CARBON DIOXIDE CAPTURE & STORAGE

RESEARCH DEVELOPMENT & DEMONSTRATION IN AUSTRALIA

A Technology Roadmap 2004

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CO2CRC

What is a Technology Roadmap?

" Technology roadmaps identify, evaluate and promote the development of collaborative projects within and between industries to fill technology gaps and/or capture technology related opportunities. " (*Scheer 2001*)

" Technology Roadmapping identifies future product, service and technology needs for industry sectors and evaluates and selects technology alternatives. " (*AusIndustry 2003*)

" Technology Roadmaps can contribute to the policy aims of Government." (DIST 2001)

Australia's CO_2 capture and storage technology roadmap…

- is provided as an example of the way in which Australian stakeholders and researchers went about establishing CCS priorities.
- will shape Australia's major RD&D direction over the next few years, but will also be regularly revisited in the light of Australia's evolving needs and international trends.
- is not a definitive text on how to produce a technology roadmap nor is it a formal policy paper outlining what Australia will do in CCS over the next 30 years.

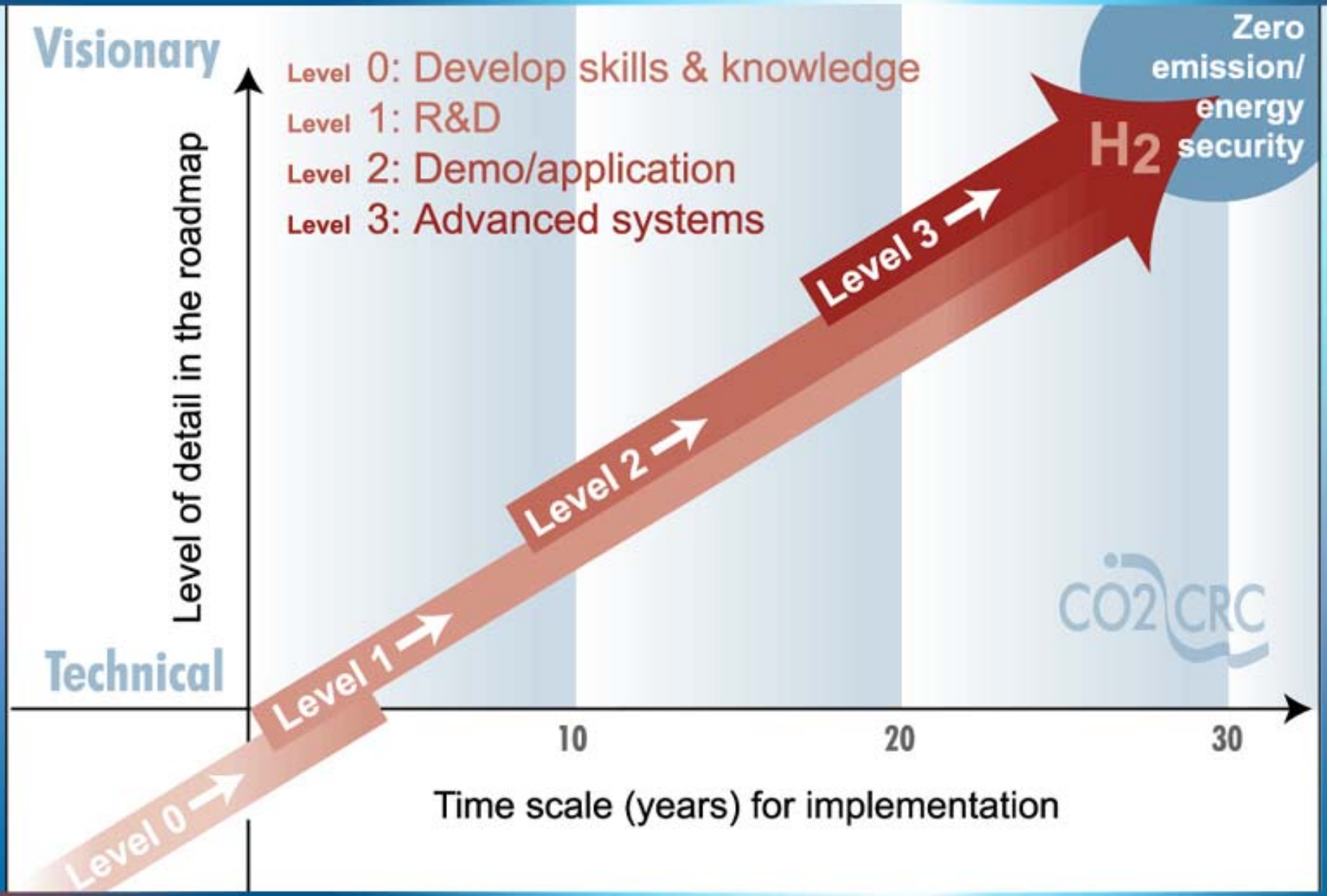
The Australian CCS Technology Roadmap has identified…

- Areas of technology strength
- Areas of technology weakness
- R&D that is of critical importance to Australia
- R&D that will be pursued
- R&D where a watching brief will be maintained
- R&D where it will seek to collaborate internationally

THE STAGES OF ROADMAPPING

CO_2 capture & storage

- Preliminary activities (Level O)
- Technology roadmap (Level 1) – the "focus"
- CO_2 capture & storage technology application roadmap (Level 2)
- CO_2 capture & storage roadmap to the hydrogen economy (Level 3)



Schema for the Australian CCS Technology Roadmap illustrating the four levels of mapping related to degree of detail and timing and commercialisation.

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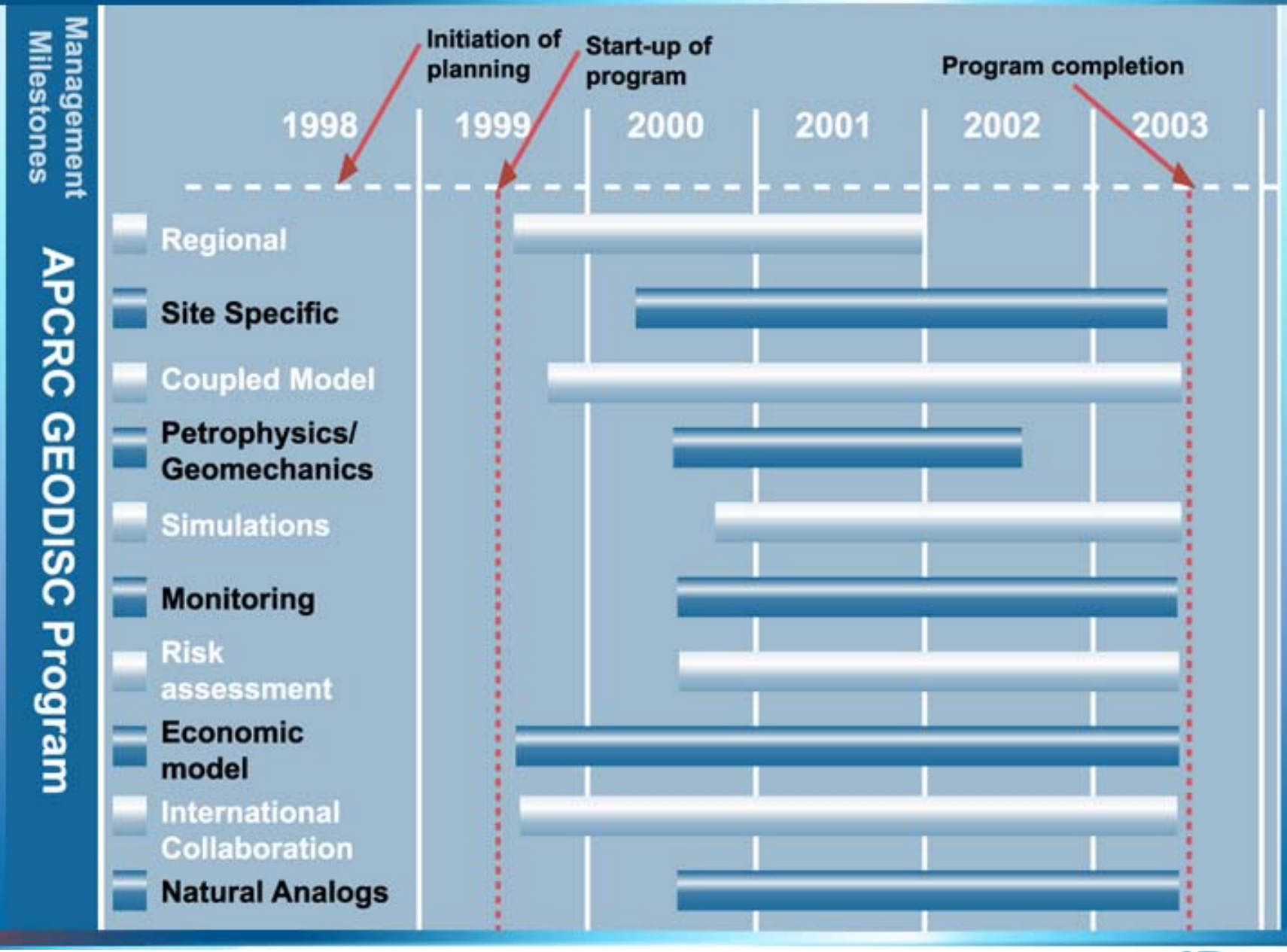
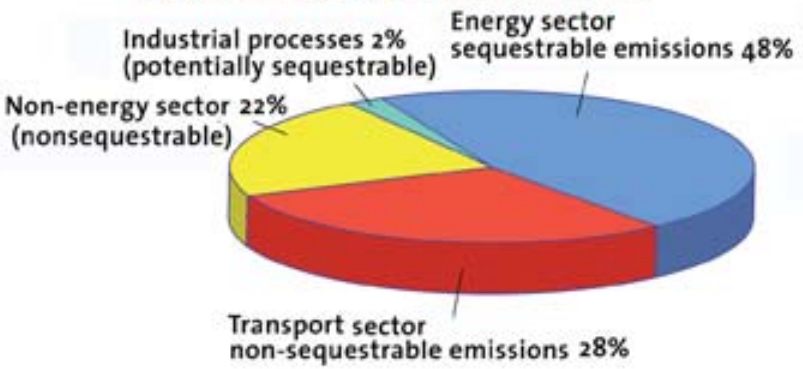
Preliminary activities (Level O)

- **Australia's CO_2 Emissions**
- **GEODISC**
- **CO2CRC**

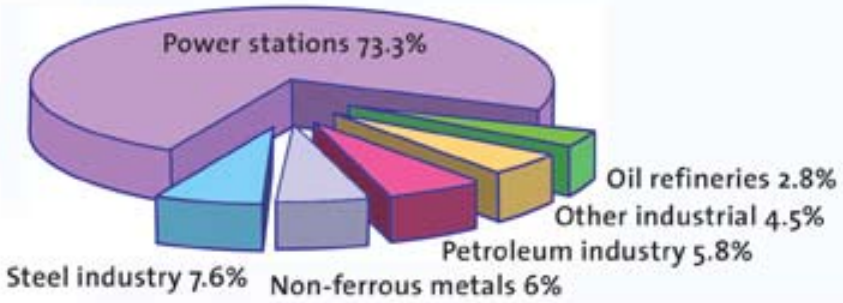


Level 0 roadmap developed for GEODISC (after Cook et al, 2000)

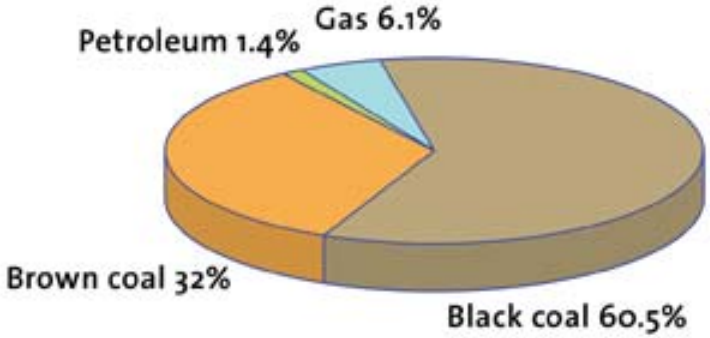
Sequestrable vs Non-sequestrable Sources



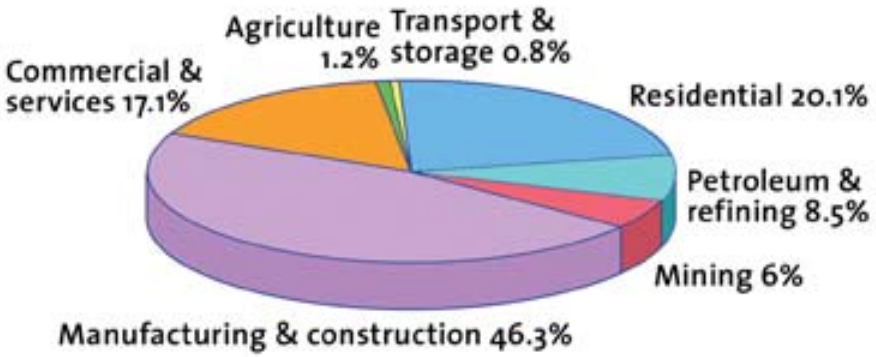
All Sequestrable Sources



Sources of CO_2 Emissions from Power Stations



Stationary (sequestrable) Sources with electricity emissions re-assigned by industry



Industries where greenhouse gas technologies might potentially be applied in Australia to stationary sources of CO_2.

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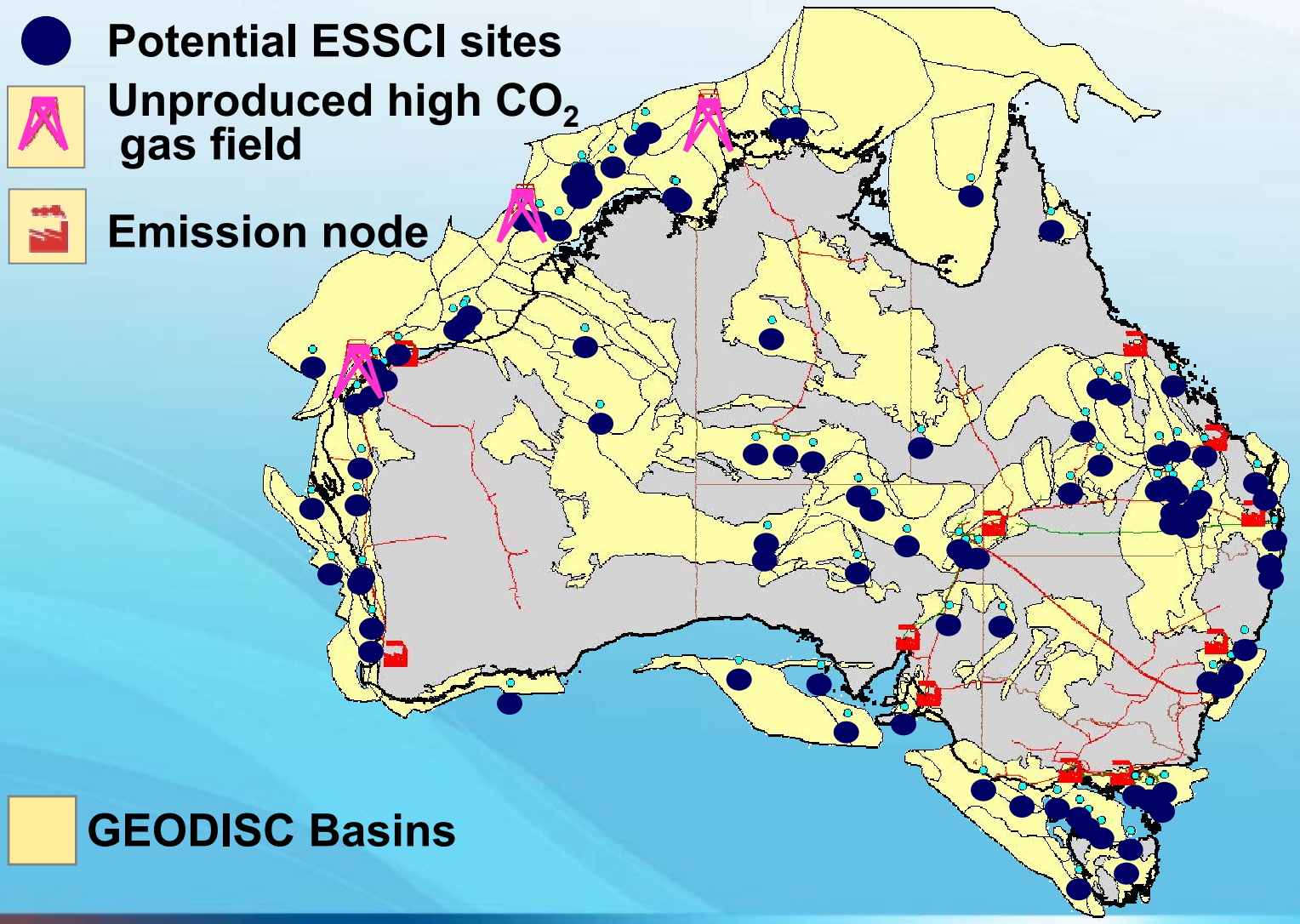
CO_2 source-sink studies (*after Bradshaw et al*)



- 48 basins were considered viable sites for study (out of > 300)
- 102 sites analysed
- 65 proved viable ESSCIs
- 22 sites not viable; 15 regional basin overviews

Location of Australian sites (ESSCIs - Environmentally Sustainable Sites for CO_2 injection) assessed for the CO_2 storage potential (after Bradshaw et al, 2001)

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Preliminary gap analysis & technology assessment showed:

- **Technology options for limiting CO_2 emissions are seen as increasingly important by industry and government.**
- **Any technology solution must embrace need to use fossil fuels for the foreseeable future.**
- **Cost of CO_2 capture must decrease considerably**
- **Australian emissions represent challenges & opportunities.**
- **Australia is geologically favourable**
- **A need to establish new collaborative links and funding – CO2CRC was the preferred route.**

The strategy adopted for CO2CRC was to:

- **Assemble an outstanding multi-disciplinary-interdisciplinary team of technology based researchers to work with industry, whilst ensuring integration of socio-economic issues**

- **Take a 'whole of industry' approach to CO_2 encompassing a variety of emissions from a range of sources.**

- **Work with leading national and international research teams to maximize technology transfer and research leverage.**

- **Focus on identification, development and application of the most cost-effective system(s) for capture of CO_2 from major stationary sources.**

Vision of CO2CRC

The VISION is to develop cost effective carbon capture and storage technologies through collaborative research, that will help Australia decrease CO_2 emissions to the atmosphere from major stationary CO_2 sources, whilst continuing to derive benefit from its abundant fossil fuels and existing industrial base.

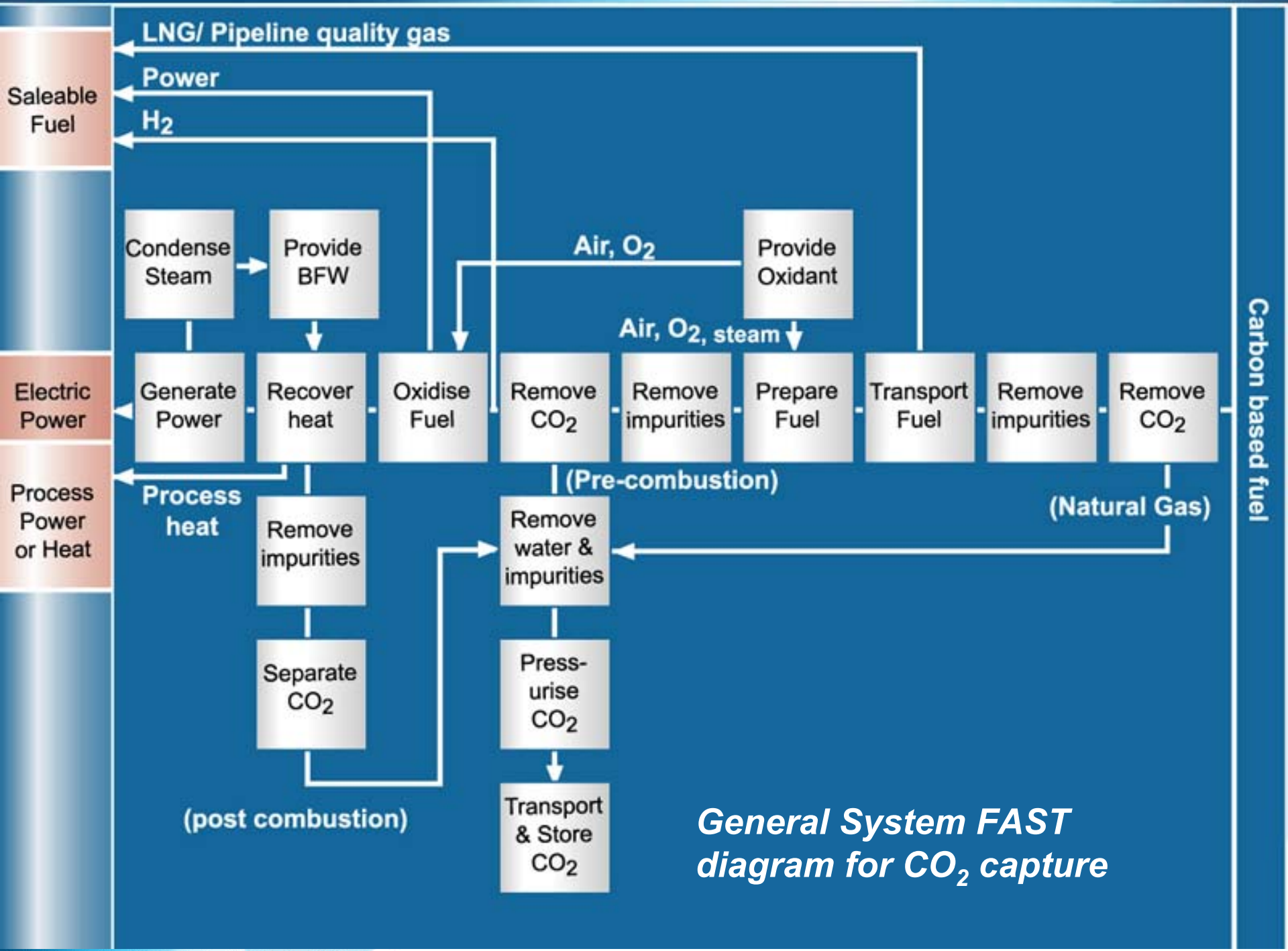
Technology roadmap (Level 1)

- Roadmapping process
- CO_2 capture roadmap
  - Technology themes
  - Australian perspective
  - Implications for capture R&D
  - Implications for CO2CRC capture program
- CO_2 Storage roadmap
  - Technology themes
  - Technology prioritization
  - Implications for storage R&D
  - CO2CRC Storage program

Methodology

The Level 1 Technology Roadmap used both a Functional Analysis System Technique (FAST) and a 3rd generation R&D approach to ensure that all opportunities were identified, and that they:

- **are realistic and timely**
- **utilize the Australian skill base**
- **take into account research activities elsewhere in the world**
- **are effectively incorporated into the CO2CRC program**
- **are compatible with national research priorities**



General System FAST diagram for CO_2 capture

Technology	Relative Importance Now	Relative Importance Future	Technology Impact	Relative position of Australian R&D	Maturity
Novel absorbent solvents	Low	Med	Emerging	Favourable	Growth
Improved solvents	Med	Low	Key	Favourable	Mature
Novel inorganic membrane materials/manufacturing	Med	Med	Emerging	Favourable-Strong	Embryonic
Novel adsorbants (low temp. mesoporous adsorbants)	Low	Med	Emerging	Strong	Embryonic
Novel adsorbants (high temperature applications)	Low	Med	Emerging	Tenable	Embryonic
Chemical looping concepts	Med	Med	Emerging	Weak	Embryonic
Low temperature/cryogenic CO_2 separation	Med	Med	Key	Favourable-Strong	Growth
Hydrate formation/separation	Med	Med	Emerging	Tenable?	Embryonic
Improved / integrated flue gas/syngas treatment (pre-CO_2 capture)	Low	Low	Base	Weak-Tenable	Mature

Categorization of some themes in CO_2 capture

Technology	Natural Gas	Post-Combustion	Pre-Combustion	Oxyfuels
Solvent Absorption	✓	✓	✓	
Membranes	✓	✓	✓	✓
Adsorption		✓	✓*	✓*
Cryogenics	✓		✓	✓
Hydrates			✓	
Chemical Looping			✓	✓

* More particularly for O_2 separation though possible application in pre-combustion

Categorization of technologies and their application to combustion and natural gas separation.

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Technology Area/Theme	Competitive Positioning
Solvents	Favourable
Membranes - polymeric and inorganic	Favourable/Strong
Adsorbents	Favourable
Cryogenics/Hydrates	Favourable/Strong
Chemical Looping	Weak

Relative positioning of Australian CO_2 capture R&D

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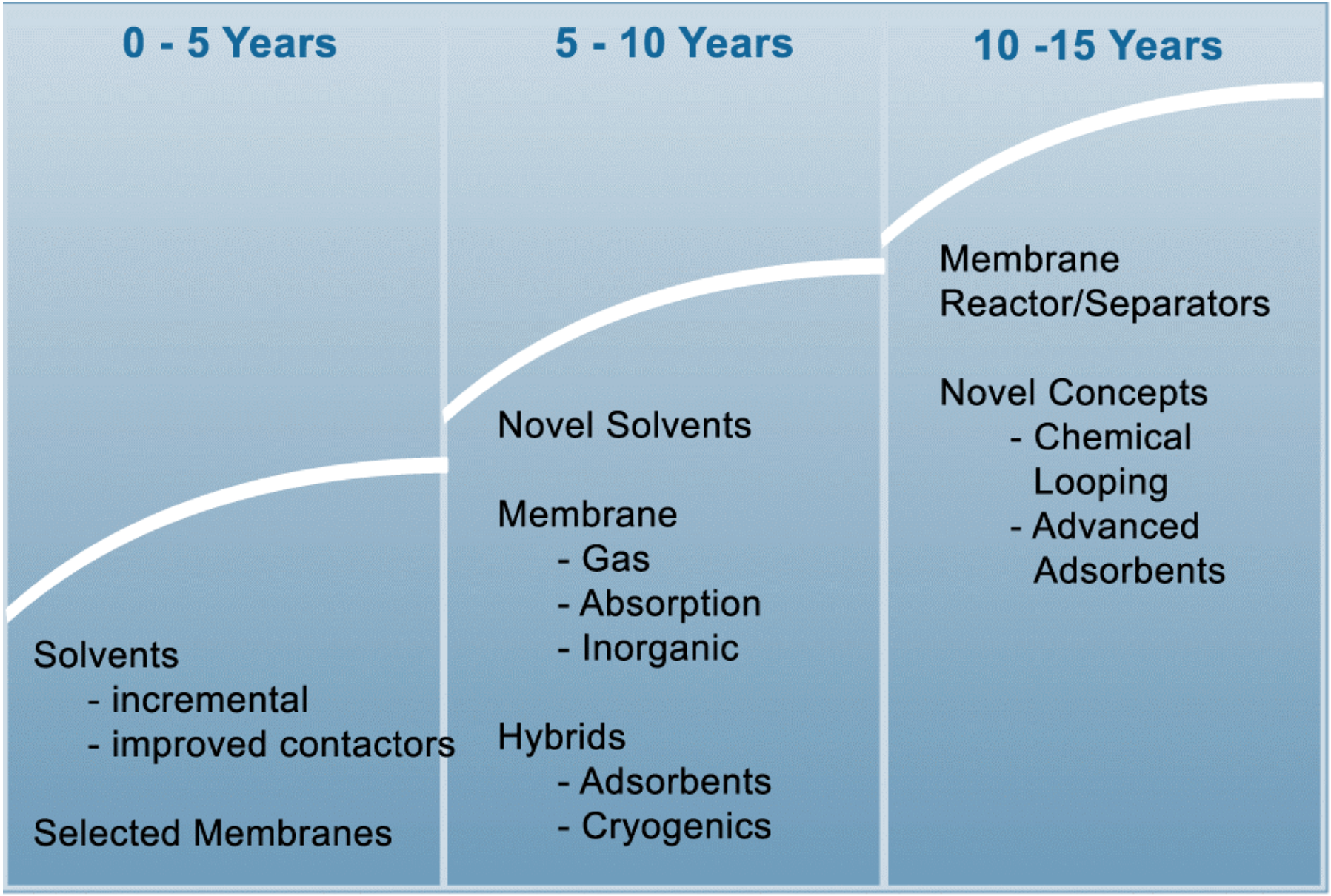

Technology horizons for CO_2 capture

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Functional Step	Technology Theme	Technology	Impact Now	Impact Future	Technical Maturity	Expertise Location
Safely and effectively inject CO_2	Geomechanics	Formation damage	Med.	High	Growth	CO2CRC
		Pore pressure; stress regime; rock strength; fault reactivation	Med.	High	Growth	CO2CRC
	Injection process	Near well bore changes, hydrates	Med.	Low	Embryonic	CO2CRC / Internat.
Monitor and verify the stored CO_2	Remote sensing	CO_2 specific scanner for airborne use	Med.	High	Embryonic	CO2CRC
	Verification	Modern analogues including leaky systems	High	Low	Growth	CO2CRC
	Geophysical methods	Gravity	Med.	Low	Embryonic	CO2CRC / Internat.
		Vertical seismic profiling	Med.		Growth	CO2CRC / Internat.

Categorization of some technology themes relevant to CO_2 storage.

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Transportation and conditioning of CO_2

- Pipeline technology
- Effects of contaminants
- Trucking, shipping and temporary storage technologies
- Issues relating to understanding the physical state of pipeline fluids
- Operational issues
- Environment, regulation and safety issues
- Compressor technology

Injection of CO_2

- Technologies for assessing, modelling and predicting geomechanical effects during CO_2 injection;
  - pore pressure prediction
  - stress regime analysis and modelling
  - rock strength measurement and prediction
  - fault reactivation modelling

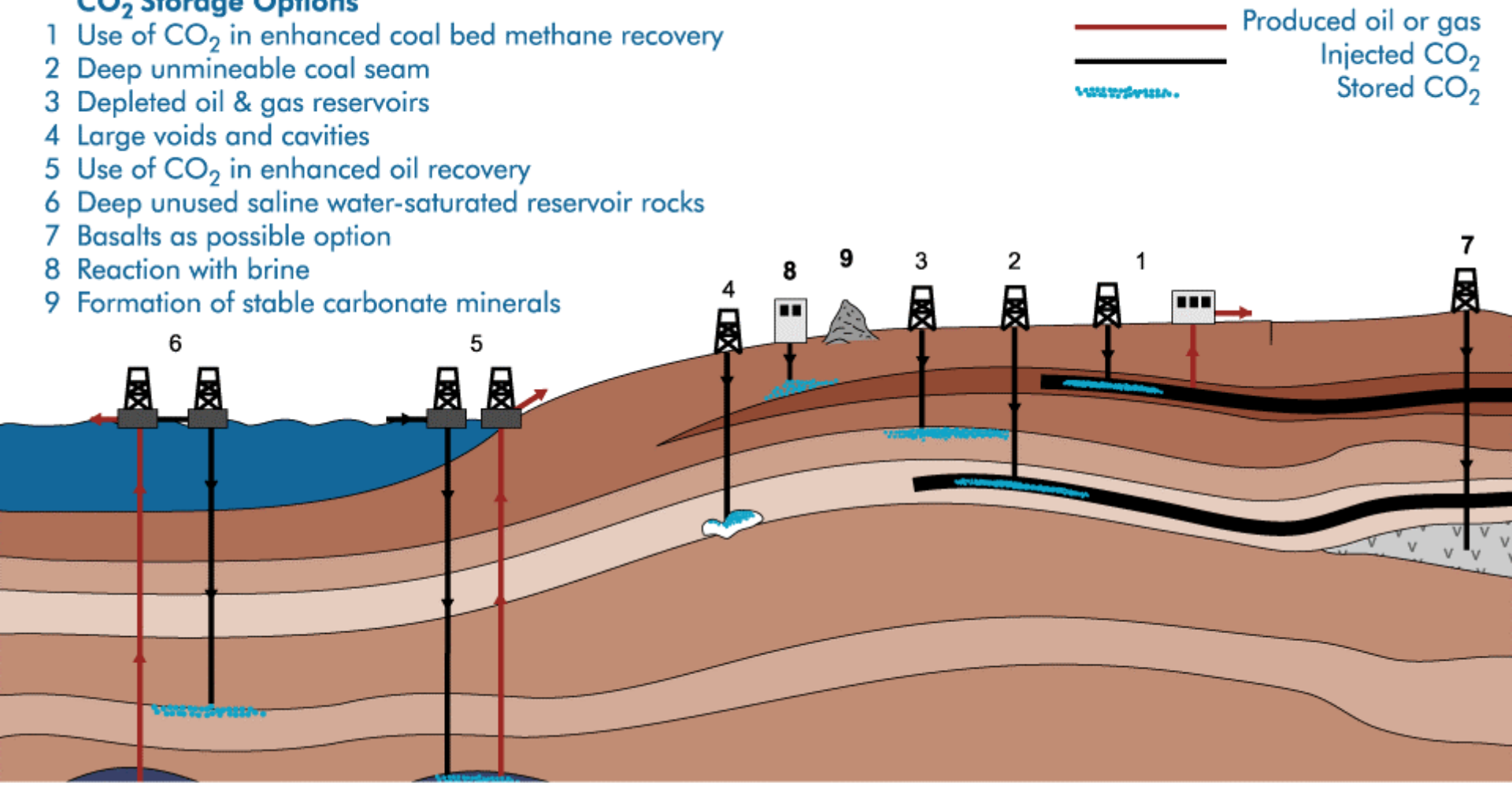
- Technologies for assessing, modelling and predicting other near-well bore formation damage during injection

- Technologies for assessing, modelling and prediction of near well bore chemical changes, inc. hydrate formation

CO_2 storage options

CO_2 Storage Options

1 Use of CO_2 in enhanced coal bed methane recovery
2 Deep unmineable coal seam
3 Depleted oil & gas reservoirs
4 Large voids and cavities
5 Use of CO_2 in enhanced oil recovery
6 Deep unused saline water-saturated reservoir rocks
7 Basalts as possible option
8 Reaction with brine
9 Formation of stable carbonate minerals



Storage Option	Feasibility	Potential Capacity	Data Availability	Expertise	Priority
Saline reservoir rocks	Very high	Very high	High	Very high	1
Depleted oil reservoirs	High	Low	High	High	2
Depleted gas reservoirs	Very high	Now - Low Future - High	High	High	2
Deep coal seems	Medium - low	Medium?	Low	Medium	2-3
Voids and cavities	High	Low	Low	Low	4
Basalts	?	?	Low	Medium	3
Serpentinites	Low	?	Low	Medium	4
Enhanced oil recovery	Low	Low	Medium	Low	2
Enhanced gas recovery	?	Low - medium	Low	Medium	2
Enhanced coal bed methane	?	Medium	Low	Low	2
Reaction with brines	High	Low?	Low?	High	3
Use of carbonate minerals	High	Low	High	High	3

Australia's position in technologies CO_2 storage (Priority 1 - highest, priority 4 - lowest)

CO_2 capture & storage technology application roadmap (Level 2)

- Pilot projects
- Demonstration projects
- Commercial projects

Pilot projects

At a smaller scale (5 - 10,000 tonnes CO_2), pilot projects offer scope for addressing specific issues such as

- **CO_2 injectivity**
- **validation of models**
- **testing of monitoring capability**
- **assessment of impact of CO_2 on the deep environment.**

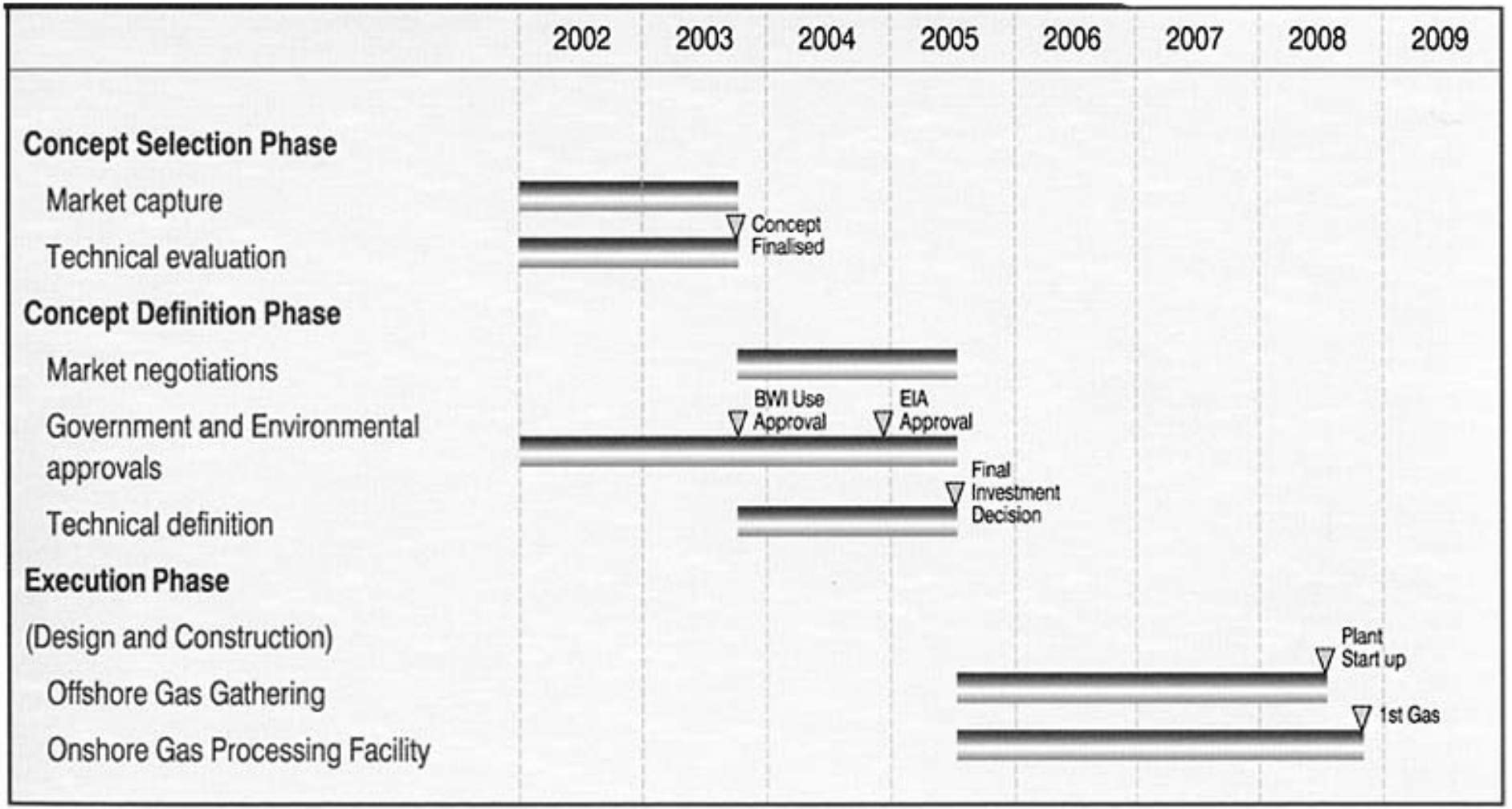
Additionally, pilot projects were seen as an important component in communicating geosequestration issues (especially storage) to the public.

Demonstration projects

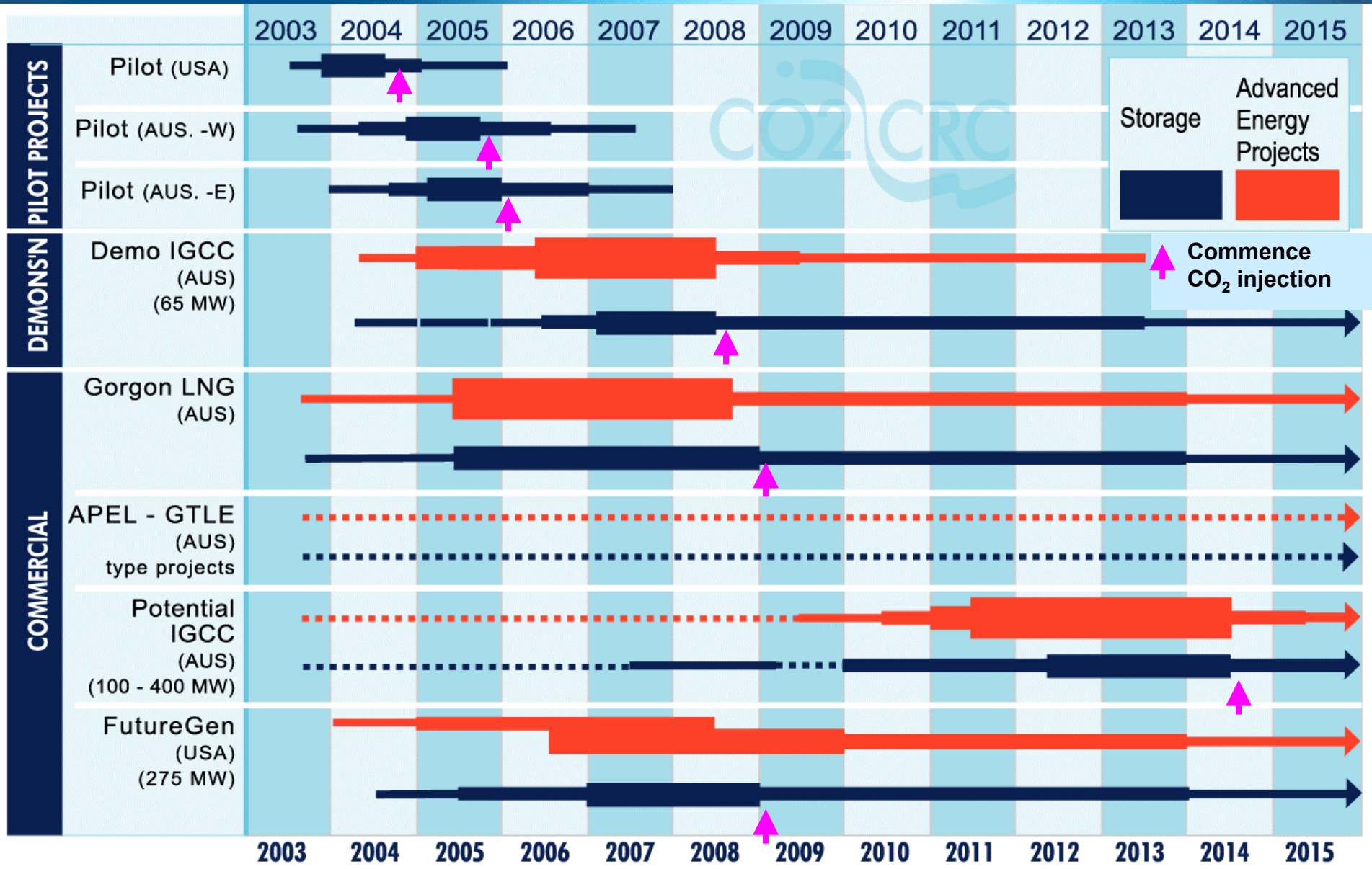
At a medium scale (50 – 100,000 tonnes CO_2) opportunities are being assessed for developing projects to demonstrate low emissions technology.

COAL 21 proposes for the construction of a black coal IGCC demonstration offering scope for CO_2 capture and storage as well as hydrogen generation to be commissioned around 2008.

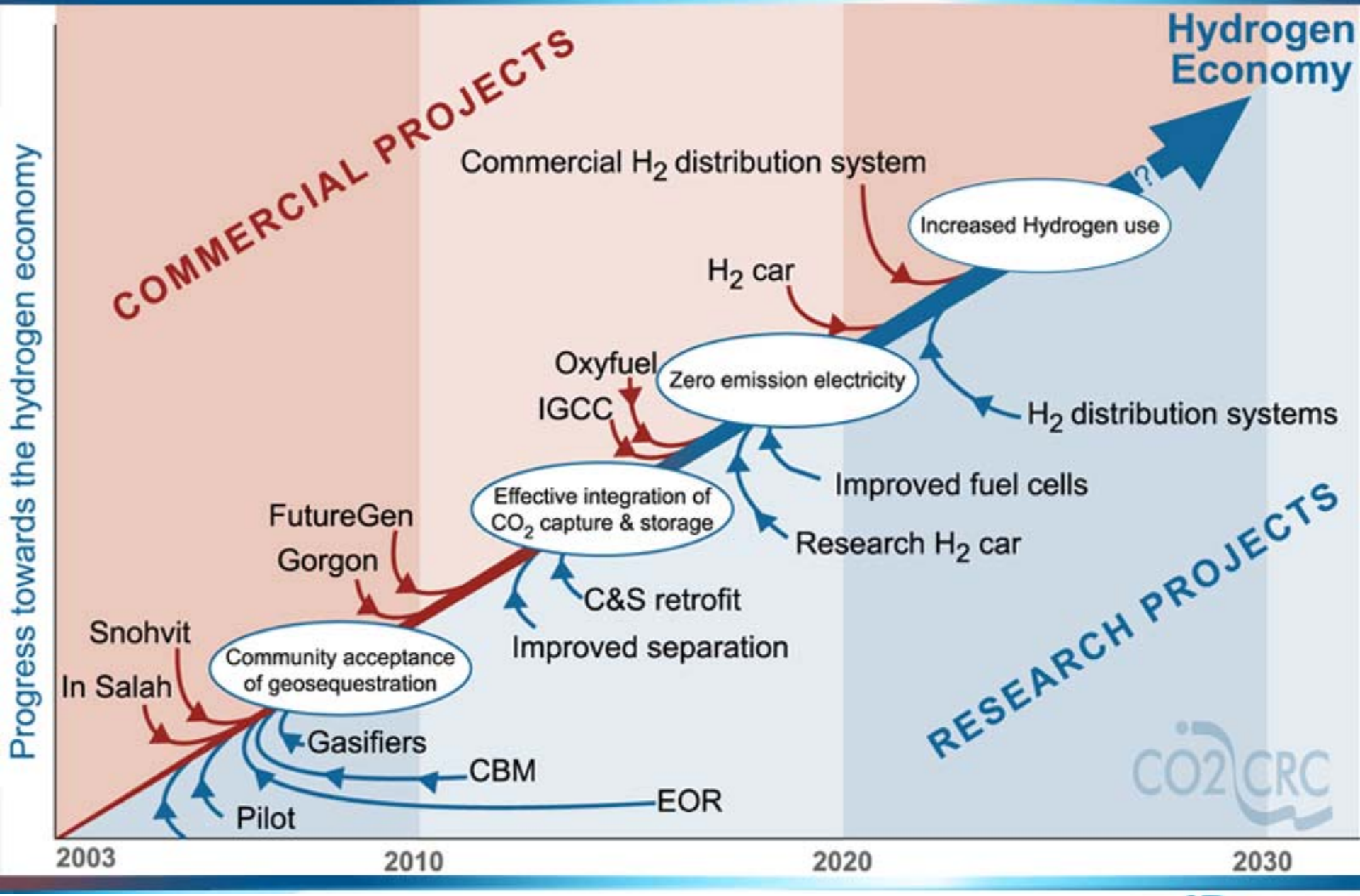
Proposed commercial projects



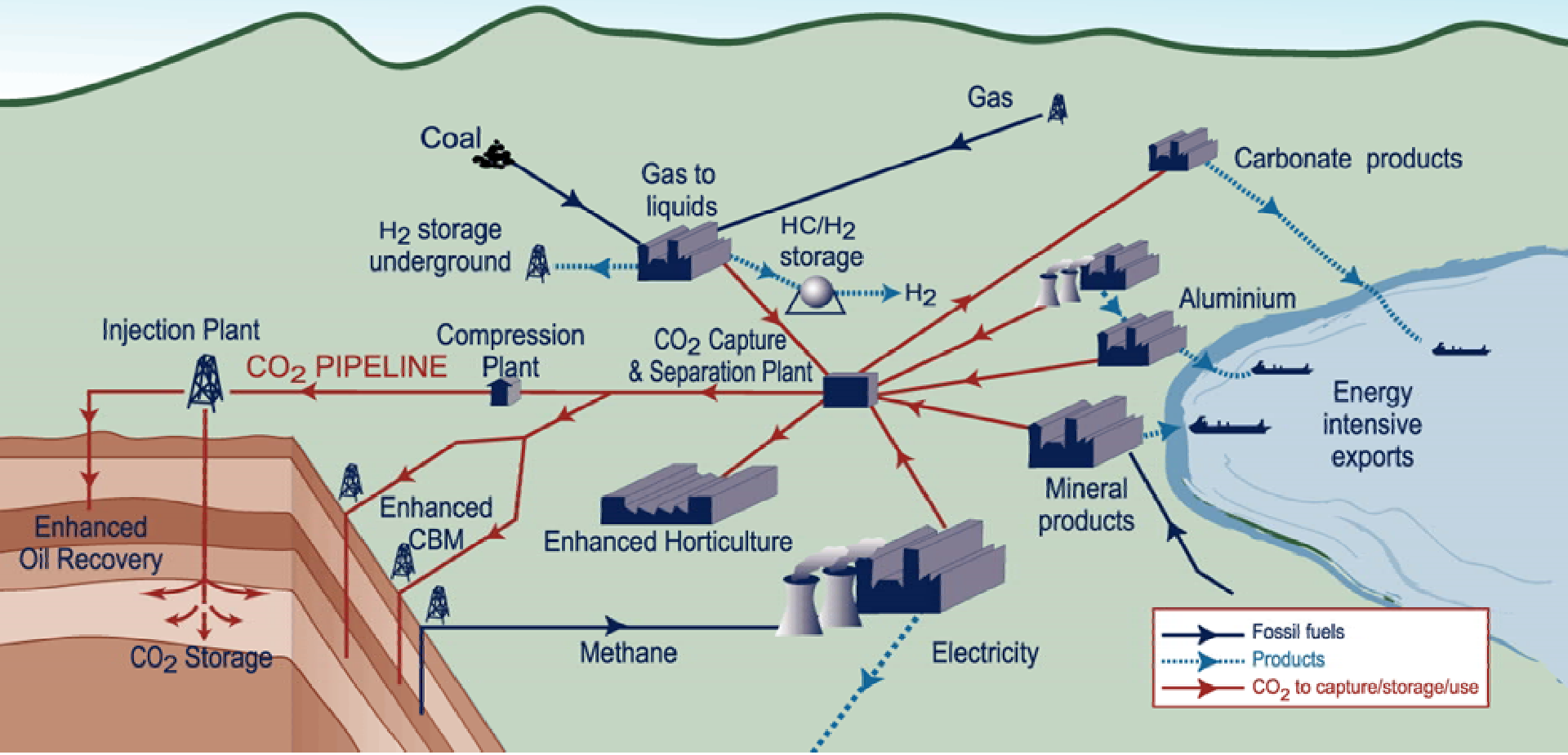
Timetable for the proposed Gorgon Project



Technology roadmap (Level 2) showing pilot (5-10,000 tonnes), demonstration (50-100,000 tonnes) & commercial projects.



Level 3 technology roadmap for CCS showing likely progress towards the hydrogen economy



An emission free vision for the future.

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SUMMARY
The Australian technology roadmap

Level 0, involved developing the national knowledge infrastructure and skill base in the four years prior to formulation of this roadmap

Level 1, which has a 5-10 year time scale provided detailed technology assessments and gap analyses for R&D related to:

- **CO_2 capture, storage & use**
- **Technology strengths & weaknesses**
- **R&D priorities that will be pursued by Australia through**
  - **Australian R&D**
  - **International collaboration**
  - **Maintaining a watching brief**

SUMMARY
The Australian technology roadmap

Level 2, with a 10-20 year timescale, provided broad scale assessments of potential demonstration and application opportunities through proposals for:

- **Pilot (small scale) R&D projects**
- **Demonstration (medium scale) R&D projects**
- **Linking R&D with commercial (large scale) projects**

Level 3, with a 20-30 year time scale, developed a roadmap for the hydrogen economy, stressing the key role of CO_2 capture and storage, in a hydrogen economy initially fossil-fuel-based.

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CO2CRC acknowledges the support of the following organisations:

Australian Government

Geoscience Australia
Australian Greenhouse Office
Department of Industry, Tourism and Resources

ACARP

ChevronTexaco

Schlumberger

Natural Resources and Environment

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