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Asia-Pacific CCS projects: Assessment and certification of CO_2 storage capacity

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Seapex Golden Jubilee SEC 2023

8 March 2023, Singapore

SOUTHEAST ASIA SEAPEX PETROLEUM EXPLORATION SOCIETY

Content

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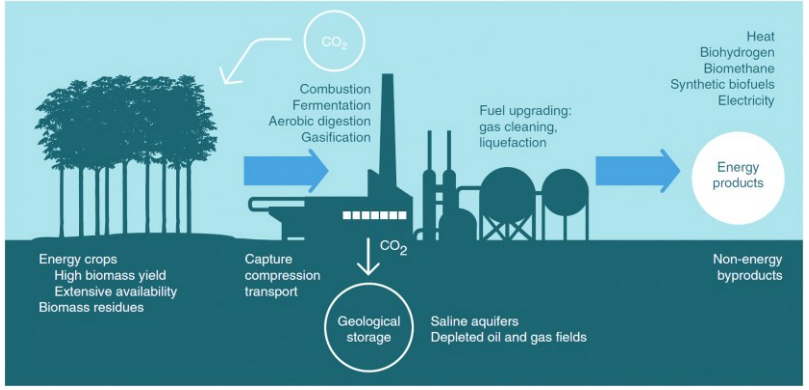
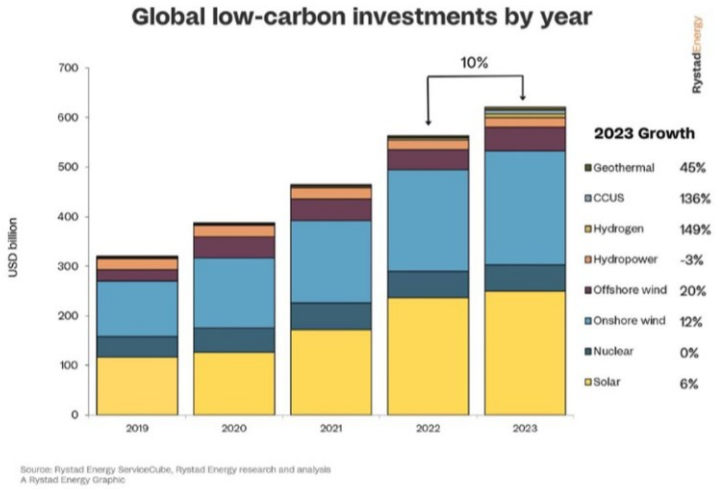
Carbon Capture Storage in APAC

CO2 Capture and Storage (CCS)

High expectations on CCS to realize short term abatement; although sector growth is out pacing the industry experience, CCS project pipeline remains small compared with requirements for Net Zero targets.

- **CCS supply chain**
  1. **Capturing CO_2 before it enters the atmosphere,**
  2. **Transporting CO_2 to storage site,**
  3. **Storing CO_2 underground for centuries or millennia.**
- **Achievements to date**
  - **37 Mtpa CO2 captured globally in 2021 (decarbconnect, Jan2023)**
  - **1/3 stored permanently (Sleipner, Gorgon, etc…); 2/3 stored as CO2 EOR**
- **Near term**
  - **A project pipeline to capture 150-200 Mtpa CO_2 under dev/construction**
  - **Total spending to reach 7.4 BUSD in 2023 (+136% yoy, Rystad Jan2023),**
  - **Most new projects are for permanent storage in depleted O&G fields and saline aquifers**
- **REMINDER: IEA Net Zero scenario assumes CCS of 8,000 Mtpa by 2050 !!!**





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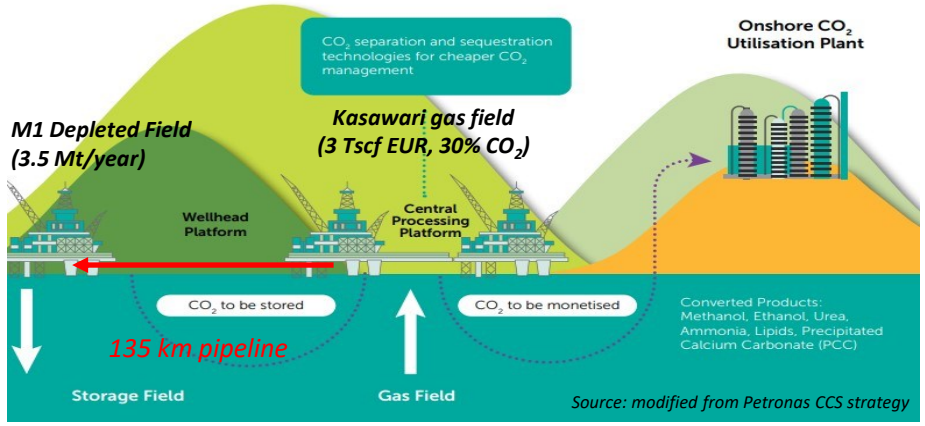
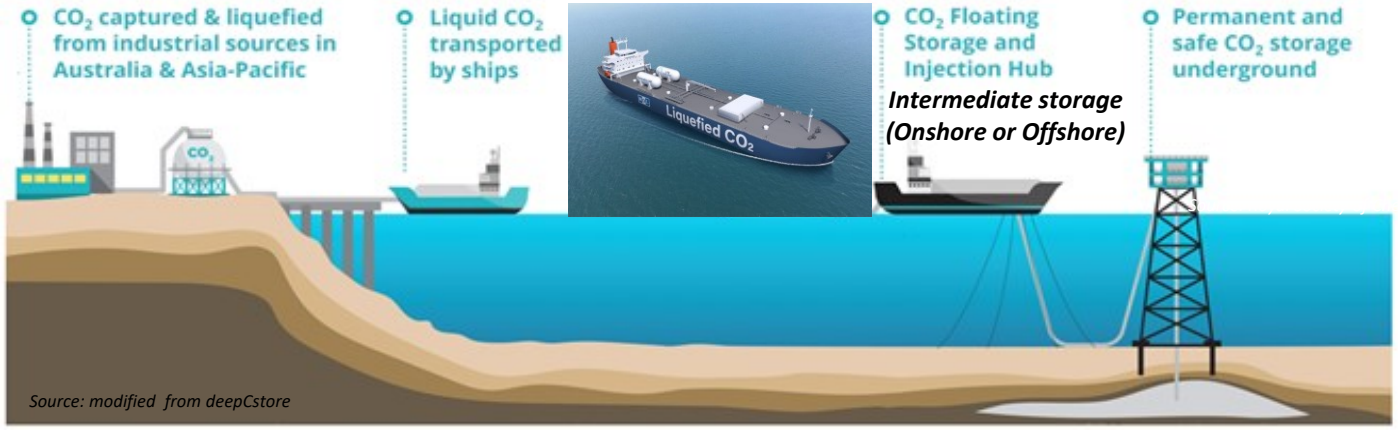
Storage Business Models

"in-situ & exclusive" vs "cross-border & shared" storage sites

- **Two main business models**
  1. **"In-situ & exclusive" where underground storage sites are near CO2 source (ex. Gorgon)**
     - **Large plants: LNG, Hydrogen, Coal Power; High CO_2 Gas developments (includes CO_2 EOR and EGR).**
     - **Captured CO2 is transported by pipeline routes.**
  2. **"Cross-border & shared" where nearby underground storage sites are not available (ex. DeepCStore)**
     - **Mainly to deal with emitted CO_2 from heavy industries of developed countries.**
     - **Captured CO_2 is liquified and transported in a similar manner as LNG to a shared site.**
     - **Offshore storage site with CO_2 floating storage and injection (FSI) hub facility**



"In-Situ & Exclusive"



"Cross-border & shared"

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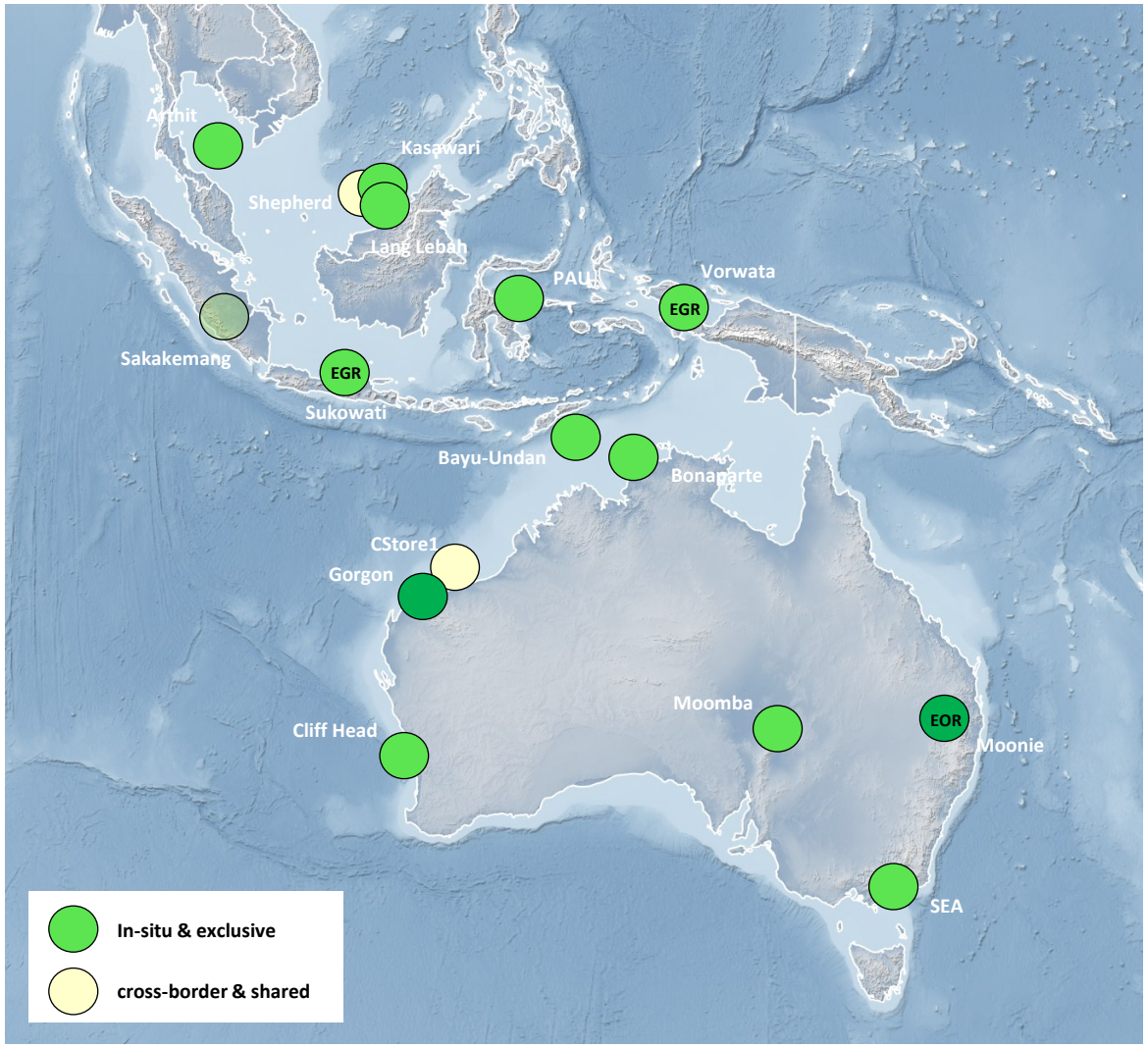
Full-scale CCS projects to follow in APAC (excludes North Asia)

Project name	Country	Operator	Stage	Storage Type	Business Model	Injection Rates (Mtpa)	Activation
Arthit	Thailand	PTTEP	FID (2023)	Depl. reservoir	In-situ	1.0	2026
Kasawari	Malaysia	PCSB	EPCIC	Depl. reservoir	In-situ	3.3	2026
Lang Lebah	Malaysia	PTTEP	FEED	TBA	In-situ	TBA	TBA
Shepherd	Malaysia	PCSB	FS	Depl. reservoir	Cross-border	TBA	TBA
Vorwata	Indonesia	BP	FEED	CO2 EGR	In-situ	2.5	2026
Sukowati	Indonesia	PEP	Pre-FEED	CO2 EGR	In-situ	2.0	2028
PAU	Indonesia	SEP	FS	Depl. reservoir	In-situ	TBA	TBA
Bayu-Undan	Australia/TL	Santos	FEED	Depl. reservoir	In-situ	10	2027
Bonaparte	Australia	Inpex	FS	Depl. reservoir	In-situ	2.0-7.0	2027
CStore1	Australia	JV	FS	Depl. reservoir	In-situ	1.5-7.5	TBA
Gorgon	Australia	Chevron	Active	Depl. reservoir	In-situ	4.0	2019
Cliff Head	Australia	JV	FS	Depl. reservoir	Cross-border	0.6	TBA
Moomba	Australia	Santos	EPCIC	Depl. reservoir	In-situ	1.7	2024
Moonie	Australia	Bridgeport	Active	CO2 EOR	In-situ	0.2	2023
Southeast Australia	Australia	ExxonMobil	Pre-FEED	Depl. reservoir	In-situ	0.2	2025

Sakakemang CCS project in Indonesia is unlikely to proceed following downgrade of resources



Distribution of key full-scale development projects in APAC

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Subsurface Characterization of Permanent CO_2 Storage

Subsurface characterization for permanent storage

Permanent CO2 storage will occur in depleted O&G fields and saline aquifers with some significant challenges; we shouldn't presume we understand CCS just because we are petroleum professionals.

- **In theory CCS is quite straight forward. However, detailed analysis, study and project learnings highlight issues that must be overcome**
- **Common aspects of CCS in both depleted fields and saline aquifers:**
  - **Efficient surface transport of CO2 must be in the liquid phase (850^{+} psia at 20°C). This reduces the volume of CO2 significantly (100 fold) for a modest (2 fold) viscosity increase.**
  - **Similarly, efficient subsurface injection of CO2 must be in the dense phase (1100^{+} psia, 70°C).**
  - **CO2 impurities can increase the pressure require to achieve dense/liquid phase.**
  - **Storage formations must be deep enough to provide these pressures. Depleted reservoir cannot be too pressure depleted. If dense/liquid phase CO2 vapourises there will be a significant drop in temperature (thermal shock).**

Depleted Petroleum Fields	Saline Aquifers
▪ Extensive database, infrastructure and confirmed trap ▪ Most likely that contingent storage resources will be defined without prospective storage resources as a precursor ▪ Time to start up could be minimal ▪ CCS must compete with H_2 or CH_4 storage	▪ Appraisal and data acquisition likely to be required ▪ Most likely that prospective storage resource will initially be defined ▪ Time to start up extended ▪ Storage potential considerably larger than depleted petroleum fields ▪ CO_2 migration a principal concern

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Depleted reservoirs:

Existing data can be used to calibrate uncertainty and projects can typically enter the SRMS as contingent resource. Legacy wells and equipment may be re-useable but also create leak vulnerability

- **Mobile CO_2 replaces petroleum removed from the trap**
  - ***Initial storage resource estimates can be determined by converting the produced petroleum volume to a CO_2 volume at the storage conditions***
- **Advantages of depleted fields:**
  - **Extensive database**
  - **Existing wells, demonstrated trap**
  - **Speed of implementation**
  - **Limited monitoring as CO2 remains within reservoir**

-> Key risks:

- **Injection pressure must be constrained to prevent seal failure**
- **Heterogeneity may cause uneven dispersement of injected CO2 with CO2 going below the reservoir spill point**
- **Potential leakage through existing and abandoned wells and less likely through reaction with formation**

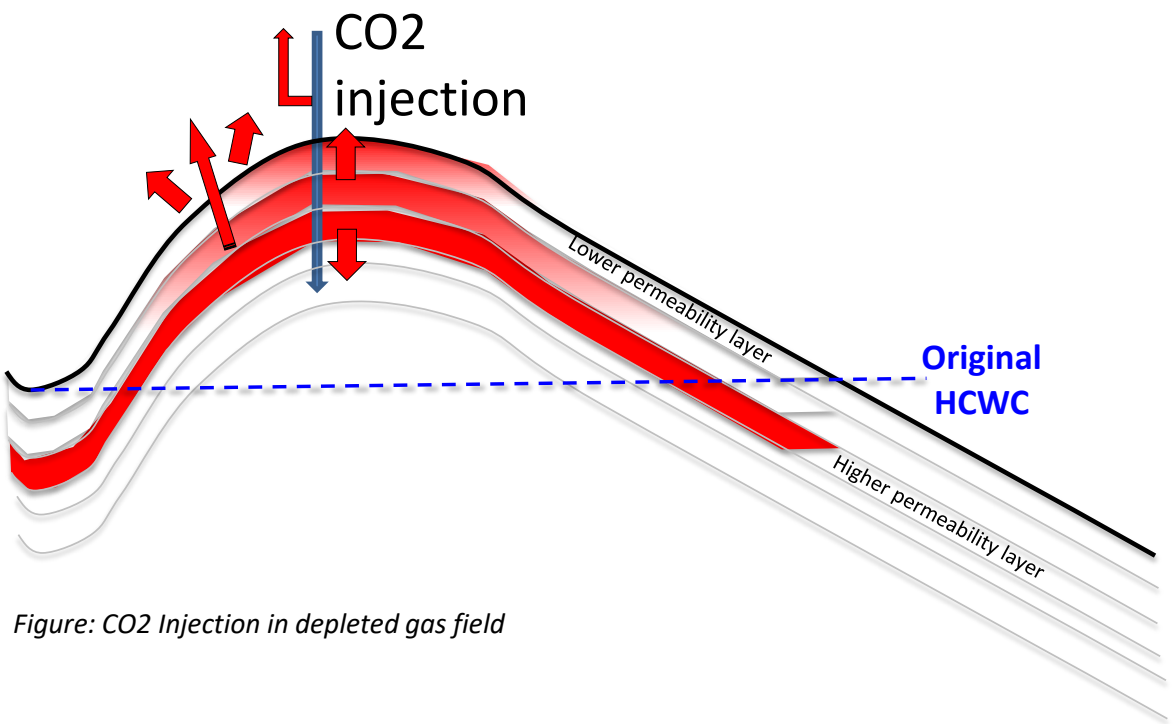
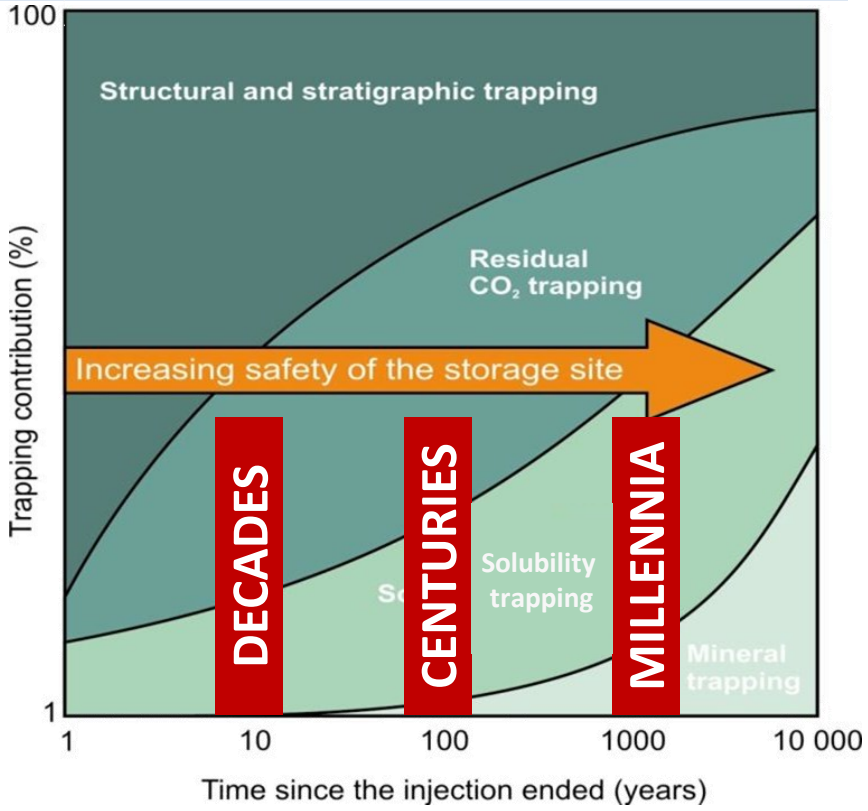


Figure: CO2 Injection in depleted gas field

Saline Aquifers:

Aquifers have the potential for much larger storage volumes in comparison to depleted petroleum fields. But trapping mechanisms are more complex, and rely on capillary pressure, solubilisation and mineralisation.

- **Complex trapping mechanism: For CO2 to become trapped it must be dispersed to a residual gas saturation, supported by dissolution in aquifer brine and mineral trapping**
- **How far does the mobile plume migrate until it is trapped?**
  - **CO2 cannot be allowed to migrate to the surface, potable aquifers or off permit**
- **Modelling and monitoring commitments ?**
- **Jurisdictionally sensitive**
  - **Australia requires wells to be permanently abandoned**
  - **The Californian CCS Protocol requires monitoring of up to 100 years**



Contributors to CO2 entrapment though time

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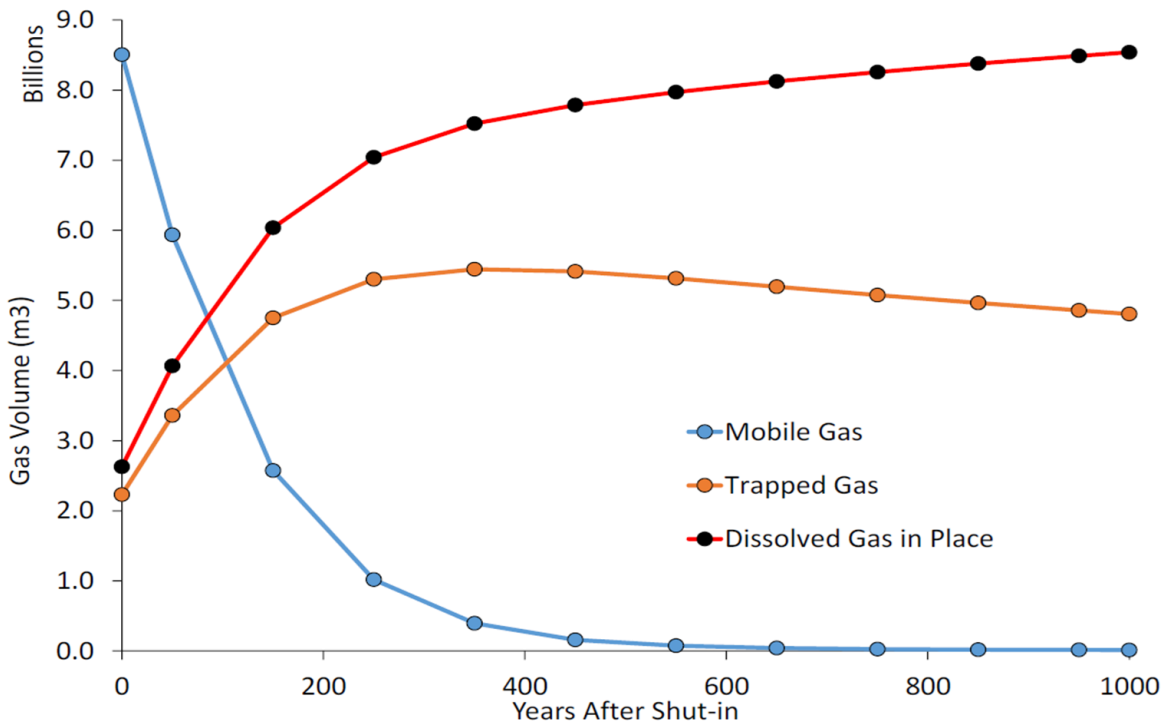
Saline Aquifers: Mobile CO2 migration (1)

How far the mobile CO2 migrates is a key uncertainty; Simulation study of aquifer storage in SW Hub Western Australia



Source: SW Hub Carbon Storage - Dynamic Modeling Final Report (WAPIMS W21531A27)

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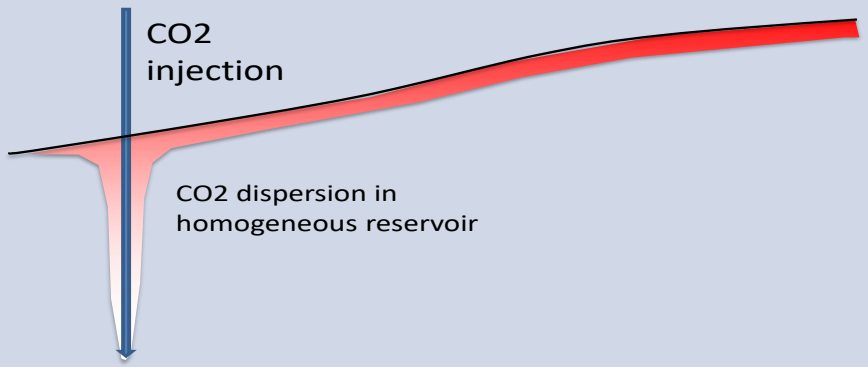
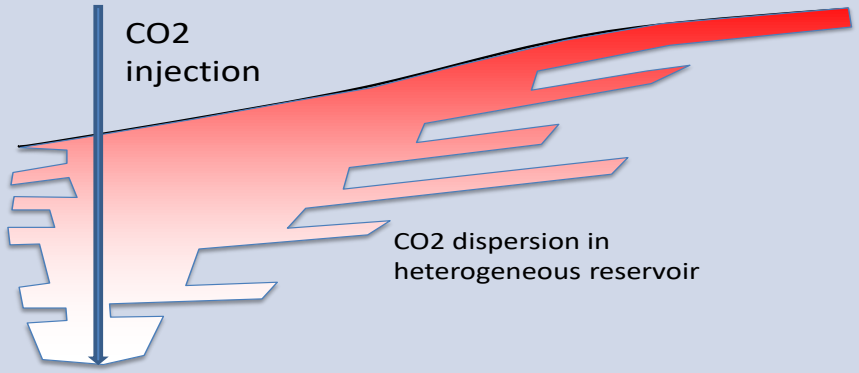
Saline Aquifers: Mobile CO2 migration (2)

The buoyancy of the injected fluid and contact with the solvent will dominate migration.



In good quality aquifers, CO_2 will rise under buoyancy and may form a mobile layer only a few metres thick.

Volume of water contacted by CO2 is limited. Storage efficiency (useable percentage of max storage capacity) is low



In contrast to depleted reservoirs, heterogeneity can be helpful and increase the fraction of the aquifer contacted by the migrating gas

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Aquifers: Key Technical Risks

Key risks are quantifying the range of potential CO2 spread in the aquifer and ensuring adequate formation connectivity to allow the injection of a low compressibility fluid into a low compressibility aquifer

RISKs:

- **Injecting a low compressibility liquid (dense CO2) into a low compressibility aquifer is challenging**
  - **Stop thinking of CO2 as a gas. With dense phase injection CO2 is more like a liquid**
  - **Extensive, well connected, high productivity formations are required to disperse pressure and sustain commercial CO2 injection rates. The operating pressure range will be limited.**
  - **Several project have had to drill water production wells to relieve pressure and allow continued CO2 injection**
- **Extensive appraisal may be time consuming and expensive**
  - **Why would an areally extensive aquifer require less appraisal well spacing than an oil field ?**
  - **Limited appraisal may not adequately define the range of geological outcomes (variation in reservoir quality, seal or barrier continuity) and hence CO2 spread**
- **Monitoring requirements, duration and cost**
  - **How much monitoring for how long (base line surveys may be required over a number of years before injection)**
  - **Mitigation strategy if CO2 migration is not as expected**

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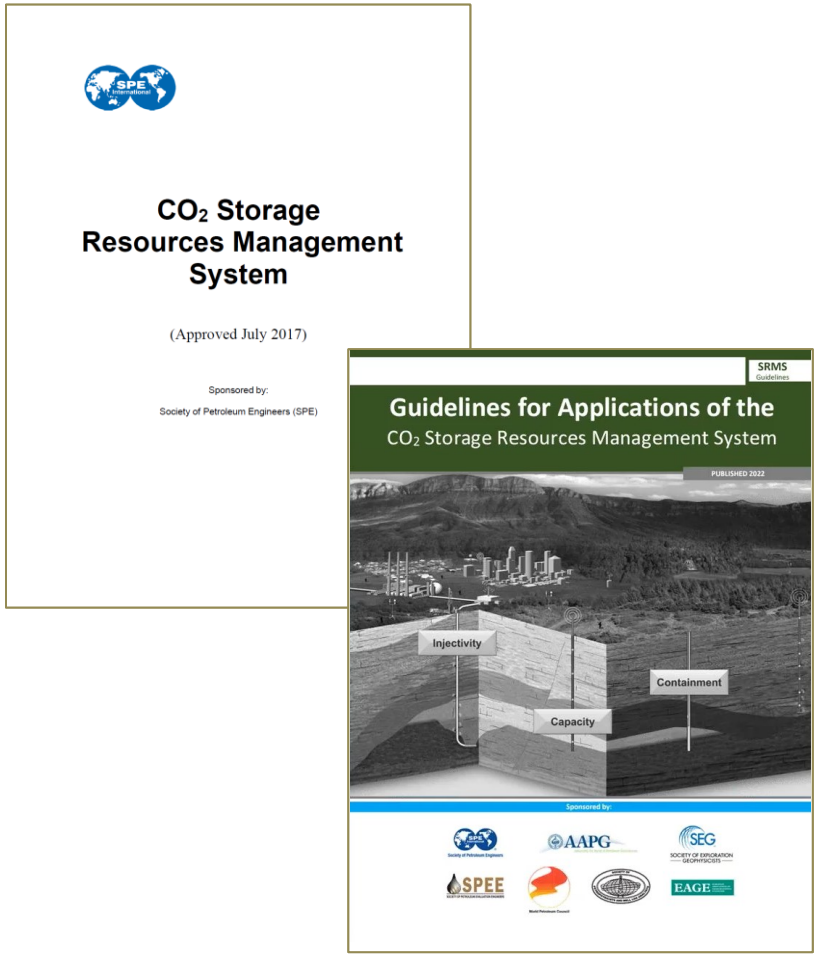
Establishing and Maturing CO_2 Storage Resources

SPE Storage Resource Management System (SRMS)

The SRMS is a useful tool to calibrate expectations, uncertainty and maturity of carbon storage projects.

- **Milestones**
  - **In 2017 the Society of Petroleum Engineers (SPE) published the SRMS at a time when regulators were still assessing their response to a future need for CCS. In August 2022 the SRMS guidelines were published.**
  - **Interest has now increased 5 fold and regulators are still developing legislative frameworks**
  - **In 2017 there were 24 CCS projects operating, in 2021 there were 27, in 2022 …..**
- **Clearly societies desire for CCS is out pacing the industry experience but the international community will rely on us to assess, and compare, CCS opportunities**
- **The SRMS is a useful tool to calibrate expectations, uncertainty and maturity of carbon storage projects for investors and stakeholders**



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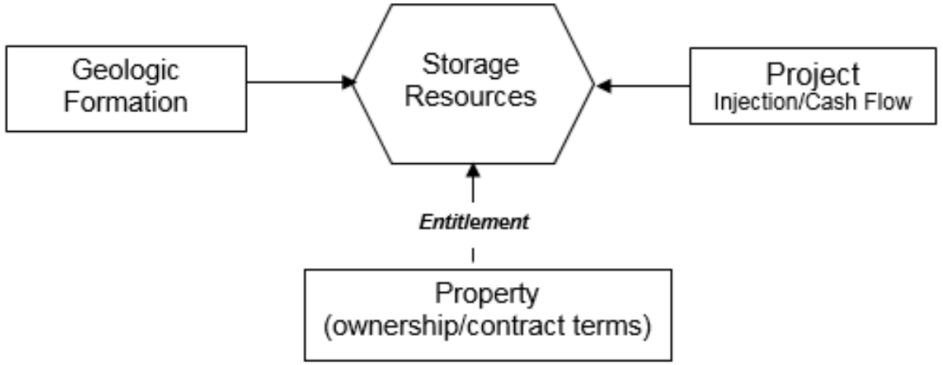
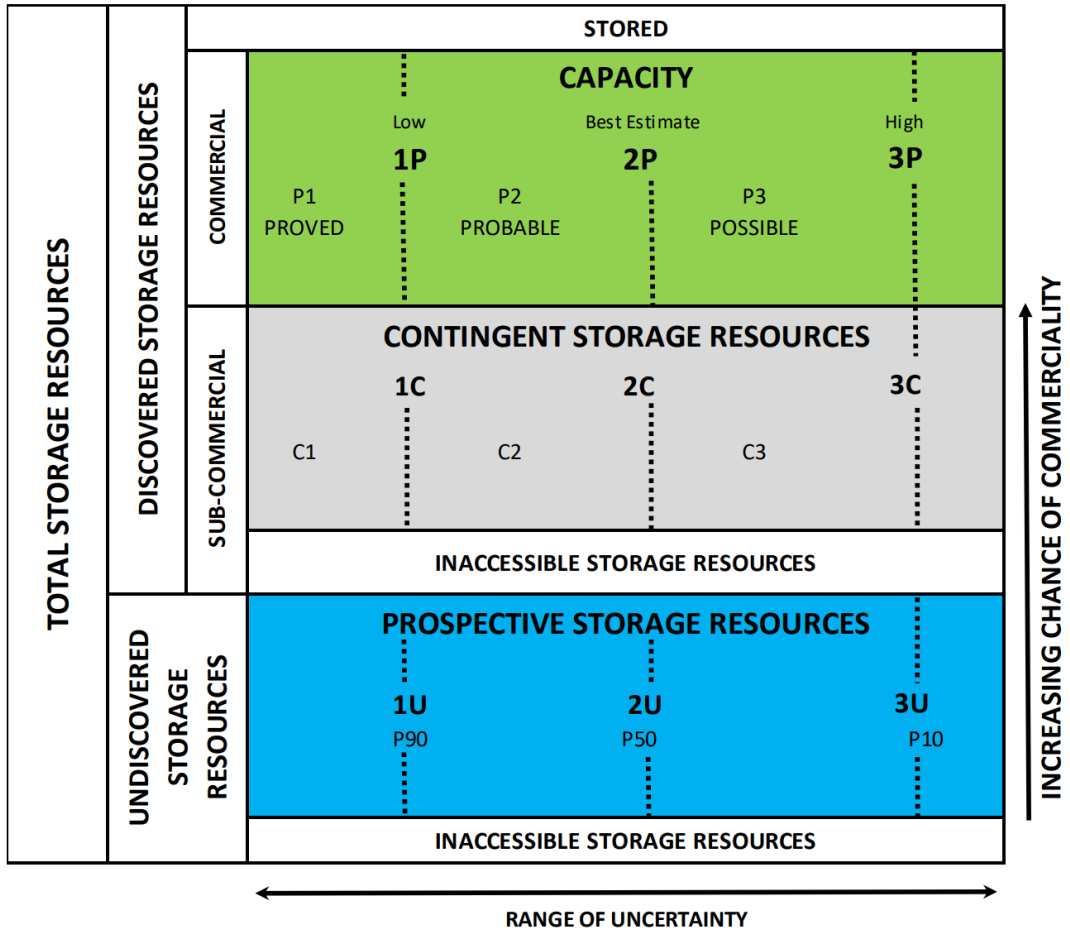
Framework

Can a classification be made?

- ✓ Ownership
- ✓ Geological characterization
- ✓ A project concept



SPE PRMS Resources evaluation data sources



SPE SRMS Resources classification framework

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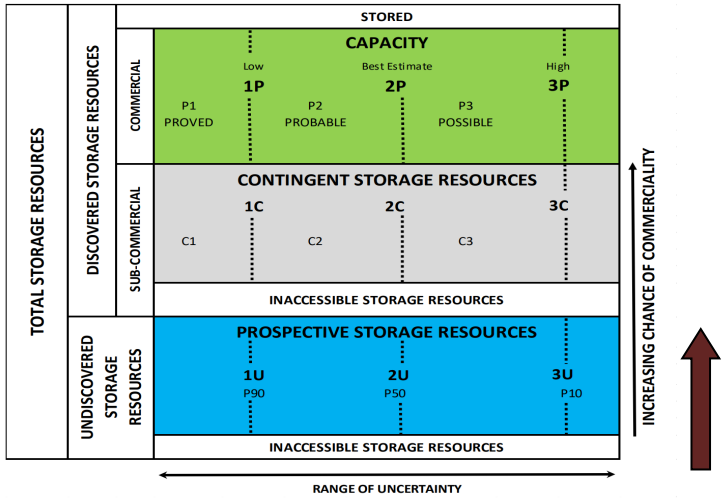
Case Study: Carbon storage exploration license, NW Shelf

- **A carbon storage exploration license has been awarded to JV**
  - **Location: Offshore, Northwest Shelf, Australia**
  - **No wells on license but some open file regional legacy wells with no modern logs or core data.**
  - **Some vintage 2D seismic on license but no recent 2D and 3D seismic available.**

Case Study: STEP#1 - Establishing prospective storage resources

- **Operator preliminary work includes:**
  - **Best depths (pressure) to operate saline aquifer CO_2 storage project**
  - **Evaluation of 4 way dip closures and potential for residual gas trapping**
  - **Investigation into possible CO2 markets**
  - **Appropriate analogues to estimate GRV storage capacity and areal extent of the CO2 plume.**
- **2D seismic is unable to identify 4 way dip closures so residual gas trapping is used as prospective trapping mechanism.**
- **A wide range of reservoir properties are used as inputs for probabilistic GRV estimation, combined with a range of storage efficiency factors.**
- **Existing gas development owned by the same JV can provide 10 Mtpa CO_2.**



Variable	Units	Low	Mid	High
Porosity	(%)	17.6	18.8	20.5
GRV	M^3x10^6	50000	75000	100000
NTG	(%)	70	80	95
Storage efficiency	(%)	1.5	2.5	4.0
Reservoir Temp.	Deg C	124	130	137
Reservoir Press.	psia	1100	1200	1300
Access to market	Mtpa	3.5	4.0	4.5

Table 1. Input parameters

Classification	Units	1U	2U	3U
Inaccessible undiscovered storage resource	Mt	0	42	156
Prospective storage resource	Mt	81	100	113

Table 2. Prospective storage resources

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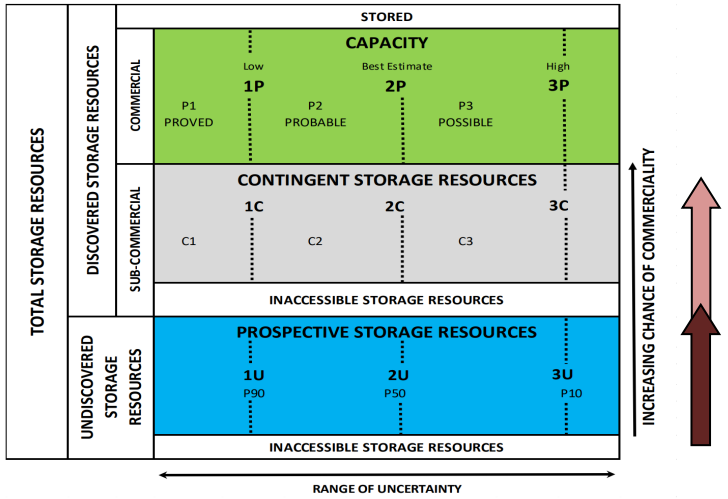
Case Study: STEP#2 - Maturing to contingent storage resources

- **New data acquisition and subsurface modeling**
  - **3D seismic campaign and one exploration well (injection testing)**
  - **Subsurface modelling evidence is mature enough to reclassify the storage volumes.**
- **However, it has not been possible to guarantee the seal at the top of the target reservoir**
  - **Scenarios with various levels of seal competency are modelled**
  - **Studies show that if the seal is not complete, the storage volumes would be lower.**



Classification	Description	Units	1C	2C	3C	Sub-classification
Inaccessible discovered storage resource	No market	Mt	0	42	156	-
Contingent storage resource	Reservoir seal	Mt	33	40	45	Development unclarified
Contingent storage resource	No reservoir seal		49	60	68	Development pending

Table 3. Reclassification to contingent storage resources

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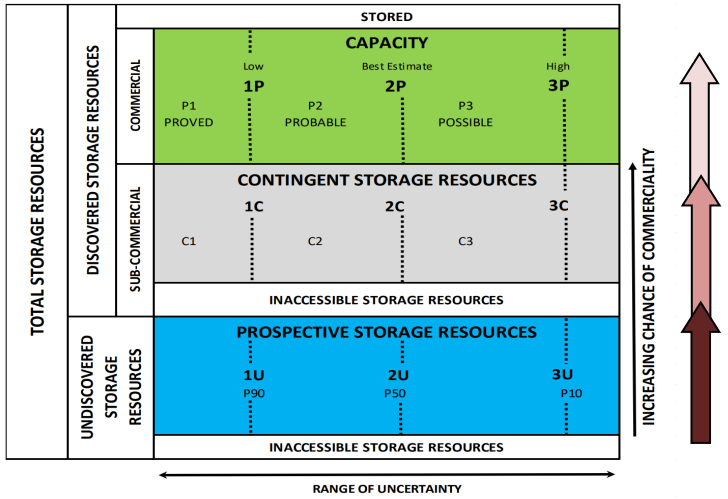
Case Study: STEP#3 - Further maturing to storage capacity

- The project is approved
  - Since it is on a different license to the CO_2 source, a Gas Sales Agreement (GSA) is established
  - This allows the contracted volumes to be classified as storage capacity.
- Immediate reclassification of firm contingent storage to storage capacity
  - 49 Mt 1P, 60 Mt 2P and 68 Mt 3P.
- Subsequent reclassification of unfirm contingent storage to storage capacity
  - Following a number of years monitoring and confirming the presence of a reservoir seal, the additional contingent storage volumes can be reclassified as storage capacity.



Key Takeaway

Key Takeaway

APAC CCS projects

- **CO_2 abatement solutions from CCS is a critical part of the Net Zero emissions**
- **Fast-growing sector, out pacing the limited industry experience to date**
- **APAC (excl. China) has c.15% of global CCS projects under dev/construction**
- **Australia, North Asian heavy industries and NOC lead the effort in APAC**
- **Global current pipeline stands only at 2% of the required CCS contribution by 2050**

Characterization and certification of CO2 storage resources

- **CO2 storage projects have geologic similarities with petroleum projects. However, there are some unique technical challenges that must be understood. Reservoir characterization is equally important.**
- **Aquifer storage is more complex than depleted reservoir storage, has longer lead time but accesses greater storage.**

SRMS provides a system for classifying storage resources

- **CO_2 markets are required to be considered at the prospective storage resource stage.**
- **In some circumstances, a deeper understanding of commercial terms is required to determine capacity.**

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