Carbon dioxide capture and storage from coal fired power plants - some of the challenges and RWE npower's responses.

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RWE npower R&D.

Coal Research Forum. Rugeley .

20 June 2007

Carbon to energy ratio for various fuels.

Approximate numbers

Fuel	H/C molar ratio	Net CV MJ/kg	CO2 produced kg/MJ	Electricity generation efficiency %	**CO2 produced. kg per kWhr**
Natural gas	4	40	0.05	55	**0.4**
Oil	1.6	40	0.08	36	**0.8**
Coal	0.8	25	0.1	36	**1.0**
Biomass	1.4	14	0.11	36 (cofiring)	**1.1**

Biomass influenced by high oxygen content.
"Short cycle CO2"

2 more useful numbers for those with a memory as bad as mine

- 1 MWe from a coal station required 10 tonnes a day of coal when I joined the industry. (CCS could bring the number back up to 10)
- 1 MWe with CCS will be around 20 tonnes per day of CO_2 emissions.

Biomass cofiring at coal stations

- The carbon dioxide emitted was in the atmosphere only a few years ago.
- Quick and relatively cheap to implement, at least up to a small % of fuel input.
- Reduces fossil fuel CO_2 emissions.
- Timescale of months compared to years for new dedicated biomass plant.
- Most generators co-fire but very few dedicated biomass plants are up and running, despite over 5 years of Renewables Obligation.
- Even the 1970s plants cofire at an efficiency better than the sophisticated small biomass plants.
- Long term uncertainty in ROC system?

What is biomass?

An example. Miscanthus – with Aberthaw P.S. in the background

Differences between Coal and Biofuels

- Wet Sawdust:
  Bulk density = ~400 kg/m3
  Calorific Value (net, as received) = ~8 MJ/kg
  => 3200 MJ/m3

- Coal
  Bulk density = ~1000 kg/m3
  Calorific Value (net, as received) = ~25 MJ/kg
  => 25 000 MJ/m3

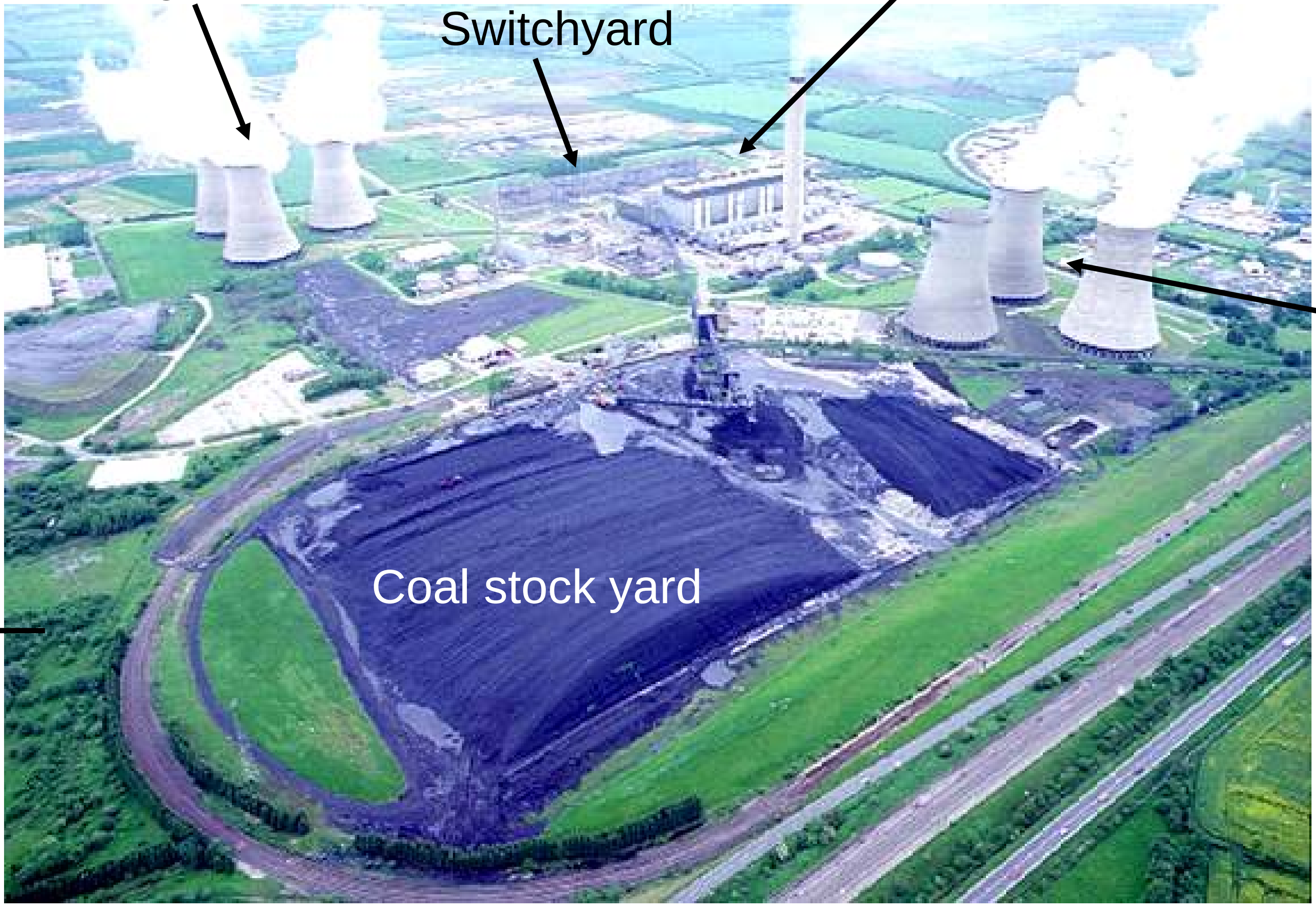
- Coal contain about 8 times as much energy per m3 than wet sawdust.

- 10% Biomass co-firing (by heat) requires 70% more fuel by volume. Look at the size of the coal stock yard in next slide and remember that most bio-fuels need storing under cover!

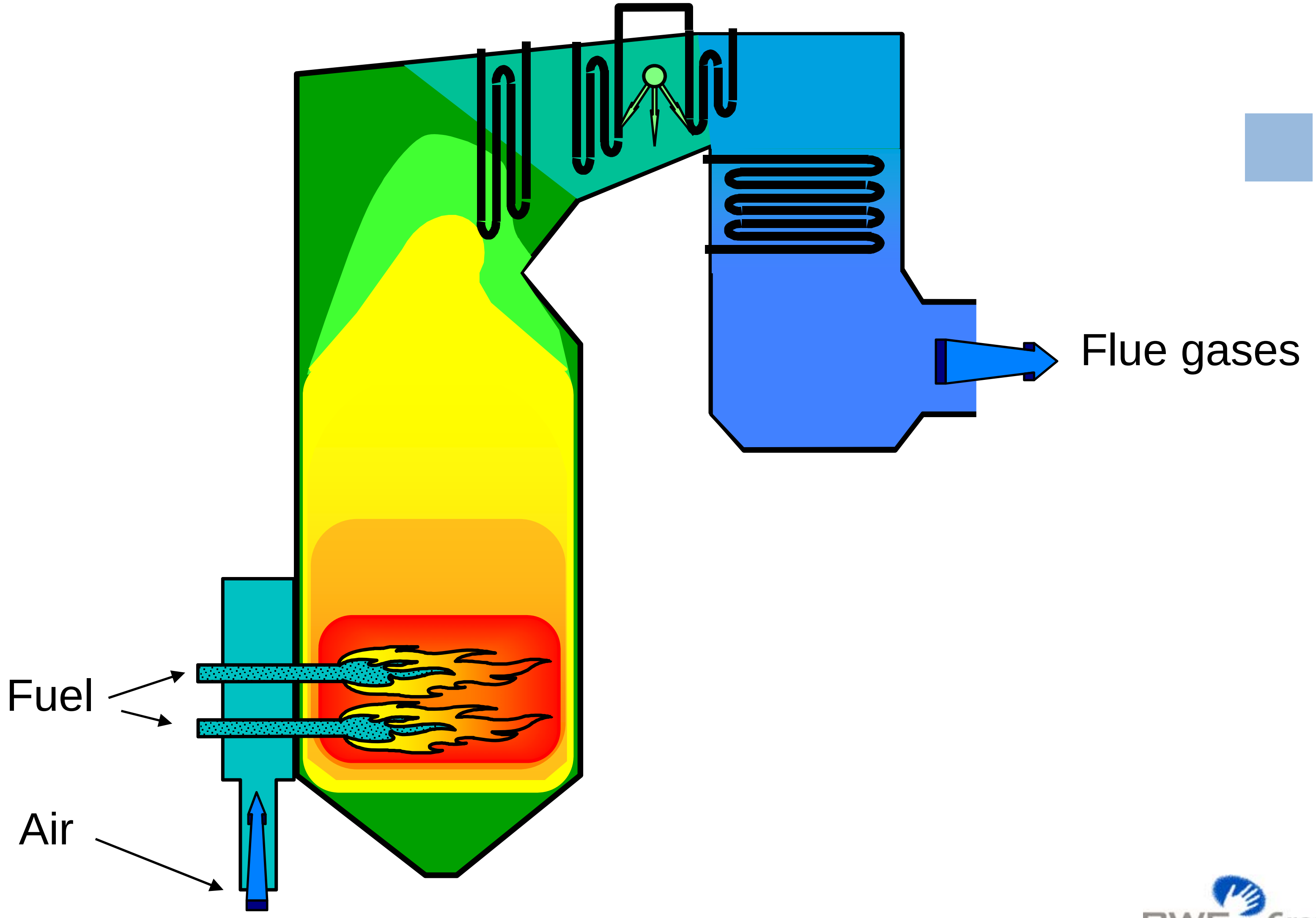
- Some biofuels are drier and denser but still require an increased total volume flow.

- CLIMATE CHANGE LEVY EXEMPTIONS AND ROC CERTIFICATES MAKE IT WORTH THE PROBLEMS?

Typical Coal fired Power station

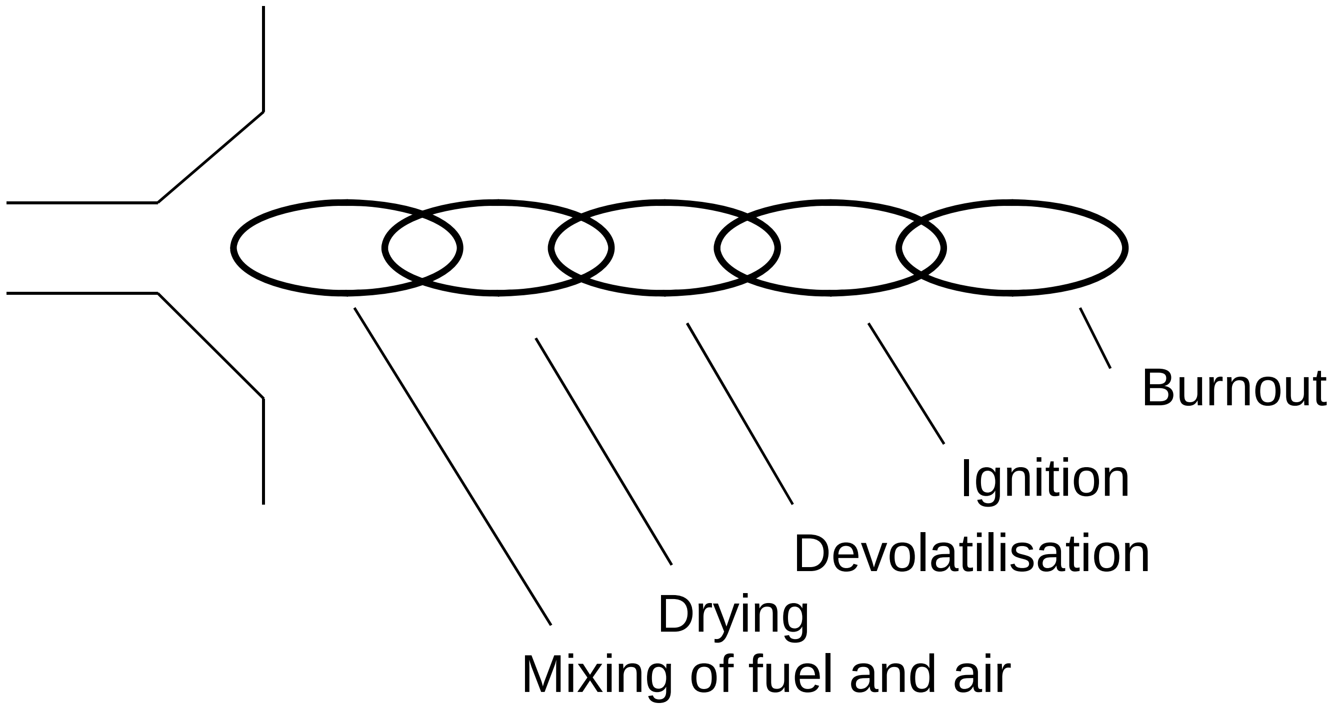


Typical Coal fired boiler



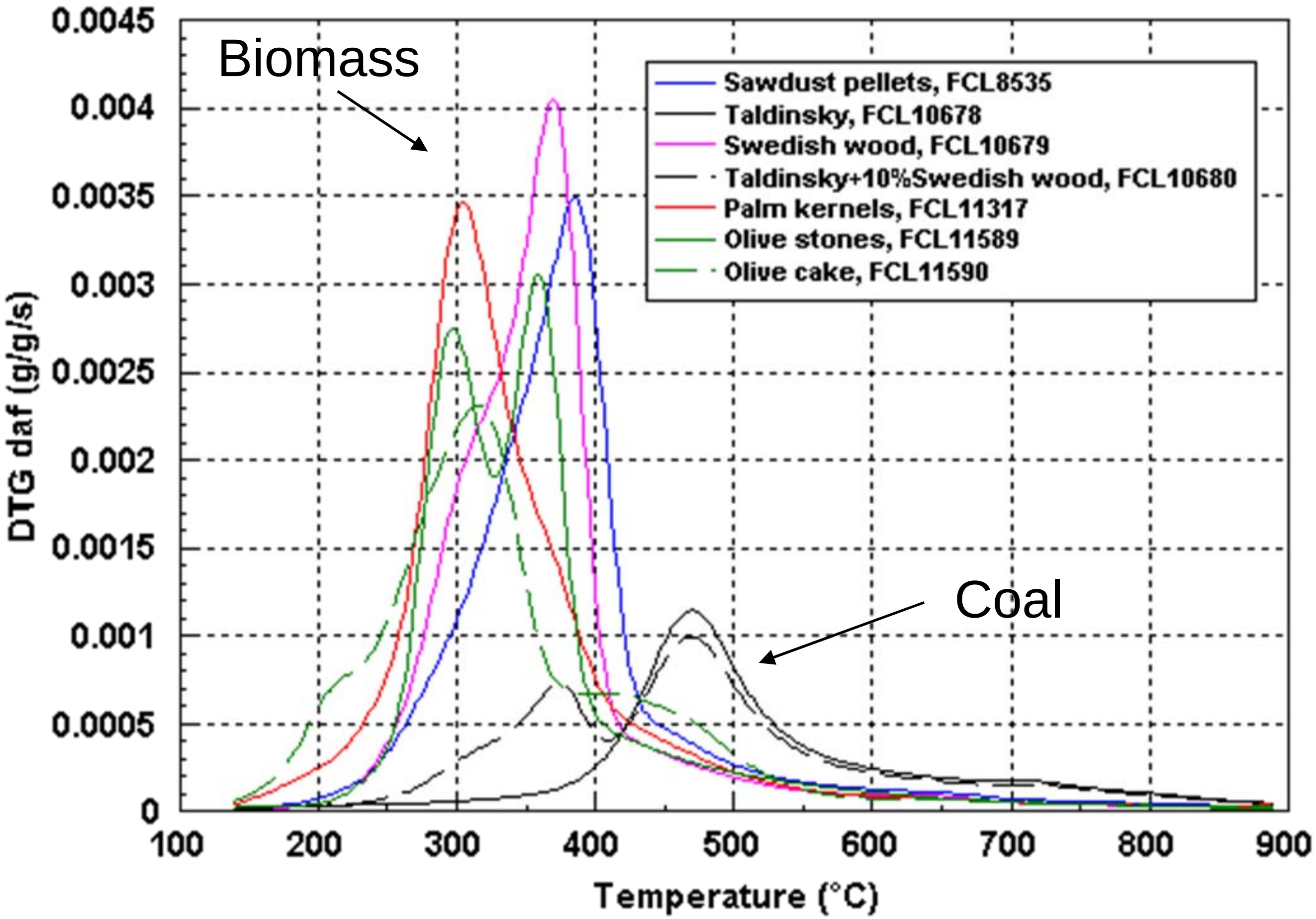
What happens during combustion?

- All links in the chain have to be intact



What happens during combustion?

Biomass devolatilises at lower temperatures than coal



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How do we co-fire?

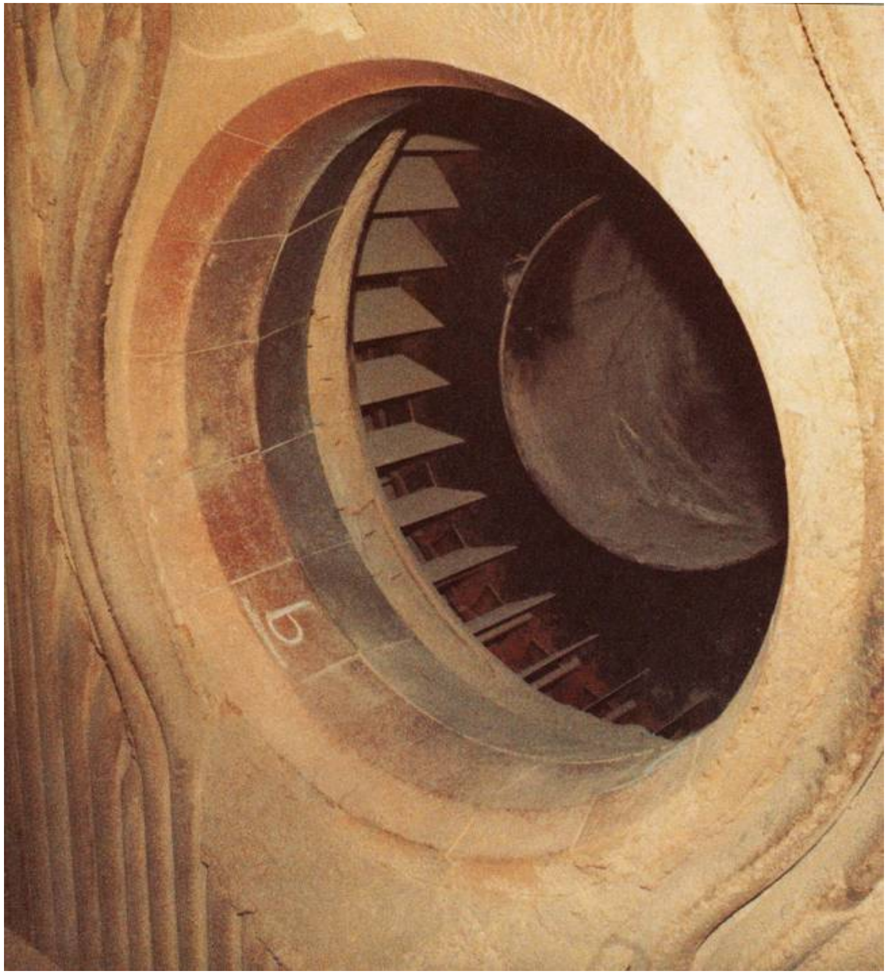
- **Co-milling** – Blend before mills. Simple but limits throughput.
- **Injecting into pf-pipe** - Needs the right particle size.
- **Separate biomass burners** - High investment but the most flexible.
- **Separate biomass injectors** - Independent of coal system but uses coal burners for stability

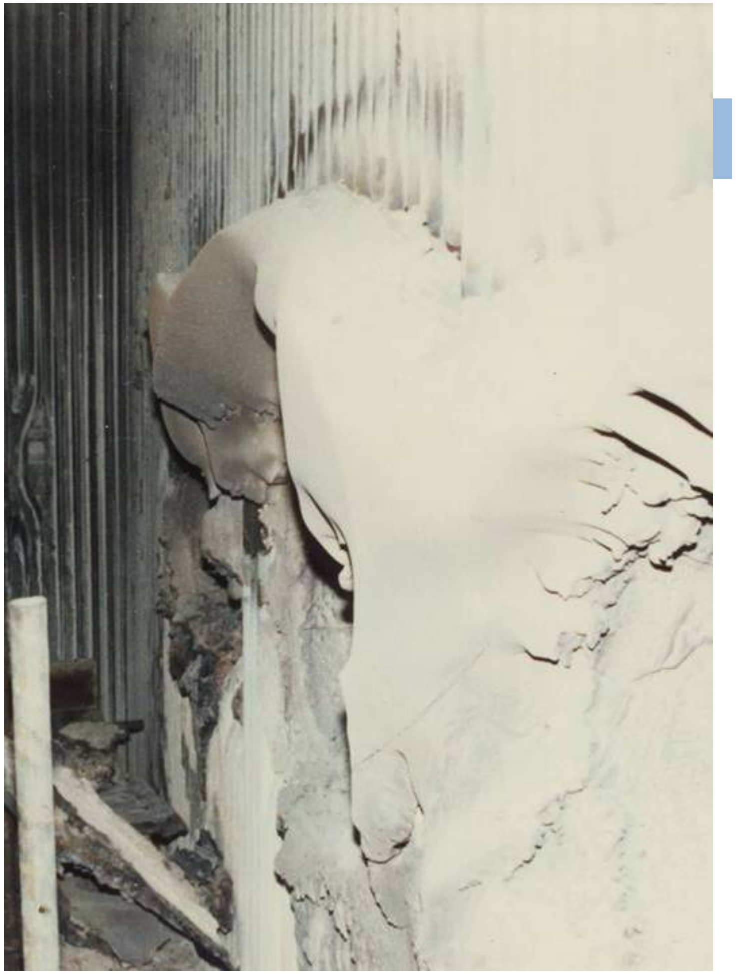
What are the cofiring problems?

Oversize particles, low temperatures or insufficient oxygen levels can cause burnout problems

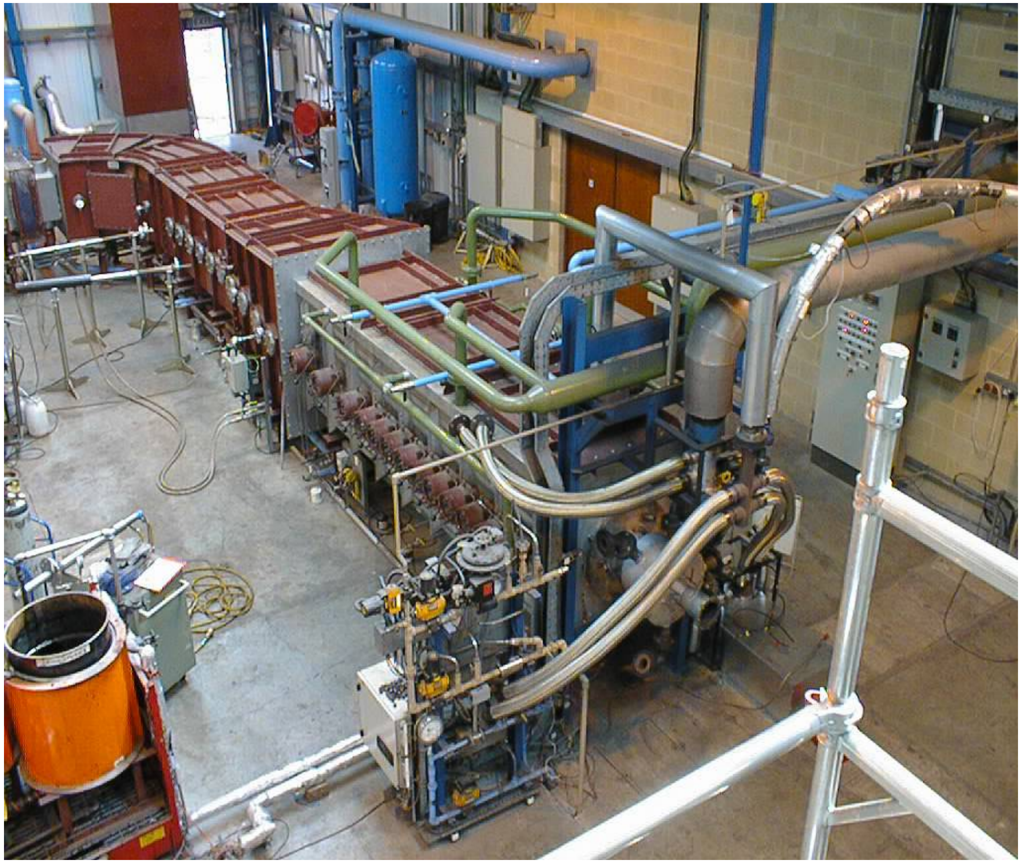
What are the problems?

Different ash composition gives increased risk for slagging and fouling

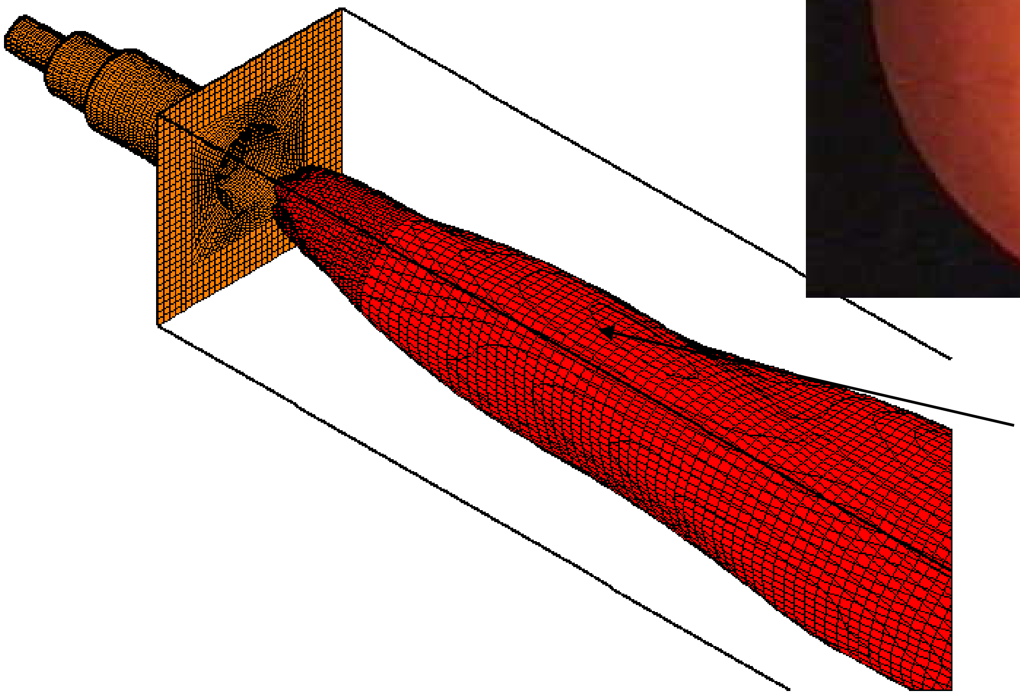




RWE npower Combustion Test Facility at Didcot power station. Tests new fuels.



CFD modelling



Where is RWE npower today?

- Tilbury
  Off site blending and co-milling abandoned due to Ofgem ruling. Now blending on site. 20,000 stack hours

- Didcot
  On site blending and co-milling. £3.5 million investment in biomass storage and handling. Displace up to 300,000 tpy of coal. 20,000 hours

- Aberthaw
  Direct injection, no co-milling.
  Entry level scheme taking sawdust, successful.
  Full scheme now installed with hammer mills and larger, better fuel reception.

- All plants have technical limits on maximum % biomass.

UK nationally

- Cofiring considerably less in last 12 months than in 2005.
- Uncertainty.
- ROC review and consultation.
- ¼ ROC for cofiring?
- Grandfathering?

Coal – Aberthaw, Didcot and Tilbury

- Aberthaw. 3 x 500 MWe

Flue gas desulphurisation (seawater) installation underway.

- Didcot. 4 x 500 MWe.

20,000 hours operation after 1 Jan 2008

- Tilbury. 3 x 350 MWe

20,000 hours operation per stack after 1 Jan 2008

- Tilbury new build. 2 x 800 MWe

Proposal and permitting process underway. 2013?

- Blyth new build. 3 x 800 MWe

Proposal and permitting process underway. 2014?

And now let us skip quickly through 5 elementary slides which experts should ignore.

Typical flue gas from coal combustion.

7 vol%   Water or Steam.

12 vol % Carbon dioxide

3 vol %   Oxygen

75 vol% Nitrogen

Small quantities of oxides of sulphur, oxides of nitrogen, unburnt fuel and ash

CO_2 in units I can understand.

1 kWhr of electricity

1 lb of coal


4x apples

+ 5 cubic metres of air

350x balloons

or inside of
a mini

= 1 kg of CO_2

Note: Carbon is often used instead of CO_2 and confusion can arise.


50x balloons

OR


1x 1kg CO_2 fire extinguisher if liquified

Electricity generation with coal fired boilers

Combustion to turn chemical energy into heat (over 99% efficient)

Steam raised at high pressure.

Steam passes through a turbine to turn a generator.

Steam is condensed and re-used

Flue gas is cleaned.

Working fluid temperatures (steam cycle)

- **Thermodynamics - Convert heat to work over the widest temperature range for best efficiency**.
- Remember (T1-T2)/T1 ? This is more important to power plant efficiency than any combustion issues.
- What limits temperatures and pressures? Materials to <u>contain</u> the steam have to be hotter than peak steam temperature
- Gasification, gas and gas turbines is different because the highest working fluid temperatures are INSIDE the materials of containment

Tilbury feasibility studies

Capture

Transport

Storage

Supercritical plant feasibility

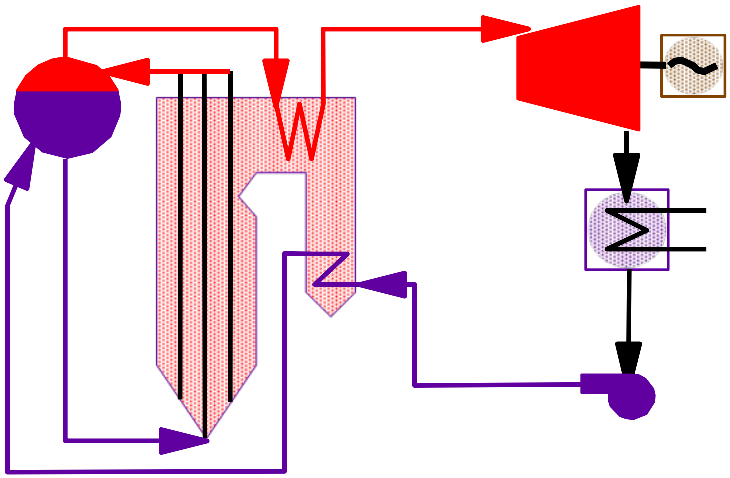
CO_2 capture & storage feasibility

- Good site from point of view of power demand and coal jetty

Supercritical pulverised coal plants

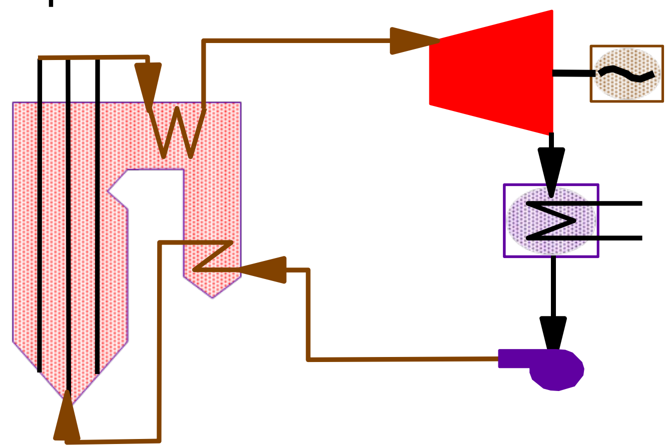
(simplified non-reheat cycle shown)

- Drum Boiler
  Steam



- P<221 bar

- Supercritical Once-through Boiler
  Supercritical Fluid



- P>221 bar

Plants with supercritical steam operating at up to 565°C have been operating for many years. They have higher efficiency than subcritical plant with the same steam temperatures but may have higher investment costs. Materials advances are now permitting steam temperatures to be raised and supercritical plant with steam conditions of up to 300 bar, 600°C/620°C and efficiencies over 45% probably commercially available.

CO_2 capture techniques –

- Absorber.

  Dissolve CO_2 from flue gas in a solvent, often amine.

- Oxy-fuel.

  Separate oxygen from air before combustion

  Little nitrogen in flue gas so separation is mainly water / CO_2

- Gasification and water gas shift.

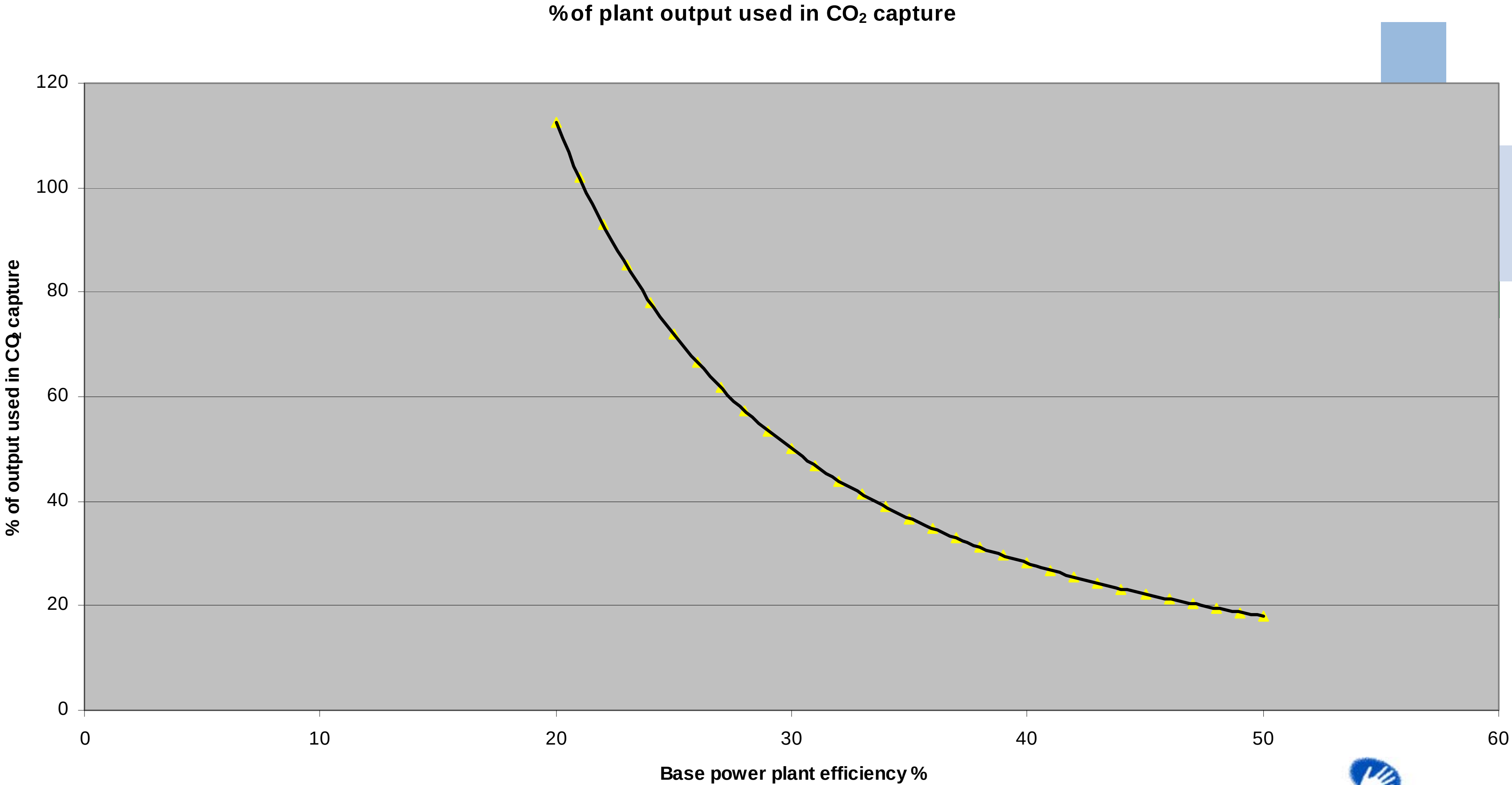
  Gasify fuel before combustion

  Shift CO to CO_2 (producing H_2 from H_2O)

  Capture CO_2 under reducing conditions before combustion.

- Others probably less well developed, including oxygen donor.

Efficiency and cost implications of most CO_2 capture options.



Tilbury study - key findings

New build. 2 x 800 MW supercritical plant with direct cooling is the preferred option

- Supercritical retrofit because it makes no sense to retrofit to inefficient plant. CO_2 capture ready.
- CO_2 storage - a number of significant technical, commercial and legal obstacles need to be overcome:

1. public acceptability
2. assignment of liabilities
3. UK government position, direction and support
4. CCS needs to be recognised within the EU ETS and the Kyoto process
5. Carbon dioxide transport and storage

Key findings

- IGCC higher capex, no efficiency advantage and significantly reduced flexibility in non-capture mode.
- If Carbon Capture is installed from the start, the through life economics of IGCC and supercritical pf plant are close.

- Carbon Capture and Storage (CCS) unproven on large scale power generation plant
  - CCS increases plant capex/kW by 50%, reduces efficiency by 10% points and requires CO_2 transport infrastructure
    - Increases through life generation costs by around 50%
  - CCS economics highly uncertain and very sensitive to assumed commodity prices

Most of the CO_2 separated from natural gas at wellheads or landing sites is vented to atmosphere.

Combustion test facility CO_2 capture programme

- £650k Oxyfuel combustion programme including coal and biomass co firing
  - Simulation using bought-in carbon dioxide instead of flue gas recirculation
- £650k Amine absorption programme, including CO_2 recovery by steam desorption
- Both the oxyfuel and the amine absorber projects are multi-partner with DTI funding.

Next stage(s) - We are not ready to discuss here but the direct step from ~ 0.1 MWe to 800 MWe is too large.

Tilbury - photo montage

(Some details omitted. South side stacks option)

Tilbury - photo montage
(East side stacks option)

Tilbury preparations for CCS

- Close the currently operating units and demolish.
- Move the coal stock
- Then build the capture plant
- In the next photo montage we are assuming amine absorption technology with significant advances in volume reduction for absorbers and desorbers, allowing 2 absorbers and 1 desorber per 800 MWe gross unit. External plant.

Tilbury with CO_2 capture

When considering sizes, remember that the boilers are tower boilers.

Other options being considered, e.g. different numbers of absorbers and desorbers.

Land requirement is comparable to non-CCS parts of power plants.

Oxyfuel land requirements are comparable.

Blyth

3 x 800 MWe. New supercritical coal units.
Brownfield former power station site.
Closer to North Sea oilfields.

Transport options to Southern North Sea?

High pressure pipeline

- No infrastructure currently available
- 250 miles pipeline required
- ~£250 million capital cost

CO_2 production with onsite storage

Ship

- Only 4 vessels currently available in Europe
- Perception about purity
- Specialist vessels
- Transportation conditions, P, T etc.

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What is capture ready?

Plant with adequate efficiency to accept penalty of CO_2 capture? (Proportion of generation lost is proportional to the reciprocal of square of efficiency)

Land area for CO_2 capture?

Ease of connection (of oxygen plant or amine scrubber + associated equipment)?

Route out for CO_2?

CO_2 storage? International law compliance?

Full planning and environmental permissions for future capture ?

Whatever is needed from the above it needs knowledge and ability to convince others.

Hence our study and test facility work.

IEA/IChemE capture ready studies underway.

1.6 GW of coal CCS is the same quantity of CO_2 as almost 4 GW of natural gas.

What is lacking today?

Currently no market mechanism to put a positive into CCS.

CCS not recognised in emissions trading.

CO_2 permits are a volatile market with major uncertainties post 2012.

Under-sea disposal legal issues, waste management issues and long term liability all outstanding, but under-sea legal issues looking closer to agreement.

Consultations and uncertainties arising from White Paper

Also technology issues

RWE Power IGCC with CO_2 Capture.
(For more details see web links at the bottom)

- 400 MWe proposal in Germany.
- Entrained gasifier if bituminous coal
- Entrained or fluidised if lignite
- Water gas shift reaction.
- CO_2 capture before combustion in a hydrogen fired CCGT
- CO_2 storage underground, onshore or offshore.
- CO_2 capture from the start, not “capture ready”.
- http://www.rwe.com/generator.aspx/konzern/fue/strom/co2-freies-kraftwerk/property=Data/id=394976/iccg.pdf
- http://www.fz-juelich.de/ptj/projekte/datapool/page/2121/201.pdf

There are natural CO2 stores and some leak.

CO2 driven geyser in the Eifel, Germany.

Thank you for your attention

For follow-up questions

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http://ortsgemeinde-wallenborn.online.de/joomla/index.php?option=com_content&task=category&sectionid=8&id=25&Itemid=46