INTEGRATED ASSESSMENT MODELLING APPLIED TO EMISSION SCENARIOS DEVELOPMENT IN ITALY

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ABSTRACT

A number of emission scenarios, concerning transboundary air pollutants as SO_x, NO_x, VOCs, NH_3 PM, which are covered both by the United Nations Convention on Long Range Transboundary Air Pollution and by the European Commission Programmes, have been developed by the application of the Integrated Assessment Model Rains-Italy. The Rains-Italy Model has been developed in the frame of a joint Research Project ENEA-IIASA (International Institute for Applied Systems Analysis, Laxenburg, Austria). The most updated Energy Scenarios and the Current Legislation control measures, currently implemented or planned in the next years, are considered. The projections of the emissions at the year 2010 are compared with the National Emission Ceilings set by the EU Directives and the Gothenburg Protocol targets. Also, the shares of total emissions, by source sector, are analysed. Through the integrated approach, the additional measures, where needed to meet the targets, are listed according their increasing marginal cost, as result of the national cost curve, calculated by Rains-Italy. The peculiar features of Rains-Italy, concerning the development, at level of administrative regions, of deeper analyses of emission and deposition scenarios, with a spatial resolution of 20x20 km, are described.

Introduction

In the past years, the Integrated Assessment Modelling (IAM) has been extensively used, with the aim of reducing air pollution, by developing control strategies, in the light of the most cost-effective measures. The Protocol to combat acidification, eutrophication and ground level ozone, signed on November 30, 1999 in Gothenburg (Sweden) by 31 Parties of the Economic Commission for Europe of the United Nations (UN-ECE), as well as the 2001/81 EC Directive, adopted on November 27, 2001 by the European Parliament and the Council, introduced Emission Ceilings based upon the analysis carried out with IAM. In both cases, emission reductions of SO_2, NO_x, VOCs and NH_3, at levels such as the adverse effects on human health, environment and materials, due to the long range transport of these pollutants are reduced, have been calculated by Integrated Assessment Models.

IAM offers to the policy makers the extremely important availability of tools and means which are suitable for the elaboration of emission projections and simultaneous verification of consistency between exposition to such emission levels and the effective protection of human health, eco-systems and materials (e.g. cultural heritage). In other words, integrated models allow to calculate current and future emission levels, transport and deposition of pollutants through the atmosphere, even at long distances, exceedances of the deposition and/or ground level pollutant concentrations compared with threshold values (established both for eco-system and human health protection), as well as costs of emission abatement through the implementation of different technologies. All the above elements are essential for

the assessment of the effectiveness of policies and measures, in the ultimate perspective of air pollution control.
In the international context, one of the most successful IAM tool is the RAINS-Europe Model (Regional Air Pollution Information and Simulation), developed by IIASA, which has been officially used for the negotiations in the context of both the Gothenburg protocol and the 2001/81/EC Directive.
In this frame, on behalf of the Italian Ministry for the Environment and the Protection of the Territory (MATT), the Italian Agency for the New Technology, Energy and the Environment (ENEA), at the beginning of 2002, started the MINNI Project for the development of an Integrated Assessment Modelling System, as supporting tool for the international negotiation concerning the air pollution, and for developing environmental policies at national, and sub-national level. The development of the RAINS-Italy model, derived from RAINS-Europe preserving its valuable features and currently in progress jointly by ENEA and IIASA, is an important part of the MINNI project.

With the aim of providing emission projections for the main air pollutants and verify Italy's compliance with the provisions of the NEC Directive and the Gothenburg Protocol targets, middle-term emission scenarios and alternative/complementary measures/options for the non compliance occurrence, have been developed by the RAINS-Italy model.

The MINNI Project: an Integrated Modelling System for Italy:
The MINNI project is a complete Integrated Assessment Modelling System able to provide detailed concentration/deposition maps for SO_2, NO_x, NH_3, O_3 e PM, for the assessment of the environmental impact in terms of acidification and eutrophication, and the evaluation of population exposure to ozone and PM. Emission Scenarios, concerning the pollutants listed above, and estimation of costs related with the implemented (or planned) abatement technologies, are carried out through the RAINS-Italy model, at local (Italian Regional Authorities) and national level.

MINNI is structured in two main modelling systems:
a) An euleriano modelling system dealing with the air pollution dynamics (transport and dispersion) and multiphase chemical transformations, able to quantify concentrations and deposition flux of air pollutants, with a spatial resolution up to few km^2;
b) the RAINS-Italy model, which is able to develop emission scenarios, abatement strategies and estimation abatement costs. In RAINS-Italy, the calculation of the deposition and the ground-level concentration of the air pollutants is carried out through an Atmospheric Transfer Matrix (ATM), whose coefficients are derived by the euleriano modelling system described in a).

An extensive description of the MINNI system is reported in (European Environment Journal, 2004) [1].

The RAINS-Italy model
The RAINS-Italy Model mirrors the features of the RAINS-Europe Model, described in an extensive and complete way in (IIASA, 1999) [2] and (IIASA), 2004)[3]. In fact, the analyses performed by the RAINS-Europe Model for the European Countries, are carried out, similarly, by RAINS-Italy with respect the 20 Italian Administrative Regions, 4 Metropolitans Area (Milan, Turin, Rome, Naples) and an additional virtual "region" called "National Sea Traffic" covering the Mediterranean Sea Area, concerning the national shipping, both freight and passengers, from port to port on the Italian territory. Moreover, 14 Large Power Sources (LPS as Power Plants, Refineries etc.) are individually represented into the Model, so that their contributions, in terms of emissions of pollutant and concentrations, can be directly estimated and compared with other sources. All the Area Sources, LPS included, are ranked at the same level and therefore the same input data specifications are

requested for each of them. This latter aspect allows the user to specify a tailored control strategy for each Area Source and detailed input data, if needed, or regional specific measures (e.g. traffic restrictions, fuel-switch in domestic combustion, etc.) and estimate their relative impact. As an example of the potential of developing local and deeper analyses, at level of administrative regions, a demonstrative map of sulphur deposition, over the Italian Territory, as effect of emissions generated in the Lombardy Region only (test data), is shown in Figure 1.

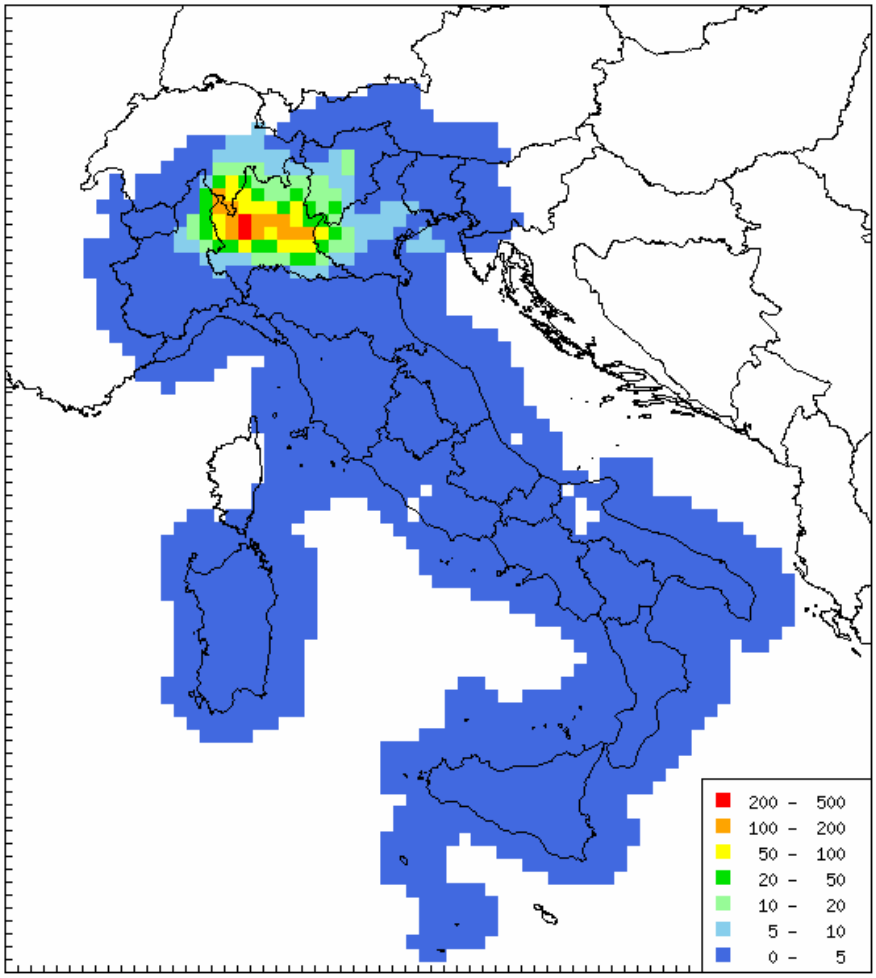


Figure 1 – Map of sulphur deposition from emissions (test data) of Lombardy Region

Development of emission scenarios for Italy

The Emission and Costs Modules (EMCO) of the Rains-Italy Model have been used to develop the national emission scenarios for Italy, in the frame of both the UN-ECE and the EU CAFE Project, for what concerns the pollutants SO_2, NO_x, NH_3, VOCs, and PM. The RAINS-Italy estimates current and future levels of pollutant emissions on the base of fuel consumption data provided by the energy scenario (energy consumption profile from 2000 till 2030), and the economic activity levels, as described in (Atmospheric Pollution, 2004)[4]. Also, the national control strategy, that is the whole set of the abatement technological measures implemented or planned in the time interval considered, must be defined by the user. RAINS-Italy also generates national cost curves, which allow to define a number of different/alternative options for emissions reduction and the related costs of implementation.

The development of the emission scenarios is based on national statistics and projections of economic activity, energy consumption levels, as well as technical information on fuel characteristics, emission factors etc. In particular, the Italian Reference Energy Scenario, updated to April 2004, whose structure is described in detail in [5], and the activity levels

scenario have been used for the purposes of the CAFE Program emission scenarios, and the related results are reported in this paper.

The International Reference Framework

With the aim of verifying the Italy's compliance with the provisions coming from the mentioned international treaties and EU Directives, a comparison between the estimated emission levels, at the target year, and the Emission Ceilings and Target Values, set at international level, is then carried out. When there is no compliance with the established targets, a number of additional reduction measures are considered, through a cost-effective approach, to ensure the fulfilling of the commitments.

A summary of the Emission Ceilings for Italy is reported in tab. 1.

	Gothenburg Protocol (kton)	**NEC Directive** (kton)
SO_2	500	475
NO_x	1000	990
VOC	1159	1159
NH_3	419	419

Tab.1: Emission Ceilings established for Ital,y at 2010, according to the provisions of the Gothenburg Protocol and the NEC Directive

Emission projections for Italy

The projected emissions for Italy, as result of RAINS-Italy calculations, are reported in figures 2,3,4,5,6 and compared with the NEC and Gothenburg Targets. The emissions at 2000 are also computed by the model, although they may not coincide with the inventory emissions, at the same year, mainly because the computing methodology and/or the data aggregation are different.

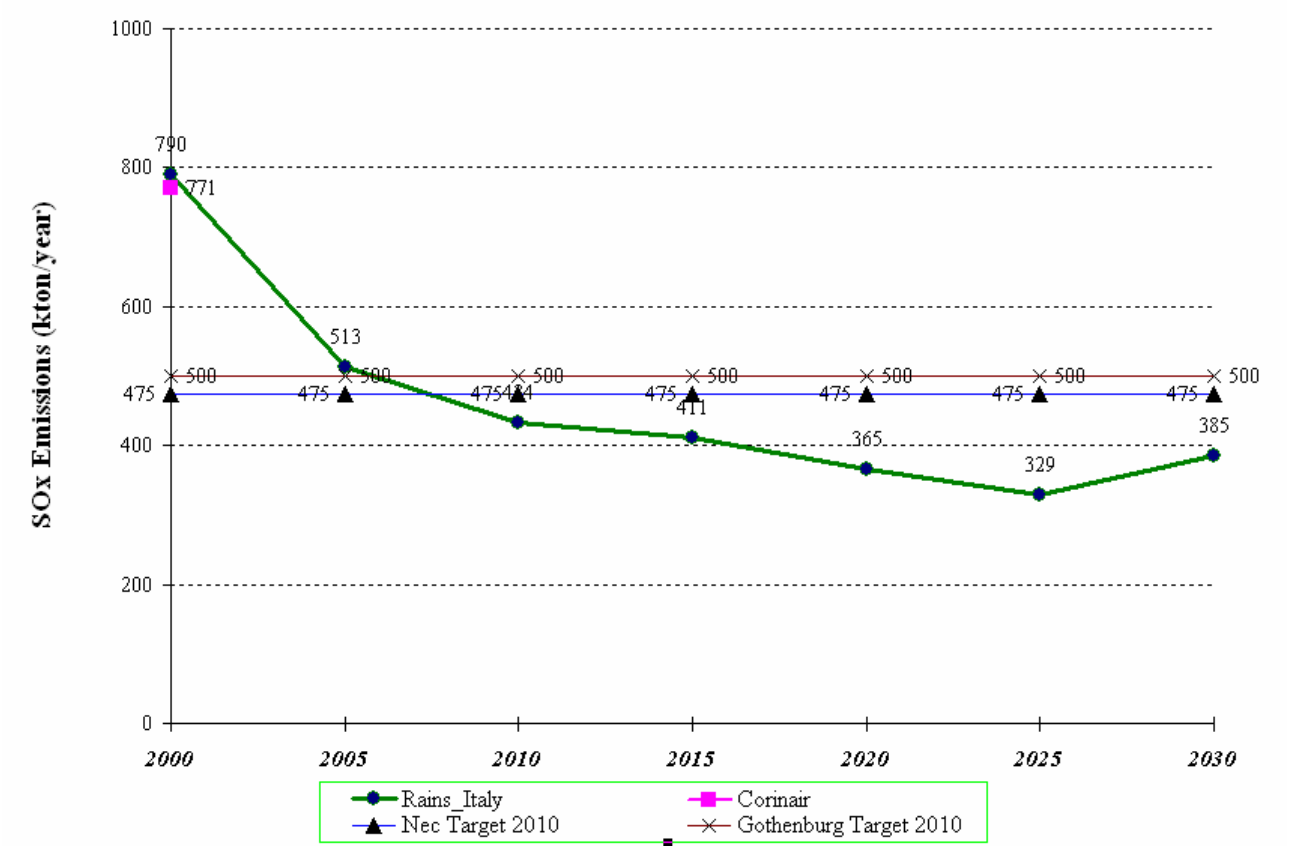


Figure 2 – SO_2 Emission Scenario (kton/year)

Figure 3 – NO_x Emission Scenario (kton/year)

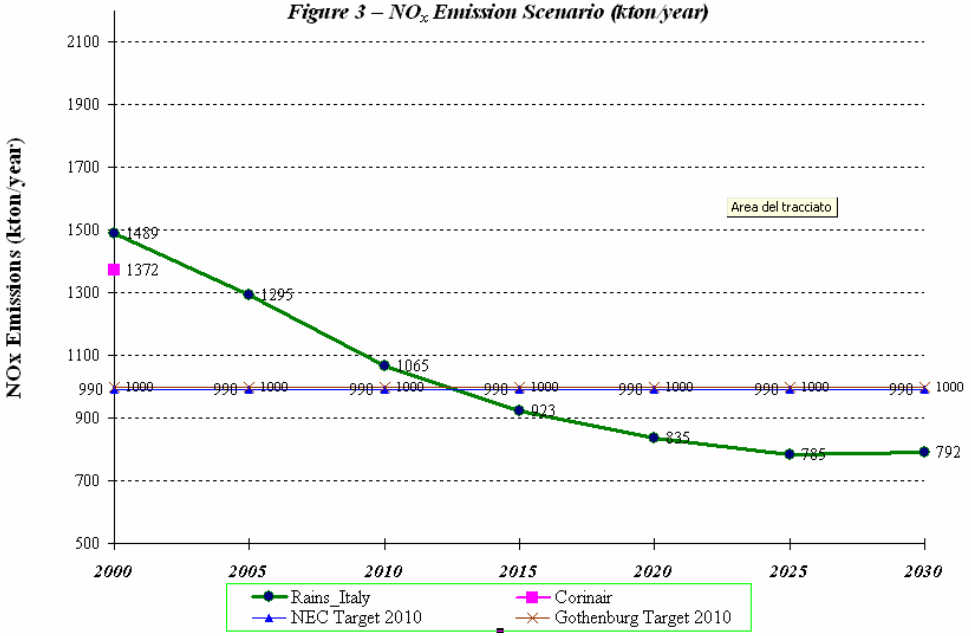


Figure 4 – VOCs Emission Scenario (kton/year)

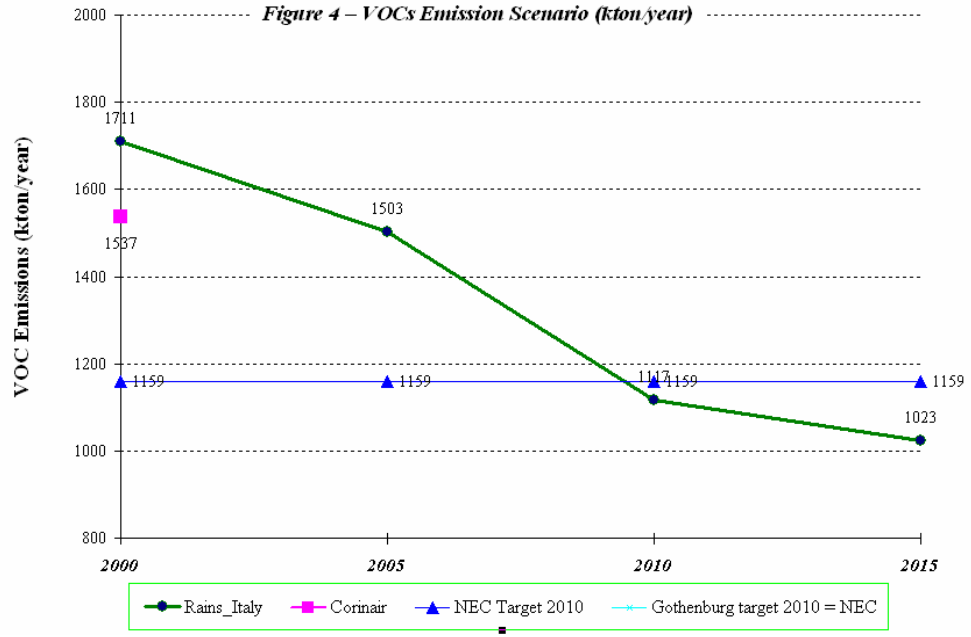


Figure 5 – NH_3 Emission Scenario (kton/year)

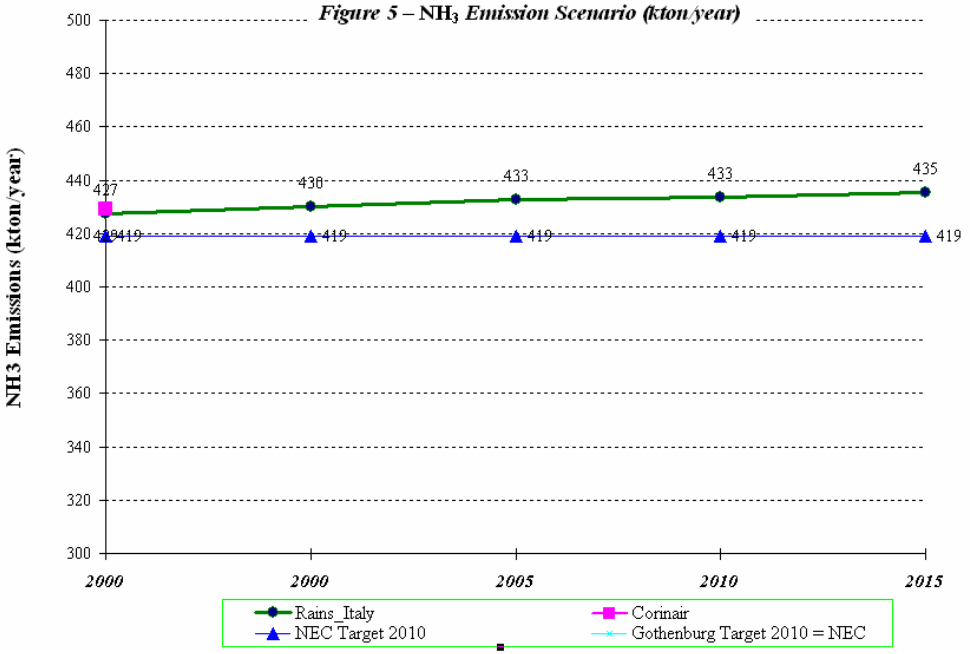
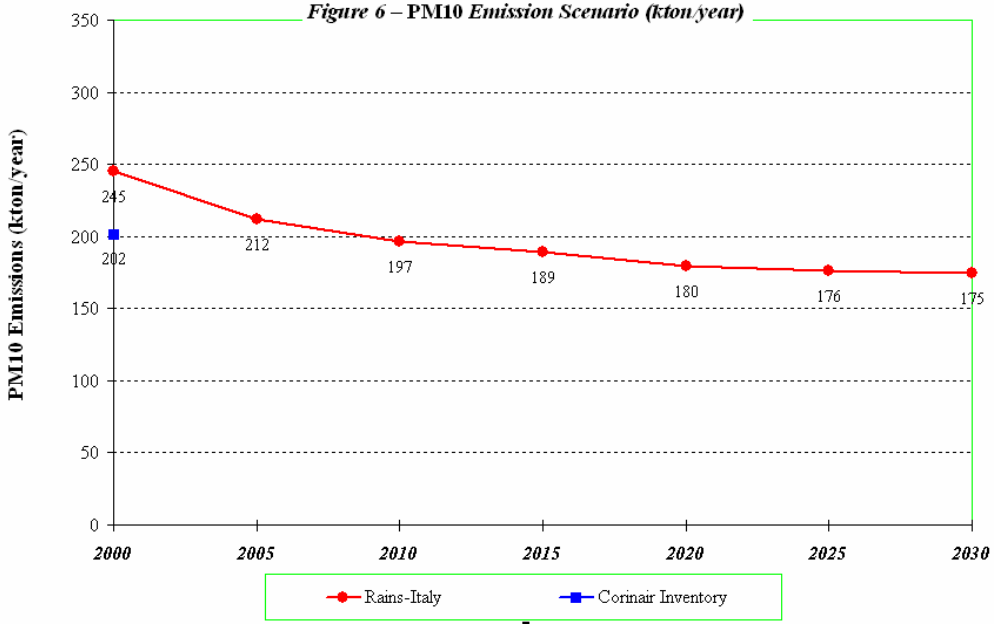


Figure 6 – PM10 Emission Scenario (kton/year)



Reduction Scenarios

The analysis of the emission scenarios shows as the compliance with the NO_x and NH_3 targets is hardly achievable. In tables 2 and 3, simplified lists of applicable additional measures, according to the cost curve developed by RAINS-Italy, are reported. For what concerns the NH_3 analysis, the additional measures imply the extension of the IPPC Directive provisions, to those livestocks (small farms) which are currently not subject to the Directive.

Additional Control Measures	**Unit Cost** (Euro/t NOx)	**Marginal Cost** (Euro/t Nox)	**NOx Removed** (kton)
Combustion Modification In Fuel Conversion and Industry	190 -:- 388	190 -:- 388	15
Combustion Modification in Power Plants	390 -:- 525	390 -:- 525	4
SCR on Large Ships	431	531	58
Industrial Processes Stage 1 Control	1000	1000	57
Euro 3 Standard in Off Road Transport	862	1021	12,6

Table 2 – Additional control measures for NO_x, according to the RAINS Cost Curve, and their maximum emission reduction potential.

Techniques	**NH_3 removed (kton)**	**Marginal cost (€/t NH_3)**
Other poultry: storage covers	2.41	9,66
Laying hens: stable adaptation	3,45	819,56
Substitution of UREA with other fertilizers	55,57	1184,44
Other poultry: stable adaptation / low ammonia application techniques	8,07	2874,61
Laying hens: stable adaptation / low ammonia application techniques	0,22	2891,79
Pig: Low nitrogen feed	8,84	4464,87

Table 3 – Additional control measures for NH_3,, according to the RAINS Cost Curve, and their maximum emission reduction potential.

The application of an appropriate mix of the above measures could lead Italy to the compliance with the international obligations.

References

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[3] IIASA Web Site (http://www.iiasa.ac.at/rains/review/index.html) – The 2004 Reviw of the RAINS Model

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