Contributions with Markal to the Flemish research program to reduce emissions of SO$_2$, NO$_x$, NH$_3$ and VOC. Practical applications for the electricity sector and steel sector

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Content

• background of the program
• methodological issues
• examples: electricity sector & iron and steel production
• practical considerations – conclusions
Background

- Cost effective approach in European strategy against acidification and tropospheric ozone
- Rains model (IIASA)
  - Emeb grid (50km x 50 km)
    - Critical loads
    - Protected and unprotected area
  - National emission reduction cost functions
    - Objective function: minimum of total reduction costs
    - Constraints:
      - acidification: reduce unprotected area by 95% in each grid
      - tropospheric ozone: AOT60 (health) and AOT40 (crops) improvement

Background (2)

- Results:
  - simulation tends to MFR level for NOx and VOC and very strong reduction for SO2 and NH3 in Belgium and Luxembourg
- Why?
  - Compensating mechanism favours bigger countries
  - Ozone hill:
    - requires very high reduction of NOX deposition
  - National emission reduction cost functions
    - big countries will never be forced to support small neighbours
### Background (3): emission reductions (2010/1990)

<table>
<thead>
<tr>
<th></th>
<th>Transport</th>
<th>Flanders</th>
<th>Wallonie</th>
<th>Brussels</th>
<th>Belgium</th>
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<tbody>
<tr>
<td>SO2</td>
<td>-87.9%</td>
<td>-73.4%</td>
<td>-71.8%</td>
<td>-75%</td>
<td>-73.4%</td>
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<tr>
<td>NOX</td>
<td>-57.8%</td>
<td>-41.1%</td>
<td>-38.4%</td>
<td>-35.4%</td>
<td>-48.1%</td>
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<tr>
<td>VOS</td>
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<td>-50.0%</td>
<td>-43.3%</td>
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<tr>
<td>NH3</td>
<td>-42.4%</td>
<td>-1.2%</td>
<td>-31%</td>
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The Flemish sectoral analysis program to define the reduction potential and associated costs

- sectoral marginal emission reduction cost functions and define
- Develop Maximum Feasible Reduction
  - Process integrated techniques, fuel substitution, primary measures and end of pipe measures
  - Concentrate on SO$_2$, NOx, NH$_3$, VOC, considering other pollutants as well
  - Target year 2010
  - New installations and retrofit of existing installations
  - Follow up by sectoral representatives and administration
The Flemisch sectoral analysis program to define the reduction potential and associated costs: sector studies

- **Electricity sector**
- **Iron & steel production**
- **Non-ferro**
- **Graphical industries**
- **Refineries**
- Production and use of coatings
- **Chemical part 1, part 2, part 3**
- Solvent use for degreasing

Methodological issues: structure for coal/gas fired plant

[Diagram showing various control options for PM, SO₂, and NOₓ emissions with existing, investment, and new operational options highlighted.]
Methodological aspects: electricity sector

Methodological issues

- Marginal abatement costs: shadow prices
- Small increment in reduction objective used to get curve
- Annuities used for investment options
- Dimensioning investment options
  - based on existing capacities
  - iterative procedure
Methodological issues: dimensioning of investment options

2 new cost evaluation

SCR: oper -> E01
SCR: invest

1

availability factor = capacity utilisation

Practical experience

Iterative procedure
- convergence achieved in 2 – 8 iterations
- global minimum > 90% local minimum < 10%
- local minimum recognised by sudden increase in marginal reduction costs

• Total calculation requirements:
  - 150 to 250 Markal runs for one marginal cost-curve
  - Approx. 3 hours computing (1600 Mhz)
## Electricity sector: reference scenario

### Graphs

- **NOx emissions**
  - Y-axis: Euro/Kg
  - X-axis: NOx emissions (kton)

- **SO2 emissions**
  - Y-axis: Euro/Kg
  - X-axis: SO2 emissions (kton)

### Table

<table>
<thead>
<tr>
<th>Project</th>
<th>NOx Reduction (kton)</th>
<th>SO2 Reduction (kton)</th>
<th>Marginal Cost (Euro/Kg)</th>
<th>Total Reduction Cost (mio Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
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<td>CHP</td>
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<td>Other</td>
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### Projects

- **Lage NOX branders langerlo**
- **Lage NOX branders Rodenhuize 4**
- **SNCR Kallo**
- **SNCR Ruien 6**
- **SCR Rodenhuize 4**
- **SCR Ruien 5**
- **SCR gasturbines WKK**
- **Sconox gasturbines WKK**
- **SCR repowering Langerlo**
- **Sconox repowering Langerlo**
- **SCR repowering Ruien**
- **Sconox repowering Ruien**
- **SCR nieuwe STEGS**
- **SCR bestaande STEGS**
- **Belasting Langerlo**
- **Belasting Rodenhuize 2-3**
- **Belasting Rodenhuize 4**
- **Belasting Ruien 5**
- **Belasting Mol11-12,Ruien 3-4**
- **Belasting Kallo, Ruien 6**
- **Belasting bestaande STEG**
- **Belasting nieuwe STEG**
- **MW STEG als reductiemiddel**
- **MW STEG met SCR als reductiemiddel**

### Costs

- **Emissies in kton**
- **Marginale kost in Euro/Kg**
- **Totale reductiekost in miljoen Euro**
Electricity sector: high gas price scenario

Electricity sector: Kyoto scenario

Electricity demand - 3 TWh and CO₂ taxes € 15/ton
Electricity sector: joint emission reduction evaluation

<table>
<thead>
<tr>
<th></th>
<th>NOx (kton)</th>
<th>SO2 (kton)</th>
<th>Cost</th>
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<tbody>
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<td>NEC target</td>
<td>16</td>
<td>5.9</td>
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<td>Reference</td>
<td>16</td>
<td>5.9</td>
<td>47 M€</td>
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<td>Kyoto</td>
<td>14.32 nb</td>
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<tr>
<td>Kyoto</td>
<td>10.87</td>
<td>3.94 nb</td>
<td>30 M€</td>
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Practical experience from electricity sector

- Single pollutant cost curves:
  - iterative procedure needs intervention for local minimum (only 5% cases)
  - retrofit investment options: always selected up to maximum capacity

- Multiple pollutant cost evaluation:
  - partial selection of retrofit options – not realistic
  - intervention excluding partial selected options (ibound 0)
Iron & steel production

- integrated steel plant
  - Cokes plant, 2 sinter plants, 2 blast furnaces, steel factory, hot and cold rolling mills
- stainless steel plant: electric arc furnace
- abatement options:
  - 2 x EOS on sinter plants
  - 3 x SCR (cokes plant and sinter plants)
  - 2 x RAC of WGF (sinter plants)
  - Ultra low NOx burners on heating fearnaces (rolling mills)

Average NOx abatement cost in steel production

LP and IP solutions
Practical experience from iron & steel production

- Single pollutant marginal cost curves
  - LP straightforward
  - iterative procedure not required
- Multiple pollutant cost evaluation
  - LP no satisfaction
  - IP required

General conclusions

- LP solutions required to get marginal costs picture
- MIP options in Markal/Times would be an advantage – especially for multi-pollutant analysis
Practical considerations

• Answer used for RES, BASE.DD and scenario building

• Excel macro use used for cost curve derivation
  – one start for 150-250 Markal runs
  – convergence testing on iterative procedure
  – relevant output selection and storing