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UNIVERSITY OF Southampton

CCS – An overview of commercialisation
by

Dr . Jonathan Lewis

The LRET Research Collegium
Southampton, 11 July – 2 September 2011

Carbon Capture and Sequestration

An overview of Commercialization

Jonathan Lewis

10th August 2011

Southampton

Jonathan Lewis

- Independent Business Development consultant
- Twenty years in business development functions
- Originally with consultancies and latterly with Rolls-Royce plc
- At RR worked in business development for Rolls-Royce Fuel Cell Systems Ltd.
- Clients include Universities (commercialisation of new technology), SMEs (growth options and development funds) through to Industrial coalitions (stationary fuel cell commercialization) and work for European Institutions (eg public policy for RTD).

Agenda

- Introduction
- Part 1
  - Context
  - Discussion
- Part 2
  - Commercialization
  - Discussion

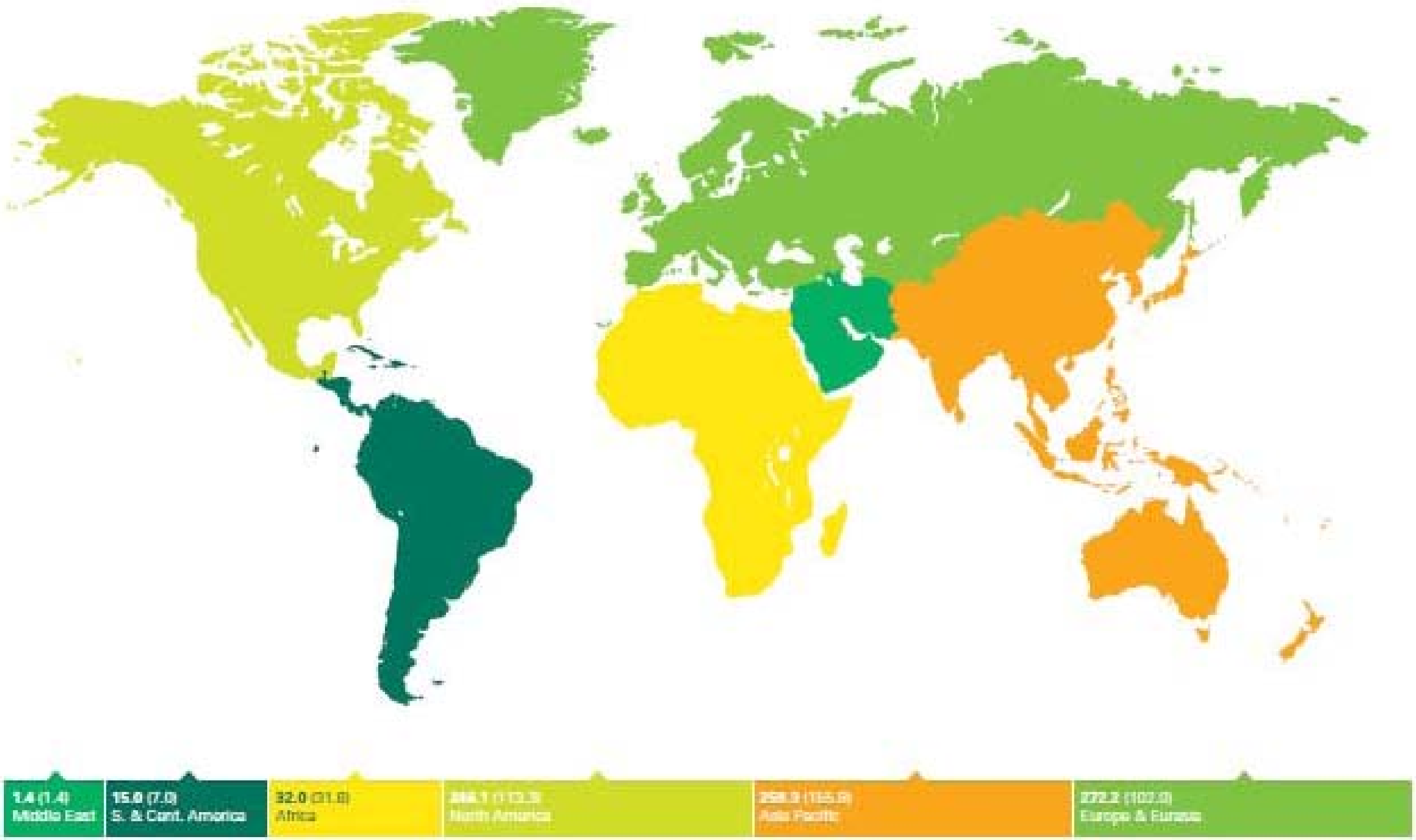
Part 1 – Context

“The US, Russia, China and India account for two thirds of coal reserves…..it’s highly unlikely that any of these countries will turn their back on coal anytime soon, and for this reason, the capture and storage of CO2 emissions for fossil fuel power plants must be aggressively pursued”

Steven Chu, US Energy Secretary.

Coal

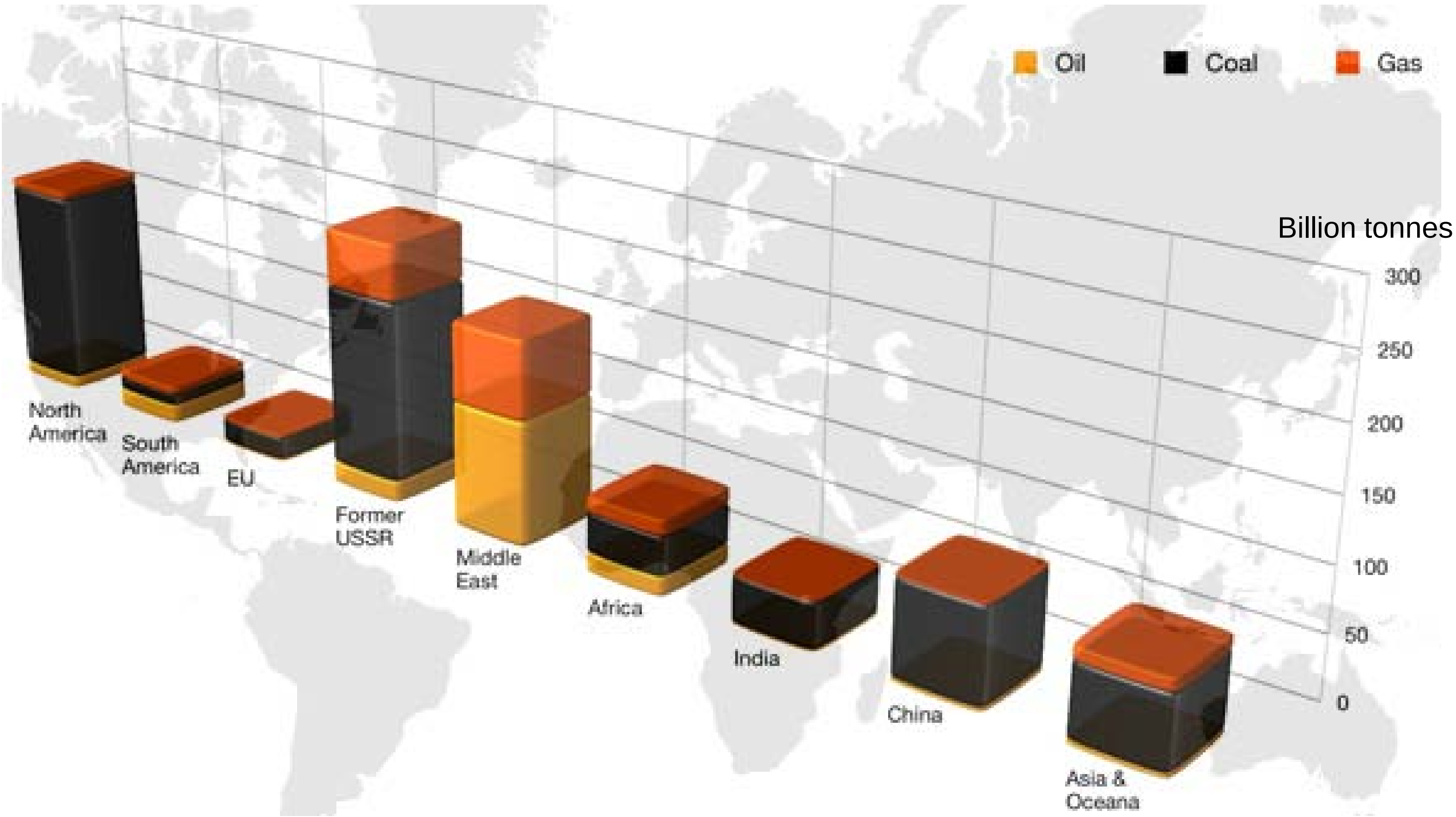
- **Proved Reserves of Coal by Region (Thousand Million Tonnes – Anthracite, bituminous coal in brackets)**



Source: BP Energy Review 2009

Total Fossil Fuel Reserves

- 847 billion tonnes of coal reserves world wide, enough for 119 years. World Coal Association (Note: Oil reserves = 46yrs, and gas = 63 yrs)

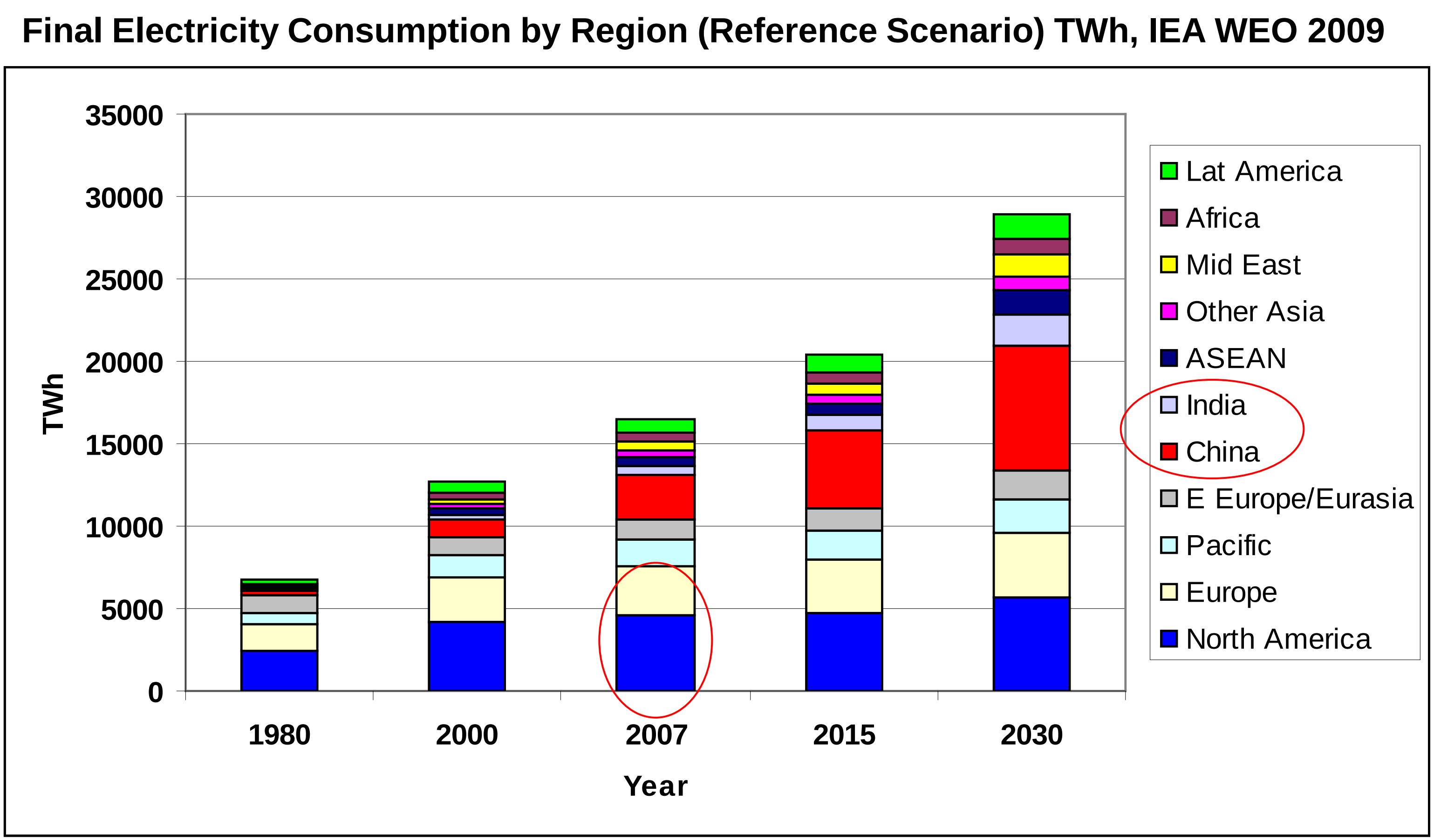


Source: World Coal Association (www.worldcoal.org)

Power Demand

- IEA World Energy Outlook 2009
- Reference Scenario
  - Primary energy demand will grow from 2007 to 2030 by 1.5%/yr (40% over the period) – driven by China and India followed by Middle East.
  - Electric power demand will increase by 2.5%/yr – 80% from non-OECD countries.
  - Coal remains the backbone of fuel sources for electricity, providing 44% of energy mix by 2030, a rise of 3% points over the period.
  - Renewables rise from 18% 2007 to 22% by 2030; Nuclear falls as a proportion of the total.

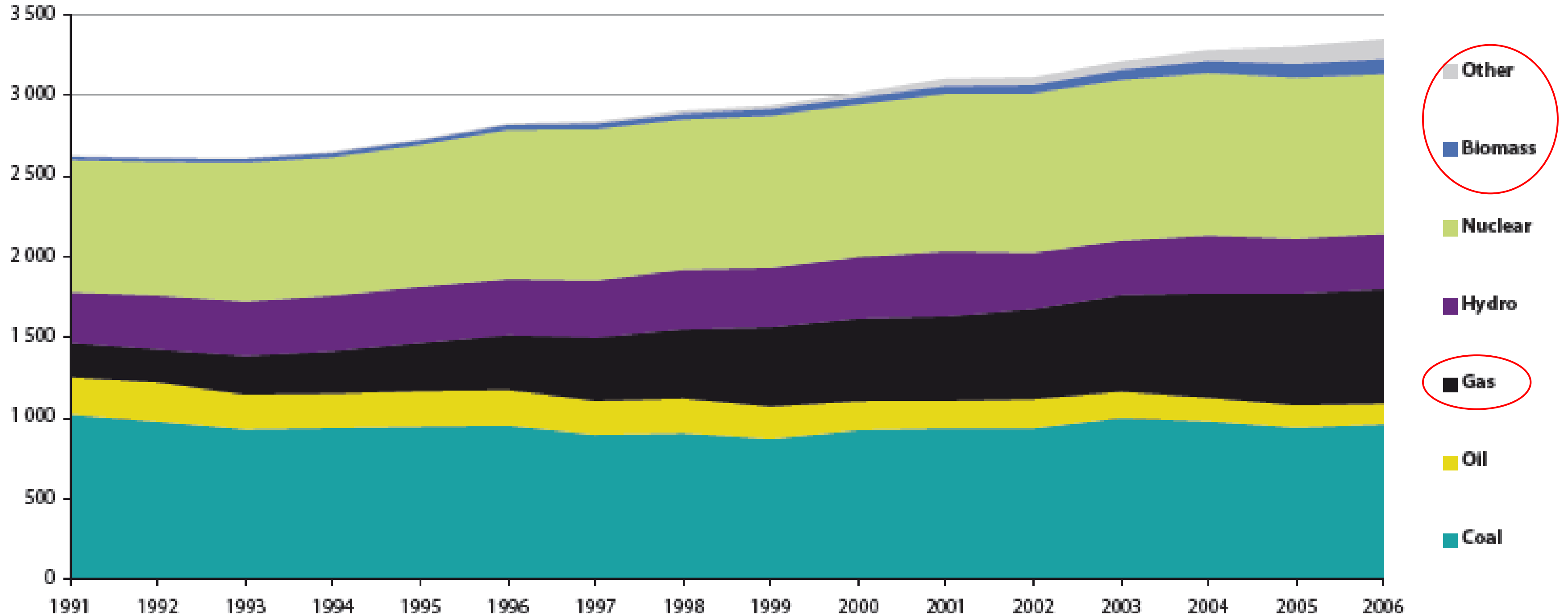
Global Electricity Demand



- Electricity consumption doubled between 1980 and 2007 and will grow further to 2030. Largest single source of demand is China.

Sources of Fuel for Electric Power

EU 27 Electric Power Generation TWh

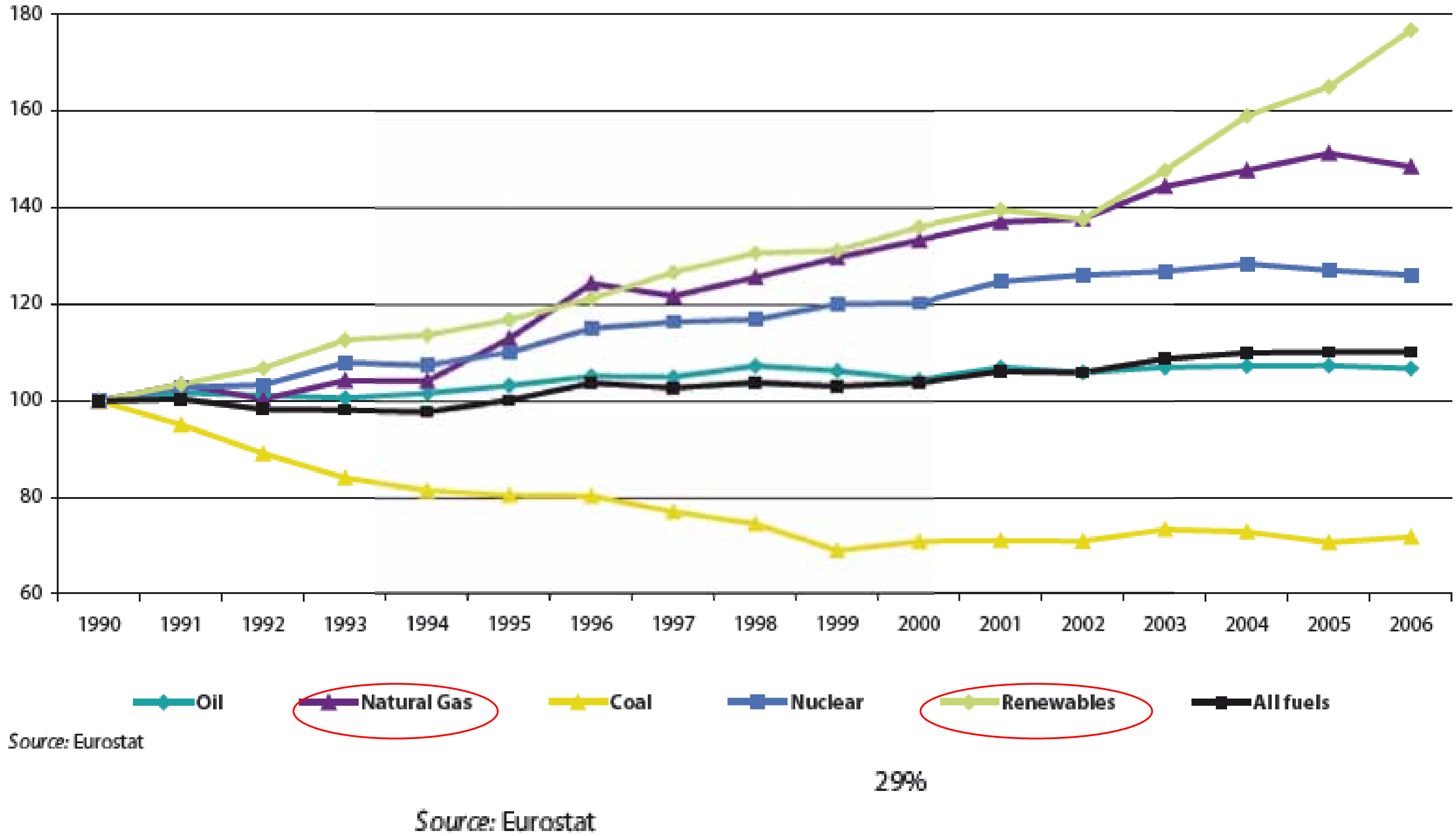


Source: Eurostat

- EU27 small increase in fossil fuelled electric power.

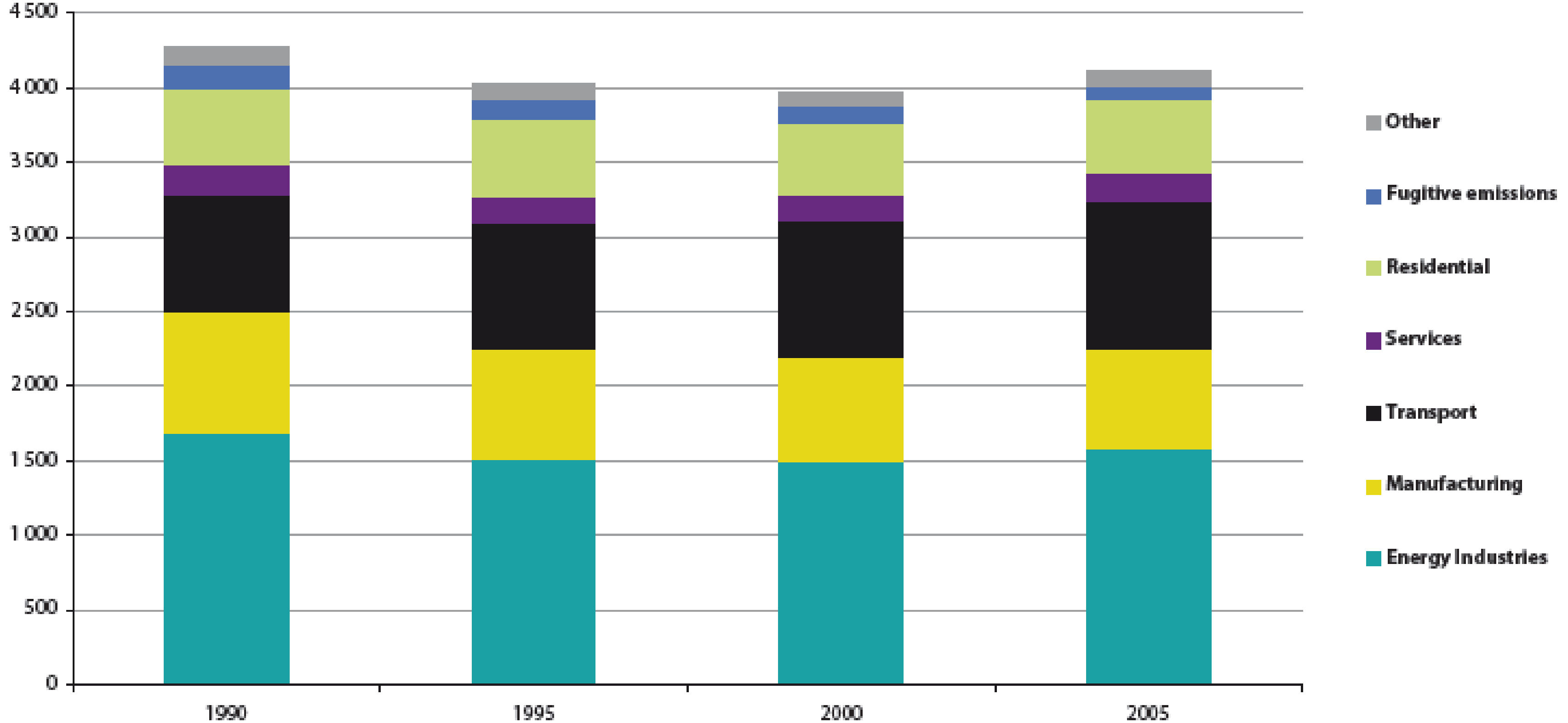
Primary Energy by Fuel Type

EU27 Development of primary energy supply by type of fuel 1990 = 100



Sources of Green House Gases – EU27

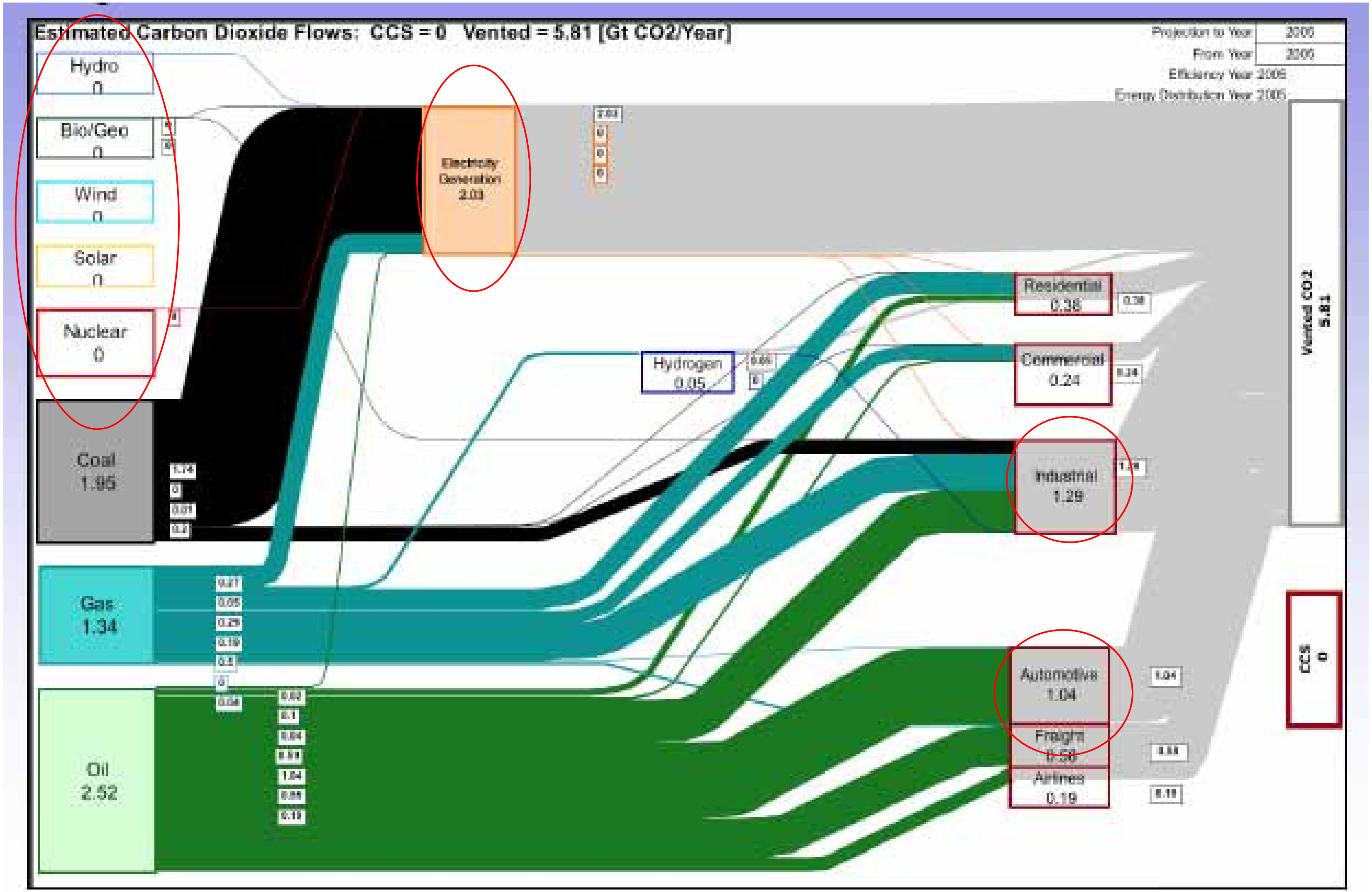
EU27 – Greenhouse gas emissions by sector (mio tonnes CO2 equivalent)



Source: EEA

- Energy industries are the largest source of GHG in EU27

Carbon Sources - USA



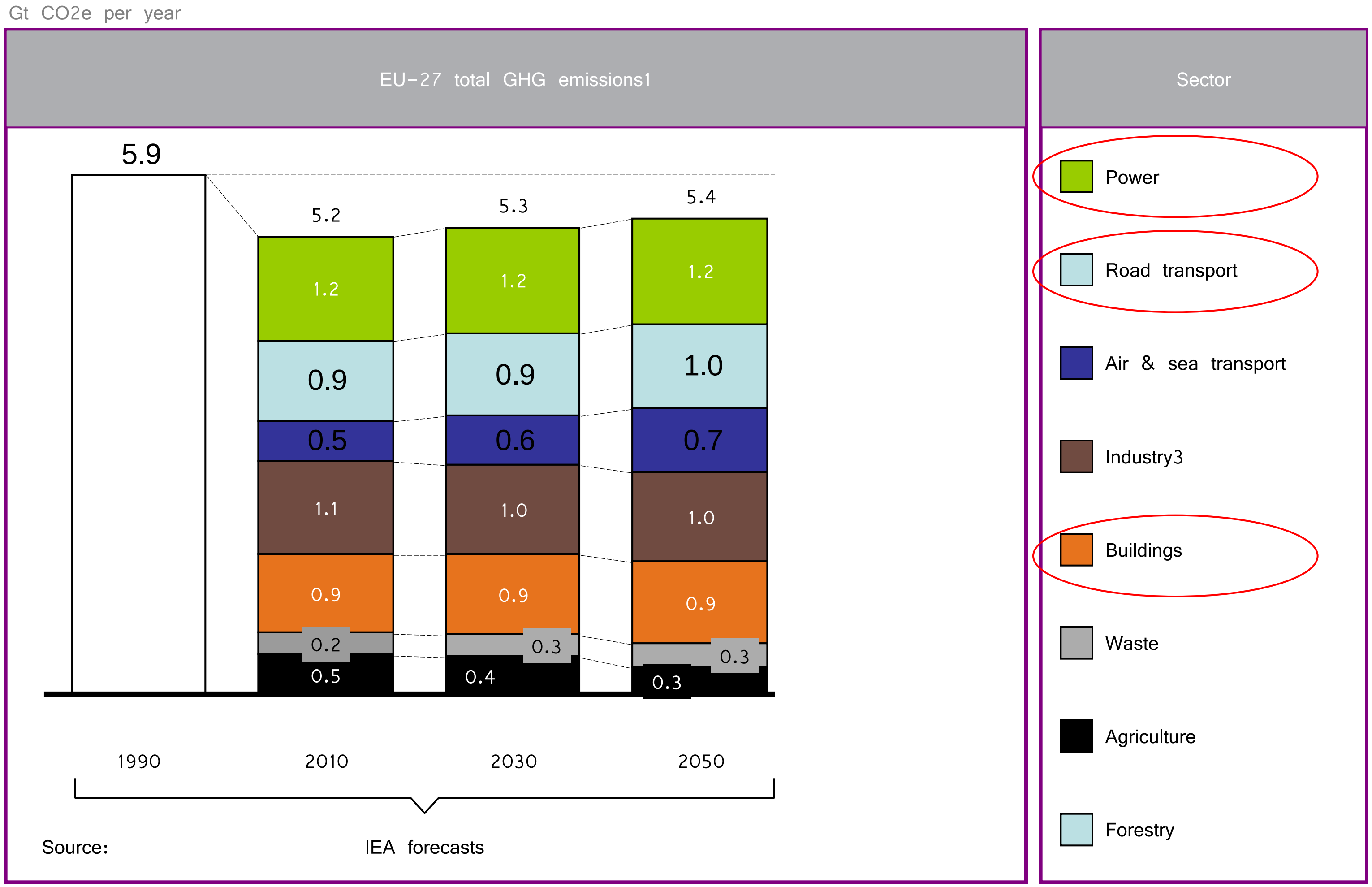
Source: Ziagos, Lawrence Livermore National Laboratory 2005

European Policies

- The European Union and Member States have developed a set of energy policies which will have an impact on CCS.
  - 20-20-20 Vision, June 2009 – 20% reduction in GHG emissions, 20% increase in use of renewable fuels/sources and 20% increase in energy efficiency. (Note 1)
  - Europe requires 712 GW of new/replacement energy capacity between 2008 and 2030, second only to China. (IEA WEO 2009)
  - European Union Emissions Trading Scheme launched 2005 – covers 10,000+ installations responsible for 50% of GHG and 40% carbon emissions.
  - 55% of Europe's energy needs met by imports in 2008 (88% oil and 64% gas).

Note 1 (UK Climate Change Act 2008 50% reduction in greenhouse gas emissions by 2050.)

Carbon Emissions by Sector – Europe



1 Large efficiency improvements are already included in the baseline based on the International Energy Agency, World Energy Outlook 2009, especially for industry

2 Abatement estimates within sector based on Global GHG Cost Curve

3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries)

SOURCE: www.roadmap2050.eu

Summary

- Fossil fuels are the backbone of the world's energy system, which will remain highly dependent on these into the future;
- GHG and carbon emissions sources are linked to energy use and electricity production and transport use in particular;
- Fossil fuel reserves are substantial, especially coal;
- Demand for energy and electricity continues to grow; with China and India being the largest single drivers;
- Electricity supply is dependent upon coal; hydro and nuclear are also large;
- Any solution to GHG and carbon emissions must tackle fossil fuel sources.

Discussion

Part 2 – Commercialization Issues

‘CCS is not an established technology in the low carbon energy mix. As with other emerging technologies, commercial costs have not been discovered, the policy context is unclear and scientific and engineering challenges remain.’

‘There is presently no market for CCS infrastructure development beyond that needed for demonstration projects’.

UKCCSC response to DECC Call for evidence on long term development of CCS infrastructure 2011

The Challenge for CCS

Intergovernmental Panel on Climate Change (IPCC) Special Report on CCS 2005, (www.ipcc.ch)

- CCS could reduce carbon emissions by 80-90%.
- CCS could potentially account for 10%-55% of carbon mitigation by 2100.
- Capturing and compressing CO2 requires energy and could increase fuel needs of coal fired power plants by 25% - 40%.
- CCS could increase energy costs for power plants by 21% to 91%, and even higher for retro-fitted power plants.

Costs of CCS

- **Installation of CCS will increase the cost of electricity for end users; this arises from higher fuel requirements, O&M and capital costs; but there are offsets.**

Table 8.3a Range of total costs for CO_2 capture, transport, and geological storage based on current technology for new power plants.

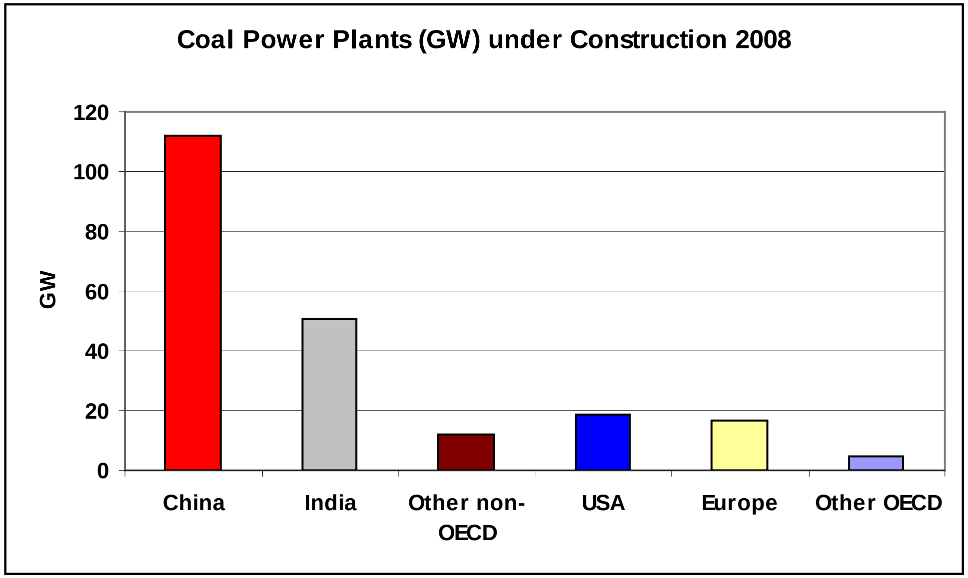
	Pulverized Coal Power Plant	Natural Gas Combined Cycle Power Plant	Integrated Coal Gasification Combined Cycle Power Plant
Cost of electricity without CCS (US\$ MWh^{-1})	43-52	31-50	41-61
Power plant with capture			
Increased Fuel Requirement (%)	24-40	11-22	14-25
CO_2 captured (kg MWh^{-1})	820-970	360-410	670-940
CO_2 avoided (kg MWh^{-1})	620-700	300-320	590-730
% CO_2 avoided	81-88	83-88	81-91
Power plant with capture and geological storage[6]			
Cost of electricity (US\$ MWh^{-1})	63-99	43-77	55-91
Electricity cost increase (US\$ MWh^{-1})	19-47	12-29	10-32
% increase	43-91	37-85	21-78
Mitigation cost (US\$/tCO_2 avoided)	30-71	38-91	14-53
Mitigation cost (US\$/tC avoided)	110-260	140-330	51-200
Power plant with capture and enhanced oil recovery[7]			
Cost of electricity (US\$ MWh^{-1})	49-81	37-70	40-75
Electricity cost increase (US\$ MWh^{-1})	5-29	6-22	(-5)-19
% increase	12-57	19-63	(-10)-46
Mitigation cost (US\$/tCO_2 avoided)	9-44	19-68	(-7)-31
Mitigation cost (US\$/tC avoided)	31-160	71-250	(-25)-120

[6] Capture costs represent range from Tables 3.7, 3.9 and 3.10. Transport costs range from 0–5 US\$/tCO_2. Geological storage cost (including monitoring) range from 0.6–8.3 US\$/tCO_2.

[7] Capture costs represent range from Tables 3.7, 3.9 and 3.10. Transport costs range from 0–5 US\$/tCO_2 stored. Costs for geological storage including EOR range from –10 to –16 US\$/tCO_2 stored.

Source: IPCC 2005

Demand for CCS

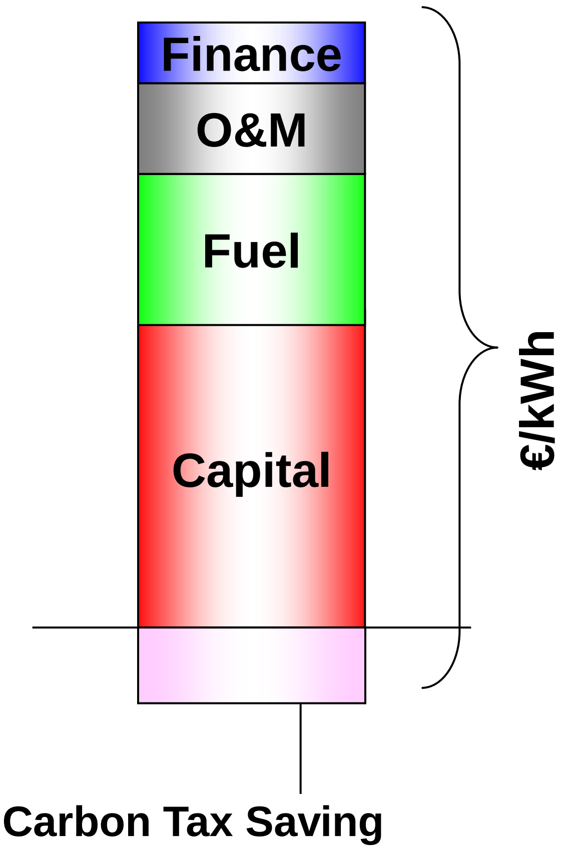


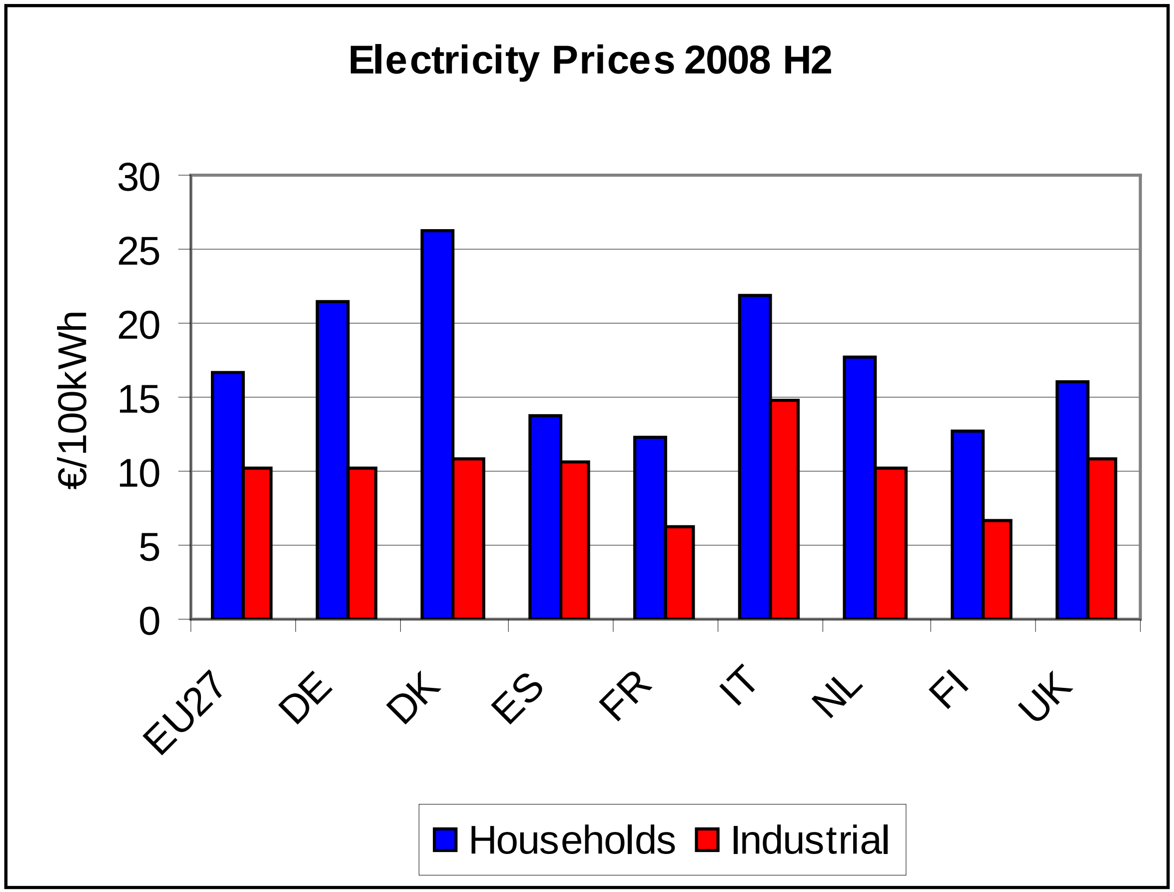
Source: IEA WEO 2009, After Platts

- **Demand for CCS technologies for Coal plants, both new and retrofitted, will be substantial once the technologies are proven.**

Power Prices

- **How does price of CCS power compare to current prices ?**

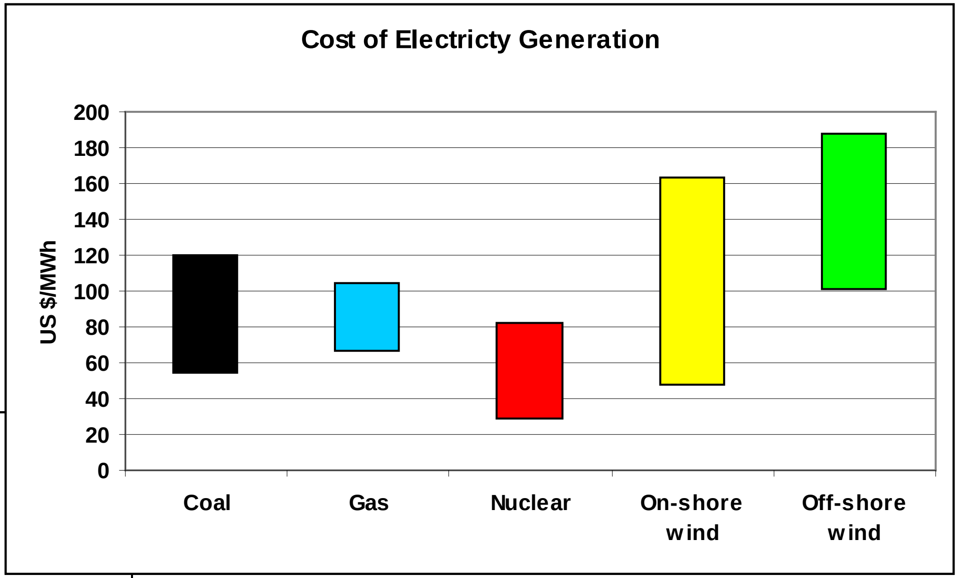




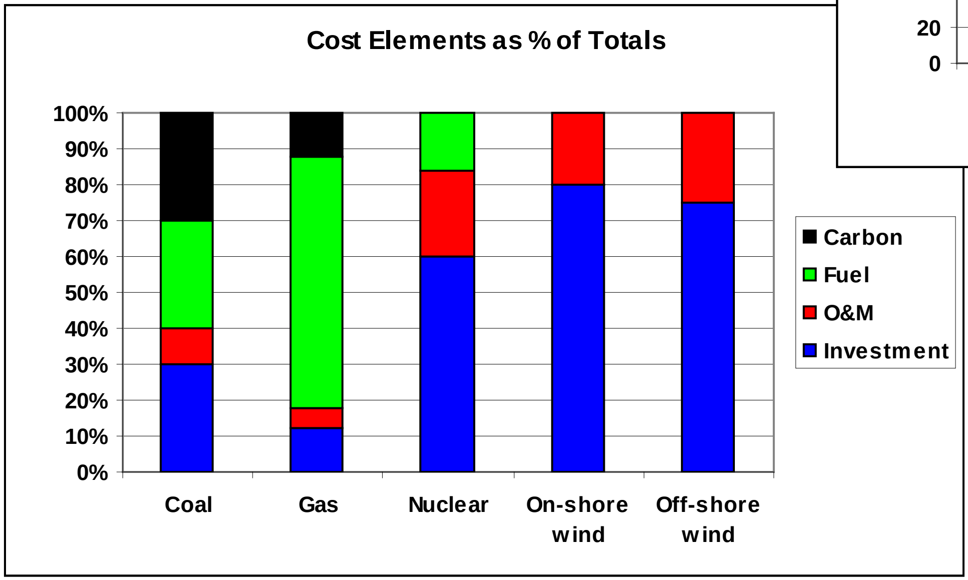
Source: European Energy Handbook

Competitive Technologies

- Cost of generating electricity varies between technologies, and is dependent on costs of differing elements and the discount rate.

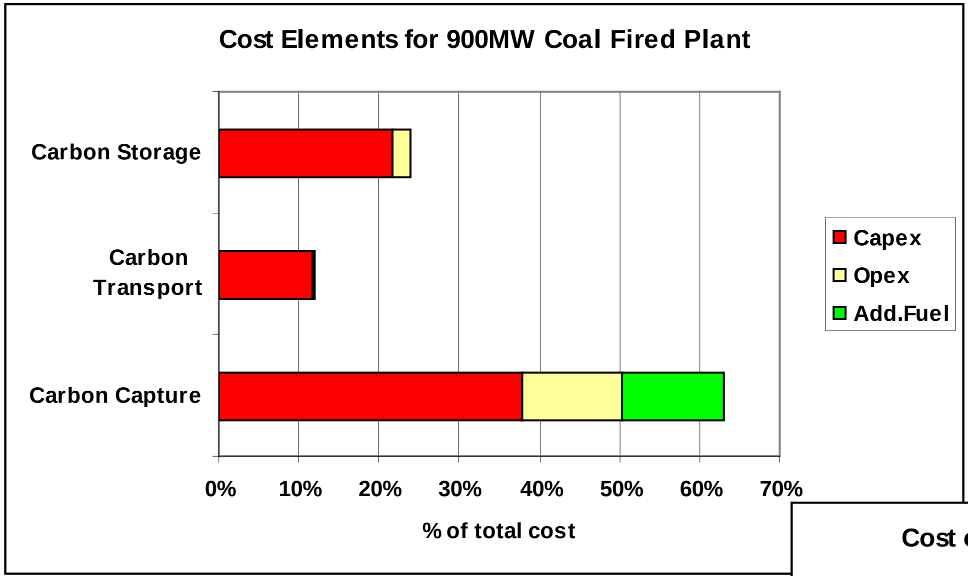


Source: Data from IEA Projected Cost of Generating Electricity 2010 Edition



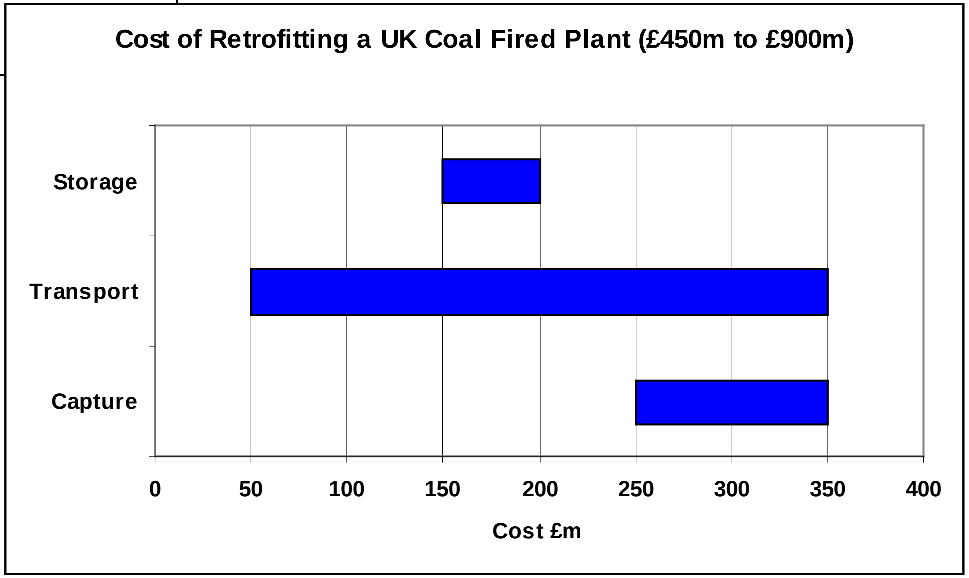
Source: Data from IEA Projected Cost of Generating Electricity 2010 Edition

CCS Costs (1)



Source: McKinsey 2008, CCS Assessing the Economics

- **CCC cost estimates vary enormously, but agree that:**
  - **Capex is the highest cost**
  - **Capture the most expensive element.**
  - **Transport costs vary depending on solution**



Source: DECC 2010, CCS business clusters in the UK

CCS Costs (2)

- **The Costs of C2 Capture, Transport and Storage, ZEP 2011**

- **Capture**
  - **There is no significant difference between three capture technologies**
  - **Levelized Cost of Electricity, €65/70/MWh (OPTI Plant).**

- **Transport**
  - **Pipeline costs are roughly proportional to distance, whilst shipping costs are stable over distance pipelines benefit from scale (volume capacity);**
  - **Shipping is more flexible, but more expensive**

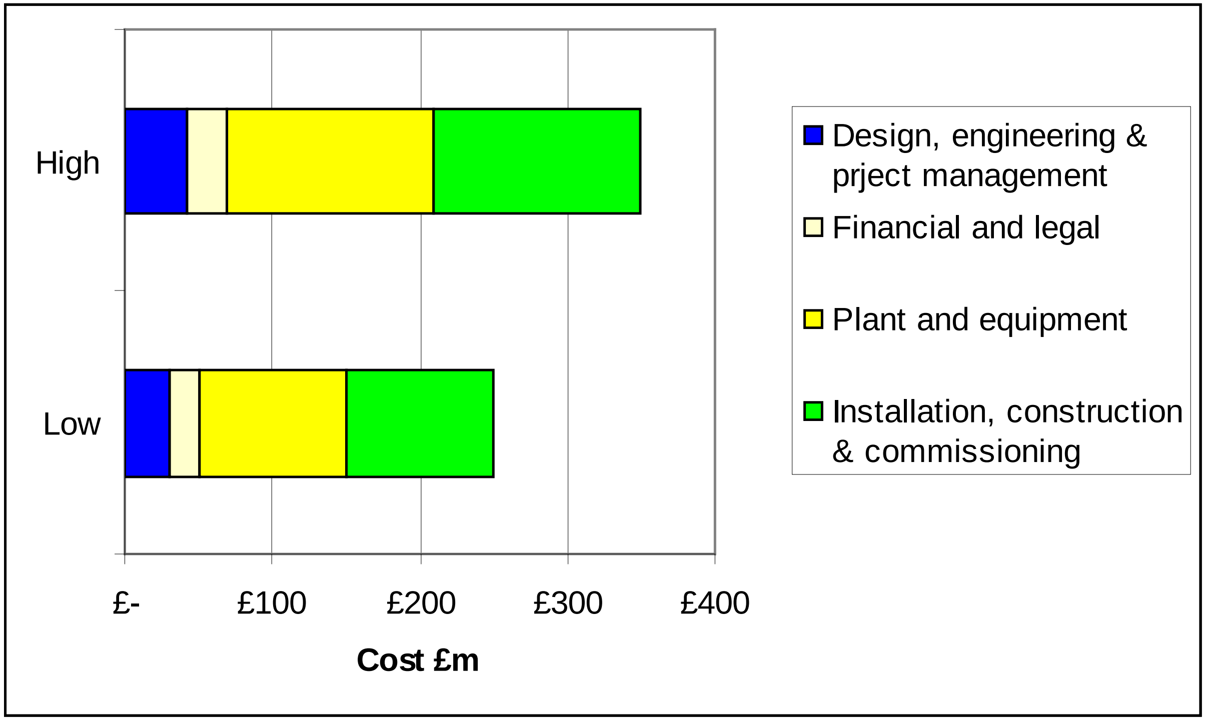
	5Mtpa 180km	**20Mtpa 180km**	**20Mtpa 500km**
On-shore pipeline	€5/tonne	€1.5/tonne	€3.7/tonne
Off-shore pipeline	€9.5/tonne	€3.5/tonne	€6/tonne
Shipping		€11/tonne	€12/tonne

- **Storage**
  - **Costs depend on whether the site is on-shore vs off-shore, Saline vs depleted oil & gas, whether existing legacy wells are available: €1 - €20/tonne**

Source: ZEP 2011, The Costs of CO2 Capture, Transport and Storage

Cost Sources

Breakdown of anticipated capital costs for capture elements of a 400MW post-combustion capture project



Source: DECC 2010, CCS business clusters in the UK

Costs will fall over time with an improving price performance resulting from:

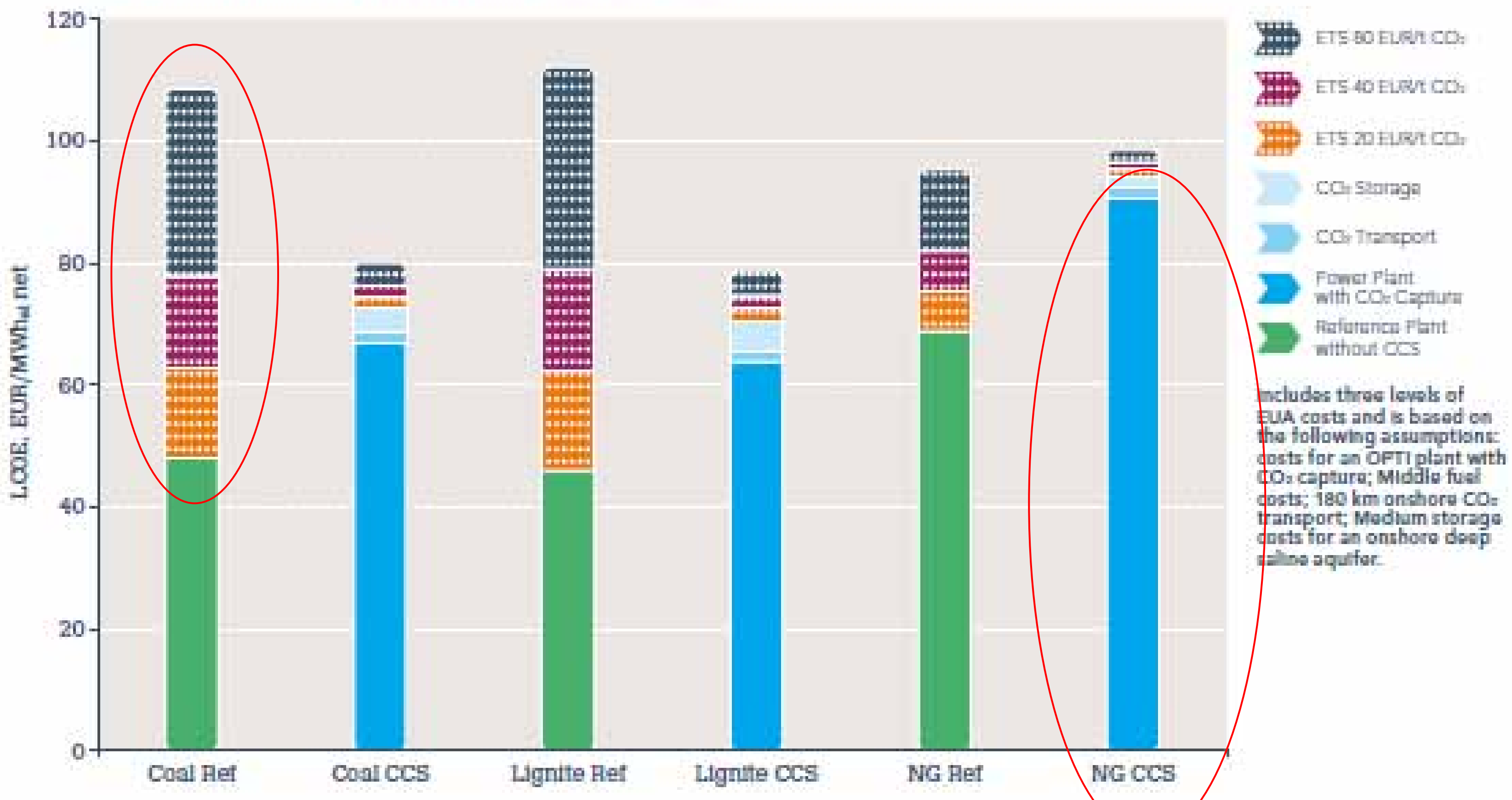
- **Learning economies**
- **Scale economies**
- **Technology innovation**

- **O&M might require on-going equivalent of 2%-3% of capital costs**

CCS Cost Comparisons

- **ZEP – competitive estimates driven by Capex and Carbon Pricing**

Figure 1: The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)

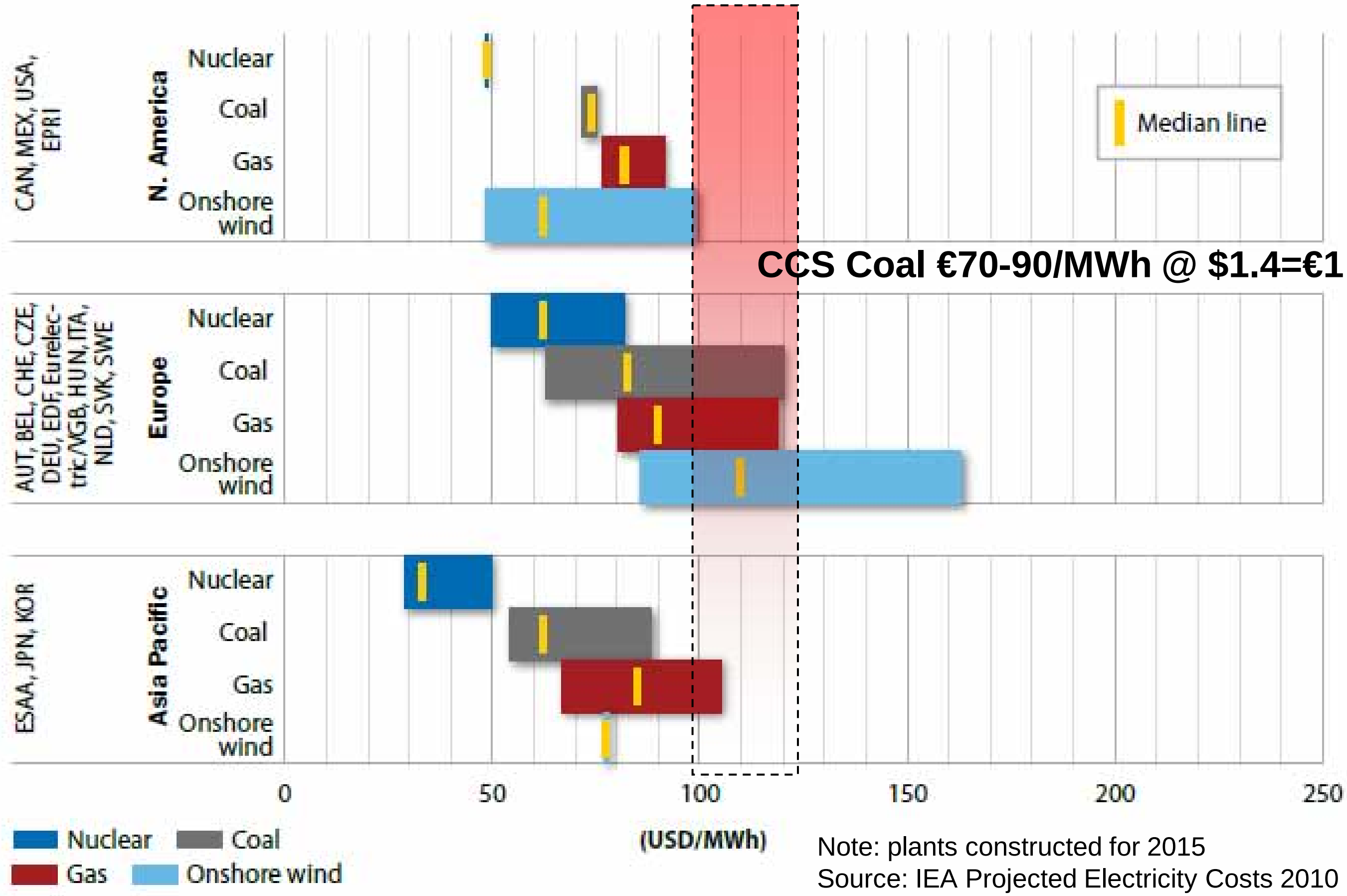


Source: The Costs of CO2 Capture, Transport and Storage ZEP 2011

CCS Comparisons

- ZEP 2011 – ‘Post 2020, CCS will be cost-competitive with other low carbon energy technologies’.

Figure ES.1: Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 5% discount rate)



Note: plants constructed for 2015
Source: IEA Projected Electricity Costs 2010

Policies to benefit CCS

- Feed-in-tariffs – available in number of Member States – focused on small scale production plus wind eg wind power (on and off shore) solar PV, Biomass and hydro.

- UK ROCS (Renewable Obligations Certificates) for renewables, could be extended to CCS ?

- Carbon taxes - European Emissions Trading scheme
  - Cover 10,000+ plus installations responsible for 40% of Europe's carbon emissions
  - Third phase starts in 2013 – further reduction in permits available
  - Reducing 1.74% per-annum to reduce emissions by 21% by 2020

Aug 2011 €11.20/tonne CO2, falling from approx €20/tonne late 2010

Summary

- The rationale for CCS is very strong – continued use of fossil fuels;
- Costs must be competitive with existing and future technologies eg nuclear, off-shore wind;
- The cost case, as well as the technology case, has yet to be proven;
- Costs are largely driven by capex, but there are also additional fuel penalties;
- Assumptions are that 2015 will see the first demonstrators, 2020 early commercial units and 2030 mature units;
- CCS can be competitive with existing fossil fuel technologies, subject to carbon pricing in the 2020s'

Discussion