Prepared for
Infrastructure South Australia
ABN: 16372487442

Carbon Capture, Utilisation and Storage

Infrastructure and National Supply Chain Study

2025

REPORT FOR PUBLIC RELEASE



Carbon Capture Utilisation and Storage

Infrastructure and National Supply Chain Study

Client: Infrastructure South Australia
ABN: 16372487442

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2025

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Acknowledgement of Country

We acknowledge and respect the First Peoples of this land and their deep ongoing spiritual and cultural connection to Country.

We will work together with our First Nations people to share our collective knowledge and recognise the enduring impact of infrastructure on Country.

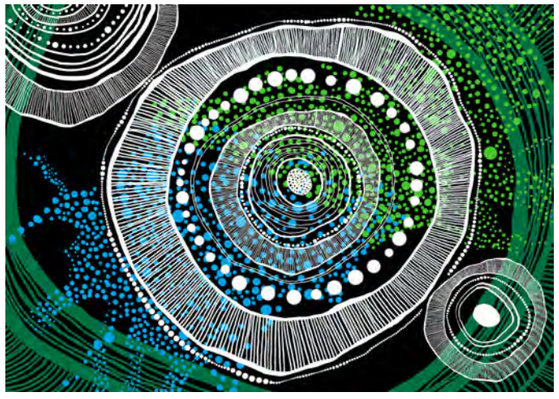


Image this page:
Artwork created for Infrastructure SA by Eastern Arrernte artist Patrick Caruso. Patrick is the founder of We Create Print Deliver, a South Australian based advertising and business agency. The artwork represents Infrastructure SA and our people, knowledge and skills, the projects and communities impacted by our work and the people travelling through the landscape via the work that we do.

Executive Summary

The path to Net-Zero Emissions includes Carbon Capture, Utilisation and Storage (CCUS), and SA holds all the elements for success:

- Demand from industry driven by federal policy
- Ample storage including depleted oil and gas reservoirs
- A supportive regulatory environment
- Adaptable infrastructure for global import
- A proven and operational CCS plant

CCUS is essential to decarbonise hard-to-abate industry

Despite global decarbonisation efforts, Greenhouse Gas (GHG) emissions and hydrocarbon consumption have likely not yet reached their peak with effective abatement of emissions at a critical juncture if we are to limit global warming in line with our Paris commitments. The International Energy Agency (IEA) estimates CCUS will be required to account for 18% of emission reductions in the energy sector from 2030 to 2050[8].
Net Zero Australia has found that in almost all modelled scenarios, CCUS is required to achieve net zero by 2050 through targeted use within hard-to-abate sectors[1]. These hard-to-abate sectors contributed 16% of Australia's total emissions in 2021[11]. Organisations including the CSIRO and Intergovernmental Panel on Climate Change (IPCC) have highlighted the role of CCUS in net-zero pathways, particularly for hard-to-abate and power generation sectors[12].

CCS will be required to address

18%

of emissions reduction in the energy sector globally from 2030 to 2050[8]

Domestically, large industrial facilities, including those within these hard-to-abate sectors, are obligated under the Safeguard Mechanism and National Greenhouse and Energy Reporting (NGER) Act, to reduce their baseline emissions by 4.9% per annum to 2030. As the year-on-year decarbonisation demand accumulates and with limited alternatives to current processes in hard-to-abate sectors, the opportunity for CCUS will increase and the presence of CCUS infrastructure may become a criteria in site selection for future industrial operations.

Across the Asia Pacific Region (APAC) countries including Japan, South Korea, and Singapore all have net-zero commitments which identify a need for CCUS as part of their Paris Agreement Nationally Determined Contributions (NDC), however have limited access to proximate and viable CO_2 storage. Australia is widely recognised as a potential storage hub in the APAC region due to our extensive storage reserves, natural gas supply chain and skilled workforce.

In November 2023, the Australian Federal Government enacted the Environment Protection (Sea Dumping) Amendment (Using New Technologies to Fight Climate Change) Act 2023 which was ratified in November 2024 allowing bilateral treaties with other countries to enable cross-border CO_2 transfer.

Economic Opportunity for SA

Analysis based on the 2024 Infrastructure Australia Carbon Value *Central Scenario* indicates by 2031 the carbon value will exceed the cost of carbon capture for iron and steel production industries, and by 2036 all hard-to-abate industries will have a carbon value above cost of capture.

The preliminary economic impact analysis demonstrates that all three proposed phases of the CCUS ecosystem rollout have a positive impact on the South Australian Economy.

Phase 1	South Australia Opportunity	$6.9 billion value added	1,341 jobs average annual employment	1.8 $MtCO_2$ p.a.
Phase 2	South Australia Opportunity	$18.3 billion value added	3,814 jobs average annual employment	20 $MtCO_2$ p.a.
Phase 3	South Australia Opportunity	$4.0 billion value added	816 jobs average annual employment	20.1 $MtCO_2$ p.a.

Further economic upside may be realised through development of industry for carbon utilisation, which is not currently considered in the economic assessment.

SA Already Has the Foundations of a CCUS Ecosystem

SA is uniquely positioned with existing geological reserves, adaptable infrastructure, and industry to form the foundational requirements of a CCUS ecosystem.

Locally, the Cooper and Eromanga Basins are estimated to provide over 500 Mt of storage capacity including depleted oil and gas reservoirs – a suitable volume to store all CO_2 from the identified sources until 2050 and beyond.

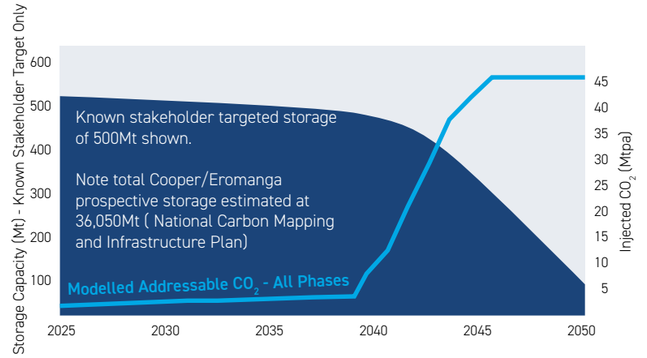


Figure 1. Available Storage vs Capacity vs Injection Rate

The total available prospective storage of the basins is estimated as 36,050Mt. These basins are well positioned to receive supply from a local Upper Spencer Gulf cluster, NSW cluster, QLD cluster, and from global imports.

The Upper Spencer Gulf region including Whyalla provides an impressive combination of existing industry and infrastructure which is well placed to support a CCUS ecosystem. The existing hard-to-abate steel industry, tied to the region through the local magnetite iron ore deposits, would form the key opportunity for Phase 1, with wider benefit afforded to smaller regional players. The complimentary port, road, and rail infrastructure in the region further raises the appeal of the area for common CCUS user infrastructure. The existing liquids pipeline to Moomba and associated easements could be leveraged to support a CO_2 pipeline to the storage basins. Existing port infrastructure provides a platform to scale via the development of a CO_2 import supply chain.

The region itself is targeted for re-industrialisation via the State Prosperity Project and is the subject of the comprehensive SA Government Green Iron and Steel Strategy. The Future Made in Australia policy and direction of the Net Zero Economy Authority also include a focus on the Upper Spencer Gulf.

South Australia hosts a highly skilled workforce associated with the oil and gas industry that have a plethora of transferrable skills relevant to CCUS, including pipeline infrastructure construction and operation. Supporting industries are numerous including engineering and logistics, further enhancing the status of the region as an industrial hub.

Tried and Tested Technology

In October 2024, Santos and Beach Energy successfully completed construction and commenced operation of a CCS plant in Moomba, SA. The plant captures CO_2 produced by the adjacent Moomba Gas facility, with a current nameplate capacity to capture and store up to 1.7 Mt per annum.

Historically, carbon capture technology has been used for decades as a method for enhanced oil recovery (EOR) – with the methods for capture, transport, and injection of CO_2 well understood. EOR is not proposed for SA, however the understandings from the EOR technologies provides a level of technological maturity to facilitate rapid uptake.

The composition of the CCUS addressable market and target sectors is provided in the chart below. Natural gas processing is included due to the Federal Government Future Gas Strategy[28], which identifies the continuance of natural gas processing and domestic use beyond 2050.

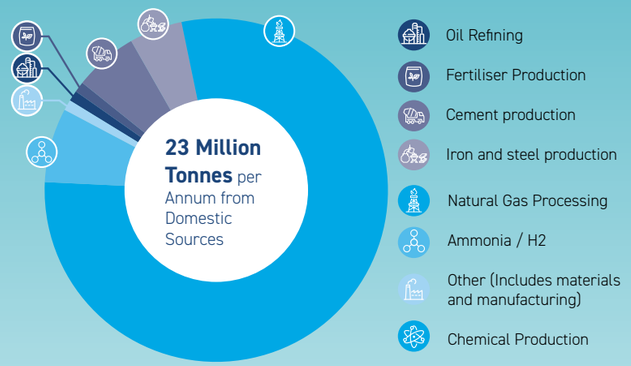


Figure 2. Composition of domestic CCUS addressable market by industry type

The modelling undertaken indicates that a combined 22Mtpa of CO_2 could be available from Japan, Singapore, and South Korea based on their current commitments to CCUS. This demand could increase to 165-265Mtpa in the long term based on the current net-zero commitments of these regions, with further upside from other APAC countries.

Three Local Clusters and Global Import Opportunity

The analysis considers three phases with three clusters of industry generating CO_2 as well as global import scenario. The phases are generally independent and the program can be modified to capitalise on the best-for-state opportunities.

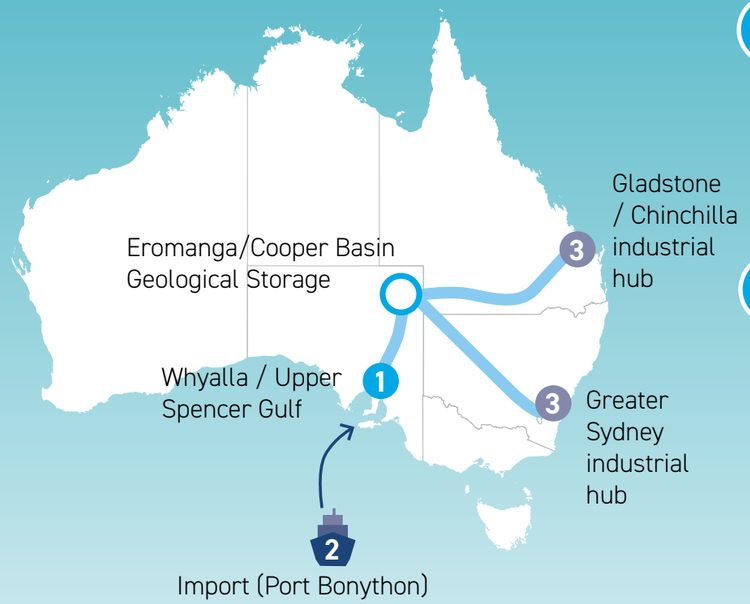
Phase 1 – Upper Spencer Gulf / Whyalla Cluster - A CCUS hub is developed at Whyalla in the Upper Spencer Gulf, with infrastructure development occurring entirely within SA to maximise state economic activity. A pipeline is constructed for the transport of CO_2 to the storage location.

Phase 2 – Global Importation – Development of CCUS import infrastructure, with CO_2 imports occurring via Port Bonython from trade partners such as Japan and South Korea. Additional pipeline infrastructure supports the transport of CO_2 for storage.

Phase 3 – Greater Sydney & Gladstone/ Chinchilla Clusters - QLD and NSW CCUS hubs are implemented with an interstate pipeline for the transport of CO_2 into SA for storage.

Next Steps

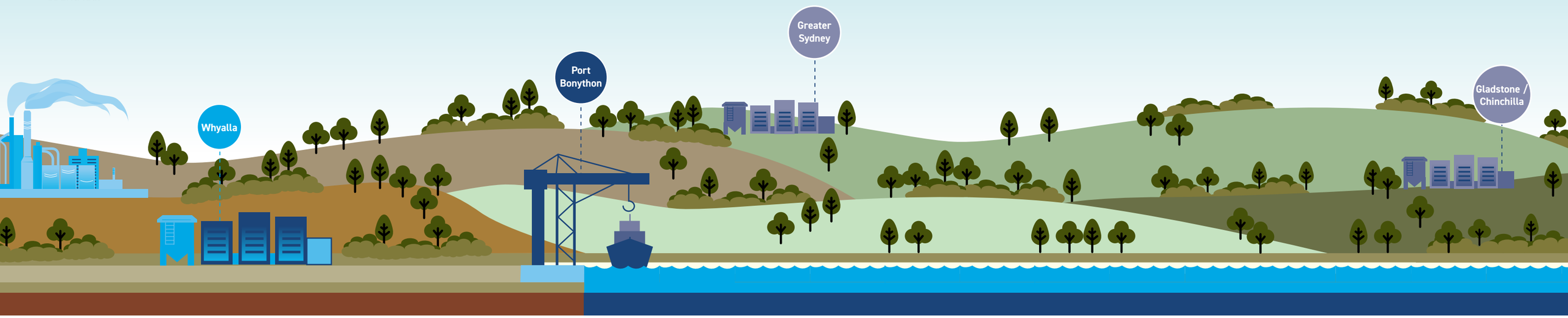
ISA undertook this study to understand the potential establishment of a CCUS industry in SA and the ability to address local, national and international opportunities. This study indicates that a range of opportunities exist for SA and presents one potential scenario for infrastructure and partnerships. The next steps will further explore the opportunities and feasibility of CCUS for SA.



1. **CCUS Partnerships –** Establish a holistic CCUS forum (network or similar) across all elements of the supply chain, including regulators, industrial emitters, technology partners, potential owners/operators, and research and development partners.

2. **Development Pathway** – Undertake a strategic assessment of the frameworks under which a CCUS ecosystem would be developed, regulatory approvals, engage with supply chain operators, and undertake analysis of discrete project elements and business models

3. **Detailed Business Case –** A detailed business case will be developed for feasible opportunities identified as part of Step 2, including preferred operating model and underpinning infrastructure



01 Introduction

ISA engaged AECOM to conduct an infrastructure and national supply chain study to identify the potential for a Carbon Capture, Utilisation, and Storage (CCUS) ecosystem within SA and the associated opportunities and benefits that may arise for the state.

Purpose of this Report
The content of this report is general in nature and solely intended as information for ISA's consideration in developing the 20-Year State Infrastructure Strategy. As such this report and associated noted findings should not be used to inform any investment decision. Key limitations and assumptions applicable are raised as footnotes on this page.

Limitations
This report is based on publicly available information, AECOM's data, input from ISA, and other agreed stakeholders. Assumptions have been made for this rapid study, requiring validation through further analysis and should not be used to inform any investment decisions.

Assumptions
Specific assumptions applied to each area of analysis are provided throughout the full report. The below summarises key assumptions that frame the report outputs: Australia's commitment to the Paris Accord targets, including an interim target of 43% reduction by 2030 and net-zero emissions by 2050 will be maintained.
Point source emission estimates are limited to existing industries and associated facilities, which are covered under the Australian Government Safeguard Mechanism regulations and are considered 'hard-to-abate'. The estimates consider total addressable market and are not forecasts of likely capture capacity at each facility. Industries not considered 'hard-to-abate' are assumed to pursue emission abatement through other mechanisms. Carbon capture from future industry growth scenarios such as sustainable fuel production are not considered nor is capacity from projects that are planned but not yet committed. These opportunities should be considered in further studies in conjunction with industry.
Storage capacity estimates assume that analyses by third parties, such as Geoscience Australia, are accurate, and the storage will be made available for use as CO_2 storage. It is assumed that a detailed, invasive analysis will be undertaken on storage locations to confirm capacity and associated risks. Assumptions associated with capital estimates, input/output economic analysis, infrastructure design basis and detailed point source addressable market are covered elsewhere within the full report prepared for ISA.

1.1 Infrastructure SA

Infrastructure SA is an independent agency of the South Australian Government which provides advice to the government on coordination, planning, prioritisation, delivery, and operation of infrastructure.

Infrastructure SA was established and operates under the Infrastructure SA Act 2018 (SA) (the Act) to serve as an independent advisory and assurance body in relation to major infrastructure projects in South Australia. It is governed by an independent board, with both public and private sector expertise, and reports directly to the Premier of South Australia.

Section 5(1) of the Act defines the objects of Infrastructure SA as:

- to promote such efficient, effective, and timely coordination, planning, prioritisation, delivery, and operation of infrastructure as is necessary for the economic, social, or environmental benefit of the State; and
- to promote the adoption and use of policies, practices, information, and analysis to support sound decision-making in relation to infrastructure.

Consistent with the Act, Infrastructure SA has four core deliverables:

- Preparing a 20-Year State Infrastructure Strategy and updating it at least every five years
- Providing project monitoring as independent assurance for projects and programs with a capital value of $50 million or more
- Preparing an annual Capital Intentions Statement that represents Infrastructure SA's views on priority infrastructure initiatives
- Providing strategic advice to the Premier of South Australia as needed.

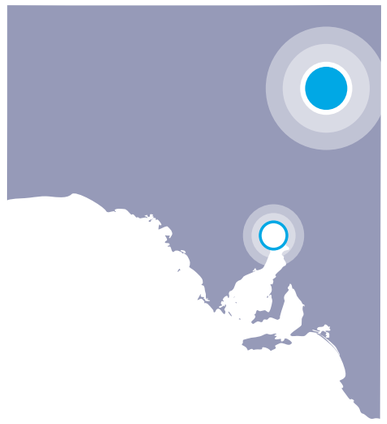
Infrastructure SA's vision is that efficient and evidence-based infrastructure planning and delivery will grow the economy, create jobs, and improve liveability for all South Australians. You can find out more about Infrastructure SA on our website infrastructure.sa.gov.au.

1.2 This Report

The intent of this report is to explore the potential for SA to develop a CCUS industry in alignment with key state priorities and goals.

This report:

1. Articulates the role that CCUS can play in the transition to a decarbonised economy and the opportunity for SA.
2. Provides an assessment of the logistics and supply chain required to support a CCUS industry.
3. Identifies key point sources of CO_2 within Australia originating from hard-to-abate industries and/or major emitters which may be candidates for the capture of CO_2 and subsequent utilisation or storage in SA.
4. Evaluates the existing, developing and known technical requirements for a domestic supply chain for capturing and transporting CO_2.
5. Summarises the existing and potential locations for CO_2 storage in SA.
6. Provides a strategic economic impact assessment for different carbon value points.
7. Summarises the potential for SA to leverage the findings from above to generate potential economic activity.
8. Provides a preliminary assessment of the opportunities available to SA.
9. Estimates the potential economic impact of establishing a CCUS industry in SA.
10. Proposes next steps and key recommendations for consideration and further investigation.



The below provides a high-level methodology by which this study was undertaken:

Undertake a rapid literature review to understand the typical drivers for the development of a CCUS ecosystem that could be implemented in Australia using existing global examples.

Understand whether the typical drivers for CCUS align with the South Australian strategic goals and commitments as represented in public strategy, including national commitments and policy.

Understand the typical physical infrastructure and supporting policy and regulatory environment that would support the growth of a CCUS ecosystem.

Establish the high-level technical requirements for local implementation within South Australia, including:

- Estimation of the carbon dioxide (CO_2) point-source addressable market using the following qualifiers:
  - The CO_2 source is considered a 'hard-to-abate' industry
  - The point source baseline emissions are of a volume that qualifies their reporting and reduction under the Federal Safeguard Mechanism
- Outline of the **technology application** for the point source CO_2 capture.
- Estimation of the **transport requirements** for the anticipated volume of CO_2
- Estimation of the **end-use cases for the CO_2**, including:
  - Geological storage available within SA
  - Utilisation cases within SA

Undertake economic analysis to estimate the economic impact available to SA should a CCUS ecosystem be established.

Identify key risks and opportunities associated with implementing a CCUS ecosystem.

Recommend items for further detailed study.

02
Australia's Commitment to Net-Zero Emissions

As part of the United Nations Framework Convention on Climate Change and the Paris Agreement, Australia has committed to net-zero greenhouse gas (GHG) emissions by 2050, with a short-term target of an emissions reduction of 43% below 2005 levels by 2030[5].



Whilst Australia's commitment to the Paris Agreement and its Nationally Determined Contributions has broad bipartisan support, major political parties differ on targets and implementation. The current Labor government legislated a 43% emissions reduction by 2030 and net-zero by 2050, reinforcing these targets through international commitments. The Coalition remains formally committed to net-zero but continues to debate the role of fossil fuels and nuclear energy in Australia's energy transition.

Greenhouse gases trap infra-red radiation in the atmosphere, leading to a global warming effect[1]. Carbon dioxide (CO_2) is the most prevalent of these gases, accounting for around two-thirds of total GHG emissions with majority of CO_2 released through the burning of fossil fuels, primarily for electricity, heat and transport, as well as releases associated with various chemical reactions in industrial manufacturing processes[2].

The 2024 Issues Paper by the Climate Change Authority indicates that an emission reduction of 65-75% below 2005 levels by 2035 remains achievable with additional actions from governments, households, businesses, and investors[3].

The Australian Government has committed a range of funding initiatives to support the orderly transition of the Australian economy to a low-carbon future. This includes programs such as Rewiring the Nation, underwriting the Capacity Investment Scheme (CIS) and empowering Australian Renewable Energy Agency (ARENA) with various funding programs such as the Powering the Regions Fund (PRF) and its associated Safeguard Transformation Stream (STS) and Industrial Transformation Stream (ITS).

The Net Zero Economy Authority Bill and associated legislation was passed in December 2024 with the agency established to guide the nation's transition to a net zero emissions economy by 2050. Its primary focus is to ensure that regions, industries, workers, and communities significantly impacted by this transition receive adequate support and opportunities[4].

Australia's next Nationally Determined Contribution (NDC) under the Paris Agreement is due in 2025, ahead of COP30 in Brazil, and will set a 2035 emissions reduction target.

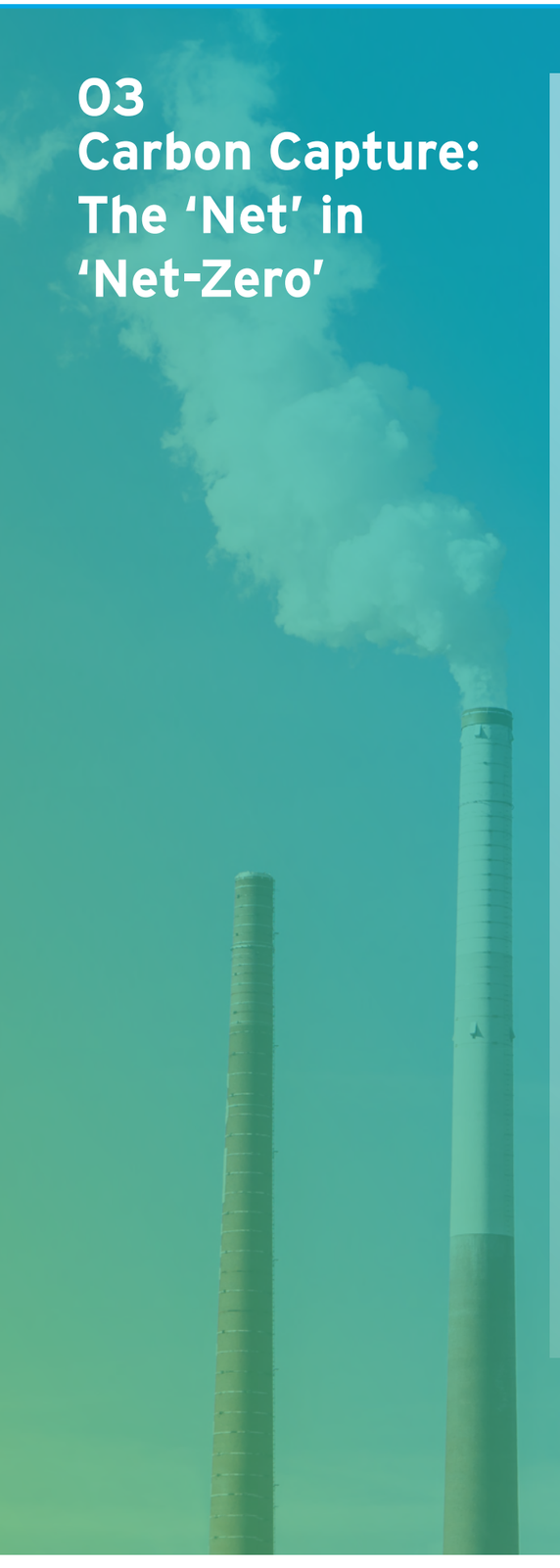


From a state perspective, SA has set ambitious climate targets, aiming to reduce greenhouse gas emissions by at least 50% by 2030 compared to 2005 levels and achieve net-zero emissions by 2050.

Our state is already world leading in renewable energy penetration with progressive plans to legislate a 100% net renewable electricity generation target by 2027. The state government agency Department of Energy and Mining (DEM) notes:

> *"Carbon capture and storage gives South Australia the opportunity to create a new industrial 'hub' for competitive abatement of emissions – especially in sectors with difficult to abate process emissions such as cement, steel and iron manufacturing; natural gas processing; and biofuel production. Furthermore, carbon capture and storage can also enable new technologies such as low carbon production from natural gas (blue hydrogen), e-fuels, and direct air carbon capture and storage."*[6]

03
Carbon Capture: The 'Net' in 'Net-Zero'



CCUS technology should not be seen as a replacement for existing decarbonisation pathways and technologies, including as a displacement for renewable energy. Instead, it should be considered as part of a comprehensive set of solutions that are necessary to achieve our climate commitments.

3. 1 What is CCUS?

CCUS is the process of capturing carbon (in the form of CO_2) and either permanently sequestering (storing) it using geological formations, or transforming it so it may be utilised in various applications.

In the case of capture from industrial applications, CCUS intercepts CO_2 that would otherwise be expelled into the atmosphere and redirects it to 'permanent' storage or for productive re-use. Storage of CO_2 typically occurs in depleted oil or gas fields and saline aquifers. Utilisation pathways typically include direct utilisation (food, beverage and agriculture industries) and indirect utilisation (fuel production).

The physical infrastructure required for a carbon capture supply chain envisioned for SA could consist of:

- Aggregated domestic point source emissions or import terminal
- A common user hub which consolidates CO_2 from multiple emitters and appropriately conditions it for transport
- Transportation via pipeline, truck, rail, shipping, or a combination thereof
- Permanent sequestration via storage or utilisation.

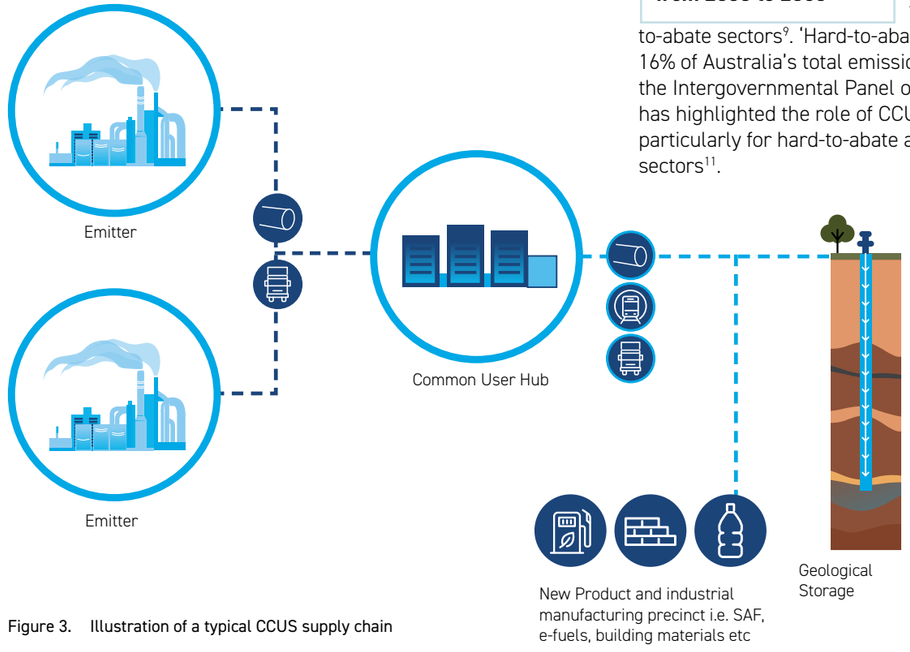


Figure 3. Illustration of a typical CCUS supply chain

CCUS and CCS

Throughout this report both the terms CCUS and CCS (carbon capture and storage) are utilised in specific circumstances. CCUS (which includes utilisation of CO_2) is commonly the broad term to discuss carbon capture as an opportunity and suite of technologies. For the proposed infrastructure in this study, the term CCUS is used to reiterate that a carbon capture ecosystem should seek opportunity to utilise CO_2 where possible for new products. Where projects and research reference "CCS" this is to indicate that utilisation pathways for CO_2 are not considered.

3. 2 Using CCUS to Help Australia Achieve Net-Zero Emissions

While efforts to develop alternate, low-to-zero emission technologies and processes progress globally, there is a consensus that CCUS is required for 'hard-to-abate' industries to achieve the net-zero target of the Paris Agreement[7]. The International Energy Agency (IEA)[8] estimates CCUS will be required to account for 18% of emission reductions in the energy sector from 2030 to 2050[8]. Net Zero Australia has found that in nearly all net-zero scenarios, CCUS is required to achieve net zero by 2050 through targeted use within hard-to-abate sectors[9]. 'Hard-to-abate' industries contributed 16% of Australia's total emissions in 2021[10]. Similarly, the Intergovernmental Panel on Climate Change (IPCC) has highlighted the role of CCUS in net-zero pathways, particularly for hard-to-abate and power generation sectors[11].

18%
of emission reductions in the energy sector from 2030 to 2050[8]

3. 3 Global Adoption

The growth in planned CCUS facilities has accelerated significantly in recent years, with over 50 facilities now in operation and another 44 under construction. As per the CCUS Institutes Global Status Report from November 2024, there are over 628 projects within the development pipeline demonstrating a 60% year on year increase with a more than doubling of projects in advanced development phase alone over the preceding 12 months (from 121 to 247).

Figure 4 shows global projects dominated by the North American and European markets. Within proximity to Australia, Indonesia, Japan, South Korea, Thailand, Singapore and Malaysia all have multiple projects in various stages of development with Papua New Guinea also having a project in early development phase.

57%
year-on-year increase in CO_2 capture capacity under construction

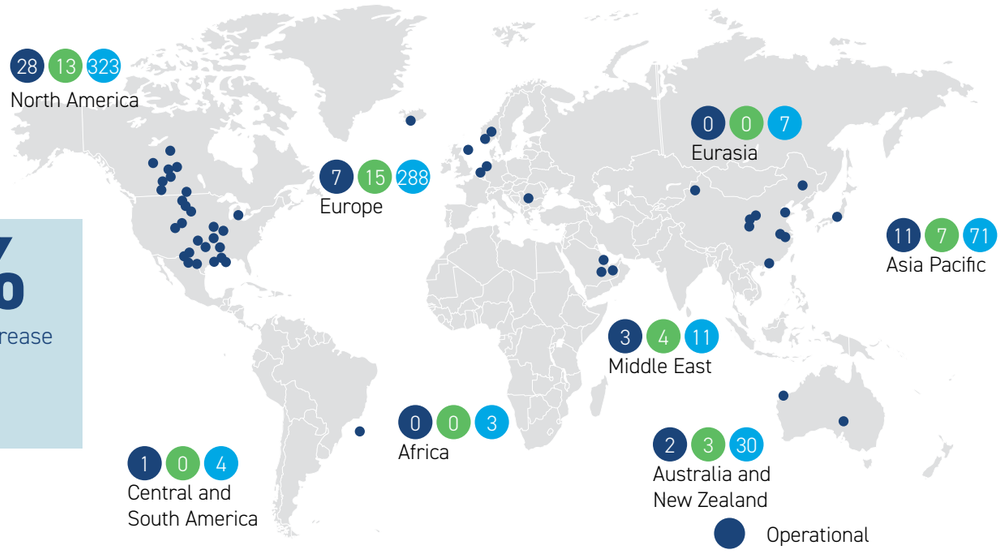


Figure 4. IEA Global CCUS Database March 2024[12]

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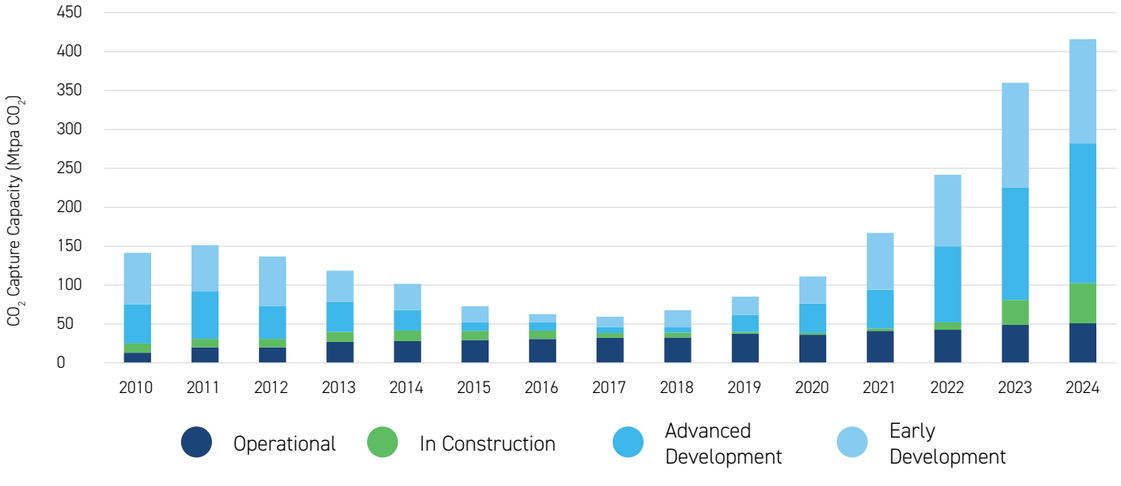
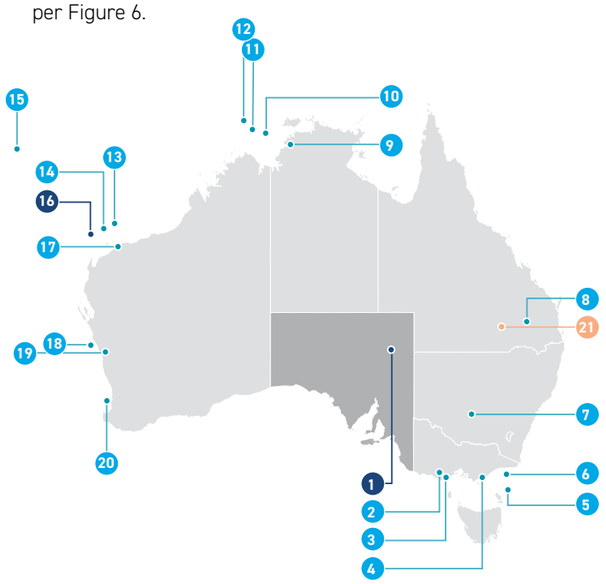


Figure 5. Capacity of commercial facility pipeline 2010-2024[13]

3. 4 Australian CCUS Projects

Figure 5 illustrates Australia's onshore and offshore CCUS projects, with the Moomba CCS Project in SA and the Gorgon Project in Western Australia the only current large operational developments. There are a significant number of planned projects at varying levels of maturity across Australia per Figure 6.



1. Moomba CCS Project
2. CO2CRC Otway International Test Centre
3. Otways CCS Hub
4. Sumitomo Hydrogen Energy Supply Chain
5. The SEA CCS Hub Project
6. CarbonNet Project
7. NSW CO_2 SAP
8. Moonie CCUS Project
9. NT Low Emissions CCUS Hub
10. G-11-AP (Bonaparte)
11. G-7-AP (Bonaparte)
12. Bayu Undan
13. Northern Carnarvon (Karratha)
14. Reindeer
15. Cstore 1
16. Chevron Gorgon
17. Geovault
18. Midwest Clean Energy
19. Low Carbon Ammonia Development /Mid West Modern Energy Hub
20. South West Hub Project
21. CTSCo Project

Operational
In Construction
In Development
Denied Approval

Figure 6. CCUS Projects in Australia by development phase[22,23]

3. 5 Australian Operational Facilities

Moomba CCS Project, South Australia

The stage 1 Moomba CCS project is a joint venture between Santos and Beach Energy located in South Australia[14]. Now complete, the plant has the capacity to capture up to 1.7Mtpa of CO_2 via four removal trains at the existing Moomba Gas facility before the CO_2 is then treated, compressed, and transported approximately 50km to various injection locations. The CO_2 is sequestered into depleted oil and gas fields within the Cooper Basin. Within 12 months Moomba CCS will achieve around 28 per cent of the total emissions reduction achieved by Australia's entire electricity sector in 2023[15].

Santos state the Cooper Basin and the Moomba CCS hub will play a significant role in the energy evolution as it transforms into a decarbonisation hub with potential to produce low-carbon fuels and offer CCS services which could reduce emissions from critical fuels such as LNG and from hard-to-abate sectors such as steel, aluminium, and cement[16].

Stage 2 of the project is currently being investigated and could provide the ability for the project to scale up to a 20Mtpa capture plant, having the capability to service CO_2 arising from third parties. Santos estimates the project could allow for permanent storage of CO_2 in the Cooper Basin at a rate of 20Mtpa for 50 years[17].

Gorgon Project, Western Australia

The Gorgon CCS Project, majority owned and operated by Chevron[18], is one of the largest CCS projects globally associated with the natural gas extraction facility on Barrow Island in Western Australia[19]. The plant captures CO_2 associated with the natural gas extracted from the offshore gas reservoirs, processing the CO_2 on Barrow Island before injection into a giant sandstone formation two kilometres beneath the island. The storage occurs within saline aquifers.

As raised by stakeholders such as the Climate Council of Australia, the project has not achieved its targeted abatement for the project, with a shortfall in captured emissions relative to the committed amount [20]. The shortfall has been caused by various technical subsurface resevoir challenges and water management issues that are largely not required for applications using depleted oil/gas reservoirs such as the Moomba CCS project[21].

Despite the shortfall, the plant is currently active and has successfully captured and stored 9Mt of CO_2 since CCS system start up in August 2019 through to December 2023.

04
Technical Analysis

The following section provides a technical overview of each step within a CCUS supply chain, from point source emissions and associated capture technology, logistics and transport prior to utilisation or injection for permanent storage.

CCUS is essential to decarbonise hard-to-abate industries

4. 1 Emission Sources

Introduction

The focus of the study was to assess CO_2 emission sources from hard-to-abate sectors where emissions are either unavoidable due to inherent processes and associated chemical reactions or where there is no clear alternative pathway to abatement. This included sectors where the technology readiness of alternative emission abatement is immature or where CCUS can play a role as part of a multi-faceted abatement pathway.

Direct Air Capture (DAC) - which directly captures CO_2 from the atmosphere - is also discussed as a form of Negative Emission Technology (NET) that features across industry net-zero pathway publications. This technology requires the same infrastructure for utilisation and storage as capture from industrial processes, potentially acting as an additional point source in future.

CO_2 point sources were assessed at both a domestic level associated with major emitters across Australia covered by the Safeguard Mechanism as well as globally for import scenarios. This included evaluation of critical mass and identification of emission clusters upon which supply chain infrastructure could then be further assessed. This high-level assessment fed into the subsequent supply chain infrastructure and associated Order Of Magnitude (OOM) CAPEX estimate and indicative development timelines.

Hard-to-abate Sectors

CCUS is one of the key technologies in decarbonising hard-to-abate sectors, where certain emissions associated with an industrial or chemical process are unavoidable and, therefore, without technologies such as CCUS, are not able to be abated.

The IEA [24], IPCC [25] and CSIRO [26] Net Zero Scenarios all forecast CCUS to play a key role in decarbonising sectors where these unavoidable process emissions occur, or where the technology or cost of alternatives points to a future where CCUS is the most likely commercially viable decarbonisation opportunity. This may include any facility where raw materials are transformed or processed into useful products through chemical, physical, thermal, or mechanical means. These plants are typically complex and can vary widely in size and scope depending on the industry and the specific processes involved.

The hard-to-abate sectors identified within the study include industrial processes where CO_2 is produced as a byproduct of the following activities critical to the manufacture of the end product:

1. **Chemical reactions:** Many process plants are designed to carry out specific chemical reactions that transform raw materials into desired products. During this chemical change, waste byproducts, such as CO_2, are often produced, which historically has been emitted into the atmosphere.
2. **Separation processes:** Process plants often use separation techniques such as distillation, filtration, and extraction to separate and purify products or remove impurities from raw materials. During this process, waste byproducts, such as CO_2, are often produced.
3. **Heat exchange:** Heat is often used in process plants to facilitate reactions, separate components, or control the temperature of the process. Heat exchange equipment such as heat exchangers and boilers are commonly used in these plants, and often, due to the temperatures involved, electricity as the energy source is unviable or uneconomic; hence, alternative fossil fuels are used, which includes CO_2 emitted upon combustion. This is, of course, separate from any upstream Scope 2 emissions associated with electricity supply for other parts of the process plant that use electrical based energy.

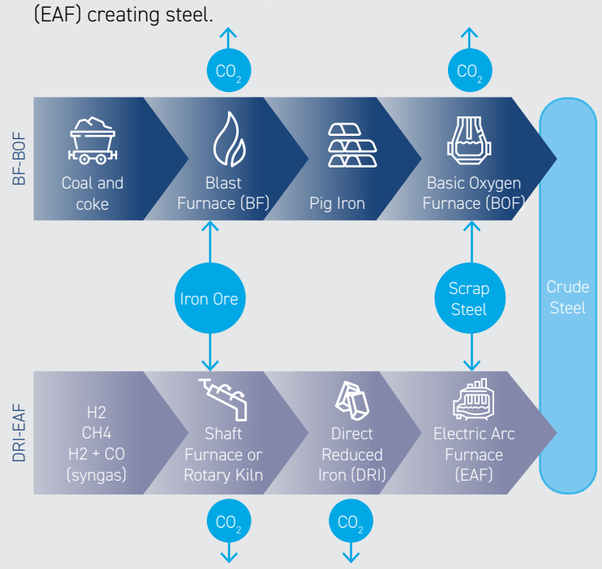
The analysis also acknowledges the role of CCUS in the decarbonisation of sectors where alternate emission pathways do exist but may be considered 'hard-to-abate' due to factors such as remaining asset lives, economic feasibility barriers, and specific critical system support. For example, the Federal Government Future Gas Strategy[27] identifies the continuance of natural gas processing and domestic use beyond 2050. In the context of this analysis, those industries are:

1. Power Generation from Fossil Fuels (excluded from domestic point sources)
2. Natural Gas Processing
3. Oil Refining

CASE STUDY: **Steel industry emissions**

7% of global CO_2 emissions

The traditional BF-BOF steel making process reduces iron ore to iron, then iron to steel. Alternative pathway uses natural gas instead of coal and coking coal to produce Direct Reduced Iron (DRI) prior to an Electric Arc Furnace (EAF) creating steel.



Cement Manufacture | Iron and Steel Production | Natural Gas Processing and Oil Refining | Chemicals | Fertilisers and Explosives | Traditional Power Generation

4. 2 Domestic Point Sources

For the purposes of this study, only Scope 1 direct emissions are assessed as those available for potential CCUS by the facility owner. Whilst not all Scope 1 emissions generated at a facility may be available for CCUS, this is highly dependent on the facility and detailed analysis on a case-by-case basis extends beyond the scope of this study. As such the total addressable market has been assessed to be the product of the facility reported direct Scope 1 emissions and the cited capture rates associated with the industry type upon which those emissions occur except in scenarios where publicly available information delineated CO_2 emissions.

Whilst noting the actual CO_2 emissions available may be significantly less than the total addressable market, it should be noted that the assessment was only limited to the facilities covered by the Safeguard Mechanism 2022-23 dataset (facilities exceeding 100ktpa of Scope 1 emissions) and in reality many other operating facilities could also contribute to the total addressable market. Additionally future projects and associated point sources were not considered unless the project was already under development or committed per the REMP. Further industry engagement and detailed analysis is required for subsequent studies and business cases.

The Clean Energy Regulator administers the NGER scheme including the Safeguard Mechanism and publishes information including the name of each covered facility, its baseline, and its covered emissions. As of March 2024, there were approximately 215 reporting facilities spanning various heavy industry sectors including mining, oil (including refining), gas (including processing), manufacturing (including ammonia, fertilisers, explosives, plastics, glass, paper, etc), transport, waste, and power generation (excluding grid connected generation). Importantly, the dataset covers all major industry emitters where emissions are unavoidable (largely due to inherent chemical processes) or considered hard-to-abate as previously defined, and therefore are potential candidates for CCUS to play a role in their required decarbonisation in line with their baseline emission reduction obligations. The dataset does not publicly report facilities emitting <100kt CO_2-e per annum and as such estimates for addressable market may be considered conservative.

The dataset for the 2022-23 reporting period was analysed and filtered to categorise all covered facilities into potential CCUS point sources and excluded facilities with the categories for each outlined in Table 1.

Table 1. CCUS potential and excluded facilities (Safeguard)

CCUS Potential Industry	Excluded Industry
Ammonia / grey H2 / derivative products	Mining – coal
Power generation (fossil fuel based)	Mining – bauxite
Iron and steel	Mining – other
Ethanol production	Alumina refining
Chemical production	Alumina smelting
Fertiliser production	Transportation and shipping
Natural gas inc. processing facilities	Metals recovery, waste, recycling
Oil and refining	Manufacturing other (non-CCS viable)
Other (includes materials / manufacturing)	Gas distribution

Domestic CO_2 Point Source Addressable Market Methodology

A literature review was undertaken to arrive at a typical capture rate from each potential CCUS point source industry which was applied to the Safeguard Facilities 2022-23 emission base to arrive at an indicative point source emission quantity available for each facility with a corresponding geographical location applied of known latitude and longitude coordinates.

To derive the potential future point sources for CCUS addressable market capacity the following methodology was then applied:

1. Historic 2022/23 NGER Safeguard Facility emissions data were used to develop a hypothetical CCUS addressable market capacity which was then baselined for future capacity point sources.
2. Underlying hard-to-abate industry growth or decline factors were applied based on published industry projections.
3. Major emitting facilities were individually researched utilising publicly available information related to planned expansion, closure or published decarbonisation goals and objectives, particularly where sustainability reports referred to CCUS as a potential abatement pathway.
4. New facilities as identified in the Australian Government Resources and Energy Major Projects (REMP)[28] annual review that fall into identified hard-to-abate industry sectors were added to the point source model. Only projects that were completed or committed were included.
5. Finally, interviews were conducted with key stakeholders to outline methodology and proposed future capacity figures for review and endorsement.

Over 23 million tonnes per annum of CO_2 could be available from the identified national clusters by 2035, with further upside from global imports.

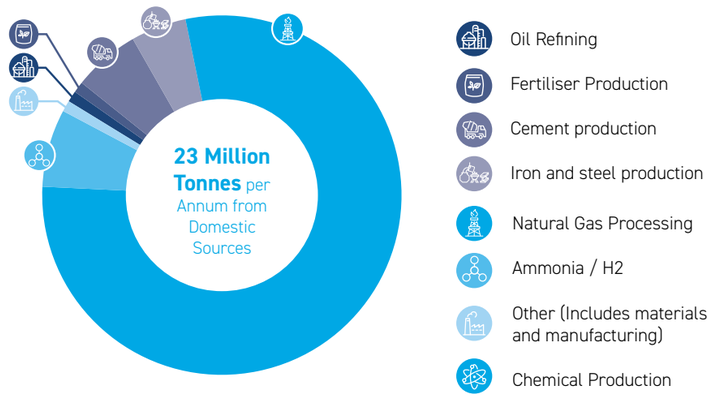


Figure 7. Composition of domestic CCUS addressable market by industry type

As shown in Figure 7, the analysis forecasts natural gas processing as the largest projected 2035 CO_2 point source, primarily due to our global dominant position in LNG production (ranked second behind Qatar).

Additional LNG production will be subject to net-zero emissions in line with the Safeguard reform as well as other ESG considerations which may slow the sectors growth, or as a minimum push the industry towards technology innovation and higher adoption of emission reduction technology such as CCUS.

Fossil fuel based power generation, whilst globally an important dataset of carbon capture plants, is unlikely to play a meaningful role in a domestic CCUS supply chain given the current trajectory and forecast outlook for the electricity sectors decarbonisation and has been excluded from the dataset for the purposes of this report. Cement, steel, ammonia and chemical manufacturing all contributed to the identified domestic point source addressable market for capturable CO_2 emissions.

CASE STUDY: **Cement industry emissions**

8% of global emissions

Australia has five integrated cement production plants that produce clinker and cement in a continuous process, accounting for 60% of domestic cement production. The remaining 40% comes from imported clinker, which is processed into cement at grinding facilities along the coastline. The cement, concrete, and aggregate sector generates $15 billion annually and employs 80,000 people nationwide. Cement is composed primarily of calcium, silicon, aluminium, and iron. Clinker, the key intermediate product, is made by heating limestone with these elements to over 1400°C. This process releases CO_2 trapped in the limestone, resulting in calcium oxide as the main product. Clinker is then ground with gypsum to produce cement, which is mixed with water and aggregates to form concrete. Producing 1,000 kilograms of cement emits approximately 700 kilograms of CO_2, mainly from unavoidable process emissions. These emissions account for about two-thirds of total cement production emissions, with the remainder due to the energy required for the process.

1t cement = **700kg CO_2-e**

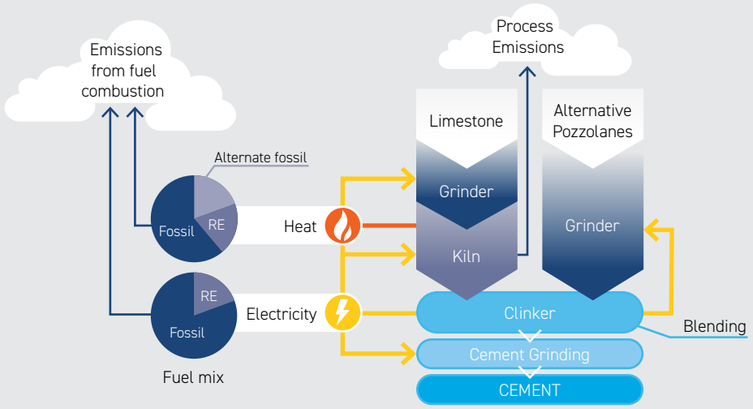


Figure 8. Cement manufacturing process diagram *RE = Renewable Energy

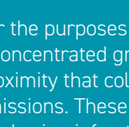
4. 3 Cluster Identification

For the purposes of this report a 'cluster' is defined as a concentrated group of industrial facilities within close proximity that collectively generate significant carbon emissions. These clusters enable cost-effective CCUS by sharing infrastructure for CO_2 transport and storage, enhancing decarbonisation efforts at scale.

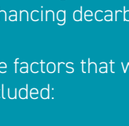
The factors that were considered when assessing clusters included:

- Identification of point sources amenable to CCUS utilising Safeguard facility data and industry type
- Sufficient size and scale to warrant cost benefit analysis to be undertaken on transportation options (taken as approximately >1Mt CO_2 pa)
- Amenable to existing infrastructure easements that could possibly be leveraged for existing capacity (i.e. reuse of existing infrastructure) or new infrastructure (i.e. using existing access rights).
- Longevity of point source, defined by structural tail winds of the industry upon which the point source originates or published information on life extension for existing assets
- Any publicly announced industrial hubs or investigations of infrastructure use to support a CCUS industry[29,30].

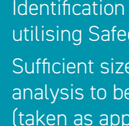
Through a strategic assessment, with consideration for local, national and international opportunities, the following clusters have been identified:



Whyalla / Pt Bonython in the Upper Spencer Gulf



Greater Sydney, including the Hunter Illawarra Region, Sydney, and Wollongong



Gladstone / Chinchilla

Aligned with Federal Policy

Each of the regions identified were also one of the four regions prioritised in draft legislation released in April 2024 for the establishment of the Net Zero Economy Authority, a new independent statutory authority to co-ordinate the decarbonisation of Australia's economy by 2050. The intent is to focus on regions that are heavily reliant on fossil fuel and emission intensive industries.



Whyalla Cluster

The Upper Spencer Gulf region including Whyalla provides an impressive combination of existing industry and infrastructure which would support a CCUS ecosystem. The key elements of this cluster are below.

Steel Industry: One of the primary drivers for this cluster is the steel industry, with the Whyalla Steelworks being a prominent feature. The steelworks, previously owned by GFG Alliance, is one of the largest employers in the region and a major producer of steel products in Australia being one of only two integrated steel works in the country (the other being Port Kembla Steel Works located in the Greater Sydney cluster).

Port Facilities: Whyalla has a deepwater port at Port Bonython, which is essential for exporting products that may leverage CCUS such as green steel as well as leveraging existing infrastructure to support a potential global import location for CO_2.

Mining, Magnetite and Green Steel: The region around Whyalla has significant magnetite iron ore deposits, which are crucial for steel production and importantly magnetite is advantageous over haematite (majority of Australia's current iron ore exports as Direct Shipping Ore DSO) within the green steel supply chain for many reasons surrounding its suitability in the production of Direct Reduced Iron (DRI). The proximity of these resources contributes to the development of both the current steel industry and potential for a green steel supply chain within the Whyalla region via an initial gas with CCS DRI pathway prior to a H_2 transition.

SA Magnetite: A key ingredient in a Green Steel Pathway, the below factors make this resource favourable feedstock for Direct Reduced Iron:

- SA has 18.6 billion tonnes of magnetite ore (JORC Resources)
- Average grades of deposits are between 16–36% Fe (in ground)
- South Australia's advantages:
  - SA magnetite ores are soft and coarse grained
  - Easier beneficiation to concentrates with >67% Fe

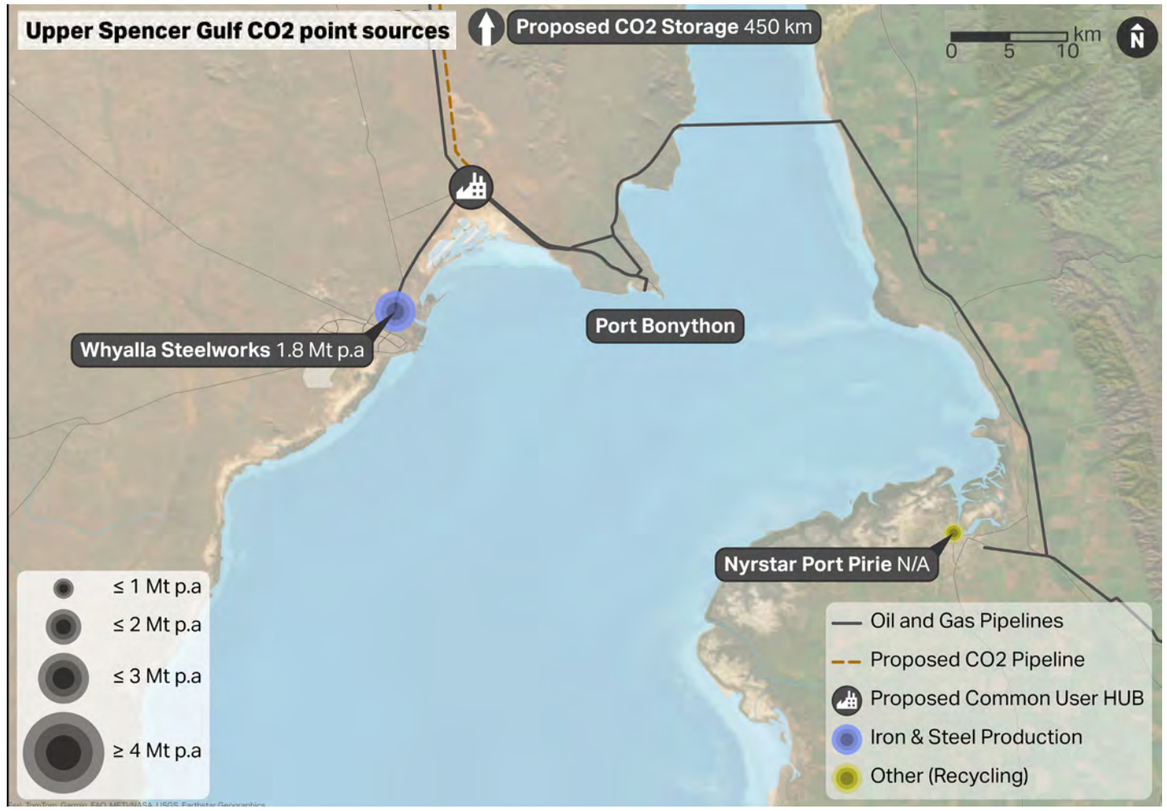


Figure 9. Whyalla / Upper Spencer Gulf Cluster



Infrastructure: Whyalla's port, rail, and road infrastructure supports industrial activities and facilitates goods transport, boosting its appeal for strategic development. The gas/liquids pipelines to Moomba and associated existing easements may be leveraged for a potential CO_2 pipeline. An MOU has been signed between APA and Santos to jointly investigate the use of this infrastructure corridor for the purposes of a CCUS industry[31].



Employment Opportunities: The industrial sector in Whyalla provides a significant number of jobs, attracting workers to the area. This, in turn, contributes to the growth and development of the local economy.



Supporting Industries: Whyalla has a range of supporting industries such as engineering, construction, and logistics, which further enhance its status as an industrial hub.



Upper Spencer Gulf: The South Australian Government's State Prosperity Project aims to reindustrialise the Upper Spencer Gulf by leveraging mineral resources, renewable energy, and green manufacturing. Nearby cities like Port Augusta and Port Pirie enhance the potential for a broader regional hub.



State Policy Support: In addition to the State Prosperity Project and South Australia's Net-Zero Strategy, the SA Government Department for Energy and Mining (DEM) in SA is actively pursuing the development of a green iron and steel industry to reduce carbon emissions and stimulate economic growth. Recognising the state's abundant renewable energy resources and significant magnetite iron ore reserves, DEM has formulated a comprehensive Green Iron and Steel Strategy.



Greater Sydney Cluster

Similar to Whyalla, Greater Sydney has also been identified as one of the four regions prioritised in draft legislation released in April 2024 for the establishment of the Net Zero Economy Authority which specifically called out Newcastle and the Hunter as regions of focus.

In November 2023 an MOU between Santos and APA was announced that identified Greater Sydney, Gladstone and Port Bonython as areas where the partnership will include an assessment of CCS pipeline routes from key emission sources to the Moomba CCS facility.

Existing Pipeline Opportunity

Following the recently announced Qenos administration and the permanent closure of the ethylene production plant at Port Botany, APA has indicated its intention to assess the potential repurposing of the existing 8-inch Moomba to Sydney ethane pipeline. In November 2023, APA also announced a Memorandum of Understanding (MoU) with Santos to explore the development of potential CCS pipelines[32]

The pipeline was purpose built to transport ethane gas from the Cooper Basin gas fields to Qenos and is currently being repurposed for sales gas transport. AECOM note the pipeline is in proximity to potential CCS capture facilities associated with the Port Kembla Steel Works (PKSW) as well as the Boral Berrima cement plant which has previously undertaken a feasibility study in conjunction with technology provider Calix to investigate the viability of a commercial scale carbon capture plant that would capture and compress up to 100kt pa initially.

Further investigations and engagement is required to validate this assumption.

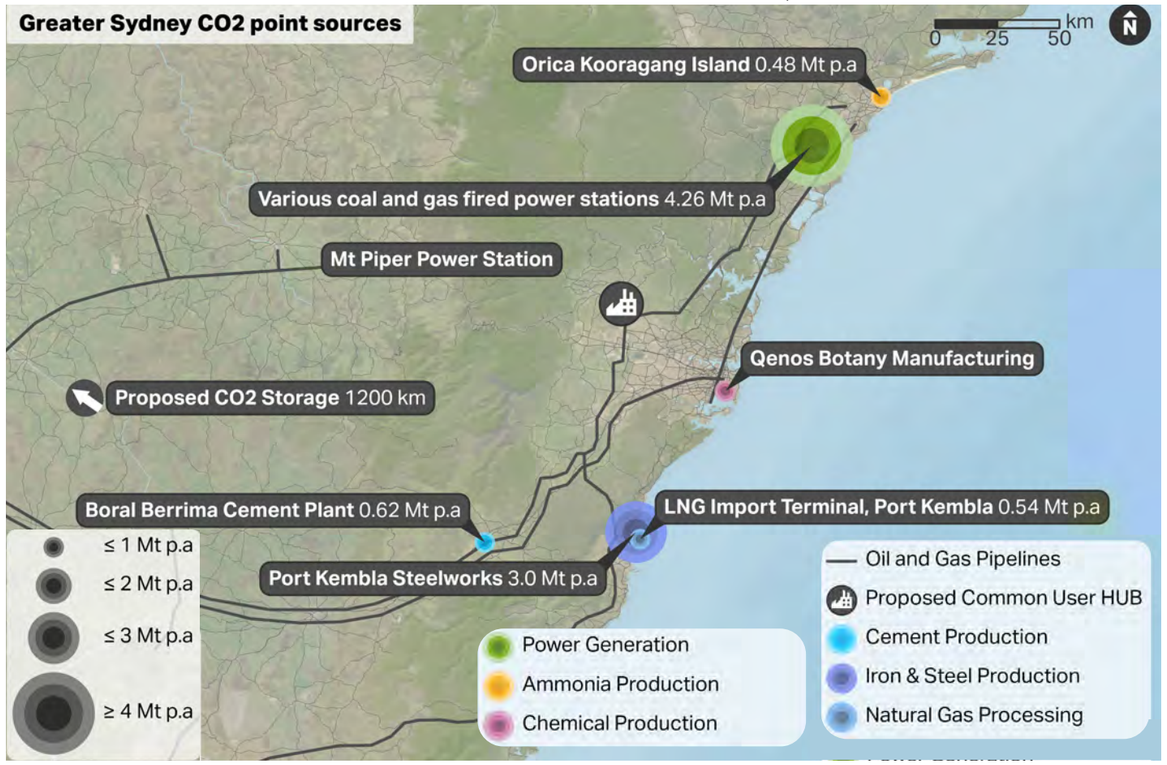


Figure 10. Greater Sydney Cluster



Gladstone / Chinchilla Cluster

The Gladstone Industrial Hub, located in Queensland, Australia, is a major centre for heavy industry and manufacturing. It is known for its strategic port, which serves as a gateway for the export of various commodities, including coal, alumina, aluminium, and LNG.

The hub's key industries include:

LNG Production: Several LNG plants operate in the Gladstone region, processing natural gas from Queensland's coal seam gas fields. These plants liquefy the gas for export, primarily to Asia.

Chemical Manufacturing: Gladstone has a significant chemical manufacturing sector, producing a range of products including ammonium nitrate, polyethylene, and other industrial chemicals.

Aluminium Smelting: Gladstone is home to one of Australia's largest aluminium smelters, operated by Rio Tinto. The smelter produces primary aluminium from alumina using an electrolysis process. This industry is not part of the CO_2 estimate in this report but represents a future upside opportunity if integrated.

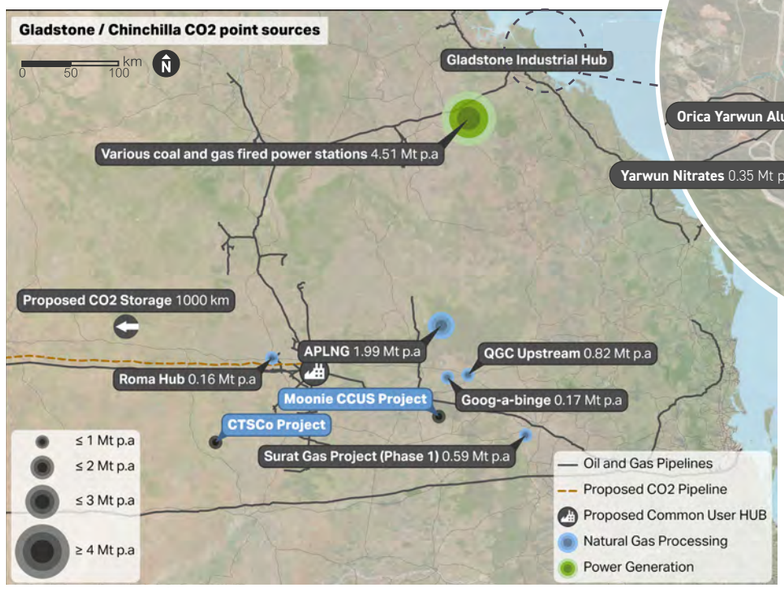


Figure 11. Gladstone / Chinchilla Cluster

Port Facilities: Gladstone's port is a major transportation hub for bulk commodities, with facilities for coal, alumina, aluminium, and LNG exports. It is a key economic driver for the region.

Supporting Industries: The hub also includes a range of supporting industries, such as engineering, construction, logistics, and services, which cater to the needs of the industrial facilities in the region.

Overall, the Gladstone Industrial Hub plays a crucial role in Queensland's economy, providing employment and contributing significantly to the state's export earnings. The region was also identified as one of the four regions prioritised in draft legislation released in April 2024 for the establishment of the Net Zero Economy Authority.

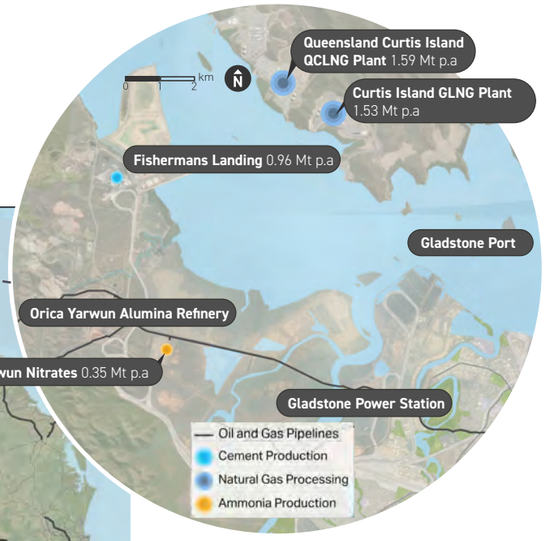


Figure 12. Gladstone Industrial Hub

4. 4 Global Point Sources

On a global level, interest in CCUS is expanding rapidly with a 60% year on year increase in project development pipeline observed as of July 2024[33]. Certain countries in Asia Pacific Region (APAC) have limited access to proximate and viable sites for CO_2 sequestration including, Japan, South Korea, and Singapore with Australia widely recognised as a potential storage hub in the APAC region due to our extensive storage resource, natural gas supply chain and skilled workforce. Importantly Japan, South Korea, and Singapore all include CCS in their Paris Agreement aligned National Determined Contributions as a vital technology to help achieve their net-zero by 2050 pledge.

In November 2023, the Australian Federal Government enacted the Environment Protection (Sea Dumping) Amendment (Using New Technologies to Fight Climate Change) Act 2023 which was ratified in November 2024 allowing bilateral treaties with other countries to enable cross-border CO_2 transfer. After the legislation was passed in the Australian Parliament, Santos announced a Memorandum of Understanding (MOU) with two major Japanese energy companies to collaborate on carbon capture and storage. The MOU aimed to explore and define commercial and investment opportunities for importing up to 5 million tonnes per annum (Mtpa) of CO_2 by 2030, increasing to 10Mtpa by 2035 and 20Mtpa by 2040, from Japan to the Moomba CCS project transported via Port Bonython in SA or Gladstone in Queensland[34]. The 2040 proposed CO_2 tonnage is used to inform the global import scenario via Port Bonython within this study.

Stage 1 of the Norway Northern Lights CCUS hub, Norway, commenced operation in 2024 with nameplate capacity for 1.5 million tonnes of CO_2 per annum.

4. 5 Common User Infrastructure

A CCUS common user hub aggregates emitters with common infrastructure to prepare the CO_2 for transport in a single location to avoid unnecessary duplication of processes including dehydration and compression. Figure 13 provides an illustration of a typical CCUS hub arrangement.

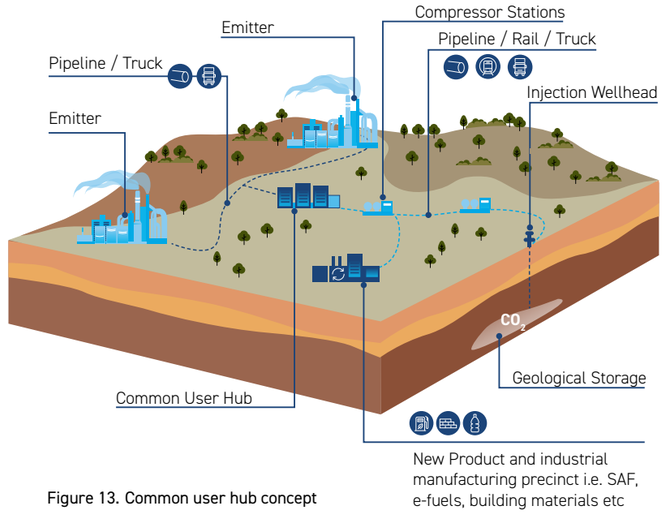


Figure 13. Common user hub concept

Establishing a CCUS hub is more complex than developing a single point source project, however, CCUS hubs offer numerous advantages, including lower costs per unit, reduced risk, and the ability to standardise and rapidly scale operations[35].

For emitters, joining a hub allows them to adopt CCUS for decarbonisation without the burden of constructing pipelines and sourcing geological storage or utilisation on a case-by-case basis.

CCUS hubs worldwide operate under various ownership and procurement models, shaped by policy, funding structures, and risk allocation. The main models include:

- **Public-Private Partnerships (PPP):** where governments and industry share costs and risks
- **Industry-Led Consortia:** with multiple members collaborating on shared infrastructure
- **Government-Owned, Industry-Operated:** ensuring public control with private expertise
- **Private Sector-Led with Government Incentives:** driven by policy incentives or tax credits
- **Build-Own-Operate (BOO):** where a single entity manages the full value chain.

Global examples of CCUS hubs are typically located near industrial clusters, where emissions sources are concentrated, such as Net Zero Teesside, Rotterdam, or China Northwest. Other examples do exist where point sources are spread out geographically, collecting emissions from sources via pipelines or ships, as seen in Northern Lights in Norway. Table 2 presents examples of advanced global CCUS hubs.

Table 2. CCUS hub global examples

CCUS HUB	Location	Proposed Throughput	Procurement Model	CO_2 Point Sources	Status
Net Zero Teesside[36]	United Kingdom	10Mtpa	Industry-Led Consortium with UK government funding and incentives under the Industrial Decarbonisation Challenge	Gas fired and, biomass power stations, H2 production, fertiliser	Construction commencing mid 2025 and operations from 2028
Northern Lights[37]	Norway	5Mtpa	Public-Private Partnership where Norwegian government funds CO_2 transport & storage whilst private operators manage infrastructure and operations	Cement production, waste to energy power generation	Operational, CO_2 receipt commenced Q4 2024
Porthos[38]	Rotterdam, Netherlands	2.5Mtpa	Industry-Led Consortium with Government Subsidies	Oil refineries, H2 production	Under construction, planned operations from 2026
China Northwest	China	3Mtpa	State-Owned, Industry-Operated	Oil refineries, cement, chemicals, power generation	Operational
Louisiana	USA	Unknown	Private Sector-Led with Government subsidies including US tax credits (45Q) and state level incentives	Refineries, petrochemicals, biofuels	Awaiting FID

4. 6 Capture Technology

There are many ways to capture carbon, either directly from the emission point source associated with heavy industry (as is the focus of this report), or by other means such as Carbon Dioxide Removal (CDR) where previously emitted CO_2 is actively removed from the atmosphere and permanently stored with various methods of capture across biological, mineral and chemical methods.

For simplicity of distinction within this study we have defined CCS capture technology as the application of technologies for the removal of CO_2 associated with industrial emissions originating from either fossil fuels or minerals (i.e. limestone).

The industrial capture of CO_2 inherently requires the separation of CO_2 from other gases and can be done with a variety of methods. These can broadly be categorised into three primary methods of capturing CO_2 shown in Figure 14 below.

Across each of the described capture method classifications there are several individual technology types that can be applied with varying levels of maturity, commercial viability, and other considerations such as energy efficiency, environmental impact, and overall effectiveness.

Capture Technology	Sub-category
Absorption	Amine based solvents
	Ammonia based solvents
	Sterically hindered amines
	Blended solvents
Adsorption	Activated carbon
	Zeolites
	Metal Organic Frameworks (MOF's)
	Amine solids
	Calcium-oxide loop
Hybrid and emerging technologies	Membrane separation
	Cryogenic
	Mineral carbonation
	Biological

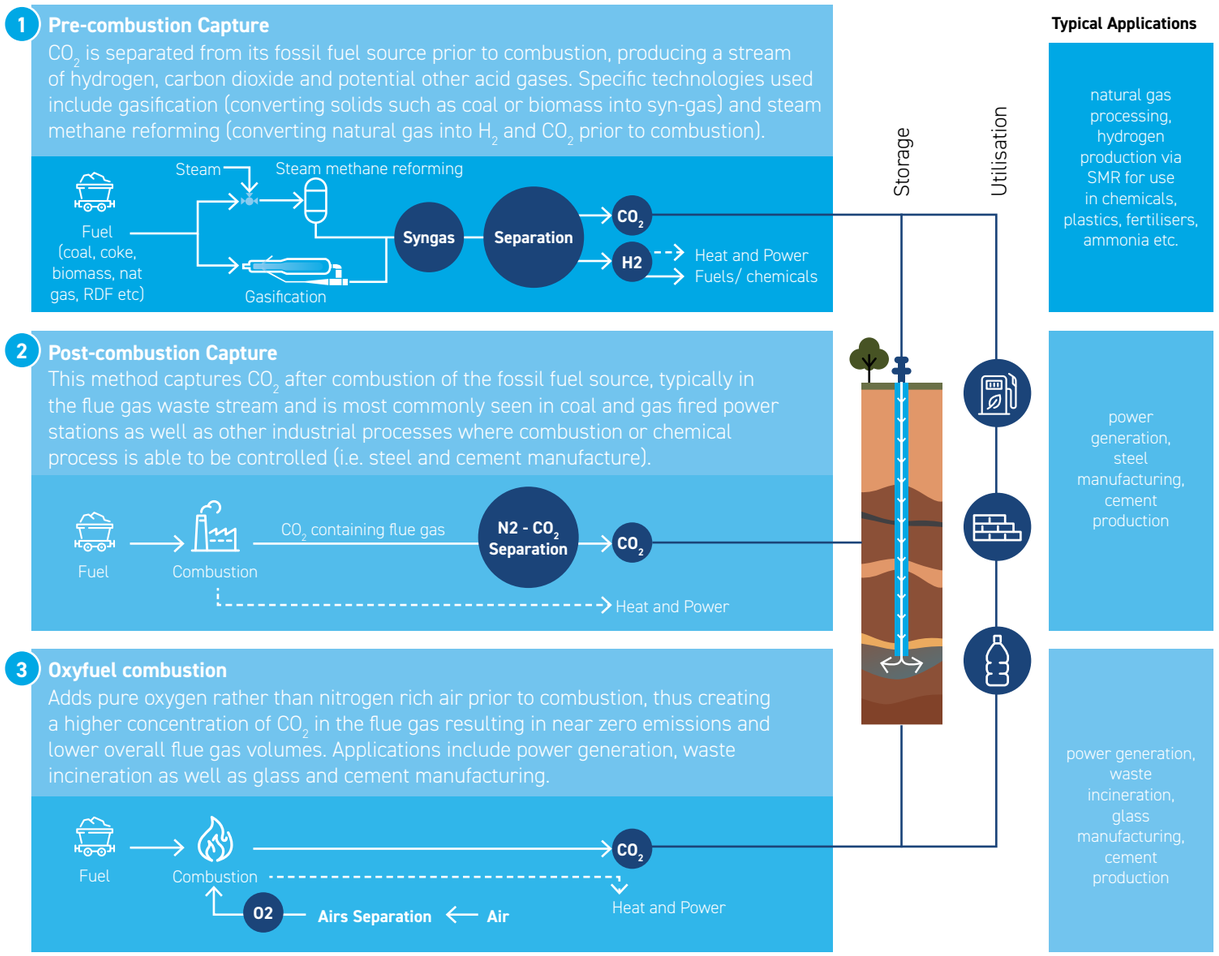


Figure 14. The three primary methods of capturing CO_2

4. 7 Geological Storage Opportunities

A thorough review of geological storage opportunities was undertaken based on existing literature and consultation with relevant industry participants and regulators. A multi-criteria analysis was then undertaken to identify, assess and prioritise potential geological CO_2 storage opportunities within South Australia. It should be noted that the assessment undertaken was conducted at a screening level only, and the development of new storage assets will require a comprehensive assessment of site and geological characteristics, followed by a robust project development process to ensure the safe and secure storage of CO_2.

Preferred Characteristics of CO_2 Storage Mechanisms

The thermodynamic and molecular properties of CO_2 influence the geological requirements for its long-term storage. For optimal results, CO_2 should be stored in a supercritical state, where it behaves like a gas, to allow effective dispersion in porous underground structures, whilst maintaining its liquid-like density to maximize storage capacity. This phase (supercritical) is also preferable for efficient transport, enhancing throughput and reducing associated energy requirements.

Preferred geological conditions for CO_2 storage include:

- A depth of at least 800 meters to maintain supercritical state
- A porous, high-permeability reservoir (e.g., sandstone or carbonates) for storage
- A non-permeable cap rock (e.g., shales) to prevent CO_2 migration
- Sufficient storage capacity, influenced by geological factors like depth, area, and porosity
- Stability with minimal faulting
- Isolation from fresh groundwater resources.

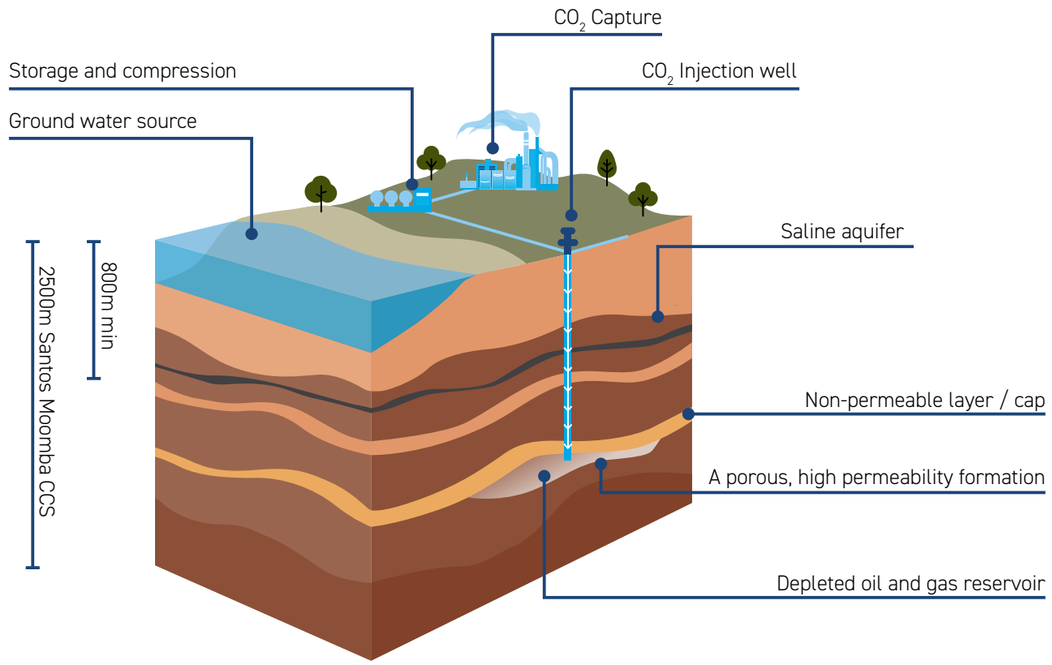


Figure 15. Preferred geological conditions for CO_2 storage

Depleted Oil and Gas Reservoirs

The reuse of depleted hydrocarbon reservoirs in petroleum-bearing basins is an established CO_2 storage option which offers distinct advantages over other geological storage hosts including:

- Proven fluid storage capacity.
- Demonstrated permeability for injection.
- Comprehensive geological data from years of exploration, appraisal, and production.

SA has a significant resource in terms of depleted fields (both now and increasingly in the future as producing fields deplete) that may be suitable for CO_2 storage. For example, the Moomba CCS project in the Cooper Basin, which has been successfully commissioned, will re-use the depleted Strzelecki and Marabooka gas fields.

Saline Aquifers

Saline aquifers, consisting of porous rock layers capped by seal rock and typically containing brine, offer significant CO_2 storage potential due to their large size. However, they are often less explored and lack detailed geological data compared to depleted oil and gas fields. When well-assessed, saline aquifers have proven effective for CO_2 storage, as demonstrated by international projects such as Sleipnir and Snøhvit in Norway and the Entropy Glacier Gas Plant in Canada.

Enhanced Oil Recovery

Enhanced Oil Recovery (EOR) involves injecting CO_2 into an oil-bearing field for the purpose of decreasing the viscosity of the oil to enable enhanced extraction. The CO_2 is partially recycled through this process, with the net result of cumulatively storing CO_2 in the oil field.

EOR is a relatively mature market, particularly in the US where the technology has been implemented for over 50 years, however it is not proposed that CO_2 be used for this purpose in SA.

Salt Caverns

Salt caverns, primarily used for short-to-medium-term storage of natural gas and hydrogen, are not recognized as viable options for CO_2 storage due to their limited storage volume and the need for cavern creation. No global projects or literature currently supports their use for CO_2 storage. As such this mechanism was not explored further in this study.

Classification of Storage Resources

The CO_2 Storage Resources Management System (SRMS), developed by the Society of Petroleum Engineers (SPE), is the industry standard for classifying CO_2 storage resources, modelled after the Petroleum Resources Management System (PRMS) used for oil and gas reserves.

This study utilises the SRMS framework for all CO_2 storage resource references and associated MCA to evaluate CO_2 storage options, ensuring consistency and transparency across industry.

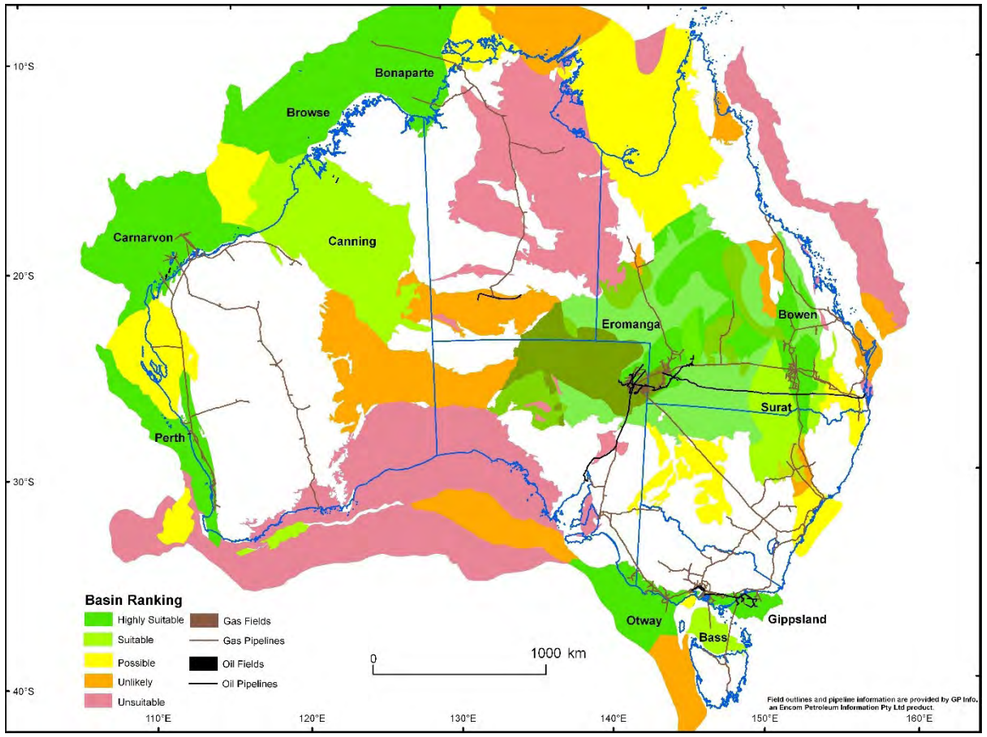


Figure 16. Australia's basins ranked for CO_2 storage potential (National Carbon Mapping and Infrastructure Plan)

Figure 15 Source: Australia's basins ranked for CO_2 storage potential (NCMIP, 2009) available at https://www.ga.gov.au/scientific-topics/energy/resources/carbon-capture-and-storage-ccs/geological-storage-studies by Geoscience Australia which is © Commonwealth of Australia and is provided under a Creative Commons Attribution 4.0 International Licence and is subject to the disclaimer of warranties in section 5 of that licence

Australian Storage Potential

The Australian Government established the Carbon Storage Taskforce in October 2008 to develop the National Carbon Mapping and Infrastructure Plan (NCMIP)[39]. The Taskforce aimed to advance carbon storage by bringing together expertise across industry and government to assess storage potential and infrastructure needs. As part of the investigation a qualitative assessment was undertaken based on 15 criteria to rank sedimentary basins for their suitability for CO_2 storage. The ranking of Australian basins was carried out by Australia's Chief Geoscientist or their staff with the results summarised in Figure 16 with highest ranked basins in green, next in yellow, then orange and lowest ranked basins in pink.

The mapping clearly indicates suitable and highly suitable storage within SA.

Storage Opportunities within South Australia

A literature review was conducted to evaluate potential CO_2 storage mechanisms and locations in South Australia. Key sources included:

- The IEA's ETP Clean Energy Technology Guide[40]
- CSIRO Geological Storage Studies
- National Carbon Mapping and Infrastructure Plan (NCMIP)[41]
- Geoscience Australia's interactive data portal

These resources informed a preliminary list of storage opportunities in SA and an assessment of the the maturity of storage technologies. The NCMIP, commissioned by the Australian government's Carbon Storage Taskforce in 2009, provided the most comprehensive overview of carbon storage options across Australia and served as the foundation for identifying opportunities within South Australia.

In South Australia, the most suitable basins for CO_2 storage include the West Otway Basin, Eromanga Basin, and Cooper Basin. The Cooper and Eromanga Basins geographically overlap but are separated geologically, with the Eromanga Basin lying above the Cooper Basin. The Cooper Basin lies below the Great Artesian Basin (GAB) as can be seen below in Figure 17.

AECOM consulted key industry stakeholders to understand storage opportunities, success factors, and regulatory frameworks in SA. Consultations included representatives from oil and gas operators, CCS project developers, and regulators.

This input supported the assessment of South Australian prospective storage opportunities by basin and storage mechanism (saline aquifer or depleted field). The storage resource data provided in the NCMIP ("undiscovered P50") was used to estimate the total prospective resource for each opportunity. Further consultation as well as a review of annual reports and reserves statements of relevant operators was then undertaken to develop a status of CO_2, storage capacity and resource bookings in SA noting that these resource bookings represent a more technically and commercially mature subset of the total prospective storage resources.

It should be noted that conversion of contingent resources to proven storage capacity typically requires further geological appraisal (e.g. drilling, modelling, flow testing) and meeting of commercial conditions under the SRMS (e.g. proven market, regulatory approvals, commercial viability etc).

A series of criteria were developed as part of the study to further assess the storage opportunities considering storage capacity, resource bookings, geological success factors, location and proximity to infrastructure, development costs, social license, environmental, regulatory and associated pathway considerations.

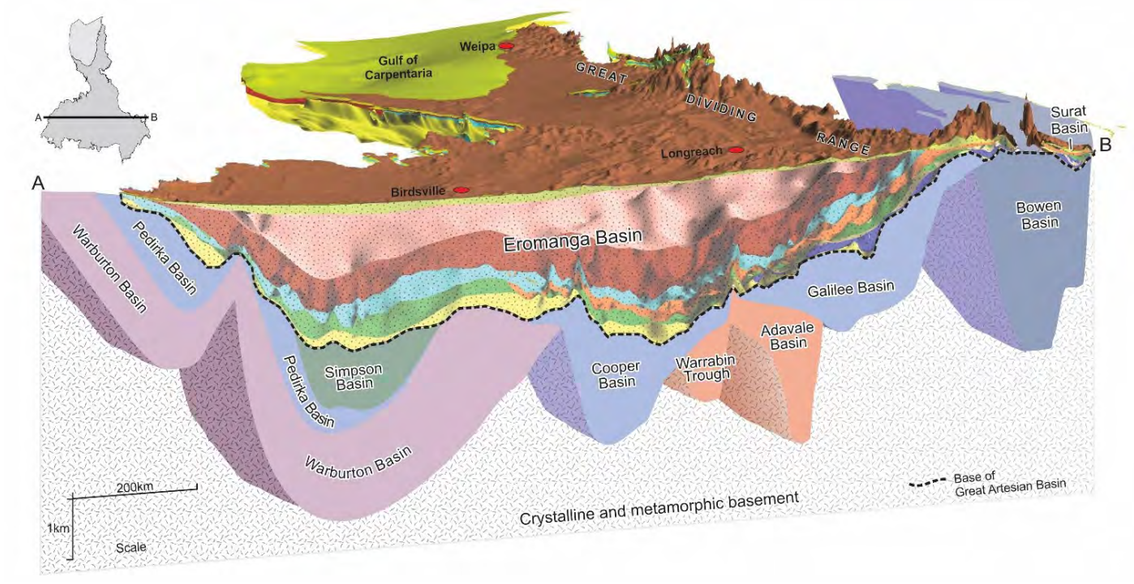


Figure 17. Australian geological basins (Source: Geoscience Australia)

The Central, Eastern and Northern (CEN) depleted gas reservoirs of the Cooper Basin were identified as the most favourable storage opportunities in SA supported by the following key strengths:

- material prospective storage resources,
- existing booked storage reserves and resources,
- high levels of geological characterisation,
- high levels of depletion (i.e. storage readiness),
- infrastructure re-use opportunities, and
- precedence with respect to social license and approvals pathways based on the existing Moomba CCS project.

SA's Cooper Basin is well positioned to capitalise on the demand for CO_2 storage should the appropriate supporting capture and transport infrastructure be available. In 2023, the South Australian Government awarded Greenhouse Gas Storage Exploration Licenses (GSELs) in the Cooper and Eromanga basins.

Table 3. Existing CO_2 storage reserves and resources in South Australia

Basin	Type	CO_2 Storage Capacity (Gross)
Cooper	Storage Capacity (2P)	13.5 Mt
	Contingent Storage Resources (2C)	103 Mt
Eromanga	Contingent Storage Resources (2C)	63 Mt
Total (2P + 2C)		**179.5 Mt**

Based on published reserve statements as at July 2024.

Geological storage in SA is well positioned with developers targeting substantial upside to the 180 million tonnes of 2P (commercial) and 2C (sub-commercial) discovered CO_2 storage resources.

4. 8 Logistics and Supply Chain

A CCUS supply chain integrates a range of technologies and infrastructure, including capture technology, conditioning and compression facilities, transportation, injection infrastructure and geological storage sites or utilisation.

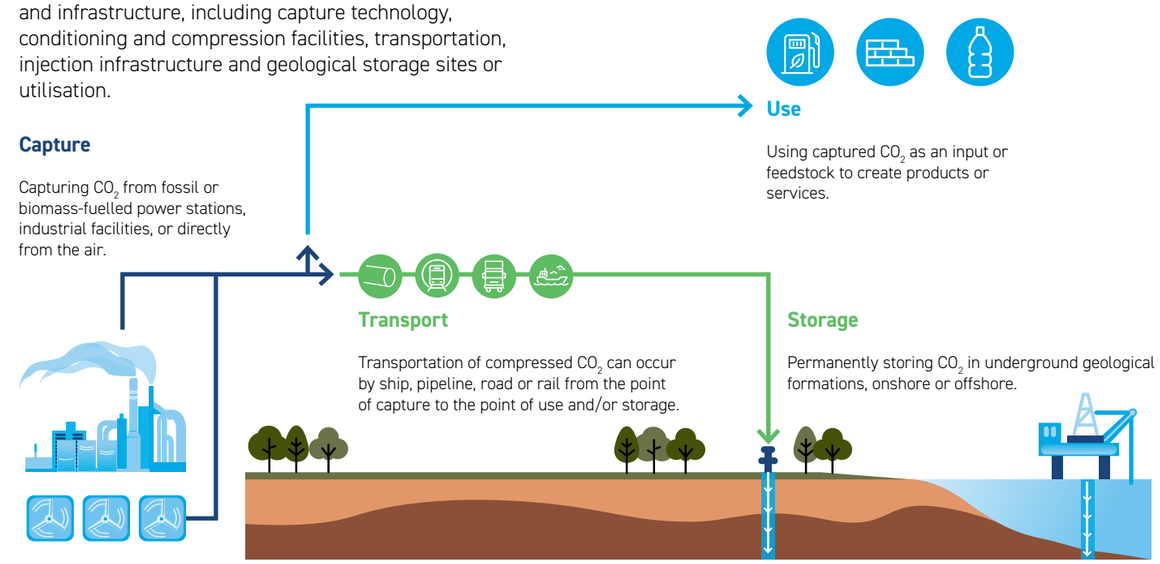


Figure 18. CCUS supply chain

Injection

The injection infrastructure is a critical component designed to sequester captured CO_2 safely and efficiently into underground geological formations once transportation has been completed. This infrastructure typically includes injection wells, surface facilities and associated post injection monitoring systems.

An example of an injection well head for the Moomba CCS project is provided to the right in Figure 19 with an injection rate of between 0.3-0.5Mtpa.

Sophisticated monitoring systems equipped with sensors and remote telemetry are installed to continuously track the integrity of the wells, the CO_2 injection rates, and the behaviour of the stored CO_2 within the geological formation.



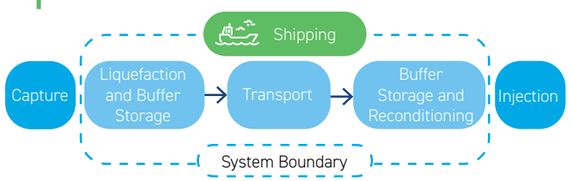
Figure 19. Moomba CCS 1.7Mtpa project, injection well

Transportation Analysis

This study investigated various transportation options including shipping, pipeline, trucking and rail.

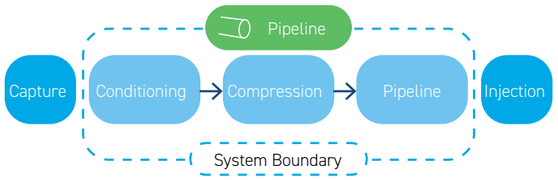
Shipping

For shipping in a global import scenario, CO_2 captured at a point source is transported to a loading port where it is undergoes liquefaction and is kept in buffer storage before being loaded onto the ship. At the unloading port LCO_2 is offloaded via loading arms and kept in buffer storage before being reconditioned prior to overland transport. A hypothetical model was evaluated to identify key factors for the import of 10Mtpa from Japan to Port Bonython using ships with a 50k m^3 capacity which would be expected to increase as the industry matures.



Pipeline

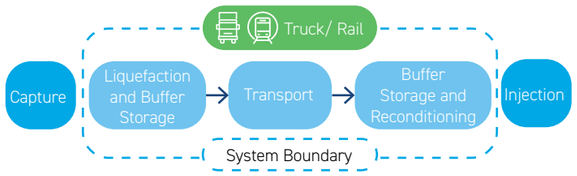
Pipeline transport is the most common method for moving large volumes of CO_2 over long onshore distances. Analysis placed a hypothetical pipeline run from each cluster to the Cooper Basin storage point. SA has a long history of overland pipeline transport of hydrocarbons, and this deep industry experience would be leveraged in a CCUS supply chain.



Truck and Rail

In the case of trucking, departures per day were calculated considering the quantity of LCO_2 that can be transported by each truck (truck capacity) and the required annual throughput for each scenario. Even at low capture rate scenarios, the scale of the required fleet size and resultant traffic densities would pose major constraints on the use of trucking for large volumes of CO_2 and based on this high-level analysis, the use of trucking was discounted for the purposes of the study.

Rail was also considered as another overland transport option for domestic CO_2 for short to medium distances with high capital cost of new or upgraded infrastructure and lack of available capacity on existing networks the primary factors that discounted rail as a likely option.



Further Investigation

While for the purpose of this study, the transport options were considered mutually exclusive, the introduction of common user infrastructure and hubs as well as consideration of both a domestic and import supply chain would allow for users and point sources to utilise varying transport modes where appropriate. For example, while a pipeline may service major emitters, smaller emitters would be able to participate in CCUS by trucking smaller quantities of CO_2 to the common user hub.

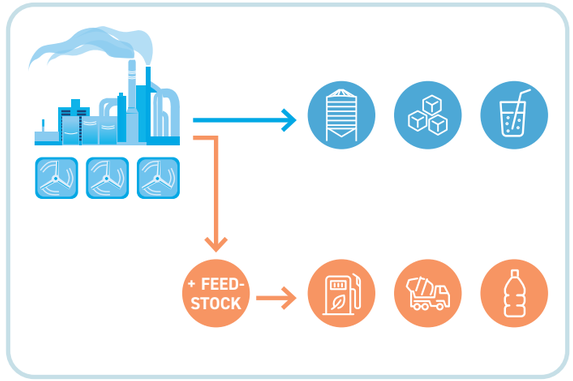
As such, a key recommendation from the study is for further investigations into a CCUS Common User Infrastructure model in South Australia.

4. 9 Utilisation Opportunities

While captured industrial carbon emissions can be stored underground, there are also a variety of potential commercial uses.

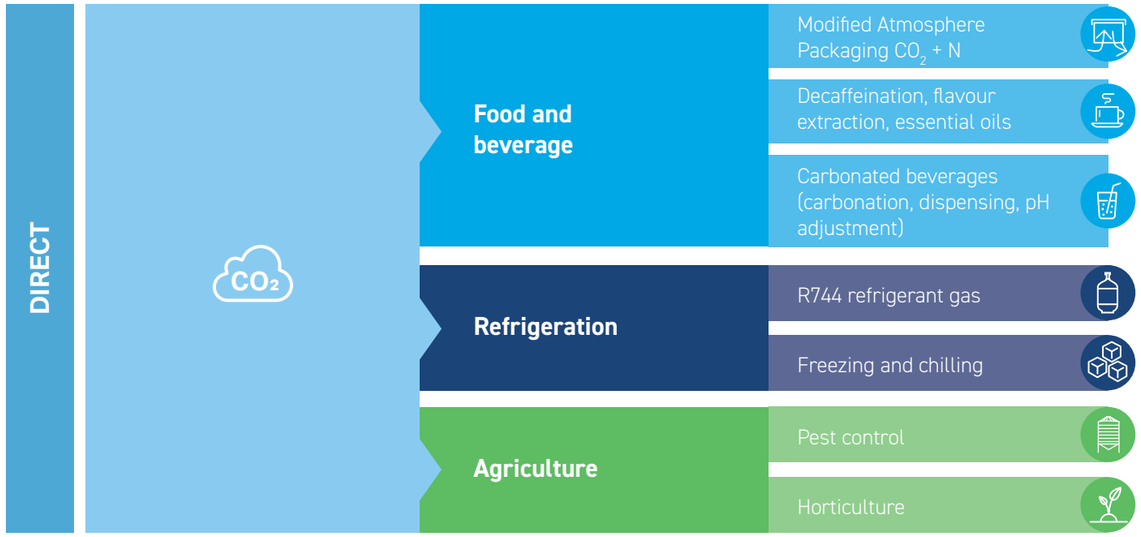
Utilising CO_2 for alternative uses is a relatively new and emerging market with the majority of the potential applications in their infancy, and in many cases, currently sub-commercial. As such, determining the suitability to South Australia's market is heavily reliant upon forecasts such as the CO_2 Utilisation Roadmap constructed by the CSIRO[42].

Utilisation represents an upside opportunity for SA for both direct and indirect use of CO_2.



Direct Use

Direct use of purified CO_2 has application across the food and beverage industry, refrigeration, chilling and freezing as well as within agriculture. Whilst volumes for direct use of CO_2 are currently, and projected to remain, quite low in comparison to the addressable market, ongoing use of CO_2 across the food and beverage, packaging and agriculture industries is projected to grow.



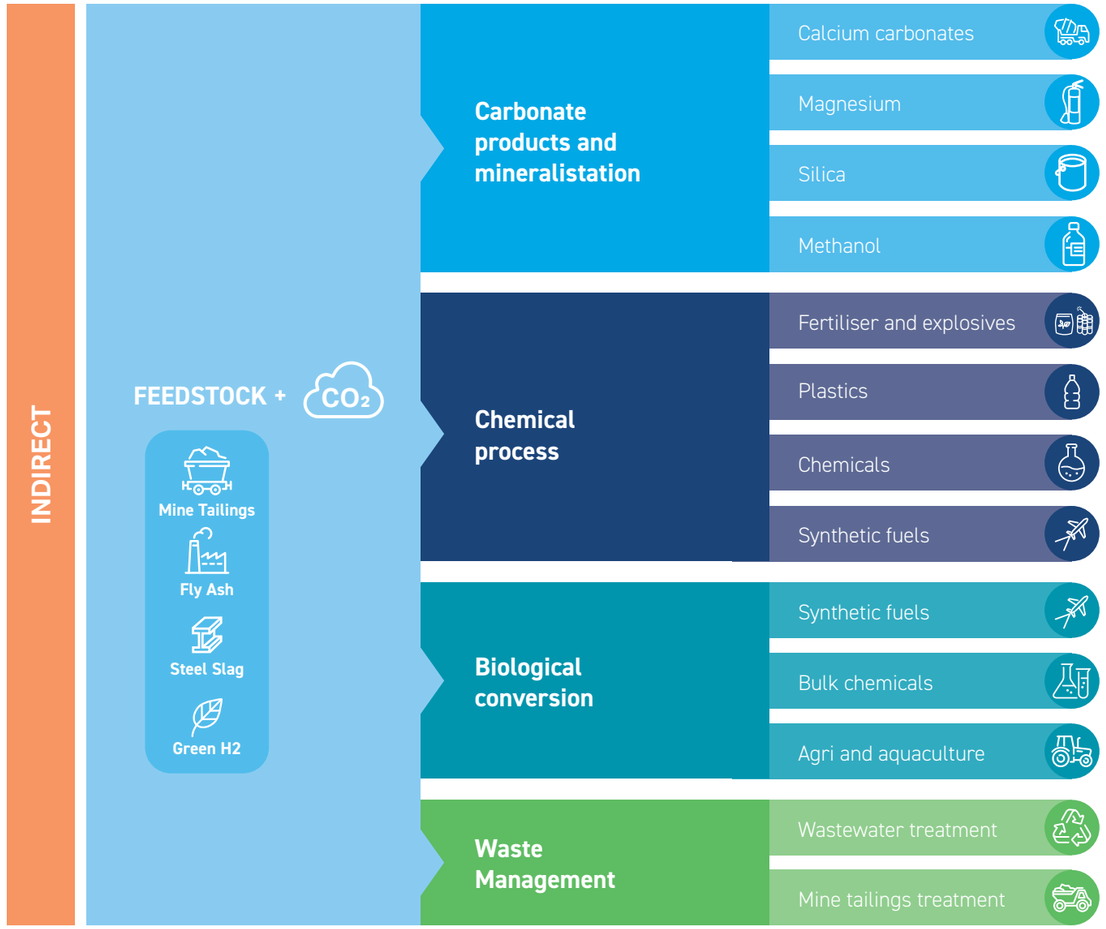
Indirect Use

Indirect use where CO_2 is value added to a feedstock is emerging as a major opportunity for CCUS with broad ranging current and potential applications in areas such as synthetic fuels (e-methane, Sustainable Aviation Fuels (SAF), renewable diesel etc), waste management (mine tailings treatment, wastewater treatment plants) and industrial manufacturing (plastics, fertiliser, explosives, bulk chemicals etc). The process involved is varied and ranges from natural mineral carbonation through the chemical and biological conversion into new products, many of which are deemed as permanent or long-duration storage of the CO_2 and others that contribute to a circular economy.

Further Investigation

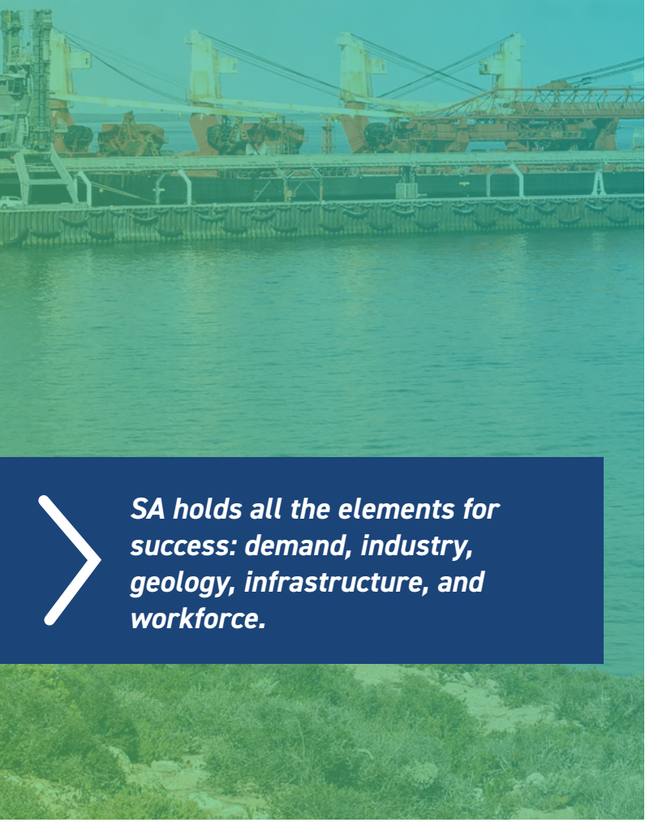
The study did not explore specific industries or use cases in detail, but it is recommended as a key next step for future business case development, especially in relation to emerging industrial centres critical to South Australia's economic growth.

A key recommendation from the study is the formation of a holistic CCUS forum including government and industry collaboration to explore opportunities across the value chain.



05
Key Findings

The following section provides an overview of the key findings from the study including a proposed phasing and implementation pathway as one potential development scenario.



SA holds all the elements for success: demand, industry, geology, infrastructure, and workforce.

5. 1 Outcomes of the Technical Analysis

The technical analysis indicates:

- Domestic demand for CCUS is likely to increase due to Safeguard Mechanism reforms, particularly for hard-to-abate sectors as well as new natural gas development.
- Technologies for carbon capture exist and are available at varying levels of maturity, commercial viability and effectiveness.
- Localised aggregation of domestic point sources raises three potential clusters which are likely to support common user infrastructure:
  - SA: Whyalla / Upper Spencer Gulf
  - NSW: Greater Sydney, including the Hunter Illawarra Region, Sydney, and Wollongong
  - QLD: Gladstone / Chinchilla
- Storage for CO_2 is available within SA which could accommodate the CO_2 generated by the identified clusters, prioritising depleted oil and gas reservoirs
- Global emitters, including across key Australian trading partners in SE Asia, are seeking partners to develop international CCUS cross-border trade, which SA could position itself to benefit from via a strategically located port at Port Bonython
- Utilisation opportunities require further study with notable prospects such as synthetic fuels (i.e. Sustainable Aviation Fuel, Renewable Diesel, e-methane etc).

5. 2 Indicative Domestic Supply Chain Infrastructure Requirement

The infrastructure needs for a domestic CCUS supply chain will depend on various factors including market dynamics and government involvement. For the purposes of this study, commercial and funding models were not assessed, nor the respective appetite from both public and private sector tested. However, for cost estimation purposes, a Public-Private Partnership (PPP) model was assumed, where private industry emitters are responsible for capturing CO_2 and delivering it to a Common User Hub at a specified pressure and quality.

A high-level concept flow sheet was developed to support an Order of Magnitude (OOM) capital cost estimate and subsequent economic analysis with battery limits defined between emitter, common user infrastructure and storage operator as demonstrated in Figure 20 (right) and described thereafter.

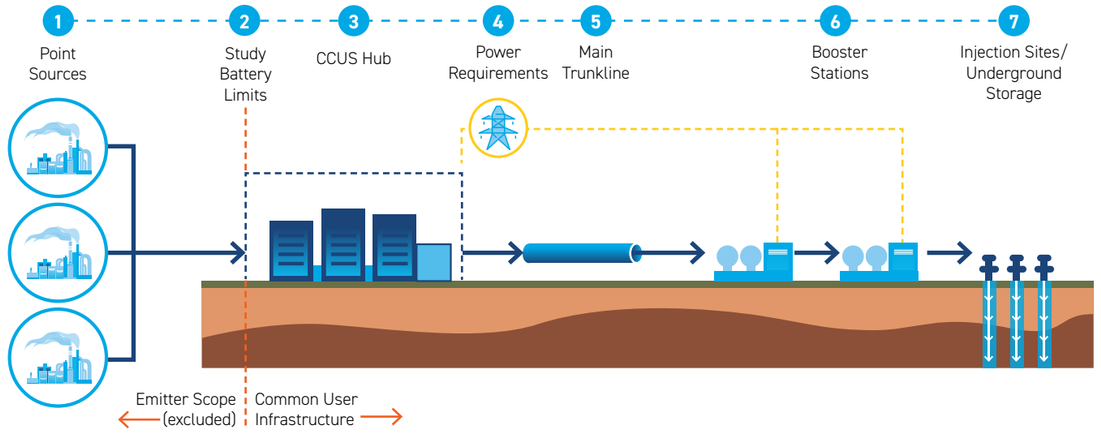


Figure 20. Domestic Supply Chain

1. **Point Sources:** Individual emitters will be responsible for capturing their emissions and transporting them to the CCUS Hub (3) at a minimum specification as defined by the CCUS Hub operator. This minimum specification will define parameters such as inlet pressure and CO_2 composition. Pre-processing by the emitter may involve purification, initial compression, cooling, and drying.
2. **Battery Limit:** The battery limit for the study was defined as the inlet to the CCUS Hub in which emitters transfer CO_2 to the Hub Operator at the required specification. Typical CO_2 purity specifications are outlined in ISO 27913 Annex A. The battery limit and scope of the Hub is dependent on the commercial model adopted and can be adjusted based on user requirements and key value drivers. Transport to the hub is not considered in this model, as this will depend on the emission point source characteristics and its proximity and owners' considerations for transportation.
3. **CCUS Hub:** The purpose of the CCUS Hub is to collect the CO_2 from various emitters and condition it into a state appropriate for transport via medium to long distance pipeline, typically in a supercritical fluid state. Conditioning will involve multi-stage compression and cooling, assuming the CO_2 has been dried and purified at the emission source.
4. **Electrical Demand:** Compressors of the scale required at CCUS Hubs can be quite large and as such require significant power demand. Therefore, it is important to ensure sufficient electrical supply is available at the CCUS Hub location. Similarly, the booster stations along the route will require power supplies either grid connected or as isolated remote power stations.
5. **Main Trunk Line:** The main trunk line will transport CO_2 from the CCUS Hub to the injection site at the storage location. Typically, CO_2 pipeline material is a grade of carbon steel (e.g. API 5L X65 PSL2 (Sour Service / NACE MR0175)) with some form of external coating such as FBE to protect it from corrosion. Due to the high-pressure nature of the pipeline, it is likely to be buried underground, to avoid accidental strike and damage. It is proposed that the pipeline follows existing domestic natural gas or liquids pipelines and share easements to minimise work required to route major pipelines, as obtaining right of way can form a significant portion of costs. CO_2 will be transported in a supercritical state for efficient transportation. Preliminary pipeline sizing was undertaken for various throughput scenarios.
6. **Booster Pump Stations:** Depending on pipe diameter and throughput booster stations may be required along the pipeline route to regulate the CO_2 pressure to maintain its supercritical phase enabling effective transportation. The CO_2 pressure should remain above its critical pressure, ~7.5MPa, to avoid phase change of CO_2 to gas-liquid causing transportation issues. The number of booster stations is dependent on the pipeline specifications including, pipeline length, diameter, material, and throughput.
7. **Injection Sites / Underground Storage:** Once the CO_2 reaches the storage site it is injected underground using specialised equipment. A sufficient number of wells needs to be drilled at the storage site to accommodate the incoming CO_2 capacity. An estimated number of wells per scenario was developed with each well head assumed to be capable of storing 0.5Mtpa of CO_2. Monitoring wells are also a requirement to ensure the captured CO_2 plume is retained within the geological storage.

The domestic infrastructure supply chain identified above draws from global literature review of completed or planned Common User Hub projects

5. 3 Indicative Global Supply Chain Infrastructure Requirement

The infrastructure requirements of a supply chain to support a global import of CO_2 have many variables and can be delivered via numerous different procurement and commercial models. For the purposes of this study, we have considered a battery limit at the domestic unloading facility with all upstream capture and shipping outside of the battery limits of the infrastructure study.

High-level preliminary infrastructure sizing for a global import scenario was undertaken, with the potential to share infrastructure with a local domestic hub. This was used to inform the OOM estimate and provide a generalised idea of the scale of infrastructure required to enable a global import CCUS supply chain. Similar to the domestic supply chain, an illustrative example, shown as Figure 21 and corresponding descriptions are provided below.

1. **Port Unloading:** CO_2 will be transported to Port Bonython as a compressed liquid via specialised ships. Port upgrades will be required to accommodate receipt of CO_2 transport vessels as well as number of anticipated vessels. It is assumed for the study that the existing wharf with upgrades is capable of accommodating the anticipated CO_2 throughput. Battery limits for the global import scenario are assumed to be inlet of the unloading arms.
2. **Buffer Storage Tanks:** Buffer storage tanks are required at the port to hold liquid CO_2 offloaded from ships. Buffer storage tanks act to balance variations in incoming CO_2 and facilitate smooth, consistent downstream transport flow rate. The tanks were assumed to hold the equivalent capacity of one ship and are cooled and pressurised in order to maintain CO_2 in a liquid state. Liquid CO_2 storage tanks typically comprise a stainless steel or carbon steel inner vessel, high quality vacuum perlite insulation, and carbon steel outer vessel.
3. **Reconditioning Unit:** Effective CO_2 transport via ship and pipeline require different CO_2 specifications and as such CO_2 will require reconditioning to pipe specification prior to transportation via pipeline. Ultimately, this process involves conversion of the CO_2 from liquid to supercritical phase, as well as other pre-transport treatment such as pigging, pressurisation and pumping.
4. **Main Trunk Line:** As per domestic supply chain.
5. **Whyalla CCUS Hub:** Global CO_2 import and Whyalla/ Upper Spencer Gulf CCUS are assumed to share common infrastructure and will tie-in at Port Bonython.
6. **Booster Pump Stations:** As per domestic supply chain.
7. **Injection Sites / Underground Storage:** As per domestic supply chain.

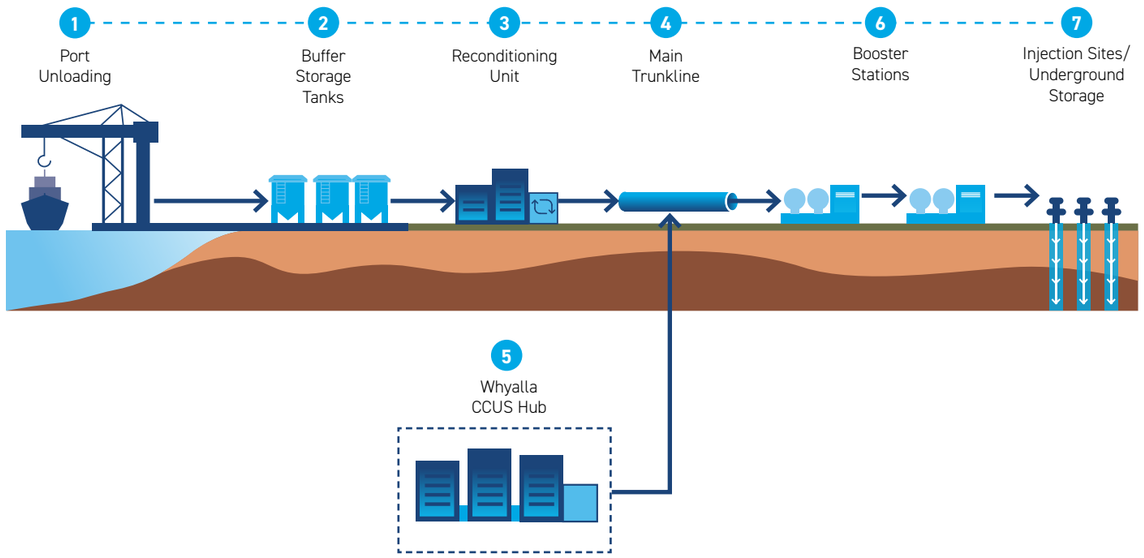
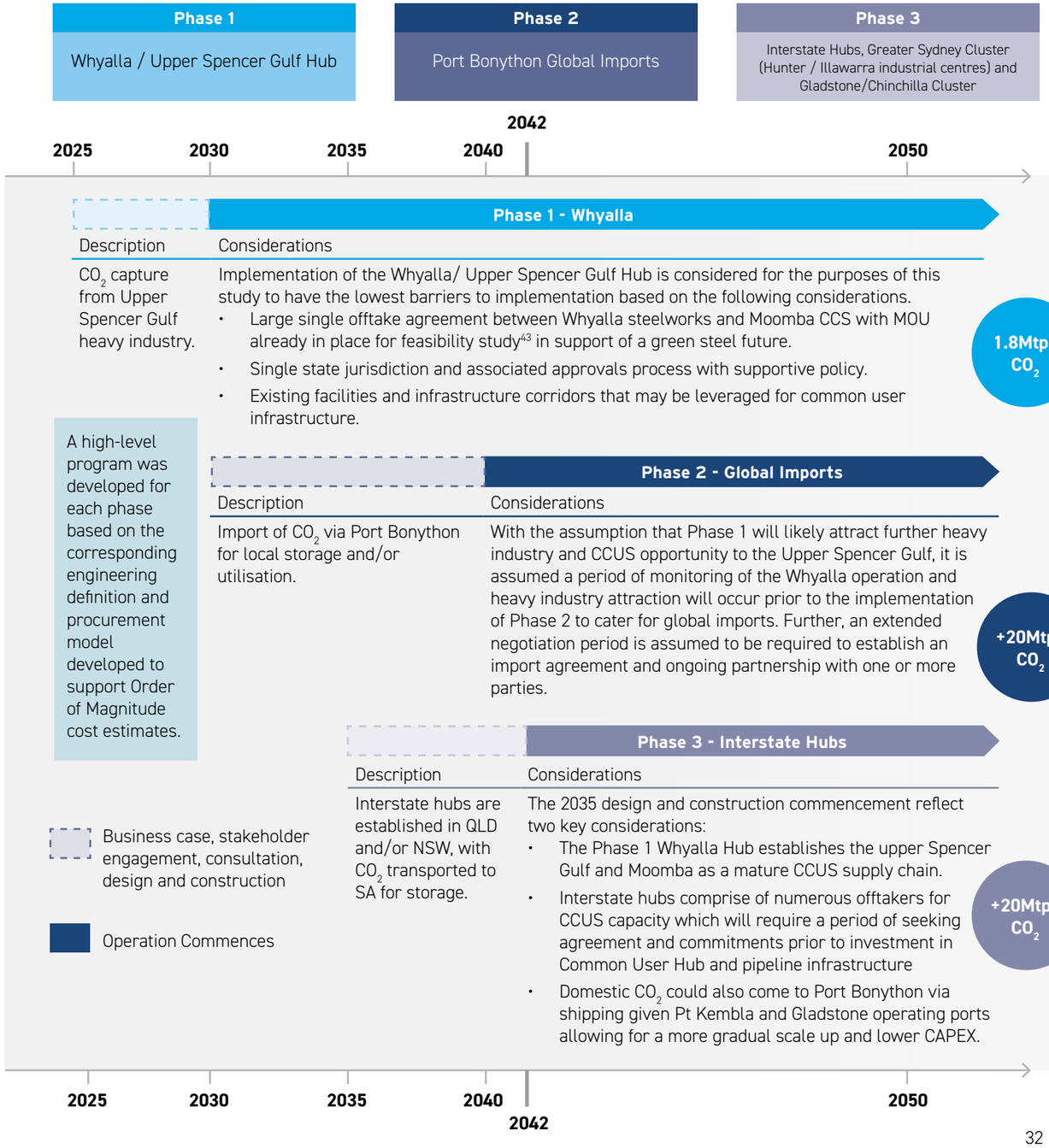


Figure 21. Global Supply Chain

5. 4 Phasing and Implementation Pathways

An indicative option for phased implementation of CCUS infrastructure deployment has been developed for the purpose of the study.

We note that the presented phasing is developed primarily through qualitative measures and responds to the purpose of the 20 Year Infrastructure Strategy to provide greatest benefit to SA. Detailed analysis and alternate scenarios will be required to be explored subsequent to this study.



5. 5 Potential Economic Impact

Economic impact analysis was undertaken to estimate the potential impacts on the South Australian economy resulting from three investment scenarios. It is important to note that the purpose of this analysis is to estimate the direct and indirect impacts for South Australia, and therefore only captures the impacts related to investment or expenditure occurring within the State. While each investment scenario may result in economic benefits for the broader Australian economy, this is outside the scope of the economic analysis undertaken. This analysis is preliminary and indicative, and further investigation may be required as planning for the project progresses.

The scenarios that have been assessed as part of this analysis are outlined in the table below and reflect the staged pathways for development outlined in the previous section.

Table 4. Economic impact analysis scenarios

Scenario	Description
Phase 1 Whyalla Hub	CO_2 capture from the Whyalla steelworks and potential future green steel export production facilities.
Phase 2 Global Import	Import of CO_2 generated internationally via Port Bonython for local storage and/or utilisation.
Phase 3 Interstate Hubs	Interstate hubs are established in QLD and/or NSW, with CO_2 transported to SA for storage and/or utilisation.

The economic impacts of each scenario have been captured by two key economic measures, these being Value Added and Employment. The primary measures are defined in Table 5 (right).

Both of these measures reflect direct and indirect impacts to the economy. Direct impacts comprise elements such as capital expenditure, the operation of capture and storage facilities within South Australia, and revenues generated by transport services within the State. Indirect impacts represent the flow on economic benefit to the rest of the economy, and have been estimated using tailored input-output multipliers.

Utilisation of CO_2 is not included within this analysis given the early nature of the industry, however this could represent further upside for SA and the economic impact.

Table 5. Economic modelling measures

Measure	Description
Value added	Value added represents the net contribution of the project to the economy, measured as the difference between gross output and the cost of intermediate goods and services. It is a measure of the project's contribution to the Gross State Product (GSP).
Employment	Employment measures the number of jobs supported by the project, both directly and indirectly, across various phases and sectors. Note that the total impact over the appraisal period does not represent the total number of jobs created over the period due to double counting as many of these jobs will be in the same positions that will persist over multiple years. Therefore, the average annual employment impact offers a more meaningful and accurate representation of a project's job creation potential.

The outcomes of the analysis (shown Table 6) demonstrate that all three phases will have a positive economic impact on the South Australian economy.

Phase 1

Phase 1 would provide a total Value Added impact of $6.9 billion over 25 years, a total of $433 million per annum.

Phase 2

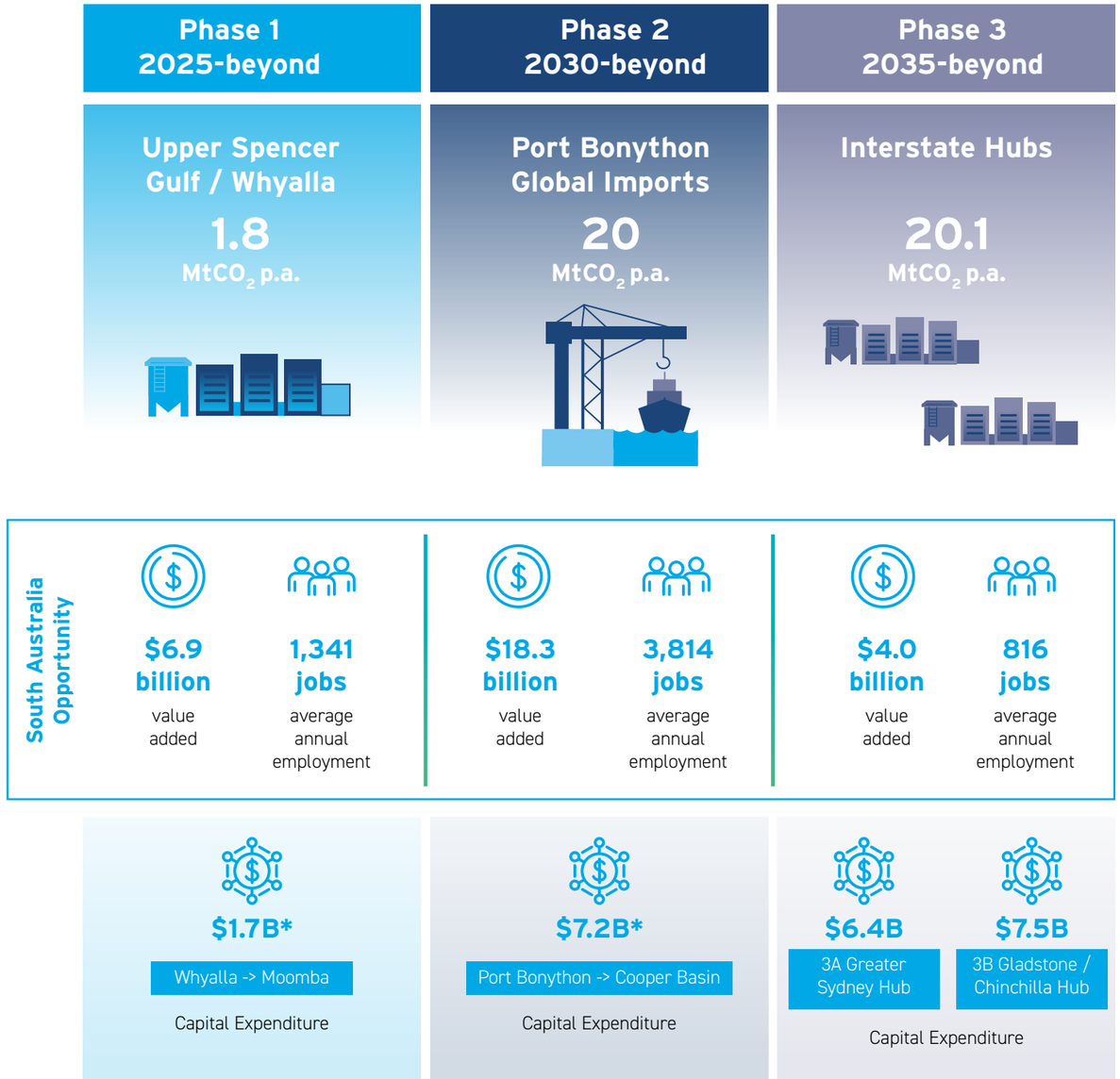
Phase 2 would have a potential impact of $18.3 billion Value Added over 25 years, equating to $705 million per annum. While this potential is significant, its realisation would be dependent on the financial feasibility for overseas companies to export carbon to South Australia, and the attractiveness of SA as a destination for their CO_2 relative to alternative storage locations.

Phase 3

Phase 3 would provide a total Value Added of $4.1 billion over 25 years, a total of $157 million in Value Added per annum. Much of this impact would be derived from the construction of infrastructure, with a smaller annual benefit expected a s a result of transport and storage of carbon from interstate.

Cost estimate information is provided as order of magnitude subject to the parameters of the provided scenarios. Figures shown represent a range based on uptake of CCUS.

Table 6. Summary of total impact on South Australian economy (direct and indirect) by Phase (FY2025-FY2050)



*Capital expenditure (CAPEX) estimates in accordance with AECOM estimate guidelines for a Order of Magnitude study with a ±50% accuracy range.

06
Opportunities for SA

This section identifies potential opportunities available for SA in developing and facilitating a local CCUS ecosystem. All opportunities will require individual validation and detailed studies for feasibility, including business case analysis where appropriate.



6. 1 Tangible Progress Toward Net-Zero

The implementation of a CCUS ecosystem provides the opportunity for immediate, tangible abatement of CO_2 from hard-to-abate industries. In the modelled scenario, an estimated over 350 Mt of CO_2 could be abated and stored by 2050 in accordance with the indicative program in this report, aiding in the pursuit of the Paris Agreement net-zero target.

Target Benefit
Abatement of emissions through the use of CCUS infrastructure

6. 2 Positive Economic Impact and Job Creation

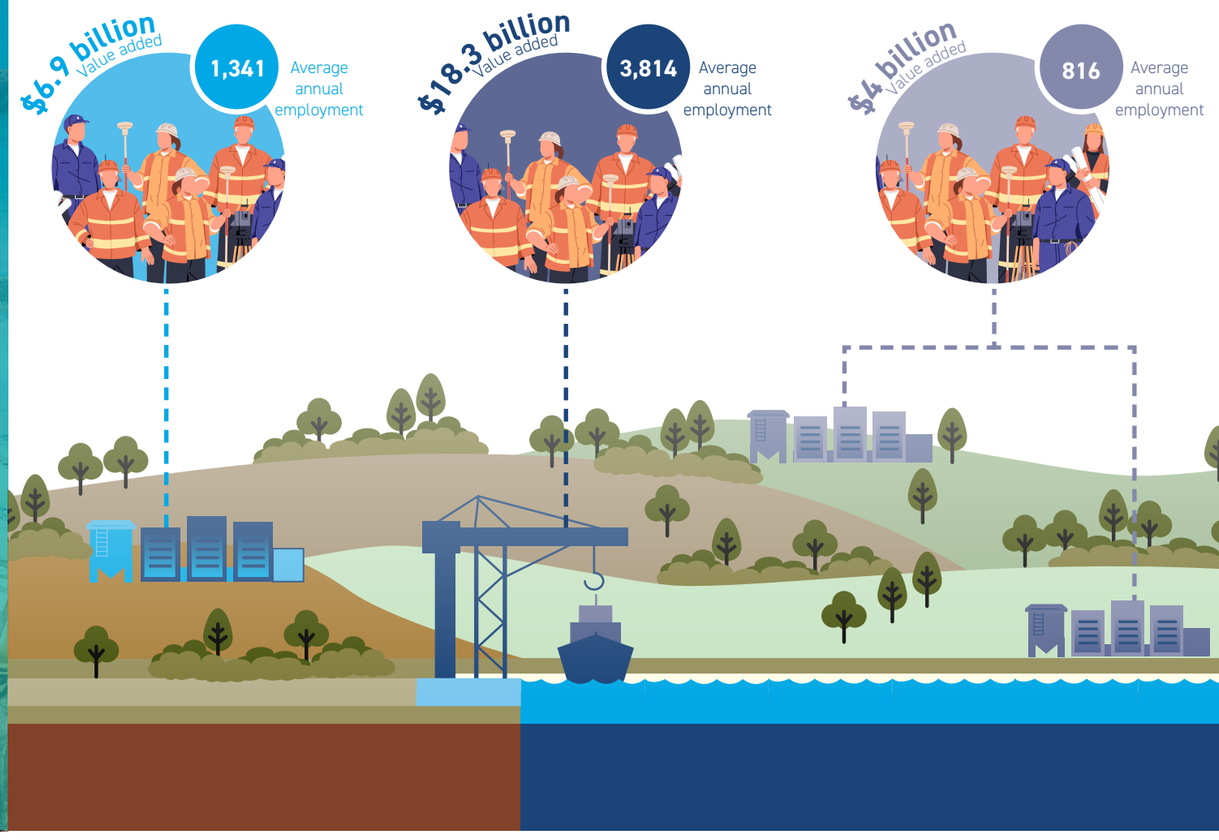
In the modelled scenario, positive economic impacts could be realised in all three phases of the project. The development of the CCUS industry in the State could, over time, lead to significant investment and provide thousands of jobs per annum.

Each of the phases investigated represents a distinct market (from carbon capture and storage locally, interstate and internationally). While each of these markets would require similar infrastructure, it is anticipated that they will develop at different rates, and be subject to different competitive and cost pressures.

In addition to the monetised impacts, the projects would also be expected to have other benefits to South Australia. These would include:

Target Benefit

- **Investment attraction.** The project could attract and leverage investment in related industries.
- **Innovation spillovers.** Investment in CCUS technology could drive innovation in related fields, leading to increased productivity and efficiency.
- **Environmental benefits.** The project will assist in abating emissions and mitigating the impacts of climate change.



6. 3 Align with Key Policy

Development of common user infrastructure targeted at supporting regional hubs and associated heavy industry decarbonisation are key themes in a number of state and federal policy initiatives. The development of a CCUS supply chain and 'hub' in the upper spencer gulf has strong alignment with these policy initiatives:

- **Future Made in Australia, Net Zero Transformation Stream:** This announced policy in the federal 2024-25 budget supports industries that will make a significant contribution to the net zero transition and are expected to have an enduring comparative advantage, with public investment needed for the sector to make a significant contribution to emissions reduction at an efficient cost. The package included $1.7 billion Innovation Fund to be administered by ARENA, which is earmarked to unlock private capital across new industries including green metals and low-carbon liquid fuels.
- **Powering the Regions Fund (PRF):** Industrial (ITS) and Safeguard Transformation Streams (STS): The PRF is a comprehensive effort to enable regional Australia to thrive in a low-carbon future, aligning economic growth with environmental sustainability and supporting the country's ambitious emissions reduction targets. The various streams could all be leveraged to access the collective $1.9B in allocated funding administered through ARENA. The STS in particular builds upon the 2023 Safeguard Mechanism reforms.
- **The Net-Zero Economy Authority:** Recently established within the Department of Premier and Cabinet, the body aims to ensure workers, industries and communities can seize the opportunities of Australia's net zero transformation. Legislation was passed in December 2024 with the department now in operation.
- **Regional Cooperation on Carbon Sequestration:** The Government has announced $32.6 million in funding over four years from 2024–25 to establish regulatory frameworks and bilateral instruments to better support heavy industry to reduce emissions to meet Paris Agreement commitments, both in Australia and overseas. This will provide industry with the option of moving CO_2 to suitable and secure geological storage sites, where proven, to support energy security, meet obligations under Australian law and provide carbon management solutions for regional partners, consistent with our obligations under international law.
- **The State Prosperity Project:** The South Australian Government recently launched its State Prosperity Project, which envisions a reindustrialised future in the Upper Spencer Gulf by unlocking mineral resources, renewable energy, and green manufacturing.

Globally international policy related to CCUS is gaining significant momentum underwritten by substantial policy initiatives such as the United States Inflation Reduction Act (IRA) 45Q tax credit, the UK's GBP£20B commitment to support its 2030 capture capacity goal via dedicated CCUS hubs as well as the European Union's Innovation Fund and its Emission Trading Scheme (ETS). Alignment with current state and federal policy to ensure SA captures the CCUS growth opportunity requires immediate action.

Target Benefit
Joint federal and state funding

Alignment with other international accommodative policy

6. 4 Leverage SA's High-Skilled Workforce to Deliver Infrastructure

SA hosts a highly skilled workforce associated with the oil and gas industry that have a plethora of transferrable skills which relate to CCUS, including pipeline infrastructure construction and operation.

As a specific example, the planned Northern Waters project (which intends to create a 600 km pipeline to transfer water to the Far North, Upper Spencer Gulf and Eastern Eyre Peninsula regions) is anticipated for completion in 2028, which could align with the design and construction of Phase 1 and keep jobs in SA with a significant pipeline of works.

Target Benefit
SA's high-skilled workforce is leveraged to deliver the CCUS infrastructure

6. 5 Support a Green Steel Industry in SA

An optimal green steel industry relies on green hydrogen as a key input into the production process and to enable the lowest carbon outcomes from the steel production process. While anticipated under future conditions, in practice the supply of green hydrogen is not available to support the rapid development of green steel, however similar low-carbon outcomes can be achieved through the use of natural gas coupled with carbon capture. This interim opportunity for the use of carbon capture can lead to the early development of green steel manufacturing, to ultimately transition to the use of green hydrogen when the supply matures technically and cost competitively.

Target Benefit
Support for rapid uptake of green iron and steel in SA via a gas-DRI with CCUS pathway

6. 6 Leverage the First-Mover Advantage of Moomba

With the Moomba CCS project having commenced operations in late 2024, SA will be provided with an operational product on which practical testing can be undertaken and the concept can be demonstrated to the community.

The facility is a tangible proof point which can be leveraged to develop a first-mover advantage for SA with respect to SA and East-Coast emitters and allow the progressive development of the industry to cater for much higher throughput.

Target Benefit
The operating facility in Moomba providing a proof-point and first-mover advantage for central and eastern Australia point sources which SA can leverage to gain support and local practical lessons learnt

6. 7 Use of Depleted Gas Reservoirs for Lower Risk Storage

The Cooper Basin has a significant depleted gas reservoirs hold lower risk and are better understood than saline aquifers. An opportunity exists to utilise this capacity first, limiting risk during initial CCUS ecosystem development.

Target Benefit
Reduce project risk by using depleted gas reservoirs for storage

6. 8 Phased Implementation to Align with Demand

The clusters presented within this report are able to be implemented independently of each other and importantly each cluster can become operational as approvals, agreements, and funding take place.

Target Benefit
Independent phases allow opportunistic growth of the CCUS industry for SA

07
Next Steps

The common user infrastructure approach of the scale presented in this report requires significant public capital investment that must coincide and coordinate with the private capital requirements associated with capture plant at industrial sites, CO_2 transportation infrastructure and injection facilities.

Public and private funding is of course in addition to substantial regulatory and policy framework analysis, necessary approvals at a state and federal level and internal business processes for private enterprise. This will require further analysis for hard-to-abate industries and facilities covered by the Safeguard Mechanism including an assessment regarding liability options and corresponding carbon value forecasts for instruments such as ACCU's, SMC's and self-funded emission reduction projects such as CCUS. These must be understood including a gap analysis for the underlying business cases across public and private infrastructure investment decisions.

Equally, stakeholder engagement across the supply chain will be required to arrive at a best-for-state outcome that meets the objectives of the ISA mandate and the recommendations put forward in the revised 20-Year State Infrastructure Strategy.

Further detailed investigations are required to confirm the viability of a CCUS supply chain within SA and potential infrastructure options such as those presented within this study to assess technical and financial perspectives, establish regulatory pathways, and to further explore the costs and benefits via a detailed business case for preferred options.

Next Steps:

1 **CCUS Partnerships –** Establish a holistic CCUS forum (network or similar) across all elements of the supply chain, including regulators, industrial emitters, technology partners, potential owners/operators, and research and development partners.

2 **Development Pathway** – Undertake a strategic assessment of the frameworks under which a CCUS ecosystem would be developed, regulatory approvals, engage with supply chain operators, and undertake analysis of discrete project elements and business models

3 **Detailed Business Case –** A detailed business case will be developed for feasible opportunities identified as part of Step 2, including preferred operating model and underpinning infrastructure

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1. This estimate is based on the conceptual arrangements detailed in this report, industry normal arrangements and construction practices with analysis of publicly available information.
2. The estimate complies with the requirements of AECOM Estimate Class 5, Order of Magnitude +-50%
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4. The costs are based on current market rates for works to be undertaken in 2024/25. No allowances for price escalations or potential exchange rate fluctuations have been included.
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Where this report includes pricing related to carbon or advice around carbon offsets:

1. Carbon offset pricing in the voluntary offset market and liability mechanisms covered by Safeguard facilities and other carbon capture and abatement costs are likely to be volatile for the foreseeable future. As more organisations, public and private, act on their carbon reduction commitments, it is expected that demand may outpace supply. Additionally, legislative changes to offset schemes and/or opening up to join existing or new global offset markets would be expected to create price shocks.
2. New, emerging low-carbon technologies and alternatives to CCUS may help drive down the costs of carbon reduction as scale and uptake increases, but this is reliant on large infrastructure projects sending appropriate economic signals to trigger market response. Volatility in the (currently) voluntary carbon market has recently been triggered by Australian federal government moves to wind-down the Emissions Reduction Fund and eliminating Kyoto Protocol carry over credits. Furthermore, increased scrutiny into the integrity of carbon offsets is likely to create some uncertainty around offset quality which may carry reputational risk for entities relying on low quality offsets to achieve their carbon reduction goals.
3. The cost of carbon abatement credits varies depending on a variety of factors, including the type of project, location, and market demand and is subject to a number of risks including price volatility and regulatory changes. As a result, the costs provided here are for informational and comparative purposes only and should not be considered a guarantee or representation of actual future prices.
4. While AECOM uses ACCUs as one suggested basis, given these offsets are supported by the Australian federal government's Clean Energy Regulator, there has been recent criticism of some of these offset types and to that end, AECOMs advice does not constitute a recommendation that ACCUs should be used to achieve decarbonisation goals.
5. The information provided with respect to carbon offset costs is based on publicly available sources and may be subject to change at any time.

Economic Analysis:

1. This analysis is based on limited publicly available data on the costs of carbon capture, use, storage, utilisation, and transport. While global estimates were used, Australian data was applied where available.
2. Due to the limited data available for the analysis, the accuracy and reliability of results may be impacted, and should be interpreted with caution.
3. CCUS is an evolving industry that is diversifying across hard-to-abate industries, and in Australia, this diversification is only now being looked at in depth. For that reason, there is limited 'real world' experience to draw on when modelling the impacts of the sector in South Australia.
4. This analysis of the project's economic impact was done using a standard modelling approach that estimates how spending flows through the economy. However, this type of modelling has some limitations — it doesn't fully account for things like limited resources or how businesses and people might change their behaviour in response to economic changes.
5. The appraisal period for this analysis is from FY2024 to FY2050, based on available data and relevant projections for demand and supply. However, it's important to note that actual outcomes may vary as conditions change over time, and some benefits may continue beyond this period.

Glossary

Australian Carbon Credit Unit – A program for the trading of carbon credits, based on the ACCU it refers to a tradable financial product representing a tonne of carbon dioxide equivalent (tCO_2-e) avoided or stored in a project. Purchasing of ACCUs allow for a business to claim reductions in their emissions through the abatement of avoidance of emissions.

Blast Furnaces – A blast furnace is a large industrial structure used primarily in the production of iron from iron ore. The process involves the combustion of coke, a form of carbon, alongside iron ore and limestone within the furnace. The high temperatures generated by the burning coke cause the iron ore to melt and separate into molten iron and slag. The molten iron is then collected at the bottom of the furnace for further processing into steel or other products. Blast furnaces operate continuously and are integral to large-scale iron and steel production, offering efficiency in converting raw materials into usable metal. However, they are associated with significant energy consumption and emissions, prompting efforts to improve their environmental impact.

Basic Oxygen Furnaces – A Basic Oxygen Furnace (BOF) is a type of furnace used in traditional steelmaking that refines molten iron from a blast furnace into steel. The process involves blowing high-purity oxygen through the molten iron, which reduces the carbon content and removes impurities such as silicon, manganese, and phosphorus. This oxidation process generates heat, which helps maintain the temperature of the molten metal. The BOF method is highly efficient and capable of producing large quantities of steel quickly, making it a dominant process in the steel industry. It allows for precise control over the chemical composition of the steel, resulting in high-quality products. However, the BOF process relies heavily on iron from blast furnaces and is associated with significant carbon emissions, leading to ongoing efforts to improve its environmental footprint.

Bioenergy with Carbon Capture Storage - Bioenergy with Carbon Capture and Storage (BECCS) is a process that combines the generation of energy from biomass with the capture and storage of the carbon dioxide (CO_2) emissions produced during energy production. Biomass, such as plant material or agricultural waste, is used as a renewable energy source. During combustion or conversion to energy, CO_2 is released, which is then captured using carbon capture technologies. The captured CO_2 is subsequently transported and stored underground in geological formations, effectively removing it from the atmosphere. BECCS is considered a negative emissions technology because it not only provides renewable energy but also reduces atmospheric CO_2 levels. It plays a critical role in climate change mitigation strategies, particularly in scenarios aiming for net-zero emissions. However, the implementation of BECCS faces challenges such as the sustainable sourcing of biomass, land use competition, and the cost and infrastructure required for carbon capture and storage.

Carbon Capture – Carbon capture is a process designed to reduce the amount of carbon dioxide (CO_2) released into the atmosphere from industrial and energy-related sources. It involves capturing CO_2 at its emission point, such as power plants or factories, before it can enter the atmosphere.

Carbon Capture Storage – Carbon Capture and Storage (CCS) is a technology designed to reduce greenhouse gas emissions by capturing carbon dioxide (CO_2) from industrial processes or power generation before it enters the atmosphere. The captured CO_2 is then transported, often via pipelines, and securely stored in geological formations deep underground, such as depleted oil and gas fields or saline aquifers.

Carbon Capture Utilisation - Carbon Capture Utilisation (CCU) involves the process of capturing carbon dioxide (CO_2) emissions and utilizing them in various applications rather than storing them underground as in Carbon Capture and Storage (CCS). This approach not only helps in reducing greenhouse gas emissions but also adds value by converting CO_2 into useful products.

Carbon Capture Utilisation and Storage - Carbon Capture, Utilization, and Storage (CCUS) is a comprehensive approach to managing carbon dioxide (CO_2) emissions. It involves capturing CO_2 from industrial processes or directly from the atmosphere, utilising it in various applications such the production of materials, and as a means of permanent or semi-permanently storing it within the product

Direct Air Capture - Direct Air Capture (DAC) is a cutting-edge technology designed to remove carbon dioxide (CO_2) directly from the atmosphere, offering a promising solution for mitigating climate change.

Direct Air Capture with Storage - Direct Air Capture and Storage (DACS) is a technology aimed at capturing carbon dioxide (CO_2) directly from the atmosphere and storing it to mitigate climate change. This process involves using chemical reactions to extract CO_2 from the air, which is then compressed and transported to storage sites, often deep underground in geological formations. DACCS is considered a negative emissions technology because it actively removes CO_2 from the atmosphere, unlike other methods that merely reduce emissions.

Electric Arc Furnace - An Electric Arc Furnace (EAF) is a type of furnace used in steelmaking that heats charged material by means of an electric arc. Unlike traditional blast furnaces, EAFs do not rely on direct fossil fuel as its primary energy source, but rather from electricity which may originate from any means of energy generation including from renewable resources, making them more environmentally friendly. The process involves placing scrap steel or direct reduced iron into the furnace, where electrodes create an electric arc that melts the metal. This method allows for precise control over the composition and temperature of the steel, resulting in high-quality products. EAFs are known for their efficiency and flexibility, as they can be quickly started and stopped, and they can use a variety of raw materials. They are widely used in the production of steel for construction, automotive, and various other industries.

Emissions Trading Scheme - An emissions trading scheme (ETS) is a market-based approach to controlling pollution by providing economic incentives for reducing emissions of pollutants. Under an ETS, a government or regulatory body sets a cap on the total amount of greenhouse gases that can be emitted by covered entities. Emission allowances, equivalent to one ton of carbon dioxide or its equivalent, are distributed or auctioned to these entities, which can include industries and power plants. Entities that reduce their emissions below their allocated allowances can sell their excess allowances to others that are struggling to stay within their limits. This creates a financial incentive for companies to invest in cleaner technologies and reduce emissions, as they can profit from selling surplus allowances. Conversely, companies that exceed their emissions cap must purchase additional allowances or face penalties. The cap is typically reduced over time, encouraging continuous improvements in emissions reductions. An ETS aims to achieve environmental goals in a cost-effective manner by leveraging market dynamics to find the most economically efficient way to reduce emissions across the economy.

Enhanced Oil Recovery - Enhanced Oil Recovery (EOR) is a set of techniques used to increase the amount of crude oil that can be extracted from an oil field. Traditional methods typically recover only a portion of the oil in a reservoir, leaving a significant amount behind. EOR aims to extract more oil by altering the physical properties of the reservoir or the oil itself. Common EOR methods include thermal recovery, which involves injecting steam to reduce the viscosity of the oil; gas injection, where gases such as carbon dioxide or natural gas are injected to increase reservoir pressure and improve oil flow; and chemical injection, which uses substances like polymers or surfactants to improve oil mobility. EOR can significantly extend the life of an oil field and increase its total output, making it a valuable tool in the oil industry. However, it often requires substantial investment and technological expertise.

Metal-Organic Frameworks - Metal-Organic Frameworks (MOFs) are a class of porous materials composed of metal ions or clusters coordinated to organic ligands. These structures form a highly porous framework, which can be tailored for specific applications by altering the metal ions or organic components. MOFs are renowned for their exceptionally high surface area and tunable pore sizes, making them ideal for applications in gas storage, separation, and catalysis. They are particularly promising for carbon capture and storage due to their ability to selectively adsorb carbon dioxide. Additionally, MOFs are being explored for use in drug delivery, sensing, and energy storage. Their versatility and modularity make them a significant area of research in materials science, with potential impacts across various industries.

Negative Emission Technologies - Negative Emission Technologies (NETs) are approaches designed to remove carbon dioxide (CO_2) from the atmosphere, thereby reducing the overall concentration of greenhouse gases. These technologies include methods such as afforestation and reforestation, soil carbon sequestration, bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), and ocean-based solutions like alkalinity enhancement. NETs are considered crucial for achieving climate goals, especially in scenarios where reducing emissions alone is insufficient to limit global warming. While they offer significant potential for mitigating climate change, challenges such as scalability, cost, energy requirements, and potential ecological impacts must be addressed to ensure their effective implementation.

The National Greenhouse and Energy Reporting scheme - The National Greenhouse and Energy Reporting (NGER) scheme is an Australian framework established to provide a consistent approach to reporting greenhouse gas emissions, energy production, and energy consumption by corporations. It was introduced under the National Greenhouse and Energy Reporting Act 2007. The scheme mandates that corporations meeting specific thresholds for emissions or energy usage report their data annually. This data is used to inform government policies, track national progress on emissions reduction targets, and provide transparency to the public. The NGER scheme supports Australia's efforts to manage environmental impacts and transition to a low-carbon economy.

Sustainable Aviation Fuel - Sustainable Aviation Fuel (SAF) is a type of fuel designed to reduce the environmental impact of aviation. SAF is produced from renewable resources, such as waste oils, agricultural residues, or non-food crops, or from green-hydrogen derivatives and can significantly lower greenhouse gas emissions compared to conventional jet fuel. It is chemically similar to traditional aviation fuel, allowing it to be used in existing aircraft engines without modifications. SAF contributes to the aviation industry's efforts to achieve carbon neutrality and reduce dependency on fossil fuels. Despite its benefits, challenges such as production scalability, cost, and feedstock availability need to be addressed to enable widespread adoption.

Safeguard Mechanism - Australia's Safeguard Mechanism is a regulatory framework designed to limit greenhouse gas emissions from large industrial facilities. It applies to facilities emitting more than a specified threshold of carbon dioxide equivalent emissions annually, requiring them to keep their emissions within set baselines. Facilities exceeding their baselines must offset the excess emissions through measures such as purchasing carbon credits or implementing emissions reduction strategies. The mechanism aims to ensure that emissions reductions achieved through other policies, like the Emissions Reduction Fund, are not negated by increases in industrial emissions. It supports Australia's climate goals by encouraging accountability and promoting sustainable practices among high-emission industries.

Safeguard Mechanism Credits - Safeguard Mechanism Credits (SMCs) are a component of Australia's Safeguard Mechanism, which aims to limit greenhouse gas emissions from large industrial facilities. These credits are issued to facilities that reduce their emissions below their baseline levels, incentivizing lower emissions and rewarding proactive environmental management. SMCs can be traded or used to offset emissions exceeding a facility's baseline, promoting cost-effective compliance and encouraging investment in emissions reduction technologies. This system supports Australia's broader climate goals by fostering accountability and innovation in high-emission industries.

Steam-Methane Reforming - Steam-methane reforming (SMR) is a widely used industrial process for producing hydrogen from natural gas. In this process, methane (CH4) reacts with steam (H2O) at high temperatures, typically between 700°C and 1,000°C, in the presence of a catalyst. This reaction produces hydrogen (H2) and carbon monoxide (CO). The carbon monoxide can further react with steam in a subsequent water-gas shift reaction to produce additional hydrogen and carbon dioxide (CO_2). SMR is the most common method for hydrogen production due to its efficiency and cost-effectiveness. However, it generates significant CO_2 emissions, which has led to interest in integrating carbon capture and storage technologies to mitigate its environmental impact. Hydrogen produced through SMR is used in various applications, including ammonia production, refining processes, and as a potential clean energy carrier.

Safeguard Transformation Stream - The Safeguard Transformation Stream is an initiative within Australia's climate policy framework aimed at supporting industries in transitioning towards lower carbon emissions. It provides mechanisms for facilities covered under the Safeguard Mechanism to implement transformative changes that reduce their greenhouse gas emissions. This stream focuses on enabling industries to adopt cleaner technologies, improve energy efficiency, and shift towards sustainable practices. By facilitating these transitions, the Safeguard Transformation Stream contributes to Australia's broader goals of reducing emissions and achieving net-zero targets while maintaining industrial competitiveness.

Acronyms

ABN	Australian Business Number
ACCU	Australian Carbon Credit Unit
APAC	Asia Pacific Region
API	American Petroleum Institute
ARENA	Australian Renewable Energy Agency
BF	Blast Furnaces
BOF	Basic Oxygen Furnances
BZE	Beyond Zero Emissions
CAPEX	Capital Expenditure
CC	Carbon Capture
CCS	Carbon Capture Storage
CCU	Carbon Capture Utilisation
CCUS	Carbon Capture Utilisation and Storage
CEN	Central, Eastern and Northern
CH4	Methane
CIS	Capacity Investment Scheme
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTSCo	Glencore's wholly-owned Carbon Transport and Storage Corporation Pty Limited Project
DAC	Direct Air Capture
DACS	Direct Air Capture with Storage
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Department of Energy and Mining
DISER	Department of Industry, Science, Energy and Resources
DRI	Direct Reduced Iron
DSO	Direct Shipping Ore
EAF	Electric Arc Furnace
ENEOS	ENEOS Corporation
EOR	Enchanced Oil Recovery
ESG	Environmental, Social, and Governance
EU	European Union
FY2024	Finanical Year 2024
FY2025	Finanical Year 2025
FY2050	Finanical Year 2050
GAB	Great Artesian Basin
GBP	Great British Pounds (£)
GHG	Greenhouse Gas
GLNG	Curtis Island LNG Plant
GSP	Gross State Product
H2	Hydrogen
IA	Infrastructure Australia
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRA	United States Inflation Reduction Act
ISA	Infrastructure South Australia
ISO	International Organization for Standardization
ISO14001	ISO 14001 is an international standard that provides a framework for organizations to establish, implement, and maintain an effective Environmental Management System (EMS)
ISO45001	ISO 45001 is an international standard for occupational health and safety management systems
ISO9001	ISO 9001 is an internationally recognized standard for quality management systems (QMS)
ITS	Industrial Transformation Stream
JERA	JERA is a 50-50 joint venture between TEPCO Fuel & Power, a wholly owned subsidiary of Tokyo Electric Power Company, and Chubu Electric Power, founded in April 2015.
JORC	Joint Ore Reserve Committee
JV	Joint Venture
JX	JX Nippon Oil
LCO_2	Liquid Carbon Dioxide
LNG	Liquid Naturual Gas
MCA	Multi-Criteria Analysis
MOF	Metal-Organic Frameworks
MOU	Memorandum of Understanding
NCMIP	The National Carbon Mapping and Infrastructure Plan
NDC	Nationally Determined Contribution
NET	Negative Emission Technoly
NGER	The National Greenhouse and Energy Reporting scheme
NSW	New South Wales
NT	Northern Territory
OOM	Order of Magnitude
OR	Oil Recovery
P50	A P50 confidence level, often used in project management and risk analysis, represents the median or 50th percentile, indicating that there is a 50% probability of the project being completed by this date or earlier.
PCC	Post-Combustion Capture
PKSW	Port Kembla Steel Works
PPP	Public Private Partnership
PRF	Powering the Regions Fund
PRMS	Petroleum Resources Management System
Q1	Quarter 1
Q2	Quarter 2
Q3	Quarter 3
Q4	Quarter 4
QCLNG	Queensland Curtis LNG
QLD	Queensland
REMP	Resources and Energy Major Projects
SA	South Australia
SACB	South Australian Cooper Basin
SAF	Sustainable Aviation Fuel
SMC	Safeguard Mechanism Credits
SMR	steam-methane reforming
SPE	The Society of Petroleum Engineers
SRMS	Storage Resources Management System
STS	Safeguard Transformation Stream
TAS	Tasmania
UK	United Kingdom
US	United States
USA	United States of America
USD	United States Dollar
VIC	Victoria
WA	Western Australia

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