Harmonization of national inventory and projections of multi-pollutant emission scenarios. The Italian experience within the European context and the UN-ECE Convention on Long Range Transboundary Air Pollution

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ABSTRACT

In the development of environmental policies, within both the context of the 27 Member States of the European Community and the larger context of the UN-ECE Convention on Long Range Transboundary Air Pollution, there is the need of accurate assessment of the national emission inventories and projections of air pollutant emissions. This task is carried out at EU27/Convention level, as well as at national level, by Member States and Parties. Especially at EU level, where the mandatory directives on air quality are driven by emissions & projections data, the consequences of unrealistic emission objectives, deriving from low quality in inventories and projections can dramatically affect the economic life of the Countries. Therefore, for a number of years, Italy has put great efforts in establishing appropriate methodologies to achieve the best quality, as possible, in the inventory and emission projection assessment. This paper describes the adopted methodology, as well as the results, in terms of harmonization between inventory and emission projections and in terms of compliance with the targets and emission ceilings established for Italy by the EU Directives and the Gothenburg Protocol of the Convention, for the concerned air pollutants. The latest inventories and emission scenarios developed for the purposes of the review process (still in progress) of the EU Directive on Emission Ceilings, through a proper Integrated Assessment Model (RAINS-Italy), are reported.

INTRODUCTION

In the development of environmental policies, within the context of both the 27 Member States of the European Union and the larger context of the UN-ECE Convention on Long Range Transboundary Air Pollution, there is the need of accurate assessment of the national emission inventories and projections of air pollutant emissions. In fact, the most recent policies on Air Pollution, regarding both international legally binding treaties on the reduction of air pollution and the EU directives, which the Member States have to endorse in their national legislations, have been developed on the basis of the quantitative estimations of the pollutants emitted into the atmosphere, by each country, in a time

period usually spanning the 2000-2020 interval, and the related impact on the human health and the environment. In such a context, it is evident that the quantification of the current and future emissions, with the best degree of accuracy, is an indispensable pre-requisite. In particular, at the level of European Union, where the directives on air quality are mandatory and are driven by the emissions projections, which ultimately determine the health/environment impact, the consequences of unrealistic emission objectives, deriving from low quality inventories and projections, can dramatically affect the economic life of the Countries, as resulting in possible undue economic burden. So, the development and use of appropriate methodologies and adequate tools, suitable for the calculation of current emissions and projections, for the concerned air pollutants, within a reasonable uncertainty range, has been an important objective pursued for a number of years, in Italy, to finally achieve the highest quality, as possible, in emission inventory and projection assessment.

For a number of years in the past, the knowledge on the emission inventory calculation has been more consolidated than the estimation of the emission evolution over time. In fact, in Europe, the CORINAIR methodology, has been a well known and widely diffused official methodology for many years, for the calculation of the emission inventory of the atmospheric pollutants. However, in the last years, a particular class of models has started to be introduced and diffused in the whole Europe, the so-called Integrated Assessment Models (IAMs), suitable to assess the efficacy and the costs of the policies and measures to be introduced in order to reduce the air pollution, through a comprehensive analysis based upon emission projections, dispersion of the pollutants in the atmosphere and related chemistry, concentrations and depositions of pollutants at soil and their effects on the environment and, more recently, estimation of health impact. Among them, the most popular in Europe, is certainly the Regional Air Pollution Information and Simulation (RAINS) model, developed by the International Institute for Applied Systems Analysis (IIASA) of Laxenburg, Austria. The RAINS model (Amman *et al*, 1999; IIASA web site) is a European scale model, developed to calculate cost effective reduction emission scenarios in Europe, in the long term (1990-2030), for what concerns SO_2, NO_x, NH_3, VOCs and PM, and to assess the effects of acidification, eutrophication, ground level ozone and PM. The RAINS model, recently upgraded to the new version GAINS, considering the GHGs also, is currently the official IAM tool for the revision of the Gothenburg Protocol of the UNECE Long Range Transboundary Air Pollution Convention (CLRTAP) on the abatement of acidification, eutrophication and ground level ozone, and for the Thematic Strategy on Air Pollution, developed by the European Commission in the framework of the Clean Air For Europe (CAFE) Program (TSPA, Commission of the European Communities, *2005*).

The European context

Mirroring on EU scale the same methodological approach, successfully adopted in the UN-ECE context, in the framework of the CLRTAP, the most recent policies on Air Pollution, like the mentioned Thematic Strategy on Air Pollution, developed within the European Union have been based on the achievement of well defined objectives in terms of reduction percentages of the adverse effects caused by the air pollution, with respect

the impact levels at the reference year 2000. The Community's Sixth Environmental Action Programme (***6th EAP***) has inspired the development of a Thematic Strategy on Air Pollution, with the ultimate objective of attaining "*levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment*". The Thematic Strategy, once defined, was deeply analysed to check if the current legislation was sufficient to achieve the 6th EAP objectives, by 2020. This analysis has looked at future emissions and impacts on the environment and the human health and was used as the best available scientific and health information. The final results have shown that significant negative impacts will persist even with effective and full implementation of the current legislation. Accordingly, the Thematic Strategy on Air Pollution has established interim objectives for air pollution, within the EU, and proposed appropriate measures for achieving them, expressing recommendations to the EU Member States to improve the national legislations, to better focus on the pollutants most seriously affecting the human health and to make more efforts to integrate environmental concerns into policies and programmes.

The achievement the 6th EAP objectives "….*levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment*" means, for the natural environment, no exceedences of critical loads and levels. For human health, the issue is more complex, as for pollutants like particulate matter and ground level ozone, no threshold is recognised, below which safe level of exposure exists. Several scenarios aimimg at achieving the TSPA objectives have been analysed, in terms of impact assessment, ranging between no additional actions, with respect the Current Legislation provisions (CLE scenarios), to the application of all most effective technically feasible measures (MTFR scenarios). Even in the latter case, where all such technical measures were applied, irrespective of costs, it still would not be possible to meet the ambitious 6th EAP objectives. Therefore, a policy choice had to be made on the acceptable level of health and environmental protection that could be achieved by 2020, taking into account the associated benefits and costs. Extensive cost-benefit analysis was carried out to determine scenarios with different levels of ambition, aiming at finding the best cost-effective level consistent with the Community's Lisbon Agreement and Sustainable Development strategies. The Strategy finally sets health and environmental reduction objectives, according to the agreed ambition level and this result has been made possible thanks to the extensive use of integrated assessment models, and in particular the RAINS/GAINS-Europe model.

Since the Thematic Strategy on Air Pollution, will lead to the definition of the whole European policy on air pollution in the next years, through the revision of all the Air Quality Directives, it is clear how the correct definition of inventories and projections, as much precise as possible, has became an essential need for all the Member states, Italy included, in order to make the objectives to be achieved feasible and realistic, and moreover based on correct assumptions, in the national context, of the anthopogenic activities and related controls implemented. Given the environment/health effect-based approach, in detemining the final emission targets, Italy first, followed by other Member States, has invested significant resources in developing a National Integrated Assessment

Model, on the basis of the best available scientific knowledge in the field and following the tracks of the continental experience.

The Integrated Assessment Model for Italy: the MINNI project

In order to allow Italy to participate in the international fora with autonomously generated evaluations, since 2002, on behalf of the Italian Ministry of the Environment, ENEA has been leading a national Project, named MINNI (National Integrated Modelling system for International Negotiation), for the development of an Integrated Assessment Modelling System. The support to the policy makers, in the elaboration and assessment of air pollution policies at international, national and local level, by means of the more recent understandings of the atmospheric processes, was the ultimate objective of the project.
The MINNI Project (Zanini *et al*, 2005) consists of two main components: a multi pollutant eulerian Atmospheric Modelling System (AMS), and the RAINS-Italy Integrated Assessment Model, this latter developed within a joint research project ENEA-IIASA. The RAINS-Italy model, which a short description can be found in Vialetto *et al*, 2005, has been used to calculate the emission projections. Starting from data concerning the anthropogenic activities (energy consumptions, industrial production, livestocks, agriculture etc.) RAINS-Italy calculates emission scenarios, at 5 year intervals, for SO_2, NO_x, NH_3, VOCs and PM, on the basis of a long list of applicable abatement technologies, which the model user includes in the so called Control Strategy, according to the implementation of measures in line with the Current Legislation (CLE Strategy) or alternative Reduction Strategies. Investment and operative costs of the considered technologies are collected in a proper internal database. Therefore, abatement cost curves can be generated to provide a list of possible additional technologies to be implemented to achieve the desired target, in the most cost-effective way or to compare alternative strategies costs and effects. A simplify flow-chart of the RAINS-Italy model is shown in fig. 1.

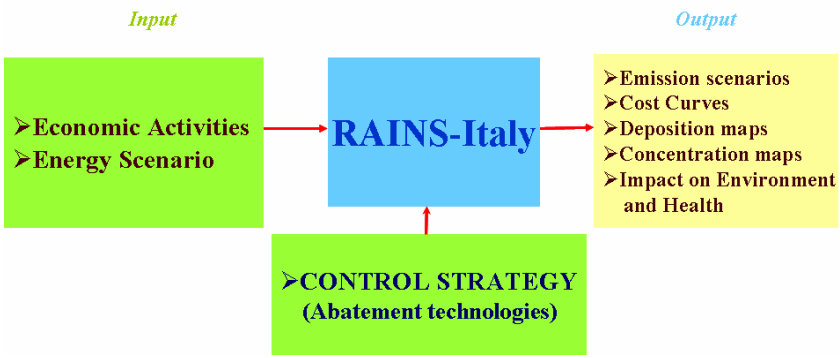


Fig. 1 – Simplified flow-chart of the RAINS-Italy model

Harmonization between Inventory and Model calculations

In order to consider the projections calculated by the model reasonably reliable, the model must be able to reproduce, at the year selected as *base year* (tipically 2000) the

same emission estimations as in the inventory, within an uncertainty margin. This process is usually called "*harmonization process"*, and it is aimed at ensuring that the emissions calculated, at the reference year, in the inventory and in the model analysis, are consistent. The need of the harmonization process arises from some important issues. First of all, the model must be validated through comparison with an independent reference. Second one, the robustness of the model projections is determined by the consistency, within an acceptable uncertainty margin, between inventory emissions and model calculations. Last but not least, since the harmonization process is a common practice in the frame of the EU and UN-ECE analyses, for reasons of comparison between national and international analysis, the harmonization is considered opportune.

Moreover, the need of the harmonization process comes from the fact that the methodologies used to calculate the emission inventories and projections, are different between them. In fact, according to the the CORINAIR methodology, the emissions are calculated on the basis of an activity level and an emission factor. In the CORINAIR methodology, the emissions from the sector j, are the result of the activity level in sector j (Act_j) multiplied by the total emission factor per unit of activity level, in sector j (EF_j):

$E_j = Act_j * EF_j$.

where : E_j = Emissions in sector J
Act_j = Activity level in sector J
EF_j = Total Emission Factor in secor J

Differently, in the RAINS-Italy methodology, unabated emission factors are used, to estimate unabated emissions, first. Then, the removal effciency η_{jk} of the technology k is considered along with the application factor (Af), for technology k. Therefore, the emissions calculated by the model are the result of the following expression:

$E_j = \Sigma_j \Sigma_k Act_j * Ef_j * (1 - \eta_{jk}) *$

Where : E_j = Emissions in sector J
Act_j = Activity level in sector J
EF_j = Unabated Emission Factor in secor J
η_{jk} = Removal Efficiency for Technology k, in sector J
Af_{jk}, = Application rate of Technology k, in sector J

where the term $(1 - \eta_{jk}) * Af_{jk}$ allows the calculation of the residual emissions after abatement, by technology k in sector j. The sum of the all contributions from the technologies k, provides the total emissions in sector j. This mechanism allows the quantification of both the abatement obtained by the technology k and the total and specific (Euro/abated pollutant unit) costs.

The comparison between the two methodologies is not always easy. In fact, quite often the sectors considered are different and/or differently aggregated, in inventory and model calculations, so, the goal of a univocal correspondence between the sectors of the

RAINS-Italy model and the SNAP codes in the inventory, is a hard job, in a lot of cases. The harmonization process is carried out according to the scheme, summarized in fig. 2.

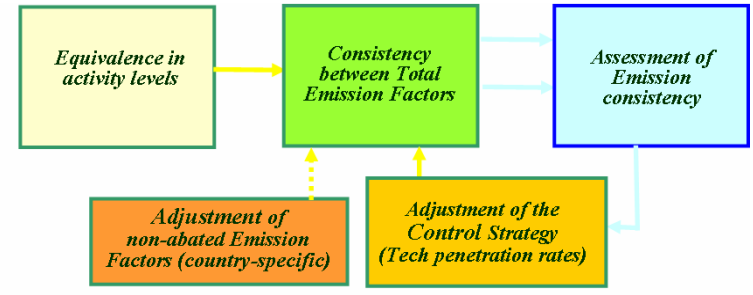


Fig. 2 – The harmonization process flow chart

In order to take into account of the differences between the model estimations and inventory, all the activity data (fuel consumption, production levels, solvent use, livestocks etc.) are compared, first. Then, when a reasonable equivalence is achieved on the activity data, the control strategy is adjusted, in order to take into account of the known degree of abatement techniques penetration, in the productive sectors. This process is always driven by the comparison of the emissions, by sector, in the inventory and in the model. In some particular cases, when the Control Startegy adjustment fails to align the emissions, the unabated emission factors in the model are then modified, being clear that incompatible differences in the emission factors exist.

The reasons which lead to the main differences between the two methodologies are due to the fact that RAINS-Italy sectors have a higher level of aggregation with respect the SNAP codes in the inventory, and very often there is no correspondence. Moreover, some sources are considered in RAINS-Italy and not considered in the inventory (or vice versa). There are some cases in which a different activity level for the same source is observed, in the RAINS-Italy model, with respect the national inventory, or few cases, in which, the RAINS-Italy sectors have a higher level of details with respect the inventory and a compromise is not always easy achievable.

The comparison between the emission inventories and the emissions calculated by the RAINS model, for the main air pollutants considered, at year 2000 in Italy, once the harmonization process is complete, is shown in fig. 3.

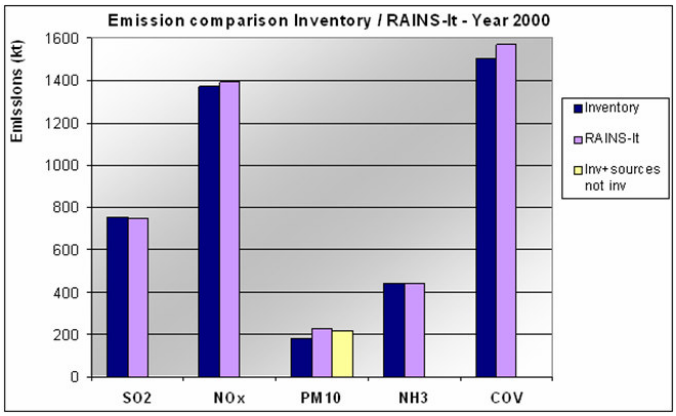
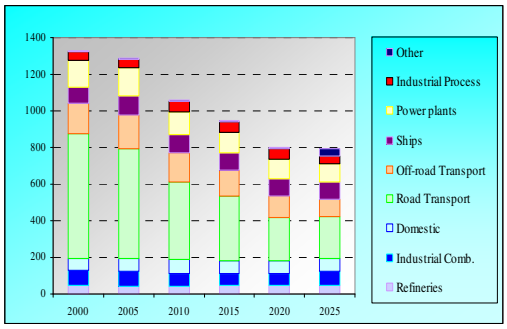


Fig. 3 – Comparison between Inventory and RAINS-Italy emissions, at year 2000 in Italy, after the harmonization process has been applied

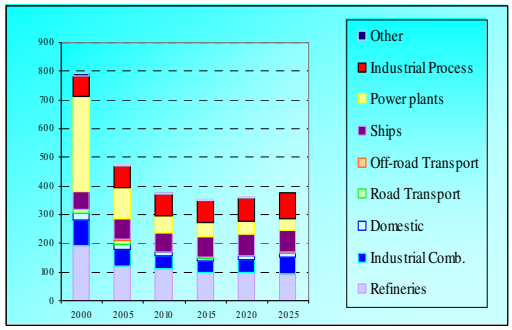
The analysis in the fig. 3 shows as the harmonization result is quite good for SO_2, NO_x and NH_3, where the discrepancies between the two estimations are about 1 – 2 %. These differences are widely within the uncertainties introduced by the model and the different methodologies used. As regards the VOCs emissions, the discrepancy is about 5 %, once again acceptable, taking into account of the uncertainties and methodological differences. The in depth analysis on VOCs emissions has shown as the discrepancy is mostly due to two sectors, only (solvent use and evaporative emissions from road vehicles), where significant differences in the methodological approache have been found. As regards the PM emissions, it has found that some emission sources seem not to be considered in the PM_{10} inventory (CORINAIR), while the same sorces are included in RAINS-Italy, e.g. agriculture (livestock and arable land), barbecue, cigarettes, fireworks and construction works. Such sources have been excluded from the inventory because the related emissions are affected by significant uncertainty and due to the lack of clear indications, in literature, on how these sources should be considered. In figure 3, the yellow bar, at the year 2000, shows what the inventory emissions would be, if the missing sources, calculated by RAINS-Italy, as mentioned above, were added,. As a result, at the year 2000, the RAINS-Italy and CORINAIR inventory estimations, after correction, are closer within an uncertainty margin of 5,9 %, definitely better acceptable. As shown by this example, the RAINS-Italy methodology has proved to be an alternative approach to estimate the contribution from PM_{10} sources not yet considered, in the inventory.

Italian emission scenarios and compliance with the EU Directive on emission ceilings (NEC Directive)

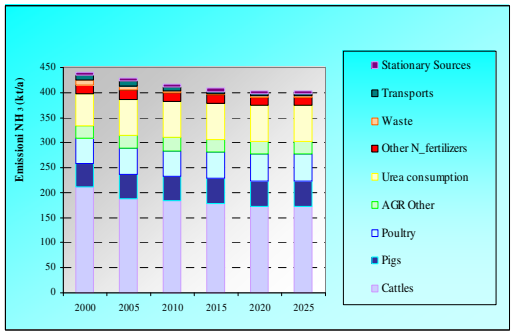
The national RAINS-Italy model has been used to develop emission scenarios for the pollutants regulated by the National Edmission Ceilings (NECD) Directive (D'Elia *et al*, 2007). As said above, the harmonization process improves the robustness of the projection analysis, the ultimate objective being the assessment of the compliance with the NEC Directive ceilings established at 2010. Moreover, the emission scenarios developed by RAINS_Italy have been compared with the similar analysis carried out by IIASA, on behalf of the EU Commission, for all the EU Member States (not reported here). The resulting emission scenarios are shown in fig. 4.



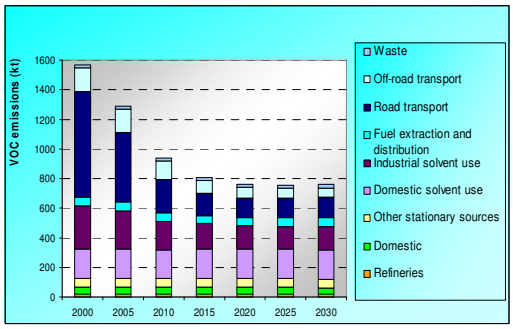
a) NOx target 2010 = 990 kton



b) SOx target 2010 = 475 kton



c) NH3 target 2010 = 419 kton



d) VOC target 2010 = 1159 kton

Fig. 4 – National emission scenarios of NO_x (a), SO_2 (b), NH_3 (c), VOCs (d) (kt/y), calculated by the RAINS-Italy model (NEC Directive review process, October 2006)

As shown in the fig. 4, Italy would be in compliance with the provisions of the European Directive on emission ceilings, with the exception of NOx emissions, as the projected NOx emissions at 2010 are exceeding the ceiling, by about 6,6 %. However, the issue is still open, since an in depth analysis, developed at national level, again by RAINS_Italy, has proved that Italy would be in compiance with the NOx ceiling, if the projections were calculated using the same parameters (namely removal efficiencies of abatement technologies) used in 1998, when the NEC Directive ceilings were established. This issue needs to be addressed at EU polical level, since it deals with methodological aspects and concerns all the EU Member States.

CONCLUSION

The most recent policies on air pollution, developed within the European Union, have been based on the achievement of well defined objectives, in terms of reduction of the adverse effects caused by the air pollution, on the environment and the human health. The definition of these objectives has been supported by Integrated Assessment Models, suitable to calculate cost-effective emission scenarios meeting the environmental/health targets. The robustness of the projections is strongly related with the development of high quality inventories, which therefore become a priority for the Member States. The harmonization process between inventories and projections, taking into account of the differences introduced by diverse methodological approaches, is aimed at providing a good agreement between the emission estimates. In Italy, the CORINAIR methodology for the development of emission inventories, and the IAM RAINS-Italy Model for

building the emission scenarios, have been adopted. The harmonization process, applied in this study with a clear and well defined methodology, has resulted in a good agreement between the two estimates, at the reference year 2000. The emission scenarios, so developed, have shown as Italy should be in compliance with the provisions set up by the European Directive on emission ceilings.

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KEY WORDS

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Harmonization
Emission Scenarios
Health Impact