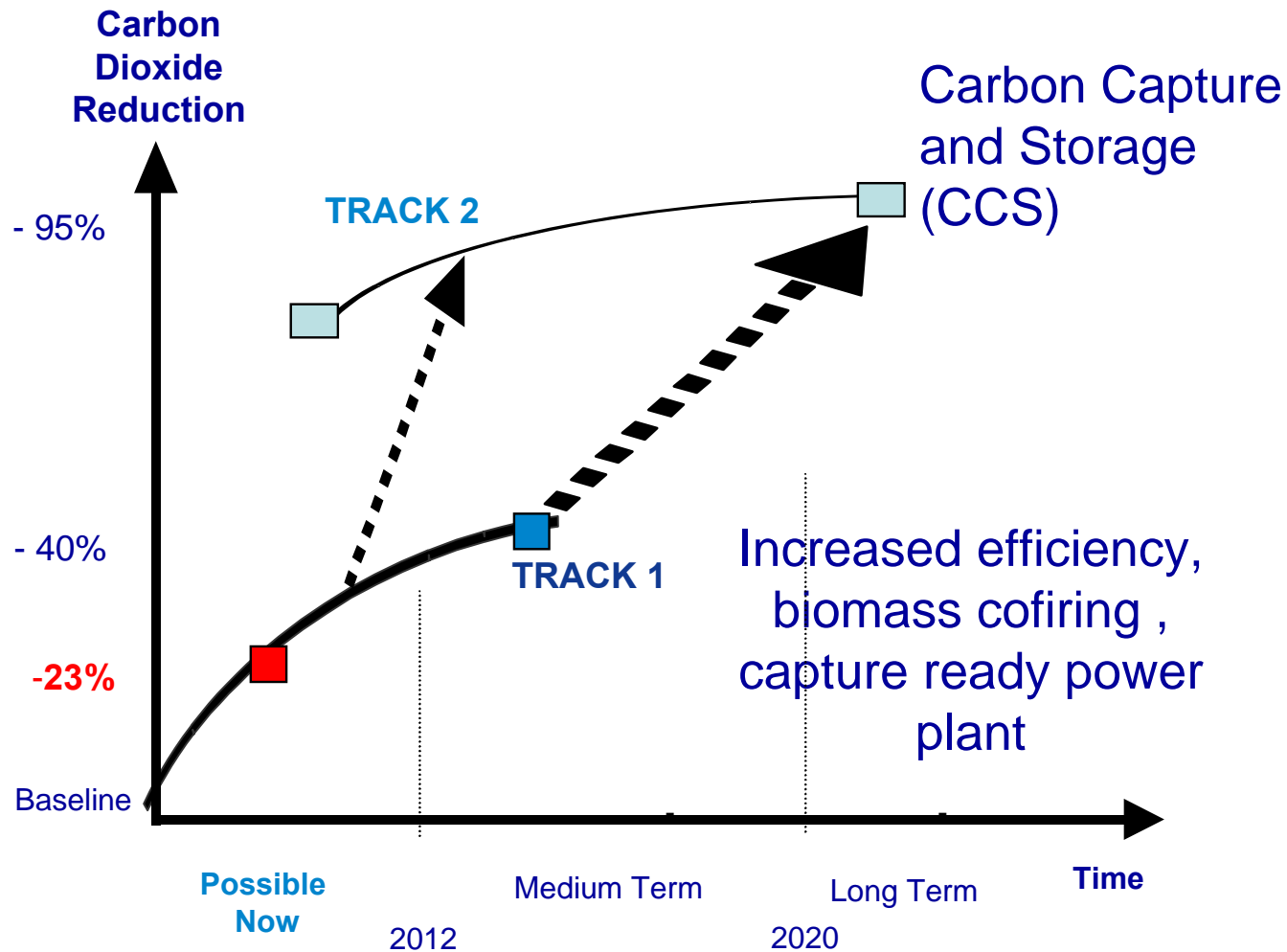


CATs R+D + Demo

Dr Mike Farley

**CATs R+D perspectives – industry view from
APGTF presented to ACCAT 17 July 2008,
updated 15 August 2008**

Twin – track approach to near - zero emissions power by 2020



Comparison of Carbon capture options for Coal power plant

Three options for medium term:

Post Combustion Capture – Amine scrubbing

Oxyfuel firing

Precombustion – IGCC

Numerous studies show these are similar in resulting efficiency and cost of electricity.

No clear winner but

PCC and Oxyfuel needed for retrofit to plants currently being built around the world (including China and India)

Few IGCC/Precombustion projects

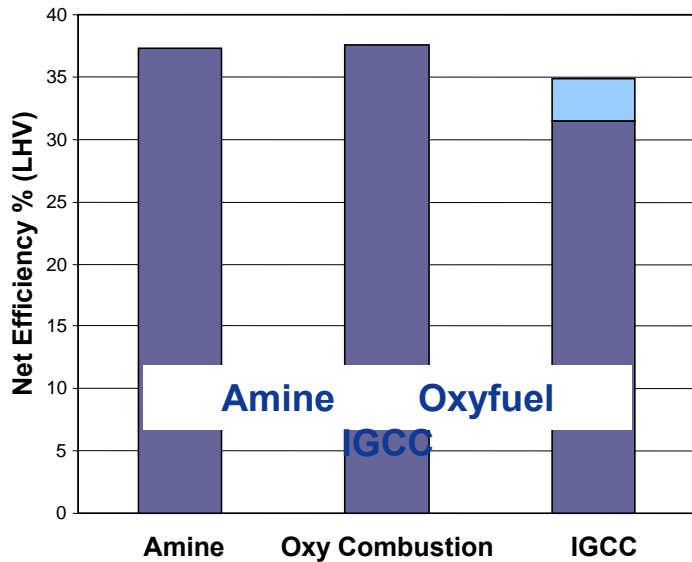
Longer term other options include chemical looping and PFBC/Carbonates



Amine Oxyfuel IGCC

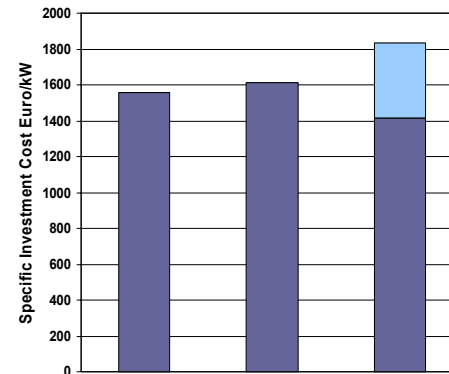
Comparison of Carbon capture options for Coal power plant

Net Cycle Efficiencies (%LHV)



From joint paper with Jacobs at Powergen 2006

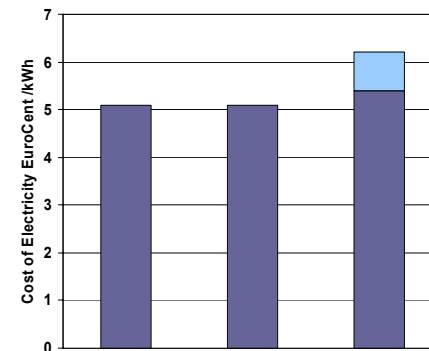
Specific Investment costs (Euro/kw)



1400-1800 Euro/kw for New build, 800 Euro/kw for Retrofit

Amine Oxyfuel IGCC

Cost of Electricity (Eurocents/kwh)



5 -6.2 Euro/kwh for New build, <5 Euro/kwh for retrofit

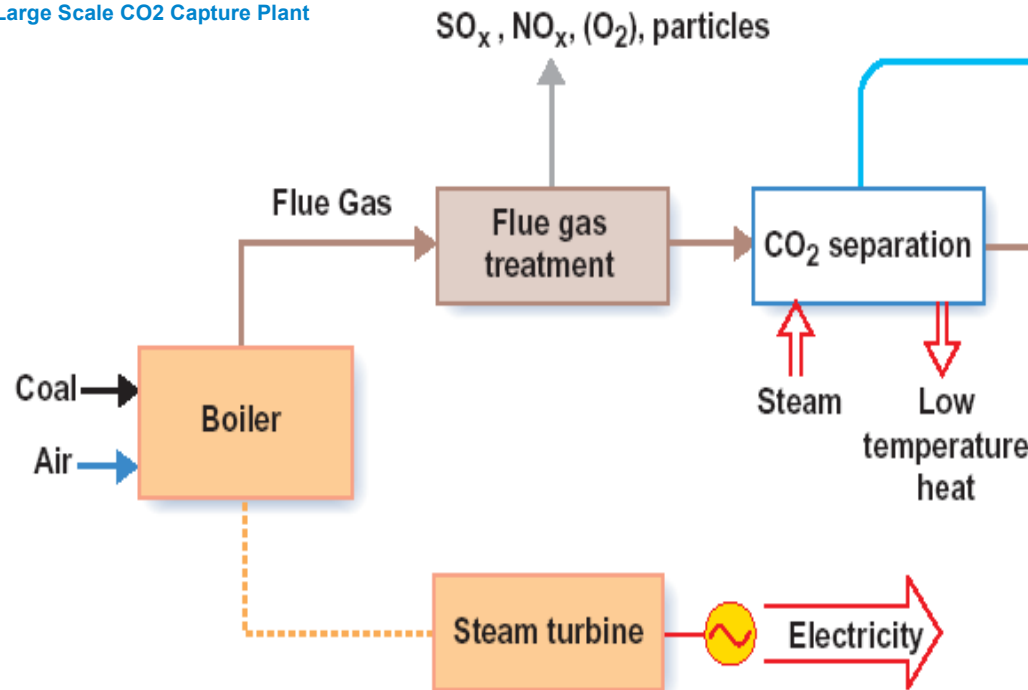
Amine Oxyfuel IGCC

Post-combustion Carbon Capture

– Flue Gas Scrubbing on Pulverised Coal Plant



Large Scale CO2 Capture Plant



- IEA studies complete
- Elsam slip stream pilot on Amine scrubbing underway
- New Alstom pilot and demo projects on chilled Ammonia scrubbing
- Collaborative UK DTI project underway, led by RWE Npower
- Requires scale up (factor of 10)
- Several other pilot demos planned
- Need larger demonstrations as a step towards large power plant, first could be the UK Demonstration

Carbon Capture by Oxyfuel firing on Pulverised Coal Plant

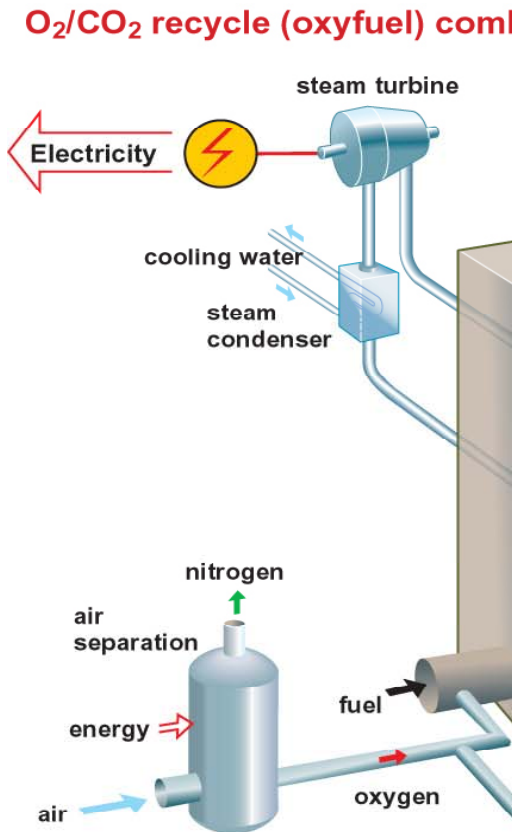


Figure courtesy of Vattenfall

- Pilot scale tests by Doosan Babcock Energy 1996
- IEA studies completed
- EU project ENCAP underway
- EON 1MW rig now operational, confirmed DBE results
- DTI funded collaborative R&D projects in progress (Doosan Babcock Energy, EON, RWE, Air Products ...)
- Vattenfall 30MW demonstration plant being built , and similar projects at Lacq and Callide
- Full scale 40 MW burner test planned by Doosan Babcock in 2008/9
- Several boilermakers developing this technology for 2012 implementation
- Intermediate scale demo needed (say 100-200MW)

UK companies are participating in EU, UK govt and international R+D projects on High Efficiency Boiler/Steam Turbine , biomass cofiring and CO₂ Capture, Transport and Storage

- **EU Research projects on Efficiency (COST 536 Materials for Advanced Plant, COMTES 700), Capture (ENCAP, CASTOR, CESAR ASSOCOCS) and Storage**
- **DTI Projects (largely complete)**
 - **Retrofit of Gasifier to CCGT,DTI Project 407- Retrofits of Boiler/Turbines with CO₂ capture, DTI - 366 'Future CO2 Capture Technology Options for the Canadian Market', High pressure coal gasification, DTI Project 410 - Materials and fabrication for 700degC power plant,**
- **BERR/TSB projects underway:**
 - **Post-combustion capture (CASSCAP), Oxyfuel combustion (Oxycoal1,Oxycoal2), High efficiency hydrogen gas turbines, Integrated Gasification Steam Cycle (IGSC), CO₂ Aquifer Storage (CASSEM), Improved Modelling of Material Properties for Higher Efficiency Power Plant (TSB - IMMP3), DTI/BERR: Modelling Fireside Corrosion of Heat Exchanger Materials in Advanced Energy Systems**
- **International R+D**
 - **Vattenfall Oxyfuel demonstration**
 - **E.ON Collaborative Pilot R&D activities(University of Texas, ITC Canada) and Bilateral Development of pilot plants (up to 5MW scale) with Alstom, Siemens**
 - **Involvement in Futuregen 275MWe Project Development**
 - **RWE npower is an industrial sponsor of the pilot amine scrubbing research facility of University of Texas at Austin**

Overview of CATs Research Agenda

- **Efficiency improvement for power plant with CCS**
 - boilers, turbines, IGCC, CHP, use of waste heat
 - **Co-use of biomass with CCS**
 - cofiring, co-gasification, ...
 - **Carbon dioxide capture**
 - post-combustion, pre-combustion, oxyfuel
 - **Carbon dioxide transport and storage**
 - pipelines
 - EOR
 - depleted gas fields, saline aquifers,
 - unmineable coal seams
- » **Improved performance, flexibility, economics, safety, environment, waste disposal and public awareness**

CATs/CCS Demonstration and Deployment - timescales and ambitions

- Research and Development
- UK Regulations
- Early Demonstration projects (incl. Capture ready)
- Phase 3 of ETS
- 10 - 12 Demonstrations in Europe
- EU target for full commercialisation
- Extensive implementation

now →

2009?

2012/15

2013

by 2015

by 2020

2020 – 2030

**BERR Competition
300MW CCS demo on
pulverised coal
operational by 2014**

**IEA Technology
Perspectives 2008
presented to G8 in Bali
requires 22 coal (800MW)
and 20 gas (500MW) CCS
power plants per year
from 2013 to 2030**

- A huge build up in industry capacity is needed as well as demonstration/proving of technology
- Need to create and build up OEM /EPC capability in UK based companies and underpinning capability in Universities
- Industry view is that the technologies that will be fully commercialised by 2020 will be based on the technologies that are known now at lab/pilot scale
- So we need industrial led R, D and Demo at TRLs 3 to 6
- But also need underpinning research and longer range research in Universities

Structure of Presentation

Ambitions:

What we should be aiming for if UK is to be a leader in Carbon abatement technologies for fossil fuels

Priorities for R+D and Demonstration:

Based on discussions at APGTF

Efficiency improvement for Power Plant with CCS

Ambition:

- a high efficiency coal power plant (efficiency 50 % before CCS and >43 % with CCS), designed for CCS, and integrated with a heat utilisation scheme
- *operating in the UK by 2016*

Priorities for R+D and Demonstration:

- **Materials, fabrication, inspection, monitoring and life assessment technologies for progressive increases in steam temperature and pressure to 350 bar and 750°C**
 - Particular issues relating to high nickel alloys
- ***Optimisation of cycles recognising***
 - *Carbon capture*
 - *Large scale CHP, utilisation of waste heat*
 - *Double reheat (towards 50% efficiency without nickel alloys)*

Biomass cofiring with CCS

Ambitions:

- **a biomass cofired 600deg coal power plant (efficiency >45 %), designed for CCS, integrated with a heat utilisation scheme, with 20% cofiring of a wide range of biomass fuels**
- **operating in the UK by 2016**

Priorities for R+D and Demonstration:

- **Advanced cofiring or co-gasification (up to 20% or more by heat input), including corrosion, slagging and fouling issues**
- **Efficient preparation and processing of sustainable biomass energy crops (e.g. pelletisation, torrefaction)**
- **Better understanding of availability of sustainable biomass resources for cofiring**
- **Impact of biomass cofiring on precombustion, post combustion and oxyfuel carbon capture processes**

Carbon Dioxide Capture Technologies – Post combustion capture

Ambitions:

- a 600deg coal power plant (efficiency >45 % before CCS and >36 % with CCS), initially capture ready by 2013, then with 400MW Post combustion capture, operating in the UK by 2014
- a 400MW CCGT with CCS operating in the UK by 2015
- *several smaller scale pilots/demonstrations of competing scrubbing technologies eg up to 100MW slip stream*
- capacity of industry built up to match market needs

BERR
competition

Priorities for R+D and Demonstration:

- *Process optimisation/ heat integration (including utilisation of waste heat)*
 - *New and less energy intensive solvents (e.g. amines, carbonates, ammonia)*
 - *Avoidance of solvent degradation*
- and for the longer term
- Improved capture technologies

Ambitions: UK demonstration and UK OEM capability

Priorities for R+D and Demonstration:

- **Gasification : process integration/optimisation, improved availability, biomass cogasification**
- **Gas cleaning : improved reliability**
- **Gas conditioning :**
 - **CO₂ capture : integration and optimisation of shift conversion and CO₂ capture processes**
 - **conditioning of H₂ fuel gas stream for GT**
- **Gas turbine : Premix burners for hydrogen requiring**
- **Air separation unit : Process optimisation, improved absorbents for contaminant removal, high efficiency packing for distilling fluids close to supercritical conditions**

Carbon Dioxide Capture Technologies - Oxyfuel combustion

Ambitions:

- *a 100 -200 MWe Demonstration of an Oxyfuel power plant on hard coals by 2012*
- **a 500 MW Demonstration CCS project by 2017**

Priorities for R+D and Demonstration:

- **Process optimisation, including start-up/shut-down/flexibility**
- **Combustion chemistry and kinetics, Heat transfer prediction**
- **Materials for oxyfuel environment, corrosion issues, ash properties**
- **FGD performance, *Flue gas cleaning to meet CO₂ specifications***
- **ASUs (including membranes)**
- ***40MW demo of new burners, more coal types***
- ***a 100 -200 MWe Demonstration of Oxyfuel power plant on hard coals***

Ambitions:

- **early stages of a transport network linked to one or more storage sites and several capture sites by 2015/7**

Priorities for R+D and Demonstration:

- **Crack formation and growth, major high pressure leaks**
- **Corrosion behaviour of pipelines as a function of material, temperature, etc and content of CO₂ stream**
- **Alternative materials, joining technologies, sealing technologies**

Carbon Dioxide Storage

Ambitions:

- **multiple storage demonstrations in UK by 2015, including EOR, depleted gas and oil fields and saline aquifers**

Priorities for R+D and Demonstration:

- **Site appraisal: methods to assess aquifer injectivity, aquifer seal performance**
- **Saline aquifers: improve estimation of storage ability e.g. atlas of seal and injectivity properties**
- **Site stability: subsurface remote sensing of geomechanical stability during re-pressurisation**
- **CO2 mobility:**
 - improved validated software for reservoir and region
 - develop measuring, hi-resolution monitoring, modelling and verification techniques
- **Site performance: reduce impact of sub-surface uncertainty on performance prediction and risk**
- **CO2 physical properties: experimental data at different groundwater salinities**
- **Geochemical impact:**
 - major reactions of minor contaminants in CO2 stream
 - validated database of equilibrium and kinetic data for modelling
- **ECBM /UCG - capacity of coal as function of depth and permeability**

Comments

- **Support by DTI, BERR, TSB , and the Research Councils has laid a foundation and we have now the opportunity to build on this**
- **Need to be open to capabilities and opportunities available overseas and leverage these**
- **Have to recognise the urgency if CCS is to be “commercialised” and ready for widespread roll out by 2020**
- **Need to join up environmental, energy and enterprise objectives – consistent with global roll out of the technologies**
- **APGTF volunteering to organise subject groups of parties interested in the seven topics to work with RCs, TSB, ETF, and ETI**
- **Headline priorities above will also require underpinning R+D in cross cutting areas such as coal science, modelling, environmental impact etc**

More comments

- **Plenty of scope for RCs and TSB over all seven topics – no need or benefit to be much more prescriptive in calls**
 - Objectives need to include capacity building in UK
 - Industry and Universities need regular calls against a declared plan
 - Need for underpinning research as well as blue skies
- **ETI and Carbon Trust should focus on bigger, more difficult opportunities that will not otherwise happen quickly enough**
 - where commercial benefit is too distant or uncertain to persuade industry to move now with the 25 % funding that might be available from ETF
 - including projects with capital investment in facilities
 - including studies to help establish the best options
 - including projects overseas where cost effective/leverage possible
- **ETF role is effectively defined by its funding rules which**
 - limit it to 25%,
 - limit it to supporting the depreciation element of the capital portion of projects but
 - do allow support of running costs
 - Might provide opportunities to assist access to projects overseas?