EMISSION PROJECTIONS

CONTENTS

1 GENERAL

1.1 Introduction

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

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

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

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

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

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

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

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

1.2 Projections: current reduction plans and baseline scenarios

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

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

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

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

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

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

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

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

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

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

1.3 UN/ECE-CLRTAP expert panel on projections

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2 GENERAL APPROACH FOR EMISSION PROJECTIONS

2.1 Main existing approaches

The main approaches used for preparing emission projections can be divided into two classes:
- socio-economic,
- technology based.

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

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

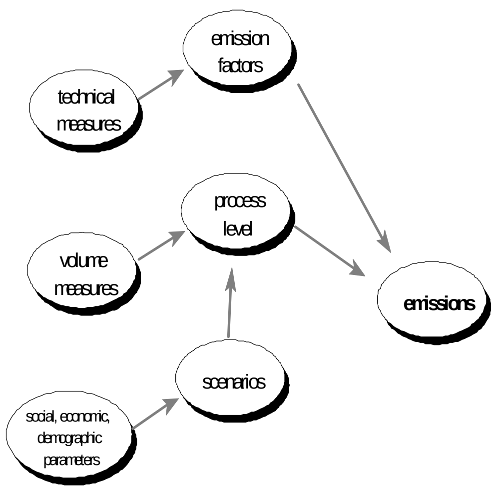

Figure 1 From economic scenarios and environmental policy to emission projections

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

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

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

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

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

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

2.2 The basic formula (emission factor approach)

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

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

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

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

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

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

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

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

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

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

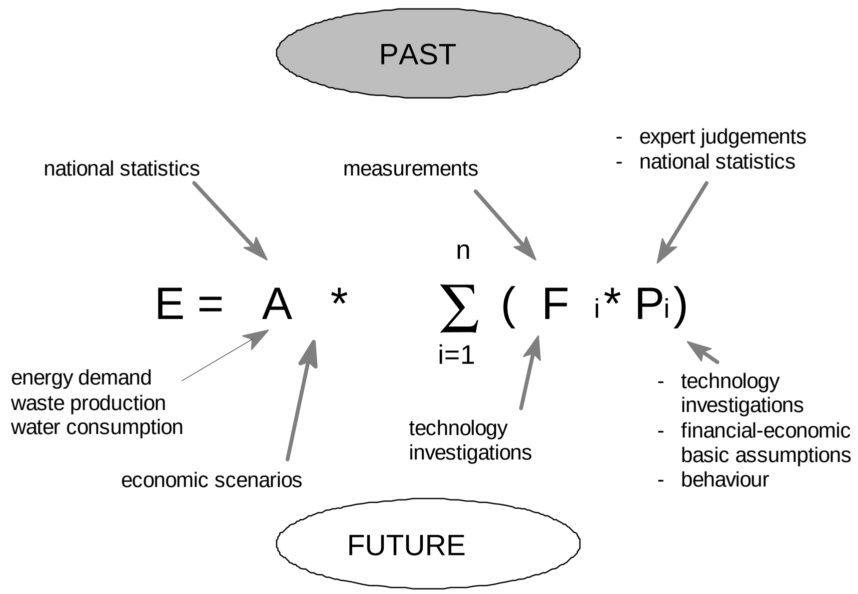

Figure 2 The fundamental formula for emission calculations and its application in inventories and projections

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

2.3 The link between inventories and projections

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

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

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

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

2.4 Scenarios (future trends of activity rates)

2.4.1 Introduction

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

General scenarios for international development

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

National economic scenarios

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

Scenarios on a process level (CORINAIR SNAP level 3)

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

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

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

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

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

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

2.4.2 General socio-economic factors

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

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

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

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

Table 1 Available projections for general socio-economic factors

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

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

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

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

2.4.3 Energy and waste scenarios

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

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

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

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

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

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

2.5 Environmental policies

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

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

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

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

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

2.6 Emission factors

2.6.1 Quality of emission factors

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

2.6.2 Aggregation Level of Sources

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

2.6.3 Emission factors on technology level

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

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

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

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

Examples of these process/technology related emission factors are:

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

2.6.4 Emission factors on sectoral level

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

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

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

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

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

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

Assumptions on the penetration rate P

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

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

Relate EF to another activity rate (A)

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

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

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

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

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

2.7 Penetration of technologies or changes in behaviour

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

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

Examples of the issues mentioned are:

- What is the potential emission reduction of certain technologies?

  For example the technology can be assumed to penetrate up to 100%, unless this is technically impossible. In this case, the technical measures to be taken are clear, but this kind of projection of penetration also shows the result of the policy with the assumption every actor actually follows this policy.
- What will be the effect of financial and other policy instruments on emissions (penetration)?

  Environmental taxes or energy taxes could be examples. They will have effect on the decisions of different consumers to invest in energy conservation or pollution reduction. If some criteria can be developed (i. e. for the rate of return) the actual penetration might be calculated.
- What will be the emissions in a future year based on the actual policy, supported by a certain budget for inspection (compliance)?

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

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

2.8 Other aspects

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

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

2.9 Future perspectives

2.9.1 Sources of emissions

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

2.9.2 Integrated Approach

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

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

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

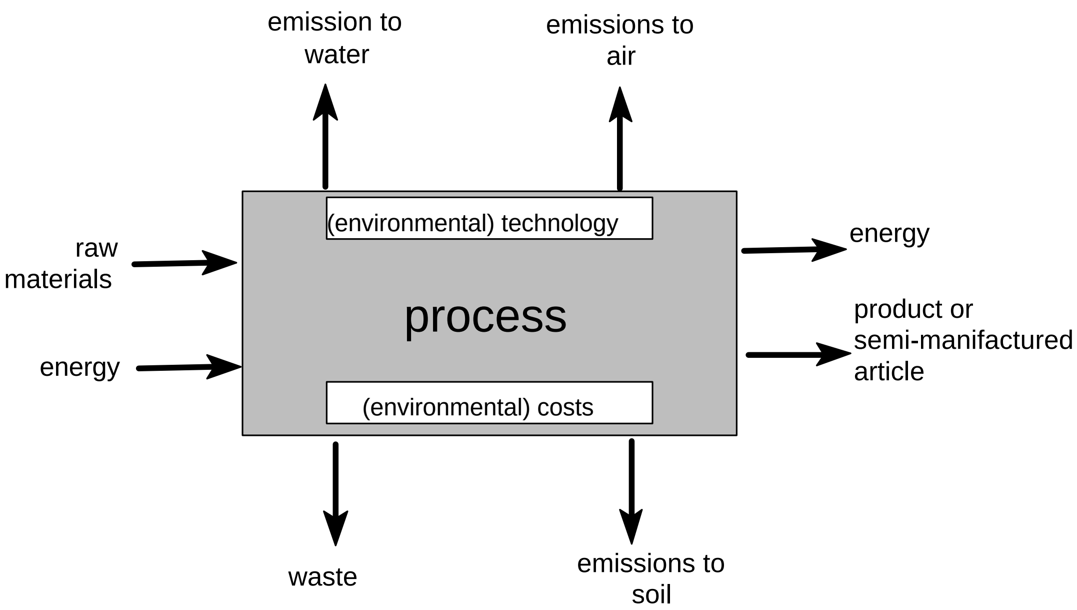

Figure 3 A schematic approach for production (and consumption) processes

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

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

2.10 Physical growth and monetary growth

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

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

2.11 Release version, data and source

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Source: André Jol
European Environment Agency
Kongens Nytorv 6,
DK-1050 Copenhagen, Denmark
phone +45 33 36 71 00
fax +45 33 36 71 99
e-mail andre.jol@eea.eu.int

With support from: Olav-Jan van Gerwen
RIVM
P.O. Box 1
NL-3720 BA Bilthoven, The Netherlands
phone +31 30 274 3850
fax +31 30 274 4435
e-mail olav-jan.van.gerwen@rivm.nl

3 INTRODUCTION TO SECTORAL PROJECTIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.1 Activities included

This chapter covers emissions related to energy use:

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

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

4.2 General description

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

4.3 Simple methodology

4.3.1 Assumptions

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

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

Energy projections, for example the RAINS OEP (official energy pathways, UNECE) scenario are available. An example of such a projection for the year 2010 is summarised in table 4.2.
The emission projection should be made using the basic equation

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

with

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

4.3.2 Projected activity rate changes (energy scenarios)

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

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

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

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

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

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

4.3.3 Technological development: emission factors

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

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

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

4.3.4 Policy development: penetration

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

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

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

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

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

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

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

4.4 Detailed methodology

Not yet developed.

4.5 Weakest aspects/priority areas for improvements in current methodology

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

4.6 Additional comments

No additional comments are given.

4.7 Verification procedures

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

4.8 References

See general references (paragraph 10).

4.9 Bibliography

See also general bibliography (paragraph 11).

4.10 Release version, data and source

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Source: Tinus Pulles
TNO Institute of Environmental Sciences, Energy Research and Process Innovation
Laan van Westenenk 501
PO Box 342
7300 AH Apeldoorn, The Netherlands
phone +31 55 549 3762
fax +31 55 549 3252
e-mail M.P.J.Pulles@mep.tno.nl

With support from:

Niels Kilde
Risoe National Laboratory
P.O. Box 49
DK-4000 Roskilde, Denmark
Phone +45 46775136 (direct)
Fax +45 46775199
e-mail Niels.Kilde@risoe.dk

5 INDUSTRIAL PROCESSES (SNAP 04 and 05)

SNAP CODE **04-05**

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

5.1 Activities included

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

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

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

5.2 General description

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

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

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

5.3 Simple methodology

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

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

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

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

5.4 Detailed methodology

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

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

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

5.5 Weakest aspects/priority areas for improvements in current methodology

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

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

5.6 Additional comments

No additional comments are given here.

5.7 Verification procedures

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

5.8 References

See general references (par. 10).

5.9 Bibliography

See general bibliography (par. 11).

5.10 Release version, data and source

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Source:
Thomas Holtmann
French-German Institute for Environmental Research
Hertzstr. 16
D - 76187 Karlsruhe
Tel.: +49 721 608 4406,
Fax: +49 721 758909
e-mail: thomas.holtmann@wiwi.uni-karlsruhe.de

6 SOLVENT AND OTHER PRODUCT USE (SNAP 06)

SNAP CODE: 06

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

6.1 Activities included

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

6.2 General description

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

6.3 Simple methodology

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

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

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

6.4 Detailed methodology

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

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

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

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

6.5 Weakest aspects/priority areas for improvements in current methodology

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

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

6.6 Additional comments

No additional comments are given here.

6.7 Verification procedures

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

6.8 References

See general references (par. 10).

6.9 Bibliography

See general bibliography (par. 11).

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Source: Thomas Holtmann
French-German Institute for Environmental Research
Hertzstr. 16
D - 76187 Karlsruhe
Tel.: +49 721 608 4406,
Fax: +49 721 758909
e-mail: thomas.holtmann@wiwi.uni-karlsruhe.de

7 TRANSPORT (SNAP 07 and 08)

SNAP CODE 07-08

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

7.1 Activities included

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

7.2 General description

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

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

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

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

7.2.1 Road Transport

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

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

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

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

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

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

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

7.2.2 Aircraft

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

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

7.2.3 Shipping

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

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

7.2.4 Other Sources

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

7.3 Simple methodology

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

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

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

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

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

Future fuel prices

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

With these statistics calculations can be made of transport volumes:

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

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

Future Aircraft movements

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

Future Shipping movements

This is similar to aircraft movements.

Future Rail transport (passengers and freight)

Also similar to aircraft (and shipping) movements.

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

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

where	$N_{y} =$	Number of vehicles in the fleet in year y
	$n_{y-1,i} =$	Number of vehicles in fleet in year y-1 of age i
	$s_{i} =$	Fraction of vehicles of age I scrapped
	$E_{y} =$	Number of new vehicles entering fleet in year y

7.4 Detailed methodology

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

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

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

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

The activity statistics that are needed are:

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

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

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

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

Future fuel prices

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

With these statistics calculations can be made of transport volumes:

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

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

Future Aircraft movements

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

Future Shipping movements

> This is similar to aircraft movements.

Future Rail transport (passengers and freight)

Also similar to aircraft (and shipping) movements.

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

7.5 Weakest aspects/priority areas for improvements in current methodology

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

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

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

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

7.6 Additional comments

No additional comments are given here.

7.7 Verification procedures

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

Furthermore consistency should be checked between energy and transport scenarios.

7.8 References

See general references (par. 10).

7.9 Bibliography

See general bibliography (par. 11).

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Source:
S. Eggleston
National Environmental Technology Centre
Culham, Abingdon
UK - Oxfordshire, OX14 3DB
tel.: + 44-1235-46-3101
fax. + 44-1235-46-3005
simon.eggleston@aeat.co.uk.

8 WASTE TREATMENT (SNAP 09)

SNAP CODE: **09**

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

8.1 Activities included

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

8.2 General description

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

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

8.3 Simple methodology

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

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

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

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

8.4 Detailed methodology

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

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

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

8.5 Weakest aspects/priority areas for improvements in current methodology

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

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

8.6 Additional comments

No additional comments are given here.

8.7 Verification procedures

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

8.8 References

See general references (par. 10).

8.9 Bibliography

See general bibliography (par. 11).

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Source:
Thomas Holtmann
French-German Institute for Environmental Research
Hertzstr. 16
D - 76187 Karlsruhe
Tel.: +49 721 608 4406
Fax: ++49 721 758909
e-mail: thomas.holtmann@wiwi.uni-karlsruhe.de

9 AGRICULTURE (SNAP 10)

SNAP CODE: 10

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

9.1 Activities included

This section covers the following agricultural sources:

10 01 Cultures with fertilizers (except animal manure)

10 02 Cultures without fertilizers

10 03 On field burning of stubble, straw, etc

10 04 Enteric fermentation

10 05 Manure management

10 06 Use of pesticides

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

9.2 General Description

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

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

9.2.1 Emissions from fertilizer use

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

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

9.2.2 Emissions from livestock

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

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

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

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

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

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

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

9.3 Simple methodology

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

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

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

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

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

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

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

9.4 Detailed methodology

Not yet developed.

9.5 Weakest aspects/priority areas for improvements in current methodology

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

9.6 Additional comments

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

9.7 Verification procedures

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

9.8 References

European Fertilizer Manufacturers Association (EFMA) (1997) Forecast of fertilizer consumption in EFMA countries to 2006/7.

Lampe, M von (1997) The Model Family developed and implemented at IAP, Eurostat and EuroCARE. Paper presented at the Workshop on Agricultural Projections, London, September 1997.

See also general references (par. 10).

9.9 Bibliography

See general bibliography (par. 11).

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Source:
David Cowell
Imperial College Centre for Environmental Technology
48 Prince's Gardens
London SW7 2PE
Tel: +171 594 9296
Fax: +171 581 0245
Email: D.Cowell@ic.ac.uk

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Annex 1A DEFINITIONS

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

activity rate

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

baseline scenario

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

current reduction plan

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

current legislation

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

emission factor

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

emission inventory

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

emission projection

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

penetration factor

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

policy in the pipeline

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

socio-economic scenario (future societal trend)

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