Challenges of Black Carbon Mitigation in Europe and the emerging Roadmap to address this Problem

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Germany
EU Legal Basis Air Quality

The International Air Quality Policy Framework

- The UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) and its Protocols
- The knowledge base (EMEP, WGE, ...)
- ...

The EU Air Quality Policy Framework

- The 2005 Thematic Strategy on Air Pollution
- The National Emission Ceilings Directive
- The Ambient Air Quality Directives
- The EU Air Pollution Source Abatement Policy Framework
- National and Local Air Pollution Abatement Measures
- ...

European Commission
## EU Air Quality Directive 2008/50/EC

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Concentration</th>
<th>Averaging period</th>
<th>Legal nature</th>
<th>Permitted exceedences each year</th>
</tr>
</thead>
</table>
| Fine particles (PM2.5)     | 25 µg/m³***   | 1 year           | Target value entered into force 1.1.2010  
Limit value enters into force 1.1.2015 | n/a                             |
| Nitrogen dioxide (NO2)     | 200 µg/m³     | 1 hour           | Limit value entered into force 1.1.2010                                       | 18                              |
|                            | 40 µg/m³      | 1 year           | Limit value entered into force 1.1.2010*                                     | n/a                             |
| PM10                       | 50 µg/m³      | 24 hours         | Limit value entered into force 1.1.2005**                                    | 35                              |
|                            | 40 µg/m³      | 1 year           | Limit value entered into force 1.1.2005**                                    | n/a                             |
Trends in Emissions

IIASA 2012 (Draft): Development of PM2.5 emissions from mobile sources in EU27
Note: Some NRMM categories do not follow trends and grow in importance (shipping, rail, ....)
Particle Elimination
with Particle-Filter

Liebherr D914 T, 2000 min⁻¹/ full load

Octimax (20 ppm Fe + 5 ppm Sr)

with particle trap

stand. fuel

without particle trap

stand. fuel

with particle trap

Octimax

ambient air
European City Ranking

Best practices for clean air

Source: www.sootfreecities.eu
# European City Ranking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Overall Mark</th>
<th>Measure Graph</th>
<th>City</th>
<th>More Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>B 84%</td>
<td>Berlin</td>
<td>Berlin is the capital of Germany and with 3.4 million citizens also Germany's largest city. It is located in the eastern part of Germany, 70km west of the Polish border.</td>
<td>More Information</td>
</tr>
<tr>
<td>02</td>
<td>B 82%</td>
<td>Copenhagen</td>
<td>Copenhagen is the capital and largest city of Denmark and with an urban population of almost 600,000 and a metropolitan population of close to 2 million people it is also Denmark's ...</td>
<td>More Information</td>
</tr>
<tr>
<td>03</td>
<td>B 82%</td>
<td>Stockholm</td>
<td>Stockholm is the capital and the largest city of Sweden and constitutes the most populated urban area in Scandinavia with a population of 851,155 in the municipality (2010). ...</td>
<td>More Information</td>
</tr>
<tr>
<td>04</td>
<td>B 80%</td>
<td>Vienna</td>
<td>Vienna is the capital of Austria and with 1.7 million inhabitants also the largest city. It hosts offices of many international organisations, in particular of the United Nations (UNW). ...</td>
<td>More Information</td>
</tr>
<tr>
<td>05</td>
<td>B 80%</td>
<td>Zurich</td>
<td>With a population of 835,000 in the city and 1.1 million people in the surrounding area. Zurich is the largest city in Switzerland. It is situated in the north of Switzerland, near to the German ...</td>
<td>More Information</td>
</tr>
<tr>
<td>06</td>
<td>C 71%</td>
<td>Amsterdam</td>
<td>Amsterdam is the largest city of the Netherlands with 783,000 inhabitants and a metropolitan population of almost 2.2 million people. The city is the official, cultural and financial ...</td>
<td>More Information</td>
</tr>
<tr>
<td>07</td>
<td>C 70%</td>
<td>Lyon</td>
<td>Lyon is the 3rd largest city in France (population: 470,000) and is situated in the east close to the Swiss border. The metropolitan area has a population of 1.3 million people.</td>
<td>More Information</td>
</tr>
<tr>
<td>08</td>
<td>D+ 67%</td>
<td>Glasgow</td>
<td>Glasgow is the largest city in Scotland and the third largest in the UK. The city has a population of almost 500,000, the greater Glasgow region almost 1.2 million and the whole region around the city around 2.4 million people.</td>
<td>More Information</td>
</tr>
</tbody>
</table>

Source: [www.sootfreecities.eu](http://www.sootfreecities.eu)
## European City Ranking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>City</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D</td>
<td>Graz, Austria</td>
<td>Graz is the capital of the state of Steiermark and with almost a population of almost 300,000 the second largest city of Austria. It is located in the south east of the country.</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>Paris, France</td>
<td>Paris is the capital of France and also its largest city. It is mentioned on a series of top ten lists. With a population of almost 12 million inhabitants in the larger ...</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>Brussels, Belgium</td>
<td>Brussels is the capital of Belgium and as a metropolitan region it has a population of 1.8 million. Brussels is a centre for international politics, among others hosting the headquarters ...</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>London, United Kingdom</td>
<td>London is the capital of the United Kingdom and the second largest city in the EU with 8.3 million inhabitants. The metropolitan area has a population of 12 to 14 million.</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>Madrid, Spain</td>
<td>Madrid is the capital of Spain and with a population of 3.4 million in the city and 6.3 in the metropolitan area it is the largest city in Spain and ranks as third largest in Europe.</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Stuttgart, Germany</td>
<td>Stuttgart is the capital of the German state Baden-Wuerttemberg and Germany's 6th largest city. The city itself has a population of only 600,000, but the metropolitan area ...</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>Duesseldorf, Germany</td>
<td>Duesseldorf is situated in Western Germany in the Rhine-Ruhr metropolitan region and is the Capital of the German state North Rhine-Westphalia.</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>Milan, Italy</td>
<td>Milan is a city in the north of Italy and the capital of the region of Lombary. The city's population is about 1.3 million, while the greater metropolitan region around Milan has 7.4 ...</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>Rome, Italy</td>
<td>Rome is located in the central-western part of Italy and is the country's capital and most-populated city with over 2.7 million inhabitants. Tourism is very important for the city and it is the ...</td>
</tr>
</tbody>
</table>

Source: www.sootfreecities.eu
Environmental Zones
Emission Factor Urban pm Diesel Car

Source: Handbook Emissionfactor, Germany 2011
LEZ in Germany

• 51 LEZs in Germany
• 42 cities require green sticker
• Berlin and Hannover started 01.01.2008
• Legal basis: air quality plans based on requirement of AQD
Instrument Environmental Zones (EZ) – Why?

PM 10 has different sources – BUT:

- In innercity situation road and off road diesel engines are the main source not only for PM but also NO2
- EZ addresses road vehicles directly
- Diesel emission are cancerogene
- Diesel emission are the most harmful part
Regulation defines stickers for different emission standards:

For diesel cars:
- Euro I or below: no sticker
- Euro II: red sticker
- Euro II plus filter or Euro III: yellow sticker
- Euro III plus filter or Euro IV: green sticker

For gasoline cars:
- No catalyst: no sticker
- Catalyst: green sticker
<table>
<thead>
<tr>
<th>Emissions class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sticker</strong></td>
<td>No Sticker</td>
<td><img src="S-UM43" alt="Image" /></td>
<td><img src="S-UM43" alt="Image" /></td>
<td><img src="S-UM43" alt="Image" /></td>
</tr>
<tr>
<td><strong>Requirement for diesel vehicles</strong></td>
<td>Euro 1 or worse</td>
<td>Euro 2 or Euro 1 + particulate filter</td>
<td>Euro 3 or Euro 2 + particulate filter</td>
<td>Euro 4 or Euro 3 + particulate filter</td>
</tr>
<tr>
<td><strong>Requirement for petrol vehicles</strong></td>
<td>Without a catalytic converter</td>
<td></td>
<td></td>
<td>Euro 1 with catalytic converter or better</td>
</tr>
</tbody>
</table>
Key points for a Label Ordinance
according to § 40 Abs. 3 BImSchG (2)

P- Cars
- Red Group
PM > 50 mg/km (Emission limits Euro 2)

- Yellow Group
PM < 50 mg/km, (Emission limit Euro 3). This limit can also achieved by retrofit.

- Green Group
PM < 25 mg/km (Emission limit Euro 4) This limit can also achieved by retrofit.
Low Emission Zones in Europe

Source: http://www.lowemissionzones.eu/
Environmental Zones in Germany

Entrance only with yellow or green sticker

Entrance only with green sticker

Source: http://www.lUmweltbundesamt.de
Berlin
Origin of Kerbside PM2.5 and NO2 in Berlin

**Sources of Roadside PM2.5 Pollution**

- **Local Traffic**
  - Road transport: 12%
  - Resuspension + abrasion by traffic: 3%
  - Other sources: 4%
- **Urban Background**
  - Combustion in energy and transformation industries: 3%
  - Production processes: 1%
  - Additional combustion: 1%
  - Non-industrial combustion: 1%
- **Homemade Vehicle Tailpipe Contribution**
  - Berlin, 2007

**Sources of Roadside NO2 Pollution**

- **Regional Background**
  - Ca. 7%
- **Traffic**
  - 32%
- **Other Sources**
  - 7%
- **Urban Background**
  - Large-scale background

Basis: NOx modelling
Air Quality Management in Berlin

- Berlin has had serious problems with ambient particulate matter (PM) pollution
  - huge excess of EU air quality standards more than a decade ago
  - even now remaining risk of exceedances in year with „difficult“ weather conditions
- Berlin has focused on Diesel soot emission control
  - emphasis on health benefits as soot particles are considered the most toxic PM component
  - recent WHO classification in highest category of cancerogenous substances
  - soot particles contribute to climate change
  - cost-efficient Diesel particle filter (DPF) technology exists
  - important element of Berlin’s strategy to attain the particle pollution standards
Air Quality Management in Berlin

**Emphasis on Diesel exhaust control**

- Berlin has a long tradition in tackling Diesel soot emissions…
  - already in 1999 launch of a **filter retrofit programme** of Berlin’s fleet of 1400 Diesel **buses**, resulted in
    - > 90% reduction of Diesel soot emissions
    - - 37 t/a Diesel soot emissions

2005 adopted a **low emission zone** for motor **vehicles**

- more **60,000 vehicles** retrofitted with DPF
- - 60% Diesel soot emissions,
- - 175 t/a in total Diesel emissions from road traffic
- - 30 t/a diesel emissions of heavy goods vehicles > 3.5t

- successful demonstration project on
  DPF retrofit of passenger cruising **ships**

  - retrofit of 3 vessels with different filter systems with **promising results**:
    - >90% filter efficiency, no extra fuel consumption
    - successful filter regeneration even under difficult operation conditions
Berlin Environmental Zone

Emission Criteria

Stage 1: since 1.1.2008
- Diesel vehicles: at least Euro 2 or Euro 1 & retrofit
- Gasoline vehicles: at least Euro 1
- 7% of vehicle fleet affected

Stage 2: since 1.1.2010
- Diesel: Particle emission Euro 4:
  - cars: Euro 3 + particle filter or better
  - goods vehicles: also retrofit of Euro 1-3 towards Euro 4_{\text{particle}}
- 10% of the vehicle fleet affected

Area:
- about 88 km² (Berlin total area: 892 km²)

Inhabitants:
- about 1 Million (Berlin total: 3.4 Mio)

More than 40 LEZ planned/in force in Germany, 30 LEZ in the EU, but with different emission criteria
Air Quality Management Berlin

Reduction of Diesel Soot-Emissions by the EZ

anhand der beobachteten Flottenzusammensetzung an der Frankfurter Allee

- Total Fleet: 379 t/a in 2007, 348 t/a in 2008, 297 t/a in 2008 EZ
  - 25% reduction
- Cars: 261 t/a in 2007, 126 t/a in 2008, 92 t/a in 2008 EZ
  - 58% reduction
- LDT < 3.5 t:
  - 207 t/a in 2007
  - 152 t/a in 2010
  - 128 t/a in 2012
  - 141 t/a in 2008 EZ
- Trucks > 3.5 t:
  - 79 t/a in 2007
  - 71 t/a in 2010
  - 55 t/a in 2012
  - 24 t/a in 2008 EZ
  - 16 t/a in 2008 EZ

Total reduction: -26 t/a
Berlin Environmental Zone Impact

Traffic related black carbon particle concentration in Berlin

-50%

Annual total carbon mean (EC+1.2*OC) in μg/m³

- Average over 10 mini samplers inside of the LEZ
- Average over 12 mini samplers outside of the LEZ

Low emission zone in force

* Local BC increment at traffic sites, adjusted to traffic volumes trend relative to 2007 before LEZ came into force
¥ Elemental carbon (EC) particles plus other deposited organic compounds (OC)

Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz, Referat III D, M. Lutz
Estimation of the positive health impact by the Environmental Zones (EZ) in Berlin and Munich

<table>
<thead>
<tr>
<th></th>
<th>Berlin</th>
<th>München</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of traffic related diesel particle concentrations by implementation of the EZ by about 60% in Berlin and about 30% in Munich</td>
<td>~ 3.530.000 inhabitants</td>
<td>~ 1,430.000 inhabitants</td>
</tr>
<tr>
<td>Early death rate by diesel particle in urban areas in Germany 240 of 1 Million in inhabitants</td>
<td>All death cases per year ~ 31.000 (100%)</td>
<td>~ 11.000 (100%)</td>
</tr>
<tr>
<td></td>
<td>Avoided death cases per year through the EZ ~ 500 (1,6%)</td>
<td>~ 100 (0,9%)</td>
</tr>
<tr>
<td>Impact of EZ inside and outside the same</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Basic assumptions: BC reduction by the EZ in Berlin 60%, in Munich only 30% because the EZ is not as strict

500 premature death per avoided in Berlin,
100 in Munich by the implementation of the EZ
EZ – What is left to do?

• Include all relevant sources…

• …not only road vehicles but also construction machinery, rail vehicles, agriculture machinery, ships…

• Bring exemptions to an end

• Advancement of EZ addressing NO2
CO$_2$, NO$_x$, and Particle Emissions of Road Transport in Germany 2000-2030

<table>
<thead>
<tr>
<th>Energie</th>
<th>Kohlendioxid</th>
</tr>
</thead>
<tbody>
<tr>
<td>in PJ</td>
<td>in kt</td>
</tr>
<tr>
<td>3,000</td>
<td>220,000</td>
</tr>
<tr>
<td>2,500</td>
<td>175,000</td>
</tr>
<tr>
<td>2,000</td>
<td>150,000</td>
</tr>
<tr>
<td>1,500</td>
<td>125,000</td>
</tr>
<tr>
<td>1,000</td>
<td>100,000</td>
</tr>
<tr>
<td>500</td>
<td>75,000</td>
</tr>
<tr>
<td>0</td>
<td>50,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stickstoffoxide</th>
<th>Partikel</th>
</tr>
</thead>
<tbody>
<tr>
<td>in kt</td>
<td>in kt</td>
</tr>
<tr>
<td>1,000</td>
<td>35</td>
</tr>
<tr>
<td>900</td>
<td>30</td>
</tr>
<tr>
<td>800</td>
<td>25</td>
</tr>
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<td>700</td>
<td>20</td>
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<td>600</td>
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<td>500</td>
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<tr>
<td>300</td>
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<td>200</td>
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<tr>
<td>100</td>
<td></td>
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<td>0</td>
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</tr>
</tbody>
</table>
Health
(Ultrafine Particles)
Ultrafine Particle Study Women in North- Rhine Westfalia

Long term Health Effects of Ultrafine Particles

Wichmann, Thiering, Heinrich 2011
Living near on traffic intensive roads

Distance less than 50 m

Increase of total mortality by 38% and of cardiopulmonal death cases by 77%

Verkehrsreiche Straßen: 5000 Fahrzeuge pro Tag; aRR: adjustiert für Sozialstatus und Rauchen

Wichmann, Thiering, Heinrich 2011
The effect of particle size on cardiovascular disorders — The smaller the worse

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b Institute for Tropospheric Research, Leipzig, Germany
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ABSTRACT

Background: Previous studies observed associations between airborne particles and cardio-vascular disease. Questions, however, remain as to which size of the inhalable particles (coarse, fine, or ultrafine) exerts the most significant impact on health.

Methods: For this retrospective study, data of the total number of 23,741 emergency service calls, registered between February 2002 and January 2003 in the City of Leipzig, were analysed, identifying 5326 as being related to cardiovascular incidences. Simultaneous particle exposure was determined for the particle sizes classes <100 nm (UFP), <2.5 μm (PM2.5) and <10 μm (PM10). We used a time resolution of 1 day for both parameters, emergency calls and exposure.

Results: Within the group of cardiovascular diseases, the diagnostic category of hypertensive crisis showed a significant association with particle exposure. The significant effect on hypertensive crisis was found for particles with a size of <100 nm in diameter and starting with a lag of 2 days after exposure. No consistent influence could be observed for PM2.5 and PM10. The Odds Ratios on hypertensive crisis were significant for the particle size <100 nm in diameter from day 2 post exposure OR = 1.06 (95%CI: 1.02–1.10, p = 0.002) up to day 7 OR = 1.05 (95%CI 1.02–1.09, p = 0.005).

Conclusion: Ultrafine particles affect cardiovascular disease adversely, particularly hypertensive crises. Their effect is significant compared with PM2.5 and PM10. It appears necessary, from a public health point of view, to consider regulating this type of particles using appropriate measurands as particle number.

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OR and 95% confidence interval in emergency calls related to hypertensive crises depending on time of exposure to airborne particles and size of particles (ultrafine [UFP]–fine [PM2.5]–coarse [PM10])

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I have a Dream: Copenhagen is everywhere!

Congestion in the rush hour in Copenhagen  Source: Fairkehr, April 2008