Who are CGSS?

- CGSS = CO₂ Geological Storage Solutions
- Independent Specialist CO₂ geological storage services firm
- Provide geoscience advice for geological storage of CO₂: Technical, Legal, Regulatory, Strategic
- Assist in deployment of geological storage at industrial scale: Regional Assessment, Prospect Exploration, Site Injection
- Combined 40 years experience in CO₂ storage
- Main Office in Canberra - with Associates and Alliances nationally (Perth, Melbourne, Adelaide, Brisbane) and Internationally
- www.cgss.com.au

**Queensland CO₂ Storage Atlas**

- Stage 1 of QDME Carbon Geostorage Initiative: 768 – 1,296 Mt storage capacity required for major emission nodes
- 36 Queensland basins assessed for geological storage prospectivity
- High-grade basins for more detailed studies & data acquisition to identify storage sites
- Geological assessment – excludes existing resources
- Product includes A3 hardcopy atlas and GIS (ArcGIS and MapInfo formats): publicly available – see www.cgss.com.au

**Outline**

1. Overview
2. Assessment approach
3. Ranking method
4. Potential Storage – “fairways”
5. Measurements – T, P, Density, Volumetrics, Reservoir Area
6. Trapping -MAS
7. Insights – Storage Efficiency

**Regional Scale Assessment – Results & Methodology**

**Queensland CO₂ Storage Atlas**

- Aim to identify with highest possible certainty prospective basins for geological storage in onshore Queensland (36 basins).
- Options assessed include: regional reservoirs (saline reservoirs & aquifers); depleted oil & gas fields; deep unmineable coal seams; and salt caverns.
- Greatest potential in regional reservoirs using migration assisted storage (MAS)
Aim of CGSS Regional Methodology

- Repeateable
  - Rely on “prospectivity” assessment to drive capacity estimate (map “fairways”)
  - Not algorithms in a spreadsheet (divorced from rocks)
- Based on actual rock characteristics and distributions
  - Not supplanted from elsewhere
  - Avoid wherever possible generic or non site specific probabilistic distribution assumptions
    - e.g. CO₂ density, net/gross, SE
- Produce reliable conservative values
  - That policy groups can plan on with certainty
    - e.g. not enormous academic / theoretical numbers – but real / sensible numbers based on “invaded area”

Conventional vs Unconventional seals

- “Conventional” seals act as a physical barrier (trap) to the migration of fluids (e.g. Jericho Formation).
- Unconventional seals potentially include greensands, siltstones and very fine-grained sandstones. The main feature is very low but effective bulk rock permeability. To be considered as an ”unconventional” seal the formation has be >300 m thick over an area of >2000 km² (Rewan Formation – Galilee Basin)

Potential Storage Area Mapping

- Maps generated for the maximum known extent of reservoir/seals intervals within a basin that are evaluated as having potential for geological storage of CO₂
- The maximum potential storage area incorporates
  - A regional seal >800 m deep at its base
  - A seal of suitable thickness to contain CO₂ (>50 m for conventional seal); >100 m for unconventional seal),
  - A suitable quality reservoir for CO₂ (porosity ≥ 10%; permeability ≥ 5 mD).
- Note: permeability should probably be much higher; depends on clients requirements
- However, the level of detail in mapping maximum potential storage area varies from basin to basin depending on the data availability and geological complexity.
**Storage Area “Fairway”**

1. Define storage area (“Fairway”)
   - Extent of regional seal (Snake Creek Mudstone/Moolayember Fm) and reservoir used to define probable storage area in Southern Bowen Basin over the Roma Shelf/Wunger Ridge.
   - Fairways difficult to map in detail due to association with thin and narrow fluvial channel sandstones, lack of 3-D seismic data, and limited palaeo-geographic maps
   - Showgrounds Sandstone most widespread reservoir—contains good quality sandstones to depths of 2,300 m in high energy fluvial channels
   - Reservoir quality generally deteriorates towards eastern flank, but difficult to map where reservoir end in Taroom Trough

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**Temperature & Pressure**

2. Calculate temperature and pressure gradients from WOFs
   - Temperature gradient ~35°C through southern Bowen Basin
   - Pressure gradient ~1.4374 psi/m

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**CO₂ Density**

- Under the normal range of pressure/temperature conditions found in sedimentary basins, the density of CO₂ can vary significantly
- Uses the industry standard method of calculating CO₂ density using pressure & temperature data (Span and Wagner 1992)
- The precision of the CO₂ density estimate depends on the accuracy of pressure and temperature estimates.
- Data obtained from CSIRO Pressureplot database, then cross-checked with well data (ideally 10–20 data points).

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**Volumetric Equation**

The equation for volumetric estimation is:

\[ MCO₂ = RV \times \phi \times Sg \times \delta_{(CO₂)} \]

- \( MCO₂ \) = mass of CO₂ stored in kilograms
- \( RV \) = total reservoir rock volume in m³ (within fairway – not whole basin)
- \( \phi \) = total effective pore space (as a fraction)
- \( Sg \) = the gas saturation within the above pore space as a fraction of the total pore space (10 %)
- \( \delta_{(CO₂)} \) = the actual density of CO₂ at the given reservoir depth (pressure and temperature) in kg/m².

Note: No use of an assumed basin wide storage efficiency factor

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**Area & Reservoir**

4. Calculate Areas & Reservoir
   Parameters:
   - Area calculated for each depth range over mapped storage area
   - Average net pay zone thickness obtained from gas fields over reservoir area
   - Average porosity obtained from QPED database
   - Drainage cells defined but not used in calculations (beyond regional scope of Atlas)
   - Alternatively, can use isopach maps and regional porosity trends if known (e.g. Eromanga Basin)
Trapping Mechanisms

- There are different mechanisms which immobilise [trap] CO₂ in the subsurface, and the timescales over which they operate (Bachu et al. 2007).
- The lower three mechanisms (dissolution, mineralisation and adsorption) are, mostly, very long-term and are not considered here further.
- The volumetric estimations calculated in this atlas are based around free-phase trapping.

MAS – Migration Assisted Storage

- The migration assisted storage (MAS) process is the main process that can theoretically store enormous quantities of CO₂ in the absence of any subsurface closure.
- The dominant primary trapping mechanism in MAS is discontinuous free-phase trapping as residual gas saturation (RGS) in the trail of a migration plume.
- Using the porosity cut-offs a residual gas saturation (Sgr) of 0.2-0.6 is likely but this is difficult to calculate without core. Therefore a likely conservative value of Sgr = 0.1 has been used for all volumetric calculations.
- Ultimately the CO₂ trapped by these mechanisms is dissolved into the surrounding formation water.

RGS efficiency factor

- Simple volumetric estimation calculations overestimates capacity; calculating the volume of CO₂ that could be stored over the entire reservoir.
- As the migrating plume will not access a large proportion of the reservoir, this value is unrealistic (assuming homogenous reservoir, injection over entire interval, & entire formation water displaced uniformly).
- Therefore to limit extreme values developed a very basic RGS efficiency factor, 15m plume estimate used.

High Prospectivity Areas – Summary

- Contain at least one reservoir-seal interval with demonstrated effectiveness for injection, storage and containment of CO₂ (i.e. have a total ranking score ≥ 13).
- Twenty reservoirs from five basin areas (Bowen, Cooper, Eromanga, Galilee and Surat basins).
- Most reservoirs have either produced hydrocarbons, and/or are major groundwater aquifers.
- Have sufficient data sets to establish their prospectivity.
Storage Capacity estimates

- Matched capacity: Detailed matching of sources and sinks including supply and reservoir performance assessment
- Practical (Viable) capacity: Applies economic and regulatory barriers to realistic capacity
- Effective (Realistic) capacity: Applies technical cut off limits, technically viable estimate, more pragmatic actual site / basin data
- Theoretical capacity: Includes large volumes of “uneconomic” opportunities. Approaches physical limit of pore rock volume; unrealistic and impractical estimate

CGSS method vs Storage Efficiency

<table>
<thead>
<tr>
<th>BASIN</th>
<th>Km²</th>
<th>CGSS Capacity (Mt CO₂)</th>
<th>SE Capacity Approach (4% of pore volume) (Mt CO₂)</th>
<th>CGSS capacity as % of pore volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaillee</td>
<td>447,000</td>
<td>2,430</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowen</td>
<td>340,000</td>
<td>339</td>
<td></td>
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<tr>
<td>Surat</td>
<td>327,000</td>
<td>2,380</td>
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<td></td>
</tr>
</tbody>
</table>

Note: The thicker the reservoir, the larger the discrepancy

Conclusions

- Queensland CO₂ Geological Storage Atlas assessed 36 basins at regional level
  - High graded basins
- Used the prospectivity in determining capacity
  - Seal and reservoir distribution, heterogeneity and quality
  - Trapping options and viability
  - CO₂ density at each location – not generic value
  - Estimated volume of “invaded area of reservoir” for RGS
- Did not use SE methodology (“couldn’t?”)
  - Relied on practical geological knowledge (looked at rocks - prospectivity) & conservative / sensible estimates
  - Must map “fairways” for sensible capacity estimates