PART B BACKGROUND

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 this 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).

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 has 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 will be further developed and tested in 1999 by Eurostat, in co-operation with EEA. In this Guidebook some NOSE-P codes have already been incorporated on a trial basis in various chapters.

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 code	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	Halogenated hydrocarbons production - By-products
	04 08 04	Sulphur hexafluoride production - By-products
2 E 2 Fugitive Emissions	04 08 02	Halogenated hydrocarbons production - Fugitive
	04 08 05	Sulphur hexafluoride production - Fugitive
2 E 3 Other	04 08 03	Halogenated hydrocarbons production - Other
	04 08 06	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)							
		SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
sector	**name**								
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)							
		SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
sector	**name**								
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

EMISSION ESTIMATES (Kilotonnes; for CO2: Megatonnes)

sector	name	SO2	NOx	NMVOC	CH4	CO	CO2	N2O	NH3
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.

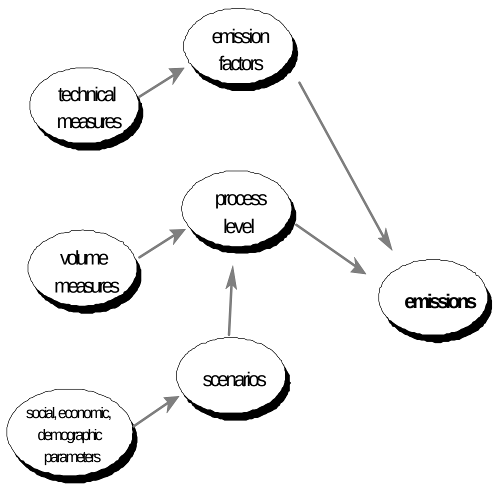

Figure 1 From economic scenarios and environmental policy to emission projections

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:

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

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.

$$FS_{i,j} = \sum_{k} \sum_{l} P_{i,j,k,l} \cdot F_{i,j,k,l} \tag{2}$$

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.

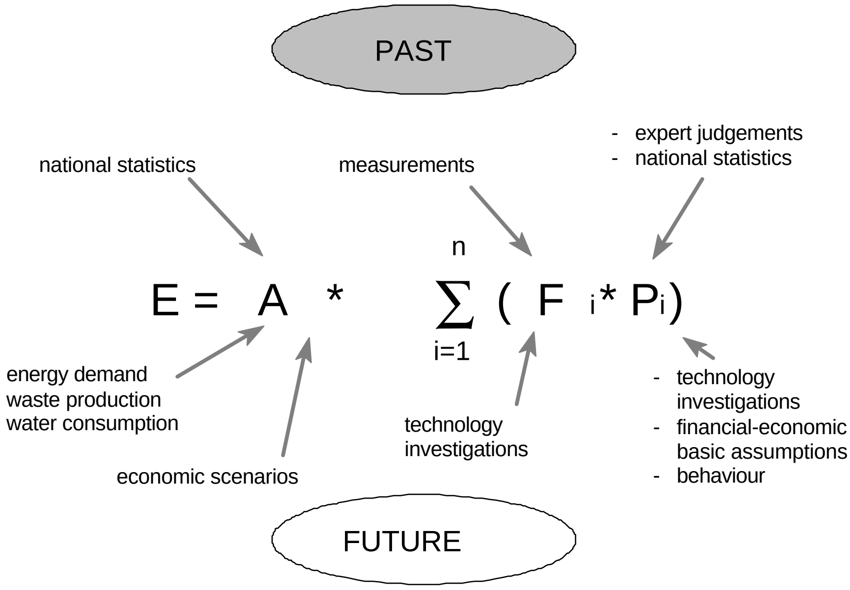

Figure 2 The fundamental formula for emission calculations and its application in inventories and projections

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.

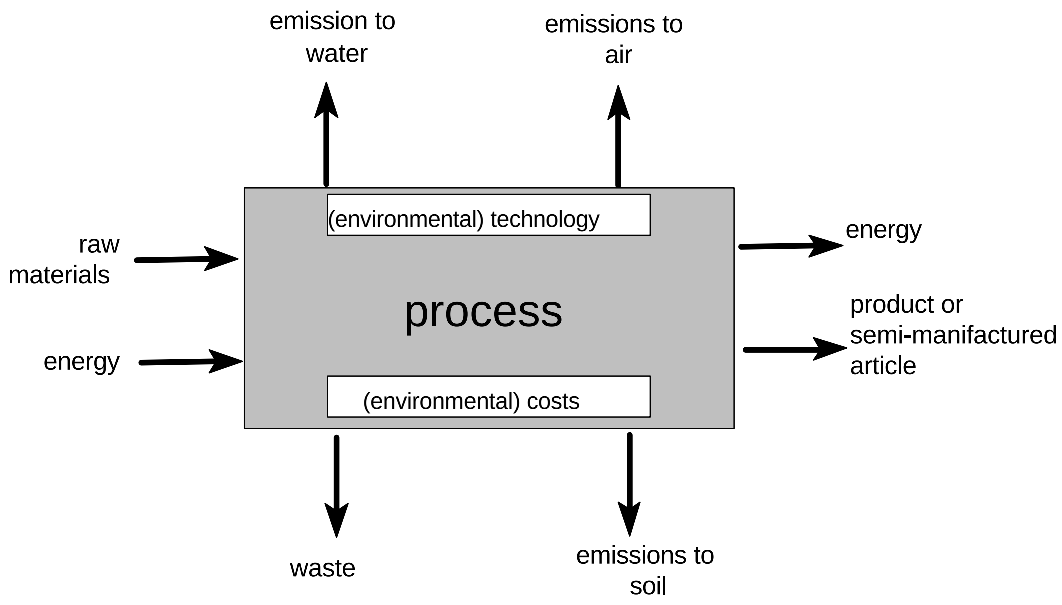

Figure 3 A schematic approach for production (and consumption) processes

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

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]

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	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 sub-divisions 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).

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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).

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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.

9.8 References

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See also general references (par. 10).

9.9 Bibliography

See general bibliography (par. 11).

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10 GENERAL REFERENCES

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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.

THE TEMPORAL VARIATION OF EMISSION DATA AND THE GENEMIS PROJECT

1 INTRODUCTION

Not much attention has been paid to the temporal variation of emissions in the past. While emission inventories and emission inventory methodologies experienced considerable improvements and the quantity of information has increased enormously, not much information is available about the temporal variation of emissions. In contrast to this lack of information, however, episodic phenomena of air pollution gained growing importance in the past years. Particularly, photo-oxidant formation is highly dependant on short-term atmospheric conditions like daily or hourly emissions of pollutants with short atmospheric lifetimes. Hence, a scientific understanding of photo-oxidant pollution and the elaboration and optimisation of responses to this growing pollution problem in Europe require sufficient knowledge about the temporal variation of emissions.

A number of sophisticated atmospheric transport and chemistry models have been developed and used to enhance the scientific understanding of pollution episodes, calculate pollution transport and balances, and provide a better basis of knowledge for political decision making. It has become evident that such model simulations require reliable information about emissions with a high temporal resolution. In past years, modellers had to use simple temporal patterns describing the temporal variation of total emissions. These patterns are based on educated guesses and only to a very small extent on empirical information. They usually do not take into consideration regional and national differences and provide only very rough and averaged information.

Such simple temporal patterns can be considered satisfactory only for rather simple atmospheric models with low temporal, spatial, and vertical resolution and low sensitivity with regard to the temporal variation of emissions. Simulation results based on simple models and rough input data, therefore, have to be treated with utmost care. Emission data, simulation mechanisms and verification procedures are imperfect and cause smaller and larger errors introducing a more or less high uncertainty of estimation results.[3] It has become evident that the increasing complexity and detail of simulation models on the one hand, and the increasing need of reliable information for environmental policies on the other hand call for an increased detail and an increased quality of input data. This is particularly true for the application of simulation models in the development, assessment, and optimisation of abatement strategies in Europe.

To address these requirements, a comprehensive investigation has been performed by the GENEMIS-project (Generation of European Emission Data for Episodes) in the framework of the EURECA-project EUROTRAC. Within GENEMIS empirical data have been collected and

3 It has to be emphasized that successful simulations with coarse data are at least partly due to little detail, coarse spatial and vertical resolution and imperfection of simulation models. For a discussion of the imperfection of atmospheric models see e.g. Carlier P., Atmosphärischer Transport und Umwandlung der VOC, Bericht der VOC- Landeskommission, Heft 21, 1993, S.91-135.

models for the simulation of the temporal variation of emissions been developed in order to examine the quality of the data used in the past, to enhance the state of the art and to provide improved monthly, daily, and hourly emission data for the whole area of Europe (e.g. Friedrich 1993, Friedrich et al. 1993, Friedrich et al. 1994, Heymann 1992, Heymann 1992a, Heymann 1993, Heymann 1993a, Heymann 1994).

The investigations of GENEMIS have shown, that:

- information about the variation of activities is available for many source sectors in many countries;
- a considerable temporal variation of emissions from all major source sectors can be observed. This variation is highly variable not only from sector to sector, but also from country to country;
- coarse time patterns as used by many modellers in the past should be improved to enhance the quality of the temporal resolution

Of course, uncertainty margins increase with higher resolution of emission data. Calculations of monthly, weekly, daily or hourly emission data can not be regarded as precise descriptions of real emissions. As for all emission inventories, high temporal resolution data also pose the general problem, that they cannot be verified easily, and uncertainty margins can only be roughly estimated. Nevertheless, the reliability of emission data increases with the amount and quality of base data used in the calculations.

This chapter will give an overview of the information about the temporal variation of emissions, which is currently available for all major source sectors.[4] Section 2 summarises calculation approaches that had been used to estimate the variation of emissions. Section 3 describes detailed new models for a more reliable estimation of the temporal variation of emissions in all major sectors and results that have been achieved with these models within EUROTRAC-GENEMIS. In section 4 results of the total variation of emissions in Europe in 1990 are presented and regional difference highlighted. In the conclusion in section 5 the progress that have been made within GENEMIS and the state of knowledge that has been achieved is summarised.

2 CALCULATION APPROACHES OF EMISSION DATA WITH HIGH TEMPORAL RESOLUTION

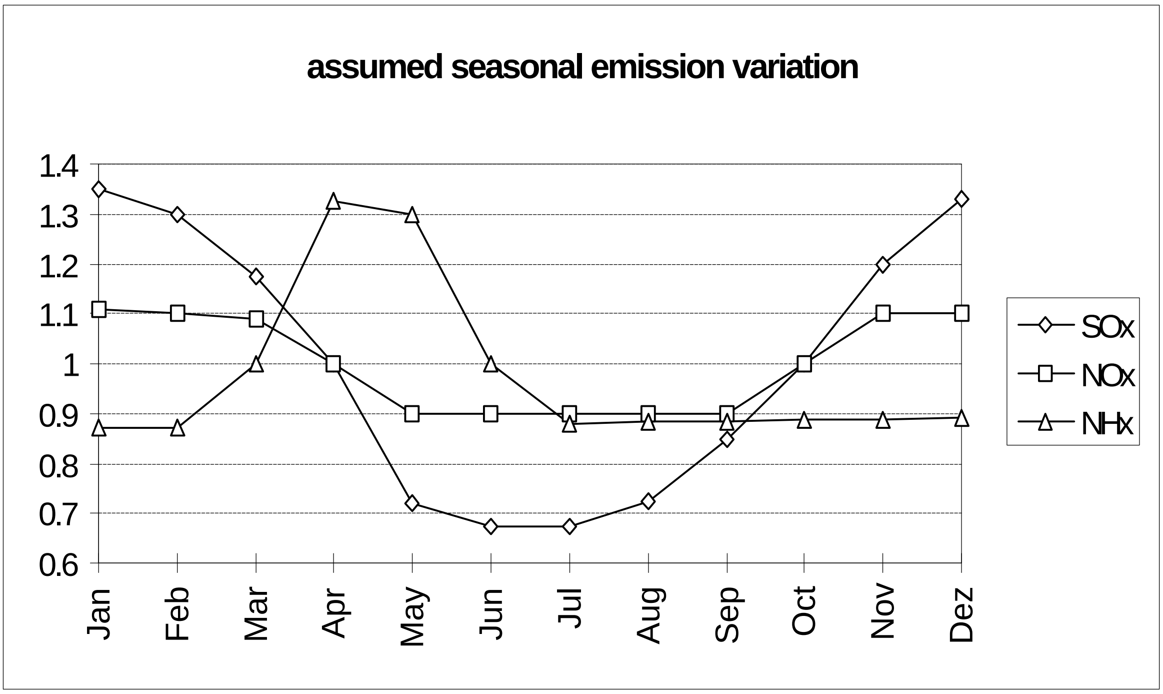
In Europe millions of vehicles, production plants, heating installations, etc. cause emissions of air pollutants. It is impossible to collect individual information about all these emission sources. Instead, simplifying top-down procedures based on averaged emission behaviours have to be applied. The averaged emission behaviour is described by emission factors, statistical activity data, and information about the temporal variation of activities.

[4] It has been considered more useful to give a comprehensive discussion of the temporal variation of emissions for all source sectors in this chapter to provide an appropriate overview.

The simplest approach to consider the temporal variation of emissions is the estimation and application of patterns of relative total emissions in time, which can be multiplied by total annual emissions in order to get monthly, weekly, daily, or hourly emission data. Such rough and general time patterns are being used by many modelers. In figure 1 such simple monthly time patterns as used by EMEP and EURAD are presented. These time patterns are based on a simple set of plausible assumptions. They do not contain detailed information about individual emission sectors in different regions.

Temporal patterns with some more detail had been estimated for the PHOXA and the LOTOS inventory (Axenfeld 1987, Meinl et al. 1989, Hulshoff 1991, Veldt 1992). These patterns are represented by different monthly, daily, and hourly time factors for 12 source sectors. By multiplication with appropriate LOTOS time factors hourly emission intensities can easily be calculated from annual emissions. LOTOS time factors take into consideration different emissions in summer and winter, on working-days and at weekend-days, and during day-time and night-time. These factors are presented in table 1.

Figure 1: Temporal patterns for the monthly distribution of total emissions as used by EMEP and EURAD



LOTOS time-factors are also based on reasonable, simplified assumptions. Statistical data have only been considered for power plants and road traffic from the Netherlands and from Germany (Veldt 1992a). The factors are assumed to be generally applicable to all European countries and to all years. National or regional differences of the temporal behaviour of emission sources are not taken into consideration.

Table 1: LOTOS time-factors for the estimation of emission data with high temporal resolution (Source: TNO, Delft).

LOTOS-Category	Sector	Winter	Summer	Working-day	Weekend-day	Day-time	Night-time	Temperature -dependency
1	Power plants	1.1	0.9	1.06	0.85	1.1	0.9	no
2	Area source combustion	1.04	0.96	1.08	0.8	1.24	0.76	no
3	Small cons. combustion	1.55	0.45	1	1	1.5	0.5	no
4	Refineries	1	1	1	1	1	1	no
5	Industrial processes	1	1	1	1	1	1	no
6	Solvent use	1	1	1	1	1	1	no
7	Road traffic gasoline	1	1	1	1	1.8	0.2	yes
8	Road traffic diesel	1	1	1	1	1.8	0.2	yes
9	Road traffic evaporation	1	1	1	1	1.8	0.2	yes
10	Coniferous	1	1	1	1	1	1	yes
11	Deciduous isoprene	1	1	1	1	1	1	yes
12	Deciduous non-isoprene	1	1	1	1	1	1	yes

The LOTOS-approach represents an attempt to include some more detail in the estimation of emission data with high temporal resolution and preserve a simple structure and minimum storage capacity needs for this information. However, these factors do not consider developments such as variations of fuel use or variation of production due to economic developments, changing climatic conditions, and changing user behaviour. The GENEMIS exercise has shown that the difference between this approach and more detailed calculations might add factor of 2 to the temporal variation of emissions for some sectors, regions, and periods.

Therefore, the LOTOS-concept has been extended and generalised within GENEMIS. In GENEMIS a large number of time factors have been derived. These calculations were based on actual statistical data, so-called *indicator data*, and on appropriate simulation models developed for the estimation of the temporal variation of emissions (e.g. Friedrich et al. 1993). The exercise of GENEMIS has proven that for the most important sectors appropriate indicator data are available. These indicator data change from sector to sector and depend on the temporal resolution to be achieved. The most important and useful indicator data used are production data (or production indices), fuel use data, traffic counts, meteorological data (temperature), and data on holidays and working times. In table 2 the most appropriate indicator data used to model the temporal variation of emissions are shown for the main sectors.

Table 2: Indicator data for the estimation of emission data with high temporal resolution (Source: GENEMIS data base, IER, Stuttgart).

Sector	Indicator data for monthly resolution	Indicator data for daily resolution	Indicator data for hourly resolution
Power plants	fuel use	load curves	load curves
Industrial combustion	fuel use, temperature, degree days, production	working times, holidays	working times
Commercial, institutional and residential combustion	fuel use, degree days	user behaviour	user behaviour
Refineries	oil throughput, fuel use	working times, holidays	working times, shift times
Industrial processes	production	working times, holidays	working times, shift times
Solvent use	production	working times, holidays	working times, shift times, user behaviour
Road traffic	traffic counts	traffic counts	hourly traffic counts
Air traffic	LTO cycles, number of passengers and freight	LTO cycles, number of passengers and freight	LTO cycles, number of passengers and freight
Biogenic emissions	temperature, radiation	temperature, radiation	temperature, radiation

These indicator data allow the estimation of representative time-factors. Actual economic developments, climatic conditions, and changes of behaviour are implicitly considered by the indicator. Therefore, these indicator data provide the best basis for a description of the average temporal behaviour of emission sources in different sectors, regions, and times.

3 MODELLING THE TEMPORAL VARIATION OF EMISSIONS IN EUROPE

Only very few investigations have been made to estimate the temporal variation of emissions thoroughly. Most modellers are still used to apply simple time patterns to total emissions in order to obtain higher resolution data as needed by atmospheric transport and transformation models. It has not been examined how good or how bad these approaches are. The more elaborated investigations within GENEMIS provide more detailed information and show the shortcomings of time patterns used in the past. The simulation models developed and the resulting time variations will be presented in this sector for the major source categories. For a comparison, other time-patterns, which represented the best information available in past years, are included in the graphs.

3.1 Snap Sector 1 - Public power plants

a. Indicator data and simulation models for public power plants

Emissions of all combustion sources are related to the actual fuel use of these sources. Fuel use data with higher temporal resolution than annual provide a good estimate for the temporal variation of emissions. In the case of public power plants monthly fuel use data by fuel types are usually available. For European Union member states such data are available from the statistical office of the European Union, EUROSTAT, in Luxembourg. For other countries fuel use data are usually available from national statistical offices or from the utilities.

Daily and hourly power plant emissions can be estimated from load curves. For all UCPTE member states total national grid loads are available for the average Wednesday of every month. In some countries more and more detailed load curves are available from national load dispatch stations or from utilities. In some countries even data on hourly total load for all power plants are available. Such load curves provide a good basis for the estimation of emissions with high temporal resolution.

In the case of aggregated national (or regional) load curves, at least base load, medium load and peak load power plants have to be distinguished. This information is available from energy statistics or utilities or can be estimated from energy production or total power of individual power plants. Base load power plants (including nuclear power plants) must be assumed to be in continuous operation, while medium power plants cover the medium share and peak power plants cover the peak share of total energy production (Adolph 1994).[5]

b. The variation of power plant emissions

Usually, power plant combustion shows a typical seasonal variation: higher loads in the winter and lower loads in the summer. Data on monthly fuel use of public utilities from 1985-1992 confirm this behaviour for many countries. The individual patterns (distribution of maxima and minima) and magnitudes of the seasonal variation, however, look very different for different countries (see figure 2). While the seasonal variation of fuel use in power plants in Germany, Italy, Poland, Hungary and the UK ranges between 30% and 40%, it is much stronger in France and reaches up to 270%. The high share of nuclear power in France causes an extreme variation of monthly fuel use with almost no fuel use from May to August.

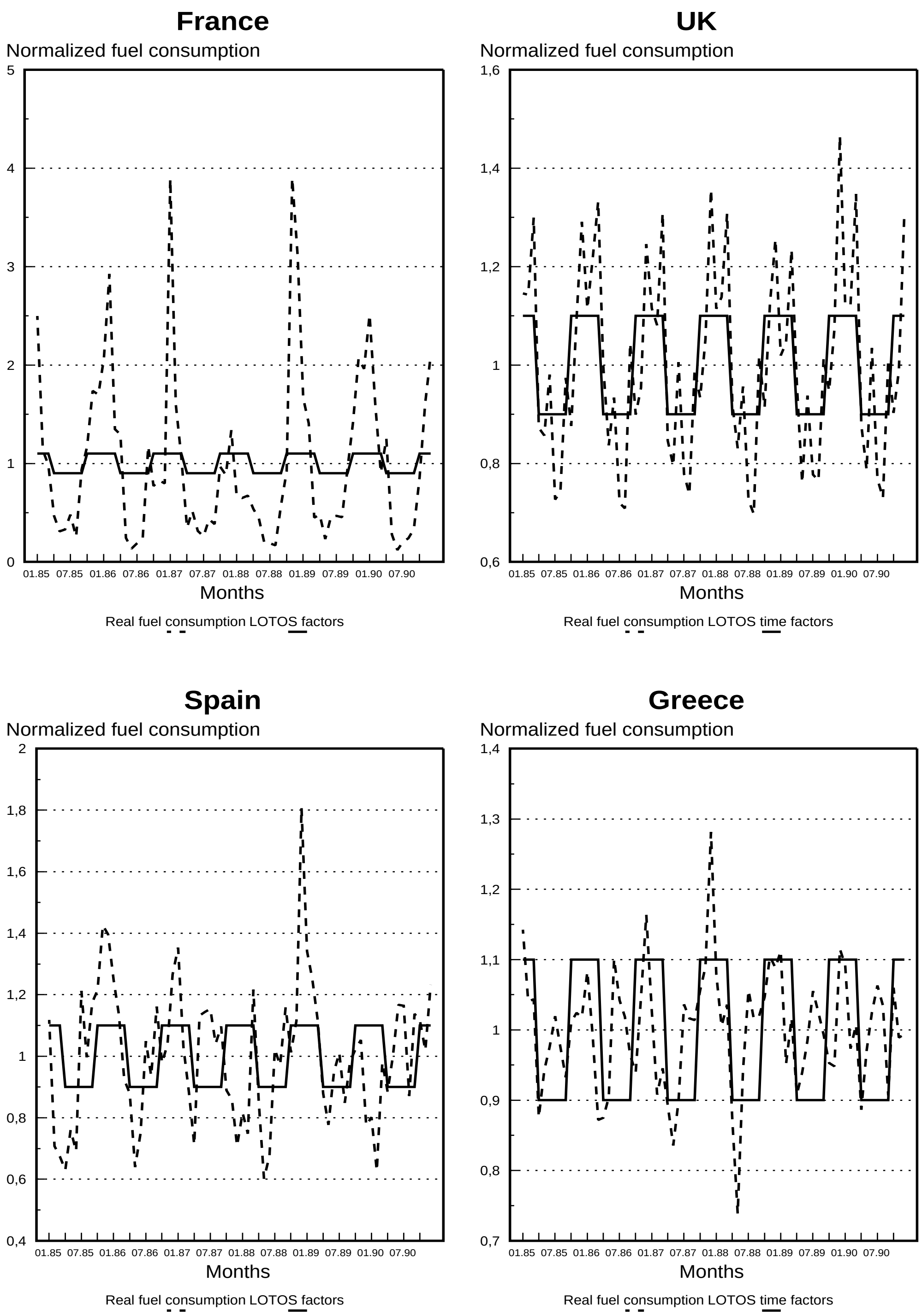
In small countries like Portugal and Greece the monthly fuel use shows a more irregular behaviour with peaks in the summer and for minimum fuel use in spring. This behaviour is due to factors like availability of water power, import of electricity, etc. The UK and Ireland, additionally, show a strong monthly oszillation. In Hungary total national load curves typically show a higher fuel use in the winter and a lower fuel use in the summer. Load curves for individual power plants, however, do not always follow this characteristic, but show a completely different temporal behaviour, especially for some big power plants.

These investigations showed considerable differences to older time factors, which generally assume a smaller seasonal variation of power plant emissions. While for most countries summer emissions from power plants are overestimated by approximately 20%, for France this overestimation reaches 600%. The overestimation in summer is contrasted by a clear

[5] Detailed data from some countries (e.g. Hungary) show, however, that single base load power plants in operation display variations of up to 20-30% (Török 1995).

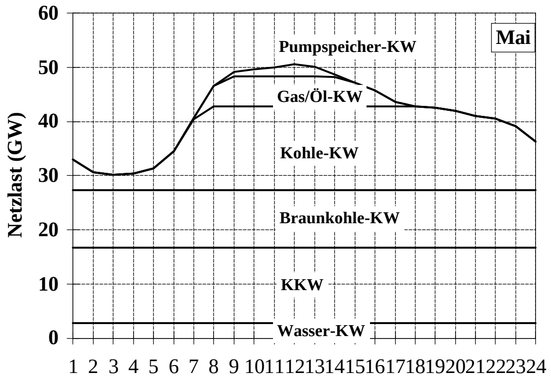
underestimation of emission in the winter. For a couple of smaller countries the reversed seasonal behaviour of power plant activity (higher activity in the summer, lower activity in the winter) is not represented by other time-factors.

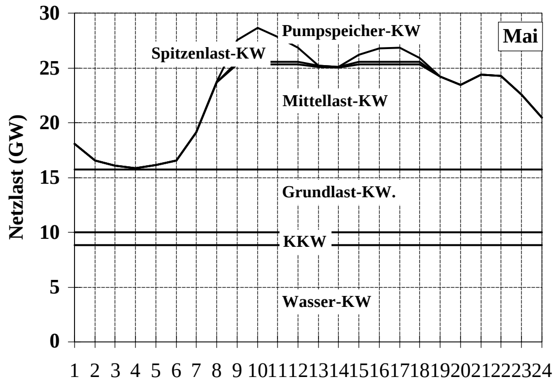
Figure 2: Monthly total fuel use of public power plants 1985-1990 for France, UK, Spain, and Greece in relative units (Source: EUROSTAT, LOTOS)



Power plant loads also show strong daily and hourly variations. Curves of total hourly loads on a Wednesday in May as presented on figure 3 all show a strong variation between night and day. The variation is strongest for Portugal and the Netherlands (40% difference between minimum night and maximum day load) and much lower for the remaining countries (usually between 20% and 25%). The individual structure of hourly load curves shows typical national differences. The morning peak is reached at 8 am in Yugoslavia, France and Austria, 9 am in Italy, Belgium, and Poland, but at 11 am in Germany, Switzerland and Portugal. Strong minima occur between 12 am and 4 p.m. especially in Mediterranean countries and in Hungary, probably due to the ‘siesta’, though most distinct in Hungary, Italy, Portugal, and Greece, and not in Spain.

Figure 3: Total hourly loads for a Wednesday in May 1990 for Germany (left) and Italy (right) (Source: UCPTE).





In Poland the average daily loads on Sundays only reach 55%, on Saturdays 67%, and on Mondays 88% of average daily loads in the remaining weekdays. Hourly maximum loads in working-days in Poland are not reached during the day, but at 8 p.m. due to high energy consumption of households (Fudala 1995). For Hungarian power plants hourly load curves are available for all power plants for the whole years. Evaluations of these curves show that average hourly loads in different weekdays also show considerable differences (Török 1995).

c. Shortcomings of the power plant model

Estimations of the temporal variation of emissions heavily depend on the availability of indicator data and of the quality of the indicator. In the case of power plants the availability of data is comparably good. In most countries monthly fuel use data and grid loads are available, in some Central and Eastern European countries much more detailed data can be found. Within GENEMIS the most detailed data base exists for Hungary.

Fuel use data and load curves can be considered an excellent indicator for the temporal variation of emissions. National totals only provide a basis for the estimation of average national behaviour and hide regional differences and different behaviour of individual power plants. The operation of individual power plant blocks may reflect considerable differences from average operation times due to different operation modes and shut down times. Therefore, regional investigations with high spatial resolution would require more detailed data, which are in many countries available from regional statistical offices, or from regional utilities or power plants.

3.2 Snap Sector 2 - Small consumer combustion

a. Indicator data and simulation models for small consumers

The small consumer combustion category includes households as well as institutional and commercial fuel consumers such as public buildings, public and other institutions, workshops, farms, etc. Data about fuel use of small consumers are only available for a few countries and a few sectors, e.g. households. Different types of small consumers, however, usually have different temporal behaviour.

The fuel consumption of households is mainly used for space heating (about 80-90%) and to a smaller extent for hot water production (about 10-20%), as investigations in Germany and Hungary have shown (Fahl 1989, Barna 1995). Commercial small consumers' fuel consumption is partly dedicated to heating purposes and partly to production processes. It has been assumed that the production dependant fuel use is directly related to working-times. So the following modelling equation is suggested for the simulation of monthly or daily small consumer fuel use:

$$E_r = s_0 + (s_1 * D_r * H_r * n_d) + (s_2 * A_r * n_a)$$

where
- E_r: small consumers relative fuel consumption in the region r;
- D_r: degree-day of the region r;
- H_r: heating-season index for the region r;
- A_r: working-time index for the region r
- n_d, n_a: normalisation factors for degree-days and working-time indices
- s_0: contribution of constant base load of small consumer fuel use
- s_1, s_2: share-factor describing the contribution of fuel use for heating and production related fuel use.

The heating-season index only has to be used for regions or countries, where heat is available for a limited season (e.g. 15. October - 15. April in Hungary). Days without limitation of heating are characterised by the value H = 1. For non-heating days the value for H has to include the information about the share of heating plants only working in a limited period (district heating plants) and the share of heating plants without limitation (single stove heatings, central heatings). In the case of 20% share of energy produced by district heating plants, non-heating days are characterised by the value H = 0.8. This is a reasonable estimate for many regions in Central and Eastern Europe.

The normalisation factors guarantee that $\int(D_r * H_r * n_d) = \int(A_r * n_a) = 1$ over the whole year under investigation. This normalisation allows to simply choose appropriate percentages for the share-factors. According to estimations from national experts within GENEMIS it is suggested to distinguish Western and Eastern European countries and define share-factors and heating season-indices as given in the following table:

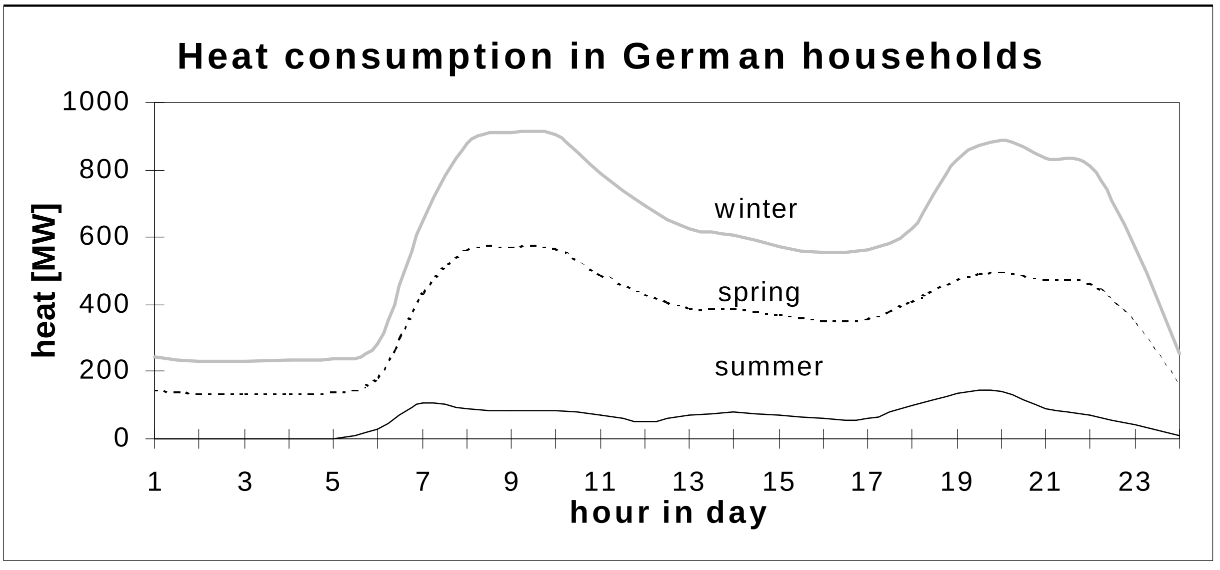
Countries	s_0	s_1	s_2	H (non-heating day)
European Union, EFTA member states	10%	60%	30%	always H = 1
Central and Eastern European countries	25%	50%	25%	0.6 - 0.8
Turkey, Albania	25%	50%	25%	always H = 1

In Central and Eastern European a rather high share of constant base fuel consumption is assumed, as a large amount of fuel is used for hot water and cooking. This is especially true for households with single coal or wood stoves that contribute a considerable share to total small consumer emissions. The share-factors given in the table represent default-factors, which can be used as long as no better information is available.

For the hourly distribution of small consumer emissions hourly patterns of fuel use for heating purposes and hourly patterns of production related fuel use have to be estimated. Within GENEMIS production related fuel use had been assumed to correspond to typical daily working times. The hourly variation of heating related fuel use, however, depends very much on the heating technology, climatic conditions and on isolation standards.

For central-heating it can be assumed a correlation to outside temperature with a reduction at night-time. For single coal or wood stoves a very strong morning and a very strong late-afternoon or evening peak can be observed. This pattern is due to fuelling the stoves in the early morning and after returning home from work. Hourly patterns for households from an evaluation of a comprehensive survey in Germany are shown in figure 4.

Figure 4: Hourly fuel consumption of households in Germany (Source: VDI /2067,5/)



b. The variation of emissions from small consumer combustion

The strong dependency on degree-days leads to strong seasonal variations of small consumer emissions, while the dependency on working-times contributes to a strong hourly variation. In figure 5 the relative daily variation of total small consumer NO_x-emissions is shown for the United Kingdom and for Spain in the year 1990.

Figure 5: Relative daily small consumer NOx-emissions in the United Kingdom, in Spain and LOTOS-factors for 1990 (Source: GENEMIS, LOTOS)

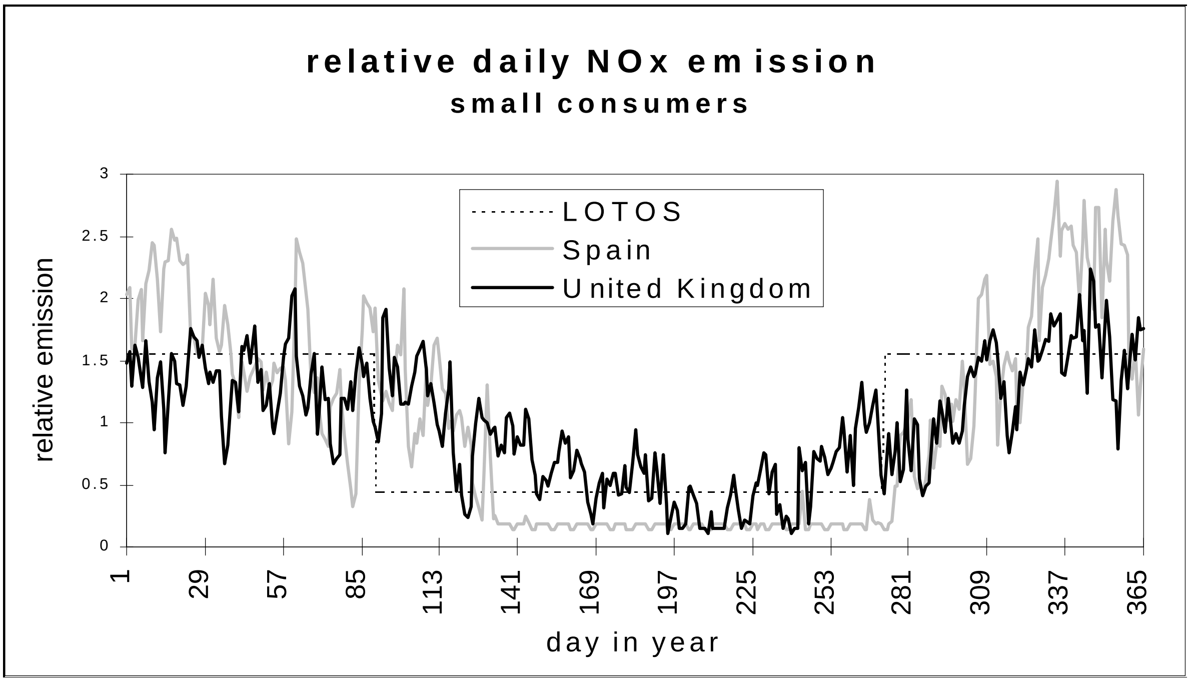
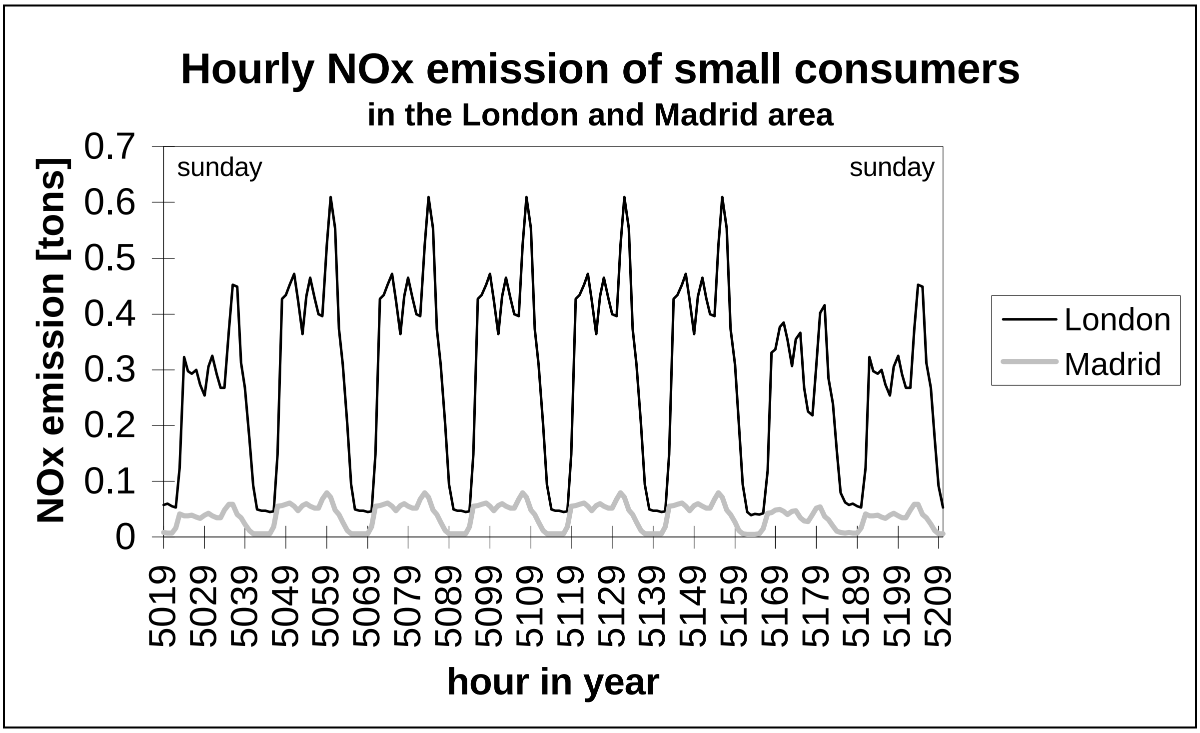


Figure 6: Total hourly small consumer NOx-emissions in the London and Madrid area for the TOR-episode in 1990 (Source: GENEMIS)



The resulting variation of total hourly emissions from small consumer combustion is shown for the London and Madrid area in figure 6. Both curves show a considerable variation of hourly emissions.

c. Shortcomings of the small consumer combustion model

The small consumer combustion model renders reasonable results for the temporal variation of emissions. Uncertainties, however, are assumed to be large. In the case of small consumers the assumption of a linear relation between total fuel use and emissions may lead to errors, as a large variety of very different small consumers with different heating technologies, different fuels, and different behaviours exist. As the availability of fuel consumption data with high temporal resolution is very limited, it is not possible to verify the modelling approach and the choice of constants in the model equation.

3.3 Snap section 3 - Industrial combustion

a. Indicator data and simulation models for industrial combustion

Emissions of industrial combustion are dependant on fossil fuel burning. Hence, it is reasonable to assume that the temporal variation of emissions follows the variation of fuel use. Data on fuel use with monthly resolution are available for some countries, but missing for many other countries. Monthly and daily fuel use, therefore, has to be simulated. The hourly energy consumption of industrial burners depends on parameters such as:

- production rates controlling energy consumption for production processes
- outside temperature controlling energy consumption for space heating
- production times, working times

Taking into account these parameters as variables, a modelling equation can be set up with regression coefficients describing the relative contribution of production dependant and temperature dependant fuel use. The value of the coefficients can be determined for different industrial sectors by reproducing measured fuel use data by a multidimensional regression analysis. Such a regression analysis can be performed for all countries or regions for which appropriate fuel use data are available. The result of the regression analyses is a model equation for the simulation of fuel use data with high temporal resolution. With such a model equation up to daily fuel use can be simulated based on actual production and temperature data.

Different model equation have been set up and tested with regression analyses. The quality of the regression and thus the quality of the model equation was described by the correlation coefficients. The best results have been achieved with a linear model equation including a constant base load (a_s) production (P_{sr}), temperature (T_{sr}), and degree-days (D_{sr}) as parameters

(Seier 1994).[6] The resulting model equation for the industrial combustion has the following general structure:

$$E_{sr} = a_s + (b_s * T_{sr}) + (c_s * D_{sr}) + (d_s * P_{sr} * A_{sr})$$

where
- E_{sr}: fuel consumption of the sector s in the region r
- T_{sr}: mean temperature of the sector s in the region r
- D_{sr}: (mean) degree-day of the sector s in the region r
- P_{sr}: monthly production index of the sector s in the region r
- A_{sr} : daily working time index of the sector s in the region r
- a_s, b_s, c_s, d_s: Regression coefficients

This model equation allows to simulate monthly, weekly, or daily fuel use in industrial sectors. The model parameters have to be provided with the appropriate temporal resolution. Temperature data with high temporal resolution are available from national weather services, from the European Centre for Medium Range Weather Forecast (ECMWF) in Reading, or from EMEP Meteorological Synthesizing Centres in Oslo and Moscow. Production indices are available with monthly resolution from international sources like the UN, OECD, and EUROSTAT, or from national statistical offices.

In order to provide a daily estimate of relative production, a working time index has additionally been defined. This working time index A describes the total workforce at all days in the year and considers reduced working times on Saturdays and Sundays and on national or regional holidays. In GENEMIS a working time index has been defined for all European countries for the years 1986 to 1992 based on calendars and information from national experts. This index considers different holidays in different countries and different national traditions like bridge-holidays and work at weekends in Eastern European countries (Bogdanov 1995, Török 1995).[7]

It is much more difficult to provide reliable estimates for hourly emissions from industrial combustion sources. If no data on production times during the week and the day exist, it seems to be the most reasonable assumption to relate fuel use and emissions to working times and working shifts. In some countries data on working times and shifts are available from statistics or from industrial surveys. In other countries the calculations have to be based on experts estimates of common working times.

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[6] The temperature dependant contribution to fuel use was best described by considering both, temperature and degree-days. Degree-days is a parameter defined by heating engineers, which describes the heating energy consumption. It is defined as follows:

$$D = T_0 - T_d, \quad \text{if } T_d \leq T_0$$
$$= 0, \quad \text{if } Td > T0$$

where, T_d represents daily average temperature and T_0 the temperature limit for heating. According to most experts T_0 is assumed to be 15°C for countries in Western Europe and 12°C for countries in Eastern Europe.

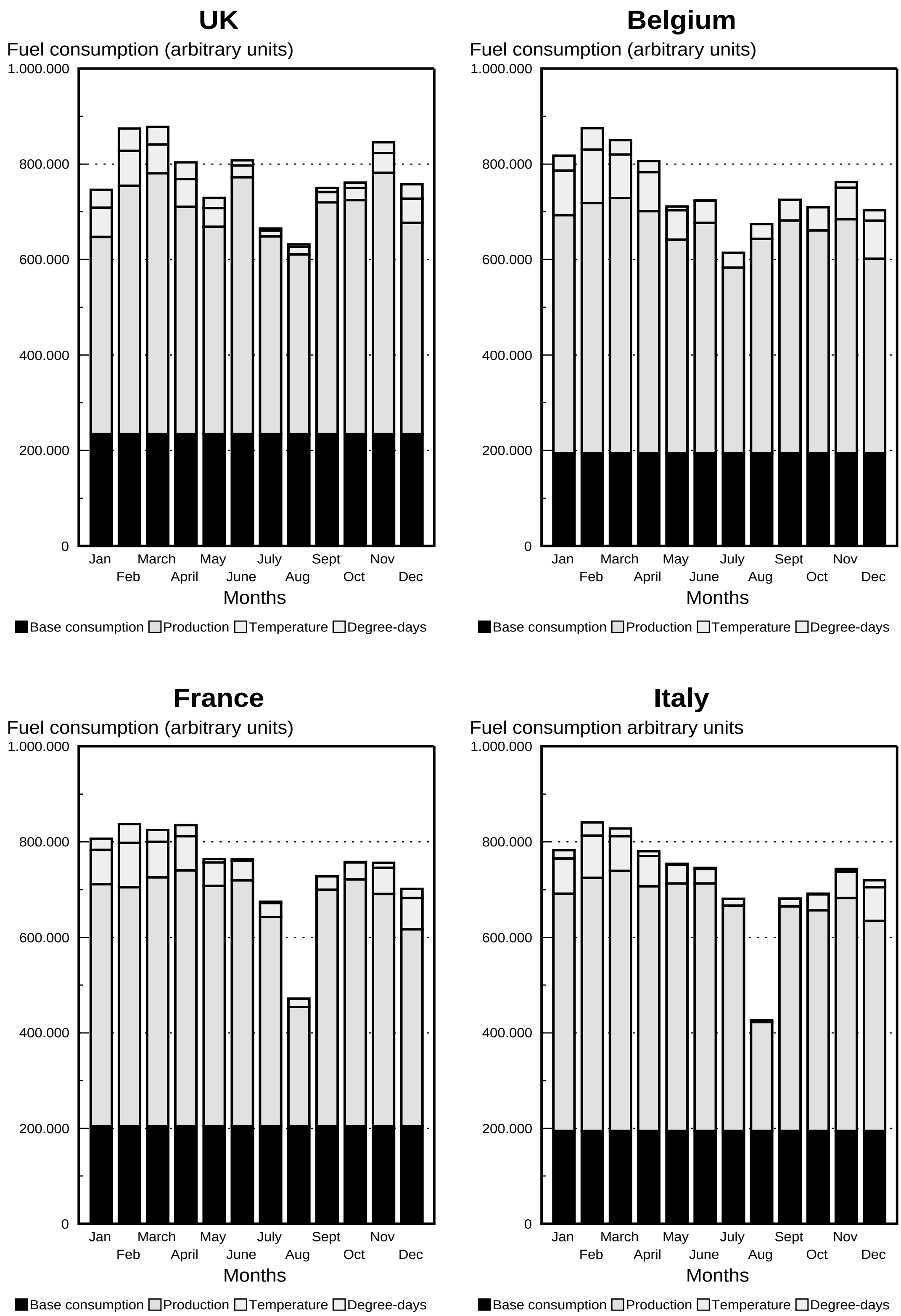
[7] If a national holiday falls on a Tuesday or a Thursday in many European countries (e.g.: Belgium, Hungary, Bulgaria) the preceding Monday or the subsequent Friday respectively are free and in some cases as a compensation a Saturday or a Sunday in the same week are working-days.

b. The variation of emissions from industrial combustion

The simulation of fuel use in industry has been performed individually for the iron and steel industry, non-ferrous metal industry, chemical industry, and paper industry. Additionally, total industrial fuel use has been simulated. The correlation coefficient, which describes the quality of the regression, ranged between 70% for the iron and steel industry and for total industrial fuel use, and more than 90% for the remaining sectors. The unsatisfactory correlation for the iron and steel industry and for total industry clearly indicates that other factors than production and temperature also have an important influence on fuel use. As such factors could not be isolated and properly described by other indicator data, they had to be neglected.

Model simulations with the present regression model clearly show that the major part of industrial combustion emissions is caused by fuel use for production purposes. A significant contribution is caused by a constant base load. The temperature dependant emissions usually ranges between 10-15% and can reach up to 25% depending on sector and climatic conditions.

Figure 7: Total monthly fuel consumption of the industry 1986 in the UK, Belgium, France, and Italy in relative units (Source: GENEMIS).



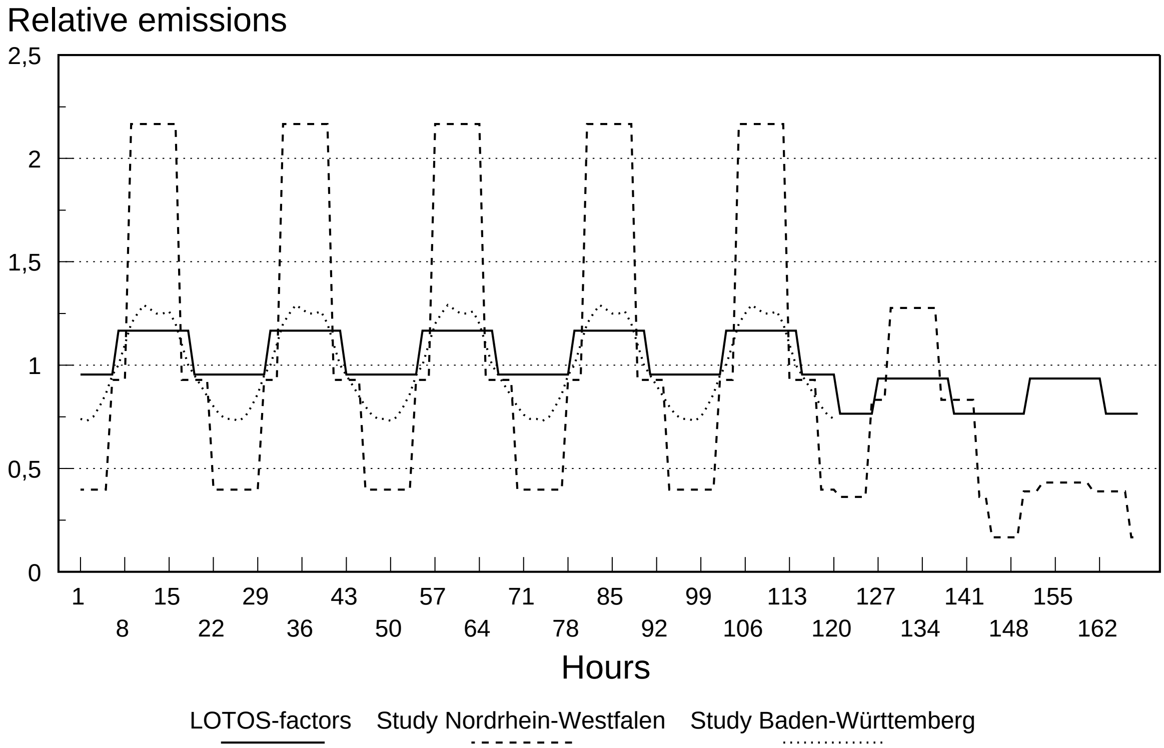
In figure 7, relative fuel consumption is presented for total industrial fuel consumption in the UK, Belgium, France, and Italy. The vertical bars show the relative share of the base load (full black), the load caused by fuel consumption for production purposes (cross-hatched), and the temperature-dependant fuel use (right- and left-hatched). The production dependant fuel consumption contributes the major share of about 50-65% to total fuel use. The base-load contributes about 20-25% of total load, while the temperature dependant part covers 5-25% of total fuel use. For most sectors a similar result can be observed.

The temporal variation of industrial combustion emissions is dominated by changes of production. In most countries summer emissions are lower than winter emissions due to vacation times. In countries like Belgium, Germany, Poland, and the UK the summer reduction reaches not more than 20-25% and is distributed over the summer months from June to August. In some countries like France and Italy, however, vacation times are concentrated in August and have a very strong effect on the reduction of production, fuel use, and emissions. Whole factories and plants are shut for two or three weeks and lead to a monthly fuel use reduction of 40-50%.

A comparison shows, that the effects of holiday-times and temperature are not taken into consideration by other available time-factors. This can lead to overestimated summer emissions of about 10 to 20% for countries like Germany and Belgium in July and August and about 40% for Italy and France. This overestimation is related to an underestimation of emissions in the winter time. So, similar as for power plant emissions, the seasonal variation of industrial combustion seems to be stronger than assumed by older patterns.

It is much more difficult to find reliable information on hourly emissions from industrial combustion. A survey of industrial plants in the German federal state of Baden-Württemberg suggests that hourly emissions during the day and during a week are mainly characterised by a strong ground load and a production dependant variation of about ±20% with a minimum at night-time. The results of this survey fit quite well to LOTOS hourly factors (see figure 8), which assume a smaller day and night variation of approximately 10%.

Figure 8: Hourly industrial fuel consumption during a week according to a survey in Baden-Württemberg and LOTOS hourly time-factors for industrial combustion (Source: IER, Stuttgart; LOTOS).



c. Shortcomings of the industrial combustion model

The simulations of monthly and daily fuel use in the industry can be considered much more reliable and nearer to reality than other approaches, because the most important parameters influencing the temporal variation of emissions (production, temperature, working times) are explicitly taken into account. With this approach, differences from region to region and from year to year due to economic changes or changed climatic conditions are considered. Problems of this approach are caused by the fact that fuel use data of industrial sectors are not available from international statistical offices or institutions. They have to be collected from national and regional authorities and institutes, which causes considerable efforts.

The simulation of fuel use data still produces some uncertainty. The quality of the simulations can hardly be assessed, because fuel use data of industrial sectors or individual industrial plants are only available for a few countries. Simulation results can in most cases not be verified by comparison with real fuel consumption.

3.4 Snap Sector 4 and 6 - Industrial production and solvent use

a. Indicator data and simulation models for industrial production and solvent use

The industrial production and solvent use categories pose severe problems for emission inventorying, as they are both characterised by a large number of small and heterogeneous emission sources. It is difficult to collect appropriate and reliable data for emission estimates of individual production processes or solvent using activities (e.g. VOC-Kommission 1994). The same is true for the estimation of the temporal variation of emissions from these sources.

It is a reasonable assumption that emissions of both emission from production processes and from solvent use are closely related to production figures of relevant production activities. Useful indicator data, therefore, are production data describing the activity of individual production processes and solvent using activities. In the case of solvent use, solvent consumption data with higher resolution than annual would provide the best indicator for the temporal variation of solvent using activities. However, such data are usually very hard to find or to estimate.

Due to the lack of detailed production data with high temporal resolution for individual processes in most countries, aggregated monthly production indices have to be applied to estimate a seasonal variation of emissions.[8] For private solvent use, assumptions about the user behaviour have to be made. Higher emissions of private solvent users can be assumed to occur in the summer and at weekends, lower emissions in the winter and at working days. Hourly emissions of production processes and solvent use can be estimated according to working times and total workforce per hour.

b. The variation of emissions from production processes and solvent use

The temporal variation of emissions from production processes and solvent use show variations according to economic cycles and working times. The seasonal variations are characterised by a reduction of emissions in summer months due to vacation times. The weekly, daily, and hourly variations are controlled by working times. Seasonal as well as hourly variations range in the order of magnitude of about 30%. LOTOS time-factors, instead, assume continuous activity all over the year and, therefore, overestimate summer emissions for most countries.

c. Shortcomings of the simulation model for production processes and solvent use

The estimations of the temporal variation of emissions from production processes and from solvent use have to be regarded as uncertain due to the lack of detailed statistical data. It has to be assumed that aggregated production data give an estimate for the temporal variation of individual production processes. But this simplification is likely to lead to estimation errors. Nevertheless, within GENEMIS it has been considered more appropriate to consider temporal variations in the way described than to neglect them completely.

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[8] E.g. for sectors like nitric acid production or paint use in the metal industry production indices for the chemical industry of the metal industry respectively have to be taken.

3.5 Snap Sector 7 - Road traffic

a. Indicator data and simulation models for road traffic

Road traffic belongs to the most important emission sources in Europe and contributes the major share of NO_x and VOC emissions. Additionally, it displays very strong temporal variations of emissions. While different vehicle types show a similar temporal behaviour, different road types like motorways, rural roads, and urban roads show a different course of road traffic densities and thus emissions.

The course of road traffic emissions in time is dependant on a variety of factors like time and day in the season, day in the week, weather conditions, working times, etc. Road traffic emissions can assumed to be directly related to total traffic density.[9] Traffic density data are usually available in form of traffic counts, which represent an excellent empirical base for the estimation of the temporal variation of emissions, because all external factors are implicitly considered. However, traffic count data are not available from international statistical offices, but only from national authorities. In some countries it is extremely difficult to obtain appropriate traffic counts or traffic density data.

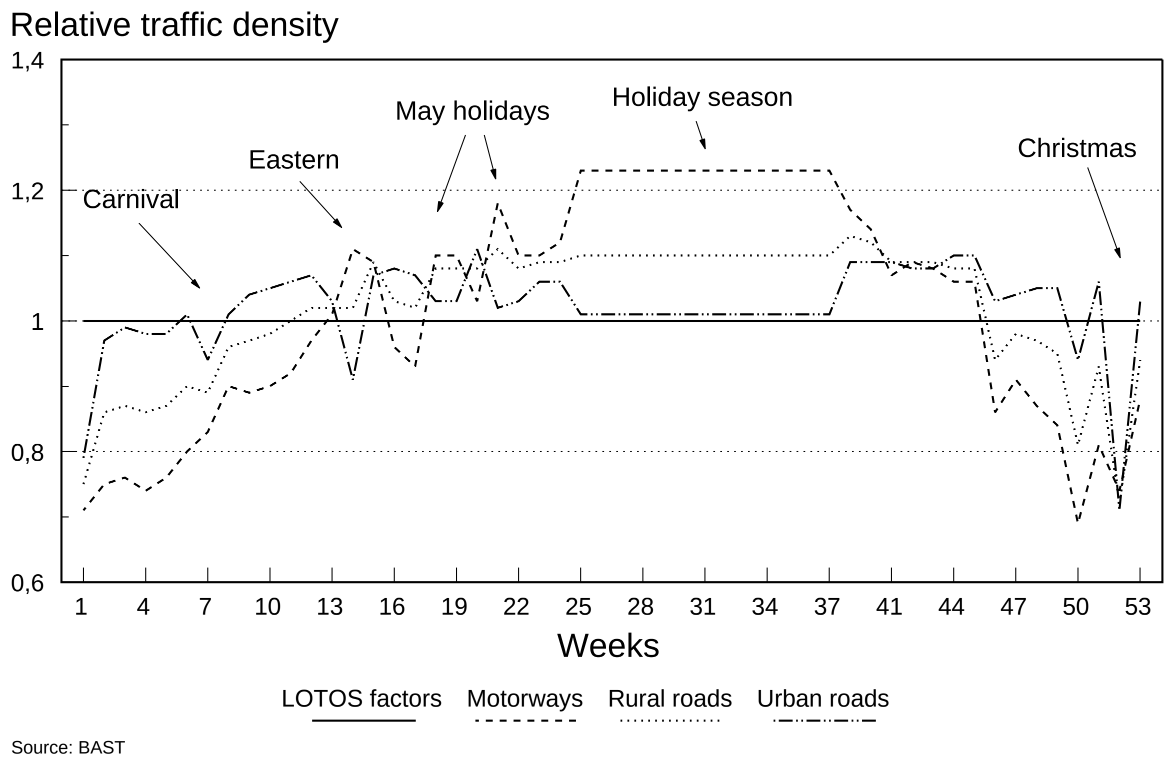
Traffic count data can be available in different states of evaluation and data processing. In some countries original data from counting stations are available (e.g. in Austria, Winiwarter 1993). Due to a high number of counting stations and a big amount of data for every single station, such data require a further evaluation that causes considerable efforts. In other countries (e.g. in Germany) counting data are associated to characteristic monthly, daily, and hourly traffic density curves annually calculated with cluster analyses (e.g. Bundesanstalt für Straßenwesen 1991). In case of Austria and Germany an average traffic density has to be calculated. In other cases a monthly traffic density index is available for different road types (e.g. in France, INSEE 1990). This index gives an average road traffic density for all motorways and rural roads and can assumed to be a good indicator for the monthly variation of traffic emissions.

b. The temporal variation of road traffic emissions

Road traffic emissions show strong seasonal as well as strong hourly variations. They display a stronger seasonal variation for motorways than for rural and urban roads, and a stronger seasonal variation in rural areas than in urban areas. Hourly variation, instead, are quite similar for different road types and regions. In figure 9 weekly average traffic densities are shown for motorways, rural roads, and urban roads for the German federal state of Schleswig-Holstein in 1986. Schleswig-Holstein represents a rather rural area with a lower population density than the average in Germany. It is strongly affected by holiday traffic to the North Sea and the Baltic Sea, and from and to the Scandinavian countries.

[9] This, of course, is a simplification, as vehicle velocity is of major importance. The assumption has to be made that a similar velocity distribution can be assumed for different motorways, different rural roads, and different urban roads.

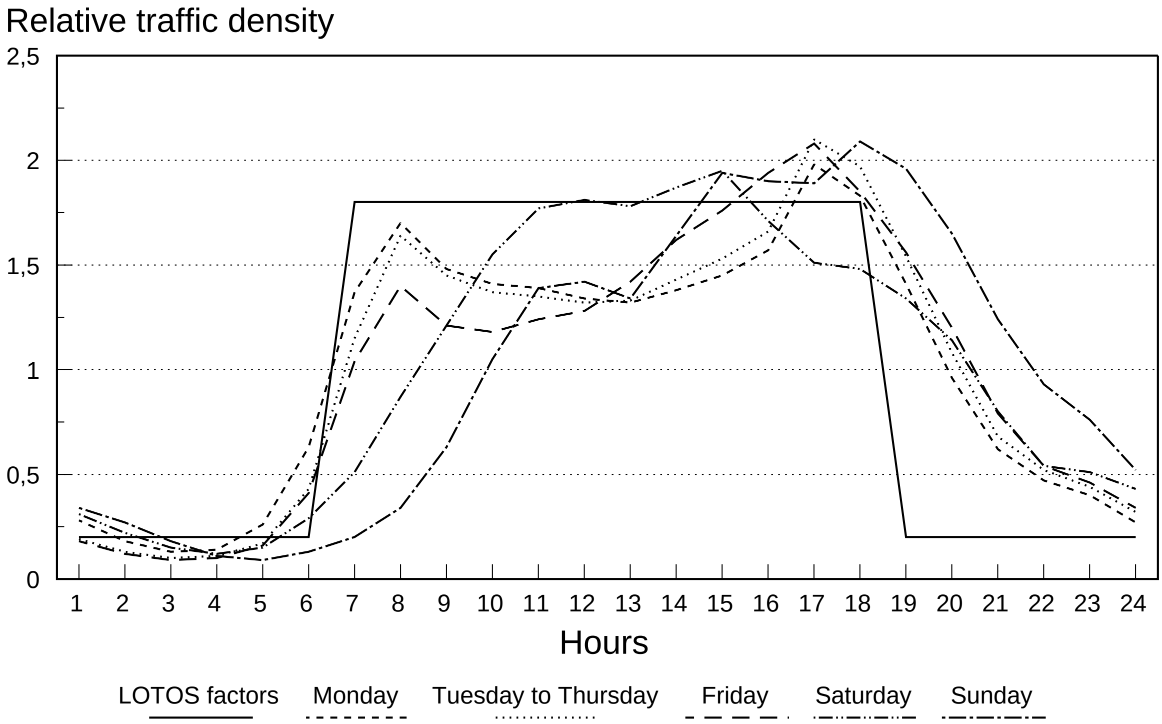
Figure 9: Weekly average traffic densities for motorways, rural roads, and urban roads for the German federal state of Schleswig-Holstein in 1986 (Source: Bundesanstalt für Straßenwesen, GENEMIS)



The influence of holiday traffic can clearly be seen especially on weekly motorway traffic density, which shows characteristic peaks at spring and summer holidays and strong minima at winter holidays. During the summer holiday season, traffic density and thus road traffic emissions on motorways were more than 50% higher than traffic density and emissions in the winter. Similar results hold for other years and other regions. Weekly rural and urban traffic density is more continuous. In spring and summer holidays, urban traffic is partly shifted from urban roads to motorways and from urban regions to rural areas, as can clearly be observed for Eastern 1986.

Road traffic is also characterised by very strong hourly variations. Emission peaks at day-time are 6-7 times as high as the lowest emissions at night-time. This feature can clearly be observed in figure 10, where hourly road traffic densities are presented for Monday to Sunday in the federal state of Schleswig-Holstein. Average hourly road traffic counts for the Greek city of Thessaloniki show even stronger emissions in the evening than load patterns for Germany. This condition is typical for Mediterranean countries.

Figure 10: Hourly road traffic densities for Monday to Sunday in Schleswig-Holstein, and according to LOTOS time-factors (Source: Bundesanstalt für Straßenwesen, GENEMIS; LOTOS)



Source: BAST

c. Shortcomings of the road traffic model

The availability of road traffic counts poses one of the main problems. Within GENEMIS traffic counts have as yet only been available for Germany, Austria, France, and Greece. More data are to be expected from Central and Eastern European countries within 1995. Moreover, it is hard to assess the representativity and reliability of the data available.

A major problem is often caused by the large amount of road traffic data with unsatisfactory homogeneity and quality caused by different data structures, missing data, or errors, which hampers automatic processing. The examination and evaluation of such data, therefore, causes enormous efforts.

Regions and countries without any traffic count data available have to be treated with the temporal patterns based on data from other regions. For sure, this generalisation causes big errors and reduces the reliability of the data calculated. However, more sophisticated simulations for such regions are not possible, as road traffic density is a very complex function of many parameters.

3.6 Snap Sector 8 - Other mobile sources

The Other mobile sources category comprises air traffic, ship traffic, railway traffic, and off-road vehicles. Emissions of other mobile sources can assumed to be proportional to total traffic activity of these sources. The estimation of the temporal variation of emissions, therefore, requires data on traffic activity with high temporal resolution.

For the estimation of aircraft-emissions with high temporal resolution at airports, landing-take-off cycles (LTO cycles), passenger numbers, and freight statistics, which are available from airports or from the International Air Traffic Association (IATA), provide the best information available. The hourly emissions from air traffic can usually assumed to be distributed over the day without strong variations, while no emission occur during night-time (usually between 23 p.m. and 6 am).

For the estimation of ship traffic emissions with high temporal resolution the number of passing ships per hour, day, week, or months in harbours or ship routes is related to the temporal distribution of ship emissions and provides a reasonable indicator, though different ship types show different emission behaviours. However, it is usually hard to find appropriate data. In the case of complete lack of data it seems reasonable to assume an equal distribution over the year and over the day.

Within GENEMIS ship traffic, railway traffic, and off-road vehicle traffic has not been treated due to a lack of data. According to new studies a more detailed treatment may be needed for off-road-vehicles, which seem to be responsible for a considerable contribution to total emissions and also are likely to show important temporal variations of emissions (Zierock 1994, see also chapter 3.5 of this handbook). As a first estimate it could be assumed that off-road vehicle emissions are higher in the summer and at day-time and lower in the winter and at night-time.

As the temporal variation of emissions from other mobile sources has not been treated within GENEMIS or other projects, no results calculated with these approaches can be presented. Shortcomings of these approaches are likely to be caused mainly by a lack of reliable data.

3.7 Snap Sector 10 - Agriculture

Only little information is available about the temporal variation of emissions from agricultural sources. Agriculture contributes a large share of ammonia emissions in Europe. Ammonia emissions are caused by animal manure and very dependant on climatic conditions, conditions of animal breeding, behaviour of the farmers, etc. It is very hard to simulate these conditions in order to estimate the variation of emissions.

From investigations of the RIVM in The Netherlands and of the National Environmental Research Institute in Denmark some information about the temporal course of ammonia emissions are available from measurements (Asman 1992, Asman 1992a). In figure 11 and 12 the averaged course of ammonia emissions over the year and over the day is presented. Actual emissions for single days and hours, however, can show a completely different pattern due to the conditions described above.

Figure 11: Monthly ammonia emissions derived from measurements (Source: Asman 1992).

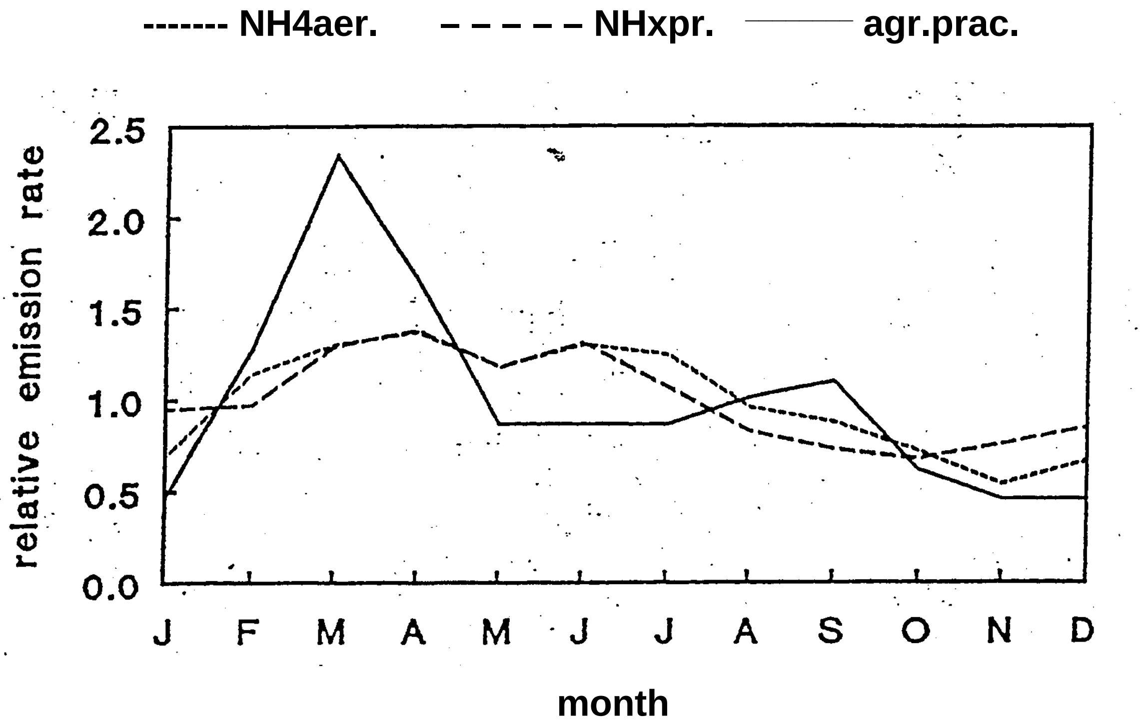
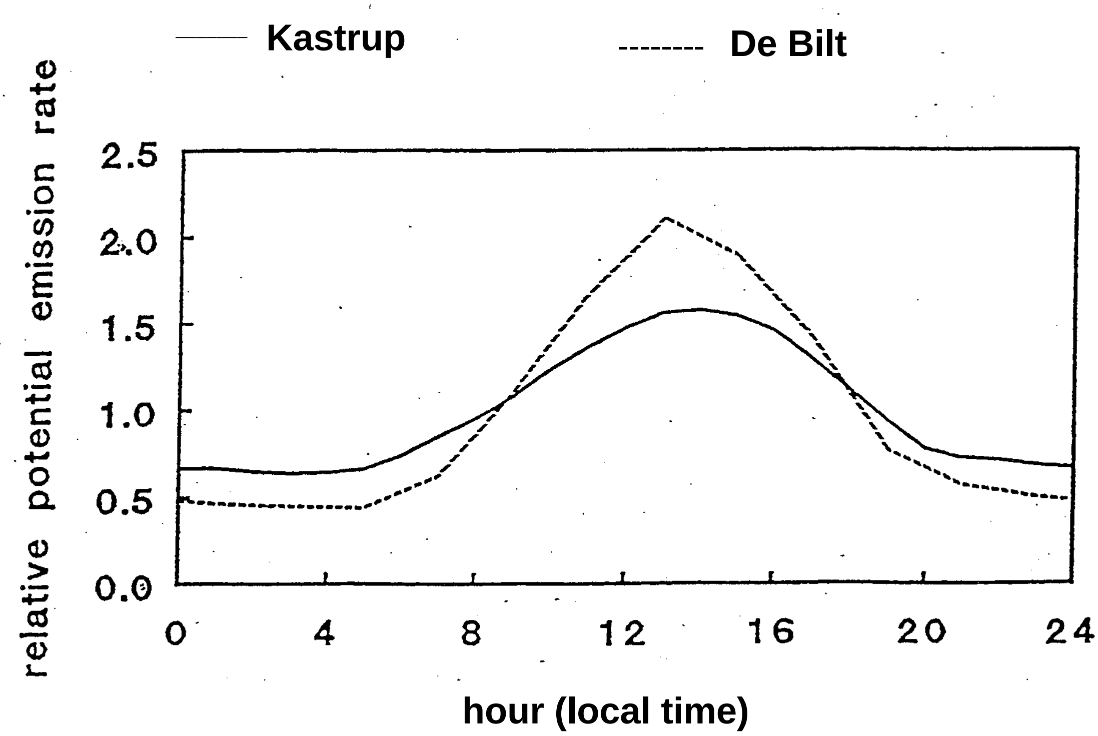


Figure 12: Hourly ammonia emissions derived from measurements (Source: Asman 1992)



At present, a more detailed investigation including a large number of measurements and careful surveys of farmers to account for the farmer behaviour is being carried through by the National Environmental Research Institute in Denmark. The goal of this project is the improvement of ammonia emission simulation.

3.8 Snap Sector 5 + 9 - Other anthropogenic sources

A number of other sectors not mentioned contribute to total emissions in Europe. To these sectors belong activities like waste disposal, gas distribution, coal mining, etc. For these sources no information on the temporal variation of emissions is available to the GENEMI project. Within the GENEMIS project these sources have been considered of minor importance. Partly, they contribute mainly to methane emissions, which are not important for short-term tropospheric pollution phenomena, partly they are assumed to show no important variation of emissions in time, and partly they only contribute a minor share to total emissions.

3.9 Snap Sector 11 - Biogenic emissions

a. Indicator data and simulation models for biogenic emissions

Biogenic VOC emissions vary from species to species and from region to region for individual species. The largest contribution to biogenic emissions is caused by trees, which emit 10 times as much as smaller plants. For an estimation of the temporal resolution of biogenic emissions it, therefore, seems reasonable to focus on tree emissions and assume a similar temporal behaviour of other species. This approach is justified, as for most other species much less information is available (Veldt 1991, Steinbrecher 1994).

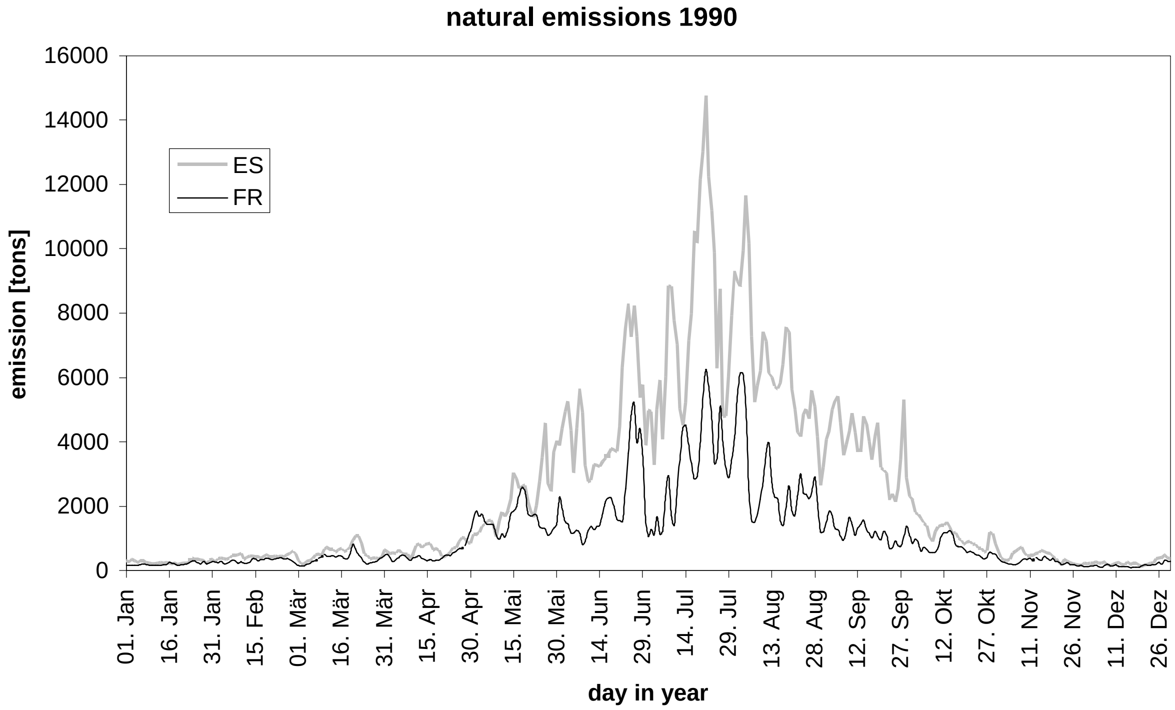
Biogenic emissions show a strong dependency on temperature, on radiation, and on the state of plant growth. Mathematical expressions for the temperature- and the radiation-dependencies are available from emission factors currently used in Europe. With the help of these emission factors emission data with high temporal resolution can be calculated (e.g. Winiwarter 1992, Moussiopoulos 1993).

As on the one hand the emission factors available are very uncertain, and on the other hand the collection and evalutation of temperature and radiation data requires considerable effort, reasonable simplifications have been introduced in the LOTOS inventory by Chris Veldt. LOTOS considered medium radiation intensities and gave general factors for the temperature dependency of coniferous, isoprene, and non-isoprene biogenic emissions (Veldt 1991). This approach can be considered sufficient as long as no better data are available.

b. The temporal variation of biogenic emissions

Due to a strong dependency on temperature, radiation, and plant growth, biogenic emission show very strong seasonal variations. In winter-times biogenic emissions are of minor importance, while they provide in summer times a major contribution to total VOC-emissions. During day-time biogenic emissions are much higher than at night-time. In the GENEMIS-project the LOTOS methodology has been adopted to calculate the temporal variation of biogenic emissions. As an example daily biogenic emissions for France and Spain are presented in figure 13 for the year 1990.

Figure 13: Daily natural emissions of France and Spain in 1990 (Source: GENEMIS)



c. Shortcomings of the biogenic emissions model

The estimation of biogenic emissions in Europe is very uncertain, because emission factors exist only for few species and existing emission factors are not very reliable.

Due to the lack of appropriate measurements in Europe, American emission factors had to be used in the past years, though it has been shown in several studies that these emission factors do not adequately represent the vegetation classes and climatic and geological conditions in Europe (Janson 1993, Steinbrecher 1994).

Moreover, the processes controlling biogenic emissions are not yet completely understood and additional factors like blossoming, stress behaviour, etc. are likely to have a major influence on emissions. Many species emit discontinuously and show different behaviours in different regions. Consequently, strong uncertainties have to be taken into consideration both for the calculation of annual VOC-emissions as well as for the temporal variations of emissions.

More detailed emission factors for biogenic emissions in Europe are being prepared in a co-operation project between EUROTRAC-BIATEX and GENEMIS. These emission factors are based on measurements performed in BIATEX and other projects in Europe and will be available in late 1995.

3.10 Temporal variations of VOC-profiles

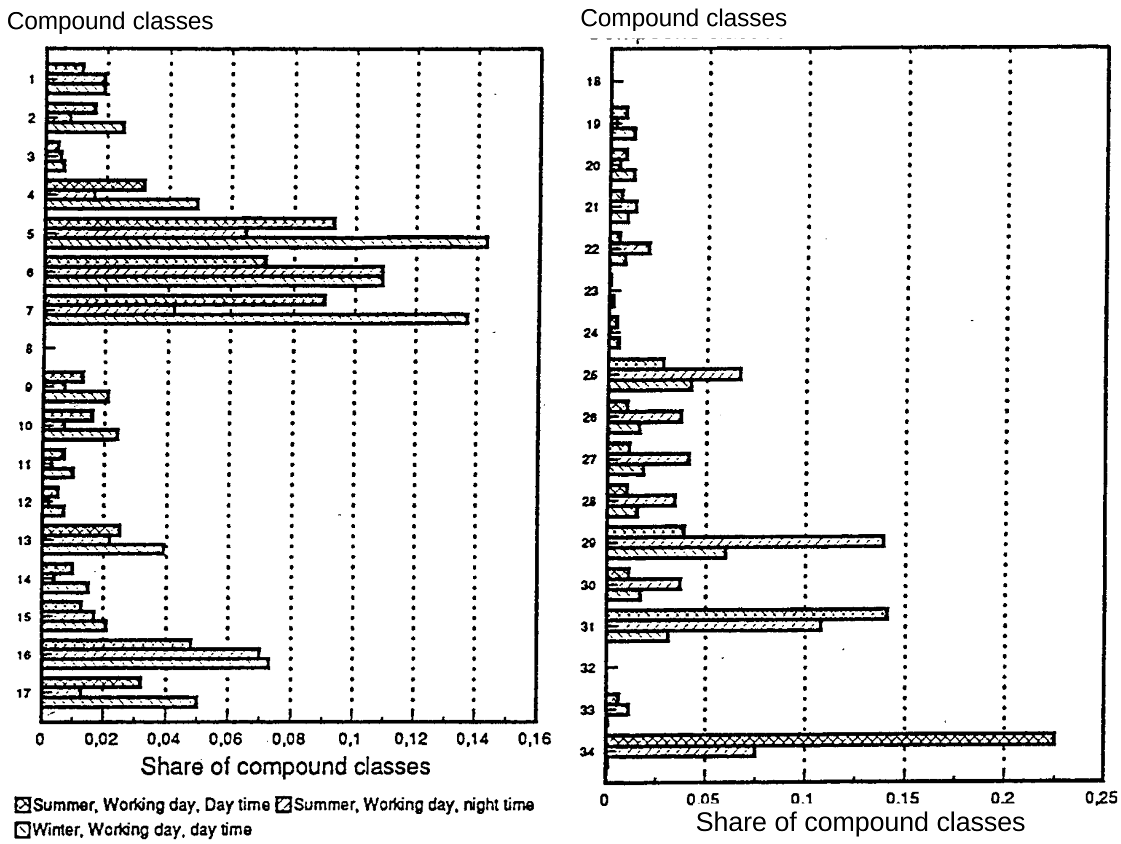
Atmospheric simulation models require detailed information on individual organic compounds or compound classes, while emission inventories currently only provide total VOC-emissions or NMVOC plus methane emissions. In the past standard VOC-profiles have been used by most modellers, assuming that total VOC-emission can be split into individual compounds or appropriate compound classes by generalised profiles. Such profiles have usually been applied for all countries and regions and for all periods.

This assumption appeared to be unsatisfactory. Investigations in GENEMIS clearly showed that the varying composition of emissions from country to country and from hour to hour may lead to fundamentally different VOC-profiles. All sectors emit VOC-species in different shares and amounts. As individual sectors contribute different shares of emissions in different regions and contribute emissions according to very different temporal patterns, the resulting total speciation for the VOC-classes looks different from region to region and hour to hour.

An example of this effect is shown in figure 14 for RADM-2 VOC-profiles for a summer working-day at day-time, a summer working-day at night-time and a winter working-day at day-time in Germany. The relative share of compound classes to total VOC-emissions changes considerably at different times. These changes affect all compound classes and reach up to 300% for some classes. Some classes contribute much more at day-time, while others contribute stronger at night time. Therefore, at every hour a different mix of VOC-compounds is emitted.

These variations are likely to have an important impact on atmospheric chemistry. As all RADM2-classes reflect different chemical behaviour of the compounds assigned to these classes, different reaction chains and different reaction velocities will have to be considered and may lead to important effects in atmospheric transport and chemistry modelling. Certainly, it has to be considered that information about VOC-profiles is far from being satisfactory for many processes and regions in Europe. Uncertainties, therefore, are expected to be high. Nevertheless, it seems reasonable to recommend at least a distinction of day and night profiles for atmospheric modelling.

Figure 14: RADM-2 VOC-profiles for a summer working-day at day-time, a summer working-day at night-time and a winter working day at day time in Germany (Source: GENEMIS).



1	Methane	18	Styrenes
2	Ethane	19	Formaldehyde
3	Propane	20	Higher Aldehydes
4	Alkanes (r=0.25-0.50*10000’1/(ppm’min))	21	Acetone
5	Alkanes (r=0.50-1.00*10000’1/(ppm’min))	22	Higher Ketones
6	Alkanes (r=1.00-2.00*10000’1/(ppm’min))	23	Organic Acids
7	Alkanes (r<2.00*10000’1/(ppm’min))	24	Acetylene
8	Alkanes/ Aromatic Mix	25	Haloalkanes
9	Ethene	26	Unreaktive VOC
10	Propene	27	other VOC (r<0.25*10000*1/(ppm*min))
11	Alkenes (Primary)	28	other VOC (r=0.25-0.50*10000*1/(ppm*min))
12	Alkenes (Internal)	29	other VOC (r<0.50-1.00*10000*1/(ppm*min))
13	Alkenes (Prim/Int. Mix)	30	other VOC (r>1.00*10000*1/(ppm*min))
14	Benzene	31	Unidentified VOC
15	Aromatics (r<2.00’10000’1/(ppm’min))	32	Unassigned VOC
16	Aromatics (r>2.00’10000’1/(ppm’min))	33	Isoprenes
17	Phenols and Cresols	34	Terpenses

4 THE VARIATION OF TOTAL EMISSIONS IN EUROPE

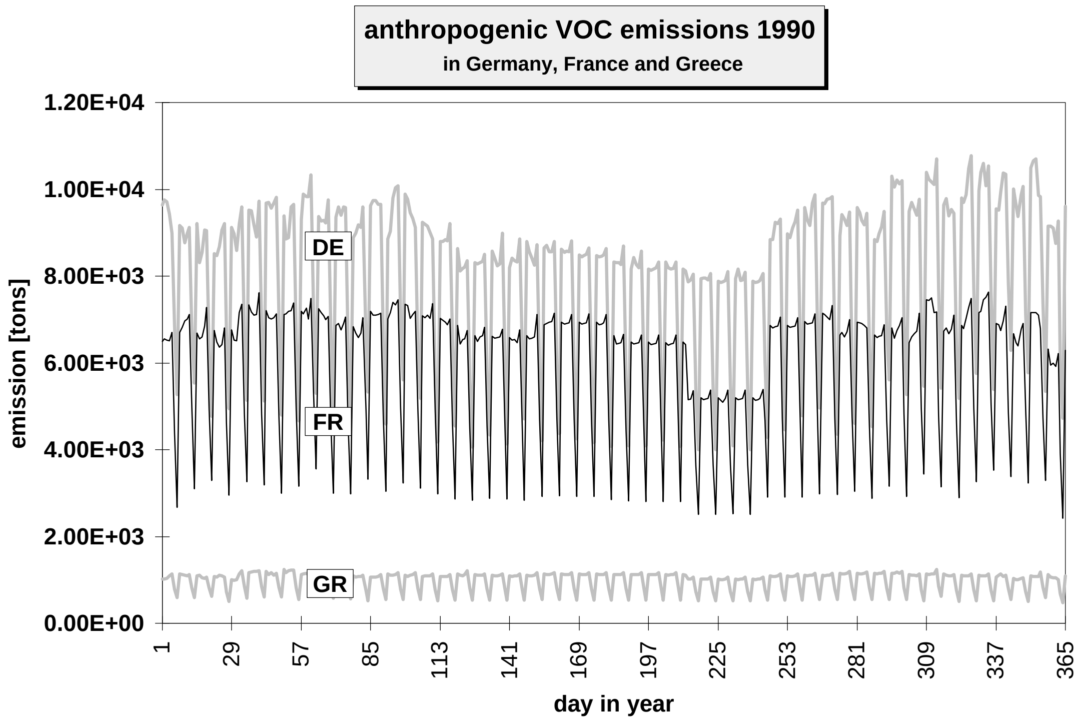
The temporal behaviour of emissions for each sector and the contribution of these sectors to total emissions differ for each country. Therefore, the temporal pattern of total emissions also show considerable differences for different countries and regions. In figure 15 total daily NO_x- and total daily VOC-emissions are shown for France, Germany, and Greece in 1990.

It is also important to note that total NO_x- and VOC-emissions do not follow the same temporal pattern. This is of major important for the simulation of atmospheric photo-oxidants formation, which are strongly dependant on the proportion of NO_x- and VOC-emissions. Consequently, these results will have an impact on emission reduction strategies, as different reduction approaches are likely to be most efficient in different regions.

A similar result has been achieved for hourly emissions over one week. In figure 16 total hourly NO_x-emissions of all main sectors are shown within 8 days of the JWC for large urban regions (Greater London, Greater Athens) and for very rural and little industrialised regions (Northern Jutland in Denmark and Alto Alentejo in the East of Portugal). It can clearly be seen that road traffic emissions have a major influence on total NO_x emissions. The contributions of other sectors like power plants, industrial combustion, and industrial processes, however, varies considerably from region to region.

In Greater London and Greater Athens the share of public power plant emissions is very low, because power plants are located outside of the city areas. Power plant emissions, however, are extremely high in Northern Jutland due to large power plants located in this region. In Alto Alentejo NO_x emissions are almost only caused by road traffic. According to these graphs the day-night variation reaches 4:1 in Northern Jutland, 5:1 in Greater London, 8:1 in Greater Athens and 12:1 in Alto Alentejo. These differences may have an influence on short term photo-oxidants formation, destruction, and deposition.

Figure 15: Total daily NOx- and total daily VOC-emissions in France, Germany, and Greece in 1990 according to GENEMIS and to LOTOS time-factors (Source: GENEMIS, LOTOS)



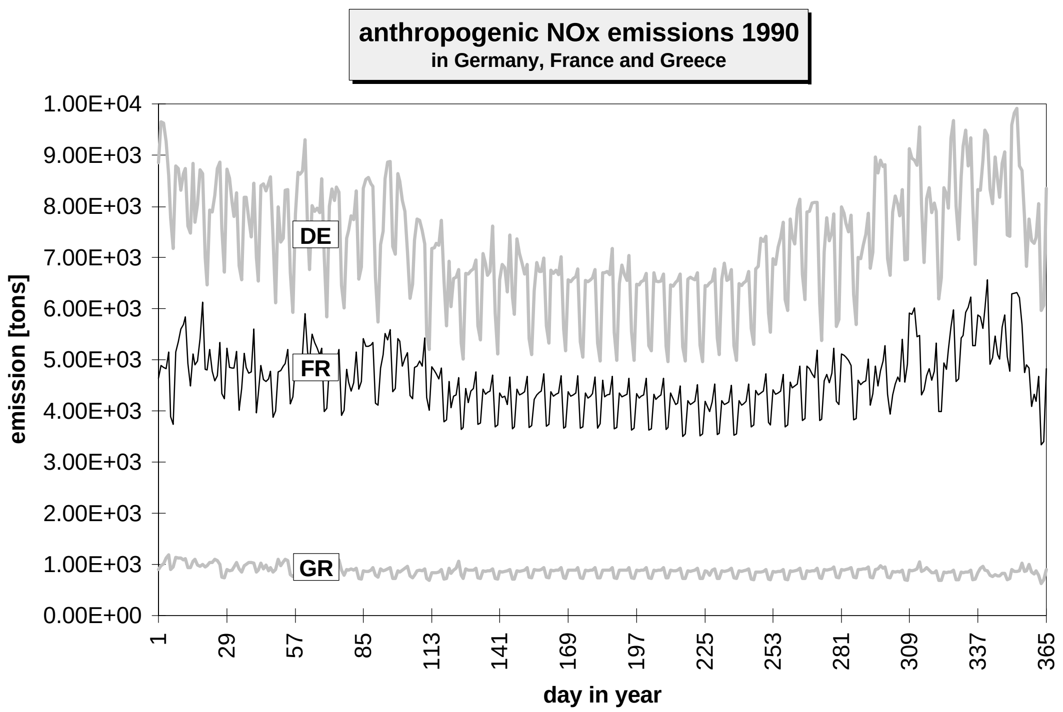
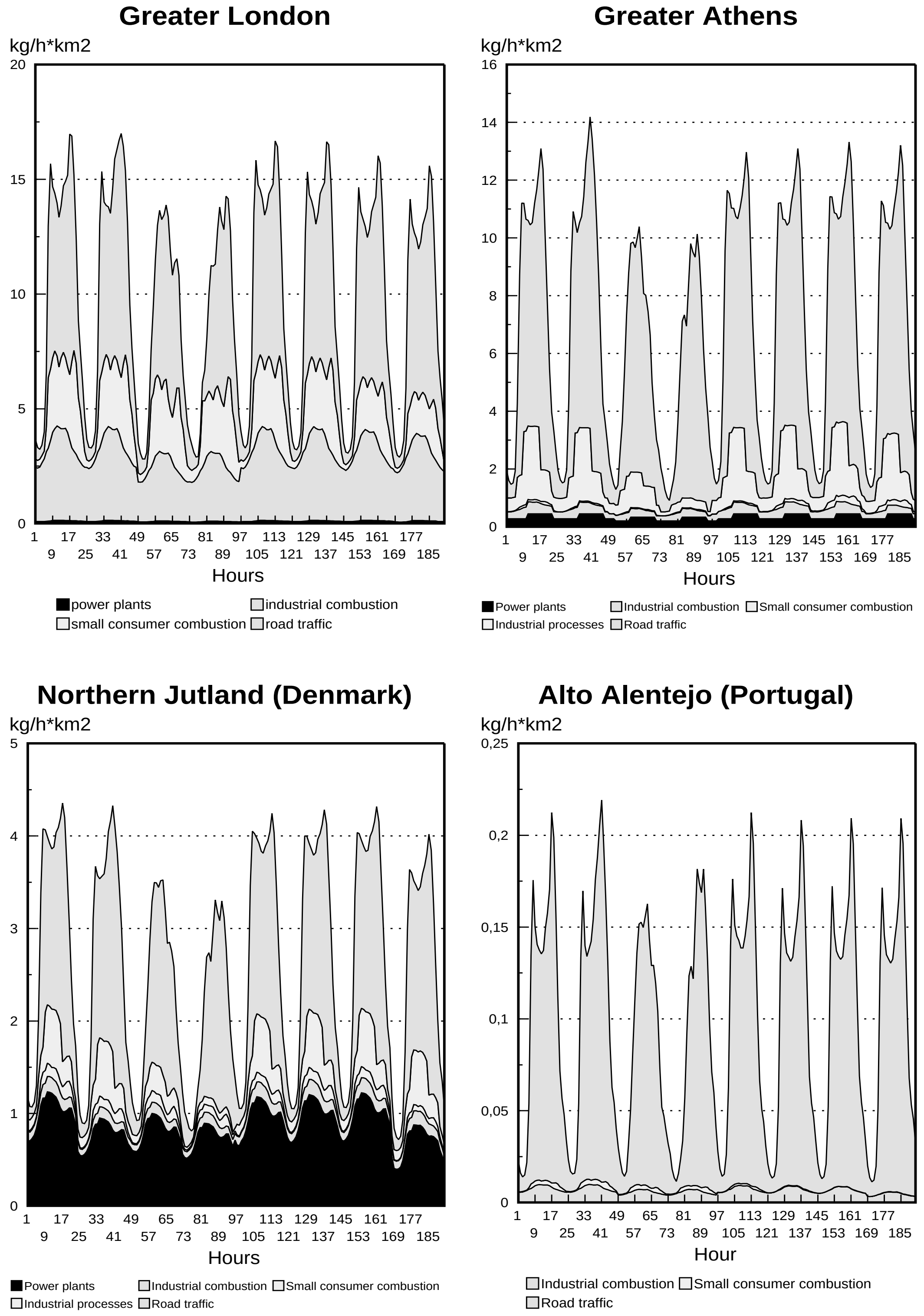


Figure 16: Total hourly NOx-emissions of all main sectors within 8 days of the JWC for big urban regions (Greater London, Greater Athens) and for rural and little industrialised regions (Northern Jutland in Denmark and Alto Alentejo in the East of Portugal; Source: GENEMIS)



5 CONCLUSION

Emissions from many major source sectors in Europe show strong temporal variations. Seasonal, daily and hourly variations often add up to several 100% deviation from average emissions. These variations should therefore be taken into consideration in atmospheric transport and transformation modelling. Though the availability of indicator data with high temporal resolution is limited and though large uncertainties are connected to the simulation of monthly, daily, and hourly emissions, the GENEMIS exercise has shown that:

- data and information describing the temporal variation of emissions are available for many countries for many sectors;
- models for the estimation of emission data with high temporal resolution have been developed and are available for many sectors;
- these models provide reasonable estimates of the temporal variation of emissions based on statistical and meteorological indicator data;
- these estimates can be considered more reliable and nearer to reality than simple and generalised temporal patterns as used in the PHOXA, LOTOS, EMEP, and other projects.

Furthermore, calculations within GENEMIS have shown that:

- the temporal variation of emissions varies considerably from sector to sector and region to region;
- the temporal variation of total emissions varies strongly from region to region and from country to country; generalised patterns applied to all European countries lead to considerable errors in many countries and periods;
- total emissions of different pollutants show very different temporal patterns and lead to changing proportions of NO_x- and VOC-emissions, which can affect photo-oxidant formation;
- the temporal variation of emissions strongly affects VOC-profiles; it is very likely that a variation of VOC-profiles will have an impact on atmospheric chemistry modelling.

The effect of these results on atmospheric modelling compared to modelling results based on less detailed data remains to be shown. It seems reasonable to assume that many atmospheric simulation models will only show limited sensitivity to the variation of emissions because of limited detail and limited resolution. However, more sophisticated models with high temporal, spatial, and vertical resolution, which have been developed and applied in the past years in several countries, are very likely to be sensitive to variations in the estimation of seasonal, daily, and hourly VOC and NO_x emissions. Therefore, it is reasonable to recommend the use of the best information available about the temporal variation of emissions to improve the quality and reliability of atmospheric modelling results.

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PROCEDURES FOR VERIFICATION OF EMISSIONS INVENTORIES

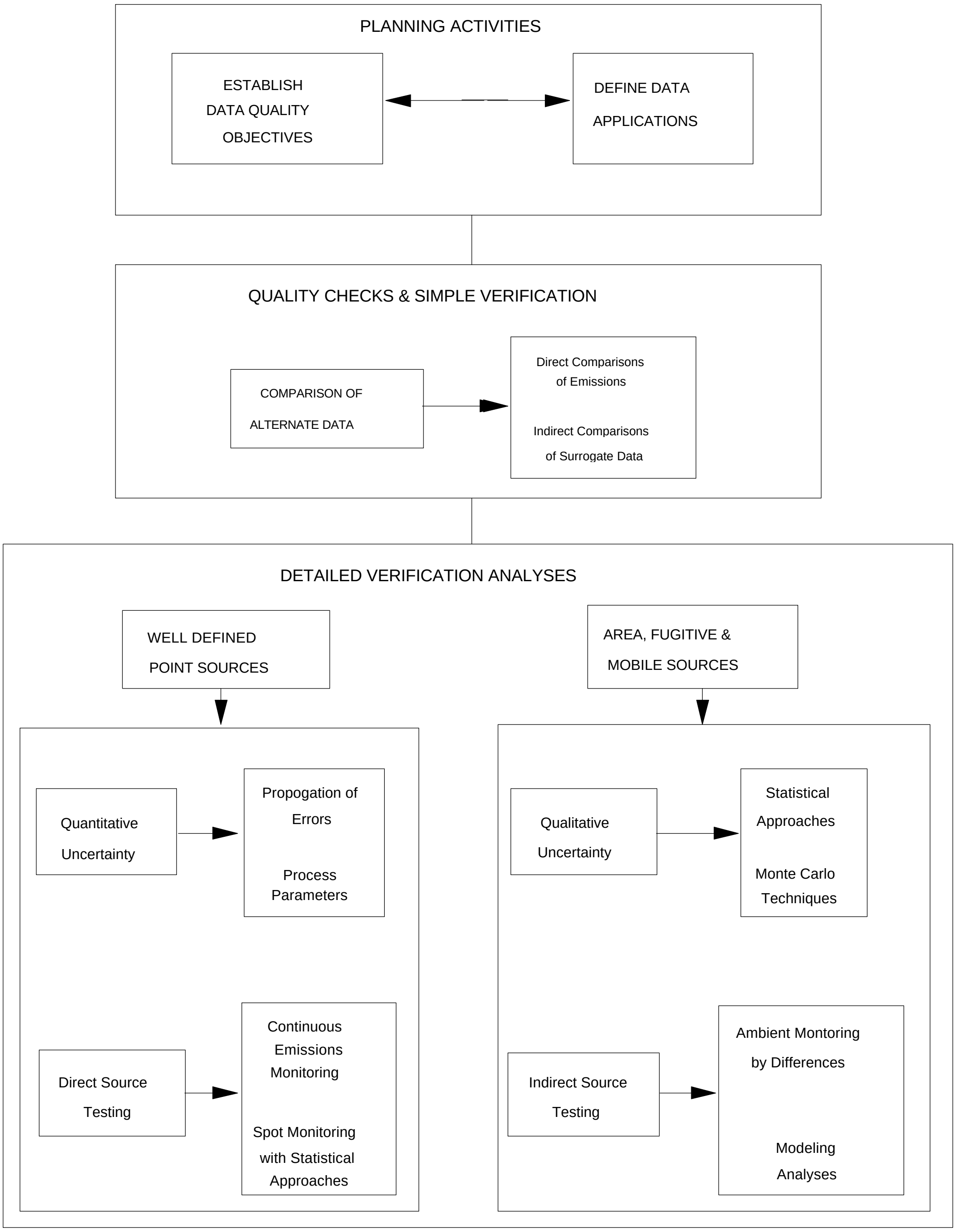
BACKGROUND

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. The formation of the Task Force on Emissions Inventories and the Verification Expert Panel demonstrates the importance of these issues to U.S. and European programs. The principles of emissions verification are equally applicable to urban, regional and global scale analyses and verification issues and procedures apply on each of these scales.

It is recognised that within the context of the Verification Expert Panel, verification procedures represent those activities that can be applied to demonstrate the applicability and reliability of emissions inventory data for the specific air quality management projects they support. While routine quality assurance and quality control activities are verification procedures, it should be kept in mind that in the context of this chapter quality assurance and quality control do not cover all of the possible verification concepts. The overall quality, completeness and level of representativeness of emissions inventory data are, however, directly related to the verification concepts discussed here, and for that reason, planning and initial implementation activities related to quality assurance are discussed in some detail. Figure 1 is a simple diagram of the activities that are discussed in this chapter to promote inherent data quality and to facilitate emissions data verification exercises.

The objective of this work is to provide guidance related to the development of emissions inventory data and suggestions for procedures and techniques that can be used to assess the validity of the emissions data included in inventories. Since most emissions data are estimates, it is often difficult to derive statistically meaningful quantitative error bounds for inventory data. Frequently, it is possible, however, to provide ranges that bound the likely minimum and maximum for an emissions estimate or to develop a qualitative data quality parameter to assess the relative confidence that can be associated with various estimates.

Figure 1 Simple Flow Diagram of Inventory Validation Programs



Solid Boxes Indicate Validation Techniques or Applications

Dashed Boxes Indicate Validation Activities

It is useful to define some key terms relative to the inventory verification process that will be used throughout the remainder of this chapter. Often individual inventory developers and/or inventory users will define these terms in the context of their own applications or goals. Therefore, the following definitions of key terms are provided to promote common usage in the context of this chapter.

Accuracy — Accuracy is a measure of the truth of a measurement or estimate. The term accuracy is often used to describe data quality objectives for inventory data, however, accuracy is hard to establish in inventory development efforts since the truth for any specific emission rate or emissions magnitude is rarely known.

Precision — The term precision is used to express the repeatability of multiple measurements of the same event. In experimental applications a measurement or measurement technique could have high precision but low accuracy. The term precision is also used to describe the exactness of a measurement. The term precision is not well suited for use in emissions inventory development.

Confidence — The term confidence is used to represent trust in a measurement or estimate. Many of the activities discussed in this chapter are designed to increase the confidence that inventory developers and inventory users have in the databases. Having confidence in inventory estimates does not make those estimates accurate or precise, but will help to develop a consensus that the data can be applied to problem solving.

Reliability — Reliability is trustworthiness, authenticity or consistency. In the context of emissions inventories reliability and confidence are closely linked. If the approaches and data sources used in an inventory development project are considered reliable, then users will have an acceptable degree of confidence in the emissions data developed from those techniques.

Quality Control — Quality control activities are those procedures and tests that can be performed during the planning and development of an inventory to ensure that the data quality objectives are being met. These activities may include criteria tests for data on operations, completeness criteria, or averaging techniques for use in developing default parameters. Quality control activities are generally applied by the developers.

Quality Assurance — Quality assurance describes the activities that are completed after the development of a product, usually by an independent party to verify that data quality objectives were met and that the product conforms to specifications. In experimental programs, audits with standard instruments and standard measures are used to establish the reliability of the experimental procedures. In emissions inventory development, however, few such standards exist. One effective activity discussed in this chapter is the use of an independent review team of experts to monitor the developments as progress is made on the inventory. The review team can identify alternate approaches and further documentation to enhance the credibility and reliability of the emissions estimates developed.

In the context of emissions inventory development, and in general use in this chapter, quality assurance is used to represent the sum of activities that are implemented to ensure the collection and presentation of high quality data.

Uncertainty

Uncertainty is a statistical term that is used to represent the degree of accuracy and precision of data. It often expresses the range of possible values of a parameter or a measurement around a mean or preferred value.

In some applications involving emissions inventory preparation, it is possible to describe in statistical terms the relative accuracy of an estimate and ultimately provide a preferred estimate or central value and a percent range that bounds the actual value. Such opportunities are frequently limited to sources that have requirements for extensive monitoring, through continuous emissions monitors, to verify emissions rates. More often, however, the data that is available is insufficient to develop statistically based quantitative measures of the data accuracy. In these cases, subjective rating schemes are often used to describe the relative confidence that is associated with specific estimates.

In the context of this emissions verification chapter, uncertainty is used to represent any of several techniques or procedures that can be applied to establish a ranking or numerical scale to compare the reliability of and confidence in the emissions estimates. In their simplest forms, such ranking procedures are subjective evaluations that reflect the accuracy or reliability of estimates based on the opinion of the developer. In other applications the evaluation is guided to a specific attribute of the data. For example, the completeness, coverage, or specificity may be of special importance and developers may be asked to rate the final emissions estimates relative to one or more of these components that can affect the quality of the estimates.

Validation

Validation is the establishment of sound approach and foundation. The legal use of validation is to give an official confirmation or approval of an act or product. Validation is an alternate term for the concept of verification as used in this context.

Verification

The term verification is used to indicate truth or to confirm accuracy and is used in this chapter to represent the ultimate reliability and credibility of the data reported.

In the context of this chapter 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 the reliability of the inventory for the intended applications of that inventory. In this context, the representativeness of the final data for the intended applications is of more importance than the absolute accuracy of the final emissions estimates. The procedures identified as verification activities will be applied to establish confidence that the data are sufficient in terms of coverage, completeness and reliability to guide decision makers to effective policy options.

These verification approaches can be used to understand the strengths and weaknesses of completed inventories relative to the desired applications of the data. In this context, verification procedures should be useful in directing research to improve the underlying data or procedures used to develop emissions estimates in future programs.

<u>Transparency</u> In the context of this chapter, transparency is used to represent the condition of being clear and free from pretense. The use of the term implies that data collected and reported by different agencies will be similar and, therefore, easily understood by other parties and comparable to the data presented by the other parties.

<u>Compliance</u> Compliance is the act of conforming or yielding to a specified norm or protocol. In the inventory development process, compliance may indicate conformity to development protocols or international agreements. In this sense the compliance issue can be thought of as verification of adherence to these established and agreed norms. The concepts of verification discussed in this chapter, however, are not intended to support the idea of compliance to norms or international protocol.

In the context of the Task Force on Emissions Inventories, the concepts of verification can be applied on two distinct levels characteristics of two different kinds of applications. One is for analytical applications, where accuracy and small uncertainty bounds are preferred to establish credibility in modeling results and in calculations of emission reductions and cost analyses. The second is for political applications, where adherence to agreed protocol and justification of the methodologies applied in a national effort are important to satisfy international agreements. The intent of this chapter is provide guidance and suggestions that will help inventory developers prepare high quality data for analytical pursuits and, therefore, the discussions favor the scientific applications over the political applications. The reader should, however, consider and be sensitive to all of the possible ramifications of emissions inventory data when constructing the inventory.

Table 1 presents a summary of the importance of the terms defined above as they relate to the analytical and political applications of inventories and the verification process. Table 1 is presented as a general summary and the reader is cautioned that in specific programs the importance of any of these terms may be more or less stringent than that presented.

Organisation of the Chapter

The chapter begins with a background discussion of the approaches for emissions inventory development and the role of emissions inventory data in air quality management activities. Considerations applicable in the planning phases of inventory development efforts that can improve the reliability of inventory data are discussed. The remainder of the chapter discusses specific analyses that can be performed to assist in validating emissions inventories. All of the activities that comprise emissions inventory verification concepts can be categorised in one of the major groupings listed below.

- Documentation of Data and Procedures
- Application of the Data
- Comparison of Alternative Estimates
- Uncertainty Estimates
- Ground Truth Verification

This discussion presents an overview of the verification procedures that can be implemented before, during, and after an emissions inventory is prepared. The success of these procedures is dependent on the overall quality of the data used in the development of the inventory and the procedures used to construct and maintain the inventory data.

TABLE 1. IMPORTANCE OF TERMS IN MAJOR APPLICATIONS

TERM	ANALYTICAL APPLICATIONS	POLITICAL APPLICATIONS
Accuracy	Very important, inaccurate data can lead to erroneous scientific conclusions; can affect credibility of policy decisions and cost/benefit analyses	Accurate data is always preferred for any application, however in some political applications adherence to protocol could be more important; accuracy of data should be within the constraints of the proposed control programs
Precision	Very important for comparative analyses and for repeatability	Numbers generated with accepted protocol should be comparable and repeatable, but for applications it is not so important
Confidence	Not important for scientific purposes if all quality control and quality assurance standards were achieved	Important in terms of following established protocol, empowers the developer and users in international programs
Reliability	Important in that it implies usefulness and credibility	More important as a reflection of method followed than for accuracy of specific numbers
Quality Control	Very important, this is a necessary part of data gathering and processing	Important as it relates to ensuring the adherence to accepted procedures and methods
Quality Assurance	Very important, in the scientific arena QA defines technique and qualifies results	Important as it relates to ensuring the adherence to accepted procedures and methods
Uncertainty	Important, the error inherent in the databases used to generate emissions data should be known to understand the error in final numbers	Important, uncertainty in policy applications translates directly to confidence and reliability concerns,
Validation	Not important for scientific applications, but is needed when data or analyses are used in policy applications	Very important, official acceptance is the critical test in the political arena
Verification	Very important, if the scientific applications of the inventory are satisfied then the effort was a success	Important only in a relative sense that data can be repeated and that two data sets can be compared
Transparency	Only important if analyses extend into neighbouring countries	Very important to demonstrate adherence to common protocol
Compliance	Important if no standard procedures exist, but is relatively unimportant if methods followed are trusted	Very important in terms of adherence to agreed protocol or methods

DOCUMENTATION OF DATA AND PROCEDURES

The activities discussed in this section are related primarily to the planning stages of an inventory development program to ensure that the resulting inventory and quality assurance program applied to the inventory will be properly documented. These activities are completed to ensure that the finished inventory will be useful for the intended projects that depend on the inventory and to facilitate the application of the inventory in future programs. These records establish the strengths and weaknesses of the inventory and can be assessed at later times to determine whether the current inventory is suitable for other applications or whether major revisions or modifications are needed to support these other applications. The major considerations discussed are itemised below:

- defining data quality objectives (DQOs)
- selecting inventory development procedures and assumptions
- defining quality assurance procedures
- planning and conducting an independent review
- conducting QA/QC, documentation

The principal objective of the planning phases is to define the needs of the users of the final inventories and to develop a set of data requirements and data quality objectives that are consistent with those needs. Data quality objectives (DQOs) can be presented as a formal written component of the inventory research plan or developed informally through consideration of the project objectives. The DQOs specify the geographic scope, the spatial and temporal resolution, and the pollutant and source coverage, and, in some cases, the accuracy criteria to be applied to inventory components. The primary purpose of DQOs is to guide the inventory development team in the completion of a final inventory database that will fill the needs of the intended user community.

The development of DQOs is directly related to the specificities of procedures and assumptions applied in the specific effort. The specific development effort, however, is also influenced by the resources and time constraints of the project. In some cases, some of the needs of the user community may not be achievable. In these cases, coordination and cooperation between the inventory development team and the intended users is required to agree on compromises and other procedures to ensure the best possible inventory to support the application program.

Another important part of the inventory development planning process is to specify quality assurance procedures.1 The QA plan specifies the types of data that will be collected, the procedures that will be used to assess the applicability of those data to the program, the steps that will be taken to correct or modify questionable or incorrect data, the procedures for documenting data corrections or modifications, and the procedures that will be applied to process the data into formats that are consistent with the inventory applications. This QA plan must address implementation and documentation approaches that are consistent with the DQOs and the resources that are available. The QA plan must also contain a contingency plan that describes an alternate approach in the event that the specified approach can not be completed. When resources permit, an independent review panel or third party review may be useful for large, complex, and high visibility programs. Such a procedure can be used as an audit, with a purpose similar to that of an laboratory or systems audit in experimental programs. The findings of a well respected panel of experts can add credibility to a well organized inventory development effort. The selection of participants, and the direction for their activities must also be considered with the DQOs established in the early phases. It is often helpful to have this independent panel available throughout the inventory development process, from planning phases through completion and delivery of the final product.

APPLICATION OF THE DATA

The intended application of the completed inventory is the principal consideration when preparing and implementing an inventory verification exercise. The two primary uses of emissions data and emissions inventories are listed below:

- assessments of the specific air quality problems in an area and identification of the most important sources and source categories that influence those air quality problems;
- input for regulatory activities associated with policy-making, including air quality modeling activities and the design, implementation, and tracking of the effects of air quality control strategies.

These major uses of emissions inventory data and the specific needs for inventory verification programs related to each of these uses are summarised. In some cases, it is possible to use data and analyses developed while conducting these activities for emissions verification exercises. The ultimate test of the quality and reliability of an emissions inventory is an appraisal of how well it has supported the goals of the program or programs to which it was applied.

Assessment Studies

The requirements for specificity and accuracy of inventory data are less stringent for assessment studies than for the other applications of inventories. Top-down inventory development methodologies are usually suitable for application to assessment studies and annual emissions estimates for an entire industrial sector are often adequate for these purposes. Assessment studies, are generally intended to provide the background understanding of the primary causes of the air quality problems being evaluated. One example of an assessment type inventory is the preparation of annual trends inventories. In these applications, it is not necessary to develop estimates for specific sources; it is usually more suitable to develop estimates for large industrial sectors such as electric power production and chemical manufacturing operations.2 Another example is an assessment study to define the ten largest source categories of VOC and NOx emissions in an urban area. For example, estimates of total emissions of NOx resulting from fuel combustion can be estimated from total energy demand estimates, and VOC emissions can be estimated from raw material feed rates. In this type of study it would not be necessary to represent the emissions for specific sources. Similarly, total emissions of VOC, CO, and NOx from mobile sources could be estimated from vehicle registration records, total regional fuel sales data, and assumptions about the fleet average fuel economy and would not require specific information on road type and speed classifications. These types of analyses are useful to confirm that the largest or otherwise most significant sources have been identified.

Regulatory Activities and Policy Making

Regulatory activities are performed by environmental agencies to define programs and policy options to reduce the negative impacts caused by air pollutants. The development of an air quality control policy usually uses an emissions inventory to estimate the potential for mitigating those problems and the costs that are associated with the control options. For example, emissions inventories facilitate the understanding of the following regulatory issues:

- relative importance of local/regional/national emissions and the impact of air contaminants that are transported from other regions
- the relative importance of biogenic or other naturally occurring sources to the anthropogenic sources in an area
- the contribution of various anthropogenic source categories to the overall controllable emissions burden

In some cases, regulatory actions and policy options are derived from model results. The requirements for emissions inventories in air quality modeling applications, and the methodologies and activities required to validate these inventories are significantly more demanding than for assessment inventories. Air quality models require meteorological and emissions input data and are used to simulate actual atmospheric conditions that result in air quality problems. Thus, for application to air quality modeling programs, representative inventories of the appropriate chemical species are needed at spatial and temporal scales consistent with the model formulation. It is necessary to develop the baseline inventory data at source-specific detail to represent the species, spatial, and temporal variability associated with the emissions.

Air quality problems, such as urban ozone formation, are influenced by local meteorological factors including wind speed, wind direction, temperature, and sunlight intensity. These factors are variable on hourly time scales, and therefore, emissions data is required at hourly intervals to adequately simulate these processes. The emissions input data must also be resolved spatially to represent a regular grid pattern covering the modeling region. Since emissions data are commonly estimated at the annual-level, and at a convenient geopolitical distribution, techniques must be applied to convert the emissions estimates into the appropriate spatial and temporal resolution. VOC, NO_x, and particulate emissions data must also be resolved to represent the source specific chemical distribution, to adequately track the complex chemistry that occurs throughout an urban area or other larger regional area.

Examples of regulatory programs that rely directly on emissions inventories are the Acid Rain Control System in the United States, permit fees and emissions trading concepts, and emissions offsets programs to compensate for the influence of new sources in areas with air quality problems. The Acid Rain Control Program established a maximum emissions allowance for all of the major sources of SO_2 and requires continuous emissions monitoring to demonstrate that each source is in compliance with its limit. Permit fees and emissions trading need a base from which to conduct transactions, and emissions offsets programs are dependent on consistent emissions inventory processes over different source types.

The use of an inventory as a component of a major research program or in response to a requirement of an international convention can benefit from these types of analyses in a verification context. Again the purpose of the resulting inventory is an important consideration in the design and implementation of such a verification exercise.

Examples of Data Applications for Emissions Verification

Some examples of data applications that can be used in the emissions verification process are discussed in the following paragraphs. This discussion does not include all possible activities related to the applications of inventory data that could be used in the verification process.

Frequently, whether the inventory is being used for an assessment or modeling purpose the largest sources of a particular pollutant are summarised. This source list can be reviewed to see if it is reasonable. That is, is it possible that the sources on the list are the largest sources. These types of reviews can sometimes identify coding errors, or otherwise incorrect emission factors, activity data units or other correctable data errors.

Some actual examples that were identified during the review and assessment of the 1985 NAPAP inventory are summarised here, but other examples from other programs are widespread. During a review of the largest SO_2 sources, one source with incorrect fuel use units was identified. Use of the incorrectly coded units resulted in orders of magnitude error in the final emissions estimate. Review of the largest NO_x sources indicated that orchard heaters were one of the most serious sources in the Southeast and Florida. This problem resulted from the use of an inappropriate emission factor. Cattle feedlots were found to be one of the largest sources of VOC emissions when these approaches were applied to the VOC database. Identification of these anomalies and proper review based on expert knowledge can help to prevent inappropriate policy decisions.

Another good example of using these kinds of application based data reviews is to calculate a rule effectiveness value from existing data. The rule effectiveness value can be used to describe the amount of control that is actual realised through the adoption of an emissions limitation regulation. Sometimes small sources within a regulated source category are exempted from a rule to avoid an unrealistic economic burden or simply because the emissions are so low that control would result in negligible affects. The overall uncontrolled emissions based on the total production of the source type can be compared to the actual emissions reported in the inventory to calculate the rule effectiveness. If that number is too high the analyst can assume that the inventory represents an unrealistic emissions total.

Although modeling results often do not match monitoring data exactly in either temporal or spatial performance, they do frequently provide a result that is conceptually similar to the observed monitoring data. In other words, a model can predict that the pollutant maxima is in the same area as the monitored maxima, and that the general distribution of the pollutant under many scenarios is similar to the measured distributions of the pollutant. Whenever general agreement between model results and monitoring data cannot be shown, the researcher should be concerned that the emissions of meteorology are not representative of the system.

Further modeling related activities can be reviewed under an emissions inventory verification program. Spatial distributions of emissions can be reviewed to verify that high source densities are in and near cities, that sources are not located over water bodies, and that emissions patterns reflect the population and transportation patterns. Temporal variations can be reviewed in this way as well. Checks can be performed to see that higher emissions occur during weekdays, and during normal working hours to help identify potential anomalies. Sometimes spatial or temporal distributions are selected as surrogates for a particular source and after application the combination will result in inappropriate emissions distributions.

Various regulatory activities require emissions inventories of different levels of specificity and accuracy. Many of the same approaches mentioned for assessment and modeling studies can be applied in regulatory applications. The primary concern in regulatory programs for application to policy making is to establish a solid base line of data and develop analytical results that are specific and suitable for the regulatory issue. The specificity and detail represented in data need to be targeted to the process covered by and the scale of the regulatory application. For example, regional and global policy issues can be treated with relatively aggregated data, whereas population exposure and risk analysis require more detailed and specific data.

COMPARISON OF ALTERNATE ESTIMATES

Various alternate approaches that exist for estimating emissions magnitudes from selected source categories can also be used to derive independent estimates of emissions. These estimates can then be compared to each other to infer the validity of the data based on the degree of agreement among the estimates. Such a process can be used to facilitate transparency among databases developed through different approaches. For example, statistical comparisons of aggregate emissions totals may be applied among countries or regions of countries that have similar population and economic status. The convergence of estimates derived through alternate emission development procedures adds reliability and validity to the final reported estimates. Table 2 lists some of the opportunities for data comparison studies that can provide a basis for determining the overall quality of emissions estimates.

The following discussion summarises information on the requirements of spatial, temporal, and species resolution of inventory data for modeling applications and provides some approaches that can be used to evaluate the quality of resolved inventory data. The verification needs for modeling inventories are dependent on the physical domain of the modeling exercise, the chemistry simulated by the model, and the specific science and policy applications that the model results will support. Specifically, these verification needs must address the data sources and methodologies that are available to transform annual and regional estimates into the detail required to support the modeling exercise. Table 3 summarises some of the issues related to inventory allocation procedures and of modeling inventories.

TABLE 2. SUMMARY OF DATA COMPARISON OPPORTUNITIES IN EMISSIONS INVENTORY APPLICATIONS

DATA COMPARISON TYPE	EXAMPLES
Alternate estimation methods	• Emissions magnitudes based on raw material feed versus product • Emissions magnitudes based on alternate measures of the inherent activity
Top-down versus bottom-up methodologies	• National- or regional-level estimates versus source-specific totals within source categories
Emission density comparisons	• Aggregate estimates for per-capita, per-employee or per-area compared to total emissions from all facilities in a source category • Aggregate emissions densities compared to similar estimates from other countries or regions
Emission factor comparisons	• Source-specific emission factors compared to default or average factors • Uncontrolled emission factors with average level of control to controlled emission factors • Emission factors based on alternate measures of the inherent activity
Control total comparisons	• National totals compared to sum of all source categories or facilities within source categories • Summed emissions totals from detailed inventories compared to national totals in trends analyses • National totals compared to national totals of nearby countries corrected for population and economic status
Completeness checks	• Comparison to earlier inventories to check that all significant sources are considered • Checks that all important source categories are considered • Checks that all important data elements are included for facility records
Consistency checks	• Internal consistency for facility data records • Consistency of methodology for source categories • Consistency of methodologies between countries in multiple country inventory development

UNCERTAINTY ESTIMATES

Experimental measurement data is commonly reported as average or preferred values with an associated error bound expressed in either absolute units or as a percentage of the preferred values. The standard techniques for estimating experimental uncertainty depend on the known accuracy and precision of the measurement methods employed in the experiments. Since the accuracy and precision specifications of the data elements associated with emissions estimates are rarely known, the application of these standard approaches for developing uncertainty are, in general, less straightforward than for experimental analyses.

There is a need, however, for reporting quantitative error bounds associated with emissions estimates. Uncertainty estimates for emissions data are important for assessing both the inherent uncertainty of the emissions estimates for individual facilities and the range of emissions magnitude represented by all sources in a study area. The uncertainty estimates for individual facilities help to understand the likely impacts of source-specific control options while uncertainty estimates for a collection of sources covering larger areas help to assess the overall quality of the emissions data and the relative quality between the estimates of specific pollutants. While the uncertainty technique discussed here[3], and others that have been presented elsewhere,[4,5] are useful for application to well-characterised sources, they are not generally applicable to most sources of air pollutant emissions. Our current understanding of the effects of the estimation assumptions on individual facilities and the effects of assumptions inherent in the emissions allocation procedures has not yet advanced to the point that allows routine uncertainty analyses of completed inventories.

It is possible to apply the techniques for classical uncertainty analyses for essentially any emissions estimate for any source category, if the inventory developers are willing to assign a range or some other quantified assessment of the error in the input parameters used to estimate emissions. If the developers are comfortable with estimated error bounds for the activity parameters, feed rates, temperatures, control efficiency and other factors that affect the final emission rate, these estimates can be applied to derive a final uncertainty estimate in the emissions estimate. Efforts to improve the procedures for such analyses are continuing in Europe and the United States.

TABLE 3. VERIFICATION ISSUES FOR DIFFERENT ALLOCATION TYPES

Allocation Type	Examples of Verification Approach	Problems or Issues That Can Affect Verification
Spatial Allocation	• Comparison of alternate allocation file surrogates	• Lack of suitable alternate surrogates • Not quantitative
Temporal Allocation	• Comparison of actual or reported operating data to surrogate operating profiles • Matching allocation profiles to typical work schedules, or density schedules or seasons	• Limited options for comparison distributions • Not quantitative • Often neglects daily temperature effects
Species Allocation	• Measured species profiles • Engineering assumptions • Mass balance considerations	• Many potential species not measured or estimated • Specific sources can vary significantly in source makeup • Not quantitative

Sensitivity studies used to test model predictions over the likely range of emissions to require an estimate of the extremes of the actual emissions range. Ideally, the sensitivity of model predictions to emissions inputs would address the individual components that contribute to the variability of the emissions. These results would assist both modeling and inventory development researchers to target the most critical issues for further research and improvements. The ultimate value of sensitivity studies is in the analyses of regulatory and policy options. If the estimated spread in emissions is large, it can be difficult to identify the most efficient option. For example, analyses at one extreme of VOC and NOx emissions estimates may suggest NOx control while analyses at the other extreme may suggest VOC control. The lack of quantifiable uncertainty bounds often leaves policy decision makers with difficult choices and limited options.

Classical Uncertainty

An approach to estimate uncertainty that relies on simple statistics including the standard deviation, the coefficient of variation, and the 90 percent relative confidence interval has been applied in the NAPAP program.[3] The standard deviation (S.D.) is a commonly used statistic that describes, quantitatively, the spread of data points in a population of measurement data. The coefficient of variation (C.V.) is a measure of the standard deviation relative to the mean value (i.e., C.V. = S.D./mean). The 90 percent relative confidence interval is used to define the limits that include 90 percent of all possible measurements in a population assuming that the distribution of the measurements is a normal distribution. In a normal distribution, 90 percent of the possible measurement values lie within a range bounded by ± 1.64 times the standard deviation.

Simple statistical approaches based on standard deviations and confidence intervals are based on the assumptions that the spread of possible results can be represented by a normal distribution and that the parameters estimated do not vary significantly with time. Alternate approaches based on distribution free statistical procedures that do not require these assumptions have also been presented.[4,5,6,7]

In summary, procedures for estimating emissions uncertainty have only recently been made available for specific, well-understood emissions sources and the specific pollutants that are unmistakably associated with those sources. While these techniques are useful to assess the relative accuracy and validity of the aggregate emissions estimates, they have not yet evolved to the level where they can be rigorously applied to sensitivity studies of photochemical air quality models and other more detailed analyses associated with emissions control options and control strategy development. Further efforts are ongoing and opportunities are being explored for analyses that can be used to evaluate the validity of an emissions inventory in terms of its influence on air quality analyses.

Data Quality Ratings

Emissions inventory estimates are often calculated as functions of process rates, manufacturing units, control technologies, and factors for spatial, temporal, and species allocation. Estimates of each of these parameters are often based on a small number of measurements and the estimate is then universally applied to all sources within a given source category.

Differences in operating characteristics, maintenance and repair procedures, and in some cases climate and local weather conditions can affect the actual emission factor and control efficiency as applied to individual sources.

Spatial allocation of point sources is generally known with a great deal of accuracy from plant-specific location data, but the spatial allocation of area and mobile sources usually requires the application of spatial allocation surrogates that often do not reflect the variability in those activities resulting from personal lifestyles or other external influences. Similarly, surrogates of temporal operating characteristics are often applied to allocate emissions to seasonal, daily and hourly levels when specific operating data are not available. Species allocation factors are the largest source of uncertainty in these applications, and only limited information is available to assess these uncertainties. In general, uncertainty estimates based on the techniques discussed here have not been developed for highly resolved species inventories, because the information to complete these analyses is simply not available.

Therefore, a meaningful measure of the overall reliability of an emissions inventory can sometimes be developed by the application of a data rating scheme. Rating schemes can have different formats, but each sets up some arbitrary scale that is applied to score individual emissions estimates at the appropriate level of aggregation. Several rating schemes have been discussed in the context of the UNECE EMEP Task Force. Each of the schemes is briefly summarised below.

The U.S. EPA has long used a rating system for its preferred emission factor listings included in its AP-42 document.[8] This technique uses a letter rating system of A through E to represent the confidence in emission factors from best to worst. In this system A factors are based on several measurements of a large number of sources, and E factors are based on engineering or expert judgement. The U.S. EPA has recently expanded this approach to include a letter based rating of the emissions estimate as well as for the emission factor. While there are some guidelines for the assignment of the letter score, this approach is largely subjective.

A similar method has been used in the United Kingdom for assessing the overall quality of emissions estimates.[9] In this approach letter ratings are assigned to both emission factors and the activity data used in the emissions estimates. The combined ratings are reduced to a single overall score following an established schedule. The emission factor criteria for the letter scores are similar to those applied in the U.S. EPA's approach and scores for the activity data are based largely on the origin of the data. Published data either by a government agency or through an industry trade association are assigned C ratings and extrapolated data based on a surrogate would receive an E rating.

The IPCC has included a rating scheme in its guidelines for reporting of greenhouse gas emissions through international conventions.[10] This scheme uses a different approach. For each pollutant associated with major source categories a code is specified to indicate the coverage of the data included in the estimate. The codes indicate if the estimate includes full coverage of all sources or partial coverage due to incomplete data or other causes. Additional codes can be specified to indicate if the estimate was not performed, included in some other category, not occurring or not applicable. An additional rating is then applied to each pollutant for each source category to indicate the quality assessment of the estimate as either high, medium, or low quality. Two additional ratings are requested that apply to the source categories without reference to specific pollutants.

These ratings cover the quality of the documentation supporting the estimates, rated as either high, medium, or low; and a rating to indicate the level of aggregation represented in the estimate. The possible choices are 1 for total emissions estimated, 2 for sectoral split and 3 for a sub-sectoral split. This rating scheme has more detail but retains a simplicity that allows the analyst to quickly review the quality ratings and to compare the quality ratings to other estimates.

Another rating approach has been developed and is being used by researchers in the Netherlands.[11] This approach recognises the difficulties in getting agreement from several organisations in international efforts on the specific needs of emissions data quality and on definitions of data acceptability criteria. In this approach two specific issues are addressed concurrently in the rating scheme. The first is an assessment of the accuracy or uncertainty in the emissions estimate, and the second is an assessment of whether decision makers have confidence in the application of the estimates for regulatory and policy activities.

In this approach two scaling indicators are applied to represent these two concerns. The first is a letter grade from A through E that indicates the inventory developers assessment of the overall quality of the estimate. A ratings imply the highest quality and accuracy and E ratings imply that the estimate is an educated guess. The second rating scale applies a letter code to indicate the purpose for which the estimate was prepared and offers the policy maker a quick assessment of the reliability of the estimate for a given application. These rating categories and their associated applicability are listed below.

Applicability Rating	**Description**
N	National Level
R	Regional Level
L	Local Level
I	Industry Level
P	Plant Level

This indicator is meant to provide information to the user to enable judgement of the level of aggregation put into the estimate. For example. when an emission factor is based on national averaged numbers and therefore aimed at estimating the national total emissions, it is assigned a rating of "N", and the user would be cautioned against the application of this factor for any specific plant, or for only one section of a country where conditions may be different. Likewise estimates based on plant level data, with a rating of "P", would not be used with high confidence to estimate the regional total emissions for an emission sector.

One more quantitative approach to address this need is being developed by the Office of Research and Development of the U.S. Environmental Protection Agency.12 In this approach a numerical value is associated with the quality of the various components or attributes of an emissions inventory. This technique, called the Data Attribute Rating System (DARS), seeks to establish a list of attributes that can affect the quality or reliability of the emission factor and activity data associated with the emissions estimate for any given source category. A numerical scale is used to rank these attributes in a relative priority against a set of criteria selected to represent the reliability of each attribute estimate. This procedure will allow a comparative assessment of the overall quality of the alternate emissions estimates for a specific category or for a group of high priority source categories in an urban or regional inventory.

A detailed approach based on these concepts is currently being developed and further information will be available during 1994.

Systematic Error and Bias

There is also the potential for systematic error or bias in the emissions estimates. Bias results when one of the parameters used in the emissions estimation algorithm is based on unrepresentative data or does not consider some essential component of the emissions process. Bias in aggregate emissions estimates can also be caused by the failure to consider all of the sources or source categories that contribute emissions in an area. Systematic error in emissions estimates is difficult to predict and the effects of the bias introduced in emissions estimates as a result of systematic error can have significant effects on air quality analyses that rely on emissions inventories.13

GROUND TRUTH VERIFICATION

The implementation of the procedures and activities discussed in the preceding sections of this chapter will provide the basis for the development of a well-documented emissions inventory database. The application of techniques to establish a likely range for the final emissions estimates, and the methodologies for the estimation of uncertainty can assist in a qualitative assessment of the representation and relative accuracy of the inventory data.

Ground truth verification involves techniques that make direct comparisons between emissions estimates and some other known quantity that is related either directly to the emissions source or indirectly to the underlying process that results in emissions. While ground truth verification procedures can be resource intensive they will often provide the most powerful and quantitative method for data validation and should be incorporated into emissions inventory development programs whenever possible. Although this discussion of ground truth verification techniques concentrates on monitoring analyses, some survey procedures are also presented.

Survey Analyses

Some common methodologies for estimating emissions from area source emission categories rely on a per-capita, per-employee, or 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 demographics, or the distribution of employment by major industrial and commercial sectors. Another possible survey approach could be implemented to evaluate the representation of emissions estimates applied in urban modeling analyses. In this approach, some of the grid cells that are thought to contribute significant emissions magnitudes could be surveyed in a methodical way. This would involve a detailed manual survey of all stationary activities in a given grid cell location that can result in emissions.

Monitoring Analyses

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. Table 4 summarises some of the monitoring activities that have been used to help verify emissions estimates.

Source Sampling. Direct measurement of stack gas emissions, using CEMs, is sometimes required to establish compliance with environmental regulations. Obviously, if such measurements are available to the agency responsible for the development of an emissions inventory, those data can be applied directly to the inventory. In these cases, there is no need for the application of an emissions estimation technique. More commonly, however, such compliance data are only available for limited periods of time, or for only a subset of the population of sources in a given area. However, compliance data collected for some specific facilities or over a limited time period, along with similar data collected specifically for application to an emissions verification program, can be used to evaluate emission factors and emissions estimation techniques.

Such direct source testing methods are primarily applied to large stationary sources where emissions are vented through a clearly identifiable stack or vent. Indirect source testing methods are used to estimate emissions from dispersed sources. These types of sources either are too numerous to consider individually, like residential space heating, or arise from unexpected sources, like leaks in chemical plants or petroleum refineries. Some examples of indirect source testing are described below.

Measurement of Operating Parameters. It is not always necessary to measure the direct emissions from a source to quantify the actual emissions. For sources that have relatively high-quality emission factors or emission estimation algorithms that have been demonstrated to predict emissions with a high degree of accuracy over the typical range of operating conditions, emissions can be monitored by collecting and processing these activity data. For example, accurate monitoring of the fuel use rate and the sulphur content of fossil fuels can be applied to make highly accurate estimates of the SO_2 emission rates as a function of time.

Random Sampling of Leak Sites. A well-organised leak detection and prevention program in chemical and petrochemical operations can be useful to estimate total fugitive emissions for a facility or group of facilities.

Remote Measurement Techniques. These are measurement methods that do not rely on the collection of a captive sample. Instead they make a determination of concentration or some other physical property in an undisturbed air parcel. Three specific examples of remote measurement technologies applicable to measure air quality parameters are Fourier Transform Infrared (FTIR), ultra violet spectroscopy (open path) and gas-filter radiometry.

TABLE 4. 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 Modeling	• 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

Each of these technologies can be used to measure the concentration of pollutants along a line of sight through the ambient atmosphere or at the mouth of an emissions source. An approach based on open path FTIR or UV Emissions Tests involves the measurement of a path averaged concentration along a line of sight that is immediately downwind of the subject source.[14,15,16] Adaptations to this basic approach could also be applied to measure emission rates from selected industrial activities such as fugitive emissions from process leaks, fugitive emissions from chemical storage facilities, and emissions from in-use motor vehicles.

The Gas-Filter Radiometer Emission Test system has been used to measure in-use motor vehicle emissions.[17,18,19] In this system, an infrared light source is mounted on one side of an on-ramp to a restricted access highway. As each car passes the detector, there is a drop in the reference signal caused by the car interfering with the light beam. This drop in the reference initiates a measurement. As the car exits the beam, a one-second voltage versus time trace is obtained and stored electronically in the device. These systems are primary examples of the use of indirect source measurements for inventory verification, and the studies suggest some cars have much larger emissions rates than are predicted by average vehicle emissions factors.

Ambient Ratio Studies. In the United States, ambient measurement programs are routinely operated in urban areas that are classified as nonattainment for the ambient ozone standard. Typically, these measurement programs include a rural measurement site in a location that is in the typical upwind sector, two or more sites in the downtown area near the urban core, and two or more sites in the downwind sector at locations that are thought to represent the location of the ozone maxima events. Both grid-based and trajectory modeling approaches are used to simulate the urban area and model predictions are compared to the observed concentrations of ozone and ozone precursors. The use of grid-based models allows the investigator to track the temporal distribution of ozone precursors in the urban centre in addition to the ozone maxima. Frequently, these models are reasonably successful in predicting the ozone maximum in the downwind locations, but are less successful in tracking the concentrations of precursors in the downtown area.[20] These types of results have led researchers to question whether the underlying emissions inventories are adequately representing the actual emissions fields, and to question if control strategies based on these modeling predictions are valid.[21,22]

Several techniques have been developed and applied that seek to relate ambient measurement data to emissions source strengths. The studies using these techniques have been conducted to assess the reliability of general overall emissions estimation methods for use in regulatory applications. These studies can be categorised in one of three major groupings: tunnel studies, aircraft monitoring studies, and receptor modeling studies. The concepts of using these types of studies for emissions verification and some examples of each are discussed in the following paragraphs.

Tunnel Studies. Highway tunnels offer an excellent location to sample the contribution of emissions from in-use highway vehicles. Concentrations of VOC, CO, NO_x, and particulate matter (PM) can be measured at both the upwind and downwind portals of the tunnel and the emissions rate can be calculated by their difference. Air flow can be determined by simultaneously monitoring the exit concentration of an SF_6 tracer, which is introduced at the upwind portal at a known release rate.[23] Video images can be recorded to accurately assess the distribution of vehicles in the tunnel during the measurement periods. Average vehicle speed can be measured in each lane of the tunnel during each experiment. The measured concentration data may be used to estimate the mass emissions rate for the sampling periods.

Aircraft Monitoring Studies. An aircraft platform outfitted with air pollution instrumentation has been used to compare emissions inventory results to ambient monitoring results.[24] Aircraft measurements are made in both the upwind and downwind direction from a cluster of sources of specific VOC emissions. The measurements are obtained at various altitudes to define a flux of the selected pollutants in both locations and the difference is attributed to the combined emissions strength of all sources in the area between the measurement locations.

Receptor Modeling. Receptor modeling relies on the analysis of ambient measurement data along with the chemical characteristics of specific source types. If certain sources in an area have unique signatures their contribution to ambient samples can be inferred. This technique is often useful to determine the relative contribution of particulate sources to measured ambient concentrations.[25] These approaches are currently being evaluated to identify the potential for adaptation of these techniques for application to VOC and other sources.[26]

The U.S. EPA Office of Mobile Sources has recently completed a brief study that offers a critical assessment of 19 studies of receptor modeling approaches and 5 studies of ambient concentration ratios to evaluate emissions inventories in urban areas across the United States. This reference is a good summary of recent work in these areas and will lead emissions inventory developers to detailed descriptions of study designs and other useful information for planning and conducting such emissions verification studies.[27]

SUMMARY

This guideline chapter represents a comprehensive review of emissions inventory development procedures and those activities that can and should be applied before, during, and after the preparation of emissions inventories to promote high quality emissions data and to provide for verification of those data. Ideally, verification procedures should be applied by the inventory developers and the results of the verification efforts should be discussed along with the inventory. It is also equally useful for the users or a third party to conduct verification analyses. Ultimately, the true test of the utility and quality of the inventory data is how well it performs in the applications it is intended to support. Good planning, careful attention to procedures and analyses, and the judicious use of other data and other techniques are the foundation of a reliable verification effort.

A companion report that presents additional details of and selected results from activities that can be applied to emissions verification efforts is available through the U.S. EPA. That report does not recommend any specific techniques over any others and does not indicate a preferred combination of techniques for any individual program. The complexity of emissions development procedures and the variable activities these inventories support make it difficult to specify any universal recommendations for all applications.

For the purposes of this guidebook, however, it is desirable to promote a consistent approach for representing the overall quality of the databases. Therefore, it is suggested that a method be applied to develop a data quality estimate for all emissions data generated through the use of the guidebook. In all cases, the preferred approach is a formal uncertainty analysis. In some cases, it may be possible to apply Monte Carlo procedures in uncertainty analyses. When it is not possible to complete an uncertainty analysis the data quality rating procedure followed in Great Britain is recommended. This approach provides a simple assessment of the underlying confidence of the inventory developer in the data used to generate the emissions estimates. Each emission factor and activity data parameter is assigned a letter data quality rating according to the following definitions. For emission factors the following guidelines apply:

A An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector.

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.

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.

D An estimate based on a single measurement or an engineering calculation derived from a number of relevant facts and some assumptions.

E An estimate based on an engineering calculation derived from assumptions only.

Similar ratings are then assigned to the activity or production data using the general guidance that a C rating is applied if the data are taken from a published source such as Government statistics or Industry Trade Association figures. Other possible ratings apply relative to the C rating. If activity was some how measured accurately and with high precision it would receive an A or a B rating and if the data were developed by extrapolation from some other measured activity or a nearby country they would be assigned rating of D or E. The overall quality rating would be determined by a combination following the schedule listed below:

Combination Factor	Final Factor	Combination Factors	Final Factor
E - E	E	C - C	C
E - D	D	D - A	C
E - C	D	C - B	B
D - D	D	C - A	B
E - B	D	B - B	B
E - A	C	B - A	A
D - C	C	A - A	A
D - B	C		

The proper emissions verification effort can be identified for each project through careful consideration of the needs of the project, the resources available to the project, and the collection of supporting data that is readily accessible. If more detailed analyses are possible, they are encouraged. It is suggested that the developer include the results of any verification procedures used in a summary of the inventory data and describe the implementation of the approach so that others may benefit in future projects from those efforts. Table 5 summarises the verification techniques discussed in the chapter that have been or could be applied to specific source categories. The table is organised to follow the second level of aggregation included in the Selected Nomenclature for Air Pollution (SNAP90) adopted for application to the CORINAIR 1990 project. The summary represented in Table 5 is intended to define cases where specific techniques have actually been or are anticipated to be applied in actual emissions inventory development projects. Many of the verification techniques listed in the table could be applied to additional categories if specific requirements demanded special attention or if resources were adequate to fully plan for their application. This summary does not specify an absolute order of preference for the application of verification procedures; however, a brief summary of the relative priority ranking of the various approaches is presented to guide inventory developers in the selection of appropriate techniques.

TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
PUBLIC POWER, COGENERATION AND DISTRICT HEATING PLANTS								
Public Power and Cogeneration Plants	X	X	X	X	X		X	X
District Heating Plants	X	X	X	X	X			X
COMMERCIAL, INSTITUTIONAL AND RESIDENTIAL COMBUSTION PLANTS								
Comm., Inst. and Res. Combustion	X		X	X	X			X
INDUSTRIAL COMBUSTION								
Combustion in Boilers, Gas Turbines, and Stationary Engines	X	X	X	X	X	X	X	X
Process Furnaces Without Contact	X		X	X	X			X
Processes With Contact	X		X	X				X
PRODUCTION PROCESSES								
Processes in Petroleum Industries	X	X	X	X	X	X	X	X
Processes in Iron and Steel Industries and Collieries	X	X	X	X	X			X
Processes in Non-Ferrous Metal Industries	X	X	X	X	X			X

DSS Direct Source Sampling
SU Statistical Uncertainty Estimate
DQR Data Quality Ratings
AE Alternate Estimates
SA Survey Analyses
ISS Indirect Source Sampling
AM Ambient Measurements
AFA Allocation Factor Assessments

TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE (continued)

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
PRODUCTION PROCESSES (continued)								
Processes in Inorganic Chemical Industries	X		X	X	X	X	X	X
Processes in Organic Chemical Industries (bulk production)	X		X	X	X	X		X
Processes in Wood, Paper Pulp, Food and Drink Industries and Other Industries	X		X	X	X		X	X
Cooling Plants			X	X	X			X
EXTRACTION AND DISTRIBUTION OF FOSSIL FUELS								
Extraction and 1st Treatment of Solid Fossil Fuels			X	X	X	X		
Extraction, 1st Treatment and Loading of Liquid Fossil Fuels			X	X	X	X		
Extraction, 1st Treatment and Loading of Gaseous Fossil Fuels			X	X	X	X		
Liquid Fuel Distribution (except gasoline distribution)			X	X	X	X		X
Gasoline Distribution			X	X	X	X		X
Gas Distribution Networks			X	X	X	X	X	X

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TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE (continued)

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
SOLVENT USE								
Paint Application	X		X	X	X	X		X
Degreasing and Dry Cleaning			X	X	X	X	X	X
Chemical Products Manufacturing or Processing	X	X	X	X	X	X	X	X
Other Use of Solvents and Related Activities			X	X	X	X	X	X
ROAD TRANSPORT								
Passenger Cars			X	X	X	X	X	X
Light Duty Vehicles < 3.5 t			X	X	X	X	X	X
Heavy Duty Vehicles > 3.5 t and Buses			X	X	X	X	X	X
Mopeds and Motorcycles < 50 cubic cm			X	X	X			X
Motorcycles > 50 cubic cm			X	X	X			X
Gasoline Evaporation From Vehicles			X	X	X	X	X	X

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TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE (continued)

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
OTHER MOBILE SOURCES AND MACHINERY								
Off Road Vehicles and Machines			X	X	X	X	X	X
Railways			X	X	X			X
Inland Waterways			X	X	X			X
Maritime Activities			X	X	X			X
Airports (LTO cycle and ground activities)			X	X	X	X		X
WASTE TREATMENT AND DISPOSAL								
Wastewater Treatment			X	X	X	X	X	X
Waste Incineration	X	X	X	X	X		X	X
Sludge Spreading			X	X	X	X		
Land Filling	X		X	X	X	X	X	
Compost Production From Waste			X		X	X		
Biogas Production	X		X		X			

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TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE (continued)

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
WASTE TREATMENT AND DISPOSAL (continued)								
Open Burning of Agricultural Wastes			X		X	X	X	
Latrines			X	X	X			
AGRICULTURE								
Cultures With Fertilizers (except animal manure)			X		X			
Cultures Without Fertilizers			X		X			
Stubble Burning			X		X	X	X	
Animal Breeding (enteric fermentation)			X	X	X			
Animal Breeding (excretion)			X	X	X			
NATURE								
Deciduous Forests			X			X		X
Coniferous Forests			X			X		X
Forest Fires			X		X	X	X	X

DSS Direct Source Sampling
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TABLE 5. EMISSIONS INVENTORY VERIFICATION APPROACHES BY SOURCE TYPE (continued)

SOURCE CATEGORY	VERIFICATION APPROACH							
	High Priority		Second Priority		Third Priority		Low Priority	
	DSS	SU	DQR	AE	SA	ISS	AM	AFA
NATURE (continued)								
Natural Grassland			X			X		X
Humid Zones (marches-swamps)			X			X		X
Waters			X			X		X
Animals			X		X	X		X
Volcanoes			X				X	X
Near Surface Deposits			X				X	
Humans			X					X

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Application

Table 6 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. While the subjective nature of this approach is recognised, the data ratings summarised in Table 6 represent a general consensus among the members of the Expert Panel on Verification, given the current understanding of emissions inventory estimation methods. The inclusion of these ratings in the summary table does not suggest that the entire membership of the Expert Panel or the Emissions Inventory Task Force are in complete agreement with every entry. The letter grade ratings summarised in Table 6 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 (for example see chapter ACOR).

The value of a rating scheme such as that summarised in Table 6 is enhanced when applied in conjunction with a table of total emissions from each pollutant organised in the same matrix format. The researcher can then compare relative quality ratings in consideration of the overall contribution of that category to the total loadings of emissions of the specific pollutant species. The appearance of sources of significant amounts of pollutants with corresponding low quality ratings can serve to caution researchers on the applications of the inventory and direct efficient research efforts in future programs to improve the quality of the overall inventories.

TABLE 6. EMISSION INVENTORY UNCERTAINTY RATINGS

	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	D	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

Highest Priority Methods

In all cases and whenever practical, a direct test or series of direct source testing is the preferred emissions validation technique. Direct source testing provides the obvious benefit of analytical data consistent with experimental method. In addition, direct source testing in combination with sampling and monitoring of operating parameters can be used in the development of a classical uncertainty estimate. The combination of direct source testing and statistical uncertainty estimates are always the most desirable and highest priority methods for emissions inventory validation.

Secondary Priority Methods

Some source categories are not suited to direct source testing and in many applications resources are insufficient to conduct extensive source testing in emissions inventory development projects. In these cases, the application of a data ranking system is the next highest priority. This type of approach provides a structured analysis that allows direct comparisons to be made between categories in the final inventory and among various suggested estimation approaches. Although the final result of such an approach can not provide an absolute assessment of accuracy, it can provide a consistent basis to assess the relative accuracy of the components of an inventory. In many applications, such an assessment can be of extreme value.

The use of two or more estimates of the magnitude of emissions from source categories using alternate estimation methodologies is often the most practical method for validation exercises. Often a second or third approach can be used to develop an estimate of the overall magnitude of emissions with limited or even minimal expense. Although an agreement of two independent estimates does not ensure accuracy of either estimate, it does provide confidence that the preferred estimate is reasonable.

If extensive source sampling is not possible, and data to support a statistical uncertainty estimate are not available some combination of a rigorous quality rating system and comparison of sector or source specific alternate estimates would be the desired approach to emissions validation.

Third Priority Methods

Survey analyses and indirect source sampling are included in the next level of priority for emissions inventory validation techniques. Survey analyses are not rated higher because they can be difficult and costly to implement, they can be affected by incomplete response or coverage, and are subject to the accuracy of the aggregate responses. Often if properly planned and implemented they can provide useful information; however, if participants have little incentive to respond, the results can be misleading. Indirect source tests can provide supportive information but are only useful as an emissions validation technique for selected sources that can be isolated and assumptions must be applied to relate the results to the overall emission rate of the source or source group. While these methods may offer reasonable approaches for some categories, in general, other approaches in higher priority classifications should be considered first.

Lowest Priority Methods

The validation method entries for ambient monitoring studies and assessments of modeling allocation factors in the matrix are listed here with the lowest priorities. The low priority ranking of these methods, however, should not be interpreted as a suggestion that these approaches are universally undesirable. In general, the application of ambient monitoring data and quick analyses of emissions distributions in inventory validation exercises require assumptions to relate the results of these studies to emissions rates and emissions factors for specific source categories. There are opportunities, such as tunnel studies that are used to evaluate mobile source emission factors and studies to relate emissions inventories to observed ambient VOC/NOx ratios, that can provide significant information concerning the usefulness and reliability of emissions estimates for air quality management programs. These approaches are assigned the lowest priority ranking for two important reasons. First, the application of ambient monitoring techniques is expensive and requires the operation of a monitoring program designed specifically for the application or require additional technical analyses and model assessment activities. Secondly, neither of these approaches are applicable to a large number of source categories and, therefore, they have rather specialised applicability.

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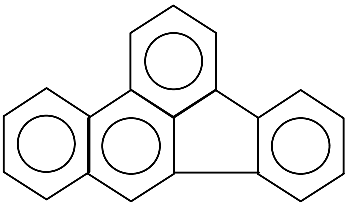
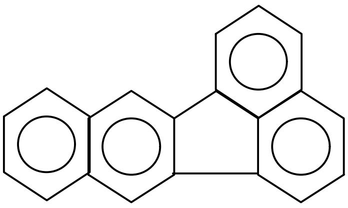
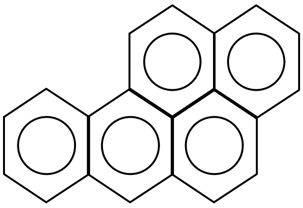
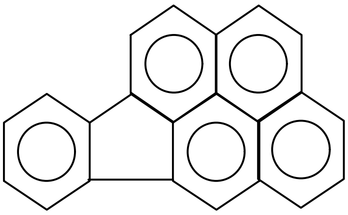
APPENDIX 1 - MOLECULAR WEIGHT, FORMULAE AND STRUCTURE OF THE FOUR PAHS IN THE POPS PROTOCOL

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

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