Trends in air emission legislation and the influence on the future of coal

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Environmental concerns:

SO$_2$ – acid rain
NO$_x$ – acid rain and eutrophication
Particulates – visibility and health effects
CO$_2$ – greenhouse issues
Trace elements – toxicity
Mercury – neurotoxic effects
Fine particulates (PM$_{10}$, PM$_{2.5}$, PM$_{1.0}$) – heart and lung complaints
Emission budgets

1 tonne of Carbon produces 3.67 tonnes of CO$_2$
1 kg of Sulphur produces c. 19.5kg of SOx
1 kg of Nitrogen produces x kg of NOx
Particulate (dust) emissions are variable
Emission limits

- are designed to reduce emissions to reduce or avoid environmental damage

- are based on two criteria:
  - to improve air quality to meet ambient standards;
  - to meet critical load levels based on ecological concerns.
Emissions limits

Air quality standards are set to protect human health

They include a margin of safety

They disregard economic and technical feasibility
Linking environmental problems to sources

IAM - Integrated assessment model
- identify major sources of the pollutant
- risk assessment to determine the urgency of the problem (atmospheric lifetime, reactivity, climatic conditions, wind influence)
- there can be controversy in determining the “Cause” of the problem (The USA is moving towards technology based legislation to avoid this problem)
The history of legislation
First ever air pollution regulation...?

Be it known to all within the sound of my voice, whosoever shall be found guilty of the burning of coal shall suffer the loss of his head.

King Edward I, 1273
In 1952 the London smog kills 4000...

... and soft coal combustion is rightly blamed.
Monitoring and control begins

Legislation on emissions at source are created

Monitoring and control are now required.
Forms of legislation

- Emission limits and fines
- Technology based legislation
- Integrated Pollution (Prevention) and Control
- Emissions trading/cap and trade
Policing compliance with emission limits

- most plants in Europe and the USA have CEMS for continuous monitoring of particulates, SOx and NOx;
- in some cases the information is sent directly online to the authorities
- if CEM data is not available, emission factors are used to estimate the maximum emission
- outages are allowed within reason, but exceedences will lead to fines.
Strict emission limits and fines can be successful

- The revenue raised can be reinvested
- Repeating offenders can be closed down
Fines and taxes

“Polluter Pays Principle”
Fines and taxes can be used to punish the guilty
They can also be used to invest in pollution prevention
In some cases, clean sources can profit
Fines can be expensive

In 2003 the US EPA charged VEPCO (coal utility in Virginia) with exceeding SO2 and NOx limits:

- $1.2 billion charge - to be spent on reducing emissions of SO2 and NOx by 63% from 8 plants;
- $5.3 million fine to be paid to the EPA;
- $13.9 million to be spent on remedial action in the area
Fines can be expensive

New South Wales, Australia;

- $1 million fines for corporations;

$250,000 fines for individuals or 7 years in jail
NOx charge and refund system in Sweden

NOx is charged at 40 Swedish Kroner/kg = A
Energy balance is 10.09 Kroner/MWh = B
Net payment calculated from: A - B

Examples:
Plant A
14.6 t NOx/y 37,495 MWh 205,715 SEK charge

Plant B
110.6 t NOx/y 548,374 MWh 1,110,014 SEK refund
Emission limits are not perfect

- it is hard to ensure that an emission limit will achieve the required reduction in emissions (they may be too stringent or too lenient);

- they may lead to disagreement between sources and authorities;

- although new legislation in the EU and USA includes emission limits, these are now regarded as secondary to total reduction requirements and technology requirements
Technology-based legislation

- often used in conjunction with other legislation
- terms need to be defined
Technology-based legislation

- **BAT** - Best available technique or technology (BATNEEC - BAT not entailing excessive cost)

- **MACT** - maximum achievable control technique or technology
BAT/MACT

SO\textsubscript{2} – low sulphur coal, coal washing, wet scrubbers, FGD
NO\textsubscript{x} – low NO\textsubscript{x} burners, SCR, SNCR
Particulates – cyclones, ESP, baghouses
Defining BAT/MACT

GOOD for the authorities:
- by requiring BAT but not defining it, the legislation continually updates itself so that new plants must use the latest technologies

COMPLICATED for the utilities:
- the definition is always being updated
- BAT/MACT can be plant/coal specific. BREF guidance documents can be confusing
Flexible mechanisms (reduction targets) are becoming far more popular

- define a reduction target for a source, group of sources or a region/area
- allow the sources to solve the problem any way they can
Flexible mechanisms (reduction targets) are becoming far more popular

- allow the best decisions to be made on a case-by-case basis
- can be far more successful than initially envisaged
- trading schemes can raise money for investment in pollution control and new technologies
- technology transfer is promoted
USA SO$_2$ trading scheme

Reduced SO$_2$ emissions faster and more efficiently than predicted

Cost a fraction of the estimated total cost
Flexible mechanisms and trading need to be well organised to succeed

- Emissions trading can be a successful and cheap method of reducing total emissions.

- However “fairness” is an issue.
Current legislation from the top down
International legislation –
UN ECE Protocols
(United Nations Economic Commission for Europe)

- Countries sign up to individual protocols committing themselves to % reductions in emissions of $\text{SO}_2$, $\text{NO}_x$, VOC, $\text{NH}_4$ and heavy metals

- Targets are voluntary

- “Best practice” is recommended
UNECE conventions

- 1983 LRTAP
- 1985 Helsinki Protocol (30% SO2)
- 1988 Sofia Protocol (NOx freezing)
- 1991 Geneva Protocol (30% VOC)
- 1994 2nd Sulphur
- 1998 Aarhus (heavy metals)
- 1999 Gothenburg (acidification and ozone)

Only apply when a minimum number of countries have signed on
The targets are voluntary but then binding
EU legislation

- regulations - directly binding on member states (EU 15 immediately, 10 new states within set time periods);

- directives - set a target and a deadline, the methodology is left to member states
  (often leads to delays and complications)
International legislation - European Union

- Old LCPD (large combustion plant directive) set emission limit values (ELVs) for particulates, NOx and SOx as well as targets:

- new LCPD lists tighter ELVs and more complex options
Compliance with new LCPD

Four options for each country:

- Adopt ELVs as specified
- minimum (%) reduction of SO2 at plants firing problem coals
- submit an alternative NAP (National Action Plan)
- Some plants can opt out of both by limiting plant operation (2000 hrs/y until 2018)
## LCPD emission limits (existing plants)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Air pollutant</th>
<th>Thermal input (MW)</th>
<th>Emission limit value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solid fuel</strong></td>
<td><strong>SO₂</strong> (1)</td>
<td>50 – 100</td>
<td>2000</td>
</tr>
<tr>
<td><strong>O₂-Content: 6 %</strong></td>
<td></td>
<td>100 – 500</td>
<td>Linear decrease from 2000 to 400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 500</td>
<td>400</td>
</tr>
<tr>
<td><strong>Existing plants</strong></td>
<td><strong>NO₂ as NO and NO₂</strong></td>
<td>50 – 500</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 500</td>
<td>650 / 1200 (3)</td>
</tr>
<tr>
<td><strong>Particulate matter</strong></td>
<td>&lt; 500</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 500</td>
<td>50</td>
</tr>
</tbody>
</table>

(1) Where the emission limit values cannot be kept due to the characteristics of the fuel, then the following desulphurisation rates shall be achieved:
- ≤ 100 MW: rate of desulphurisation > 60 %
- 100 < MW ≤ 300: rate of desulphurisation > 75 %
- > 300 MW: rate of desulphurisation > 90 %
- > 500 MW: rate of desulphurisation > 94 %; with waste gas desulphurisation > 92 %

(2) From 01.01.2016

(3) Only in case of the "Outermost Regions"; 1200 if volatile content is less than 10%

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### LCPD emission limits (new plants)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Air pollutant</th>
<th>Rated thermal input (MW)</th>
<th>Emission limit value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Biomass</td>
</tr>
<tr>
<td><strong>Solid fuel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O₂-Content: 6%</td>
<td><strong>SO₂</strong></td>
<td>50 – 100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td><strong>New plants</strong></td>
<td><strong>NO₂ as NO₂</strong></td>
<td>50 – 100</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 - 300</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 300</td>
<td>200</td>
</tr>
<tr>
<td><strong>Particulate matter</strong></td>
<td></td>
<td>50 - 100</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 100</td>
<td></td>
</tr>
</tbody>
</table>

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(1) **Where the emission limit values cannot be kept due to the characteristics of the fuel, than the following desulphurisation rates shall be achieved:**

- **≤ 300 MW:** 300 mg/m³ or rate of desulphurisation > 92 %
- **> 300 MW:** 400 mg/m³ and rate of desulphurisation > 95 %

(2) **Only in case of the "Outermost Regions":** linear decrease 850 – 200 mg/m³ (100 – 300 MW)

(3) **Only in case of the "Outermost Regions":** 300 mg/m³
Requirements for plants which cannot meet these limits due to fuel characteristics

<table>
<thead>
<tr>
<th>MWth</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing plants:</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;100</td>
<td>&gt;60% S removal</td>
</tr>
<tr>
<td>&gt;100-&lt;300</td>
<td>&gt;75% S removal</td>
</tr>
<tr>
<td>&gt;300</td>
<td>&gt;90% S removal</td>
</tr>
<tr>
<td>&lt;500</td>
<td>&gt;94% S removal or &gt;92% where FGD is being installed</td>
</tr>
<tr>
<td><strong>New plants:</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;300</td>
<td>300 mg/m3 SO$_2$ or &gt;92% S removal</td>
</tr>
<tr>
<td>&gt;300</td>
<td>400 mg/m3 SO$_2$ or at least 95% S removal</td>
</tr>
</tbody>
</table>
Other new European Union legislation

- NECD (national emission ceilings directive) caps the total amount of $\text{SO}_2$, $\text{NO}_x$, $\text{VOC}$ and $\text{NH}_4$ from member countries for 2010;
- IPPC directive for plants >50MWt
Countries within the EU set their own national legislation

Countries can set their own legislation over and above that of the EU, as long as it is more stringent.

Individual states/regions within countries may also set tighter legislation if they have particular problems or sensitive ecosystems.
UK legislation during the 1980s and 1990s

- 1988 UNECE NOx Freezing Protocol
- 1994 UNECE Sulphur Protocol
- EU LCPD 1990
- IPC, Integrated Pollution and Control
- HMIP emission standards
- LAAPC, local authority air pollution control
- now new LCPD, IPPC, NECD and more
Reduction in fine particle emissions

Source: NETCEN on behalf of Defra
Reduction in SO$_2$ emissions
Reduction in NOx emissions

Source: NETCEN on behalf of Defra
Reduction in lead emissions

Source: NETCEN on behalf of Defra
Reduction in Greenhouse gas emissions in the UK

Source: NETCEN
Reduction in methane emissions

Source: NETCEN on behalf of Defra
Compared to other countries in Europe, our record is good:

Reduction in emissions of ozone precursors, 1990-2000

- Germany: -31
- United Kingdom: -23
- Finland: -19
- Luxembourg: -16
- Sweden: -14
- Denmark: -13
- EU: -12
- Netherlands: -6
- Italy: -5
- Austria: -5
- Belgium: -3
- France: -1
- Greece: 6
- Spain: 9
- Ireland: 16
- Portugal: 22

Change in emissions, %
Reductions for a number of reasons

SO$_2$ emissions from electricity generation in the EU

- Reduction due to efficiency improvements
- Reduction due to increased share of nuclear and renewable energy
- Reduction due to fossil fuel switching
- Reduction due to flue gas desulphurisation and the use of low sulphur fuels
Growth in FGD capacity

North America, 33%

W Europe, 46%

Japan, 70%

Eastern & Central Europe, 20%

Asia, 6%
Legislation and BAT clearly have an effect

NOx emission reductions from electricity generation in the EU

[Graph showing NOx emissions from 1990 to 1998, with annotations indicating emission reductions due to efficiency improvements, increased share of nuclear and renewable energy, fossil fuel switching, and combustion modification and flue gas treatment.]
The future for the UK?

DEFRA hopes to see:

- FGD increased to 12 GW by 2008;
- A switch to low sulphur coal and reduced operating periods;
- Low NOx burners on all plants (except Aberthaw) by 2008;
- Over-fire air on 12 GW by 2008;
- SCR on 6GW by 2016
Different targets to be met

UK Emissions of SO₂
Problems

Eg

Italy had problems with compliance with the 1990 LCPD

The Italian government issued a decree excluding 3 plants on the grounds of security of supply

The exemption was temporary until new plants could be built
USA legislation

The Federal government sets legislation for the whole country
Individual states may set tighter legislation
The legislation is changing to deal with specific problems in specific areas
Legislation is changed to suit:
  some legislation is now seasonal
  the north-east has more stringent legislation than the west
  reduction targets and trading are used in preference to emission limits
Japan

Emission limits are calculated for each plant based on local air quality standards and concentrations.

Emission values are kept secret between the utility and the authorities - “administrative guidance” is provided from the government to individual companies.

Social responsibility is strong.

Most plants are extremely clean.
World Bank emission limits for new plants

Limits are around:
- 2000 mg/m³ for SO2
- 750 mg/m³ for NOx
- 50-100 mg/m³ for particulates

Reduced emission limits are recommended for “degraded airsheds” based on a maximum increase in the ambient concentrations
EU ETS: What is it?

• Industry and power sector in EU-25 Installations (production plant or combustion facility) are allocated annual CO₂ emission rights

• If installation A emits less than allocated, it can sell its allowances to installation B that emits too much

• Price for CO₂ will emerge from market
Why?

• Climate impact of CO$_2$ not dependent on where it is emitted
• Reducing CO$_2$ emissions requires investments
• Large difference in cost of implementing reduction measures across countries and industry sectors
  – E.g. from negative cost to 200 €/tCO$_2$
Why?

• Trading facilitates reductions at lowest overall cost
  – Example: inefficient factory A implements efficient technology at 0 cost, sells emission rights for 10 €/t to factor B where reductions would cost 50 €/t

• Certainty over CO₂ reduction (absolute cap)

• Provides flexibility: more acceptable to industry
How?

• Cap and trade: national government allocates annual emission rights to every affected installation
• Emissions are monitored by individual installations throughout the year
• End of year: carbon balance must be issued, with or without trading (CDM/JI also allowed)
• Penalty of 40 €/t CO$_2$
  • if emissions>rights (allocated+bought)
• Appr. 10000 installations in EU (~50% of EU CO$_2$)
CO$_2$ Prices on EUA market (1 January 2005 - 12 June 2006)
Compliance

What are the incentives for companies to participate?

Strict non-compliance penalties:
- 40 euros/t CO₂ will apply in 2005-2007
- From 2008 the penalty rises to 100 euros/t of CO₂
“New” pollutants of concern:

- Mercury
- Fine particulates
Overall partitioning of trace elements in a coal-fired power plant

Overall partitioning, %

Increasing volatility

Bottom ash  ESP capture  Emitted fly ash  Emitted vapour

Element symbols followed by ‘-m’ indicate measured values from the KEMA study
## Global Mercury Emissions

<table>
<thead>
<tr>
<th>Source Category</th>
<th>Emissions (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions from Natural Sources (Volcanoes, Forest Fires, etc.)</td>
<td>1540</td>
</tr>
<tr>
<td>U.S. Coal-Fired Power Plants</td>
<td>48</td>
</tr>
<tr>
<td>Re-Emission of Prior Anthropogenic Emissions</td>
<td>440</td>
</tr>
<tr>
<td>Other Anthropogenic Emissions*</td>
<td>2820</td>
</tr>
</tbody>
</table>

*Source: UNEP Global Mercury Assessment, December 2002
## Baseline mercury removal for various plant configurations

<table>
<thead>
<tr>
<th>Technology</th>
<th>Baseline mercury removal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bituminous</td>
</tr>
<tr>
<td>ESP</td>
<td>31.0</td>
</tr>
<tr>
<td>SCR+ESP</td>
<td>31.0</td>
</tr>
<tr>
<td>ESP+wet FGD</td>
<td>79.3</td>
</tr>
<tr>
<td>SCR+ESP+FGD</td>
<td>96.2</td>
</tr>
<tr>
<td>SDS+BH</td>
<td>39.0</td>
</tr>
<tr>
<td>SCR+SDS+BH</td>
<td>39.0</td>
</tr>
</tbody>
</table>

SDS = spray dry scrubber  
BH = baghouse
Europe - Emissions to air have fallen...

Changes in total anthropogenic mercury emissions in Europe (tonnes/year)

- Other sources
- Industrial processes
- Combustion of fuels

Source: Pacyna, 2003
...yet coal combustion remains the largest source.

Source: Pacyna, 2003
Coal combustion >50MWth

Hg emissions from coal combustion in power plants 1995 and 2000

<table>
<thead>
<tr>
<th>Country</th>
<th>1995 (tonnes per year)</th>
<th>2000 (tonnes per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland</td>
<td>20.6</td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>5.39</td>
<td>5.24</td>
</tr>
<tr>
<td>U.K.</td>
<td>5.7</td>
<td>5.24</td>
</tr>
<tr>
<td>France</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1.5</td>
<td>2.06</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1.7</td>
<td>1.09</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.8</td>
<td>1.06</td>
</tr>
<tr>
<td>Hungary</td>
<td>1.7</td>
<td>1.09</td>
</tr>
<tr>
<td>Greece</td>
<td>1.6</td>
<td>1.06</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.7</td>
<td>0.73</td>
</tr>
<tr>
<td>Italy</td>
<td>0.5</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Source: Pacyna 2003, Pirrone 2001
EU Stakeholders meeting March 2004

Discussions by experts in Europe concluded that:

- existing legislation for SO$_2$ and NO$_x$ will mean that FGD and De-NO$_x$ systems will be installed on ALL plants eventually
- These systems can also reduce mercury by 40-90%
- NO legislation would be placed on emissions of mercury from large coal-fired power plants in the immediate future
EU will concentrate on “larger/easier” targets first

for example:
- imports and exports of Hg containing material;
- batteries and light switches
- chlor-alkali plants
### Mercury emissions in Sweden (kg/y) (Hovsenius, 1998)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>coal and peat combustion</td>
<td>400</td>
<td>300</td>
<td>300</td>
<td>210</td>
</tr>
<tr>
<td>waste incinerization</td>
<td>2,500</td>
<td>1,500</td>
<td>1,000</td>
<td>90</td>
</tr>
<tr>
<td>cement kilns</td>
<td>700</td>
<td>500</td>
<td>500</td>
<td>3</td>
</tr>
<tr>
<td>chlor-alkali plants</td>
<td>10,000</td>
<td>400</td>
<td>400</td>
<td>120</td>
</tr>
<tr>
<td>sulphide ore smelting</td>
<td>2,000</td>
<td>800</td>
<td>300</td>
<td>74</td>
</tr>
<tr>
<td>steel production</td>
<td>1,000</td>
<td>700</td>
<td>700</td>
<td>110</td>
</tr>
<tr>
<td>crematoria</td>
<td>100</td>
<td>200</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>mining</td>
<td>4,000</td>
<td>200</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>dentists, hospitals, labs</td>
<td>?</td>
<td>?</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>deposits</td>
<td>?</td>
<td>?</td>
<td>800</td>
<td>~</td>
</tr>
<tr>
<td>other industrial activities</td>
<td>?</td>
<td>?</td>
<td>1,600</td>
<td>~</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>&gt;25,000</td>
<td>&gt;8,000</td>
<td>6,700</td>
<td>1,700</td>
</tr>
</tbody>
</table>
Action on large coal-fired facilities beyond 2007/8

- information gathering on mercury monitoring, BAT options and co-benefit results under IPPC -2008
- review of the IPPC directive
- EU Framework 7 project on Hg in the EU
## Canada Wide Standard

<table>
<thead>
<tr>
<th>Province</th>
<th>Emissions, kg/y</th>
<th>2010 cap, kg/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta</td>
<td>1,180</td>
<td>590</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td>710</td>
<td>430</td>
</tr>
<tr>
<td>Manitoba</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Ontario</td>
<td>495</td>
<td>to zero</td>
</tr>
<tr>
<td>New Brunswick</td>
<td>140</td>
<td>25</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>150</td>
<td>65</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,695</strong></td>
<td><strong>1,130</strong></td>
</tr>
</tbody>
</table>
USA-wide standards have been tightening over time

1970 - CAA - original Clean Air Act - to improve air quality at whatever cost
1977 - CAAA - Clean Air Act Amendments
1986 - TRI - toxics release inventory established
1990 - PPA Pollution Prevention Act - to prevent or reduce pollution at the source, wherever feasible
1990 - CAAA tightened controls in cities, for existing plants and for toxic air pollutants (Titles IV and V)
2002 - CSI - Clear Skies Initiative - 70% reduction in air pollution (Nox, Sox, etc)
2003 - NSPS - New Source Performance Standards - emission limits for sources emitting over 100 tons/y (90 t/y)
2005 - CAIR Clean Air Interstate Rule - Sox and Nox trading in worst affected states
2005 - CAMR - Clean Air Mercury Rule - cap and trade on mercury
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>CAMR issued</td>
</tr>
<tr>
<td>2007</td>
<td>US DOE plan to complete field demonstrations of technologies capable of 50-70% mercury capture</td>
</tr>
<tr>
<td>2010</td>
<td>CAMR Phase I - 38 t/y cap (expected to be achieved through co-benefit from FGD and de NOx)</td>
</tr>
<tr>
<td>2010</td>
<td>US DOE plan to complete field demonstrations of technologies capable of &gt;90% mercury capture</td>
</tr>
<tr>
<td>2006-2015</td>
<td>Full-scale commercial demonstrations</td>
</tr>
<tr>
<td>2012-2018</td>
<td>Deployment of technologies</td>
</tr>
<tr>
<td>2018</td>
<td>CAMR Phase II - 15 t/y cap - via mercury specific controls</td>
</tr>
</tbody>
</table>
Examples of US States with their own mercury regulations (as of 8/8/2006)

<table>
<thead>
<tr>
<th>State</th>
<th>Control req.</th>
<th>Trading?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>90% control</td>
<td>no</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>85-95%* control</td>
<td>no</td>
</tr>
<tr>
<td>Maryland</td>
<td>80-90%* control</td>
<td>no</td>
</tr>
<tr>
<td>Minnesota</td>
<td>90% decline</td>
<td>no</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>80% control</td>
<td>yes</td>
</tr>
<tr>
<td>New Jersey</td>
<td>90% control</td>
<td>no</td>
</tr>
<tr>
<td>Virginia</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Indiana</td>
<td>90%</td>
<td>yes</td>
</tr>
</tbody>
</table>

* two phases
Action which may be taken by coal-fired plants

– Coal switching to coals which produce more mercury in the oxidised form;
– Installation of FGD systems;
– Activated carbon or similar sorbents;
– Emission trading....
Why does the USA have to legislate Hg when the EU does not?

- SO2 trading allowed plants to avoid installing FGD
- DeSOx and deNOx technologies STILL not obligatory as in the EU
- mercury has NOT been reduced to the same extent
- mercury specific approach is required
Incremental Cost of Control, $/lb Hg Removed

- w/o Byproduct
- w/ Byproduct Impacts

DOE 2007 Goal: ~$45,000/lb Hg Removed

For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal is included.
UNEP/UNIDO programmes

- preparation of emission inventories for Asian countries (eg Thailand, Philippines, Syria, Yemen, Pakistan in phase 1);

- proposal of action plan for best approach to mercury reduction in each country;

- establish partnerships and work groups to put proposals into action.
Total Hg emissions by province in China, 1999, Chinese estimate
“Economics of mercury control”: Draft due Jan 2008

- review co-benefit approaches
- summarised mercury-specific control technologies
- basis of technology selection
- application of strategies for developing countries

- new projects on specific strategies for China
Fine particulates – PM$_{10}$ and PM$_{2.5}$ – are the new pollutant of concern in many countries....

.... And are the only legislated pollutant for which there is no chemical definition.
Why?

Over 20 major studies around the world since 1973 have indicated a link between fine particulates and early mortality.

Legislation was a foregone conclusion.
Impending legislation: USA

$\text{PM}_{10}$ (current):
- 24 hour average 150 microgram/m$^3$
  not to be exceeded more than once/year
- 99$^{\text{th}}$ percentile of 24 hour values in a year averaged over three years
- annual average 50 microgram/m$^3$
  averaged over 3 years

$\text{PM}_{2.5}$ (impending):
- 24 hour average 65 microgram/m$^3$
- 98$^{\text{th}}$ percentile of 24 hour values in a year (at highest monitor) averaged over three years
- annual average 15 microgram/m$^3$
  3 year average and spacial averaging
Fine PM in the Atmosphere

Primary Fine Particulate Matter
- Inorganics: Carbon (soot)
- Condensable Organics

Secondary Fine Particulate Matter
- Sulfates
- Nitrates
- Ammonium sulfate
- Ammonium nitrate
- Organics

Total Fine Particulate Matter

Oxidation

NOx

VOC

Sunlight

Ozone

Condensable Organics

Water Vapor

Visibility
Emission sources of atmospheric particulate matter.

**Natural sources**
- Primary particles
  - Soil
  - Marine
  - Volcano, Forest fire, Cosmic dust
- Secondary products
  - Volatile organic carbon (VOC)
  - S-cycle (SO$_4^{2-}$)
  - N-cycle (NO$_3^-$, NH$_4^+$)

**Anthropogenic sources**
- Fixed sources
  - Iron & steel industries
  - Oil combustion, oil refinery
  - Coal combustion
  - Cement industry
  - Incineration
  - Non-fossil fuel
  - Others
- Moving Sources
  - Primary particles
  - Secondary products
  - Motor Vehicles
  - Ships
  - Air-craft
  - Hydrocarbon
  - Sulfate (SO$_4^{2-}$)
  - Nitrate (SO$_3^-$)
  - Cl$^-$

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Cause of the health problem?

Could be any or none of the following:
- Size effect;
- Morphology;
- Chemical effect:
  - Acidity;
  - Toxin;
  - Transition metals

*If we knew, we could refine the legislation appropriately.*
Breakdown of PM$_{2.5}$ composition in SCAB

- Nitrate: 38%
- Ammonium: 17%
- Organic carbon: 21%
- Elemental carbon: 12%
- Sulphate: 10%
- Crustal: 2%

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Average contribution to PM$_{2.5}$ from sources in the USA

- Electric utilities: 56%
- Area source combustion and motor vehicles: 38%
- Other: 6%
- 0%
What sources will require control?

Most sources of PM$_{2.5}$ and precursors are natural, unavoidable or “untouchable”;

The majority of PM$_{2.5}$ is secondary particulate from precursor formation - tightening of emissions of precursors is relatively simple.
Control for fine particulates, $\text{PM}_{10}$ and $\text{PM}_{2.5}$

Fine particulates are a combination of primary particles and secondary reaction products ($\text{SO}_2$, NOx and VOC)

Controlling fine particles is a multi-pollutant problem

Multi-pollutant controls:
- enhanced particulate controls (wet ESP, AHPC)
- enhanced gaseous pollutant controls (FGD, SCR)
- new systems (plasma/corona treatments)
Interstate Air Quality Rule, USA

Proposed by the US EPA in December 2003.
Targets SO$_2$ and NOx emissions specifically from electric utilities in 29 eastern US states and the District of Columbia in two phases:
- 3.6 Mt (40%) reduction in SO$_2$ emissions in 2010 and a further 2 Mt/y when the rules are fully implemented;
- 1.5 Mt (65%) reduction in NOx emissions in 2010 and 1.8 Mt annually to 2015.

The IAQR is regarded as the largest single industry investment in any clean air programme in US history.
Will this solve the problem?

Not necessarily

The background concentration of fine particulates in the Netherlands in several regions is above the legislated limit.

In the USA, Pittsburgh will not meet the fine particulate standard even if they were to turn off everything - much of their pollution comes from Ohio.
“The simplest and cheapest way to bring down European emissions of carbon dioxide as well as several other air pollutants would be to phase out the use of coal”

Swedish NGO Secretariat on Acid Rain
But in fact:

Coal is likely to remain a predominant source of fuel, it will continue to remain so in many countries and its use will grow.
Clean Coal Technologies are needed for about 1,400 GW of additional capacity

Source: IEA WEO, 2002, Business as usual scenario
Main technology choices:

- Supercritical PCC
- Circulating fluidised bed combustion (CFBC)
- Pressurised fluidised bed combustion (PFBC)
- Integrated gasification combined cycles (IGCC)
- IGCC-fuel cells
- Hybrid gasification/combustion systems
- Zero emission or near-zero emission technologies
Global demand grows by more than half over the next quarter of a century, with coal use rising most in absolute terms.
Conclusions – the future for coal?

In the short-term, emission legislation is tightening such that coal is being pushed from the market-place.

In the long-term emission legislation will continue to tighten to the point where existing pulverised coal-fired plants will become obsolete.

Coal is an abundant fuel which will continue to be available for hundreds of years, unlike other fossil fuels.

New clean coal technologies will ensure that coal can be used with minimal/zero emissions (post-2020 ZETs).
THANK YOU FOR YOUR ATTENTION

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