Feasibility Study on the Development of a Design for an Emission Projection Model Based on the CORINAIR-Approach

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0 Executive Summary

The objective of this report is to analyse the feasibility of the development of an emission projection model for all relevant stationary and mobile sources of anthropogenic emissions. This model shall be used to fulfil reporting obligations in the frame of international programmes, to fill gaps in the elaboration of inventories, and to analyse the impact of environmental policies on future emissions.

In a first step, requirements from binding international reporting obligations as well as from reports on a voluntary basis have been reviewed. These are in particular reporting obligations under the UN/ECE Convention on Long-Range Transboundary Air Pollution, the UN Framework Convention on Climate Change, the Oslo, Paris and Helsinki Conventions, the CORINAIR inventory programme, EUROSTAT and EU legislation. It turned out that a high level of sectoral disaggregation in both inventories and projections is requested by these reporting requirements. Therefore, the emission projection tool has to be designed on this level of detail.

With regard to the requirements mentioned above, existing models for inventories and projections have been investigated. These are in particular the COPERT/FOREMOVE model, the TREMOD model, the TRENDS model, the CollectER model, the CASPER model, the RAINS model, and the PERSEUS and ARGUS models. Among these models, CollectER and COPERT are specifically designed for emission inventorying. FOREMOVE (based on the databases included in COPERT), TREMOD and TRENDS focus on projections for mobile source emissions. RAINS is an integrated assessment model which has been used for the elaboration of multi-pollutant and multi-effect strategies on UN/ECE and EU level. PERSEUS and ARGUS are energy and mass flow optimisation models referring to the analysis of emission reduction strategies (SO_2, NO_x, CO_2, VOC) at the national level. It appeared that projection tools for emissions from mobile source have achieved a high status of sophistication, and can thus be further used in an overall model. Concerning stationary sources, a considerable amount of information is already available from existing tools (e. g. the models for environmental strategy development).

Concerning the development of a new projection tool, the following requirements have been identified:

- The model should be basically designed for the use in individual countries by e. g. experts compiling national inventories.
- It should consider, as far as possible, existing projection tools and methodologies.
- It should be possible to elaborate both short term and long term emission projections.
- The model should allow the analysis of the impact of environmental policies on future emissions, in particular the impact of environmental legislation. This requests in many cases a high sectoral resolution of the model down to installation/process level.

The proposed model design is based on the CORINAIR methodology, using the emission factor approach.

The emission factors and the efficiency of abatement options are specified for so-called reference installations which allow to account for emission relevant factors on the process or installation level. The reference installations and the corresponding emission reduction options are used to characterise the country specific emission source structure of a given country. This structure (production and energy conversion processes) is characterised in terms of sectoral activity rates, market shares of reference installations and implementation shares of the emission reduction options. The proposed approach allows for clear differentiation of "technological data" (emission factors and efficiencies of abatement techniques) and country specific data. The use of the same set of reference installations with the same characteristics ensures the consistency and comparability of the input data and of the projections between different countries. Verification and quality control of results is then possible. In a further step, the model could thus be used for application onto a group of countries such as the European Union, e. g. by international organisations.

Forecasts of activity rates are performed on different levels of aggregation by projecting past activity rates to the future via an adequate projection procedure and baseline parameters (population, GDP, etc.) for correlation. Changes in the structure of the emission sources and the status of implementation of emission reduction options due e. g. to autonomous technology change or to the implementation of legislative requirements are described in terms of changes in market shares of reference installations and implementation shares of the emission reduction options, specified exogenenously.

In order to provide a user friendly tool, scenarios for short and long term projections will be predefined reflecting e. g. autonomous technological progress, current legislation, and application of best available techniques/practice.

1 Introduction

The fulfilment of environmental targets such as air quality standards and critical loads/levels for acidification, eutrophication and tropospheric ozone requires the implementation of more and more stringent emission abatement options with an increasing economic impact. In this context, the cost-effectiveness of measures and the achievement of environmental targets are major criteria for the evaluation of abatement strategies. Key elements in the development of any strategy are besides the cost aspects, the availability of reliable and consistent emission inventories and projections. Mid- and long-term projections are used to analyse the future development of emissions and, in particular, to assess the influence of any emission reduction strategy or environmental legislation (e. g. emission limits for certain categories of plants) on this development. Emission projections for greenhouse gases are requested by the UN Framework Convention on Climate Change. Furthermore, in the frame of reporting obligations, short-term projections (1-5 years) can be used to complete missing emission data.

A variety of emission projection models has been developed in different countries covering mobile and stationary sources. On the international level, the emission forecasting model COPERT/FOREMOVE for road transport is in use and the TRENDS model covering all mobile sources is under development. However a similar tool for stationary sources is still missing. An European wide harmonised projection model covering all relevant pollutants and sources is urgently needed for the elaboration of emission reduction strategies on the multinational level (e. g. Clean Air Programme of the European Union, Protocols in the frame of the UN/ECE Convention on Long-range Transboundary Air Pollution).

In this context, the German Federal Environmental Agency commissioned the French-German Institute for Environmental Research to perform a feasibility study concerning the design of a projection model which should fulfil the following requirements:

- be applicable to all European countries including countries with economies in transition and provide consistent and comparable results,
- cover all relevant pollutants and sectors with a CORINAIR compatible source nomenclature,
- enable for the representation of international agreements, environmental legislation (e. g. legislation setting emission limit values for given source categories) and emission reduction technologies (e. g. Best Available Techniques) as well as structural changes (e. g. change of fuel or technology mix),
- be flexible with regard to sectoral aggregation and temporal and spatial resolution according to the layout of international reporting obligations, the availability of input data, the required accuracy, etc.,
- provide an input to strategic models e. g. integrated assessment models.

In order to avoid duplicate work and to improve acceptance on international level, the model should rely on and integrate as much as possible available databases and methodologies. Guidance should be given regarding the projection of activity rates in terms of correlation with adequate parameters.

The objective of this project is to analyse the feasibility of the development of an emission projection model for all relevant stationary and mobile sources. The practical realisation of the model is beyond the scope of this project and will be part of a future project.

The report starts with an outline of the basic methodology of emission inventories' and emission projections' development, followed by a description of the CORINAIR methodology and international standards for statistical classifications (Chapter 2).

Requirements to emission projections by international organisations (including binding reporting obligations and reports on a voluntary basis) are described in Chapter 3.

In Chapter 4, the characteristics of existing models providing emission inventories/projections are summarised. The characterisation is oriented towards the main aspects of sectoral aggregation, temporal and spatial resolution, pollutants covered, input/output formats.

Based on the analysis of the requirements to emission projections by international bodies and the characteristics of existing models, the characteristics and the methodology of the model to be designed are specified in Chapter 5. This chapter also deals with relevant aspects in the designing of the emission projection model, e. g. sectoral aggregation, emission factors, forecasts of activities, etc.

2 General

2.1 Definitions

An *emission inventory* is “a collection of data (expressed in e. g. Mg/year) for past and present times, according to given requirements or a given methodology with a certain sectoral, pollutant specific, temporal and spatial resolution”. An *emission projection* is defined as “a possible future development of emissions on the basis of certain boundary conditions with regard to scenarios, future emission factors, and future penetration status of corresponding technologies”. [Guidebook]

Most emission projections are based on the ***emission factor approach***. According to this approach, a sectoral emission value for a given pollutant and a given timeframe (here, one year) is obtained by multiplication of an emission generating activity (e. g. production of goods) and a specific emission of this activity (emission factor, here: emission of a pollutant per produced unit of a good). This procedure can take place on different sectoral aggregation levels and for different pollutants. The following formula applies in this respect on any chosen level of sectoral aggregation, for a given pollutant and a given year *t*:

$$E_s(t) = a_s(t) \cdot \overline{e_s}(t) \qquad (1)$$

with

$E_s(t)$: emission value of sector *s*

$a_s(t)$: activity rate of sector *s*

$\overline{e_s}(t)$: sectoral average emission factor (weighed according to emission sources in the considered sector)

The elaboration of an emission projection requires, for each defined sector, a projection of *activity rates* and a projection of average *emission factors*.

An *emission factor* gives a quantitative representation of emission characteristics for a given pollutant, a given year, and a given source characterised by combination of a production technology and a(n) abatement measure / combination of abatement measures. An average emission factor for a group of sources depends on the sectoral technology mix and the characteristics of the technologies (cf. eq. (2)). [Holtmann]

A sectoral average emission factor, for a given pollutant and a given year *t*, is given by the following formula:

$$\overline{e_s}(t) = x_i(t) \cdot e_i \qquad (2)$$

with

$\overline{e_s}(t)$: sectoral average emission factor (weighed according to emission sources in the considered sector) for the year *t*

$x_i(t)$: penetration rate of technology *i* for the year *t*

e_i : emission factor of technology *i*

An *activity rate* is defined as "a quantitative representation of the variables that "explains" the emissions in a given source category and in a given year, in physical (e. g. produced mass of glass [Mg/year]) or monetary (e. g. value of glass production [€/year]), or other dimensions. This activity can be understood as the quantitative reason for which emissions are released." [Guidebook]

2.2 The link between inventories and projections

Since emission inventories are often needed within very short time periods, preliminary projected emission data may be necessary in order to fill gaps induced by lack of available data. Emission projections may thus be needed to support emission inventories.

The calculation of emission data for the elaboration of inventories requires activity rates and emission factors for a considered year. Emission projections assess the possible development of emission generating activities in the future and thus corresponding future emissions. Emission projections require time series for both activity rates and emission factors. Time series for activity rates are usually available from official statistics, however at rather aggregated level. The development of sectoral emission factors over time has to be determined according to the structure of the emission generating activity in a considered sector (cf. eq. (2)). Here, the implementation status of emission abatement options in a given year, described by so-called *implementation shares* (also called "penetration rates"), is used to determine sectoral emission factors for inventorying and can serve as a starting point for projections. The assessment of sectoral emission factors for future years may consist in a forecast of the development of these implementation shares throughout the years.

Generally speaking, an emission projection can be considered as the establishment of an emission inventory for a year in the future. There is thus a significant overlap in the applied methodologies. Therefore, consistency between inventories and projections is a significant issue to be considered in the development of an emission projection model. In this respect, the outline of existing tools (cf. Chapter 4) will cover both, inventories and projections.

2.3 Description of CORINAIR

In recent years, the CORINAIR (COoRdination of INformation on AIR emissions) methodology and structure has become an European standard with regard to the reporting obligations of emission inventories and projections in the framework of international conventions. Procedures for the elaboration of national emission inventories are provided in the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook [Guidebook].

Sectoral aggregation

The classification of emission source categories used within the CORINAIR system is based on the Selected Nomenclature for Air Pollution (SNAP). In accordance with this classification, three aggregation levels may be considered:

- *SNAP97 level 1* corresponds to the 11 main emission source categories with the highest aggregation level (sectors), listed in Table 1.

Table 1: Main emission source categories within the CORINAIR system

SNAP	Sector Description
01	Combustion in energy and transformation industries
02	Non-industrial combustion plants
03	Combustion in manufacturing industry
04	Production process
05	Extraction and distribution of fossil fuels and geothermal energy
06	Solvent and other product use
07	Road transport
08	Other mobile sources and machinery
09	Waste treatment and disposal
10	Agriculture
11	Other sources and sinks

- *SNAP97 level 2* represents the intermediate level, consisting of approximately 60 subsectors, represented by a 4 digit code, e. g. paint application (SNAP 06 01);
- *SNAP97 level 3* corresponds to the lowest level, including more than 300 activities, represented by a 6 digit code, e. g. service stations (SNAP 05 05 03).

A complete list of SNAP codes (‘97 version) with their respective descriptions is attached in Annex V.

Fuels

In the CORINAIR system, a set of default fuels is defined according to NAPFUE (**N**omenclature for **A**ir **P**ollution of **Fue**ls). This set of fuels is defined with regard to default composition and characteristics in order to avoid major discrepancies between countries. However, since fuel specifications are different from country to country, each specified fuel/fuel group can include different types of fuel; therefore, inventory experts may add further fuels specifying the corresponding characteristics and composition (e. g. carbon, sulphur, ash content, lower heating value, etc.).

Spatial resolution

The CORINAIR system considers four territorial splits called NUTS[1/]. These four levels are designated as NUTS 0 (the highest level corresponding to the national level), NUTS 1, NUTS 2 and NUTS 3. As a common basis, EUROSTAT has defined a list of NUTS for each EU member state. For non-EU members, it is assumed that territorial splits follow administrative units as well. Table 2 provides an example of the NUTS list as defined in the CORINAIR-system.

Table 2: Examplarily extract of the NUTS list as defined in the CORINAIR-system

NUTS Level	Name	Territorial Units
0	Bundesrepublik Deutschland	DE
1	Baden-Württemberg	DE1
2	Karlsruhe, Regierungsbezirk	DE12
3	Karlsruhe, Stadtkreis	DE122
3	Karlsruhe, Landkreis	DE123

Temporal resolution

In the CORINAIR-system, national emission data on SNAP level 1 and/or 2 is reported annually on NUTS 0. Every five years, a spatially detailed inventory (on NUTS 3 and SNAP level 3) is produced.

Conversion from the previous CORINAIR system

A conversion of the CORINAIR90 structure into the CORINAIR94 resp. CORINAIR97 structure may be necessary in the framework of actualisation of emission inventories. The main differences between emission inventories compiled using CORINAIR90 and CORINAIR94 resp. CORINAIR97 are:

- the SNAP codes have changed between these two versions;
- a greater number of pollutants is considered (cf. section 3.1);
- for some countries, changes in NUTS codes have occurred.

2.4 International Standards for Statistical Classifications

EUROSTAT is the organisation of the European Union in charge of the creation of common classifications, methods and organisational structures for compiling comparable statistics on the EU Member States, and of the delivery of official statistics.

EUROSTAT initiated the development of the NOSE (**NO**menclature for **S**ources of **E**missions) nomenclature. NOSE combines the standard European nomenclature for

[1/] NUTS: **N**ational **U**nits for **T**erritorial **S**plit economic activities (NACE) with a nomenclature of emission generating processes, the NOSE Process List, which is derived from the SNAP nomenclature used in the CORINAIR programme. Such a standard statistical classification shall ensure the consistency and comparability of statistical data collected at different times, for different purposes, and in different countries. Statistical data on activity rates provided by EUROSTAT are mainly available on CORINAIR SNAP level 3, allowing for very detailed series of activity rates. For countries difficulties occurring when reporting activity data are mainly due to the divergences between nomenclatures used on national level and official ones, e. g. the NOSE nomenclature. A correspondence table CORINAIR SNAP to NOSE is given in Annex VI [EUROSTAT 1998].

Increasing co-operation between EUROSTAT and EU Member States is expected to lead to constant improvement of the European Statistical System (ESS). The next objective is to include Central and Eastern European countries in this process; in this respect, the European Union is supporting and co-ordinating the implementation of a statistical system in those countries. Beyond Europe, EUROSTAT is co-ordinating statistical systems with international organisations and the USA, Canada and Japan.

In addition, EUROSTAT also holds an inquiry on air emissions in two year intervals in the frame of the OECD/EUROSTAT Joint Questionnaire (JQ). This questionnaire provides data for related EUROSTAT publications. For OECD, the purpose is the update of the OECD database on resources and the environment (SIREN), and to provide data for the OECD Compendium of Environmental Data. For the 1998 data collection, the questionnaires (JQ 1998) have been sent out in February 1999 and the deadline for receiving replies was the 12th of June. The return of this questionnaire by countries is on a voluntary basis.

In a Joint Note of EUROSTAT/OECD/EEA, it was agreed upon a better co-ordination of international programmes. In this respect, a correspondence table between JQ2000, JQ1998, IPCC (Intergovernmental Panel on Climate Change) and EMEP/CORINAIR was developed. [EUROSTAT 1999]

3 Requirements to Emission Projections by International Organisations

The model to be designed has to support the fulfilment of various international reporting requirements, which are outlined below. Requirements for emission projections by international organisations result from binding reporting obligations concerning national emission inventories and projections as well as from frame programmes asking for reports on a voluntary basis.

3.1 Requirements set by CORINAIR

The CORINAIR inventory is an exercise co-ordinated by the European Environment Agency (EEA). Its objective is the compilation of European wide emission data of air pollutants from all anthropogenic and natural sources.

The first emission inventory on European level (for the year 1985) has been initiated by the European Commission and carried out in the framework of the CORINAIR project, which was part of the experimental CORINE programme [CORINAIR 1985]. This programme has opened the way to the regular establishment of inventories for all European countries, co-ordinated by the European Environment Agency (EEA), in cooperation with other international organisations, especially OECD and UN/ECE. The EEA’s European Topic Centre on Air Emissions (ETC/AE) was created to assist national experts of participating countries to collect emission data and to make estimates using the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook. The programme COPERT II (cf. section 4.1.1) is specifically used for the determination of emissions from road transport. The CORINAIR exercise is not of mandatory nature: contributions of countries to CORINAIR inventories rely on contributions on a voluntary basis.

ETC/AE prepares the European air emission database from the submitted national emission estimates. The collected emission data in CORINAIR are often more detailed than required to report under international obligations (UN/ECE/EMEP, OECD/IPCC, EU CO_2 Monitoring Mechanism).

Table 3 summarises the profile of reporting within CORINAIR valid currently.

Table 3: **Profile of reporting within CORINAIR**

Profile categories	Specification
Considered source categories	Stationary and mobile sources
Sectoral aggregation	SNAP level 1 down to level 3 (cf. below)
Pollutants covered	SO_2, NO_x, CO, CO_2, NMVOC, CH_4, NH_3, N_2O, PFC, SF_6, HFC, HM, POP, dust (in total, 30 pollutants/groups of pollutants)

Profile categories	Specification
Temporal resolution	Yearly
Spatial resolution	National, every 5 years on NUTS level 3

The CORINAIR90 inventory covers Europe completely (29 European countries) for the year 1990 for the pollutants contributing to acidification, eutrophication and climate change: SO_2, NO_x, NH_3, NMVOC, CH_4, CO, CO_2, N_2O. Emission data are available on a regional level (NUTS 3, EUROSTAT classification) and on SNAP90 level 3.

The CORINAIR94 covers the 18 EEA countries (EU15, Iceland, Liechtenstein and Switzerland) for the year 1994. In addition to the eight “classical” pollutants of the CORINAIR90 inventory, nine heavy metals (HM) and ten persistent organic pollutants (POP) are considered (however, reporting on HM and POP is incomplete). Only a part of participating countries has provided emission data on a regional level; the others delivered data on the national level only. In the central database, emission data is partly available on SNAP94 level 2, partly on level 1.

3.2 Requirements set by EMEP

The main objective of the EMEP programme (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) [EMEP 1998a] is to regularly provide Governments and subsidiary bodies under the Convention on Long Range Transboundary Air Pollution with qualified scientific information to support the development and further evaluation of the international protocols on emission reductions negotiated within the Convention. The EMEP programme relies on the following main elements: collection of emission data, measurements of air quality and precipitation, and modelling of atmospheric transport and deposition of air pollution. Within EMEP, the storage and distribution of reliable information on emissions and emissions projections is the task of the Meteorological Synthesizing Centre-West (MSC-W). [EMEP 1998a]

Parties to the Convention are obliged to submit their official emission data and deliver related information to the ECE Secretariat before 31 December for the year preceding the year concerned, including updates of emission projections for the years 2000, 2005 and 2010. The quality of the national totals should be controlled within three months from receipt. During this time Parties are expected to complete missing data with respect to source classification. Thus, by April emission data are expected to be ready for the modelling activities of EMEP which should be completed by the end of May [EMEP 1998b].

Table 4 summarises the profile of reporting within EMEP. Details on the required minimum reporting and the recommended extended reporting are provided in Table 5. [EMEP 1998b]

Table 4: **Profile of reporting within EMEP**

Profile categories	Specification
Considered source categories	Stationary and mobile sources
Sectoral aggregation	CORINAIR SNAP level 1 required, level 2 resp. level 3 recommended
Pollutants covered	SO_2, NO_x, NH_3, NMVOC, priority HM: Pb, Cd, Hg, selected POP: PAH (polyaromatic hydrocarbons), HCB (hexachlorobenzene), PCB (polychlorinated biphenyls)
Temporal resolution	Yearly
Spatial resolution	National

Table 5: **Reporting guidelines by EMEP**

Required minimum reporting
▪ submission of annual national emissions as totals as well as divided into eleven source sectors (SNAP level 1)
▪ submission of spatial distribution of annual totals and source sector split data in the 50 km x 50 km EMEP grid every five years starting with the year 1990 for SO_2, NO_x, NH_3, NMVOC, CO, Pb, Cd and Hg
▪ report on low (below 100 m) and high (above 100 m) emissions of SO_2, NO_x, NH_3, NMVOC, Pb, Cd, Hg, PAH (polyaromatic hydrocarbons), HCB (hexachlorobenzene) and PCB (polychlorinated biphenyls)
▪ annual updates on any substantial changes in distribution of emissions (e. g. in large point sources)
Recommended extended reporting
▪ monthly resolution of SO_2, NO_x, NH_3, NMVOC, HM and POP as national totals and for the 11 main source sectors (SNAP level 1),
▪ historical emissions of POP,
▪ size, spatial and height distribution of HM other than the three priority ones,
▪ gridded land-use statistics (periodically) in order to facilitate biogenic VOC estimation,
▪ specified information on individual large point sources (within certain time intervals)

ECE emission reporting is assisted by the Task Force on Emission Inventories under EMEP, which intends to provide a sound technical basis for exchange of information, evaluate methodologies and achieve harmonisation through co-operation with other international organisations working on emission inventories. An important product has been the completion of the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, the first edition released in early 1996. The Guidebook provides assistance to Parties in fulfilling reporting tasks and to enhance quality control. [EMEP 1998b]

The emission inventories are used for modelling and need to be complete. When no official emission data are provided by countries, estimates are taken from available open sources (e. g. CORINAIR, OECD, IIASA, etc), or in some cases are made in collaboration with certain experts. Annual totals for missing years are based on linear interpolation or extrapolation of the most recent officially reported value.

3.3 Requirements set by UNFCCC[2/]

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are requested to deliver annually (by 15 April) their national greenhouse gas inventories (annually) and projections (for 2010 and 2020) [EIONET], using the “IPCC Guidelines” (Article 5 to 8 of the Convention [UNFCCC]). These Guidelines have been developed and are being continuously updated under the auspices of the IPCC (Intergovernmental Panel on Climate Change).

The Secretariat processes and publishes the data submitted by the countries. The core of the reporting system is the establishment and use of a standard table format using common source/sink categories and common fuel categories. Besides, common definitions of pollutants, units, and time intervals are necessary. The standard tables can be adapted to the appropriate level of detail for the reporting country. The link to CORINAIR can be made via a correspondence table of IPCC-CORINAIR source categories provided in the IPCC Guidelines.

Table 6 summarises the profile of reporting within UNFCCC.

Table 6: **Profile of reporting within UNFCCC**

Profile categories	Specification
Considered source categories	Stationary and mobile sources
Sectoral aggregation	CORINAIR compatible IPCC source categories at 3 different aggregation levels [3/]

[2/] Modifications of these requirements are expected, resulting from the Fifth Session of the Conference of Parties to the UNFCCC (COP5), held in Bonn (Germany), October 25 - November 5, 1999.

[3/] A correspondence table of IPCC – CORINAIR source categories is provided in Annex VII.

Profile categories	Specification
Pollutants covered	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, PFC, SF_6, HFC
Temporal resolution	Yearly
Spatial resolution	National

In order to ensure transparency of national inventories and projections and thus to allow for review and comparability, the reporting countries are recommended to submit, along with the greenhouse gas emission figures and standard tables, a description of the method(s) used, any definitions, activity data and emission factors, as well as other relevant assumptions.

3.4 Requirements set by HELCOM and OSPARCOM

The new Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention"), drafted to merge and review the Oslo and Paris Conventions[4/] and adopted in 1992, consists of a series of provisions on the reporting of emissions. The Contracting Parties shall report to the OSPAR Commission at regular intervals the input of substances via the atmosphere, based on emission inventories of relevant pollutants, in particular heavy metals and persistent organic pollutants. Periodical reports have to be submitted. Data and information from Contracting Parties are collected on an annual basis and have been published in the reports listed in Table 7. [OSPAR]

Table 7: Profile of reporting within OSPAR

Title	Reporting formats (OSPAR Agreement)	Annual deadline for the submission of data
OSPAR Report on Mercury Losses from the Chlor-Alkali Industry	1997-13	30 September
OSPAR Report on Dumping at Sea	1996-1	1 November
OSPAR Report on Discharges, Waste Handling and Air Emissions from Offshore Installations	1995-3	1 November
OSPAR Report on Discharges from Nuclear Installations	1996-2	30 September

[4/] Initially, the Oslo Commission's task was to regulate and control the dumping at the North-East Atlantic of industrial wastes, sewage sludge and dredged material and the incineration on sea of liquid industrial wastes. The Paris Commission regulated and controlled inputs of substances and energy to the North-East Atlantic from land-based sources (via the atmosphere, rivers, or direct discharges) and also from offshore platforms.

The HELSINKI COMMISSION (HELCOM) is an international Cooperation for the Protection of the Marine Environment of the Baltic Sea. The second Convention on the Protection of the Marine Environment of the Baltic Sea Area was signed by all countries bordering on the Baltic Sea and by the European Union. Unlike the OSPAR Convention, only (non-binding) recommendations are given and no emission inventories are requested. However, the Contracting Parties shall report to the Commission at regular intervals on the measures taken for the implementation of the recommendations as given in the Convention and the effectiveness of the measures. [HELCOM]

3.5 Requirements set by EU

Various requirements to emission inventories and projections are set by the European Union via e. g. Directives. In the following, such requirements are outlined exemplarily for Directive 88/609 ("LCP Directive") and Directive 96/61 ("IPPC Directive"), as well as for the proposal for a Directive on National Emission Ceilings for Selected Air Pollutants ("NEC Directive") .

3.5.1 Directive 88/609 on the limitation of emissions of certain pollutants into the air from large combustion plants ("LCP Directive")

In the frame of the 88/609 Directive, reporting of emission inventories is required for verification of compliance. Article 16 and Annex IX of the LCP Directive request Member States to annually submit their national emission inventories for the pollutants SO_2 and NO_x to the Commission of the European Union, before September 30 of the year following the year concerned. The general profile of reporting is given in Table 8. Detailed reporting on methodologies and basis data used for the elaboration of the inventories may be requested as well by the Commission.

The LCP Directive is currently being amended. The "Draft Proposal Amending Directive 88/609" includes a strengthening of the provisions relating to data collection for the annual inventory of polluting emissions. Member States might be requested to establish an annual inventory of SO_2 and NO_x emissions from all combustion plants with a rated thermal input of 50 MW or more. Furthermore, they might be required to collect, for each plant in operation, the total annual emissions of SO_2, NO_x and dust as well as the total annual amount of energy input. It is intended to require from Member States the report of a summary of this inventory to the Commission every three years within twelve months from the end of the three year period, and to provide a yearly plant-by-plant inventory upon request of the Commission.

Table 8: **Profile of reporting in the framework of the LCP Directive (88/609)**

Profile categories	Specification
Considered source categories	Large combustion plants (> 50 MW_{th})
Sectoral aggregation	Plant level
Pollutants covered	SO_2, NO_x, *(dust)*
Temporal resolution	Yearly
Spatial resolution	National, plant

Information in brackets refers to the Draft Proposal Amending Directive 88/609

3.5.2 Directive 96/61 concerning integrated pollution prevention and control ("IPPC Directive")

Article 15 of the IPPC Directive requires that "an inventory of the principal emissions and sources responsible shall be published every three years by the Commission on the basis of the data supplied by the Member States". Until now, no detailed requirements to Member States are known with regard to reporting of emissions, since the Commission is currently establishing the formats and the particularities for the transmission of data. The first reporting may take place in the frame of a pilot project by mid of 2003, and may concern emission data of the year 2000 or 2001.

The general profile of reporting is given in Table 9.

Table 9: **Profile of reporting in the framework of the IPPC Directive**

Profile categories	Specification
Considered source categories	Cf. [IPPC]
Sectoral aggregation	Installation/process level
Pollutants covered	Cf. [IPPC] *
Temporal resolution	Not currently known
Spatial resolution	National

* The list of pollutants mentioned in the Directive is only of indicative nature, and may be modified in the future.

3.5.3 Proposal for a Directive on National Emission Ceilings for Selected Air Pollutants

In the frame of the Directive on National Emission Ceilings for Selected Air Pollutants ("NEC Directive"), which is currently in the state of a proposal, national total emissions of selected pollutants are restricted for the target year 2010. Verification of compliance with these targets is requested. Articles 6 and 8 of the NEC Directive require the reporting to the Commission and to the European Environment Agency at latest 31 December of each year of:

- the National Programmes, including quantified estimates on emissions;
- a definitive national emission inventory for the second year preceding the year of reporting;
- a preliminary national emission inventory for the year preceding the year of reporting;
- projections of national emissions for the year 2010, with a documentation of the socio-economic hypothesis taken into account for calculation of the projections.

A further requirement to Member States concerning the elaboration of emission inventories and projections is the use of procedures agreed upon in the framework of the Convention on Long-Range Transboundary Air Pollution (cf. section 3.2: requirements of EMEP), and namely the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook.

A general profile of reporting is given in table 10.

Table 10: **Profile of reporting in the framework of the NEC Directive**

Profile categories	Specification
Considered source categories	Mobile and stationary sources
Sectoral aggregation	CORINAIR SNAP level 1 required, level 2 resp. level 3 recommended
Pollutants covered	SO_2, NO_x, NMVOC, NH_3
Temporal resolution	Yearly
Spatial resolution	National, plant

3.6 Conclusions of the Analysis of the Requirements by International Organisations

The main characteristics of the reporting to international organisations are summarised in Table 11.

Table 11: **Main characteristics of the reporting to international organisations**

Profile categories	Reporting of Inventories	Reporting of Projections	Binding Obligation	Voluntary Basis
CORINAIR	X			X
EMEP	X	X	X	

Profile categories	Reporting of Inventories	Reporting of Projections	Binding Obligation	Voluntary Basis
UNFCCC	X	X	X	
HELCOM	X			X
OSPARCOM	X		X	
LCP-Directive	X		X	
IPPC-Directive	X		X	
NEC Directive	X	X	X	

Binding obligations on the international level mainly refer to the reporting of up-to-date emission data. In the case of EMEP and UNFCCC for instance deadlines are set 15 months after the end of the reference year; for verification of compliance of the LCP Directive of the EU, only 9 months after the end of the concerned year. In many countries national statistics on relevant activities are not yet available within this period. Therefore, short term emission projections are needed in order to fill gaps concerning reported information and to ensure the timely delivery of data. Consequently, these short term projections have to comply with the sectoral split and the spatial resolution of the inventory of concern.

Long term projections are requested in the frame of EMEP, UNFCCC and the EU NEC Directive. Here, estimated national totals of certain pollutant emissions shall be delivered. In order to provide a sound estimate of such figures, it is not sufficient to extrapolate related activity data. The impact of environmental policy on emissions is of major importance. Therefore, the influence of environmental legislation in force and of measures planned to be taken in the near future has to be taken into account.

The EU Directives mentioned above include reporting obligations concerning specific industrial production processes. In general, such obligations are fulfilled on the basis of reports delivered by plant operators. Short-term projections become relevant, if such reports are not available in time. Concerning long-term projections, the impact of these regulations on sectoral and total emissions has to be considered, in particular in the framework of the Directive setting national emission ceilings (here: for the year 2010). In this case, emission projections are used to check compliance with these ceilings when the commitments of the Directive are implemented. Therefore, the projection methodology should allow for setting limit values and/or introducing “Best Available Techniques” for specific groups of industrial processes (including the distinction of capacity classes, new and existing plants, etc.).

4 Characteristics of Existing Models

This part focuses on specific models supporting the elaboration of emission inventories/projections which have been developed and used in an international context, in Europe: COPERT/FOREMOVE, TRENDS, TREMOD, CollectER and CASPER. The models described below are based on the emission factor approach (cf. Chapter 2) and differ from each other by

- the considered emission sources,
- the considered pollutants,
- the sectoral aggregation level (compatibility with CORINAIR),
- the level of detail with regard to the applied emission factors (e. g. representation of technologies),
- the spatial and temporal resolution,
- the methodology for the projection of activities ($a_s(t)$ from eq. (1)),
- the methodology for the projection of average emission factors ($\overline{e_s}(t)$ from eq. (1)),
- and the possibility to model effects of legislation.

In addition, the integrated assessment model RAINS and the techno-economical mass-flow optimisation models PERSEUS and ARGUS have been described. They are designed for the assessment of emission reduction strategies, but they also provide emission projections. These models however require activity projections as exogenous input data (e. g. projections of fuel consumption in RAINS, projection of final energy demand in PERSEUS).

4.1 Existing Models providing Emission Inventories/Projections

4.1.1 COPERT and FOREMOVE

COPERT, a model for emission inventorying for mobile sources

COPERT (**CO**mputer **P**rogramme to Calculate **E**missions from **R**oad **T**ransport) is a rather detailed model for the establishment of emission inventories for mobile sources (on-road and off-road) based on the CORINAIR methodology and thus on the emission factor approach [COPERT 1997]. The following description is mainly referring to the current COPERT II version. Relevant aspects of COPERT III, which is scheduled to be available in autumn 1999, are addressed briefly. COPERT is calibrated onto the European level and destined to EEA member countries. The methodology and the software has been worked out by the Laboratory of Applied Thermodynamics, University of Thessaloniki, for the CORINAIR Working Group of the European Union (EEA, European Topic Centre on Air Emissions). Beyond emission inventorying, COPERT includes an option to produce short-term emission projections, provided that respective input data for future properties of emission sources is available. Therefore, emission factors according to future legislation as already planned, are included in COPERT. Future activity data has to be provided by national experts and are put in the model exogenously. However, for certain countries, default values are proposed.

FOREMOVE, a model for emission projection for mobile sources

FOREMOVE (**FOR**ecast of **E**missions from **MO**tor **VE**hicles) is an emission projection model for mobile sources (on-road and off-road activities), developed by LAT, University of Thessaloniki and designed for long-term emission projections. The FOREMOVE model is a package of algorithms that allow for elaboration of emission projections, using the databases of the COPERT model with regard to the composition of the vehicle park, the driving conditions, the emission factors, etc. In this respect, both models show the same characteristics with regard to sectoral aggregation, spatial resolution, etc.

Unlike the COPERT model which is used by a wide range of experts of various institutions, companies, etc., the FOREMOVE model is used in the framework of specific emission forecast projects e. g. the Auto Oil II programme for ACEA (the European Association of Car Manufacturers). A part of a project currently running at EUROSTAT is the integration of the COPERT/FOREMOVE model into the TRENDS model (cf. section 4.1.3). Fleet estimations from FOREMOVE can be found in a data base called “deliverable 16 of the MEET project” [COST 319]. [Ntziachristos]

An overview of the main characteristics of the COPERT and FOREMOVE models is given in Table 12.

Table 12: Profile of COPERT and FOREMOVE

Profile categories	Specification
Type of model	COPERT: Emission inventorying model for mobile sources (airborne anthropogenic emissions) with limited options for short-term emission projections FOREMOVE: Model for the projection of long-term emissions
Sectoral aggregation	CORINAIR SNAP levels 1, 2, 3 and CORINAIR compatible subdivisions of SNAP level 3
Pollutants covered	NO_x, N_2O, SO_2, VOC, CH_4, PM, CO, CO_2, NH_3, diesel particu-lates, and heavy metals (lead, cadmium, copper, chromium, nickel, selenium and zinc).
Considered source categories	CORINAIR SNAP 07, 08: on-road and off-road activities
Technological level of detail	Technologies, fuels, capacities
Temporal resolution	From yearly down to hourly
Spatial resolution	National down to urban (grid resolution of 1 * 1 km)

Profile categories	Specification
Output formats	Spreadsheet formats, e. g. Excel
Availability	COPERT: Handbooks [COPERT 1997, COPERT 1999], internet download [LAT] FOREMOVE: available at LAT

The vehicle category split available in CORINAIR has been enlarged in COPERT, in order to take into consideration further emission relevant aspects, in particular technology and age of the vehicles.

For countries for which the required input data are not available at NUTS level 3, a top-down approach is possible: the input data for COPERT are given at NUTS level 0 and the emissions can be allocated to another NUTS level with the help of available surrogate data such as distribution of population. National particularities can be considered in terms of composition of the vehicle park, driving conditions, and temperature dependency of some emission factors, as well as the influence of road gradients on heavy vehicles emissions. For countries that have the required input data at lower NUTS level available, a bottom-up approach can be used, starting for example with emission inventories at urban level.

In order to perform the emission inventory, further parameters are necessary. The following are the main parameters used for calculations with COPERT:

- the composition of the vehicle park: number of vehicles per defined vehicle category, age distribution of the vehicle park per vehicle category;
- the total fuel consumption: per fuel type and per vehicle category;
- the driving conditions: annual mileage per vehicle class, annual mileage per road class, average speeds of vehicles;
- the emission factors: per vehicle class, per production year of vehicle, per road class (vehicle speed);
- other parameters: fuel properties, climatic conditions, road gradient, load of the vehicle.

The following significant modifications can be found in the COPERT III version [COPERT 1999] compared to the COPERT II version:

- the results can directly been exported from COPERT III to the CollectER format;
- revised vehicle category split, including future emission technologies for different classes, and updated and representative emission reduction factors over existing vehicle technologies;
- modelling of the effect of vehicle age (mileage) on emissions and the effect of an enhanced Inspection and Maintenance scheme;

- emission factors for 23 PAHs and POPs and additional toxicity equivalent emission factors for dioxins and furans;
- revisited emission factors of non regulated pollutants;
- updated hot emission factors and consumption factors for Euro I gasoline and diesel passenger cars and light duty vehicles;
- revised cold start over-emission ratios for Euro I gasoline vehicles;
- extended NMVOC species profile, providing values for 68 different components;
- the effects of the use of improved fuels on the emissions of present and future vehicle technologies

are integrated in the COPERT III version to be available in fall 1999.

4.1.2 TREMOD

TREMOD is a detailed model for the elaboration of emission inventories and projections for mobile sources (road, rail, ship, aircraft) based on the emission factor approach [TREMOD, KNÖRR]. The TREMOD model has been continuously updated since 1993. TREMOD is dedicated to emission inventories and projections for Germany and was primarily destined to the German Federal Environmental Agency (Umweltbundesamt, Berlin) in order to fulfil national and international reporting obligations. Further users of this tool are e. g. various German Ministries, the German Association of the Automobile Industry, the German Association of the Petroleum Industry. The methodology and the software has been worked out by the Institute for Research on Energy and Environment (IFEU, Heidelberg), on behalf of the German Federal Environmental Agency.

As an overview of TREMOD properties, respective details are given in Table 13.

Table 13: Profile of TREMOD

Profile categories	Specification
Type of model	Emission inventorying and projection model for mobile sources (airborne anthropogenic emissions); short-term and long-term projections
Sectoral aggregation	Several aggregation levels possible, down to CORINAIR SNAP level 3
Pollutants covered	NO_x, SO_2, VOC, benzene, toluene, xylene, CH_4, CO, CO_2, diesel particulates, dust, and heavy metals (lead)
Considered source categories	Mobile sources (road traffic, rail traffic, shipping, air traffic)
Technological level of detail	Technologies, fuels, capacities, ages, loading charge

Profile categories	Specification
Temporal resolution	Yearly, seasonal, and lower resolution possible
Spatial resolution	National, and lower resolution possible
Output formats	Windows application: Microsoft Access (97 Version), import/export with Excel
Availability	Handbook [TREMOD], model available at IFEU

With regard to sectoral aggregation, the current version of the TREMOD model (1.1 version) is not based on the CORINAIR methodology, but complies with it. The scheduled version 2.0 will integrate the CORINAIR system, at least concerning the source category classification.

TREMOD has primarily been developed for the inventory and projection of emissions from road traffic at a relatively high aggregation level: on a yearly basis at national level, in order to fulfil national and international reporting obligations. In contrast to the COPERT/ FOREMOVE model, the TREMOD model also takes into account the other types of traffic (rail, ship, air traffic). The TREMOD methodology also allows for a higher temporal and spatial resolution: emission inventory and projection can be realised on regional, urban and even street level, for temporal resolutions down to 1 hour. However, the corresponding data is not available in the model so far.

Data sets from the year 1980 until 1996 are available in the model, and emission projections can be performed on a yearly basis until the year 2020. For years anterior to 1993, the data are split for the western and the eastern parts of Germany; after that date, the results are given for Germany as a whole.

The databases integrated in TREMOD are provided by the “Handbook - Emission Factors for Road Transport”, jointly developed by the German Federal Environmental Agency and the Swiss Agency for the Environment, Forests and Landscape. This database includes emission factors, based on technology data. In addition, the database “CITAIR”, developed by the German Federal Environmental Agency, provides information on e. g. street types, emission abatement measures, emission calculation procedures.

Data such as activity rates, implementation shares of emission abatement options, vehicle park were provided by various experts from e. g. the German Federal Environmental Agency, the German Ministry of Environment, the German Association of the Automobile Industry. Forecasts of activity rates and related data are thus integrated exogenously into TREMOD.

4.1.3 TRENDS

TRENDS (**TR**ansport and **EN**vironment **D**atabase **S**ystem) is a project running currently at EUROSTAT and aiming at developing emission projections for the transport sector, primarily for decision making purposes [TRENDS]. It consists in a database system for the calculation of a variety of environmental pressure indicators related to transport, in particular energy consumption, emissions of pollutants into air, waste generation, and noise emissions.

The following sectoral modules are under development:

- Road transport: A computer model, performing calculations of the road transport module, is currently under development. It will be probably developed within MS Access. This module is based on the COPERT II methodology and can be considered as an updated version of the FOREMOVE model.
- Railway mode: This module is also under development. A database already exists providing indicators regarding energy consumption and related air emissions from tractive movements (diesel and electric sources, freight and passenger traffic).
- Air traffic: Until now, an Access tool does exist, called AvioMEET and complying with the COST 319 proposal. The data and methodology already available are partly based on the MEET/Deliverable 18 [MEET]. Other databases providing information on air traffic are the Central Route Charging Office (CRCO), delivering data on route charging (e. g. aircraft type, aerodrome of departure and arrival), and the Integrated Initial Flight Plan Program System (IFPS) from Eurocontrol, delivering a set of data for each registered flight.

Table 14 provides an overview of the characteristics of the TRENDS model.

Table 14: **Profile of TRENDS**

Profile categories	Specification
Type of model	Database system for the calculation of environmental indicators related to transport
Sectoral aggregation	• Road: CORINAIR SNAP levels 1, 2, 3 and compatible subdivisions of SNAP level 3 • Railway: train type • Air traffic: aircraft type
Pollutants covered	• Road: CO, CO_2, NMVOC, CH_4, NO_x, N_2O, SO_x, Pb, PM_{10} • Railway: CO, CO_2, NO_x, NMVOC, CH_4, SO_x, PM_{10} • Air traffic: CO, CO_2, NMVOC, NO_x, SO_x
Considered source categories	Mobile sources

Profile categories	Specification
Technological level of detail	• Road: technologies, fuels, capacities • Railway: types of trains, energy consumption for each type • Air traffic: aircraft types, fuels, flight parameters
Temporal resolution	Yearly, seasonally, monthly
Spatial resolution	• Road: Country, region, city and even lower (infrastructure) • Railway: NUTS 2 zones • Air traffic: airports
Output formats	(Microsoft Access) and related formats
Availability	Not yet available (under development)

Input data to the TRENDS model are provided by EUROSTAT (e. g. the TRAINS and SIRENE databases) and other sources of information (with emphasis on CORINAIR/COPERT data).

Within TRENDS, several spatial resolution levels can be represented: for each of the EU 15 Member States, country, region, city and even infrastructure (e. g. motorways, high-speed train lines, ports and airports) levels are integrated. Also different levels of temporal resolution can be represented: annually, seasonally and monthly resolution.

Concerning road transport, the COPERT II calculation module for air emissions and fuel consumption is applied. After annual air emissions have been estimated on territorial units, a spatial disaggregation module allocates these annual air emissions to the different parts of the countries, using the initial COPERT estimates for urban, rural and highway split of the emissions for the different vehicle categories. The forecasts of the main vehicle categories are performed using a Gompertz function, simulating the evolution of vehicle density. The results are combined with EUROSTAT population forecasts per country in order to produce estimates of vehicle stocks per country. The simulation of the vehicle turnover for the main vehicle categories is done using appropriate lifetime functions which will be developed using a Weibull based function. The approach is calibrated on the basis of the EUROSTAT data on vehicle stock and new registrations evolution.

4.1.4 CollectER

CollectER (**Collect E**mission **R**egister) is a software tool, based on the emission inventorying methodology of CORINAIR, created to facilitate data collection in the frame of the CORINAIR programme (cf. section 2.3) [CollectER]. It is a Windows application running on PC under MS Windows95 operating system. All data (1 country/1year) is stored in one database file of the Microsoft Access type. The profile of CollectER is given in Table 15.

Table 15: Profile of CollectER

Profile categories	Specification
Type of model	Emission inventorying model for air pollutants from mobile and stationary sources (no emission projections)
Sectoral aggregation	CORINAIR SNAP level 1 down to 3
Pollutants covered	• first group of pollutants: SO_2, NO_x, NMVOC, CH_4, CO_2, CO, NH_3, N_2O • heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn), and • persistent organic pollutants (HCH, PCP, HCB, TCM, TRI, PER, TCB, TCE, dioxines, PAH).
Considered source categories	All stationary and mobile sources
Technological level of detail	Technologies, processes, fuels, products, according to chosen split of SNAP level 3
Temporal resolution	Yearly
Spatial resolution	From NUTS 0 down to NUTS 3
Output formats	Windows application: Microsoft Access (Version 1.0)
Availability	Handbook [CollectER], internet download [SPIRIT]

For each attribute defining the emission (pollutant, emission source category, location and eventually fuel type), different aggregation levels can be distinguished.

The used classification of emission source categories is based on the CORINAIR Selected Nomenclature for Air Pollution (SNAP). In the case a further subdivision of the SNAP level is required for selected activities, a so-called “split table” can be used. This table contains various predefined extensions of the SNAP level 3 such as more details on processes, process technologies, products, emission reduction options, etc. A selection of splits is given in Table 16.

Table 16: **Selection of splits as defined in the “split table” of CollectER**

Split ID	Name	Split ID	Name
004	Controlled	440	Red wine
005	Uncontrolled	484	Bleaching
006	Old plants	491	Black liquor oxidation
007	New plants	4F1	Capacity < 100 Mg

Split ID	Name	Split ID	Name
101	Dry bottom boiler	4F2	Capacity > 100 Mg
112	Dry bottom boiler/dust control	681	Open circuit machines
322	Portland cement	682	Closed circuit machine
3A8	Chlorination/uncontrolled	8A7	Boeing 747
3B1	Low NOx burner	8B2	Caravelle
439	White wine	896	Airbus A310

A source category is entirely defined when the SNAP code is enlarged by a fuel and/or split, or the indication that no fuel is used.

CollectER includes a set of about 7,000 default emission factors from the Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook. These default emission factors are defined for combinations of SNAP source categories and eventually split categories and/or fuel/fuel group. Such a combination of SNAP and split and/or fuel/fuel group is called within CollectER "base or default activity" in opposition with "elementary activity" which corresponds to the single SNAP source category (SNAP level 3). To enable broader use of the system, further pollutants and emission factors can be added by the user.

4.1.5 CASPER

CASPER (**CA**lculation **S**cheme for **P**redicting **E**missions into Ai**R**) is an emission projection model for both stationary and mobile sources [CASPER]. This model is based on the CORINAIR methodology, incorporates the FOREMOVE model for mobile sources and includes specific approaches for stationary sources. It has been jointly developed by IFARE, the LAT Aristotle University of Thessaloniki, and EnviCon. It includes all relevant emission and activity data for all EU Member States. Table 17 provides a summary of the characteristics of CASPER.

Table 17: **Profile of CASPER**

Profile categories	Specification
Type of model	Emission projection model for mobile and stationary sources (airborne anthropogenic emissions)
Sectoral aggregation	CORINAIR SNAP levels 1, 2, 3 and compatible subdivisions of SNAP level 3
Pollutants covered	NO_x, N_2O, SO_2, NMVOC, CH_4, CO, CO_2, NH_3
Considered source categories	All mobile and stationary sources categories

Profile categories	Specification
Technological level of detail	Technologies, fuels
Temporal resolution	Yearly
Spatial resolution	Country
Regional coverage	EU 12
Output formats	Microsoft Access 2.0
Availability	Handbook and model available at EEA and IFARE

CASPER has been developed on behalf of the European Commission - DG XI for the elaboration of long-term emission projections. (central use by the Commission) In this respect, CASPER includes not only technology specific data e. g. emission factors (mainly provided by CORINAIR, US-EPA, OECD), but also country specific statistical data (widely provided by EUROSTAT) for the EU 12 countries. The CASPER model is very disaggregated and allows for projections on SNAP level 3.

4.1.6 RAINS

The RAINS (**R**egional **A**ir Pollution **IN**formation and **S**imulation) model, developed at the International Institute for Applied Systems Analysis (IIASA) provides a consistent framework for the analysis of the cost-effectiveness of alternative emission reduction strategies, focusing on acidification, eutrophication and tropospheric ozone. [IIASA a]

The following modules are relevant with regard to emission projections/inventories [IIASA b]:

- The Emission-Cost (EMCO) Module, estimating current and future levels of SO_2, NO_x, VOC and NH_3 respectively. The EMCO module also estimates costs for the reduction of emissions: these cost estimates for specific fuel types, economic sectors and abatement technologies are combined with the projected pattern of energy consumption. The RAINS model provides also “national cost curves”, which are built up by ranking abatement measures according to their marginal abatement costs.
- The Optimization (OPT) Module for multi-pollutant and multi-effect optimisation, identifying for given sets of regional target deposition levels, the cost-minimal allocation of measures to reduce emissions.

The RAINS model includes a range of databases on:

- energy consumption for 38 regions in Europe, distinguishing 22 categories of fuel use in six economic sectors;

- emissions of SO_2, NO_x, VOC and NH_3 for 1990, based on information collected by the CORINAIR90 inventory and on national information;
- emission factors derived from the CORINAIR90 emission inventory database and guidebook [Guidebook], information by national experts;
- options and costs for controlling emissions of the considered pollutants characterised by technical and economic features of the most relevant emission reduction options and technologies;
- the "Official Energy Pathway" compiled from the UN energy database (1990-2010);
- the "Conventional Wisdom" energy scenario (1990-2010) of DG XVII of the European Commission (for the EU Member States);
- an "Agricultural Pathway" up to the year 2010, based on national and international projections.

A profile of the characteristics of RAINS is provided in the following table.

Table 18: **Profile of RAINS**

Profile categories	Specification
Purpose of the model	Integrated assessment model for the elaboration of combined strategies for the abatement of acidification, eutrophication and ground-level ozone
Sectoral aggregation	CORINAIR SNAP level 2, partly level 3 or below
Pollutants covered	SO_x , NO_x , VOC, NH_3, PM under development
Considered source categories	Stationary and mobile sources
Technological level of detail	Mainly aggregated level, partly down to process level
Temporal resolution	Base year (1990), target year (2010) (static model)
Spatial resolution	Country
Regional coverage	EU 15, UN/ECE
Input formats	Excel
Availability	Model available at IIASA

The RAINS model provides an emission forecast for the year 2010 for all 44 Parties to the UN/ECE CLRTAP taking into account the implementation of technical emission reduction options according to different scenarios (uncontrolled case, maximum feasible emission rate, current legislation). Activity forecasts are thus required for the year 2010.

4.1.7 PERSEUS and ARGUS

These models [PERSEUS, ARGUS] can be used to determine the cost-optimised development of the production system (structure of sources/technologies, applied emission reduction options) which fulfills the exogenously specified demand (e. g. final energy demand in PERSEUS[5/], demand of product/services on sectoral level in ARGUS[6/]) taking into account various restrictions (e. g. sectoral or national emission ceilings). ARGUS has been designed for VOC-emissions. PERSEUS includes all relevant SO_2, NO_x and greenhouse gas emission sources. In contrast to specific projection models described above, the temporal variation of technology mix and the implementation shares of abatement options are determined endogenously, based on the criteria of minimisation of the discounted costs. Therefore, these models can be used to estimate evolution of technology shares which could be used as input for projection models.

Table 19 and Table 20 provide information on the profiles of PERSEUS and ARGUS. Both techno-economical mass-flow optimisation models require activity projections for each year between the base year and the target year.

Table 19: Profile of PERSEUS

Profile categories	Specification
Purpose of the model	Model for the establishment of strategies for the cost-effective reduction of NO_x, SO_2, and greenhouse gas emissions from mobile and stationary sources
Sectoral aggregation	Partly CORINAIR SNAP level 3 and below (PERSEUS-NO_x), partly CORINAIR compatible aggregation level (PERSEUS-SO_2 and GHG)
Pollutants covered	Acidification and eutrophication NO_x, SO_2 Climate Change: CO_2, N_2O, CH_4, O_3
Considered source categories	Mobile sources (road transport, railways, aircraft and shipping) and stationary sources (SNAP source categories 01, 02, 03, 09)
Technological level of detail	Technologies (production, transformation, emission abatement), fuels, capacities, technical lifetime; partly reference installation approach (capacity and technology classes) for the NO_x model
Temporal resolution	5 years (national and regional level) down to daily (installation level) from 1995 to 2020
Spatial resolution	Country down to installation level

[5/] Programme Package for Emission Reduction Strategies in Energy Use and Supply

[6/] **A**llokationsmodul zur **r**echnergestützten **G**enerierung wirtschaftlicher **U**mweltschutz**s**trategien

Profile categories	Specification
Input formats	Access, Excel
Availability	Model available at IFARE

Table 20: **Profile of ARGUS**

Profile categories	Specification
Purpose of the model	Model for the establishment of strategies for the cost-effective reduction of NMVOC emissions from stationary sources
Sectoral aggregation	CORINAIR SNAP level 3 and below
Pollutants covered	NMVOC
Considered source categories	About 40 sectors (stationary sources only)
Technological level of detail	Reference installation approach (capacity and technology classes)
Temporal resolution	1 year from 1995 to 2015
Spatial resolution	National
Input formats	Excel
Availability	Model available at IFARE

4.2 Conclusions of the Analysis of the Presented Models

The compilation of consistent and comparable emission inventories in Europe in the frame of the CORINAIR programme is supported by the software tool CollectER. This tool is fully in line with the structure and the methodology of CORINAIR, but it does not allow for emission projections.

The major part of existing models is dealing with the assessment of emissions from mobile sources, such as COPERT/FOREMOVE, TREMOD, and TRENDS. These models are characterised by a high level of detail for technical data and socio-economic indicators. Since mobile sources have since long been identified as relevant sources of pollution, these models can look back to a long tradition and have achieved a high status of sophistication today. They provide the possibility to investigate the effects of possible changes in technologies, driving modes, fuel composition, etc. on future emissions. Therefore, these models are already in line with the user’s needs concerning projections and can be integrated into an overall emission projection methodology.

A specific model to project emissions from stationary and mobile sources is CASPER. It is designed for application to a group of countries (EU12) including a comprehensive database of statistical data for these countries. It incorporates the FOREMOVE model for mobile sources.

The models RAINS, PERSEUS and ARGUS for environmental strategy development provide information e. g. on the impact of environmental policy on future emission of selected pollutants. Concerning the structure of emission data, they are in line or compatible with the CORINAIR methodology. As these tools are not designed to project emissions, activity rates are not extrapolated but have to be introduced exogenously.

With regard to the design of an overall emission projection model based on the CORINAIR methodology, the existing models described in this chapter provide already many elements (cf. Table 21) which should be integrated into this tool as far as possible, in accordance with the needs of the user and the requirements of reporting obligations. These needs are outlined in more detail in the following Chapter 5.

Table 21: **Summary of profiles of the described existing models**

Model	COPERT/ FORE-MOVE	TRENDS	TREMOD	CollectER	CASPER	RAINS	PERSEUS	ARGUS
Focus on								
inventories	X	X	X	X				
projections	X	X	X		X	X	X	X
the analysis of emission abatement strategies						X	X	X
Source Categories								
Stationary sources				X	X	X	X	X
Mobile sources	X	X	X	X	X	X	X	
Aggregation for activity data								
CORINAIR level 1	X	X	X	X	X	X	X	X
CORINAIR level 2	X	X	X	X	X	X	X	X
CORINAIR level 3	X	X	X	X	X	X	X	X
CORINAIR subdivisions	X	X	X	X	X	X	X	X

Model	COPERT/ FORE-MOVE	TRENDS	TREMOD	CollectER	CASPER	RAINS	PERSEUS	ARGUS
Pollutants								
8 "classical" [a]	X	X	X	X	X	[b]	[c]	[d]
HM	X	X	X	X				
POP				X				
PM	X	X	X					
Diesel particulates	X		X					
Temporal resolution	Yearly to hourly	Yearly, seasonally monthly	Yearly, seasonally	Yearly	Yearly	Base year, target year	5 years to daily	Yearly
Spatial resolution	National to urban	National to urban	National	National to urban	National,	National	National to installation	National, regional
Regional coverage					EU 12	EU 15, UN/ECE		
Output Format	Excel	Access and related	Access and related	Access	Access	Excel	Access, Excel	Access, Excel

[a] SO_x, NO_x, CO, CO_2, N_2O, CH_4, NMVOC, NH_3

[b] SO_x, NO_x, VOC, NH_3, PM under development

[c] SO_x, NO_x, CO_2, N_2O, CH_4, O_3

[d] VOC

5 Model Concept

5.1 Characteristics of the Model

Based on the analysis of needs by users and requirements by international organisations (cf. chapter 3), the main characteristics of the model to be developed are specified in the following.

5.1.1 Users of the Model

The binding reporting obligations mainly address countries. Therefore, the model is intended to be used by experts for the development of national emission inventories and projections. In a first step, the model shall be designed for use in individual countries. An extension for centralised applications (consideration of groups of countries) may be included in a further step. The model has to be developed for the use on personal computers, in an Access/Excel compatible environment, the structure of which should be determined in close collaboration with the users (e. g. national experts, national environmental agencies). Compatibility between the output format of the model (relying on the CORINAIR format) and the formats requested for international reporting obligations are to be taken into consideration, in some cases via existing conversion schemes for the reporting in other formats.

5.1.2 Main Function of the Model

The main function of the model to be developed resides in:

- the development of *short-term* emission projections aiming at filling gaps within emission inventories in the framework of reporting obligations, and
- the development of *long-term* emission projections (e. g. 1995 – 2020) for the analysis of
    - the influence of the evolution of emissions, and
    - the influence of environmental legislation (expressed in terms of emission abatement options for considered sectors/activities) on this evolution.

The use of short term projections in emission inventories

Since emission inventories are often needed within very short time periods (cf. Chapter 3), preliminary projected emission data may be necessary in order to fill gaps induced by lack of available data. Consequently, projections have to provide data on the same level of sectoral aggregation as inventories. The “maximum requirement” to a projection model resulting from the international binding obligations is outlined in Table 22.

Table 22: **Specification of the profile derived from the reporting obligations considered in Chapter 3**

Profile categories	Specification
Considered source categories	Stationary and mobile sources
Sectoral aggregation	SNAP level 3
Pollutants covered	SO_2, NO_x, CO, CO_2, NMVOC, CH_4, NH_3, N_2O, HM (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn), POP (HCH, PCP, HCB, TCM, TRI, PER, TCB, TCE, dioxines, PAH), particulate matter
Temporal resolution	Yearly
Spatial resolution	National

5.1.3 Aspects of Pollutants and Environmental Media to be Covered

The model will be designed to cover emissions into air. The air pollutants to be covered by the emission projection model will be the same as in CORINAIR. The respective catalogue includes 30 categories of air pollutants: acidifiers, ozone precursors and greenhouse gases (SO_x, NO_x, NMVOC, CH_4, CO, CO_2, N_2O, NH_3, PFC, SF_6, HFC), heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn), and persistent organic pollutants (HCH, PCP, HCB, TCM, TRI, PER, TCB, TCE, dioxines, PAH). Provided that emission factors are available to the adequate extent, additional air pollutants may be integrated in a further step.

Furthermore, as demonstrated by current activities of the Task Force on Emission Inventories, the emission factor approach is also applicable to characterise emissions/discharges into other environmental media. Concerning activities to be covered, additional sources have to be included. Therefore, the SNAP 97 has to be extended. Current activities on international level e. g. within EUROSTAT are defining respective sources categories (NOSE code), which should be considered to allow for a harmonised approach, if the model has to be extended.

5.1.4 Aspects of Countries to be Covered

The model will be designed for the use by countries participating in the CORINAIR exercise. These include EEA Member States as well as central and eastern European countries (PHARE and TACIS countries). The application of the model in these countries should lead to consistent results. This consistency can be ensured on one hand by the use of the CORINAIR structure, on the other hand by the use of consistent baseline statistics (e. g. GDP, population) and technological data (emission factors, abatement efficiencies) as a basis for estimations.

5.1.5 Representation of Environmental Legislation

In particular long-term emission projections are used to analyse the impact of possible emission reduction options on the emissions, such as the introduction of emission limit values. In relevant environmental legislation (e. g. the EU Solvent Directive and the EU Directive on Large Combustion Plants) requirements are defined according to the characteristics of the installation (e. g. process and size of installation). In this respect, a further subdivision of the CORINAIR source category structure might be necessary, i. e. accounting for different legislation on installation resp. process level (cf. section 5.2.1).

5.1.6 Scenario Analysis

The medium and long term development of emissions are mainly controlled by global socio-economic factors (GDP, population), structural changes in economy, technological change and the application of environmental legislation.

A major task of the projection model is the assessment of the influence of these factors on the medium and long term evolution of emissions. Therefore predefined default scenarios will be proposed to the user e.g.

Socio-economic scenarios

Prospective studies performed by the countries or international organisations are available which provide possible evolutions of global socio-economic factors and the development of main economic sectors (e. g. projection of the energy demand). Based on these studies, different scenarios will be defined, reflecting the possible temporal development of that factors.

Technology/legislative scenarios

- Autonomous technological progress: at the end of their technical (or economical) lifetimes, old technologies/installations are replaced by new technologies corresponding to "current market standard".
- Current legislation: the installations have to fulfil the requirements of relevant EU Directives (e.g. EU Solvent Directive and the EU Directive on Large Combustion Plants) or national regulations (TA-Luft for Germany).
- Best available techniques: best available techniques to reduce emissions are applied to new (and existing) sources.

All relevant data and assumptions characterising the scenario (e. g. technologies considered as BAT, abatement options selected to fulfil the requirement of a given regulation) will be presented in a transparent way in order to allow for modification/adjustments by the user. The model will allow an expert user to define own scenarios (e. g. scenarios illustrating national legislation and/or country specific issues).

5.1.7 Aspects of Temporal and Spatial Resolution

In the framework of binding reporting obligations and the development of emission reduction strategies, a yearly resolution is widely used. In this respect, the temporal resolution of the model to be designed is on a yearly basis. However, if a more detailed temporal resolution is required, respective methodologies such as seasonal variation profiles may be applied to the annual data. International reporting obligations focus on emission data on national level. However, if a further spatial resolution is required, the national data may be disaggregated by appropriate surrogate data such as distribution of population and GDP.

5.1.8 Aspects of Sectoral Aggregation

In particular, the possibility to define scenarios reflecting environmental policies request a high level of detail concerning emission source characteristics (mainly expressed by emission factors). For this purpose, corresponding activity rates have to be available. However, data on activity rates are only partly available on a high level of detail. Therefore, a flexible methodology in terms of sectoral aggregation is necessary. Consequently, methodologies to aggregate, or disaggregate either emission factors or activity rates to the required level of detail are necessary.

5.1.9 Output Format

With regard to international reporting obligations, the structure of the source categories should ideally correspond to the reporting format, which relies on the CORINAIR structure: the output data can thus be given in the CORINAIR format either for a given source category (e. g. cement production; SNAP level 3), for a given industry branch (e. g. paint application; SNAP level 2), or for a whole range of emission sources (e. g. solvent use, SNAP level 1). Therefore, basic emission data from existing inventories have to be integrated in the CORINAIR format. However, the possibility should be given to use existing conversion schemes (e. g. the ReportER software) for the reporting in other formats such as IPCC.

5.2 Emission Projection Methodology

In order to avoid duplication of work, emission projections for mobile sources can be provided by existing models such as COPERT/FOREMOVE, TREMOD, TRENDS. The model should thus integrate the results from these tools and the development of projection procedures should focus on stationary sources, and more precisely on those sources which contribute significantly to national total emissions. The identified key sectors can vary between countries, and have to be chosen e. g. by checking the most recent available emission inventory and selecting all sectors contributing more than e. g. 2 % to the total national emissions. Annex IV provides the list of relevant emission source categories for selected countries.

5.2.1 General

The projection model is based on the emission factor approach. If we assume that the activity is specified on the sectoral aggregation level (statistics are often available on SNAP level 3, cf. section 2.4), the evolution of emissions of a given pollutant is given by

$$E = \sum_{s} A_s(t) \cdot \bar{e}_s(t)$$

where $A_s(t)$ is the activity rate of sector *s* at time *t* and $\bar{e}_s(t)$ the corresponding average emission factor.

The average emission factor reflects the emission behaviour of all sources within the considered sector. The modelling of the evolution of emissions due to technological change and legislation (cf. scenarios defined in section 5.1.6) implies that the emission sources are characterised on an aggregation level which is sufficiently low to account for relevant factors such as production processes used, implemented abatement measures, size of installations, etc. Furthermore, as the applicability and the efficiency of emission reduction measures strongly depend on the characteristics of installations, they can only be unambiguously defined on installation or process level. However, due to the multitude and diversity of individual sources within a sector (in particular for VOC emissions), it is impossible to consider each individual installation. The solution developed for this problem consists in the assignment of individual installations to categories of installations which can be considered as "homogeneous" with regard to the following criteria:

- the same abatement options are applicable to all installations of a given category,
- the abatement efficiency of a given option are comparable for all installations of the category considered.

In practice, the production process, the size of the installation (expressed e. g. in terms of production capacity, fuel input) are relevant factors for the definition of such categories. For each category, a so-called "reference installation" is defined as a virtual installation reflecting the typical characteristics of the installations of that category.

In the framework of the so-called reference installation approach, the average emission factor $\bar{e}_{s,i}(t)$ of a given pollutant can be expressed by the following equation

$$\bar{e}_{s.i}(t) = \sum_i x_{s,i}(t) \cdot e^0_{s,i} \cdot (1 - \sum_j y_{s,i,j}(t) \cdot \eta_{s,i,j}) \qquad (3)$$

with

$e^0{}_{s,i}$ uncontrolled average emission factor of reference installation *i* in sector *s*

$x_{s,i}(t)$ market share of production technology i: contribution of reference installation *i* to sectoral activity of sector *s* in the year *t*

$y_{s,i,j}(t)$ implementation rate of abatement option j : share of option *j* to the activity of reference installation *i* in sector *s*

$\eta_{s,i,j}$ abatement efficiency of option *j* applied to reference installation *i* in sector *s*

On the aggregation level of reference installations, the emission factors $e^0{}_{s,i}$ and abatement efficiencies $\eta_{s,i,j}$ mainly depend on the "intrinsic" properties of techniques and are only weakly country and time dependant. The reference installations and the corresponding emission reduction options can be used to characterise the country specific emission source structure of a given country. This structure is characterised in terms of sectoral activities $A_s(t)$, market shares of reference installations $x_{s,i}$ and implementation shares of the emission reduction options $y_{s,i,j}$.

This approach allows for clear differentiation of "technological data" (emissions factors and efficiencies of abatement techniques) and country specific data (cf. **Figure 1**). The use of the same set of reference installations with the same characteristics ensures the consistency and comparability of the data between different countries. Of course this does not preclude some adjustments of the emission factors and abatement efficiencies to account for country peculiarities e. g. solvent content in coatings for VOC emissions.

The configuration of the emission sources for the base year T_B and the corresponding emissions are defined by specifying the values of sectoral activities $A_s(T_B)$, market shares of reference installations $x_{s,i}(T_B)$ and implementation shares of abatement options $y_{s,i,j}(T_B)$. As the uncontrolled emission factors and the efficiency of abatement options are assumed to remain constant over time, the evolution of emissions results from the temporal variation of sectoral activities $A_s(t)$, market shares of reference installations $x_{s,i}(t)$ and implementation shares of abatement options $y_{s,i,j}(t)$. Methodologies to project these parameters are given in the following.

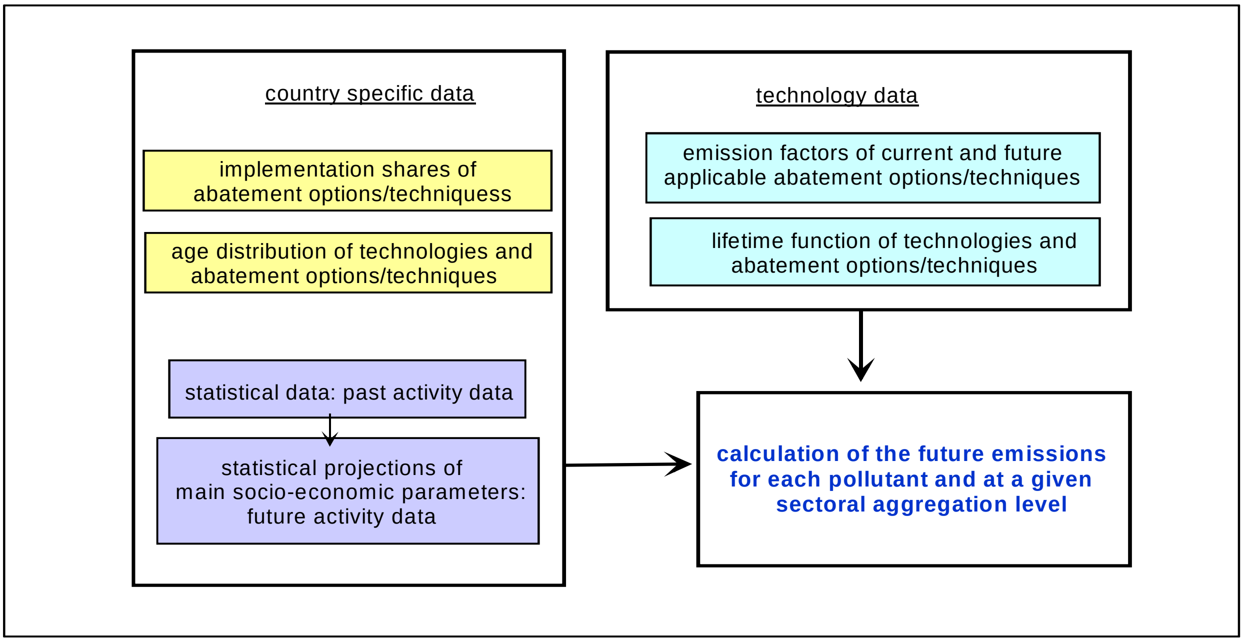

Figure 1: Scheme of the model design

Choice of the aggregation level

To overcome problems linked to the lack of homogeneous knowledge between sectors (especially with regard to available activity data: for a range of sectors, data on activity rates are available only on aggregated level), the model provides a flexible methodology in terms of sectoral aggregation, offering various levels of aggregation, all compatible to the CORINAIR system (SNAP source categories nomenclature). Consequently, methodologies to aggregate, or disaggregate either emission factors or activity rates to the required level of detail are available within the model. In practice, when it is not possible to deal with each sector on the same level of aggregation, the envisaged model makes it possible to calculate emissions of some detailed sectors, to aggregate them on a higher level, and to continue for other sectors on such a higher level. Thus, lack of homogeneous knowledge between sectors will no more hamper the feasibility of emission projections.

5.2.2 Projection of Sectoral Activities

Forecasts of activity rates can be performed on different levels of aggregation by projecting past activity rates to the future via an adequate projection procedure (extrapolation, saturation, etc.) and an adequate correlation parameter. On an aggregated level, activities can be correlated to basic statistical indicators, such as population and GDP; on a detailed level, time series for a specific activity rate have to be available, but they can also be based on or completed by expert knowledge concerning possible future developments of an activity.

For $T_s \leq t \leq T_p$ (with T_s: starting year of the considered time range; T_p: present year), the past activity data $a_p(t)$ is known in principle. Time series of future activity rates (for $t > T_p$) are given through adequate functions $y(t)$. (cf. **Figure 2**)

The following main projection procedures will be included in the model:

- *Extrapolation approach:* this simple approach is most suitable for short term forecasts, whereas for long term forecasts results can turn into non-realistic ranges. The approach can be applied for absolute and relative data (e. g. energy demand in [GJ] and [GJ/capita]).
- *Saturation approach:* some activities show a temporal evolution that can be described on hand of a S-shaped showing an asymptotic upper limit (saturation value) and characterised by a Gompertz function.
- *One criterion correlation approach:* this approach enables for correlation of requested future activity data with exogenous forecasts (general data such as population or Gross National Product (so-called baseline statistics)) and allows for long term forecasts. The time series (past and forecasts) of the baseline data $a_B(t)$ is given exogenously, and used for the elaboration of the function $y(t)$.
- *Two criteria correlation approach:* this approach also allows for long term forecasts. It simultaneously uses two baseline statistics to be correlated to the past activity data. Past and forecasts of two baseline data $a_{B1}(t)$ and $a_{B2}(t)$ are considered for expressing the required function $y(t)$.

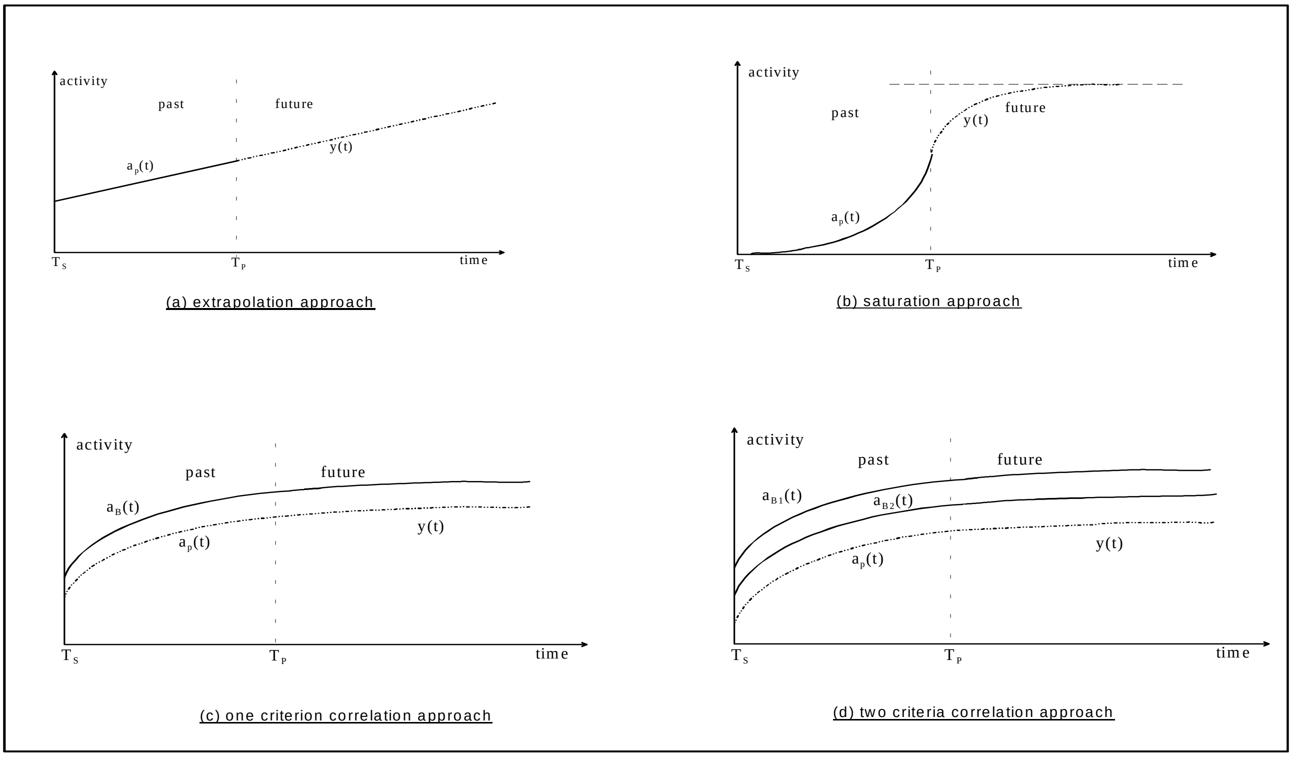

Figure 2: Projection procedures with regard to activity rates [West and Harrison]

An adequate projection procedure will be selected for each sector. If available e. g. from expert statements, the evaluation of activities can also be specified directly on the sectoral level. Projection of baseline statistics (e.g. population, GDP) will be derived exogenously from a compilation of existing studies. Various socio-economic scenarios will be considered to reflect the uncertainties on the development of these baseline data (low, high, medium case, etc.).

The consistency between output data from different emission projection models is ensured due to the use of the same baseline statistics.

5.2.3 Projection of Market Shares of Technologies and Implementation Shares of Abatement Options

The evolution of market shares of production/conversion technologies and implementation shares of abatement options are specified exogenously according to the different scenarios on legislation and technological development (cf. section 5.1.6).

The implantation of a specific regulation on the technological level can be represented either by retrofitting existing installations with an adequate abatement option (change of $y_{s,i,j}(t)$) or by replacing the existing installation by a new installation complying with the new regulation (change in $x_{s,i}(t)$ and $y_{s,i,j}(t)$). For instance the retrofit of installation (*s*, *i*) equipped with abatement option (*s*, *i*, *j*) at time t' is described by equation

$$y_{s,i,j'}(t) = 1 \quad \text{for } t \geq t', \qquad \text{and} \qquad y_{s,i,j}(t) = 0$$

where (*s*, *i*, *j'*) denotes the abatement option allowing for compliance to the new regulation.

The scenario "application of best available technologies/practice" can be modelled in a similar way.

The scenario "autonomous technological progress" implies that installations/technologies reaching the end of their technical lifetime are replaced by new technologies (internal technology turnover). The decrease of the market share of a given technology in a given time period is determined using an adequate lifetime model based on lifetime functions and the age distribution of technologies for the base year. The lifetime function describes in practice the probability that a certain technology implemented at time t_o is still in use at time *t*.

Practical feasibility, link to energy and mass flow optimisation models

The representation of emissions sources in terms of reference installations and the corresponding country specific parameters has already successfully been used in the development of the energy and mass flow optimisation models PERSEUS and ARGUS (cf. section 4.1.7). These models also include a lifetime model to describe the internal turnover of technologies. The data required to represent the country specific structure of emission sources (activity rates, market shares of technologies and implementation shares of abatement options) have been elaborated for VOC emissions sources (ARGUS model) in France [ADEME a] and Germany [ARGUS] and for energy related emissions sources (PERSEUS) e. g. SO_2 and NO_x in many European countries [ADEME b, EURIO]. This shows that the proposed approach is feasible.

Furthermore, the energy and mass flow optimisation models mentioned above provide the evolution of the technology shares $x_{s,i}(t)$ and implementation shares of abatement options $y_{s,i,j}(t)$ within a given planing horizon (e. g. 1995-2020). The evolution of the system is driven by a cost optimisation criterion, taking into account various restrictions concerning the fulfilment of the demand of products or services (e. g. demand of final/useful energy), legislative requirements, the limitation of emissions on sectoral or national level, etc. Thus, these models can be used to determine time series of $x_{s,i}(t)$ and $y_{s,i,j}(t)$ exogenously which will be included in the projection model.

5.2.4 Available Input Data

The output data of an emission projection model is highly dependent on the characteristics of input data, e. g. emission factors and statistical data.

5.2.4.1 Emission Factors

The model will include a database containing default (uncontrolled) emission factors and the efficiency of all relevant applicable abatement options.

Emission factors available in literature are usually provided for a given number of installations equipped with emissions reduction options. The link between the controlled emission factor $e_{s,i,j}$ and uncontrolled emission factor $e^o_{s.i}$ is given by equation (4):

$$e_{s,i,j} = e^o_{s,i}(1-\eta_{s,i,j}) \qquad (4)$$

where $\eta_{s,i,j}$ denotes the efficiency of abatement option (*s*, *i*, *j*).

The database will include emission factors provided by CollectER and the Joint EMEP/CORINAIR Atmopheric Emission Inventory Guidebook. For VOC and NO_x emissions the database established in the framework of the Task Force on Abatement Options/Techniques for Nitrogen Oxides and Volatile Organic Compounds [TFAT VOC, TFAT NO_x] will be used. This database has been structured according to the reference installation approach and also includes cost data of emission reduction options. It covers all stationary emission sources of VOC and NO_x, which show a relevant contribution to the total emissions and for which the emission reduction potential is significant. The results are presented in sectoral technical data sheets (40 sectors described by about 180 reference installations for VOC and 7 sectors split in about 130 reference installations for NO_x). The results of a further project dedicated to the techno-economic characterisation of abatement options for emissions of SO_2, NO_x and heavy metals for stationary sources in Germany can be used as well [UBA]. Furthermore, in the framework of various projects

(e. g. [BWPLUS, PEF]), a database has been established including technical data (among others emission factors) covering about 540 power plant boilers in Germany.

For further pollutants e. g. POP, the availability of emission factors of a given combination of production technology and emission abatement option is rather scarce, and thus a wide range of emission factors are still to be determined before integration into the model. However, adequate estimation procedures of emission factors are compiled and emission data can be provided by e. g. plant operators.

5.2.4.2 Statistical Data

At least for the EU member states, time series of past activity rates of a wide range of activities are available from organisations such as EUROSTAT, European Commission DG XVII, OECD/IEA, Worldbank, or from other national or international databases and models. In some cases, statistical projections of activity rates (on Gross National Product, energy consumption, population) are available as well. A list of available activity data and respective data sources is provided in Annex I. However, for a range of sectors, data on activity rates are available only on aggregated level.

For combustion processes, one further component has to be accounted for, which is the development of the energy efficiency of respective processes. Since according to the CORINAIR methodology, activities are mainly expressed in terms of thermal energy input, production rates have to be converted into such dimensions before applying emission factors. However, also on a detailed level this does not incur major difficulties since respective data are to a large extent available (cf. Annex II) due to the long tradition of energy related research activities.

6 Conclusions

Emission projections are requested to fulfill reporting obligations in the frame of international programmes, fill gaps in emission inventories, but also analyse possible future development of sector specific emissions. For these purposes, a variety of emission projection models, based on the emission factor approach, has been developed in different countries, but no European wide harmonised projection model currently exists.

Through the analysis of international reporting obligations, it turned out that a high level of detail in both inventories and projections is requested. Therefore, an emission projection tool has to be compatible with this level of detail.

In the past, emission projection tools have already been developed, partly based on the CORINAIR methodology. With regard to the requirements mentioned above, in particular existing projection tools for mobile sources seem to be appropriate. Therefore, future activities of model development should focus on stationary sources. Nevertheless, a considerable amount of information is already available from other tools such as models for environmental strategy development.

Concerning the development of a new projection tool, the following requirements have been identified:

- The model should be basically designed for the use in individual countries by e. g. experts compiling national inventories.
- It should consider, as far as possible, existing projection tools and methodologies.
- It should be possible to elaborate both short term and long term emission projections.
- The model should allow the analysis of the impact of environmental policies on future emissions, in particular the impact of environmental legislation. This requests in many cases a high sectoral resolution of the model down to installation/process level.

A proposal for an appropriate model design has been made, based on a bottom-up approach, covering stationary sources, and using available databases and methodologies of existing emission projection tools. In order to provide a user friendly tool, scenarios for short and long term projections will be predefined reflecting e.g. autonomous development of technologies, current legislation, and application of best available techniques/practice.

Since the model is based on CORINAIR, the emission projection results are consistent with existing inventories. In addition, the application in countries will lead to an inter-comparability of projections between countries. Therefore, verification and quality control of results will be possible. In a further step, the model can be used for application onto a group of countries, e. g. by international organisations.

In order to support wide acceptance of such a tool, it should become part of existing frameworks of emission inventory and projection activities such as the Task Force on Emission Inventory and Projection. This link would enable continuous update of the databases included in the model.

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UNFCCC	United Nations Framework Convention on Climate Change, Document FCCC/CP/1997/L.7/Add.1
West and Harrison	WEST, M.; HARRISON, J.: Bayesian Forecasting and Dynamic Models, New York, 1989

8 Abbreviations

BAT	**B**est **A**vailable **T**echnique
CASPER	**Ca**lculation **S**cheme for **P**redicting **E**missions into Ai**r**
CORINAIR	emission inventorying methodology for air pollutants co-ordinated by EEA
CORINE	**Co**-**or**dination d'**In**formation **E**nvironnementale
ECE	**E**conomic **C**ommission for **E**urope
EEA	**E**uropean **E**nvironment **A**gency
EMEP	Co-operative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe
EPA	**E**nvironmental **P**rotection **A**gency (USA)
ETC/AE	**E**uropean **T**opic **C**entre on **A**ir **E**missions
EU	**E**uropean **U**nion
EUROSTAT	Statistical Agency of the European Commission
GHG	**G**reen**h**ouse **G**ases
HELCOM	**Hel**sinki **Com**mission
HM	**H**eavy **M**etals
IIASA	**I**nternational **I**nstitute for **A**pplied **S**ystems **A**nalysis
IPCC	**I**ntergovernmental **P**anel on **C**limate **C**hange
LCP	**L**arge **C**ombustion **P**lant
NACE	Economic Nomenclature on a European Level
NAPFUE	**N**omenclature for **A**ir **P**ollution **Fue**ls; CORINAIR-methodology
NMVOC	**N**on-**M**ethane **V**olatile **O**rganic **C**ompounds
OECD	**O**rganisation for **E**conomic **C**o-Operation and **D**evelopment
PARCOM/ATMOS	**Par**is **Com**mission - Working Group on **Atmos**pheric Input
PHARE	acronym of the Programme's original name : "**P**oland and **H**ungary: **A**ction for the **R**estructuring of the **E**conomy"; current members: Albania, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia
PM (resp. PM 10)	**P**articulate **M**atter (resp. **P**articulate **M**atter, aerodynamic diameter < 10 µm)
POP	**P**ersistent **O**rganic **P**ollutants
RAINS	**R**egional **A**cidification **In**formation and **S**imulation Model
SNAP	**S**elected **N**omenclature for **A**ir **P**ollution (out of NAPACT and NAPTEC) (CORINAIR-source categories)
TACIS	European Union's assistance programme for the Newly Independent States, formerly members of the USSR

UBA	Federal Agency for the Environment, Germany
UN/ECE	**U**nited **N**ations **- E**conomic **C**ommission for **E**urope
UNFCCC	**U**nited **N**ations **F**ramework **C**onvention on **C**limate **C**hange
VOC	**V**olatile **O**rganic **C**ompounds

List of chemical substances

As	Arsenic
Cd	Cadmium
CH_4	Methane
CO	Carbonmonoxide
CO_2	Carbondioxide
Cr	Chromium
Cu	Copper
Hg	Mercury
NH_3	Ammonia
Ni	Nickel
NO_x	Nitrogenoxides (NO and NO_2)
NO	Nitrogenmonoxide
NO_2	Nitrogendioxide
N_2O	Nitrous oxide
Pb	Lead
Se	Selenium
SO_x	Sulphuroxides (SO_2 and SO_3)
SO_2	Sulphurdioxide
SO_3	Sulphurtrioxide
Zn	Zinc