

Supporting Spain's national emission projections with the EmiPro tool

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ABSTRACT

The “Universidad Politécnica de Madrid” (UPM) has recently finished the first stage of the SEP (Spain's Emission Projection) project, under contract with the Ministry of Environment of Spain. In order to evaluate the alternatives to improve Air Quality, yearly emissions up to 2020 have been projected under several scenarios, compatible with the CAFE (Clean Air For Europe) program methodology.

Such a study involves the future emission assessment for all the sources taken into account in the National Emission Inventory (NEI) at the lowest level. The SEP methodology provides a flexible framework to project emissions and allows the consideration of very-specific hypotheses for each activity. In order to assure national emission projections consistency, it is indispensable to develop methods to assure that individual projections are compatible. That is, there is no contradiction in trends or particular values for the variables involved in projection estimation at activity level, and therefore, they can be merged in a fully consistent way.

EmiPro is a piece of software designed to implement SEP's methods. It is intended not only to support the projections QC/QA, but also to assure consistency with the NEI database. In addition, it includes a set of utilities for organizing the work and for reporting to the Ministry.

This paper summarizes the methodology of the SEP project and provides a brief insight into the design, capabilities and utilities implemented in the EmiPro tool

INTRODUCTION

Emission projections are more and more an essential tool to support environmental policy design and decision making. It has been recognized for a long time that efficient air pollution policy can only be based on quantitative information on both current and future emissions of pollutants [1]. In fact, national emission projections have become a compulsory requirement for European Union member states as input to the CAFE (Clean Air For Europe) program [2]. CAFE is a program of technical analysis and policy development which will lead to the adoption of a thematic strategy on air pollution under the Sixth Environmental Action Programme (expected to be finished by mid 2005). Its aim is to develop a long-term, strategic and integrated policy advice to protect against significant negative effects of air pollution on human health and the environment.

The quality of Emission Inventories has considerably increased in the last years due to the important efforts made in the compilation of technology-based emission factors and activity data and the development of more robust estimation methodologies, like those of EMEP/CORINAIR [3], IPCC [4] or US EPA [5]. To some extent these enhancements have also reached the field of forecasts or projections of future emissions, both in Europe [6], [7], [8] and the USA [9], [10].

However, there is still a lack of clearly stated procedures and methodologies for making national emission projections suitable for international information requirements and fully consistent with national emission inventories. The SEP (Spain's Emission Projections) project is intended to fill this gap in the Spanish case [11]. This project was jointly initiated by Spain's Ministry of Environment and the Technical University of Madrid and has the aim to provide sound information regarding projections of air pollutants under the Kyoto Protocol and the Geneva Convention.

BACKGROUND

Some relevant information for understanding the design of the SEP project and the EmiPro tool is summarized under this epigraph.

Spain's National Emission Inventory

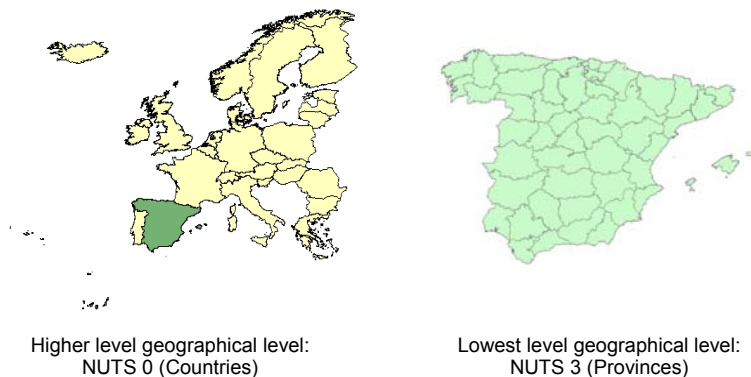
Spain's National Emission Inventory [12], [13] is based in the CORINAIR methodology [3]. It uses the associated nomenclature called SNAP (Selected Nomenclature for Air Pollution), developed as part of the CORINAIR project and harmonized with the nomenclature included in the IPCC/OECD (the Intergovernmental Panel on Climate Change and the Organization for Economic Co-operation and Development) and with that of the EMEP (European Modeling and Evaluation Program) of the United Nations Economic Commission for Europe (UNECE). This classification has a structure based on the following three level hierarchy: Group, Sub-group, and Activity.

- The highest level, **Group**, comprises of 11 divisions reflecting the largest categories of anthropogenic and natural activities.
- The middle level, **Sub-group**, divides the previous level into 76 classes reflecting the structure of the emission-producing activities in accordance with their technological and socio-economic specifications.
- The most disaggregated level, **Activity**, includes the core activities and those of some sub-groups (16) which do not appear disaggregated in activities. In total, SNAP-97 incorporates 414 core activities which, together with the 16 sub-groups without any further breakdown into activities, add up to 430 emitter activities/sub-groups.

It should be borne in mind that this classification does not follow a purely economic or technological criterion, but is rather the result of a merger of both. Each level is identified by a 2-digit code, so every activity has a unique 6-digit code.

The inventory is calculated in a yearly basis. As for the spatial resolution, the geographical reference is provided by the European Statistical Office through the European administrative classification (NUTS, Nomenclature of Territorial Units for Statistics). This is a hierarchical classification scheme with 4 levels, whose higher and lowest level for the Spanish case are illustrated in Figure 1. European national inventories are disaggregated at level 3.

Figure 1. Administrative division



Legislative aspects

There are two fundamental references that determine the conception of the SEP project and the design of EmiPro. Firstly, the Kyoto Protocol, which entered into force in February 2004. According to Spain's ratification of the Protocol [14], it is legally bound to achieve its targets for green house gases emissions for the first period of compromise (2008-2012). The individual target

for Spain inside the European bubble is not to increase the emission level of CO₂ equivalent over a +15% in respect to the Protocol base-year emissions, as shown in Table 1. All the GHG emissions released in the national territory are accounted for the Protocol. The Protocol allows the parties to take advantage of the so-called “flexibility mechanisms”, but as far as the SEP project is concerned, they are not taken into account. That means that the Target scenario regarding GHG emissions is introduced when the emission level according to the Base scenario is greater than the +15% threshold.

Table 1. Kyoto Protocol base year GHG emissions and emission target for Spain.
All figures are in kt of CO₂ equivalent.

Year	CH ₄	CO ₂	N ₂ O	HFC	PFC	SF ₆	Total
1990	31982	224471	26465				282918
1995				4645	790	94	5529
Total Kyoto Protocol Base Year							288447
Spain's Kyoto Protocol Target for the first period of compromise (assumed 2010)							331715

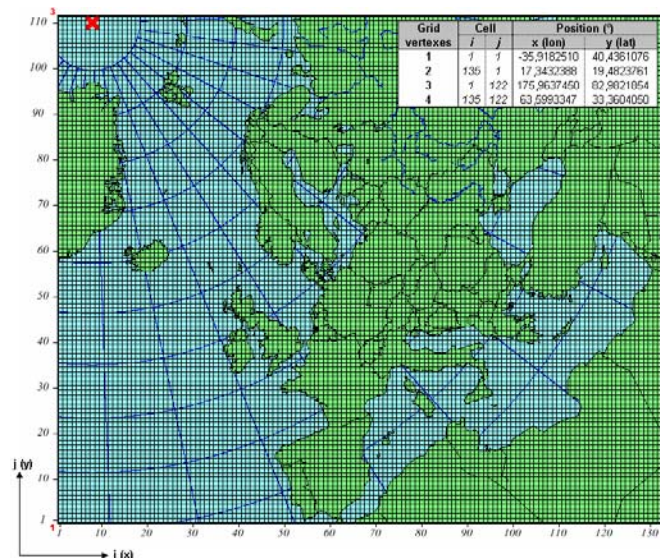
Secondly, there is the European Union National Emission Ceiling Directive [15], (hereinafter NEC Directive). This Directive is intended to reduce the emission of acidifying, eutrophying and photochemical air pollutants precursors across Europe. In order not to exceed the critical loads previously calculated, each EU Member State is bound to a specific emission level of NO_x, SO₂, NMVOC and NH₃ in 2010. The values assigned to Spain for that date are shown in Table 2.

Table 2. Spain's National Emission Ceilings for 2010

Pollutant	Emisión (kt)
SO ₂	746
NO _x	847
NMVOC	662
NH ₃	353

In the case of the NEC, only anthropogenic emissions are computed, so emissions from SNAP group 11 (nature) and the NMVOC from group 10 (agriculture) are not taken into account. Moreover, the Directive is only applicable for the territories inside the EMEP grid [16], illustrated in Figure 2. In the Spanish case, that implies that the emissions from the Canary Island (NUTS-3 administrative unit) are not affected by the NEC Directive

Figure 2. EMEP 50x50 grid system.



THE SEP PROJECT

Aim and scope

The aim of the SEP project is the development of useful information for policy decisions within the atmospheric pollutant emission field. The main objectives are:

- To obtain emission projections for the period 2001-2020.
- To determine possible future scenarios
- To estimate the efficiency of the adopted measures in each scenario
- To evaluate the fulfilment of the Directives and the Protocols

The considered activities are all those included in the most up-to-date version (SNAP 97) of the SNAP nomenclature. The 2000 National Emission Inventory edition accounts for 282 SNAP activities.

The pollutants considered are those included in:

- The **Geneva Convention**: Sulphur oxides (SO₂+SO₃), measured as mass of SO₂, Nitrogen oxides (NO+NO₂), measured as mass of NO₂, Ammonia (as mass of NH₃), Volatile organic compounds except methane (NMVOC), Carbon monoxide (as mass of CO), Particles (as TSP, PM₁₀ and PM_{2.5}), Lead and its solid and gaseous compounds (as mass of Pb), Cadmium and its solid and gaseous compounds (as mass of Cd) and Mercury and its solid and gaseous compounds (as mass of Hg).
- The **Kyoto Protocol**: Carbon dioxide (as mass of CO₂), Methane (as mass of CH₄), Nitrous oxide (as mass of N₂O), Perfluorocarbons (as mass of PFC for the CORINAIR inventory; in the latter case each individual compound is weighted according to its global warming potential), Hydrofluorocarbons (as mass of HFC for the CORINAIR inventory; in the latter case each individual compound is weighted according to its global warming potential) and Sulphur hexafluoride (as mass of SF₆).

It is important to highlight that this project is not intended to forecast future emission levels, but to discuss alternatives in order to evaluate the possible emission levels under several scenarios. On the other hand, the projections do not try to forecast the evolution of the activity rates either. The methodology developed allows the integration of prospective studies and official planning available for all the sectors covered in the study in a consistent way.

Methodology

As mentioned earlier, Spain's National Emission Inventory is the main reference regarding the procedures to estimate emissions. Therefore, the way in which a particular activity is addressed determines the typology of the different projections, usually, following the same approach used in the Inventory (bottom-up or top-down, sources of information, etc.). This feature ensures the consistency with the historical data set.

In consequence, the detail and type of projection vary widely, depending on the basic methodology, the relevance of each activity and the information available. Basically the projections are made on yearly, national basis for each SNAP activity, corresponding to the third hierarchical level of this classification, that is, at the highest possible detail. Regardless of the method used, all the projections are reduced to either one of the two following simple algorithms:

$$\text{Equation (1)} \quad E_i = A_i \cdot FE_a \cdot \prod_{j=1}^n FC_j$$

$$\text{Equation (2)} \quad E_i = G_{a-i} \cdot E_a \cdot \prod_{j=1}^n FC_j$$

where

- E_i – Pollutant emission for year i
- E_a – Pollutant emission for year a (base year, 2000)
- A_i – Rate activity for year i
- FE_a – Pollutant Emission Factor for the base year
- G_{a-i} – Emission Growth Factor between years a and i
- FC_j – Control Factors; that can be expressed as:

$$\text{Equation (3)} \quad FC_j = 1 - R_j \cdot p_j$$

where

- R_j – Abatement per j measure (technology, legislation, etc) as the index of emission factor reduction respect the base year [0, 1]
- p_j – Penetration of j measure [0, 1]

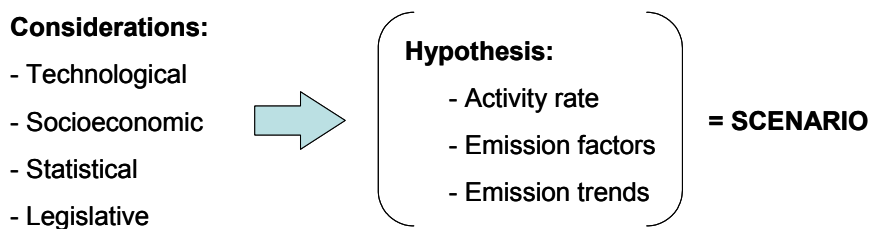
First type of estimates is based on the yearly rate of underlying activities, whilst the second type is based on the emissions of the previous year. The first type is used whenever possible, and the use of common activity rates and factors throughout the estimates is a way to ensure the consistency of the results.

This reduction to a common basis allows an establishing of a unified methodology for the storage and treatment of results and makes it easier to assure the uniformity and compatibility between the outputs. On the other hand, it complies with the methodological framework of other emission projections' studies [7], [8], [9], [10]. Furthermore, this formulation fits in with the flexibility required in the projection method, so that it is possible to include later variations in whatever aspect is necessary.

Scenarios

Considering the equations shown above, for a given activity there could be as many projections as combinations of hypotheses regarding the values of each of the factors involved in the algorithms. These values arise as a result of a series of considerations about different issues that somehow influence the emissions for the future years. The set of hypotheses assumed for all the factors involved in the algorithms determines a scenario, as illustrated in Figure 3.

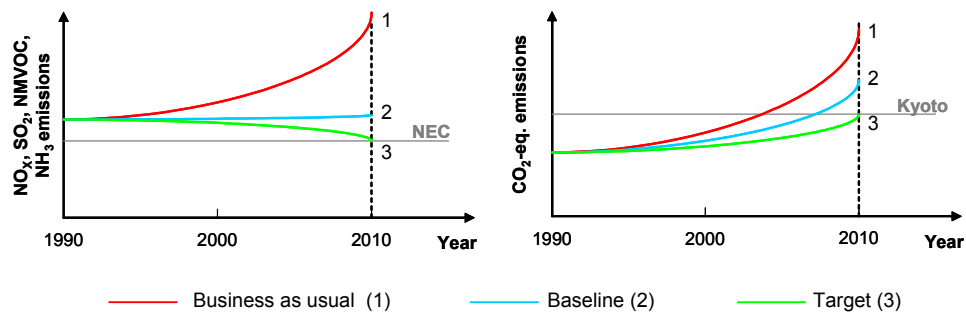
Figure 3. General scenario definition scheme



In order to standardize the procedure to define specific activity hypothesis and assure global consistency, three different types of scenarios have been identified to reflect three hypothetical situations that are interesting from the air quality management and decision making point of view. These scenarios are the following:

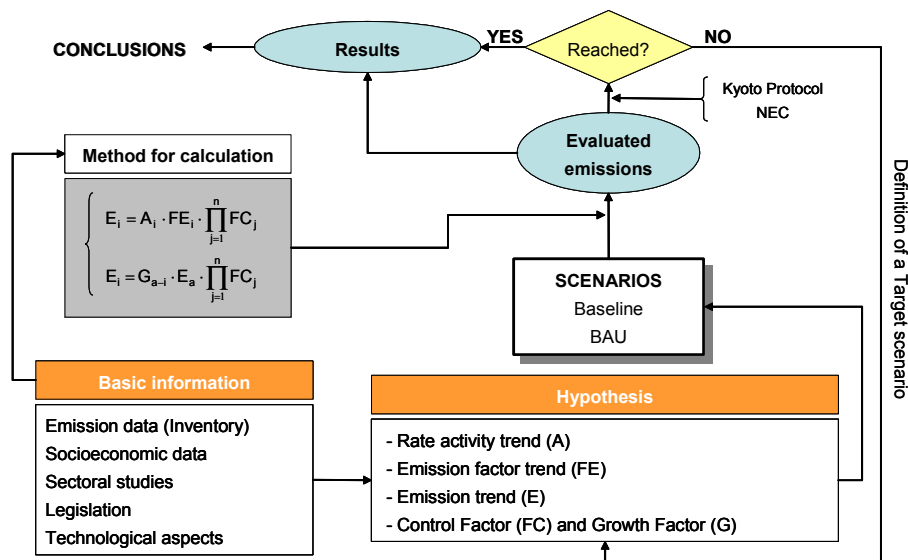
- **Business as usual (Tendencial).** The business as usual scenario uses statistical methods to project emissions, activity rates and/or emission factors, taking into consideration data exclusively from the past but not considering any additional future measures that might have an impact on these emissions.
- **Baseline (Base).** The baseline scenario is intended to provide national emission projections according to the baseline scenario under the Clean Air for Europe Programme. This scenario has been defined taking into consideration all sectoral plans and measures enacted and in force published by official organizations. Hence, it is supposed to be the most likely scenario.
- **Target (Objetivo).** The target scenario incorporates some additional measures to the baseline scenario (measures intended for the fulfilment of Spain's commitments under the National Emission Ceilings Directive and the Kyoto Protocol). These measures are based on the technical references available for each sector, as for instance, the documents prepared by the Expert Group on Techno Economic Issues (EGTEI) [17]. This scenario may also include assumptions about alternative activity rate evolution patterns.

Figure 4. Schematic representation of typical emission patterns under the SEP's scenarios.



The logical sequence followed in the definition of scenarios at activity level is shown in Figure 5. It must be noted that the Target scenario is introduced only when the emission level associated to the Baseline scenario in 2010 is higher than the reference assigned to a particular activity as an index to assess the fulfilment of the international commitments mentioned before.

Figure 5. General projection scheme for a detailed activity



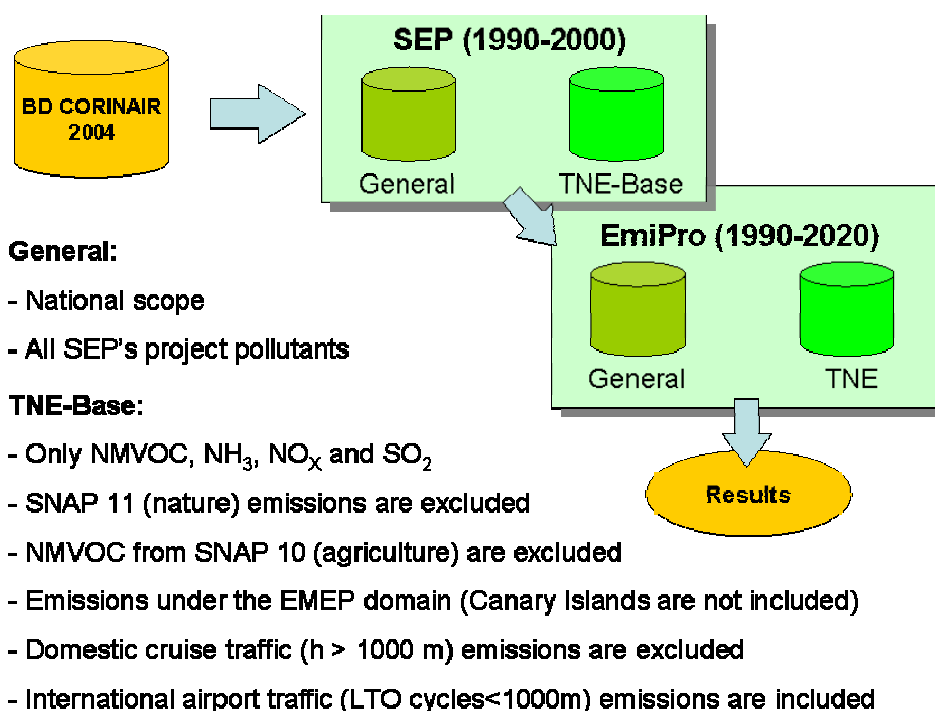
As stated in the background section, the international commitments that the activity-level thresholds are derived from are defined on a country basis. Therefore there is a need for establishing a subjective criterion to assign threshold values at the most disaggregated level (activity). At this point, the SEP calculation model is flexible, allowing several options. For the time being, this criterion has been based on a proportionality rule considering the activity-level emission in 1990 [11].

Databases

The EmiPro tool was specifically developed to suit the requirements of the SEP project. As mentioned earlier, the projections are made on national basis, so it was not necessary to keep NUTS-3 level information in the database. However, the setting of thresholds derived from NEC Directive's commitments must be done taking into account only a subset of the total national emissions (since some provinces are excluded).

Eventually, it was decided to implement a parallel database system, both for the past series (SEP 1990-2000) and EmiPro (2001-2020). The first one is called "General" and includes the national totals for all the pollutants covered by the project for all the SNAP activities. The second one is called "TNE-Base" and keeps information only for the emissions released in the EMEP domain for the pollutants affected by the NEC Directive (NH₃, NO_x, NMVOC and SO₂). Both databases come from the Ministry's database "CORINAIR" that stores all the information produced by the National Emissions Inventory. Under this approach it is possible to project the emissions without having to keep any geographical disaggregation inside any of the databases, as illustrated in Figure 6.

Figure 6. Parallel projection scheme and information stored in each database



The NEC projections are derived from the projections made for the whole country. The procedure relies on the study of the NUTS-3 level activity-rate historical datasets (1990-2000) stored in the CORINAIR database. For each SNAP activity a meaningful variable is selected in order to perform the disaggregation of the territories outside the EMEP domain. The ratios obtained in this way are assumed to be constant across the entire projected period.

Integration criteria. Macroscenarios

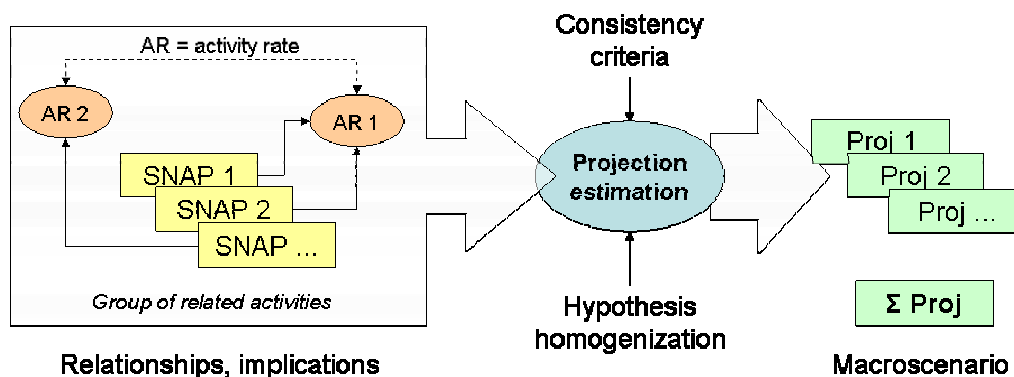
The projection scheme shown above allows the formulation of very specific, high-detail hypotheses for each activity. This is an important advantage when it comes to perform the assessment of the measures assumed under any scenario, both from the technical and the cost-efficiency points of view.

The counterpart is the difficulty that arises when all the individual projections have to be merged or aggregated in a superior level (SNAP group, national total, etc.). As every SNAP activity is projected taking into account specific methods and assumptions, it is really hard to assure the compatibility and consistency of the different results. It must be kept in mind that the activity rate considered is often (mostly) an exogenous variable to the model, coming from a very wide range of methods. Moreover, the demand forecast models that produce data, used as future activity rate input to the SEP model, are not always considering the same basic socioeconomic inputs or drivers such as GNP, interest-rates, population projections, etc. All these parameters are out of control in the SEP project, so some kind of QA/QC process regarding this issue is required.

The procedure developed to solve this problem is based on the analysis of the relationships existing among SNAP groups, subgroups and activities. Any group of activities identified in having a clear connection through the activity rates involved in the emission estimation is called "Macroscenario", as it is shown in Figure 7. This name is also applicable to the joint projection of these groups of activities. Some examples are the energy generation scenario, the industrial scenario or the livestock-agriculture scenario.

Once the relationship mapping has been clearly identified, it is only a matter of introducing consistency conditions into the hypothesis made under each scenario for a particular activity rate. Those relationships can be not only of identity, but also proportionality (direct or inverse). For those activities using the same activity rate, the same values are considered across all the SNAP activities involved. Otherwise, a qualitative analysis is done.

Figure 7. The macroscenario concept and individual results merging process



EmiPro is the computer tool tailored for the SEP Project that implements the comparison and analysis utilities required to support this procedure so it is possible to detect and fix possible errors or inconsistencies.

THE EMIPRO TOOL

Overview

The volume of managed data in the SEP project, both for the algorithm factors of the projections and the results of projections themselves revealed the need of a software tool to handle them. A specific tool, called EmiPro (from Emission Projections), currently v2.02, was developed for that purpose. Its main functionalities are:

- Storage and recovery of past (history) emissions.
- Generation of projections from history data and algorithm factors.
- Storage and recovery of projected emissions.
- Reports generation.

Working procedures

The tool is able to cope with two main kinds of inputs.

Massive data input

From past emissions series, as provided by the Spanish Environmental Administration [12], [13]. As indicated in Figure 6, data belongs to two subsets, the “General” and the “TNE” databases. Once information is loaded, reports are available for it. Editions and corrections of the information are also possible.

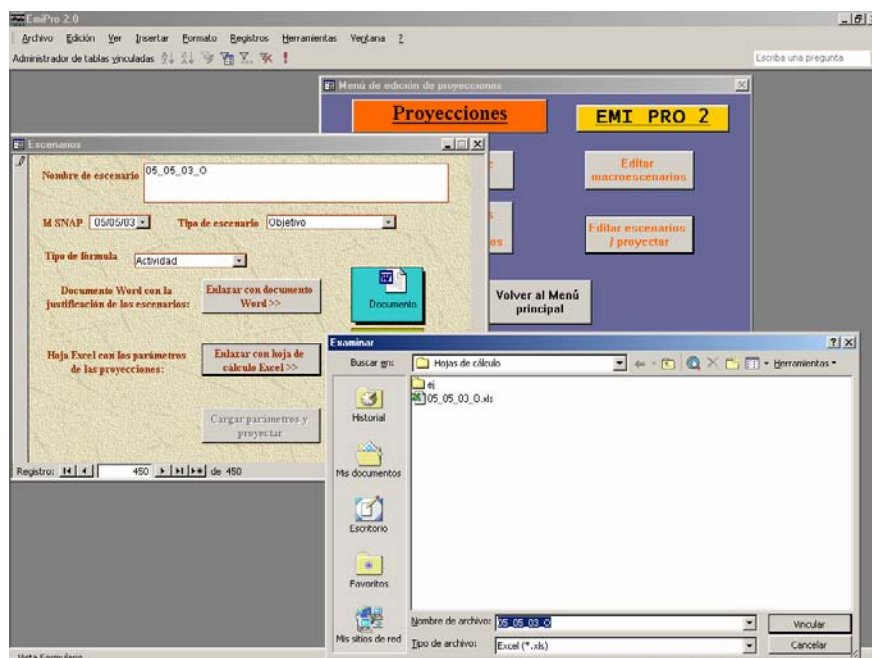
Projection parameters

Once the hypotheses for a given activity are ready, they can be fed into Emipro, which loads them and automatically proceeds with the projections for the given activity and time frame. Reports on projections are then available. Once all activities are projected, global reports –both graphical and numerical - may be generated.

For each SNAP activity, two files are expected (for each scenario), as illustrated in Figure 8. One of them is a MSTM ExcelTM file containing two worksheets; one with the parameters to be used for the “General” database and the other with the parameters for the “TNE” database. The files must be generated in a predetermined format and must contain valid values of the parameters needed in accordance with the type of projection selected (equation 1 or 2).

The other file is not used in calculations, but it is required in order to make the process as transparent as possible. For each combination of SNAP activity and scenario, a MSTM WordTM file must be provided. This document is intended to contain an explanation of the procedures followed to generate the correspondent parameters, the units they are expressed in and other relevant information.

Figure 8. Projection parameters input dialogue and browser



EmiPro is also fed with the information of activities' relationships, grouped in macroscenarios (e.g. electricity generation). The macroscenario concept is useful also for other purposes:

- Projection results aggregation (e.g. SNAP group or national total)
- Translation of the results to report under other nomenclatures categories (e.g. Nomenclature for Reporting (NFR) of UNECE CLRTAP [3])

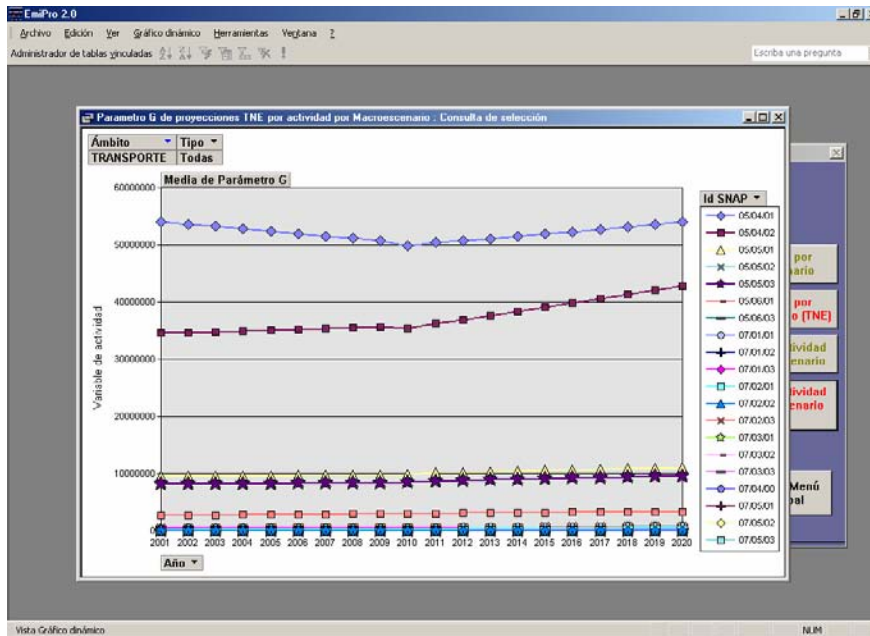
It is important to note that EmiPro does not just add the results of individual projections under a given scenario, but it follows an aggregation rule for the Baseline and Target scenarios. The projection under those scenarios (specially the last one) may exist or not for a given SNAP activity. When adding projections for the Target scenario, if this is missing for a certain SNAP activity, EmiPro will add the result of the projection under the Baseline scenario. If this scenario does not exist either, then it will use the results from the Business as Usual scenario.

Helper functions

The tool has some helper functions to make the tracking of tasks easier, as indicating the list of activities not yet projected for each scenario (BAU, Baseline or Target).

It also helps to ensure the consistency of results within a macroscenario, allowing the user to easily compare the input data of related activities (as long as they share common activity rates and factors). The results for a macroscenario can be displayed both graphically or in tabular form. An example of a plot showing all SNAP 3-level (activity) activity rates considered inside a macroscenario is shown in Figure 9.

Figure 9. SNAP 3-level activity rates comparison for the “Transport” macroscenario (Baseline Scenario)



Data model structure

Data model is summarized in

Figure 10. The entity-relationship model is shown in Figure 11.

Figure 10. EmiPro data model

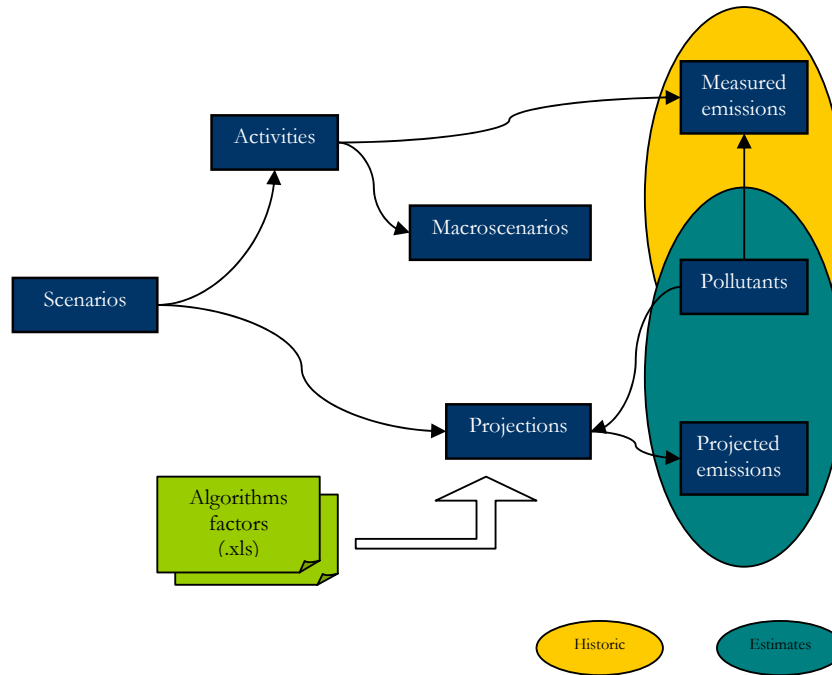
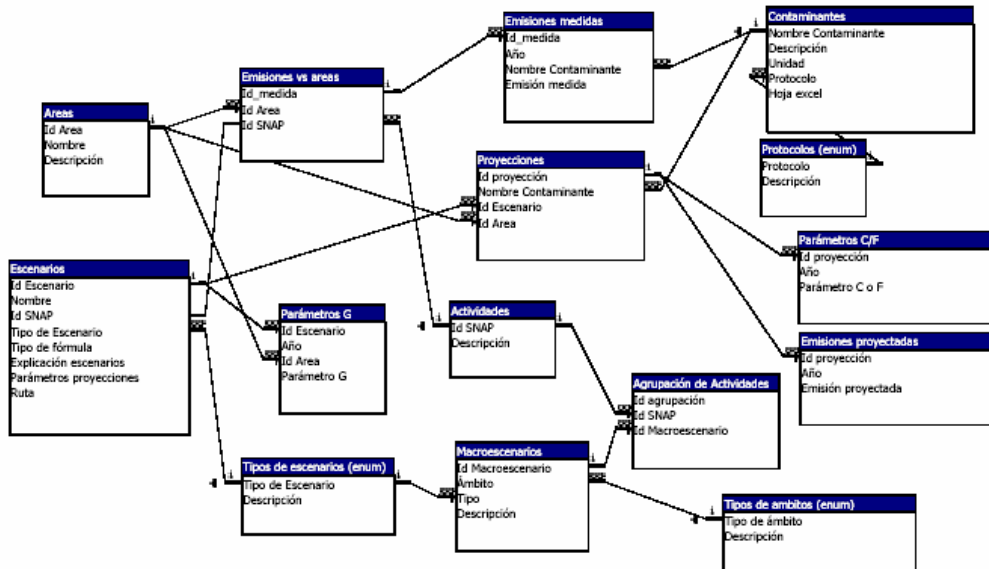


Figure 11. Entity-relationship model

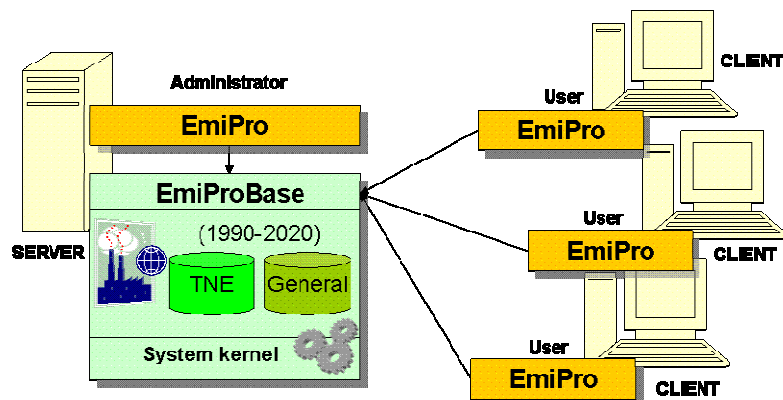


Technology

EmiPro is a MS™ Access™[18] built-on PC tool specifically designed to support the SEP project. It is intended to be used in a local area network under any MS™ Windows-NT based operating system.

It is made up of two components; EmiPro.mdb and EmiProBase.mdb. The first one is the user interface and may be installed in every client PC. EmiProBase includes the kernel of the system and all the data, both for the General and TNE (NEC) databases, covering the 1990-2020 period. This second element resides in a PC acting as server and it is protected so it cannot be edited directly. The users are not allowed to access the raw data directly and need to link their local interface with EmiProBase.mdb as illustrated in Figure 12.

Figure 12. EmiPro LAN configuration



For the input of algorithmic factors, Excel™ tables are used. For most complex functions, code in Microsoft Visual Basic™[19] was written.

CONCLUSIONS

The development of a computer tool to support the implementation of the SEP methodology to produce Spain's national projections was essential. The EmiPro tool is the specifically designed software that meets all the requirements of the SEP project. EmiPro is a key element to guarantee the consistency and quality of the national projections. Moreover, it helps in the data management, synthesis and analysis of the results. Finally, it provides the user with several utilities to generate reports useful to submit to Spain's Environment Ministry.

Although EmiPro must still be considered as a work in progress, it has successfully supported the generation of the final report of the first stage of the SEP project [11]. Now that all the databases inside EmiPro are installed, the macroscenarios identified and the work routine has been tested, this tool can serve as a basis for the updating and revision of national emission projections.

Therefore, EmiPro can give support to the annual revision and publication of national emission projections, in coordination with the National Emission Inventory. This would allow Spain to fulfill the information requirements at the scheduled time in the framework of the UNFCCC, the UNECE Convention on Long-Range Transboundary Air Pollution and the EU CAFE program.

KEY WORDS

Emission projections
EmiPro
Macroscenarios

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