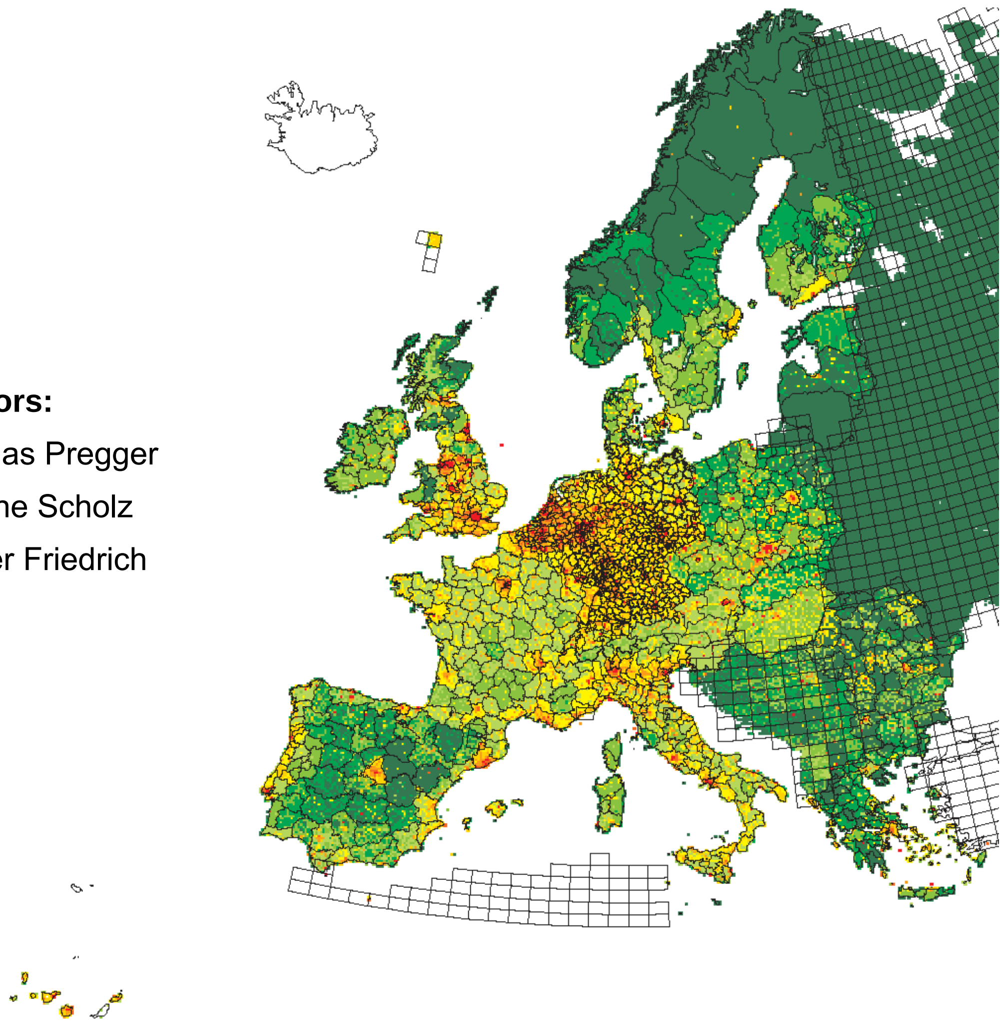
Universität Stuttgart
Institut für Energiewirtschaft und Rationelle Energieanwendung

Documentation of the Anthropogenic GHG Emission Data for Europe Provided in the Frame of CarboEurope GHG and CarboEurope IP



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Glossary

CAREAIR	Computer aided Analysis of Reduction strategies for Emissions and ambient Air pollution
CH_4	Methane
CHP	Combined heat and power plants
CO	Carbon monoxide
CO_2	Carbon dioxide
CORINAIR	Core Inventory of Air Emissions, EU Programme, European Topic Centre on Air Emissions
CORINE	Coordination of Information on the Environment, EU Programme
CRF	Common Reporting Format
CTM	Chemistry Transport Model
DVG	German Network Association (Deutsche Verbundgesellschaft)
DWD	German Met Office (Deutscher Wetterdienst)
ECM	Emission Calculation Module (of the IER emission model)
EMEP	Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants (LRTAP) in Europe (in the frame of UNECE LRTAP Convention)
EPER	European Pollutant Emission Register
ESPREME	Estimation of willingness-to-pay to reduce risks of exposure to heavy metals and cost-benefit analysis for reducing heavy metals occurrence in Europe (EC project)
EURAD	European Air Pollution Dispersion (EURAD) model system
EUROTRAC	EUREKA Project on the Transport and Chemical Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe; Second Phase
FZK-IMK	Forschungszentrum (Research Center) Karlsruhe, Institute of Meteorology and Climate Research
GENEMIS	Generation and Evaluation of Emission Data, EUROTRAC-2 subproject
GHG	Green house gases
GIS	Geographic information system
HP	District heating plants
IATA	International Air Traffic Association
IPCC	International Panel on Climate Change
LCPD	Large Combustion Plants Directive
LISA	Laboratoire Inter-Universitaire des Systèmes Atmosphériques
LOTOS	Long Term Ozone Simulation, dispersion model of TNO (Netherlands)
LPS	Large point sources reported to CORINAIR
LTO	Landing and take-off cycles on airports
MERLIN	Multi-Pollutant Multi-Effect Modeling of European Air Pollution Control Strategies - an Integrated Approach (EC project)
N_2O	Nitrous oxide
NFR	Nomenclature for Reporting
NH_3	Ammonia
NMVOC	Non methane volatile organic compounds
NO_x	Nitrogen oxides (nitrogen monoxide (NO) + nitrogen dioxide (NO_2))
NUTS	Nomenclature of Units for Territorial Statistics
PP	Power plants
PRTR	European Pollutant Release and Transfer Register
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
TFS	German Tropospheric Research Programme
UCTE	Union for the Co-ordination of Transmission of Electricity
UNECE	United Nations, Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
VDEW	German Association of Electric Works (Verband der Elektrizitätswirtschaft)
VDI	The Association of German Engineers (Verein Deutscher Ingenieure)

1 Introduction

Within the EU-funded research project “Concerted action: Synthesis of the European Greenhouse Gas Budget” (CarboEurope GHG) and the integrated project “Assessment of the European Terrestrial Carbon Balance” (CarboEurope IP), IER had the tasks to

- provide methodology and basic data for the temporal and spatial disaggregation of greenhouse gas (GHG) emissions and
- provide calculated emission datasets for anthropogenic GHG emissions in Europe.

National greenhouse gas emissions are reported periodically to the Intergovernmental Panel on Climate Change (IPCC) by all member states to the United Nations Framework Convention on Climate Change (UNFCCC). Based on these annual and country total emission data the aim was to generate hourly emission data on regional scale for the year 2000 and different model domains/grids applying the best methodologies available.

A lot of work in the field of spatial and temporal emission resolution has already been conducted for other trace gases, e.g. in the EUROTRAC subproject GENEMIS, or in the frame of the German Tropospheric Research Programme (TFS), but yet there has not been much work done on the spatial or temporal resolution of greenhouse gas emissions. In most cases, the disaggregation methodology developed for ‘classic’ air pollutants (NO_x, NMVOC, SO_2, CO etc.) can be applied for greenhouse gases as well because they depend on the same source activities. This report documents the approach applied for the generation of different GHG emission datasets in high spatial and temporal resolution. UNFCCC emission data were implemented in the European scale emission model developed at IER. Because of the complexity of the IER model system a complete documentation of the input data used can not be provided in the framework of this report. Furthermore, methodologies and input data are continuously updated and further developed if new information is available. A complete documentation of the temporal profiles used in the model is intended after the ongoing update and improvement process has reached a final stage.

The delivered emission data sets have the following main characteristics:

- Input data are based on the official UNFCCC Greenhouse Gas Inventory Data (excluding biomass burning, international bunkers, agriculture (except enteric fermentation for CH_4), and land-use change and forestry) (download March 2004).
- Calculated data sets in spatial resolution (Europe 50 km x 50 km and 10 km x 10 km) were generated with the help of the IER emission calculation model that was developed in the frame of EUROTRAC-2 subproject GENEMIS and includes a separate treatment of point, area and line sources and a GIS intersection with administrative units, land use data, digital road maps and a point source data base.
- Calculated data sets in spatial and hourly resolution were generated using the comprehensive time curve data base of the IER model that distinguishes country specific temporal profiles of different activities with more than 300 time curves.

2 Structure of the IER Emission Model

A European scale emission model was developed at IER within the last 12 years and applied to provide emission data for various projects (on European scale e.g. GENEMIS (EUROTRAC), MERLIN, ESPREME) and several CTMs (e.g. EURAD, REM/CALGRID (FU Berlin), KAMM/DRAIS and LM-ART (FZK-IMK), M-SYS (U of Hamburg), CHIMERE (LISA)). Model development was mainly realised within the German Tropospheric Research Programme financed by the German Ministry of Research (see Wickert 2001, Schwarz 2002 and Friedrich et al. 1998). A significant amount of work on the generation and evaluation of emission data has been conducted in the frame of the EUROTRAC 2 subproject GENEMIS, with final results having been published in (Friedrich & Reis 2004). During the main development phase the model was termed CAREAIR/ECM and calculated European data were referred to as GENEMIS emission data. Both the methodology and the database are regularly updated to assure an actual state of the art model. The model includes a detailed integrated German model and is able to provide input data for macro- and meso-scale modelling. On European scale, hourly emissions down to about 10 km x 10 km grid cell size are provided. The data base contains annual emissions of more than 250 source groups and distinguishes between point, area and line sources. The integrated meso-scale German emission model provides emission data down to 1 km x 1 km grid cell size and includes more than 48.000 industrial point sources, 83.000 line sources/road segments and more than 500 source groups. The temporal resolution is realised through more than 300 source specific temporal profiles. For high spatial resolution of area source emissions, statistical data for administrative units and land cover data are used. Within the CarboEurope projects, officially reported GHG emission data from UNFCCC database were implemented into the model and highly resolved emission data were provided for several different grids. The implementation of an improved methodology for spatial emission allocation as well as improved temporal profiles will be realised within the near future.

The basic methodology of the IER approach is shown in Figure 1. The model starts with a yearly emission table that includes point, area and line sources using different geographic data for spatial allocation of these source types. Point sources are intersected with the model grid by geographic coordinates applying a geographic information system (GIS). Area and line source emission data stored in the yearly emission table are already distributed on administrative units using statistical information (currently usually population density). Areas for which no statistics on administrative units were available are represented in the model domain by 1 x 1 degree grid cells originally based on the LOTOS model and emission data base for the year 1990 (Builtjes 1992). In a second step, emissions from area sources are allocated using 1 km x 1 km or 3 km x 3 km land use maps, distinguishing residential area, industrial area, agriculture, forest, water surface and other area. The land cover information was derived from CORINE for Western countries (EEA 1997) and USGS for Eastern countries (RIVM-NOAA 1996). The allocation of non-urban road and rail traffic to line segments is an important issue but due to lacking information still not sufficiently solved. For most of Germany it was possible by (Wickert 2001) to realise a sophisticated methodology using a digitised road net including all categories and segments of non-urban roads and linked annual mileage data for different vehicle categories. For other countries than Germany, a more simple approach was realised, based on digitised road maps (ESRI 1993) and the allocation of total highway emissions per administrative units to road sections.

Figure 2 shows structure and data interfaces of the IER emission model. Spatial allocation based on GIS intersection leads to grid- and cell-shares of emission sources considered. The resulting shares are stored in two data base tables and used by the Emission Calculation Module (ECM) for multiplication with the yearly emission data and temporal profiles. A control program allows to modify parameters (e.g. select emission table, pollutants, year, geographic data of profiles and assignments) and starts the calculation for each project (project name e.g. urop_ghg_50). The data delivery is usually done including a readme file describing and documenting the emission datasets (see example in the Annex for Europe 50 x 50 km data).

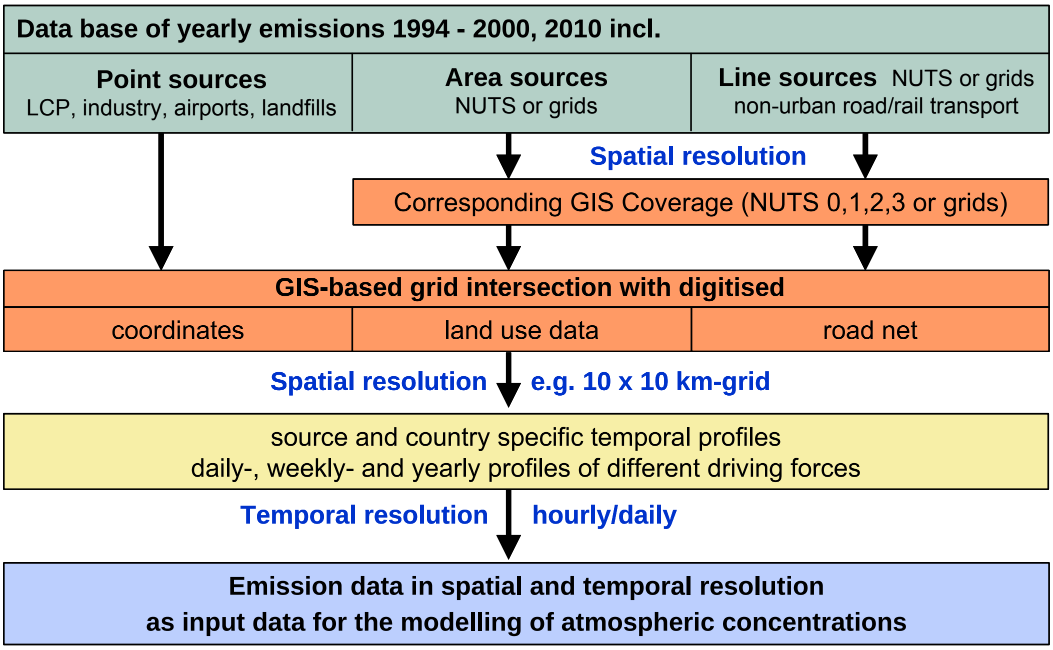

Figure 1: General approach for the generation of emission data in high spatial and temporal resolution within the IER emission model

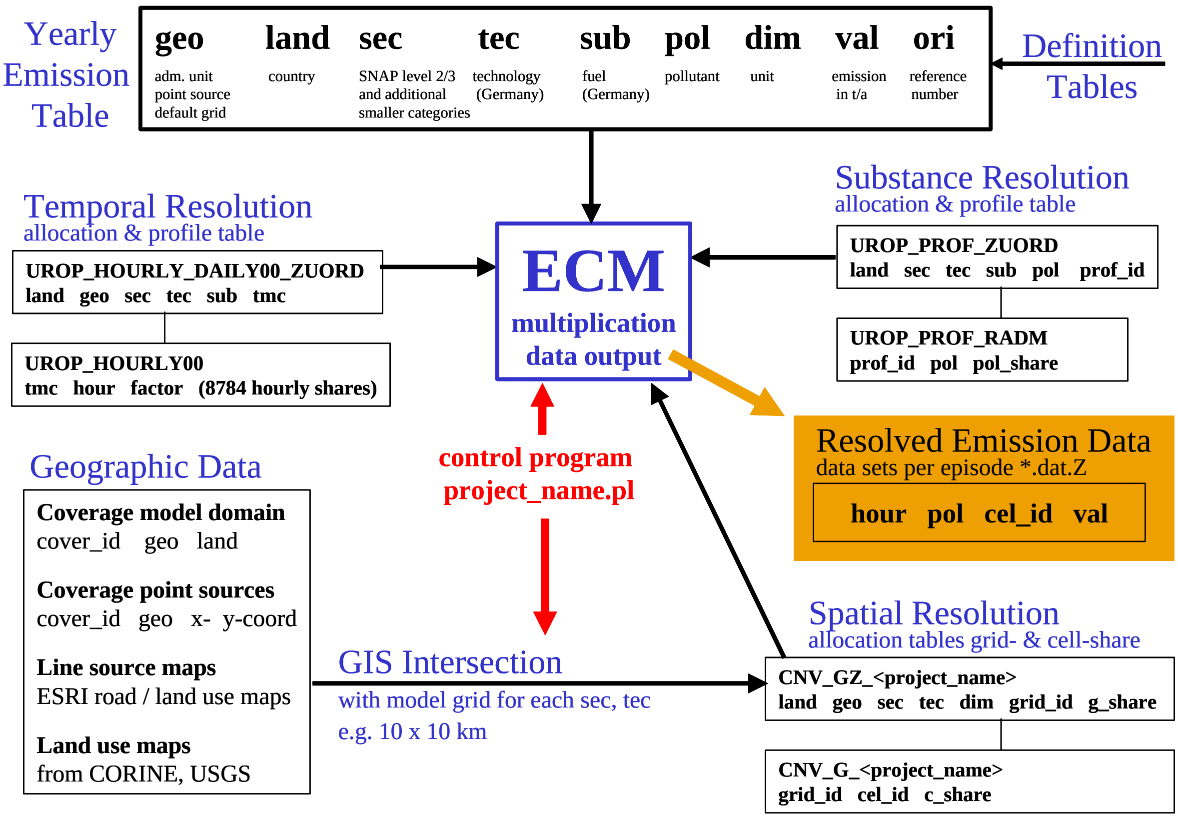

Figure 2: General structure and data interfaces of the IER emission model

Figure 3 shows the domain covered by the emission model and the structure of administrative units (polygons, e.g. Germany, France and the Netherlands on NUTS level 3) and default 1 x 1 degree grids that corresponds to the structure and distribution of emission data in the yearly emission table. It is planned to update this structure and add polygons for areas where statistical data is available meanwhile and to update and improve the resolution of Eastern areas by implementing gridded population data in 50 km x 50 km resolution.

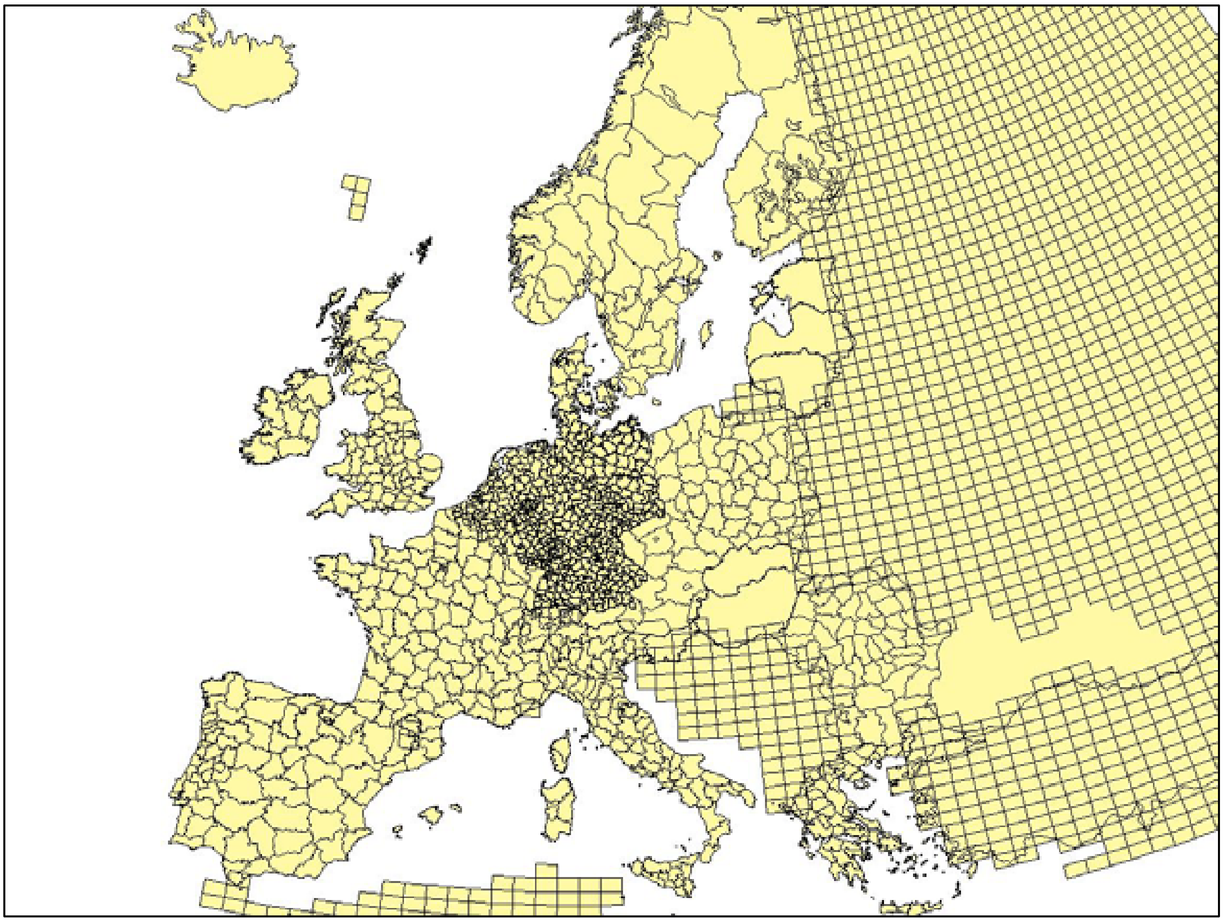

Figure 3: Spatial structure of the yearly emission table and of administrative units/grid cells within the IER emission model domain

3 Annual Country Total Emissions Used as Input

A major part of the work for CarboEurope was the generation of a yearly GHG emission table that could be implemented in the IER emission model. National annual emission data were taken from national GHG inventories for the year 2000 as submitted to UNFCCC (UNFCCC 2004) according to the International Panel on Climate Change (IPCC) guidelines (IPCC 1996 resp. IPCC 2000). Emission sources are thus categorised following the IPCC Common Reporting Format (CRF) since 2000. For some member countries, a data reporting for the year 2000 was not available. Data for 2001 were used instead for these countries. For several countries a consistent dataset did not exist or no data at all was available from UNFCCC. Table 1 summarises the GHG emission data availability/processability for European countries. The following steps were required for the generation of highly resolved GHG emission data:

- Download and processing of the available UNFCCC GHG emission database
- Assignment of source groups to temporal profiles for temporal resolution
- Assignment of emissions to administrative units for spatial allocation
- Assignment of UNFCCC emission data in Common Reporting Format (CRF) to the more detailed CORINAIR Selected Nomenclature for Air Pollution (SNAP) for the generation of a yearly GHG emission data table and implementation of the UNFCCC data into the detailed IER emission model
- Application of the IER emission model to the defined model domain/grids, pollutants and episodes, calculation of hourly emission data for the year 2000

Table 1: GHG emission data availability/processability for European countries

Year 2000 inventories available	Year 2001 inventories available	No utilisable UNFCCC data	Implementation was not feasible
Austria	Czech Republic	Albania*	Iceland
Belgium	Estonia	Andorra	Liechtenstein
Bulgaria	Greece	Bosnia-Herzegovina*	Monaco
Croatia	Italy	Cyprus	Belarus
Denmark	Poland	Lithuania	
Finland	Romania	Liechtenstein	
France	Switzerland	Malta	
Germany		Macedonia*	
Hungary		Moldova	
Ireland		Russia (European part)	
Latvia		San Marino	
Luxembourg		Serbia und Montenegro*	
Netherlands		Turkey (European part)	
Norway		Ukraine	
Portugal		Vatican City	
Slovakia			
Slovenia			
Spain			
Sweden			
United Kingdom			

* emissions were calculated in addition to UNFCCC data based on activity rates and emission factors

To apply the IER model for temporal and spatial resolution, the UNFCCC data had to be translated from CRF to SNAP sectors. The EMEP/CORINAIR Emission Inventory Guidebook - Third edition (EEA 2003) provides an allocation table which was used for that purpose. As CRF and SNAP are not consistent nomenclatures a one-to-one allocation is to some extent not possible. To generate a further allocation to the more detailed SNAP-sectors (SNAP levels 2 and 3), CORINAIR NO_x emissions were used as an allocation parameter for all CRF-groups apart from agriculture, for which CH_4 emissions were used as a proxy to allocate UNFCCC data to SNAP sectors (CORINAIR 1999).

Some additional modifications had to be made for the implementation of the UNFCCC data. Entries in the emission tables were set to zero if emissions are not occurring (NO), not estimated (NE) or estimated but included elsewhere (IE). Emissions from international bunkers (aviation and marine), emissions from biomass burning and from CRF sectors 4 C, D, E, F (agriculture) and CRF sector 5 (Land-Use Change and Forestry) were not taken into account. Emissions for Albania and some countries of former Yugoslavia (Macedonia, Bosnia-Herzegovina, Serbia und Montenegro) were calculated using activity rates derived from IIASA RAINS PM Module (IIASA 2001) and emission factors from EMEP/CORINAIR Emission Inventory Guidebook (EEA 2003). Reported emission data for Slovenia and Croatia were implemented separately.

Table 2 shows reported GHG emissions for the European Community for 2000, downloaded from the UNFCCC Greenhouse Gas Inventory Database (UNFCCC 2004). Table 3 shows resulting country total CO_2 emissions that were implemented into the IER emission model and applied for the generation of hourly emission maps. IER resp. UNFCCC data are for several countries quite lower (especially former Yugoslavian countries, Norway and Bulgaria) compared to the EDGAR Fast Track data for 2000 (EDGAR 2005, domestic total excluding biomass burning). These differences indicate the overall uncertainties of the generated emission maps that result only from calculation/reporting uncertainties without even regarding uncertainties due to spatial and temporal disaggregation. The total sum of CO_2 emission of the hourly 10 km x 10 km emission maps (urop_ghg_10…) after grid intersection account for 4 204 560 kt. Table 4 shows country total CH_4, N_2O and CO emissions that were implemented into the IER emission model. CO emissions were primarily derived from (CORINAIR 1999) and extrapolated to the year 2000 using statistical information.

A more detailed table is provided in the Annex documenting used UNFCCC CO_2 emission data distinguishing main source groups for each country.

Table 2: Total emissions reported for European Community in 2000 in kt (Gigagrams) (UNFCCC download March 2004)

	CO_2	CH_4	N_2O	CO
Energy Industries (Fuel Combustion)	1 100 865	91	47	427
Manufacturing Industries and Construction (Fuel Combustion)	593 411	54	27	3 535
Transport (Fuel Combustion)	824 558	153	75	17 033
Other Sectors (Fuel Combustion)	622 455	377	30	6 039
Other (Fuel Combustion)	7 703	1.03	0.43	105
Total Fuel Combustion	**3 148 991**	**676**	**180**	**27 139**
Total Fugitive Emissions from Fuels	23 861	2 403	0.17	80
Total Industrial Processes	142 721	21	161	2 428
Total Solvent and Other Product Use	5 258		10	
Total Agriculture	2 023	9 780	699	150
Total Waste	4 623	4 433	27	755
Total European Community	**3 328 207**	**17 338**	**1 083**	**30 846**
Total International Bunkers	236 416	10	5	374

Table 3: Total CO_2 emissions per country in kt (Gg) implemented in the IER emission model (UNFCCC download March 2004) in comparison to EDGAR data (EDGAR 2005)

Country	IER for 2000/2001 (UNFCCC 03/2004)	EDGAR 2005 for 2000**	Deviation IER/EDGAR
Austria	64 928	68.503	-5,2%
Belgium	126 331	138.006	-8,5%
Switzerland	44 828	44.856	-0,1%
Germany	857 968	960.644	-10,7%
Denmark	52 764	52.238	1,0%
Spain	308 201	325.069	-5,2%
Finland	60 260	58.556	2,9%
France	407 199	431.381	-5,6%
United Kingdom	544 359	592.925	-8,2%
Greece	105 875	99.760	6,1%
Ireland	44 160	42.451	4,0%
Italy	460 763	476.763	-3,4%
Luxembourg	8 923	10.120	-11,8%
Netherlands	173 840	206.737	-15,9%
Norway	41 012	93.139	-56,0%
Portugal	63 493	68.490	-7,3%
Sweden	53 766	57.340	-6,2%
Bulgaria	45 363	88.452	-48,7%
Czech Republic	127 996	125.706	1,8%
Hungary	59 009	59.412	-0,7%
Poland	317 844	316.764	0,3%
Romania	112 459	96.371	16,7%
Slovakia	40 061	37.848	5,8%
Latvia	6 935	8.196	-15,4%
Estonia	17 083	17.262	-1,0%
Slovenia	15 198	13.468	12,9%
Croatia	19 379	61.181	-68,3%
Other former Yugoslavia, Albania	63 546*	126.816	-49,9%
Total implemented	**4 243 542**	**4 678 455**	**-9,3%**

* emissions were calculated based on activity rates and emission factors

** including EDGAR sectors F10, F20, F30, F40, F51, F54, F57, F60, F80, I41

Table 4: Total CH_4, N_2O and CO emissions per country implemented in the IER emission model (UNFCCC download March 2004, CO based on CORINAIR 1999, extrapolated to 2000)

Country	**CH_4 in t (Mg)**	**N_2O in t (Mg)**	**CO in t (Mg)**
Austria	434 967	8 297	857 024
Belgium	498 287	22 931	1 099 056
Switzerland	207 357	4 598	398 501
Germany	2 597 329	59 623	4 767 734
Denmark	263 575	3 989	579 475
Spain	1 855 293	38 091	2 824 781
Finland	258 432	12 011	535 280
France	3 022 561	74 265	6 636 138
United Kingdom	2 322 919	50 705	4 030 847
Greece	518 276	15 123	1 306 547
Ireland	608 791	9 939	274 964
Italy	1 659 749	78 450	4 953 706
Luxembourg	22 762	235	48 546
Netherlands	983 220	31 159	681 180
Norway	331 985	8 840	558 416
Portugal	499 598	10 850	1 069 181
Sweden	279 125	11 609	832 954
Bulgaria	482 748	13 913	407 623
Czech Republic	496 712	26 746	648 554
Hungary	479 304	12 682	612 856
Poland	1 847 117	42 615	3 527 899
Romania	1 348 944	6 072	1 122 078
Slovakia	214 199	2 934	284 299
Latvia	85 584	911	229 960
Estonia	93 774	168	207 622
Slovenia	111 715	1 800	109 111
Other former Yugoslavia, Albania	1 063 578*	27 240*	1 128 372
Total implemented	**22 587 902**	**575 795**	**39 732 704**

* emissions were calculated based on activity rates and emission factors (except for Croatia)

4 Spatial Allocation of Emission Sources

Data reported to UNFCCC is available as country total information without spatial differentiation. National emission data can be further resolved by downscaling with statistical data for administrative units and intersection with geographic information such as point coordinates, land use maps and digital road and railway maps. Point, line and area emission sources are distinguished according to their geographic structure. Emissions from each source type require different information for spatial allocation. Figure 4 shows the IER methodology for GIS intersection of point, line and area sources with geographic information and a defined model grid.

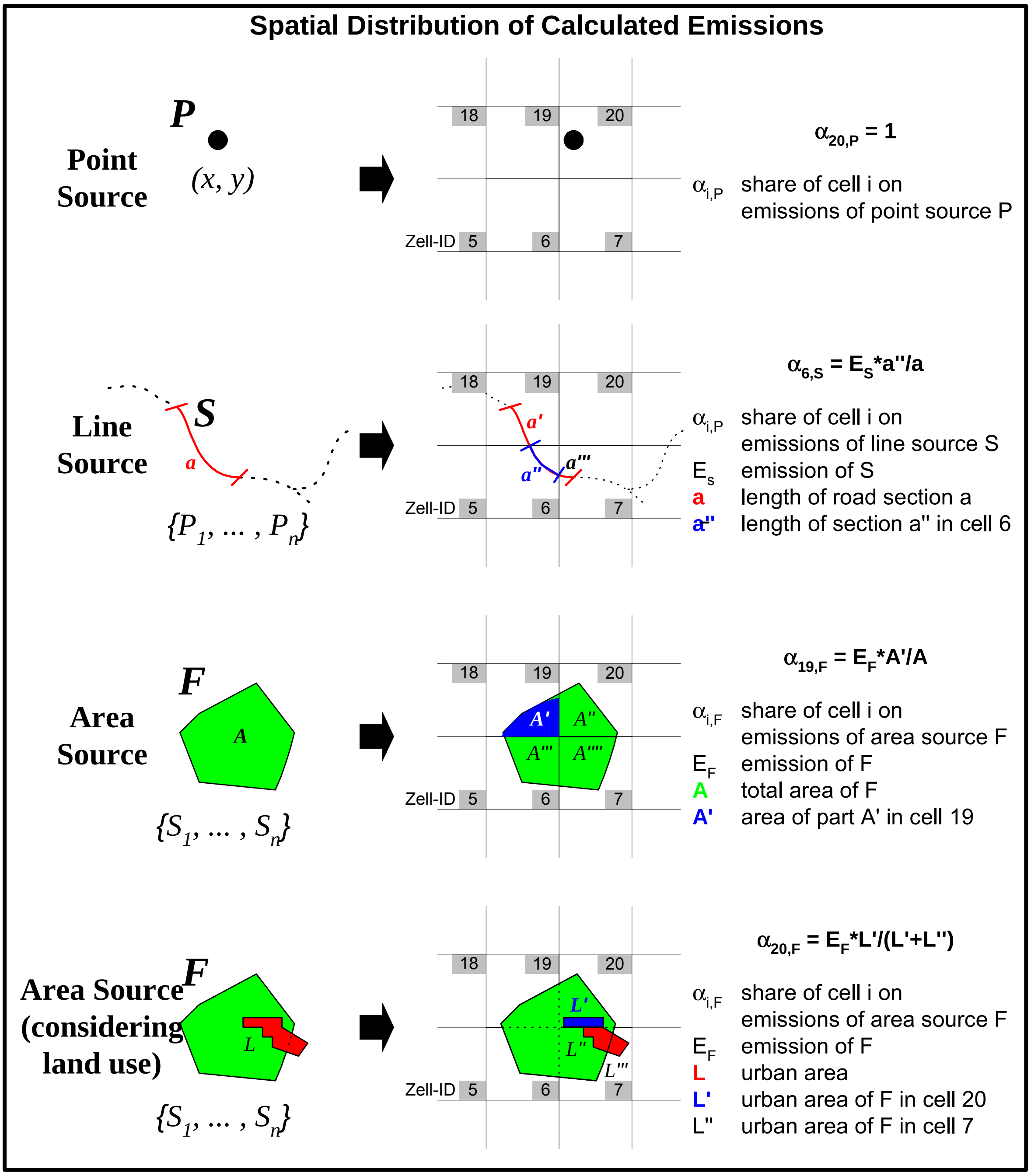

Figure 4: Methodology for spatial distribution of calculated emissions in the IER emission model

Emission data can be distributed in resolutions that are limited by the availability and level of detail of proxy information used for distribution. The geographic position of point sources is defined by the coordinates (x, y). Line sources are intersected with the emission grid by vector data for e.g. road sections. On regional scale (macro-scale) and if no other information than section length is used for the allocation of road transport emissions, vector data of a road map can alternatively be converted into raster data. Thus, grid intersection is done according to area sources in a resolution of e.g. 1 km x 1 km. Two alternative methods are shown in Figure 3 for area sources (see last two pictures). The first shows the intersection of an administrative unit (polygon, e.g. NUTS level 3) with the emission grid. Annual emissions within the administrative unit are directly allocated to the grid cells according to the intersected areas. The second shows that a much higher accuracy can be obtained if emissions of an administrative unit are allocated to a land use category first (e.g. urban area). This can be realised by an intersection with a land use map (raster data). In a second step, emissions allocated to land use area are intersected with the emission grid and allocated to grid cells.

4.1 Large Point Sources

The following emission sources are considered as large point sources in (EEA 2003). Their geographical location is clearly defined by their coordinates.

- Power plants with a thermal capacity ≥ 300 MW
- Refineries
- Nitric acid and sulphuric acid production plants
- Iron & steel plants with a production capacity of ≥ 3 Mt per year
- Paper & pulp industry with a production capacity of ≥ 100 kt per year
- Automotive paint shops with a capacity of ≥ 100 000 cars per year
- Airports with at least 100 000 landing-take-off-cycles per year
- All other sources emitting more than 1 000 t SO_2, NO_x or more than 300 kt CO_2 per year.

The last category includes district heating plants, waste incineration plants and various industrial production and combustion plants.

In the IER emission model version used for the generation of the GHG emission data, geographical coordinates and source strength of point sources were taken from the CORINAIR LPS data (CORINAIR 1999, description see (Radunsky & Ritter 1996)) for 1990/1994, extrapolated to the year 2000 based on statistical activity rates. The data were implemented by (Wickert 2001) and (Schwarz 2002) (~ 5 500 sources). For Germany, a large number of additional industrial point sources could be included in the point source data base (~ 48 000 sources). These data had to be officially reported to the individual State Agencies for licensing purposes required by the German Federal Immission Control Act (BImSchG 2002) and could be implemented during the . Based on these sources IER provided as well information for the determination of the vertical emission distribution (stack height, average flue gas temperature, flue gas flow rate and velocity).

More up to date data are collected in the frame of the EC Large Combustion Plants Directive (LCPD) and in the European Pollutant Emission Register (EPER) (http://www.eper.de/). These data might be used for future improvements but could not yet be implemented for the work in CarboEurope. The data base for the first EPER reporting year 2001 is available since the end of 2004 but comprises only information for the western European countries. However, for some countries uncertainties of the first reporting are estimated to be quite high. The second year of reporting has been 2004, data can be downloaded since 2006. For the third reporting year 2007, EPER will be replaced by the European Pollutant Release and Transfer Register (PRTR, see Regulation (EC) No 166/2006). The future reporting for PRTR will include as well point sources from further Eastern European countries. Unfortunately neither the point source reporting to EPER nor to PRTR requires the provision of additional information, which would allow determining effective emission heights.

If single source information is not available or not suitable for the calculation of effective emission heights, general information might be used for the vertical emission allocation. The vertical emission distribution applied to EMEP emission inventory is shown in Table 5 as an example. A distribution of the effective emission height is given for SNAP source groups level1. Information used by EMEP was partly derived from a European emission dataset that was provided by IER within the GENEMIS subproject of EUROTRAC.

Table 5: Distribution of gas and aerosols in the EMEP emission inventory according to different height levels based on the source sector (de Meij et al. 2006)

Source category (SNAP)	**Height emission gases**				**Height emission aerosols**			
	ground	**~150m**	**~250m**	**high**	**ground**	**~150m**	**~250m**	**high**
1.Combustion in energy and transformation industries			8%	92%	20%	20%	40%	20%
2. Non-industrial combustion plants	50%	50%			100%			
3. combustion in manufacturing industry	50%	50%			70%	7.5%	15%	7.5%
4. Production processes	90%	10%			100%			
5. Extraction of fossil fuel	90%	10%			20%	20%	40%	20%
6. Solvents	100%				100%			
7. Road transport	100%				100%			
8. Other mobile sources and machinery	100%				100%			
9. Waste treatment and disposal	80%	20%			100%			
10. Agriculture	100%				100%			
11. Nature	100%				100%			

4.2 Line Sources

GIS based vector data are available for non-urban roads (mostly for highways and federal roads) and railways. Due to the high density of roads in urban areas, urban traffic is treated as an area source. The allocation of traffic emissions to line segments is important for meso-scale resolution of primary emissions but still not sufficiently solved due to lacking information as well as personnel capacities. (Wickert 2001) realised a sophisticated methodology for Germany using a digitised road net including all categories of non-urban roads and linked annual mileage data distinguishing passenger cars, two-wheelers, lorries with trailer, lorries without trailer, buses and light duty vehicles. For other countries than Germany, highway traffic is attributed to line segments with the aid of a digital European road network (ESRI 1993). The average length of a street section between two points of the digital road network is 1.5 km. Emissions from railway traffic as well are localised with the ESRI digital European network. In order to increase the performance of GIS intersection digital road networks (vector data) were converted to gridded land use maps (1 km x 1 km raster data). It was not possible to include mileage data in order to improve the representation of hot spots within the administrative units. Rural traffic on smaller roads has to be treated as area sources because of lacking geographical information (road segments) on European scale. This leads to one of the most significant limitation of the spatial allocation for meso-scale resolution.

Only national shipping is included in the IER emission model as well the UNFCCC data used for the GHG emission data generation. The coastline separates national from international shipping.

Emissions from national shipping are mostly much lower than emissions from international shipping. Emissions from inland waterway transportation are allocated with the aid of land use data (water surface). Emissions from international shipping can be taken from EMEP for air pollutants such as SO_2, NO_x, NMVOC and CO. These data were calculated by (Jonson 2000) with a spatial resolution of 50 x 50 km from which the spatial distribution of emissions of greenhouse gases can be derived as emissions are proportional to fuel consumption. In addition EDGAR provides gridded international marine ship emissions.

Emissions from air traffic occur during LTO's (landing and take-off cycles, limited by a height of 1 000 m and including activities on ground like taxi and idle) and during cruise (any air traffic activity above 1 000 m). LTO's are allocated to airports and attributed to the category of large point sources. Emissions from cruising are not included in the IER emission data base.

4.3 Area Sources

All emission sources that can not be represented as point or line sources are classified as area sources. Area sources comprise all fugitive processes and activities which are attributed to a large number of small individual sources, e.g. urban traffic, residential combustion and product use and small industrial and commercial plants. Yearly emission data (country totals) - already distributed on administrative units - were spatially resolved in a second step by intersection with a land use map. Detailed land use data are available for Western Europe from (EEA 1997), generated in the scope of the EU CORINE - Programme (Coordination of Information on the Environment). It is planned to update the land use maps with the already available datasets for the year 2000. In addition, USGS data was used for Eastern countries (RIVM-NOAA 1996). Combined land use maps with 1 km x 1 km resolution were implemented, distinguishing residential area, industrial area, agriculture, forest, water surface and other area. All area source groups are assigned to these categories.

4.4 Applied Model Grids for CarboEurope

Emission maps for the following grids were calculated and provided by IER within CarboEurope. Table 6 shows the name of the projects/grids and coordinates of the corners (projection Lambert Conformal Conical (lc), for comparison geographic lat/long coordinates are listed in addition). Figure 5 shows the geographical position of the model grids.

CE_IP:

- Southern France (D1) (1 km x 1 km)
- France (additional) (10 km x 10 km)
- The Netherlands (additional) (1 km x 1 km)

CE_GHG:

- Europe (D2: 50 x 50 km, D3: 10 km x 10 km)
- Heidelberg (additional, with sectoral resolution) (10 km x 10 km)

Table 6: Name of the projects/grids calculated for CarboEurope and coordinates of the corners

	Left lower corner		Right upper corner	
Region/grid name	**geo-long** **geo-lat**	**lc-x** **lc-y**	**geo-long** **geo-lat**	**lc-x** **lc-y**
Southern France sf_klein_lc	-2.000 42.500	-950530.4785 -734371.7446	3.000 46.000	-523035.2306 -407094.9810
France sf_gross_lc	-3.000 41.000	-1055143.9090 -881160.4379	7.000 49.000	-212315.9742 -103676.6883
Netherlands nld_ghg_lc	2.81925711 49.79168736	-500000 0	7.65042406 54.13934003	-150000 450000
Europe urop_ghg_50_lc urop_ghg_10_lc	-23.44530600 24.16628512	-3400000 -2100000	53.74586526 68.73784951	1800000 2600000
Heidelberg heidelberg_lc		-200000 -200000		0 0

lc = Lambert Conformal Conical Projection (definition see last page)

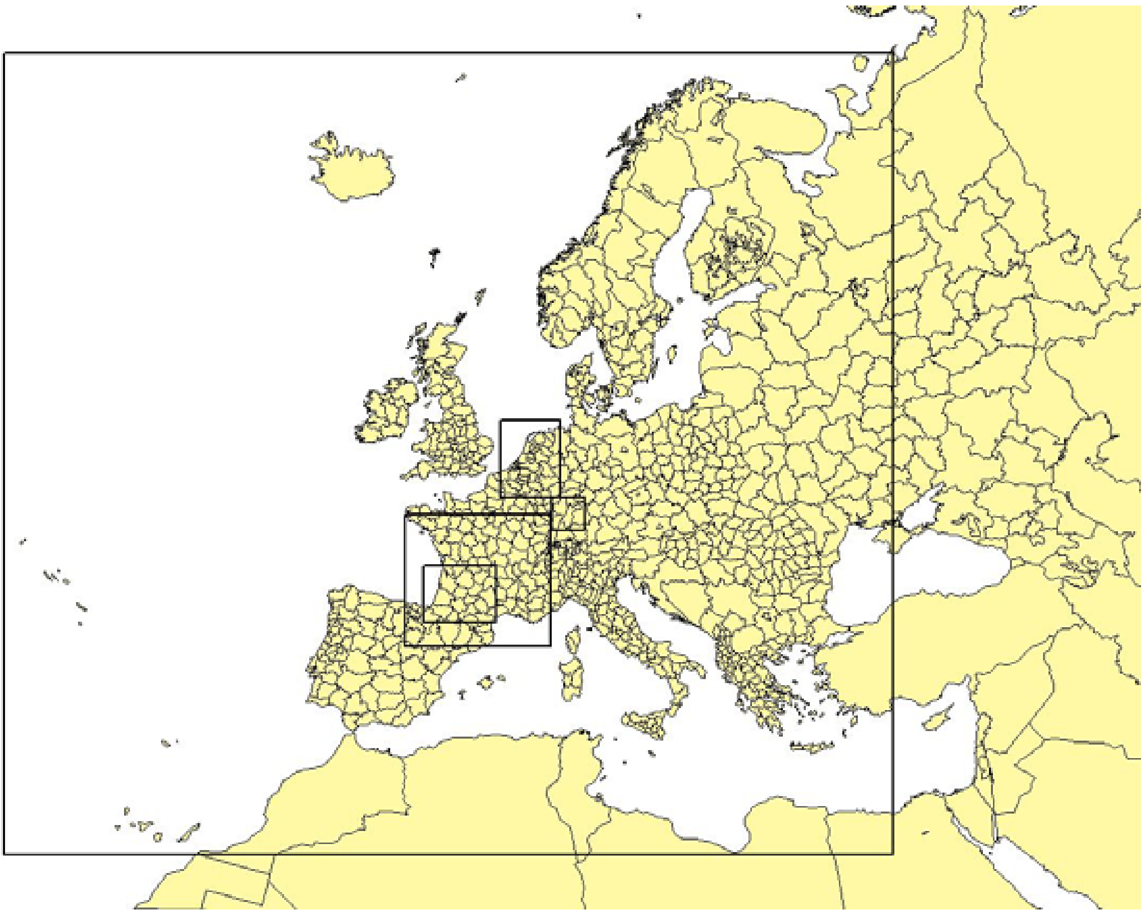

Figure 5: Geographical position of model domains/grids within CarboEurope GHG and IP

5 Temporal Resolution of Emission Data

A high number of source specific temporal profiles were developed at IER within different studies (e.g. Müller et al. 1990, Adolph 1997, Seier 1998, Wickert 2001, John 1999, Schwarz 2002) and applied for several projects. Table 7 gives an overview on socio-economic data used to describe driving forces for the variation of activities and emissions. The current allocation of temporal profiles to the detailed source sectors is done for different geographic units (NUTS 0 to 3 depending on the structure of the annual emission table) and documented in the model data base by a large allocation table. Currently more than 300 temporal profiles are used, stored as hour factors of a complete year (8 760 resp. 8 784 values) in a profile table. Calculated hourly emission data are usually lumped across all detailed sectors to total hourly emission maps or emission maps for different SNAP level 1 source groups.

Table 7: Temporal resolution: used driving forces - socio-economic data describing temporal activity variation of significant emission sources

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 plants	fuel use, degree days (temperature), production	working times, holidays	working times
Small combustion plants	fuel use, degree days (temperature)	user behaviour	user behaviour
Refineries	oil troughput, fuel use	working times, holidays	working times, shift times
Industrial processes	production	working times, holidays	working times, shift times
Road transport	traffic counts	traffic counts	hourly traffic counts
Air transport	LTO cycles, passenger and freight numbers	LTO cycles, passenger and freight numbers	LTO cycles, passenger and freight numbers

Because of limited resources, it was not possible to consider regional or local conditions/information for all European countries/regions. For most of the source categories, temporal profiles depend on the activity and the emissions follow a process specific activity profile. Temporal profiles for some sources depend on regional or local climatic conditions (e.g. small combustions in households). But only for Germany temperature dependence was included based on measured hourly temperature data for different years. As an example Figure 6 shows measured hourly temperature in Karlsruhe for the year 2000 (DWD 2004). Temperature dependence was taken into account for small combustion plants as well as vehicle cold starts and gasoline evaporation based on the work of (Wickert 2001). Including this information enables to take into account the seasonal variation of the weekly and diurnal profile and to improve accuracy. For other countries, temperature dependence was included as an average seasonal and regional variation independent from the year considered. Currently used country specific temporal profiles can lead to inconsistencies because of this difference and because the profiles are a result of different studies and approaches depending on availability of information. Inconsistencies might be observed especially if the variation of emission data for Germany is compared with data for other European countries. The following information on how temporal profiles were developed is mainly a summary of a discussion paper (Friedrich et al. 2003) originated from a workshop at IER and published in the frame of CarboEurope GHG. Additional information can be found there. Examples of typical IER temporal profiles for main sectors can be found in the Annex.

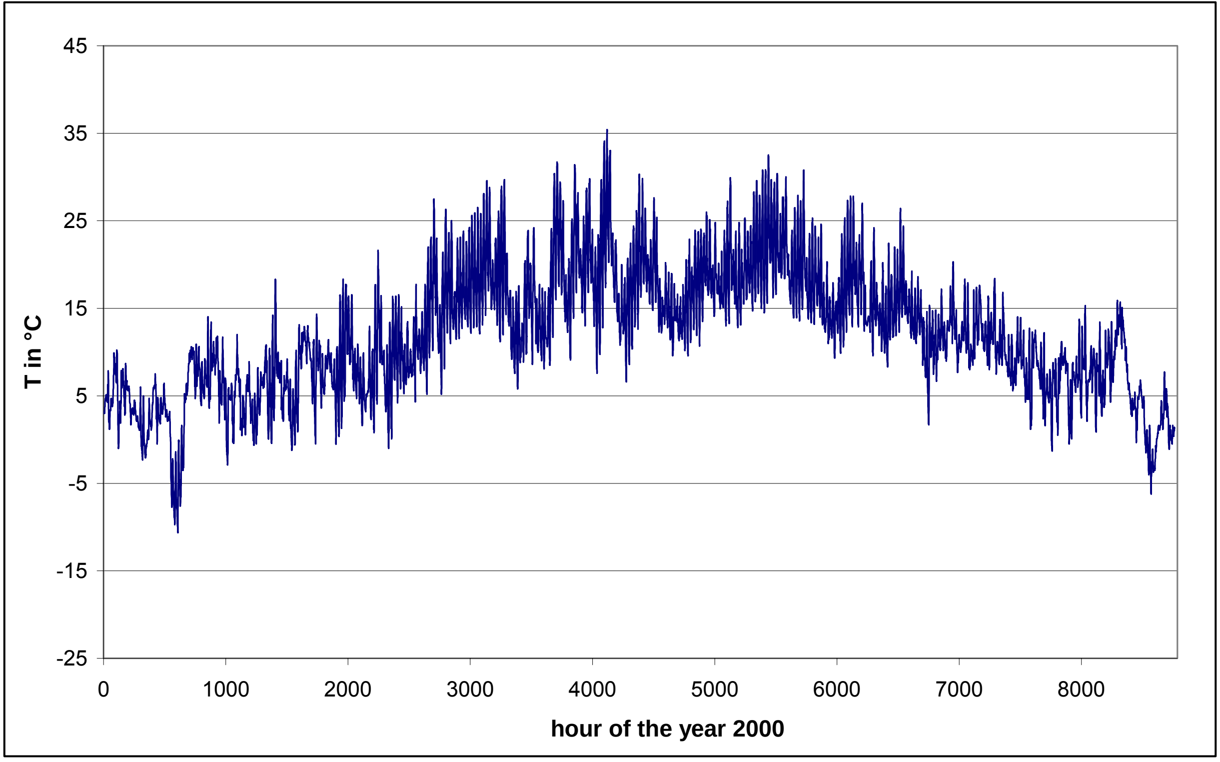

Figure 6: Measured hourly temperature data of the meteorological station in Karlsruhe for the year 2000 (DWD 2004)

5.1 Public Power and District Heat

Because public power and district heat plants are major CO_2 sources, their temporal patterns are of great importance. Measured hourly emission data theoretically exist since the Large Combustion Plant Directive LCPD (2001/80/EU) specifies the duty for operators of large combustion plants with a nominal capacity ≥ 300 MW to perform continuous emission measurements. Practically, such data are usually kept confidential by energy producers due to issues of competitiveness, especially since the deregulation of the European electricity market has taken place. Therefore, typical variations in energy demand were used to derive temporal variations of fuel use and emissions from power plants.

Within the EUROTRAC subproject GENEMIS, temporal emission patterns of European public power and heat plants have been simulated based on annual emission data from CORINAIR and LOTOS emission inventories. A method for calculation of emissions from public power and heat supply in Europe with high temporal resolution was developed and described in (Adolph 1997). It was used to calculate hourly emissions from power and heat plants in Europe based on available annual emission data. Emissions were disaggregated gradually for months, days and hours. Monthly disaggregation was based on monthly energy statistics available from EUROSTAT (e.g. EUROSTAT 2003) and other international and national statistics. The influence of weekdays was taken into account to calculate variations from day to day. Daily emissions were resolved to hourly emissions using typical heat and electricity demand profiles according to the method developed by (Adolph 1997). It was assumed that energy demand is the most important command variable for power plant operation. Information which can be used to derive temporal variations of energy demand is typically available on national level. Even before the electricity market liberalisation happened, collecting information about energy demand in specific energy supply areas would not have been practicable. Therefore, each country was treated as one supply area with a homogeneous demand structure. Concerning electricity production, this simplification seemed acceptable as in an integrated network regional differences are compensated. Today, the whole European electricity grid would basically have to be regarded as one integrated network because of the liberalisation of the market. However, taking into account that not only economic considerations determine electricity supply but as well issues such as security of supply and self-reliance, the national approach can still be assumed to be valid to some extend.

For monthly and daily disaggregation, the influence of ambient temperature on electricity and heat demand should be taken into account. Correlation between electricity demand and ambient temperature was analysed in several studies (e.g. (Nitz 1992), a study on grid load variations in Hamburg and (Thorn 1976), a study about procedures to predict short- and medium-term daily grid load curves). Winter and summer time are treated separately because in winter, electricity demand depends more on ambient temperature. The reason for that is basically the additional energy demand for heating but also an increased energy demand for cooking due to higher need for warm meals when temperatures are lower. The change of sign is assumed to occur at about 15 °C mean daily temperature. Temperature has less influence on electricity demand in summer but the influence increases on very hot days. While in winter electricity demand rises with decreasing temperature, in summer the demand can rise with temperature due to increasing need for warm water for bathroom and shower and indoor cooling.

Below 7.5 °C the dependency of electricity demand from ambient temperature p_{elec} [%/°C] was calculated based on (Nitz 1992). The calculated relative temperature dependency of 1 %/°C coincides with the results of a Swiss study on temperature and price dependency of electricity demand. It is also in agreement with the experiences of the German Network Association (DVG), the German Association of Electric Works (VDEW) and several other energy supply companies in Germany. For district heat it was assumed that heating only occurs when the daily mean temperature is lower than 12.5 °C and that the highest energy demand for heating occurs at the design temperature of –15 °C. Energy demand for water warming is nearly independent from temperature changes. More information can be found in (Friedrich et al. 2003).

As an example, Figure 7 shows total monthly factors based on fuel consumption MF_F and specific monthly factors for power plants (PP), district heating plants (HP) and combined heat and power plants (CHP) for Germany. The VDEW medium load weekday factors (VDEW 1985) used and the estimated factors for base and peak load PPs are shown in Figure 8. If an attribution of a power plant to one of these categories was impossible because of too little information given in emission inventories, the power plant was treated as a medium load PP.

Hourly load time-variation in electricity networks was determined by the diurnal rhythm of electricity consumers. It shows a typical low at night time and characteristic peaks at day time. The pattern of grid load during a day can be different in summer and in winter and varies in particular from country to country. The biggest differences occur between northern and southern European countries.

In VDI guideline 2067 (VDI 1988) typical temporal profiles are provided for heat demand. Different curves are given for summer (June, July, August), winter (October till February) and transit time (March, April, May, September). The curves are shown in Figure 9. They were applied only for heat plants. Time curves for combined heat and power plants are based on the considerations for power plants.

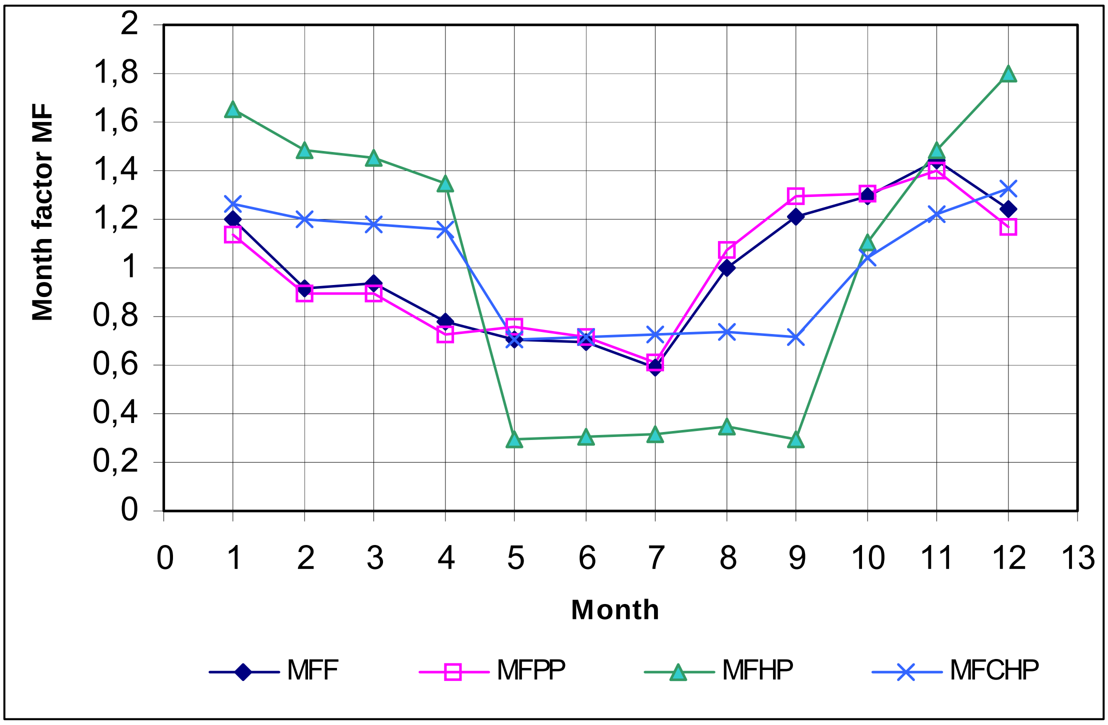

Figure 7: Total monthly factors MFF based on fuel consumption and specific monthly factors MFPP, MFHP and MFCHP for power plants (PP), heat plants (HP) and combined heat and power plants (CHP) for Germany (year 1990).

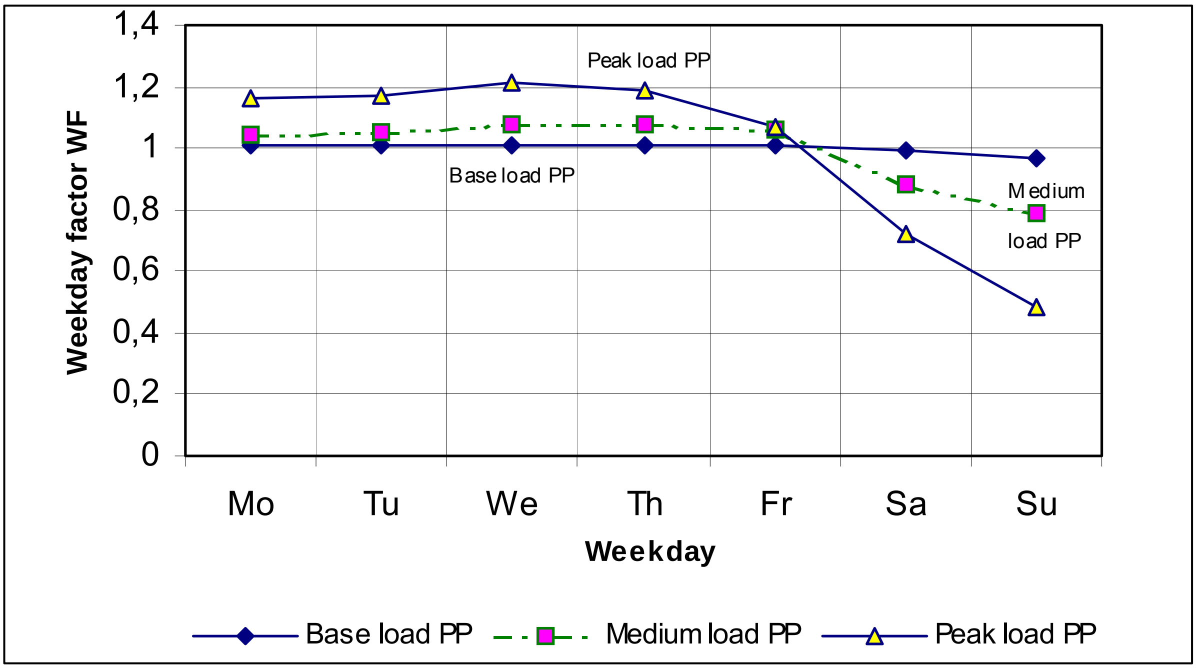

Figure 8: Weekday factors for base load, medium load and peak load power plants (PP)

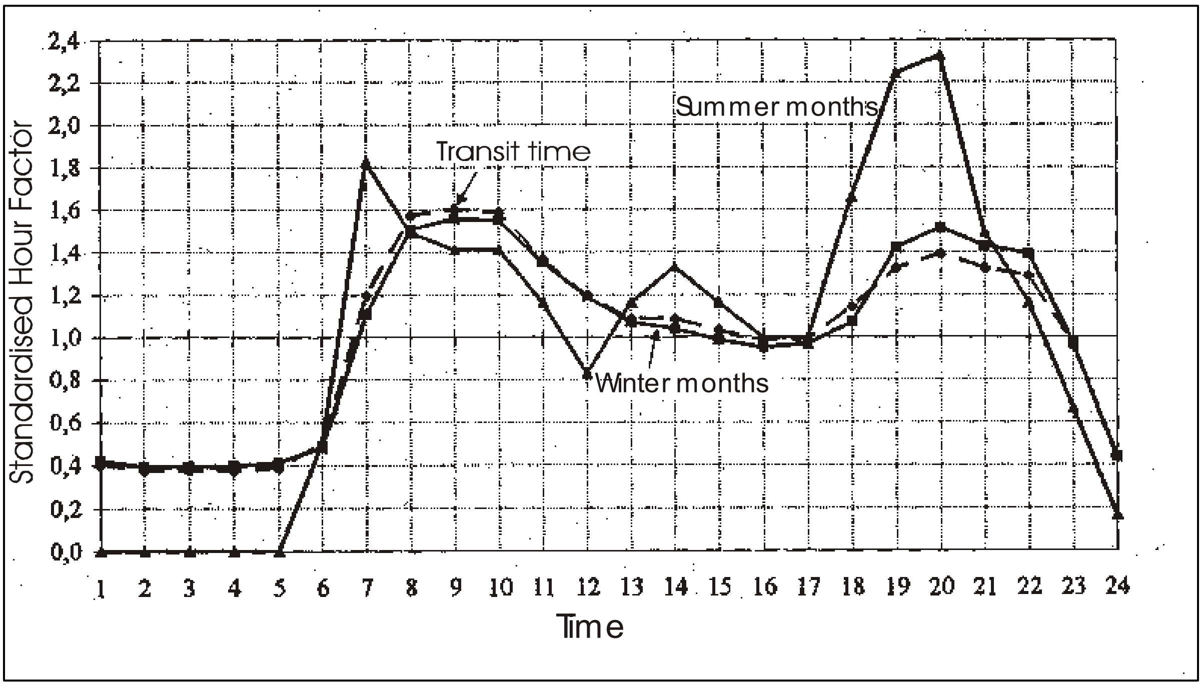

Figure 9: Hour factors for heat demand for winter, summer and transit time to represent hourly variation of heat production in heat plants

The Union for the Co-ordination of Transmission of Electricity (UCTE) provides annual and monthly grid load statistics and electricity production shares that were used for the generation of temporal profiles for different European countries. The following power plant categories were taken into account:

- Base load power plants (lignite)
- Medium load power plants (coal)
- Peak load power plants (oil/gas)

In addition, storage and pumped storage hydro power plants, run-of-river power plants and nuclear power plants are considered in the UCTE statistics. Power plants are assumed to be operated in the hierarchy in which the categories are listed here. Temporal profiles were composed from bottom to top according to the electricity production shares of the power plant categories. Figure 10 shows total hourly loads for a Wednesday in May 1990 for Germany (above) and Italy (below) (Source: UCTE) and the distribution to power plant categories.

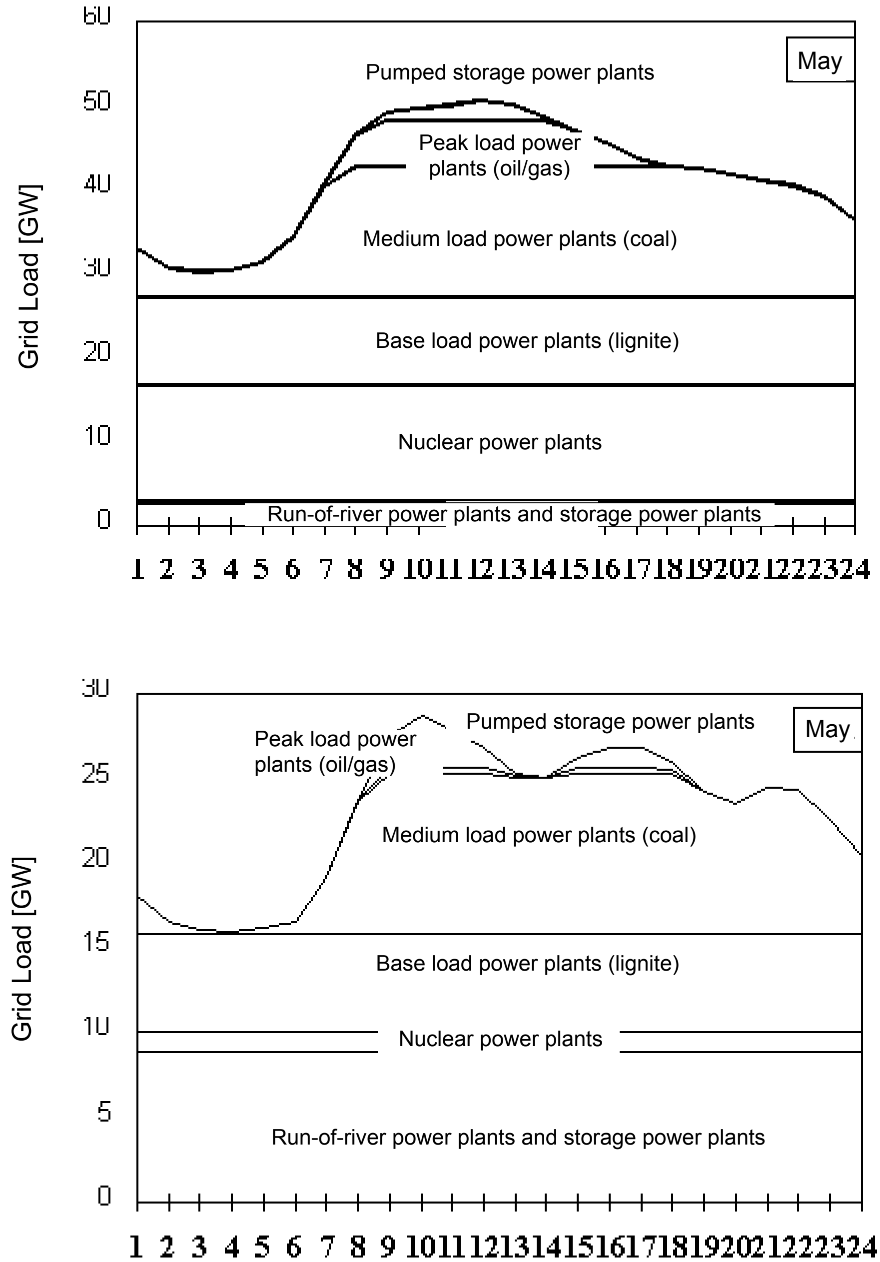

Figure 10: Total hourly loads for a Wednesday in May 1990 for Germany (above) and Italy (below) (Source: UCTE).

5.2 Industry

The temporal variation of CO_2 emissions from industrial combustion follows the variation of fuel use. Data on fuel use with a monthly resolution are available for some countries and were used to take into account seasonal variations by creating production dependent monthly factors. Temporal profiles were mainly developed by (Müller et al. 1990) and (Seier 1998).

Industrial production processes are characterised by a large number of small and heterogeneous emission sources. It is difficult to collect appropriate and reliable data for emission estimates as well as the temporal variation of emissions from these sources. It is a reasonable assumption that emissions from production processes are closely related to production figures of relevant production activities. Useful indicators are production data describing the activity of individual production processes. The availability of this information is usually very limited. Therefore aggregated monthly production indices were often applied to estimate a seasonal variation of emissions. Daily and hourly emissions of production processes were estimated according to process specific information on working times derived from German industrial data that could be compiled by (Müller et al. 1990) and (Seier 1998).

In order to provide a daily estimate of relative production, a working time index was additionally defined considering reduced working times on weekends. Standardised day factors for main economic sectors are shown for Germany as an example in Figure 11. The working time index describes the total working time at all days in the year. Apart from day factors for Weekdays, Saturdays and Sundays, it also takes into account national or local holidays. In GENEMIS a working time index has been defined for all European countries based on calendars and information from national experts. This index considers different holidays in different countries and different national traditions like bridging days and five- and six-day working weeks.

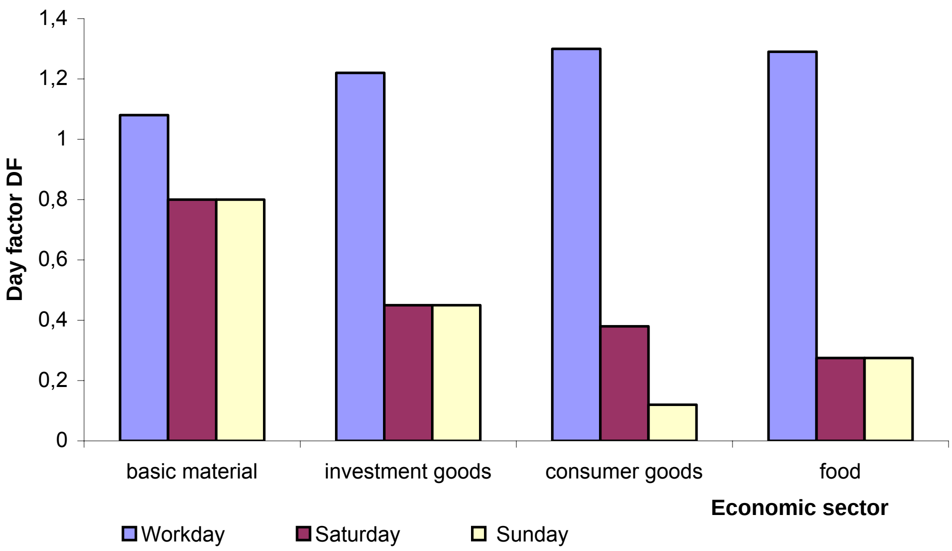

Figure 11: Standardised average day factors for main economic categories in Germany

It was not possible to provide reliable regional/local data for hourly emissions from industrial sources. Therefore, as a reasonable assumption fuel use and emissions were related to available information on working times and working shifts for different industrial sectors. As only for some countries data on working times and shifts were available from statistics or from industrial surveys, profiles for other countries were based on expert estimates.

Refineries and facilities for extraction and distribution of fossil fuels are considered to be generally operated in three shifts 24/7 and without seasonal variation. Emissions from these plants were therefore assumed to show a uniform annual distribution.

5.3 Small Consumer Combustion

Emissions from different types of small combustion plants have a different temporal variation. The fuel consumption of households in Germany is mainly used for space heating (about 80-90%) and to a smaller extent for hot water production (about 10-20%). Commercial small consumer fuel consumption is partly dedicated to heating purposes and partly to production processes. It was assumed that production dependent fuel use is directly related to working-times. Strong dependency on degree-days leads to strong seasonal variations of small consumer emissions, while dependency on working-times contributes to a strong hourly variation.

For the hourly distribution of small consumer emissions hourly patterns of fuel use for heating purposes and hourly patterns of production related fuel use were estimated. Within GENEMIS, production related fuel use was assumed to correspond to typical daily working times. Hourly variation of heating related fuel use, however, depends very much on heating technology, insulation standards and climatic conditions (see example Figure 12 for residential heating).

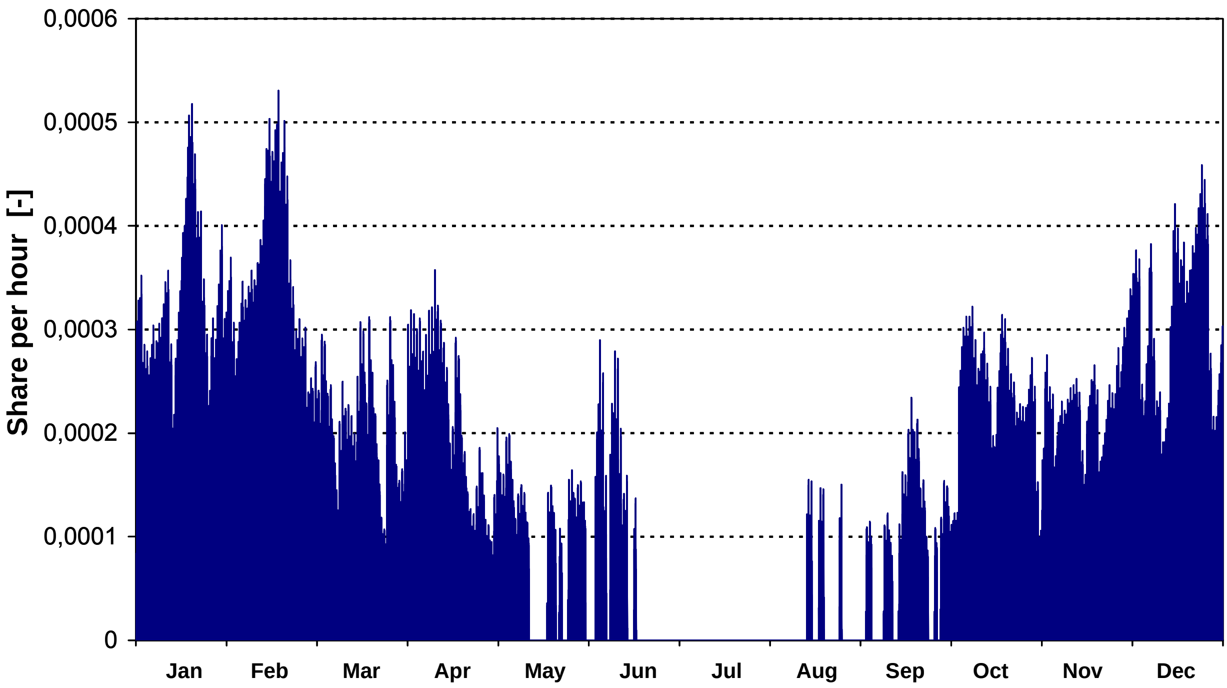

Figure 12: Example of temporal profiles for residential combustion: heat demand of households (based on meteorological data of Augsburg)

For central-heating, a correlation with ambient temperature can be assumed, alongside a reduction at night time. For single coal or wood stoves a very strong morning and 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 were derived from an evaluation of a comprehensive survey in Germany in VDI guideline 2067 (VDI 1988). If no other information exist about commercial and institutional heat plants, their hourly patterns were assumed to be similar to the variation in household combustion activities. Additional information was included from surveys in different small consumers groups conducted by (Seier 1998).

5.4 Road Traffic

Road traffic emissions have a very strong temporal variation. While different vehicle types show a similar temporal behaviour, different road types like motorways, rural and urban roads show different patterns of traffic density and thus emissions. 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.

Monthly variations of road traffic emissions can be gathered from monthly national energy statistics available from EUROSTAT (EUROSTAT 2003), but factors like e.g. type of road and vehicle can not be taken into account. More information can be derived from traffic flow data. Traffic flow data are usually available in the form of traffic counts (automatic or manual), which represent an excellent empirical base for the estimation of temporal profiles, because all external factors are implicitly considered. However, traffic count data on European scale are not available from international statistics, but only from national authorities. In some countries it is extremely difficult to obtain appropriate traffic counts or traffic density data. Traffic counts could be used so far only for Germany, Austria, France, and Greece. In case of Austria and Germany an average traffic density could be calculated. For France a monthly traffic density index was available for different road types. This index gives an average road traffic density for all motorways and rural roads and can be assumed to be a good indicator for the monthly variation of 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 variations, instead, are quite similar for different road types and regions. Figure 13 illustrates as an example the temporal variation of different type of emissions from road traffic sources. Whereas evaporation emissions mainly depend on temperature, exhaust emissions are connected with the variation of traffic volume.

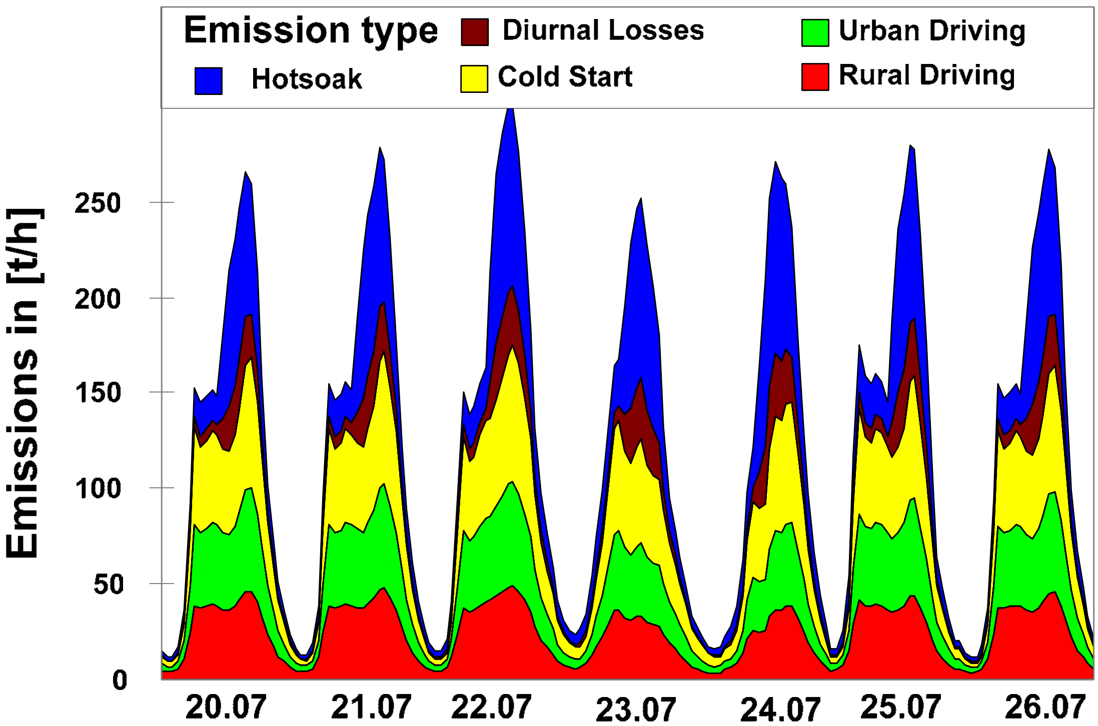

Figure 13: NMVOC emissions from road transport for a typical week in July in Germany

5.5 Other Mobile Sources

Other mobile sources comprise air, ship and railway traffic, and off-road vehicles. Landing and take-off cycles (LTO cycles), passenger numbers and freight statistics available from airports or the International Air Traffic Association (IATA) were used to generate profiles for aircraft emissions. Hourly emissions from air traffic can usually be assumed to be distributed over the day without strong variations, while no emissions occur during night time (usually between 23 pm and 6 am).

For ship traffic, the number of passing ships per hour, day, week, or months in harbours or on ship routes has a good relation to the temporal distribution of ship emissions. However, it was not possible to use appropriate data on European scale. Therefore an equal distribution over the year and over the day was assumed.

It was assumed for off-road vehicles (e.g. construction machinery, agricultural machinery) that temporal emission variation is similar to activities of production processes in small enterprises (night/day, working day/weekend). A strong seasonal variation was taken into account for activities of agricultural machinery.

5.6 Waste

Emissions from landfills, incineration plants and sewage treatment plants were assumed to be constant during the year and to show no significant daily or hourly variations. Regarding landfills, seasonal ambient temperature changes have no significant influence on waste temperature in layers deeper than two metres below surface. Energy released by biodegradation keeps the temperature in the landfill at 25 - 40 °C.

5.7 Agriculture

No specific models were available for determining temporal patterns of CO_2, CH_4 and N_2O emissions from agriculture. Therefore the temporal variability of agricultural ammonia emissions was applied to derive hourly emission data within CarboEurope. Since anthropogenic emissions of CO_2, CH_4 and N_2O are not necessarily equally distributed, the resulting temporal variation has additional uncertainties.

One influencing factor on temporal (annual) variability in agriculture is the particular production status. As production over the year is kept as constant as possible, no seasonality was expected for indoor husbandry (mainly cattle, pigs and poultry). Variation of emissions during one day follows animal activity, even so in the case of CO_2. CO_2 emissions from e.g. pigs show a typical variation of about 20% of mean daily respiration. The activity is mainly influenced by times of feeding, drinking and resting and thus shows a clear day/night-rhythm. The typical course of emissions was examined by e.g. Comberg & Wolfermann (1964), Hahne et al. (1999), Hinz & Linke (1998), Kaiser (1999), Mayer (1999).

Temporal variability of emissions from manure management is mainly dependent on temperature and grazing period, but it is unclear how big and relevant the amplitude of the seasonality is. No detailed information was available about hourly emission variations. Therefore it seemed reasonable to assume a simple day/night-rhythm caused by the influence of temperature.

6 Discussion of Uncertainties and Future Improvements

Yearly GHG country total emission data officially reviewed and reported to UNFCCC are commonly associated with uncertainty estimations of 10 % up to 50 % depending on pollutant and statistical/methodological level of the national reporting. IPCC provides these default values for uncertainty in statistics. Uncertainty of CO_2 emissions are estimated to be usually only 10 % up to 30 %, because emission factors are mostly depending on the statistical fuel use only.

An in depth uncertainty analysis of emission data needs to address not only the total magnitude of emissions but as well uncertainty in spatial allocation, temporal resolution and if necessary in substance resolution. It is quite difficult and needs a significant personnel capacity to quantify uncertainties due to the spatial allocation and temporal profiles. Because bottom-up emissions can not be calculated for a whole regional modelling domain and a comparison with measured true/real spatial emission information is not possible, an uncertainty quantification can not be done for the complete emission dataset. Therefore, a validation of emission data requires a scientific approach considering model application/uncertainty, parameter sensitivities and the comparison of modelled and measured concentrations/source contributions for selected grid cells/locations. A clear distinction between uncertainties resulting from emission data and uncertainties coming from the atmospheric dispersion models applied should be achieved. In addition, the generation of monitoring data has uncertainties and measured concentrations might have an insufficient representativeness for the spatially averaged value of the grid area obtained by the model. Therefore, a scientific spatial and temporal analysis of model and parameter sensitivities should be done in cooperation between experts for modelling, monitoring and emission calculations. Feedback from modellers is important for a further improvement of the emission data base and the emission model.

An in depth sensitivity case study was done for the IER emission model with regard to Ozone modelling applying the EURAD model (Wickert 2001), (Wickert et al. 2001). The reference case emission model without changes represents the current model used for the generation of GHG emission data in CarboEurope. The share of biogenic NMVOC emissions calculated by the CTM for a 2-days period in July 1994 was 60 - 70 %. The modelled NO_x emissions on 25th July, 12:00 UTC are shown for the three different model domains in Germany in Figure 14. Following sensitivity cases were considered:

- REF: reference case, no changes
- OANT: no anthropogenic emissions
- OBIO: no biogenic emissions
- BIO[z]: decrease or increase of biogenic NMVOC totals by a factor of z
- NM[x]N[y]: decrease or increase of anthropogenic NMVOC/NO_x totals by factors x/y
- OLANU: no land use data for allocation of area sources
- OLIN: OLANU + no road network for allocation of road traffic
- OPKT: OLIN + no coordinates for allocation of point sources
- TMINUS: emissions 1 hour earlier
- TPLUS: emissions 1 hour later
- TSIMPLE: simple rectangular time curve for hourly emissions
- NMSIMPLE: only one standardized VOC profile

Calculated deviations from the reference case were compiled and sorted for all grid cells and hours. 0.95 quantiles of all deviations are shown in Figure 15. The results are showing the importance of anthropogenic as well as biogenic emissions for the ozone concentrations and higher sensitivities for NO_x versus NMVOC emission variations. Very interesting are the relatively small effects due to variations/simplifications of the spatial allocation and the temporal profiles applied. Only the inclusion of point sources and the vertical distribution of these emissions have a significant sensitivity on this quite regional air quality issue.

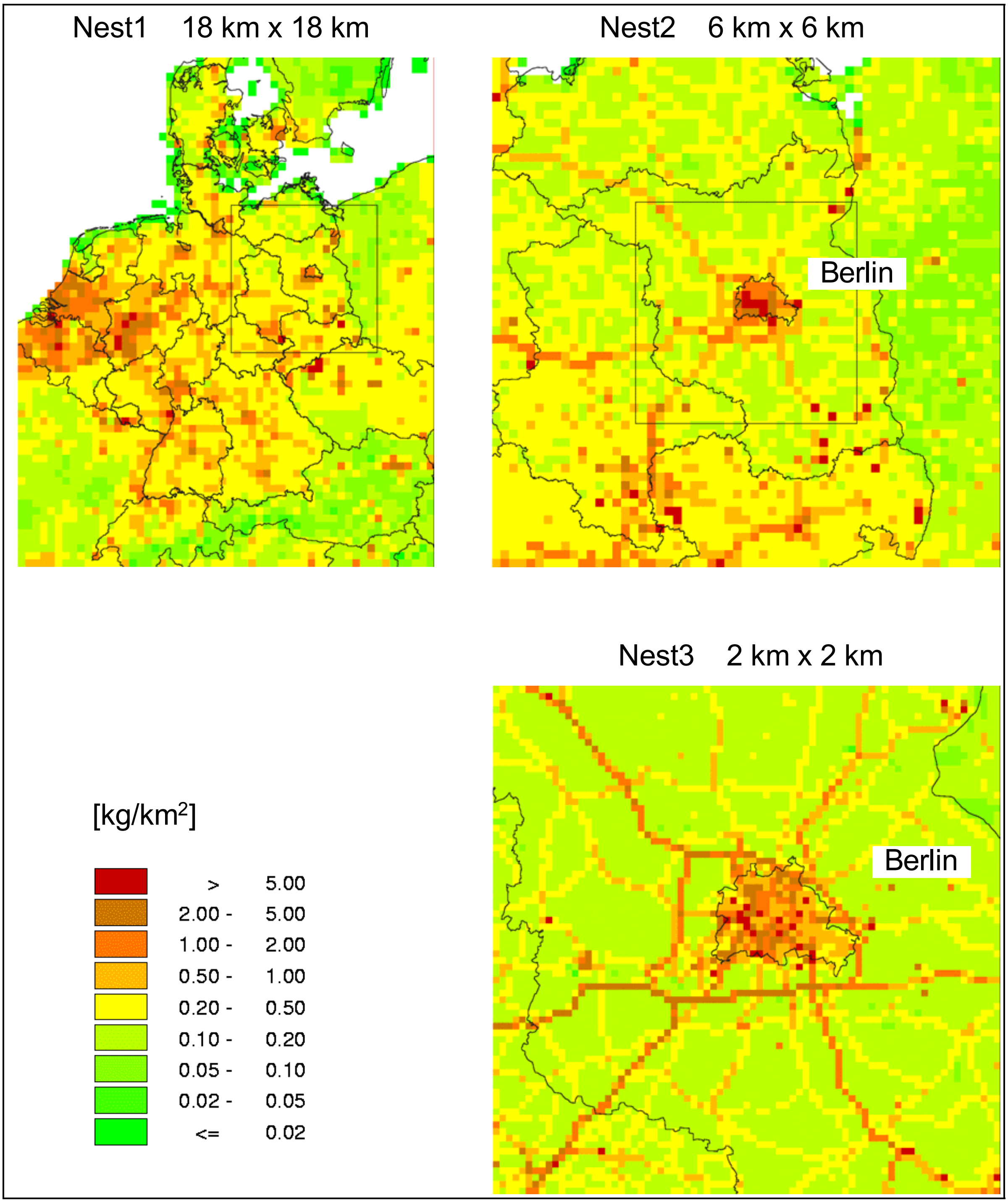

Figure 14: Sensitivity test cases Ozone, EURAD model: modelled NO_x emissions on 25th July, 12:00 UTC for three different model domains in Germany (Source: Wickert et al. 2001)

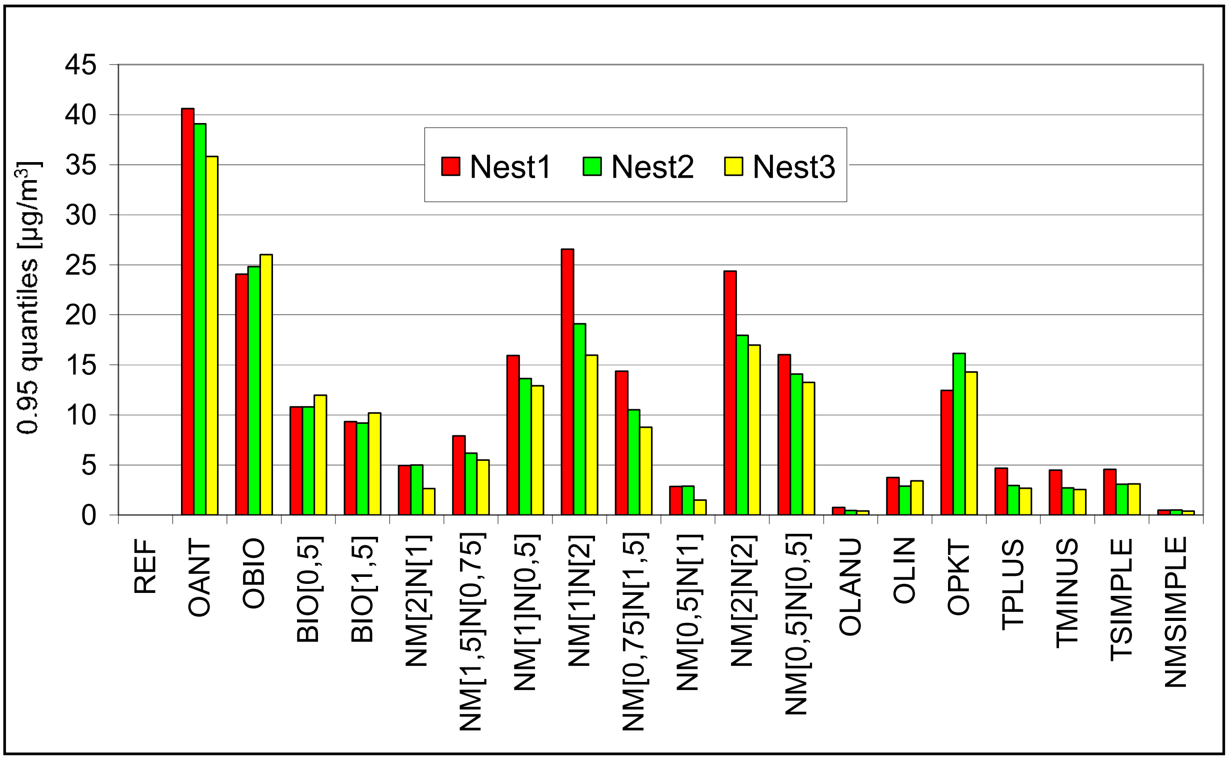

Figure 15: Sensitivity test cases Ozone, EURAD model: 0.95 quantiles of all deviations from the reference case for each hour, grid cell and modelling domain, 2 days in July (Source: Wickert et al. 2001)

The use of CO_2 emission data for atmospheric modelling should take into account a vertical distribution, because a high proportion of the anthropogenic emissions are generated by power plants and large industrial plants with possible effective emission heights (stack height plus plume rise) up to ~1 000 m (mainly depending on stack height and heat flux). As IER GHG emission data was so far used without vertical distribution within CarboEurope, this might have caused overestimations of modelled CO_2 concentrations in the near ground layer.

Generating hourly emission data by applying sector specific temporal profiles may entail additional uncertainties that can lead to a discrepancy between the variation of modelled and measured concentrations. A validation of the temporal emission variation can be done by comparing - as far as possible - representative hourly monitoring data with modelled hourly concentrations for selected model grid cells. Temporal profiles used for the generation of hourly emission data were developed within different studies applying different methodologies. Hence, inconsistencies can result especially comparing the more detailed German data base to simpler approaches for other countries. The further development of sector specific temporal profiles will therefore be one important task for the future.

Uncertainties and possible further developments of temporal profiles that are currently used were discussed within (Friedrich et al. 2003). The simulation of monthly and daily fuel use in industry can be considered much more reliable and closer to real patterns than other approaches, because the most important parameters influencing the temporal variation of emissions (production, temperature, working times) are explicitly taken into account. Because fuel use data of industrial sectors or individual industrial plants are only available for a few countries, the use of local and real information is limited. Estimations of the temporal variation of emissions from production processes 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 use temporal variations in the way described than to neglect them completely.

The availability of road traffic counts poses one of the main problems for the generation of temporal profiles for road traffic emissions. Within GENEMIS, traffic counts were only available for a few countries. Moreover, it is hard to assess the representativeness and reliability of the data available. Regions and countries without any traffic count data available had to be treated with temporal patterns based on data from other regions. This generalisation can cause errors and reduces the accuracy of the data calculated. An implementation of traffic count information for additional regions is desirable but depends on data availability and personnel capacities in the future.

Shortcomings of approaches for agriculture, small combustion and other area sources are caused by a lack of reliable data. The approach used for small combustion plants provides reasonable results for the temporal variation. Uncertainties, however, can be significant depending on regional/local conditions and sources. Assuming 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, fuels and behaviours exist. As the availability of real fuel consumption data with hourly resolution is very limited, it is not possible to verify current approaches.

Further improvements of the IER emission model as well as the generation of GHG emission data in spatial and temporal resolution are planned. This can lead to improved and more transparent 10 km x 10 km emission data compared to the first version IER provided within Deliverable 3 for CarboEurope GHG. The following tasks are intended:

- Update of the IER emission data base for the years 2000 and 2002 based on up-to-date downloads from UNFCCC Emission Database and EMEP Web-Database (http://webdab.emep.int/)
- Extension of the research area to include omitted Western and Eastern European countries like Russia as far as a UNFCCC emission reporting is available
- Provision of integral emissions per country and per sector
- Provision of average emission heights for each SNAP level for a vertical emission distribution
- Provision of emission maps for different SNAP source groups (level 1) in order to analyse the contribution of each sector in space and time
- Improved spatial allocation via statistical data on administrative units
- Implementation of a new and consistent set of temporal profiles for the research area
- New coherent documentation of methods, input data and semi quantitative uncertainty statement

More attention should be turned to the generation of a coherent and traceable dataset with a consistent methodology for different European countries depending on the availability of statistical and other input data. A closer working relationship with modellers is necessary in order to include their feedback and validate and improve the emission datasets.

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8 Annex

8.1 UNFCCC CO_2 emission data for 2000/2001 and different source sectors (UNFCCC 2004) implemented into the IER emission model

Sector (CRF-Code)	Austria	Belgium	Bulgaria	Switzerland	Czech. Rep
	2000	**2000**	**2000**	**2001**	**2001**
Energy Industries (1A1)	12 236	27 482	26 267	1 070	59 538
Manufacturing Industries & Construction (1A2)	9 061	34 001	8 605	5 384	34 879
Road Transportation (1A3b)	16 583	23 386	5 008	14 954	11 286
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)	898	662	874	371	776
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	13 368	29 269	1 896	18 125	14 581
Other Fuel Combustion Activities (1A5)			661	646	1 188
Fugitive Emissions from Fuels (1B)	187			93	551
Industrial Processes - Mineral Products (2A)	3 060	5 298		1 754	2 000
Industrial Processes - Chemical Industry (2B)	484	1 498	570	13	
Industrial Processes - Metal Production (2C)	8 591	1 514	1 483	136	2 524
Industrial Processes - Other Production (2D)	53				
Industrial Processes - Other (2G)		1 449		1	
Solvent & Other Product Use (3)	396				317
Waste (6)	11	1 772		2 280	357
Other (7)					
Sum (Domestic Total)	**64 928**	**126 331**	**45 363**	**44 828**	**127 996**
Excluded international bunkers total	1 675	19 720	475	4 461	439
Aviation	1 675	3 675	270	4 461	439
Marine		16 046	205		

Sector (CRF-Code)	Germany	Denmark	Estonia	Spain	Finland
	2000	**2000**	**2001**	**2000**	**2000**
Energy Industries (1A1)	340 043	25 121	13 912	104 082	19 815
Manufacturing Industries & Construction (1A2)	136 199	5 823	588	59 717	15 956
Road Transportation (1A3b)	171 505	11 230	1 695	77 315	10 648
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)	11 192	816	227	7 793	1 731
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	170 467	7 505	306	34 041	5 796
Other Fuel Combustion Activities (1A5)	2 426	111			986
Fugitive Emissions from Fuels (1B)		593		4 249	3 525
Industrial Processes - Mineral Products (2A)	23 515	1 453	356	17 074	1 072
Industrial Processes - Chemical Industry (2B)	1 835			603	
Industrial Processes - Metal Production (2C)	787			1 860	
Industrial Processes - Other Production (2D)					
Industrial Processes - Other (2G)					
Solvent & Other Product Use (3)		112		1 267	
Waste (6)				200	
Other (7)					730
Sum (Domestic Total)	**857 968**	**52 764**	**17 083**	**308 201**	**60 260**
Excluded international bunkers total	24 266	6 629	313	27 810	3 059
Aviation	17 582	2 348		8 314	1 027
Marine	6 684	4 281	313	19 496	2 032

Sector (CRF-Code)	France	Greece	Hungary	Ireland	Latvia
	2000	2001	2000	2000	2000
Energy Industries (1A1)	63 694	55 579	22 403	16 016	2 454
Manufacturing Industries & Construction (1A2)	82 691	10 390	10 826	4 743	1 249
Road Transportation (1A3b)	128 462	16 407	8 272	9 544	1 756
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)	9 277	6 041	245	667	250
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	96 807	9 300	13 996	10 364	827
Other Fuel Combustion Activities (1A5)			326		
Fugitive Emissions from Fuels (1B)	4 077			71	
Industrial Processes - Mineral Products (2A)	12 203	7 752	1 913	1 761	131
Industrial Processes - Chemical Industry (2B)	2 933		666	883	
Industrial Processes - Metal Production (2C)	3 025	251	111		182
Industrial Processes - Other Production (2D)	626				
Industrial Processes - Other (2G)					
Solvent & Other Product Use (3)	1 708	154	106	109	83
Waste (6)	1 698		144		3
Other (7)					
Sum (Domestic Total)	**407 199**	**105 875**	**59 009**	**44 160**	**6 935**
Excluded international bunkers total	23 986	13 984	634	2 043	236
Aviation	14 361	2 954	634	1 566	51
Marine	9 625	11 030		477	185

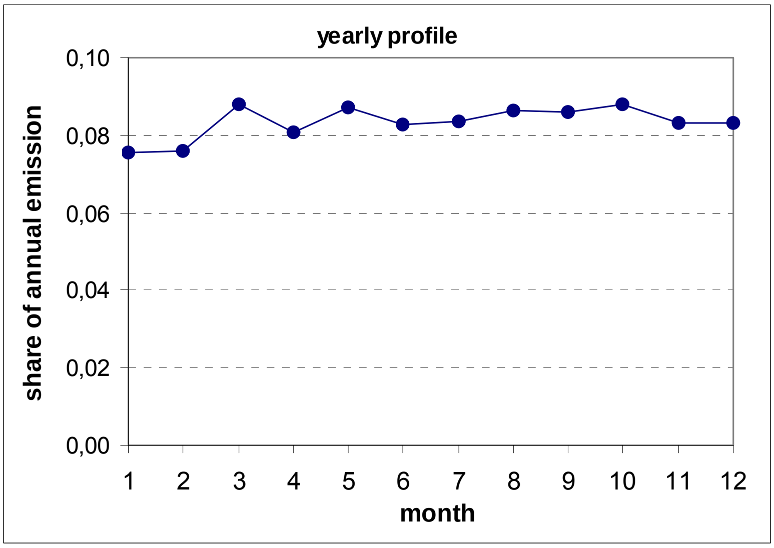
Sector (CRF-Code)	Netherland	Norway	Poland	Portugal	Romania
	2000	2000	2001	2000	2001
Energy Industries (1A1)	61 222	10 488	177 878	21 280	62 180
Manufacturing Industries & Construction (1A2)	39 677	4 131	47 184	10 651	23 715
Road Transportation (1A3b)	31 468	8 749	28 353	17 486	9 662
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)	3 744	4 275	1 768	1 699	1 963
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	34 550	3 206	50 084	6 539	7 292
Other Fuel Combustion Activities (1A5)		178	1 842		
Fugitive Emissions from Fuels (1B)	1 591	2 730	216	289	
Industrial Processes - Mineral Products (2A)	857	967	8 841	4 349	5 484
Industrial Processes - Chemical Industry (2B)		733	1 214	499	1 888
Industrial Processes - Metal Production (2C)	22	5 248	458	60	275
Industrial Processes - Other Production (2D)		50		0.4	
Industrial Processes - Other (2G)	380				
Solvent & Other Product Use (3)		127		279	
Waste (6)	350	130	6	361	
Other (7)					
Sum (Domestic Total)	**173 861**	**41 012**	**317 844**	**63 493**	**112 459**
Excluded international bunkers total	53 496	3 624	1 162	2 596	
Aviation	17 582	2 348		8 314	1 027
Marine	6 684	4 281	313	19 496	2 032

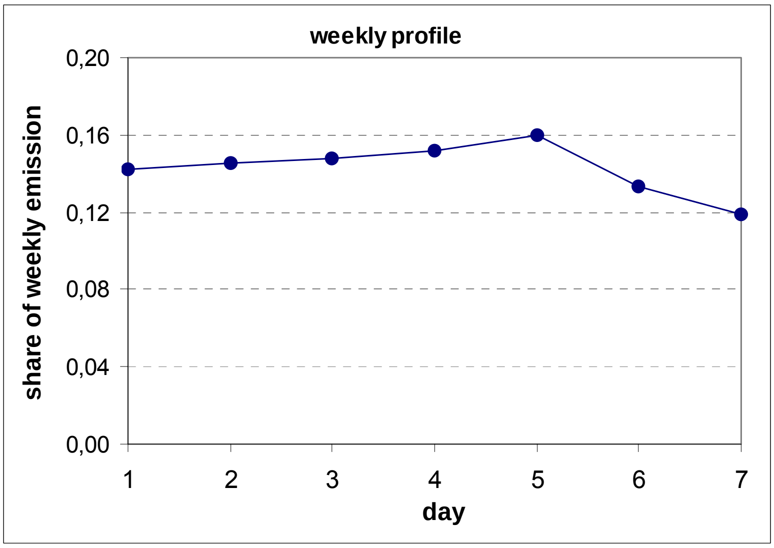
Sector (CRF-Code)	Sweden	Slovakia	U. Kingdom	Italy	Croatia
	2000	2000	2000	2001	2000
Energy Industries (1A1)	8 336	10 473	190 184	155 279	5 156
Manufacturing Industries & Construction (1A2)	12 652	14 406	87 428	77 095	3 805
Road Transportation (1A3b)	17 896	4 017	117 372	114 835	4 114
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)	1 686	302	6 846	10 356	282
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	7 682	6 168	117 812	78 120	3 359
Other Fuel Combustion Activities (1A5)	394	1 600	2 902	354	99
Fugitive Emissions from Fuels (1B)	293		7 477	1 296	633
Industrial Processes - Mineral Products (2A)	1 592	2 998	8 500	18 473	1 386
Industrial Processes - Chemical Industry (2B)	72		1 301	694	525
Industrial Processes - Metal Production (2C)	2 976		3 187	1 585	20
Industrial Processes - Other Production (2D)				522	
Industrial Processes - Other (2G)					
Solvent & Other Product Use (3)	186			1 265	
Waste (6)		98	1 348	888	
Other (7)					
Sum (Domestic Total)	**53 766**	**40 061**	**544 359**	**460 763**	**19 379**
Excluded international bunkers total	6 549		35 006	12 878	172
Aviation	1 926		29 412	8 689	115
Marine	4 622		5 594	4 189	57

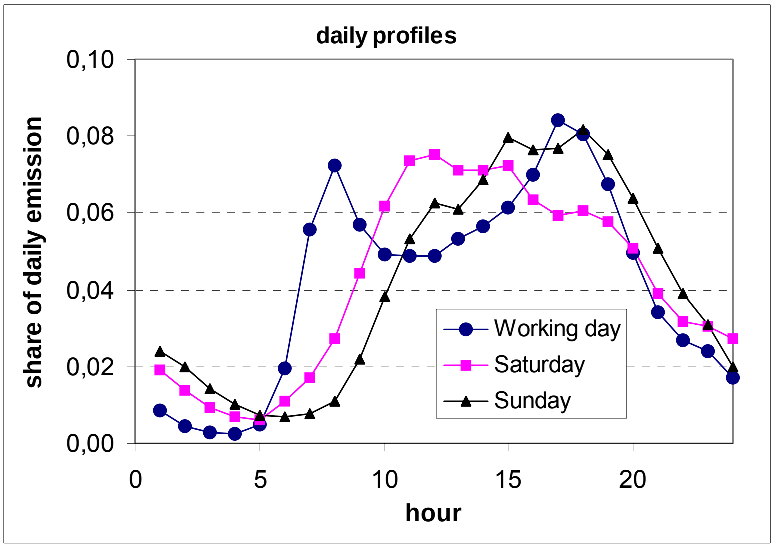
Sector (CRF-Code)	Luxembourg	Slovenia
	2000	2000
Energy Industries (1A1)	255	5 487
Manufacturing Industries & Construction (1A2)	1 734	2 300
Road Transportation (1A3b)	4 975	3 613
Other Transport (1A3a, 1A3c, 1A3d, 1A3e)		41
Other Sectors - Commercial/Institutional, Residential, Agriculture (1A4)	1 268	2 885
Other Fuel Combustion Activities (1A5)		
Fugitive Emissions from Fuels (1B)		37
Industrial Processes - Mineral Products (2A)	547	576
Industrial Processes - Chemical Industry (2B)		53
Industrial Processes - Metal Production (2C)	131	171
Industrial Processes - Other Production (2D)	3	
Industrial Processes - Other (2G)		
Solvent & Other Product Use (3)	10	36
Waste (6)		
Other (7)		
Sum (Domestic Total)	**8 923**	**15 198**
Excluded international bunkers total	971	71
Aviation	971	71
Marine		

8.2 Examples of typical IER temporal profiles for main sectors

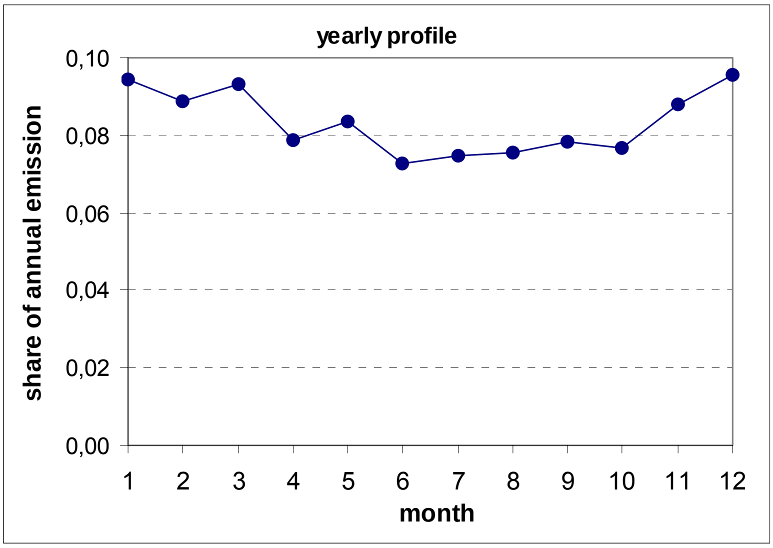
Mobile sources (passenger transportation, federal roads, Germany)

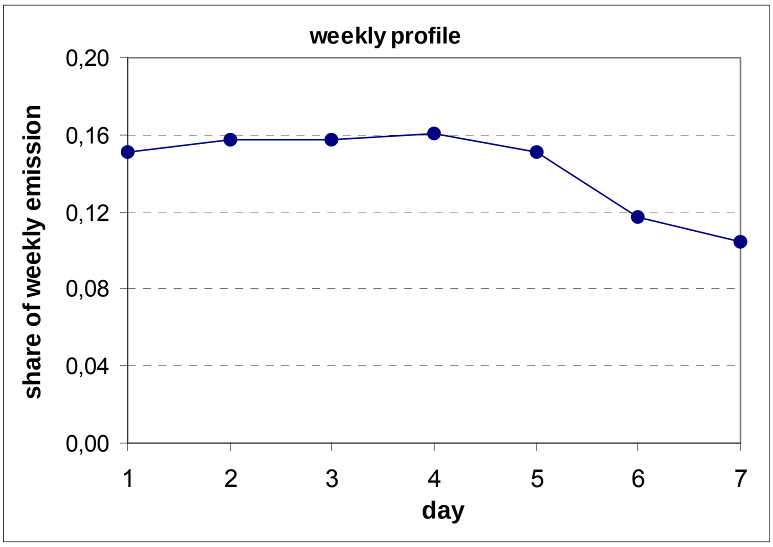


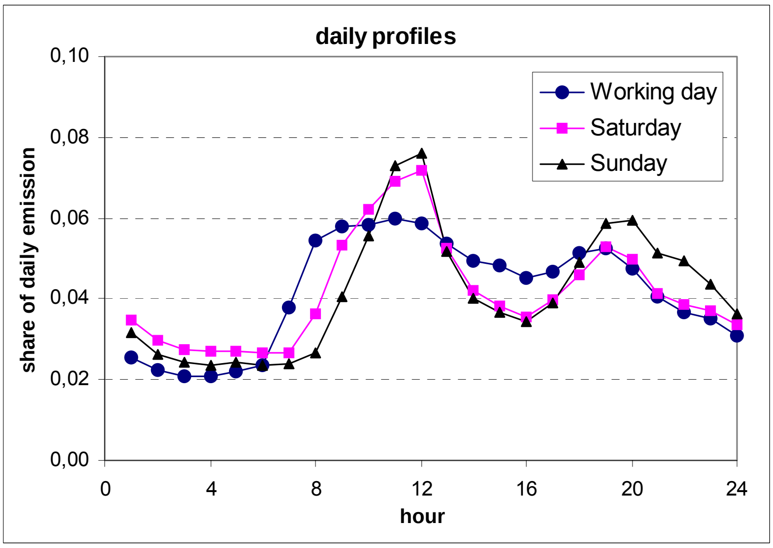




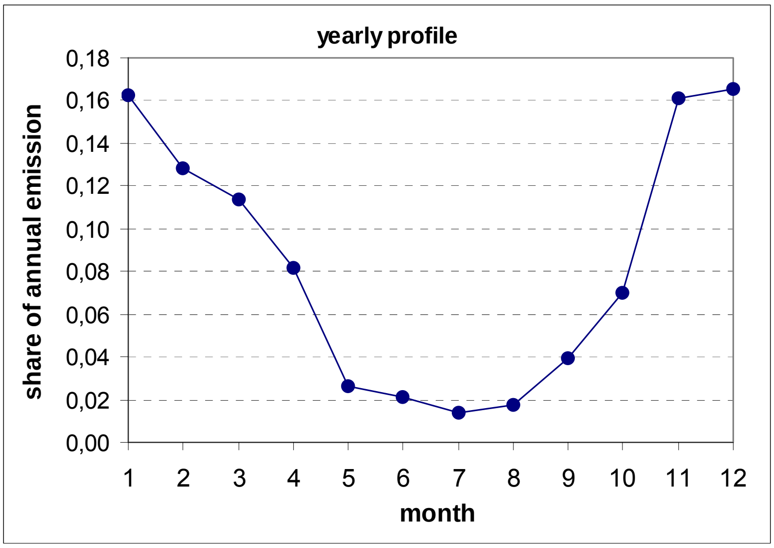
Power plants and industry **(average for combustion plants, Germany)**

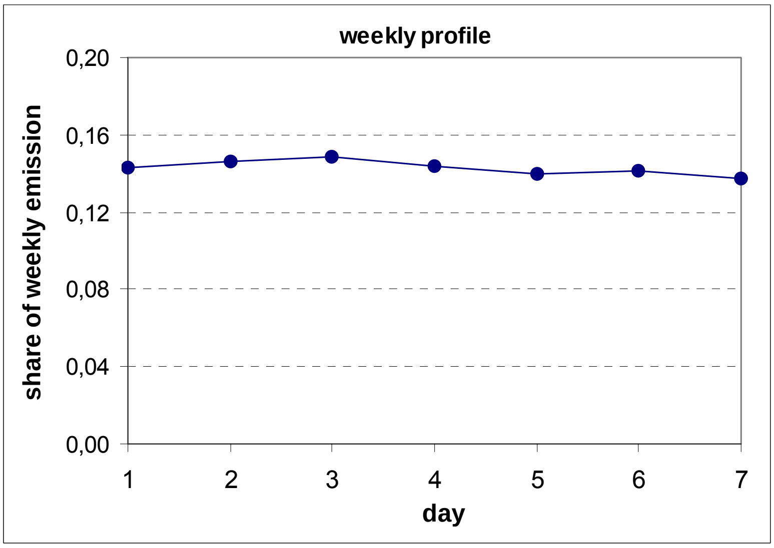


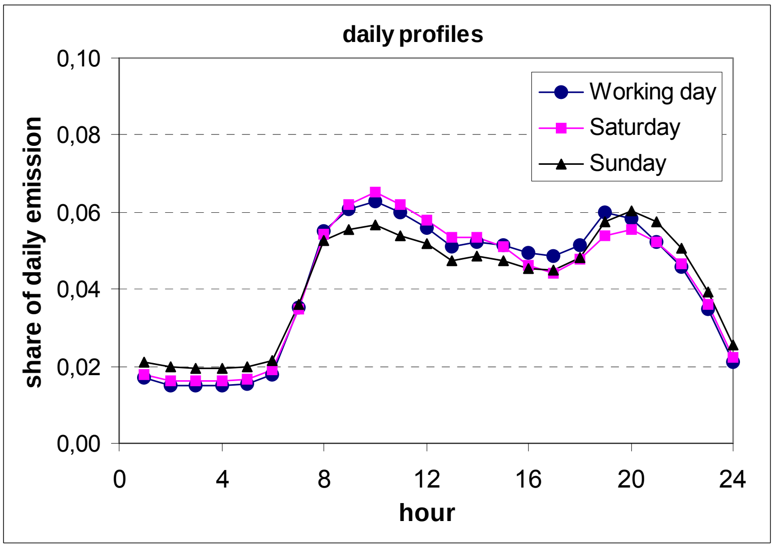




Small combustion plants (average for households and services, Switzerland)







8.3 Example of a Readme file for data description, Europe 50 x 50 km data (CarboEurope GHG)

Contents:

****

* readme.txt (this file)
* urop_50.bmp picture of the position of the grid (cell size: 50km*50km) (see below)
* urop_ghg_50_0101012000-2431012000_17122004.dat.Z
  hourly emissions in January 2000
* urop_ghg_50_0101022000-2429022000_17122004.dat.Z
  hourly emissions in February 2000
* urop_ghg_50_0101032000-2431032000_17122004.dat.Z
  hourly emissions in March 2000
* urop_ghg_50_0101042000-2430042000_17122004.dat.Z
  hourly emissions in April 2000
* urop_ghg_50_0101052000-2431052000_17122004.dat.Z
  hourly emissions in May 2000
* urop_ghg_50_0101062000-2430062000_17122004.dat.Z
  hourly emissions in June 2000
* urop_ghg_50_0101062000-2430062000_17122004.dat.Z
  hourly emissions in July 2000
* urop_ghg_50_0101082000-2431082000_17122004.dat.Z
  hourly emissions in August 2000
* urop_ghg_50_0101092000-2430092000_17122004.dat.Z
  hourly emissions in September 2000
* urop_ghg_50_0101102000-2431102000_17122004.dat.Z
  hourly emissions in October 2000
* urop_ghg_50_0101112000-2430112000_17122004.dat.Z
  hourly emissions in November 2000
* urop_ghg_50_0101122000-2431122000_17122004.dat.Z
  hourly emissions in December 2000

Use the UNIX-command 'uncompress' for the emission data files *.dat.Z

****

Description of the Data:

The data format of the emission files (*.dat) is as follows:

```
  Hour-No  Pollutant  cell-Id   Emission (hourly emissions)
   or "0"    Pollutant  cell-Id   Emission (yearly emissions)
example:
  87649  39  1  2.1253e+03
  87649  39  2  1.1776e+01
  87649  39  3  1.3348e+01
  87649  39  4  8.8891e+00
```

1st column: hour (87649: 01.01.2000, 00:00 - 01:00 a.m.; 96432: 31.12.2000, 23:00 - 24:00 p.m.)

2nd column: pollutant

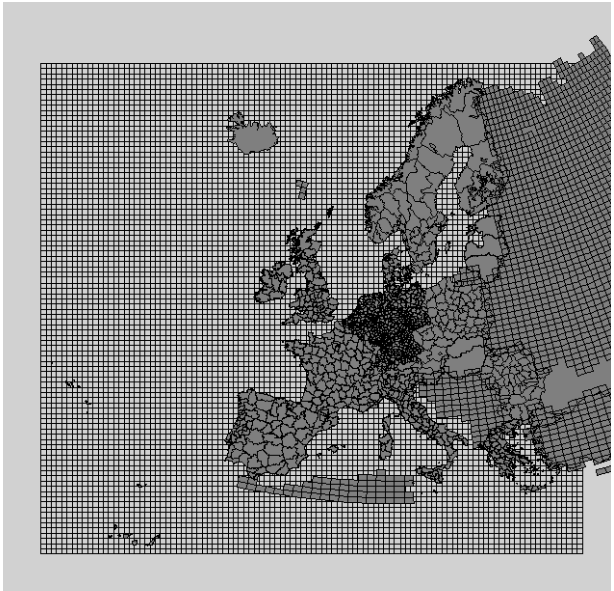
5 - CO 7 - CH4 39 - CO2 44 - N2O

3rd column: cell-Id (see figure below)
grid description:
projection: Lambert conformal conical
30 00 00 /* 1st standard parallel
60 00 00 /* 2nd standard parallel
10 00 00 /* central meridian
50 00 00 /* latitude of projections origin
left lower corner (m): -3400000, -2100000
cell size: 50000 m x 50000 m
i,j: 104,94

4th column: emission in t/h cell
All emissions are tons per hour and grid cell

Figure "cell-Id of the transeuropean grid":

```
******************************************
------------------------------------------------------
| …. |…                                   | 9776 |
------------------------------------------------------
| .... |…                                 |      |
------------------------------------------------------
| …. |…                                   |      |
------------------------------------------------------
| …. |…                                   |      |
------------------------------------------------------
| 105|…                                   |  208 |
------------------------------------------------------
|   1 |   2 |   3 |...                    |  104 |
------------------------------------------------------
```



The IER emission model and calculated emission data are in a continuous improvement process.

The emissions are delivered on condition that they are not passed to third parties.
Exceptions are valid only on written agreements!
Users of the data are obliged to acknowledge the source of the data in all related publication, submit copies of the main results related to the emission data to the address below and take part in the verification and validation process of the data.
The data are generated with the help of landuse data of
* ETC Landcover Data, 1997,
  European Environment Agency, European Topic Centre on Land Cover, Kiruna, Sweden
* ESRI, Digital Chart of the World, 1993, Environmental System Research Institute
* RIVM-NOAA, Pan-European Land Use and Land Cover, 1996, U.S. Department of
  Commerce, NOAA National Oceanic and Atmospheric Administration, Wageningen, NL

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