# Emission Inventory and Emission Factor Projections for Modeling Air Pollution in the CAM (Spain)

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## ABSTRACT

The "Universidad Politécnica de Madrid" (UPM) is currently studying industrial activities that can produce air pollutants. The CORINAIR methodology[1] is being used and the associated nomenclature called SNAP (Selected Nomenclature for Air Pollution) has been selected to complete an inventory. This inventory considers all the pollutant sources declared in CORINAIR'94. The study covers industrial activities collected in the SNAP nomenclature (SNAP-1, SNAP-2, SNAP-3, SNAP-4, SNAP-5, SNAP-6, SNAP-9 and SNAP-10) for the CAM (Autonomous region in the centre of Spain that includes the city of Madrid). Several future scenarios are proposed for each activity and future years in order to compare their associated emissions. The inventory is being time and spatially disintegrated.

The aim of the study is to obtain detailed information about air pollutant activities and their current and future emissions in order to identify the incidence of each activity in air quality, to give useful information for regulatory decisions and to support decisions in the cases of great air quality disturbances.

The reference methodology developed in this project is very close to those used in the European Union and the Geneva Agreement and could be a guidance for other Spanish regions. The time period considered begins in 1995 and lasts until 2020. Official data are obtained from years 1995 and 1996, so the period between 1997 and 2020 provides only estimated data.

Available data from 1998, 1999 and 2000 are used for validating and evaluating the goodness of the methodology. The incidence of changing technology and equipment to reduce air pollutant emission is also studied. Scenarios are based in statistical predictions, socioeconomic data, regulatory purposes and estimated consumed energy. Different emission factors are used applying the Best Available Techniques (BAT) and future legislation. The projected emission inventory is being prepared for modeling.

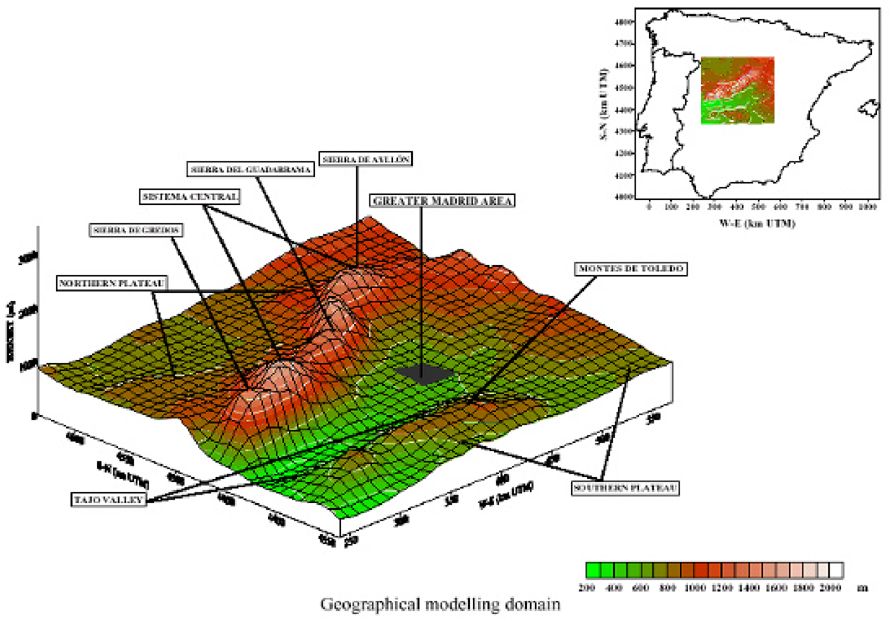
## INTRODUCTION

The aim of this work is to obtain detailed information about industrial activities and their current and future emissions in order to identify the incidence of each activity in air quality, to give useful information for regulatory decisions and to support decisions in the cases of great air quality disturbances.

The area of the study covers the autonomous region of Madrid (CAM). However, in order to model the emissions it is necessary to work with a larger domain than the one just including the CAM, the domain is shown in Figure 1.

The goal of the technological study is first to analyze the techniques that are now being used in the autonomous region in several source categories and second, to compare possible future alternatives. The technologies are classified according either to the European directive on integrated pollution prevention and control[2] in Best Available Techniques (BAT) or to emission reduction techniques (ERT) or both to BAT and ERT.

**Figure 1**: Map of Spain with detailed geographical modeling domain including the CAM.




## COVERAGE AND BASE YEAR EMISSIONS

The study covers the following air pollutants:

- Volatile Organic Compounds (VOC), disintegrated in methane ($CH_4$) and Non-Methanic Volatile Organic Compounds (NMVOC)
- Carbon dioxide ($CO_2$)
- Oxides of nitrogen ($NO_x$)
- Sulfur dioxide ($SO_2$)
- Nitrous oxide ($N_2O$)
- Ammonia ($NH_3$)
- Carbon monoxide (CO)

The geographic coverage includes the above-mentioned domain, although particular emphasis is placed on the autonomous region of Madrid. The study covers the period 1990-2020. The base year for most of the projections is 1996 but there are also data for the 1990-1996 period. In some cases, more current data are available and they are used to evaluate the methodology. In these cases the current data are also used as base year for new projections.

All anthropogenic sources excluding mobile ones are considered. The source categories considered according to SNAP97[4] nomenclature and their base year emissions (1996)[5] are shown in table 1. This nomenclature includes about 200 activities[6] grouped in 11 macro-sectors: public power plants, co-generation and district heating; combustion-commercial, residential and public administration; industrial combustion; production processes; fuel extraction and distribution; solvent use; road transport; other mobile sources; waste treatment and disposal; agriculture; nature.

In order to complete the base year emission inventory, the sources are split in three categories:

1. point sources;
2. area sources;
3. mobile sources.

Within the fixed sources, if the total emission of one pollutant is larger than a fixed threshold value (minimum pollutant amount emitted at a certain time), the plant is considered a point source. The point sources are characterized by the emission site coordinates, area and height of the emission point, and the dynamic characteristics of the emissions (gas flow, outflow speed, gas temperature). For point sources, information is gathered through a questionnaire which allows to collect general data (identification, location, etc.), structural data (stacks and unit characteristics), quantitative data (pollutant concentrations at the stacks, pollutant emissions, production capacity, current production, fuel consumption) and operational data (annual operation hours, hourly emissions, etc).

The area sources are characterized collecting data on suitable indicators (activity variable) using bibliographic sources and ad hoc inquiries at qualified groups. In the absence of specific indicators it is possible to use surrogate variables that, because of their great correlation with the activity to estimate, allows obtaining quite reliable results. Area sources emissions are evaluated through suitable emission factors found in the literature, such as those published by the UNECE Task Force on Emission Inventories or US EPA[7].

**Table 1:** Base year emissions (1996) for the CAM

| | GROUP | CH4 | CO | CO2 | COVNM | N2O | NOx | SO2 | NH3 |
|---|---|---|---|---|---|---|---|---|---|
| | | (t) | | (kt) | (t) | | | | |
| 1 | Combustion in energy and transformation industries | 0.12 | 2.14 | 7.29 | 0.13 | 1.47 | 21.90 | 0.75 | - |
| 2 | Non-industrial combustion plants | 3286.92 | 25340.5 | 4374.69 | 1689.13 | 485.91 | 3321.04 | 8926.19 | - |
| 3 | Combustion in manufacturing industry | 218.74 | 5008.71 | 3106.79 | 511.75 | 375.21 | 7130.49 | 16374.8 | - |
| 4 | Production processes | 6.88 | 5843.82 | 654.96 | 3840.10 | 2.92 | 116.87 | 75.97 | - |
| 5 | Extraction and distribution of fossil fuels and geothermal energy | 24064.1 | 7974.76 | - | - | - | - | - | - |
| 6 | Solvent and other product use | 52344.7 | 179.00 | - | - | - | - | - | 89.0 |
| 7 | Road transport | 1523.81 | 316964 | 7304.62 | 50541.17 | 508.74 | 66932.5 | 5670.05 | 383.92 |
| 8 | Other mobile sources and machinery | 35.82 | 3338.96 | 956.91 | 691.70 | 38.59 | 4871.61 | 442.64 | 0.22 |
| 9 | Waste treatment and disposal | 141503 | 2299.35 | 26.97 | 252.08 | 12.10 | 226.70 | 19.66 | 19.12 |
| 10 | Agriculture | 9437.11 | 1272.13 | 7878.34 | 1308.04 | 199.80 | 14.54 | | 5635 |
| 11 | Other sources and sinks | 1043.35 | 134.31 | 15360 | 0.24 | 747.30 | 0.99 | | 252.3 |

## EMISSION PROJECTION METHODS

We have evaluated emission projections from representative sources. The equations used in the projections are different depending on the activity but they can be represented by two general equations according with the US EPA methodology[8,9]: equation (1) for stationary sources and equation (2) for mobile sources.

Equation (1) $E_{a+x} = E_a \cdot (FA)_a^{a+x} \cdot (FC)_{a+x}$

Equation (2) $E_{a+x} = VA_a \cdot (FA)_a^{a+x} \cdot (FE)_{a+x}$

where

$a$ = base year
$a+x$ = projection year
$E_i$ = emission in year i
$(FA)_i^j$ = growth factor between year i and year j
$(FC)_i$ = control factor for year i
$VA_i$ = activity for the year i
$(FE)_i$ = emission factor for year i

Many factors have been taken into account. The most important ones are: product output, regulatory decisions, population projections, energy projections[10, 11, 12], best available techniques[13], other reduction techniques[14, 15] and statistical projections[16].

## TECHNOLOGY-BASED PROJECTIONS

We have evaluated 2000, 2010 and 2020 emissions for activities listed in table 2. The technology used in the activity determines the emission factor or the control factor. The emission projections depending on the technological scenarios are shown in figures 3 through 5.

**Table 2:** Source categories for which a technology-based projection was done.

| Activity description | SNAP Code |
|---|---|
| Electric furnace steel plant | 04.02.07 |
| Gasoline distribution | 05.05.xx |
| Paint application | 06.01.xx |

Results for electric furnace steel plants and some of the emissions caused by gasoline distribution are shown in figures 3 and 4.

In paint application projection emissions many factors have been considered. We have also considered employment of different application sectors, product output and statistical projections. The different possibilities also generate many scenarios. As a sample, the projected emissions from each scenario for paint application on construction and buildings (SNAP 06.01.03) are shown in figure 5.

**Figure 3.** CO emission projections for electric furnace steel plants (t)

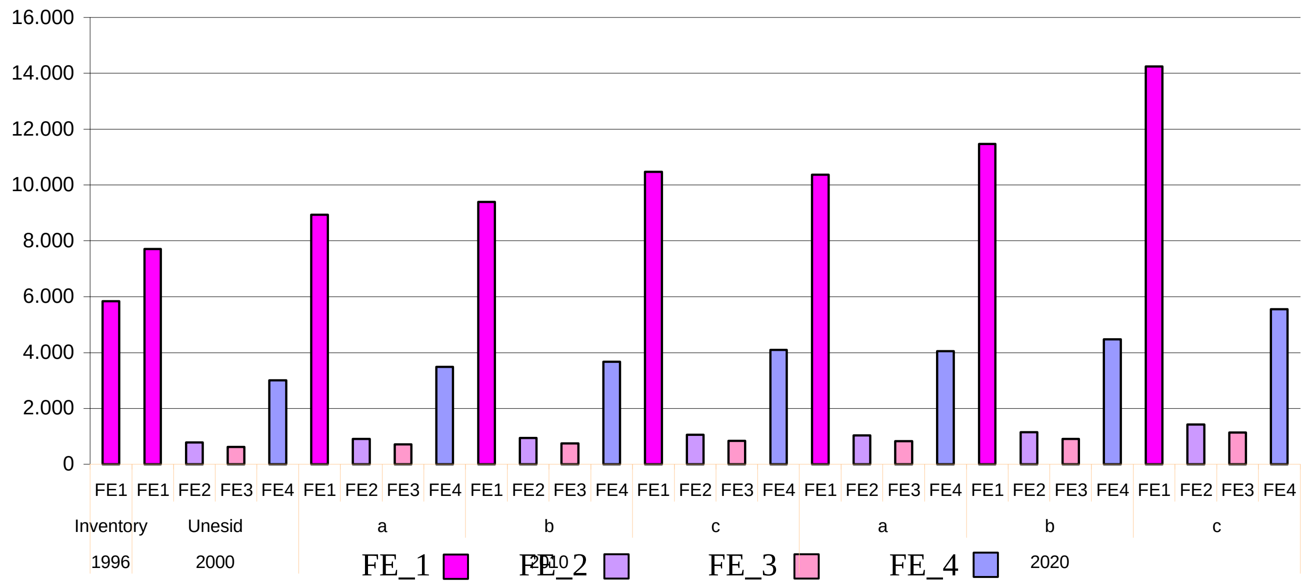



**Figure 4:** NMVOC emission projections for gasoline distribution (t)

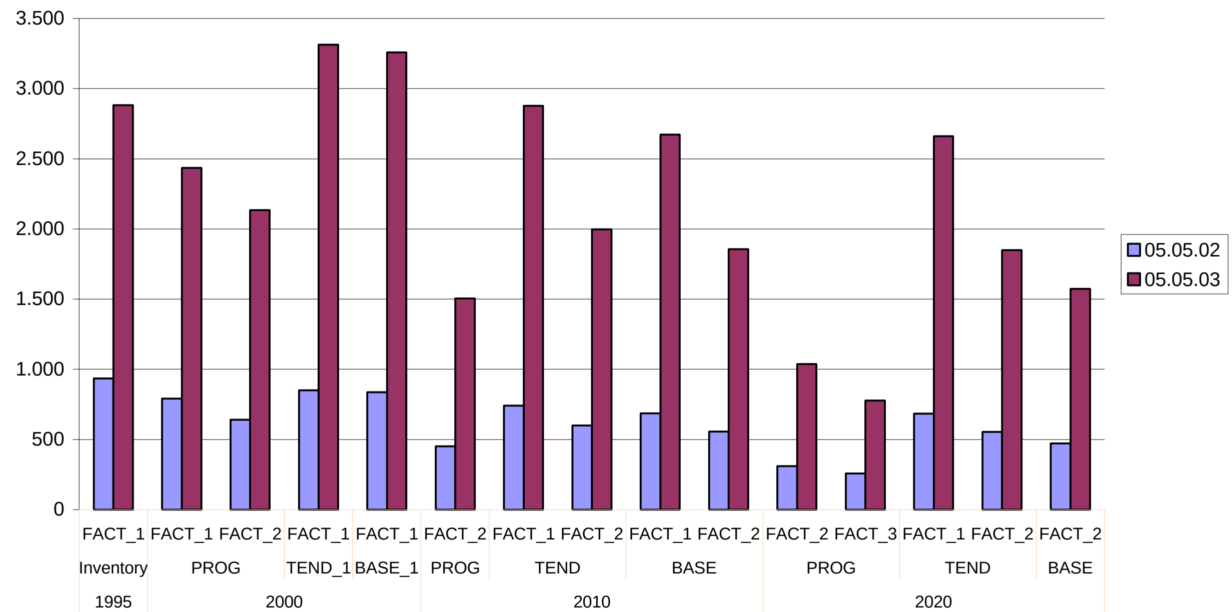
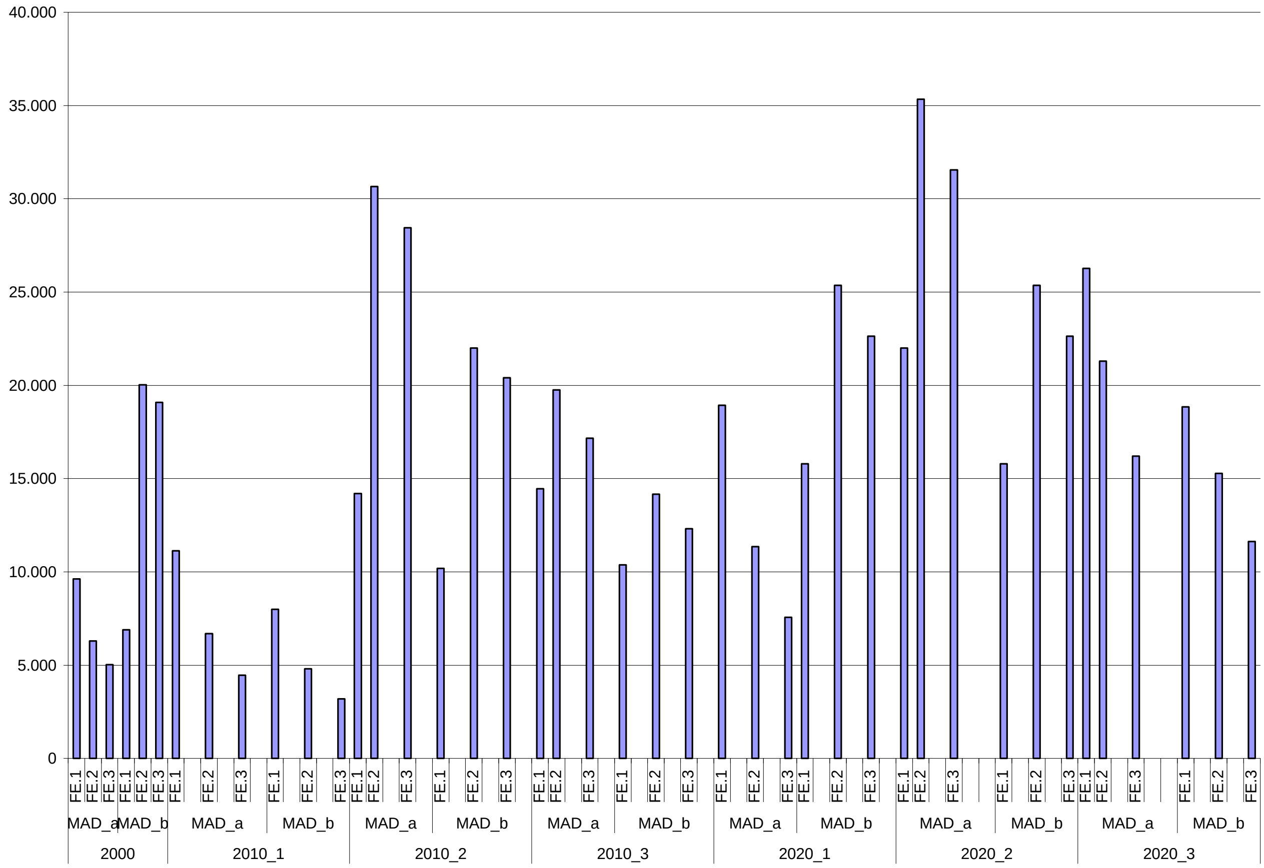


**Figure 5.** NMVOC emission projections for paint application on construction and buildings (t)




## REGULATORY-BASED PROJECTIONS

We have evaluated 2000, 2010 and 2020 emissions for activities listed in table 3. For public power plants, we have considered three sub-scenarios based on energy production apart from regulatory considerations because nowadays there is no public power plant in Madrid. We only show 2010 emissions as a sample of the work.

**Table 3:** Source categories for which a regulatory-based projection was done.

| Activity description | SNAP Code |
|---|---|
| Public power | 01.01.xx |
| Residential combustion plants | 02.02.xx |

**Figure 7:** Emission projections for public power combustion plants (t except kt for $CO_2$)

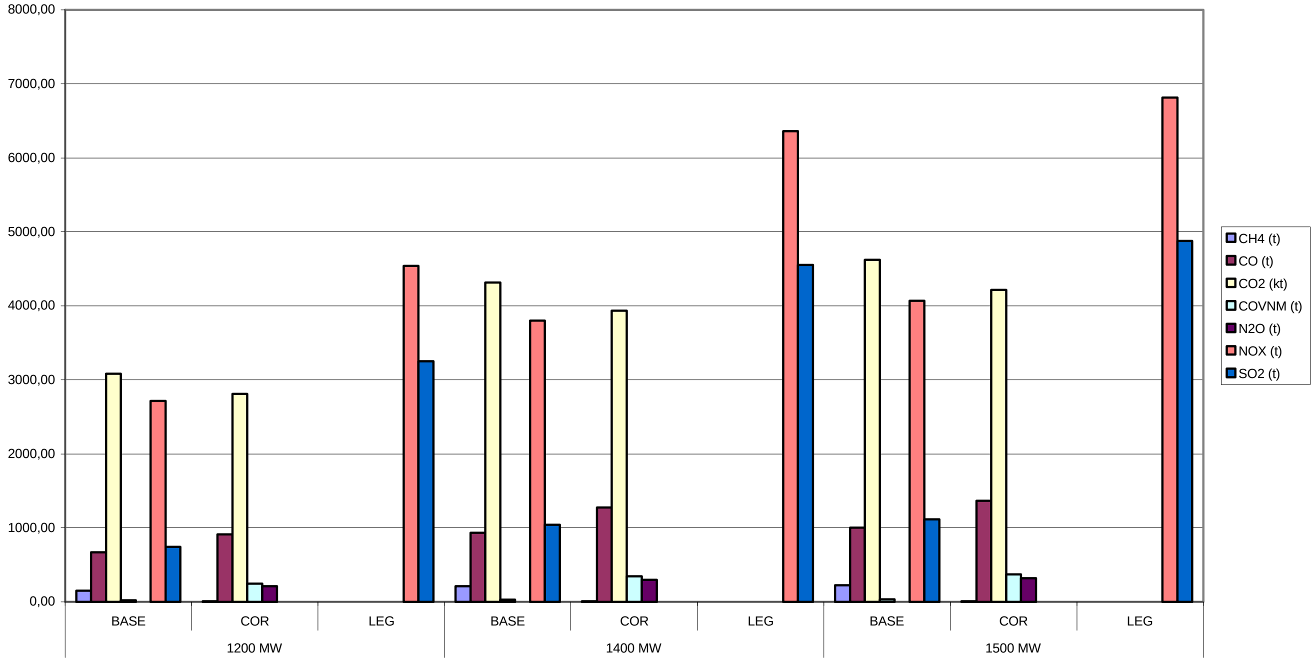
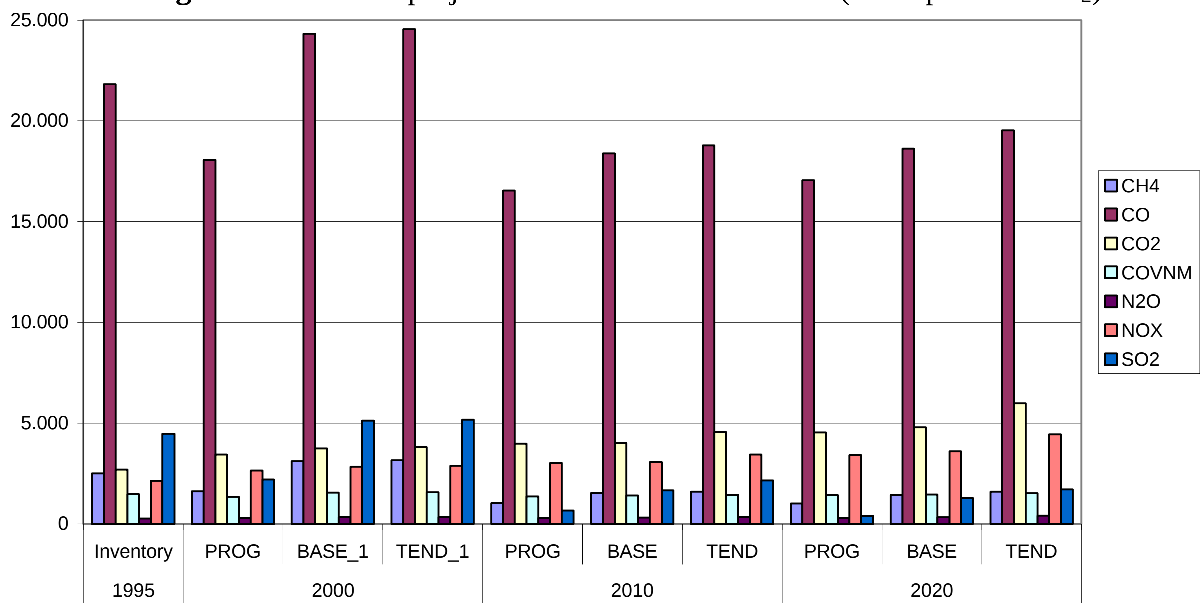



**Figure 8:** Emission projections for residential boilers (t except kt for $CO_2$)




## STATISTICAL-BASED PROJECTIONS

We have evaluated 2000, 2003 and 2010 emissions for activities listed in table 4. In these activities we have projected the emissions with Box-Jenkins models. We have thus applied univariate time series analysis using ARIMA models. The main idea behind these models is to profit from the inertia of the data to make forecasts. We have not calculated 2020 emissions because for a period larger than 10 years, their associated uncertainty could be at least of 50%. ARIMA models are very useful for predictions up to a 5 year period.

For waste incineration and compost production 1998, 1999 and 2000 emissions prove the goodness of the methodology. The forecast errors where respectively of 1.32%, 1.45% and 1.28% which are very satisfactory. The projected emissions are shown in figures 9 and 10.

**Table 4:** Source categories for which a statistical-based projection was done.

| Activity description | SNAP Code |
|---|---|
| Cement | 03.03.11 |
| Waste incineration | 09.02.xx |
| Compost production | 09.10.05 |

**Figure 9:** Emission projections for waste incineration plants (t except kt for $CO_2$)

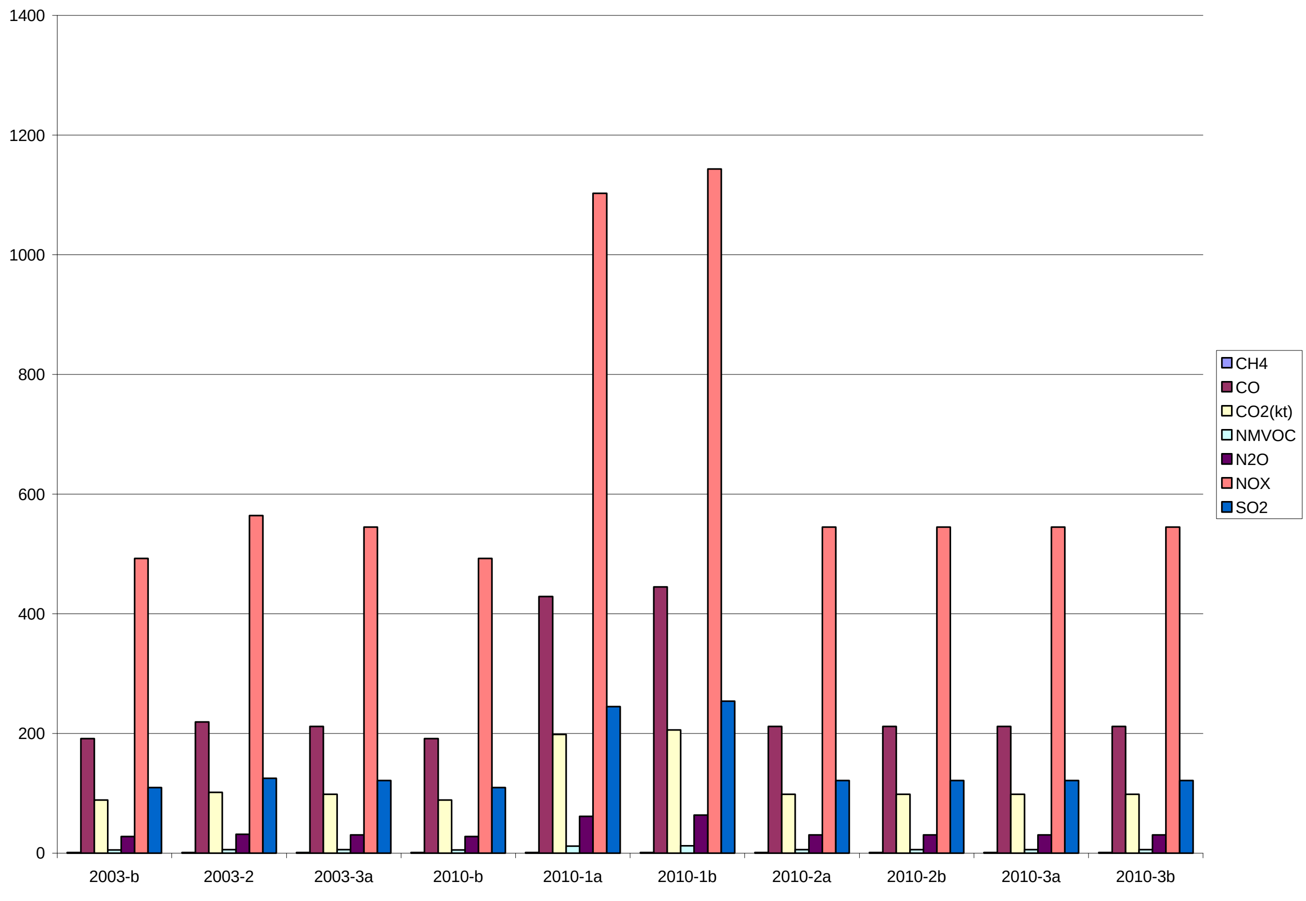
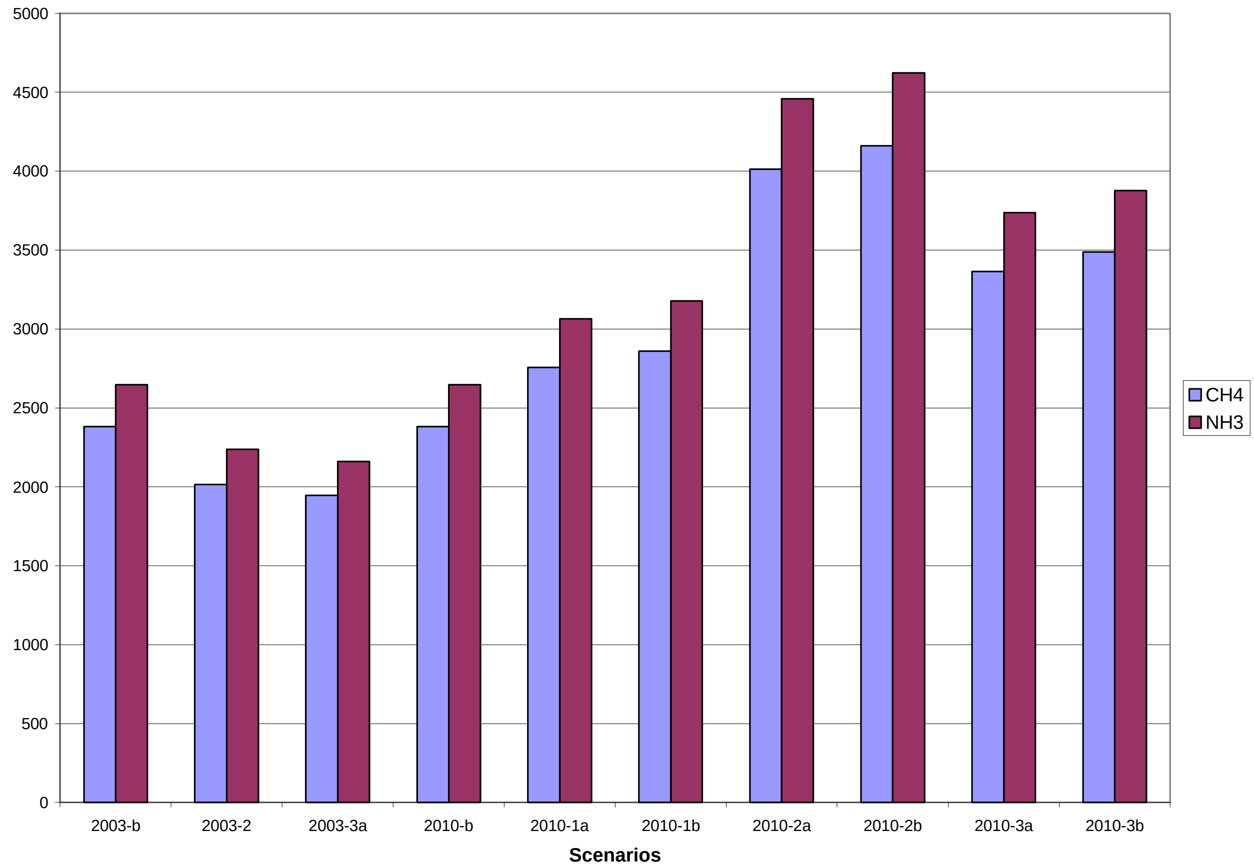


**Figure 10:** Emission projections for compost production plants (t)




## CONCLUSIONS

With 1996 data as base year emissions, we have computed the emission projections for the most representative anthropogenic stationary source categories of the Madrid domain. These categories include non-mobile point and area sources except natural ones.

We have elaborated several scenarios for each SNAP source category. The aim of the construction of such a great number of scenarios is to provide a comparative analysis between scenarios depending on technological trends, sector growth or decrease, inertia of the historic data, industry output or the implementation of current or future European regulations. Thus, 2000, 2010 and 2020 emissions are projected for most of the representative sources in the CAM domain.

In some cases official 2000 data are available and are now part of emission inventory data. In these cases, the official 2000 data are used for validating and evaluating the goodness of the methodology and the rates and factors applied. The results from the comparison are satisfactory (the errors are all under 5%).

The aim of these projections is their inclusion in an air quality modeling system in order to evaluate the future ambient values in the domain studied and probably in a greater one. For modeling, we will choose those scenarios with the highest reliability and we will disintegrate them using the US-EPA methodology and the one used in Palacios (2001)[3]. We will use EPA's CMAQ for modeling. We will also compare the results with those obtained when using Models-3 system for the whole process (projection + modeling) and evaluate the reliability, accuracy and uncertainty associated with the two methods.

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## KEYWORDS

Emission Inventory
Emissions Modeling
Emission Projections
SNAP nomenclature
CORINAIR methodology



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