and source

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8 WASTE TREATMENT (SNAP 09)

SNAP CODE: **09**

SOURCE ACTIVITY TITLE: **Waste treatment and disposal (SNAP 09)**

8.1 Activities included

This source category is being addressed by many current environmental policies due to ist high emission relevance. It covers waste incineration (municipal and industrial wastes) open burning of agricultural wastes and other waste treatment such as treatment of waste water. Also cremation is part of this category of activities.

8.2 General description

Municipal and industrial waste incineration is a common activity to reduce the amount of waste to be landfilled in many countries. The specific properties of these wastes lead to hazardous emissions, which have to be reduced by technological, mainly secondary measures.

For the sectors considered here, mainly the respective process performance and the properties of the materials treated are relevant for the emissions of pollutants. The dimension of any emission factor used must be compatible to the activity dimension, either both according to the CORINAIR SNAP structure or to any other approach. Moreover, further parameters may influence the emission performance of relevant processes, such input material, process design, available primary and secondary measures, etc. With regard to projections, specific assumptions are required for these parameters.

8.3 Simple methodology

Since rather different source categories are concerned, only some specific ones may be considered on an aggregated level, such as waste incineration or waste water treatment.

Concerning future activity rates for aggregated sectors, existing country specific waste scenarios are useful concerning different waste producing sectors and the composition of wastes. With regard to other relevant sectors, such external projections normally are not available.

Emission factors as given in the respective sections of this Atmospheric Emission Inventory Guidebook for single technologies and materials to be treated have to be aggregated onto the required level. Here, additional knowledge on their respective contributions is required.

The frame of the development of technology shares is given by environmental legislation for waste treatment processes in the respective countries. In this framework, autonomous technological change in terms of technology application has to be accounted for.

8.4 Detailed methodology

The required level of detail for the assessment of activities on the sectoral level normally exceeds what is available from statistics, and thus assumptions may be required in order to derive these detailed activity rates from aggregated data. Concerning future activity rates for the concerned sectors, existing country specific waste scenarios are useful concerning different waste producing sectors and the composition of wastes.

Emission factors for e.g. waste incineration and waste water treatment on process level are widely available, e.g. from sources such as this Atmospheric Emission Inventory Guidebook, and others. For some other sectors, emission factors are scarcely available.

The frame of the development of technology shares is given by environmental legislation for waste treatment processes in the respective countries. In such a given framework, autonomous technological change in terms of technology application takes place. In this respect, lifetime models can be applied, requiring data on average technology lifetime and age distribution of the collective of technologies considered within a sector. Technology implementation shares are rather well known for waste incineration and waste water treatment, mainly due to stringent legislative requirements. However, for the other sectors of this source category, more research is required in order to gather such information.

8.5 Weakest aspects/priority areas for improvements in current methodology

For some sectors no activity data and emission factors are available at all, since they have not yet been addressed by specific research projects. Consequently, information on technology implementation shares and activity contribution is scarce as well for these sectors.

With regard to technology implementation shares, for the detailed methodology data are required in terms of average technological lifetime for specific processes. However, such data are scarcely available in the necessary detail. Here, some more research is required.

8.6 Additional comments

No additional comments are given here.

8.7 Verification procedures

Verification of activity data only seems possible to a limited extent, since external projections are scarce if not missing at all. Here, reference to some projected waste scenarios may be the only option. Available emission factors have to be checked whether they fit to the considered case out of a wide range of processes with many possible modifications. Moreover, the respective technology implementation shares in the countries may not simply be in line with legislative requirements. They may not meet or even exceed them due to local agreements between authorities and companies, mainly due to the public sensitivity as regards e.g. waste incineration plants. Thus, the real technological background has to be verified in several respects.

8.8 References

See general references (par. 10).

8.9 Bibliography

See general bibliography (par. 11).

8.10 Release version, data and source

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9 AGRICULTURE (SNAP 10)

SNAP CODE: 10

SOURCE ACTIVITY TITLE: Agriculture, forestry and land use change (SNAP 10)

9.1 Activities included

This section covers the following agricultural sources:

10 01 Cultures with fertilizers (except animal manure)

10 02 Cultures without fertilizers

10 03 On field burning of stubble, straw, etc

10 04 Enteric fermentation

10 05 Manure management

10 06 Use of pesticides

SNAP sources 10 07 - 10 19, covering managed forests and land use change, are not considered within this section.

9.2 General Description

Agriculture comprises a wide range of activities typified by small units, dispersed sources, and heterogeneous production practices. In addition, unlike pollutants produced instantaneously by combustion of fuels, generally under controlled conditions, emissions from agricultural processes tend to be released intermittently, over long time periods, and at rates strongly influenced by uncontrolled ambient physical conditions.

The main pollutants from agriculture are NH3, N20 and CH4. Overall the main sources are manure management, fertilizer use and enteric fermentation.

9.2.1 Emissions from fertilizer use

Being relatively simple compounds, fertilizer composition is unlikely to change significantly; any changes in emissions will therefore be due to changes in the type and volume of fertilizer applied, as well as the method of application in some cases. Therefore the activity level, or fertilizer application rate is the main parameter determining future emission levels from fertilizer use.

In general application rates of N fertilizers, the main source of agricultural N2O and a significant one of NH3, are gradually declining in the Europe. This trend is expected to continue in the EU due to extensification of beef production with resulting reductions in fertilizer application to grassland, better management of livestock wastes yielding higher N inputs from manure application, and developments in nutrient use efficiency for grain maize. Smaller sectoral increases in N fertilizer application, for example in fruit production (especially Spain and Portugal) will be outweighed in the overall trend (EFMA, 1997). Fertilizer consumption in the CEECs is likely to remain depressed in the medium term due to capital shortages.

9.2.2 Emissions from livestock

Emissions from livestock are dominated by ammonia from manure management. Livestock wastes contribute around three quarters of all ammonia emission in Europe, which in the context of increasingly effective controls on emissions of pollutants from fuel combustion, is itself becoming increasingly prominent in the total budget of acidifying air pollution in Europe.

Due to the complex interactions between emission at different stages of the waste management system, a new detailed methodology has been devised for calculating ammonia emissions from manure management. This replaces the emission factor approach, which forms the basis of most emission calculations in this guidebook, with a process-based model allowing integration of combined abatement techniques. This allows all technical aspects of future emissions, including penetration and effectiveness of abatement techniques, to be calculated together. In the calculation of future emissions with which this section deals, therefore, we need only be concerned with forecasting the activity level within each specified sector (see Section 2.2).

For the purposes of emission calculations, activity levels are usually defined in terms of livestock numbers, while sector forecasts are usually concerned with production volumes of meat and other animal products. Although the relationship between the two is not static, and depends on factors such as yield (e.g. milk, eggs as well as meat) and weight at slaughter, in practice this does not seem to be a major difficulty.

Various techniques are used to predict future livestock production levels. For short-term forecasts, demographic analysis can often provide accurate projections for sectors with longer turnover periods (especially dairy cows), due to the lag time in replacement. Longer-term forecasts generally use econometric methods to predict interactions between supply and demand, market prices and policy instruments. These forecasts vary greatly in scale and complexity, construction of policy constraints, treatment of markets, interaction with external markets and trade balances, etc.

The complexity of economic and policy influences on future agricultural activity levels, and the diversity of different approaches to forecasting them results in a generally high degree of uncertainty in livestock projections beyond the short-term, and a lack of consistency between forecasts at different scales. For example national forecasts may provide the most accurate projections for individual countries, but when combined may not be mutually consistent in terms of trade and markets; while multi-national models may provide consistency in trade balances and production totals but give anomalous values for individual countries.

In the context of ammonia abatement, the accuracy of projections is particularly crucial, since the magnitude of potential abatement through technical measures is of a similar order to possible emission reductions resulting from changes in activity levels.

In addition to ammonia, activity level forecasts in the form of animal number projections could also be used in calculating future emissions of N2O from manure management, and CH4 from enteric fermentation.

9.3 Simple methodology

Several agricultural forecasting models and institutions exist in Europe, with a range of methodologies, coverage and types of output:

The ECAM model (European Community Agriculture Model), developed at IIASA (Laxenburg, Austria) and currently maintained at the Netherlands Bureau for Economic Policy Analysis (CPB), forecasts the effect of policy scenarios on production in the EU, including livestock number projections.

A family of models has been developed in collaboration between the Institute of Agricultural Policy (IAP, Bonn), the European Centre for Agricultural, Regional and Environmental Policy Research (EuroCARE, Bonn/Luxembourg) and Eurostat. SPEL was developed in the early 1980s as a tool for combining data on agricultural production and markets within the EU. WATSIM (World Agricultural Trade Simulation Model) is used for analysing the effects of EU policy on interactions with the world market. RAUMIS (Regionalised Agricultural and Environmental Information System) was developed to analyse the impact of policy and economic conditions on agricultural production and related environmental impacts in the German federal regions. CAPRI (Common Agricultural Policy Regionalised Impact analysis model) was initiated in 1997, and will use the RAUMIS approach to model production and environmental impacts in the EU regions, incorporating demand-side simulations and interactions with the world market.

AGLINK is a partial equilibrium model developed at OECD to analyse international agricultural markets. It is a policy-specific model, integrated with the OECD macro-economic model INTERLINK, and is used to produce market forecasts for the multi-sector outlook procedure.

Agricultural forecasts are also produced by FAO and DG VI of the European Commission, but more information is required on the outputs available from these. In the case of the latter there may be constraints on access to this information in the interests of confidentiality.

Forecasts of fertilizer use in the EU plus Scandinavia and a few CEECs are produced by the European Fertilizer Manufacturers Association (EFMA) up to ten years ahead.

National forecasts are also produced in several countries, though as discussed above, there may be considerable inconsistencies between these and forecasts made at international scales.

9.4 Detailed methodology

Not yet developed.

9.5 Weakest aspects/priority areas for improvements in current methodology

The main difficulties in the determination of activity projections for agriculture in Europe relate to choosing between the range of forecasts available, and ensuring consistency between countries in the overall volume of agricultural production and trade. Emission projections would benefit greatly from the establishment of guidelines on the use and adjustment of available projections, and the development of a thorough verification procedure to ensure consistency between countries.

9.6 Additional comments

A workshop was held under the Expert Panel on Emission Projections and Verifications in London in September 1997 to discuss agricultural projections in Europe. One of the main practical recommendations arising from the meeting was to establish a database of information on the structure, availability, coverage and outputs from the various forecasting models and bodies in Europe.

9.7 Verification procedures

Given the difficulties of ensuring consistency between countries discussed above, the establishment of a verification procedures for national forecast submission is particularly relevant for agriculture. However, no such guidelines have been determined as yet, and this should be a major priority for future work in this section.

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See also general references (par. 10).

9.9 Bibliography

See general bibliography (par. 11).

9.10 Release version, date and source

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IIASA : Sensitivity Analyses for a Central Scenario to Control Acidification, Eutrophication and Ground-level Ozone in Europe Report prepared for the 23rd Meeting of the UN/ECE Task Force on Integrated Assessment Modelling, Authors : Markus Amann, Imrich Bertok, Janusz Cofala, Frantisek Gyarfas, Chris Heyes, Zbigniew Klimont, Marek Makowski, Wolfgang Schöpp, Sanna Syri, March 1999.

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Annex 1A DEFINITIONS

The improvement of the methodological background of emission projections requires sound definitions in order to establish a consistent approach for all concerned countries. In this respect, the following definitions and explanations are proposed:

activity rate

Quantitative representation of the variable that "explains" the emissions in a source category, preferably in physical dimensions (e.g. produced mass of cement [Mg/year]) or otherwise in monetary dimensions (e.g. value of glass production [ECU/year]), either in emission inventories or in emission projections.

baseline scenario

Scenario that assumes no fundamental change in socio-economic developments and also implementation of current legislation (national and international regulations). This scenario is also sometimes referred to as a "business-as usual" scenario.

current reduction plan

Politically determined intention to reach specific national emission reduction targets (or "emission ceilings"), as defined in the various Protocols of the UN/ECE-CLRTAP. Such an emission reduction target is not regarded an emission projection.

current legislation

National (and/or EU wide) legal and regulatory measures in place at a certain date (e.g. within UN/ECE-CLRTAP often 31 December of the previous year is used as a criterion for determining current legislation).

emission factor

Specific value of an emission, mostly given in physical terms, related to the respective sectoral or process activity rate (e.g. for energy related emissions Mg/GJ).

emission inventory

Collection of emission data (Mg/year) for past and present times, according to a methodology (e.g. this Guidebook) with requirements regarding sectors, pollutants and the temporal and spatial resolution.

emission projection

Possible future development of emissions on the basis of socio-economic scenarios (future societal trends), future emission factors and future penetration rates.

penetration factor

Rate of implementation of a certain technology (e.g. an abatement technology) in a source sector. It represents the behaviour factors of the sectors in which the processes/technologies occur. It comprises a mixture of various aspects: legislative requirements, market shares in different sectors and dynamic behaviour of public technology acceptance.

policy in the pipeline

Proposed (inter)national legal and regulatory measures that are expected to be adopted within a short period, to be defined in each specific case (future measures can include emission limit values and economic instruments).

socio-economic scenario (future societal trend)

The future, estimated/modelled, trends of the most important and relevant socio-economic activities that influence the magnitude of emissions of a specific source sector and pollutant (e.g. energy scenario). Socio-economic scenarios are often use as external input for compilation of emission projections, as described in this Guidebook.

EUROPEAN TOPIC CENTRE ON AIR AND CLIMATE CHANGE (ETC/ACC)

UNDER CONTRACT TO

THE EUROPEAN

ENVIRONMENT AGENCY

Good Practice Guidance for CLRTAP Emission Inventories

Draft chapter for the UNECE Corinair Guidebook on Emission Inventories

To replace the

"Procedures for Verification of Emission Inventories" chapter

(Part B, verifn2)

Editors: Tinus Pulles and John van Aardenne

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Date: 7 November 2001

Contents

Section 1 Introduction

Tinus Pulles and John van Aardenne, ETC-ACC & Centre of Expertise on emissions and Assessment TNO-WUR.

1.1 Background

An emissions inventory is the foundation for essentially all air quality management programs. Emissions inventories are used by air quality managers in assessments of the contributions of and interactions among air pollution sources in a region, as input data for air quality models, and in the development, implementation, and tracking of control strategies. The importance of emissions inventory data increases with advances in the sophistication of the models and other analysis tools used in air quality management, and as a result, the interest in emissions verification is widespread.

This chapter on Good Practice is aimed at supporting parties to the convention in preparing inventories and reports that allow for [1]

(a) "*the process of considering Parties' reports on emission inventories and projections, including their technical analysis and compilation; and*

(b) *the process of verification and technical assessment, including expert review, of the emission reports and the evaluation of data quality for the purpose of the functions of the Implementation Committee (Executive Body Decision 1997/2, annex, para. 3 (c)).*"

This chapter replaces a similar chapter in earlier versions of the Guidebook. A revision was needed to reflect all aspects of verification and validation, including uncertainty estimation, identification of key sources, systematic resource prioritisation and quality assurance and quality control. This review also considers the major step forward that was made in the Greenhouse Gas Inventory Program of IPCC by publication of the report "Good Practice Guidance and Management of Uncertainties" in 2000 (IPCC GPGAUM)[2]. Although the approach in this report is comparable with the one chosen in the earlier versions of the Guidebook, improved harmonization asked for a rearrangement and rephrasing of major parts of its text. This chapter thus presents an approach to inventory verification and validation that is consistent with the approach chosen in the field of Climate Change and uses the achievements in this respect also within the framework of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP).

The table below presents the relation between the sections of this chapter and the chapters and annexes of the IPCC GPGAUM [2] report.

Sections in this document:	Related section of IPCC GPGAUM [2]
✓ Introduction & application of data	Chapter 1, Annexes 1 and 3
✓ Documentation of Data and Procedures	Chapter 8
✓ Good practice in inventory preparation - Methodological Choice	Chapter 7
✓ Uncertainty Estimates	Chapter 6 and “sector” chapters 2, 3, 4 and 5.
✓ Verification	Annex 2

This section will briefly summarize the line of thinking as described in IPCC GPGAUM as far as relevant for the UNECE/CLRTAP processes. It will define the three separate issues that are relevant with respect to inventory quality:

1) Verification and validation
2) Uncertainties; and
3) Good Practice

1.2 *“Verification” and “Validation”*

The purpose of verification/validation is to ensure that parties report accurately reasonable and reliable emissions data. In this paragraph we consider both the functions that should be carried out during the verification/validation process.

It is important to start by clarifying the distinction between *verification* and *validation*. In this chapter we use the following definitions, taken from the glossary of IPCC-GPGAUM[1], which are fully consistent with earlier versions of the Guidebook:

Verification	refers to the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of that inventory. Typically, methods external to the inventory are used to check the truth of the inventory, including comparisons with estimates made by other bodies or with emission and uptake measurements determined from atmospheric concentrations or concentration gradients of these gases.
Validation	is the establishment of sound approach and foundation. In the context of emission inventories, validation involves checking to ensure that the inventory has been compiled correctly in line with reporting instructions and guidelines. It checks the internal consistency of the inventory. The legal use of validation is to give an official confirmation or approval of an act or product.

[1] It is recommended to all user of this Guidebook to explicitly and exclusively use the terminology and definitions as presented in this Glossary.

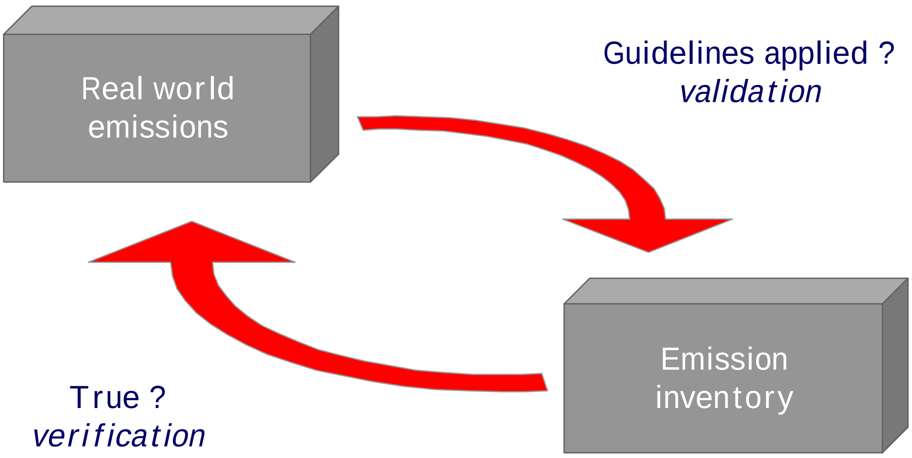

Figure 1 Schematic representation of the concepts of validation and verification

In Figure 1 the difference between validation and verification is schematically explained. *Validation checks whether or not the guidelines have been applied, whereas verification checks whether the data are true*. When the inventory is validated, it has been agreed that the guidelines have been correctly applied; therefore the emissions report is accepted for compliance purposes[2]. If verification then shows that the emissions report does not accurately reflect true emissions, this means that emissions determination guidelines need to be changed. But because the inventory compiler has followed programme rules, the emissions inventory and report is still accepted.

Over the long-term, verification may improve the emissions data quality and help to ensure that emissions determination methods accurately reflect true emissions. In the short-term, however, ensuring both that reporting is complete, transparent, consistent and in conformity with accepted standards, and that monitoring guidelines have been applied correctly, will give the user sufficient confidence in the possible application of the inventory in any policy process.

1.3 Uncertainties in an emission inventory

Uncertainty estimates are an essential element of a complete emission inventory. This concerns the ensemble of uncertainties associated with the data collected and with the aggregation thereof towards sector or national totals.

Given the uncertainty in the inventory, verification and validation of an inventory are two different aspects of the quality of an inventory. Validation is aiming at the acceptance of the inventory estimation procedures and verification is aiming at getting the true values. Tools to support these activities include quality assurance / quality control (QA/QC) and verification.

A third aspect of an emission inventory is the ensemble of uncertainties associated with the data collected and with the aggregation thereof towards sector or national totals.

[2] The Task Force on Emissions Inventories does not decide what will be accepted for compliance purposes.

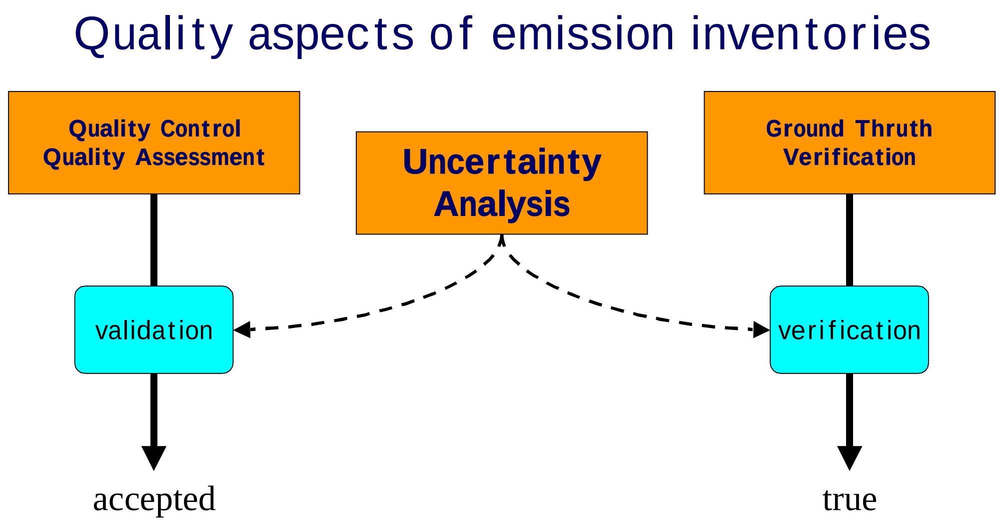

Figure 2 Uncertainty analyses to improve the quality of an emission inventory

It is important to realize that uncertainty information is not intended to dispute the validity of the inventory estimates, but to:

1) Help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice.

2) Inform users of inventory data on the scientific quality of the data, supporting them to perform uncertainty evaluations of their own applications and to consider the usability of the results of air quality models and projection studies.

Understanding the uncertainties in an emission inventory can support both the validation and verification of emission inventories (Figure 2).

Inventory practitioners understand that for many countries and source categories, emissions estimates are reasonably accurate. However, national inventories will typically also contain a wide range of emission estimates, varying from carefully measured and demonstrably complete data for some sources to order-of-magnitude estimates for others.

1.4 Good practice

In order to ensure that quality evaluation of an emission inventory and an emission report is possible, such an inventory and report should be compiled using "Good Practice". The IPCC GPGAUM report defines good practice as follows:

Good Practice	is a set of procedures intended to ensure that inventories are accurate in the sense that they are systematically neither over nor underestimates so far as can be judged, and that uncertainties are reduced so far as possible.

The IPCC GPGAUM definition of Good Practice covers

- ✓ choice of estimation methods appropriate to national circumstances,
- ✓ quality assurance and quality control at the national level,
- ✓ quantification of uncertainties and
- ✓ data archiving and reporting to promote transparency.

These requirements are to ensure that emissions estimates, even if uncertain, are bona fide estimates, in the sense of not containing any biases that could have been identified and eliminated, and that uncertainties have been minimized as far as possible given national circumstances. Estimates of this type would presumably be the best attainable, given current scientific knowledge and available resources.

Good practice aims to deliver these requirements by providing guidance on:

1) Quality assurance and quality control procedures to provide
   a) cross-checks during inventory compilation and
   b) definition of data and information to be documented, archived and reported;
2) Choice of estimation method within the context of this Guidebook;
3) Quantification of uncertainties at the source category level and for the inventory as a whole, so that the resources available for research can be directed toward reducing uncertainties over time, and the improvement can be tracked.

1.5 This chapter

This chapter provides guidance for emission inventory compilers to enable inventory compilation according to Good Practice. The chapter should be understood in close conformity with the IPCC GPGAUM report. It does not repeat all the explanations and procedures as described therein. We therefore recommend the reader to have a copy of this report at hand, while planning, preparing and compiling an emission inventory using good practice. A copy of the GPGAUM report can be down loaded from URL: http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm.

This chapter provides tools and methods the user might need for Good Practice inventory compilation.

Section 2 presents an overview of QA/QC aspects and proposes a general inventory QA/QC procedure

Section 3 deals with the planning phase of the inventory compilation and supports the selection of the most relevant sources, enabling the user to prioritise data collection efforts

Section 4 summarises the uncertainty analysis methods as described in the IPCC GPGAUM report for application in inventories under CLRTAP and its protocols

Section 5 finally gives some guidance on verification.

Section 2 Assessment and Management of Data Quality

Lee Tooly, *US EPA, OAQPS, Emission Factors and Inventory Group*

2.1 Introduction

The purpose of this section is to define the practice of quality control and quality assurance, as well as other techniques that may be used to assess and document the reasonableness of the emissions inventory data. Recommendations included here regarding QC / QA good practices are consistent with the IPCC GPGAUM. Excerpts from the Guidelines are included here to provide a context for discussing QC / QA activities for the CLRTAP emissions data. The reader should also obtain and read the noted chapters of the IPCC Guidelines, as they are incorporated here by reference and serve as the basis for this discussion.

In addition, this discussion describes a systematic approach that may be used to determine data quality objectives for the CLRTAP emission inventories. The approach is intended to help guide the inventory preparers in assessing and targeting the quality of the inventory data based on its anticipated uses.

2.2 Definition of QC / QA and verification

The terms ‘quality control’, ‘quality assurance’, and ‘verification’ are often used interchangeably, and in a non-distinct manner. The terms are distinguished here using the same definitions applied in IPCC GPGAUM, and are adopted for application to quality assessment activities for the CLRTAP inventories. (The following is taken directly from IPCC GPGAUM)

Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

- ✓ Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
- ✓ Identify and address errors and omissions;
- ✓ Document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source categories, activity and emission factor data, and methods.

Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, should be performed upon a finalised inventory following the implementation of QC procedures. Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC programme.

Verification processes are, in the present context, intended to help establish an inventory's reliability. These processes may be applied at either national or global levels of aggregation and may provide alternative information on annual emissions and trends. The results of verification processes may:

- ✓ Provide inputs to improve inventories;
- ✓ Build confidence in emissions estimates and trends;
- ✓ Help to improve scientific understanding related to emissions inventories.

The verification process can help evaluate the uncertainty in emissions estimates, taking into account the quality and context of both the original inventory data and data used for verification purposes. Where verification techniques are used, they should be reflected in the QC/QA plan. Improvements resulting from verification should be documented, as should detailed results of the verification process. Options or tools for verification are discussed in Annex 2 of IPCC GPGAUM.

2.3 Applying QC / QA techniques

The level of QA/QC activities should be compatible with the methods or tiers used to estimate emissions for particular source categories. Resources should be focused on priority areas, such as the key categories described in the section on 'Methodological Choice', and on priority areas identified when establishing data quality objectives. When much of an emission inventory is developed using default emission factors and aggregated activity data methods, QC procedures should focus on checking calculations and documentation. This is referred to as a "Tier 1" QC/QA approach. When national methods and data are used, instead of default data, and changes made in methods and data characteristics, a more extensive QC/QA approach should be used – this level of QC/QA is referred to as "Tier 2".

Under Tier 1, general QC procedures and a QA review of the inventory should be performed. General QC techniques focus on the processing, handling, and reporting procedures common to all inventory sources. The following table is reprinted from IPCC GPGAUM, Chpt 8, and summarises the Tier 1 General Inventory Level QC Procedures.

TIER 1 GENERAL INVENTORY LEVEL QC PROCEDURES	
QC ACTIVITY	**PROCEDURES**
Check that assumptions and criteria for the selection of activity data and emission factors are documented.	Cross-check descriptions of activity data and emission factors with information on source categories and ensure that these are properly recorded and archived.

TIER 1 GENERAL INVENTORY LEVEL QC PROCEDURES	
QC ACTIVITY	**PROCEDURES**
Check for transcription errors in data input and references.	Confirm that bibliographical data references are properly cited in the internal documentation. Cross-check a sample of input data from each source category (either measurements or parameters used in calculations) for transcription errors.
Check that emissions are calculated correctly.	Reproduce a representative sample of emissions calculations. Selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy.
Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used.	Check that units are properly labelled in calculation sheets. Check that units are correctly carried through from beginning to end of calculations. Check that conversion factors are correct. Check that temporal and spatial adjustment factors are used correctly.
Check the integrity of database files.	Confirm that the appropriate data processing steps are correctly represented in the database. Confirm that data relationships are correctly represented in the database. Ensure that data fields are properly labelled and have the correct design specifications. Ensure that adequate documentation of database and model structure and operation are archived.
Check for consistency in data between source categories.	Identify parameters (e.g. activity data, constants) that are common to multiple source categories and confirm that there is consistency in the values used for these parameters in the emissions calculations.
Check that the movement of inventory data among processing steps is correct.	Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. Check that emissions data are correctly transcribed between different intermediate products.
Check that uncertainties in emissions and removals are estimated or calculated correctly.	Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. Check that qualifications, assumptions and expert judgements are recorded. Check that calculated uncertainties are complete and calculated correctly. If necessary, duplicate error calculations or a small sample of the probability distributions used by Monte Carlo analyses.

TIER 1 GENERAL INVENTORY LEVEL QC PROCEDURES	
QC ACTIVITY	**PROCEDURES**
Undertake review of internal documentation.	Check that there is detailed internal documentation to support the estimates and enable duplication of the emission and uncertainty estimates. Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. Check integrity of any data archiving arrangements of outside organisations involved in inventory preparation.
Check methodological and data changes resulting in re-calculations.	Check for temporal consistency in time series input data for each source category. Check for consistency in the algorithm/method used for calculations throughout the time series.
Undertake completeness checks.	Confirm that estimates are reported for all source categories and for all years from the appropriate base year to the period of the current inventory. Check that known data gaps that result in incomplete source category emissions estimates are documented.
Compare estimates to previous estimates.	For each source category, current inventory estimates should be compared to previous estimates. If there are significant changes or departures from expected trends, recheck estimates and explain any difference.

In contrast to general inventory (Tier 1) QC techniques, source-specific QC procedures are directed at specific types of data used in the estimation methods for individual source categories. As a result, source-specific, Tier 2, QC activities include:

- ✓ Emission factor QC (including emission comparisons, and order-of-magnitude checks)
- ✓ Activity level QC (national and site-specific)
- ✓ QC of uncertainty estimates

The reader is referred to IPCC GPGAUM, Chpt 8 for a full description of these Tier 2 techniques.

2.4 Documentation

The QC/QA objectives and desired time frames should be documented in a written QC/QA plan. The results of all QC/QA checks, audits, and reviews performed should also be documented in an organised manner, which can be produced for an independent review.

2.5 Data quality objectives

This discussion of data quality objectives is not about statistical acceptance criteria, as the term may imply, but instead is intended to guide the inventory preparer's (and the user's) perception of data quality based on how well the data performs in its anticipated use(s). It is important that the data preparer has a clear understanding of how the data will be used, including any conditions that may constrain or limit successful use of the data, as well as consequences of submitting poorly formed data for a specific analysis. This may help facilitate a decision by the data preparer to participate more actively and fully in making relevant data checks and corrections early on in the data development process. At a minimum, such a process of establishing data quality objectives can fully disclose to both data preparers and users, the expectations of the data.

Besides assessment of compliance with the protocol, it is expected that the most rigorous uses of the CLRTAP/EMEP emission inventories will be the role they serve in integrated assessment modelling. The EMEP Task Force on Integrated Assessment Modelling identifies that more interaction is needed to provide the national data needed for the integrated assessment modelling (TFIAM, April 2000)[3].

Several models are used by the different EMEP modelling centres. One of the most prevalent models is the RAINS model, implemented by the Centre for Integrated Assessment Modelling (CIAM) at IIASA (International Institute for Applied Systems Analysis). Using the RAINS model as an example, what circumstances of the emissions inventory data may constrain or limit its successful use in RAINS? Instances are described in which the RAINS modeller must first solve for missing emissions inventory data prior to using it (On-line RAINS)[4]. For instance, for missing source sectors, or sectors with incomplete emissions information, emissions data values are assumed, including:

- ✓ uncontrolled emission factors;
- ✓ process control devices and efficiencies;
- ✓ process specific energy (activity) scenarios; and
- ✓ emissions

To help refine or reduce the assumptions made about the data, while it is being used, the quality assessment of CLRTP/EMEP emission inventories should then also involve collaboration between the data developers and the users, such as the integrated assessment modellers. Establishing shared data quality objectives in a collaborative manner, and early in the data development process, may help ensure successful use of the emissions data by the models. The result of such collaboration may include a specific list of data checks that can or should be occurring as part of the emissions data development effort, and an agreement on the type of documentation useful to indicate what checks were done and those findings. As part of the quality assessment activities, inventory data developers are encouraged to contact their EMEP modelling centres to discuss and define these data objectives.

Section 3 Good Practice in Inventory Preparation - Methodological Choice

By Kristin Rypdal, Statistics Norway

3.1 Introduction

The Emission Inventory Guidebook gives for most sources a tiered methodology, at least at two levels. The simple methodology will frequently be quicker to perform, but also less accurate, than the detailed methodology. At the same time an inventory compiler has limited resources and will be unable to implement the detailed methodology for all sources. By identifying the key parameters (or sources), the inventory compiler may be able to better prioritise the inventory resources. The identification of key sources may be based on a simple sensitivity analysis. A sensitivity analysis may also be useful to test the influence of individual assumptions on the inventory conclusions. Application of sensitivity analysis for the identification of key sources is described in section 3.2.

Emissions reporting obligations for CLRTAP Protocols include the development of a time series of data usually beginning with a base-year. It is desirable that the reporting for all years are consistent (in applied estimation methods) with the base-year. If methodologies are changed and the new methodology cannot be implemented for all years, it might be difficult to maintain a consistent time series. In this case, methodologies are spliced, approximating the consistency of the time series. Options are summarised in section 3.3.

Inventory methodologies are continuously in progress. The implementation of a new methodology often has an effect on previous estimates and the whole time-series needs to be recalculated. When to recalculate is discussed in chapter 3.4.

3.2 Identification of key parameters and assumptions

As different sources have variable uncertainty, the contribution to total inventory uncertainty will vary among sources. Clearly most is gained by reducing the uncertainty in the sources contributing mostly to the overall uncertainty. In the dynamic process of improving the inventory is it consequently essential to be able to identify the sources where choice of methodology is critical for the inventory applications. Which sources that are identified as key are will vary among countries. Some sources are likely to be identified as significant in all countries, while other sources e.g. specific production processes may be absent or small in some countries and very important in others.

This chapter outlines criteria for determining key parameters (emission factors and activity data separately or measured emission levels) and describes how to apply them to national inventories. Theory is taken from IPCC GPGAUM [2], which is based on Flugsrud et al (1999) [5] and Flugsrud and Rypdal (2001) [6].

As described below the evaluation can be at the source level or at the parameter level. The evaluation is made for each gas separately (for the GHG the GWP weighted emissions).

3.2.1 Criteria for identifying key parameters

Which parameters to consider key will depend on the *inventory applications*. An accurate emission inventory shall give as correct figures as possible for the level and trend of the emissions.

For compliance assessments the trend is essential, while for scientific assessments and evaluation of the most cost-effective abatement measures, a more rigorous assessment is necessary. When emission-reporting obligations are formulated as emission ceilings, the emission level uncertainty only is relevant. A key parameter is here defined according to the main applications of inventory data:

A key parameter is a parameter that has significant influence on either the inventory total emissions or trend or their uncertainties.

Thus, parameters that contribute significantly to the total emissions and parameters contributing to rapid changing emission level should generally be considered key. Other considerations can also make a source key, such as:

- point sources (the major pollutants emitted)
- sources with a high estimated uncertainty, even if the contribution to total emission is low
- sources where national emission factors used are far lower than the information given in the 1996 Revised IPCC guidelines [7] or Emission Inventory Guidebook imply
- sources being abated when the simple methodologies not are detailed enough to detect mitigation options, and
- sources where future growth or decrease is expected

3.2.2 Sensitivity analysis

A typical inventory is based on a large number of data of which many have high uncertainties. Some of these data are likely to be more important for the inventory conclusions (level and trend) than others. According to Morgan and Henrion (1990)[8] a sensitivity analysis may be defined as *the computation of the effect of changes in input values or assumptions on the output*. It is generally expected that the variability of the output can be related to variability of a limited number of input parameters (Cullen and Frey, 1999)[9]. The purpose of a sensitivity analysis for inventory compilers is to identify which individual parts of the inventory might influence their conclusions.

A sensitivity analysis may be performed at several levels [8]:

a) analysis of each parameter separately, holding other factors constant

b) deterministic joint analysis, varying more than one factor at the time

c) parametric analysis, moving one or more input parameters across reasonable selected values

d) probabilistic analysis, using correlation or other means to examine how much uncertainty in conclusions is attributable to which inputs

All these approaches are relevant and useful for inventory applications. a) and d) can be used to identify key sources in a systematic manner, while b) and c) are in particular useful to test out the effect of assumptions or selected parameters.

3.2.3 Approaches to identify key sources

a) Sensitivity analysis - state of the art methodologies

In combination with a modelling of uncertainties is it simple to perform various types of sensitivity analysis. Both option a) and d) above can be a part of a standard analysis.

Option a) will often be based on compiling the terms elasticity and uncertainty importance as shown below. Nomenclature is based on [8]:

The elasticity:

$$U_E(e_i, E) = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \frac{e_i^{\,0}}{E^0} \qquad 1)$$

Where E is the total emission and e_i is input parameter *i*

The uncertainty importance:

$$U_G(e_i, E) = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \sigma_{e_i} \qquad 2)$$

Where σ_{ei} is the standard deviation of the input parameter e_i.

This may also be modified into a normalised quantity, the "uncertainty importance elasticity" (U_{GE}), that is

$$U_{GE}(e_i, E) = U_E(e_i, E) \times \frac{\sigma_{e_i}}{e_i^{\,0}} = \left[\left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \frac{e_i^{\,0}}{E^0}\right] \times \frac{\sigma_{e_i}}{e_i^{\,0}} = \left[\frac{\partial E}{\partial e_i}\right]_{E^0} \times \frac{\sigma_{e_i}}{E^0} = \qquad 3)$$

If uncertainty estimates are available, the best option to identify key parameters is to compile the uncertainty importance. Sources can then be ranked by decreasing value of uncertainty importance. For the greenhouse gases it is suggested to rank sources until 90 % of the total uncertainty is accounted for [2], [5], [6]. This value is probably appropriate as a rule of thumb for other pollutants as well.

When using the state of the art methodologies it is possible to assess separately the contribution from emission factors and activity data.

b) Sensitivity analysis - simplified approaches

Uncertainties in inventory data are often not known. The simplified approach proposed can be used to assess the key sources without specific knowledge of uncertainties. The assessment can be made with the aid of a spreadsheet in a quite short time. The level (detail) of analysis is very important, see section 1.3.3.

For the greenhouse gases the approach given in [2] is recommended.

The approach below is suggested for the other pollutants.

It is assumed that for a given pollutant the uncertainty of each source is approximately equal. If this assumption not is valid, one of the state of the art approaches must be used. The simple approach is applicable on the source level only.

Level evaluation

The recommended approach is to list and rank the contribution from each source (fraction of total emission) until 95 % of the total emission is accounted for. In addition, possible additional sources accounting for more than 1% of total emissions should individually be included. This simply means that the largest sources are the key sources.

Trend evaluation

The trend elasticity with respect to source emissions level can be expressed as [6]

$$U_E(e_i^0,T) = U_S(e_i^0,T) \times e_i^0 = \frac{e_i^0}{E_0} \times (t_i - T) \qquad 4)$$

Where t_i is the source trend and T is the total trend.

When goals are formulated as percentage reductions the recommended approach is to list and rank the contribution from each source according to this equation until 90 % of total the total values is accounted for. In addition to the largest sources, the sources with highly changing trend will be identified as key.

When goals are expressed as emission ceilings, key parameters can be evaluated by ranking the absolute changes in source level. However, the large sources will usually dominate the changes in absolute terms so the results will likely be quite similar to the level evaluation.

c) Correlations and level of analysis

The output of a sensitivity analysis is obviously very dependent on the level of aggregation of the analysis. Several of the input data may be correlated for instance if they are assumed equal, based on the same basic data or restricted for example by a top down distribution. In the detailed approaches such dependencies may be modelled. In a simplified analysis the dataset will need to be aggregated to a level where correlations are eliminated. A detailed analysis is the best in order to properly assess what parameters actually are key (which may be masked by aggregation).

For the GHG a suitable level of analysis was suggested in IPCC GPGAUM. This level of aggregation has been suggested to avoid dependencies, but may mask some information.

For the other gases the starting point of analysis should be SNAP level 2or 3 with a rough fuel split. Further aggregation should be made to get rid of dependencies for example in the case of SO_2 where the same emission factors may have been used for many sources.

When analysing the trend it should be taken into account that the same emission factors often are used for both the start and end year, which implies that they should be treated as correlated. Activity data are often assumed independent in such an analysis. Measured emission data may also be considered independent if there not are any apparent systematic errors.

3.2.4 Practical consequences

For greenhouse gas inventories decision trees have been proposed guiding the inventory compiler to choose the correct level of methodology [2]. Such decision trees have not been made for the LRTAP gases. However, the same principle can be followed for all types of pollutants. In principle, the detailed methodology (or a state-of-the-art national methodology) should be selected for key sources. For non-key sources a simpler methodology is appropriate. If a methodology not proposed in the Emission Inventory Guidebook is used, this methodology (and emissions factors) should be properly documented.

An emission inventory is based on a large number of assumptions. An inventory compiler will often feel uneasy about many of these. Performing a simple sensitivity analysis is extremely useful for testing out the effects of the various assumptions made in the inventory on the level and trend. Obviously, if the conclusions are sensitive to an assumption made more work should be prioritised for that particular assumption while an assumption that proves to have a minor effect could be left as it is.

3.3 Splicing of methodologies

The option of splicing of methodologies implies that consistency of a data time series is approximated without using the same methodology for every year.

The methodologies below are not ranked; they may all be applicable depending on data and circumstances. It may be a good idea check out several of the splicing methods suggested below for consistency. No clear distinction is made between splicing due to discontinuity of input data and other problems using the same method for every year.

In general, few of the splicing methodologies are valid when technical conditions are changing throughout the time series e.g. as abatement is introduced. These can only be captured by using a complete methodology or have to be corrected for ad hoc.

The methodologies below are taken from [2] and [5], these reports also provide more details and examples.

a) Overlap

Whenever the methodology is changed, the output from the new and old method should be compared, both the level and trend. If the new methodology cannot be used for all years, an option is to use the overlap deviation to adjust the time-series. If x_o is the base year, and if the first year with estimate from the new methodology is *m*, the new emission estimate for this year is y_m, and the original estimate x_m, then a revised emission estimate for the base year may be expressed as

$$x_0^* = x_0 \times \frac{y_m}{x_m}$$

This simple method follows from the following three requirements to the revised estimates:

1. Estimates with the new methodology are assumed to be most correct in all years of overlap between methods.
2. There should be no break in the time series between the revised original estimates and the new methodology, *i.e*, the combined time series is consistent.
3. The revised time series should be a simple scaling of the estimates from the original method. This is equivalent to assuming that the new methodology would give the same trend for the period as the original method (as yearly percent changes).

The third requirement may be inappropriate for some sources. For example, the difference between the new and original estimates might be assumed to be constant. In this case, the revised estimate for the base year should be estimated as

$$x_0^{**} = x_0 + (y_m - x_m)$$

If there is more than one year of overlap between the new and the original methodologies, the first two requirements leads to the conclusion that only the first year of overlap should be used for recalculation. If we relax the second requirement and accept a break in the time series, we can reformulate the first expression, replacing the simple ratio y_m/x_m with an average over the overlap period (*n* is the last year with estimates from both methodologies):

$$x_0^{***} = x_0 \cdot \left(\sum_{i=m}^{n} y_i \middle/ \sum_{i=m}^{n} x_i \right)$$

It seems to be a conflict between the wishes on one hand to get a consistent time series without breaks, and on the other hand to use all information from the overlap of the methodologies (a break in time series is not according to good practice). However, if the trend is the same in both methodologies, *i.e*., they differ only in level, then both methods for recalculating x_o will give the same result. If the difference in trend between the methodologies can be ascribed to random errors, then using only one year as the basis for rescaling may lead to bias, and the last expression using the average ratio should be used. If the trends are very different, then it may be more appropriate to use one of the extrapolation techniques described below.

b) Extrapolations and interpolations

If the methodology is too resource demanding to perform every year an option is to perform a complete calculation for some years and interpolate for the years in between. The interpolation could be arithmetic, but preferable simple corrections for variations in activity level should be made.

If an estimate for the base year not is feasible it may be extrapolated from the estimate most close in time using rate of change of activity and possibly other corrections. See “surrogate extrapolations” below for an equivalent description.

c) Surrogate extrapolations

When data are missing to estimate the emissions in the base year, surrogate extrapolations may be a useful technique. Data here can be activity data or measurements. The reason for missing data may be a changed data collection systems that has led to a non consistent time series, new data collection that does not include the inventory base year or former data collection that has been stopped. The extrapolation technique may also be used when the methodology is too resource demand to perform every year.

The technique relies on the possibility to find a statistical source that explains the time variations of the emission source in the best way. This is not necessarily the activity data actually used for the estimation (as this could be missing).

$$y_0 = y_i \times \frac{s_i}{s_0}$$

Where *y* is the emission estimate and *s* is the surrogate statistical parameter.

Care should be taken to find the best statistical parameter and it is recommended to try various options and compare the results. It is also possible to weight several of the options.

3.4 Recalculations

Application of new data, methodologies, and correction of data will often change earlier estimates. This is called recalculations. Recalculations based on better information will clearly improve the scientific value of the inventory, it may, however, also cause problems when assessing compliance for environmental protocols. How to deal with recalculations when reporting to the various protocols is finally a policy decision.

When reporting GHG data to UNFCCC the rules for recalculations have been described in [2] based on recommendations from the *Subsidiary Body on Technological and Scientific Advice* (SBSTA). These can in short be summarised saying that countries shall always recalculate when information is available to increase the inventory quality. It is possible that inventories will be "frozen" in the first commitment period from 2008-2012, so that recalculations no longer are allowed in this period.

Recalculations have traditionally been encouraged when reporting to LRTAP. However, the former generation of protocols was based on percentage reductions. The new generation of protocols is based on emission ceilings[3]. Any decision on whether or not recalculations should be encouraged (or should be allowed at all) has not been taken. Some options for consideration by LRTAP policy groups may be:

- Not to allow recalculations (this will mean that inventories not necessarily are based on the best scientific information as methodologies cannot be changed nor errors corrected).
- To report two data sets, one "frozen" and one recalculated (will be extremely confusing and will also require far more work for the inventory compilers)
- To have a mechanism to adjust emission ceilings when necessary recalculations have been performed (is that feasible?)
- To encourage recalculations and accept the consequences (that will probably mean that recalculations only are made one way...)

We note however, that in order to meet the goal in the reporting instructions to produce complete, accurate and consistent inventories it sometimes will be needed to change the methodology used, and to obtain consistency, also change previously submitted estimates. Such methodological improvements, when leading to changes in emission estimates, will mean that obligations are easier or harder to meet. It is however in both cases good practice to always change the methodology whenever the overall inventory completeness, accuracy and consistency can be improved. This may be the case when new scientific results become available, when the methodology applied is not according to GP or when gross errors in the inventory have been detected.

[3] For HM and POPs the targets are more general, that the emission level in 2010 shall not exceed the one in 1990.

Section 4 Uncertainty Estimates[4]

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4.1 Introduction

The “Draft Guidelines for Estimating and Reporting Emission Data” [1] request in article 14:

> “*Parties should estimate the uncertainties of their inventories using the best methodologies (see para. 8 above) available to them, taking account of guidance provided by the EMEP/CORINAIR Guidebook.*”

This section will provide guidance in this respect, based on the achievements within the Greenhouse Gas Inventory Programme of IPCC.

The IPCC GPGAUM[2] report states that a structured approach to estimate inventory uncertainty is needed. Such an approach includes:

- ✓ A method of determining uncertainties in individual terms used in the inventory;
- ✓ A method of aggregating the uncertainties of individual terms to the total inventory;
- ✓ A method of determining the significance of year to year differences and long term trends in the inventories taking into account the uncertainty information;
- ✓ An understanding of the likely uses for this information which include identifying areas requiring further research and observations and quantifying the significance of year to year and longer term changes in inventories;
- ✓ An understanding that other uncertainties may exist, such as those arising from inaccurate definitions that cannot be addressed by statistical means.

Chapter 6 of [2] presents a comprehensive overview of these issues in the context of a greenhouse gas inventory. This section will give some additional guidance to the GPGAUM report with special reference to the application within a CLRTAP / EMEP emission inventory. Please refer to the GPGAUM report for definitions and explanations of all concepts and quantities.

4.2 Expressing uncertainty

An important aspect of an uncertainty analysis concerns the ways on how to express the uncertainties associated with individual estimates or the total inventory. It is recommended to use the same quantity to express uncertainty in a CLRTAP inventory as required in a greenhouse gas inventory, namely the 95 % confidence interval.

This 95 % confidence interval is specified by the confidence limits defined by the 2.5 percentile and 97.5 percentile of the cumulative distribution function of the estimated

[4] This section makes a broad use of the concepts and texts of the GPGAUM report.

quantity. Put another way, the range of an uncertain quantity within an inventory should be expressed such that:

- ✓ there is a 95% probability that the actual value of the quantity estimated is within the interval defined by the confidence limits, and
- ✓ it is equally likely that the actual value, should it be outside the range quoted, lies above or below it.

In practical terms, the 95 % confidence interval for a normal distribution lies between ± 2 standard deviations around the mean. Therefore, when uncertainties are not too large (standard deviations less than 30 % of the mean value), the (cumulative) distribution function of the estimated quantity might be assumed to be normal and the 95 % confidence can be estimated as being two times the standard deviation.

4.3 Quantifying uncertainties

4.3.1 Variables and parameters

The bulk of an emission inventory is compiled by collecting activity data and appropriate emission factors according to

$$Emission_{pollutant} = \sum_{activitiess} Activity\ rate_{activity} \times Emission\ \ factor_{activity,pollutant} \qquad (1)$$

Although for some sectors the equation to be used to estimate emissions is more complicated than a simple multiplication of a-variable ($Activity\ rate_{activity}$) and a parameter ($Emission\ factor_{activity,\ pollutant}$), in this section we present for reasons of simplicity, the quantification methods and principles using this simple equation. In case of a more complicated algorithm, the calculation becomes also more complicated but not essentially different.

4.3.2 Methods

For emission estimation both variables, and-parameters quantitative uncertainty ranges are needed to enable a quantitative uncertainty analysis as proposed here. This paragraph copies some essential parts from the GPGAUM report on this issue.

a) Measurements

In some cases, periodic emission measurements may be available at a site. If these measurements can be linked to representative activity data, which of course is crucial, then it is possible to determine a site-specific emission factor, together with an associated probability density function to represent annual emissions.

This can be a complex task. To achieve representativeness it may be necessary to partition (or stratify) the data to reflect typical operating conditions. For example:

- ✓ *Start-up and shut down can give different emission rates relative to activity data*. In this case, the data should be partitioned, with separate emission factors and probability density functions derived for steady state, start-up and shut down conditions.

- ✓ *Emission factors can depend on load*. In this case, the total emissions estimation and uncertainty analysis may need to be stratified to take account of load, expressed, for example, as percentage of full capacity. This could be done by regression analysis and scatter plots of the emission rate against likely controlling variables (e.g. emissions *versus* load) with load becoming part of the activity data needed.
- ✓ *Measurements taken for another purpose may not be representative*. For example, methane measurements made for safety reasons at coalmines and landfills may not reflect total emissions. In such cases, the ratio between the measured data and total emissions should be estimated for the uncertainty analysis.

If the data sample size is large enough, standard statistical goodness-of-fit tests can be used, in combination with expert judgement, to help in deciding which probability density function to use for describing variability in the data (partitioned if necessary) and how to parameterise it. However, in many cases, the number of measurements from which to make an inference regarding uncertainty will be small. Typically, as long as there are three or more data points, and as long as the data are a random representative sample of the quantity of interest, it is possible to apply statistical techniques to estimate the values of the parameters of many two-parameter distributions (e.g. normal, lognormal) that can be used to describe variability in the data set (Cullen and Frey, 1999)[9]. With small sample sizes, there will be large uncertainties regarding the parameter estimates that should be reflected in the quantification of uncertainty for use in the emissions inventory. Furthermore, it is typically not possible to rely on statistical methods to differentiate goodness-of-fit of alternative parametric distributions when sample sizes are very small[9]. Therefore, considerable judgement is required in selecting an appropriate parametric distribution to fit to a very small data set. In situations where the coefficient of variation is less than approximately 0.3, a normal distribution may be a reasonable assumption (Robinson, 1989)[10]. When the coefficient of variation is large and the quantity is non-negative, then a positively skewed distribution such as a lognormal one may be appropriate. Guidance on the selection of distributions is provided in Annex 1, Conceptual Basis for Uncertainty Analysis, and the use of expert judgements in this context is outlined below.

b) Literature and other documented data

When site-specific data are unavailable, good practice will usually be to develop emission estimates using average emission factors drawn from references consistent with this Guidebook. These factors will have been measured under particular circumstances that are judged to be typical. There will be uncertainties associated with the original measurements, as well as with the use of the factors in circumstances other than those associated with the original measurements.

It is a key function of good practice guidance for each source category to guide the choice of emission factors to minimise this second source of uncertainty to the extent possible. Where such emission factors are used, the associated uncertainties should be estimated from:

- ✓ *Original research including country-specific data*: For measurement-based emission factors, the data from the original measurement programme may enable an assessment of the uncertainty and possibly the probability density function. Well-designed measurement programmes will provide sample data that cover the range of types of plants and their maintenance, size and age, so that the factors and their uncertainties can be used directly. In other cases, expert judgement will be needed to extrapolate from the measurements to the full population of plants in that particular source category.
- ✓ *This Guidebook*: the source category-specific guidance in this Guidebook (methodological chapters, section 10 in each activity description) also indicates, wherever possible, the uncertainty ranges likely to be associated with using these factors.

Unless clear evidence to the contrary is available, the probability density functions are assumed to be normal. However, the inventory agency should evaluate the representativeness of the default for its own situation. If the default is judged to be unrepresentative and the source category is important to the inventory, improved assumptions based upon expert judgement should be developed.

c) Expert judgement

When empirical data are lacking, estimates of uncertainty in emission factors or direct emission measurements will need to be based on expert judgement. Experts are people who have special skills or knowledge in a particular field. A judgement is the forming of an estimate or conclusion from information presented to or available to the expert.

It is important to select appropriate experts with respect to the emission inventory inputs for which uncertainty estimates are needed.

The goal of expert judgement here is to develop a probability density function, taking into account relevant information such as:

- ✓ Is the emission source similar to other sources? How is the uncertainty likely to compare?
- ✓ How well is the emission process understood? Have all possible emission sources been identified?
- ✓ Are there physical limits on how much the emission factor can vary? Unless the process is reversible it cannot emit less than zero, and this may constrain a very wide uncertainty range. Mass balance considerations or other process data may place an upper limit on emissions.
- ✓ Are the emissions consistent with atmospheric concentrations? Emissions are reflected in atmospheric concentrations at site-specific and larger scales and again this may limit the possible emission rates.

A degree of expert judgement is required even when applying classical statistical techniques to data sets, since one must judge whether the data are a representative random sample and, if so, what methods to use to analyse the data. This may require both technical and statistical judgement. Interpretation is especially needed for data sets that are small, highly skewed or censored. The formal methods for obtaining data from experts are known as expert elicitation.

The IPCC GPGAUM report proposes a protocol for expert elicitation. The use of this protocol is strongly recommended to minimise misunderstandings between inventory compiler and the expert and to avoid unintentional bias.

4.3.3 Default uncertainty ranges

a) Activity data

Activity data are usually derived from (economic) statistics, including energy statistics and balances, economic production rates, population data etc.. It is possible that these agencies have already assessed the uncertainties associated with their data as part of their data collection procedures. These uncertainties can be used to construct probability density functions.

In some cases uncertainty data for activity rates are not easily available. Since any uncertainty analysis needs quantitative input, quantitative uncertainty ranges are needed. The table below proposes indicative ranges that could be applied in all cases where no independent data are available.

Data source	Error range	Remarks
The national (official) statistics	-	The official statistics of a country will in principle be assumed to be “fixed” data, with no uncertainty. In fact however for energy data an indication of the uncertainties could be derived from the entry under “Statistical Differences” representing the mismatch between production and consumption.
An update of last year’s statistics, using gross economic growth factors	2-5 %	The economic system of a county will probably not shift more than a few percent between successive years. Hence, if an update of last year’s data is used, an uncertainty of a few percent seems reasonable
IEA Energy statistics	OECD: 2 - 3 % non-OECD: 5 - 10 %	The International Energy Agency (IEA) publishes national energy statistics for many countries. For OECD countries these statistics will ideally be equal to the official energy statistics. For other countries the uncertainties could be expected to be in the order of 5 to 10 % (educated guess)
UN Data bases	5 - 10 %	These data might have a similar uncertainty as the ones provided by IEA
Default values other sectors and data sources.	30 - 100 %	

The table proposes for the uncertainty range, when official statistics are used, a value of 0 %. This can of course not be a true uncertainty range. The value here is given to facilitate for selection of a certain range. It is recommended to always use experts' opinions to make the final selection.

b) Emission factors

In many cases uncertainty ranges for emission factors are rather difficult to obtain. The table below represents an application of the concepts of qualitative data rating schemes for all pollutants of concern in the guidebook. The Table is organised by major SNAP code groupings. It is important to note that any such qualitative summary is subjective and individual opinions will differ.

MAIN SNAP CATEGORY	SO_2	NO_x	VOC	CO	NH_3	HM/POP	CO_2	CH_4	N_2O
1. public power, cogeneration and district heating	A	B	C	B		D	A	C	E
2. commercial, institutional & residential combustion	B	C	C	C		E	B	C	E
3. industrial combustion	A	B	C	B		D	A	C	E
4. industrial processes	B	C	C	C	E	E	B	D	D
5. extraction & distribution of fossil fuels	C	C	C	C		E	D	D	
6. solvent use			B			E[1]			
7. road transport	C	C	C	C	E	E[2]	B	C	E
8. other mobile sources and machinery	C	D	D	D		E	C	D	D
9. waste treatment	B	B	B	C		D	B	C	E
disposal activities	C	C	C	C	E	E	C	D	E
10. agriculture activities		D	D	D	D	E	C	D	E
11. nature	D[3]	D	D	E	E	E[3]	D	E	E

[1] In some cases, solvents may be toxic compounds

[2] Rating representative of typical pollutant source category combination; some specific cases may have higher ratings

[3] Natural sources could be contributed from volcanoes and other geothermal events

The letter grade ratings are primarily applicable to the estimation approaches for emissions inventory preparation that rely on emission factors and estimates of activity indicators. In all cases, the application of more direct approaches based on measurement would receive higher quality ratings.

The application of these subjective ratings for the aggregated source category groupings represented by the major SNAP code groupings can be misleading in some specific cases. For example, the rating specified for heavy metals/persistent organic pollutants for road transport is listed as E to apply in general to the understanding of the contribution of these pollutants from mobile sources. In fact, for the specific case of lead from mobile sources, the emission factors and emissions estimates are known with significantly more confidence. In such an analysis at that level of disaggregation, lead from mobile sources would receive a B rating. Also at this level of aggregation several source category pollutant combinations are irrelevant in that emissions of the pollutant from that source category are zero or so minimal as to be of little or no importance.

Definitions of the ratings are presented in the table below. This table also proposes default error ranges associated with each quality rating. The error ranges are obtained from the EU Guidance Report on Supplementary Assessment under EC Air Quality Directives, where they have been defined for application in air quality models.

Rating	Definition	typical error range
A	An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector	10 to 30 %
B	An estimate based on a large number of measurements made at a large number of facilities that represent a large part of the sector	20 to 60 %
C	An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts	50 to 150 %
D	An estimate based on single measurements, or an engineering calculation derived from a number of relevant	100 to 300 %
E	An estimate based on an engineering calculation derived from assumptions only	order of magnitude

4.4 Aggregating uncertainties

Once the uncertainties in the source categories have been determined, they may be combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time.

The error propagation equation, as discussed more extensively in Annex 1 of this report, and in Annex I of the *IPCC Guidelines* (Reporting Instructions), yields two convenient rules for combining uncorrelated uncertainties under addition and multiplication:

1) *Rule A:* Where uncertain quantities are to be combined by addition, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms (this rule is exact for uncorrelated variables).

   Using this interpretation, a simple equation can be derived for the uncertainty of the sum, that when expressed in percentage terms becomes:

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + ... + (U_n \bullet x_n)^2}}{x_1 + x_2 + ... + x_n} \quad (2)$$

   Where:

   U_{total} is the percentage uncertainty in the sum of the quantities (half the 95% confidence interval divided by the total (i.e. mean) and expressed as a percentage);

   x_i and U_i are the uncertain quantities and the percentage uncertainties (half the 95% confidence interval) associated with them, respectively.

2) *Rule B*: Where uncertain quantities are to be combined by multiplication, the same rule applies except that the standard deviations must all be expressed as fractions of the appropriate mean values (this rule is approximate for all random variables).

   A simple equation can also be derived for the uncertainty of the product, expressed in percentage terms:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2} \qquad (3)$$

   Where:

   U_{total} is the percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

   U_i are the percentage uncertainties (half the 95% confidence interval) associated with each of the quantities.

The inventory is principally the sum of products of emission factors and activity data. Therefore, Rules A and B can be used repeatedly to estimate the uncertainty of the total inventory.

In practice, uncertainties found in inventory source categories vary from a few percent to orders of magnitude, and may be correlated. This is not consistent with the assumptions of Rules A and B that the variables are uncorrelated with a standard deviation of less than about 30% of the mean, but under these circumstances, Rules A and B may still be used to obtain an approximate result. Alternatively, a stochastic simulation (the Monte Carlo method) can be used, that can combine uncertainties with any probability distribution, range, and correlation structure, provided they have been suitably quantified. Thus, two tiers for uncertainty analysis are described below:

1) *Tier 1*: Estimation of uncertainties by source category using the error propagation equation via Rules A and B, and simple combination of uncertainties by source category to estimate overall uncertainty for one year and the uncertainty in the trend.

2) *Tier 2*: Estimation of uncertainties by source category and in the overall inventory by stochastic simulation for one year and the uncertainty in the trend.

In most cases a quantitative indicator of inventory uncertainty will be enough and the resource intensive application of a Monte Carlo analysis can be avoided. Paragraph 0 will present this Tier 1 approach for CLRTAP pollutants in a simple calculation scheme.

Tier 1 method does not account for correlation and dependency between source categories that may occur because the same activity data or emission factors may be used for multiple estimates. Correlation and dependency may be significant for fossil fuels because a given fuel is used with the same emission factor across several sub-categories, and if (as is sometimes the case) total consumption of a fuel is better known than consumption disaggregated by source category, hidden dependencies will exist within the statistics because of the constraint provided by overall consumption.

Dependency and correlation can be addressed by aggregating the source categories to the level of overall consumption of individual fuels before the uncertainties are combined. This entails some loss of detail in reporting on uncertainties but will deal with the dependencies where they are thought to be significant (e.g. where the uncertainties in fossil fuel emissions when aggregated from the source category level are greater than expected)

4.5 Uncertainties in trends

An emission factor that over or underestimates emissions in the base year will probably do so in subsequent years. Therefore, uncertainties due to emission factors will tend to be correlated over time. The Tier 1 uncertainty aggregation method, as proposed by GPGAUM is in principle able to deal with this issue.

Trend uncertainties are estimated using two sensitivities:

1. *Type A sensitivity*: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source category and gas in both the base year and the current year.
2. *Type B sensitivity*: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1% increase in emissions of a given source category and gas in the current year only.

Conceptually, Type A sensitivity arises from uncertainties that affect emissions in the base year and the current year equally, and Type B sensitivity arises from uncertainties that affect emissions in the current year only. Uncertainties that are fully correlated between years will be associated with Type A sensitivities, and uncertainties that are not correlated between years will be associated with Type B sensitivities.

IPCC GPGAUM suggests that emission factor uncertainties will tend to have Type A sensitivities, and activity data uncertainties will tend to have Type B. However, this association will not always hold and it is possible to apply Type A sensitivities to activity data, and Type B sensitivities to emission factors to reflect particular national circumstances. Type A and Type B sensitivities are simplifications introduced for the analysis of correlation.

Once the uncertainties introduced into national emissions by Type A and Type B sensitivities have been calculated, they can be summed using the error propagation equation (Rule A) to give the overall uncertainty in the trend.

4.6 The Tier 1 uncertainty aggregation scheme

The calculation scheme reproduced below is an adaptation of the spreadsheet scheme as presented in the IPCC GPGAUM report [2].

Tier 1 Uncertainty Calculation and Reporting																
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
NRF sector	Pollutant	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers	Footnote reference number
		Input data	Input data	Input data	Input data	$\sqrt{E^2+F^2}$	$\frac{G \bullet D}{\sum D}$	Note B	$\frac{D}{\sum C}$	$I \bullet F$ Note C	$J \bullet E \bullet \sqrt{2}$ Note D	$\sqrt{K^2+L^2}$	Note E	Note E		
		Mg	Mg	%	%	%	%	%	%	%	%	%				
1a																
1b																
…																
Etc.	…															
		$\sum C$	$\sum D$				$\sqrt{\sum H^2}$					$\sqrt{\sum M^2}$				
Total																

Note A

If only total uncertainty is known for a source category (not for emission factor and activity data separately), then:

- ✓ If uncertainty is correlated across years, enter the uncertainty into column F, and enter 0 in column E;
- ✓ If uncertainty is not correlated across years, enter the uncertainty into column E and enter 0 in column F.

Note B

$$\frac{0.01 \bullet D_x + \sum D_i - (0.01 \bullet C_x + \sum C_i)}{(0.01 \bullet C_x + \sum C_i)} \bullet 100 - \frac{\sum D_i - \sum C_i}{\sum C_i} \bullet 100$$

Note C

In the case where no correlation between emission factors is assumed, sensitivity B should be used and the result multiplied by √2:

$$K_x = J_x \bullet F_x \bullet \sqrt{2}$$

Note D

In the case where correlation between activity data is assumed, sensitivity A should be used and the √2 is not required:

$$L_x = I_x \bullet E_x$$

Note E

Please use the following abbreviations:
D – IPCC source category default
M – measurement based
R – national referenced data

The columns of the table are labelled A to Q and contain the following information:

- ✓ A and B show the NFR source category and pollutant.
- ✓ C and D are the inventory estimates in the base year and the current year[5] respectively, for the source category and gas specified in columns A and B, expressed in CO_2 equivalents.
- ✓ E and F contain the uncertainties for the activity data and emission factors respectively, derived from a mixture of empirical data and expert judgement as previously described in this chapter, entered as half the 95% confidence interval divided by the mean and expressed as a percentage. The reason for halving the 95% confidence interval is that the value entered in columns E and F then corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus x%', so expert judgements of this type can be directly entered in the spreadsheet. If uncertainty is known to be highly asymmetrical, enter the larger percentage difference between the mean and the confidence limit.
- ✓ G is the combined uncertainty by source category derived from the data in columns E and F using the error propagation equation (Rule B). The entry in column G is therefore the square root of the sum of the squares of the entries in columns E and F.
- ✓ H shows the uncertainty in column G as a percentage of total national emissions in the current year. This is a measure of the degree of uncertainty introduced into the national emissions total by the source category in question. The entry in each row of column H is the entry in column G multiplied by the entry in column D, divided by the total at the foot of column D. The total at the foot of column H is an estimate of the percentage uncertainty in total national emissions in the current year, calculated from the entries above using Rule A. This total is obtained by summing the squares of all the entries in column H and taking the square root.
- ✓ I shows how the percentage difference in emissions between the base year and the current year changes in response to a one percent increase in source category emissions in both the base year and the current year. This shows the sensitivity of the trend in emissions to a systematic uncertainty in the emissions estimate (i.e. one that is correlated between the base year and the current year). This is the Type A sensitivity as defined above. Appendix 6A.1 provides the derivation for the formula for the entries in column I.
- ✓ J shows how the percentage difference in emissions between the base year and the current year changes in response to a one percent increase in source category emissions in the current year only. This shows the sensitivity of the trend in emissions to random error in the emissions estimate (i.e. one, that is not correlated, between the base year and the current year). This is the Type B sensitivity as described above. The formula for the entries in column J is derived in Appendix 6A.

[5] The current year is the most recent year for which inventory data are available.

- ✓ K uses the information in columns I and F to show the uncertainty introduced into the trend in emissions by emission factor uncertainty, under the assumption that uncertainty in emission factors is correlated between years. If the user decides that the emission factor uncertainties are not correlated between years then the entry in column J should be used in place of that in column I and the result multiplied by $\sqrt{2}$. The formula for the entries in column K is derived in Appendix 6A.
- ✓ L uses the information in columns J and E to show the uncertainty introduced into the trend in emissions by activity data uncertainty, under the assumption that uncertainty in activity data is not correlated between years. If the user decides that the activity data uncertainties are correlated between years then the entry in column I should be used in place of that in column J and the $\sqrt{2}$ factor does not then apply. The formula for the entries in column L is derived in Appendix 6A.
- ✓ M is an estimate of the uncertainty introduced into the trend in national emissions by the source category in question. Under Tier 1, this is derived from the data in columns K and L using Rule B. The entry in column M is therefore the square root of the sum of the squares of the entries in columns K and L. The total at the foot of this column is an estimate of the total uncertainty in the trend, calculated from the entries above using the error propagation equation. This total is obtained by summing the squares of all the entries in column M and taking the square root. The formula for the entries in column M and the total at the foot of column M is shown in Appendix 6A.1.
- ✓ Columns N to Q are used for indicators and cross-referencing to footnotes.
- ✓ N contains D, M or R, depending on whether the emission factor uncertainty range is based on default (D) information in source category guidance, measurements (M) made for the purpose or national referenced (R) information.
- ✓ O contains D, M or R, depending on whether the activity data uncertainty range is based on default information in sector guidance, measurements made for the purpose or national referenced information.
- ✓ P contains the reference numbers of any expert judgements used to estimate uncertainties in this source category.
- ✓ Q contains the number of an explanatory footnote to go at bottom of table to identify documentary reference of uncertainty data (including measured data) or other comments relevant to the line.

4.7 Reporting uncertainties

The "Draft Guidelines for Estimating and Reporting Emission Data" [1] request in article 26:

> "*When reporting emissions, the level of uncertainty associated with these data and their underlying assumptions should also be reported. The methodologies used for estimating uncertainties should be indicated in a transparent manner. Parties are encouraged to report quantitative information on uncertainties, where this is available.*"

In accordance with the guidance in the GPGAUM report, the uncertainties could be reported in a table analogous to the one given in paragraph 4.6. The draft Reporting Guidelines do not include a specific requirement in this respect.

Section 5 Verification

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5.1 Introduction

Verification checks whether the emission inventory is true. Tools to perform a verification involves techniques that make comparisons between emission estimates and some other known quantity that is related either directly to the emission source or indirectly to the underlying process that results in emissions. The following tools can be used for verification purposes: (i) survey analysis, (ii) monitoring analysis, (iii) comparison with other inventories, (iv) forward air quality modelling and (v) inverse air quality modelling. In this revised Guidebook information on survey analysis and monitoring analyses has been included from the former Guidebook. The brief discussion of other tools for verification is taken from a study by Van Aardenne (2001) [11] in which a framework is proposed for a systematic analysis of uncertainties.

This chapter describes a brief overview of the different tools that can be applied for verification purposes for a more detailed description of tools see [11] or specific references in the text.

5.2 Survey analysis

Some common methodologies for estimating emissions from area source emission categories rely on a per-capita, per-employee, per area emission factor. While these approaches may be adequate for estimating national or regional emissions, they may introduce bias when applied to specific locations or during specific time periods. Statistical sampling techniques can identify the population of establishments in a specific industry that need to be sampled in detail to provide useful statistical results on the regional and temporal characteristics of that activity. The results of a statistical sampling based on these principles could be applied to develop regionally specific emission or allocation factors that depend on population density, economic demography, or the distribution of employment by major industrial and commercial sectors.

5.3 Monitoring analysis

Monitoring analyses include three principal types of measurement activities: direct source testing, indirect source testing and ambient measurements. All monitoring programs are expensive to implement and should be well planned and executed to maximise the data recovery and to ensure the collection of high-quality measurement data. It is possible, in some cases, to apply measurement data that is routinely collected as part of a government- sponsored air quality management program and data that is routinely collected by individual facilities related to process operation and efficiency, to an emissions verification exercise. Whenever a monitoring program is considered, a thorough review of all existing measurement data should be completed and the program should be designed to make use of these data whenever possible. The following table summarises some of the monitoring activities that have been used to help verify emissions estimates.

MONITORING TYPES, EXAMPLES, AND USES FOR EMISSIONS INVENTORIES

Monitoring Class	Examples of Monitoring Programs	Uses of the Data for Emissions Inventories
Direct Measurements	• In process emissions measurements • Process operating parameters • Random sampling of process units or potential leak tests	• Comparison to estimated values • Identification of ranges of application estimates (operating parameters, emissions factors) • Specification of fugitive emissions or process leaks
Indirect Measurements	• Remote measurement systems: FTIR, UV, Gas Filter Correlation • Ambient VOC/NO_x ratio studies	• Comparison of estimated emission rates with near source concentrations • Estimation of emission factors for sources that do not have stacks or vents
Ambient Studies	• Tunnel Studies • Aircraft Studies • Upwind-downwind difference studies • Receptor Modelling	• Identification of obvious weaknesses in procedures or underestimation of emissions • Checking of ambient impacts of sources or mixtures of sources • Identification of principal emissions sources in a region

5.4 Comparison with other inventories

When comparing emission inventories that have been constructed independently from each other, the difference between emission inventories could be used to verify whether the emission inventory is an accurate representation of the true emission [11]. Verification is in theory possible but only when information on the accuracy of one of the emission inventories is available. The reason for independency of the emission inventories is the facts that agreement is easily found between two inventories when the same activity data and emission factors are used. This principle has been applied by Van Amstel et al. (1999)[12]. In their study, emission estimates of greenhouse gases calculated by country for the year 1990 using the EDGAR database have been compared with National Communications of several countries. In some cases the reasons for the differences was clear and lead to conclusions about either the EDGAR or national emission estimates (e.g. different emission factors, different activity data, gaps in inventories).

5.5 Forward air quality modelling

In forward air quality modelling an emission inventory is used as input into an atmospheric dispersion model, which calculates the atmospheric concentration of the pollutant **[11]**. When accurate atmospheric concentration measurements are available, the difference between model result and observation can be used as an indicator whether the emission inventory is an accurate representation of the true emission. An example of such a study is the work performed by Iversen (1993)[13]. By using scatter plots of measured versus calculated concentrations, comparison of yearly averaged modelled and measured concentrations, comparison of both measured and modelled concentrations with emissions estimates per grid cell and calculation of variation in measured concentrations from year to year, Iversen attempted to diagnose model error, emission error or inaccurate measurement as cause for the difference between EMEP/MSC-W acid deposition model calculations and EMEP measurement network observations for NO_2, SO_2 and sulphate in the period 1985-1989. One of the important aspects with this tool for verification is the distinction between uncertainty in the model, measurement or emission inventory.

5.6 Inverse air quality modelling

In inverse modelling atmospheric concentrations are used as input into an atmospheric dispersion model to calculate the emissions needed to reproduce the observed concentrations **[11]**. Comparison of the 'back-casted' emission estimates with the emission inventory can be used to ‘verify’ whether the emission inventory is an accurate representation of the true emission. Inverse modelling studies have been applied both on a global, regional and national scale. Hein et al. (1997)[14] have used inverse modelling with a three-dimensional transport model to analyse the global methane budget. They describe inverse modelling as an optimisation problem of the difference between calculated and observed concentrations. The solution to this optimisation provides emission patterns that result in an optimal agreement between calculated and observed concentrations, the so-called ‘back-casted’ emission estimates. Other examples on a regional scale can be found in Seibert (2000)[15] or in Vermeulen et al. (1999)[16] on a national scale.

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AN APPROACH TO ESTIMATION OF PAH EMISSIONS

1 INTRODUCTION

One of the agreed priorities of the UNECE Task Force on Emission Inventories has been to improve the relevant Guidebook chapters with respect to emissions of heavy metals and POPs, in view of the respective UNECE Protocols.

Polycyclic aromatic hydrocarbons (PAHs) are a group of compounds composed of two or more fused aromatic rings. The UNECE POPs Protocol specified that the following 4 PAHs should be used as indicators for the purposes of emission inventories:

- benzo[b]fluoranthene
- benzo[k]fluoranthene
- benzo[a]pyrene
- indeno[123-cd]pyrene

Appendix 1 shows the molecular weight, formulae and structures of these 4 PAHs.

The importance of PAHs as persistent organic pollutants is increasing due to concerns regarding health effects, particularly their carcinogenic properties. The semi-volatile property of PAHs makes them highly mobile throughout the environment via deposition and re-volatilisation between air, soil and water bodies. It is possible that a proportion of PAHs released are subject to long range transport making them a global environmental problem.

Limited data are available on emission factors for PAHs, and the data that are available are often reported in different manners which means comparison of data for verification purposes is difficult. This is because:

- many of the reported emissions of PAHs only give a figure for ‘total PAHs’, without indicating which PAH compounds are included in the total;
- where emissions of individual PAHs are given, there is a lack of consistency between reports on which PAHs are included in the measurements taken;
- most of the reported emissions of individual PAHs only give data for one or two compounds (usually including benzo[a]pyrene).

In this chapter a methodology is proposed that can be used for estimating PAH emissions where limited measurement and/or emission factor data are available.

Appendix 2 indicates the well-known categories of PAHs. Emission factor profiles are given in this chapter for the 4 PAHs covered by the POPs Protocol.

Details of the processes and control technology covered by the profiles and emission factors in this chapter can be found in the relevant sector-specific chapters.

2 CONTRIBUTION TO TOTAL EMISSIONS

The main PAH sources are likely to include:

- Domestic coal combustion
- Domestic wood combustion
- Industrial coal combustion
- Industrial wood combustion
- Natural fires / open agricultural burning
- Anode baking (for pre-baked aluminium industry)
- Aluminium production
- Vehicles

The above list is not ordered in terms of size of likely emission. The contribution to total national emissions for each source will depend on the extent of the relevant activity in each country.

3 DEFINITIONS

B[b]F - benzo[b]fluoranthene

B[k]F - benzo[k]fluoranthene

B[a]P - benzo[a]pyrene

ESP - electrostatic precipitators

I[cd]P - indeno[123-cd]pyrene

PAHs - polycyclic aromatic hydrocarbons.

POPs - persistent organic pollutants.

4 SIMPLER METHODOLOGY

The simpler methodology involves the standard approach of emission factor multiplied by activity statistic.

In most sectors in most countries, emission factors are unlikely to be available for many PAHs because of the lack of measurements that have been made. It is likely that in many cases, for example, an emission factor only for benzo[a]pyrene is available.

In these cases the emission factors for other PAHs can be estimated by multiplying the known emission factors by the appropriate ratios in the default profile data in Section 7.

Where no emission factors are available for any PAHs, the emission factors for benzo[a]pyrene in Appendix 3 can be used as default, and the profile data applied to these emission factors.

The methodology is summarised by the equations and example below.

Standard equation for estimating PAH emissions

Emission estimate = emission factor x activity statistic ....[1]

Equation for estimating PAH emission factor *(example equation for B[b]F)*

Emission factor (B[b]F) = Emission factor (B[a]P) x Profile ratio B[b]F/B[a]P ....[2]

Example *(domestic wood combustion)*

Activity statistic = 2 Mt / year for Country Y

B[a]P country-specific emission factor = 1000 mg/t
(NB use default emission factor 1300 mg/t from Appendix 3 if no country-specific data available)

Profile ratio B[b]F/B[a]P = 0.05 (from Section 7)
Emission factor (B[b]F) =1000 x 0.05 = 50 mg/t

Estimated emission of B[b]F for Country Y from domestic wood combustion
= 2 Mt x 50 mg/t = 100 kg (data quality E)

A key assumption for this methodology is that for a given process the relative profiles of PAHs are similar between countries.

Emission estimations should be made for the 4 PAHs specified by the UNECE POPs Protocol:
- benzo[b]fluoranthene
- benzo[k]fluoranthene
- benzo[a]pyrene
- indeno[123-cd]pyrene

The relevant sector-specific chapters of the Guidebook contain information on processes, control technology, point source criteria etc.

5 DETAILED METHODOLOGY

The detailed methodology involves the use measurement data where available in the generation of country-specific and plant-specific emission factors.

In addition, but of secondary importance, estimations of emissions of other PAHs (for example others within the 16 US EPA priority PAHs) should be made if the data are available.

6 RELEVANT ACTIVITY STATISTICS

The required activity statistics depend on the emission source for which estimates are made (e.g. tonnes of aluminium produced, tonnes of wood burned in domestic appliances, etc). The relevant sector-specific chapters of the Guidebook indicate where activity data can be found.

7 EMISSION FACTORS, PROFILES, QUALITY CODES AND REFERENCES

Profiles for main sources, estimated in a ratio to benzo[a]pyrene, are given in the table below:

Stationary Sources

PAH	Coal combustion (industrial and domestic)	Wood combustion (industrial and domestic)	Natural fires / agricultural biomass burning	Anode baking
Benzo[b]fluoranthene	0.05	1.2	0.6	2.2 B[b]F & B[k]F
Benzo[k]fluoranthene	0.01	0.4	0.3	
Benzo[a]pyrene	1.0	1.0	1.0	1.0
Indeno[123cd]pyrene	0.8	0.1	0.4	0.5

(Profiles in the above table were estimated from emission factors in Wenborn et al. 1998, which were developed from several other references)

Vehicles

PAH	Passenger cars – gasoline (conventional)	Passenger cars – gasoline (closed loop catalyst)	Passenger cars – diesel (direct injection)	Passenger cars – diesel (indirect injection)	Heavy Duty Vehicles (HDV)
Benzo[b]fluoranthene	1.2	0.9	0.9	0.9	5.6
Benzo[k]fluoranthene	0.9	1.2	1.0	0.8	8.2
Benzo[a]pyrene	1.0	1.0	1.0	1.0	1.0
Indeno[123cd]pyrene	1.0	1.4	1.1	0.9	1.4

(Profiles in the above table were estimated from emission factors in BUWAL (1994), TNO (1993), VW (1989) and Koufodimos (1999))

8 CURRENT UNCERTAINTY ESTIMATES

Limited data are available on PAH emissions relative to data on many other pollutants. The emission factors that are currently available for PAHs therefore have a high uncertainty. This uncertainty is demonstrated by the wide ranges and poor data quality ratings of the default emission factors for benzo[a]pyrene in Appendix 3.

The data quality rating for any emission estimates made using the profile data in Section 7 should be assumed to be E.

9 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The methodology of using profiles to estimate PAH emissions is required because limited measurement data are available. Measurements of PAH emissions from the main sources are urgently required. This would enable more reliable emission factors to be developed and these could be used directly to estimate emissions, rather than having to use the less reliable method involving emission profiles.

The priority source for improvement of emission factors is Primary Aluminium Production and Anode Baking.

10 VERIFICATION PROCEDURES

Verification of this methodology and the profiles is required through measurement of PAH emissions directly from the priority sources.

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13 POINT OF ENQUIRY

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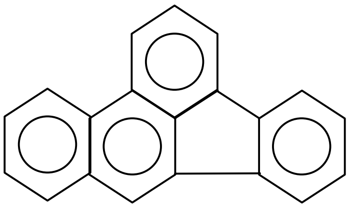
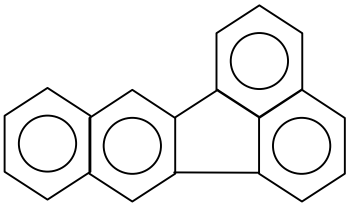
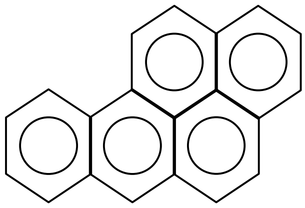
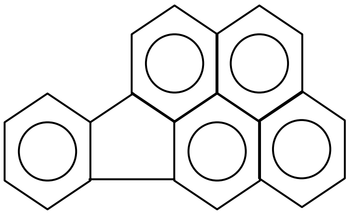
APPENDIX 1 - MOLECULAR WEIGHT, FORMULAE AND STRUCTURE OF THE FOUR PAHS IN THE POPS PROTOCOL

PAH	**Molecular Weight**	**Formula**	**Structure**
Benzo[b]fluoranthene	252	$C_{20}H_{12}$	
Benzo[k]fluoranthene	252	$C_{20}H_{12}$	
Benzo[a]pyrene	252	$C_{20}H_{12}$	
Indeno[1,2,3-cd]pyrene	276	$C_{22}H_{12}$	

APPENDIX 2 - CATEGORIES OF PAHS

The table below indicates the PAHs included in the following well-known categories :

- The 16 PAHs designated by the United States Environmental Protection Agency (US EPA) as compounds of interest under a suggested procedure for reporting test measurement results (US EPA 1988).
- The 6 PAHs identified by the International Agency for Research on Cancer (IARC) as probable or possible human carcinogens (IARC 1987).
- The Borneff 6 PAHs, which have been used in some emission inventory compilations.
- The 4 PAHs to be used as indicators for the purposes of emissions inventories under the UNECE POPs Protocol.

	US EPA Priority pollutants (16 PAHs)	**IARC** Probable or possible human carcinogens (6 PAHs)	**Borneff** (6 PAHs)	**UNECE POPs Protocol** Indicators for the purposes of emissions inventories (4 PAHs)
Naphthalene	✓			
Acenaphthylene	✓			
Acenapthene	✓			
Fluorene	✓			
Anthracene	✓			
Phenanthrene	✓			
Fluoranthene	✓		✓	
Pyrene	✓			
Benz[a]anthracene	✓	✓		
Chrysene	✓			
Benzo[b]fluoranthene	✓	✓	✓	✓
Benzo[k]fluoranthene	✓	✓	✓	✓
Benzo[a]pyrene	✓	✓	✓	✓
Dibenz[ah]anthracene	✓			
Indeno[123cd]pyrene	✓	✓	✓	✓
Benzo[ghi]perylene	✓		✓	

APPENDIX 3 - DEFAULT EMISSION FACTORS FOR BENZO[A]PYRENE

Source	Process type / fuel type	Emission Factor	Abatement type and efficiency	Data quality	Country or Region	Reference
Domestic coal combustion	Bituminous coal	500-2600 mg/t [best estimate 1550 mg/t]*	no control	D	W Europe / USA	TNO (1995), Radian Corporation (1995), Smith (1984), CRE (1992)
Domestic coal combustion	Manufactured smokeless coal	330 mg/t	no control	E	W Europe	Wenborn et al. (1997)
Domestic coal combustion	Anthracite	30 mg/t	no control	E	W Europe	Wenborn et al. (1997)
Domestic wood combustion	Wood	600-2000 mg/t [best estimate 1300 mg/t]*	no control	E	W Europe / USA	Radian Corporation (1995), Smith (1984)
Industrial coal combustion	Large plant	0.14 mg/t	effective end-of-pipe control	D	USA	Radian Corporation (1995)
Industrial coal combustion	Small plant	1550 mg/t	no control	E	UK	Wenborn et al. (1997)
Industrial coal combustion		[best estimate 775 mg/t]*		E		
Industrial wood combustion	Large plant	2 mg/t	effective end-of-pipe control	D	USA	Radian Corporation (1995)
Industrial wood combustion	Small plant	1300 mg/t	no control	E	UK	Wenborn et al. (1997)
Industrial wood combustion		[best estimate 650 mg/t]*		E		
Natural fires / open agricultural burning		0.2-14.3 g/t [best estimate 7.2 g/t]	no control	D	USA	Jenkins et al. (1996), Radian Corporation (1995)
Anode baking (for pre-baked aluminium industry)		5.6-135 g/t	Ranges from effective end-of-pipe technology to limited control	D	UK	Coleman (1999)

* best estimates of emission factors can be used when estimating total emission for sector for cases where no information on plant types and abatement is available

APPENDIX 3 - DEFAULT EMISSION FACTORS FOR BENZO[A]PYRENE (CONTINUED)

Source	Process type / fuel type	Emission Factor	Abatement type and efficiency	Data quality	Country or Region	Reference
Aluminium production	Pre-baked process	30-8600 mg/t [best estimate 100 mg/t]*	Ranges from effective end-of-pipe technology (e.g. dry scrubber system) to limited control	E	W Europe / USA	TNO (1995), Radian Corporation (1995), Wenborn et al. (1997)
Aluminium production	HSS process	*Emission factors to be developed*				
Aluminium production	VSS process	172 g/t	Wet scrubber and ESP	D	UK	Wenborn et al. (1997)
Vehicles	Passenger cars – gasoline	0.02 – 6.4 µg/km [best estimate 1.1 µg/km]*	conventional	D	Europe / USA	BUWAL (1994), TNO (1993), VW (1989) and Koufodimos (1999))
Vehicles	Passenger cars – gasoline	0.001 – 5.8 µg/km [best estimate 0.4 µg/km]*	closed loop catalyst	D	Europe / USA	As above
Vehicles	Passenger cars – diesel	0.3 – 1.0 µg/km [best estimate 0.7 µg/km]*	direct injection	D	Europe / USA	As above
Vehicles	Passenger cars – diesel	0.2 – 6.9 µg/km [best estimate 2.8 µg/km]*	indirect injection	D	Europe / USA	As above
Vehicles	Heavy Duty Vehicles (HDV)	0.02 – 6.2 µg/km [best estimate 1.0 µg/km]*		D	Europe / USA	As above

* best estimates of emission factors can be used when estimating total emission for sector for cases where no information on plant types and abatement is available

SNAP CODE: **N/A**

SOURCE ACTIVITY TITLE: **PRODUCTS CONTAINING MERCURY**

NOSE CODE: **112.09.14**
112.09.15

NFR CODE: **N/A**

1 ACTIVITIES INCLUDED

This chapter considers mercury emissions from the manufacturing, use and disposal of products containing mercury.

The main products containing mercury are divided into four categories:

- batteries;
- measuring and control equipment;
- electrical equipment;
- lighting.

The ‘destination’ of these products after their use has been divided into five different pathways including recycling, recovery and different ways of disposal. Emissions of mercury from products which have been disposed in landfill are included in this chapter.

Emissions from incineration and secondary steel/copper production are not covered in this chapter since they are included in chapters in SNAP Group 3 and 9 respectively.

2 CONTRIBUTION TO TOTAL EMISSIONS

Mercury emissions from products containing mercury have been estimated for Western and Eastern Europe by WS Atkins (1997), and are given in Table 2.1, below:

Table 2.1 Estimated annual mercury emissions in Western and Eastern Europe

Source	Western Europe (1995) (tonnes)	Eastern Europe (1995) (tonnes)
Batteries	0.09	0.015
Measuring and Control Equipment	1.81	0.500
Electrical Equipment	0.77	0.125
Lighting	0.21	0.121
Total	**2.88**	**0.761**

(WS Atkins, 1997)

Table 2.2 Contribution to total mercury emissions of the OSPARCOM-HELCOM-UNECE emission inventory *(up to 39 countries)*

Source-activity	SNAP-code	Contribution to total mercury emissions [%]
Mercury thermometers and vapour lamps		0.3 %

The contribution to total mercury emissions from products containing mercury varies significantly from country to country. It has been estimated (AEAT Environment 1998) that the total Hg emission for the UK was 20.5 tonnes in 1995. The contribution to total mercury emissions for the UK in 1995 was estimated to be 2% (AEAT Environment 1998).

3 GENERAL

3.1 Description / Definitions

The sources of emissions representing this sector have been divided into four groups:

1. Batteries, including button cells (used in hearing aids, calculators, photographic equipment etc.);
2. Measuring and control equipment including laboratory and hospital equipment (including thermometers) and devices such as barometers;
3. Electrical equipment;
4. Lighting.

In the third group, mercury is used in a range of electrical equipment, including Level, Multipoled, Thermo and mechanical switches, which are used for railway signals, telecommunications, computer communications and data transmission, portable telephones, burglar alarms and hearing aids.

For lighting, mercury is used in discharge lamps including fluorescent tubes, high pressure mercury vapour, metal halide and high and low pressure sodium lamps.

Other products containing mercury are paints, pharmaceuticals, other medical/health products and dental amalgams, but the emissions from those products are unlikely to be significant and have not been included in the calculations (Maxson 1991).

3.2 Techniques

Not applicable.

3.3 Emissions

Mercury emissions from products containing mercury can derive from the manufacturing process, the different 'final destination' sources after disposal and fugitive emissions from the different stages of the disposal procedure.

Disposal has been divided into 6 different pathways (WS Atkins 1997):

- Recollection/Recycling;
- Incineration/burning of waste including products containing mercury;
- Steel/copper scrap;
- Disposal via landfill;
- Release by breaking;
- Accumulation/recovery.

From the distribution factors tabulated below (Tables 3.1 and 3.2), it is evident that the biggest proportion of the mercury content of products ends up in landfill. In Eastern Europe, a big proportion of the disposed products is openly burnt rather than incinerated, or dumped rather than disposed in a covered landfill.

Table 3.1 Distribution factors for Western Europe

Pathway	Batteries	Measuring and control equipment	Electrical equipment	Lighting
Recollection / recycling	0.3	0.1	0.1	0.1
Incineration	0.14	0.1	0.08	0.09
Steel / copper scrap	0	0	0.1	0
Landfill	0.55	0.4	0.32	0.36
Release by breaking	0.01	0.05	0	0.05
Accumulation / recovery	0	0.35	0.4	0.4

(WS Atkins 1997)

Table 3.2 Distribution factors for Eastern Europe

Pathway	Batteries	Measuring and control equipment	Electrical equipment	Lighting
Recollection / recycling	0	0	0	0
Open burning / incineration	0.495	0.3	0.25	0.275
Steel / copper scrap	0	0	0.1	0
Dumped / Landfill	0.495	0.3	0.25	0.275
Release by breaking	0.01	0.05	0	0.05
Accumulation / recovery	0	0.35	0.4	0.4

(WS Atkins 1997)

Regarding the steel/copper scrap pathway, the electrical equipment that ends up in a steel/copper scrap are fragmentised and the steel/copper parts recycled. Mercury may also be emitted through the fragmentisation process.

Additionally, mercury is emitted via the incineration of wastes that include products containing mercury. Emissions from recycling of steel/copper scrap and from incineration are covered in other chapters.

Studies (Maxson 1991 and WS Atkins 1997) have considered the recovery of mercury from products as a separate destination before disposal. It can be assumed that the currently recovered mercury will be disposed and potentially emitted through the above mentioned pathways in the future. This additional emission has not been included in the calculation of mercury emission factors in this chapter.

In summary, the annual mercury emissions from products have been calculated by considering emissions from landfills and releases from the breaking of products containing mercury. Mercury emissions from the manufacturing process of products containing mercury, the recycling process and the fragmentisation of the electrical components that end up in a metal scrap are considered to be relatively low and are not included in the calculation of mercury emissions. Future emissions from currently recovered mercury has not been considered either.

Figure 3.1 Pathways of emission sources in Western Europe

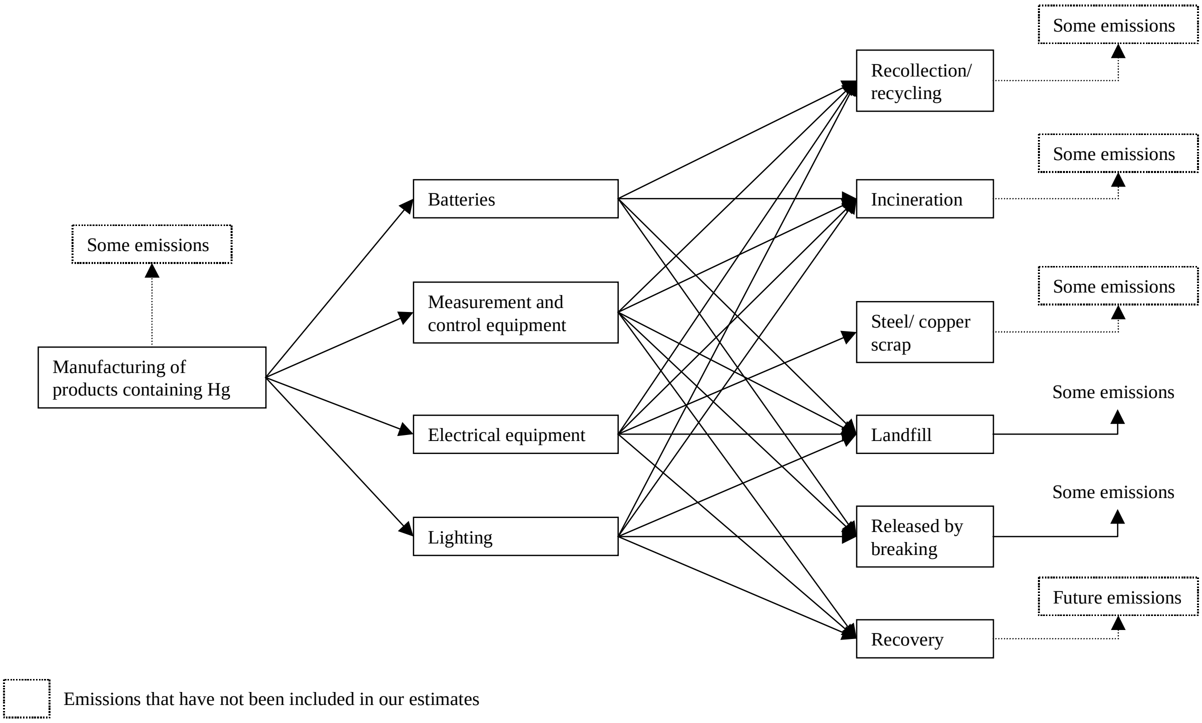
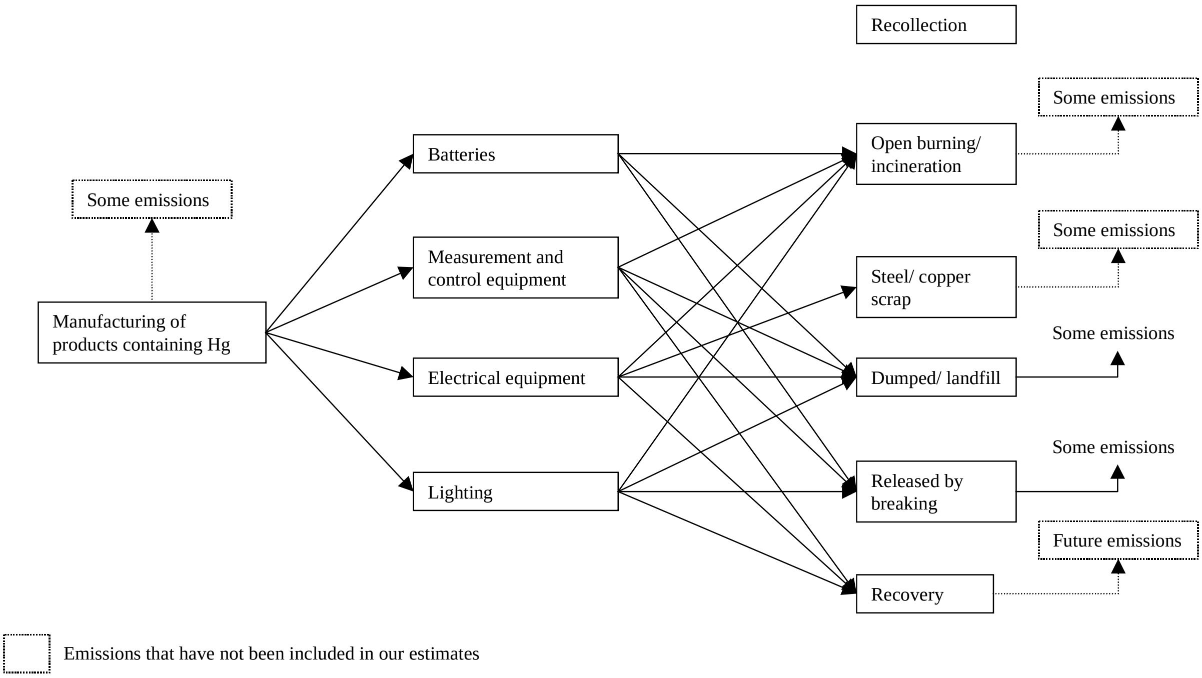


Figure 3.2 Pathways of emission sources in Eastern Europe



The emission factors differ depending on the product and destination. In general, the emission factors are higher in Eastern Europe, mostly because of less modern technology (WS Atkins 1997).

Considering the fact that almost 50% of the products containing mercury end up in the landfill in Western Europe, landfills/dumping can be considered as the major source of mercury emissions for the whole of UNECE.

3.4 Controls

Options to reduce mercury emissions from this sector include:

- Banning/phasing out of the production and sale of products containing or needing metallic mercury for their functioning;
- Limitation of the amount of mercury in products.

These will depend on the availability of substitutes not containing mercury and the actual need to use products containing mercury in the future.

3.4.1 Batteries

Since 1990, mercury consumption in primary batteries has declined significantly in the EU due to the introduction of the Directive 91/157/EEC on batteries and accumulators containing certain dangerous substances. The Directive came into force in 1994 (NSCA 1998).

The Directive covers, amongst the other types of batteries, the commonly used alkaline-manganese energy cell, the zinc-carbon battery, the zinc-air button cell as well as the silver oxide button cell and the mercuric oxide battery (two small battery types which also contain mercury). Most of mercury-oxide batteries can be substituted by zinc-air (whose power characteristics are being improved rapidly), silver-oxide and lithium batteries. Zinc-carbon and a significant percentage of alkaline-manganese batteries will soon be mercury-free (Maxson 1991). Silver Oxide batteries, are being recycled by jewellers and watch repairers and mercuric oxide batteries (used in hearing aids) are declining in number (Haigh 1995).

Consequently, the biggest part of current mercury emissions from batteries in the EU originates from special purpose mercury button cells.

3.4.2 Measuring and control equipment

Until now there is no legislation regarding the consumption of mercury in measuring and control equipment. Studies have shown that mercury thermometers are likely to be replaced by digital electronic ones or heat sensitive instruments based on liquid crystals (Maxson 1991).

3.4.3 Electrical Equipment and Lighting

There is no legislation regarding electrical equipment and lighting.

Two Directives establishing the ecological criteria for the award for the Community eco-label to single-ended (95/533) and double ended (96/337) light bulbs can probably be used as an incentive towards the reduction of the use of mercury in these products.

Due to the likely forthcoming legislation, some industry is trying to find mercury-free substitutes, in order to reduce the use of mercury in different items. For example in the electrical equipment category, mercury usage in reed switches is being phased out, but mercury is still used in tilt switches in the automotive industry.

Consumption estimates for fluorescent tubes in the mid-1990s, based on 1989 figures, have found that the levels had remained almost unchanged. In Western Europe, mercury consumption in individual lamps is declining, but use of fluorescent lamps is increasing slightly. It has been estimated, that since 1990, mercury consumption in lamps has declined by about a third (WS Atkins 1997). Additionally, discharge lamps are more energy efficient than incandescent lamps and their longer life contributes to lower mercury emissions in electricity generation (WS Atkins 1997).

4 SIMPLER METHODOLOGY

The simpler methodology involves the combination of emission factors according to different category from the four product types mentioned earlier (e.g. Hg emissions per million population) with activity statistics (e.g. population of each country for a certain year). Equation (1) gives an example of the simple methodology:

$$\text{Total Emission} = \sum_{\text{different products}} [\text{Hg emission per capita}] \times [\text{Population}] \qquad (1)$$

Emissions from the manufacturing process, the recycling and the fragmentisation stages are not included.

5 DETAILED METHODOLOGY

The detailed methodology for Hg emissions may initially involve a mercury audit to find out the amount of the Hg content in different products and the amount of products sold per year. Collection of data can take place by sector after the manufacturing plants have been located. Estimates for each sector would be combined to give a more accurate estimate of the total emission.

Audits on the destinations of the different products have to be carried out for better estimates on the distribution factors.

Emissions from the manufacturing process should be added. Also, emissions from the recycling process of products that have been recollected, as well as an estimate of emissions from the fragmentisation of products that end to the metal scrap, can be included.

Equation (2) is an example of how to calculate Hg emissions for each category:

$$\begin{aligned}
[\text{Hg emission}]_{\text{product}} = {} & \{[\text{Mass of Hg used in each item}] \times [\text{Items consumed per year}]\} \times \\
& \sum_{\text{Distribution f(pathway)}} \{[\text{Distribution factor}]_{\text{Distribution f(pathway)}} \times [\text{Emission factor}]_{\text{Distribution f(pathway)}}\} + \\
& [\text{Emissions from manufacturing process}]_{\text{product}} \times [\text{Number of manufacturing plants}]_{\text{product}} + \\
& [\text{Emissions from recycling process after recollection}]_{\text{product}} + \\
& [\text{Emissions from fragmentisation of metal scrap}] \qquad (2)
\end{aligned}$$

However, it is unlikely that information is available at present to enable the detailed methodology to be used in order to improve emissions estimated by the simple method.

6 RELEVANT ACTIVITY STATISTICS

6.1 Simpler methodology

The simpler methodology requires the following activity statistics:

- population of the country

6.2 Detailed methodology

The detailed methodology requires the following activity statistics for each plant:

- mass of mercury contained in products containing mercury per year;
- amount of items consumed per year;
- number of plants producing products containing mercury;
- details about the extent of recollection/recycling;
- details about the fragmentisation process.

For some countries, national statistics are not easy to obtain and it may be necessary to directly contact manufacturing plants and trade organisations.

7 POINT SOURCE CRITERIA

The biggest part of the emissions for the whole of Europe derives from the landfills or because products have been dumped. Therefore, landfills should be considered as a point source where site specific data are available. Otherwise they should be considered as area sources.

As the contribution of the mercury emissions from products containing mercury to the overall mercury emissions represents only a small percentage, other emission pathways covered by this chapter can be considered as an area source.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

Table 8.1 Emission Factors for Hg from products containing Hg

Compound	Product	Emission factor (tonnes per million population)		Data Quality	Reference
		Western Europe	Eastern Europe		
Hg	Batteries	0.0002	0.00004	E	WS Atkins 1997
Hg	Measurement and control equipment	0.0044	0.0013	E	WS Atkins 1997
Hg	Electrical equipment	0.0019	0.0003	E	WS Atkins 1997
Hg	Lighting	0.0005	0.0003	E	WS Atkins 1997

8.2 Detailed Methodology

Emission factors should be derived through any measurement data. However, these are unlikely to be available in sufficient detail to improve emission estimated by the simple method.

9 SPECIES PROFILES

Species profiles are not applicable.

10 UNCERTAINTY ESTIMATES

There is an uncertainty in estimating mercury emissions from mercury containing products:

- during the manufacturing process;
- during the recycling process, after products containing mercury have been recollected;
- during the fragmentisation stage of the products containing mercury that have ended in a steel/copper scrap.

There is also much uncertainty in the distribution factors, the emission factors and the activity statistics.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the methodology is the accuracy of the emission factors and the lack of field-based emission data.

The recommended emission factors should be improved through measurement. However since there is a difficulty in making these measurements, activity data should be investigated first. If the investigation shows that activities are decreasing, then it will be less necessary for measurements to be carried out.

The EPBA (1992) report suggests that emissions via disposal of dental amalgams might be as significant as some of the main four product categories, and this needs to be reviewed.

If the chapter on landfills (90400) is updated to include mercury emissions, then the potential for double counting should be addressed.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Mercury emissions from products may be considered to be distributed according to population. However, given that most of the emissions come after the products have been disposed and particularly from landfills, a significant improvement in the spatial disaggregation would be made if the main territorial units were identified according to landfills.

The figures that derive from landfills have to then be combined with the population that uses the specific landfill.

In case landfill locations are not available, population should be used for measuring emissions from all sources.

13 TEMPORAL DISAGGREGATION CRITERIA

Unless better information is available, emissions may be considered to occur evenly through out the diurnal and annual cycles. However, emissions of mercury are likely to vary with temperature.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

No supplementary documents are required.

16 VERIFICATION PROCEDURES

Verification of the emission factors given for the simple methodology should involve the audit-type activities described as the detailed methodology (section 5).

17 REFERENCES

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European Commission (1996) 96/337 Commission Directive of 8 May 1996 establishing the ecological criteria for the award of the Community eco-label to double-ended light bulbs.

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19 RELEASE VERSION, DATE AND SOURCE

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Source: Elena Lymberidi
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20 POINT OF ENQUIRY

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SNAP CODE: **N/A**

SOURCE ACTIVITY TITLE: **ELECTRICAL EQUIPMENT CONTAINING PCBS**

NOSE CODE: **112.09.13**

NFR CODE: **N/A**

1 ACTIVITIES INCLUDED

This chapter covers emissions to atmosphere from electrical equipment containing PCBs. It covers emissions which result from existing electrical equipment containing PCBs, through leaks or spills, and from the recycling of this equipment by fragmentising / shredding.

This chapter does not cover emissions from landfill, from the burning of electrical equipment containing PCBs through accidental or deliberate fires (SNAP 09), from the processes of utilisation of electrical equipment, and emissions from open applications of PCBs.

2 CONTRIBUTION TO TOTAL EMISSIONS

The major use of PCBs, and so the main source of secondary environmental pollution by PCBs, is electrical equipment. In the UK, for example, it is estimated that over 90% of PCB emissions arise from leaks from transformers and capacitors and from fragmentising operations (APARG, 1995). Recent estimates of the European emissions in 1990 indicate that as much as 94% of PCB emissions come from this source (Berdowski et al., 1997). Electrical equipment containing PCBs is unlikely to be a significant source of any pollutant other than PCBs.

Table 2.1 Contribution to total emissions of the CORINAIR90 inventory

Source-activity	**SNAP-code**	**Contribution to total emissions [%]**							
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
Electrical equipment containing PCBs		-	-	-	-	-	-	-	-

- = no emissions are reported

Table 2.2 Contribution to total POP and heavy metal emissions of the OSPARCOM HELCOM-UNECE emission inventory *(up to 39 countries)*

Source-activity	**SNAP-code**	**Contribution to total emissions (including emissions from nature) [%]**									
		As	Cr	Cu	Pb	Cd	Hg	PCBs	PCDD/Fs	HCB	PCP
Electrical equipment		0	0	0	0	0	0	94	0	0	0

- = no emissions are reported

3 GENERAL

3.1 Description

PCBs are synthetic organic compounds, which mix well with organic solvents and plastics, etc. They are stable to strong acids and alkalis. This high chemical stability, together with their electrical stability (particularly at variable voltage), as well as their resistance to degradation at high temperatures, have in the past resulted in a range of industrial applications. PCBs were widely used as dielectric fluids for a long period (approx. from 1929 to 1988), mainly in industrial transformers and capacitors.

The main difficulty in compiling an inventory of PCB emissions is the tracking and identification of PCB-containing equipment, since there are no relevant readily available statistics.

3.2 Definitions

Capacitor - a device for accumulating and holding a charge of electricity. Some were made with PCBs as the dielectric fluid.

Dielectric fluid - insulating material used in electrical equipment, separating the conduction surfaces (sometimes containing PCBs).

Fragmentising operations - the breaking up of household appliances (e.g. cookers, refrigerators) for recycling.

PCBs - polychlorinated biphenyls. A subset of the synthetic organic chemicals known as chlorinated hydrocarbons; this includes any chemical substance of the biphenyl molecule that has been chlorinated to varying degrees. The chemical formula for PCBs can be represented as $C_{12}H_{(10-n)}Cl_n$, where n is number of chlorine atoms within the range of 1-10. A total of 209 individual isomers exist; these range from liquids to high-melting crystalline solids.

Transformer - a device that is used to raise and lower voltage. PCB-containing transformers are typically located in electricity facilities and industrial sites.

3.3 Activities

3.3.1 Electrical equipment and PCB use

The main use of PCBs has been as dielectric insulating materials in electrical equipment such as capacitors and transformers (see Table 3.1). Most countries have not manufactured PCBs for many years, but many of the old appliances still exist; the useful life of such appliances is 20-30 years.

Table 3.1 Use of PCBs in USA, Germany, Japan and Russia

Country	% of total PCBs used as dielectric fluids	Reference
USA	until 1971, 61%; after 1971, 100%	USEPA, 1987
Germany	55.5%	Dobson and van Esch, 1993
Japan	66%	Neumeier, 1998
Russia	75%	Kakareka et al., 2000

The majority (70%) of capacitors are used as power capacitors; high frequency capacitors have the next highest usage (Gulevich, 1981, data for the former USSR). Power capacitors are used in high and low voltage transmission lines or in high frequency transmission units for a variety of purposes, such as:

- to increase the capacity factor of industrial electrical units;
- to increase the capacity factor of induction electrical and thermal units;
- to compensate for reactive resistance of long-distance power transmissions;
- to take off power from high voltage transmission lines;
- to filter traction substation;
- to generate impulse current and voltage;
- to start capacitor electric motors;
- in mine electric locomotives;
- in ultrasonic units.

They can be used both as separate units and in the form of complex capacitor units or batteries.

Power capacitors produced in different countries have similar size parameters. Large high voltage capacitors typically weigh 54 kg, of which 11 kg are PCBs (USEPA, 1987); power factor correction capacitors produced in the USSR have 2 typical sizes, weighing 28-35 kg and 54-60 kg, of which 10 and 19 kg are PCBs respectively (Kakareka, 2000).

Small capacitors include motor start capacitors and ballast capacitors. Motor start capacitors are used with single phase motors to provide starting torque; these capacitors can be found also in household electrical appliances including refrigerators, cookers, washing machines, air conditioners, dishwashers, etc (UNEP, 1999). Many such appliances are still in use but it is difficult to establish what proportion of these goods have PCB-containing components. Ballast capacitors are found within fluorescent, mercury, and sodium lighting fixtures, and neon lights; they typically weigh 1.6 kg, of which 0.05 kg are PCBs (USEPA, 1987).

Transformers are used for electric power transformation in power transmission lines and in power energy receipt and use units. The transformer is a very important component in different types of electrical circuits, from small-signal electronic circuits to high-voltage power transmission systems. The physical size and shape of transformers, and therefore the volume of PCBs in them, vary greatly. Transformers can range in size from not much bigger than a pea up to the size of a small house (UNEP 1999); the volume of PCBs typically ranges from 0.2 to 4.1 tonnes (Kakareka, 2000).

3.3.2 PCBs as dielectric fluid

Commercial products known generically as PCBs are mixtures of individual isomers in which the chlorine content is between 21 and 68%. Registered trade names for some commercial brands of PCBs are: Aroclor, Chlorinol, Askarel, Dykanol, Pyranol (USA), Pyralene (France), Clophen (Germany), Kannechlor (Japan), Delor (Czechoslovakia), Sovol, Trichlorobiphenyls, Sovtol (USSR). Arochlor is the best known of the PCB formulation and has served as a standard. Example characteristics are shown in Table 3.2.

Table 3.2 Chlorinated liquid dielectric characteristics (Kakareka, 2000)

Name	Composition	Density at 20°C, kg/m^3	Chlorine content, %
For capacitors			
Sovol	Pentachlorobiphenyl	1.55	54.6
TCB	Trichlorobiphenyl	1.4	42
Aroclor 1232	Dichlorobiphenyl	1.27-1.28	32
Aroclor 1242	Trichlorobiphenyl	1.38-1.39	42
Aroclor 1248	Tetrachlorobiphenyl	1.405-1.415	48
Aroclor 1254	Pentachlorobiphenyl	1.495-1.505	54
Clophen -30	Trichlorobiphenyl	1.35	42
Pyralene 1460	Polychlorobiphenyls+Polychlorobenzenes	1.41	
Pyralene 1499	Trichlorobiphenyl	1.38	42
Pyralene 2000	Dichlorobiphenyl	1.29	32
Pyralene 3010	Trichlorobiphenyl	1.38	42
Pyralene 5000	Pentachlorobiphenyl	1.55	54
For transformers			
Askarel	Polychlorobiphenyls (60-70%) + Chlorobenzene (30-40%)		
Sovtol-10	Pentachlorobiphenyl (90%) + Trichlorobenzene (10%)	1.52-1.54	
Hexol	Pentachlorobiphenyl (20%) + Hexachlorobutadiene (80%)	1.64	

3.3.3 Leaks from transformers and capacitors

The majority of emissions of PCBs arise from leaks from electrical transformers and capacitors which contain PCBs and which are in a poor condition and/or are poorly maintained.

It is likely that the oil of some transformers that were not originally deliberately filled with PCBs has become contaminated with PCBs. However, it is estimated that over 90% of these transformers are contaminated to levels less than 50 ppm (APARG 1995). The source of this contamination is likely to be the lack of segregation in the past of oil and PCB filling lines at manufacturers' works, and the subsequent use of recycled oil.

3.3.4 Fragmentising operations

Some small capacitors containing PCBs will be landfilled with household waste, but most will be in appliances that will be partly recycled by fragmentising. This is the process by which domestic electrical appliances are shredded and the fragments separated into the following 3 fractions:

- ferrous metal, which is recycled to steel producers;
- a non-ferrous metal enriched 'heavy' fraction, which is mainly disposed to landfill following processing to remove the non-ferrous metals;
- a 'light' or 'dirt' fraction that consists largely of non-metallic waste materials (e.g. wood, glass, plastic etc), which is mainly disposed to landfill.

There is the potential for PCB release both from fragmentiser wastes disposed to landfill and from the fragmentiser process itself, as well as during metal processes when recycled ferrous metal is used. The release of PCBs to atmosphere greatly depends on the process temperatures.

3.3.5 Disposal of electrical equipment containing PCBs

Large quantities of PCBs have been disposed to landfill in the past, mainly in the form of electrical components or fragmentiser residues, but discarded electrical equipment known to contain PCBs is now often disposed of by chemical waste incinerators. However, emissions from disposal of electrical equipment are not covered by this chapter.

3.4 Emissions

The major source of PCBs arises from leaks of dielectric fluid containing PCBs from large electrical transformers and capacitors which are in poor condition. PCB emissions from transformers and capacitors during normal operation are negligible (section 3.3.3).

In addition, fragmentising operations are also likely to be significant sources of PCBs where electrical appliances containing PCBs are involved (section 3.3.4).

3.5 Controls

Not all PCB-filled transformers are identifiable, although many of the ones that are known are owned by organisations that operate to rigorous safety standards. In such cases the environmental impact of leaks from the transformers has therefore been minimised. These transformers can be landfilled after being drained and flushed, and the PCBs are accessible for controlled disposal, usually by incineration.

4 SIMPLER METHODOLOGY

There are limited data available on emissions of PCBs from electrical equipment and therefore the simple methodology is based on emission factors which have been developed by calculation, using population as the activity. The emissions can be estimated using the equations below. Default emission factors are given in Section 8.

4.1 Transformers and Capacitors

Atmospheric emission of PCBs from transformers/capacitors
= (per capita emission factor) x (population)

4.2 Fragmentising Operations

Atmospheric emission of PCBs from fragmentising operations
= (per capita emission factor) x (population)

For the emission of PCBs from fragmentising operations, the emission can also be estimated using an emission factor based on the quantity of ferrous scrap recycled, using the equation:

Atmospheric emission of PCBs from fragmentising operations
= (emission factor per unit mass of ferrous metal recycled) x (mass of ferrous metal recycled)

5 DETAILED METHODOLOGY

The detailed methodology involves a review of the estimated number of transformers and capacitors in a country and an analysis of the proportion of these which contain PCBs and the proportion which have the potential to leak. This analysis would therefore require a more detailed audit of electrical equipment within a country.

Similarly, for fragmentising operations, the detailed methodology involves an analysis of the types of ferrous scrap recycled, and requires more detailed knowledge of the quantity of PCBs within the different types of ferrous scrap.

The first stage in the inventory of electrical equipment with PCBs requires the identification of power capacitors and power transformers, ie those devices where most of the PCBs have been used. This group alone can consist of thousands of appliances distributed over hundreds of users, so their full inventory is a very complicated task. As the first approximation a selective inventory of main users can be proposed.

This inventory should detail separately transformers and capacitors, with an indication of their type, dielectric type, equipment number, year of manufacture, producer. Electrical equipment that was in operation, in reserve or damaged must also be taken into account. It is not always possible to determine the capacitor type and the year of its manufacture; there are problems of dielectric type determination (often it is defined under a general name ‘synthetic’). It is difficult to track equipment as in many cases capacitors have no registration certificates, as there are no regulations for PCB-containing equipment operation; also some equipment may have been stored at dumps or used for other purposes.

The second stage of PCB inventory includes calculation of the volume of dielectric fluids. The amount of dielectrics in large capacitors varies depending on its type from 2.7 kg to 22-24 kg; most of the widely used power capacitors contain 14 kg of PCBs. The volume of PCBs in transformers varies depending on its type from 0.2 t to 4.1 t (Kakareka, 2000).

Default emission factors are given in Section 8.

6 RELEVANT ACTIVITY STATISTICS

6.1 Simple methodology

The simple methodology for estimating PCB emissions from leaks from transformers and capacitors requires knowledge of the population in a country. This information will be available from national statistics offices.

The simple methodology for estimating PCB emissions from fragmentising operations requires knowledge of the population or the quantity of ferrous scrap recycled in a country.

6.2 Detailed methodology

The detailed methodology for estimating PCB emissions from leaks from transformers and capacitors requires detailed knowledge of the quantities of transformers and capacitors which contain PCBs and their state of maintenance. This information might be available from national Electricity Associations.

The detailed methodology for estimating PCB emissions from fragmentising operations requires knowledge of the quantities and types of ferrous scrap recycled and the quantity of PCBs in the types of ferrous scrap.

7 POINT SOURCE CRITERIA

Although leaks from electrical equipment sites might be significant, limited information is likely to be available on the location and scale of leaks. Therefore electrical equipment should be treated as area sources unless reliable site specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Concerning emission factors presented in Table 8.1, Berdowski et al. (1997) have calculated emissions of PCBs due to leaks from transformers and capacitors for each of the European countries in 1990. The range of the per capita emission factors is large; almost two orders of magnitude. This indicates a difficulty in choosing a proper emission factor and the high uncertainty of emission estimates on the basis of these emission factors.

Table 8.3 gives default emission factors for calculating emissions to air from the amount of leakage of PCBs. The process of evaporation is very complex and has not been well studied, although it is known that rate of evaporation decreases with increase of level chlorination of PCB; therefore Trichlorobiphenyl, which is used in, and leaks from, capacitors, will evaporate more rapidly than Pentachlorobiphenyl (Sovtol-10 or other brand) from transformers.

Table 8.1 Emission factors for leaks from transformers and capacitors

Compound	Equipment / process	Abatement type	Abatement efficiency	Fuel type	Emission factor	Data Quality	Country or region	Reference
Total PCBs	Leaks from transformers	None	N/A	N/A	**0.006 - 0.5 g/capita/year [1]**	**E**	Europe	Berdowski et al. (1997)

[1] Recommended emission factor 0.13 g/capita/year

Table 8.2 Emission factors for fragmentising operations (recycling of ferrous scrap)

Compound	Equipment / process	Abatement type	Abatement efficiency	Fuel type	Emission factor	Data Quality	Country or region	Reference
Total PCBs	Fragmentiser operations (recycling of ferrous scrap)	None	N/A	N/A	**0.004 g/capita/year**	**E**	UK	Harrad et al. (1993)
Total PCBs	Fragmentiser operations (recycling of ferrous scrap)	None	N/A	N/A	**0.25 g/t of ferrous scrap recycled**	**E**	UK	Harrad et al. (1993)

Table 8.3 Leaks (releases) and emission factors of PCBs from electrical equipment, kg/t

Equipment	Leaks (releases)	Emission to air	Country or region	Reference
Transformers	0.06	-	Europe	TNO, 1995
	0.3	-	North America	USEPA, 1997
	0.3	0.06	CIS countries	Belarusian report to EMEP, 2000
Capacitors	1.6	-	Europe	TNO, 1995
	4.2	-	North America	USEPA, 1997
	2.0	0.8	CIS countries	Belarusian report to EMEP, 2000

9 SPECIES PROFILES

No information is available on the PCB species profiles from electrical equipment.

10 UNCERTAINTY ESTIMATES

The majority of PCB emissions arise from electrical transformers and capacitors in poor condition, and by the nature of this source emissions are difficult to estimate. The use of per capita emission factors is uncertain because the emission factors are likely to vary significantly between countries. For example the quantity of PCBs remaining in electrical equipment will vary as well as the standard of maintenance and quality of safety procedures to prevent leaks.

The emission factors in Section 8 are based on calculations rather than measurement. The emission factors therefore have a data quality of E.

A key uncertainty is that, although the approximate quantity of PCBs produced in the past is known, the exact quantity of PCBs still in existence is unknown. Other uncertainties include the possibility of double counting in the total PCB inventory as PCB emissions from landfill are likely to include emissions that arise from electrical equipment disposed to landfill. However, this uncertainty is less important compared with those described above.

11 WEAKEST ASPECTS / PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the methodology is the emission factors, which are very uncertain for the reasons described in Section 10. The emission factors can be improved by improving the knowledge of the quantity of PCBs in existing electrical equipment and the rate of leakage.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

PCB emissions from electrical equipment can be assumed to be spatially disaggregated according to population unless reliable data are available on leaks from specific sites.

13 TEMPORAL DISAGGREGATION CRITERIA

Until better information becomes available, emissions may be considered to occur evenly through out the diurnal and annual cycles. However, as electrical equipment containing PCBs continues to be replaced, emissions will in reality decrease with time.

14 ADDITIONAL COMMENTS

There are no additional comments.

15 SUPPLEMENTARY DOCUMENTS

Supplementary documents are not required.

16 VERIFICATION PROCEDURES

Verification procedures are in line with the priority requirements for improvement described in section 11, i.e. improved knowledge of the quantity of PCBs in existing electrical equipment and the rate of leakage is required to verify the emission factors. In addition, the research into the variation in leakage between countries could verify whether the use of per capita emission factors is reliable.

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