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SUCCESSES AND PROSPECTS OF REGULATORY EMISSION REDUCTIONS UNTIL 2010 WITH AIR-QUALITY MODELS

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Abstract: The emission abatement efforts for the target year 2010 are examined following the recommendation introduced in Europe after the first and second AutoOil programmes. These Programmes started since 1992 and were a partnership between the European Commission and the automobile and oil industries. These regulatory aims tried to identify the most cost-effective way to meet desired future air quality in the European Union (EU). In their times these were considered an important step in a new approach to setting European emission limits. Since then, and in the absence of industrial partnerships, various NGOs have driven the aim of emission reductions towards on population exposure with objectives that are driven by vague indicators as is the statistical expectations of days of live lost. In the absence of advance knowledge and with rather simplistic tools, these regulatory objectives will become difficult to fulfil without the emergence of new technologies and the involvement of citizens in monitoring personal exposure. With this work we examined the targets set of the early emission reduction efforts and how were these realised with real measurements in the target years at the respective domains. The successes of these regulatory models provide recommendation for the implementation of new technologies for setting the targets of new prospects in regulatory tools that can achieve realistic emission reductions beyond the present capabilities.

Key words: *Emission reductions, Air-quality modelling and monitoring, European regulations, AutoOil***.**

INTRODUCTION

The key elements of utilising modelling for showing compliance with the requirements of European Environmental Policy is not new (Olesen and Mikkelsen, 1992). The use of these models for regulatory purposes requires the coherent coupling of many disciplines representing anthropogenic and natural processes. For policy purposes, these were then linked to economic data for identifying cost-optimum solutions achieving maximum pollutant reductions over regional and urban domains. This has been the case when industrial partners' participated in common actions with regulatory authorities for achieving best air-quality concentrations over large regional territories. In the past, vehicle emission limits have been set using the 'best available technology' approach. As standards have become increasingly stringent, it will be essential to adopt new approaches for future emission reductions. During the first two AutoOil programmes, extensive studies for Automotive Fuel Quality, Engine Technology and Emission Studies and in the end have sparked many legislative efforts like the so-called Daughter Directives, the Ozone and PM studies and eventually the Clean Air for Europe Programme. All these had as a target year 2010 and were based on several forecasts for emission reduction scenarios.

Despite several emission reduction efforts, air pollution remains in many areas at levels above acceptable levels. With this work, we are reviewing the effectiveness of options that were available at the time of forecasts and we compare these with actual air-quality measurements for the target year 2010. We examine also, why air quality problems have become more complex at regional level with a wider impact of oxidants on population and rural ecosystems. Evidence for why integration in regulatory applications is necessary across scales (local, regional), sectors (transport, energy) and issues (ozone, particulate matter) together with health effects as identified at the European Commission Action plan for Environment and Health (COM-2004-416). Especially for "reducing the disease burden and for identifying and preventing new health threats caused by environmental factors".

REGULATORY METHODOLOGY
In planning for the abatement and control of air pollution in regional and urban domains several complex issues might arise. Certain aspects can be addressed by integrating emission and air-quality and then by carrying out a cost effectiveness assessment; especially for chemically reacting pollutants there are no alternative means of examining the critical issues.

The spatial resolution of an ambient air quality model (that is, the area over which the predicted concentrations are averaged) may vary from several meters to several thousand kms. The partial differential equations are solved numerically. The choice of the spatial grid on which the equations are solved is governed by the degree of spatial detail in the emissions inventory and the accuracy of the meteorological variables. Sometimes it is desired to predict pollutant concentrations in the immediate vicinity of sources, city centre as well as the greater downwind area. In such a case, the spatial resolution of the concentrations might be as small as a few km at the centre but coarser at the outer regions. The coupling of these resolutions in multi-nested layers and the on-line interaction of the solution schemes (two way nesting) provides the basis of accurately examining man-made emissions and their impact in greater geographical areas. Apart from the improved treatment of boundary, the other obvious advantage of these models is that the coarser domains can be allowed to carry simulations over long modelling periods (several months).

The key issue related with the desired accuracy of regulatory impact assessments is the spatial resolution in the horizontal and vertical directions. Naturally, the finer the model in the horizontal direction the more accurate is the physical representation of the overall processes. On the other hand, emission of pollutants at different heights from industrial and traffic coupled with the vertical atmospheric transport requires that the models have a reasonable number of levels in the vertical direction. The proximity of maximum ozone concentrations near large urban agglomerations at South Europe and the existence of significantly varying conditions in densely populated areas means that average representation in coarse regional grid sizes (more than 100x100 km^2) is rather inappropriate.

The temporal resolution of air-quality models (that is, the time period over which the predicted concentrations are averaged) may vary from several minutes to one year. For example, a model may predict the 15-min average pollutant concentration at various locations. The requirements in implementing a model are strongly governed by its temporal resolution. Spatial resolution is frequently considered of secondary importance in order to provide simulations over long modelling periods.

REGIONAL ASSESSMENTS
The scope of regulatory simulations is to analyse compliance for pollutants that have regional impact. A typical example is ozone, for which the regional impact of emission reduction scenarios needs to be estimated. The ozone concentrations over Europe are shown in Fig. 1 (left). Simulations are carried out with EMEP (Simpson, 1992) a single layer Lagrangian model every six hours on a scale of 150x150 km^2. The advantage of this model is its simplicity for calculating over long time-periods. By assuming that ozone concentrations are highest during afternoon hours, the 8-hour averaged concentrations were estimated by averaging the calculated concentrations at 12:00 and 18:00.

For photochemical simulations it is essential to relate the ozone concentrations with emissions on an annual basis. In the past, this problem was prohibitive in terms of computational time and for this reason the overall processes were severely simplified. However, even today the EMEP grids (Dore and Vidič, 2012) are used even if they introduce 27% more area averaging in northern latitudes (Fig. 1 right). Although, this is perhaps acceptable for emissions due to small spatial variations, it introduces significant underestimation of concentrations emitted and transported due to large area averaging for each grid cell. Recent advancements in computational speeds coupled with the reduced costs of electronic storage can resolve these restrictions. Yet, remains the accurate representation of emissions, which needs to be given at each grid cell for the corresponding temporal resolution especially for natural sources.

The aim of legislation requirements in Auto Oil-1 at Sub Group-2 (1996) was to identify suitable measures that could be introduced in the coming years and will lead in achieving compliance to the desired air-quality is reached by say 2010. The application of regulatory models in this type of long-term forecasts requires first the suitable updating of emission inventories and second the identification of suitable emission reductions in order to achieve compliance to specific target air-quality values. Despite the fact that the projection of emissions inventories is uncertain due to the complexity of anthropogenic activities and the statistical nature of forecasts, the updating of emission inventories can be described as a purely logistical process. However, it is a process which by no means will ever become 100% accurate.

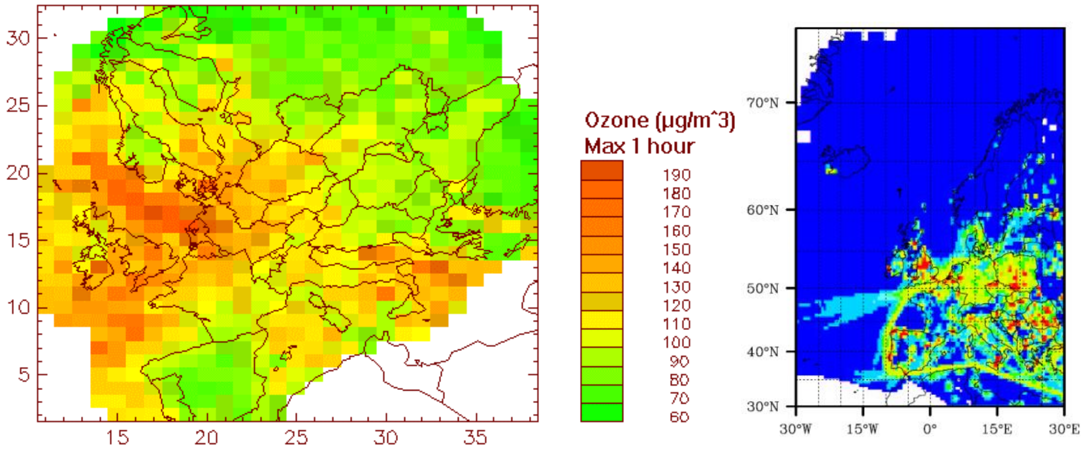

Figure 1. The EMEP max one-hour ozone concentrations at Europe plotted (left) over the 150km polar-stereographic projection, and the SOx emissions (right) in spherical coordinates for the 50km grid.

Taking into consideration already agreed technological measures until 2010 the emission inventories can be updated according and photochemical calculations were carried out in AutoOil-1 with EMEP. As shown in Fig.2 the reduction of emissions will improve the percentage of European area which achieves compliance but with varying impact. With the straight line at the same figure are shown the limit values. The intersection of the distribution curve with the limit value indicates the percentage of the area above which the limit value is exceeded. It is evident that the 8-hours average is practically exceeded all over Europe. The same figure shows that 73% of the European territory exposed to one-hour average concentrations of 180 μg/m³ in 1990 this will be reduced to 47% at 2010.

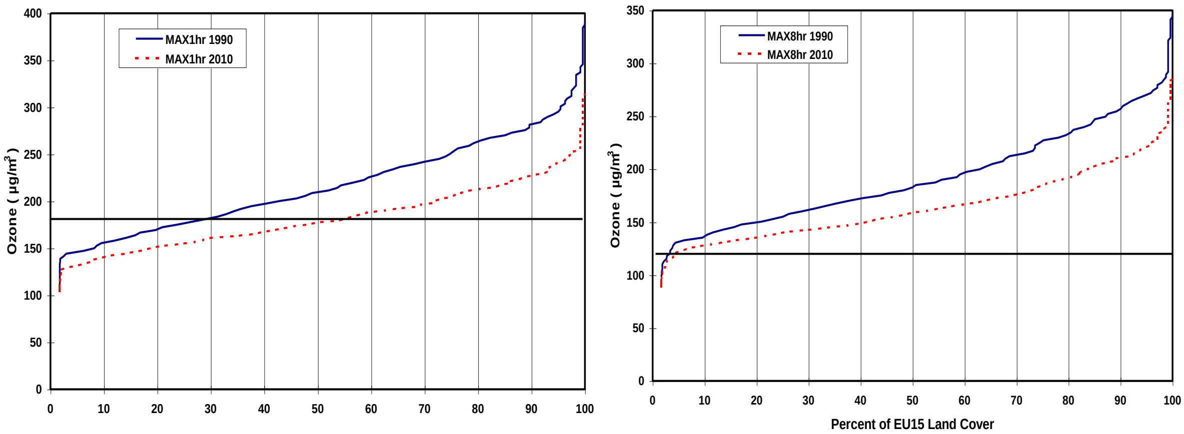

Figure 2. Ozone concentrations at the EU15 states and the percent of land cover effected area. Impact of agreed measures until 2010 on maximum 1-hour, and maximum 8-hours.

In order to improve the compliance area further reductions on NOx and VOCs emissions are needed. Sensitivity calculations for 2010 have shown that despite significant improvements of the European territory experiencing high one-hour concentrations there are still areas where the targets are exceeded.

URBAN ASSESSMENTS

Article 4 of the European Directive on passenger car emissions states that the Commission's future proposals "shall be designed to produce effects to meet the requirements of the Community air quality standards and related objectives at least cost". However, the major challenge of the AutoOil-2 programme was to take account of all emission sources in an integrated manner and without compromising or frustrating on going policy initiatives directed at products or sources which give rise to atmospheric pollution. For assessing the impact of emission reduction in metropolitan areas the existing and projected air-quality conditions were analysed with advanced 3D photochemical models for assessing the impact of emission reductions under annual mean and the most severe episodic conditions.

Emission Source Attributions

The attribution of pollutant concentrations into emission source categories is essential prior to establishing cost-effective solutions for future scenarios or for implementing legislation related to emission reductions (Skouloudis, 2000). Naturally, the emission inventories need to be sufficiently disaggregated into the same source categories. Because in AutoOil-2 simulations were carried out separately for 18 categories it was possible to identify directly the attribution of Traffic Sources (CAT_20), the Elevated Area Sources (CAT_21), the Large Point Industrial Sources (CAT_22), the Other Area Sources & Nature (CAT_23) as well as the Non-Attributable Secondary Concentrations (NASC) part of primary emissions which was due to chemical reaction potential the different portions concentration originating from natural background and the portion originating from the boundaries (i.e. the imposed lateral boundary concentrations). The “non-attributable” portion in Fig. 3 means simply not directly attributable to anthropogenic sources. In reality, this portion also “indirectly” originates from the existence of primary emissions as a whole in the atmosphere.

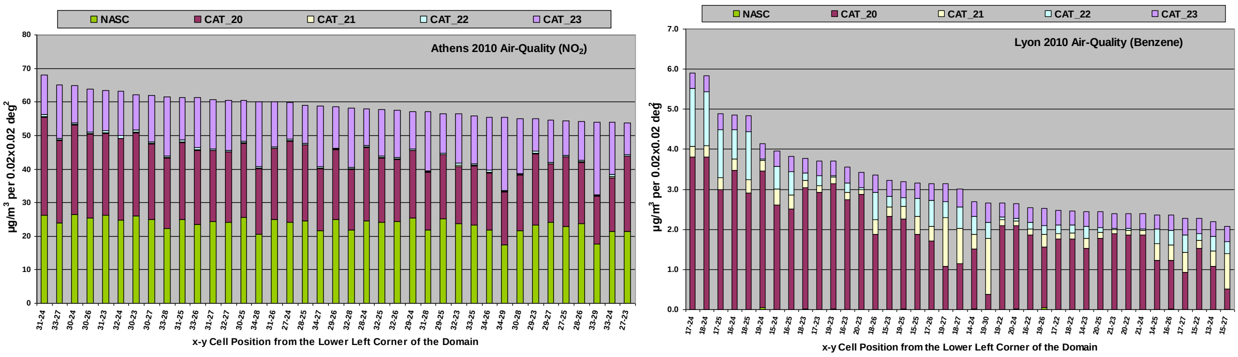

Figure 3. Source attribution of Air-Quality for 40 grid-cells with the largest concentrations at the city domains of Athens and Lyon.

For the implementation of abatement strategies it is necessary to establish an accurate relationship between air-quality concentration and emissions. Despite the complexity of establishing this link (especially for photochemical processes), the models utilized in AutoOil-2 characterized the "physical reality". Yet for meeting the current and future economic objectives the modelling process needs to be further coupled with cost-effective models that utilise off-line the air-quality rather than emission files.

Spatial compliance

Following the emission projections for the target year, the photochemical simulations for the target year produced spatial contours maps showing the detailed areas of exceedance over the target year. From these the population exposure and the percentage of the urban area above the WHO target values are calculated. The latter is shown in the following Fig. 4 for the ten AutoOil-2 domains.

Most urban domains contain a number of air-monitoring stations operated under the auspices of air pollution control authorities, at which average pollutant concentrations levels are reported ranging from minutes to hours. Comparisons have been carried out with the actual measurements for the target year. Such results cannot be shown due to space limitations in this short abstract. However they will be part of the full version of the manuscript. The data from AutoOil-2 confirmed the trends for the annual mean projections much better that the projections forecasted by the multiplications of AutoOil-1. In addition the comparisons are also satisfactory for most of the 98 percentile episodes. The remaining issues concerning these comparisons are the representativeness of the monitoring sites over the domain of our interest.

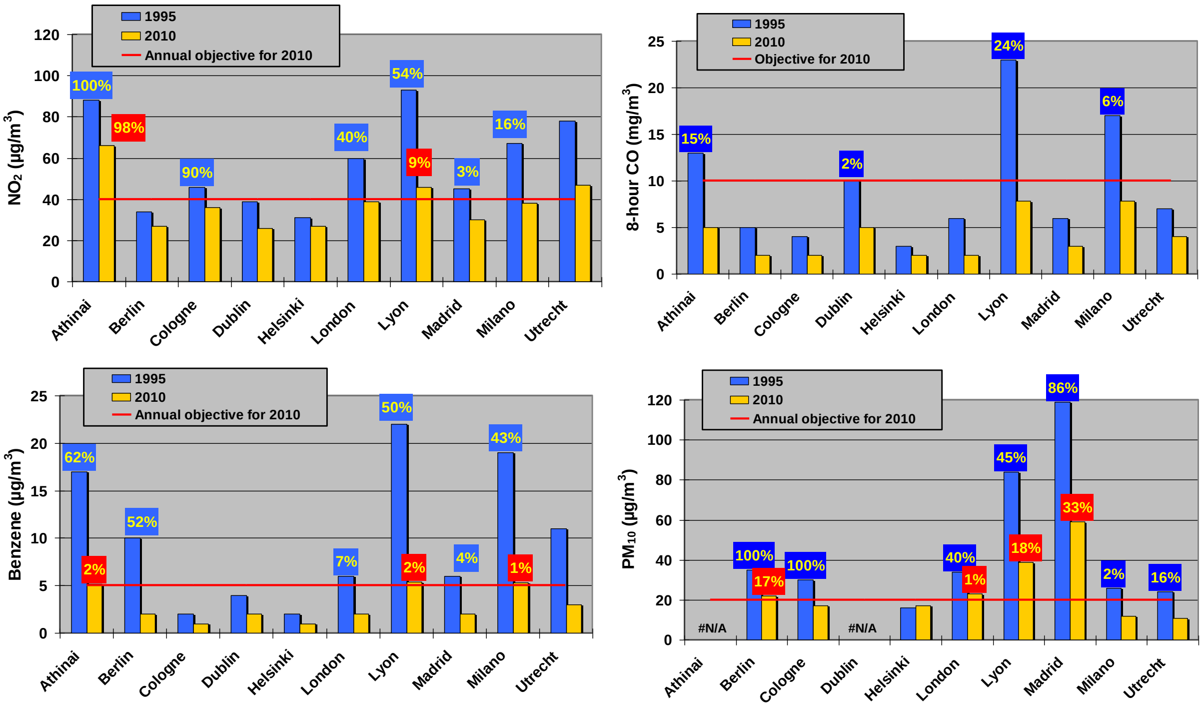

Figure 4. Max concentration comparisons for NO_2, CO, Benzene and PM10. The urban area above the 2010 objectives is indicated with the percentages.

CONCLUSIONS AND PROSPECTS FOR REGULATORY METHODOLOGIES

In the past, emission control strategies that were fundamentally linked to the strength of the emission sources and all atmospheric processes were assumed to be static. Subsequently these strategies were coupled with measurements of air-quality through networks of measuring stations, which also had limitations in representing reality over large areas.

The verification with actual air-quality measurements for the target year shows that approaches that represent more realistically the atmosphere can estimate accurately the potential of regulatory measures. The integrated use of urban and regional models in this study has shown deterioration in ozone concentrations. However these were more significant outside the urban areas where the mechanisms of ozone formation is more closely related to the background concentrations and to the enhancement due to the climatological conditions. New technologies of monitoring can further enhance all steps of regulatory simulations and introduce significant advancement in the actual verification of abatement strategies.

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