CARBON CAPTURE AND STORAGE

The Economics of CCS Projects

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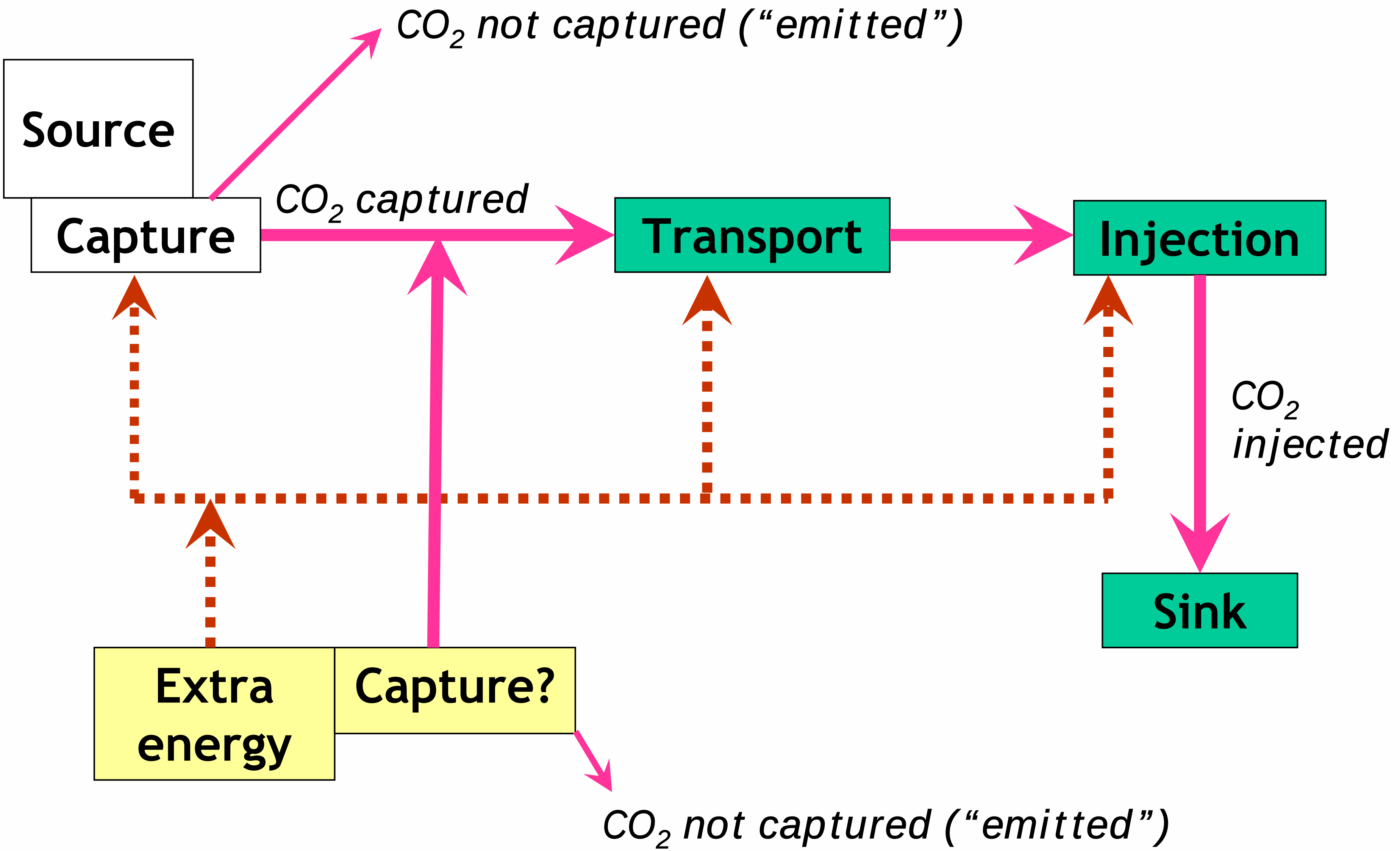
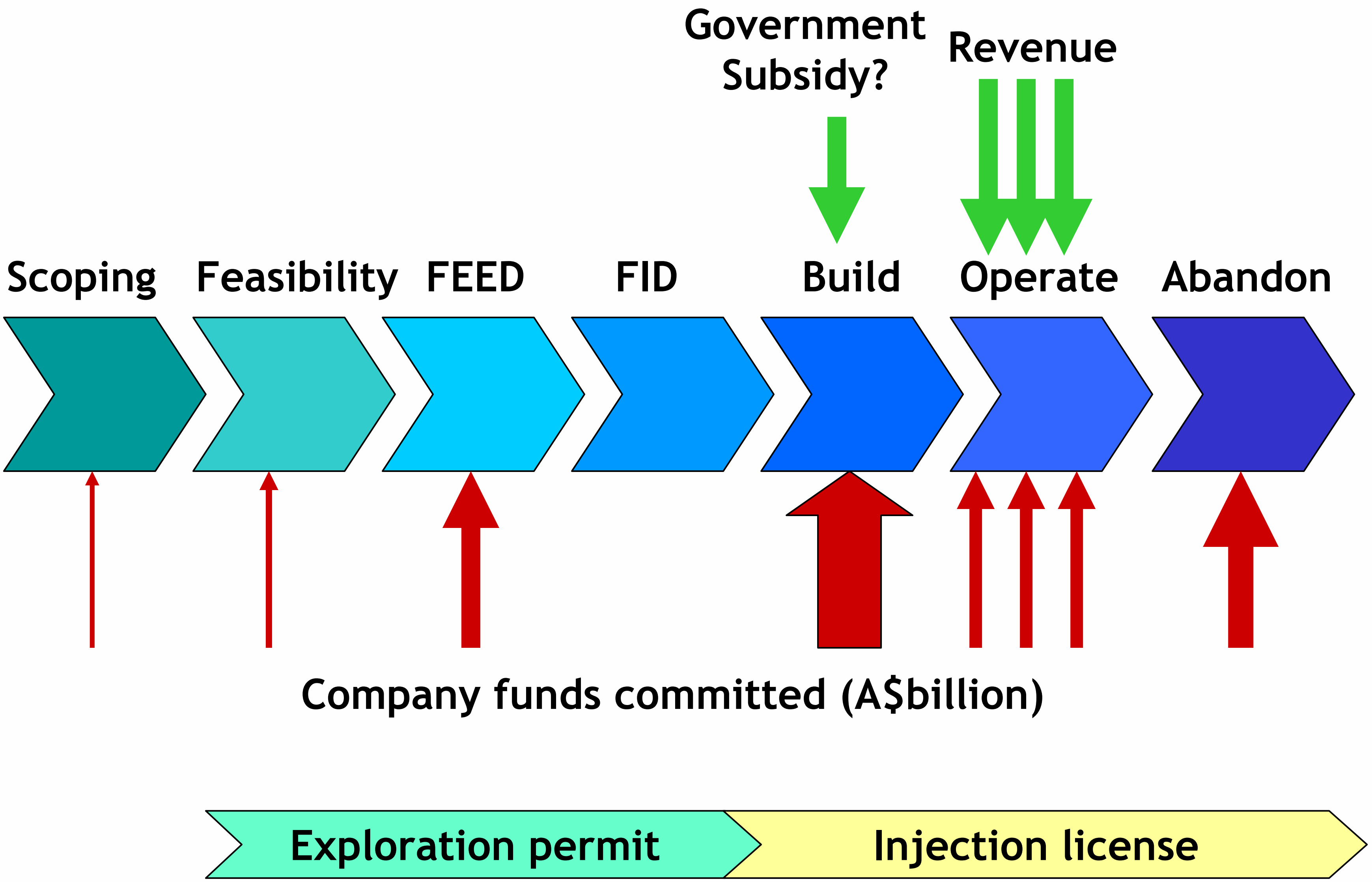
CCS Project Economics

A generic CCS process



CCS Project Flowchart



Typical project cashflow

Build (2-3 yrs)	Operate (20-40 yrs)	Abandon (1+ yrs)
	Revenue (sales, credits)	
Capture plant, compressors, pipelines, platforms purchased and installed; wells drilled.	Energy, replacement chemicals, cooling water, fixed operations and maintenance, insurance, monitoring, remediation of existing wells.	Ongoing monitoring, site remediation, platform removal.
	Government Take	
Net Cash Flow		

Government Take

Effects of

- Corporate income tax
- Royalty
- Resource rent tax

Resolved by legislation

CCS Project Metrics

In addition to common investment decision tools (NPV, IRR, etc.)

CO_2 avoided

Measures a CCS process' effectiveness at reducing CO_2 emissions

It is defined as:

CO_2 emitted without CCS

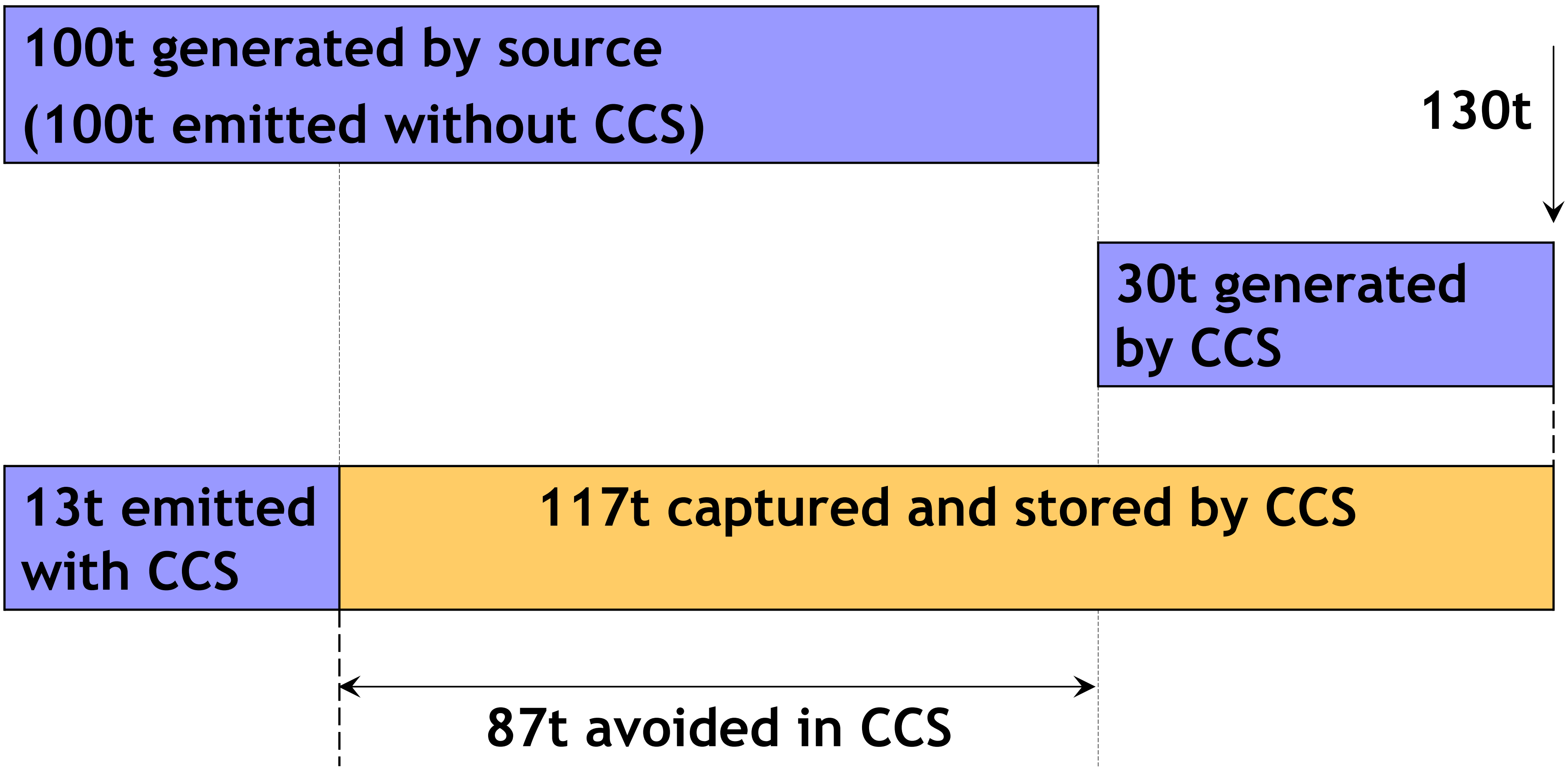
less

CO_2 emitted with CCS

equals

CO_2 avoided

CO_2 avoided


100t generated by source
(100t emitted without CCS)
130t
30t generated by CCS
13t emitted with CCS
117t captured and stored by CCS
87t avoided in CCS

Specific Cost of CO_2 Avoided (A$/t)

- Standard industry-independent metric for comparing projects
- Could be calculated with annualized capital
- Simpler using PV of NCF and CO_2 Avoided
- = break-even price of carbon

$$\text{Specific Cost of } CO_2 \text{ Avoided} = \frac{\text{PV of all costs}}{\text{PV of } CO_2 \text{ Avoided}}$$

Change in Cost of Net Electricity Sent Out (A$/MWh)

- Commonly used in regard to power stations
- Change in cost of generating the electricity sent out to grid

Change in Cost of Net Electricity Sent Out	=	Cost of Net Electricity Sent Out with CCS	–	Cost of Net Electricity Sent Out without CCS

Case Studies

Case Study Assumptions

- NGCC for additional power
- 7% real discount rate
- A$ (2004/5/6)
  - being updated to Q2/3 2007
- Operates 85% of year
- Costs before tax

Case study 1: Perth network

Capital and operating costs
The effect of storage site and transport distance

Allinson, W.G., Dunsmore, R.E., Neal, P.R., Ho, M.T.; "The Cost of Carbon Capture and Storage in the Perth Region", In *Proceedings of the 2006 SPE Asia Pacific Oil and Gas Conference and Exhibition*, Adelaide, Australia, 11-13 September 2006 (Paper #101122)

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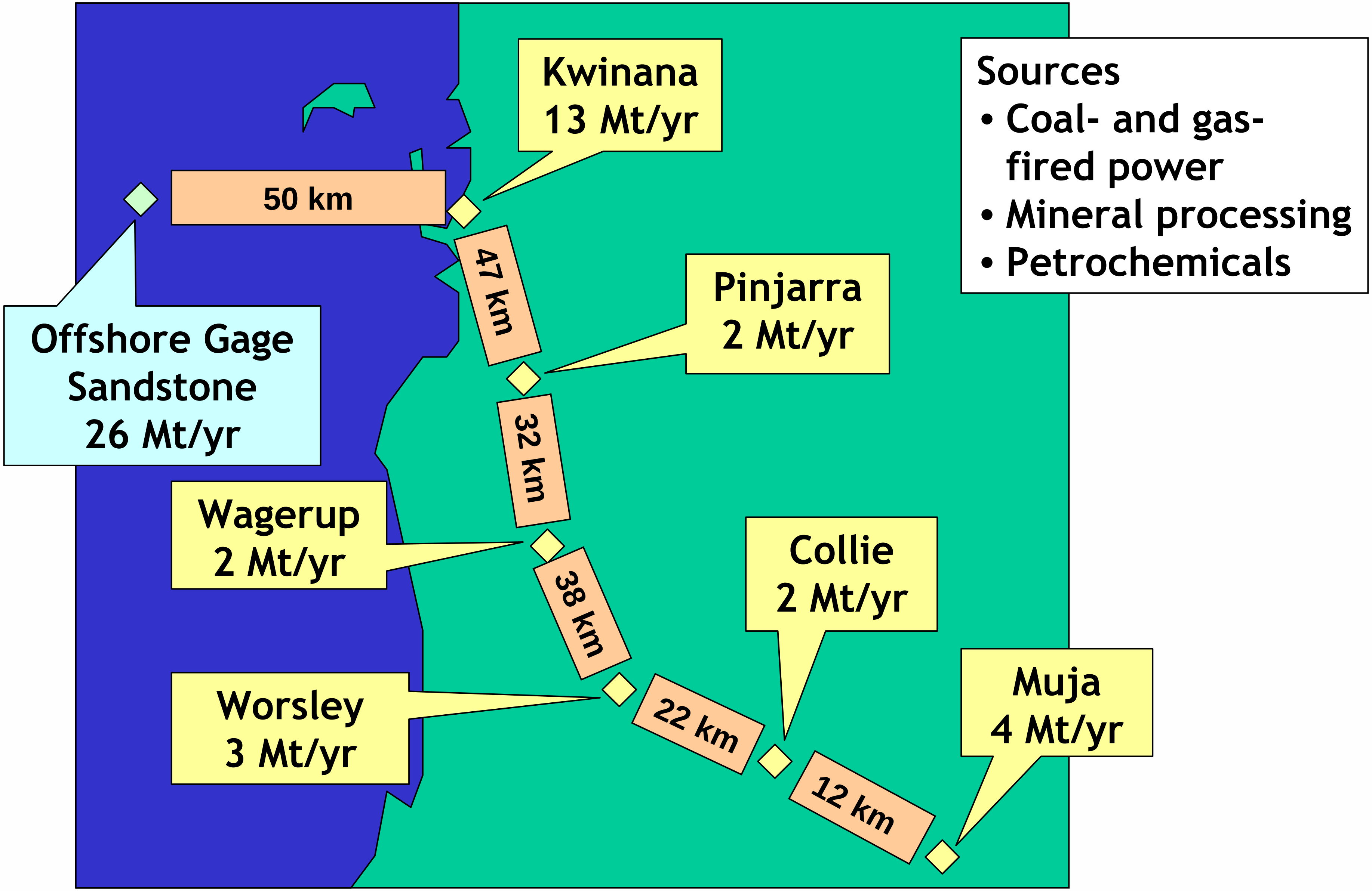
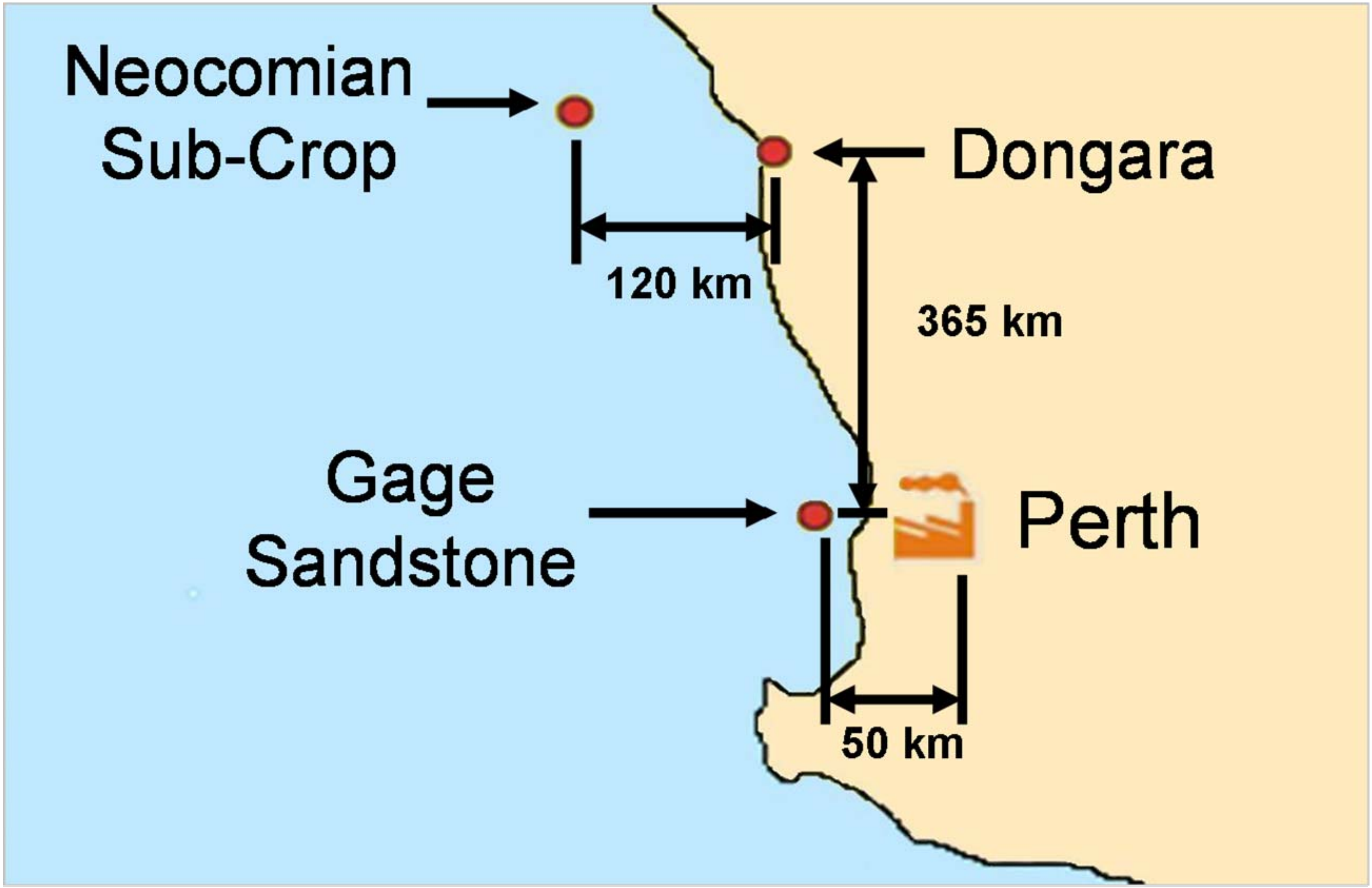
Project Map


Kwinana
13 Mt/yr
Sources
• Coal- and gas-fired power
• Mineral processing
• Petrochemicals
50 km
47 km
Pinjarra
2 Mt/yr
Offshore Gage Sandstone
26 Mt/yr
32 km
Wagerup
2 Mt/yr
38 km
Collie
2 Mt/yr
Muja
4 Mt/yr
Worsley
3 Mt/yr
22 km
12 km

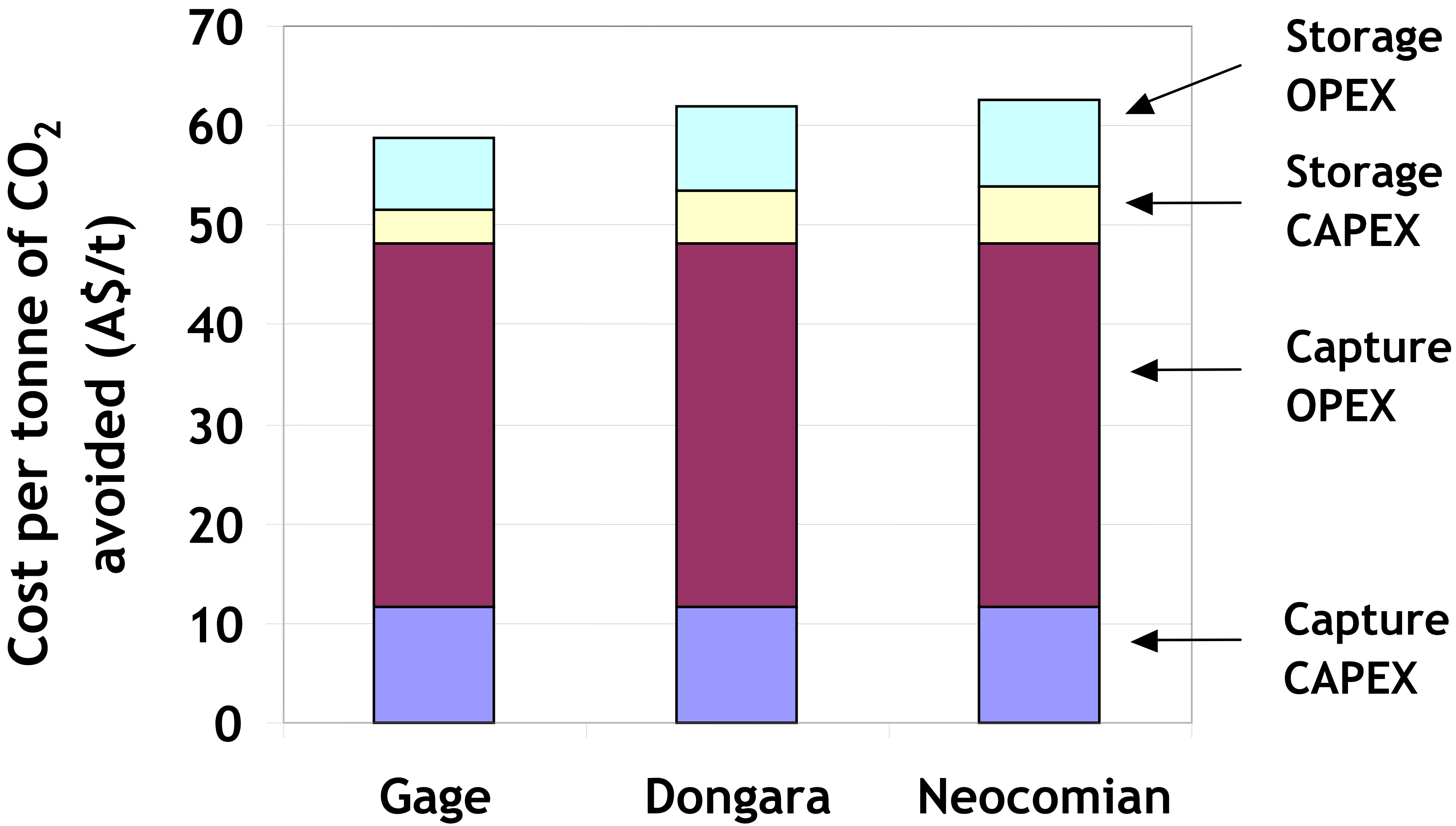
Potential Sinks



Summary of capture and storage costs

	Units	Gage	Dongara	Neocomian
CCS capital cost	A$billion	3.62	4.05	4.17
CCS operating cost	A$billion per year	0.92	0.95	0.95
Total CO_2 avoided	Million tonnes	528	527	527
Specific cost of CO_2 avoided	A$ per tonne	58.8	62.0	62.6

Cost per tonne avoided

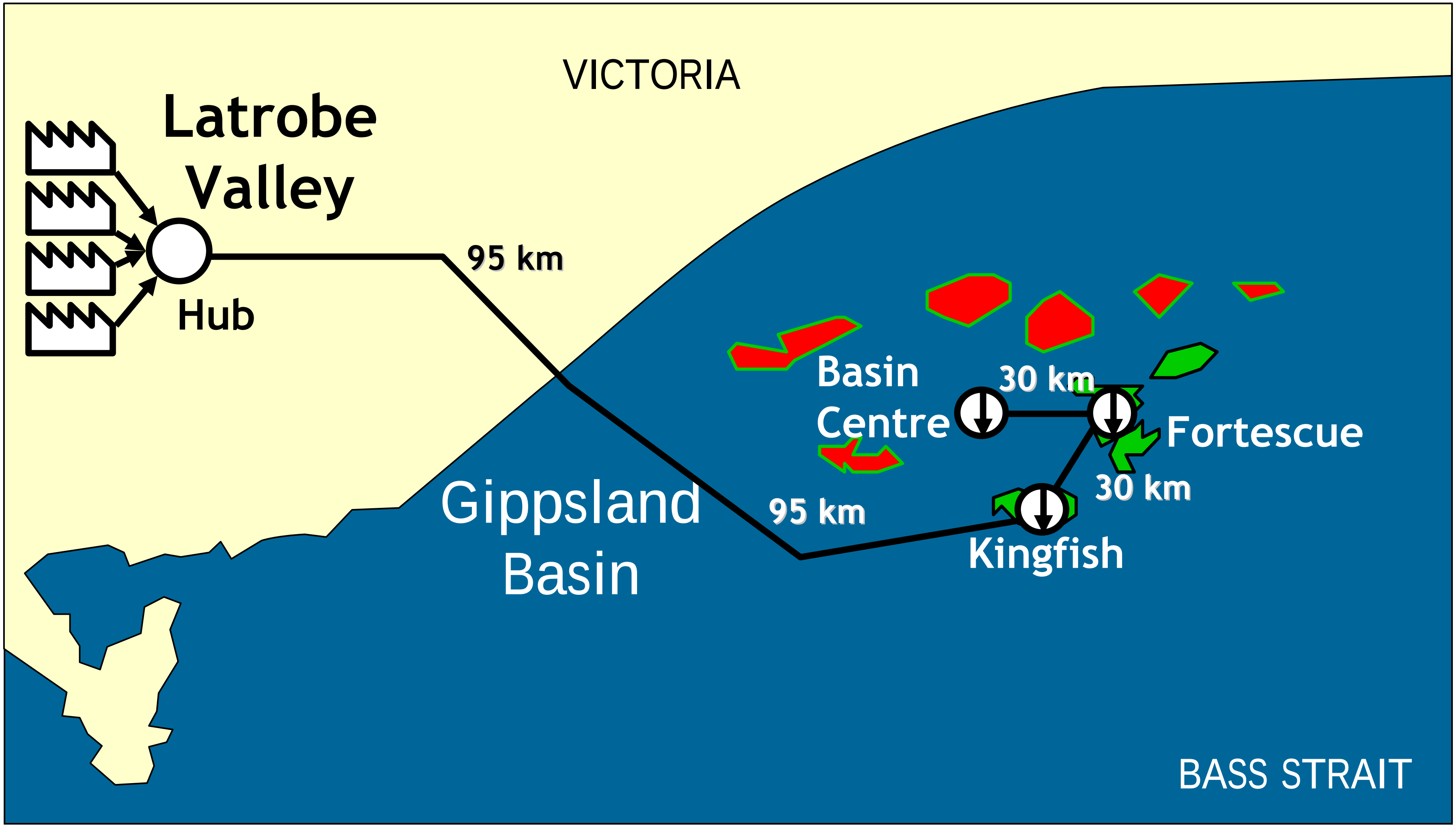


Case study 2: Latrobe Valley

The effect of throughput, permeability and well type

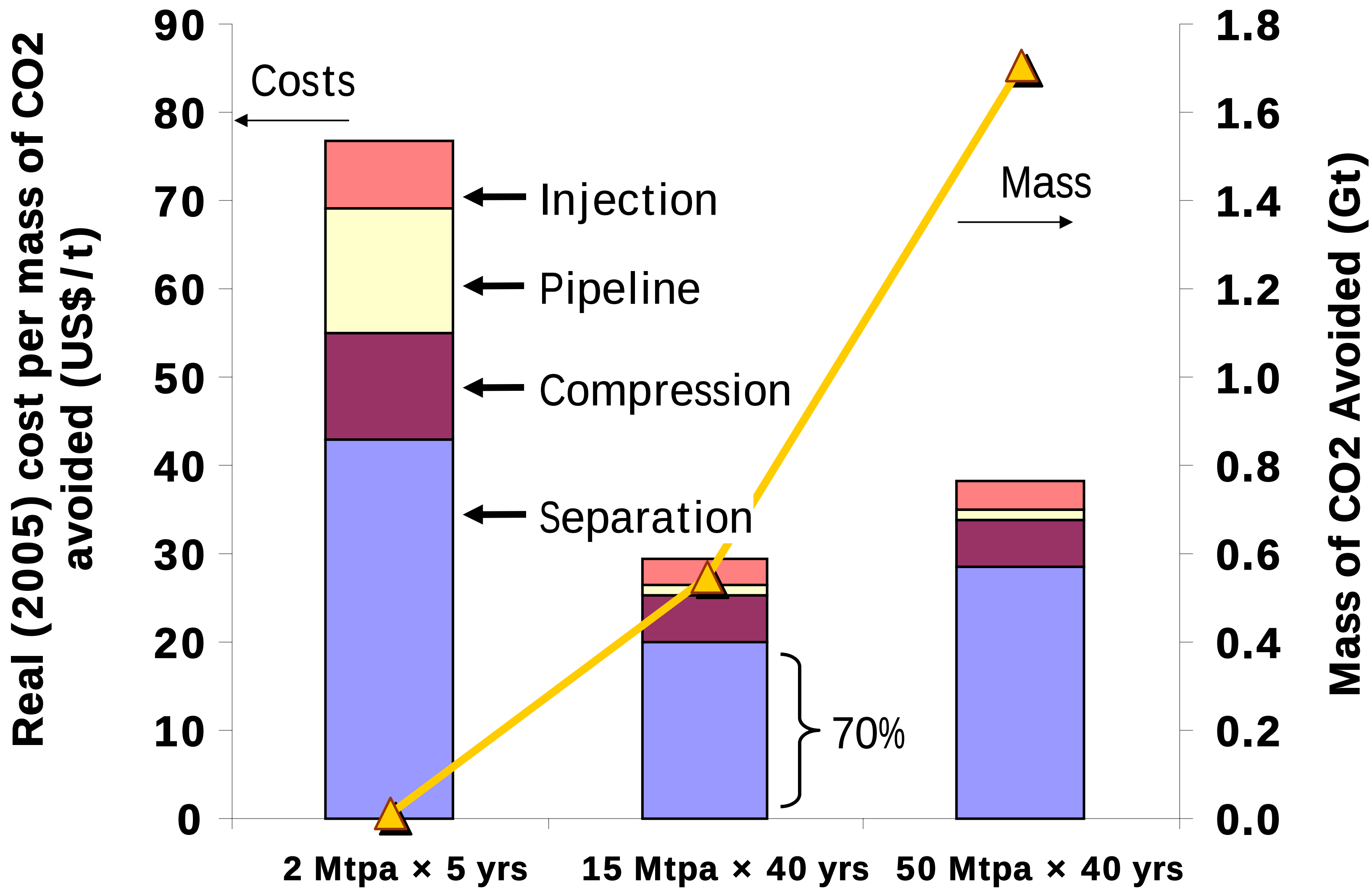
Neal, P.R., Ho, M.T., Dunsmore, R.E., Allinson, W.G., McKee, G.A.; "The economics of carbon capture and storage in the Latrobe Valley, Victoria, Australia", In ***Proceedings of the 8th International Conference on Greenhouse Gas Control Technology*****, Trondheim, Norway, 19-22 June 2006 (Paper #192)**

Project Map

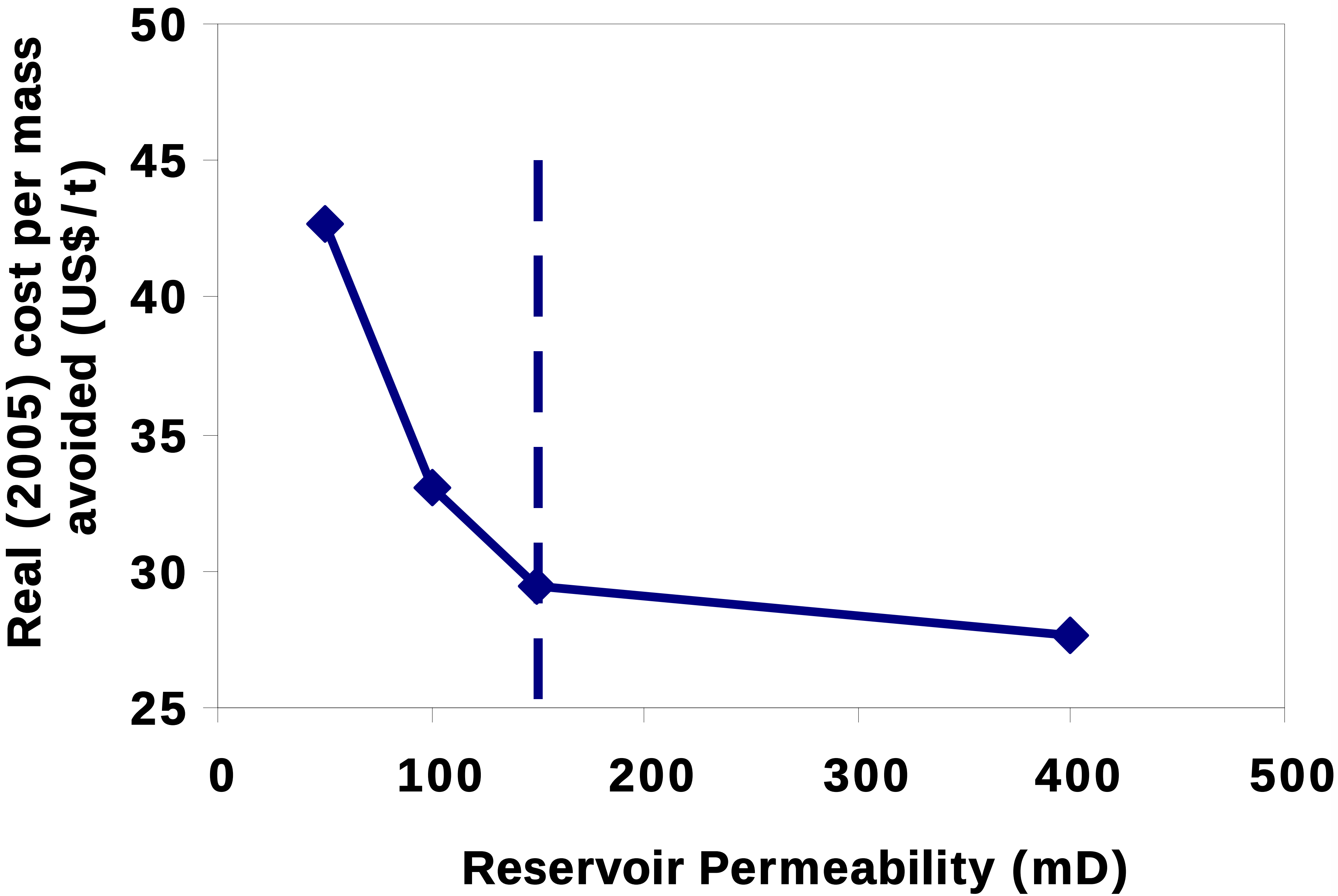


- Operates for 40 years

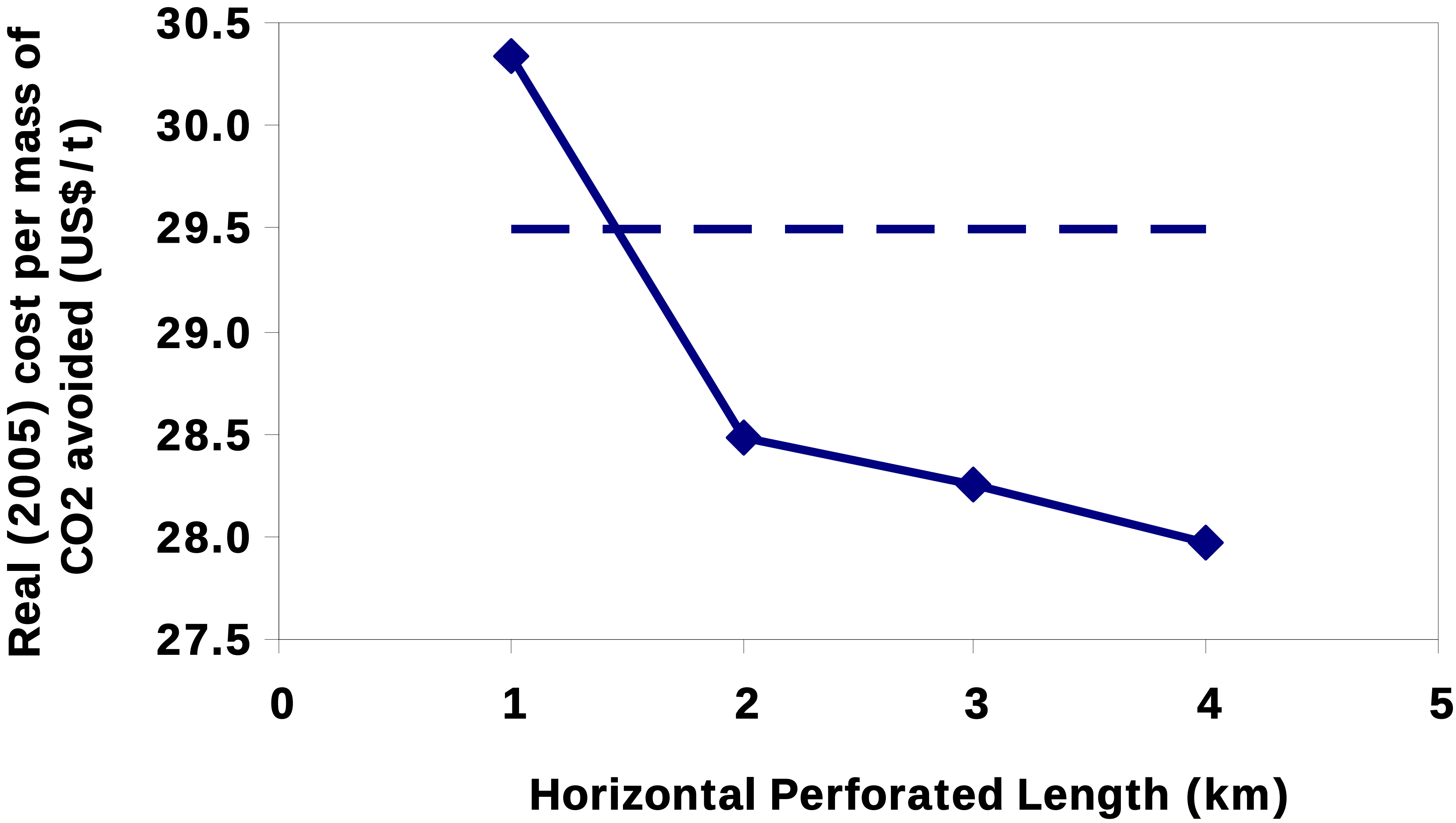
Base Case US$/t Avoided



Sensitivity to permeability for 15 Mtpa Case



Sensitivity – Horizontal wells for 15 Mtpa Case



The challenge of CCS Networks

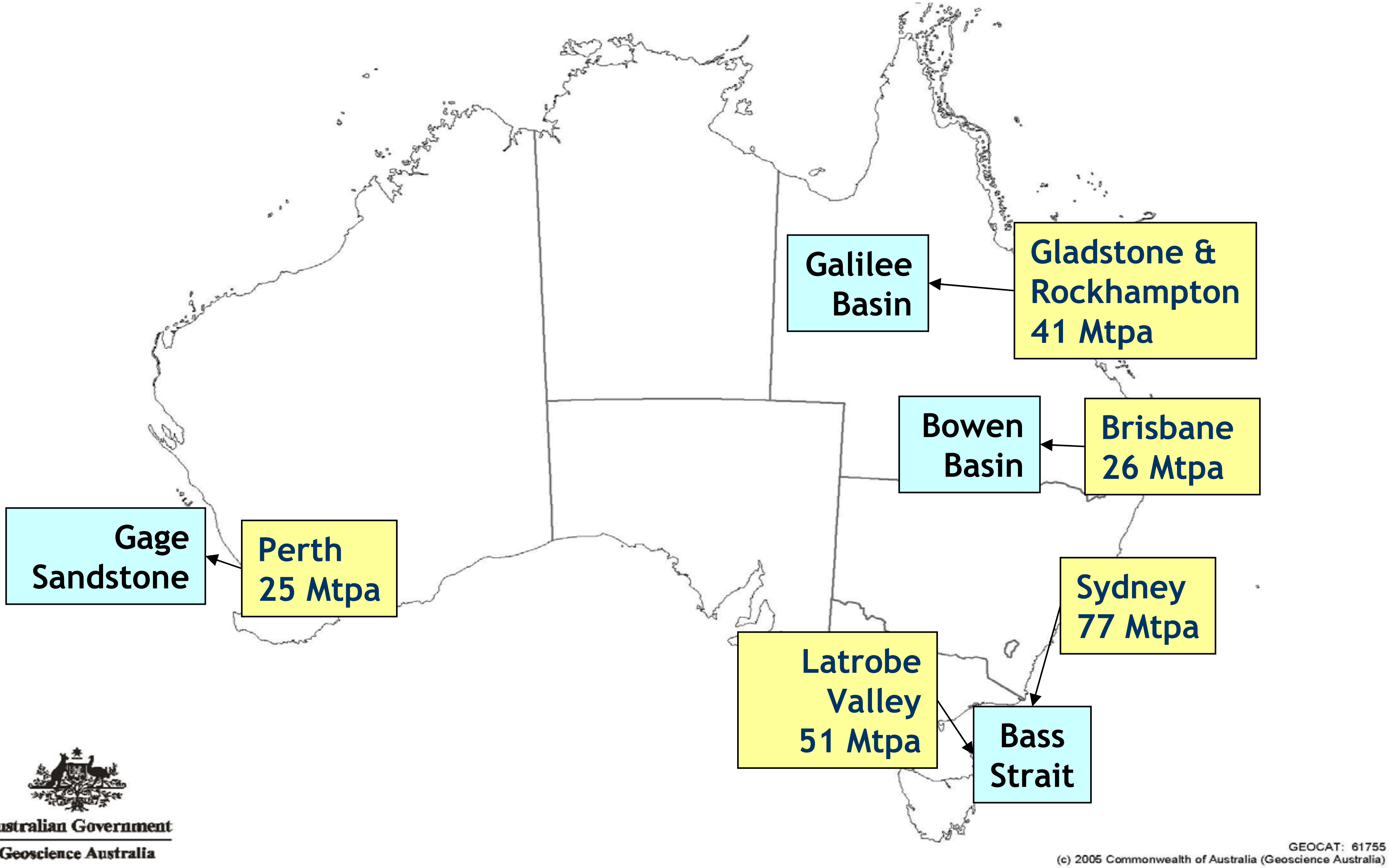
A rough sketch

Neal, P.R., "The Economics of CCS Networks", Presented at SPE Applied Technology Workshop (ATW) "Capture and Geological Storage of CO2", Perth, Australia, 7-10 October 2007

The scale is significant

- An example case
- VERY much a scoping study (order of magnitude)
- Using current costs of current technology
- Retrofit all power and some industrial sources
- Point sources ≥ 0.5 Mt/yr
- Solvent-absorption capture (MEA)
- Max pipeline pressure 186 bar (2,700 psi)
- Max pipeline diameter 1.1 m (42”)
- 3 years build, 25 years operate, 1 year abandon
- Additional power from NGCC+CCS

The scale is significant (example case)



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Scale challenges

- 12 Bscf/day = CO_2 captured & stored (231 Mt/yr)
  4.2 Bscf/day = Australian nat gas production ('06)

- 195 Mt/yr = CO2 avoided (~10 Bscf/day)
  34% of total emissions (565 Mt/yr, 12 Bscf/day)

- 14.6 GW of extra power required
  29.3 GW = existing capacity

Note: 1 Bscf = 1 billion cubic feet of CO_2 at 15°C & 1 atm

Commodity challenges

- Line pipe steel
  - Required 2.25 Mt
  - Produced <100 kt (Australia)
- Using very high grade steel and 'the boom'
- Solvent quantities
- Volumes of water for cooling
- Natural gas for power
  - Extra required 1.9 Bscf/day
  - Australian production 4.2 Bscf/day (2006)

Equipment/technology challenges

- Very large compressors (up to 23 kt/day)
- Equipment lifetime (25-30 yrs)
  vs. source lifetime (40-60 yrs)
- Ensure there is enough pore space

Economic challenges

- Australia's storage reserves are currently zero
  Reserves = f(volume, injectivity, economics)
- Cost not measured in $MM or $Bn
  But %GDP (Australia's GDP >A$ 910 Bn)
- Total initial CAPEX ~A$ 90 Bn
  That's ~10% of Australia's GDP (2005)
  or 3 times promised tax cuts
- Possibly spread over a decade or more
- Operating cost ~ A$ 7 Bn/yr (2005)

How to reduce costs

- There are many opportunities for cost saving
- Electricity from nat. gas / coal-gasification
- Geological assessment
- Reservoir engineering
- Capture RD&D
  - Selectivity
  - Energy demand

The challenge of CCS networks

- Approximately 34% of 2006 emissions avoided
- In this example, CCS <u>tomorrow</u> would require
  - A network handling 3 times existing NG flows
  - 50% increase in electricity generation (NGCC)
  - 45% increase in natural gas production (supply)
  - 22 times Australian linepipe production
  - Total capital ~ A$ 90 Bn (2005)
  - Operating cost ~ A$ 7 Bn/yr (2005)

Final comments

CCS costs are project specific

- Source of CO_2
- Capture technology
- Through-put of the system
- Terrain & distance between source & sink
- Onshore/offshore/water depth
- Reservoir pressure
- Reservoir permeability
- Reservoir depth

CCS costs are also uncertain

Conclusions and comments

- CCS could provide significant emission reductions
- CCS projects require large amounts of capital and operating cash
- Large CCS projects will impact commodity markets
- Uncertainties over costs, storage capacity, reservoir quality
- CCS costs are site specific
- Permeability has a strong impact on cost
- CCS costs currently A$30/t to over A$100/t
- Scope for cost reductions in capture and storage

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