Coal Combustion Plant with Carbon Dioxide Capture and Storage .

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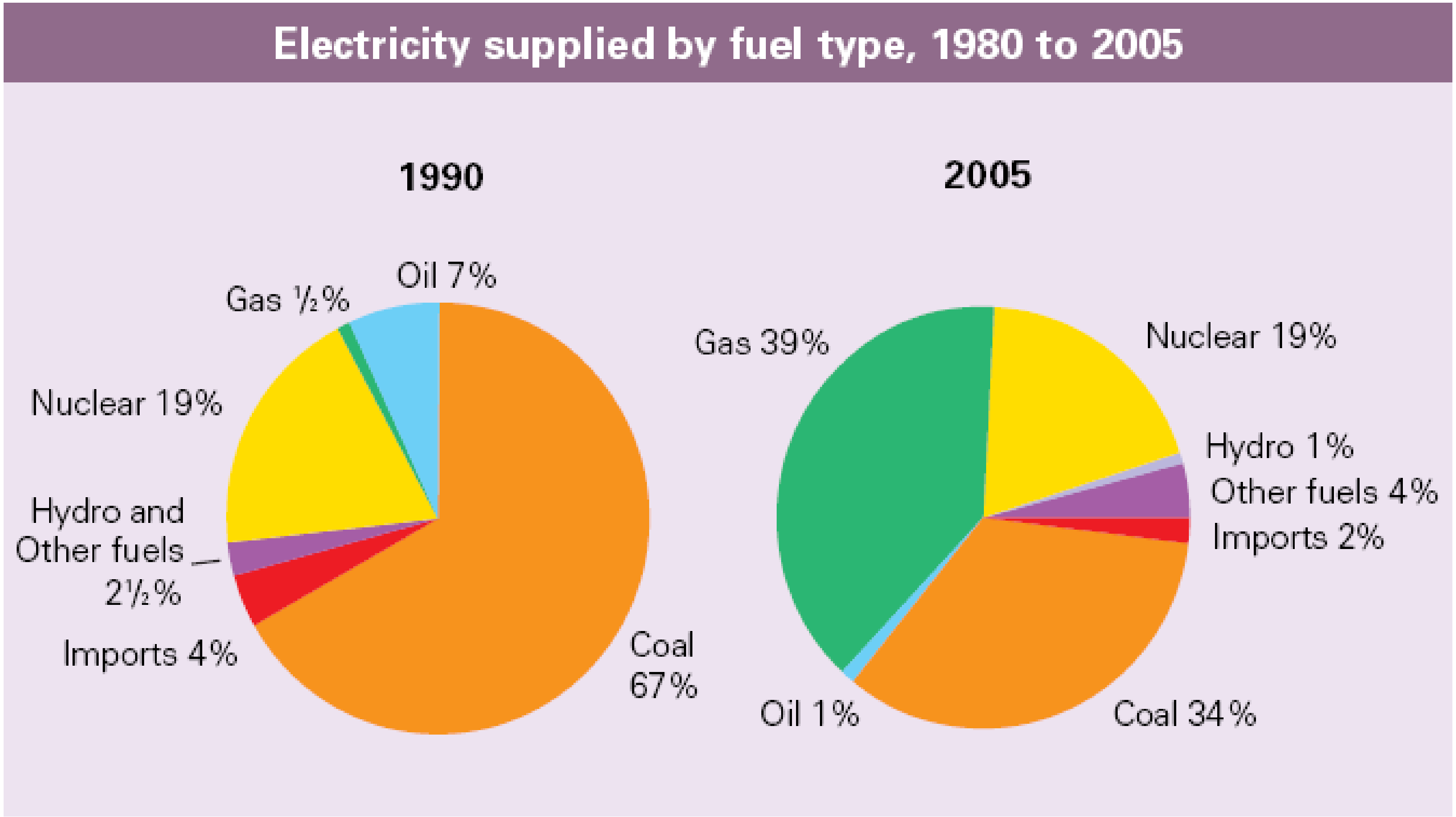
RECENT DEVELOPMENTS IN CARBON CAPTURE AND STORAGE

COMBUSTION DIVISION OF THE COAL RESEARCH FORUM . **17 April 2007**

UK electricity production by Fuel



Source : http://www.dti.gov.uk/files/file32387.pdf

What is the future of RWE npower coal units?

- Tilbury
 (3 x 350 MWe plus 1 mothballed unit)

Existing units have 20,000 hours of operation from 1 Jan 2008.

- Didcot
(4 x 500 MWe)

Existing units have 20,000 hours of operation from 1 Jan 2008.

- Aberthaw
(3 x 500 MWe)

- Flue gas desulphurisation under construction to give plant life beyond 2015

- All plants cofiring biomass which complies with our sustainability criteria.

So if we do nothing

- We would only have 1 coal fired power plant in operation after expiry of 20,000 hours or at latest by 2015.

If we wish to retain something approaching the current coal proportion of generation

- We need to build.
- What is important?
- Fuel route
- Grid access, including financial and technical issues of power plant relative to electricity consumption.
- Ability to obtain permissions
- Advantages in continuing on existing sites.

Coal – but what about CO2?

- Combustion

  Carbon + Oxygen = Carbon dioxide   plus heat

  Hydrogen + Oxygen = Water   plus heat.

- Most fuel consists of hydrocarbons,
  i.e. carbon + hydrogen.

Why is CO_2 reduction so important (environmentally)

- Greenhouse gas.
- Global warming.
- Sea level rise (trebled over last 5 years).
- Ocean acidification and effect on marine life.
- Public opinion – even if you disagree with majority views.

Where can it go?

- Depleted gas wells
- Oil wells (EOR)
- Saline aquifers
- Small quantities to commercial uses

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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


50x balloons

OR


1x 1kg CO_2 fire extinguisher if liquified

Do not confuse Carbon and CO_2

- This audience should not have a problem but some others do.
- Carbon molecular weight is 12
- CO_2 molecular weight is 44

- Difference is a factor of 44/12 = 3.6667
- People talk about £/tonne of Carbon
- Some mean as elemental carbon
- Some mean as carbon dioxide CO_2

- And many have no idea which they mean.

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.

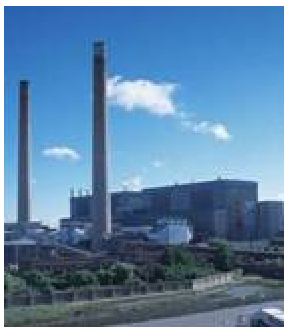
Steam is condensed and re-used

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 ?
- What limits temperatures and pressures? Materials to contain 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

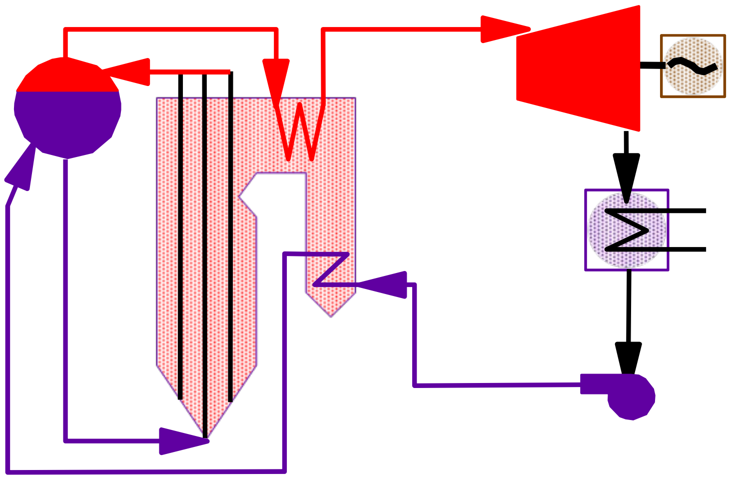
CO_2 capture & storage feasibility

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

Supercritical pulverised coal plants

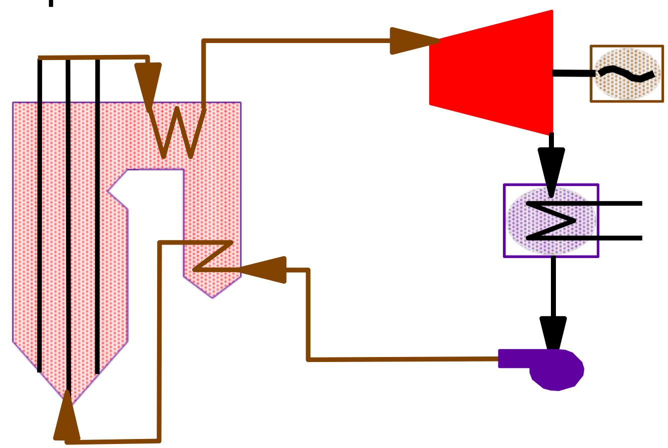
(simplified non-reheat cycle shown)

- 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 275 bar, 580°C/600°C or higher and efficiencies over 45% are now 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.

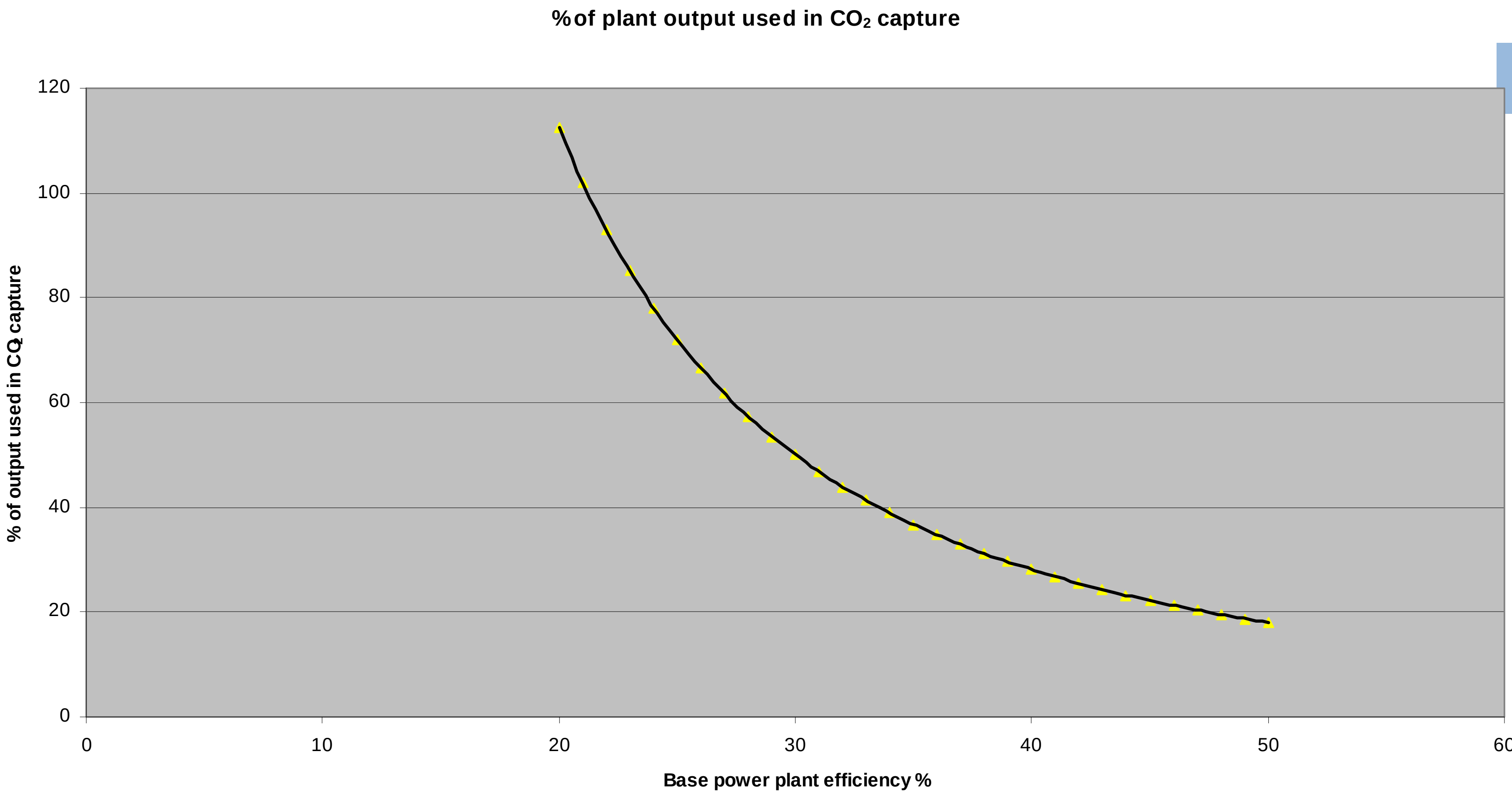
  Gasify fuel before combustion

  Shift CO to CO_2 (producing H_2 from H_2O)

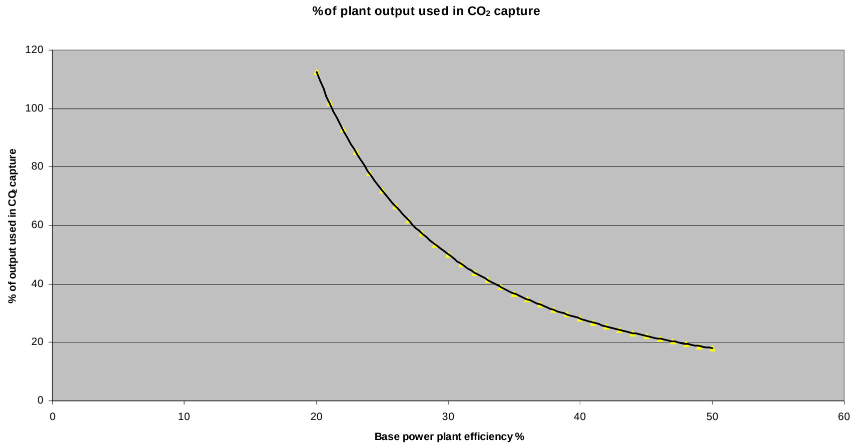
  Capture CO_2 under reducing conditions before combustion.

- Others probably less well developed, including oxygen donor.

Efficiency and cost implications of most CO_2 capture options.



Efficiency and cost implications of most CO_2 capture options.



This curve means that it makes no sense to retrofit carbon dioxide capture to old power plants with efficiencies well below today's .

First make the power plant as efficient as practicable, then take the efficiency hit of CCS.

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. Fraction of plant output lost is inversely proportional to square of efficiency.
- 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

Key findings

- IGCC higher capex, no efficiency advantage and significantly reduced flexibility in non-capture mode compared to supercritical boiler.
- If Carbon Capture is installed from plant construction the through life economics of IGCC and supercritical pf plant are close.
- Risk issues depend on dates and size of CCS retrofits.

- Carbon Capture and Storage (CCS) is currently uneconomic and technological unproven on large scale power generation plant
  - Very approximite generic estimates. 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%
    - Major reduction in NPV for Tilbury
  - CCS economics highly uncertain and very sensitive to assumed commodity prices
  - Our proposed supercritical pf plant will be Carbon Capture Ready, which we interpret as space allocated for capture plant and studies on implementation of the retrofit.

Most of the CO_2 currently 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 – We are not ready to publicise today.

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Tilbury.
Capture ready- photo montage
(some details omitted)

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.

Tilbury Capture ready- photo montage

(some details omitted)

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.

Transport options to Southern North Sea?

High pressure pipeline

- No infrastructure currently available
- 250 + miles pipeline required
- ~£250 million capital cost
- Optimum pressure and temperature conditions not obvious.

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 study and test facility work.

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 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.

Also technology issues

RWE Power IGCC with CO_2 Capture.

- 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”.

Thank you for your attention

- For follow-up questions
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