Economic impact modules for the EUROS model

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Abstract

EUROS is a European atmospheric dispersion model calculating ozone concentrations as a function of NOx and NMVOC (non-methane volatile organic compounds) emissions and meteorological and geographical data. In this paper we will present a module for evaluation of costs and benefits of emission reduction scenarios and hence of emission reduction policy measures. The data in the module can be located with high geographical detail and can be linked with reduction measures. This link and cost calculation is possible because of the technological and economical data available. 85% of the NOx and 65% of the NMVOC emissions from stationary resources in Belgium were identified in the model and can be linked with reduction technologies.

Different scenarios were worked out. Even under maximum reduction the NEC emission ceilings for NMVOC could not be reached. This underlines the importance of a detailed bottom-up approach. EUROS calculated ozone concentrations for different scenarios and locations in Belgium. For the calculation of the benefits, the concentrations are linked with regional data. The cost-benefit analysis indicated that maximum reduction was not profitable for ozone reduction. But indirect benefits are important and equal to costs for NOx reduction. Since foreign emissions were kept constant in this project, it can be concluded that ozone reduction in Belgium is strongly dependent on emission reduction abroad. The combination of EUROS and cost-benefit modules allows quantification and balancing measures and impacts, taking into account geographical location. Further research taking into account foreign countries can lead to interesting conclusions.
1 Introduction

High atmospheric ozone concentrations are frequently observed in summertime. The formation of ozone results from the oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NOx) and high temperatures and sunlight.

Because of its oxidizing character, ozone is damaging for public health and vegetation [1][2]. If the ozone concentration is higher than 180 μg/m³, the government warns the public for negative impacts on health.

To reduce the ozone concentrations, both long-term and short-term measures have to be taken by the government. The long term policy concentrates on sustainable reductions of the emissions of the two ozone precursors NOx and NMVOC. The Göteborg Protocol to the Convention on Long-Range Transboundary Atmospheric Pollution (CLRTAP) of the UN/ECE prescribes emission ceilings for the emissions of NOx, NMVOC, SOx and NH3 in 2010. The European directive on National Emission Ceilings (NEC) is even stricter.

Several models were built to simulate ozone formation in Europe. They enable the policy maker to set of the emission ceilings [3]. Given the small size of Belgium, it is interesting to refine these models. [4] The BELEUROS project [5] adapted the EUROS model for Belgium. This paper presents the cost-benefit module developed for the BELEUROS model.

2 Objective

EUROS is a atmospheric dispersion model developed by RIVM (Netherlands) and adapted for Belgium by Vito, calculating ozone concentrations as a function of NMVOC and NOx emissions as well as meteorological and geographical data. The aim of the presented project was to build a module for evaluation of costs and benefits of emission reduction scenarios and hence of emission reduction policy measures. With costs being the costs for the installation of emission reduction measures, calculated per installation. The benefits are the reduced costs for health care and the reduced crop yields. Not only reduced costs linked directly to the reduction of ozone, but also the indirect benefits from the reduction of nitrates were evaluated.

3 Methodology

The major difference with the RAINS model is the spatial dimension of the emission sources. All emission data, stationary and mobile, were located bottom-up. The classification of the emissions permits to locate the sources geographically, to link the emissions with reduction technologies and to serve as input for the EUROS model. This allows us to locate the costs and effects of measures geographically.

It is important to reduce the uncertainty in the emission data. In [6] an analysis is made on the robustness of emission reduction cost functions. A national
emission reduction cost function for VOC emissions and the Monte Carlo Method are used to demonstrate the high degree of uncertainty in the global cost estimations due to uncertainties in volume (emission) components of the emission reduction cost function. It is demonstrated as well that uncertainties in the price components are less critical although a small downward bias is observed.

Emission reduction measures abate emissions. These measures can be primary or secondary. Primary measures prevent emissions, secondary measures abate emissions. The necessary information to link the technology with the installations is abatement efficiency, investment and operation costs and technical information.

The model includes a lot of emission, technology and economical data. It includes 85% of the NOx-emissions from stationary resources. For each installation responsible for those emissions, technologies for emission reduction were identified. For NMVOC 65% of the emissions are identified in the model. All emissions in the model can be located geographically. They are divided into two categories: point sources and area sources. For NOx the greatest part of the stationary emissions are identified as point sources.

The model allows calculating for a certain year in the future the emissions in a business as usual scenario, the possible emission reduction for this year and the costs linked to this reduction. The model calculates also the mean and marginal costs for each combination. These data are used to calculate total costs and draw cost curves.

Mobile sources were not included in the cost module. The results from the study of I. De Vlieger (VITO) et al. (2001) “Measures in the transport sector for the reduction of CO2 and tropospherical ozone” [7] are located geographically. These mobile emissions are considered as line sources and split out over the Belgian transport infrastructure (roads, railways & waterways).

4 Results

4.1 Emission projection

In the following table an overview is given of the results of the different scenarios that are calculated. 1997 served as the reference year. All the collected data are for this year. For the Business As Usual (BAU)-scenario 2010, the data from 1997 are projected with sector evolution factors, taking into account the current legislation and known end-of-life replacements till 2010. The sector evolution factors used are from the MIRA-S scenarios (Flemish environmental report) [8], calculated by the Federal Planning Agency and from the EPM model of ECONOTEC [9]. Based on the data for 2010 the maximum reduction scenario is calculated. Because the hypothesis ‘the emissions grow as fast as the sector’ is
contestable, we calculated a BAU-scenario with the hypothesis that the emission growth stands still and only reduction is possible.

Although the business as usual (BAU) scenario 2010 does not reduce enough to meet the Göteborg Protocol and the European directive on National Emission Ceilings (NEC), extra emission reduction measures could be found to meet the emission ceilings for the NOx-emissions, but not for the NMVOC-emissions. The volume of the NMVOC-emissions are not well known, nor costs and effectiveness of NMVOC-emissions reduction measures. Further research on this subject could reveal new reduction potentials.

Table 1: Total emissions for the different scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>NOx</th>
<th>NMVOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Göteborg</td>
<td>184</td>
<td>144</td>
</tr>
<tr>
<td>NEC</td>
<td>176</td>
<td>139</td>
</tr>
<tr>
<td>IIASA MFR 2010</td>
<td>127</td>
<td>102</td>
</tr>
<tr>
<td>1997</td>
<td>305</td>
<td>292</td>
</tr>
<tr>
<td>2010 BAU</td>
<td>227</td>
<td>196</td>
</tr>
<tr>
<td>2010 BAU 0% growth emissions</td>
<td>204</td>
<td>179</td>
</tr>
<tr>
<td>2010 MAX RED</td>
<td>159</td>
<td>174</td>
</tr>
<tr>
<td>2010 0% growth MAX RED</td>
<td>147</td>
<td>160</td>
</tr>
</tbody>
</table>

The emissions of the reference year, the BAU scenario 2010 and 2010 MAX RED (maximum reduction) were geographically located and converted to a grid with square cells of 15 by 15 kilometers. Those grids were used by the EUROS model which calculates the ozone concentrations given the emissions. The ozone concentrations are used to calculate the benefits from ozone reduction. The figures 2 and 3 show the total NOx emissions for the reference year 1997 and BAU 2010.

1 Maximum Feasible Reduction scenario, as calculated by IIASA (International Institute for Applied System Analysis) in preparation of the Göteborg protocol.
4.2 Cost calculation

For the cost calculation, the emission reduction costs borne to satisfy current legislation or end-of-life replacements are not taken into consideration. Only the costs for extra reduction were calculated. Cost curves were set up based on the emissions for the BAU 2010 scenario.

In the figure below the total cost curve for NOx reduction in the BAU 2010 scenario is presented. The different policy goals: Göteborg and NEC are indicated. From the figure can be read that the Maximum Feasible Reduction scenario of IIASA is far from realistic for the Belgian situation.

![Figure 1: Total Cost curve NOx BAU 2010](image)

The BAU 2010 scenario was also calculated with 0% growth of the emissions to simulate a stand still of the emissions. Based on these emissions, cost curves for NOx and NMVOC were set up. The maximum reduction that could be reached by cost curves can be seen in table 1. The costs associated with it can be found in table 2. Although the emissions do not grow, the MFR scenario of IIASA could still not be reached. The maximum reduction that can be reached with 0% growth is also smaller.

<table>
<thead>
<tr>
<th></th>
<th>NOx kton reduction</th>
<th>NOx MEURO per year</th>
<th>NMVOC kton reduction</th>
<th>NMVOC MEURO per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 MAX RED</td>
<td>68</td>
<td>392</td>
<td>22</td>
<td>372</td>
</tr>
<tr>
<td>2010 0% growth MAX RED</td>
<td>57</td>
<td>435</td>
<td>18.3</td>
<td>353</td>
</tr>
</tbody>
</table>
Figure 2: Total NOx Emissions (in kg) per grid cell of 15 by 15 km, 1997

Figure 3: Total NOx Emissions (in kg) per grid cell of 15 by 15 km, BAU 2010
4.3 Benefit calculation

For the calculation of the benefits, the model uses the ozone concentrations of ten points distributed over Belgium, generated by the EUROS model. Based on the difference between the ozone concentrations of two scenarios, the model calculates the benefits of NOx and NMVOC reduction. Benefits can be a direct or indirect effect of ozone reduction. With the direct effects is meant the change in health effects and agricultural effects caused by a change in ozone concentrations. Lower ozone concentrations gives lower negative health or agricultural effects, thus benefits, higher ozone concentrations means negative benefits or costs.

Indirect effects are effects caused by NOx in the formation of nitrates. The reduction of those effects is not a direct consequence of the reduction of the ozone concentration, but of the reduction of NOx.

4.4 Cost-benefit analysis

In table 3, the costs and benefits of the transition from one scenario to another are put together. As mentioned before, the costs for satisfying current legislation or End-Of-Life replacements are not taken into account.

<table>
<thead>
<tr>
<th>Reduction (kton)</th>
<th>Costs (MEURO)</th>
<th>Benefits (MEURO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOx</td>
<td>NMVOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997 – BAU 2010</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>2010 – MAX RED</td>
<td>68</td>
<td>22</td>
</tr>
</tbody>
</table>

Based on the direct effects, benefits in health and agricultural effects, there appear to be no benefits from NOx and NMVOC reduction in BAU 2010 MAX.

This result is due to the fact that NOx-emissions can create and delete ozone. The relation between the amount of NOx-emissions and the ozone concentrations is non-linear. Till a certain point, ozone concentrations are increasing with lower NOx concentrations, after this point ozone concentrations are lowering. In this study, it was not possible to indicate how much NOx reduction gives lower ozone concentrations. The calculation time limited the number of scenarios that could be worked out. The only conclusion that can be
drawn is that the maximum reduction in the BAU 2010 scenario creates no direct
benefits in comparison with BAU 2010.
On the other hand, the indirect effects of NOx reduction, health effects from the
reduction of nitrates, are more important than the direct effects, even taking into
account the uncertainty of the benefits of the indirect effects. The indirect effects
make further NOx reduction cost-effective.

5 Conclusions

The estimations for the different scenarios were made with constant emissions
for foreign countries. The effect from emission reductions abroad were not taken
into account. The effects outside Belgium from emission reductions in Belgium
were not calculated either. Further research taking into account foreign countries,
on this subject can lead to interesting conclusions.
It must be stressed that a complete cost-benefit analysis is an ambitious task
because of the long calculation times of the EUROS model and the extensive
work in making data compatible. However the cost and benefit modules could be
used independently. The cost module could be applied to generate emission
reduction cost curves in detail (sector, region, technology, ...). The benefit
module could be used to evaluate output of the EUROS model.
With the setup of this model, we could demonstrate the importance of the high
degree of geographical detail necessary to evaluate the emission reduction
potential of a small country.

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