

**Westminster Energy Forum
Carbon Markets & Climate Impacts Seminar
6th December 2006
Herbert Smith, Exchange House,
Primrose Street, London EC2A 2HS**

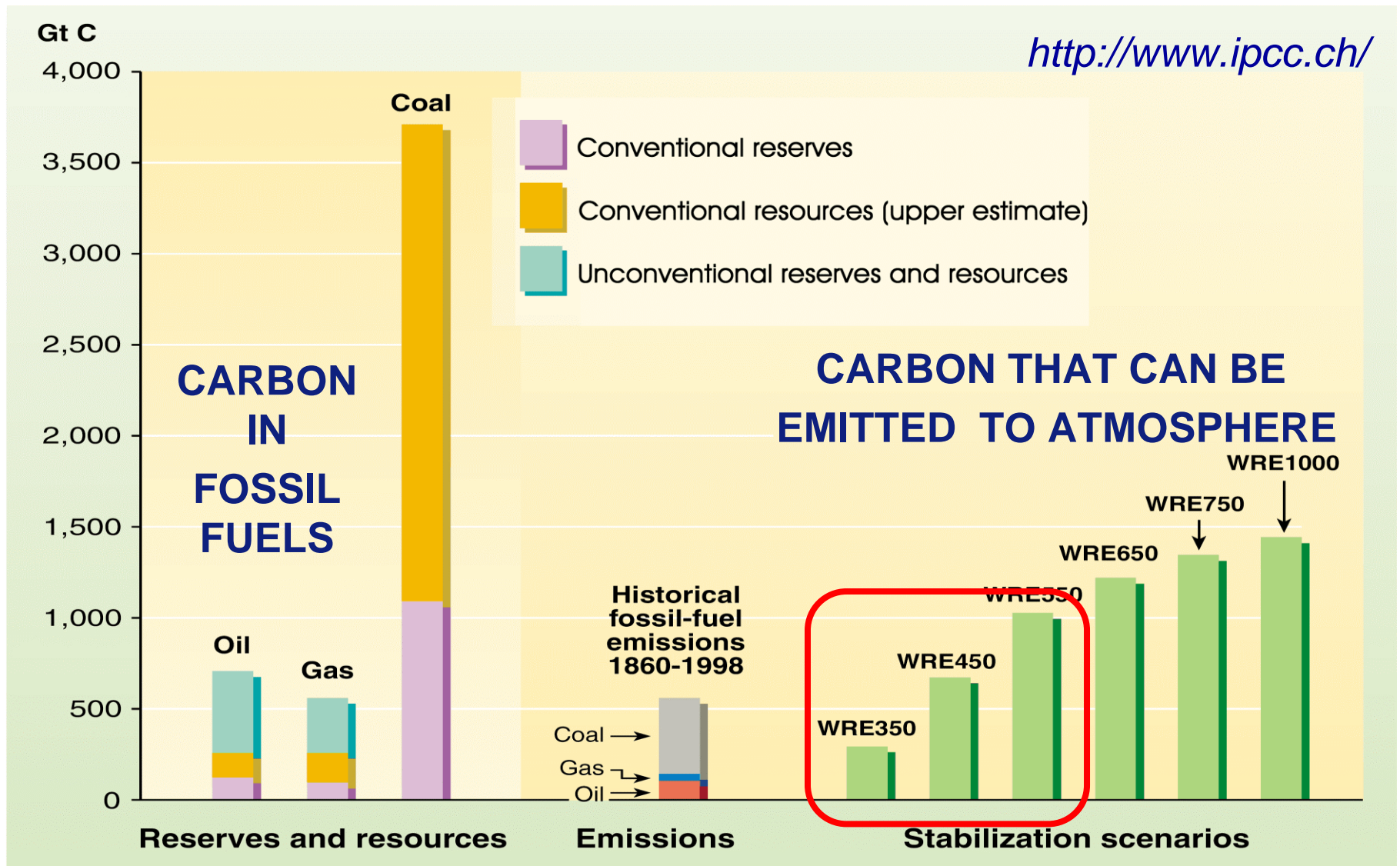
**Key Strategic Issues
in the
Deployment of Carbon Capture and Storage**

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CRITICAL ROLE FOR CARBON CAPTURE & STORAGE?

<http://www.ipcc.ch/>



‘Unconventional oil’ includes oil sands and oil shales but not CTL. ‘Unconventional gas’ includes coal bed methane, deep geopressured gas etc. but not gas from coal and a possible 12,000 GtC from gas hydrates. (www.ipcc.ch/pub/un/syrenq/q1to9.pdf)

Ocean Acidification

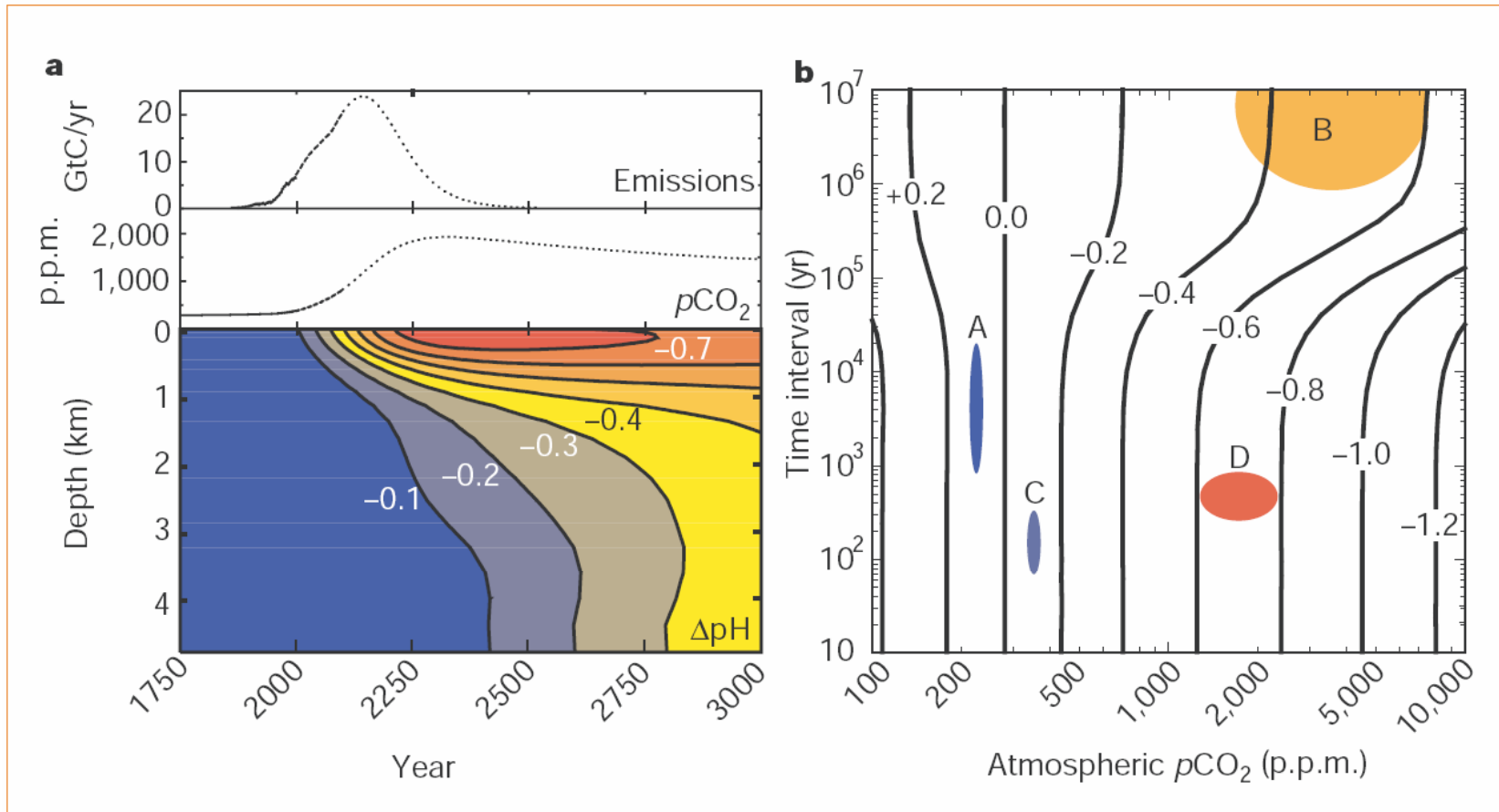
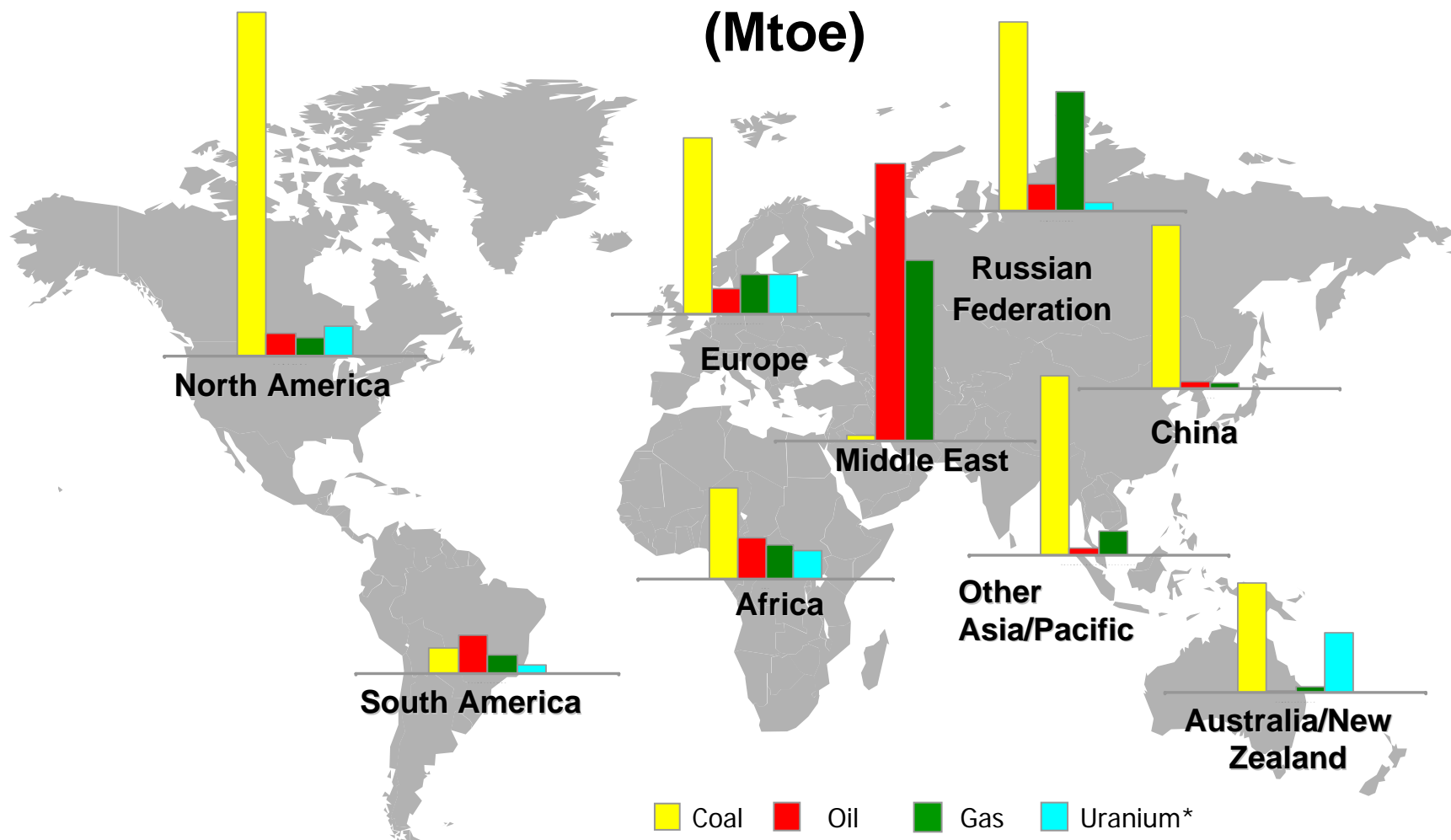


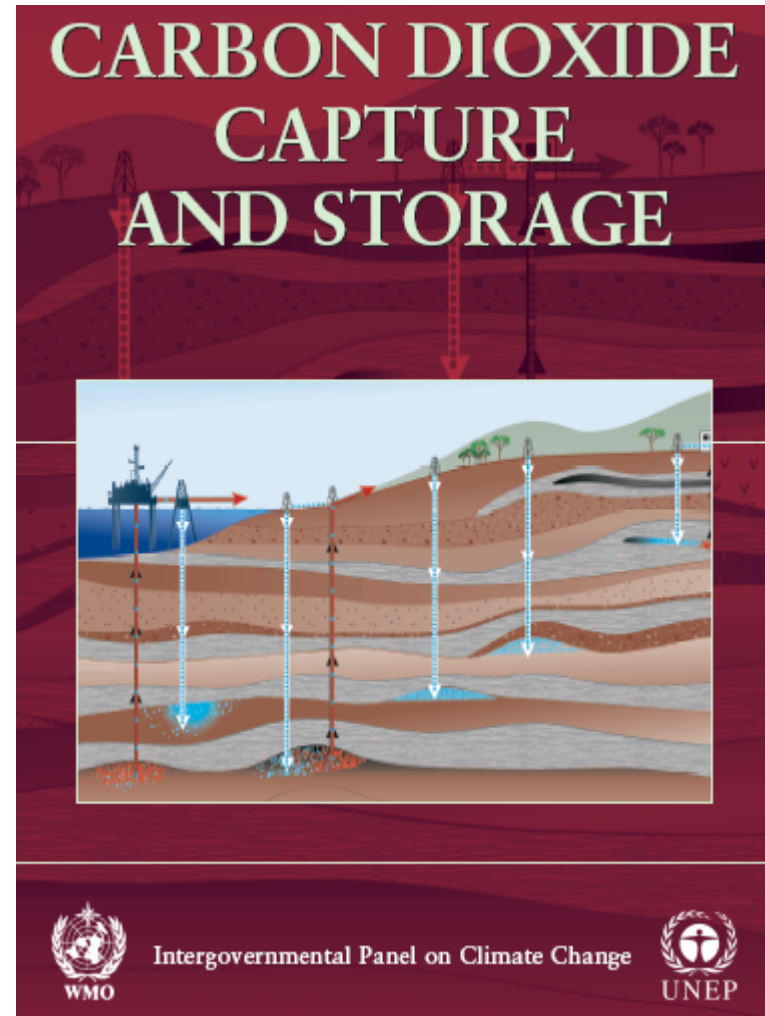
Figure 1 Atmospheric release of CO₂ from the burning of fossil fuels may give rise to a marked increase in ocean acidity. **a**, Atmospheric CO₂ emissions, historical atmospheric CO₂ levels and predicted CO₂ concentrations from this emissions scenario, together with changes in ocean pH based on horizontally averaged chemistry. **b**, Estimated maximum change in surface ocean pH as a function of final atmospheric CO₂ pressure, and the transition time over which this CO₂ pressure is linearly approached from 280 p.p.m. A, glacial–interglacial CO₂ changes¹³; B, slow changes over the past 300 Myr; C, historical changes¹ in ocean surface waters; D, unabated fossil-fuel burning over the next few centuries.

World Energy Reserves 2004 (Mtoe)



Sources: BP Statistical Review 2005; WEC Survey of Energy Resources 2001; Reasonably Assured Sources plus inferred resources to US\$80/kg U 1/1/03 from OECD NEA & IAEA Uranium 2003; Resources, Production & Demand updated 2005; *energy equivalence of uranium assumed to be ~20,000 times that of coal

www.ipcc.ch



Reservoir type	Lower estimate of storage capacity (GtCO ₂)		Upper estimate of storage capacity (GtCO ₂)	
Oil and gas fields	675 ^a	185 GtC	900 ^a	245 GtC
Unminable coal seams	3-15	<4 GtC	200	55 GtC
Deep saline formations	1,000	270 GtC	Uncertain, but possibly 10 ⁴ 2700 GtC	

Figure 7.14: Global Savings in CO₂ Emissions in the Alternative Policy Scenario Compared with the Reference Scenario

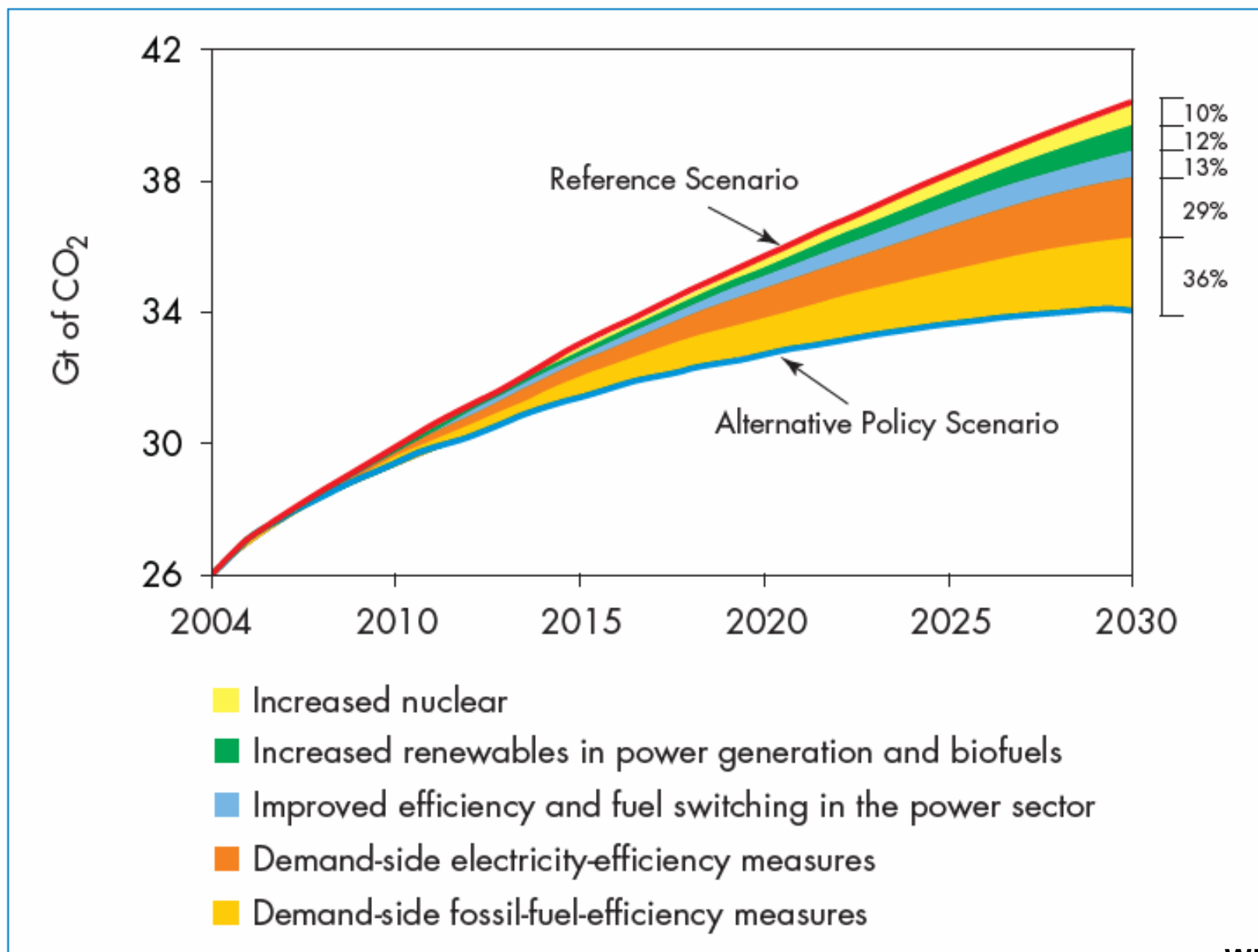


Figure 10.2: Reduction in Energy-Related CO₂ Emissions in the BAPS Case Compared with the Alternative Policy Scenario by Option

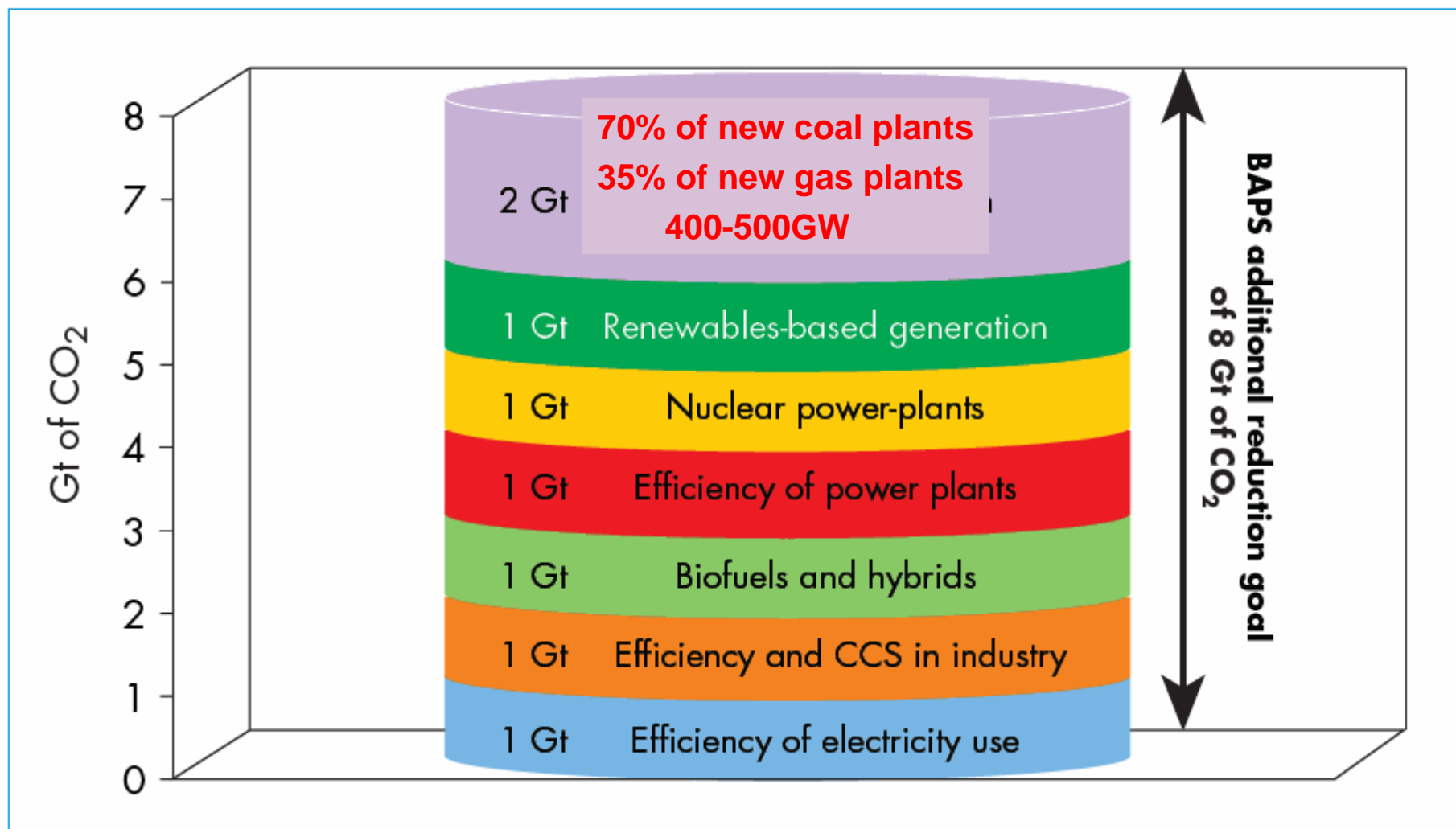


Figure 10.3: Fuel Mix in Power Generation in Different Scenarios

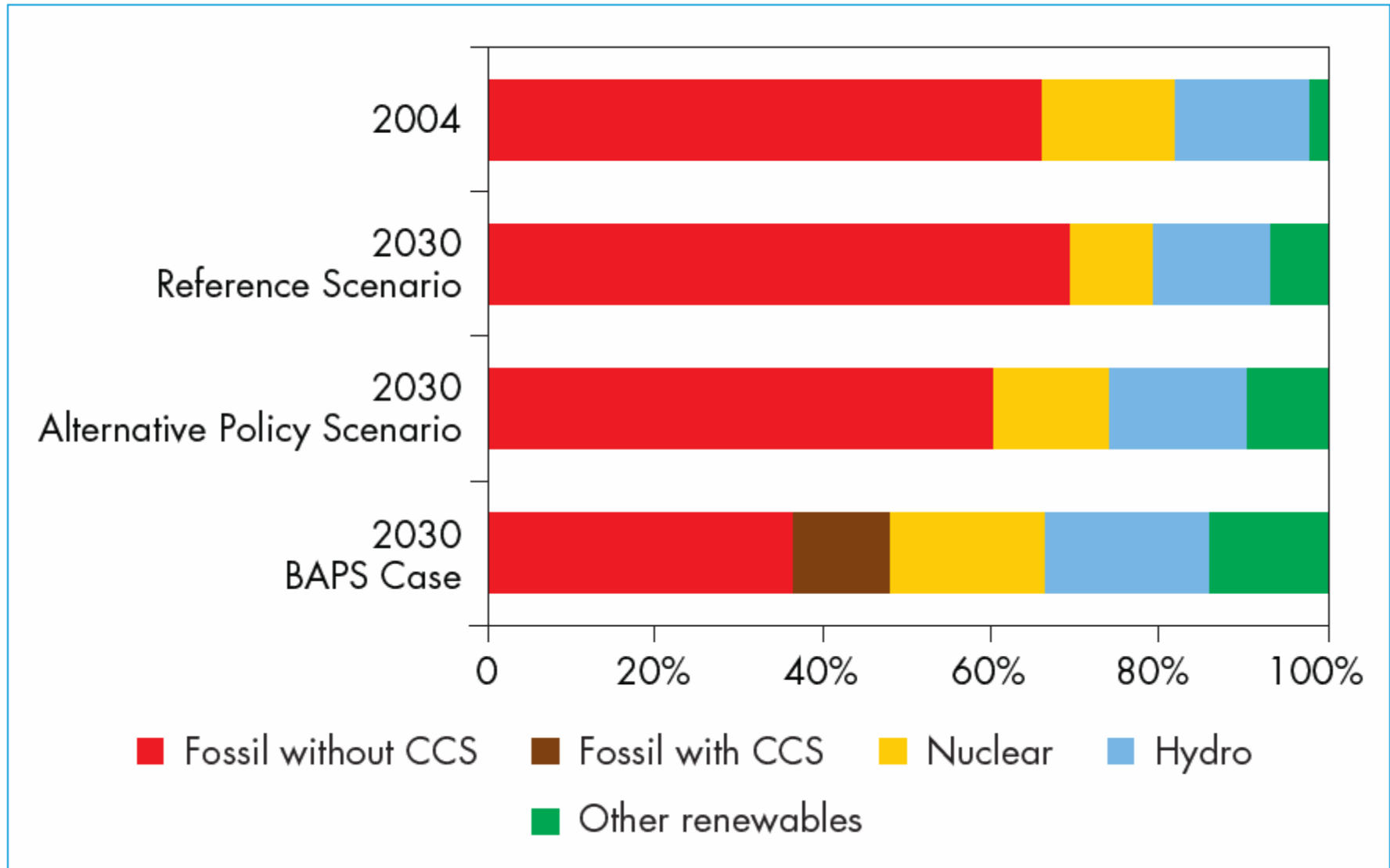
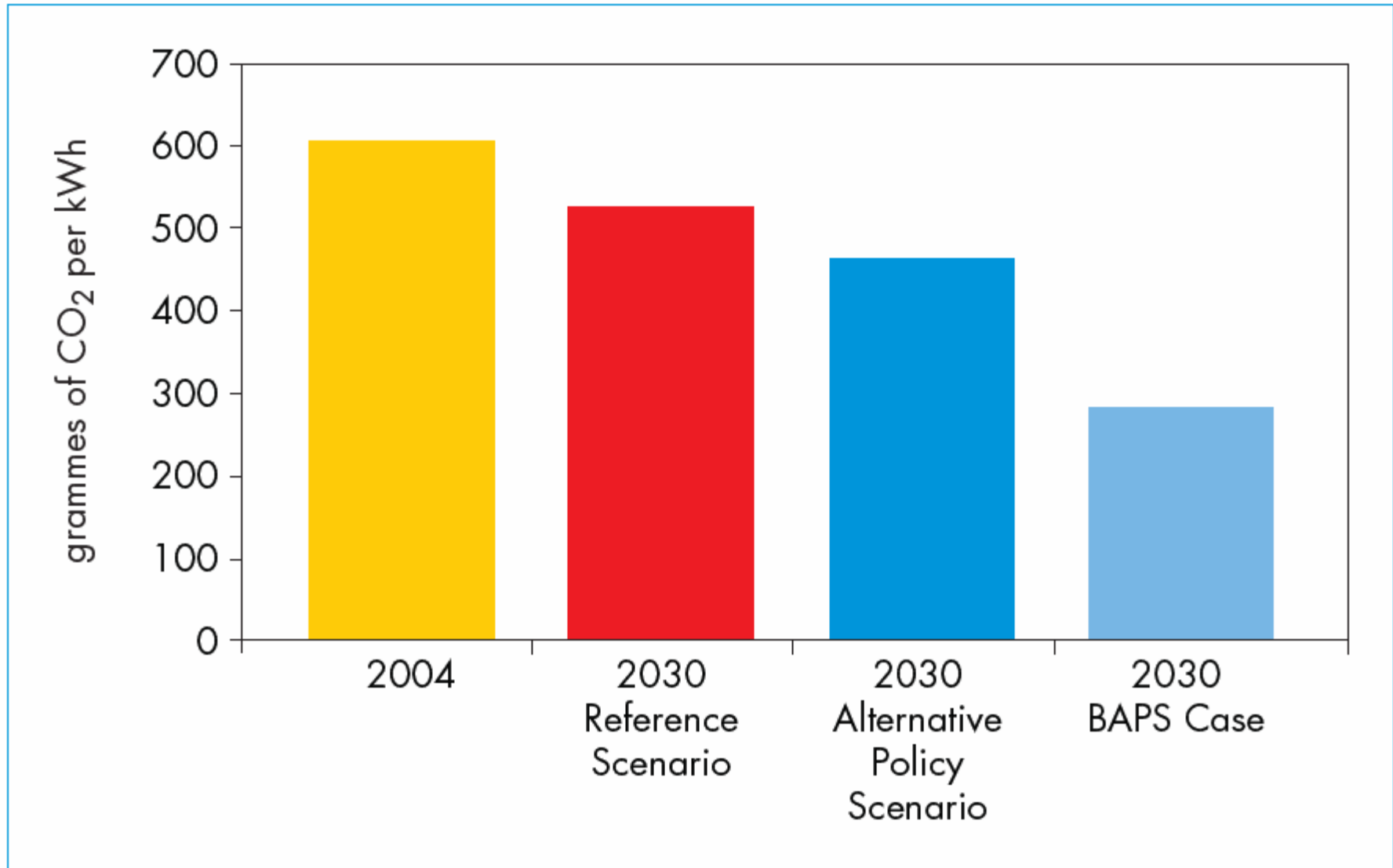
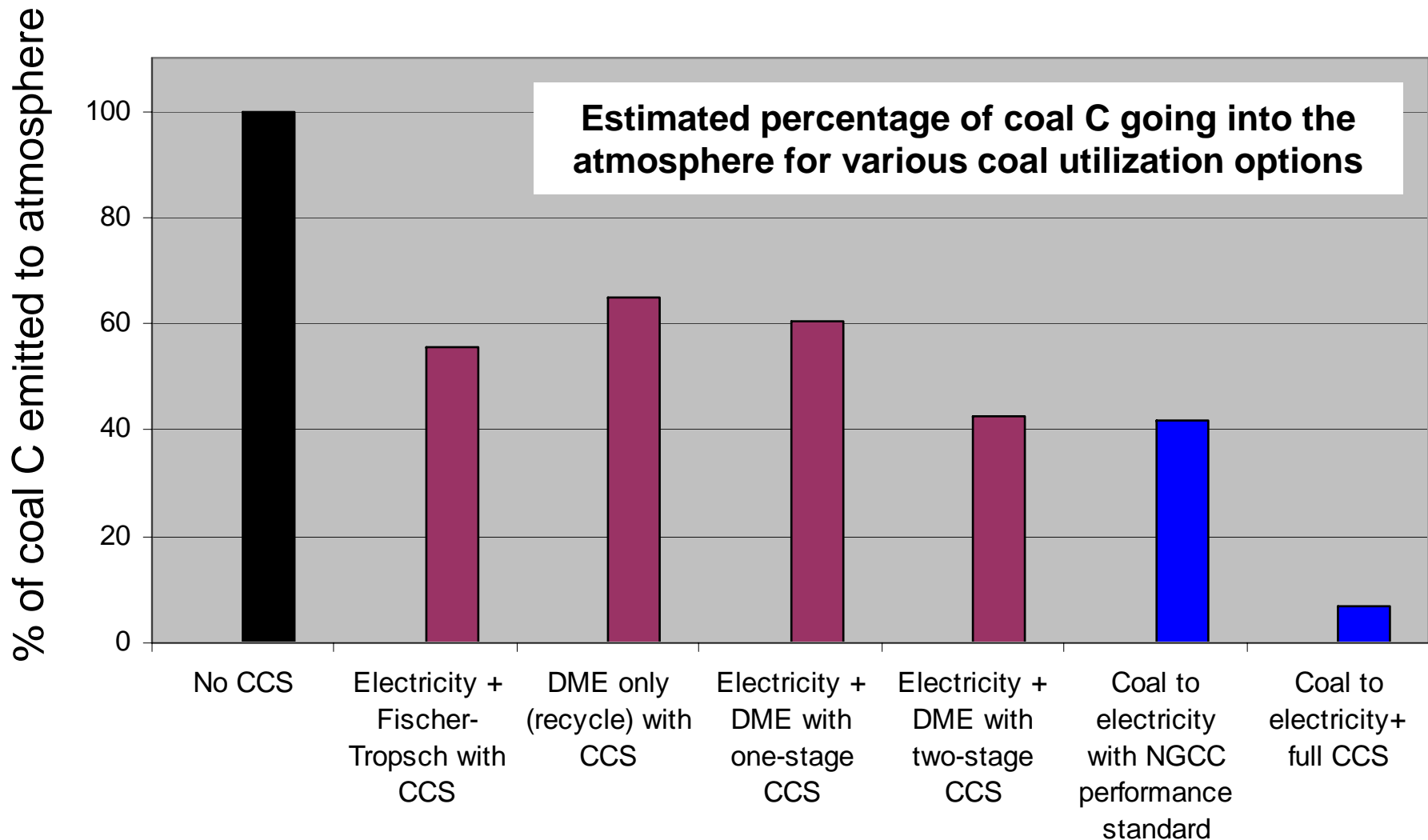


Figure 10.4: CO₂ Intensity of Electricity Generation

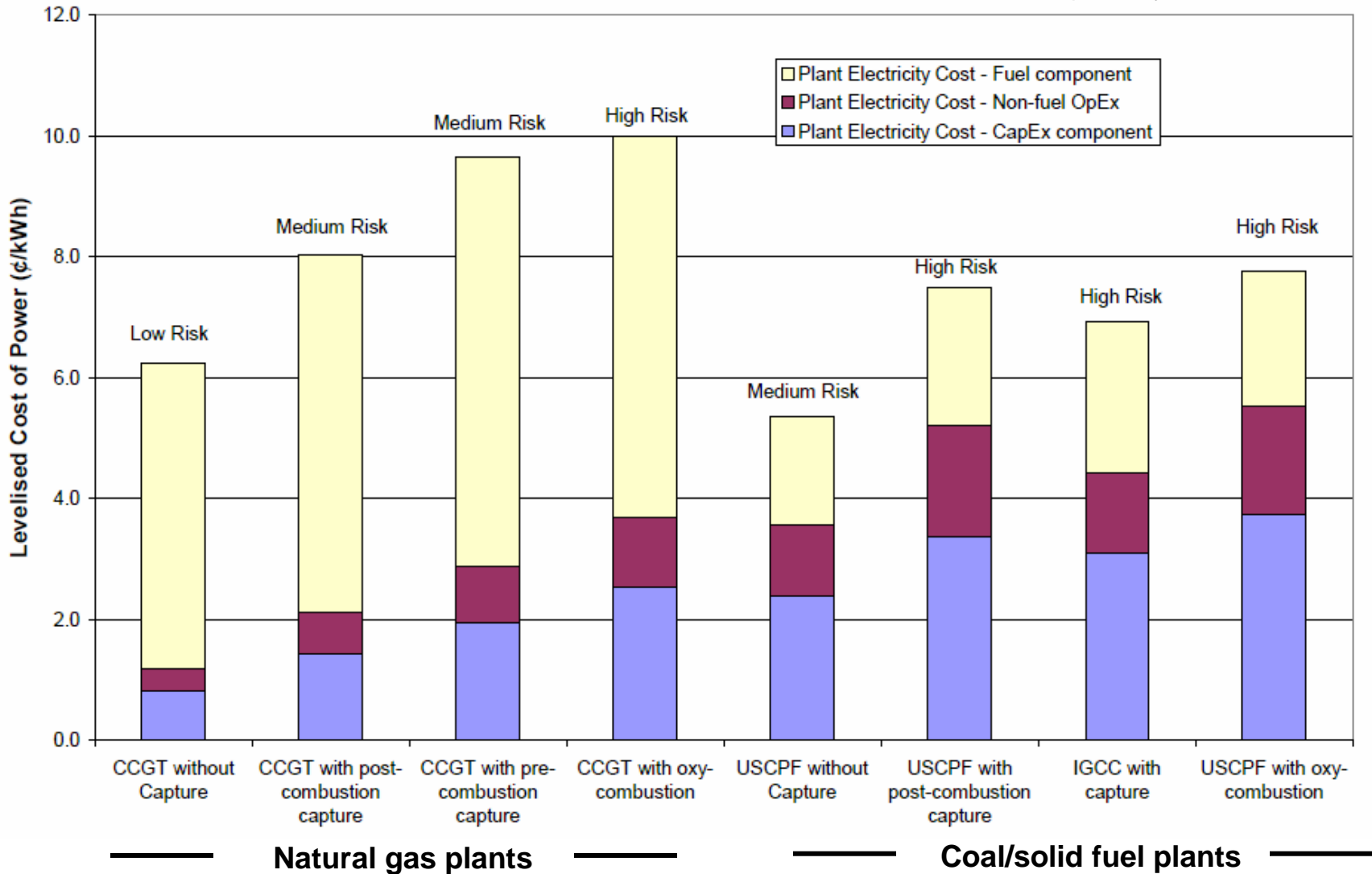


ALSO POSSIBLE FROM COAL-TO-LIQUIDS AND OTHER UNCONVENTIONAL FUELS BUT NOT ALL CCS HAS EQUAL ENVIRONMENTAL BENEFIT

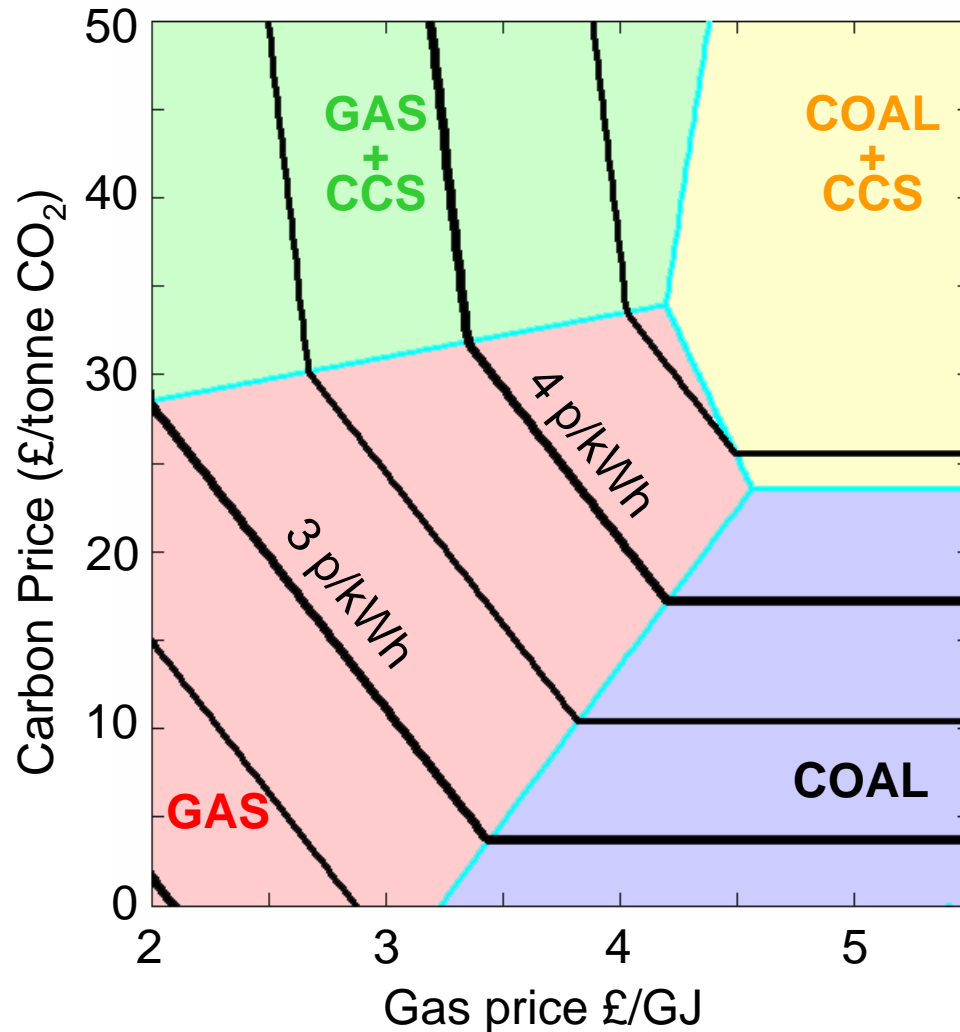


Costs of Capture

Costs include compression to 110 bar but not storage and transport costs.
 These are very site-specific, but indicative aquifer storage costs of \$10/tonne CO₂ would increase electricity costs for natural gas plants by about 0.4 c/kWh and for coal plants by about 0.8 c/kWh.



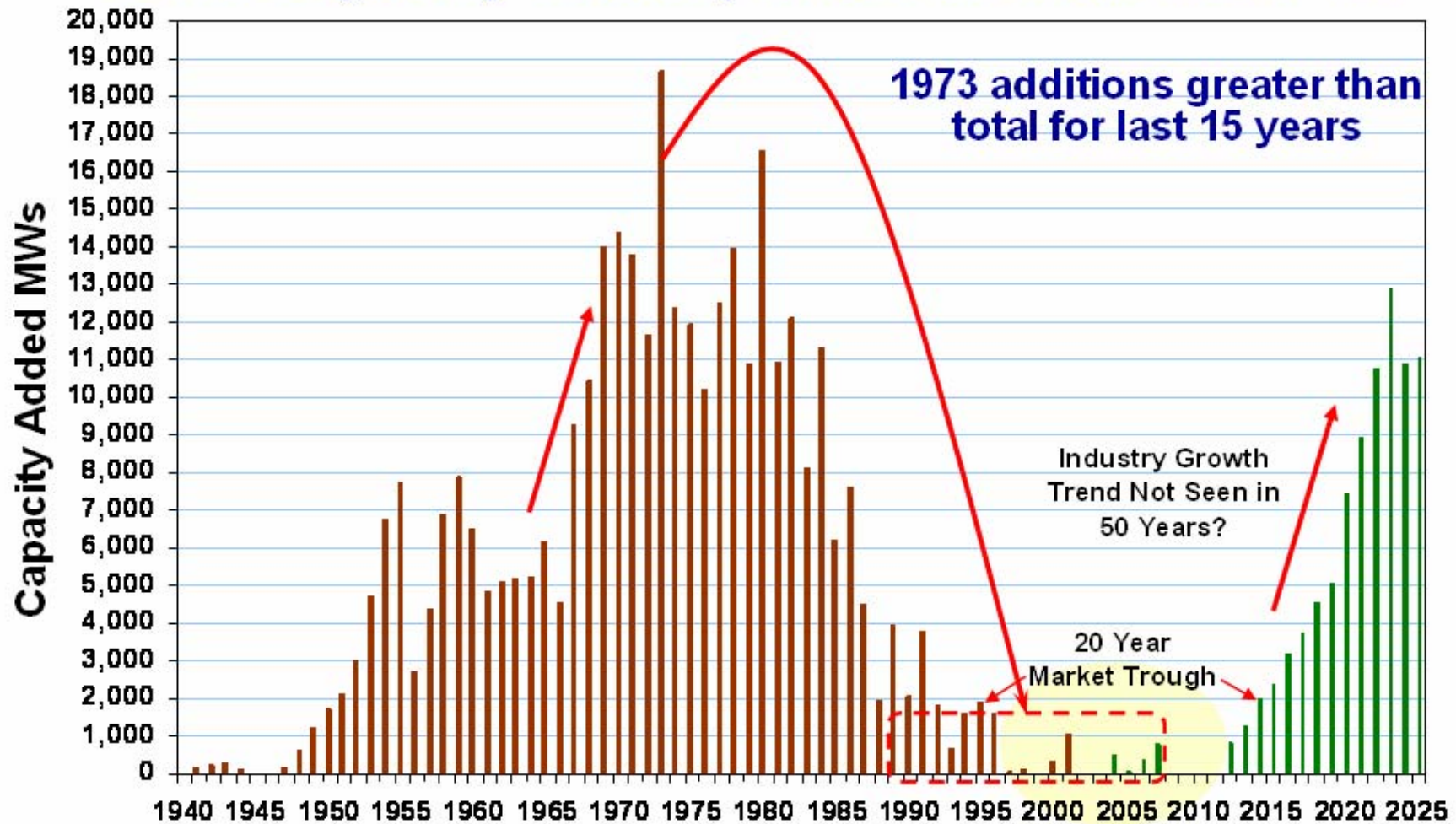
CCS Uncertainty - Fuel and Carbon Prices Matter



- Discount rate of 10%
- Investment lifetime of 25 years
- 8000 hours operation per year
- Coal price, £1.4/GJ (net)
- CO₂ delivery pressure of 110 bar (and pipeline quality)
- Indicative cost of transport to offshore aquifer storage, £5.50 per tonne CO₂ stored

From Gibbins, J. et al. (2006) Interim Results from the UK Carbon Capture and Storage Consortium Project Proc. 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, 19th-23rd June 2006. www.ghgt8.no. Also quoted in Stern Review

Coal Capacity History and Forecast AEO'05



*Will the Nation's Industry be Prepared and Capable
of Meeting This Coal Plant Forecast?*



**ACTUAL
IMPLEMENTATION
PLANS**

CCS Implementation Proposals – UK

- Proposed full-scale (~300 MWe and above) CCS projects
- Based on media reports, press releases and personal communication so indicative only!

Company/ Project Name	Fuel	Plant output/cost	Capture technology	Start
Progressive Energy/Centrica, Teeside, UK	Coal (petcoke)	800 MW (+ H2 to grid) (\$1.5bn)	IGCC + shift + precombustion	2009
BP/SSE DF1, Peterhead/Miller, Scotland	Natural gas	475 MW, (>\$600M)	Autothermal reformer + precombustion	2010
Powerfuel/ Kuzbassrazrezugol Hatfield Colliery, UK	Coal	~900 MW	IGCC + shift + precombustion	2010
Conoco-Phillips, Immingham, UK	Coal (+petcoke?)	450 MW (or more, with retrofit)	IGCC+CCS addition to planned NGCC CHP plant	2010 (for CHP)
E.ON, Killingholme, Lincolnshire coast, UK	Coal (+petcoke?)	450 MW (£1bn)	IGCC + shift + precombustion? (may be capture ready)	2011
RWE, Tilbury, UK	Coal	~500 MW (£800m)	PC (supercritical retrofit) + post-combustion (may be capture ready)	2016

- Plus capture-ready plants at Ferrybridge (SSE) and Kingsnorth (E.On)

CCS Implementation Proposals – World (not UK)

- Proposed full-scale (~300 MWe and above) CCS projects
- Based on media reports, press releases and personal communication so indicative only!

Company/ Project Name	Fuel	Plant output/cost	Capture technology	Start
Statoil/Dong, Mongstad, Norway	Natural gas	280 MW	NGCC+ Post-combustion amine 100,000 tCO ₂ /yr from 2010, 1.3Mt CO ₂ from 2014, CO ₂ for EOR (Gulfaks and others)	2010
BP DF2, Carson, USA	Petcoke	500 MW, (\$1bn)	IGCC + shift + precombustion, CO ₂ for EOR	2011
Statoil/Shell, Tjeldbergodden, Norway	Natural gas	860 MW	NGCC+ Post-combustion amine, CO ₂ for EOR (Draugen)	2011
SaskPower, Saskatchewan, Canada	Lignite coal	300 MW	PC oxyfuel	2011
Stanwell, Queensland, Australia	Coal	275 MW	IGCC + shift + precombustion	2012
Futuregen, USA	Coal	275 MW	IGCC + shift + precombustion	2012
Xcel Colorado, USA.	Coal (sub.bit)	300-350MW	IGCC, may be partial capture only	2013
RWE, Germany Germany	Coal	450 MW (€1bn)	IGCC + shift + precombustion	2014

<http://biz.yahoo.com/prnews/061106/nym208.html?>

**See Imperial BCURA Project B70
& new IEA GHG report coming soon**

TXU Corp. Outlines Vision to Displace Older Power Generation with Advanced Technologies

Monday November 6, 8:30 am ET

Progress on Texas Projects; Expansion of Plans Outside of Texas; Update of Financial Outlook; Board Declaration of Increased Dividend, Authorization of Share Repurchases

- TXU's power generation strategy has progressed substantially, and now includes line of sight on the development of 16 to 23 gigawatts (GW) of new capacity, including new opportunities outside of Texas.

-TXU has engineered its reference plant design to be the most advanced supercritical coal technology of any plant under construction in the U.S. today and to meet carbon capture and storage ready criteria.

Table 1: TXU reference plants - carbon capture ready design

Criteria	TXU Design
Sufficient space in critical access locations	Allows space in ductwork to provide ample access for the addition of a future system. Space is also available for placement of that system near the chimney.
Options for CO2 storage	Provides options for CO2 storage including enhanced oil recovery (EOR) and deep saline aquifer deposition.
Design study	Includes unit specific design studies on a schedule to support the company's long-range planning process.
Pre-investments including plant siting	Reference plants are located on existing TXU sites, which offer advantages for capture including access to EOR sites.

Legal and Regulatory Issues

- HMG has a regulatory task force which is reviewing current regulations, gaps and required changes
 - Offshore Licensing
 - Decommissioning and long term liability
 - Licensing onshore installations
 - Licensing onshore storage
- Making progress with international conventions on the marine environment (London/OSPAR)
- CCS within EUETS and CDM?

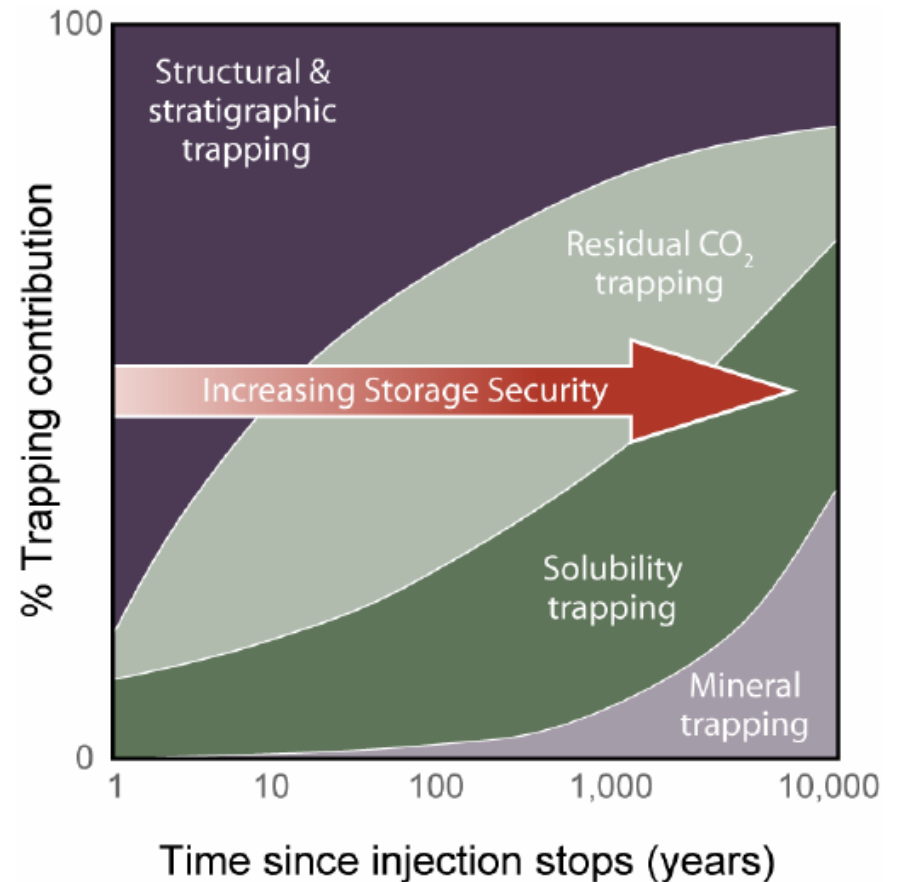


Figure from IPCC (2005)

GETTING TO GENERATION 3 ON CCS

- **Learning requires time to observe results of earlier plants and feed experience into later designs**
- **Build times 3-5 years plus couple of years to shake down**
- **Real experience from maybe 10 or so first-of-type plants maximum by 2013/2014?**
- **2nd generation plants that will come on line by 2016-2019, shakedown by 2018-2020**
- **New build planned after 2020 could be 3rd generation**

IF FIRST CCS PLANTS ARE BUILT SOON

- **Building continues using experience gained during design**
- **10 first generation plant teams would each build 2-4 further plants over the next 8 years to 2020. Say $10 + 30 = 40$ plants.**
- **30 more teams for 2nd generation? Say 60 plants before 2020**
- **Perhaps 50-100 GW of new build with CCS by 2020 without forcing building rates beyond feedback learning**
- **BAPS target of 400-500 GW by 2030?**
- **Need retrofit to be able to catch up – capture-ready**

POLICY BACKGROUND



THE GLENEAGLES COMMUNIQUÉ

14. We will work to accelerate the development and commercialization of Carbon Capture and Storage technology by:

(a) endorsing the objectives and activities of the Carbon Sequestration Leadership Forum (CSLF), and encouraging the Forum to work with broader civil society and to address the barriers to the public acceptability of CCS technology;

(b) inviting the IEA to work with the CSLF to hold a workshop on short-term opportunities for CCS in the fossil fuel sector, including from Enhanced Oil Recovery and CO₂ removal from natural gas production;

(c) inviting the IEA to work with the CSLF to study definitions, costs, and scope for 'capture ready' plant and consider economic incentives; (E.ON, Mitsui Babcock, Imperial IEA GHG project)

(d) collaborating with key developing countries to research options for geological CO₂ storage; and

(e) working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.

CCS in Stern Review – Role of CCS

- “There is still time to avoid the worst impacts of climate change, if we take strong action now.”
- “Carbon capture and storage is essential to maintain the role of coal in providing secure and reliable energy for many economies.”
- “[CCS] is a technology expected to deliver a significant portion of the emission reductions. The forecast growth in emissions from coal, especially in China and India, means CCS technology has particular importance.”

CONCLUSIONS

- **CCS offers unique solution for fossil carbon**
- **Geological storage capacity probably comparable to fossil C (but need to assess this resource)**
- **Political support growing**
- **Industry ready to go**
- **But need to get funding and regulation established – lagging behind**
- **Make any new plants capture-ready (urgent - UK & US will help with India and China)**
- **Build some full-scale plants with capture for learning by doing**
- **Train some young people – key university role**

Acknowledgements

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- The opinions and interpretations expressed are, however, entirely the responsibility of the author.

Further Information

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