Assessment of measures for reducing impacts of particulate matter - partly based on results of the German PAREST Project (PAREST = PArticle REduction STrategies)

Rainer Friedrich
Universität Stuttgart

39 th TFIAM Meeting
Stockholm
Feb 2011
PAREST = PArticle REduction STStrategies

- Supported by UBA
- Partners: TNO (coordinator), Freie Universität Berlin, Universität Stuttgart, IZT Berlin, IfT Leipzig, VTI Braunschweig, IVU Freiburg
- Atmospheric model used: REM-CALGRID (RCG),
- European emissions according to NEC6-CP scenario: includes energy and climate package;
- Not included: IED; EcoDesignDir.; revised NEC
- New emission scenario for Germany

R.Stern, PAREST, 10. Juni 2010
Europe:
Resolution circa 32x28 km²,
0.25° latitude,
0.5° longitude

Germany fine:
resolution circa 8 x 7 km²,
0.0625° latitude, 0.125° longitude

Calculations presents regional background, no direct „hot-spot“-assessment!
PM emissions in Germany

- Resuspension
- On-road mobile sources - tyre, brake wear and road abrasion
- On-road mobile sources - Diesel
- Agriculture
- Off-Road activities
- Industry
- Small combustions
- Large combustions

<table>
<thead>
<tr>
<th>Year</th>
<th>PM2.5</th>
<th>PM10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NH₃-Emissions in Germany

kt

Agriculture

Other (Industry & Energy)

Mobile sources (on- and offroad)

2010

2020
Relative Change of PM10 Concentrations 2005-2020

Rainer Stern et al., PAREST-Projekt
Reduction of PM10-Concentrations from 2005 to 2020 – reference case

Quelle R. Stern et al, PAREST

- 3.9 µg/m³ -18%
  - AEI-ST: 2.5 µg/m³
  - DEU: 2.1 µg/m³
  - BVK4: 2.6 µg/m³
  - BVK3: 2.0 µg/m³
  - BVK2: 1.9 µg/m³
  - BVK1: 1.7 µg/m³

- 2.9 µg/m³ -20%

μg/m³

0 0.5 1 1.5 2 2.5 3 3.5 4

Quelle R. Stern et al, PAREST
Results are given for six area

- AEI-Stations, Average concentration at AEI-stations (Average Exposure Indicator für PM2.5)
- Germany: average concentration in Germany
- Class 4: Population density > 945 inhabitants/ km²
- Class 3: Population density 510 - 945 inhabitants/ km²
- Class 2: Population density 100 - 510 inhabitants/ km²
- Class 1: Population density < 100 inhabitants/ km²
Reduction of PM10-Concentrations from 2005 to 2020 – reference case

Quelle: R. Stern et al., PAREST

- 3.9 µg/m³ (-18%)
- 2.9 µg/m³ (-20%)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AEI-ST</td>
<td>2.5</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>DEU</td>
<td>2.1</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>BVK4</td>
<td>2.6</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>BVK3</td>
<td>2.0</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>BVK2</td>
<td>1.9</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>BVK1</td>
<td>1.7</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Relationship between the number of days exceeding the 50 µg/m³ threshold for PM10 and the yearly average PM10 concentration values.
Days of exceedance of 50 µg/m³ for different stations in Germany 2005 and 2020, meteorology 2005

Anzahl der beobachteten PM10-Überschreitungstage 2005

- Ueberschreitungstage 2020
- Minderung Hintergrund
- Minderung Straßenbeitrag
Days of exceedance of 50 µg/m³ for different stations in Germany 2003 and 2020.
# Emission reduction potential 2020 in kt – maximum feasible reduction (MFR)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Measure</th>
<th>NO$_x$</th>
<th>PM10</th>
<th>PM2.5</th>
<th>NH$_3$</th>
<th>SO$_2$</th>
<th>NMVOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference emissions (2020)</td>
<td></td>
<td>904</td>
<td>228</td>
<td>101</td>
<td>609</td>
<td>455</td>
<td>1381</td>
</tr>
<tr>
<td>Max. reduction</td>
<td></td>
<td>126</td>
<td>24</td>
<td>16</td>
<td>102</td>
<td>110</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>14%</td>
<td>11%</td>
<td>11%</td>
<td>17%</td>
<td>24%</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Small combustion</td>
<td>3</td>
<td>12,3</td>
<td>9,9</td>
<td>9,2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large combustion</td>
<td>8</td>
<td>37,0</td>
<td>3,5</td>
<td>3,1</td>
<td>88,3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>10</td>
<td>30,1</td>
<td>4,8</td>
<td>2,1</td>
<td>1,1</td>
<td>21,6</td>
<td></td>
</tr>
<tr>
<td>On-road</td>
<td>12</td>
<td>22,0</td>
<td>2,7</td>
<td>0,7</td>
<td>0,2</td>
<td>0,07</td>
<td>7,0</td>
</tr>
<tr>
<td>Off-road</td>
<td>10</td>
<td>24,2</td>
<td>0,5</td>
<td>0,5</td>
<td>0,2</td>
<td>0,4</td>
<td>15,4</td>
</tr>
<tr>
<td>Solvent use</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>72,7</td>
</tr>
<tr>
<td>Agriculture</td>
<td>13</td>
<td>2,9</td>
<td>0,4</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Measures – Industrial processes

<table>
<thead>
<tr>
<th>Activity</th>
<th>Measure</th>
<th>Pollutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinter</td>
<td>NO$_x$ &lt; 100 mg/Nm$^3$ (SCR)</td>
<td>NO$_x$</td>
</tr>
<tr>
<td>Cement, Rolled steel</td>
<td>NO$_x$ &lt; 200 mg/Nm$^3$ (SCR)</td>
<td>NO$_x$</td>
</tr>
<tr>
<td>Glass</td>
<td>NO$_x$ &lt; 500 mg/Nm$^3$ (SCR)</td>
<td>NO$_x$</td>
</tr>
<tr>
<td>Sinter</td>
<td>SO$_2$ &lt; 100 mg/Nm$^3$ (wet desulfurisation)</td>
<td>SO$_2$</td>
</tr>
<tr>
<td>Sulphuric acid production</td>
<td>secondary abatement measures for SO$_2$ (activated carbon filter, wet scubber, other absorption techniques (only for double contact process!))</td>
<td>SO$_2$</td>
</tr>
<tr>
<td>Sinter, Cement, Glass</td>
<td>PM &lt; 10 mg/Nm$^3$ (fabric filter, improved electric precipitator)</td>
<td>PM10, PM2.5</td>
</tr>
</tbody>
</table>
Reduction of PM10-Concentrations 2005 -2020
maximum feasible reduction scenario
(further ca 5% reduction of 2005 concentrations)

Absolute PM10 reduction potential from 2005 to 2020 + MFR 2020

- AEI-ST: 2.5, 0.8, 0.5, 1.1
- DEU: 2.1, 0.8, 0.5, 0.9
- BVK4: 2.6, 0.8, 0.5, 1.1
- BVK3: 2.0, 0.8, 0.5, 0.9
- BVK2: 1.9, 0.8, 0.5, 0.8
- BVK1: 1.7, 0.7, 0.5, 0.7

μg/m³

- 2005-2010
- 2010-2015
- 2015-2020
- MFR 2020

From here on:

Use of the ExternE methodology and the integrated assessment model ECOSENSE.

- Includes: estimation of health impacts (health endpoints including YOLL and DALYs)
- Estimation of crop yield losses and material damage (e.g. soiling)
- Estimation of damage to ecosystems due to acidification, eutrophication (in pdfs)
- Monetising all effects using contingent valuation (willingness to pay)

However: impacts on climate due to GHG emission changes not included, although they should be taken into account!!
<table>
<thead>
<tr>
<th>Health effect</th>
<th>Relative Risk</th>
<th>Age Group</th>
<th>Population</th>
<th>Impact Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM2.5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality (all cause)</td>
<td>6% (95% CI: 2%, 11%) change per 1 μg/m3 PM2.5</td>
<td>Adults 30 years and older</td>
<td>General Population</td>
<td>250.4 YOLLs</td>
</tr>
<tr>
<td>Work loss days (WLDs)</td>
<td>4.6% (95% CI: 3.9%, 5.3%) increase per 10 μg/m3 PM2.5</td>
<td>15-64 Years</td>
<td>General Population</td>
<td>20,700 (95% CI: 17,600, 23,800) additional work lost days per 10 μg/m3 increase in PM2.5 per 100,000 people aged 15-64 in the general population per year</td>
</tr>
<tr>
<td>Minor Restricted Activity Days (MRADs)</td>
<td>7.4% (95% CI: 6.0%, 8.8%) change per 10 μg/m3 PM2.5</td>
<td>18-64 Years</td>
<td>General Population</td>
<td>57,700 (95% CI: 46,800, 68,600) additional MRADs per 10 μg/m3 increase in PM2.5 per 100,000 adults aged 18-64 (general population) per year</td>
</tr>
<tr>
<td>Restricted activity days (RADs)</td>
<td>4.75% (95% CI: 4.17%, 5.33%) change per 10 μg/m3 PM2.5</td>
<td>18-64 Years</td>
<td>General Population</td>
<td>90,200 (95% CI: 79,200, 101,300) additional RADs per 10 μg/m3 increase in PM2.5 per 100,000 adults aged 18-64 (general population) per year</td>
</tr>
</tbody>
</table>
## Air pollutants: Impact functions  Ozone

<table>
<thead>
<tr>
<th>Health effect</th>
<th>Relative Risk</th>
<th>Age Group</th>
<th>Population</th>
<th>Impact Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mortality (all cause)</strong></td>
<td>0.3% (95% CI:</td>
<td>All Ages</td>
<td>General Population</td>
<td>2.8 (95% CI: 0.92, 3.7) additional deaths (or life years lost) per 10 µg/m³ increase in O₃ per 100,000 population (all ages), per year</td>
</tr>
<tr>
<td></td>
<td>0.1%, 0.4%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>change per 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>µg/m³ O₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Respiratory hospital admissions</strong></td>
<td>0.5% (95% CI:</td>
<td>Adults</td>
<td>General Population</td>
<td>12.5 (95% CI: -5.0, 30.0) additional emergency respiratory hospital admissions per 10 µg/m³ increase in O₃ per year per 100,000 people aged 65+, per year</td>
</tr>
<tr>
<td>(adults aged 65+)</td>
<td>-0.2%, 1.2%)</td>
<td>aged 65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>change per 10</td>
<td>years and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>µg/m³ O₃</td>
<td>older</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8-hr daily average)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bronchodilator usage in children</strong></td>
<td>21% (95% CI:</td>
<td>5-14 Years</td>
<td>General Population</td>
<td>24,500 (95% CI: 3,400, 45,600) additional days of bronchodilator usage per 10 µg/m³ increase in O₃ per 100,000 children aged 5-14 (general population), per year</td>
</tr>
<tr>
<td>(general population)</td>
<td>2.9%, 39%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>change per 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>µg/m³ O₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bronchodilator use in adults</strong></td>
<td>0.6% (95% CI:</td>
<td>Adults</td>
<td>Adults with asthma</td>
<td>70,100 (95% CI: -23,400, 164,000) additional days of bronchodilator usage per 10 µg/m³ increase in O₃ per 100,000 adults aged 20 and older with persistent asthma, per year</td>
</tr>
<tr>
<td>(aged 20 and older with asthma)</td>
<td>-0.2%, 1.4%)</td>
<td>aged 20</td>
<td>(10.2% of adults in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>change per 10</td>
<td>years and</td>
<td>EU27 have asthma)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>µg/m³ O₃</td>
<td>older</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The typically higher pollutant levels in urban areas for most pollutants can be referred as urban increment, i.e., the difference between regional and urban background pollutant concentrations.
Urban increment (PM2.5) developed by Torras Ortiz (2010), USTUTT

\[
C_{i\text{ urban}} = \bar{\omega}_i + \phi_i \frac{E_{iUE}}{A_{UE} \cdot u_{avg}} + \gamma C_{i\text{ rural}}
\]

where

- \(C_{i\text{ urban}}\) = Urban increment of pollutant i.
- \(E_{iUE}\) = Total emission of pollutant i within the urban entity in tons.
- \(A_{UE}\) = Urban entity area in km\(^2\).
- \(u_{avg}\) = Urban entity average wind speed in m/s.
- \(C_{i\text{ rural}}\) = Rural background concentration of pollutant i in µg/m\(^3\).
- \(\bar{\omega}_i, \phi_i, \text{ and } \gamma_i\) = Multiple-regression parameters for pollutant i.

Are all PM10/PM2.5 species equally important?

- **Weighting scheme 1 (WHO-recommendation):**
  Same damage for all content of PM10/PM2.5.

- **Weighting scheme 2  (recommendation of ExternE and HEIMTSA):**
  Primary PM$_{2.5}$ from combustion: *1,5
  Nitrates: *0,5
  Sulfates: *0,6
DALYs: Disability Adjusted Life Year

duration as fraction of year, DALY = weight * duration,

<table>
<thead>
<tr>
<th>endpoint</th>
<th>weight</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchodilator Usage Adults and Children</td>
<td>0.22</td>
<td>0.00274</td>
</tr>
<tr>
<td>Cardiac Hospital Admissions</td>
<td>0.71</td>
<td>0.038</td>
</tr>
<tr>
<td>Chronic Bronchitis</td>
<td>0.099</td>
<td>10</td>
</tr>
<tr>
<td>Infant Mortality</td>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>Lower Respiratory Symptoms Adults and Children</td>
<td>0.099</td>
<td>0.00274</td>
</tr>
<tr>
<td>Respiratory Hospital Admissions</td>
<td>0.64</td>
<td>0.038</td>
</tr>
<tr>
<td>Minor Restricted Activity Day</td>
<td>0.07</td>
<td>0.00274</td>
</tr>
<tr>
<td>Restricted Activity Day</td>
<td>0.099</td>
<td>0.00274</td>
</tr>
<tr>
<td>Work Loss Day</td>
<td>0.099</td>
<td>0.00274</td>
</tr>
<tr>
<td>Years Of Life Lost chronic. Mortality</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cough Days</td>
<td>0.07</td>
<td>0.00274</td>
</tr>
<tr>
<td>Lower Respiratory Symptoms Children Excl Cough</td>
<td>0.099</td>
<td>0.00274</td>
</tr>
<tr>
<td>Respiratory Hospital Admissions</td>
<td>0.64</td>
<td>0.038</td>
</tr>
</tbody>
</table>
## Monetary values of health endpoints (EUR 2010)

<table>
<thead>
<tr>
<th>Health End-Point</th>
<th>Low</th>
<th>Central</th>
<th>High</th>
<th>per case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased mortality risk - VSLacute</td>
<td>1,121,433</td>
<td>1,121,433</td>
<td>5,607,164</td>
<td>Euro</td>
</tr>
<tr>
<td>Life expectancy reduction - Value of Life Years chronic</td>
<td>40,500</td>
<td>59,810</td>
<td>213,820</td>
<td>Euro</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>400</td>
<td>1,045</td>
<td>1,320</td>
<td>Euro/year</td>
</tr>
<tr>
<td>Hypertension</td>
<td>740</td>
<td>800</td>
<td>930</td>
<td>Euro/year</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>2,200</td>
<td>4,470</td>
<td>31,660</td>
<td>Euro</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>69,080</td>
<td>719,212</td>
<td>4,187,879</td>
<td>Euro</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>2,045,493</td>
<td>3,974,358</td>
<td>7,114,370</td>
<td>Euro</td>
</tr>
<tr>
<td>Neuro-development disorders</td>
<td>4,486</td>
<td>14,952</td>
<td>32,895</td>
<td>Euro</td>
</tr>
<tr>
<td>Skin cancer</td>
<td>10,953</td>
<td>13,906</td>
<td>26,765</td>
<td>Euro</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>2,990</td>
<td>5,682</td>
<td>8,074</td>
<td>Euro</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>22,788</td>
<td>30,406</td>
<td>40,977</td>
<td>Euro</td>
</tr>
<tr>
<td>Anaemia</td>
<td>748</td>
<td>748</td>
<td>748</td>
<td>Euro</td>
</tr>
</tbody>
</table>
## Air pollutants – monetary values (EUR 2010)

<table>
<thead>
<tr>
<th>Health End-Point</th>
<th>Central</th>
<th>per case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased mortality risk (infants)</td>
<td>4,485,731</td>
<td>Euro</td>
</tr>
<tr>
<td>New cases of chronic bronchitis</td>
<td>66,000</td>
<td>Euro</td>
</tr>
<tr>
<td>Increased mortality risk - Value Of Life Years</td>
<td>89,715</td>
<td>Euro</td>
</tr>
<tr>
<td>Respiratory hospital admissions</td>
<td>2,990</td>
<td>Euro</td>
</tr>
<tr>
<td>Cardiac hospital admissions</td>
<td>2,990</td>
<td>Euro</td>
</tr>
<tr>
<td>Work loss days (WLD)</td>
<td>441</td>
<td>Euro</td>
</tr>
<tr>
<td>Restricted activity days (RADs)</td>
<td>194</td>
<td>Euro</td>
</tr>
<tr>
<td>Minor restricted activity days (MRAD)</td>
<td>57</td>
<td>Euro</td>
</tr>
<tr>
<td>Lower respiratory symptoms</td>
<td>57</td>
<td>Euro</td>
</tr>
<tr>
<td>LRS excluding cough</td>
<td>57</td>
<td>Euro</td>
</tr>
<tr>
<td>Cough days</td>
<td>57</td>
<td>Euro</td>
</tr>
<tr>
<td>Medication use / bronchodilator use</td>
<td>80</td>
<td>Euro</td>
</tr>
</tbody>
</table>
Health Impacts in Europe Caused by Anthropogenic Emissions in Germany (-23%)  

For German population ca. 1.5 DALYs/a corresponding to 3 months per lifetime  

Ca 27 billion € = 1% of German GDP
Morbidity effects in Europe caused by emissions in Germany

- Bronchodilator usage
- Cardiac hosp.admissions
- Minor RAD
- LRSwo cough
- chronic bronchitis
- resp. hosp. admission
- netRAD
- Lower resp. symptoms
- Work loss days
- Cough

Comparison of DALYs for 2005 and 2020:
- Bronchodilator usage:
  - 2005: X
  - 2020: X
- Cardiac hosp.admissions:
  - 2005: X
  - 2020: X
- Minor RAD:
  - 2005: X
  - 2020: X
- LRSwo cough:
  - 2005: X
  - 2020: X
- chronic bronchitis:
  - 2005: X
  - 2020: X
- resp. hosp. admission:
  - 2005: X
  - 2020: X
- netRAD:
  - 2005: X
  - 2020: X
- Lower resp. symptoms:
  - 2005: X
  - 2020: X
- Work loss days:
  - 2005: X
  - 2020: X
- Cough:
  - 2005: X
  - 2020: X
Reduction potentials

- All measures
- Less meat consumption
- UBA proposal IED/NOx
- 1. BImSchV/PM
- Optimised fertiliser application
- Filter hog house
- Improved fertiliser application
- IED/PM
- EcoDesign Directive
- Cement production/NOx
- Kerosene tax
- Solid manure technique
- Limits inland navigation
- SCR retrofit HDV
- Limits for diesel locomotives
- Speed limit highway
- 1. BImSchV/NOx
- Speed limit non-urban roads
- Speed limit urban
- NOx limit LPG machinery

[DALY]
Benefits – costs (without utility losses)

[Diagram showing benefits and costs for various measures including:
- Less meat consumption
- Speed limit highway
- IED/NOx
- Speed limit non-urban roads
- Optimised fertiliser application
- Filter hog house
- IED/PM
- Improved fertiliser application
- Promotion economic driving
- 1. BImSchV/PM
- Kersene tax
- Cement production/NOx
- Promotion bicycle use
- NOx limits LPG machinery
- Limits inland navigation
- SCR retrofit HDV
- Solid manure technique
- 1. BImSchV/NOx
- EcoDesign Directive]
Efficiency in costs per benefit (no utility losses)

-30
-25
-20
-15
-10
-5
0
5
10
speed limit non-urban roads
promotion economic driving
promotion bicycle use
improved fertiliser application
less meat consumption
kersone tax
optimised fertiliser application
NOx limits LPG machinery
limits for diesel locomotives
cement production/NOx
IED/NOx
filter hog house
UBA proposal IED/NOx
1. BimSchV/NOx
all measures
1. BimSchV/PM
limits inland navigation
SCR retrofit HDV
speed limit urban
solid manure technique
EcoDesign Directive

cost/benefit [Euro2010/Euro2010]
Efficiency in costs per benefit (with utility losses)

-20
0
20
230
250
1,880
1,870
1,860

1. BImSchV/NOx
2. BImSchV/PM
SCR retrofit HDV
less meat consumption
solid manure technique
EcoDesign Directive
all measures
speed limit non-urban roads
speed limit urban

promotion economic driving
improved fertiliser application
IED/PM
NOx limits LPG machinery
limits for diesel locomotives
cement production/NOx
IED/NOx
filter hog house
UBA proposal IED/NOx
cement production/PM
kerosene tax
1. BImSchV/PM
limits inland navigation
promotion bicycle use
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less meat consumption
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all measures
speed limit non-urban roads
speed limit urban
Conclusions

- Methodologies for supporting decisions about environmental pollution control with cost-benefit-analyses are available and are able to deliver useful results.
- Further reductions of PM and PM precursor emissions are necessary to meet thresholds and reduce impacts, especially health impacts.
- The assessment of policies and measures crucially depend on assumptions about the toxicity of PM ingredients or other measures like number.
- Effective and efficient additional measures for Germany would be:
  - Promotion of economic driving (small effect), speed limit on motorways (small)
  - Improved application and amount of fertilizer and manure (large), filter in hog houses (large),
  - Less animal protein consumption on voluntary basis (very large)
  - Offroad: diesel locomotives (small), gasoline/LPG mobile machinery (small), kerosine tax (medium), inland navigation (small)
  - Emission reduction industrial processes (cement, glas, sinter) (large)
  - Further PM reduction large coal combustion (10 mg/m³) (medium)

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