



An update on CCS technologies & costs

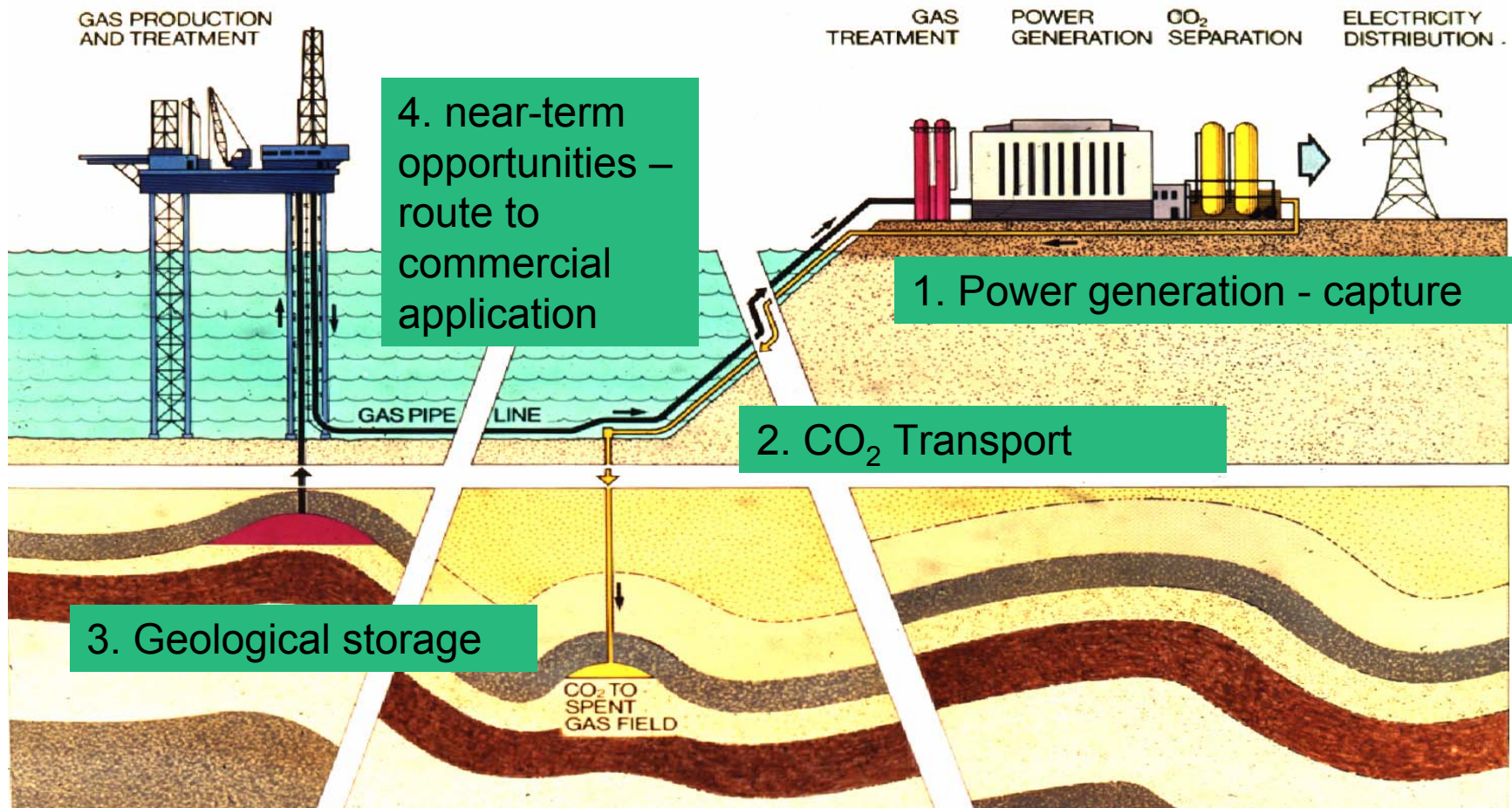
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**Presented at: EU-OPEC Roundtable on CCS
Riyadh, Saudi Arabia, 21st Sept. 2006**



CCS UPDATE: STRUCTURE OF PRESENTATION



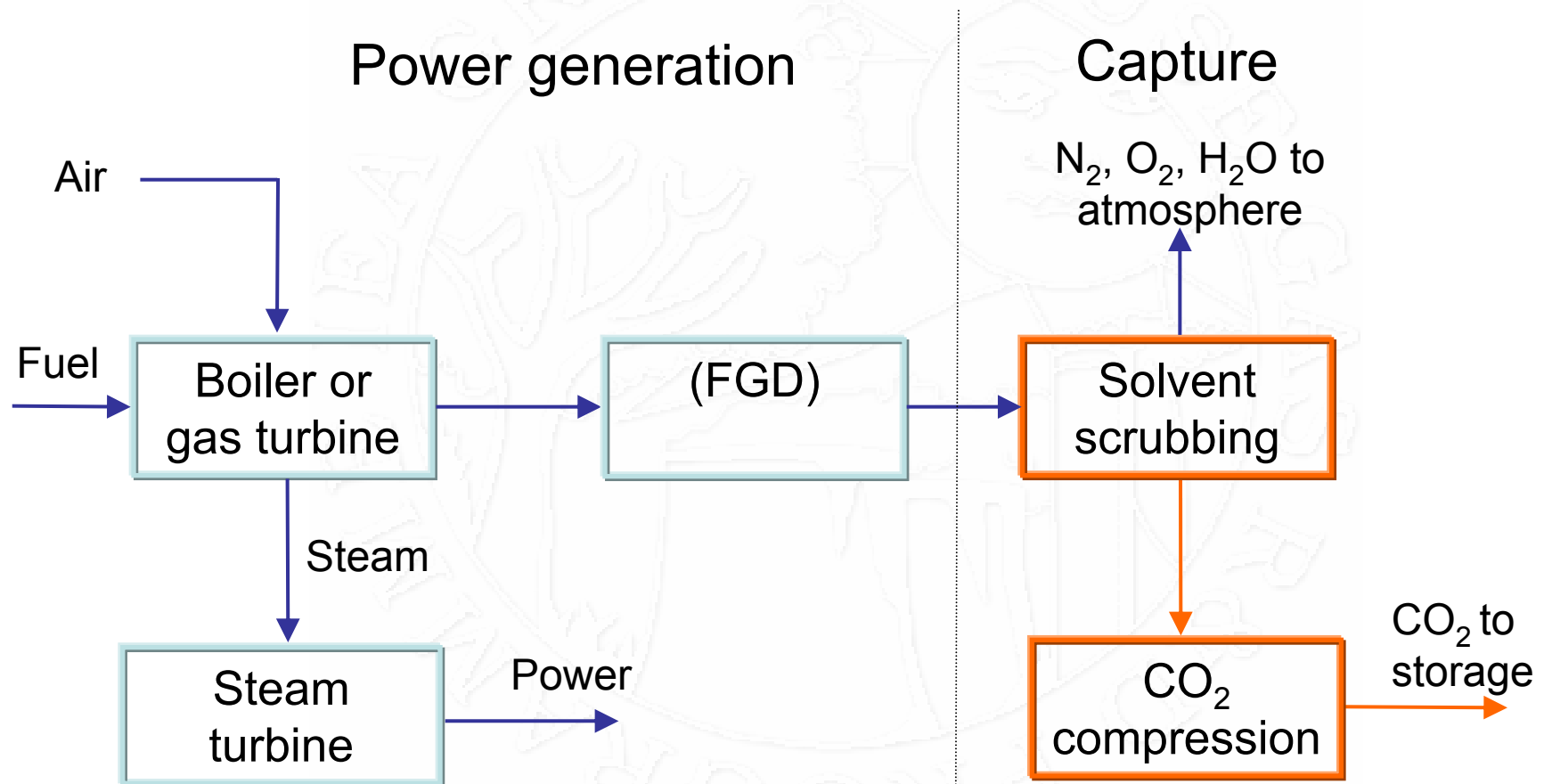


Leading CO₂ capture technologies

- Capture of CO₂ from flue gases:
 - Post-combustion capture
- Burning fuel in oxygen instead of air:
 - Oxy-combustion
- Conversion of fuel to H₂ (and CO₂) before combustion:
 - Pre-combustion capture



Post-combustion capture: process





Post-combustion capture: solvent

- Widely used on reducing gases, e.g. natural gas
- Less widely used for oxidising flue gases
- MEA¹ used in post-combustion capture plants
 - CO₂ is used mainly for chemicals and food and drink
- New solvents being developed and used
 - e.g. hindered amines
 - Lower energy consumption, solvent losses, <corrosion
- Low SO_x (<10 ppm) and NO₂ (<20ppm) is needed
 - Possible with limestone-gypsum FGD and SCR

1. MEA: mono-ethanolamine



Post-combustion capture: status



- Warrior Run power plant, USA
- 180 MW_e coal fired circulating fluidised bed combustor
- 150 t/d of CO₂ captured from a slipstream
 - About 5% of the total

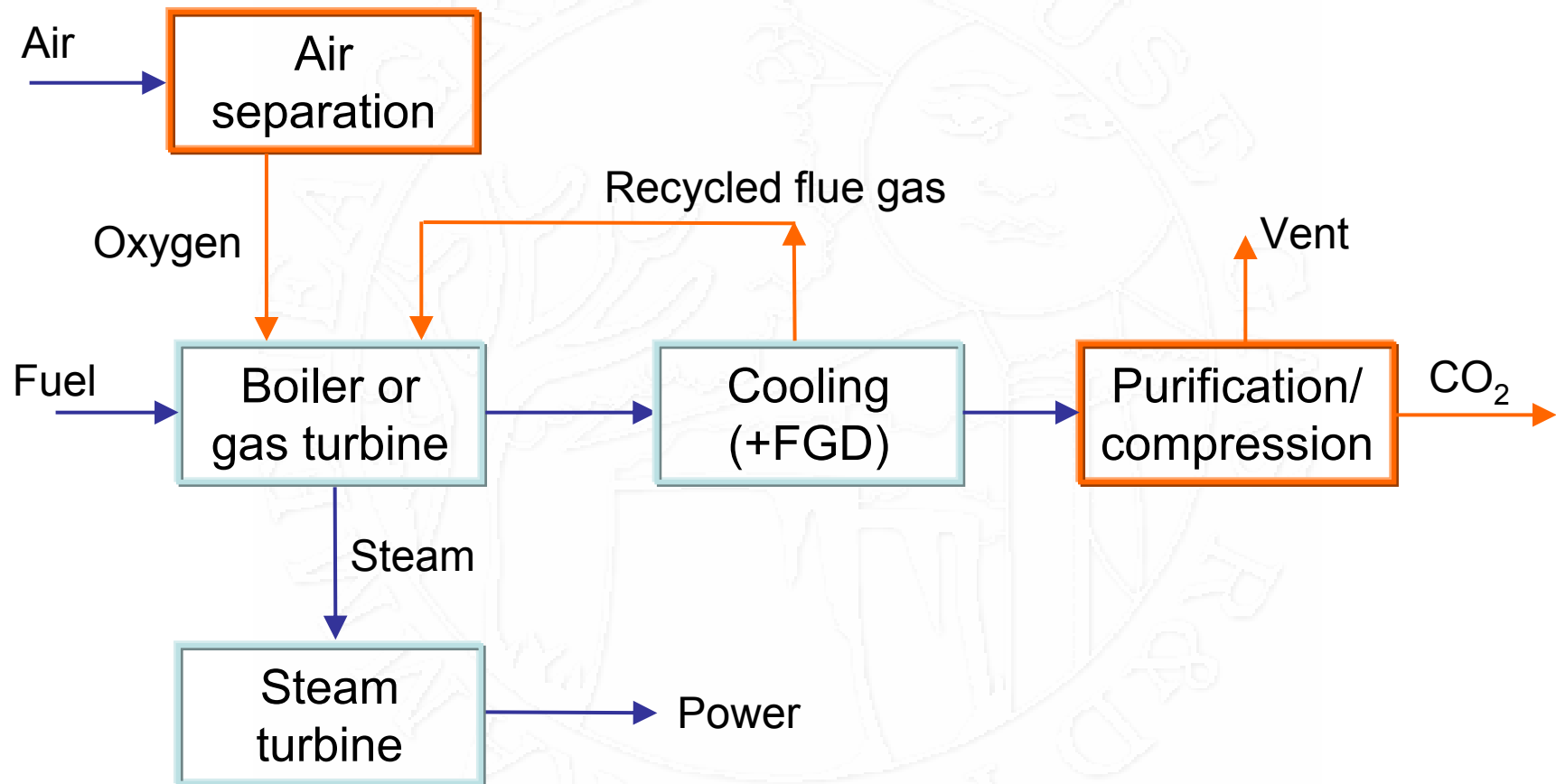


Post-Combustion capture: summary

- Advantages
 - Existing combustion technology can be used
 - Retrofit to existing plants is possible
 - Retrofit to old inefficient plants is not attractive
 - Demonstrated at small power plants
- Disadvantages
 - Energy penalty has been relatively high
 - Penalty is being reduced by process developments
 - Solvents are degraded by oxygen and impurities
 - Environmental issues



Oxy-combustion capture: process





Oxy-combustion capture: status



5 MW_e CES water cycle plant at Kimberlina, California

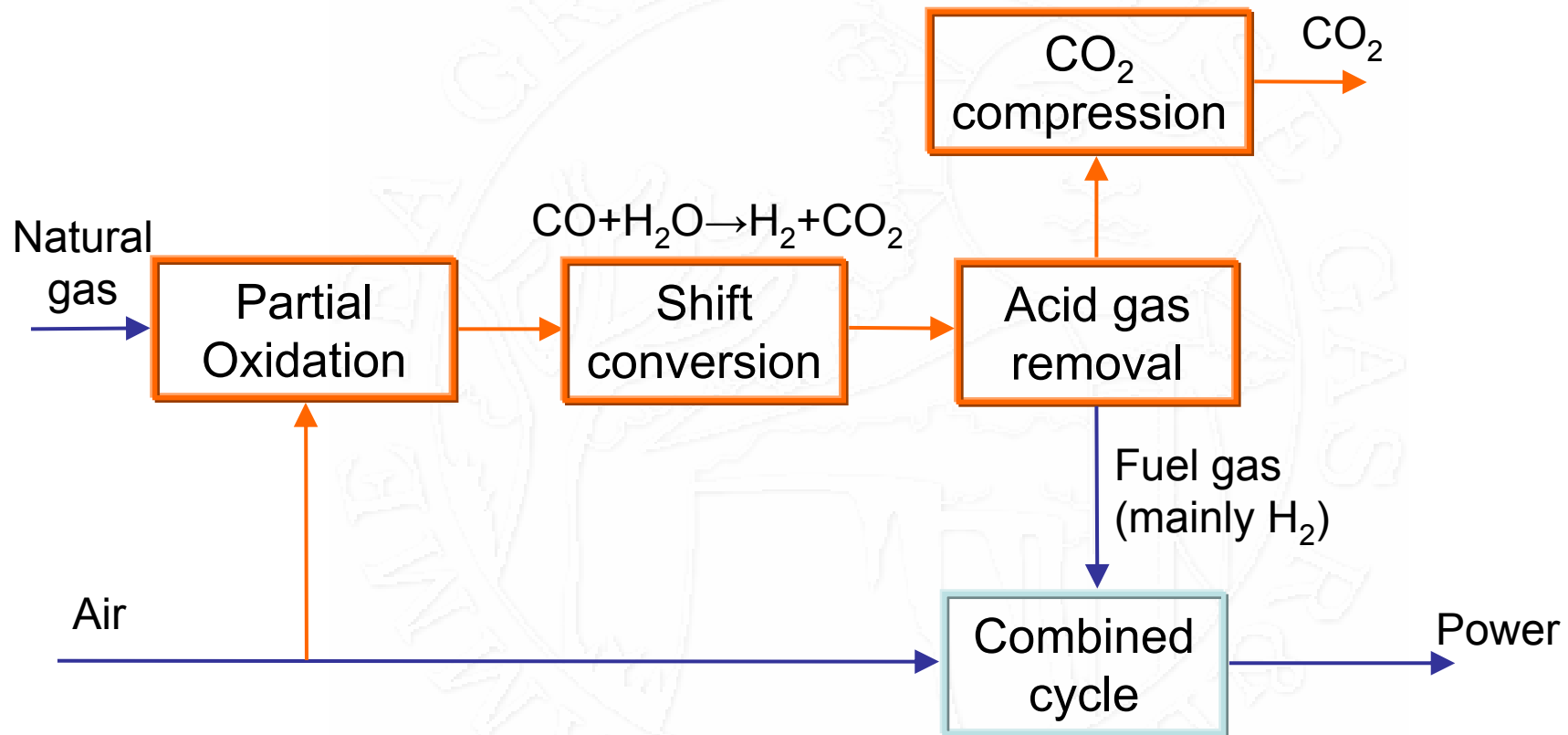


Oxy-combustion capture: summary

- Advantages
 - Combustors could be fairly conventional
 - Possibility of compact boilers with lower quantities of flue gas recycle
 - Possibility of avoiding separate FGD step
- Disadvantages
 - Only tested at a small scale
 - High cost of oxygen production
 - Advanced oxygen separation membranes with lower energy consumptions are at pilot plant scale
 - If gas turbines, new designs are needed
 - Will only be developed if there is a large market

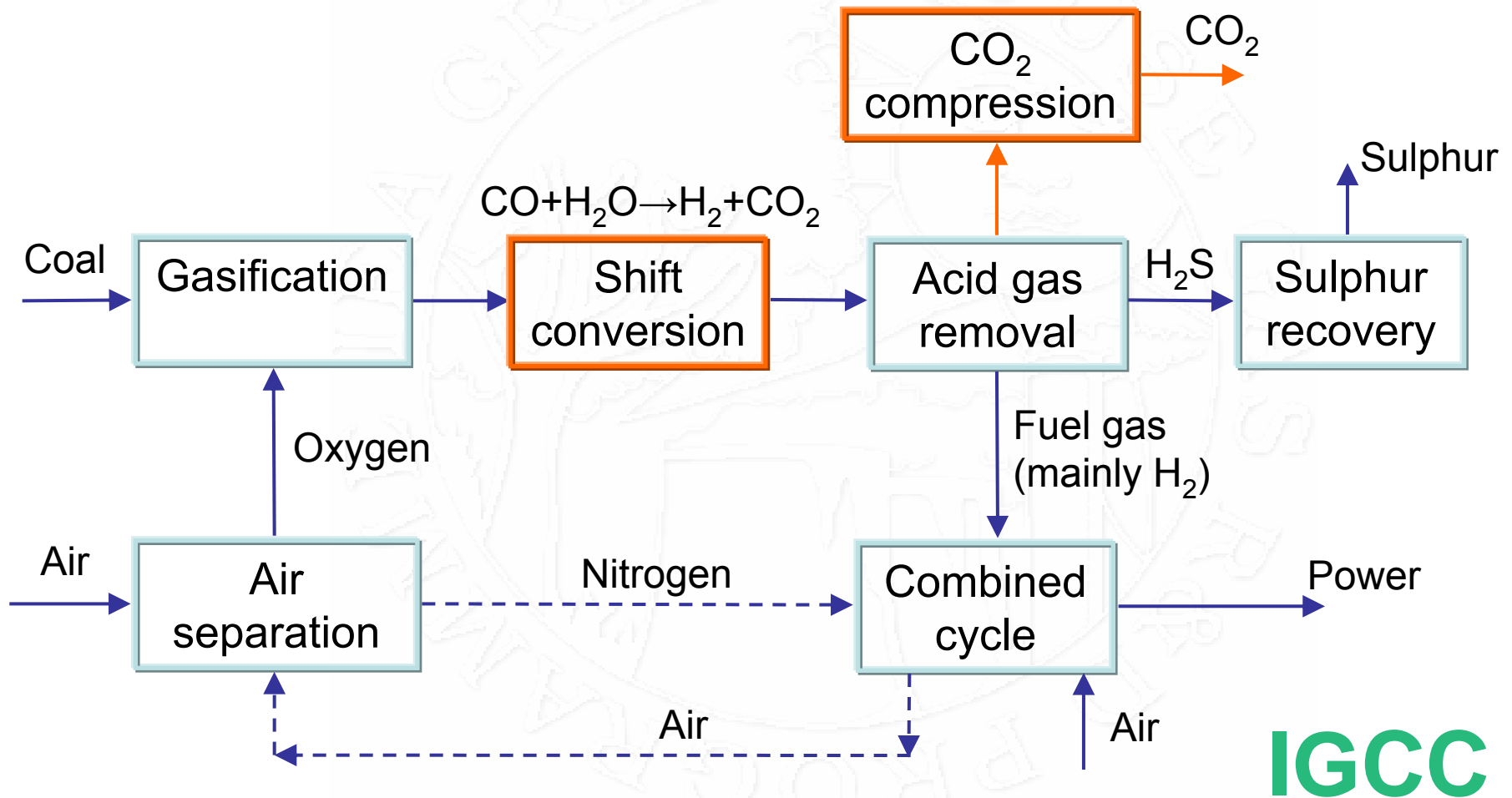


Pre-combustion capture: process (gaseous fuel)





Pre-combustion capture: process (non-gaseous fuel)



IGCC



Pre-combustion status: IGCC without CO₂ Capture

- 4 coal-based IGCC demonstration plants (USA, Netherlands, and Spain)
- Availability has been poor but is improving
- IGCC is not, at present, the preferred technology for new coal-fired power plants
- Main commercial interest in IGCC is for use of petroleum residues



Pre-combustion status: IGCC without CO₂ capture



Shell gasifier IGCC plant, Buggenum, Netherlands



Pre-combustion capture: summary

- **Advantages**

- High CO₂ concentration and high overall pressure
 - Lower energy consumption for CO₂ separation
 - Compact equipment
- Proven CO₂ separation technology can be used
- Possibility of co-production of hydrogen

- **Disadvantages**

- Unfamiliar technology for power generators
- Coal-fired IGCC plants have had low availability
- IGCC without CO₂ capture has generally higher costs than pulverised coal combustion

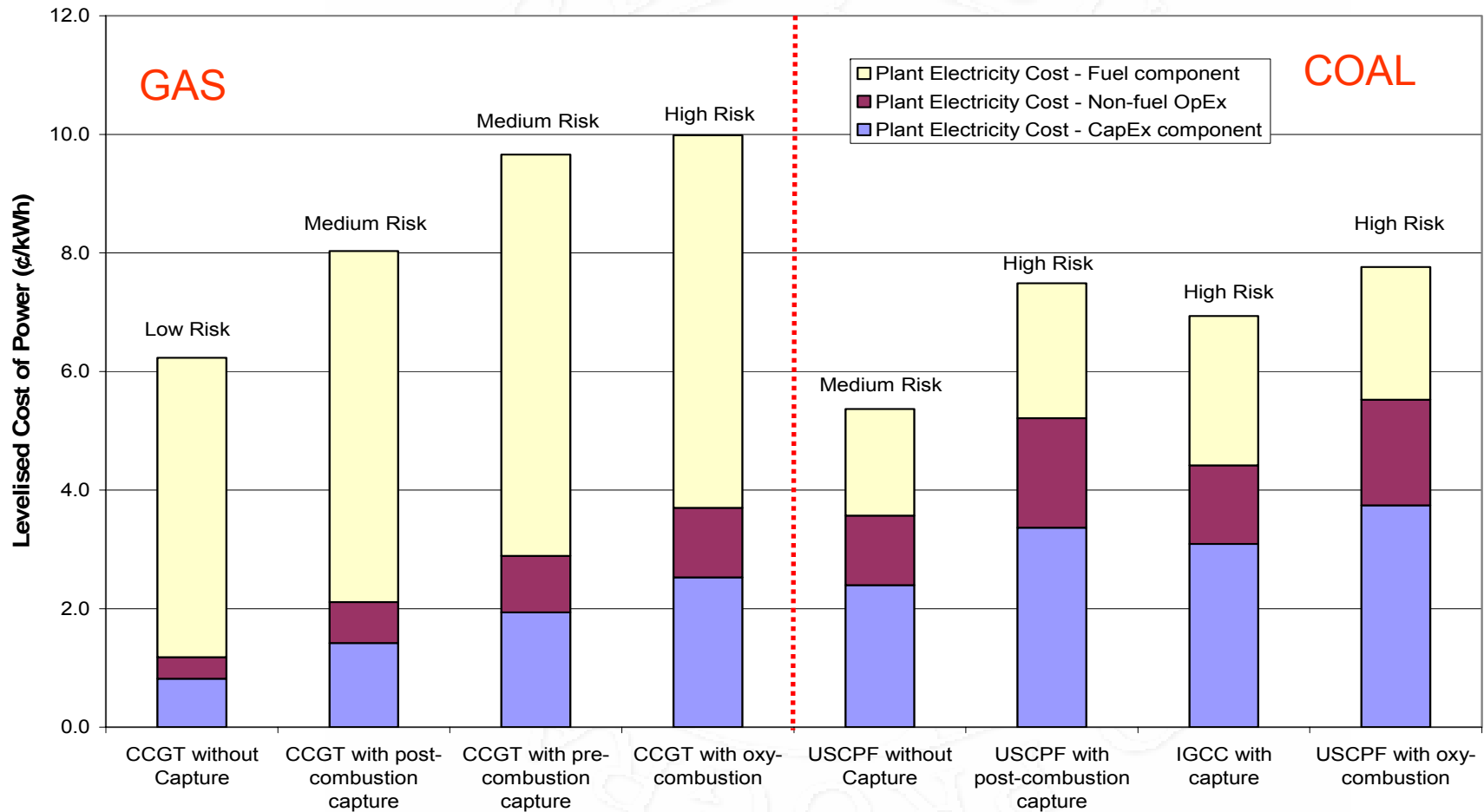


Update of IEAGHG cost estimates: basis

- Updated fuel prices based on predictions of prices up to 2025
 - Coal: \$2.2/GJ
 - Natural gas: \$7.8/GJ
- 1.23:1 \$/€ exchange rate
- Sensitivities to fuel price, capital cost, discount rate and load factor were assessed
- CO₂ transport and storage are excluded (Adds approximately 0.5c/kWh for gas and 1c/kWh for coal to overall cost of CCS)



Power generation costs





Cost-reduction potential: conclusions of IEAGHG study

- Cost of electricity with CO₂ capture is predicted to decrease by 10-18% after installation of 100 GW
- Overall electricity costs are dominated by costs of technologies already used on a large scale
 - Gas turbine combined cycles, coal boilers etc.
- Cost of capture predicted to decrease by 13-40%
- Post combustion capture has the greatest potential reduction in capture cost
- IGCC has a slightly greater overall reduction in electricity cost
 - Cost reduction for gasifier is greater than for boilers

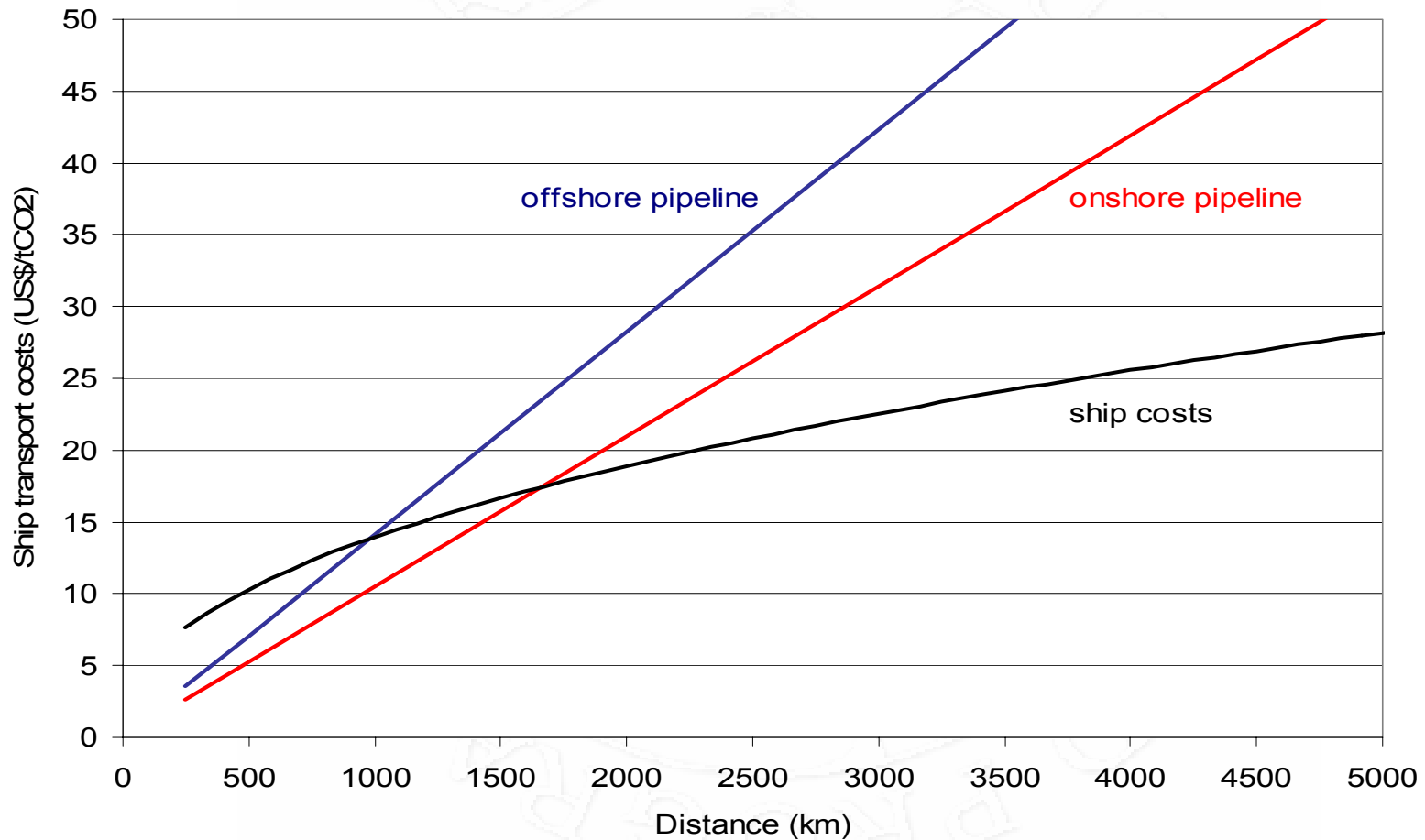


CO₂ capture: summary

- CO₂ can be captured using 'existing' technology
 - 3 options to chose from
- Capture technology needs to be demonstrated at larger scales
- CO₂ capture reduces power plant efficiency by about 6-11 percentage points
- Cost of capture is about 1-3 US cents/kWh, excluding storage (\$20-60/t CO₂-avoided)
- Cost-reduction likely from learning-by-doing



CO₂ transmission: costs





Pipeline transmission: status

- CO₂ pipeline transmission is well established
 - Large CO₂ pipelines have been in use since the early 1970s
 - CO₂ supplied for enhanced oil recovery
 - About 4000 km in use today
 - Most pipelines are in the USA (Texas/New Mexico)
 - Most of the CO₂ is from natural sources
 - Individual pipeline capacities up to 20 Mt/y



Weyburn Pipeline



- USA to Canada
- CO₂ from coal gasification used for enhanced oil recovery
- CO₂ about 1% H₂S and traces of other sulphur compounds, including mercaptans
 - Good for detecting small leaks



Shipping CO₂ by tanker



CO₂ tanker



LPG tanker

- CO₂ tankers:
 - CO₂ transported as a liquid (>6 bar, <-55C)
 - Construction similar to LPG tankers
 - Attractive for long distances

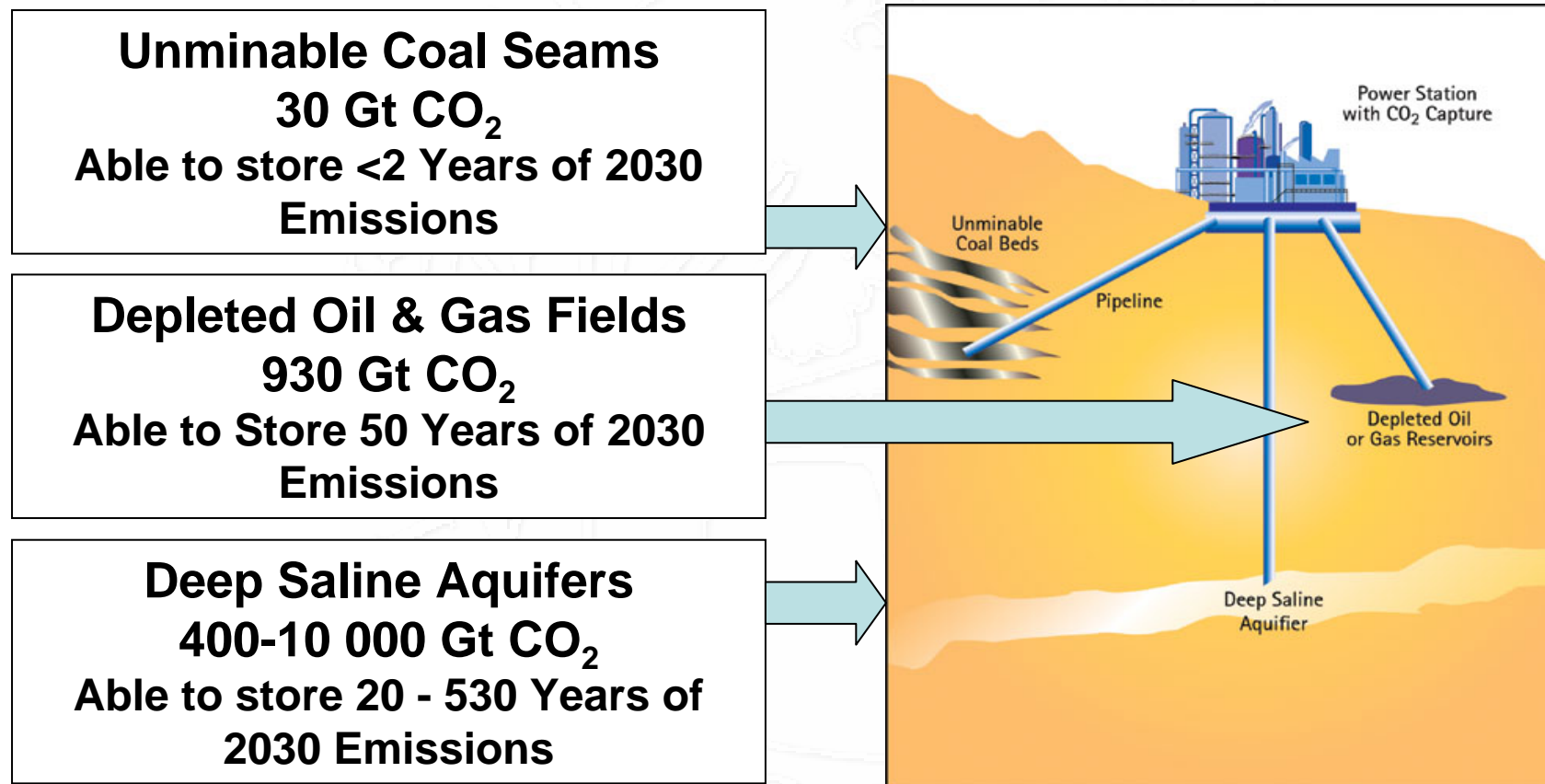


CO₂ transmission: summary

- CO₂ pipeline transmission is well established
- Existing pipelines have a good safety record
- Ships can be attractive for long distance transport
- Costs <10\$/tCO₂ if the source is within 500km of the store



Geological storage: Options



Note: CO₂ Storage capacity at cost of 20 US \$ per tonne of CO₂



Geological storage: commercial-scale operations



Sleipner



Snøhvit



Weyburn

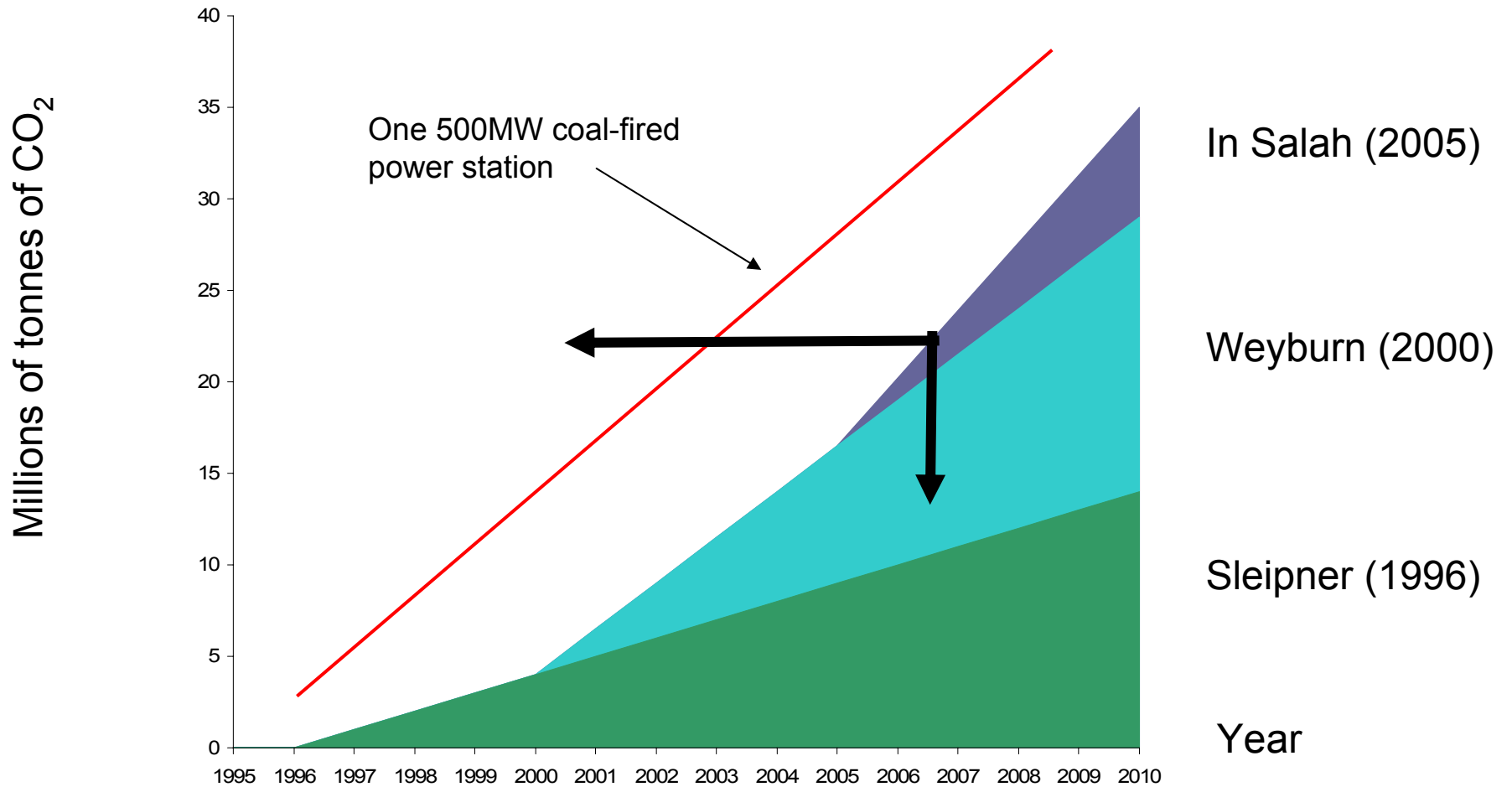


In-Salah

Images Courtesy of BP, Statoil, and PTRC



Monitored CO₂ Stored Underground





Costs of storage (US\$/tCO₂)

Storage formation	IEA GHG results for Europe	IEA GHG results for North America	Range from IPCC SRCCS
Saline aquifer	2	12	0.2 – 12
Depleted gas field	3	12	0.5 – 12.2
Depleted oil field	3	17	0.5 – 4

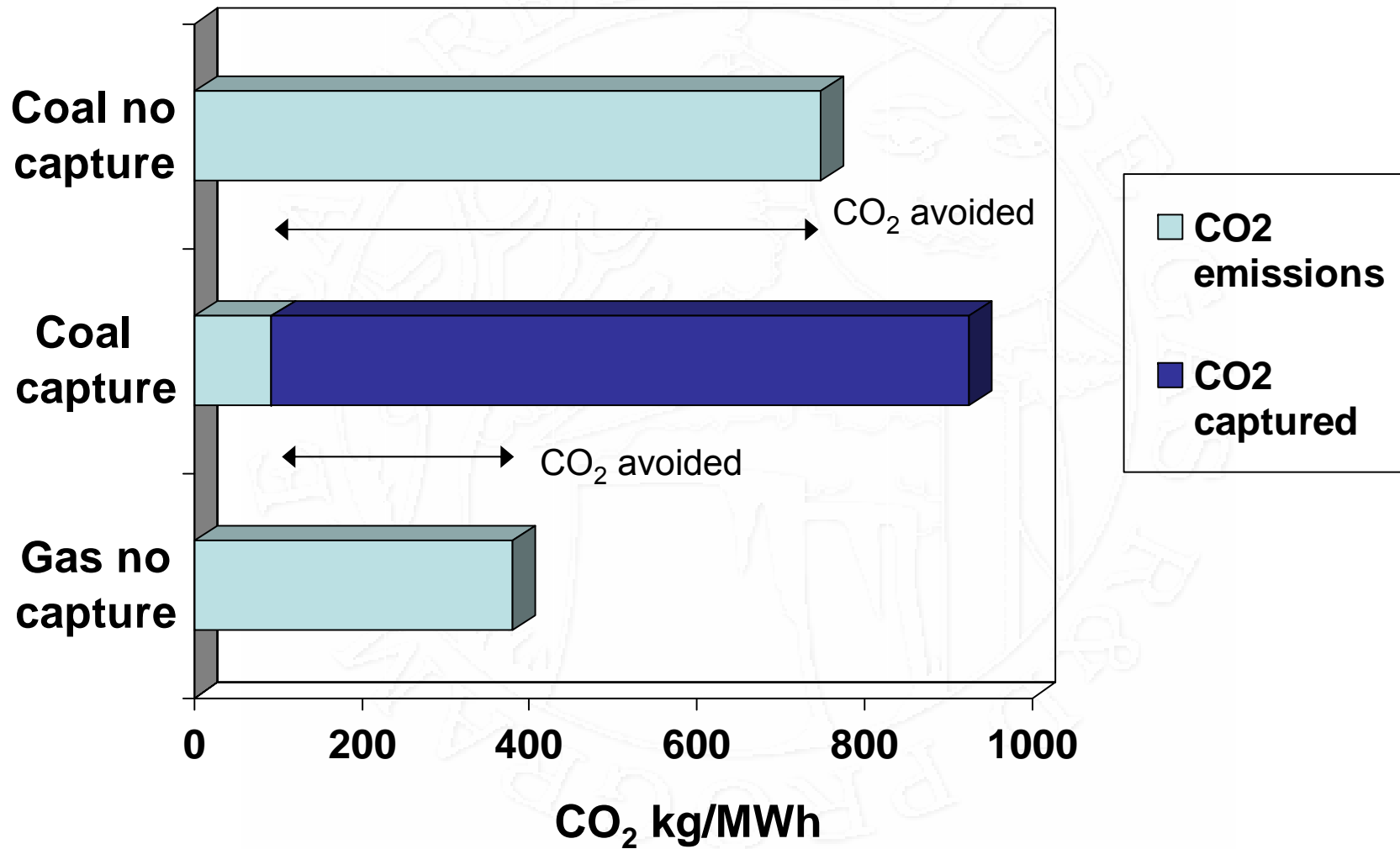


Geological storage: summary

- Demonstration of storage more advanced than demonstration of capture
- Confidence more of an issue than cost
- Key issues:
 - Permitting/Licensing
 - Long term liability
 - Environmental Impact Assessment
 - Monitoring requirements
 - Remediation practises



CO₂ Produced and Avoided





Cost summary: For CO₂ Supply

	US\$/tonne CO ₂
Capture at power station	25-35
Transmission	5-10
Storage	5-10

Overall Cost of CO₂ from CCS is about 35 - 55 US\$/tonne CO₂

Cost of 'early opportunity' CO₂ could be about 20 US\$/tonne



A route to wide-spread application

- **Target for wide-spread application:** Power generation – coal – deep saline aquifers
 - **Introduce** the technology – using near-term opportunities
 - ‘cheap’ CO₂
 - EOR
 - Financial instruments (Kyoto, CDM, JI, ETS)
 - **Establish** the technology- by demonstration and development
 - International co-operation & funding
 - Establishing a value-chain
 - Infrastructure use and development
 - **Apply** the technology – through fuel supplier-user equity
 - Carbon management
 - Allocation of responsibility for carbon between supplier and user
 - Supply security
 - capture-ready power generation



CONCLUSIONS

- The costs of CCS are not excessive and can be reduced by application of the technology.
- The main potential for cost-reduction is in the capture step.
- Confidence in geological storage needs consolidating.
- Demonstrations needed; particularly of capture at power stations.
- A road-map to commercial application is required.



IEA Greenhouse Gas R&D Programme



IEA GHG thanks you for your attention



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