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The Strategic Significance and Practicalities of CO2 EOR and Storage

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Carbon Storage Specialist

Melbourne, Australia, September 2009

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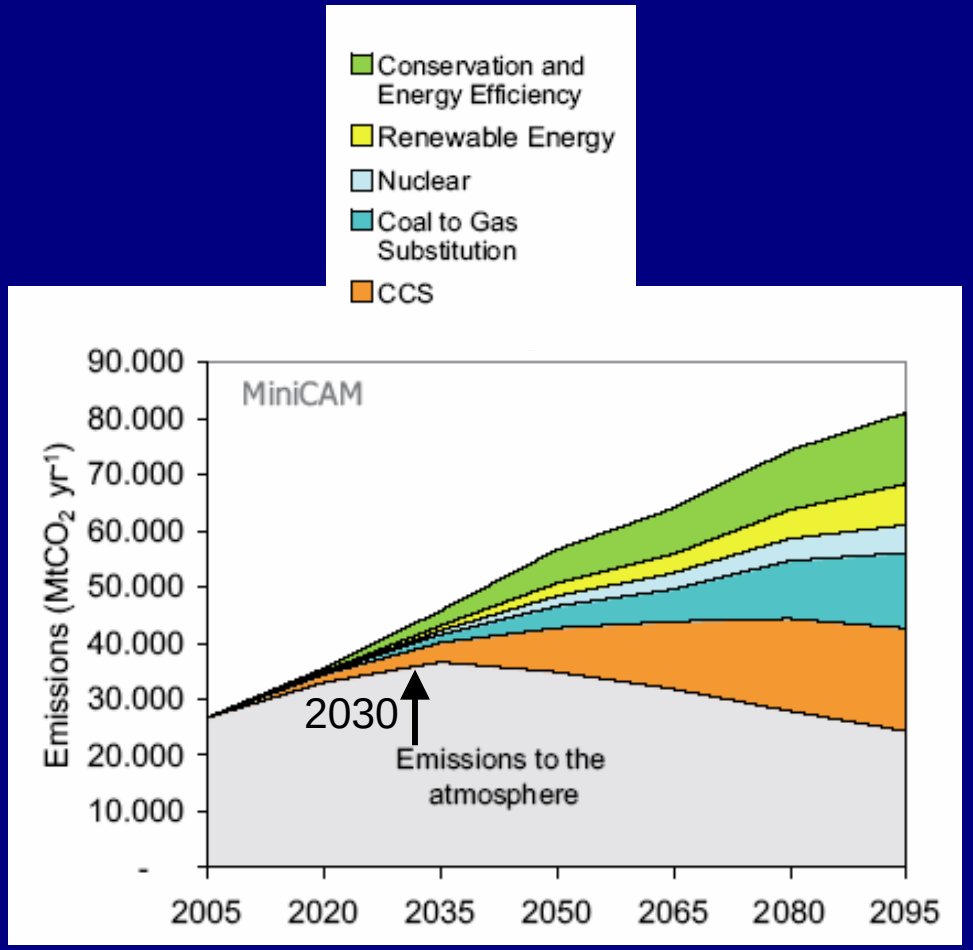
Geological Storage of CO2

- New business stream for oil industry
- Store liquid CO2 in depleted oil and gas fields and also saline aquifers
- Synergies with existing operations through reuse of infrastructure etc. and possibility of increasing hydrocarbon recovery
- Contributes to the fight on global warming
- Has value through Cap and Trade arrangements such as the EU emissions trading scheme
- But comes with regulations and liabilities
- Uses all our skills

IPCC Prediction of Requirement for Carbon Capture and Storage (CCS)

- From ~2030 amount of CO2 that requires to be stored is ~4 billion tonnes/year, rising to ~18 billion tonnes/year in 2095
- c.f.3.9 billion tonnes/year oil production and 2.5 billion tonnes oil equivalent/year gas production in 2005

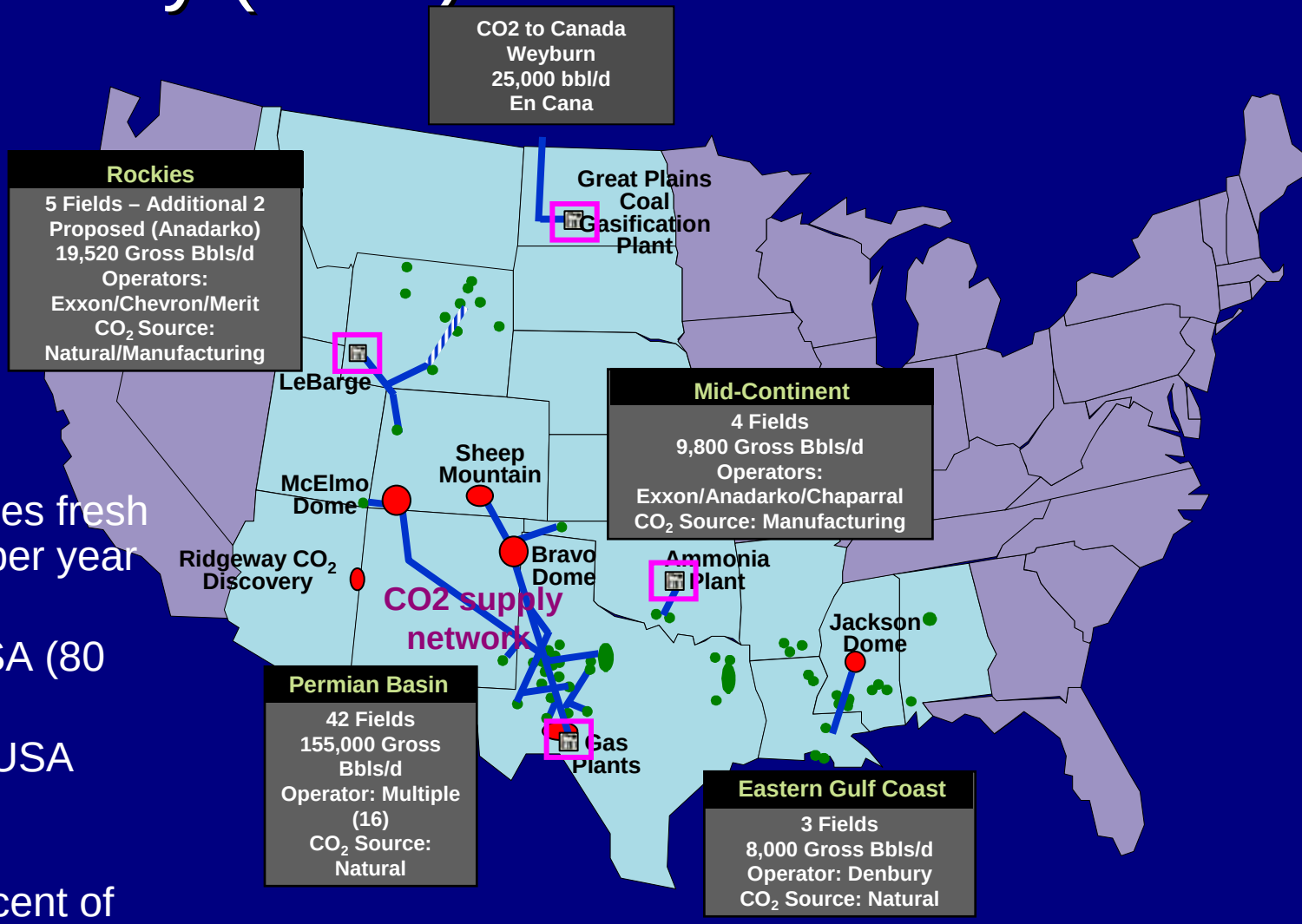


From IPCC Special Report on Carbon Dioxide Capture and Storage 2005 and BP Statistical Review, 2006

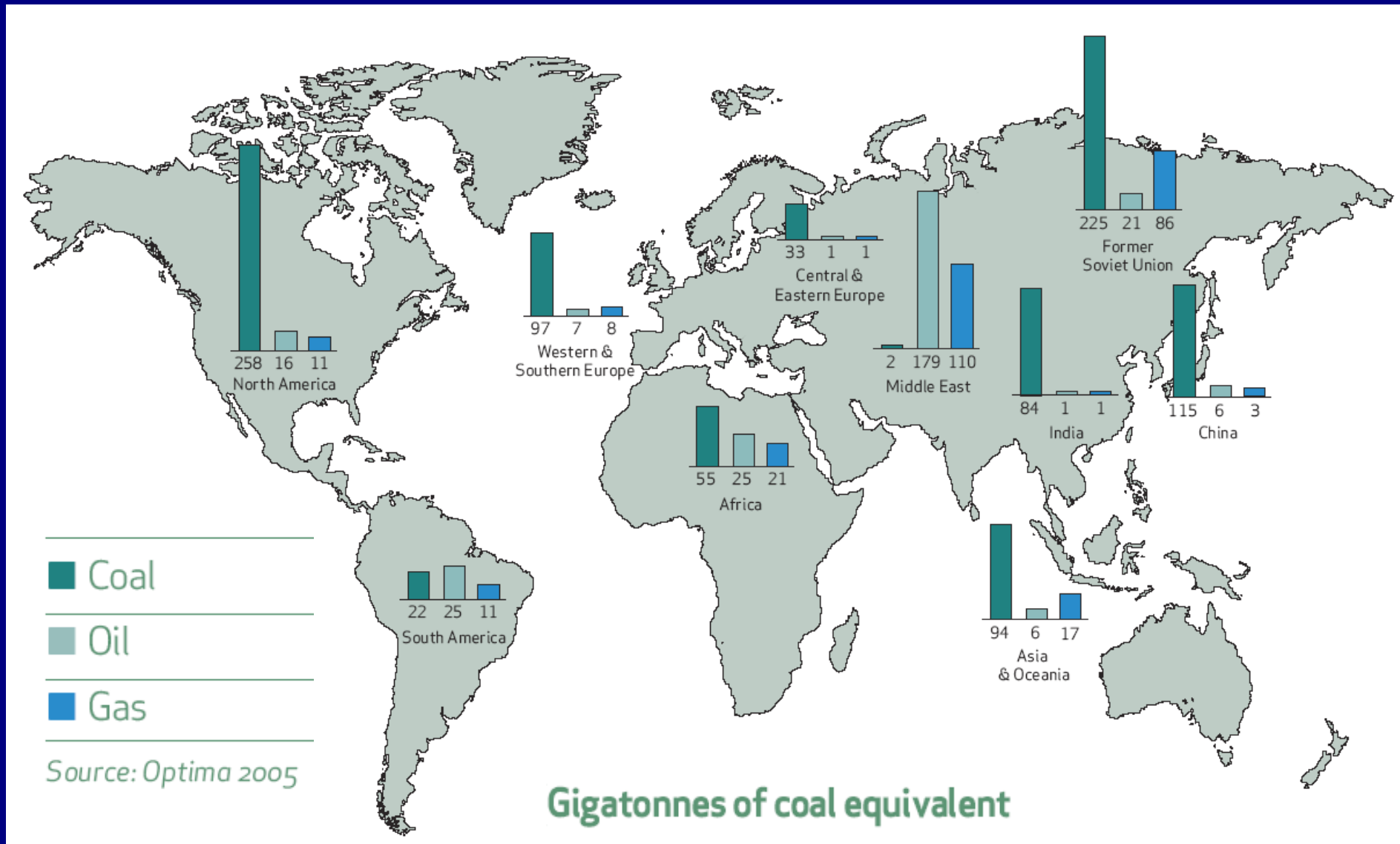
CO2 Flooding is a Major Enhanced Oil Recovery (EOR) Process in USA

2006 statistics

- 45 million tonnes fresh CO2 injected per year (USA)
- 53 projects USA (80 worldwide)
- ~180,000 b/d USA (~260,000 b/d worldwide)
- 1/3 of one percent of world production



World Coal Resources



UK Commitment to Reduction in CO2 Emissions

- Under Kyoto Protocol, UK committed to reducing greenhouse gas emissions by 12.5% from their 1990 levels by 2012 – met already: 20% 2008 (or 23% with purchases under EU ETS)*
- UK implemented legal requirement for 80% reduction in 1990 CO2 emissions by 2050, with intermediate target of at least 26% (aiming for 34%) by 2020 - progress so far: 10% 2008 (or 14% with purchases under EU ETS)*
- Capture of CO2 emitted from fossil fuelled power plants seen as one means of reducing emissions, with geological CO2 storage in depleted oil and gas fields, and saline aquifers

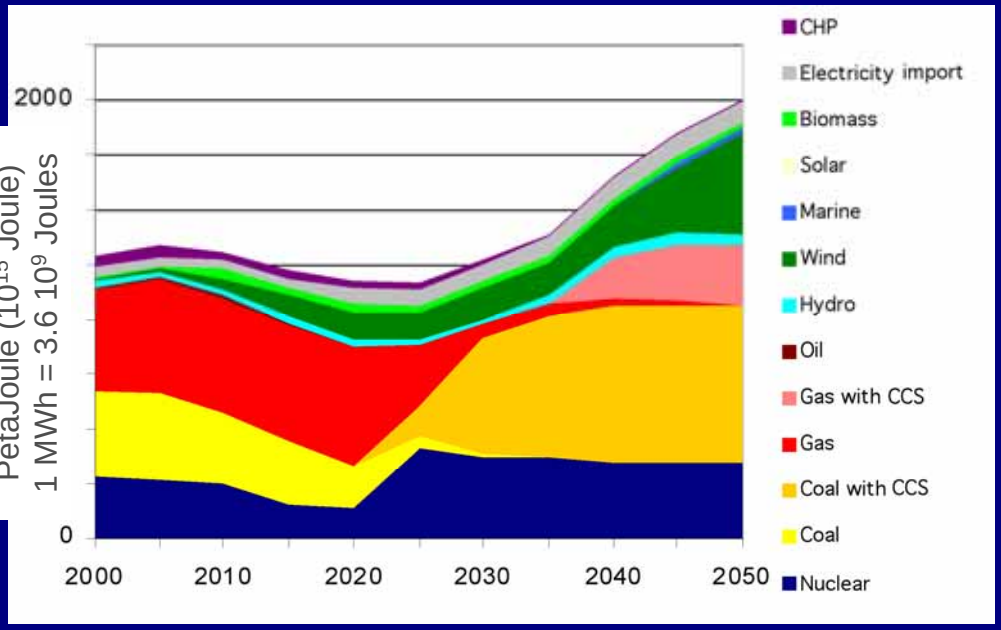
*DECC, 9 February and 26 March 2009

Contribution to UK CO2 Emissions From Power Sector

- UK CO2 emissions 2006 561 million tonnes
- About 1/3 from fossil fuelled power stations
- 23 million tonnes at Drax in North Yorkshire
- 10 million tonnes at Longannet

Decarbonisation of UK Fossil Electricity Supply

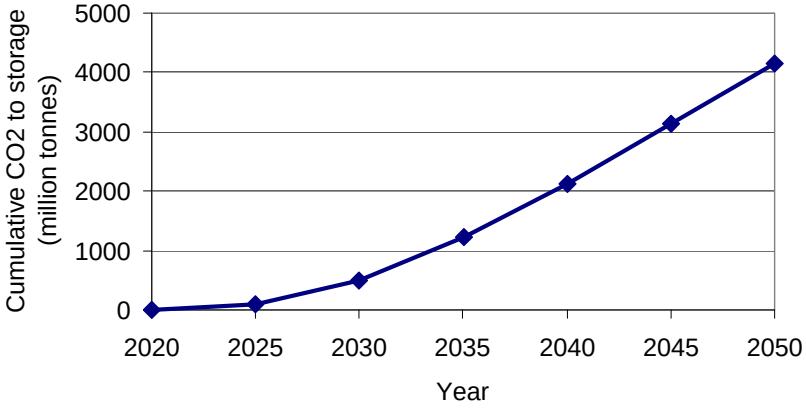
UK Power Generation – Scenario with 80% cut in CO2 Emissions



From Heather Haydock, AEA, City and Financial CCS Summit, 2 and 3 December 2008

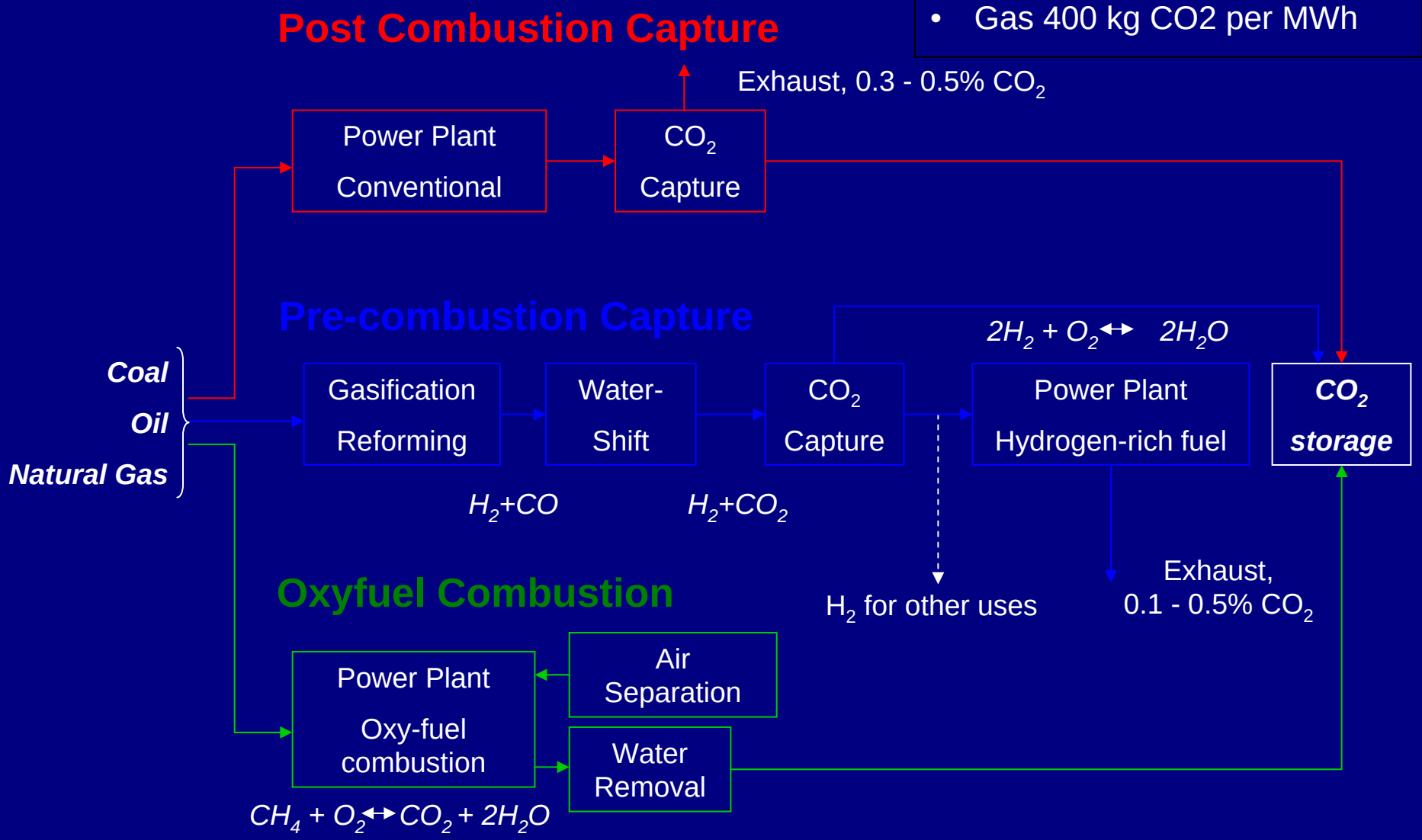
- Plan for UK fossil power supply to be decarbonised (coal) by 2030
- CO2 Capture rates (million tonnes per year)

2020-25	2025-30	2030-35	2035-40	2040-45	2045-50
18	82	145	180	202	206

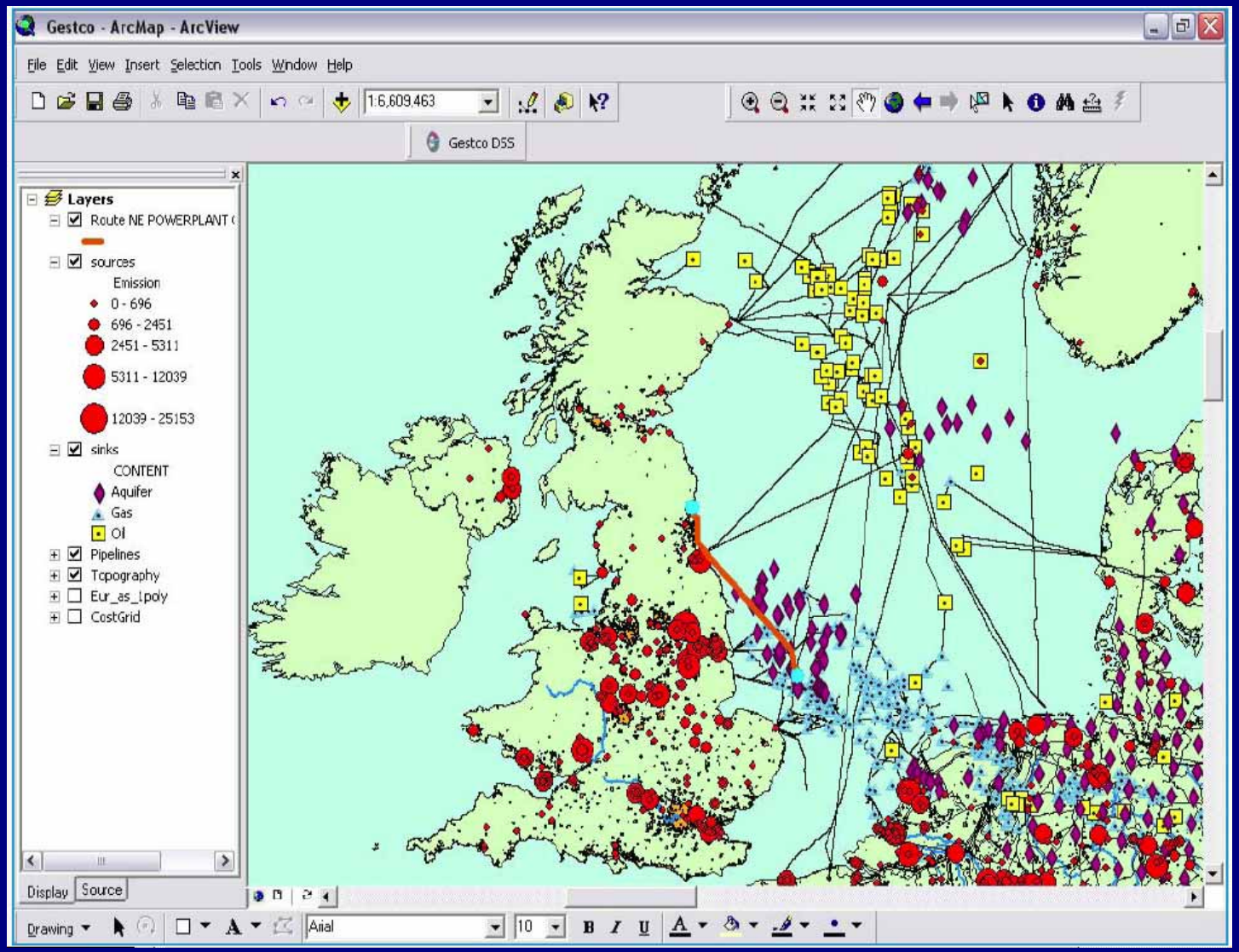


Capture Options (~90%)

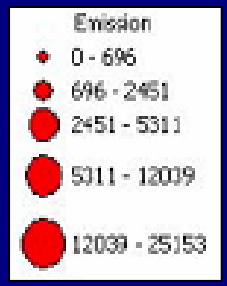
- Coal 900 kg CO2 per MWh
- Gas 400 kg CO2 per MWh



Sources and Potential Sinks of CO2 Around North Sea



Geographical Information System – Decision Support System
Part of EU GESTCO Project



British Geological Survey, February 2005

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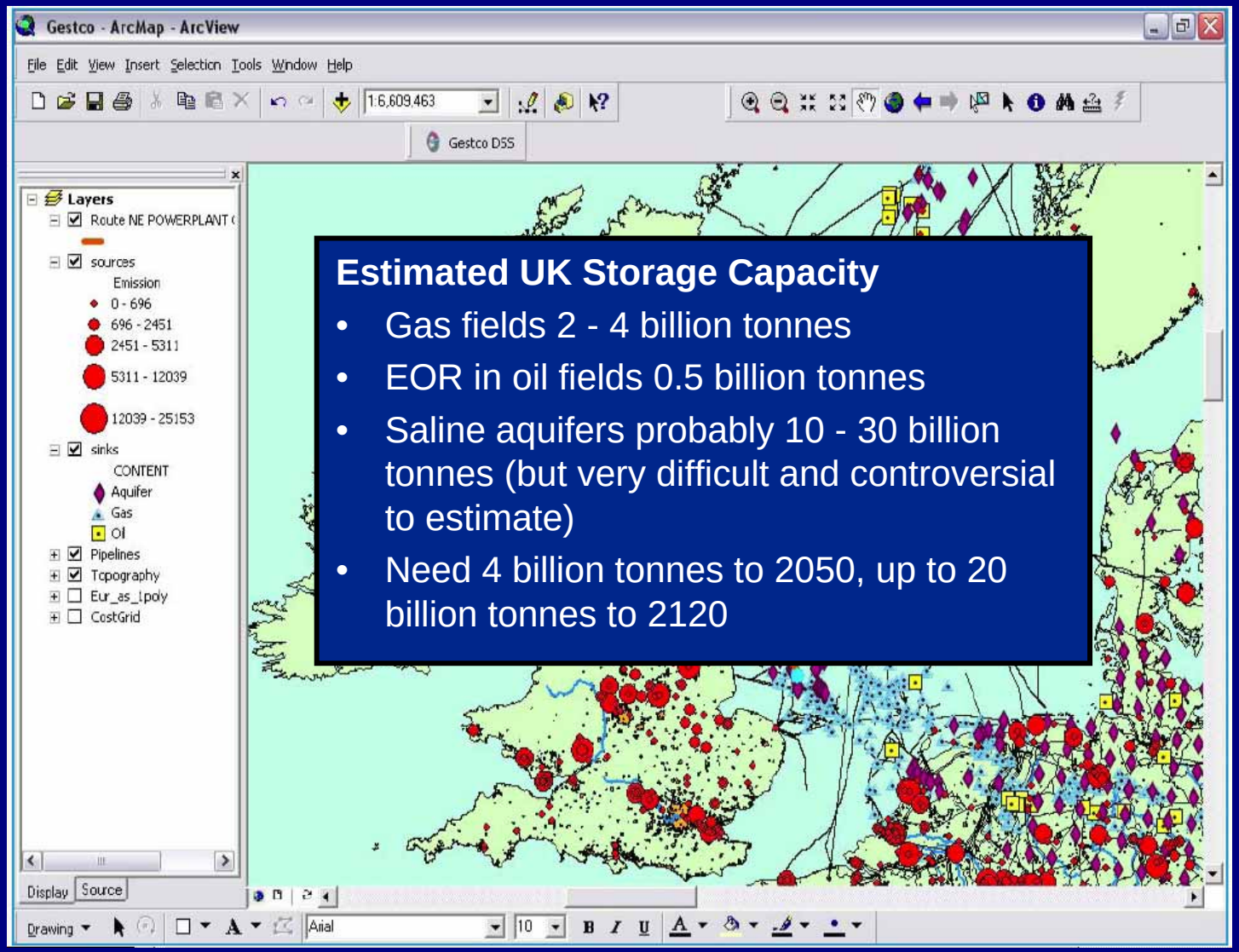

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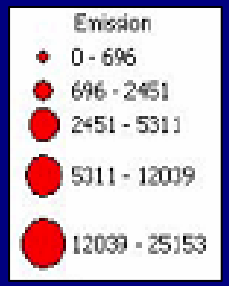
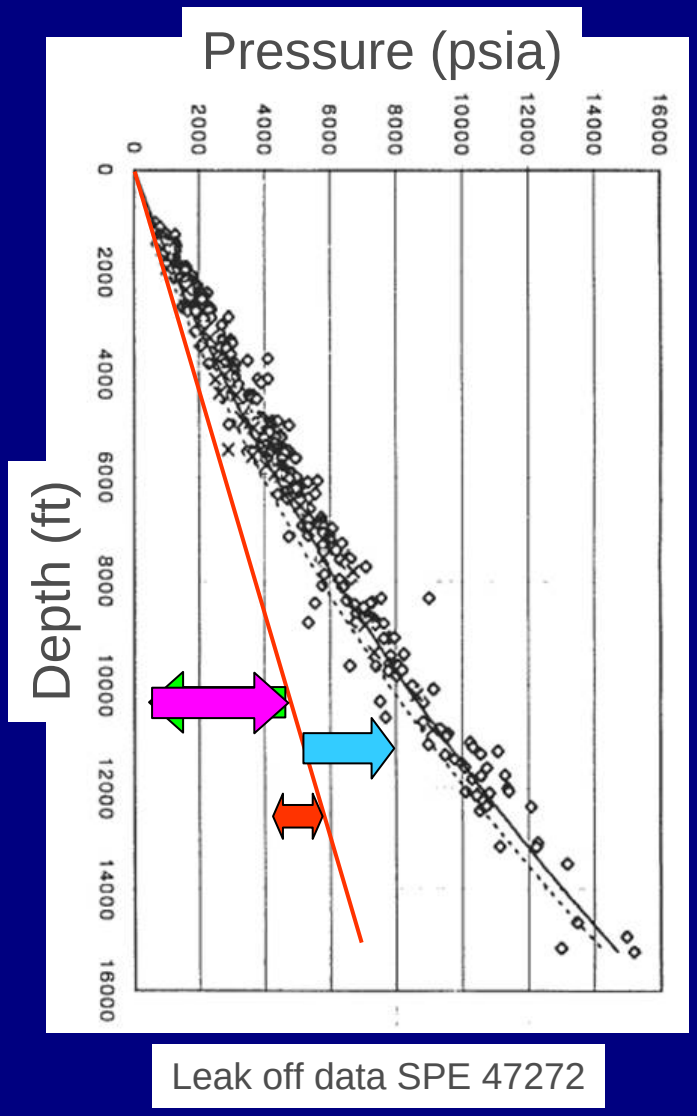


British Geological Survey, February 2005

Concept of Pressure Space



Leak off data SPE 47272

- Black points are North Sea leak off data showing **lithostatic** or **fracture** pressure (gradient 0.6-0.85 psi/ft)
- Red line is ‘normal’ **hydrostatic** pressure using gradient of 0.45 psi/ft
- Because of prior depletion pressure space for **gas field** disposal is to the left of the red line
- **Oil fields** generally operate just below hydrostatic pressure with production balanced by injection
- Pressure space for **aquifer** storage lies between the red and the black lines

CO2 EOR Onshore - Advantages

- CO2 supply network
- High well density, pattern flood, relatively cheap to redrill/refurbish
- Relatively low secondary recovery (35-45%)
- Phased implementation
- Large surface area available for facilities
- Economic with tax breaks

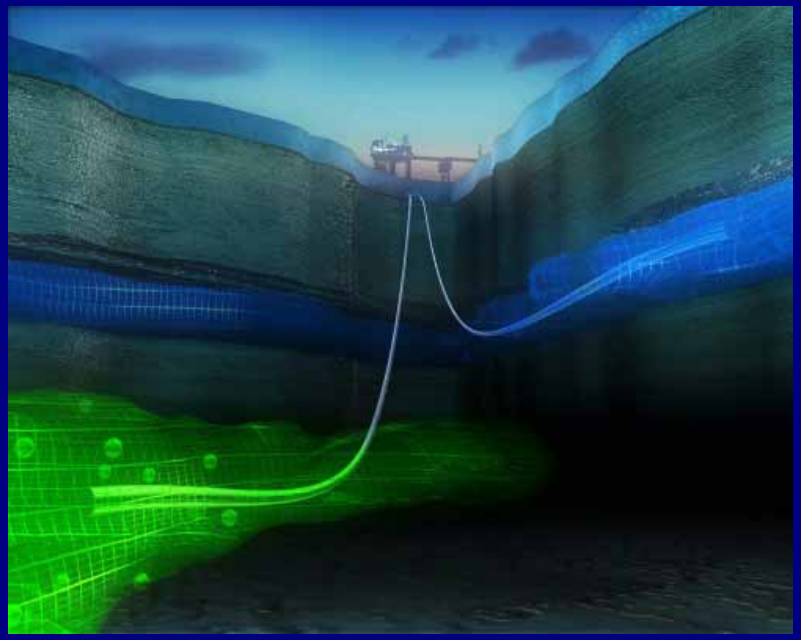
CO2 EOR Offshore - Challenges

- Limited CO2 supply (at least at present)
- Fewer wells, peripheral flood, expensive new wells and workovers
- High secondary recovery (50-70%)
- Single implementation (i.e. no chance to introduce the project in phases)
- Existing facilities mainly incompatible with high CO2 content in fluids
- Limited weight and space for new facilities
- Expensive
- Estimated UK North Sea EOR-related CO2 capacity 0.5+ billion tonnes (1+ billion barrels incremental oil)

UK Carbon Capture, Transport and Storage Competition

- Single CCS project up to 100% funding (around £1 billion)
- Offshore disposal of CO2
- Coal (including oxyfuel) with post-combustion capture (i.e. using technology that can be retro-fitted and capable of being deployed in China etc.)
- 300 - 400 MW (~ 2 million tonnes/y of CO2)
- First CO2 capture and storage by 2014
- Discussions ongoing with three consortia to identify those to take forward to FEED study (decision expected around now)
- One of 10 - 12 demonstration projects in EU by 2015 (UK also want to fund up to 3 additional projects)

Sleipner CO2 Storage Project

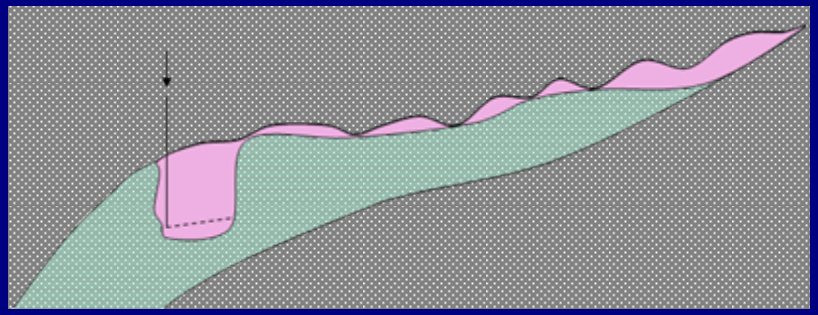


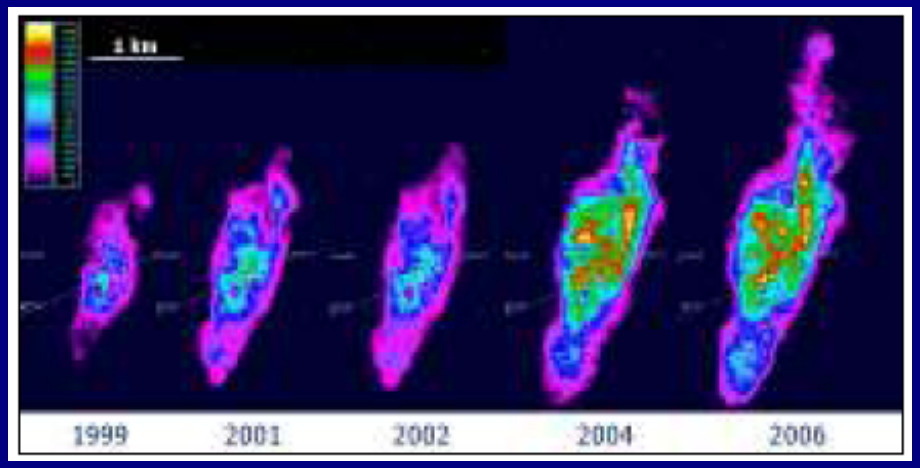
Images: Alligator film /BUG / Øyvind Hagen StatoilHydro

- Natural gas in Sleipner contains 9 mol% CO2
- Offshore chemical capture plant reduces CO2 content of gas for export to <2.5 mol% CO2
- To avoid $50 tonne tax captured CO2 compressed an reinjected into shallower (3000 ft) Utsira formation
- 0.85-1 million tonnes/y CO2 reinjected, started 1996 and lasts for ~20 years

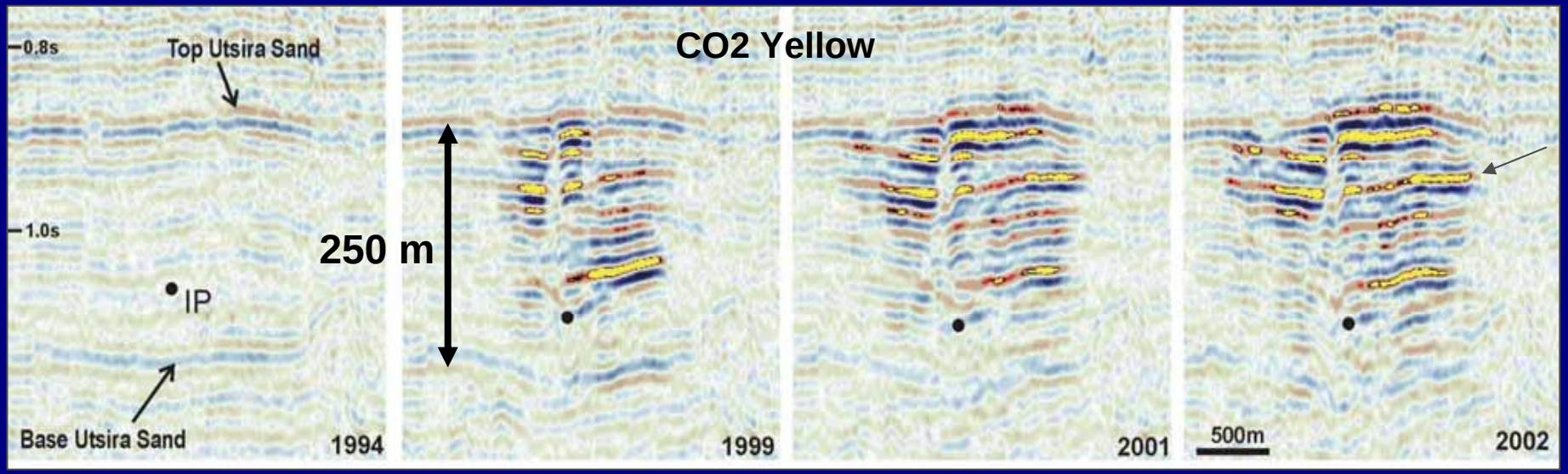
Seismic Monitoring at Sliepner

CO2 Injection

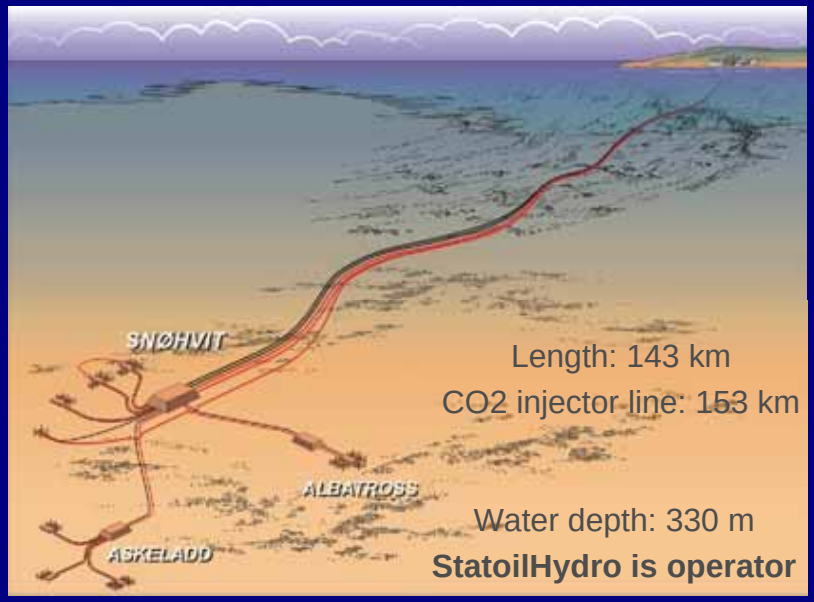


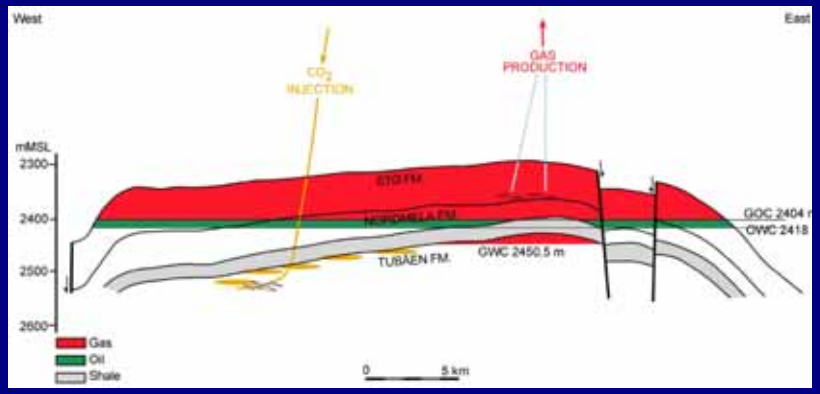


Areal images of layer arrowed below



Snøhvit CO2 Storage Project



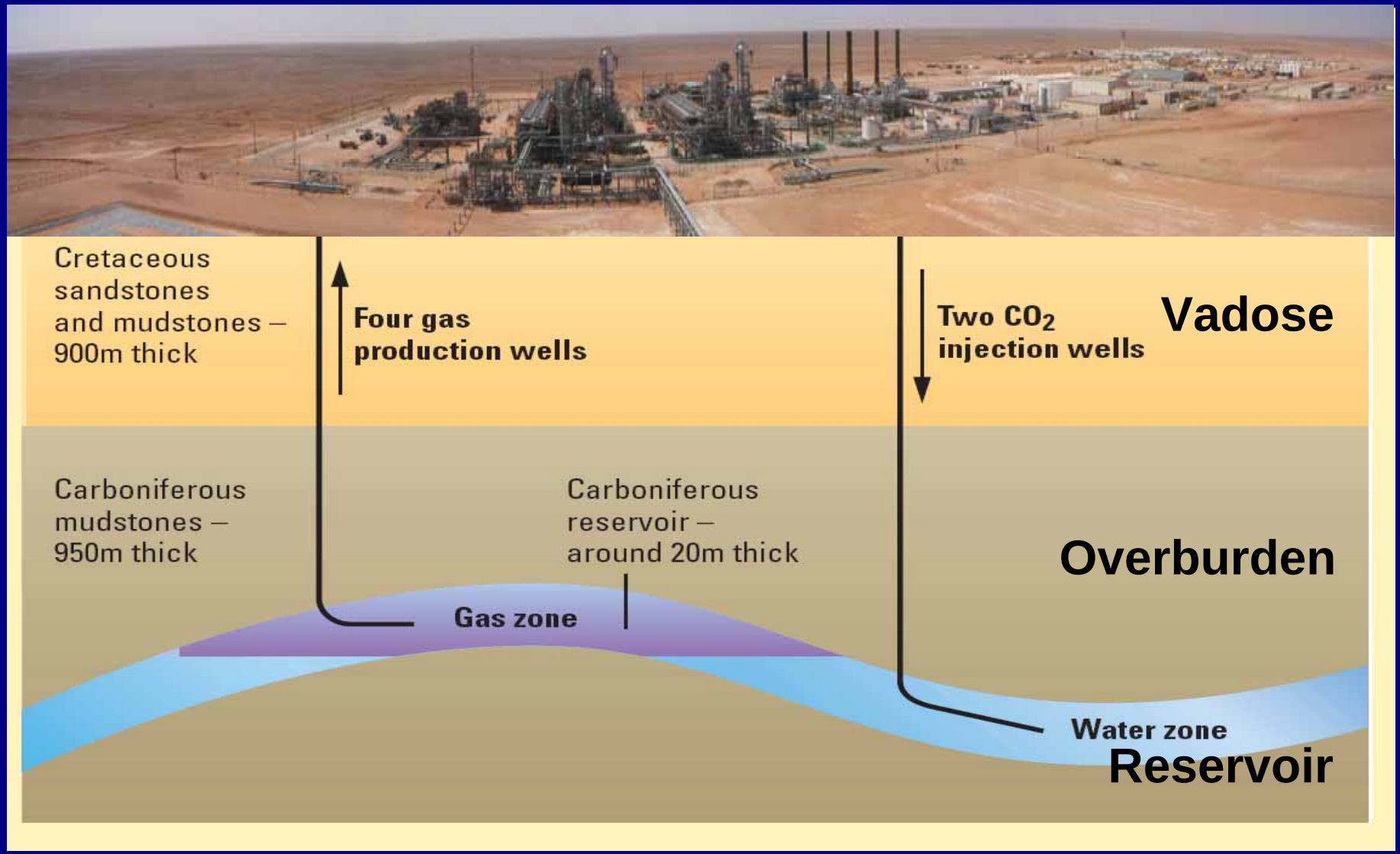


- Reduce CO2 content of natural gas from 6% to 50 ppm (to export as LNG)
- Separating and storing ~0.7 million tonnes/y
- CO2 captured onshore at amine plant
- CO2 piped offshore for storage in aquifer
- Started up in Spring 2008 and due to last 20 years
- Driver is CO2 tax, environment

In Salah, Algeria

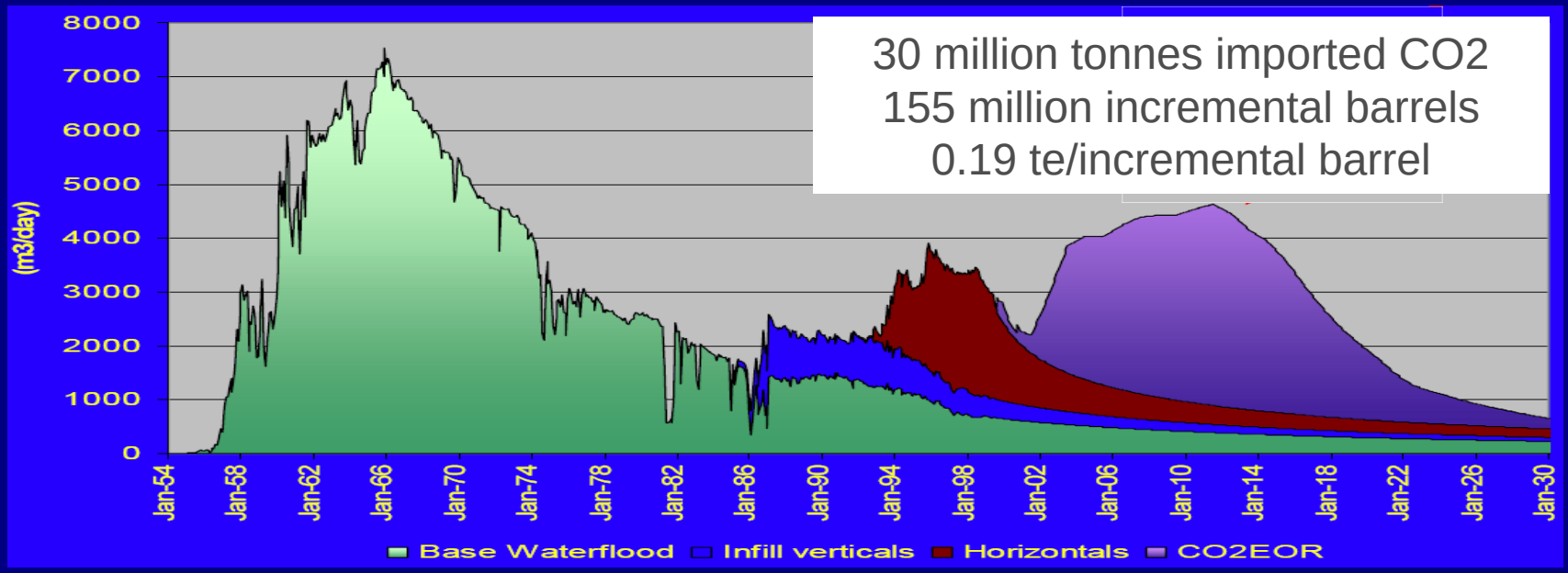
- In Salah Gas (ISG) is a Joint Venture (JV) between BP (33%), Sonatrach (35%) and Statoil (32%)
- Gas fields located in the Ahnet-Timimoun Basin in the Algeria Central Sahara
- 3 northern fields of Krechba, Teguentour and Reg to deliver 900 million scf/d
- Contain CO2 concentrations ranging between 1 to 9% which is above the export gas specification of 0.3%
- 1 million tonnes/year (50 million scf/d) CO2 is separated from the natural gas at Krechba
- CO2 stream compressed and re-injected into the Krechba reservoir

Krechba Monitoring



Weyburn CO2 EOR, Saskatchewan, Canada

200 mile pipeline – currently 2.4 million te/year (~125 MMscf/d)



30 million tonnes imported CO2
155 million incremental barrels
0.19 te/incremental barrel

Source: HTC Purenergy, Carbon Capture & Storage Congress, 28-29 October 2008, Abu Dhabi, UAE, Green Power Conferences

Weyburn - 4D Seismic Monitoring

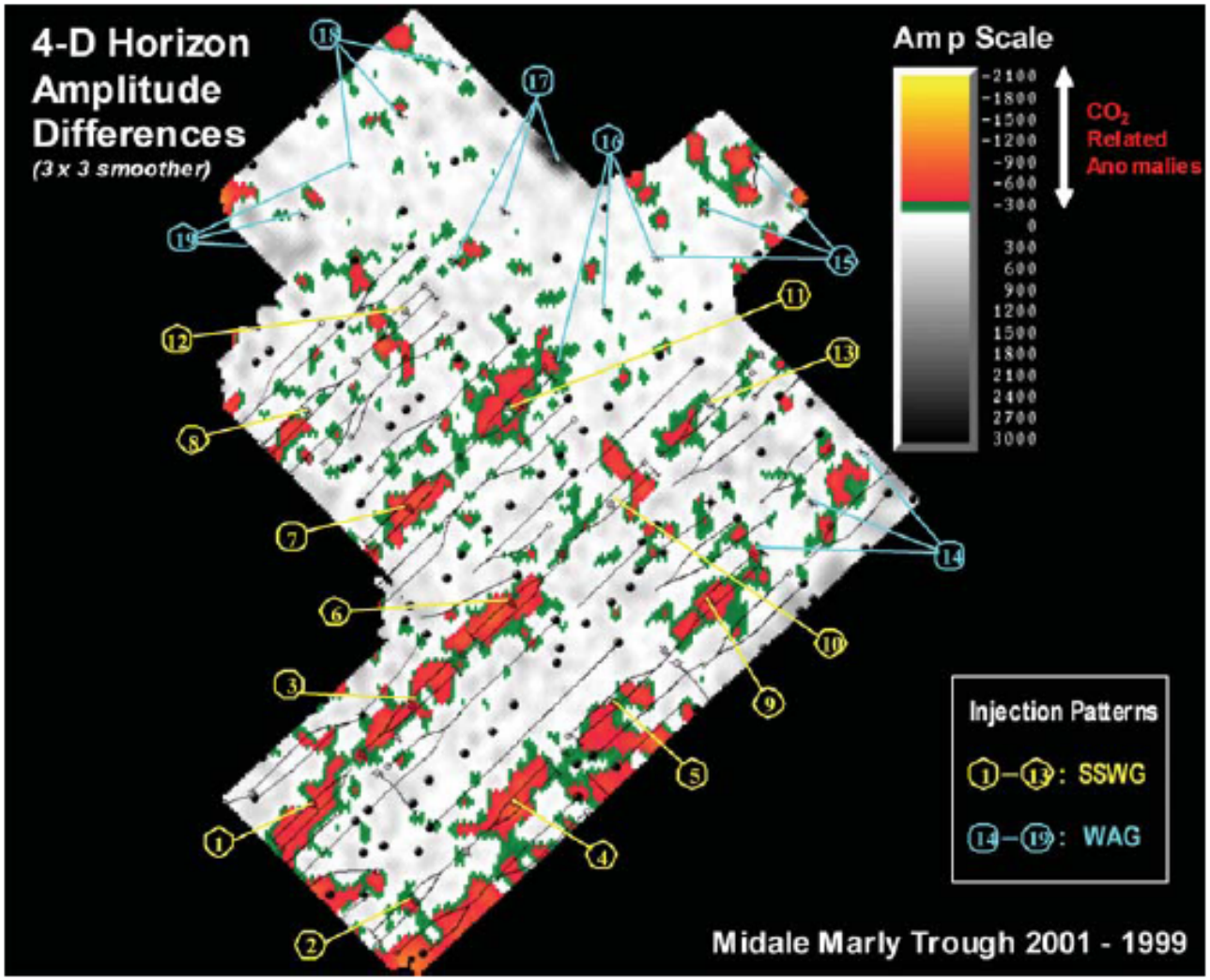
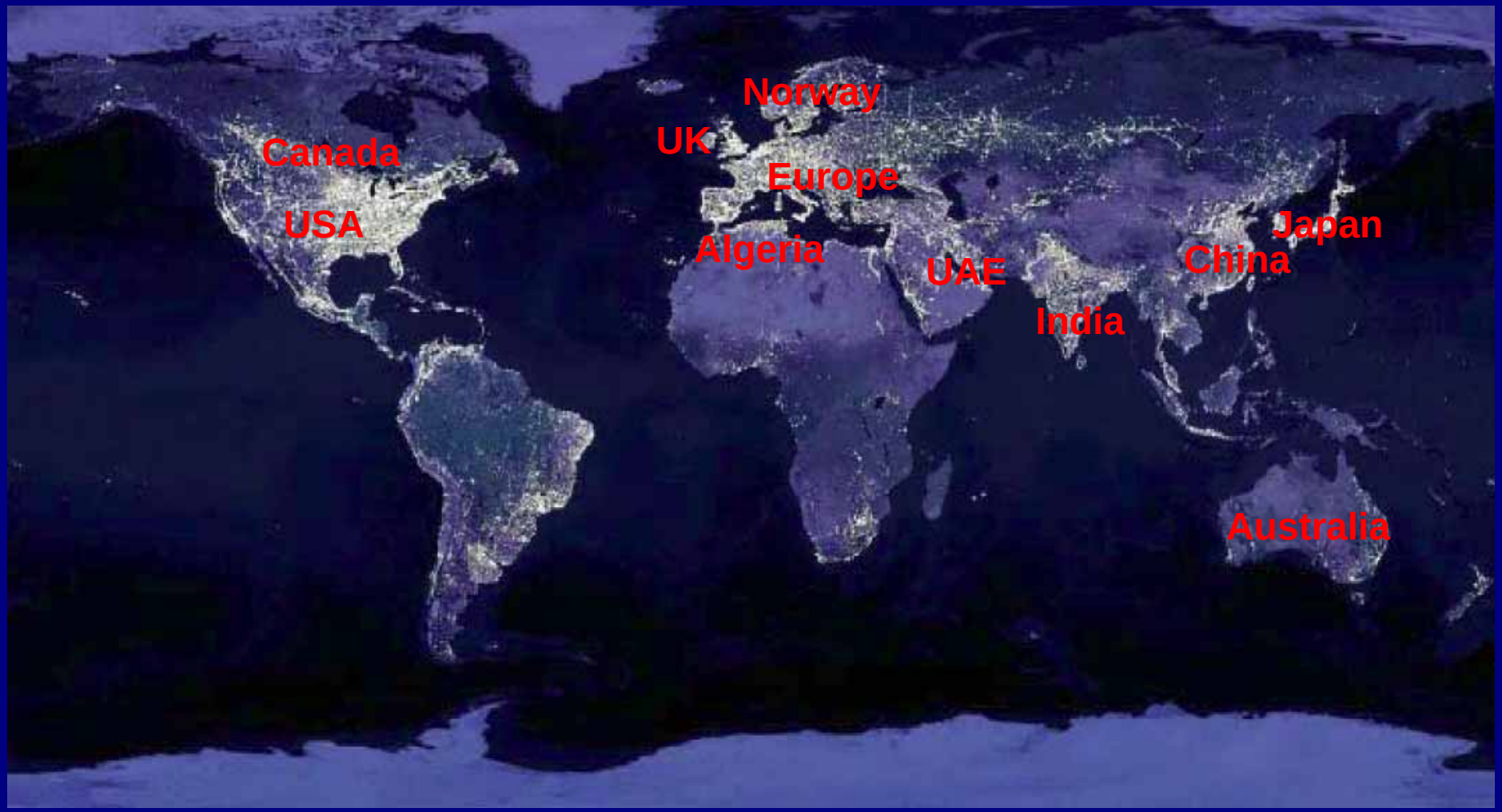


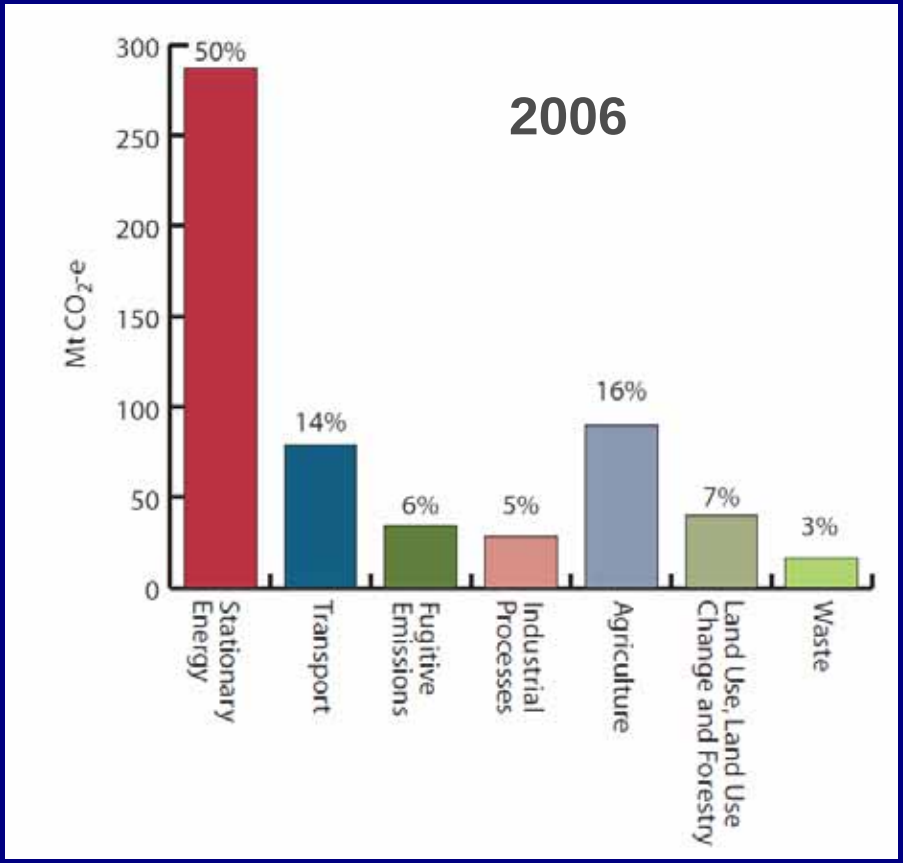
Figure 1 - Monitoring CO2 - Guoping Li, The Leading Edge, 2003.

CCS Activity Map

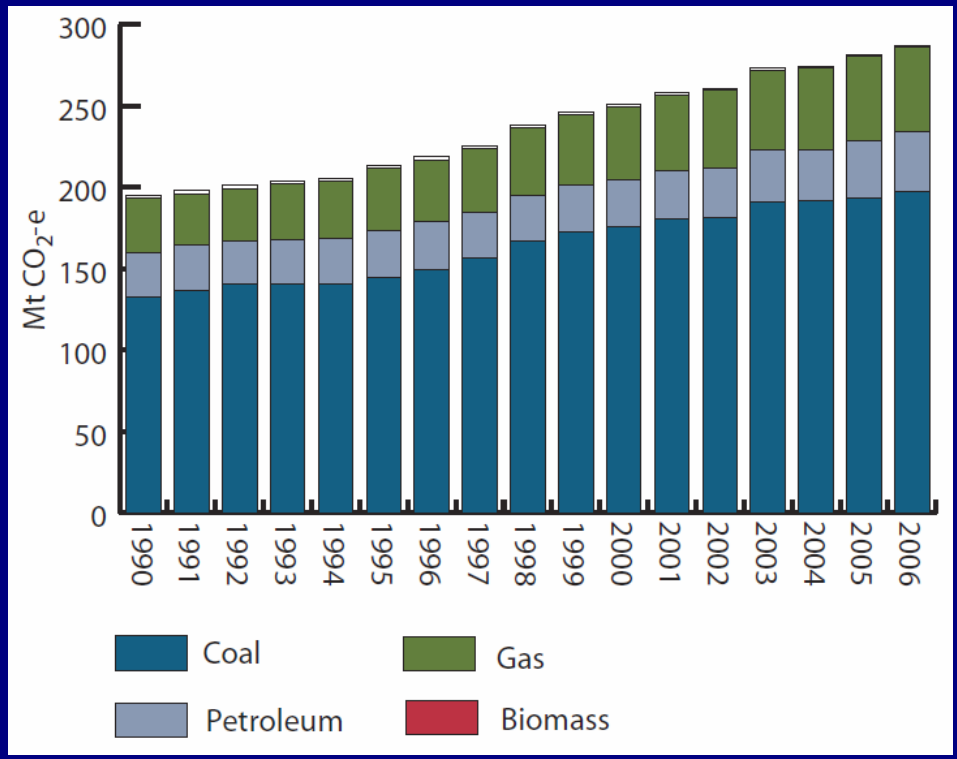


Australia's Emissions by Sector

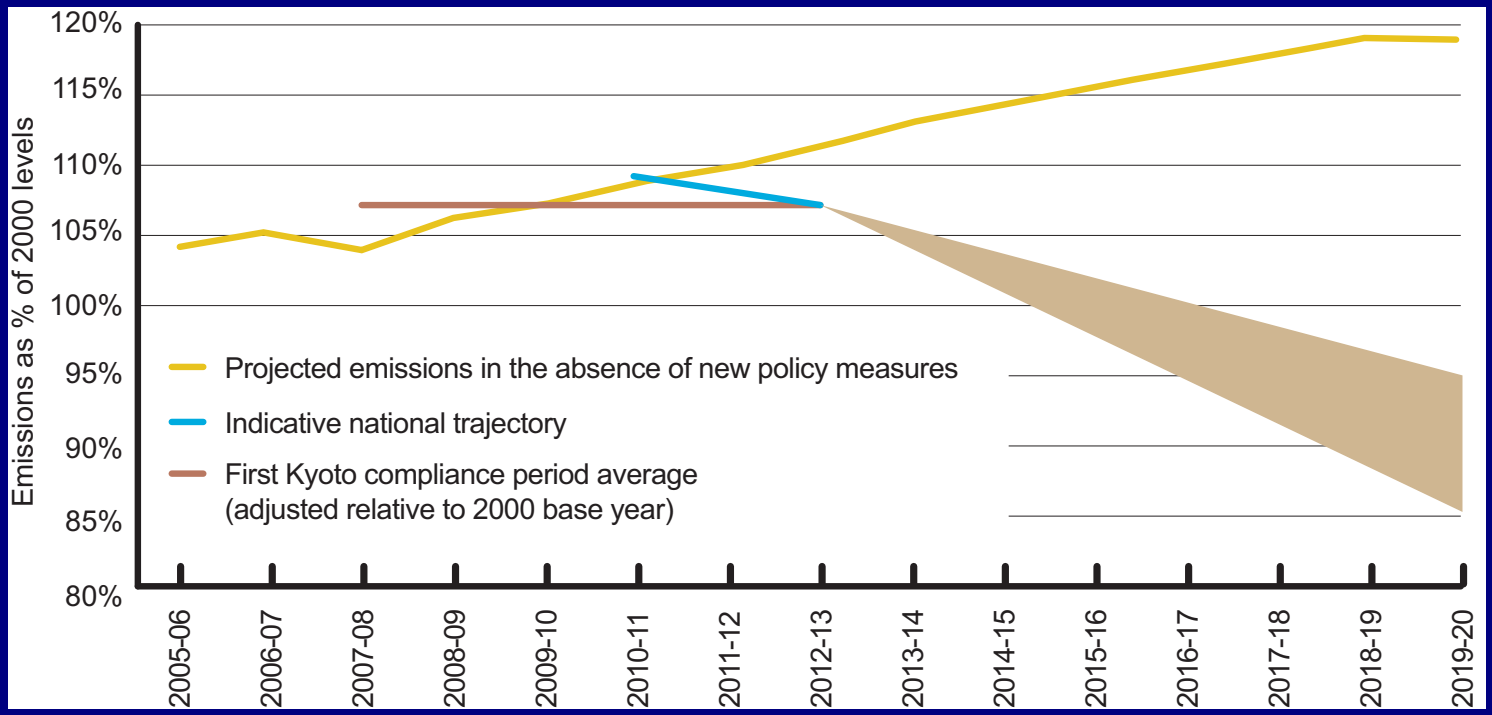
- Total 576 million tonnes CO2-e in 2006
- Nearly half from point sources



- Recent point source increase from burning coal
- Australia will increasingly depend on burning coal for power generation

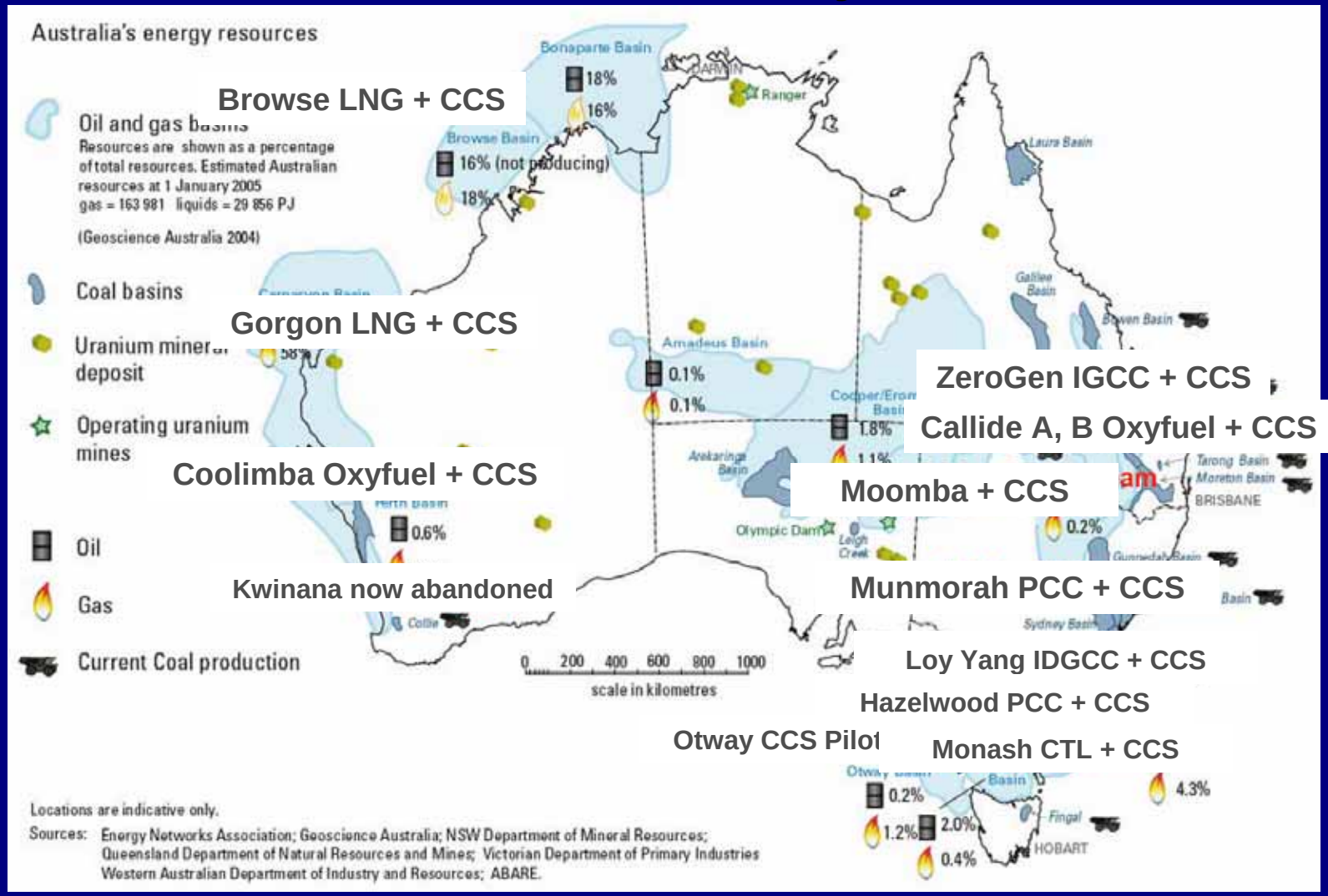


Australia's Projected Emissions Reductions



- Australia now signed up to Kyoto with target to limit increase to 8% from 1990 base between 2008 and 2012
- New targets going forward
  - 4 -14% below 1990 by 2020
  - 60% below 1990 by 2050

Plans for Power Generation with CCS and other CCS Projects



http://www.gassnova.no/gassnova/frontend/files/CONTENT/CCSWorld/Austalia/summary-australia.pdf

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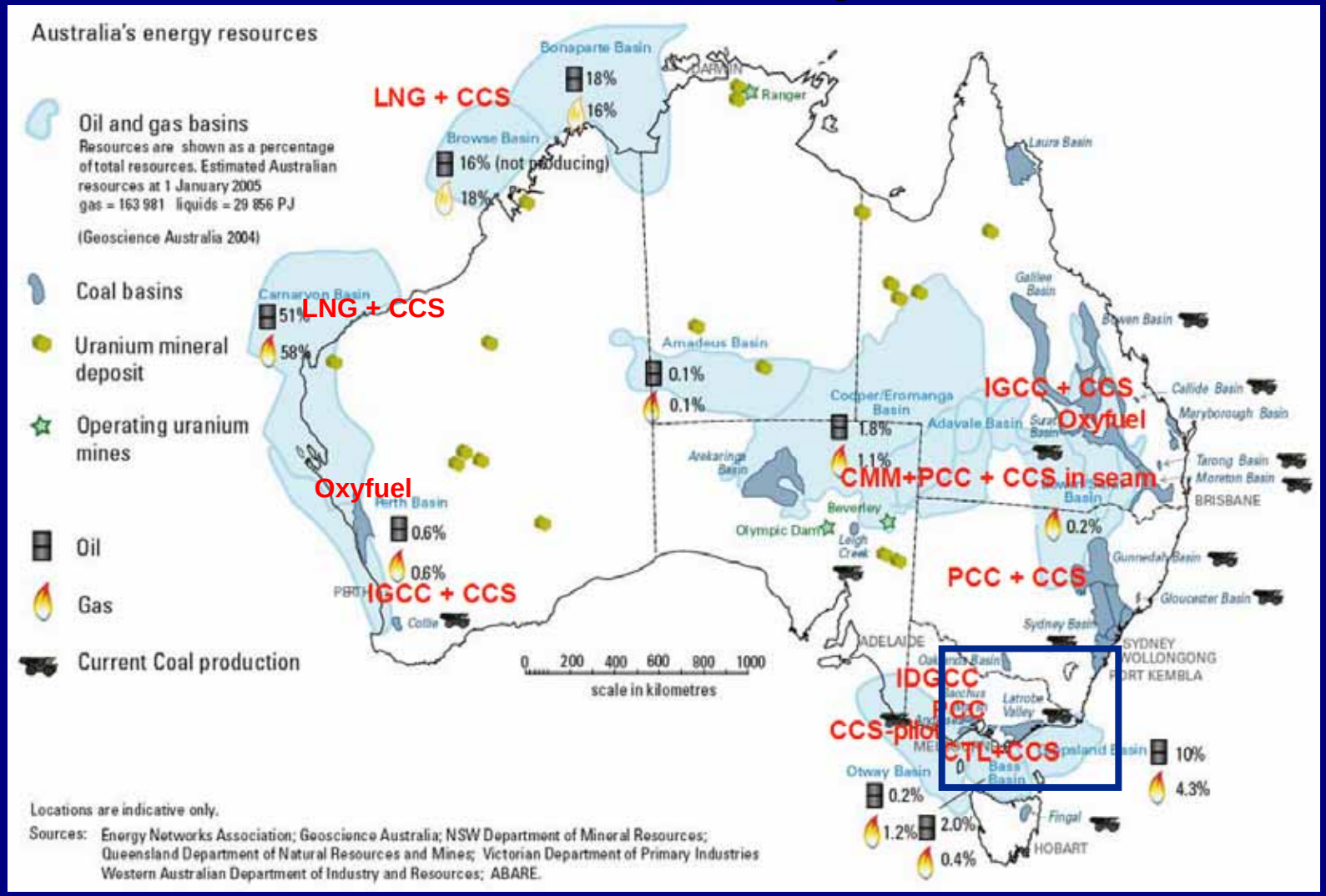


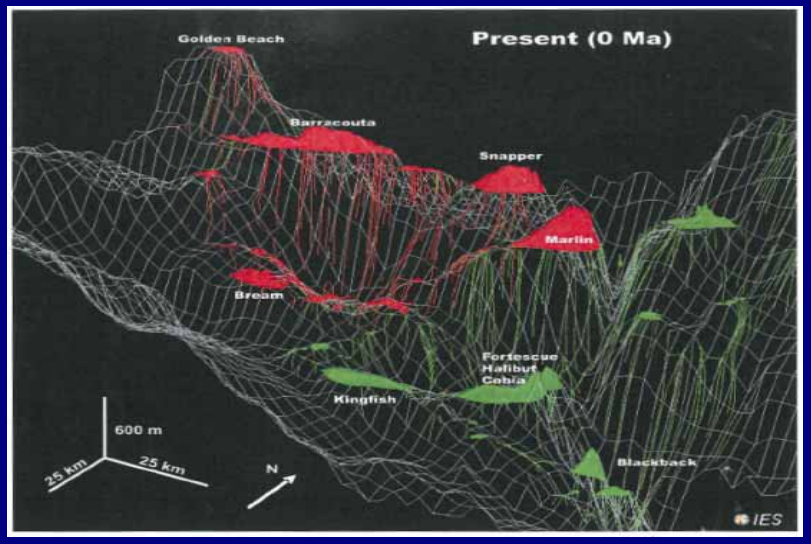
http://www.gassnova.no/gassnova/frontend/files/CONTENT/CCSWorld/Austalia/summary-australia.pdf

Latrobe Valley

- Power generation in Victoria dependent on Latrobe Valley brown coal
- Proposed IGCC power plant with CCS at Loy Yang
- Also proposed PCC power plant with CCS at Hazelwood
- Also plans (on hold as of January 2009) for a coal to liquids (diesel) plant at Monash
- Likely requirement to store 20+ million tonnes CO2 per year

Gippsland Basin Storage Issues

- Hydrocarbons migrated into oil and gas fields via fill and spill river and lake system
- If CO2 injected downdip how long would it take to reach producing fields?
- Requirement to wait until all production ceased?
- Inject where CO2 will migrate away from oil and gas fields?
- Is this feasible without physical trap?
- GeoScience Victoria identified suitable cap rock over most of basin



O'Brien et al, PESA, Sydney, Sept 2008

Estimated Storage Capacity

- Estimating storage capacity is a tricky business!
- A study (Bradshaw, 2004) screened 300 sedimentary basins using criteria such as depth, thickness and lithology
- Identified 65 suitable sites with estimated capacity of 750 billion tonnes mostly in ‘hydrodynamic’ traps (aquifers with no physical stratigraphic or structural trap)
- But the methodology behind these gross volumetric estimates is no longer best practice
- Capacity is being reviewed but is still judged to be large
- Less contentious is estimating potential capacity in depleted oil and gas fields
- Gippsland Basin capacity estimated at 2.2 billion tonnes with the bulk of this capacity in Snapper, Marlin, Barracouta and Kingfish (Gibson-Poole et al, 2008)
- Otway Basin capacity 42 million tonnes with over half in Minerva (Gibson-Poole et al, 2008)
- Perth Basin gas fields capacity 63 million tonnes with most of this in Dongara (Cadman et al, 1994 and Owad-Jones and Ellis, 2000)

CCS Economics

- Presently not economic and no mechanism for crediting storage; but CCS projects to be included in EU Emissions Trading Scheme (ETS) soon (from 2012)
- Credit required probably €50 tonne CO2 abated or greater (Phase II 2008-2012 ETS price currently €13-15 – September 2009)
- Australia introducing ETS with links internationally
- Clean Development Mechanism (CDM) currently considering whether to accept CCS projects
- Hope that CCS will be incorporated into successor to Kyoto (Copenhagen 2009) and carbon trading will be less complicated

Conclusions

- CO_2 storage is a substantial new business for the oil industry
- Uses most of our skills but is a significant challenge
- Is an absolute necessity to make significant reductions in CO_2 emissions
- Opens up the use of vast coal stocks
- Provides energy security through diversity
- Enables hydrogen to be used as energy carrier

Thank you for your attention

Senergy one day training course

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Locally tailored versions previously presented in Perth, Melbourne, Canada, USA and on seven occasions in UK

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david.hughes@senergyworld.com

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