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Carbon dioxide-enhanced oil recovery in Australia – techno-economic evaluation, carbon dioxide source/sink networks and current policy landscape

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ABSTRACT

This paper presents the results of a techno-economics analysis to quantify the potential for storing CO_2 and producing lower carbon intensity oil from mature, onshore Australian oil fields located in the Cooper/Eromanga and Surat/Bowen Basins. The work explores the impact of incentivisation, identifies possible sources of CO_2 to support CO_2-EOR (enhanced oil recovery) deployment, and discusses global CO_2-EOR policy. The hypothetical 'carbon incentive' assessed in this study resulted in unlocking an additional 40 million metric tons (Mt) of CO_2 storage and 73 million barrels (MMBO) of domestic oil production compared to the base case scenario that most closely represent Australia's current policy and economic settings. Further, the results of this study indicated that, with incentivisation, net-negative carbon dioxide emissions could be achieved by deploying CO_2-EOR practices in certain mature oil fields. The study found that there are currently sufficient industrial sources of CO_2, particularly from black coal-fired power generation and hard-to-abate industries such as cement and steel production, to support this deployment. An opportunity to explore the co-development of 'stacked storage' using both CO_2-EOR and concurrent geologic storage of CO_2 in adjacent, unconnected reservoirs is proposed. This may significantly reduce development costs compared to stand-alone geologic storage projects, providing more favourable techno-economics, and accelerating the physical connection of CO_2 sources and sinks.

Keywords: carbon dioxide, carbon intensity, emissions reduction, energy policy, enhanced oil recovery, net zero, techno-economics, utilisation.

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Introduction

In 2020, the Australian Government released its Technology Investment Roadmap: First Low Emissions Technology Statement (Department of Industry, Science, Energy & Resources (DISER) 2020) which identified carbon capture and storage (CCS) as one of five priority technologies in meeting net-zero emissions by 2050. The Roadmap outlines how technology, rather than taxation, is a key principle for Australia's emissions reductions strategy.

CO_2-enhanced oil recovery (EOR), a form of CO_2 'utilisation' is the practice of injecting CO_2 into an oil-bearing reservoir. This results in the permanent storage of significant volumes of CO_2 in the subsurface as well as enabling the CO_2 to mix with any oil that it contacts, which can result in increasing the recoverable oil from mature fields. Although CO_2-EOR has been implemented successfully for decades, particularly in the United States, it has not gained traction in Australia to date.

In conventional CO_2-EOR applications, the aim is to maximise oil production using minimal CO_2. However, alternative reservoir management practices focussing on permanently storing higher ratios of CO_2 per barrel of oil produced have previously been discussed in literature (Tenthorey *et al.* 2021). A net-negative emissions position may be achieved when the CO_2 stored per barrel of oil produced is greater than the full lifecycle emissions of the combusted oil. Further, additional domestic oil production via CO_2-EOR

Table 1. Economic cost model – basic components.

Cost element	Components
CAPEX – wells	Well drilling and completion, recompletion and plugging costs
CAPEX – facilities	CO_2 recycling and gathering systems
CAPEX – pipeline	CO_2 delivery pipeline from anchor field to cluster fields
OPEX	Water disposal, recycled CO_2, purchased CO_2, gathering system maintenance, fluid lifting
Tax/royalties	Royalty taxes – gross revenue from oil production (QLD/SA 2021)

can also reduce the need to pursue higher intensity oil imports and more environmentally challenging settings for new oil reserves.

Bagheri *et al.* (2022) previously developed an oil field database for Queensland and South Australia, and subsequently quantified technically viable oil recovery and CO_2 storage through implementation of CO_2-EOR using Advanced Resources International's (ARI) CO_2 Prophet software (Attanasi 2017).

This paper (1) quantifies the potential for storing CO_2 and producing lower carbon intensity oil from mature, onshore Australian oil fields located in the Cooper/Eromanga and Surat/Bowen Basins through a techno-economic assessment, (2) quantifies the sensitivity of these parameters to incentivisation, (3) identifies plausible sources of CO_2, and (4) addresses global policies for CO_2-EOR.

Methodology

Project development parameters

Several development parameters were defined to simulate actual development and operation of CO_2-EOR projects in Australia. These development parameters included (1) utilising and recompleting existing wells in the oil field for CO_2-EOR operations (minimum of 25% new wells drilled per field) and (2) staggering the development of the CO_2-EOR patterns to a maximum of ten, five-spot patterns to be developed per project per year.

Economic cost model

A detailed economic model was developed and benchmarked against cost estimates provided by oil field companies operating within the Cooper/Eromanga and Surat/Bowen Basins (Table 1).

Incentivisation

In Australia, Australian Carbon Credit Units (ACCUs) can be claimed for carbon storage, but ACCUs are not currently eligible for CO_2-EOR activities. Therefore, a hypothetical 'carbon incentive' was applied to quantify the potential impact on CO_2 storage and oil recovery. A 'carbon incentive' was applied for the purchased CO_2 only (not recycled CO_2) via the OPEX stream with a 5% price escalation per year for subsequent years.

Industrial sources of CO_2

The data underpinning the industrial sources of CO_2 is derived from publicly available sources (Clean Energy Regulator 2022*a*, 2022*b*) and converted into estimates of theoretically capturable CO_2 by applying CO2CRC's knowledge of applicable capture technologies for the respective industrial processes. For example, it has been assumed that 70% of the emissions (in the form of CO_2) from coal power plants could be theoretically captured using known technologies.

Results

Techno-economics

The results of the techno-economic modelling demonstrated that 35 Mt of CO_2 can be permanently stored, and 106 million barrels (MMBO) can be produced under modelled economic conditions that most closely represent Australia's current policy and economic settings (Fig. 1)[1]. The direct impact of implementing economic CO_2-EOR in the identified regions alone would extend the life of the currently producing oil fields, thereby maximising the utilisation of existing project assets, adding significant amounts to the national fuel reserve, while reducing emissions and the cost of new investments.

However, under an 'incentivised, low purchased CO_2 price'[2] scenario – potentially achieved through government subsidy or the allocation of theoretical ACCUs – the CO_2 storage and additional economic oil recovery increased from 40 to 75 Mt of CO_2 and 106 to 179 MMBO, respectively. In some cases, net-negative carbon dioxide emissions can be achieved.

[1]Key economic assumptions: Oil price = AUD$85/barrel, CO_2 purchase price (delivered to CO_2-EOR hub flange) = AUD$70/ton, internal rate of return hurdle (IRR) 10%.

[2]Incentive, low purchased CO_2 price scenario: Oil price = AUD$85/barrel, hypothetical carbon incentive = AUD$20/ton, CO_2 purchase price = AUD$20/ton, internal rate of return hurdle (IRR) 10%.

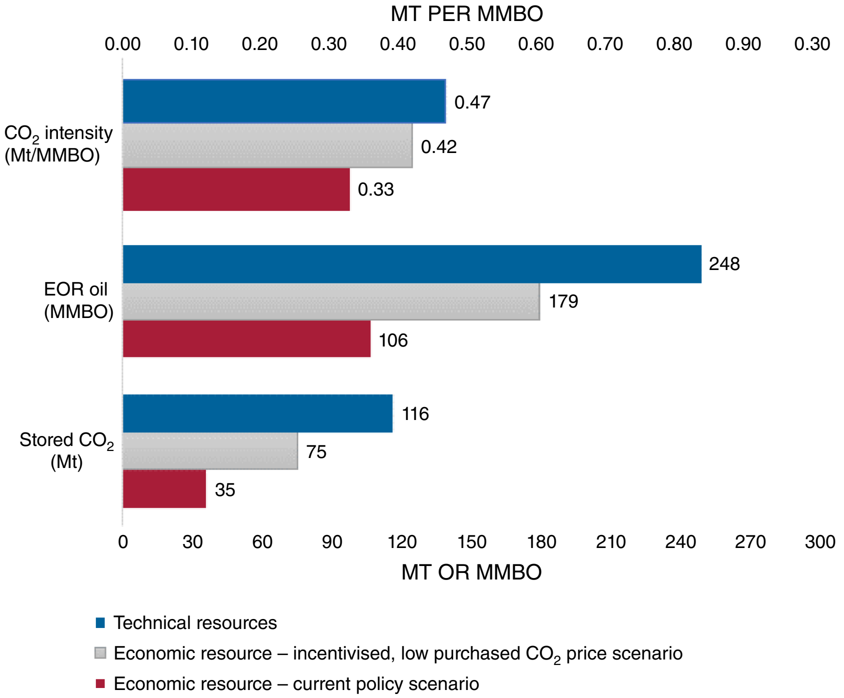

Fig. 1. Resource impact of applying the techno-economic model for different scenarios.

Industrial sources of CO_2

In the Australian states and territories included in the study (QLD, SA, NSW, NT), the largest emission sources presented are black coal-fired power stations, with nine facilities generating over 5 Mt of CO_2-e Scope 1 emissions per annum; power generation sector emissions are dominated by the states of QLD and NSW.

There are also significant CO_2 sources that could be captured from other major industries, including cement and steel. Thus, there is an opportunity to establish CO_2 source clusters around the large industrial centres, helping to reduce capital and operating expenditures for transportation to CO_2-EOR hubs, in which case over 75% of the potential capturable industrial CO_2 source volumes are in the regions of Newcastle/Hunter Valley, Gladstone and Darling Downs/Tarong (Fig. 2).

Global CO_2-EOR policy

The USA is a global leader in incentivising CO_2-EOR. The availability of low-cost, proximal, naturally occurring CO_2, tax incentives, and a high oil price in the 1970s and 1980s were major factors that facilitated development of the CO_2-EOR industry in the USA (Tanner 1992; Hustad and Austell 2004; National Energy Technology Laboratory/U.S. Department of Energy 2010). In 2008, the 45Q tax credit was first enacted in the United States (Congressional Research Service 2021) and originally provided a US\$10/tCO_2 credit for stored CO_2 via EOR increasing to US\$35/tCO_2 by 2026 (thereafter linked to inflation). The policy is both technology and fuel-neutral, and therefore aligns with one of the key principles outlined in the King *et al*. review (Department of Industry, Science, Energy & Resources (DISER) 2020).

Incentivisation of CO_2-EOR in the United States contrasts with Canada, where there are four CO_2-EOR projects currently in operation. A CCS/CCUS Investment Tax Credit (ITC) was announced in the 2022 Budget after a period of consultation. However, under the current proposals, CO_2-EOR is not defined as an eligible use and therefore cannot claim the credit (International CCS Knowledge Centre 2021). In the UK, field allowances indexed to unit technical cost, reduction of headline tax rates and low-interest loans (Durusut and Pershad 2014) have been identified as potential policy levers.

Summary and conclusion

In this study, a CO_2-EOR cost model was developed to quantify the potential for storing CO_2 and producing lower carbon intensity oil from mature, onshore Australian oil fields located in the Cooper/Eromanga and Surat/Bowen Basins. The modelling demonstrates that 35 Mt of CO_2 can be permanently stored, and 106 MMBO can be produced under modelled economic conditions that most closely represent Australia's current policy and economic settings. Under current Australian policy, CO_2-EOR activities are not currently eligible for ACCUs. By applying a hypothetical 'carbon incentive', an additional 40 Mt of CO_2 can be stored and 73 MMBO could be recovered and therefore added to the national fuel reserve. Alternative national policies have been outlined and highlight the significant incentives available for implementing CO_2-EOR in the USA.

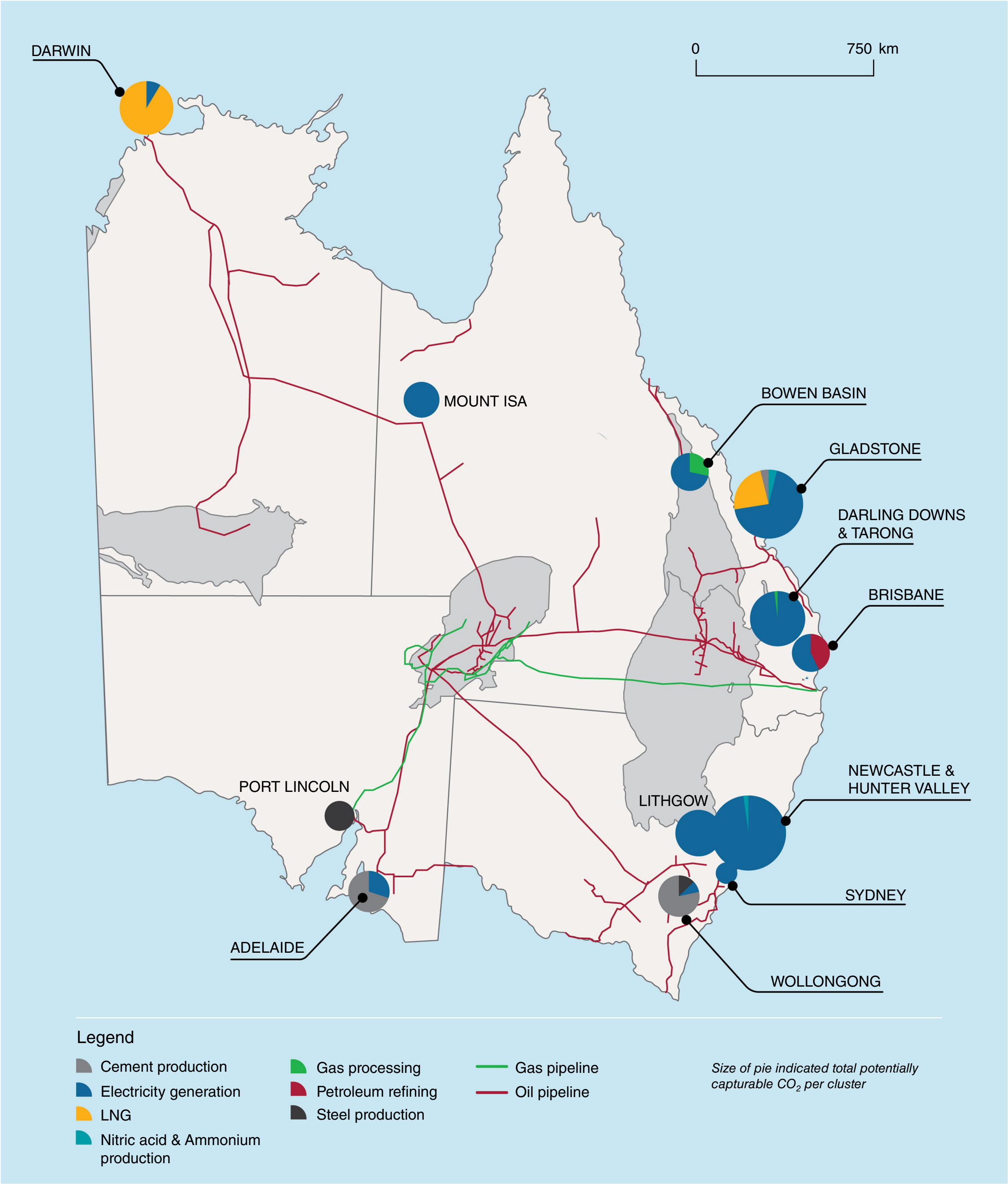

Fig. 2. Potentially capturable CO_2 sources by industry, Map (QLD, SA, NSW, NT). Regions with identified annual potentially capturable CO_2 sources greater than 0.2 million metric tons are presented and exclude Moomba. Data is primarily sourced from company sustainability reports and Safeguard facility data.

Industrial CO_2 sources were also identified, highlighting that there is currently a significant supply of CO_2 to support the deployment of CO_2-EOR. However, the reduction of power generation from coal-fired sources in New South Wales will materially change the geographic balance and magnitude of CO_2 sources in Australia. Hence, the pace of this transition will be an influential factor in any future development of CO_2 source/sink connecting infrastructure in Australia.

CO_2-EOR also has the potential to unlock additional utilisation and large-scale, lower-cost, geological CO_2 storage opportunities. By concentrating industrial CO_2 sources and developing infrastructure in areas with other sizable CO_2 storage reservoirs, CO_2-EOR has the potential to accelerate the uptake of CCS in Australia, create new industries and businesses, and assist the country in meeting its net-zero commitments.

As a long-term consideration, EOR with CCS can give Australia a strategic advantage in the global energy market by reducing its dependence on foreign oil and improving its domestic energy production. Furthermore, by reducing its dependence on foreign oil, Australia can better align its energy needs with its national interests and reduce its vulnerability to global energy supply disruptions.

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Data availability. The data cannot be shared due to privacy reasons.

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