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The need of nationally reported activity and emission data for UN/ECE-EMEP

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Joint CIAM and MSC-W Note

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Executive Summary

Quality emission data and related information is essential to assess the state of air pollution, to track progress towards the attainment of environmental goals and to evaluate the cost-effectiveness of strategies to reduce emissions. Parties to the Convention on Long-range Transboundary Air Pollution are required by the Protocols to report annually on the amount and extent of their national emissions.

Reported emission data are used by the Meteorological Synthesizing Centre-West (MSC-W) of EMEP for modeling the dispersion of air pollution in the atmosphere to quantify the transboundary exchange of pollutants in Europe and to underpin the need for internationally coordinated strategies for emission reductions. To strengthen the analytical capability of EMEP to provide guidance on cost effective emission reduction strategies, the Executive Body of the Convention has decided to include integrated assessment activities as an official part of the EMEP activities (ECE/EB.AIR/68). The formal decision to extend the EMEP activities towards integrated assessment modeling calls for a coordination of the request for and use of emission related input data between atmospheric dispersion and integrated assessment models.

For obtaining accurate results on concentration and deposition of air pollutants, atmospheric dispersion models developed by MSC-W require quality emission data. Source-allocation model calculations are crucially influenced *inter alia* by the chemical composition, the spatial distribution, the sectoral origin, the temporal pattern and the release height of the emissions in the various European countries. Integrated assessment models attempt to gain insight into the mechanisms that cause emissions, to understand their temporal development, the scope for policy interaction and the costs of measures to reduce emissions. While for atmospheric models the accuracy of emission estimates is crucial, integrated assessment is not so much interested in emission data *per se*, but more in the various factors determining the quantity of emissions. Relevant information includes the rates of activity in the various economic sectors, the physical, technical and economic properties determining the emission rates in absence of emission controls and information about the available emission control options. The potential for further controlling emission is strongly influenced by the (autonomous) turnover of the capital stock, the typical size distribution of installations in a country and the present legal requirements for controlling emissions. Such information has not been included before in the suggestion for reporting guidelines, but knowledge about these factors will be essential for extending EMEP activities towards a cost-effectiveness analysis.

An ideal set of emission-related input data would become rather voluminous, describing the specific situation of individual Parties to the Convention. Experience shows that most countries allocate limited resources for providing data on air pollution to international organizations, so that only

concise, focused and coordinated requests for data submission have chances for practical success. To facilitate the collection and use of national input data for the EMEP modeling activities without unnecessarily increasing the burden of reporting from individual countries, a two-track concept is proposed:

- A set of **key national input data** is periodically reported by national experts. Such a set of key input data should be limited in volume, so that it is possible for national experts to provide quality data. The collection of national data should be further facilitated by aligning as far as possible with other international reporting obligations, e.g., for the UNFCC Convention, EUROSTAT, etc.

- The EMEP Centres compile **additional databases** on other country-specific data relying on various official UN/ECE documents, literature review, expert judgment or by extrapolating experience from other countries. For maximum transparency, all databases should be made available on the Internet, so that Parties can review them and suggest improvements. Review of these databases by the countries should optimally occur at least every five years.

The contents of these two sets of data are summarized as follows:

KEY NATIONAL INPUT DATA

Annual reporting:

- National total emissions of the various substances by specified sectors for the preceding year.

Reporting in five years intervals:

- Spatial distribution of national emissions by specified sectors, using the 50*50 km EMEP grid;
- Vertical distribution of sectoral emissions, by specified sectors;
- Specific characteristics of large point sources;
- Economic, energy, road transport and agricultural statistics for the base year and projections up to 2020 in 5-year steps.

ADDITIONAL DATA BASES

- Land use data;
- Temporal patterns of emissions, by specified sectors;
- The present and future legislation on emission controls in a country;
- The age structure and turnover (autonomous replacement) of capital stock over time;
- Uncontrolled emission factors

As a basis for discussion, the need of EMEP for input data to its models could be fulfilled using the approach outlined in this note. The proposal would be further discussed at the forthcoming Workshop on Emission Reporting.

Preface and Acknowledgements

This note was prepared for consideration at the twenty-fourth session of the Steering Body to EMEP (Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe). Recognizing that the new structure of the EMEP has implications for emission reporting under the Convention on Long-range Transboundary Air Pollution (CLRTAP), the needs for emission and activity data related to both atmospheric dispersion modeling and integrated assessment modeling are considered here. The note does not present a final set of requirements for reporting emission and activity data. It is intended as a clarification of EMEP modeling needs in order to facilitate the discussion with national experts and other international activities compiling emission and activity data. This background information on the EMEP use of emission data is expected to be useful for the on–going revision of emission reporting requirements under the Convention.

The authors are thankful to Mike Woodfield and Chris Evers, Chairpersons of the Task Force on Emission Inventories and Projections and Henning Wuester from the UN/ECE secretariat for stimulating discussions and useful comments.

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1. Introduction

Good quality emission data and related information is essential to assess the state of air pollution, to track progress towards the attainment of environmental goals and to evaluate the cost-effectiveness of strategies to reduce air emissions. As described in its vision for 2005/2010 (EB.AIR/GE.1/1998/3), EMEP under the Convention on Convention on Long-range Transboundary Air Pollution (CLRTAP) provides sound scientific evidence to assist countries in developing effective emission control strategies and to track their implementation.

To strengthen the analytical capability of EMEP for providing guidance on cost effective emission reduction strategies, the Executive Body of the Convention has decided to include integrated assessment activities as an official part of the EMEP activities (ECE/EB.AIR/68). The formal decision to extend the EMEP activities towards integrated assessment modeling calls for a coordination of the request for and use of emission related input data between atmospheric dispersion and integrated assessment models. This concerns in particular emission and activity data necessary for the evaluation of emission scenarios and projections.

For coordinating and streamlining the demand for and the use of emission related information, close interaction with national experts is crucial. EMEP has long benefited from the support of national experts and relies on their guidance to provide methodologies for estimating emission data and to evaluate and verify the reported emission data and related information. To continue this process EMEP realizes the need for

- further clarification of the data requirements and formats for reporting emissions and activities to UNECE, and
- enhanced harmonization and collaboration with other groups concerned with the collection of environmental emission information, such as the United Nations Framework Convention on Climate Change (UNFCCC), the Statistical Office of the European Communities (EUROSTAT), the European Commission (DG Environment) and the European Environmental Agency (EEA).

The analysis presented here concerns explicitly the main pollutants: sulphur compounds (as SO_2), nitrogen oxides (as NO_2), ammonia (NH_3), non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2). To a certain degree, the needs specified in the following can be extended also to heavy metals (HMs), persistent organic pollutants (POPs) and particulate matter (PM). However, the design of effect-based cost-effective policies for heavy metals, persistent organic pollutants and particulate matter is still at a preliminary stage. The specifications and data requirements on emission information for these pollutants should be revised as their inclusion in abatement strategies becomes more evident.

This note reviews the role of information on national emissions in the context of EMEP modeling, both from the point of view of atmospheric dispersion modeling and of integrated assessment modeling. To facilitate the discussion with national experts and other international activities compiling emission and activity data, the note clarifies the use of emission and activity data in EMEP and identifies the essential information necessary for estimating present and future emission levels in Europe. Relations are established to reporting requirements established by UNFCCC and EUROSTAT. This note does not intend to propose a final set of data reporting requirements to UNECE/EMEP but, by providing a documentation of the actual data needs for EMEP modeling, to serve the ongoing discussion about a revision of the formal reporting requirements under the Convention. Therefore this note is also designed as a background document for the forthcoming Workshop on Emission Reporting.

2. Data Requirements for Atmospheric Dispersion Modeling - MSC-W

The contracting Parties to the CLRTAP are required by the Protocols to exchange relevant information on monitoring and modeling activities and to report annually on the amount and extent of their national emissions. Parties have been submitting emission data and agreed related information to the UNECE secretariat by the end of each year since the eighties. These data are presently stored and managed at the Meteorological Synthesizing Centre-West (MSC-W).

Emission data have been primarily used by MSC-W to operate its atmospheric dispersion models with the main purpose to assist Parties in the negotiations of international protocols and to support them in developing and implementing air pollution control measures at national level. EMEP/MSC-W contributes to these objectives by

- analyzing the state of air pollution in Europe, quantifying the transboundary exchange,
- determining the progress in reducing emissions, deposition and air concentrations, in particular with regard to the exceedances of critical loads and levels, and
- providing source allocation estimates and quantifications of the environmental impact of individual sources or groups of sources.

2.1 The Rationale for Using Emission Data in Atmospheric Dispersion Models Developed by EMEP

Comparisons of modeled and measured values on air pollution form the core of EMEP assessment. While measured values are compiled from an extensive monitoring network, modeled air concentration and deposition of pollutants is derived from the atmospheric dispersion models developed by EMEP. Using parameterizations of the continuity equation, such models describe how pollutants are emitted to the atmosphere where, depending on the meteorological conditions, they are advected and diffused, experience chemical transformation and are ultimately removed by dry and wet deposition processes. The agreement between modeled and observed data is one important indicator for the present understanding of the processes involved in the dispersion of pollution, including the quantification of the volumes of pollutants emitted into the atmosphere.

Statistical methods (inverse modelling) have been used by EMEP in order to estimate emission levels in Europe from observed air quality data (Høst, 1996; Dimakos and Høst, 1997). The particular methodology for inverse analysis turned out to produce inconclusive results for acidifying and eutrophying pollutants. Uncertainties in model results and measurement data affect statistical model results in such a way that for the volumes of emissions no clear margins of confidence could be determined. Consequently, EMEP puts its main emphasis on the direct comparison of model results and observations in order to test the confidence on reported emission data.

This process for validation and quality control of emission data should be complemented by a direct verification of reported emission data by national experts, supported and co-ordinated through the Task Force on Emission Inventories and Projections. EMEP centres should contribute to this verification process by indicating possible data faults or inconsistencies.

In addition, the modelling capacity at EMEP/MSC-W allows the separate study of different sources or groups of sources and the determination of their environmental impact. This represents an important evaluation tool to support planning of emission distribution by individual countries. A direct output of this modelling capacity are source-receptor relationships, which are useful to integrated assessment models in their analysis of cost-effectiveness of emission reductions.

2.2 Annual Emission Totals

Establishing the progress on the implementation of existing international agreements requires yearly updated information on emission data. Reported emission data are introduced in atmospheric transport models and the resulting air concentrations and depositions are then compared with observations. Agreement between observed and modeled values contributes to the credibility of the reported emission data. Systematic differences between modeled and measured data are carefully analyzed and model sensitivity studies to different emission estimates are carried out as necessary. Deficiencies and inconsistencies in the emission data were identified in the past by the apparent disagreement between modeled and observed data. A good example is the comparison that led to the identification of the need to include international ship traffic emissions in the EMEP assessment. (Iversen *et al*., 1991; Jonson *et al*., 2000).

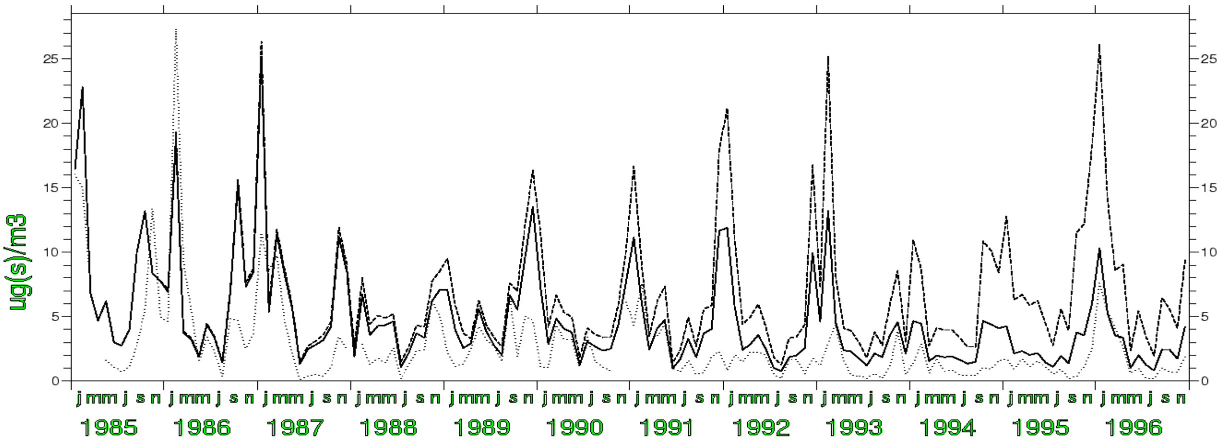

Figure 1. Example of sensitivity analysis where observations of SO_2 in air at Brotjacklriegel, Germany (thick line) are compared to modeled values considering that a) emissions have not been reduced and continue at since 1985 level (dashed line) and b) emissions have been reduced as reported (dotted line). The comparison shows that emission reductions have contributed to a clear reduction of the air concentrations at the station.

The introduction of updated emission data in atmospheric dispersion models allows evaluating successful reductions of adverse effects of air pollution. Trends in the exceedances of critical loads and levels are derived from the modeled concentration and deposition fields and trace the progress in the implementation of emission reduction policies. Examples of such analysis can be found in all EMEP reports (see for example Tarrasón and Schaug, eds. (1999)). Detailed evaluations per country are available at the EMEP website (http://www.emep.int).

These activities can only be carried out if national emission totals are reported every year to UNECE/EMEP. Since reporting of national total emissions is presently required under the Convention, to this end no changes of the present reporting guidelines about total annual emissions are necessary for EMEP purposes.

2.3 Spatial and Temporal Distributions of Emissions

The residence time of pollutants in the atmosphere and their characteristic travel distances determine the spatial and temporal resolution of numerical models so that they can meaningfully describe their dispersion in the atmosphere. Acidifying and eutrophying compounds, atmospheric aerosols and ground level ozone have relatively short residence time in the atmosphere, varying from 1-2 days up to few weeks and therefore their concentration and depositions patterns show significant variations within Europe. The choice of the EMEP grid with the 50x50 km^2 horizontal resolution is considered appropriate to describe the long-range transport of these pollutants.

As the interest for effects of pollution in urban areas increases, the need to link long-range transport with local air pollution becomes more evident. This may have consequences for the spatial resolution of the emissions to be reported. Although the work of EMEP and the CLRTAP will continue to focus on the long-range transport, relevant links with organizations compiling emission data at higher resolution may be necessary in the future.

Most countries in Europe extend over more than one cell of the 50x50km^2 EMEP grid. The location of emissions within national boundaries is thus essential for accurately describing the distribution of pollutants in the atmosphere, also for transboundary air pollution. The air concentration and deposition patterns over Europe will vary considerably depending on the distribution of emission sources within countries. Socio-economical changes in European countries can lead to significant variations in the distribution of air pollution and consequently of the areas affected by exceedance of critical loads and levels. Spatially disaggregated data is expected to become increasingly relevant as the analytical capacity of EMEP develops to support national emission planning by the Parties to the Convention

Therefore, Parties to the Convention are requested to report their national emission data within grid elements of 50x50 km^2 every five years (1990, 1995, 2000 etc.). Updates on any substantial changes in the distribution of emissions should be reported annually in the context of UNECE reporting.

At present, EMEP/MSC-W uses results from the GENEMIS project to model the temporal resolution of emissions. The meteorological conditions at the time pollutants are emitted determine to a great extent their dispersion in the atmosphere. Due to significant differences in stability conditions between day and night, the diurnal variations of emissions can affect the transport patterns.

For the long-range transport of air pollutants also seasonal variations of emissions are relevant, as meteorological conditions vary significantly with season.

It would be useful for improving the accuracy of EMEP modeling results if Parties could verify and, if necessary, revise the results from the GENEMIS project and provide estimates of the seasonal (monthly) and diurnal variations of their emissions, distinguishing the main economic sectors. For transparency, these data could be made available on the Internet and Parties would be invited to review them at periodical intervals (e.g., . five years). This implies a relaxation from thereporting requirements on the temporal characterization of emissions as they are specified in EB.AIR/GE.1/1997/5.

2.4 The Vertical Distribution of Emissions

The vertical distribution of emissions is a part of the spatial distribution discussed above. Because the EMEP Lagrangian models had a coarse vertical resolution, emission reporting to UNECE/EMEP has only distinguished between emissions from ’high’ and ’low’ stacks with 100 m as the crucial stack height. The introduction of the operative EMEP Eulerian models, which distinguish at least four different vertical layers below 500 m (Figure 2), considerably improved the possibility for describing the vertical mixing of pollution.

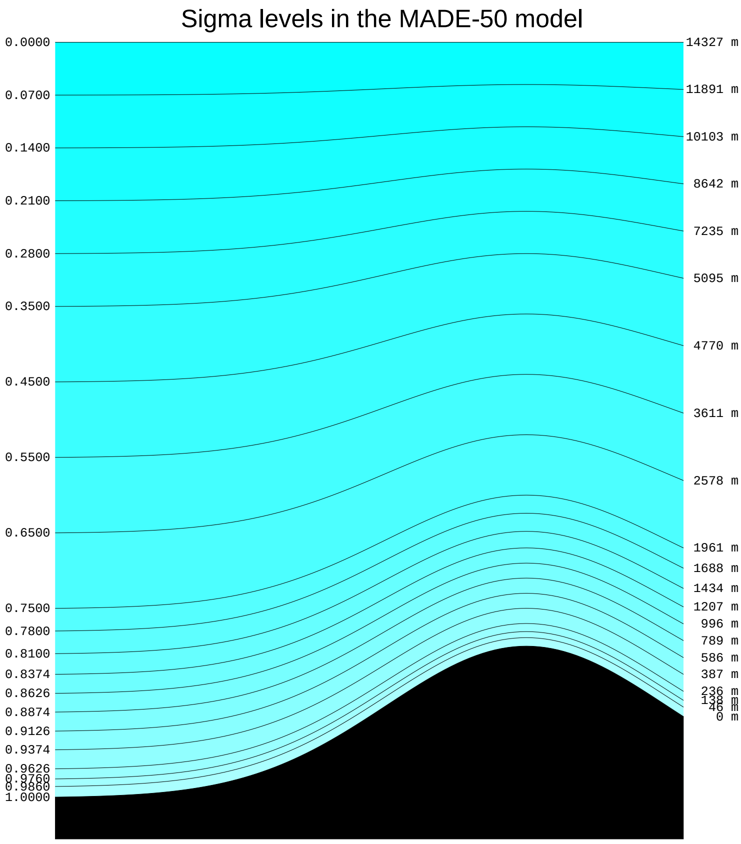

Figure 2. Example of the vertical resolution used by the Eulerian EMEP models (from Bartnicki *et al*., 1998).

With the Eulerian EMEP models, calculation results could be improved by using information on the actual effective height of emissions. In principle it would not be necessary to report the vertical effective heights of emissions per grid square. However, in practice a considerable improvement could be reached by simply reporting the effective height of the emission per source sector.

Therefore, instead of annual reporting of high and low emissions, Parties should report on the vertical distribution of the emissions by sector every five years. Reporting of the vertical distribution of emissions should be complemented by information on Large Point Sources.

2.5 The Need and Use of Information on Large Point Sources

The vertical distribution of emissions determines to a great extent their dispersion in the atmosphere. Large Point Sources should be explicitly specified for use in the models by MSC-W, especially after the proposal to discontinue reporting emissions from "low" and "high" sources. The study of the environmental impact of Large Point sources requires the identification of their geographical coordinates (longitude, latitude), physical properties of their stack (effective and physical height of stack, diameter or exit surface), information on the emission quantities of relevant pollutants and on the speed and temperature of exhaust gases. Detailed information on diurnal, weekly and seasonal (monthly) temporal variation of emissions is also desirable. The evaluation of the atmospheric dispersion of pollution from Large Point Sources requires in many cases coupling different scales of transport from local to long-range.

Information on Large Point Sources was requested in the draft procedure for estimating emission data under the Convention on Long Range Transboundary Air Pollution. The definition of this type of sources was provided either by their thermal capacity or by the volume of their discharges. The European Commission has recently drafted a proposal for a new regulation on reporting of Large Point Sources. The present proposal is to harmonize the definition of Large Point Sources and clarify the emission reporting requirements on physical characteristic of the sources so that periodical reporting to UNECE is compatible with reporting to EU.

2.6 Land-use Data

Atmospheric dispersion models of EMEP require accurate data on land use for estimating biogenic emissions of VOC and PM and for assessing deposition velocities.

Biogenic emissions and emissions from agricultural sources depend strongly on the meteorological conditions (temperature, relative humidity, stability, etc.). The performance of the EMEP models was significantly improved when, instead of resulting fluxes of biogenic emissions, emissions from natural sources were calculated based on the meteorological conditions. In the EMEP models, biogenic emission fluxes are parameterized using physiographic data. The requested data consists of information that is difficult to deduct from satellite data, namely, the area coverage (in km^2) within each grid of all significant vegetation types (Norway spruce, sessile oak…) and if possible, the foliar biomass density (in g/m^2) for all significant vegetation types within each grid.

For modeling dry deposition of pollutants, EMEP/MSC-W has developed an appropriate database for all of Europe, based *inter alia* on information provided by the Coordination Centre for Effects at RIVM. This data provide a first estimate for the calculation of biogenic emissions but is not satisfactory. It is proposed to open this database for review by national experts. Parties are invited to comment on this data and propose improvements particularly on vegetation coverage, within regular intervals of at least 5 years.

2.7 Sector Discriminated Emission Data

The atmospheric dispersion models developed by MSC-W use information on the sectoral origin of emissions to differentiate the vertical and temporal resolution of emissions, and to consider different profiles in the emissions of VOC and PM species that are characteristic for the various source categories. The data is also used in sensitivity analysis to determine the environmental impact of certain sectors.

Following the recommendations of emission experts at the Task Force on Emission Inventories, and as a result of collaboration between CORINAIR, EMEP and OECD experts, eleven source categories were originally selected to report to UNECE/EMEP. These eleven source categories follow the Selected Nomenclature for Air Pollution (SNAP) at level 1.

To gain insight in the contributions of the various activities included in these sectors, an increased level of detail in the reported emissions to UNECE has been considered as desirable. For the purposes of modeling at MSC-W, more detail would enable a more accurate chemical speciation of pollutants, especially of volatile organic compounds (VOC), and allow the study of the chemical composition of atmospheric aerosols (PM). As indicated later in this report, integrated assessment requires more detailed sectoral emission data for calculating abatement costs for the various economic sectors.

It is not obvious, however, that the most appropriate level of reporting would be SNAP level 2 as earlier suggested. In many cases this may lead to over-dimensioned data collection, which however, would not necessarily be useful for the analysis of emission control strategies. Future reporting should remain at SNAP1 level, but where necessary more detailed data (SNAP1+) without going to the details of SNAP2 should be included to the reporting requirements. The definition of SNAP1+ should be further discussed during the forthcoming Workshop on Emission Reporting.

2.8 Summary of the Need for Emission Data at MSC-W

Table 1 summarizes the need for emission data in atmospheric dispersion modeling at EMEP/MSC-W. The data is divided between emission information to be reported and updated every year, and emission information to be updated every five years or only when significant changes take place. It is important to avoid reporting the same data year by year. It is not necessary to repeat trend information if no recalculations have taken place: only significant changes should be reported.

In Table 1, sector category data is referred to SNAP 1+. This nomenclature indicates the need for a revision of the sector aggregation level to be reported to UNECE/EMEP. It is beyond the purpose of this note to present a concrete proposal on the definition of SNAP1+. Such a proposal is expected to result from the discussions to take place at the forthcoming TFEIP workshop on emission reporting. To be meaningful, such a proposal needs to be discussed with national emission experts and to be considered in view of the requirements of integrated assessment modeling specified further in this note.

In principle, sector data to be reported to UNECE/EMEP should

- be manageable for national reporting experts so that the reliability of the data can be traced,
- secure consistency between base year estimates and the emission projection scenarios, and
- be harmonized as much as possible with related data reporting to UNFCCC, EUROSTAT and the European Union.

The extension of the EMEP activities to integrated assessment implies a need for additional data to project emissions into the future and estimate emission control costs. The resulting data needs are discussed in the following Section.

Table 2: The need of EMEP/MSC-W for emission information to operate its atmospheric dispersion models

Reporting for main components *(SO_2, NOx, NMVOC, NH_3, CO, CH_4 and CO_2)*	Initial reporting year	Temporal resolution	Spatial resolution	Sectoral split	Methodology	Format
ANNUAL REPORTING						
National emission totals per sector	1980	Annual	National	Total and SNAP 1+	E/C Manual*	ASCII files/ Pre-filled tables
REPORTING IN FIVE YEARS INTERVALS						
Horizontal distribution of national emissions	1980	Annual	50x50 km^2	Total and SNAP 1+	E/C Manual*	ASCII files/Pre-filled values
Large Point Sources	1980	Annual/ monthly, daily	Geographical coordinates	Total and SNAP 1+	Stack height E/C Manual**	ASCII files
DATABASES CRETATED BY MSC-W, TO BE REVIEWED BY PARTIES						
Temporal distribution of national emissions	1980	Monthly, daily	-	Total and SNAP 1+	E/C Manual*	ASCII files/Pre-filled values
Vertical distribution of national emissions	1980	Annual	-	Total and SNAP 1+	E/C Manual*	ASCII files/Pre-filled values
Land use data	1980	Annual	50x50 km^2	-	E/C Manual**	ASCII files

* Differences in use of methodology from EMEP/CORINAIR Manual should be explicitly reported

** EMEP/CORINAIR Manual should be updated

SNAP 1+ needs to be further defined

3. Data Requirements for Cost-effectiveness Analysis, Integrated Assessment Modeling and Emission Projections – CIAM

Integrated assessment modeling puts together information on economic development, emissions, the potential and the costs for controlling emissions, the dispersion of pollutants in the atmosphere and the environmental impacts of pollution in such a way that policy alternatives can be explored in a systematic way.

The critical importance of close interaction between integrated assessment modelers and national experts is highlighted in the recent draft EMEP Strategy for 2000-2009 (ECE/EB.AIR/68).: *"One of the main tasks* [for integrated assessment modeling] *is to foster closer links with experts working at national level. The integrated assessment modeling should integrate, as far as possible, input from national experts into models, evaluate national reports submitted under the Convention and comment on the data and information received. … "*

The deep involvement of national experts in the integrated assessment process will be even more crucial since "… *One of the biggest challenges for integrated assessment modeling remains increasing model complexity while keeping the model highly transparent."* (ibid.)

Past experience demonstrates that in general it has been possible for national experts to familiarize themselves with the principle concepts and methodologies of integrated assessment models. However, understanding how national (emission-) data were interpreted and translated into the databases of integrated assessment models has often been more difficult.

The UN/ECE Task Force on Integrated Assessment Modelling in its 25th Session (EB.AIR.GE.1/2000/11; EB.AIR/WG.5/2; UN/ECE, 2000) recognized the need for a clear and transparent format to help national experts preparing input data to integrated assessment models. It decided to recommend that the EMEP Steering Body should include activity data in the emission data requests in line with the reporting requirements for similar data under the United Nations Framework Convention on Climate Change and to suggest that the Task Force on Emission Inventories should amend the reporting guidelines accordingly.

This Section reviews the role of information on national emissions in the context of integrated assessment models, using the Regional Air Pollution Information and Simulation (RAINS) model. In a further step the paper distills the essential information relevant for estimating present and future emission levels in the various countries. If such information were directly supplied by national experts, (a) critical country-specific conditions could be reflected to the maximum extent based on nationally supplied data, and (b) national experts would find it easier to recognize their own data in the databases of integrated assessment models and consequently to interpret the results of model calculations.

3.1 The Rationale for Using Emission-related Data in Integrated Assessment Models

Integrated assessment models attempt to gain insight into the mechanisms that cause emissions, to understand their temporal development, the scope for policy interaction and the costs of measures to reduce emissions. This information is then combined with knowledge about the dispersion of pollutants in the atmosphere and estimates of the effects of pollution for a range of receptors (human health, ecosystems, etc.) originating from independent studies.

With this perspective it is clear that integrated assessment is not so much interested in emission data *per se*, but more in the various factors determining the quantity of emissions. Present integrated assessment models explain/calculate present and future emissions based on information on

- the rates of anthropogenic/economic activities (current and future) leading to emissions (**'activity rates'**),
- the physical, technical and economic properties determining the emission rates for a unit of a given activity in absence of emission controls (the **'unabated emission factors'**),
- the legal requirements for controlling emissions (the **'current legislation'**) for the various activities, i.e., to which extent it is required to reduce emissions from the various sources and how this is done in practice,
- the (autonomous) turnover of the capital stock and the size distribution of installations (the **'size and vintage structure'**) to quantify the impacts of a temporally phased emission control legislation and to estimate the (possible) penetration of cleaner technologies in the future, and
- information about the control options (the **'abatement technologies'**), i.e., their efficiency, costs, etc.

With these five categories of information, the RAINS model estimates the present contribution of the various source categories to national emissions in the various countries, how emissions from a source sector would develop over time given an exogenously specified pace of economic development, and to what degree emissions could be reduced in the future and at what costs. The information flow in these calculations is illustrated in Figure 3.

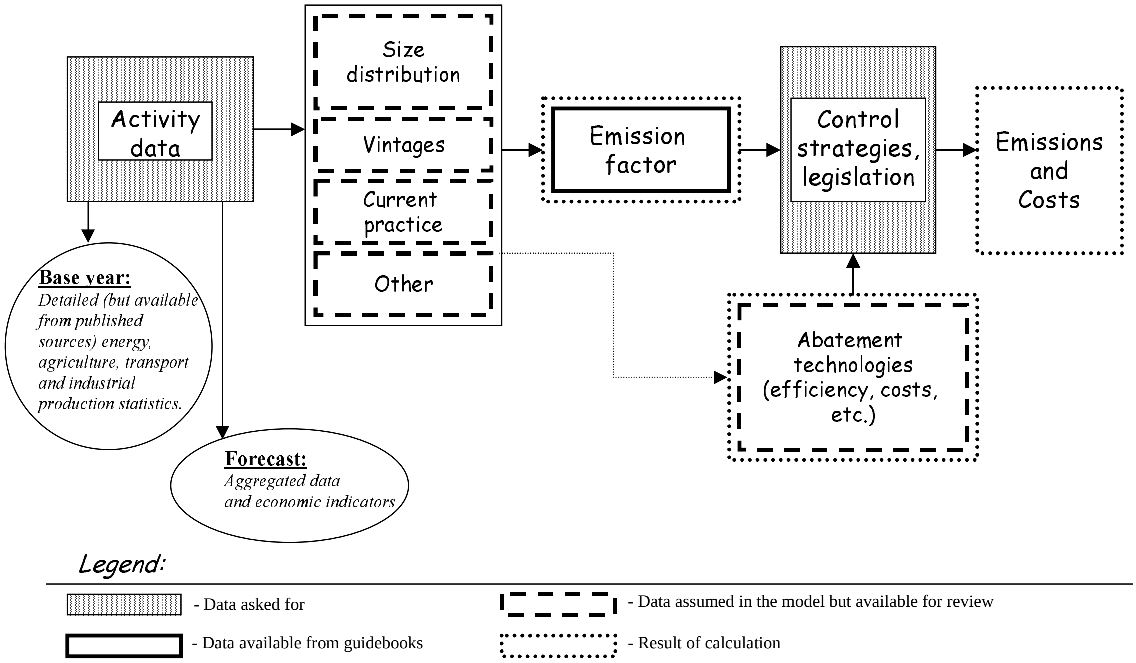

Figure 3: The general scheme for calculation of emissions and emission control costs in the RAINS model

As it is indicated in Figure 3, emission data are rather an output of an integrated assessment model (calculated from economic statistics, emission factors, technical information about emission control technologies, etc.) than an input to the model calculations. Therefore, from the perspective of integrated assessment modeling, there is a strong need for having access to nationally reported input data that explain emission levels. It might be worth mentioning that for compiling the databases on activity data and emission factors in the RAINS model information at the SNAP 2 level of the CORINAIR inventory was not found useful. Reported emission data are, however, essential for verifying the calculations of integrated assessment models, but they do not directly influence calculations.

The following paragraphs explain the elements of the calculations and the sources of background information.

Activity data

All calculations start from an exogenously specified database on activity rates, providing for each country and each economic sector the level of anthropogenic activities that cause emissions. One set of activity data is stored for the 'base year', taken from national and international statistics. For future years, usually alternative projections of economic development ('scenarios') are stored in the database, derived from national submissions or from specialized studies. The RAINS model stores activity data on energy consumption, agricultural activities, industrial production, traffic levels, etc. On one hand activity data reflect structural differences among countries leading to differences in emissions, and they indicate the possible future development of the national economies that may lead to changes in emissions.

Additional structural information

Unfortunately, published statistics and future projections of economic development that are the basis for the activity data provide only a relatively coarse sectoral detail, so that additional structural information is necessary to accurately estimate present and future emission levels. For this purpose the RAINS model contains databases on important structural features of the emission sources in a country, such as the characteristic size distribution of emission sources, the age structure (vintages of plants), about current practices of emission controls and others (driving patterns, applicability of control measures in agriculture, etc.). Wherever possible, this information is extracted from national statistics and sector specific studies. If no information was available, structural conditions of comparable countries were extrapolated.

Emission factors

While activity data and accompanying structural information are used to construct the levels of emission generating activities at the degree of detail that is required for accurate emission calculation, corresponding emission factors describe, for each of these activities, the typical release of emissions per unit of economic activity. These emission factors are usually country-specific (e.g., taking into account the characteristic fuel qualities), and they were derived from the Joint EMEP/CORINAIR guidebook (EEA, 2000). They were adapted to country-specific conditions based on nationally reported data contained in the CORINAIR 1990 inventory and supplied by national experts to IIASA in the course of the 1998 RAINS database review. In the RAINS model, these emission factors represent the hypothetical 'uncontrolled' emissions, i.e., as they would result in absence of any emission control measures. By multiplying activity rates and emission factors, the hypothetical level of 'unabated' emissions is then calculated by the model.

Emission control options

The RAINS model also contains databases about available options to control the emissions of the various pollutants. These databases distinguish the most relevant emission control options, their emission removal efficiencies and their costs, calculated for the characteristic conditions of a country. Data about technologies and about their costs were compiled by IIASA, based *inter alia* on information prepared by the UN/ECE Task Forces on Abatement Technologies. These databases were reviewed by national experts in the course of preparing the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone in 1998.

Emission control legislation

The RAINS model estimates emission levels and control costs for a given country based on the 'unabated' emissions that are calculated as described above and on information about the actual application of emission control measures in a given country. This database on control strategies describes for each emission source category the control measures that are required by legislation in a country. The database reflects the penetration of the available emission control options in the various economic sectors in the base year, and their future evolution over time as implied by the legislation that is presently decided. Information about national legislation is extracted from the UN/ECE Review of Policies and Strategies and supplemented by additional national and international (European Union) sources.

The description of the 'current legislation' is then used as a starting point for the search for cost-optimized emission control strategies aiming at the least-cost achievement of politically determined environmental targets. The optimization identifies for each country those measures (on top of current legislation) that would be necessary to achieve the environmental targets expressed, e.g., in terms of acid deposition or concentrations of ground-level ozone.

3.2 The Scope for Nationally Reported Data

The RAINS model, in its present implementation, contains a full data set with the above mentioned fields of information for all European countries covering the period from 1990 to 2010. These databases were constructed by IIASA from nationally submitted data (e.g., energy projections), from the Joint EMEP/CORINAIR guidebook (EEA, 2000) and the CORINAIR inventory databases (emission factors), from UN/ECE reports about emission control options and their costs (technology databases) and about the present state of emission control legislation in the various countries (based, *inter alia*, on the UN/ECE Review of Policies and Strategies).

In the ideal case an integrated assessment model like RAINS should be seen as a common language for seeking a cooperative cost-effective solution in an international context. In such a situation, the RAINS model would provide a framework for linking the information provided by the Parties to the Convention in a consistent and comparable way. The Center for Integrated Assessment Modeling would perform quality control and consistency checks of the national input data and it would conduct the necessary scenario analyses in co-operation with the other EMEP centres.

In practice, however, the diversity of information required for the RAINS databases is quite voluminous and it is a formidable task for national experts to provide all required information in an internationally consistent way. Experience shows most countries allocate limited resources for providing data on air pollution to international organizations, so that only concise and limited requests for data submission have chances for practical success. Fortunately, much of the required information is already available in other international databases or countries are requested to report similar information to other organizations (such as the European Union or the Framework Convention on Climate Change).

Keeping in mind the objective of the EMEP strategy paper to involve national experts to the maximum possible extent while maintaining transparency of all databases and model calculations, a two track concept was designed to facilitate the input of national input data into the RAINS databases:

- One line of action specifies the **key national input data** that have the largest influence on the overall model response in terms of required emission reduction. Such a data set of key input data should be limited in volume, so that there is a practical chance that national experts find the possibility to provide quality data. Submission of national data should be further facilitated by supplying information on from where statistical information on such key input parameters can be usually derived, or by aligning with international reporting obligations (e.g., for the UNFCC Convention, EUROSTAT, etc.).

- While national experts are encouraged to provide such key input data, the integration team at the Center for Integrated Assessment Modeling will compile **all other detailed data sets** based on other official UN/ECE documents, literature review, expert judgment and by extrapolating experience from other countries. For maximum transparency, all databases will be made available on the Internet, so that national experts can review them and suggest improvements if they wish so. Parties are welcomed to provide the full data set describing their situation. Data would be subject to quality control and consistency checks at the EMEP Center for Integrated Assessment Modeling.

The remainder of this Section introduces a set of key input data that were identified by the developers of the RAINS model as having the largest influence on model results.

3.3 A Set of Key Input Data

Out of the five types of input data listed in Figure 3, insight from national experts about the country-specific situations is most crucial for (present and future) activity data. Default data on the structure of emission sources (age distribution, size distribution, etc.) can be derived from the present RAINS databases as well as from a series of specialized analyses (e.g., Hein *et al*., 1994; ERM, 1996) and international statistics. General information about emission factors is provided in the Joint EMEP/CORINAIR guidebook, country-specific details can be extracted from the existing CORINAIR databases. Information on emission control options and their costs was collected by the UN/ECE Task Forces on NO_x and VOC control. The ongoing work at the JRC-IPTS in Sevilla on the IPPC BAT-REF notes will provide valuable further information. Legislation about air pollution control must be reported by countries in the context of the UN/ECE Review of Strategies and Policies.

In the ideal case, information about activity data would be most useful if the historical base year and projections for the future years were reported in the same data format. However, it is recognized that most projections of economic activities are usually available only at a highly aggregated level, so that a distinction is made between a more detailed key data set for the base year and a more aggregated data set for emission projections, restricted to some key economic indicators.

3.3.1 The Key Data Set for the Base Year

Data on Energy Use

The RAINS model describes the structure of energy consumption in a country in form of energy balances, specifying the consumption of 15 fuel types of 17 activity categories in eight economic sectors. Table 3.1 describes the fuel categories used in the RAINS database, the sectoral disaggregation of fuel consumption is provided in Table 3.2. Furthermore, the tables indicates typical data sources and specifies the relation to the UNFCCC data reporting format. It should be stressed that the RAINS data format is to a large extent a subset of the UNFCCC data reporting format; there are only few cases (coal grades, types of boilers) where more detailed information is necessary to calculate emissions and the control potential for 'conventional' pollutants such as SO_2, NO_x and VOC.

Table 3.1: Fuels distinguished in the energy database

Fuel type	***Data source***
Brown coal/lignite, two grades	National and international (e.g. IEA, OECD, UNECE, EUROSTAT) energy statistics as well as data sets reported to the UNFCCC based on the UNFCCC Guidelines on Reporting and Review (UNFCCC, 2000). The data on fuel consumption should be reported for each of the sectors listed in Table 2.2 below. This table includes also reference to the specific tables/sheets in the UNFCCC reporting format.
Hard coal, three grades	
Derived coal (coke, briquettes)	
Other solid-low S (biomass, waste, wood)	
Other solid-high S (incl. high S waste)	
Heavy fuel oil	
Medium distillates (diesel, light fuel oil)	
Light fractions (gasoline, kerosene, naphtha, LPG)	
Natural gas (incl. other gases)	
Renewable (solar, wind, small hydro)	
Hydro	
Nuclear	
Electricity	
Heat (steam, hot water)	
No Fuel use	

Table 3.2: Sectors distinguished in the energy database

Sector	***UNFCCC guideline reference***
Power Plants & distr. heat plants	**Table 1.A(a)/1a**
- Existing, wet bottom boilers	n.a.
- Existing, other	
- New	
Fuel production and Conversion (other than power plants)	**Table 1.A(a)**
- Combustion	Table 1.A(a)/1b,c
- Losses	n.a.
Industry	**Table 1.A(a)/2**
- Combustion in boilers	Table 1.A(a)/2a-f
- Other combustion	Table 1.A(a)/2a-f
- Process emissions	n.a.
Non-energy use (feedstocks)	**Table 1.A(d)**
Households and other (residential/commercial)	**Table 1.A(a)/4a-c**
Transport - Road	**Table 1.A(a)/3b**
- Cars, motorcycles, light duty trucks, 2-stroke	n.a.
- Cars, motorcycles, light duty trucks, 4-stroke	
- Heavy duty vehicles (trucks and buses)	
Transport - Other, land based (rail, inland water, mobile machinery)	**Table 1.A(a)/3c,e**
- Sources with 2-stroke engines	n.a.
- Sources with 4-stroke engines	
Maritime activities (seagoing ships operating within the coastal zone)	**Table 1.A(a)/3d**
Medium vessels	n.a.
Large vessels	n.a.

Data for Process Emissions

For calculating emission from non-energy related industrial processes, RAINS uses a limited set of indicators for industrial production (see Table 3.3). The table also specifies what activity rates are used and where they can be found with a specific reference to the UNFCCC tables.

Table 3.3: Sectors distinguished for process emissions

Sector	***Activity rate***	***Base year value***	***Unit***	***Typical data sources***	***UNFCCC guideline reference***
Oil refining	oil input to refinery		Mt	Data listed in column 'activity rate' can be found in national statistical yearbooks and in international statistics, e.g., UN Commodity Statistics, OECD Oil and Gas Statistics, EUROSTAT	Table 1.B.2/a
Coke production	coke output		kt		Table 2(I).C/1
Sintering	sinter output		kt		Table 2(I).C/1
Pig iron production	pig iron output		kt		Table 2(I).C/1
Non-ferrous metal smelting	copper, lead, zinc output		kt		Table 2(I).C/5
Sulfuric acid production	100% acid output		kt		n.a.
Nitric acid production	100% acid output		kt		Table 2(I).B/2
Cement and lime production	cement/lime output		kt		Table 2(I).A/1,2
Pulp and paper production	air-dried unbleached pulp output		kt		Table 2(I).D/1

Data on Agricultural Activities

Nearly all data needed in the agricultural (NH_3) module of RAINS are available from international statistical sources and are part of the UNFCCC data reporting format. For calculating NH_3 emissions, additional information about the shares of animals kept on different (slurry/solid) waste systems is essential, which can only be derived from national expert's knowledge.

Table 3.4: Additional data on agricultural activities

Activity	*Base year value*	*Unit*	*Typical data sources*	*UNFCCC guideline reference*
Dairy cattle - slurry waste system		10^3 heads	FAO, EUROSTAT, national statistics, CORINAIR as well as national experts	Table 4.A*)/1
Dairy cattle - solid waste system		10^3 heads		
Other cattle - slurry waste system		10^3 heads		Table 4.A/1,2
Other cattle - solid waste system		10^3 heads		
Pigs - slurry waste system		10^3 heads		Table 4.A/8
Pigs - solid waste system		10^3 heads		
Laying hens		10^3 heads		Table 4.A/9
Other poultry		10^3 heads		
Sheep		10^3 heads		Table 4.A/3,4
Horses		10^3 heads		Table 4.A/6,7
Fur animals		10^3 heads		Table 4.A/10
Fertilizer use - urea		kt N	IFA, FAO, national statistics as well as national experts	Table 4.D
Fertilizer use - other nitrogen fertilizers		kt N		
N-fertilizer production		kt N	FAO, UN commodity statistics, national statistics, CORINAIR	n.a.

*) - If no data reported in Table 4.A, similar information should be provided in Tables 4.B(a) and 4.B(b)

Additional Data for Volatile Organic Compounds

In order to estimate emissions of VOC there is a need to know production levels of several industrial branches, the use of solvent-based products in industry and households, and the amount of disposed waste (Table 3.5). Most of the required information can be extracted at least from international statistics, but some information will only be available from specialized studies or from industrial associations.

Table 3.5: Additional data for Volatile Organic Compounds

Activity	*Base year value*	*Unit*	*Typical data sources*	*UNFCCC guideline reference*
Oil production		Mt	UN Commodity Statistics, OECD, CORINAIR and national statistics.	Table 1.B.2/a
Gas production		Bcm		Table 1.B.2/b
Emissions from air traffic (LTO)		kt VOC	CORINAIR	n.a.
Production of passenger cars and light duty vehicles		10^3 veh.	WMCD, EUROSTAT (industry) and national statistics	n.a.
Production of trucks and busses		10^3 veh.		
Cars - total registration		10^3 veh.	WMCD, IRF and national statistics	n.a.
Cars - new registration		10^3 veh.		
Textiles cleaned (dry cleaning)		kt	Jourdan, Rentz 1991; EU, derived from CORINAIR	Table 3.B
Population		million	UN, national statistics	Table 6.A (add. info)
Use of paint - 'Do it yourself'		kt	CORINAR, Paint association, EU studies	Table 3.A
Use of paint - professional (architectural)		kt		
Use of paint - industrial		kt		
Use of paint - vehicle refinishing		kt	CORINAR, Paint association, EU studies, Hein *et al.*, 1994	
Solvent use - degreasing		kt	CORINAIR, national experts	Table 3.B
Solvent use - pharmaceutical industry		kt	CORINAIR, national studies , ENTEC	n.a
Solvent use - wood preservation, industrial roundwood treated		kt	FAO Forestry Statistics, UN Commodity Statistics, EUROSTAT (industry), CORINAIR, national statistics	n.a.
Printing inks - offset		kt ink	CORINAIR, national experts, national statistics	n.a.
Printing inks - publishing		kt ink		
Printing inks - packaging		kt ink		
Printing inks - screen printing		kt ink		

Activity	***Base year value***	***Unit***	***Typical data sources***	***UNFCCC guideline reference***
Paint production		kt	UN Commodity Statistics, CORINAIR, national statistics	n.a.
Ink production		kt		
Glue production		kt		
Adhesive tape production		kt		
Glue applied in industry		kt	CORINAIR	n.a.
PVC production		kt	UN Commodity Statistics, EUROSTAT (industry), CORINAIR, national statistics	n.a.
Rubber production (split into synthetic and tires)		kt / 10^6 tyres		n.a.
Polystyrene production		kt		n.a.
Ethylene production		kt		Table 2(I).B/5
Propylene production		kt		n.a.
Polyethylene - LD production		kt		n.a.
Polyethylene - HD production		kt		n.a.
Polypropylene production		kt		n.a.
Vinylchloride production		kt		n.a.
Emissions - storage in organic chemical industry		kt VOC	CORINAIR	n.a.
Emissions - other use of solvents in industry *)		kt VOC	CORINAIR	n.a.
Steel production		kt	UN Commodity Statistics, EUROSTAT (industry), CORINAIR, national statistics	Table 2(I).C/1
Asphalt production and use (split into roofing and paving useful)		kt		Table 2(I).A/5,6
Carbon black production		kt		Table 2(I).B/5
Bread production		kt		Table 2(I).D/2
Beer production		kt		
Wine production		kt		
Spirits production		kt		
Industrial waste disposal - landfills		kt	national statistics	Table 6.A
Municipal waste disposal - landfills		kt		
Other waste disposal		kt		
Agricultural residues burned		kt	national statistics	Table 4.F

*) - Several activities included: textile finishing, leather tanning, asphalt blowing, edible oil extraction, use of agrochemicals

Data for Primary Emissions of Particulate Matter

According to present thinking, the activity data listed above are sufficient for estimating at least the majority of particulate matter (PM) emissions. Further research may identify additional sources with relevant contributions to total national PM emissions.

3.3.2 Key Input Data for Emission Projections

As mentioned above, the RAINS model uses essentially the same internal data structure for estimating present and future emissions. Experience shows, however, that in many cases projections of future economic activities are only available at a much more aggregated level than it is used to estimate emissions in the base year. Therefore, the RAINS model contains the same data entries as described in Section 3.3.1 also for all future time steps and uses these activity data for estimating future emissions. However, due to the fact that in many cases some of these detailed projections are not readily available, a key data set for projections was developed to describe the overall economic development trend based on a limited number of key economic indicators. From these key projection data, the standard data are constructed based on a number of default assumptions. Historical data enable the verification of the detailed submissions and calibration of the default assumptions.

The key indicator set includes general assumptions on the gross domestic product (GDP) in constant prices of year 1990, gross electricity production, export-import balance of electricity, and population (Table 3.6).

Table 3.6: General assumptions in the reported scenario

Parameter	***Unit***	***Year***				
		1990	1995	2000	…	2020
Gross domestic product						
Gross electricity production						
Export-import balance of electricity						
Population						

Notes: export-import balance = export minus import

In addition, more detailed information on some key indicators are useful to derive more precise estimates for future years. Such information includes energy consumption in some of the key economic sectors according to the format of Table 3.7, road transport activities (vehicle mileage by category and fuel, Table 3.8), livestock numbers (cattle, pigs, poultry, etc.), fertilizer use (Table 3.9) and production indices for some important industrial branches (Table 3.10).

Table 3.7: Primary energy consumption for sector … (indicate relevant sector or SNAP 1 category) in the reported scenario [PJ]

Fuel	***Year***				
	1990	1995	2000	…	2020
Hard coal					
Brown coal					
Natural gas					
Heavy Fuel oil					
Other liquid fuels [1)] *gasoline* *liquid petroleum gas (LPG)* *diesel* *compresses natural gas (CNG)*					
Biomass (fuelwood)					
Other solid fuels					
Nuclear					
Hydro					
Renewables (solar, wind)					

[1)] the split is only necessary for road transport

Table 3.8: Road transport in the reported scenario

Vehicle category	***Unit***	***Year***				
		1990	1995	2000	…	2020
Total cars *(of which):*	10^6 veh-km/a					
Gasoline and LPG						
Diesel						
Gas (CNG)						
Total light duty vehicles (LDV) *(of which):*	10^6 veh-km/a					
Gasoline and LPG						
Diesel						
Gas (CNG)						
Total heavy duty vehicles (HDV) *(of which):*	10^6 veh-km/a					
Gasoline and LPG						
Diesel						
Gas (CNG)						

Notes:
LDV - vehicles with gross vehicle weight (GVW) below 3.5 t.
HDV - vehicles with gross vehicle weight (GVW) above 3.5 t.
LPG - liquid petroleum gas
CNG - compressed natural gas

Table 3.9: Agriculture in the reported scenario

Category	*Unit*	*Year*				
		1990	1995	2000	…	2020
Dairy cattle	10^3 heads					
Other cattle	10^3 heads					
Pigs	10^3 heads					
Poultry	10^3 heads					
Sheep and goats	10^3 heads					
N-fertilizer use[1)]	10^3 t N (%)					
N-fertilizer production	10^3 t N					

[1)] Indicate the share of urea in percent

Table 3.10: Activities in major economic sectors in the reported scenario [index, value added in 1990=100]

Sector	*NACE Rev1*[1)]	*Year*				
		1990	1995	2000	…	2020
Industrial production	C-F	100				
Extraction of crude petroleum and natural gas	C.11	100				
Manufacture of food products and beverages	D.15	100				
Manufacture of textiles and leather products	D.17-19	100				
Manufacture of pulp, paper and paper products	D.21	100				
Publishing, printing	D.22	100				
Manufacture of chemicals and chemical products	D.24	100				
Manufacture of rubber and plastic products	D.25	100				
Manufacture of cement, lime and plaster	D.26.5	100				
Manufacture of basic iron and steel and ferro-alloys	D.27.1	100				
Manufacture of basic precious and non-ferro metals	D.27.4	100				
Manufacture of fabricated metal products, except machinery and equipment	D.28	100				
Manufacture of motor vehicles, trailers and semi-trailers	D.34	100				

[1)] EU standard statistical nomenclature for economic activities (NACE). Revision 1 was adopted in Council Regulation (EEC) No 3037/90 of October 1990.

For future years the accuracy of emission projections depends crucially on the quality of information about the planned implementation of emission control legislation. Such information is routinely reported by Parties as part of the UN/ECE Review on Policies and Strategies. A modification of the data format of these reporting guidelines to better match the needs of emission projection activities might be considered in the future.

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