The future role of natural gas in Australia and the region

Australian Energy Producers

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Executive summary

Natural gas and its infrastructure are one of the major pillars of the current global energy system. Planning for the potential pathways for gas, which are to be considered as part of Australia's Future Gas Strategy, will be crucial to achieving deep emissions reductions whilst enhancing energy security and affordability, and promoting sovereign industrial capacity.

Global net zero scenarios and implications for gas demand

This study reviewed a range of global long-term emissions scenarios, including scenarios from the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), the Network for Greening the Financial System (NGFS), the World Bank and bp. The review highlighted three major aspects for the future of gas:

- There is a wide range of outcomes for global natural gas demand which depend on future technology development and deployment. While almost all net zero scenarios show gas demand declining, they also show a need for gas in 2050. Moreover, global industrial demand for gas is likely to remain persistent due to the energy needs of hard-to-abate industries and strong regional economic development.

- All of the scenarios analysed included deployment of Carbon Capture Utilisation and Storage (CCUS) alongside gas production in order to achieve net zero by 2050, with the volume of CO_2 captured varying across scenarios.

- Hydrogen production from natural gas with CCUS is also expected in each of the scenarios analysed.

Australia's net zero pathway will likely look very different to the global picture

The global scenarios focus on global emissions and energy pathways. In accordance with their design focus, they explore system-level dynamics and mitigations which could occur to achieve net zero. While these global factors may be reflected to some extent in Australia, taking these macro features and applying them to regional and individual country economies needs careful consideration.

The economic and energy structures and issues in Australia will not necessarily follow the same global pathways. Australia, as a relatively small, open economy and major energy and resources exporter, will have unique energy transformation challenges:

- Australia is a key energy and resource supplier to one of the fastest growing regions in the world. Under each of the scenarios analysed, this region is expected to have higher residual natural gas demand as Asia-Pacific nations initially shift from coal to gas and are on a longer timeline to net zero than other regions.

- Australia has significant resources to support a range of technologies needed to reach net zero, including renewable energy resources and potential CCUS sites. This factor, coupled with Australia's strong environmental, social, and governance standards, could attract investment into the country.

- Australia has some of the world's most advanced CCUS projects, including the Gorgon project. Additionally, significant investment is flowing towards proving up hydrogen projects in Australia.

Reflecting such issues, Australia's pathway to net zero will be unique and be integrally linked with the energy security and net zero requirements of the Asia-Pacific region.

Four key technologies are likely to be central to driving decarbonisation

Four key technologies are likely to drive decarbonisation in hard-to-abate industries: electrification, CCUS, biomethane and hydrogen (see table below). The respective development and deployment of these technologies has considerable uncertainty and could influence future gas demand, and each scenario analysed reported varying assumptions to reflect this.

CCUS has the highest level of current deployment, with several large-scale projects in operation globally, as well as the highest Technology Readiness Level (TRL) for hard-to-abate industries. Hydrogen and electrification represent prospective opportunities to reduce emissions in hard-to-abate industries but require further development to reducing retrofitting and ongoing costs.

Table 1: Overview of each key technology's deployment and potential across hard-to-abate industries

Technology	Current level of deployment	Average TRL* across hard-to-abate industries	Scalability	Switching cost (retrofit and ongoing costs)	Ability to reduce emissions
Hydrogen	Low	Moderate	High	High	High
Electrification	Low	Moderate	High	High	Very high
Biomethane	Low	Moderate	Low	Low	Moderate
Carbon Capture, Utilisation and Storage	Moderate	Very high	High	Moderate	Very high

Source: EY analysis, IEA Energy Technology Perspectives Clean Energy Technology Guide, ARENA, Climateworks Centre.
*Technology Readiness Levels (TRLs) are a method of measuring the maturity of technologies.

Three distinct scenarios for Australia's gas industry

The report sets out three scenarios for potential gas demand over the next 30 years as Australia and the world transition to net zero, consistent with the Paris Agreement's goal of limiting climate change to well below 2°C.

The scenarios showcase the potential range of domestic and regional demand for Australian gas production, based on uncertainties around the advancement and rollout of technologies, energy exports and policy environment. They have been designed to inform investment and decision-making, representing a set of plausible outlooks for Australian gas production for export and domestic use, and are not intended to be 'bookend' scenarios exploring maximum and minimum volume outlooks. Additionally, each scenario acknowledges the current contractual arrangements surrounding Australian exports, which effectively 'lock-in' demand over the short-term.

The three scenarios are all aligned with Australia's net zero by 2050 target. Accordingly, all scenarios have equivalent emissions reductions outcomes for Australia. For the region, the scenarios reflect plausible pathways for energy importing countries to meet their net zero targets on their committed timeframes while meeting their energy security and affordability needs. Each scenario falls well within the boundaries set by international, regional and national net zero scenarios and, as such, can be considered moderate relative to the broad range of scenarios reviewed.

Scenario 1: Electrify

The *Electrify* scenario is premised on strong renewables technology development and deployment. Strengthened global supply chains see rapid technology improvements and cost reductions in solar and wind technologies and in electrolysers for the production of renewable-based hydrogen. Emissions reduction actions from all nations are coordinated, limiting supply chain constraints and increasing technology availability in Australia. CCUS deployment rates see moderate improvements.

Under this scenario, demand for Australian gas peaks in 2030 before falling to around 60% of today's gas production (around 3,600 PJ per year). Domestic gas demand begins to fall immediately and sees a strong decline through to 2050 as renewable energy and renewable based hydrogen become increasingly cost competitive. LNG exports moderately decrease over this period, although there is some growth in LNG demand from China and some emerging Southeast Asian countries.

Scenario 2: Blended

The *Blended* scenario is premised on a less coordinated global approach to energy and emissions reductions. Improvements in renewable technologies and cost reductions see significant increase in deployment rates relative to today but not reaching the levels seen in Scenario 1: *Electrify* due to some global supply constraints. A lack of coordinated action sees hydrogen transport and storage challenges persist, limiting the export of hydrogen to the region. CCUS deployment rates see strong improvements.

Under this scenario, demand for Australian gas increases by around 15% to 2040 (around 7,000 PJ per year) before falling to around 10% below today's production (around 5,500 PJ per year). Domestic gas demand remains stable in the medium-term as falls in residential and commercial gas demand are offset by growth in energy-intensive critical minerals extraction and processing industries.

Domestic demand falls over the long-term as alternative technologies become increasingly available and cost competitive. Australian exports grow over the medium-term, buoyed by growing demand from China, India and Southeast Asia. In the long-term, LNG exports fall as renewables and renewable-based hydrogen increase their market share in the region.

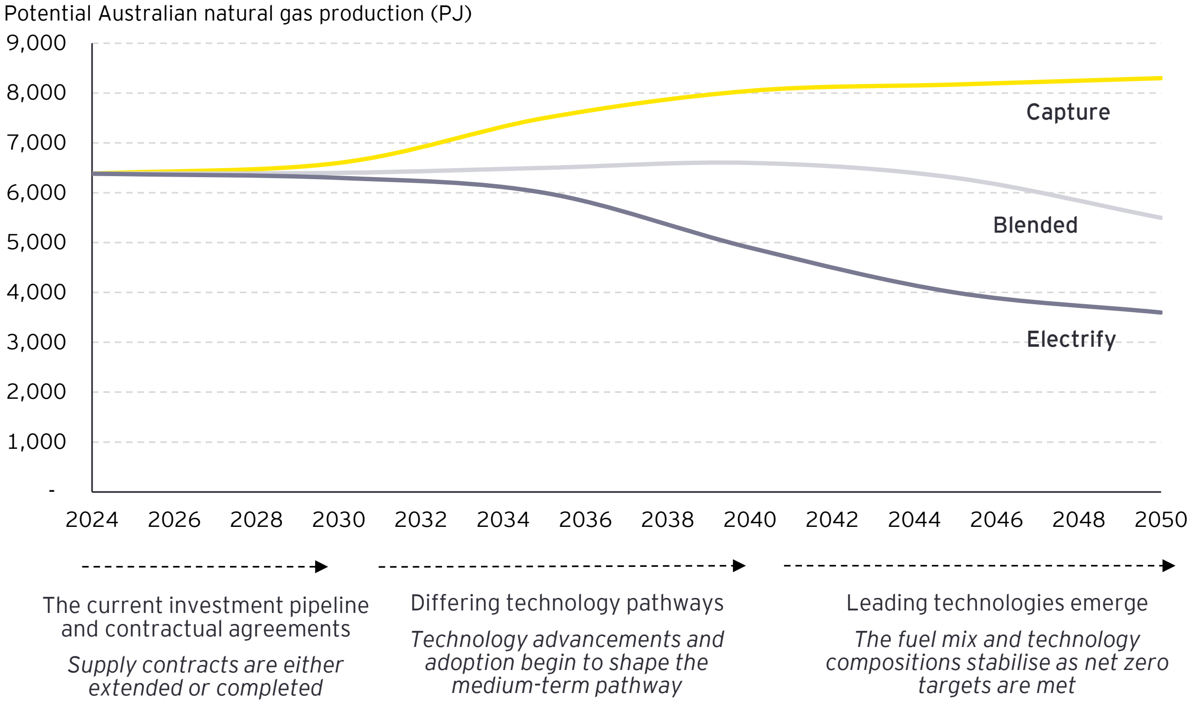
Scenario 3: Capture

The *Capture* scenario is premised on ongoing constraints to the deployment rates of renewable energy. As is seen today, this scenario sees global supply chains and competition for renewable and electrolyser technologies limiting availability and cost reductions in Australia and the region. Renewable deployment rates are many times faster than today and will provide the majority of energy supply in 2050. Hydrogen demand is met with significant deployment of natural gas with CCUS-based production.

Under this scenario, gas demand increases over the period by around 30% relative to today's levels by 2050 (around 8,200 PJ per year) largely driven by increased LNG and hydrogen exports as Australia's gas becomes a key energy source for decarbonisation and energy security in the region. Australia gains a greater share in a declining global gas market. Domestic gas demand falls modestly over the period as household and commercial consumption falls, however industrial consumption remains relatively stable.

The figure below shows potential natural gas production in Australia under the three scenarios.

Figure 1: Potential pathways of Australian natural gas production



Source: EY analysis

Prospects and challenges facing Australia's gas industry

The scenarios analysed from the IEA, IPCC, NGFS and others all include continued gas demand in the short and medium term as part of the global net zero transition. Its future development will be predominantly influenced by Australia's position as a global gas market supplier, how competitive and complementary energy and climate technologies evolve, and what economic activities will require gas as a proven and flexible source of energy to support the global energy transformation.

Australia finds itself at a pivotal juncture, holding a crucial position as a key global gas market supplier. This position provides both opportunities and challenges as the country navigates the complex landscape of transitioning towards a more sustainable energy future.

The analysis highlights a range of issues for consideration in the Future Gas Strategy:

- **A portfolio of technologies will be needed to reach net zero while ensuring secure, affordable energy to Australia and the region** – No single technology or fuel will be able to deliver the energy and industrial inputs needed in Australia and the region. Australia's energy policy should ideally adopt a technology-neutral approach to mapping a responsive pathway to net zero.

- **Investment requirements in gas –** Potential gas supply shortfalls have been identified across parts of Australia's east coast. For example, AEMO's central scenario (Orchestrated Step Change), indicates that gas supply shortfalls, relative to total east coast domestic and LNG demand, could be between 100 and 130 PJ per year from 2033 onwards, with a range of market, regulatory and global risk factors impacting the investment environment. Projected shortfalls elevate risks to domestic consumers, particularly large industrial gas users, with material implications for broader energy security.

- **CCUS and hydrogen are key complements to natural gas in a zero emissions future** — All plausible net zero pathways involve CCUS and hydrogen at different scales. In the near-term, proven and deployable CCUS technologies will be essential to addressing Australia's hard-to-abate industry emissions. Hydrogen from natural gas with CCUS could be particularly important as the hydrogen industry scales up from a low base today, reflecting the lower costs and more advanced status of the technology relative to electrolytic hydrogen production.

- **A robust energy and climate policy framework is needed to ensure Australia can thrive irrespective of future geopolitical and technological developments** — The scenarios presented in this analysis represent a plausible 'possibility space' for how energy and emissions reductions technologies and demand could evolve over the period to 2050. To manage the risks associated with the transition to net zero Australia's energy and climate mitigation policy needs to prepare for all three future scenarios, with policy and regulatory actions that keep as many pathways to net zero viable for as long as possible. Preparing for only one pathway leaves Australia extremely vulnerable to developments that are outside Australia's control.

- **Ensuring the long-term sustainability of the gas sector will be pivotal to managing risks to energy security, cost-of-living, and emissions reductions targets in Australia and the region** — In light of the uncertain gas and energy market pathways, it is important that Australia continues to leverage its strengths across different forms of energy and storage to maintain transition pathway options. There are risks that underinvestment in new gas capacity, especially as mature reserves reach end-of-life, could narrow the energy options available to the country and increase the economic costs of achieving net zero.

- **The natural gas sector represents an ongoing economic opportunity for Australia** — The natural gas sector has a long history of generating investment, tax revenue and jobs. Going forward, LNG demand in the region is likely to grow as countries look to transition their economies to net zero. While Australia has a range of competitive advantages as a key energy partner to the region, these opportunities should not be taken for granted. Competition for LNG supply to the region is growing from countries which are looking to ramp up their role in global LNG markets, in particular the US and Qatar. Without concerted attention, there is a risk that the economic opportunities from LNG supply to the region will be realised by countries other than Australia.

- **Government attention to address forecast near term gas supply shortfalls and promote an open and competitive gas market could be warranted** — The cost and performance of Australia's electricity and gas systems has become a major economic risk to Australia, especially in the context of rising energy prices for businesses and residential consumers. Australia's ability to secure additional gas exploration and production will be highly dependent on establishing policy settings which can deliver a long-term price signal and investment certainty, lower costs, and enhance project commerciality.

- **Australia is strategically well-placed as an enduring energy partner for the region** — Australia has the natural resources, skills and experience, and strong regional relationships to remain a key energy partner to the region. By advancing renewable energy developments, natural gas, CCUS and a range of hydrogen pathways, Australia can contribute to meet the energy and emissions reduction needs of the region, however they evolve.

1. Introduction

Australian natural gas plays a central role in the energy systems and economies of Australia and the region. As the world progresses to net zero, the demand for, and supply of, natural gas will be heavily dependent on a range of factors, many of which are outside the control of Australian government and industry. Planning for a range of possibilities will be crucial to developing a secure, affordable and resilient net zero energy market and to maximising Australia's economic opportunities.

Natural gas consumption has increased significantly over the past 30 years – now contributing 27% to Australia's total energy consumption. As a major exporter of liquified natural gas (LNG), Australian gas also has an important role to play to power nearby economies. As Australia and the region progress to net zero and beyond, demand for Australian gas — both domestically and from the countries in the region — will be shaped by economic growth, the development of new energy and emissions reductions technologies, and governments' energy and climate policies.

The challenge for energy markets will be to maintain reliability, while eliminating emissions and keeping costs affordable. Global net zero scenarios developed by organisations such as the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) demonstrate the rapid technological development and deployment required to meet net zero. These scenarios are highly sensitive to assumptions around the timing, scale, and commercial viability of clean energy technologies. If these assumed technological pathways do not eventuate, challenges could arise in meeting net zero.

For example, recent issues around energy prices, supply chain constraints, and renewable cost overruns have created uncertainties around the feasibility of some near-term emissions reduction targets, with Wood Mackenzie reporting that no major country is currently on track to meet their 2030 emissions reduction targets.[1]

Should any energy pathway or technology face challenges in its deployment, it will be critical to have alternative energy sources in the mix to maintain energy security and affordability and to keep emissions reductions efforts on track.

Further, the global scenarios focus on global emissions and energy pathways. They explore system-level dynamics and mitigations which could occur to achieve net zero. Taking these macro features and applying them to a regional or Australian context needs careful consideration.

Indeed, the economic and energy structures and issues at regional, national and localised levels can be very different. Australia, as a relatively small, open economy and major energy and resources exporter, will have unique energy transformation opportunities and challenges, including around the demand for Australian natural gas. As such, implementing a strategy for gas in Australia will help maximise Australia's capabilities to reach net zero and provide resilience in energy markets.

EY has been engaged to support Australian Energy Producers' submission to the Australian Government's Future Gas Strategy through outlining the current state of the Australian gas sector, the current net zero scenarios developed by major energy authorities, and developing Australian scenarios to understand the potential range in demand for Australian natural gas.

[1] Wood Mackenzie, 2023 Energy Transition Outlook

2. The current role for natural gas in Australia and the region

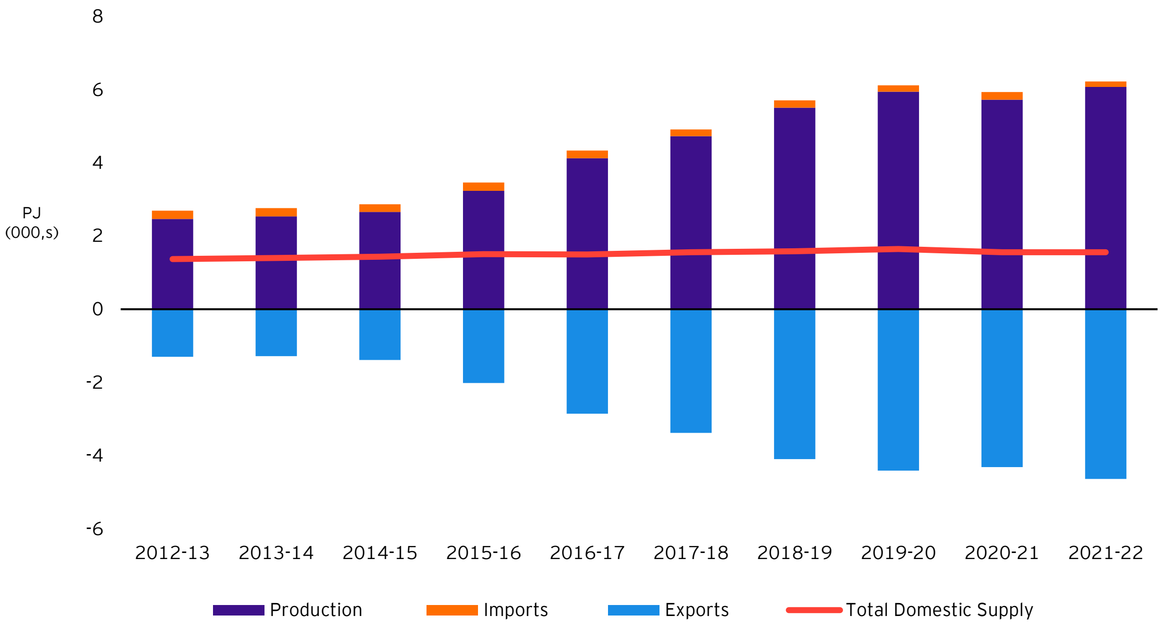
Demand for Australian gas – both domestic and from international markets – has been substantial, with LNG exports contributing significantly to the country's export earnings and economic growth. However, a challenging and uncertain investment environment sees shortfalls forecast in the domestic market in coming years, with potential repercussions extending beyond national borders.

Australia consumes natural gas domestically for electricity generation, industrial processes, and residential use. At the same time, Australia is a world leading exporter of LNG, supplying energy to a range of Asia-Pacific countries. The balance between Australia's domestic consumption and gas exports reflects the nation's role in meeting domestic energy requirements and global energy needs.

The gas market remains at risk of future supply shortfalls

Australia is a net exporter of energy, with gas exports equating to over two thirds of local production. Gas production has more than doubled since 2012, while domestic demand has seen modest growth – increasing at an average of 1.5% per year over the past 10 years (see Figure 2).[2] Looking forward, the AEMO Orchestrated Step Change scenario forecasts stable east coast domestic and LNG demand out to 2034. Under this scenario, a slight decrease in domestic demand is offset by increased east coast LNG demand, with west coast domestic demand set to increase by around 10% over the same period.[3, 4]

Figure 2: Total domestic supply of natural gas



Source: DCCEEW Australian Energy Statistics 2012-2023

While demand is forecast to remain relatively stable, the Australian Competition & Consumer Commission (ACCC) considers that the supply outlook to 2034 will remain tight and uncertain.[5] The ACCC reports that, on the east coast, forecast supply from both developed and undeveloped proven

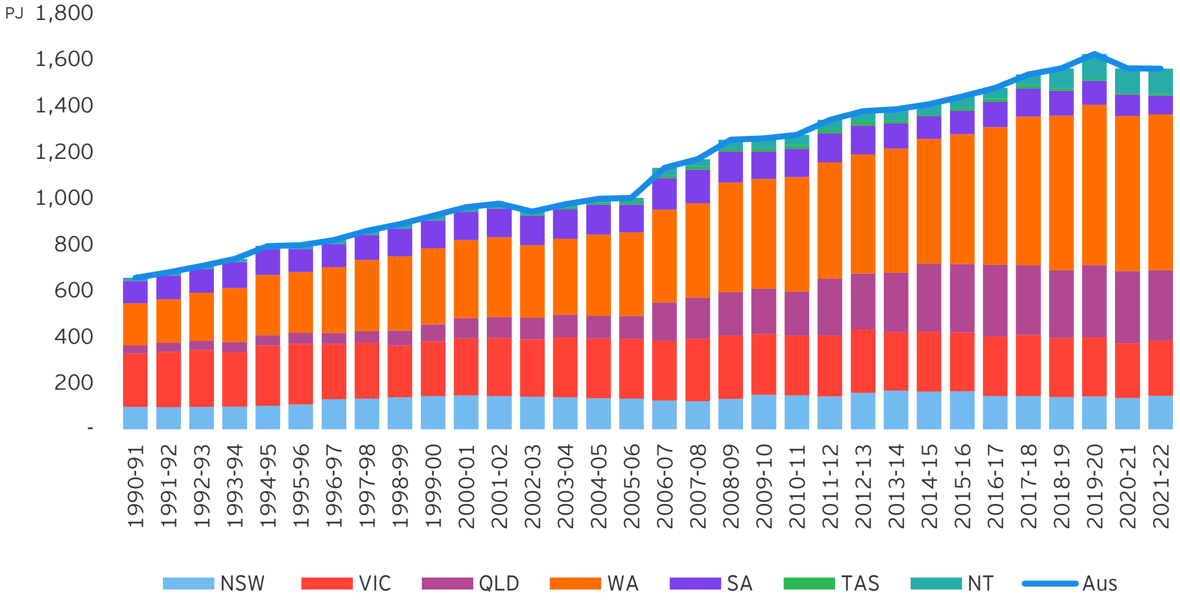
[2] DCCEEW, Australian Energy Update 2023
[3] AEMO, 2023 Gas Statement of Opportunities
[4] AEMO, 2022 Western Australian Gas Statement of Opportunities
[5] ACCC, Gas inquiry 2017-2030 reports

and probable (2P) reserves is expected to fall below projected demand as soon as 2026, with steep declines in production in the Gippsland Basin fields expected as they reach end-of-life. On the west coast, notable shortfalls are forecast from 2029 when demand is expected to jump at the same time as supply is expected to dip.[6] Ongoing investment in gas supply is required to maintain production levels from operating fields. As these fields begin to decline, investment in new supply options will be required to meet projected demand.[7] Investment in supply is also required to meet current long-term LNG commitments with the current committed and anticipated production also declining over time to below contracted levels in the medium-term.

There are several gas projects at varying stages of development (committed, feasibility and publicly announced) and type (expansion and new) that could lift natural gas supply. However, a range of factors are impacting these projects including commercial, financial, infrastructure access, market uncertainty, global conflicts and regulatory approvals.[8] Additionally, underinvestment due to investor concerns regarding returns on investment in a market subject to increasing government intervention and development delays is also impacting the likelihood of project completion.[9] Lack of certainty, along with regulatory restrictions on gas exploration in NSW and Victoria, has also impacted gas exploration. Exploration spending in Australia remains subdued and has failed to lift despite high energy prices. As a leading indicator of broader capital investment within the industry, future investment may continue to be sluggish, resulting in untapped reserves.

The use of natural gas differs significantly between states and territories, with Western Australia (WA) currently the largest consumer of natural gas at 673 PJ in FY22, making up 43% of Australian's natural gas consumption.[10] Gas consumption in WA, Northern Territory and Queensland has grown most significantly, driven by the resources sectors in these jurisdictions.

Figure 3: Australian natural gas consumption by jurisdiction



Source: DCCEEW Australian Energy Update

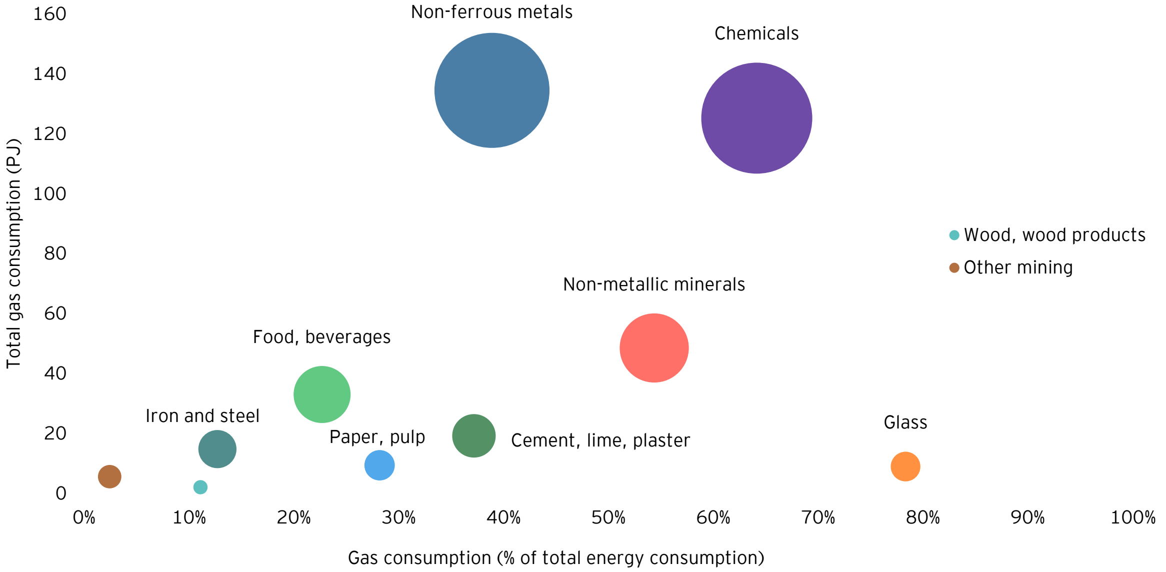
[6] AEMO, 2022 Western Australian Gas Statement of Opportunities
[7] AEMO, 2023 Gas Statement of Opportunities
[8] AEMO, 2023 Gas Statement of Opportunities
[9] ACCC, Gas inquiry 2017-30 reports
[10] DCCEEW 2023, Australian Energy Update

Heavy industrial gas consumption

Gas is key feedstock into several hard-to-abate Australian industries. It represents over 40% of total energy consumption in non-ferrous metals, non-metallic minerals, chemicals manufacturing, and glass production.[11] In many instances, CCUS applied to existing gas-based processes in these hard-to-abate industries could be a viable decarbonisation option, with few electrification or hydrogen technologies currently available (see Section 4).

Hard-to-abate processes in cement manufacturing and non-ferrous metals are expected to rely on CCUS technologies. Hydrogen-based production of chemicals remains a prospective decarbonisation technology that could compete with gas-based production with CCUS but it is highly unlikely to be deployable until the 2030s. These sectors will therefore likely remain major gas consumers. Considering the growing importance of Australia's non-ferrous metals and chemicals manufacturing sectors, including ambitions to commence onshore processing of critical minerals, gas demand in these industries could remain stable or increase over the medium-term.

Figure 4: Gas energy consumption profiles



Source: DCCEEW Australian Energy Update
Note: Size of the bubble represents total gas consumption (PJ)

Gas could firm up electricity supply as renewables roll-out and coal generators retire

Natural gas comprises about a fifth of total electricity demand in Australia and plays a key role in providing firming capacity.[12] As renewable capacity increases and is deployed across the grid, and coal-fired generators retire, gas is likely to become an increasingly important source of generation as it is flexible in providing either peak or base load power to supplement intermittent renewable sources.[13]

After an initial decrease in domestic gas consumption, AEMO estimates gas consumption in Australia will be relatively stable from 2025 through to 2042 under the Orchestrated Step Change scenario, as seen in the figure below. As gas consumption plateaus, however, there is a growing need for gas to meet peak demands during the winter. Winter gas demand peaks are also expected to grow due to the expected increased electrification of household and commercial heating and low variable renewable energy production during the darker months of winter.

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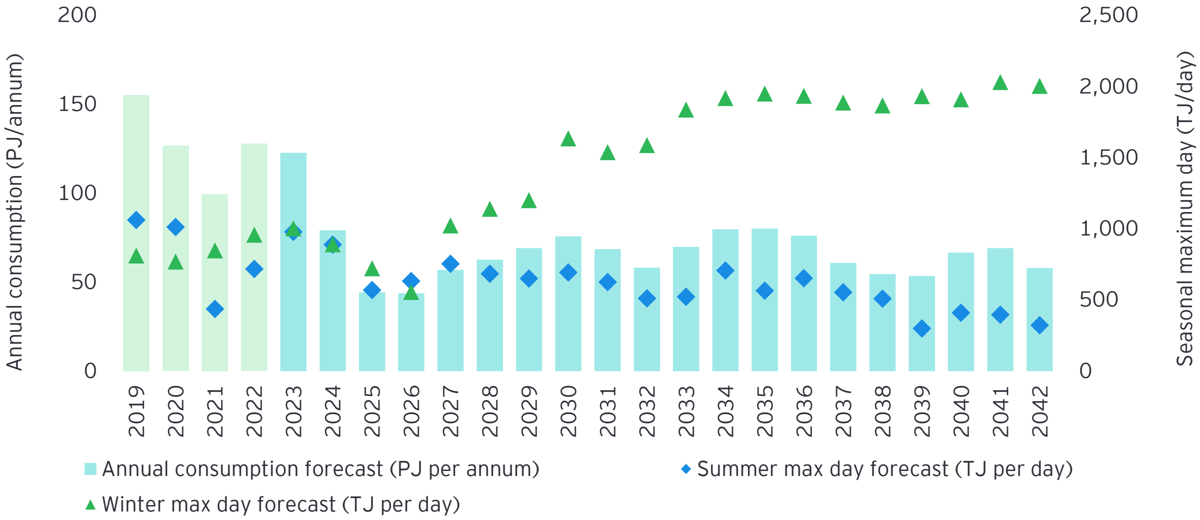
[11] DCCEEW 2023, Australian Energy Update
[12] DCCEEW, Australia Energy Statistics 2012-2023
[13] AEMO, Gas Statement of Opportunities

Figure 5: Actual and forecast NEM gas generation annual consumption and seasonal maximum daily demand in the Orchestrated Step Change scenario



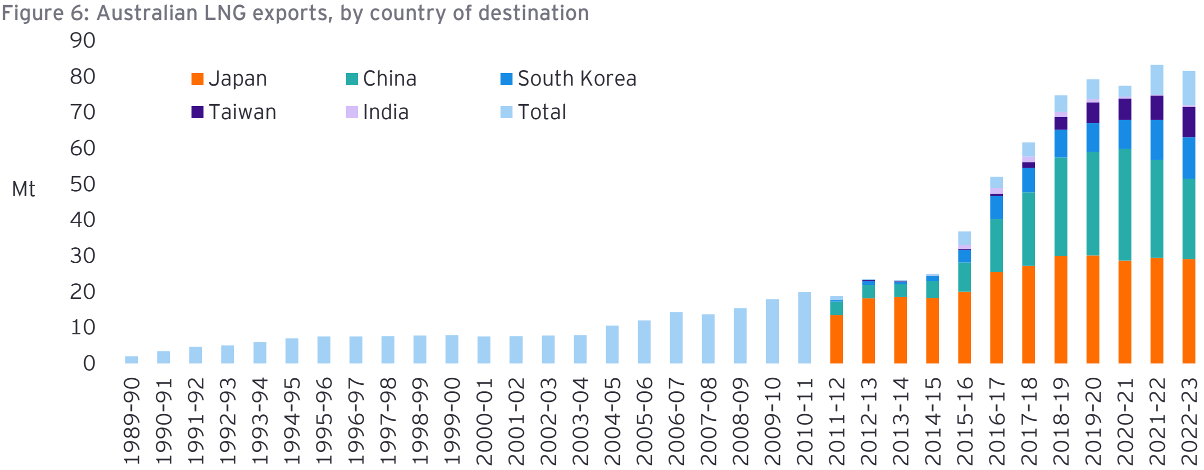
Source: AEMO Gas Statement of Opportunities

Australia is a world-leading LNG exporter

Australia is amongst the world's leading LNG exporters, along with the US and Qatar.[9] Much of its export market is centred around the Asia-Pacific with exports to Japan, China, South Korea and Taiwan currently accounting for 88% of Australian LNG exports.

Australia's LNG exports have more than tripled over the past decade. Australia exported 82Mt of LNG in FY23, valued at a record high $92 billion driven by a spike in energy prices. The Department of Industry, Science and Resources (DISR) forecasts earnings to moderate to $71 billion in FY24 as global energy prices come down.[14] However, export volumes are expected to remain strong over the next two years.

Figure 6: Australian LNG exports, by country of destination



Source: DISR Resources and Energy Quarterly September 2023

Many of Australia's major LNG customers, such as Taiwan, South Korea and Japan, have recently pledged to reduce their greenhouse gas emissions to net zero by 2050 in line with Paris Agreement targets. In these counties, Australian natural gas can be expected to support manufacturing and industry, the roll-out of renewable power and the phase-out of coal. Further, a range of other countries in the region including China and India as well as emerging markets in Southeast Asia (particular Vietnam) see LNG imports as an important element of their energy transition.[15] The

[14] DISR, Resources and Energy Quarterly September 2023

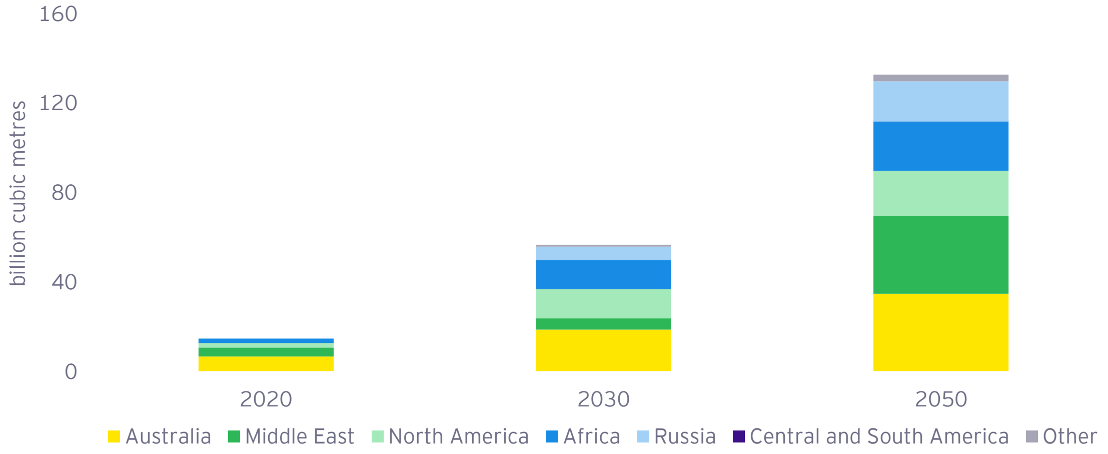
[15] IEA, World Energy Outlook 2023

Australian Government estimate that Australian LNG has the potential to reduce global emissions by up to 166 million tonnes per year by displacing the use of coal and other more emissions-intensive fuels in the region.[16]

Depending on the development and rollout of renewable energy generation and abatement technologies, demand for natural gas in Asia-Pacific countries, and LNG in particular, could continue to grow in the medium-term, potentially lifting demand for Australian LNG. Under the IEA's Stated Policies Scenario, Southeast Asian demand for imported LNG could grow by a factor of 10 between 2020 and 2050 (see figure below).[17]

Growth in natural gas and LNG demand in these countries could come primarily from increases in industrial activity, as well as a transition from coal to natural gas, and declining gas production in some countries. For example, India has targeted a 15% share of gas in the energy mix by 2030 to underpin the country's transition away from coal, which could result in an increase in India's LNG demand. Natural gas demand in Europe is expected to fall most rapidly, with developing countries in Asia-Pacific representing the largest sources of future demand growth.

Figure 7: Natural gas demand in China, India, and Southeast Asia under IEA's Stated Policies Scenario by country of export



Source: IEA Southeast Asia Energy Outlook 2023

[16] Australian Government, Australia's Long-Term Emissions Reduction Plan 2021

[17] IEA Southeast Asia Energy Outlook 2022

3. Net zero scenarios: Considering the role of gas

Natural gas and its infrastructure are one of the major pillars of the global energy system. Given its deeply embedded role in providing reliable and dispatchable power, heating and other industrial uses, gas will play an important role in supporting the energy system transition.

There is an extensive body of international work examining potential future emissions pathways, their main underlying drivers, changes to energy systems, and how these might be affected by policy responses.

This study reviewed a range of these global long-term emissions scenarios, including scenarios from the IEA, IPCC, NGFS, World Bank and bp. The following section summarises the potential range of low-carbon futures that could play out and examines the linkages between gas demand and the technological development, scale up, cost reduction, uptake and competitiveness of alternative and complementary energy technologies, such as electrification and hydrogen.

Interpreting global net zero scenarios — instructive and powerful narratives, not forecasts

Scenarios describe possible future developments based on permutations and assumptions around many very uncertain variables. They are alternative narratives of what could happen in the future but are not forecasts or predictions of the future. Accordingly, the global emissions scenarios examined, while plausible, have no inherent predictive power and instead represent possible eventualities that should be prepared for and not a suite of options that can be selected from.

A prime example is the question of where global emissions are headed. The net zero scenarios examined, as well as many others (which have not been included in the subsequent analysis), look at this question from different angles — future emissions could be based on current policies, climate pledges, historic trends with no policy actions, rapid advancement in some or all low emissions technologies, or a combination of these things. Each scenario examines a different aspect of a future emissions reduction pathway but would not directly reveal where global emissions are tracking.

The scenarios reviewed, while extensive, are also not exhaustive. They do not — and simply cannot — encompass all potential futures. Accordingly, some potential outcomes to global energy systems may exist outside of the main scenario sets. This could include policy constraints on biofuels, geopolitical reshaping or disruptions to global energy markets, widespread green tariffs or Carbon Boarder Adjustment Mechanisms, and major trade restrictions on technologies or critical minerals, among a myriad of possible long-term policy and technology developments. The existence of scenarios, and their distribution, does not provide definitive evidence about their likelihood of becoming reality (that is, they are not statistical samples).

Further, the scenarios examined in this section had a focus on global emissions and energy pathways. In accordance with their design focus, they explore system-level dynamics and mitigations which could occur to achieve net zero. Taking these macro features and applying them to regional and individual country economies needs careful consideration and should not be bluntly applied. The economic and energy structures and issues at localised levels can be very different. Australia, as a relatively small, open economy and major energy and resources exporter, will have unique energy transformation challenges (as discussed below), compared with Indonesia, Japan and Thailand or indeed other countries.

Setting out some of the key limitations of scenarios, and how they can be misinterpreted, is not to devalue their power. On the contrary, scenarios are powerful tools. What scenarios are very good at is to better understand and frame uncertainty, and thus inform the development strategy and policy that can cover a range of potential future outcomes, especially beyond typical planning horizons. This has been a core focus of the analysis.

Key findings from the global net zero scenarios

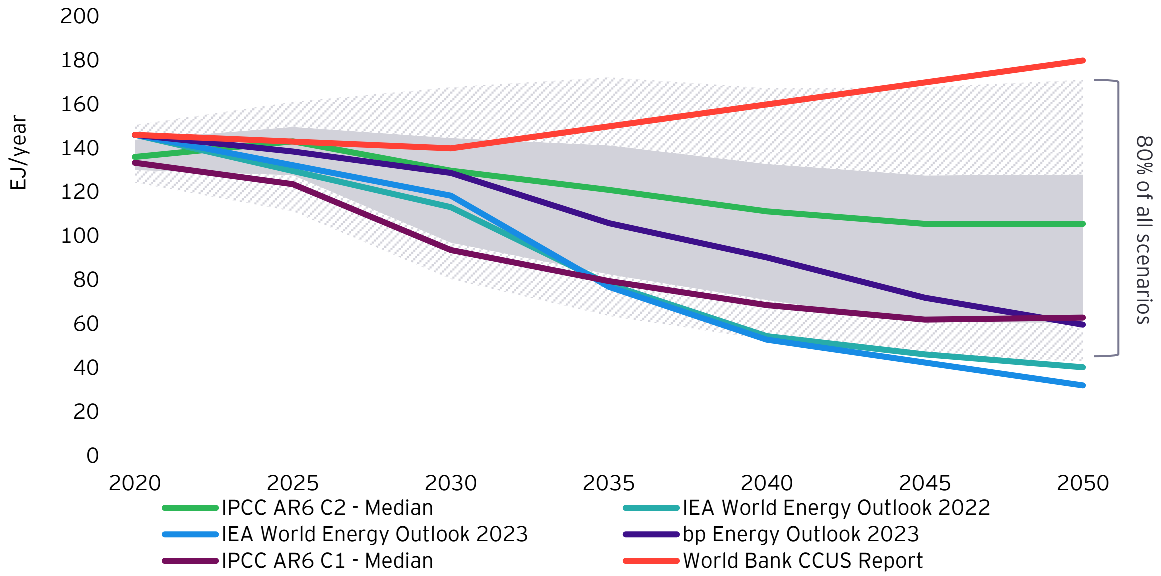
A review of around 350 different global net zero pathways from the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), the Network for Greening the Financial System (NGFS), bp and the World Bank was undertaken. The following section highlights key findings from the review. Further information and key variables considered in the net zero scenarios are in Appendix C.

Across the net zero scenarios there is a wide range of outcomes for global natural gas demand, but all show a need for gas in 2050

All scenarios reviewed showed a continued role for gas in 2050. While some scenarios see an increase in gas demand over this period, the balance of pathways show total global gas demand decreasing over the next 30 years. There is, however, significant uncertainty – the middle 50% (the solid shading in the figure below) of scenarios indicate that gas declines to between 62-128 EJ/year by 2050. This equates to a reduction in gas demand from today of between 57% and 12% respectively. A broader 80% of all scenarios show gas demand in 2050 ranging from 180 EJ/year to 44 EJ/year – an increase of 20% relative to today's levels to as low as 70% below today.

The median 1.5°C IPCC scenarios show that 2050 gas demand could be between 105 EJ/year (C2) and 60 EJ/year (C1) – reductions of 27% and 59% from today respectively. The IEA's Net Zero Emissions scenarios shows the steepest decline, forecasting reductions in primary energy from gas of 72% and 78% in the 2022 and 2023 releases.[18] The World Bank shows the largest increase in primary energy demand from gas at 25% above today's levels.

Figure 8: Primary energy from gas under net zero aligned scenarios and IPCC C2 Scenarios



Source: EY Analysis of the IPCC AR6 scenario data, the IEA World Energy Outlook 2022, IEA World Energy Outlook 2023, bp Energy Outlook 2023, and the World Bank Decarbonizing Natural Gas through Carbon Capture, Utilization and Storage (CCUS), 2023.

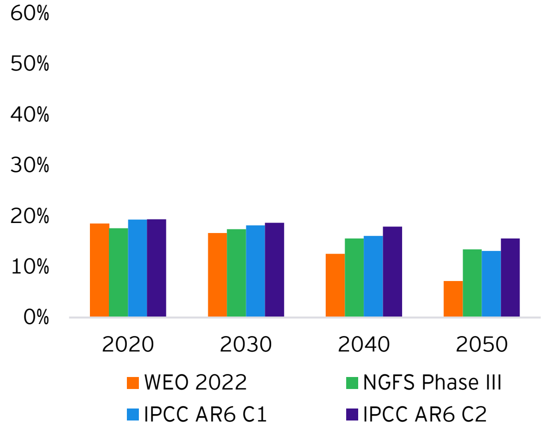
Note: Some net zero scenarios have different starting years. The fall in demand in the 2023 IEA scenario from 2022 is a reflection of hydrogen production from electrolysis increasing and displacing the demand for hydrogen production from natural gas with CCUS.

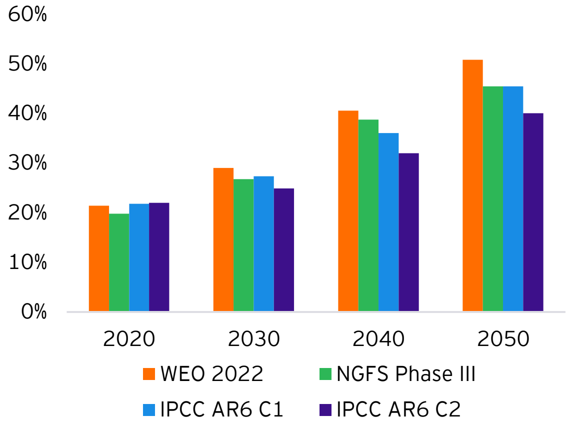
[18] EY Analysis of the IEA World Energy Outlook 2023

Global industrial demand for natural gas is likely to remain stable

Gas demand from industrial processes is expected to remain stable to 2050. This is driven by the energy needs of hard-to-abate industries, coupled with strong economic development in the Asia-Pacific region. Across the scenarios analysed, it is estimated that the share of demand for gas in industrial processes will fall from around 20% of the overall industrial fuel demand today, to between 7-14% in 2050.

Figure 9: Scenario based industrial demand for gas (left) and electricity (right) from 2020 to 2050



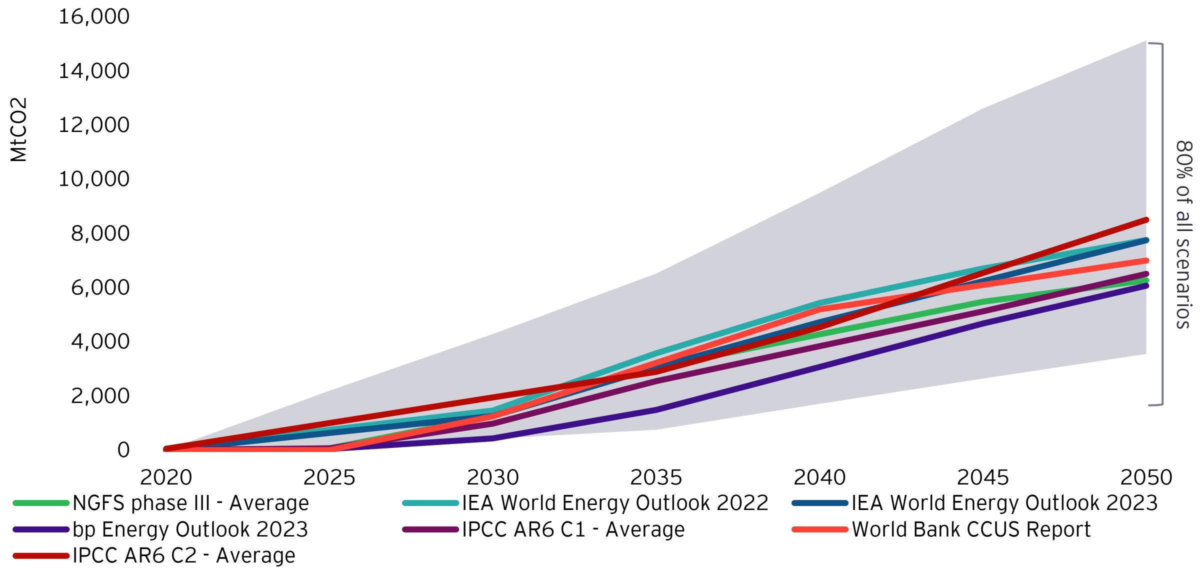


Source: EY Analysis of the IPCC AR6 scenario data, NGFS phase III scenario data

Carbon Capture Utilisation and Storage (CCUS) will be essential to reach net zero emissions by 2050, but the volume of CO_2 captured varies widely across scenarios

In each scenario considered, CCUS plays an important role, with volumes of CO_2 captured in 2050 falling between 6 and 8.5 Gt across most scenarios. There is broad consensus across the scenarios of the need for significant deployment of carbon capture technologies to reach net zero, including in association with natural gas use. The IEA Net Zero Emissions scenario sees 57% of total natural gas supply and use associated with CCUS in 2050.

Figure 10: CO_2 capture under Net Zero Scenarios (Includes IPCC AR6 C2 Scenarios)



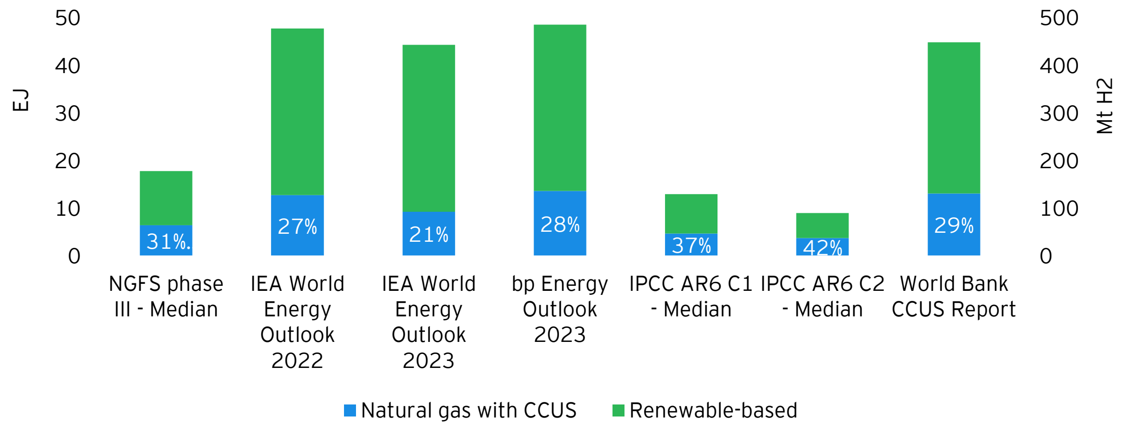
Source: EY Analysis of the IPCC AR6 scenario data, NGFS phase III scenario data, the IEA World Energy Outlook 2022, IEA World Energy Outlook 2023, bp Energy Outlook 2023 and, the World Bank Decarbonizing Natural Gas through Carbon Capture, Utilization and Storage (CCUS), 2023.

Hydrogen from natural gas with CCUS could be a major source of global gas demand

The level of hydrogen produced from natural gas with CCUS and renewable energy differs based on the scenario. This is sensitive to assumptions around the uptake of hydrogen, the scale up rates of key technologies including renewables, electrolysers and CCUS, and the costs of renewable energy and natural gas. For example, the World Bank CCUS scenario sees an increase in gas with CCUS of around 160 EJ/year by 2050. The form of production and amount of hydrogen forecast by 2050 is very different depending on the scenario.

All the scenarios considered feature hydrogen produced from natural gas with CCUS. The median IPCC and NGFS results are much lower than the forecasts from the IEA, bp and the World Bank which are expecting this production pathway to contribute around 20-30% to total hydrogen demand in 2050.

Figure 11: Final hydrogen demand by 2050 under net zero aligned scenarios



Source: EY Analysis of the IPCC AR6 scenario data, NGFS phase III scenario data, the IEA World Energy Outlook 2022, IEA World Energy Outlook 2023, bp Energy Outlook 2023 and, the World Bank Decarbonizing Natural Gas through Carbon Capture, Utilization and Storage (CCUS), 2023.

Australia's net zero pathway will likely look very different to the global picture

Global scenarios typically focus on global economic, energy and emissions reduction outcomes with limited focus or disaggregation of findings to Australia. Australia's economy and resource endowments provide a range of unique circumstances which will make its transformation to net zero a lot different from other countries and the global average.

Some of these circumstances include:

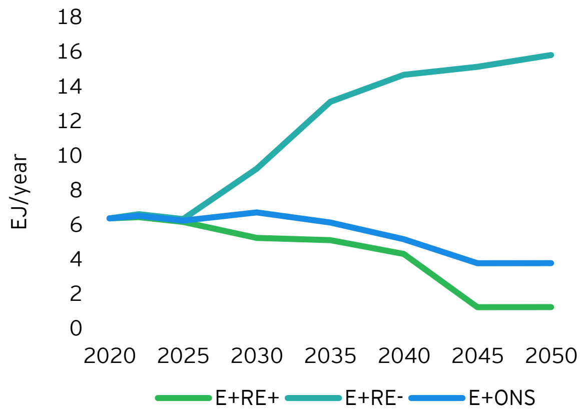
- Australia is a key energy and resource partner to one of the fastest growing regions in the world.
- Australia has significant mineral and energy resources and experience in technologies needed to reach net zero, including renewable energy, natural gas, critical minerals and CCUS.
- Australia's resource-based economy is highly energy intensive.
- Australia operates with some of the highest environmental, social, and governance standards globally.
- Energy exports are a key contributor to the Australian economy, generating foreign investment, government revenue, and jobs.

These characteristics mean Australia's pathway to net zero will be unique and is integrally linked with the energy security and net zero requirements of the Asia-Pacific region.

Net Zero Australia recently released a set of climate scenarios specifically focused on the Australian energy transition in light of these unique characteristics.[19] The analysis produced five individual net zero pathways. Three of the scenarios that represent the spectrum of gas demand profiles include:

- **Full renewables rollout (E+RE+)** – there is unconstrained renewable rollout with no fossil fuel use allowed by 2050 and constrained deployment of CCUS
- **Constrained renewables rollout (E+RE-)** – the renewable rollout is limited and there is a much higher cap on CCUS to achieve net zero
- **Onshoring (E+ONS)** – increased domestic production of iron and aluminium using clean energy which displaces iron ore exports and fossil fuels, with CCUS deployment capped

Figure 12: Primary energy from gas under Net Zero Australia scenarios

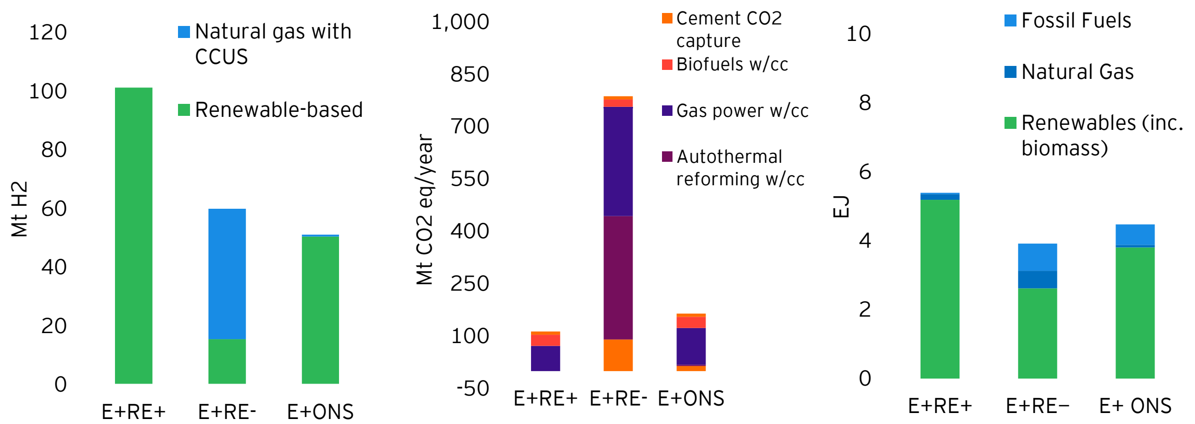


Source: Net Zero Australia 2023

An overview of the demand pathway for natural gas is to the right. Both the full renewables rollout and the onshoring scenarios – which in 2050 see 140 times and 110 times today's total renewable energy production respectively – see reductions in primary energy from gas in 2050 of 81% and 41% relative to 2020. The constrained renewables rollout scenario – which sees renewable energy production in 2050 increasing by 60 times relative to today's levels – shows a large increase in primary energy demand from gas, reaching 250% of 2020 levels by 2050.

The significant increase in gas demanded under Net Zero Australia's constrained scenario is primarily associated with hydrogen production with natural gas using CCUS, supported by the deployment of CCUS. Hydrogen from natural gas with CCUS makes up 74% of total hydrogen production in 2050 (see figure on the left below) in the constrained renewables scenario. The amount of CCUS under the constrained scenario is almost six times that of the unconstrained renewable rollout and onshoring scenarios (see figure on the right below), which both see CCUS deployment capped.

Figure 13 Top Left: Hydrogen production by type in 2050 under Net Zero Australia scenarios. Right: CCUS by technology in 2050 under each Net Zero Australia scenario. Bottom Left: Domestic demand by fuel type in 2050 under Net Zero Australia scenarios.



Source: EY Analysis of Net Zero Australia 2023

[19] Net Zero Australia, How to make net zero happen

4. Emerging technology landscape

Clean energy technologies will be key for the transition to net zero. But many technical barriers still exist to decarbonisation, particularly for hard-to-abate industrial processes with substantial process heat requirements. For industries such as chemicals and cement, emissions reduction technologies are far from commercialised, are currently costly and their development path is uncertain.

Four key technology types will likely have the biggest impact on the demand for gas over the coming decades: electrification, carbon capture, utilisation and storage (CCUS), biomethane and hydrogen. Inherent in each of these technologies is uncertainty about their respective development pathways, as well as their overall deployment costs. Across all emerging technologies, there are a range of development factors:

- Investments into abatement technologies can require extensive retrofitting and infrastructure costs, such as hydrogen-compatible production processes and sufficient renewable electricity supply to enable electrification.
- Potential 'first mover disadvantages' which could arise from installing a technology before it is sufficiently commercially developed.
- As a global technology importer, there are potential challenges to transferring globally developed technologies to Australia, particularly in remote parts of Australia. Additionally, Australia lacks the domestic manufacturing base to produce many of these clean energy technologies, leaving us vulnerable to potential global supply chain constraints.

These factors could impact on the deployment of each of these technologies, potentially leading to challenges in the net zero transition. This chapter provides an overview of each technology, and highlights how each technology could influence the role of gas over time.

Table 2: Summary of the technologies available to reach net zero

Technology	Current level of deployment	Average TRL* across hard-to-abate industries	Scalability	Switching cost (retrofit and ongoing costs)	Ability to reduce emissions
Hydrogen	Low	Moderate	High	High	High
Electrification	Low	Moderate	High	High	Very high
Biomethane	Low	Moderate	Low	Low	Medium
Carbon Capture, Utilisation and Storage	Medium	Very high	High	Moderate	Very high

Source: EY analysis, IEA Energy Technology Perspectives Clean Energy Technology Guide, ARENA, Climateworks Centre
*TRL (Technology Readiness Level) is a scale ranging from 1-11 used to reflect the maturity of a technology.

Hydrogen

Hydrogen could be a central technology to reach net zero. Hydrogen offers a solution for long-term, scalable, and potentially cost-effective option for deep decarbonisation in some hard-to-abate sectors such as steel, maritime, aviation, and ammonia.[20] Australia is attracting significant interest in hydrogen pilots and projects, reflecting Australia's abundance of renewable resources and the opportunities to meet energy demand in regional export markets.

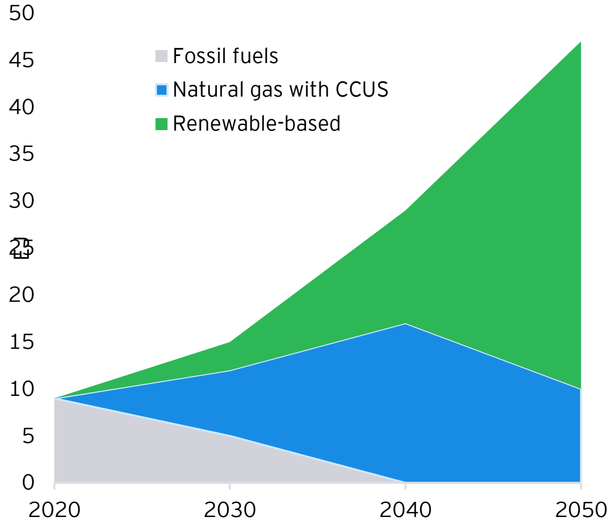
While a significant number of hydrogen projects have attracted interest in Australia, these are primarily focused on the production of hydrogen. Projects related to transitioning heavy industry towards hydrogen are less prominent, reflecting some of the technical and commercial factors still needing to be addressed.

For example, an existing direct reduced iron (DRI) facility producing 1 million tonnes each year could be required to invest $4 billion in upfront capital costs to retrofit to renewable hydrogen-based DRI production. Additionally, production costs using renewable hydrogen could be more than 75% greater compared with coal-based production.[21]

Currently, hydrogen produced with natural gas and CCUS has the lowest levelised costs at around US$1.5 – 3.0 per kilogram, compared to hydrogen produced from renewable electricity (US$4.0 – 9.0 per kilogram).[22] Thus, industries looking to transition to hydrogen could focus on hydrogen from natural gas with CCUS in the medium-term as costs for renewable-based hydrogen come down in the long-term (2050) outlook. The figure on the right describes this potential trajectory.

Hydrogen produced with natural gas and CCUS is likely to remain competitive in regions with abundant low-cost gas, with current costs of shifting to hydrogen produced with natural gas and CCUS sitting at around $25–35/t CO_2.[23]

Figure 14: Hydrogen mix under the World Bank 1.5˚C scenario



Source: The World Bank

Hydrogen's technology development pathways remain uncertain, particularly around the overall cost of producing hydrogen. Costs vary considerably across countries, depending on their natural gas supply, and renewable endowments. Australian natural gas demand could be supported by the development of a domestic hydrogen industry. This would rely on advancements in both thermochemical hydrogen production and CCUS technologies.

The United States Inflation Reduction Act could attract Australian innovation and R&D to the US in hydrogen production. Domestically, DCCEEW manage the $526 million funding in the *Regional Hydrogen Hubs Program* support of the development of seven regional hydrogen hubs initiatives across Australia, as well as several design and development studies. DCCEEW and ARENA have also recently launched the *Hydrogen Headstart Program* which will provide $2 billion in funding to renewable-based hydrogen projects.

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[20] McKinsey & Company, Hydrogen for Net-Zero: A critical cost-competitive energy vector

[21] S&P Global, BHP, Linde see high steel decarbonisation costs for hydrogen DRI

[22] IEA, Global Hydrogen Review 2022

[23] World Bank, Decarbonising Natural Gas through Carbon Capture, Utilisation and Storage

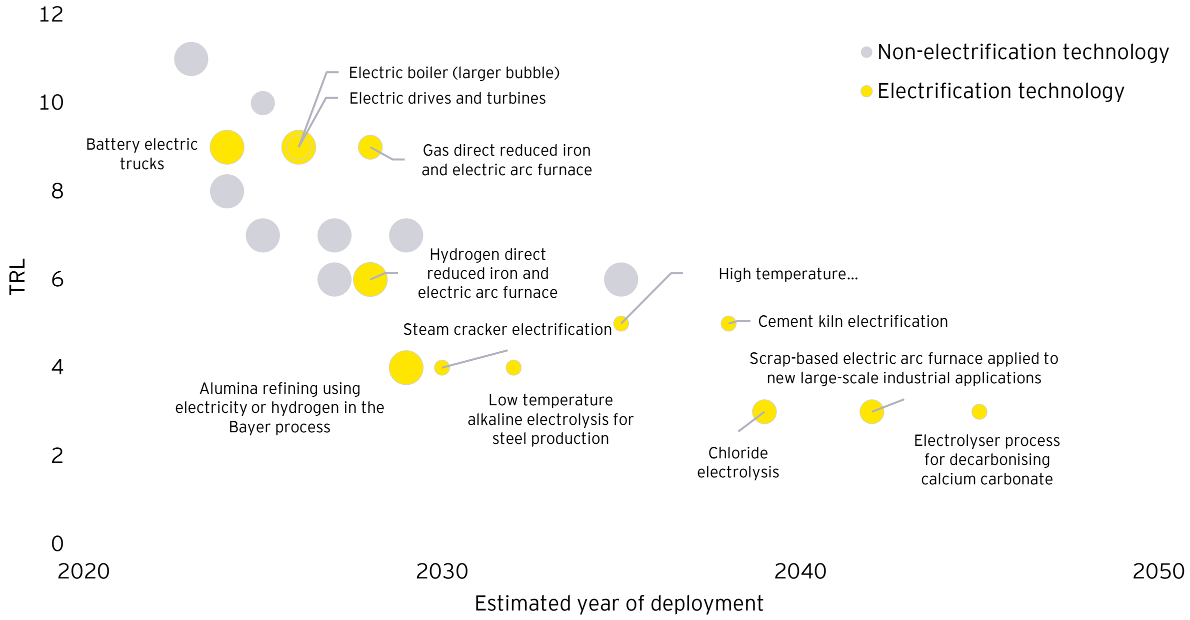
Electrification

There are a range of electrification and energy efficiency technology options set to be developed over the next three decades, with electrification potentially playing a major role in meeting energy demand among households, businesses, transport, and low-heat industrial processes. However, in hard-to-abate sectors with high-heat industrial needs, electrification may not be a viable decarbonisation pathway in the medium-term.

Few electrification pilots and projects in hard-to-abate industries are being undertaken in Australia, with a primary focus on assessing the feasibility of electrifying alumina refineries.[24] Additionally, for industrial processes which require very high-heat such as DRI, electrification may not be suitable. Electric Arc Furnaces (EAF) are one possible decarbonisation technology for the steelmaking industry, however they are only technically capable of processing and recycling scrap steel.

As seen in the figure below, there is a wide range of electrification technologies with various TRLs and deployment timeframes. Industries such as cement and metal refining sectors are the least likely to utilise electrification technologies due to their high process heat and chemical requirements.

Figure 15: TRLs and estimated year of deployment of key electrification technologies



Source: IEA ETP Clean Energy Technology Guide

Retrofitting electrification technologies comes with significant upfront capital hurdles, in particular around securing sufficient, stable, and low-cost electricity supply. For highly energy-intensive industries, electrification represents a coordination challenge with electricity providers and often different levels of government. For example NZ Steel's decision to invest $300 million into an EAF required coordination between NZ Steel, the NZ Government, and Contact Energy to deliver this electricity supply.[25]

The electrification of households, businesses, and low-heat industrial processes could lead to a fall in domestic gas demand. However, depending on the pace of electrification in heavy industry, gas demand in these sectors could remain persistent. Where industrial processes occur off-grid, particularly in critical minerals processing in the Pilbara, gas may continue to be a key input into these processes as both a primary energy supply as well as providing firming capacity.

[24] DISR 2022, Major Projects List

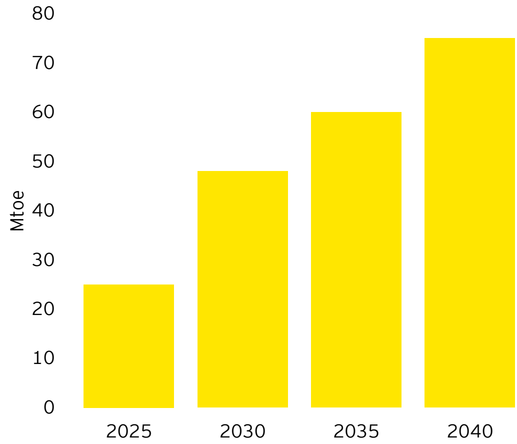
[25] New Zealand Steel, Electric Arc Furnace: The Future of Steelmaking

Biomethane

Biomethane is a clean renewable gas which is 98% methane and can be used interchangeably with conventional natural gas. The use of biomethane technologies is currently very small, representing about 0.1% of natural gas demand although it is set to see broad-based growth across all sectors. Currently, a small number of biomethane pilots and projects are underway in Australia, focused on both production and end-uses of the fuel.

Due to its similarities with natural gas, existing infrastructure can be used without the need for any changes in distribution infrastructure or end-user equipment. This leads to a much lower upfront cost of switching to these technologies compared to hydrogen and electrification. There is a possibility of repurposing gas pipelines to transport other gases biomethane. While biomethane could represent an opportunity for existing industrial gas users to reduce their carbon emissions, the scalability of production which is dependent on 'natural' feedstocks remains uncertain.[26]

Figure 16: IEA Global biomethane demand



Source: IEA World Energy Outlook for biogas and biomethane

While Australia currently does not have any upgrading plants, some efforts are underway to develop the technology. ARENA supported the development of the Australian Biomass for Bioenergy assessment which provides a national database of biomass resources for bioenergy across Australia.

Further, as seen on the right, all IEA scenarios assume the share of biomethane in total biogas demand increases. This is largely driven by the value attached to its use as a dispatchable source of energy and drop-in substitute for natural gas. Future developments in biomethane could reduce domestic demand for natural gas, while leveraging existing pipeline infrastructure and minimising transition costs for end-users.

Carbon capture, utilisation and storage

CCUS has been deployed at scale for over 25 years across a range of power and industrial applications.[27] Major investment is flowing to a number of CCUS pilots and projects in Australia, including the Gorgon project in operation and the Moomba project that is currently under construction. The significant value of these projects reflects the potential for CCUS to decarbonise a range of hard-to-abate industries, as well as capture potential opportunities in export markets. Countries with limited CO_2 storage potential such as Japan and Korea may look to Australia for the permanent storage of their emissions.

Chevron's Gorgon project represents one of the world's largest CCS projects globally, storing 1.6 million tonnes of CO_2 each year since 2018, with more than 100 million tonnes of CO_2 expected to be mitigated over the life of the project. Santos' Moomba CCS project is on track to deliver its first carbon injection in 2024 and is expected to store up to 1.7 million tonnes of CO_2 each year.

Different industries face different costs of installing CCUS, with gas processing/liquefication, ammonia, and hydrogen production representing lower cost industries. Typically, CCUS technologies can be installed modularly to existing facilities, mitigating some technical risks as technologies are further developed and scaled up. The technology readiness levels and costs of CCUS for different industries are detailed in the following table.

[26] IEA, World Energy Outlook for biogas and biomethane

[27] World Bank, Decarbonising Natural Gas through Carbon Capture, Utilisation and Storage 2023

Table 3: CCUS readiness levels, costs and carbon concentration potential

Industry	TRL	Levelised cost (USD/tonne)	Carbon stream concentration
Gas processing	9-11	$15-25	High
Ammonia and methanol production	9-11	$25-35	High
Hydrogen production	9-11	$50-80	High
Iron and steel production	4-9	$40-100	Low
Power generation	3-9	$50-100	Low
Cement production	4-7	$60-120	Low

Source: World Bank Decarbonising Natural Gas through Carbon Capture, Utilisation and Storage 2023

While the importance of CCUS is recognised through policy support and increased project development across many countries including the United States, the Netherlands, the United Kingdom, Norway and Germany, Australia does not currently have a national CCUS strategy, or any policy specifically aimed at encouraging or facilitating the development of a CCUS industry in Australia. An initial $250 million in funding under the 'Carbon Capture, Use and Storage Hubs and Technologies Program' announced in 2021, was replaced by the $65 million Carbon Capture Technologies Program in the 2023-24 Federal Budget.[28]

[28] DCCEEW, Funding launched for carbon capture, use and storage hubs and technologies

5. The key determinants driving the demand for gas

Considering the range of global and national net zero scenarios, the assessment of the key technologies that may complement or compete with the use of natural gas, and the unique circumstances facing Australia, a set of key determinants has been established to have the largest influence of future natural gas demand in Australia.

The future demand for Australian natural gas, domestically and in the region, will be heavily dependent on how technologies advance and costs reduce globally, as well as by the availability of key technologies to the Australian markets and the reliability and security of their supply chains. To develop a robust and resilient energy and emissions reductions approach in Australia, particular attention should be placed on the key determinants for gas demand that are outside the control of the Australian government, companies and stakeholders:

Renewable energy maximum deployment rate – The rate of renewable technology deployment is dependent on a range of factors: global technical progress, affordability, supply chain constraints, as well as local factors such as permitting, upgrading of transmission lines and grid infrastructure, and public acceptance.

- At low levels of renewable deployment, natural gas demand should be paired with renewables to phase-out higher emitting fuels including coal and oil. As the most emissions intensive fuels in the network, phasing them out will have the most emissions reductions benefit per unit of additional renewables output.[29]
- At very high deployment rates of renewables, much higher than deployment rates seen today, renewable deployment will transition to being inversely related to gas demand.
- The Net Zero Australia study demonstrates the relationship between renewable deployment rates and gas demand. The constrained renewables scenario sees renewable output reaching 60 times today's levels in 2050 - adding Australia's current renewable output to the system every 6 months. In this scenario, demand for Australian gas increases by 2.5 times relative to today. In the unconstrained renewable scenario renewable rollout reaches 140 times today's levels, and gas demand decreases to around 20% of today's levels in 2050.

Renewable deployment rate	Low/slow	High/fast
Impact on the demand for gas	Increased ▲	Decreased ▼

Hydrogen demand and electrolyser maximum deployment rate – Hydrogen demand is dependent on the scale-up and affordability of hydrogen along with the rollout of hydrogen infrastructure and industrial facilities that can utilise the fuel. Electrolyser deployment rates are dependent on technical progress, affordability, and supply chain constraints, as well as the availability of low-cost firmed renewable energy.

- The development of hydrogen demand and electrolyser capacity are interlinked when considering their relationship with gas demand. In some instances, where sufficient volumes of hydrogen are available at low costs, it may substitute for uses of gas including in some industrial applications.

[29] BCG, The Role of Gas Infrastructure in Australia's Energy Transition

- However, depending on the rollout of electrolysers, this hydrogen demand may also be a demand centre for gas, with hydrogen produced from gas with CCUS currently being the lowest cost and most deployed hydrogen pathway.

- Therefore, if demand for hydrogen remains low, demand for gas in industry and elsewhere can be expected to remain higher. If hydrogen demand is high and electrolyser deployment is low, then demand for gas is likely to increase. Whereas if hydrogen demand is high and electrolyser deployment is also high, it will likely reduce the role of gas across the economy.

Demand and deployment rate	Low demand for hydrogen	High demand for hydrogen and slow electrolyser deployment	High demand for hydrogen and fast electrolyser deployment
Impact on the demand for gas	Increased ▲	Increased ▲	Decreased ▼

Hydrogen shipping and storage maximum deployment rate – Exports of hydrogen and hydrogen-derivatives such as ammonia are commonly cited as the most viable alternatives to LNG exports to support energy security in the region. Technical challenges remain with the transport and large-scale storage of hydrogen and while the transport of hydrogen derivatives such as ammonia are less technically challenging, the decomposition of ammonia to hydrogen is currently an energy intensive process.

- The deployment of hydrogen shipping and storage is dependent on technical developments and improvements in affordability. The timeframes for these technical and economic advances will influence the balance of Australian energy exports to the region over time.

- Should they occur rapidly – in the next 10-15 years – and scale up at pace, hydrogen exports are likely to decrease the long-term demand for LNG in the region. However, if technical challenges continue and costs remain high, LNG will continue to be the primary energy carrier to the region to 2050 and beyond.

Hydrogen shipping and storage deployment rate	Slow/high cost	Rapid scale up
Impact on the demand for LNG	Increased ▲	Decreased ▼

CCUS maximum deployment rate – CCUS is a key technology for the decarbonisation of natural gas use across the economy, including in hard-to-abate industry. The IEA Net Zero Emissions scenarios finds that 57% of energy derived from natural gas in 2050 will be in conjunction with CCUS.

- The deployment rate of CCUS will be dependent on the development of CO_2 storage resources, the affordability of capture from hard-to-abate industry as well as policy recognition, permitting processes, development of shared transport and storage infrastructure, and public acceptance.

- If high rates of CCUS deployment are possible then natural gas with CCUS can be expected to play a greater role in Australian and regional decarbonisation efforts. If CCUS deployment is constrained, the role of natural gas with CCUS will necessarily be reduced.

CCUS deployment rate	Slow/high cost	Rapid scale up
Impact on the demand for gas	Decreased ▼	Increased ▲

Phase-out rate of coal use – Coal currently produces 27.5% of all energy used in Australia and 49% of all electricity produced.[30] The phase out of coal use is dependent on the rollout of cost-competitive, functionally equivalent energy sources. In power generation this means sufficient volumes of firmed power. In industry, this involves the provision of firmed power, high temperature and controllable heat, or the substitution of the chemical components or behaviour of coal.

- Renewable energy deployment is central to the phase-out of coal in power generation but needs to be firmed to fully substitute for the higher-emitting energy source. Batteries, pumped hydro and gas are all expected to play a role in firming renewable power. AEMO's Integrated Systems Plan Step Change scenario sees a requirement to double gas power generation capacity by 2050 to 10 GW to support the large-scale rollout of renewables.[31] This gas capacity is not expected to operate for long durations, but when it is required, it will be essential to keeping the power system operating.

- If this gas capacity is not available, it can be expected that coal power generation will be required to stay in the system for longer. If the phase-out of coal is fast-tracked, the importance of gas in the network increases. If the phase-out of coal is delayed, the need for additional gas capacity decreases relative to expected levels.

Phase-out of coal	Slow	Rapid
Impact on the demand for gas	Decreased ▼	Increased ▲

The onshoring of manufacturing and mineral processing in Australia, including critical mineral processing – Manufacturing and mineral processing are energy intensive processes that require a range of energy and fuel inputs including power, heat, and chemical feedstocks. Natural gas provides 42% of the energy needs for the Australian manufacturing sector today. Currently, a significant portion of Australia's natural resources are processed and refined overseas.

- If Australia were to bring this mineral processing onshore, and focus on onshore processing of critical minerals, it will be expected to increase the need for reliable, affordable, low-carbon power, heat, and chemical feedstocks in Australia from natural gas with and without CCUS.

- If onshoring of manufacturing and mineral processing increases in Australia, so too will demand for natural gas. If manufacturing and mineral processing are not increased in Australia, no increases in gas demand are expected.

Onshoring of manufacturing and critical minerals	No onshoring	More onshoring
Impact on the demand for gas	Decreased ▼	Increased ▲

[30] DCCEEW, Australian Energy Statistics 2012-2023

[31] AEMO, 2022 Integrated Systems Plan

6. Development scenarios for the Australian gas industry

There is considerable uncertainty surrounding the trajectory of global and Australian gas supply and demand. It will be dependent on the current investment pipeline, differing technology pathways, and demand from regional neighbours. In light of the uncertainty, three potential development scenarios have been canvassed which each meet Australia's net zero target, energy security and affordability needs, and align with existing global and local development pathways.

Australia's natural gas production will be dependent on a range of technological, geopolitical, local public policy, regulatory and commercial factors, in particular the key determinants discussed above (See Section 5). Critically, many of these factors are outside the control of Australians. Therefore, it is essential that the scenarios presented are not considered 'options' but rather different eventualities, all of which must be prepared for to avoid impacting energy security, energy affordability and emissions reductions targets.

In the transition to net zero by 2050, it is helpful to frame the factors and uncertainties influencing future gas production across three key phases:

- **The current investment pipeline and contractual agreements (today to 2030)** — The current investment pipeline and contractual agreements under which gas is exported is well-known. This period comes with the least uncertainty, as these export agreements effectively 'lock in' demand for Australian gas until 2030, although continued investment will be required in existing and new supply to meet this domestic and export demand levels. Thus, while each scenario described follows a very similar production trajectory up to 2030 with small differences stemming from potential changes in Australia's demand for gas as an input into electricity generation and industrial processes, they are all contingent on ongoing gas sector investment.

- **Differing technology pathways (2030 to 2040)** — During the medium-term, abatement technologies will 'compete', and their relative technology development pathways and deployment rates will begin to shape the net zero transition. This period sees considerable uncertainties, particularly around the development and deployment of key determinate technologies including renewables, hydrogen and its derivatives and CCUS.

- **Leading technologies emerge (2040 to 2050)** — The most prospective fuel mix and technology compositions will appear to stabilise with the ongoing role of Australian gas to 2050 and beyond in Australia and the region becoming clearer.

Three distinctive scenarios for Australia's gas industry

The three developed scenarios aim to showcase the potential range of domestic and regional demand for Australian gas production, based on uncertainties around the advancement and rollout of technologies, energy exports and policy environment. They all reach net zero by 2050 through varying technology pathways, supply chain constraints and government action.

Table 4: A summary of the proposed scenarios

Scenario 1: Electrify	Scenario 2: Blended	Scenario 3: Capture
The *Electrify* scenario is premised on strong renewables technology development and deployment. Strengthened global supply chains see rapid technology improvements and cost reductions in solar and wind technologies and in electrolysers for the production of renewable-based hydrogen. Emissions reduction actions from all nations are coordinated, limiting supply chain constraints and increasing technology availability in Australia. CCUS deployment rates see moderate improvements.	The *Blended* scenario is premised on a less coordinated global approach to energy and emissions reductions. Improvements in renewable technologies and cost reductions see significant increase in deployment rates relative to today but not reaching the levels seen in Scenario 1: *Electrify* due some global supply constraints. A lack of coordinated action sees hydrogen transport and storage challenges persist, limiting the export of hydrogen to the region. CCUS deployment rates see strong improvements.	The *Capture* scenario is premised on ongoing constraints to the deployment rates of renewable energy. As is seen today, the *Capture* scenario sees global supply chains and competition for renewable and electrolyser technologies limiting availability and cost reductions in Australia and the region. Renewable deployment rates are many times faster than today and will provide the majority of energy supply in 2050. Hydrogen demand is met with significant deployment of natural gas with CCUS-based pathways as CCUS emerges as an important net zero technology.

The scenarios are examined over the medium-long term (2035 to 2050) and cover a range of uncertainties for Australia's transition to net zero. The scenarios are not designed to represent high, medium or low scenarios, and they are not 'bookend' scenarios. The scenarios aim to showcase plausible contexts for the transition to net zero for Australia and the region, but do not necessarily limit warming to 1.5°C as is the case with the majority of international scenarios. Additionally, while each scenario is plausible, analysis of the probabilistic likelihood of each scenario was not considered.

Importantly, the scenarios are not intended to represent a prescription or advocate for specific policy settings. Instead, they are intended to illustrate the uncertainties and range of plausible technology deployment and global energy market developments, and how these might affect demand for Australian gas over the forecast period. Further, the outcome of each scenario is not unique to the parameters selected and could be produced from different combinations of the scenario parameters.

A summary of each scenario parameter is provided in the table below, with further details on each assumption in Appendix B.

Table 5: Assumptions of each key determinant by scenario

Scenario parameter	Scenario 1: Electrify	Scenario 2: Blended	Scenario 3: Capture
Renewable and electrification technology uptake	Rapid	Medium	Medium-low
Cost of renewable technologies	Low	Medium	High
Hydrogen and electrolyser uptake	Significant ramp up of renewable-based hydrogen	Significant ramp up of renewable and hydrogen	Increased hydrogen with CCUS
Hydrogen shipping and storage	Rapid	Medium	Low
CCUS deployment	Low	Medium	High
Phase-out of coal	Steady	Fast to moderate	Fast
Critical minerals mining fuel mix	Hydrogen and electricity	Gas as a transition fuel	Predominately gas

Source: EY analysis

The *Electrify*, *Blended*, and *Capture* scenarios are all aligned with net zero in Australia, with the analysis taking a normative approach with net zero in 2050 as a prescribed outcome of the analysis. Accordingly, all three scenarios have equivalent emissions reductions outcomes for Australia. For the region, all three scenarios reflect plausible pathways for energy importing countries to meet their net zero targets on their committed timeframes while meeting their energy security and affordability needs. Each scenario falls well within the boundaries set by international, regional and national net zero scenarios and, as such, can be considered moderate relative to the broad range of scenarios reviewed.

Scenario 1: Electrify

The *Electrify* scenario represents a future where renewable technologies, including wind, solar, renewable-based hydrogen, energy storage, transmission and distribution infrastructure are able to be rolled out at very high rates with renewable costs and supply constraints easing significantly due to highly coordinated global action to scale up the technologies. Permitting processes for renewable energy and transmission lines are streamlined with limited public objections to the expansion of renewable energy production into new regions.

This scenario reflects a pathway where there is ample renewable energy available to rapidly electrify many parts of the economy and to support the rapid scaling up of renewable-based hydrogen, as the technology scales up.

Australia's domestic gas demand falls to 2050, although gas remains in the mix as an important feedstock for hard-to-abate industries. Additionally, as a result of limitations in building out gas and CCUS infrastructure as they are not a priority approach to lowering emissions, the ability to onshore manufacturing and critical mineral processes is limited.

In this scenario, regional demand for LNG continues in the near term with LNG increasing its share of Australian energy exports. Renewable hydrogen exports become increasingly cost competitive, displacing coal exports in the medium term and a portion of LNG exports over the longer term. In this scenario, Australia develops its domestic renewable-based hydrogen industry at scale and begins exporting to developed Asian economies from 2035-2040.

Scenario 2: Blended

The *Blended* scenario represents a future where production capacity increases across all lower emissions technologies including wind, solar, all hydrogen pathways and CCUS. Although, a less coordinated global approach sees supply constraints limit the rate at which wind, solar, electrolysers and other key technologies can be deployed in Australia. Technology costs moderate but are also limited by some ongoing supply chain constraints.

Permitting processes for renewable energy and transmission lines are streamlined with good public support for the expansion of renewable energy production, although there are some objections to the rollout of renewables in new regions. Renewable energy technology rollout increases significantly relative to today's levels although, given some constraints in the pace of deployment, some prioritisation of renewable applications is required.

The deployment of seaborne international hydrogen transport technology is more limited than in the *Electrify* scenario, resulting in slower global transition away from gas and higher LNG exports. Medium-term demand for Australian natural gas is buoyed by the import of natural gas as a feedstock into hydrogen industries in Japan and South Korea.

This scenario reflects a pathway where renewables and natural gas combine to displace coal from the fuel mix. Natural gas remains an important part of Australia's electricity generation fuel mix, reducing reliance on coal-fired generators by providing firming capacity to enable greater renewable penetration. Its firming capacity is incrementally complemented by deep battery storage and hydrogen. Similar to the *Electrify* scenario, gas remains an important feedstock for hard-to-abate industries.

Here, hydrogen transport technology advances are delayed, requiring sustained LNG exports to meet regional energy demand. Demand for Australia's natural gas is also buoyed by the scaling up of hydrogen using natural gas and CCUS in Japan and South Korea, based on LNG imports and CO_2 exports. Australia LNG export levels to the region initially increase in the 2030-2040 period before returning towards today's levels in 2050. Australia leverages existing industry and export infrastructure to deliver low-cost gas both to existing markets as well as to growth markets in Southeast Asia, China and India. In the long-term, LNG export demand shift toward the new markets. Australia's gas supply chain becomes increasingly decarbonised through electrifying the gas liquefication process, increased used of hydrogen for compression, reducing fugitive emissions, and deploying CCUS including on reservoir CO_2.

Scenario 3: Capture

The *Capture* scenario reflects a future where production capacity for emissions lowering technologies and transmission lines increases but is impacted by persistent supply chain constraints. Developed economies are taking considerable action to reduce emissions, while developing economies are transitioning more slowly and choosing more diversified energy sources. Investment into gas and its infrastructure continue as a precautionary measure to limit energy security risks. Less ambitious and coordinated global action to advance energy and emissions reductions technologies results in costs for wind and solar plateauing and costs for electrolysers remaining high, resulting in renewable-based hydrogen remaining largely uncompetitive.

Permitting processes for renewable energy and transmission lines are improved with good public support for the expansion of renewable energy production, although there is continuing concern about local trade-offs and objections to the rollout of renewables in new regions. Renewable energy technology rollout increases significantly relative to today's levels although deployment rates are constrained by costs and access to technologies.

With constrained access to sufficient renewable energy, natural gas power generation, CCUS on gas use, and hydrogen from natural gas with CCUS are required to play a more prominent role in powering the economy. Synergies are established between the various applications of CCUS, with the development of shared CO_2 capture and storage infrastructure in various locations around the country.

LNG exports are increasingly accompanied by hydrogen exports produced using natural gas with CCUS, as it becomes more cost competitive. Australia makes significant headway in the Indian energy market and other Southeast Asian countries with both LNG in the near-term and hydrogen in the long-term, contributing to a rapid and large transitions from coal.

The demand pathways for Australian gas under each scenario

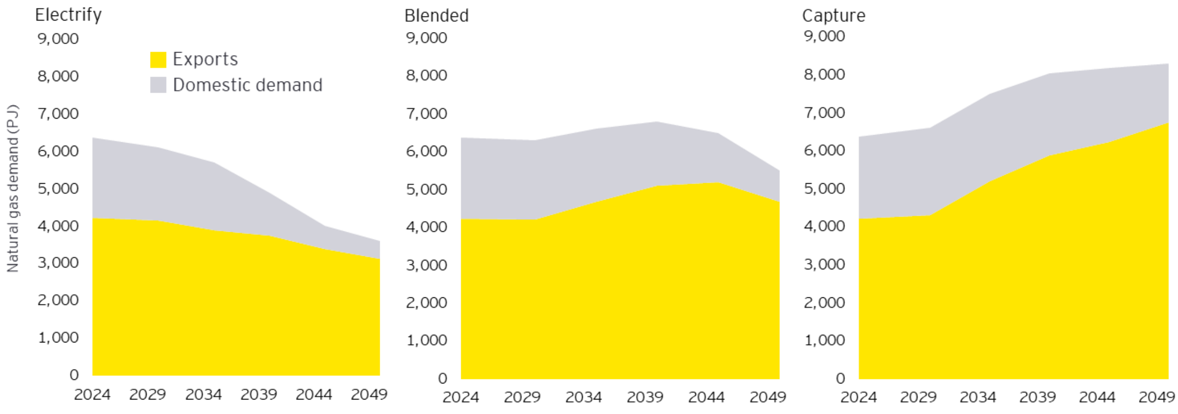
The figure below provides an illustration of Australia's potential gas production under each scenario. The pathways are indicative and align with estimates from the range of scenarios analysed in Chapter 3.

- Under the ***Electrify*** scenario, gas demand peaks in 2030 before falling to around 60% of today's gas production (around 3,600 PJ per year) in 2050. Domestic gas demand begins to fall immediately and sees a strong decline through to 2050 as renewable energy and renewable based hydrogen become increasingly cost competitive. LNG exports see moderate decreases over this period although there is some growth in LNG demand from China and some emerging Southeast Asian countries.

- Under the ***Blended*** scenario, gas demand increases by around 15% to 2040 (around 7,000 PJ per year) before falling to around 10% below today's production (around 5,500 PJ per year). Domestic gas demand remains stable in the medium-term as falls in residential and commercial gas demand are offset by growth in energy-intensive critical minerals extraction and processing industries. Domestic demand falls over the long-term as alternative technologies become increasingly available and cost competitive. Australian exports grow over the medium-term, buoyed by growing demand from China, India and Southeast Asia and Australia winning a larger share of the export market. In the long-term, exports fall as renewables and renewable-based hydrogen increase their market share in the region.

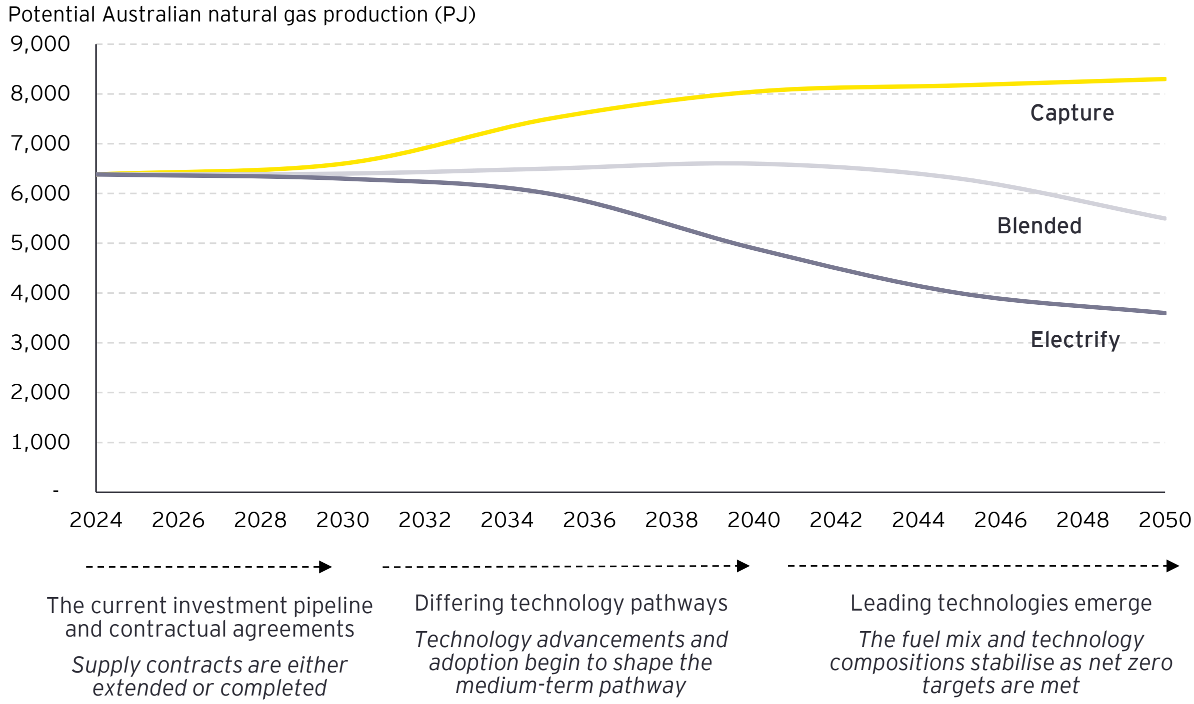
- Under the ***Capture*** scenario, gas demand increases over the period by around 30% relative to today's levels by 2050 (around 8,200 PJ per year) largely driven by increased exports as Australia's gas becomes a key energy source for decarbonisation energy security in the region. Australia gains a greater share in a declining global gas market. Domestic gas demand falls modestly over the period as household and commercial consumption falls, however industrial consumption remains relatively stable.

Figure 17: Domestic demand and exports under each scenario



Source: EY analysis

Figure 18: Potential Australian natural gas production



Source: EY analysis

Prospects and challenges facing Australia's transformation to net zero

When developing a national net zero plan and Future Gas Strategy, Australia needs to prepare for a range of different scenarios. Failure to develop sufficiently responsive and robust policies and approaches risks impacting energy security, energy affordability, emissions reductions targets and economic outcomes in Australia. To explore this in further details, a range of key national outcomes and policy objectives are considered against the backdrop of the three potential future scenarios.

Table 6: Summary of the circumstances of each scenario

	Scenario 1: Electrify	Scenario 2: Blended	Scenario 3: Capture
Why it might happen	There is concerted global action to accelerate decarbonisation. Renewable energy and renewable-based hydrogen see rapid technology advances and cost reductions allowing them to be deployed significantly faster than today.	There is sustained global action to decarbonise. There are no breakthrough technologies, but energy and emissions reductions technologies continue to develop over time.	Cost pressures and supply chain constraints hold back the development of renewables and renewable-based hydrogen. Hydrogen from natural gas with CCUS becomes increasingly cost competitive with gas. CCUS is rapidly deployed, building on Australia's strengths in the technology. Growing demand for LNG in the region boosts demand for Australian gas.
Why it might not	Cost pressures and supply chain constraints hold back the significant amounts of investment required. Cost competitiveness and commercial viability of renewable-based hydrogen is delayed.	Renewable energy and renewable-based hydrogen can be rolled out faster than expected. Renewable technologies face considerable impediments, delaying their rollout.	Renewable energy and renewable-based hydrogen can be rolled out faster than expected. CCUS and CCUS-based hydrogen faces considerable impediments, delaying their rollout.

Australia's energy and emissions reductions strengths

Australia has substantial energy and emissions reductions resources that will be critical to reaching net zero and maintaining secure, affordable energy globally, regionally and in Australia. This includes abundant natural gas, renewable energy, CO_2 storage capacity, and mineral resources. Across all three scenarios, these resources will be required both domestically and in the region. Only the balance of them and the contribution from Australian industry changes: while the *Electrify* scenario is premised on strong renewable deployment, it will still require continued investment in natural gas and CCUS and while the *Capture* scenario is premised on ongoing constraints to the deployment of renewables, it will require orders of magnitude increases in renewable energy deployment compared to today's levels.

Australia is well placed for the transition to net zero. Irrespective of future eventualities, Australia's ability to utilise its vast natural resources, extensive industrial capacity and experience has the potential to benefit all Australians. Should any of Australia's resources be left out of the nation's net zero and energy planning and development, opportunities will likely be lost, and energy and climate outcomes risk being compromised. Similarly, as countries in the region determine their optimum energy security and emissions reductions pathway in response to global developments, Australia is well placed to continue as a key energy partner.

Emissions reductions and reaching net zero

Regional efforts to reach net zero present an opportunity to Australia, including in the gas industry

While Australia has abundant energy and emissions reductions resource, many countries in the region are reliant on energy imports to run their economies and maintain security and a reliable energy supply. These countries are also increasingly looking to Australia to support their pathway to net zero, with LNG imports today, followed by CO_2 exports and hydrogen imports in the future. Australian LNG is already playing an important role in the region, helping transition away from coal use as well as supporting the rollout of renewable energy.

Australia has significant advantages to make the most of this growing demand. However, there is also growing competition in the region. The US and Qatar are both rapidly scaling up their LNG exports including to the region. Counties including Malaysia and Indonesia are advancing CCUS storage hubs with the aim of tapping into potentially lucrative CO_2 import opportunities from countries such as Japan, Korea and Singapore who have limited domestic storage capacity. Similarly, there are many countries and regions that are looking to become major hydrogen exporters, including the Middle East. While regional net zero ambitions present an important opportunity to Australia, this opportunity cannot be taken for granted, and concerted action will be needed for it to be realised.

Shortfalls in energy supply represent a threat to reaching net zero

Across all three scenarios it will be critical to ensure energy demand remains well supplied. Should access to these energy resources become restricted, recent history has shown that coal demand is likely to increase to make up any shortfall. In Australia, that means that if there is insufficient gas supply or policy constraints around the development of gas-powered generation capacity and gas infrastructure, it will likely lead to a delayed phase-out of coal from Australia's energy system.

Energy security and affordability

Energy security and affordability is contingent on sufficient energy supply being available at all times, including during unexpected shocks to the market. The nature and balance of energy demand changes over the period but the requirements of well supplied markets and reliable and trusted energy partners stays the same.

An undersupplied gas market could impact energy security and cost-of-living in Australia

The gas supply shortfalls forecast on the east coast of Australia from 2026 and on the west coast from 2029 pose a threat of disruptions to energy supply in the electricity market as well as for industry, small businesses and households. At the same time, shortages in the market could result in spikes in energy prices to all consumers. These forecast shortfalls already take into account forecast reductions in gas demand on the east coast in line with the AEMO Orchestrated Step Change scenario,[32] whereas demand on the west coast is expected to increase with new resource projects due to come online along with the need for gas to replace retiring coal power generation.[33] Increasing supply primarily through increased domestic production will likely be necessary to maintain energy security over the coming years. Even in the *Electrify* scenario, demand for Australian LNG is still over 3,000 PJ per year in 2050 – representing a decrease of around 25% from 2020 levels. In the *Blended* and *Capture* scenarios, demand for Australian LNG exports increases in 2050 by 12% and 70% respectively compared with 2020 levels.

Australia has the opportunity to remain a trusted LNG supplier to the region, while uncertainty of LNG supply presents a threat to energy security in the region

The development of significant LNG production capacity in Australia has been a collaborative effort by Australian industry and government in partnership with governments and industry in the region - primarily Japan and Korea. This collaborative effort provides significant mutual benefits with countries in the region, ensuring a secure energy supply. As a result, Australia has received significant economic returns through substantial expenditure in the Australian economy, significant contributions in taxes and royalties to Australian governments as well as a vast number of well-paid jobs for Australians, particularly in the regions. These opportunities persist to 2050 and beyond under all three scenarios.

Conversely, should Australia not be willing or able to meet these levels of LNG demand, not only would this represent a missed opportunity for Australia, but it will also represent a significant energy security and affordability threat to countries in the region. If Australia is unable contribute to meeting LNG demand in the region, LNG markets could tighten, prices could increase, and gas shortages could become a risk for the region. Such a situation could lead to the perpetuation of coal demand in the region.

Natural gas with CCUS presents an opportunity to fast-track the affordability of hydrogen

The availability of cost-competitive hydrogen encourages demand and supports the rollout of hydrogen transport and storage infrastructure. With costs for hydrogen from natural gas with CCUS currently less than half that of hydrogen produced from renewable electricity,[34] hydrogen from natural gas with CCUS is not only the lowest cost, but also the most advanced route to rollout across Australia and the region. Further, it can leverage Australia's natural gas and CO_2 storage resources.

Fast-tracking the development of a domestic hydrogen industry could be of particular benefit in the *Electrify* and *Capture* scenarios where hydrogen demand in the region grows significantly in the 2035-2050 period. In the *Electrify* scenario hydrogen from natural gas with CCUS would help build the Australian hydrogen industry and to secure market share in the region for the benefit of renewable-based hydrogen. In the *Blended* scenario, which sees technical limitations on hydrogen storage and transport limiting the opportunity for direct hydrogen exports, natural gas-based hydrogen with CCUS provides an opportunity for our export partners to build a domestic hydrogen industry on the back of Australian LNG exports that can be reformed in country with CO_2 being shipped back to Australia for permanent storage.

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[32] AEMO, 2022 Integrated Systems Plan

[33] AEMO, 2022 Western Australian Gas Statement of Opportunities

[34] IEA, Global Hydrogen Review 2022

If Australia limits its hydrogen industry to just renewables-based hydrogen, then the development of the industry may be slowed and Australia's opportunity to get a foothold in the international hydrogen market could be threatened. This is particularly the case in the *Capture* scenario where regional demand for hydrogen increases significantly over the period while the opportunity for Australia to produce commercial volumes of renewable-based hydrogen is contained.

A balanced transition allows for greater energy security

The commitment to a balanced energy supply and emissions reductions strategy for achieving net-zero emissions — combining renewables, natural gas, and a variety of hydrogen pathways — supports a resilient and sustainable energy system. Natural gas in Australia's energy system provides a reliable and flexible energy source, contributing to a smoother decarbonisation pathway. Some investment flows into CCUS projects in Australia which are proved up and deployed could support decarbonisation in hard-to-abate industry as well as the development of a domestic hydrogen industry.

Threats appear as global dynamics in the energy transition may impact Australia's ability to source energy and emissions reductions technologies and integrate them effectively. Further, delays in bringing hydrogen on stream represents a challenge, limiting the timely integration of hydrogen as a cleaner energy source. Changes in international energy policies or market trends could also impact the cost and availability of technologies crucial for Australia's energy security.

Economic opportunities for Australia

The economic contribution of Australia's energy sector has long been a pillar of State and Federal government budgets as well as Australian households and businesses. Economic opportunities exist across the three scenarios, however, only if Australia's energy production continues to align with the energy needs across the Australian economy and the region.

Natural gas presents an opportunity to establish a critical minerals processing sector

Natural gas has a key role today in providing the reliable 24/7 power, high temperature and controllable heat, and chemical feedstocks to the manufacturing sector as well as hard-to-abate industry. Across the scenarios, this role continues to 2050 given the technical and economic limitations for alternative technologies and fuels to provide these services. The expansion of the processing and upgrading of mineral resources and critical minerals will likely require an increase in natural gas supply to these sectors. This can be seen in the *Capture* and to a lesser extent the *Blended* scenarios where increased domestic manufacturing and industry leads to more resilient gas demand out to 2050. In contrast, in the *Electrify* scenario critical mineral processing and onshoring of manufacturing and industry is constrained by the rapid transition to renewable energy and the constraints in gas and CCUS infrastructure and this opportunity is lost.

Increasing the domestic value-add before realising their export value could require significant ongoing domestic natural gas supply to 2050, along with the rollout of CCUS technologies.

Energy exports represent an ongoing economic opportunity for Australia, provided energy exports can align with evolving regional demand

LNG exports therefore LNG exports continue to represent a significant export revenue opportunity for Australia across all three scenarios, even where LNG exports are complemented by hydrogen exports over time. Meeting these export levels, even in the *Electrify* scenario, will require significant ongoing natural gas production in Australia — both in existing and backfill fields for existing LNG trains, as well as new LNG-focussed developments including Scarborough, Browse, Beetaloo. Should investment in LNG production in Australia fall short of the required levels, Australia stands to miss out on the economic contribution that these developments will provide, with the economic benefits instead going to competing LNG producers such as the US or Qatar, or instead to coal producers if the LNG market is undersupplied.

Natural gas exports will increasingly be complemented by CO_2 imports for permanent storage, in particular in the *Blended* and *Capture* scenarios, representing a new economic opportunity for Australia. Countries in the region who have limited domestic CO_2 storage capacity of their own, may look to Australia for the permanent storage of their emissions. This regional need, combined with Australia's CO_2 storage potential, geographical proximity, skills and experience with developing CCUS projects, and existing trade relationships means that Australia is well placed to develop a new regional business in CO_2 storage. To realise this opportunity, Australia needs to proactively develop the CO_2 storage projects required as well as provide the policy signals and regulatory certainty to the region. If Australia does not embrace the opportunity, the potential economic contributions could be lost and achieving regional decarbonisation efforts will become harder and more expensive, ultimately threatening the regions transformation to net zero.

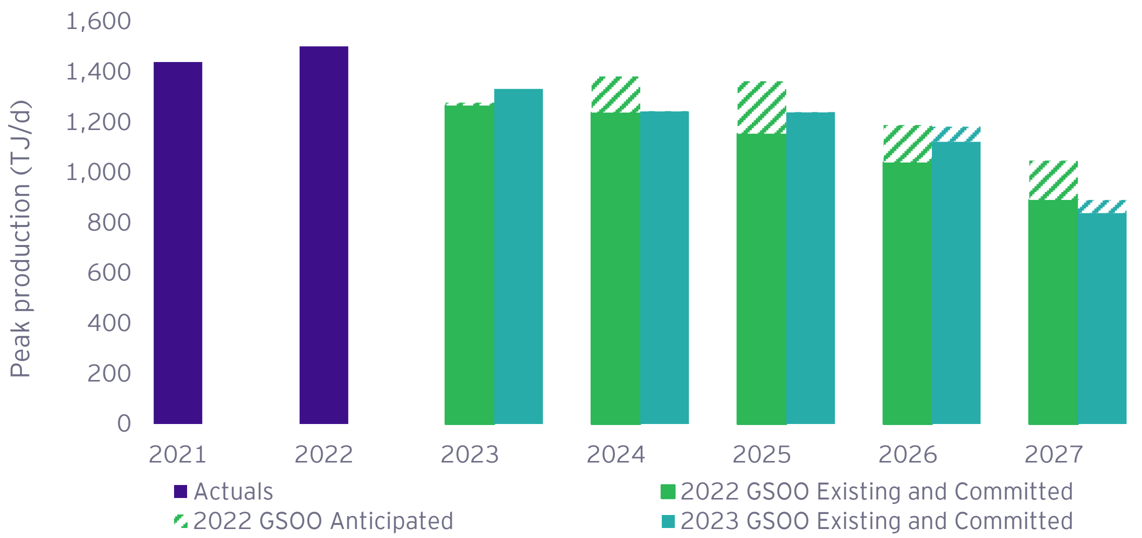
Under all three scenarios, hydrogen exports increase over the period to 2050 – particularly in the *Electrify* and *Capture* scenarios where technical barriers to hydrogen storage and transport are quickly addressed. In the *Blended* scenario technical challenges hydrogen transport and storage persist but are eventually overcome towards the end of the assessment period. In the *Electrify* scenario hydrogen exports will be particularly important to offset the lost revenue from decreased LNG exports.

Across all three scenarios, a lack of alignment between Australia's energy exports with regional demand presents a threat to Australia's energy sector and to government budgets. If Australia focuses exclusively on hydrogen exports, and the *Blended* or *Capture* scenarios eventuate, there will likely be insufficient demand for the hydrogen produced and LNG export revenue will likely be forgone. Similarly, if only LNG exports are developed and the *Electrify* scenario materialises, then not advancing hydrogen exports could be a significant lost opportunity.

Investment requirements in gas

Potential gas supply shortfalls have been identified across parts of Australia's east coast. According to AEMO, supply and demand on the east coast are both expected to fall over the short-term, with supply declining more rapidly, in particular from southern fields which decline from close to 1,500 TJ per day in 2022 to less than 900 TJ per day in 2027.[35] The near-term gas production profile is shown in the figure below.

Figure 19: Actual and forecast maximum daily production capacity from southern gas fields



Source: AEMO 2023 Gas Statement of Opportunities

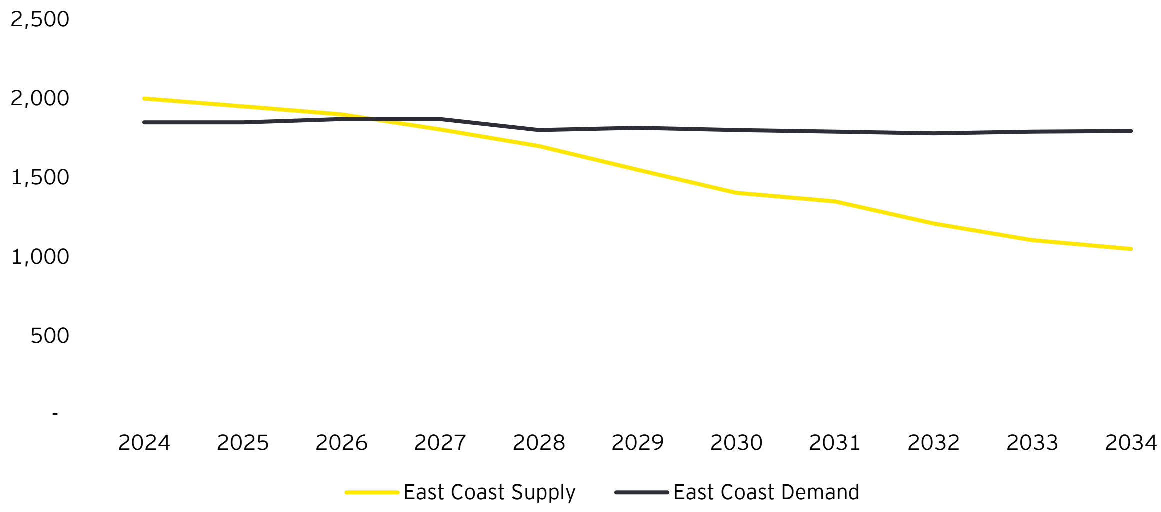
[35] AEMO, 2023 Gas Statement of Opportunities

AEMO has identified a range of factors impacting the current investment environment, including:[36]

- **The Russia-Ukraine conflict** has led to significantly higher international energy prices, creating instability in gas markets.
- **Persistently high inflation**, combined with rising interest rates, has increased borrowing costs and challenged project economics. Some project costs are not keeping pace with long-term gas price projections.[37]
- **Financing challenges** have materialised as some investors are beginning to limit their exposure to fossil fuels.
- **Regulatory approvals** for gas projects have become increasingly stringent. AEMO's consultations with industry have identified the December 2022 Federal Court decision to set aside NOPSEMA's approval of Santos' Barossa Gas Project as a key investment uncertainty. This decision, which was extended in November 2023, reflects increased approval times for environmental plans of almost two years.[38]
- **Contractual uncertainties** potentially arising from the Australian Government's price cap on new domestic wholesale gas contracts for 12 months.[39]
- **Capital and investment are shifting overseas** including major investments in key energy producing countries such as the US Department of Energy's US$7 billion hydrogen hubs program.

These factors could potentially exacerbate projected gas supply shortfalls. AEMO's modelling of gas supply and demand suggests that domestic supply gaps could materialise across all scenarios and all years (2027-2042). Further, DISR has projected a significant gas supply shortfall of over 40% in 2034. These projected shortfalls elevate risks to domestic consumers, particularly large industrial gas users, with material implications for broader energy security. Considering this, market uncertainties, if persistent, could result in significant underinvestment in Australia's domestic gas industry, leading to lost economic opportunity and potential energy security implications.

Figure 20: Gas supply shortfalls forecasted for the east coast



Source: Adapted from DISR Future Gas Strategy consultation paper

[36] AEMO, 2023 Gas Statement of Opportunities, pp. 15-16
[37] AEMO, 2023 Gas Statement of Opportunities, p. 15
[38] SMH, Court stalls Santos pipeline amid gas project dispute
[39] AEMO, 2023 Gas Statement of Opportunities, p. 15

7. Some concluding perspectives

Gas is expected to play a major role in the global net zero transition. Its future development will be predominantly influenced by Australia's position as a global gas market supplier, how competitive and complementary energy and climate technologies evolve, and what economic activities gas will continue to be needed as a proven and flexible source of energy to support the global energy transformation.

This analysis has highlighted that there are multiple future scenarios that will influence the pathway to reach net zero, and that differing eventualities need to be considered to maximise the opportunities and manage the challenges of the transition.

In each scenario analysed, global demand for gas reflects the potential role of the fuel to 2050 and beyond, delivering firming capacity for power systems, particularly in emerging Asian markets, and as a low-emissions fuel and feedstock for industry, including in conjunction with CCUS technologies.

Managing the energy transition

Australia finds itself at a pivotal juncture, holding a strategic position as a major global gas supplier. This provides both opportunities and challenges as the country navigates the complex transition towards a more sustainable energy future.

- The effective integration of new energy and emissions reduction technologies and fuels into the national energy portfolio will support Australia's efforts to meeting net zero commitments while delivering secure and affordable energy to the economy and the region.

- Conversely, a failure to balance the transformation of the energy system could pose a threat to Australia's economy, climate commitments and competitiveness in the changing global energy market.

Indeed, the uncertainties surrounding the energy system's development underscores the importance of Australia's adaptability and strategic foresight in shaping its energy policies and investments.

The Government has an opportunity in developing its Future Gas Strategy that balances Australia's renewable and energy strengths with managing uncertainties on the timing, scale, and end-uses of renewable fuels. This could lay the foundations for a smooth transition to net zero while maintaining energy system reliability and costs. Leveraging Australia's strengths across different forms of energy and storage, and preserving transition pathway options, will be essential to this.

Considering the future role of gas

As this analysis has shown, Australian natural gas will continue to have an important role powering the economy of Australia and the region to 2050 and beyond and is a crucial tool for the path to net zero. Australia's ability to balance its position as a gas supplier with an openness to innovative energy solutions will help determine success in the global energy landscape.

Key messages from this analysis for consideration in the Future Gas Strategy include:

- **A portfolio of technologies will be needed to reach net zero while ensuring secure, affordable energy to Australia and the region** — No single technology or fuel will be able to deliver the energy and industrial inputs needed in Australia and the region. Across plausible net zero scenarios developed as part of this analysis (as well as international, regional and national net zero analysis), significant deployment of renewable energy, natural gas, CCUS and a range of hydrogen pathways will be needed. The mix of technologies will vary based on future eventualities and will likely change over time. However, it is important to note that, across all major scenarios, all technically and commercially viable technologies will be needed in 2050 and beyond, as they are today. Australia's energy policy should ideally adopt a technology-neutral approach to mapping a responsive pathway to net zero.

- **Investment requirements in gas —** Potential gas supply shortfalls have been identified across parts of Australia's east coast. For example, AEMO's central scenario (Orchestrated Step Change), indicates that gas supply shortfalls, relative to total east coast domestic and LNG demand, could be between 100 and 130 PJ per year from 2033 onwards, with a range of market, regulatory and global risk factors impacting the investment environment. Projected shortfalls elevate risks to domestic consumers, particularly large industrial gas users, with material implications for broader energy security.

- **CCUS and hydrogen are key complements to natural gas in a zero emissions future** — All plausible net zero pathways involve CCUS and hydrogen at different scales. In the near-term, proven and deployable CCUS technologies will be essential to addressing Australia's hard-to-abate industry emissions. Australian CCUS developments could also be needed to support countries in the region meet their net zero goals. Over the medium- to long-term, scaling up hydrogen production technology could complement renewable electricity and natural gas use. hydrogen from natural gas with CCUS could be particularly important as the hydrogen industry scales up from a low base today, reflecting the lower costs and more advanced status of the technology.

- **A robust energy and climate policy framework is needed to ensure Australia can thrive irrespective of future geopolitical and technological developments** — The scenarios presented in this analysis represent a plausible 'possibility space' for how energy and emissions reduction technologies and demand could evolve over the period to 2050. The scenarios represent the uncertainty of future developments. To manage the risks associated with the transition to net zero Australia's energy and climate mitigation policy needs to prepare for all three future scenarios, with policy and regulatory actions that keep as many pathways to net zero viable for as long as possible. Preparing for only one pathway leaves Australia extremely vulnerable to development that are outside Australia's control.

- **Sustainability of the gas sector will be pivotal to managing risks to energy security, cost-of-living, and emissions reductions targets in Australia and the region** — In light of the highly uncertain pathways for gas and energy markets, it is important that Australia continues to leverage its strengths across different forms of energy and storage to maintain transition pathway options. There are risks that underinvestment in new gas capacity, especially as mature reserves reach end-of-life, could narrow the energy options available to the country and increase the economic costs of achieving net zero.

- **The natural gas sector represents an ongoing economic opportunity for Australia** — The natural gas sector has a long history of generating investment, tax revenue and jobs. Going forward, LNG demand in the region is likely to grow as countries look to transition their economies to net zero. While Australia has a range of competitive advantages as a key energy partner to the region, these opportunities should not be taken for granted. Competition for LNG supply to the region is growing from countries which are looking to ramp up their role in global LNG markets, in particular the US and Qatar. Without concerted attention, there is a risk that the economic opportunities from LNG supply to the region will be realised by countries other than Australia.

- **Government attention to address forecast near term gas supply shortfalls and promote an open and competitive gas market could be warranted** — The cost and performance of Australia's electricity and gas systems has become a major economic risk to Australia, especially in the context of rising energy prices for businesses and residential consumers. All levels of government have a role in devising and administering frameworks governing the approval of project investments and licenses to operate. Delays in approving and constructing major projects can increase costs and add to investment uncertainty. Australia's ability to secure additional gas exploration and production will be highly dependent on establishing policy settings which can deliver a long-term price signal and investment certainty, lower costs, and enhance project commerciality.

- **Australia is strategically well-placed as an enduring energy partner for the region** — Australia has the natural resources, skills and experience, and strong regional relationships to remain a key energy partner to the region. By advancing renewable energy developments, natural gas, CCUS and a range of hydrogen pathways, Australia can contribute to meet the energy and emissions reduction needs of the region, however they evolve.

Appendix A Our scenario framework

Scenario development frames different policy, market and technology influences, including their potential scale and direction. We have unpacked the critical drivers to critically examine the possible pathways for global and Australian gas demand.

Developing the scenarios followed the following steps:

Identify driving forces

- Global and local demand for gas
- Technology development to enable low emissions
- Infrastructure and other costs
- The policy and regulatory settings
- Demand for hydrogen production

Draw out critical uncertainties

- Structural changes in our major export partners and global competitors
- Geopolitical issues and stability
- Technology innovation breakthroughs
- Global energy and commodity prices
- Energy market uncertainty
- Workforce and skills shortages

Develop scenarios

- The 'possibility space': consider the bounds indicated by global
- Alternate roadmaps and supply scenarios
- Government policies and the potential to increase market share
- Production outputs, transition pace and scale, technology availability and expectations

Explore implications and pathways

- SWOT: Analyse the strengths, weaknesses, opportunities and threats of the scenarios
- Identify strategic responses to capitalise, address, unlock and neutralise the pathways

Further, we utilised the following principles to underpin the development of the scenarios:

Australia meets its Net zero target	Core to each of our Australian scenarios is meeting our 2050 Net zero target, however the pace and composition of this transition differs.
Building block approach	The scenarios are built from analysing and piecing together key drivers and uncertainties.
Internally consistent	The underpinning assumptions in each scenario form a cohesive narrative.
Plausible	The scenarios are tested for their plausibility by comparing and bounding them to existing scenarios.
Distinctive and broad	Each scenario is distinctive from other scenarios to canvass potential future states.
Commercial parameters	Consider the contractual structure of export market and the risks of overdevelopment (stranded assets) and underdevelopment (lost economic opportunity).

Leveraging the analysis of the global and local scenarios, we developed 3 scenarios which are most plausible, and fits within all scenarios analysed.

Appendix B Proposed scenarios and underlying parameters

Assumption	Rapid transition	Mixed deployment	Gradual pathway
Common policy and macroeconomic elements			
Australia's emissions targets	Net zero by 2050, existing Safeguard Mechanism		
Regional emissions targets	NDCs (Nationally Determined Contributions)		
Energy exports	Remains relatively constant from current exports		
Economic growth	Australian Government long term forecasts (approximately 2.5% pa)		
Population	Australian Government forecasts: ABS, Population Projections, Australia 2017 (base) — 2066		
Technology environment			
Technology overview	A massive and sustained rollout of renewables, including wind, solar, green hydrogen, and energy storage. Costs and renewable supply constraints significantly ease. CCUS is not a priority approach to lowering emissions.	Production capacity increases across all lower emissions technologies including wind, solar, all hydrogen pathways and CCUS. Supply constraints limit the rate at which wind, solar and electrolysers, and other key technologies, can be deployed in Australia. Relative costs moderate but are limited by the constrained supply environment.	Production capacity for emissions lowering technologies and transmission lines increases but is impacted by persistent supply chain constraints. Costs for wind, solar and electrolysers remain high. Green hydrogen is remains uncompetitive, with constrained access to sufficient renewable energy. hydrogen production increases in Australia. This is driven by natural gas with CCUS that can utilise CCUS infrastructure developed in coordination with hard-to-abate industry.
Renewable technology uptake, pathways and build out	**Rapid** with major investments occurring from 2027. Renewables roll out increases significantly including solar PV and onshore wind are rolled out to reach 350 GW by 2050.[40]	**Medium** with major investments occurring from 2030. Roll out is increased; Solar PV and onshore wind are rolled out to reach 210 GW by 2050.[41]	**Medium** to low with major investments occurring from 2035. Capacity increases but with a focus on transmission lines: Solar PV and onshore wind are rolled out to reach 170 GW by 2050.[42]

[40] Greater than AEMO's Hydrogen superpower scenario (Grid-scale wind and solar and distributed solar PV) and sits at the top of the Net Zero Australia installation rates

[41] Aligning with AEMO's Step Change scenario (Grid-scale wind and solar and distributed solar PV) and sits within the Net Zero Australia installation rates

[42] Aligning with Australian Industry Energy Transitions Initiative's coordinated action scenario

Assumption	Rapid transition	Mixed deployment	Gradual pathway
Electrification	**Rapid** – Large investments are made for electrification technologies where possible.	**Medium –** Electrification for homes and businesses are deployed first, with industry employing electrification as it becomes economical.	**Low** – Only homes and businesses can electrify completely. Electrification remains extremely costly.
Costs of renewable technologies	**Low** – Costs rapidly decrease across all technology pathways and fossil fuel costs are increased.	**Medium –** Costs remain high but begin to fall as technologies become more available.	**High** – Costs for new technologies are high, supply chains are delayed, shortages of skilled labour, and delays in access to transmission infrastructure.
Hydrogen price pathway, uptake, and export	**Significant ramp up** of mature domestic **green** hydrogen production and exports. Any constraints are rapidly addressed including ship transport and the facilitation of exports.	**Significant ramp up of a mix** of **green and blue** hydrogen production and exports, led by natural gas with CCUS. Constraints are addressed over the long term and electricity demand for hydrogen must be balanced.	Some **blue** hydrogen production and exports is developed leveraging new and existing CCUS infrastructure. Investment is developed in collaboration with high emission industry. Costs for hydrogen remain high.
Extent and use of CCUS	**Low** – hydrogen technologies play a leading role in the transition and CCUS is not prioritized but is deployed where essential.	**Medium –** CCUS begins to become increasingly more critical as renewables are more constrained.	**High –** CCUS plays a key role in the transition as renewable technologies face challenges. CCUS is deployed at a projected level of sequestered $CO_2$of 300Mt- CO_2/year.
Energy developments			
Energy context	LNG and coal exports continue in the near term, but there is accelerating decrease in domestic gas demand. Renewable hydrogen export becomes increasingly cost competitive. Hydrogen exports displace coal exports in the medium term and a significant portion of LNG exports over the longer term. Some critical mineral processing is constrained by limitations in gas and CCUS infrastructure.	Delays in hydrogen transport technology help sustain LNG and some coal exports. Demand for Australia's natural gas is buoyed by the development of grey hydrogen industries in Japan and South Korea. In-country low carbon hydrogen production using imported LNG (from Australia and elsewhere) is increasingly adopted.	LNG and coal exports continue in the near term, with LNG securing an increasing share of energy exports. Natural gas based (mostly blue) hydrogen exports become increasingly cost competitive.
Domestic gas demand	**Decreases significantly** – Significant local public commitment to emissions reduction.	**Decreases slightly –** Good local commitment to emissions reduction. Industrial facilities defer large scale investments until technologies become	**Stable** – Industrial demand remains stable, and demand for electricity generation falls. Growth in domestic gas demand primarily comes from blue hydrogen production.

Assumption	Rapid transition	Mixed deployment	Gradual pathway
	Industrial users are early adopters of low emissions technologies once they become available, and there a few commercial or technical constraints to deployment.	proven globally and their costs improve.	
LNG exports to APAC region	**Low** – Australia gives up market share. Exports align with IEA WEO 2023 Announced Pledges scenario and AEMO's energy exports.	**Steady** – Australia maintains market share. Exports fall between IEA WEO 2023 Announced Pledges and Stated Policies scenarios and AEMO's energy exports.	**Increase** – Australia gains market share in the APAC region. Exports align with IEA WEO 2023 Stated Policies scenario and AEMO's energy exports.
Critical minerals extraction and processing fuel mix	**Hydrogen and electricity** are used in the mining and processing of critical minerals, However this is limited with increased supply chain constraints from the rapid deployment of renewables.	**Gas supports growth in the short-term –** Gas is used support growth in critical minerals extraction and processing in the short-term, before transition to clean energy alternatives.	**Predominately gas –** Critical mineral mining and processing is prioritised, forcing a coordinated roll of renewables, gas, hydrogen and CCUS infrastructure to implement the strategy.
Phasing out of domestic coal fired generation	**Steady** – Low investment in gas requires continued use of coal until renewables are fully deployable.	**Fast to moderate** – Coal is replaced with gas and renewables.	**Fast** – Coal is phased out quickly as gas can substitute during the transition to renewables.
Potential gas pathways			
Overview	This scenario represents a decarbonisation pathway based on strong renewables technology development and deployment. The most prospective areas of green hydrogen, as well as extensive solar and wind developments take hold. The transition from natural gas begins around 2030.	This scenario depicts a more incremental transition to net zero. Australia's energy system, marked by persistent capacity constraints for new investment as well as some delays in bringing hydrogen on stream, mean that natural gas plays a more prominent role. Gas production peaks in 2040 before declining over the next decade.	This scenario involves a slower and more turbulent decarbonisation pathway. There are pressing challenges to renewable energy build rates due to supply and price pressures, and the cost competitiveness of green hydrogen does not eventuate. As a result, gas and CCUS play a pivotal role in shoring up energy and export markets. The transition from gas is delayed until the mid-2040s.
Domestic gas production	Low 44% decrease over 26 years (-1.68% decrease on average each year)	Medium-low 14% decrease over 26 years (-0.53% on average each year)	Medium 30% increase over 26 years (1.15% increase on average each year)
Peak gas production	2025 (6,384 PJ)	2040 (7,000 PJ)	2045 (8,300 PJ)

Appendix C Global scenario analysis

There are a wide range of scenarios and scenario providers that produce net zero aligned pathways for natural gas. We reviewed over 350 different global net zero pathways in total from the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), the Network for Greening the Financial System (NGFS), bp and the World Bank.

Table 7: Selected Net Zero scenario providers

	IEA	IPCC	NGFS	bp	World Bank
About	The IEA is an intergovernmental organisation which was established to focus on energy security and the global energy transition.	The IPCC is the United Nations body responsible for assessing the science related to climate change.	NGFS is a group of central banks and regulators focused on assessing the risks to the financial services sector from climate change.	bp is a global oil and gas company focused on shifting towards providing lower emissions solutions and moving towards Net Zero by 2050.	The World Bank is an international financial institution that
Current release	The IEA releases a World Energy Outlook (WEO) yearly which focuses on two likely scenarios. Their Net Zero scenario is included in this report but so far has only had two major updates (originally in 2021[43] and again in 2023[44]).	The IPCC is currently working on its Sixth Assessment Report (AR6). As part of AR6, 188 unique modelling frameworks submitted over 3,000 scenarios.	NGFS releases updated scenarios and modelling results on an annual basis. The current release is phase III (released September 2022[45]).	bp releases the World Energy Outlook[46] annually, which includes a Net Zero scenario focusing specifically on the energy sector.	The World Bank released the report Decarbonizing Natural Gas Through Carbon Capture, Utilization, and Storage (CCUS) in 2023.[47]
Number of Net Zero aligned scenarios	2 – Net Zero Emissions by 2050 from the 2022 and 2023 World Energy Outlook.	74 – this is all the scenarios which are classified as C1 (limiting warming to below 1.5°C with >50% and with no or limited overshoot) and passed the IPCCs vetting process with no flags.	6 - there are two distinct net zero aligned scenario narratives: Net Zero and Divergent Net Zero, which have been interpreted by three different modelling teams.	1 – Net Zero	1 – 1.5°C

[43] IEA, Net Zero by 2050
[44] IEA, Net Zero Roadmap: a global pathway to keep the 1.5°C goal in reach
[45] NGFS, Climate Scenarios for central banks and supervisors
[46] bp, bp Energy Outlook 2023 edition
[47] World Bank, Decarbonizing Natural Gas through Carbon Capture, Utilization and Storage 2023

	IEA	IPCC	NGFS	bp	World Bank
		267 – This includes all the scenarios classified as C2 (return warming to 1.5°C (>50%) after a high overshoot, and have passed the IPCCs vetting process with no flags.[48]			
Modelling framework	The IEA uses the Global Energy and Climate Model (GEC) to model the WEO. The GEC is a bottom-up partial optimisation model with detailed energy demand, transformation, and supply modules.[49]	The most common modelling frameworks to pass vetting are Integrated Assessment Models (IAM) or general equilibrium frameworks although there are also submissions from sectoral models and econometric modelling teams.[50]	Three Integrated Assessment Model (IAM) teams interpret the NGFS scenarios and make their results available on the NGFS scenario explorer. All three models have detailed subsector models for energy and agriculture as well as either general equilibrium or partial equilibrium economic representation.[51]	The World Energy Outlook is produced using detailed energy sector modelling. It does not consider other sectors or emissions other than CO_2.	The World Bank used the TIAM-Grantham Energy System Model, followed by separate power system modelling to estimate electricity generation. These models both provide bottom-up detailed energy sector results, driven by socioeconomic factors.
Net Zero scenario narrative	The IEA's net zero scenario is based on achieving net zero energy sector related CO_2 emissions by 2050, as well as meeting other energy related sustainable development goals.	The IPCC scenarios vary considerably based on the interpretation of the modelling team that produced them. Net Zero scenarios are classified as such purely based on the eventual warming outcome of the modelling submission (C1).	All the NGFS' scenarios are based on consistent socioeconomic assumptions, but with differing technological development and timing of emissions abatement. The Net Zero 2050 scenario focuses on achieving net zero through global cooperation, while Divergent Net Zero assumes specific regions and sectors shoulder more of the burden with a faster transition away from fossil fuels.	The bp Net Zero scenario only considers energy sector emissions and is modelled based on assuming a reduction equivalent to that of the IPCC C1 scenarios.[52]	The World Bank's 1.5°C scenario assumes each region must meet their Nationally Determined Contributions (NDC) and the world achieves net zero emissions by 2050.

48 Scenarios failed vetting by the IPCC if they had key indicators outside of a reasonable range in the baseline period. Scenarios received a warning if future variables (negative CO_2 emissions before 2030, CCS from energy in 2030, nuclear energy, and CH_4 emissions in 2040) were outside of specified ranges. For the purposes of comparison, C1 classified scenarios that failed vetting or received a warning were not included in this analysis.

49 IEA, Global Energy and Climate Model Documentation

50 Detailed information about each modelling framework submitted is included in the IPCC WGIII report: AR6 Climate Change 2022: Mitigation of Climate Change, April 2022, page 1841-1893.

51 An overview of each framework is included in the NGFS documentation: NGFS, Climate Scenarios Database: Technical Documentation, November 2022

52 bp, bp Energy Outlook 2023 edition

The full range, interquartile range and median for some of the key variables from the global scenario review is included in Table 8, below. Not every scenario provider reports every variable, and some models do not include sectors other than energy, so the number of scenarios has also been included for each variable as well. In general, the IPCC and NGFS scenarios provide better whole-of-economy representation, including all greenhouse gases. In contrast the IEA, bp and World Bank provide more energy sector detail, but do not model the rest of the economy. Noting that both IPCC C2 and C1 scenarios have been included within Table 8.

Table 8: Key variables for the range of scenarios assessed

Variable		Units	Min	P25	Median	P75	Max
Primary Energy in 2030	Total	EJ/year	320	501	543	609	734
	Gas (unabated and with CCS)	EJ/year	23	119	138	159	213
	Oil	EJ/year	87	159	181	202	267
	Coal (unabated and with CCS)	EJ/year	8	42	76	119	221
	Renewables (includes biomass)	EJ/year	46	112	134	166	365
	Nuclear	EJ/year	7	11	13	17	67
Primary Energy in 2050	Total	EJ/year	294	501	562	645	799
	Gas (unabated and with CCS)	EJ/year	11	61	91	128	258
	Oil	EJ/year	19	65	99	138	226
	Coal	EJ/year	0	6	18	46	177
	Renewables	EJ/year	46	244	302	373	821
	Nuclear	EJ/year	3	14	21	34	97
	Change in primary energy from today (2021)	%	-53	-19	-8	8	108
Share of primary energy in 2050	Gas (unabated and with CCS)	%	2	11	17	23	35
	Oil	%	3	12	18	22	32
	Coal (unabated and with CCS)	%	0	8	15	22	35
	Renewables (includes biomass)	%	10	40	53	66	88
	Nuclear	%	0	0	0	1	12
Emissions Abatement	Kyoto gas emissions	$MtCO_2$ eq	-3,106	10,330	14,002	17,769	34,932
	Emissions reduction from today (2021)	%	-106	-80	-71	-62	-32
	Net CO_2 emissions from energy	$MtCO_2$	-12,766	-1,771	-51	1,751	15,074
CCS	Gas with CCS	EJ/year	0	7	23	48	160
	Share of gas with CCS/total gas	%	0	10	30	44	100
	Carbon capture and removals (excludes land use sequestration, weathering, and feedstocks)	$MtCO_2$eq	1,674	5,080	6,953	10,688	24,627
Hydrogen and Electricity	Inputs into hydrogen production (secondary energy)	EJ/year	0	9	26	38	133
	Hydrogen demand	Mt H2	420	424	439	454	460
	Blue hydrogen demand	Mt H2	89	105	122	123	125
	Hydrogen demand	EJ	0	6	10	16	64
	Electrical capacity	GW	9,343	23,390	30,398	39,435	58,783
Socioeconomic assumptions	Population	millions	8,461	9,169	9,187	9,242	9,771
	GDP (CAGR from model start to 2050)	%	2.00	2.27	2.42	2.86	3.66

Source: Source: EY Analysis of the IPCC AR6 scenario data, NGFS phase III scenario data, the IEA World Energy Outlook 2022, IEA World Energy Outlook 2023, bp Energy Outlook 2023 and the World Bank Decarbonizing Natural Gas Through Carbon Capture, Utilization, and Storage (CCUS), 2023

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