Emission scenario of PM_{10} in Italy and its source territorial distribution: analysis and perspective

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Abstract

The modern modelling instruments (e.g. IAM - Integrated Assessment Models) provide a clear relationship between the policy measures and the effects both in terms of pollutant emissions and concentrations/depositions. Notwithstanding, the secondary organic components of PM (a significant share of the total particles) are not considered in the model, the accurate knowledge of the PM primary emissions is still a good starting point for the characterization of the pollution from PM. Moreover, the territorial distribution of the emission sources and emissions is an important aspect in order to have a complete analysis of the PM pollution in the country. In this paper, a revised estimation of the PM_{10} emissions in Italy at the year 2000 as well as the projections at 2010 are presented. The calculations have been carried out by the RAINS-Italy model, an IAM tool under development jointly by ENEA and IIASA, in the framework of a scientific research agreement with the Italian Ministry for the Environment and the Territory. Through appropriate scaling factors, elaborated by ENEA, the input national data have been disaggregated for the 20 Italian administrative regions to allow the calculation of regional emissions. The analysis shows as the PM_{10} emissions are distributed on the Italian territory following a very inhomogeneous pattern, since the major share of the emissions is concentrated in the most populated area in northern Italy, but also in some southern, not adjacent, regions. At national level, the preliminary analysis of the cost-curve shows, as in traditional energy sectors, like road transport, industry and electricity production, the most cost-effective measures are exhausted.
Keywords: integrated assessment model, particulate matter, emission scenarios, abatement technologies, RAINS.

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1 Introduction

There is a rising interest related to the health effects of fine particles. Recent scientific studies have demonstrated a close connection between the exposure to fine PM concentrations in the air, usually monitored in Europe and North America, with several significant adverse health effects, such as premature death, aggravated asthma, acute respiratory symptoms, chronic bronchitis, decreased lung function (Pope et al. [1]).

Airborne suspended PM can be either primary or secondary, in nature. Primary particles are emitted directly into the atmosphere by natural and anthropogenic sources, while secondary particles are formed in the atmosphere from chemical and physical reactions of SO2, NO_x, NH_3 and VOC.

The RAINS (Regional Air pollution INformation and Simulation) model, in its Italian version, RAINS-Italy, an Integrated Assessment Model, under development jointly by ENEA and IIASA (International Institute for Applied Systems Analysis), is the tool, used in this study commissioned by the Italian Ministry for the Environment and the Territory, to estimate primary PM emissions and the least-cost measures for controlling particles concentration in the ambient air.

2 Integrated assessment model

An integrated assessment model (IAM) represents an effective tool to help policy makers in defining different options and environmental policies to reduce air pollution (Vialetto et al. [2]). In order to develop environmental policies and control measures, IAM reckons with the scientific research results in many different fields, such as economy, ecology, technology, atmosphere science, according to a cost-benefit approach (see fig.1).

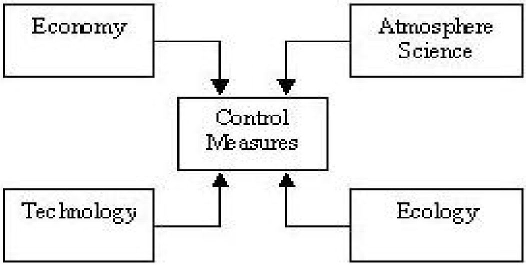

Figure 1: Simplified Scheme of an IAM.

IAM consists of the following elements:

- quantitative analysis of the pollutant emissions;
- transport of the pollutants through the atmosphere and their deposition at soil level;
- definition of environmental targets;

- cost assessment of the related abatement technologies;
- cost benefit analysis of different reduction strategies complying the selected targets.

3 The RAINS-Europe and the RAINS-Italy models

The RAINS-Europe model developed by IIASA (Amman et al. [3]) is an Integrated Assessment Model adopted within both the UNECE context (United Nations Economic Commission for Europe), for the definition of the most recent protocols under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), and the EU framework, for the establishment of the recent directives related to the emission reduction of air pollutants.

RAINS-Europe allows to elaborate long term (1990-2030) optional reduction emission scenarios for SO_2, NOx, NH_3, VOC, which are the pollutants responsible for acidification, eutrophication and ground-level ozone, and for PM, which is responsible with ozone of adverse effects on human health (Klimont et al. [4]). RAINS-Europe calculates emission scenarios, cost curves and deposition /concentrations maps, on the base of the energy scenario, the anthropogenic activity levels and the implementation of the abatement technologies (control strategy), in all the European Countries (see fig.2) [5].

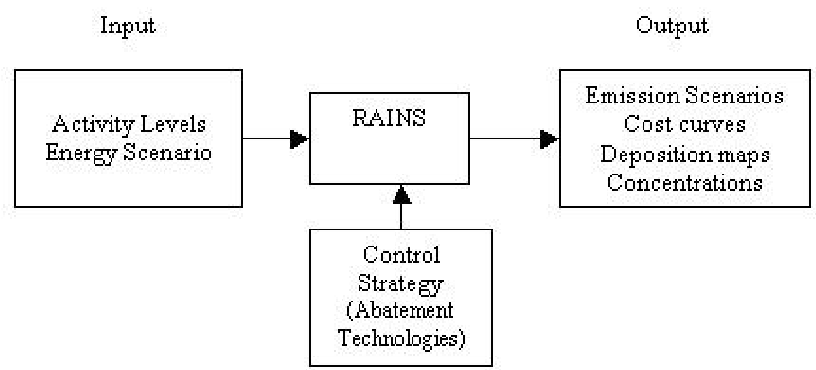

Figure 2: RAINS model scheme- simplified flow chart.

In the framework of a scientific research agreement between ENEA and the Italian Ministry for the Environment and the Territory, regarding the development of an IAM for Italy (the MINNI Project for the development of an Integrated Assessment Modelling system as supporting tool for the International Negotiation concerning the air pollution), ENEA and IIASA are developing the Italian version of RAINS-Europe model, the so-called RAINS-Italy model (Pignatelli et al. [6]).

RAINS-Italy works in a quite similar way with respect to RAINS-Europe, but two main significant differences have been designed to make the model better fitting some peculiar Italian characteristics, both morphological-geographical and administrative-institutional:

- 20 administrative regions, 4 metropolitan areas (Milan, Turin, Rome and Naples), 1 national sea traffic and 14 large power sources (LPSs) are individually considered in RAINS-Italy as source areas;
- the Atmospheric Transfer Matrix is derived by the euleriano Atmospheric Modelling System (AMS), developed by ENEA and ARIANET, with a 20x20 Km^2 spatial resolution.

4 Baseline national emission scenarios of primary PM_{10}

The quantification of both the anthropogenic emission activities and the control strategy (see fig.2) is needed to develop an emission scenario, using the RAINS-Italy model.
The quantification of the anthropogenic emission activities requires:

- ✓ an energy scenario, in terms of energy consumptions, for each energy sector (e.g. power plants, domestic, transport, fuel conversion). The energy scenario is an "exogenous" collection of data developed, for our analysis, through the macro-economic model, MARKAL-Italy (Gracceva and Contaldi [7]);
- ✓ a scenario of productive processes, industrial and non, taking into account non-combustion emission sources of PM_{10} (e.g. metallurgical processes, mining, agriculture, people-related sources like smoking, etc.).

The control strategy is expressed in terms of implementation rate, for each combination fuel/sector/technology, of the considered PM abatement technology, already applied or planned to be applied in the future. The strategy based upon the current national or EU legislation provides the Current LEgislation (CLE) scenario.

4.1 Analysis of the Italian baseline emission scenario

The Italian baseline emission scenario is represented in fig.3. The estimated PM_{10}emissions, at the year 2000, and the projected emissions, at the year 2010, calculated by the RAINS- Italy model, are 230 kt and 213 kt, respectively.

A discrepancy is observed, at the year 2000, between PM_{10} emissions calculated by RAINS-Italy and CORINAIR inventory elaborated by APAT [8]. Such discrepancy is ascribable to a number of differences between the RAINS and Inventory methodologies concerning the calculation approach, the quantification of the activity levels, and the uncertainty in emission factors. Moreover, it should be highlighted that the PM_{10} CORINAIR inventory does not seem to consider some emission sources, included in RAINS-Italy, e.g. agriculture (livestock and arable land), barbecue, cigarettes, fireworks and construction. These sources are excluded from the inventory because affected by significant uncertainty and due to the lack of clear indications, in the literature, on how these sources should be considered. In order to highlight these considerations, in figure 3, the right bar, at the year 2000, shows the CORINAIR inventory emissions, corrected by adding the sources included in RAINS-Italy only, as mentioned above. As a result, at the year 2000, the RAINS-Italy (*230 kt) and* CORINAIR (224 kt corrected) estimations are very close within the uncertainty margin of 2.4%. The RAINS-Italy methodology can be then regarded as an alternative approach to estimate the contribution from PM_{10} sources not considered yet in the inventory.

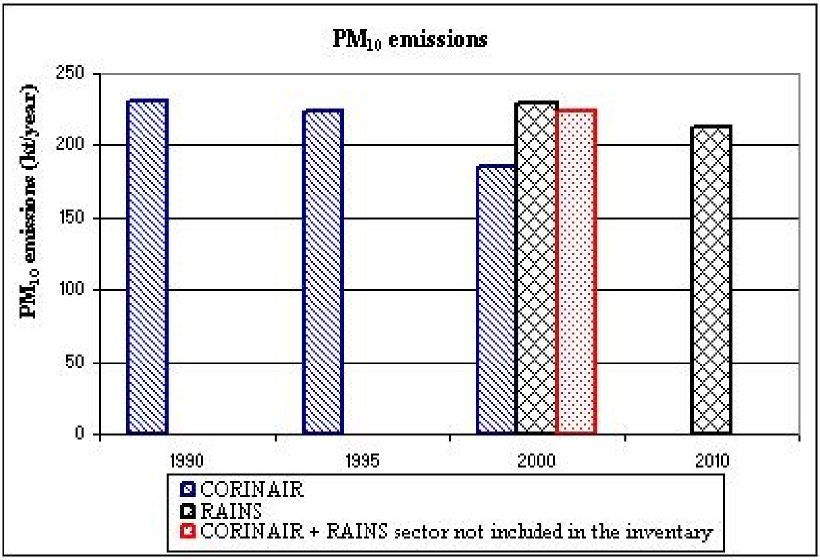

Figure 3: Baseline emission scenario of PM_{10} (*Baseline CLE*), calculated with RAINS-Italy at the years 2000 and 2010, and comparison with CORINAIR emission inventory.

The sectoral distribution of PM_{10} national emissions at the year 2010 is provided in Figure 4. The figure shows as Transport, Industry and Domestic sectors remain, in the short term, the most contributing sectors.

4.2 Cost-curve

RAINS-Italy also allows one to elaborate cost-curves, i.e. the list of the abatement technologies which can be additionally implemented to further reduce emissions, beyond the initial baseline level. The national cost curve for PM_{10} at 2010 is reported in Fig. 5. As additional control technologies are added (in the figure from left to right on the x axis), sector by sector, according to their increasing marginal cost (the segmented line), the remaining emissions decrease. The marginal cost is defined as the cost of removing the additional ton of PM with respect the current level of emissions. The cost curve also shows as the same sector may appear twice or more (e.g. the off-road transport-4 stroke-agriculture sector); this is due to the fact that different control technologies may be applied in the same sector, with increasing marginal costs. The analysis of such additional controls shows as the traditional energy sectors (road transport, combustion in industry and electric generation) do not provide scope for cost-effective measures because of the high penetration level of the control technologies, already achieved. On the other hand, major reductions, at lower marginal costs, could be obtained introducing additional measures in agriculture, combustion in the domestic sector and off-road land based transport (agricultural machinery, 2 and 4 strokes).

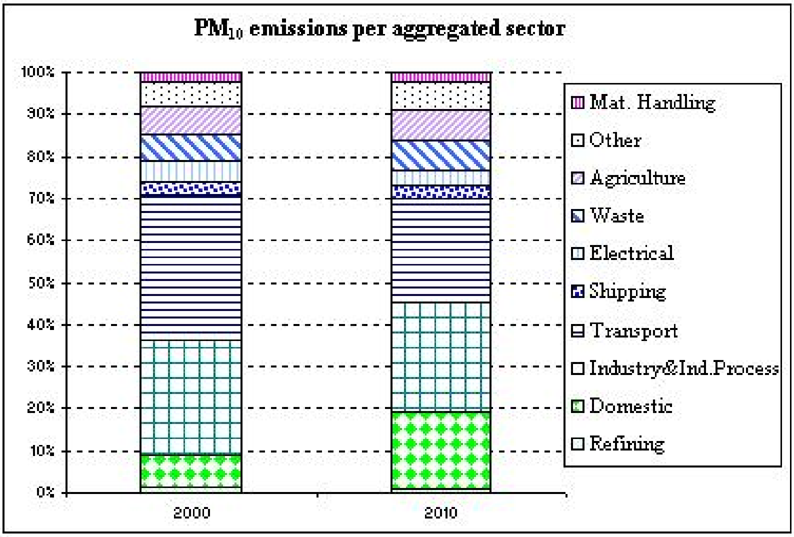

Figure 4: National PM_{10} emissions per aggregated sector – calculated by the RAINS- Italy model, at the years 2000 & 2010.

5 Baseline regional PM_{10} emission scenarios

A first qualitative analysis of the distribution of PM_{10} emissions on the national territory has been carried out starting from the national baseline scenario described in par. 4.1.

Through the selection of appropriate scaling factors, the national activity levels have been disaggregated at regional level, to obtain energy scenarios, industrial processes, etc, for each of the 20 Italian administrative regions, while the same control strategy, as in the national scenario, has been adopted in all the regions, as first approximation. Then the emission scenarios have been individually calculated for each region.

Obviously, a more accurate analysis will be possible when the exact territorial distribution of the activity levels and the abatement technologies penetration levels will be known. Such a survey is still in progress with the local authorities.

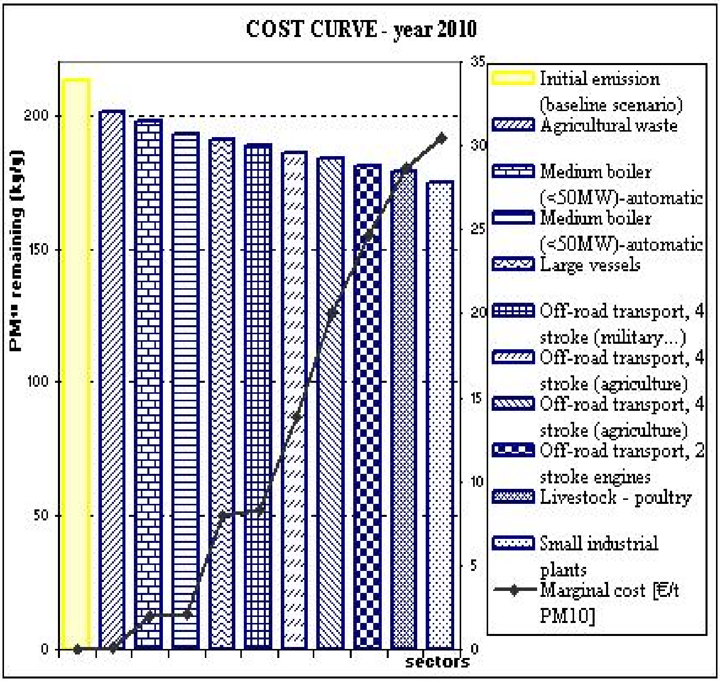

Figure 5: National cost curve for PM_{10} at 2010, calculated by the Rains-Italy Model.

5.1 Brief description of the scaling factors

The choice of the "scaling factors", also called "proxy variables", has been carried out by ENEA on the basis of the best available information. Many variables have been found depending on the concerned sector and affected by the information availability. However, the leading criterion in selecting the proxies has been a strict proportionality with the activity levels. For instance, the thermo-electric energy generated has been used as proxy in the electric sector, the estimated number of cars, motorcycles, heavy duty vehicles or the fuel consumption have been used in the road transport sector, the number of employees per sector has been assumed as proxy in some industrial processes and so on.

5.2 Regional emission scenarios and their sectoral analysis

The PM_{10} regional emissions, at the year 2010, are shown in fig.6, where the share of each region is highlighted.

The regional sectoral analysis mirrors the national one, with few exceptions only. In fact, the PM_{10} emissions in material handling and industrial processes, in Puglia, are higher than the share at national scale. Also, Liguria, Campania, Calabria, Sicilia and Sardegna have pronounced shipping emissions, compared with the shipping share in national emissions.

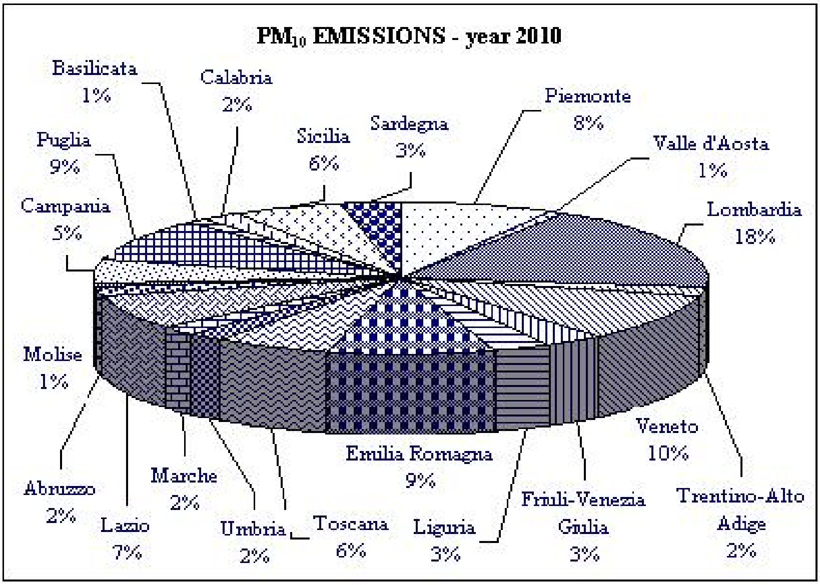

Figure 6: PM_{10} emissions (% of national total), at the year 2010, in each administrative region.

6 Conclusions

The PM_{10} emissions reach very high levels in Italy.

The most contributing sectors are: road transport, industry and domestic sector both at national and regional level. Some significant differences among few regions can be observed.

The territorial distribution of primary PM_{10} emission is irregular; emissions are mostly concentrated in some northern regions, where Lombardy is the region with the highest PM_{10} emission values, followed by Veneto and Puglia. The Po-valley represents a particularly critical area, in terms of emission sources.

At national level, and on the basis of assumed penetration level of the abatement technologies, the analysis of the cost-curve shows as the traditional energy sectors (i.e. road transport, industry and electric sector) do not provide scope for cost-effective measures in reducing PM_{10} emissions, because the low-cost technologies are already exhausted.

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