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Asia-Pacific CCS Overview & Gorgon – ‘Not a CCS problem’

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Explaining value, ranges and uncertainty

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Helping resolve differences of opinion

Pathfinding the route to low emissions energy

Helping responsible investment and development

Guiding the transaction processes

Content

1. CCS Overview
2. Key CCS projects in APAC region, (excluding North Asia)
3. Key aspects and challenges for CCS
4. Gorgon – Not a CCS problem
5. Key takeaways

Gorgon LNG plant, with domgas and CO_2 compression /injection facilities

Carbon Capture Storage in APAC

Injection of CO2 underground has been going on for over 50 years…

- EOR technology was introduced in the 50's and deployed in both the US and the North Sea in the 70's and 80's.
- Sleipner (Norway), the first project to target dedicated storage, through injection into a saline aquifer, started up in 1996, and is still operating.
- Approximately 30 operational sites worldwide, many more being studied.
- As EOR it's been very successful:
  - Paid for via oil revenues.
- Capture has mainly focussed on reservoir or pre-combustion projects:
  - But technologies are transferable to post combustion.
  - Boundary Dam (Canada, 2014) was the first project to capture CO_2 from a coal-fired power station.
- International Energy Agency Sustainable Development Scenario, CCUS accounts for 15% of the cumulative CO_2 emissions reduction required, a capacity of 10.4 Gtpa (current capacity is 40mtpa).

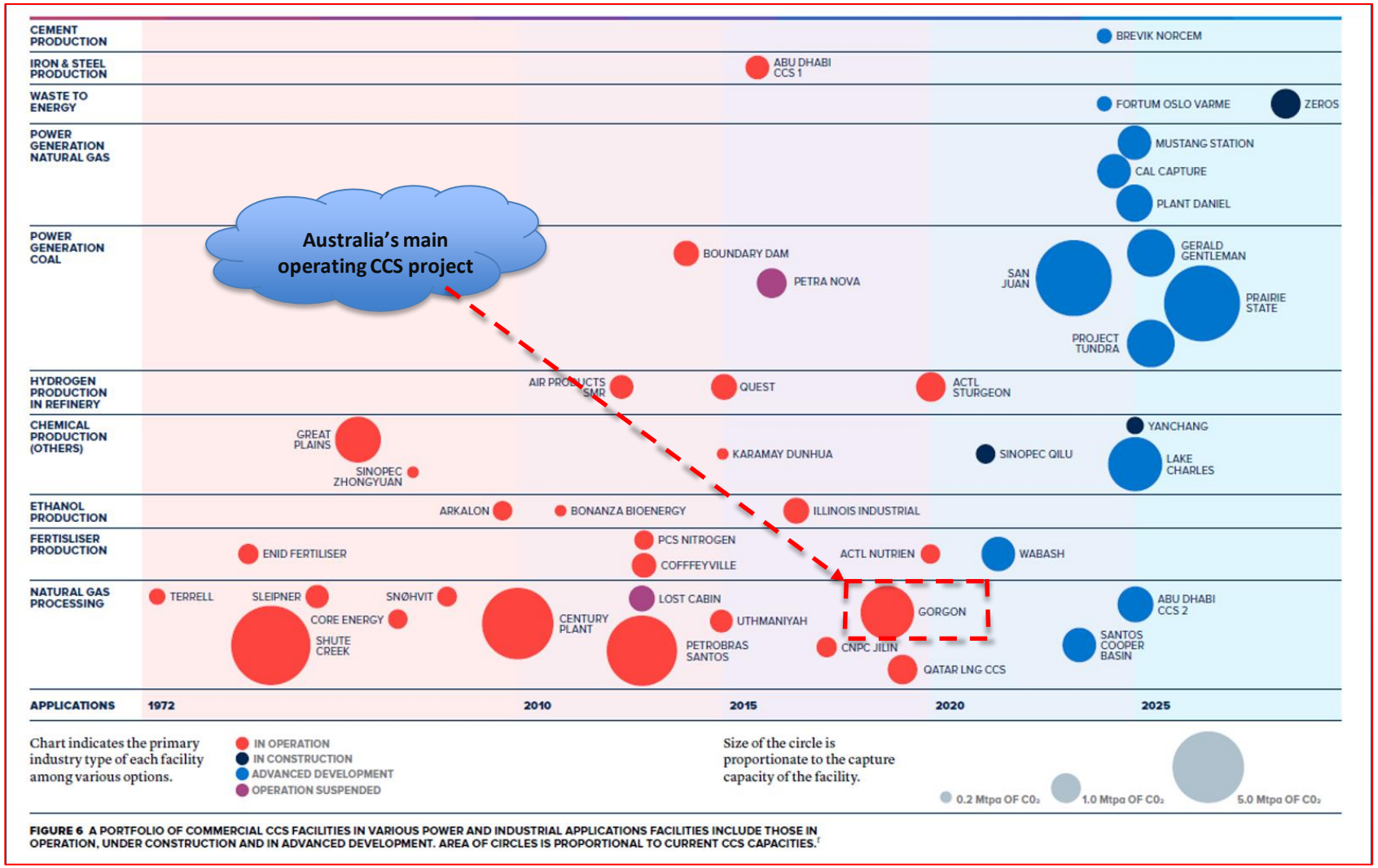


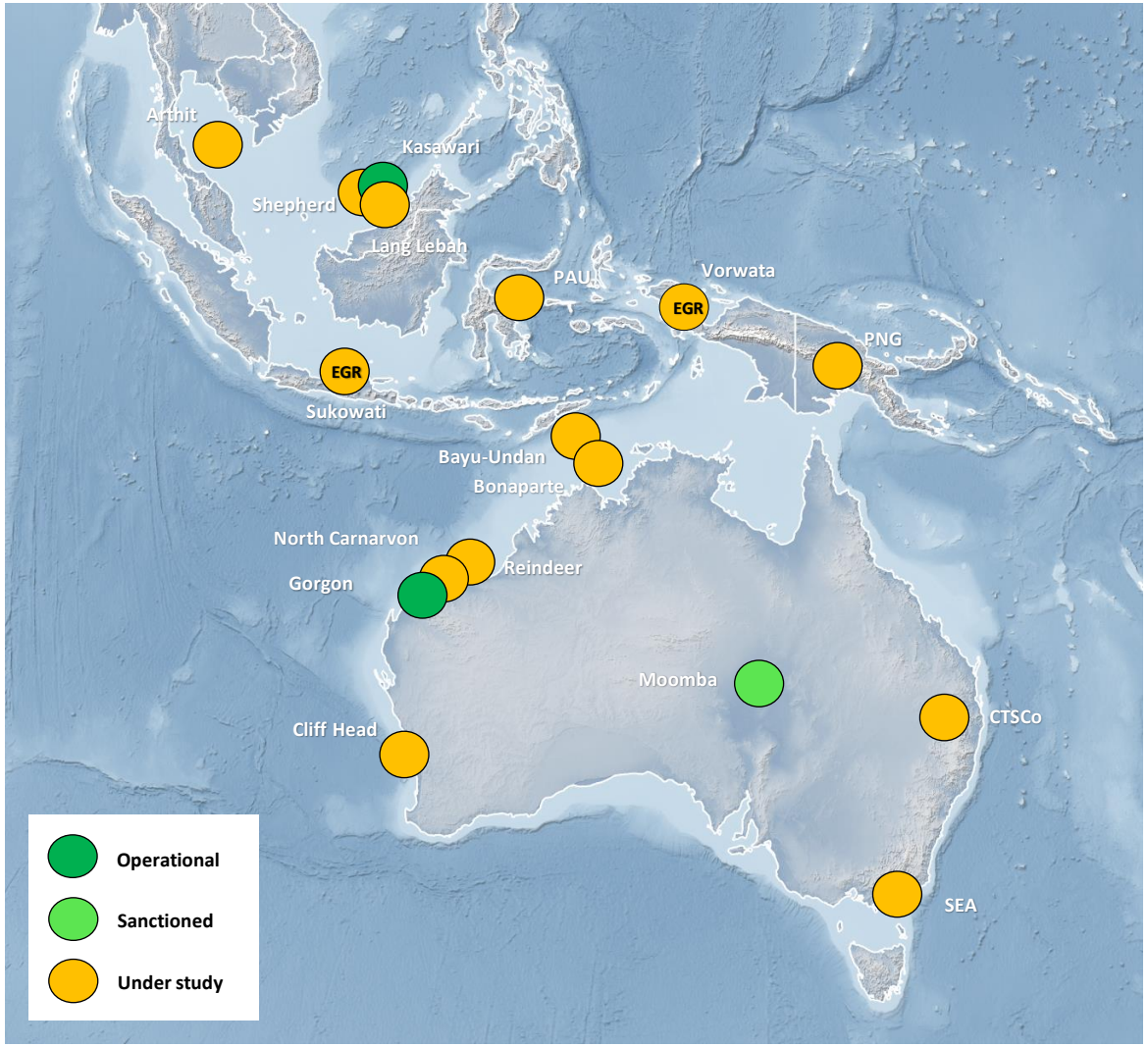
FIGURE 6 A PORTFOLIO OF COMMERCIAL CCS FACILITIES IN VARIOUS POWER AND INDUSTRIAL APPLICATIONS FACILITIES INCLUDE THOSE IN OPERATION, UNDER CONSTRUCTION AND IN ADVANCED DEVELOPMENT. AREA OF CIRCLES IS PROPORTIONAL TO CURRENT CCS CAPACITIES.[7]

Global Carbon Capture Institute – Commercial CCS facilities in operation worldwide

Sample of CCS projects in Australia and SE Asia

Summary of CCS projects

Project name	Country	Operator	Stage	Storage Type	Injection Rate (Mtpa)
Gorgon	Australia	Chevron	Operational	Aquifer	4
Moomba	Australia	Santos	Execution	Depl. field	1.7
Kasawari	Malaysia	PCSB	Execution	Depl. Field	3.3
North Carnarvon	Australia	Woodside	Study (FID 2023)	Depl. Field	5
Arthit	Thailand	PTTEP	Study (FID 2023)	Depl. Field	1
Bayu-Undan	Australia/TL	Santos	Study	Depl. Field	10
Reindeer	Australia	Santos	Study	Depl. Field	TBA
Lang Lebah	Malaysia	PTTEP	Study	TBA	TBA
Shepherd	Malaysia	PCSB	Study	Depl. Field	TBA
PAU	Indonesia	SEP	Study	Depl. Field	TBA
Bonaparte	Australia	Inpex	Study	Depl. Field	2.0-7.0
Cliff Head	Australia	JV	Study	Depl. Field	0.6
Southeast Australia	Australia	ExxonMobil	Study	Depl. Field	2
Arun	Indonesia	JV	Study	Depl. Field	TBA
CarbonNet	Australia	Victorian gov.	Study	Deep saline	1.0-5.0
Papua LNG	PNG	Total	Study	Depl. Field	1



Sample of CCS projects in Australia and SEAsia

Challenges to CCS projects

Technical challenges

Many technical challenges to CCS projects are universal but each project is unique in its surface subsurface interactions. The petroleum industry is the natural starting place for CCS as it already has the skill sets required.

Carbon capture

- Dominated by natural gas processing in Australia.
- Easier to remove the natural reservoir CO2 - less energy intensive than post combustion capture.
- Emissions are close to potential storage sites.
- Single emitter and single storage reservoir easy to manage.
- Cost of capture remains high due to low capture pressure and significant compression requirements.

Storage

- Assessment of potential storage resource potential needs to be understood.
- Projects likely to focus on known reservoirs.

Injection rates

- Operating envelopes need to be established to ensure reservoir integrity maintained.

Monitoring

- Monitoring plans (and mitigation methods) to meet regulatory requirements
- CO_2 plume development in line with reservoir model.

CCS as a system

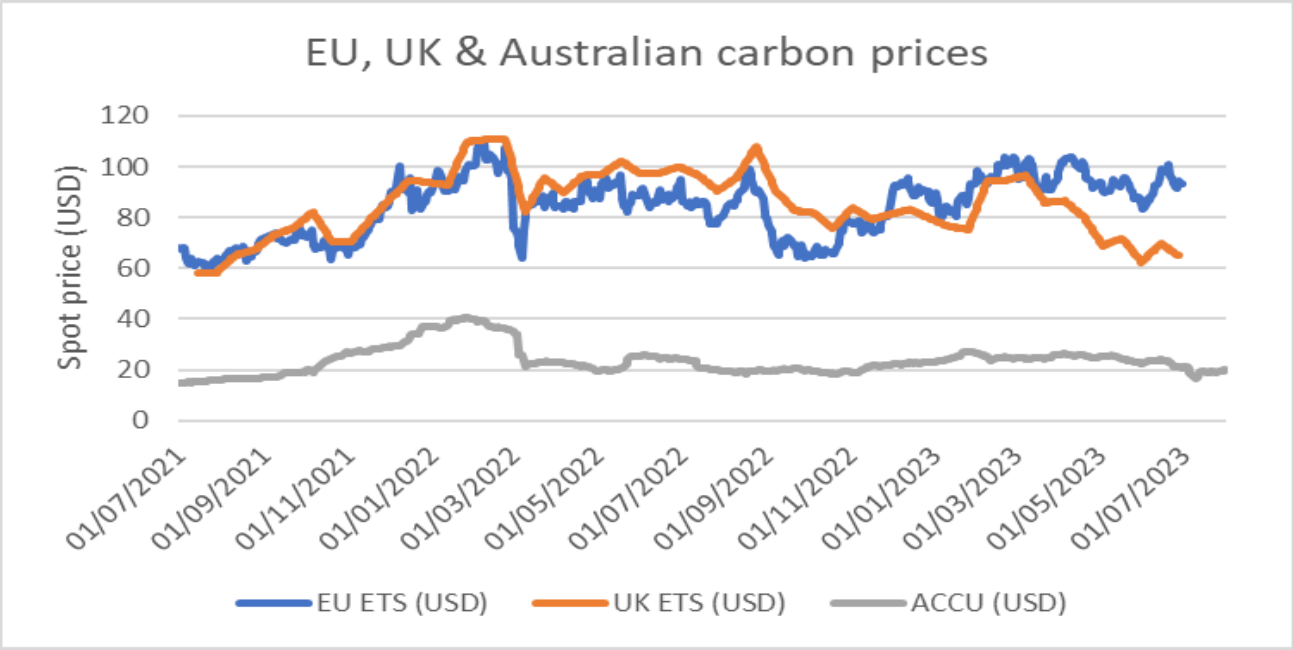
- It is always important to consider a CCS project as a system.
- The interaction between the point at which carbon is captured, treated, transported, injected and stored needs to be considered.
- Each project will have a unique sub-surface geology, set of injection operating envelopes, number and type of carbon capture points.

Key takeaways:

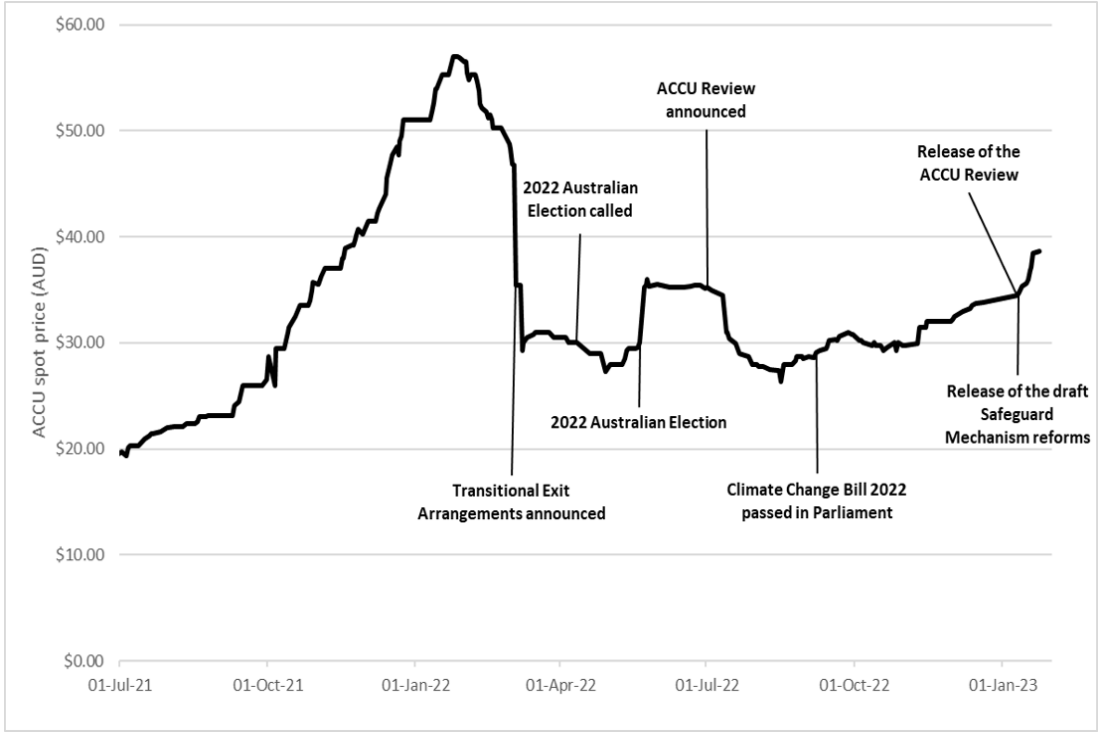
- Most early CCS projects will be:
  - for sequestering CO_2 captured from natural gas production.
  - Likely to focus on use of depleted reservoirs
- CCS will be dominated by the petroleum industry for foreseeable future as it has the relevant skills.
- Although there are many technical challenges that are similar to all CCS projects each one will be unique in its interaction between surface facilities and sub-surface geology and injection requirements.

Australian Carbon Credit Units, ACCUs

- Similar style system to EU & UK.
- Cost of emissions highly volatile. Difficult to predict potential revenue from emissions avoidance.
- Government announcements can impact price.
- UK issuing more carbon allowances, June 2023.
- Australian Government policy shifts.



*ETS = Emissions Trading System



Spot Price ACCUs – Source: Australian Government Clean Energy Regulator

- As of October 2021, CCS projects qualify for Carbon Credits.
- Allows for CCS projects to have a 'revenue stream'.
- Santos delayed the Moomba CCS project until CCS project were included in the ACCU system.

Long term storage liabilities associated with CO_2 leaks

Australia has developed a regulatory framework for potential leaks associated with CCS projects and RISC anticipates that ultimately all jurisdictions in the rest of the Asia-Pacific region will invoke some form of time-based transfer of liability to the State.

Offshore - Federal Government

- *For offshore projects the Commonwealth requires a closing certificate to be issued when injection operations cease. The holder of this certificate (the operator) remains responsible for any issues within the next 15 years. If, after at least 15 years, the Minister is satisfied that there is no significant risk of significant adverse impacts the Minister may declare a "closure assurance period", after which the Commonwealth will indemnify the certificate holder against future liability.*
- Coupled with Offshore Petroleum and Greenhouse Gas Storage Act. Consequently, CCS activities are approved by the same regulators.

Onshore legislation

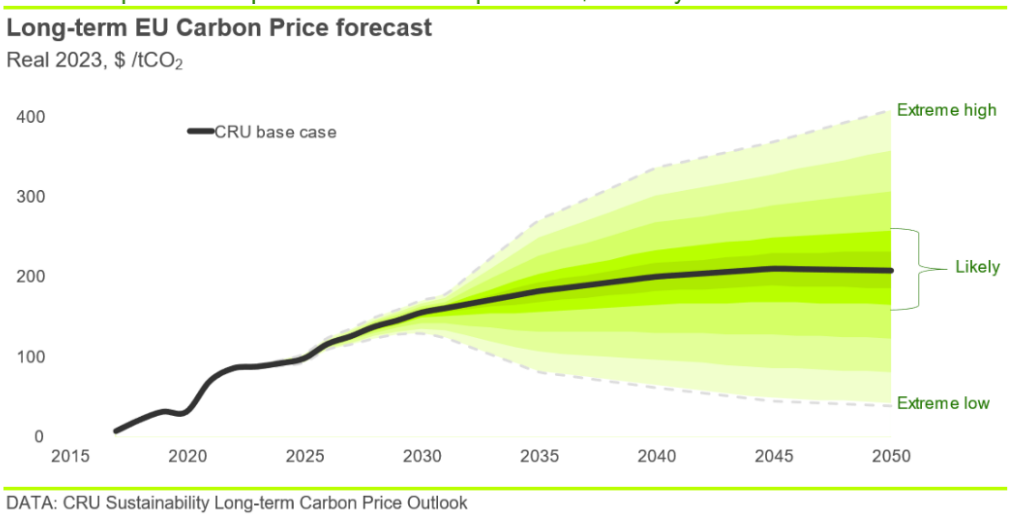
- In Western Australia; The Barrow Island Act was altered in 2003 specifically for the Gorgon project. The State will indemnify the Gorgon joint venture parties from post-closure liabilities after a 15-year period post cessation of injection.

RISC notes that legislation has yet to be tested and there is no guarantee that the authorities would declare a closure assurance period.

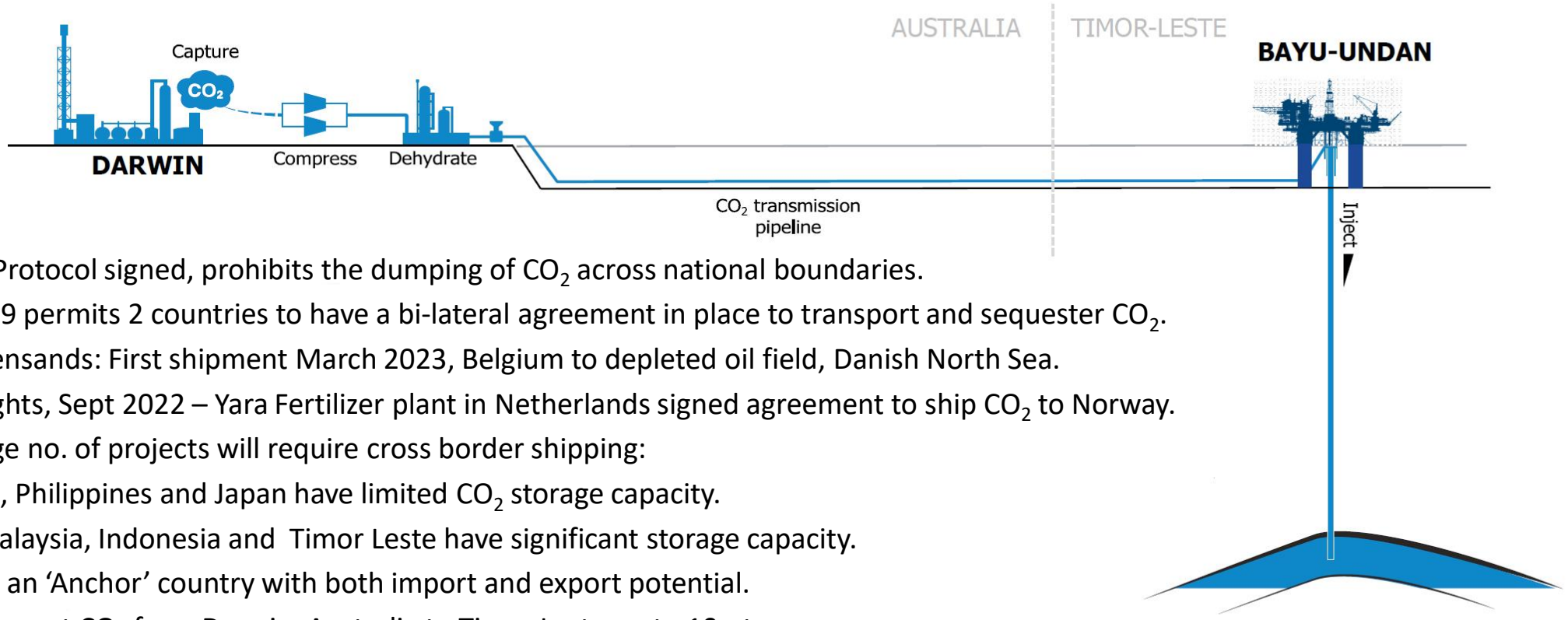
Potential liabilities

- Department of Energy & Climate Change conducted an assessment.
- For a field with 200mt storage capacity, 6 abandoned wells there is a 0.12 to 0.5% probability of a CO_2 leak of up to 220,00te over a 100 year period.
- **Potential price tag - 18 to 77US$million for carbon credits.**
- Doesn't include costs for environmental damage.

'Fit for 55' policies will push the EU carbon price to >$150 /t by 2030



Shipping of CO_2 across borders



- In 1996 London Protocol signed, prohibits the dumping of CO_2 across national boundaries.
- Amendment 2009 permits 2 countries to have a bi-lateral agreement in place to transport and sequester CO_2.
  - Project Greensands: First shipment March 2023, Belgium to depleted oil field, Danish North Sea.
  - Northern Lights, Sept 2022 – Yara Fertilizer plant in Netherlands signed agreement to ship CO_2 to Norway.
- Asia Pacific – large no. of projects will require cross border shipping:
  - South Korea, Philippines and Japan have limited CO_2 storage capacity.
  - Australia, Malaysia, Indonesia and Timor Leste have significant storage capacity.
- Australia seen as an 'Anchor' country with both import and export potential.
- Bayu Udan – To export CO_2 from Darwin, Australia to Timor Leste up to 10mtpa
  - Anchor project, CO_2 from Barossa development, 2.4mtpa.
- **Bi-lateral agreements are complex**
  - Which government is ultimately responsible for the CO_2 stored underground?
  - Does one state have more stringent regulations than the other?
  - Defining who is responsible/which regulations shall be followed for the CO_2 along the whole value chain.

Society of Petroleum Engineers SRMS – Demonstrating resource potential

RISC has successfully implemented the SPE's SRMS in certifying Santos's contingent storage resources on the Moomba Phase II project as well as in evaluating prospective storage resource potential for our clients and the Australian Government.

- **Society of Petroleum Engineers published the Storage Resource Management System in 2017**
  - Useful tool to calibrate expectations, uncertainty and maturity of carbon storage projects for investors and stakeholders.

Step 1 Establishing prospective resources

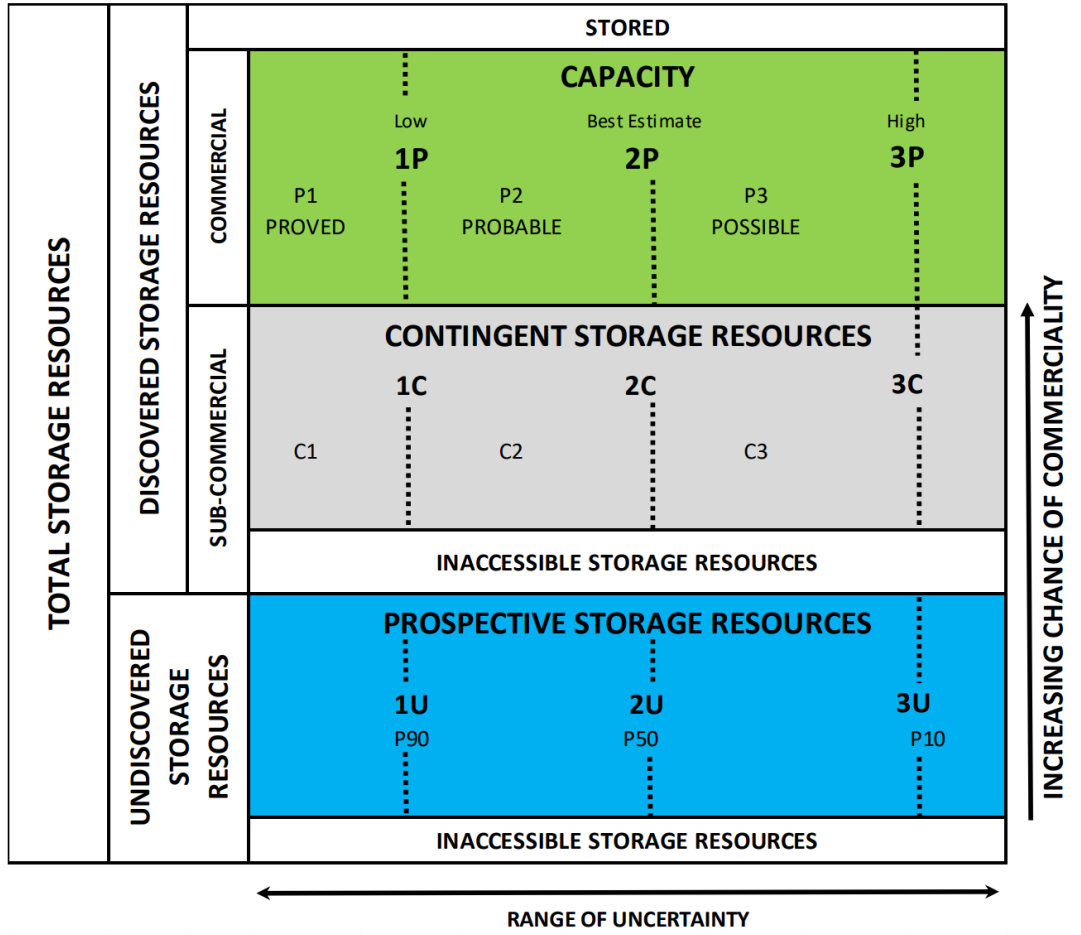
- Operator preliminary work includes:
  - Best depths (pressure) to operate saline aquifer CO_2 storage project.
  - Evaluation of 4 way dip closures and potential for residual gas trapping.
  - Investigation into possible CO2 markets.
  - Appropriate analogues to estimate GRV storage capacity and areal extent of the CO2 plume.

Step 2 Maturing to contingent resources

- New data acquisition and subsurface modeling:
  - 3D seismic campaign, exploration wells/injection testing.
  - Mature subsurface modelling sufficiently to reclassify the storage volumes.

Step 3 Maturing to storage capacity (certified resources):

- Project approval.
- Immediate reclassification of firm contingent storage to storage capacity.
- Subsequent reclassification of unfirm contingent storage to storage capacity.

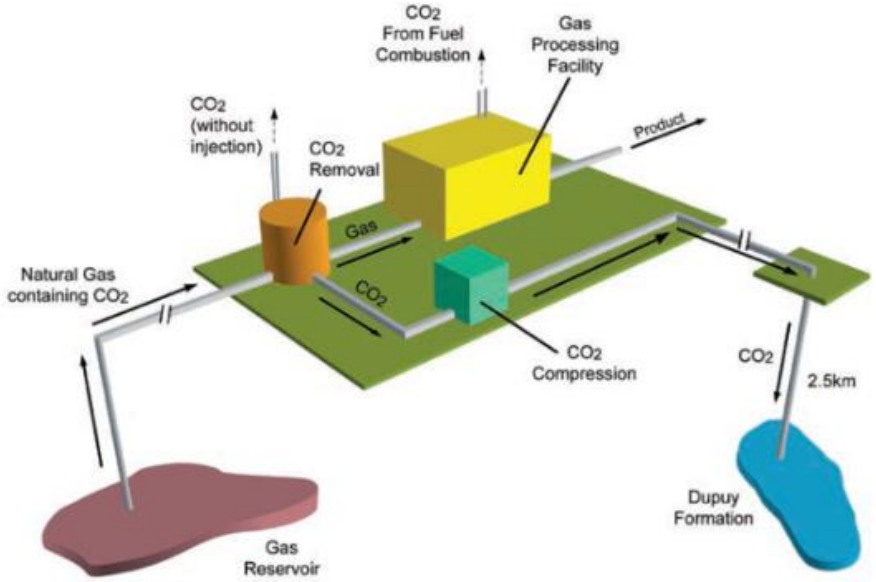


SPE SRMS Resources classification framework

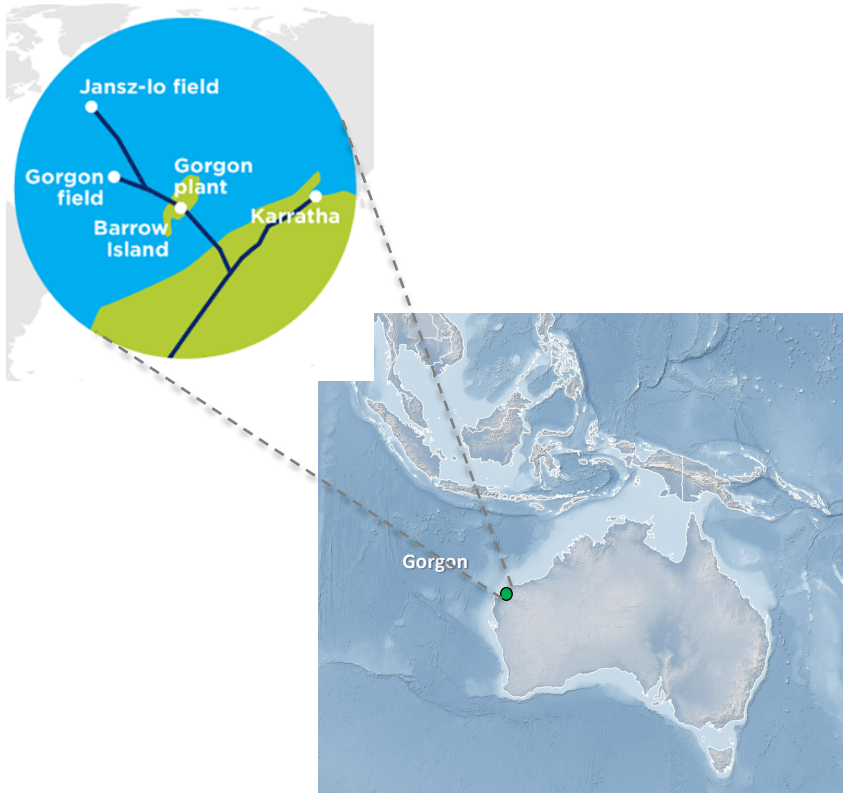
Gorgon – Not a CCS problem

Gorgon CCS project overview

- Located 1200km north of Perth on Barrow island nature reserve.
- Multiple large gas fields: Jans IO and Gorgon initially – others later.
- 3 LNG trains - 15.6tmtpa
- Domestic gas processing plant 300TJ/day of gas to WA market.
- Chevron (operator) 47.3%, Exxon Mobil and Shell (25% each), Tokyo Gas and Jera (2.7%).
- 14-16mol % CO_2.
- 9 CO_2 injection wells with total capacity of 4mtpa (Circa 40mtpa currently injected worldwide)
- Started up 2019.
- Operational life – 40 years.



Gorgon processing facility
Source – Government of Western Australia Department of Mines, Industry Regulation and Safety



Location of the Gorgon gas processing and CCS facilities

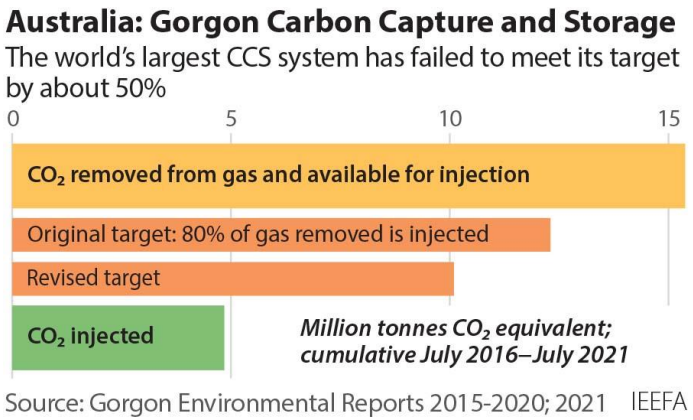
Poor performance has been picked up by the press…

Chevron has faced teething issues with the Gorgon CCS project. Since start up it has not been able to meet full capacity – up to the end of 2022 approximately 5.5 million tonnes had been injected compared to a target of 12 million tonnes.

Institute for Energy Economics and Financial Analysis

April 26 2022 the Institute for Energy Economics and Financial Analysis wrote

"IF Chevron, Exxon and Shell can't get Gorgon's carbon capture and storage to work who can?"



upstream ENERGY EXPLORED

Chevron's flagship Gorgon CCS project still failing to live up to expectations

Carbon capture and storage project in Western Australia only operated at just over half of its stated capacity in the 2021 financial year

10 February 2022 8:29 GMT UPDATED 18 February 2022 18:19 GMT

The Guardian Newspaper of the year

Gas giant Chevron falls further behind on carbon capture targets for Gorgon gasfield

While scale of shortfall is uncertain, conservationists claim admission is proof the project isn't working

The Sydney Morning Herald

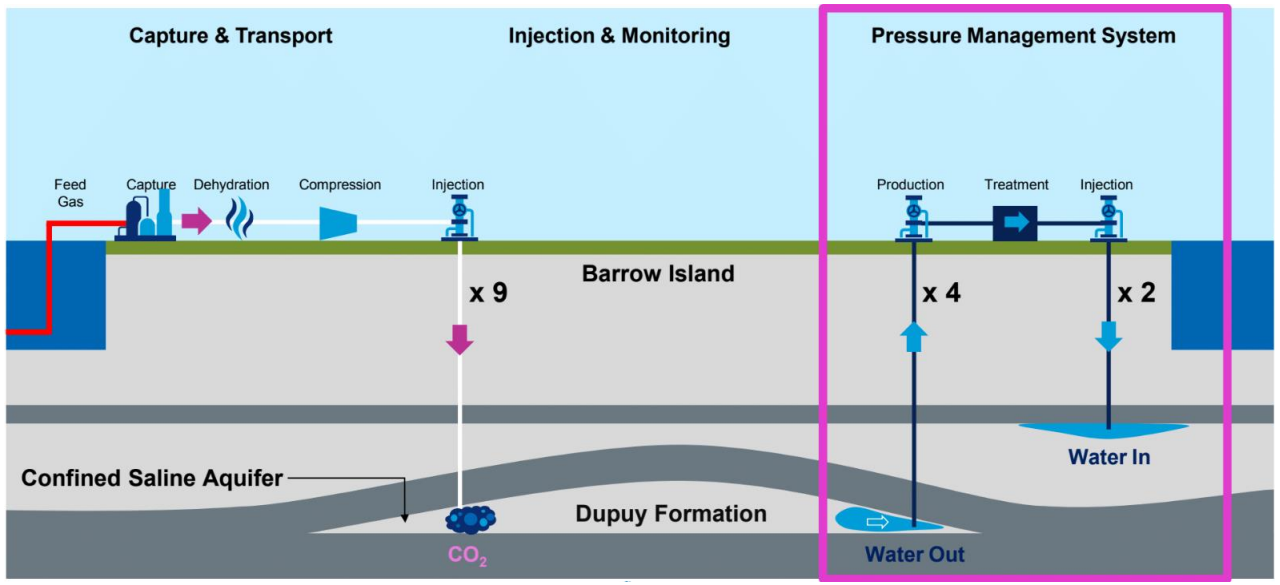
Chevron's five years of Gorgon carbon storage failure could cost $230 million

- Gorgon CCS has failed to meet its injection target of 4 MTPA.
- But is still successful when one considering the current capacity of CCS projects is circa 40mtpa.

So what's the issue?

Gorgon has water injection problems (not CO_2 injection)!

- CO_2 is injected into the Dupuy formation – a closed Saline Aquifer.
- To maintain integrity of the reservoir, water is extracted to maintain reservoir pressure.
- This water is reinjected into another shallower aquifer in the Barrow Group.
- Water extracted contained more solids (produced sand) than expected:
  - This caused fouling in the water injection wells and a decrease in injection capacity.
  - Water extraction had to be reduced, and this, in turn, led to reduced CO_2 injection.
- Chevron's plans to resolve:
  - Increase the number of water injection wells from two to four.
  - Increase water treatment (filtration) capacity.
- Noteworthy:
  - CO_2 injection and reservoir performance is as expected.
  - Excellent match between the predicted CO_2 plume growth and that observed in surveys.
  - Good confidence in long term predictions.
  - ~8 million tonnes CO_2 stored as of May 2023.
- Hindsight – If water extraction had started earlier, when they started injecting CO_2 the problems would have been picked up earlier and could have been addressed.



Gorgon CCS simplified flow diagram
Chevron SPE Presentation Insights and Lessons Learnt, June 22, 2023

Key Takeaways

CCS is a well proven technology and can demonstrably safely store CO_2

- Capture and injection of CO_2 has been proven in operations for over 5 decades.
- Dedicated CCS projects are not new – Sleipner has been operating for nearly 30 years.
- All (CCS) projects are unique and face unique as well as common problems.
- Gorgon CCS works but has highlighted some potential problems that others can learn from.
- Australia has the most advanced regulatory framework in place in the Asia Pacific region (but it is not comprehensive or complete).
- CCS is the only proven technology that can remove significant quantities of CO_2 emissions (currently at ~40 MTPA capacity and growing).
- The petroleum industry has both the skill sets and the asset knowledge required to enable CCS project development.
- The petroleum industry must lead the way with CCS.
- **This has been a brief overview of CCS in the APAC region; RISC has completed numerous technical due diligence activities on CCS projects as well as evaluation of CO storage potential, reservoir modelling, CO_2 injection modelling, set up CO_2 measurement and monitoring programmes. Please don't hesitate to get in touch if you would like to know more.**

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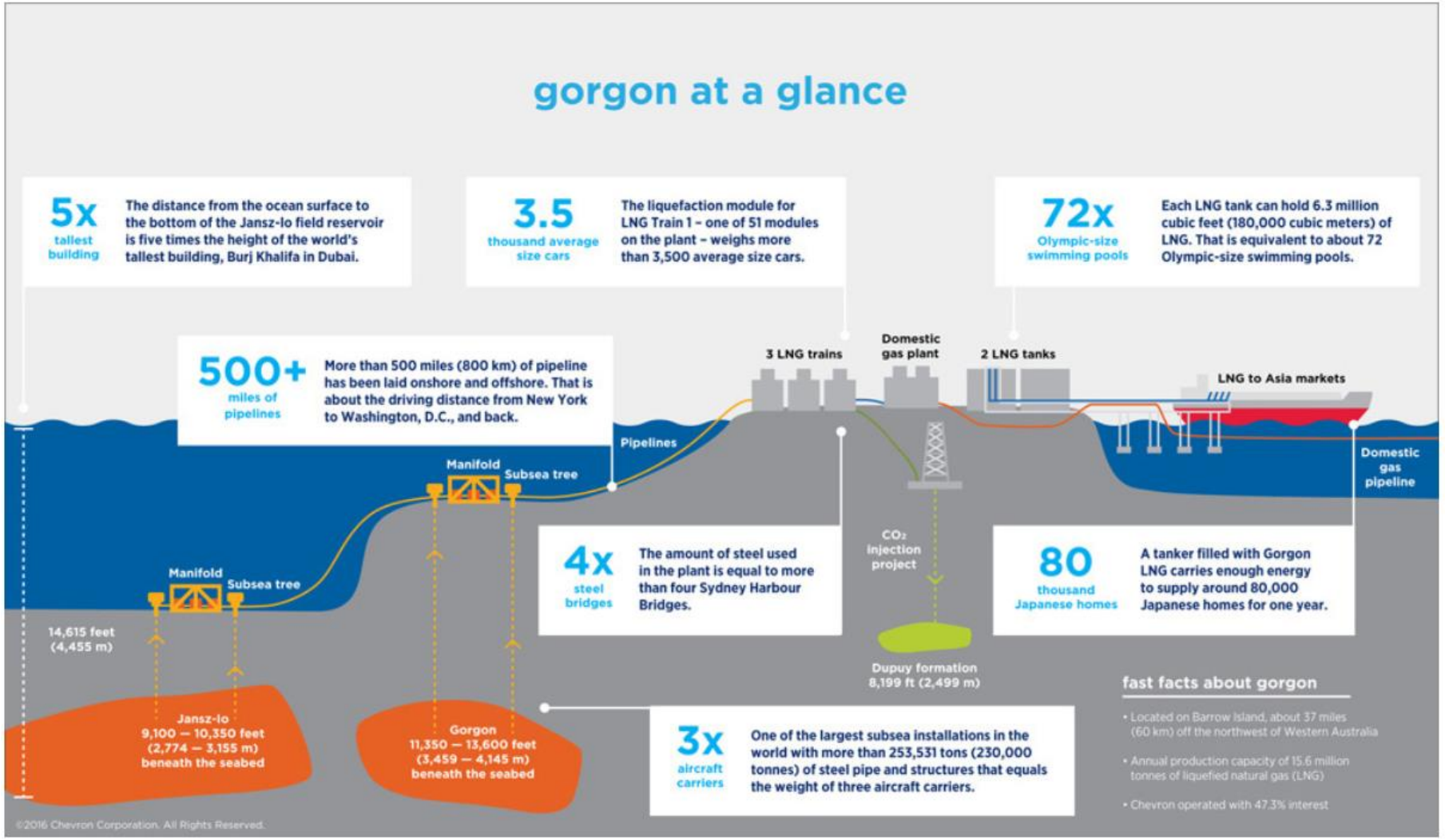
Appendix I - Gorgon at a glance



Chevron Australia – Gorgon at a glance
https://australia.chevron.com/our-businesses/gorgon-project