# Managing uncertainty across the Clean Coal value chain

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# CO$_2$, not other pollutants, is the current coal story

## Clean coal

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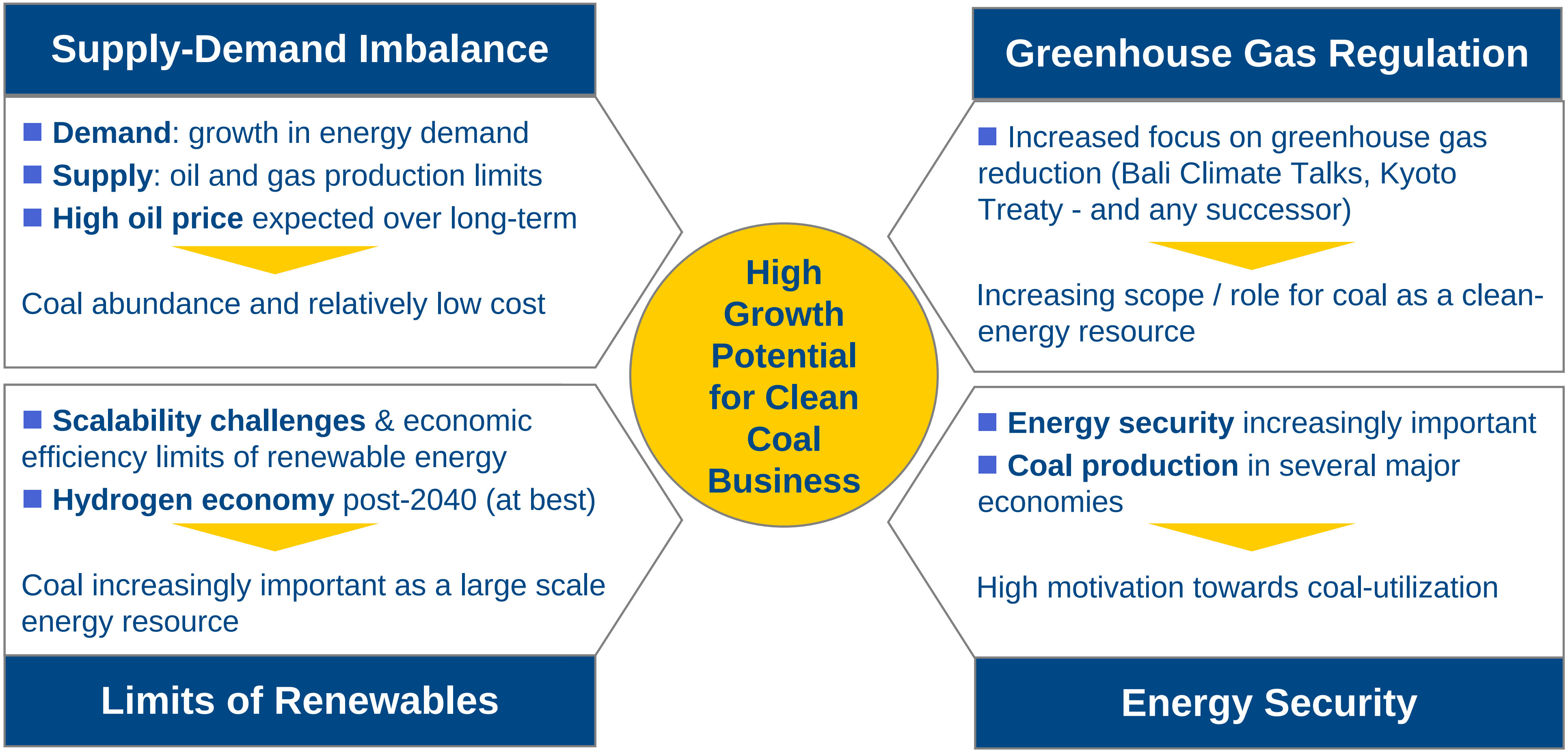
## Why is coal important ? Development and use of Clean Coal generation capacity is being driven by a range of complementary factors



### Supply-Demand Imbalance

- **Demand**: growth in energy demand
- **Supply**: oil and gas production limits
- **High oil price** expected over long-term

Coal abundance and relatively low cost

### Greenhouse Gas Regulation

- Increased focus on greenhouse gas reduction (Bali Climate Talks, Kyoto Treaty - and any successor)

Increasing scope / role for coal as a clean-energy resource

### Limits of Renewables

- **Scalability challenges** & economic efficiency limits of renewable energy
- **Hydrogen economy** post-2040 (at best)

Coal increasingly important as a large scale energy resource

### Energy Security

- **Energy security** increasingly important
- **Coal production** in several major economies

High motivation towards coal-utilization

**High Growth Potential for Clean Coal Business**

Source: ADL Analysis

# There are many commercial scale Carbon Capture projects worldwide planned / operating

## Europe excl. UK

1 Sleipner gas field, Statoil, North Sea, First large scale offshore $CO_2$ removal

2 Castor $CO_2$ capture pilot plant, Esbjerg power plant, Denmark, Capacity: 1t$CO_2$/h 5000Nm3/h flue gas. In operation since early 2006

3 Hydro, 400 MW by 2011

4 Hammerfest Natural Gas Power Plant, Hammerfest Energi, construction of a pilot 100 MW gas fired power plant with $CO_2$ and NOx capture by 2008

5 Mongstad, Statoil, 300 MW by 2014

6 RWE IGCC power plant, Germany, 400 MW by 2014

7 Vattenfall pilot plant at Cottbus- planned operation by 2010, 30MW in 2008, 250 MW in 2020

8 Draugen, Shell and Statoil, 700 MW by 2011

## UK

PCC proposals:

1 ■ RWE, Tilbury, 500 MWe (2016)

2 ■ Eon, Kingsnorth, 1 600 MWe

3 ■ Scottish & Southern Energy, Ferrybridge, 500 MWe

IGCC + CCS proposals:

4 ■ Progressive Energy, Teesside, 800 MW by 2011

5 ■ Powerfuel + Kuzbassrazrezugol, Hatfield, 800-900 MWe

6 ■ Eon, Killingholme, 450 MWe

7 ■ (Valleys Energy Ltd, Drym, South Wales, 450 MWe)

8 ■ Conoco Phillips, Immingham 450+ MWe by 2010 for CHP[1]

## Asia

1 Luzhou Natural Gas Chemicals, China, Captured $CO_2$ (160 t/d)

2 The Indo Gulf Fertilizer Company Plant, India

3 Kedah, Malaysia

4 Mitsubishi Plant, Petronas Fertilizer Co, Nagasaki, Japan

5 IHI Callide, Aioi, Japan, 1,2 MWt

6 Sumitomo Chemicals Plant, Chiba, Japan

## North America

1 AES Shady Point, 320MWe

2 Bellingham Cogeneration Facility, Bellingham, Massachusetts, Gas-fired 320 MWe combined cycle unit

3 Warrior Run Power Plant, 180 MWe coal fired circulating fluidised bed combustor, 150 t/d of $CO_2$ captured (5%)

4 Dakota Gasification Plant, the only commercial-scale coal gasification plant in the US that manufactures natural gas

5 Fluor, Boundary Dam

6 IMC Global Inc. Soda Ash plant, Trona, a capacity of 1,3 mta soda ash

7 SaskPower, Canada, 300 MW by 2012

8 FutureGen, 275 MW by 2012

9 Lockwood IGCC, 1200 MW

## South America

1 Prosint Methanol Production Plant, Brazil

## Africa

1 In Salah, BP, Sonatrac, Algeria, $CO_2$ Geological Storage Demonstration Project

## Australia

1 Callide A, ZeroGen, Queensland, 100 MW by 2010

2 Gorgon Gas field

Source: IEA Greenhouse Gas R&D Programme, Arthur D. Little analysis; 1. Immingham may be positioned to the decline in the Hewitt Field.

# The Clean Coal value chain involves Carbon Capture and Storage from $CO_2$ production through to capture and storage

## Separation & Capture

**Post-Combustion separation**
Oxycombustion + Pulverised Coal
Advanced/supercritical pulverised coal combustion (PC or PF)

**Pre-combustion separation of $CO_2$**
Integrated Gasification & Combined Cycle

**Separation of $CO_2$ from Natural Gas**

***Separation of $CO_2$ through other processes***

## Transport & Storage

**Transportation**

Pipeline

Shipping

***$CO_2$ storage feasibility & development***

***$CO_2$ Storage***

*Mineralisation*

**$CO_2$ Storage**

Enhanced Oil Recovery (EOR)

Enhanced Gas Recovery (EGR)

Enhanced Coal-Bed Methane (ECBM)

**$CO_2$ Storage**

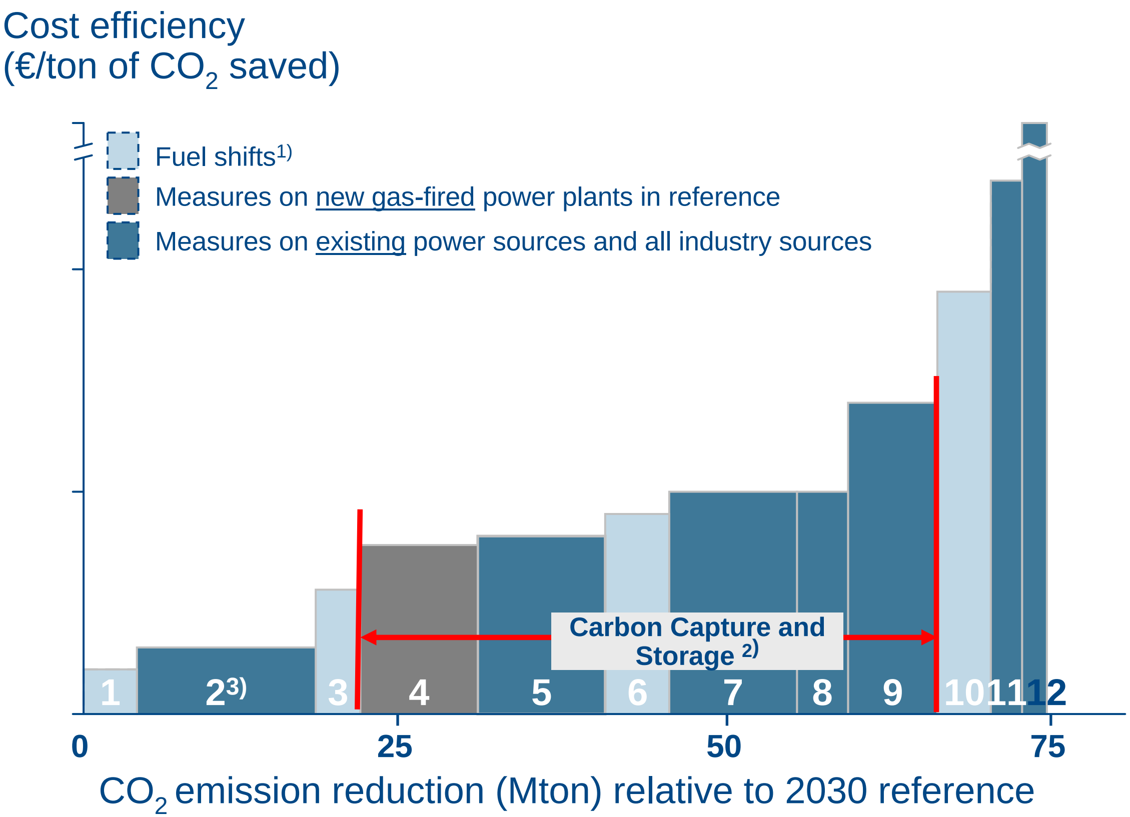
Depleted Oil / Gas field

Saline Aquifer

Note: Topics in italics are not assessed in this presentation

# Even without enhanced recovery, the CCS value chain can play a significant role in delivering European low-carbon ambitions – but at a price…

## Cost efficiency 2030, (subsidies excluded)



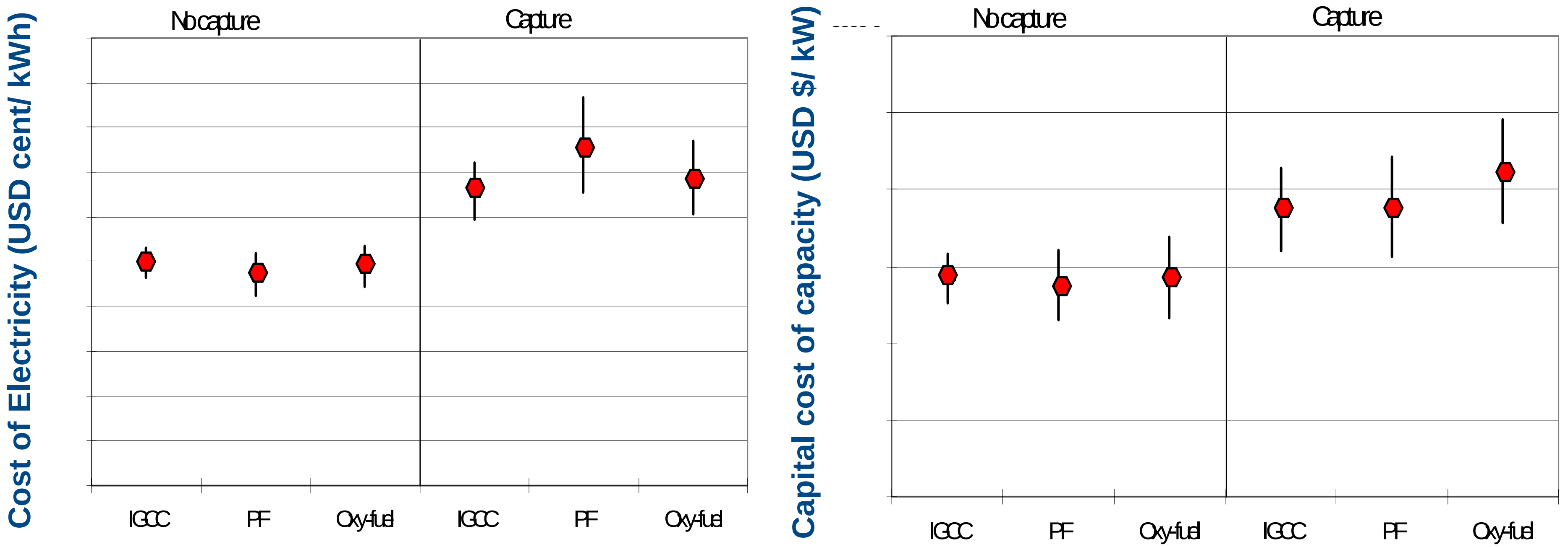
## Industrial reduction measures

1. New nuclear power plant (1000MWe)
2. Energy demand management in manufacturing industry[3)]
3. New gas power plant (1000MWe)
4. **CCS; new gas plants (4000MWe)**
5. **CCS; industry sources of non-combustion $CO_2$ refineries, ammonia)**
6. **CCS; new coal IGCC plants (1000MWe)**
7. **CCS; existing coal plants (2000MWe)**
8. **CCS; existing gas plants (2000MWe)**
9. **CCS; new large scale CHP (industry)**
10. New offshore wind (1000MWe)
11. Biomass purified co-firing (500MWe)
12. Biomass conventional co-firing (500MWe)

Source: ECN/MNP, EU IPPC BREF, Expert interviews, Arthur D. Little analysis and estimates ; These costs relate to the whole project cost (i.e. including both capture and storage)

# Whilst IGCC is more expensive than supercritical pulverised coal systems for ‘no capture’ scenarios, it is less expensive for the ‘capture’ scenario

## Coal capacity / power costs with & without $CO_2$ capture

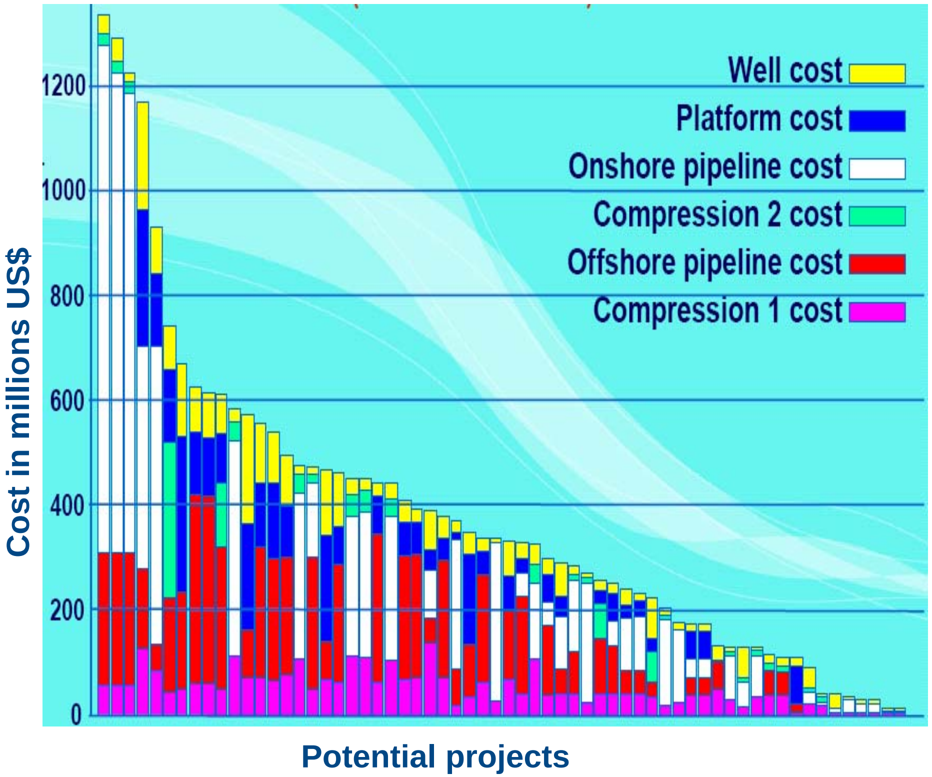


**Costs are rising due to materials price rises, risk averse contract provisions and supply capacity constraints**

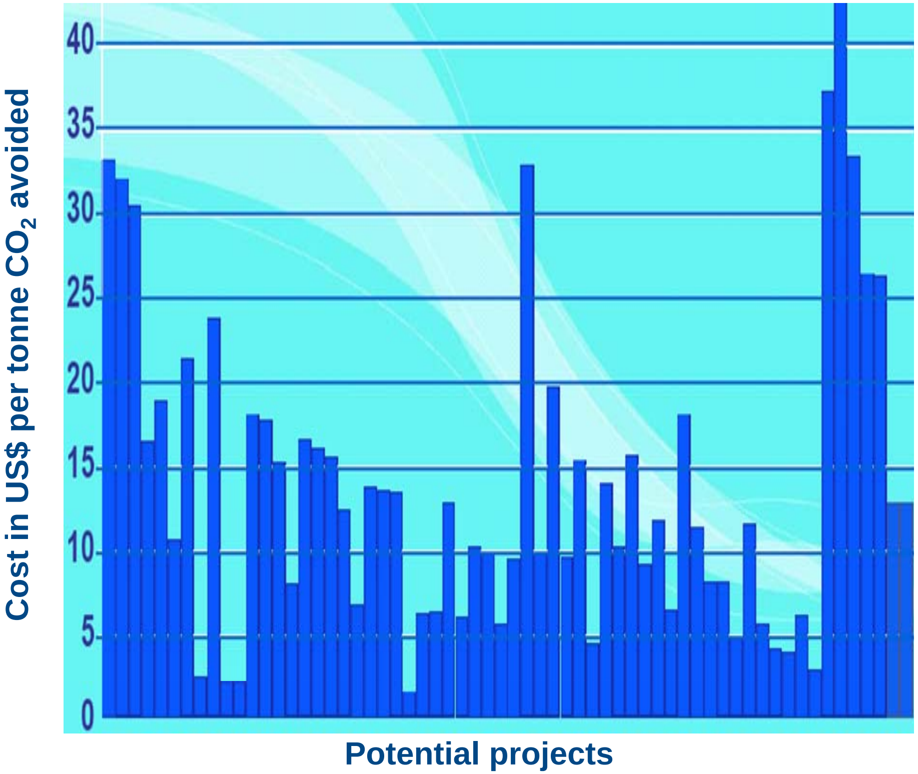
Note: These figures are the summarises of the mean and standard deviation of the economic analysis of 20 studies analysed by Arthur D. Little in 2007

# Storage Costs are highly site-specific and thus extremely variable. Proximity is a key CCS driver, with project costs being site-specific and requiring project specific analyses

## Capital costs for some potential CCS projects in Australia



## Break-even Carbon prices for a range of potential Australian CCS projects



Source: Allinson, W.G, D.N. Nguyen and J. Bradshaw, 2003: The economics of geological storage of $CO_2$ in Australia

# Project-specific analysis is necessary as field variability is high and proximity is a key CCS driver

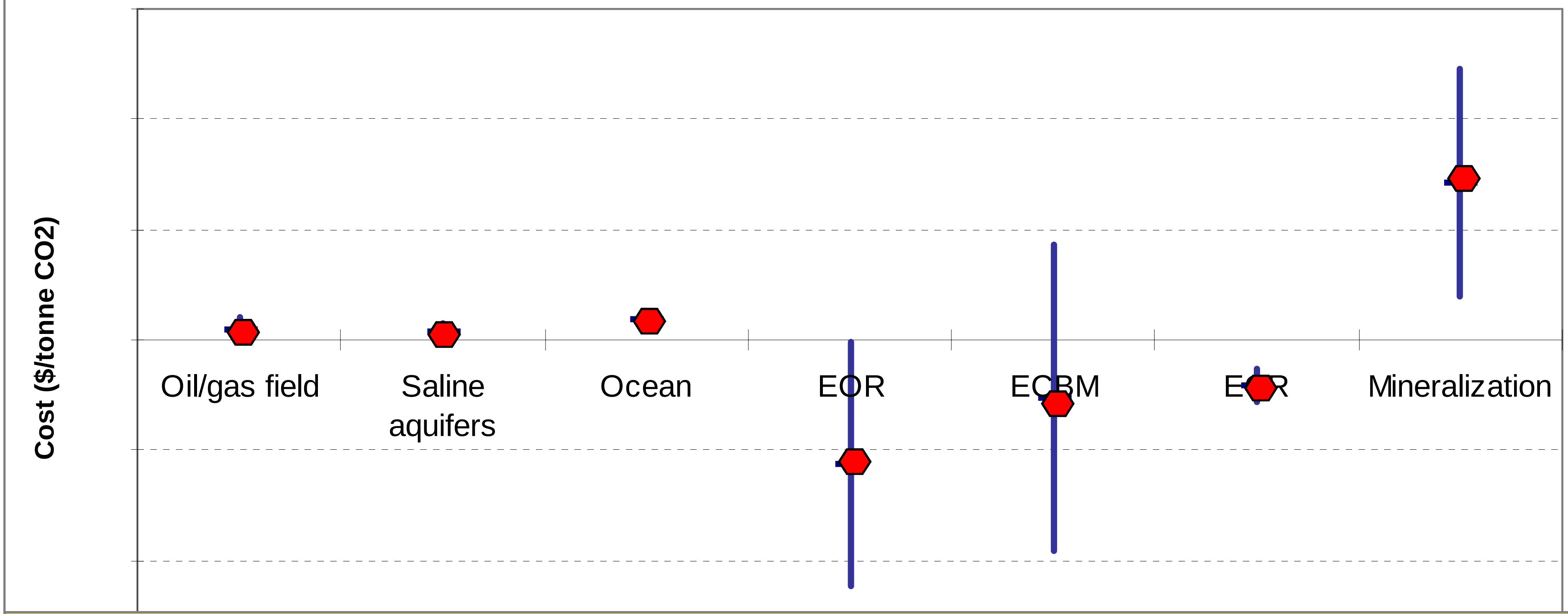
## Issues for assessing economics of transportation & storage solutions

- **Field conversion costs**
  - assess corrosion/ inhibition / metallurgy needs
  - need for replacement /upgrades of existing facilities
  - need for new wells and/or new topsides
  - timing until field abandonment
  - EOR capacity requirements and benefits
- **Transportation / gathering system viability**
  - capacity & compression needs, diameter, pressure, scalability / flexibility issues
  - quality of captured $CO_2$, contaminant content, dehydration needs
  - metallurgy issues, corrosion, difficult sourcing of appropriate pipeline materials
  - pipeline costs, ship tanker conversions, trucks
  - shortest distance from capture to sequestration
  - access to wayleaves,
  - potential locations for $CO_2$, gathering systems
  - planning & implementation time-frames
  - options for facilities sharing between fields

- **Identify field short-listing criteria**
  - Location/distance offshore, Size, current depletion status, Reservoir compartmentalisation, Physical state of existing facilities
  - Ownership issues, complexity of existing JV's
  - Pressure profiles, down-hole miscibility and permeability limits interstitial precipitation
- **A CCS strategy needs to be based on an understanding of both existing and new project specific infrastructure**

# Enhanced Oil Recovery shows the greatest potential for offsetting the significant capture, transportation and storage costs

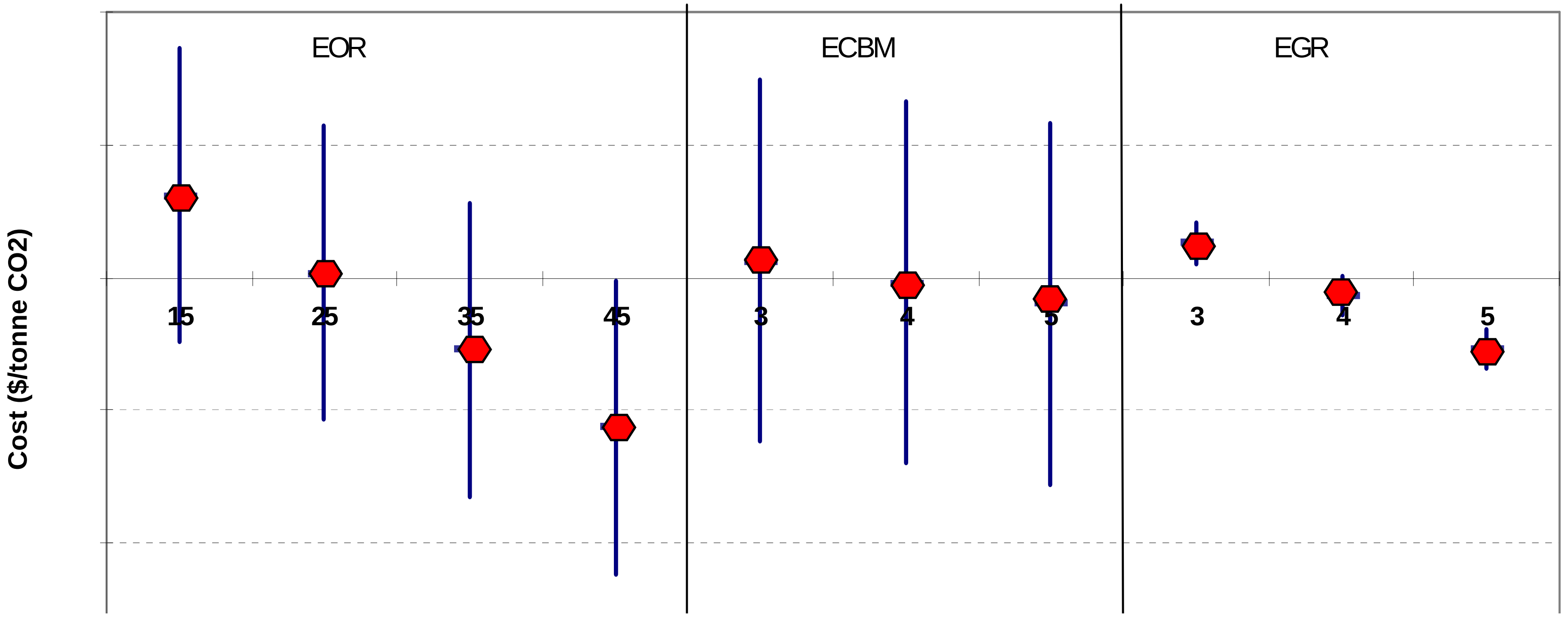
## Storage costs per tonne of $CO_2$



**The costs only reflect storage components of a CCS project driven by requirements related to Compression, Injectivity. Reservoir continuity and Monitoring.**

# Costs of value-added storage options vary significantly with Oil & Gas commodity prices

## Storage costs per tonne of $CO_2$



**The costs only reflect storage components of a CCS project**

Source: Arthur D. Little Analysis; Note: Shell recently indicated there was an incentive to harness EOR with a crude price of $35/bbl. Oil majors may be reluctant to chase small incremental yields of EOR if more profitable fields exist for development.

# Capacity bottlenecks are possible at some points along the CCS value-chain as players are limited in some areas

| | Blue Sky R&D | Front-End Engineering Design | Construction | | Operation | Decomm-issioning |
|---|---|---|---|---|---|---|
| **Power Plant** | 8 | 19 | c 8<br>s 18<br>I 15 | 41 | 9 | 2 |
| **Capture** | 14 | 18 | c 1<br>s 4<br>I 19 | 24 | 3 | 0 |
| **Transport** | 2 | 10 | c 3<br>s 4<br>I 10 | 17 | 4 | 1 |
| **Storage** | 3 | 11 | c 2<br>s 1<br>I 24 | 27 | 25 | 0 |

Key: C = component; S = Sub-system; I = Integration

ASU technology provided by less than 4 companies…

… but China can copy technology such as GE/Shell gasifier

Offshore storage dominated by Oil & Gas companies

**Landscape is actively changing, with new partnerships emerging (e.g. BP and Rio Tinto; StatoilHydro, Dong, Vattenfall, Shell et al)**

# The public sector has a major role in the economic attractiveness of CCS projects

- **Incentives for RD&D** – R&D grants, tax breaks or sponsorship for demonstrations would encourage RD&D
- **Carbon credits** - To be commercially attractive, carbon credits need to be legally recognised as $CO_2$ abatement rather than just storage
- **Longevity and clarity of CCS policies**: investors want to be reassured that a future generation market is likely to favour low carbon technologies.
- **Revenue streams from value-added storage** – A concession on the royalty for recovered oil would help to initiate CCS since governments would stand to gain substantial revenues that would not accrue without EOR
- **Government based reward schemes** –alterations to the tax regime or subsidies based on national aims for carbon emissions
- **Wider public awareness and acceptance** of safety implications of $CO_2$ storage
- **Risk sharing** - a commercial risk sharing framework needed between Government, oil companies and utilities. If the carbon price is locked into the ETS without recognising the volatility of the scheme and allocation process, the installation of capture technology is less likely to be bankable.
- **Regulatory risks** especially those associated with environmental legislation needs to be considered (e.g. offshore: OSPAR and London regulations; onshore: Local planning and environmental regulations). Stored $CO_2$ ownership also need to be resolved