



Australian Industry
Energy Transitions
Initiative

Setting up industrial regions for net zero

Phase 2 report: A guide to decarbonisation
opportunities in regional Australia

JUNE 2022

Analysis by Climateworks Centre and
Climate-KIC Australia

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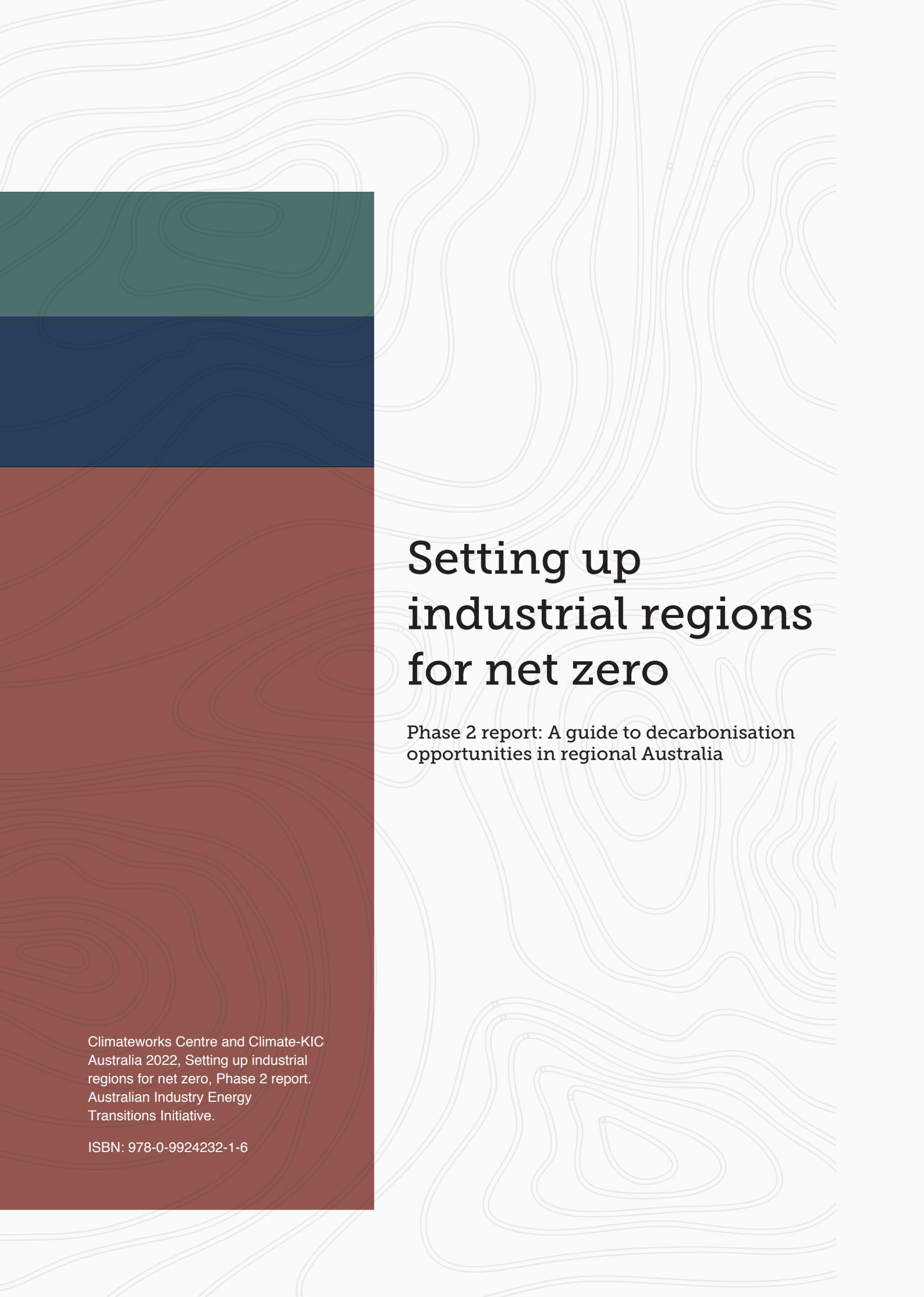
The Australian Industry ETI's industry partners and supporters have contributed to the research, findings, conclusions and messages in this report. This report provides an evidence-based, independent analysis informed by consultation with industry, but does not necessarily reflect the position of each individual partner.

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Jobs figures in this report were provided by Accenture and developed from data provided by Climateworks Centre on a range of carbon abatement opportunities in Australian Industry ETI supply chains in five key regions. The data provided focused on capital costs which are based on current production capacities in each supply chain and do not take into consideration changes in demand or production capacity.

We acknowledge and pay respect to the Traditional Owners and Elders – past and present – of the lands and waters on which program partners operate nationally.



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Forward

by Simon McKeon

In the last year there has been an incredible shift with strong tailwinds building behind achieving net zero emissions. Net zero targets are now set across states and at a national level and industry is seeing the opportunities of the decarbonised global economy on the horizon.

In 2022, industry is taking real steps forward on the development and deployment of emissions reduction technologies and investing in projects to decarbonise operations in the regions they operate in. This investment in our future is only accelerating as momentum towards decarbonisation builds. It is no longer an option to wait and see what happens next – action is urgently needed now or we risk falling behind other nations. Planning and implementing changes in operations, strategy, regulatory environment and financing are underway now to ensure emissions are reduced in line with limiting warming below dangerous levels and to capture early-mover advantages in the transition to a global green economy.

The role of industry in decarbonisation cannot be underestimated. Industry's early uptake and effective integration of renewable electricity, electrification and clean hydrogen will shape our future energy systems and enable access to future markets, giving Australia a very strong chance of realising the positive outcomes that will flow from the decarbonisation transformation. There is no doubt that the changes needed will be tough and there will be significant short-term challenges to navigate in the decarbonisation of existing operations and associated infrastructure.

With our 'can-do' Australian spirit, we can remain competitive in a decarbonising global economy. Australian companies and governments can lead together to invest in and transform the energy system, infrastructure and markets to capture and hold an early mover advantage. Our spirit is not our only advantage. Australia has the natural resources, workforce and ability to expand infrastructure to support the development of new decarbonised industries, including in the existing industrial regions covered in this report: the Pilbara, Kwinana, Hunter and Illawarra. Where these opportunities can be realised, there are clear benefits for long term employment within these regions as well as for the nation as a whole.

The scale, pace and importance of decarbonisation in hard to abate sectors in key regions is clear and with industry leading the way, we have the opportunity of a generation to bring together our efforts as a nation and work together to support the momentum already underway for the benefit of our regions, the nation's economy and all Australians.



Simon McKeon AO
Chair, Australian Industry ETI



Executive summary

Australia's industrial regions are significant in terms of their emissions, energy use and contribution to the economy. With net zero emissions targets now set at state and national levels, targets for industrial regions can facilitate planning and action, and guide decision making for the long-term transition.

Across the heavy industry supply chains of iron and steel, aluminium, liquefied natural gas (LNG), other metals and chemicals, the five Australian regions of Pilbara, Kwinana, Hunter, Illawarra and Gladstone make a combined contribution of A\$166 billion to Australia's gross domestic product (GDP) and account for about one-eighth of Australia's total emissions.

This report on regional decarbonisation opportunities finds these key industrial regions also hold substantial opportunities for emissions reductions if timely, effective action is taken. The 70 megatonnes of carbon dioxide equivalent (MtCO₂e) of potential abatement identified in these regions is significant and represents an 88 percent reduction in current emissions. This would be equivalent to removing all emissions from cars and light commercial vehicles across Australia (National Greenhouse Gas Inventory – Paris Agreement Inventory, 2019). These decarbonisation efforts can build climate resilience and contribute to reaching state and national net zero emissions targets by 2050, while driving job growth.

This study profiles the decarbonisation potential of four industrial regions. The regions were selected on the basis of their proximity to Australian Industry ETI partner operations as well as for the materiality of current emissions profiles and the diversity of decarbonisation opportunities they represent. The industrial regions considered in detail are the Pilbara, Kwinana, Hunter and Illawarra. This study also provides analysis of a fifth region, Gladstone, but the qualitative work was not undertaken with Australian Industry ETI partners. While each region is unique with its own context, stakeholders, advantages and challenges, cross-cutting themes have emerged that are central to the effective decarbonisation of industrial regions. Other industrial regions will also be critical to decarbonising heavy industry including, among others: Bell Bay in Tasmania, the Upper Spencer Gulf in South Australia, Portland and the LaTrobe Valley in Victoria, and Darwin in the Northern Territory.

Summary of decarbonisation opportunities in Australian industrial regions

Pilbara

TOTAL ABATEMENT POTENTIAL:	30.6 MtCO₂e
ADDITIONAL RENEWABLE ENERGY REQUIRED:	25.3 to 53.8 TWh
ADDITIONAL INVESTMENT REQUIRED:	A\$17.8 to A\$38.4 billion
ESTIMATED JOBS OPPORTUNITY:	102-243k

Kwinana

TOTAL ABATEMENT POTENTIAL:	2.1 MtCO₂e
ADDITIONAL RENEWABLE ENERGY REQUIRED:	4.8 to 9.7 TWh
ADDITIONAL INVESTMENT REQUIRED:	A\$3.9 to A\$7.3 billion
ESTIMATED JOBS OPPORTUNITY:	15- 31k

Gladstone*

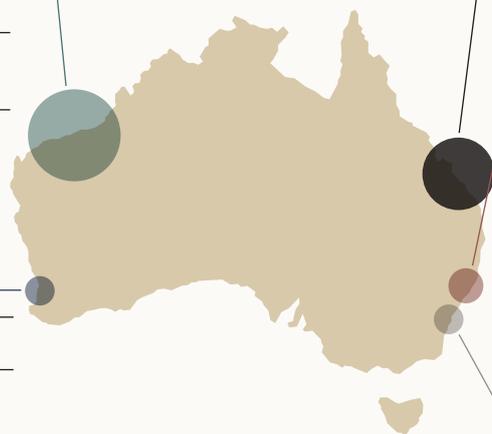
TOTAL ABATEMENT POTENTIAL:	21.2 MtCO₂e
ADDITIONAL RENEWABLE ENERGY REQUIRED:	14.8 to 37.5 TWh
ADDITIONAL INVESTMENT REQUIRED:	A\$14.2 to A\$33.6 billion
ESTIMATED JOBS OPPORTUNITY:	34-89k

Hunter

TOTAL ABATEMENT POTENTIAL:	9 MtCO₂e
ADDITIONAL RENEWABLE ENERGY REQUIRED:	11.2 TWh
ADDITIONAL INVESTMENT REQUIRED:	A\$10.3 billion
ESTIMATED JOBS OPPORTUNITY:	24k

Illawarra

TOTAL ABATEMENT POTENTIAL:	6.6 MtCO₂e
ADDITIONAL RENEWABLE ENERGY REQUIRED:	12.1 to 13.7 TWh
ADDITIONAL INVESTMENT REQUIRED:	A\$6.6 to A\$10.7 billion
ESTIMATED JOBS OPPORTUNITY:	37-74k



Bubble size is related to total potential abatement.

*Analysis of the opportunity in Gladstone is presented in appendix, a detailed focus on this region was not undertaken

A large-scale transformation of the energy system is needed to achieve regional decarbonisation

Realising the opportunities of decarbonisation requires an unprecedented transformation of the energy system, with a priority of delivering low cost, decarbonised, firmed electricity supply and establishing a market for green hydrogen at scale. The scale of renewable energy required would be an additional 68 - 126 TWh of energy and A\$53 billion to A\$100 billion in investment. This would be equivalent to 26 percent to 47 percent of Australia's total electricity generation and 107 percent to 197 percent of total current generation from renewable sources (Australian electricity generation – fuel mix, 2021).

Achieving emissions reductions at this scale is a significant task and one that will require an appropriate level of ambition and planning to facilitate investment across industry, investors and government.

The development of clustered industrial precincts presents an opportunity to leverage multi-user infrastructure and existing workforce skills. The deployment of a range of efforts at a precinct level, such as demand side response, sector coupling and integrated hydrogen systems to balance energy loads from renewables, can allow for more effective use of transmission, distribution and storage infrastructure as part of decarbonisation transformation.

Strategic alignment of supporting mechanisms is also needed to provide long term investment signals to achieve the required scale of decarbonisation in line with net zero targets. Strategic planning and alignment of incentives is needed to underpin the required scale of additional, competitively priced, firmed and well-planned energy supply.

System plans such as the National Electricity Market (NEM) Integrated System Plan (ISP) and the Whole of System Plan (WOSP) in Western Australia's South West Interconnected System (SWIS) should plan for a rapid and accelerating transition towards firmed, zero-emissions electricity and hydrogen networks at the scale needed. Planning should be consistent with 1.5°C warming scenarios, including planning for energy and green metals export scenarios in key regions.

Renewable Energy Zones (or equivalent in WA) in proximity to industrial regions at the required scale for industrial decarbonisation are needed today to develop the energy systems of tomorrow.

Coordination is needed to facilitate system wide transition

The complex systems challenge of industrial transition will require coordination of stakeholders across industry, governments, finance, communities and the energy sector to manage the simultaneous shifts needed. This includes changes to infrastructure and the energy system, regulation and policy, workforce and skills, corporate strategy, technology solutions, new demand and markets, and finance and investment.

Support is needed to align stakeholders in industrial regions on the vision, timing, and scale required for infrastructure, energy systems and technology solutions through co-developed decarbonisation roadmaps. Policy, regulations and programs need alignment across different levels of government to create clear goals and investment confidence. Coordination and market development are needed to build early supply, demand and the enabling infrastructure that allows new opportunities to scale. This can mean incentives and the removal of market barriers.

'Missions' offer an approach that can focus government efforts on a common goal. e.g. the United Kingdom's mission to establish the world's first net-zero carbon industrial cluster (UK Research and Innovation, n.d). Additionally, a central navigation support service for industry would support and enable their efficient engagement in government programs. e.g. Sweden's Transition Boost program (Johansson, 2021) is making it easier for industry to engage relevant support.

Efforts to support decarbonisation should balance accelerating the scale-up of proven and commercially available technologies alongside support for emerging and not yet commercial technologies. Coordinated support is needed for research, development, demonstration and deployment of technical solutions needed to decarbonise, and shared learning is needed across the suite of technologies. This can be facilitated by robust, open and practical knowledge sharing, linked to government funding.

Enhanced collaboration between stakeholders in industrial regions

Industry increasingly recognises that the scale and complexity of the net zero emissions opportunity and challenge cannot only be addressed by individual organisations acting on their own. Although collaboration is seen as necessary, the norms of competition need to be navigated and overcome.

Collaboration between industry organisations and with other stakeholders will be key to the effective development and demonstration of new solutions as well as scale-up of renewables, hydrogen, energy storage and related infrastructure. Government program funding that requires multiple industry partners can facilitate this collaboration. In addition, further efforts are needed to bring insight into regional efforts on the models and frameworks for multi-stakeholder collaboration, with an opportunity to learn from other industry sectors as well as international experience.

It is also important for industry to work together to inform government on policy and regulations needed to support industrial decarbonisation. Better outcomes can be achieved for government and industry if knowledge and challenges are shared in public consultations for policy and regulation development. Industry organisations should explore opportunities to work through existing groups and come together in new constellations where coordination is not happening or is not sufficient. Industry actively engaging together in regional leadership and coordination efforts and working with other stakeholders is important to enabling shared visions and developing regional roadmaps. Knowledge exchange between leadership groups domestically and internationally can accelerate learning for the transition.

An urgent need for action now

Urgent action on decarbonisation is needed to ensure a manageable transition that limits emissions to those consistent with limiting warming to below 1.5°C. Action now will lay the foundations needed to realise effective decarbonisation, capitalise on the opportunities of a decarbonising global economy and avoid more costly emissions reduction measures in the future.

Early action can strategically build the competencies and comparative advantages required to ensure Australian industry is well placed for competitiveness in a decarbonising global economy. Early action should prioritise near-term opportunities, such as developing multi-user infrastructure and investing in the creation of demand and supply for hydrogen, which can lay the groundwork for much larger scale deployment of decarbonisation opportunities.

An appropriate level of ambition that acknowledges the scale of the transition, as well as the coordination, collaboration and urgency of action required, will be key to the effective decarbonisation of Australia's industrial regions. Opportunities exist now to drive emissions reductions in these regions and effectively position Australia's industrial regions for prosperity into the future.



FIGURE 01: Regional decarbonisation at a glance

Kwinana

- 40 kilometres south of Perth in Western Australia.
- 65 year history of industrial activity.
- Home to alumina refining, ammonia, fertilisers, chemicals production, nickel refining and other battery mineral processing, as well as cement and a range of supporting industries.
- Significant effort to collaborate around industrial activity and exchanges in the Kwinana strategic industrial area and the broader Western Trade Coast.
- Due to land constraints in the strategic industrial area, there are limited options for onsite renewable generation although opportunities to connect renewable generation of electrons and hydrogen via transmission and pipelines
- Potential to build on existing collaboration to develop a thriving ecosystem centred around clean technologies such as green metals, chemicals and hydrogen.

What is needed

- Kwinana can achieve significant emissions reductions and will require a substantial investment in the energy system.
- Coordinated planning and development of multi-user infrastructure to facilitate efficient decarbonisation.
- Regulatory changes to facilitate hydrogen and carbon dioxide transmission and storage.
- Policy development to further stimulate near-term hydrogen demand
- Building on activities being identified in Kwinana Industry Council's Carbon Reduction Plan
- Investment is required to facilitate the delivery of decarbonised energy into the region, either in the form of electricity or molecules such as ammonia or hydrogen.

TOTAL ABATEMENT POTENTIAL:

2.1MtCO₂e

ADDITIONAL RENEWABLE ENERGY REQUIRED:

4.8 to 9.7 TWh

ADDITIONAL INVESTMENT REQUIRED:

A\$3.9 to A\$7.3 billion

ESTIMATED JOBS OPPORTUNITY:

15- 31k

Hunter

- One of Australia's largest and most diverse regional economies.
- Contributes \$50 billion to NSW Gross State Product (~8 percent) indirectly driving 28 percent of state economic output.
- Diversified mix of industry spread across aluminium, steel, chemicals, manufacturing, agriculture, coal mining and energy.
- **The Hunter has strong potential for competitive advantage for decarbonised industrial production through existing infrastructure, workforce, manufacturing skills, supply chains, ports, and supportive communities to enable a larger scale transition to net zero industry.**

What is needed

- Build on NSW's Electricity Infrastructure Roadmap, taking into consideration new demand from decarbonisation and electrification.
- Leverage momentum from existing policy to join up existing networks, collaborations and research and development efforts. and support joint heavy industry leadership.
- Facilitation of market development to enable scale-up of green products and renewable energy with, for instance, government procurement, mandates, feed-in tariffs.
- Development of large scale electricity generation and transmission infrastructure from nearby renewable energy zones

TOTAL ABATEMENT POTENTIAL:

9 MtCO₂e

ADDITIONAL RENEWABLE ENERGY REQUIRED:

11.2 TWh

ADDITIONAL INVESTMENT REQUIRED:

A\$10.3 billion

ESTIMATED JOBS OPPORTUNITY:

24k

Pilbara

- Extensive region in northwest WA, equivalent in size to Spain.
- Responsible for a major portion of the production, value, exports and investments of extraction industries commodities.
- Annual economic output of A\$88 billion.
- Low-cost, decarbonised energy systems are needed to enable net zero emissions production and new decarbonised industries such as green iron production at scale.

What is needed

- Leverage the region's huge renewable energy potential to support future industries.
- Coordinated regional approach to renewable electricity, hydrogen and energy infrastructure, to enable effective, large scale electrification and integrated hydrogen, supported by new multi-stakeholder models and ways of working.
- Coordinated industry and government support for new low carbon iron and steel technologies research and development and demonstrations, including post extraction processes for hematite ores for green steel manufacture.
- Industry in the region to work together with original equipment manufacturers to accelerate decarbonisation of haulage and shipping
- Large scale development of the North-West Interconnected System, off-grid and stand-alone grids in the region at the scale needed to support large scale electrification of extraction industries.

TOTAL ABATEMENT POTENTIAL:

30.6 MtCO₂e

ADDITIONAL RENEWABLE ENERGY REQUIRED:

25.3 to 53.8 TWh

ADDITIONAL INVESTMENT REQUIRED:

A\$17.8 to A\$38.4 billion

ESTIMATED JOBS OPPORTUNITY:

102-243k

Illawarra

- Narrow coastal strip south of Sydney.
- Modern industry dominated by steel production.
- Significant recent economic diversification with the introduction of advanced manufacturing, ICT and professional services into the economy, as well as the defence sector.
- Emissions from steelmaking, the major heavy industry in the Illawarra, can be reduced by around 20 percent through mature and commercial technologies.

What is needed

- Coordinated efforts between industry and government on current and future energy need to plan generation and infrastructure such as transmission, storage and grid firming.
- Regional industry stakeholders, agencies and communities need to come together to develop one industry decarbonisation roadmap.
- Market development support for green products.
- Coordinated industry and government support for new low carbon iron and steel technologies research and development and demonstrations, including post extraction processes for hematite ores for green steel manufacture.
- Full decarbonisation will require the development, commercialisation and implementation of new low emissions iron and steelmaking technologies requiring a substantial increase in energy systems to deliver electricity and hydrogen for these processes.

TOTAL ABATEMENT POTENTIAL:

6.6 MtCO₂e

ADDITIONAL RENEWABLE ENERGY REQUIRED:

12.1 to 13.7 TWh

ADDITIONAL INVESTMENT REQUIRED:

A\$6.6 to A\$10.7 billion

ESTIMATED JOBS OPPORTUNITY:

37-74k

1. Introduction

The Australian Industry Energy Transitions Initiative (Australian Industry ETI) aims to position Australian industry to maximise opportunities in the shift to net zero emissions supply chains by 2050 and help Australia build an economy that takes advantage of the transition.

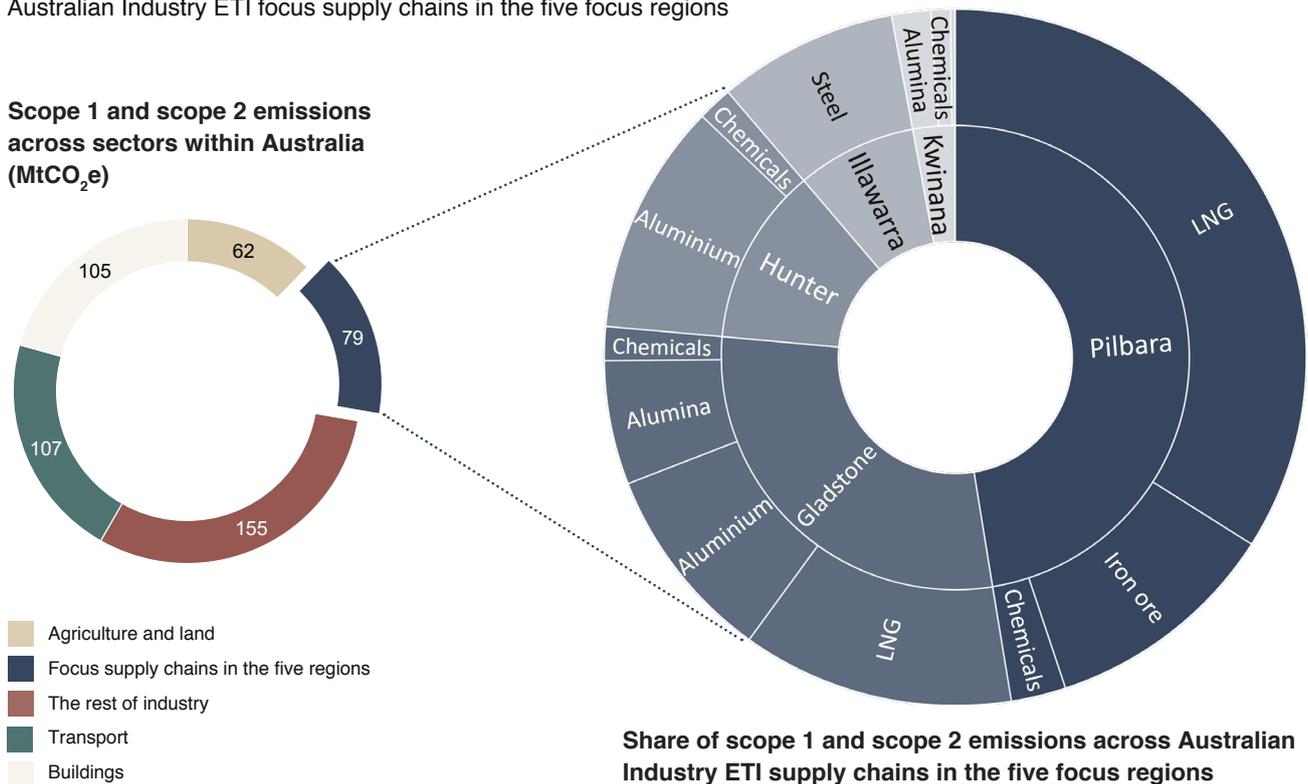
The Australian Industry ETI brings together some of Australia’s largest companies to share knowledge and accelerate action towards achieving net zero emissions supply chains by 2050. The Australian Industry ETI is working collaboratively with heavy industry and business partners, focusing on five key industrial supply chains: iron and steel, aluminium, other metals (copper, nickel and lithium), chemicals (fertilisers and explosives), and liquified natural gas (LNG).

The Australian Industry ETI focus supply chains are significant in terms of their emissions, energy use and contribution to the Australian economy.

These focus supply chains make a critical contribution to Australia’s economy, collectively contributing 12.3 percent to Australia’s gross domestic product (GDP), generating exports worth over A\$160 billion per annum to the Australian economy, and employing 2.9 percent of Australia’s workforce.

Industrial regions contribute significantly to Australia’s emissions. The supply chains in focus for the Australian Industry ETI in the five regions analysed for this report make up 16 percent of Australia’s total emissions, releasing 79 MtCO₂e each year (figure 2). Of these regions, the Pilbara is the most significant emitter with 37.4 MtCO₂e, followed by Gladstone contributing 22.9 MtCO₂e. Abating emissions from heavy industry in Australia is therefore critical to achieving net zero emissions targets set by federal and state governments. Industrial processes in these regions are typically considered harder-to-abate, as addressing them poses more technological and commercial challenges than in other sectors such as buildings and road transport. As the world accelerates towards decarbonisation in line with Paris Agreement commitments to limit warming to well below 2, preferably, 1.5°C, compared to pre-industrial levels, there is a clear need to shift away from emissions-intensive energy sources. Companies across the world are embracing the decarbonisation challenge, often leading the development and deployment of technologies to shift away from emissions.

FIGURE 02: Share of emissions across sectors within Australia and within the Australian Industry ETI focus supply chains in the five focus regions



Heavy industry is already investing in projects to decarbonise operations in the regions they operate in. This investment is accelerating as momentum towards decarbonisation builds and the response to climate change becomes an issue of core strategy and risk management.

The Australian Industry ETI's first report in mid-2021 found that industry can shape a decarbonised system with a deliberate, coordinated effort by stakeholders across supply chains. These efforts can help accelerate decarbonisation and catalyse the associated technologies and market development, to fully realise the wide-ranging economic potential of transition.

This report looks at the role four key industrial regions might play in a decarbonised future, seeking to deepen the understanding of what is required, and what stakeholders could do together, to maintain economic prosperity.

To produce this report, the Australian Industry ETI consulted program partners, engaged stakeholders in relevant regions, and undertook a techno-economic analysis of emissions and abatement opportunities for existing operations in those regions.¹ This report profiles four regions with which the Australian Industry ETI is deeply engaged:² Kwinana and the Pilbara in Western Australia (WA) as well as Hunter and Illawarra in New South Wales (NSW). Analysis is also presented for Gladstone in Queensland given its interest to industry partners, economic contribution, and greenhouse gas emissions, although further consultative engagement would be needed for the development of a detailed focus for this region.

The economic urgency for climate action is increasing globally. Under the Paris Agreement (United Nations Framework Convention on Climate Change, 2015), 197 countries have signed or acceded to limiting global warming to well below 2°C, preferably to 1.5°C. In 2021, the Intergovernmental Panel on Climate Change (IPCC) (Climate Change 2021: The Physical Science Basis, 2021) projected the Earth is likely to reach the crucial 1.5°C warming limit in the early 2030s, and the urgency to meet – and exceed – targets has only increased.

The Paris Agreement includes a ratchet mechanism (Yeo, 2015), which requires increasing levels of ambition in countries' nationally determined contributions (NDCs). The Paris Agreement provided for NDCs to be submitted every five years but the Glasgow Conference of the Parties (COP) in 2021 brought the next round of commitments forward to 2022 in recognition of the emissions reductions required by 2030 to keep 1.5°C warming in sight. The ratchet mechanism (Yeo, 2015) has seen signatories set progressively more ambitious national goals. Of significance to the heavy industry sector, Australia's major trading partners, covering 70 per cent of exports, have recently committed to more ambitious near-term emissions targets. The United States of America (USA) has committed to a 52 per cent reduction in emissions by 2030 (NDC Registry – United State of America, 2021), China has committed to reach carbon neutrality before 2060 (NDC Registry- China, 2021) South Korea has committed to a 40 per cent reduction by 2030 (NDC Registry – Republic of Korea, 2021), and the United Kingdom (UK) has raised its ambition to now cut emissions by 68 percent by 2030 (NDC Registry – United Kingdom, 2020).

The commitments by Australia's trading partners are made in the context of carbon border adjustment mechanisms being progressed in the European Union and under consideration by the USA, the UK, Canada and Japan. Carbon border adjustments apply an additional tax on imports from countries without an adequate compliance framework aligned to net zero emissions by 2050, and provide a compelling reason for Australia to introduce frameworks to reduce the risk of export disadvantage.

Accelerating international decarbonisation commitments presents risks, but also opportunities for Australian exports in energy-intensive supply chains.

Pressure is also mounting on companies to address decarbonisation from investors and consumers. BlackRock, the world's largest asset manager, has advised that companies in its portfolio should disclose their Scope 1 and 2 emissions³ and is also asking that companies in carbon-intensive industries, including major oil and gas firms, disclose their Scope 3 emissions (BlackRock, 2021). The Net-Zero Asset Owner Alliance (NZAOA) established in 2019 and the Glasgow Financial Alliance for Net Zero (GFANZ) established in April 2021 demonstrate increasing asset-owner led movements catalysing decarbonisation of the global economy and investing in climate resilience.

1 The basis and assumptions for the analysis are included in Appendix one.

2 These four regions represent significant bases of operations for partners of the Australian Industry ETI. The Australian Industry Energy Transitions Initiative received philanthropic funding for a regional focus on Western Australia and was supported by the NSW Department of Planning and Environment to undertake a scoping study on regions in NSW.

3 Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.

Large companies in particular are experiencing heightened pressure from clients to act on climate change (Coppola, 2019). Furthermore, the global market for clean technologies is projected to almost double by 2025, based on 2016 levels, and then continue to expand at an increasing pace to 2050 (Burdon et al., 2019). For Australian industry, these combined pressures create an enormous pull for action.

Australian regions are well positioned to capitalise on the shifts of a global decarbonised economy.

Australia has some of the most enviable renewable resources in the world, with both abundant solar radiation and strong onshore wind resources (Energy Transition Hub, 2019). Many industrial regions in Australia are well placed for the decarbonisation transition with an abundance of renewable energy resources in proximity to existing and planned industrial centres. Australian regions can also capitalise on other important resources such as access to port capacity, existing infrastructure such as gas and electricity networks, suitably zoned land and a skilled workforce. In the Australian Industry ETI's first report, we found that effectively integrating decarbonised energy systems with industrial demand through demand response and green hydrogen networks can firm electricity production (Australian Industry Energy Transitions Initiative, 2021).

A key solution for decarbonisation, as well as a key opportunity for Australian industry and governments, is the development of renewable energy systems alongside industrial clusters and regions to reduce overall decarbonisation costs. By taking a whole-of-cluster approach, governments and industry could drive new investment in regions, helping to create new jobs and opportunities, thus contributing to a just transition, while also supporting the regions' traditional industry and supply chains. The Federal Department of Industry, Science, Energy and Resources (DISER) is showing interest in industrial clustering and low carbon opportunities, seeking to work with stakeholders to understand the barriers and opportunities to support the development of new energy industrial hubs. It is critical that this approach considers suitable locations for clustering and zoning for strategic industrial areas.

The shift required to develop clustered infrastructure at the speed and scale required is sizable. Australian Industry ETI partners are investing in decarbonisation measures and in many cases collaborating, or looking to collaborate, to make the transition.

INFORMATION BOX 1:

Powering fossil-fuel infrastructure with green hydrogen

Fortescue and Incitec Pivot – Queensland

Australian Industry ETI partner, Fortescue Future Industries (FFI), and Incitec Pivot Limited (IPL) are collaborating on an initial research project to convert IPL's Gibson Island ammonia production facility near Brisbane in Queensland, to operate on green hydrogen, instead of fossil-fuel gas. Importantly, this will assist in understanding whether fossil-fuel gas infrastructure conversion is both technically and economically feasible.

The collaboration will support the development of an innovative and competitive green hydrogen industry. FFI plans to construct an on-site electrolysis plant, which could produce up to 50,000 tonnes of green hydrogen per year for conversion into green ammonia, replacing the current fossil-fuel gas feedstock (First milestone reached for Fortescue Future Industries and Incitec Pivot's green ammonia collaboration in Queensland, 2021).

In the first project phase, FFI found the project to be technically feasible and has issued IPL with a notice to proceed to the next phase. FFI and IPL will now enter negotiations for an agreement to progress this project to a front-end engineering design study. The study will inform a potential final investment decision.

The project, if successful, will safeguard manufacturing jobs in Queensland, and create a new domestic and export market for green, renewable ammonia. Green hydrogen and green ammonia from the project could also provide a low-carbon fuel supply to the Port of Brisbane, Brisbane airport and other heavy transport users (First milestone reached for Fortescue Future Industries and Incitec Pivot's green ammonia collaboration in Queensland, 2021).

Information provided by Fortescue Metals Group

INFORMATION BOX 2:**Ark Energy sets sights on zero emissions hydrogen powered trucks**

The Ark Energy Corporation is developing the SunHQ hydrogen hub in Townsville, which will include a 1MW PEM hydrogen electrolyser, compressors, storage and refuelling infrastructure. In producing up to 158 tonnes of green hydrogen a year, the hub is a key part of plans to enable the Sun Metals zinc refinery to become the first in the world to produce green zinc. In 2021, the CEFC has committed up to \$12.5 million to Ark Energy, through the Advancing Hydrogen Fund, alongside ARENA, which has committed a further \$3.02 million.

The investment will support the construction of hydrogen production and refuelling infrastructure for the Sun Metals zinc refinery, with green hydrogen produced from an electrolyzer powered by the Sun Metals solar farm. It will also finance five purpose-built, zero emissions ultra-heavy duty Hyzon hydrogen trucks.

The electric trucks will deliver zinc ore from Townsville Port to the Sun Metals zinc refinery where they will refuel with green hydrogen before transporting the refined zinc ingots to port in a 30 kilometre clean energy round trip. Replacing their diesel equivalents in the Townsville Logistics fleet, the five 140 tonne-rated zero emissions Hyzon Motors trucks will significantly improve the sustainability of the zinc supply chain, with an expected abatement of about 1,300 tonnes CO₂ per year.

The Sun Metals Refinery is aiming to be the first refinery in the world to produce green zinc. In addition to the use of green hydrogen, the refinery plans to power its entire operations with 100 per cent renewable electricity by 2040, with an interim target of 80 per cent by 2030.

Information supplied by the CEFC

INFORMATION BOX 3:**Collaborating to reduce carbon emissions on a global scale****AustralianSuper and Climate Action 100+**

Investors have a vital role to play in driving the transition to net-zero emissions across the global economy. As a founder of Climate Action 100+, AustralianSuper is working with investors and companies to advance progress towards this goal.

Climate Action 100+ is the world's largest investor engagement initiative on climate change, bringing together the power of more than 615 investors responsible for US\$65 trillion in assets under management. It provides a powerful platform for investors to engage deeply with 167 of the world's largest listed corporate emitters to accelerate action on climate change.

Andrew Gray, AustralianSuper's Director of ESG and Stewardship and member of the Climate Action 100+ global Steering Committee said: 'one of the keys to the success of Climate Action 100+ has been the clarity and consistency it brings to companies on investor expectations for emissions reductions, governance and disclosure.'

As of September 2021, 111 of the Climate Action 100+ focus companies had set net zero targets for 2050 or before, including companies in hard-to-abate sectors like those in the Australian Industry ETI.

Andrew Gray said: 'While commitments focused on Net Zero 2050 are important, companies need to have credible decarbonisation strategies in place to meet this goal. By providing a consistent set of guideposts the benchmark is helping companies align their transition plans and actions to investor expectations while providing a clear pathway to net zero 2050.'

Collaborations like Climate Action 100+ and the Australian Industry ETI are helping investors and companies alike work through the challenges, risks and opportunities of the net zero economic transition so they can continue to deliver long-term value for their beneficiaries.

Information provided by Australian Super

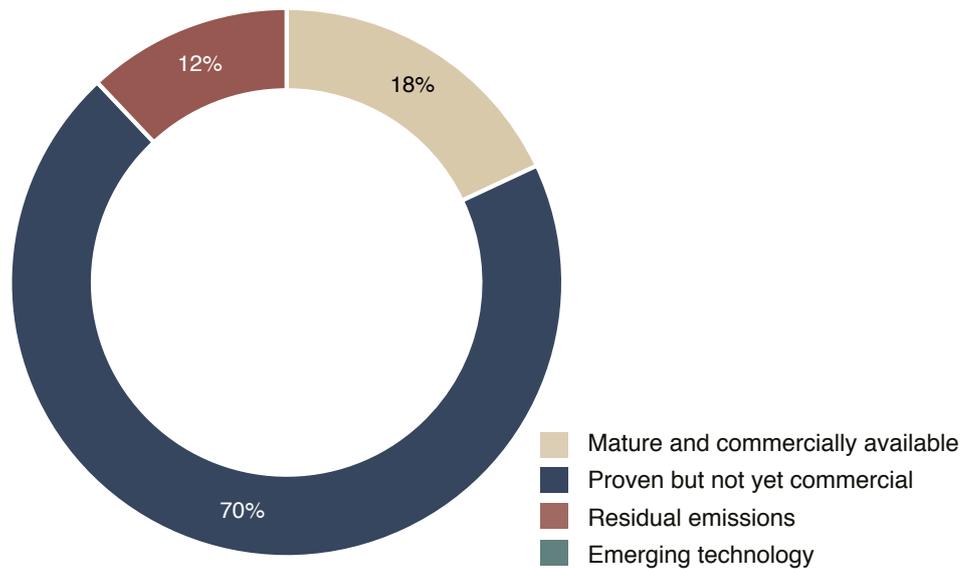
While many of the abatement opportunities identified in this report are considered both technologically and commercially mature, others are technologically proven but not yet commercial – or are emerging opportunities requiring stimulation to enable future deployment. For the purposes of this analysis, ‘commercially available’ technologies are defined as those able to be procured and practically deployed in a commercial setting, rather than indicating cost-competitiveness relative to incumbent or other technologies.

The analysis in this report does not include all abatement options available and focuses on technologies seen as the most promising to provide emissions reductions in line with the scale needed to achieve net zero emissions by 2050. This may differ from some industrial organisations’ planned approach to reduce emissions, which may prioritise other abatement options as part of the transition prior to other opportunities being economic at scale. Blue hydrogen which includes the use of CO₂ sequestration, may play a role in the near to mid term as industry and other sectors build a hydrogen economy but is not considered as part of the data analysis as the analysis prioritised the technology options with the greatest abatement potential. A more complete overview of technologies available across industrial processes is available in the Australian Industry ETI’s Phase 1 Technical Report (Australian Industry Energy Transitions Initiative, 2021). Techno-economic modelling is currently underway on the least-cost deployment of technologies, to be published at the completion of Phase 3 of the Australian Industry ETI work plan.

88 percent of identified abatement potential is technologically proven, but there are still commercial barriers to overcome

As shown in Figure 3, deploying mature and commercially available technologies to support decarbonisation could reduce emissions from existing processes in these regions by 18 percent. Implementing proven but not yet commercial technologies, like green hydrogen and electrified haulage trucks, could eliminate a further 70 percent of emissions.

FIGURE 03: Abatement potential per technology category⁴



Category	Technology readiness level	Commercial readiness
Mature and commercially available	8-9	High
Proven but not yet commercial	>6	Medium
Emerging technology	<=6	Low

⁴ Abatement potential from ‘emerging technologies’ is estimated at around 10 percent of total emissions; however, to avoid double counting with alternative technologies with higher technology readiness levels, these have been omitted from the Figure 3. ‘Residual’ emissions are primarily due to unabated emissions in the LNG sector (which range from 30 percent to 60 percent of non-energy emissions) and small amounts of remaining nitrous oxide emissions in chemicals. Numbers may not sum to 100 percent due to rounding.

Support for the deployment of mature and commercial decarbonisation solutions must be undertaken concurrently with support for technology which is proven but not yet commercial and stimulation for emerging technologies

Further efforts are needed to accelerate the scale-up of ‘mature and commercial’ technologies. Full technological deployment would require significant investment in the energy system through additional decarbonised electricity capacity,⁵ energy storage capacity, hydrogen electrolyzers and carbon sequestration facilities. These estimates do not include estimates of key enabling infrastructure such as transmission, distribution, pipelines, microgrids and charging infrastructure that would also be required.⁶

TABLE 01: Mature and commercially available⁷ technologies for acceleration

Region	Major, long-term abatement options	Percentage region emissions abatement potential / year	Energy requirements (per year)	Energy capital costs (excluding infra-structure) ⁸
Hunter	Ammonia and ammonium nitrate: <ul style="list-style-type: none"> Switch current electricity use to renewables nitrous oxide abatement 	~6 percent = 0.6 MtCO ₂ e	0.1 TWh	VRE: A\$0.05 b Battery storage: A\$0.07 b
The Pilbara	LNG: ⁹ <ul style="list-style-type: none"> Reduce fugitive emissions through LDAR¹⁰ and vapour recovery – Waste heat recovery during gas liquefaction Ammonia and ammonium nitrate: <ul style="list-style-type: none"> Switch current electricity use to renewables Nitrous oxide abatement Iron ore: <ul style="list-style-type: none"> Switch to renewable electricity for iron ore mining site operations (excluding haulage) 	~16 percent = 5.9 MtCO ₂ e	3.4 TWh	VRE: A\$1.9 billion Battery storage: A\$0.11 b

5 Assuming variable renewable energy (VRE) sources such as solar and wind are the lowest cost forms of new generation.

6 Further efforts to model the infrastructure needs and required capital for these assets is a focus of the Australian Industry ETI’s Phase 3 work.

7 For the purposes of this analysis, ‘commercial’ technologies are those able to be purchased and practically deployed in a commercial setting, rather than indicating cost-competitive relative to incumbent or other technologies.

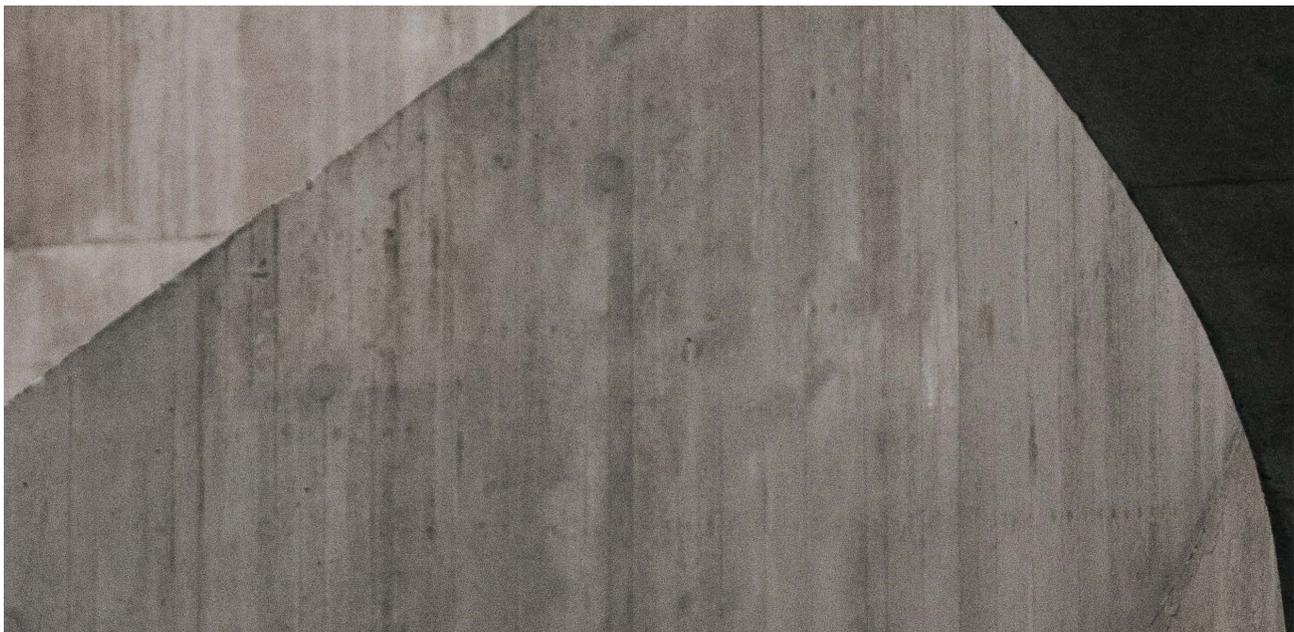
8 Capital costs are based on current production capacities of each supply chain. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4–5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

9 The abatement potential, energy requirements and energy capital costs are estimated for LNG based on its current near-record-high production.

10 Leak detection and repair.

TABLE 01 continued: Mature and commercially available⁷ technologies for acceleration

Region	Major, long-term abatement options	Percentage region emissions abatement potential / year	Energy requirements (per year)	Energy capital costs (excluding infra-structure) ⁸
Kwinana	<p>Alumina:</p> <ul style="list-style-type: none"> • Electric boilers for digestion heat powered by renewables <p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> • Switch current electricity use to renewables <p>Nickel refining:</p> <ul style="list-style-type: none"> • Switch current electricity use to renewables¹¹ 	<p>~53 percent =1.2 MtCO₂e</p>	4.1 TWh	<p>VRE: A\$1.4 billion Battery storage: A\$1.76 b</p>
Gladstone	<p>Alumina:</p> <ul style="list-style-type: none"> • Electric boilers for digestion heat powered by renewables <p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> • Switch current electricity use to renewables • Nitrous oxide abatement <p>LNG:</p> <ul style="list-style-type: none"> • reduce fugitive emissions through LDAR¹²and /waste heat recovery/vapour recovery. Waste heat recovery during gas liquefaction 	<p>27 percent = 6.1 MtCO₂e</p>	12.1 TWh	<p>VRE: A\$4.9 billion Battery storage: A\$5.15 b</p>



¹¹ Excludes the 50 percent of Kwinana Nickel Refinery’s electricity use that has already been contracted to a solar PPA in 2021.

¹² Leak detection and repair.

TABLE 02: Proven but not yet commercial technologies

Region	Major, long-term abatement options	Percentage region emissions abatement potential / year	Energy requirements (per year)	Energy capital costs (excluding infrastructure) ¹³
Illawarra	<p>Steelmaking:</p> <ul style="list-style-type: none"> Green hydrogen for DRI-EAF steel production¹⁴ 	<p>~100 percent = 6.6 MtCO₂e</p>	12.3 TWh	<p>VRE: A\$4.3 b Electrolysers: A\$4.3 b</p>
Hunter	<p>Aluminium smelting:</p> <ul style="list-style-type: none"> switch to renewable electricity for smelting¹⁵ switching current carbon-based anodes to inert anodes <p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> Green hydrogen for feedstock and electrification of Haber Bosch powered by renewables 	<p>~86 percent = 8.4 MtCO₂e</p>	11.1 TWh	<p>VRE: A\$5.3 b Electrolysers: A\$0.7 b Battery storage: A\$4.2 b</p>
The Pilbara	<p>LNG:¹⁶</p> <ul style="list-style-type: none"> electric drives for gas liquefaction, powered by renewable electricity¹⁷ Carbon Capture and Storage for reservoir gas <p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> Green hydrogen for feedstock and electrification of Haber Bosch powered by renewables <p>Iron ore:</p> <ul style="list-style-type: none"> Battery electric trucks with trolley assists (BEV+TA) or hydrogen fuel cell electric trucks (FCEV) for haulage 	<p>~66 percent = 24.6 MtCO₂e</p>	37.6–50.4 TWh ¹⁸	<p>VRE: A\$13.8–18 b Electrolysers: A\$8.21 b Battery storage: A\$13.9 b</p>

13 Capital costs are based on current production capacities of each supply chain. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4–5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

14 Hematite is not yet able to be used in hydrogen direct reduced iron processes which currently rely on very high concentrations of iron

15 Although renewable energy technologies are mature and commercially available, constant and reliable supply of variable renewable energy for large energy users such as aluminum smelters are still not commercially viable.

16 The abatement potential, energy requirements and energy capital costs are estimated for LNG based on its current near-record-high production.

17 Electric drives for greenfields are 'mature and commercially available' but for brownfields are considered 'proven but not yet commercial' due to various retrofitting and operational challenges.

18 The lower end of the range represents a complete switch to battery electric trucks with trolley assists while the upper end of the range represents a complete switch to hydrogen fuel electric trucks.

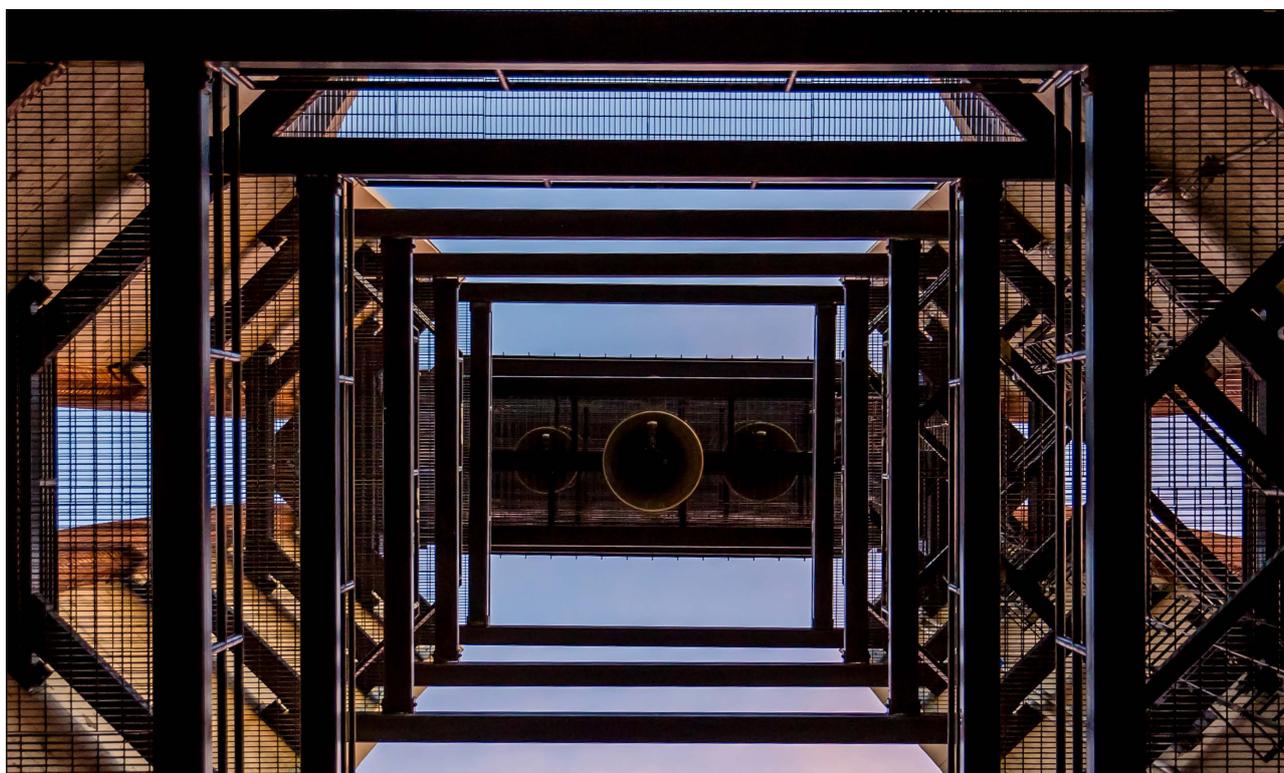
TABLE 02 continued: Proven but not yet commercial technologies

Region	Major, long-term abatement options	Percentage region emissions abatement potential / year	Energy requirements (per year)	Energy capital costs (excluding infrastructure) ¹³
Kwinana	<p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> Green hydrogen for feedstock and electrification of Haber Bosch powered by renewables <p>Alumina:</p> <ul style="list-style-type: none"> Mechanical vapour recompression for digestion heat Green hydrogen for process heat in calcination <p>Nickel refining:</p> <ul style="list-style-type: none"> Green hydrogen for high heat processes 	<p>~58 percent = 1.8 MtCO₂e</p>	6.4 TWh	<p>VRE: A\$2.6 b Electrolysers: A\$1.7 b Battery storage: A\$0.5 b</p>
Gladstone	<p>Aluminium:</p> <ul style="list-style-type: none"> switch to renewable electricity for smelting switching current carbon-based anodes to inert anodes <p>Ammonia and ammonium nitrate:</p> <ul style="list-style-type: none"> Green hydrogen for feedstock and electrification of Haber Bosch powered by renewables <p>LNG:</p> <ul style="list-style-type: none"> electric drives for gas liquefaction CCS for reservoir gas <p>Alumina:</p> <ul style="list-style-type: none"> Mechanical vapour recompression for digestion heat Green hydrogen for process heat in calcination 	<p>~80 percent = 18.4 MtCO₂e</p>	24.0 TWh	<p>VRE: A\$13.4 b Electrolysers: A\$0.2 b Battery storage: A\$8.1 b</p>

TABLE 03: Emerging technologies

Region	Major, long-term abatement options	Percentage region emissions abatement potential / year	Energy requirements (Per year)	Energy capital costs (excluding infrastructure) ¹⁹
Illawarra	Steelmaking: <ul style="list-style-type: none"> Green hydrogen for DRI-Melter-BOF²⁰ Ore electrolysis 	~100 percent = 6.6 MtCO ₂ e	DRI-Melter-BOF 12.1 TWh	VRE: A\$3.8 b Electrolysers: A\$2.6 b Battery Storage: A\$0.3 b
			Electrolysis: 13.7 TWh	VRE: A\$4.3 b Battery Storage: A\$6.4 b
Kwinana	Alumina: <ul style="list-style-type: none"> Electrification of calcination, powered by renewables 	~12 percent = 0.4 MtCO ₂ e	0.6 TWh	VRE: A\$0.3 b Battery storage: A\$0.3 b
Gladstone	Alumina: <ul style="list-style-type: none"> Electrification of calcination, powered by renewables 	~5 percent = 1.2 MtCO ₂ e	2.0 TWh	VRE: A\$1 b Battery storage: A\$0.8 b

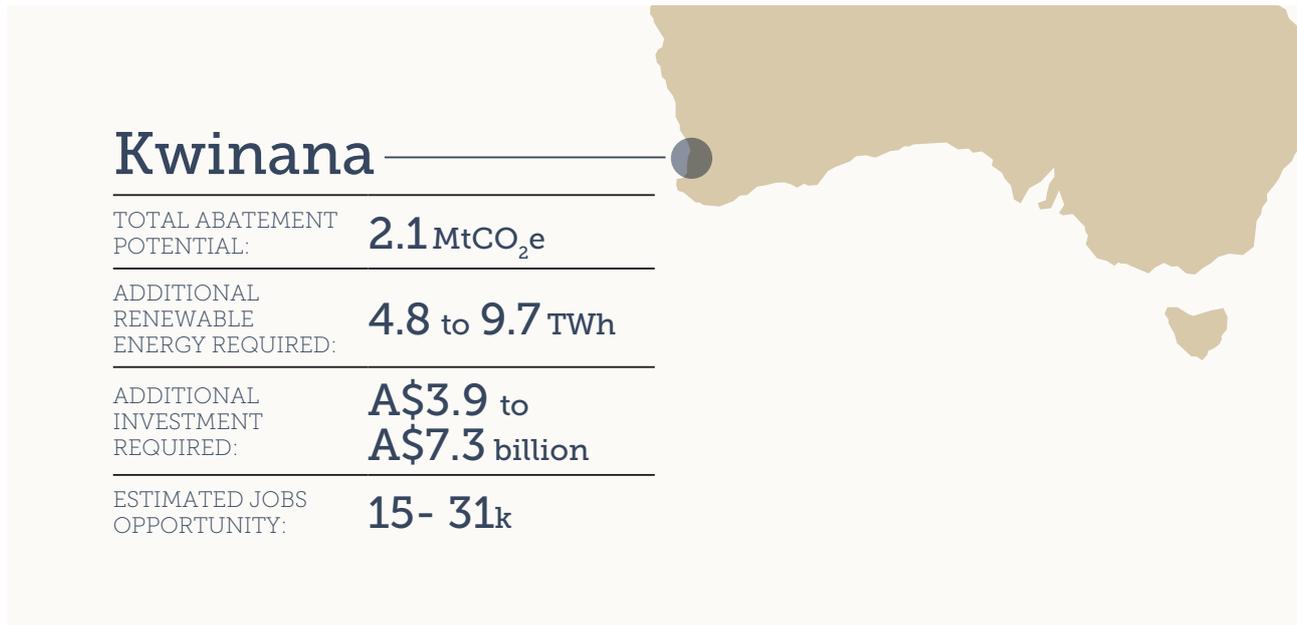
The regional factors associated with these opportunities are discussed further in the focus sections on the Pilbara, Kwinana, Hunter and Illawarra.



¹⁹ Capital costs are based on current production capacities of each supply chain. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4–5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

²⁰ DRI: Direct reduced iron; BOF: Basic oxygen furnace.

1.1 Focus on Kwinana



- 40 kilometres south of Perth in Western Australia.
- 65 year history of industrial activity.
- Home to alumina refining, ammonia, fertilisers, chemicals production, nickel refining and other battery mineral processing, as well as cement and a range of supporting industries.
- Significant effort to collaborate around industrial activity and exchanges in the Kwinana strategic industrial area and the broader Western Trade Coast.
- Due to land constraints in the strategic industrial area, there are limited options for onsite renewable generation although opportunities to connect renewable generation of electrons and hydrogen via transmission and pipelines.
- Potential to build on existing collaboration to develop a thriving ecosystem centred around clean technologies such as green metals, chemicals and hydrogen.

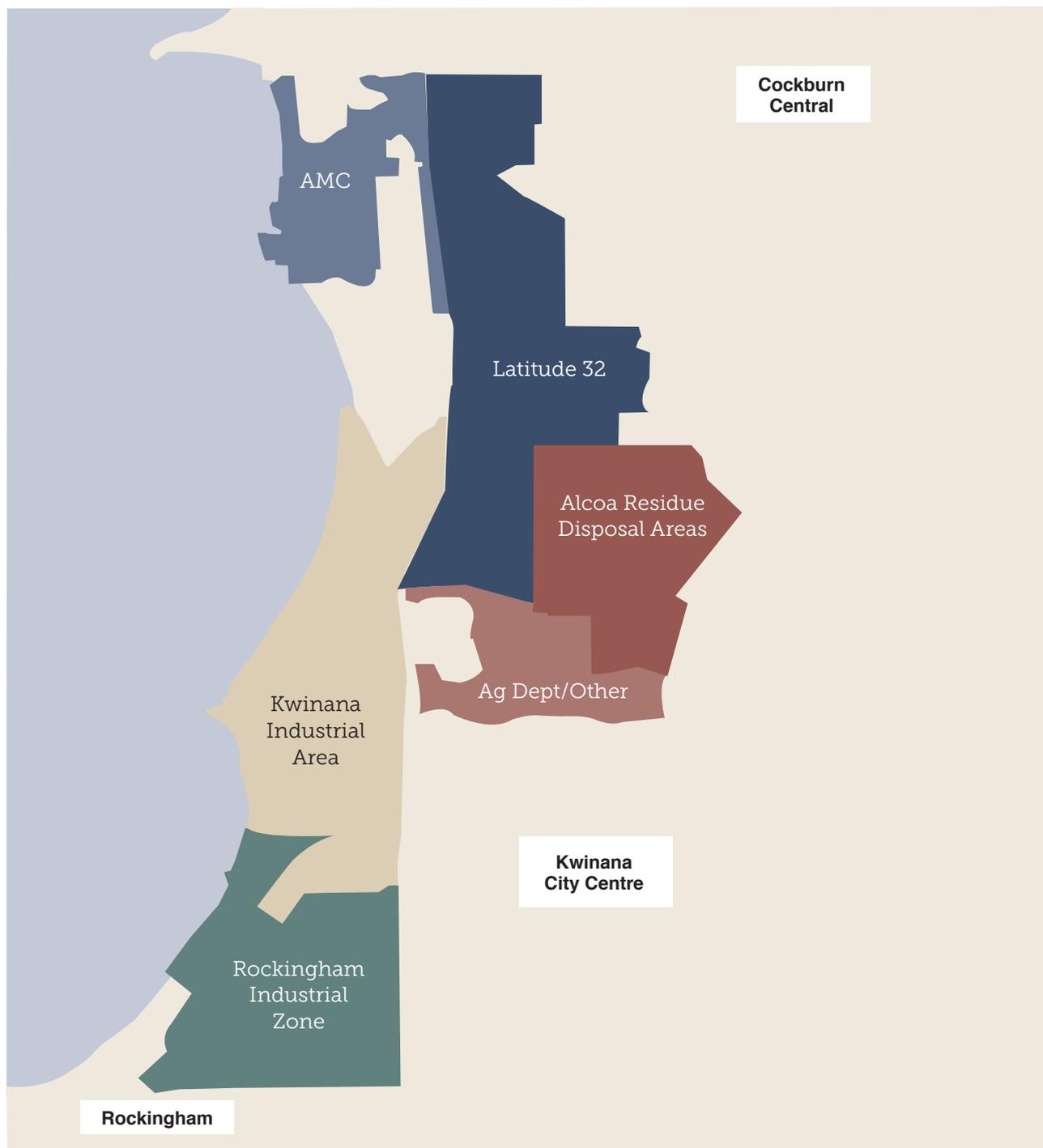
What is needed

- Kwinana can achieve significant emissions reductions and will require a substantial investment in the energy system.
- Coordinated planning and development of multi-user infrastructure to facilitate efficient decarbonisation.
- Regulatory changes to facilitate hydrogen and carbon dioxide transmission and storage.
- Policy development to further stimulate near-term hydrogen demand.
- Building on activities being identified in Kwinana Industry Council's Carbon Reduction Plan.
- Investment is required to facilitate the delivery of decarbonised energy into the region, either in the form of electricity or molecules such as ammonia or hydrogen.

The Kwinana Industrial Area (KIA) is a strategically important centre for chemical and resource-based processing industries, located 30 kilometres south of Perth in Western Australia.

Industry in the area has grown significantly since the initial development of the bp refinery in the early 1950s. Most industry is concentrated in a strip of land about eight kilometres long and two kilometres wide, bordered by the Indian Ocean on the west and metropolitan Kwinana on the east.

FIGURE 04: Kwinana Strategic Industrial Area and the Western Trade Coast



The Western Trade Coast (WTC) is an industrial estate in Western Australia, located approximately 30km south of Perth CBD on the eastern side of Cockburn Sound. The WTC covers an area approximately 14km north-south and an average of 4km east-west, and comprises the Kwinana Industrial Area (KIA), Rockingham Industrial Zone (RIZ), Australian Marine Complex (AMC) and Latitude 32 Industrial Zone (Latitude 32). This focus incorporates analysis for the Western Trade Coast.

The Kwinana Strategic Industrial Area (SIA) is part of the larger Western Trade Coast (WTC) industrial estate. The mix of industries in the WTC provides proponents with ‘direct access to customers, suppliers, end-users and services all in the one location’. Business activities within the broader WTC are a major contributor to the economy, generating A\$16 billion per annum and employing 11,000 people directly and up to 30,000 indirectly (Kwinana Industries Council, 2020). The value of regional exports generated by the Kwinana economy is estimated at A\$8.478 billion (Economy, Jobs and Business Insights, n.d.). Manufacturing and mining are the main exports from this region with major trading partners being Singapore, Malaysia, China, and Japan (Infranomics, 2018). Approximately two-thirds of employees live within 15km of the WTC.

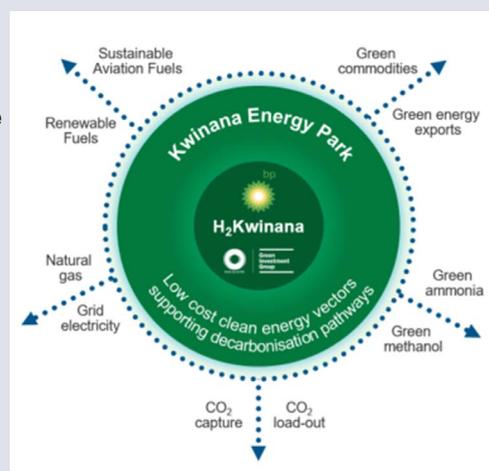
INFORMATION BOX 4:

Breathing new energy life into fuel refinery

bp’s proposal to establish an integrated energy hub to decarbonise heavy industry

After 65 years of fuel operations in Kwinana, bp Australia is reshaping the bp Kwinana site into an integrated energy hub with a world class import terminal, production of renewable fuels, and potentially green hydrogen production to help decarbonise the Kwinana Industrial Area, as well as the heavy transport and aviation sectors.

Situated next to the fuel import terminal, the bp renewable fuels plant project will repurpose equipment that was used for oil refining to produce two key ‘drop-in’ fuels that can be used in existing infrastructure and internal combustion engines: sustainable aviation fuel (SAF) and renewable diesel. The plan for the new renewable fuels plant is to receive waste oil feedstocks, such as tallow and used cooking oil, that will be refined to produce SAF and renewable diesel. These two key renewable fuels have the potential to reduce emissions by up to 90 percent relative to conventional fossil-fuels.



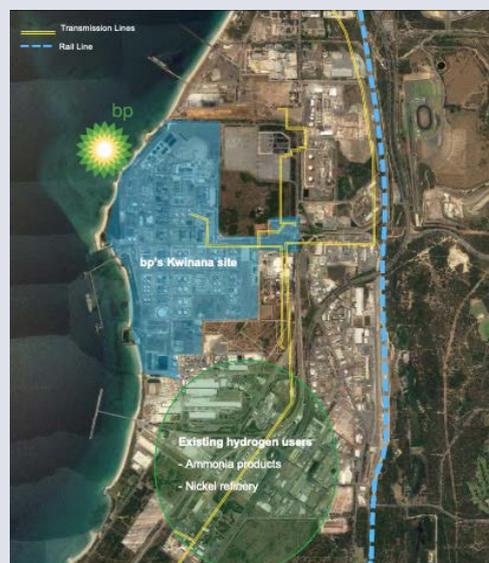
In addition to the renewable fuels plant, bp and Macquarie are jointly undertaking a feasibility study on the development of a hydrogen hub, H2Kwinana, at bp’s Kwinana site. The creation of H2Kwinana could provide a platform to transition existing carbon-intensive sectors and create new green industries. The feasibility study seeks to identify sources of green hydrogen demand in the KIA from a variety of industrial hydrogen users, including bp renewable fuels and other chemical and mineral processors within the Kwinana precinct. Other potential green hydrogen demand sources are also being explored in the transport sector (e.g. heavy haul trucks, waste trucks, buses) and pipeline blending to meet the WA government’s 10 percent hydrogen blending target by 2030. The role a large demand source like the H2Kwinana electrolyser could play in stabilising the grid of the SWIS is also being investigated.

bp’s broader vision is to create Kwinana Energy Park, a fully integrated energy hub to supply Kwinana, Perth and the south-west’s energy needs for a transition to net zero.

bp’s Kwinana site has the following benefits as an integrated energy hub:

1. **operational infrastructure**, that can be expanded or repurposed, run by a skilled workforce with decades of hydrogen experience
2. **connectivity to domestic and export customers**, with established transmission and pipeline networks, and rail, road, and sea links
3. **existing shared infrastructure** and product exchanges between Kwinana industrial businesses
4. **significant local industrial demand** across sectors including chemicals, minerals processing and heavy transport (such as back-to-base and long-haul trucks and buses, with potential for marine services at a new container port).

Information supplied by bp



Kwinana is home to several key components in the battery supply chain, including lithium processors Tianqi Lithium and Covalent Lithium and BHP Nickel West's nickel refinery and nickel sulphate production. Other major industrial operations in Kwinana include alumina refining, cement production, lithium hydroxide production, ammonia and ammonium nitrate production. Kwinana is also the site of high-efficiency gas turbines operated by Synergy, the state government owned gentailer, and NewGen Power Kwinana. The Synergy site will also soon be home to WA's first transmission-scale battery. There are six existing users of hydrogen, produced from natural gas via steam methane reforming (SMR). This provides a potential customer base for hydrogen to facilitate the transition to lower carbon fuels (Material Exchange – Kwinana Industries Council, n.d.)

Industry in Kwinana has an established collaboration structure in the Kwinana Industries Council (KIC) which acts as an industry representative body working on behalf of member organisations to achieve legislative and regulatory simplification, resolution of competitive disadvantages through infrastructure provision, and the continuation of a positive public image (Kwinana Industries Council, 2021). Having this established collaboration mechanism is a significant advantage for heavy industrial entities navigating decarbonisation in Kwinana. This is evident in KIC's Carbon Reduction project for the Kwinana Industrial Area (CRKIA) which seeks to move the KIA to net zero through collective initiatives implemented by members of KIC. CRKIA seeks to leverage each member's effort in support of others seeking to achieve the same and support each other's success and pace of reducing carbon emissions.

INFORMATION BOX 5:

Collaboration in action

Kwinana Industries Council

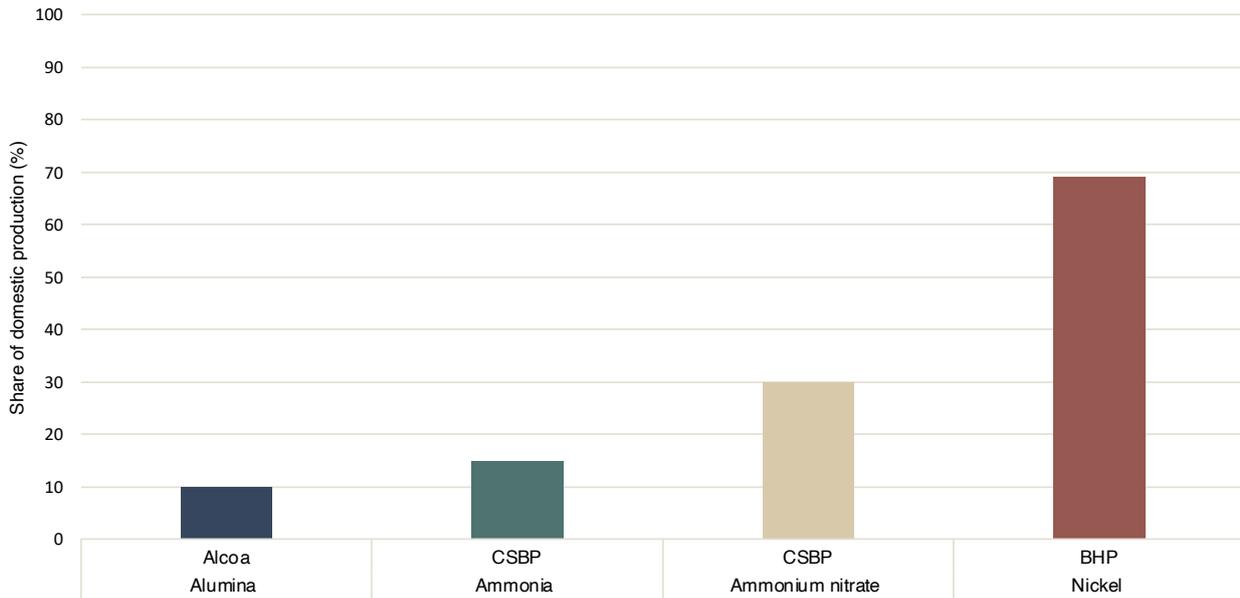
The Kwinana Industries Council is a not-for-profit incorporated business association with membership comprised of major industries and businesses in the Kwinana Industrial Area.

KIC and its members have worked together to develop a decarbonisation plan for the KIA. Kwinana's work on decarbonisation has been recognised globally and was recently used as a case study of industrial precinct collaboration by the World Economic Forum at COP26 in Glasgow.

Production in Kwinana

Industrial activity in supply chains where Australian Industry ETI partners have operations in Kwinana, make a significant contribution to Australia's production of alumina, nickel, ammonia and ammonium nitrate (Figure 5).. Alcoa's Kwinana alumina refinery produces 2.2 Mt of alumina each year, representing 10 percent of Australia's domestic production. CSBP produces 14 and 19 percent of Australia's ammonia and ammonium nitrate respectively, while BHP contributes 69 percent of Australia's domestic nickel supply.

FIGURE 05: Share of domestic production of major industrial sub-sectors in Kwinana



Energy in Kwinana

Kwinana is connected to Western Australia’s principal power network, the SWIS, which has a Wholesale Electricity Market (WEM). Generators and major users and retailers predominantly trade under power purchase agreements for energy and capacity. They can also trade energy a day ahead through the short-term trading market.

A material difference to the National Energy Market (NEM) is WA’s Reserve Capacity Market which ensures sufficient capacity is available to meet demand and maintain essential system service requirements during the summer peak. Capacity providers are paid for making their capacity available regardless of whether they are actually called on. Retailers and electricity users fund the payments to capacity providers in proportion to their contribution to the peak (Wholesale Electricity Market Design Summary, AEMO, 2021, p 11-12). This is particularly important given the isolation of the SWIS compared with the NEM.

The capacity market component is designed to ensure the stability of the system, particularly important given the isolation of the SWIS compared with the NEM and large energy customers (consuming more than 50MWh of electricity each year) are ‘contestable’ customers, meaning they can choose their electricity retailer.

The state government has prioritised significant energy reforms and energy network planning to facilitate high penetration of renewables, integration of distributed energy resources (such as rooftop solar and household batteries), battery firming and microgrids. Electricity generation utilised by the key sectors in Kwinana is mostly supplied by gas (60 percent), followed by diesel (23 percent), and black coal (12 percent). The remainder (5 percent) is supplied by wind and solar (Electricity sector, 2021).

Infrastructure in Kwinana

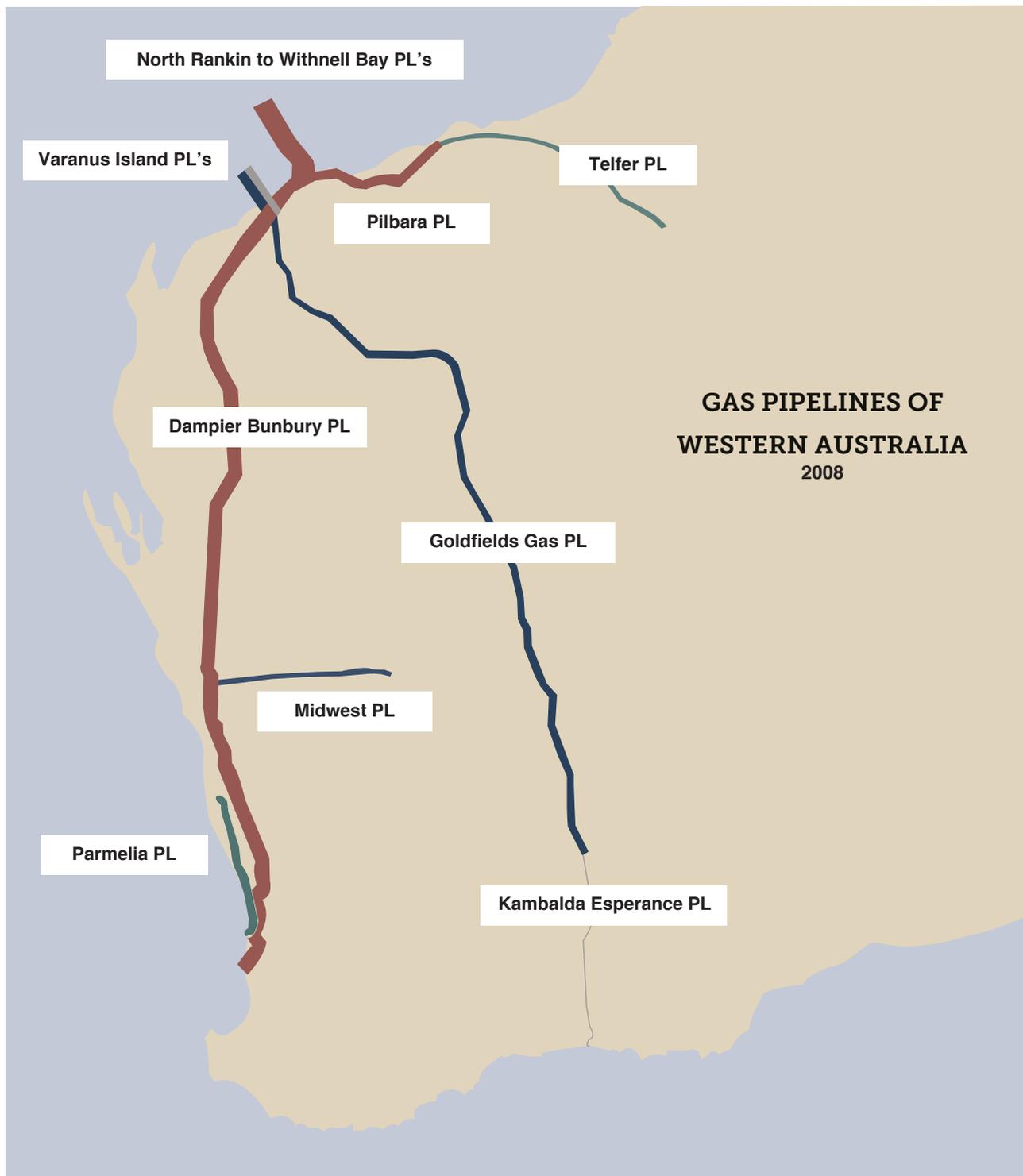
The Kwinana SIA has direct access to a deep-water port with bulk handling capability. The Kwinana Bulk Terminal and the Kwinana Bulk Jetty serve for the import and export of bulk cargoes and liquids, among them iron ore, coal, cement clinker, gypsum, liquefied natural gas, petroleum and fertiliser. Kwinana is serviced by major road, rail, power, gas, industrial water, industrial wastewater and potable water services.

A key constraint for the Kwinana area is land availability, given its location within a metropolitan area. There are also emerging electricity network capacity and water availability constraints.

The WA government intends to build a major container port and modern freight network at Kwinana, known as Westport. This provides a significant opportunity for economic growth within the Kwinana Industrial Area and an opportunity for government and industry to take a coordinated approach to planning and development of low carbon energy infrastructure as Westport navigates constraints from conflicting land use, business operations and infrastructure (government of Western Australia, n.d.).

Gas is readily available in Kwinana with access to transportation to the Perth area via the Dampier to Bunbury Natural Gas Pipeline (DBNGP) and then into Kwinana via the Parmelia pipeline. Kwinana is an important industrial region in several hydrogen trials presented below.

FIGURE 06: Gas distribution and transmission in WA



Differing line thickness indicates relative diameter of each pipeline; colours show different pipelines (PL).

INFORMATION BOX 6:**Australia's first hydrogen-ready transmission pipeline****APA Group, FFCRC and Wollongong University**

Working with research partners at the Future Fuels Cooperative Research Centre (FFCRC) and Wollongong University, and with A\$300k support from the WA government Renewable Hydrogen Fund, APA Group has launched a landmark hydrogen pilot project attempting to convert 43 kilometres of Parmelia Gas Pipeline in Western Australia into the first 100 percent hydrogen-ready transmission pipeline. The A\$3 million project under APA's pathfinder program will fund three phases: research and testing of the material for embrittlement in the laboratory, development of safe operating guidelines, and full-scale testing on-site.

APA is aiming to achieve the safe and efficient conversion of the pilot section into a hydrogen-ready service that could supply the Kwinana industrial precinct, where a number of existing customers already rely on hydrogen for industrial processing.

If successful, this world-leading initiative will help unlock energy solutions for the future (APA Group, 2021).

Information provided by APA Group

INFORMATION BOX 7:**Understanding the introduction of hydrogen into low-pressure gas distribution networks and the renewable hydrogen supply chain****Australian Gas Infrastructure Group**

In 2021 the Australian Gas Infrastructure Group (AGIG) completed a feasibility study supported by the WA government to determine the suitability of the Dampier to Bunbury gas pipeline for the introduction of hydrogen into its mix. The study included both technical assessment and development of a roadmap to support development of industry regulation (Department of Jobs, Tourism, Science and Innovation, 2022).

With a \$28.7m grant from ARENA, AGIG is working with ATCO to build on the feasibility study and develop a Clean Energy Innovation Park (CEIP) in Western Australia to deliver a commercial renewable hydrogen supply chain.

The CEIP is planned to be co-located with the 180MW Warradarge Wind Farm in Western Australia's mid-west, which will provide the renewable energy to power the electrolyser. Hydrogen will then be transported via truck to markets such as the existing gas network.

Information provided by Australian Gas Infrastructure Group

Emissions in Kwinana

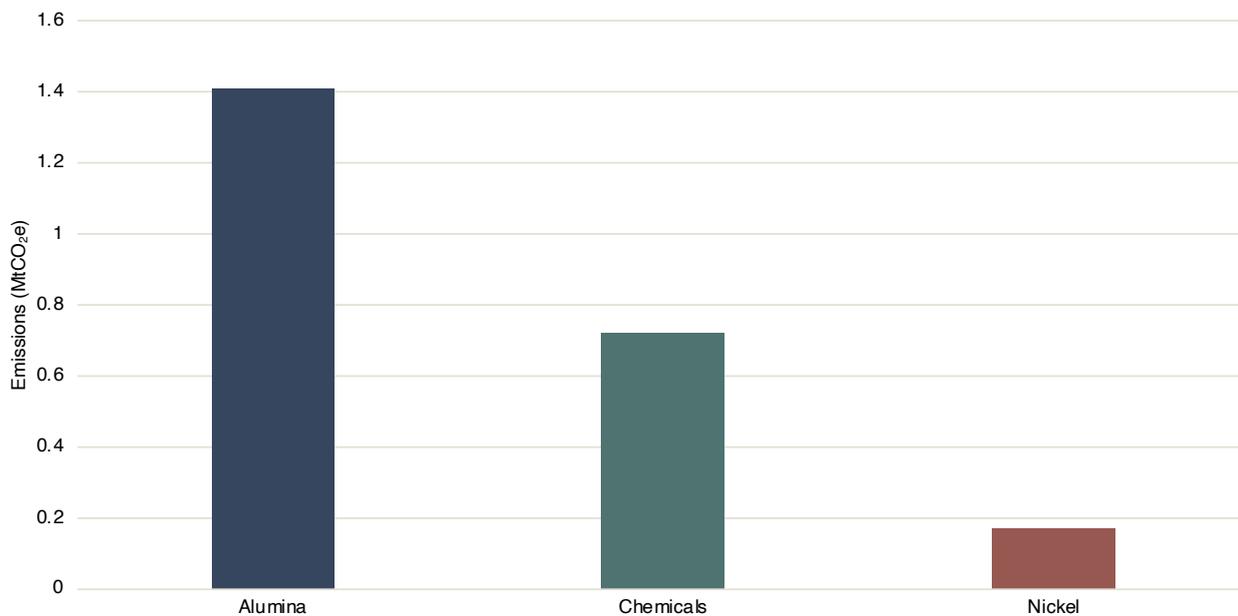
Industrial activity in supply chains where Australian Industry ETI partners have operations in Kwinana, are collectively responsible for 3 percent of Western Australia's annual emissions. There are more than 170 symbiotic exchanges that take place within the WTC area, such as 'coal companies supplying fly ash to cement firms, the neutralisation of alumina residue via carbon dioxide from local chemical plants, and a pigment plant supplying hydrochloric acid to a chemical manufacturer to produce sodium hyperchloride' (Kwinana Industries Council, 2020).

The production of ammonia and its derivatives is responsible for the majority of these emissions, with the conventional process of ammonia production consuming approximately 35 GJ of energy and generating 1.77 tonnes of CO₂e per tonne of ammonia produced. The conversion of ammonia to ammonium nitrate generates a further 0.25 tonnes of CO₂e per tonne of ammonium nitrate, due to the release of nitrous oxides (see Box 8).

The main source of emissions during alumina refining is the direct combustion of fossil-fuels for process heat and electricity. For every tonne of alumina produced, 10 GJ of energy is consumed, releasing 0.64 tonnes of CO₂e.

While nickel refining is emissions-intensive, requiring 52 GJ of energy and producing 1.91 tonnes of CO₂e per tonne of nickel produced, the scope 2 emissions of nickel refining in Kwinana are expected to be significantly reduced after BHP Nickel West signed a power purchase agreement (PPA) with Merredin Solar Farm. The agreement is expected to reduce emissions by up to 50 percent by 2040, based on 2020 levels.

FIGURE 07: Annual emissions of major industrial sub-sectors in Kwinana



Abatement opportunities in Kwinana

Mature and commercially available technologies like electric boilers in alumina refining, nitrous oxide abatement in chemicals and the use of renewable electricity are available to reduce Kwinana’s industrial emissions in the short term; however, not yet commercial and emerging net zero technologies are required to fully decarbonise the region’s heavy industry supply chains. Table 4 shows a number of key abatement options for Australian Industry ETI partner supply chains in Kwinana, including energy requirements and capital costs.

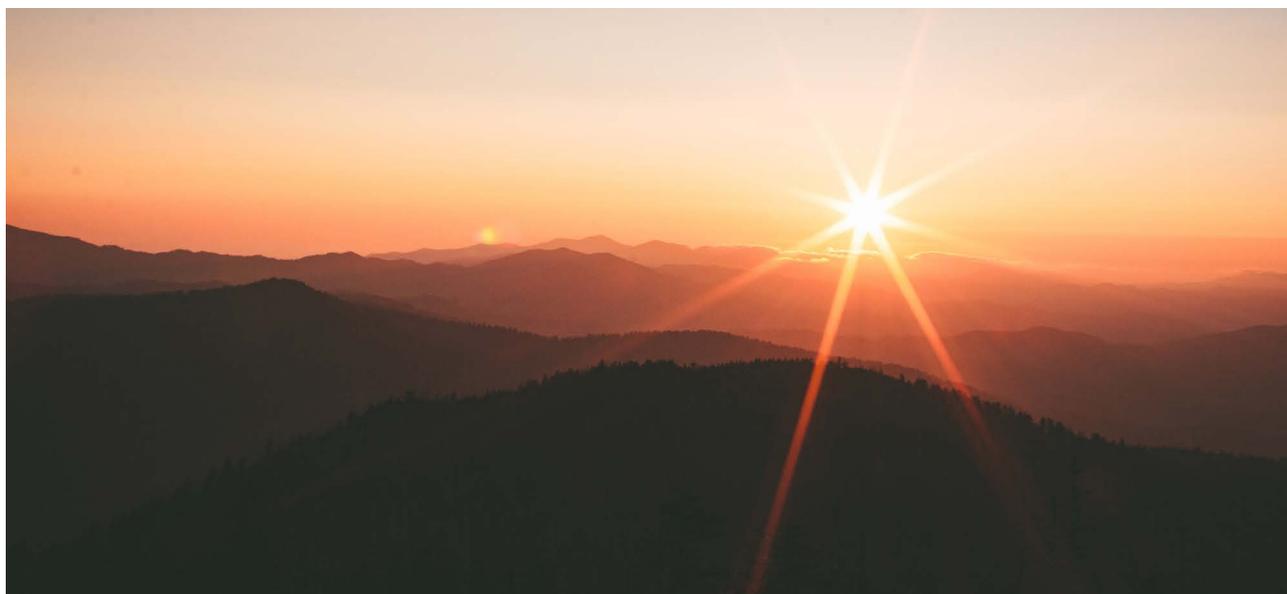


Table 04: Major abatement opportunities for Australian Industry ETI partner supply chains in Kwinana

Industry	Major, long-term abatement options	Readiness	Percentage identified industry abatement potential / year	Energy requirements	Energy capital costs (excluding infrastructure) ²¹
Alumina Refining	Electric boilers for digestion heat, powered by renewable electricity	Mature and commercially available	~71 percent = 1.0 MtCO ₂ e	3.8 TWh	VRE: A\$1.3 b Battery storage: A\$ 1.7 b
	Mechanical vapour recompression for digestion heat	Proven but not yet commercial		0.7 TWh	VRE: A\$0.3 b Battery storage: A\$ 0.3 b
	Green hydrogen for process heat in calcination	Proven but not yet commercial	~ 29 percent = 0.4 MtCO ₂ e	2.5 TWh	VRE: A\$0.8 b Electrolyser: A\$0.9 b
	Electrification of calcination powered, by renewable electricity	Emerging technology		0.6 TWh	VRE: A\$0.3 b Battery storage: A\$ 0.3 b
Ammonia and Ammonium Nitrate	Switch current electricity use to renewable electricity	Mature and commercially available	~ 6 percent = 0.1 MtCO ₂ e	0.1 TWh	VRE: A\$0.1 b
	Green Hydrogen as feedstock and Haber Bosch electrified and powered by renewable electricity	Proven but not yet commercial	~25 percent = 0.4 MtCO ₂ e	2.4 TWh	VRE: A\$1.0 b Electrolyser: A\$0.5 b Battery storage: A\$ 0.2 b
Nickel Refining	Switch current electricity use to renewable electricity ²²	Mature and commercially available	~59 percent = 0.1 MtCO ₂ e	0.1 TWh	VRE: A\$0.1 b
	Green Hydrogen for high heat processes	Proven but not yet commercial	~59 percent = 0.1 MtCO ₂ e	0.8 TWh	VRE: A\$0.4 b Electrolyser: A\$0.3 b

Alumina: The two major steps in alumina refining are digestion and calcination, both of which use process heat that is currently derived from fossil-fuels. Electric boilers can be used to provide the low heat demand of digestion, and if powered by renewable energy, could reduce emissions by 71 percent. Alternatively, mechanical vapour recompression (MVR) can be used to provide digestion heat and is currently undergoing feasibility studies to be implemented in Alcoa’s Wagerup refinery in Western Australia (Alcoa, 2021). Emissions reductions for calcination will rely on developments in emerging technologies, owing to the significantly higher temperatures required (around 1000 °C). The two major opportunities are the use of green hydrogen or electrification, which would further reduce emissions by 29 percent.

Ammonia and ammonium nitrate: Switching to zero emissions energy and feedstocks for ammonia and ammonium nitrate are the main solutions to decarbonising chemical production. For ammonia production, technologies to switch the current gas-based hydrogen feedstock to one produced entirely from renewables exist. However, in the absence of incentives for green ammonia production, this route is currently not cost-competitive with fossil fuel-based production.

21 Capital costs are based on current production capacities of each supply chain in Kwinana. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4–5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

22 Excludes the 50 percent of Kwinana Nickel Refinery’s electricity use that has already been contracted to a solar PPA in 2021.

INFORMATION BOX 8:

WesCEF's decarbonisation journey began 10 years ago

Wesfarmers Chemicals, Energy and Fertilisers

Wesfarmers Chemicals, Energy and Fertilisers (WesCEF) is a division of Wesfarmers and comprises nine industrial businesses that operate in domestic, national and international markets. Most of its facilities are located in Kwinana, producing and distributing essential products for the agricultural, mining, construction and manufacturing industries and energy for households and businesses.

WesCEF businesses include CSBP Chemicals and Fertilisers, which has a 110-year operating history in WA and natural gas provider Kleenheat which is WA's largest LPG and LNG retailer.

Both businesses are located in Kwinana and play a key role in WesCEF's three phase decarbonisation journey to achieve net zero by 2050.

The installation of abatement catalysts in CSBP's Nitric Acid Ammonium Nitrate plants in 2012 kicked off the first phase of WesCEF's decarbonisation journey. The catalysts resulted in the avoidance of over 700,000 tonnes of CO₂e emissions in FY2020; a 40 percent reduction compared to emissions WesCEF would have had, were it not for these catalysts.

Due to these catalysts, the Scope 1 emissions intensity associated with the production of Nitric Acid Ammonium Nitrate is approximately 0.25 tonnes of CO₂e per tonne of Ammonium Nitrate, compared to unabated levels of approximately 1.5 tonnes of CO₂e per tonne of Ammonium Nitrate.

In a great example of cross-industry collaboration, WesCEF's abatement performance led to an Australian-first in sustainability financing. In March 2020, Wesfarmers Limited entered into a sustainability linked loan with the Commonwealth Bank of Australia, the first of its kind in Australia. One of the criteria of this loan was WesCEF lowering the emissions intensity of its NAAN plants.

A year later, Wesfarmers built on the success of the loan by issuing an \$A1 billion denominated sustainability linked bond and a €600 million sustainability linked bond. These bonds were based on WesCEF's commitment to limit average emissions intensity to 0.25 tonne CO₂e per tonne of Ammonium Nitrate produced, or lower, over a two-year period, ending 31 December 2025. WesCEF's performance against this target will be reported by the end of March each year. The bonds also included a commitment by other Wesfarmers Divisions, including Bunnings, Kmart Group and Officeworks to increase their levels of renewable energy.

The ground-breaking nature of these bonds has been acknowledged globally, and Wesfarmers was recognised for its efforts by winning Finance Asia's 'Best Issuer Sustainability' 2021, as well as KangaNews' 2021 Awards in the following categories:

- Australian Sustainability Issuer
- Australian Innovative deal
- Australian Sustainability bond deal
- Australian Dollar Corporate bond deal
- Australian Origin Offshore corporate bond deal

WesCEF Managing Director Ian Hansen said the sustainability linked loan and bonds are great examples of what can be achieved when collaboration occurs across industries to deliver the aligned objective of tackling climate change.

Information provided by Wesfarmers Chemicals, Energy and Fertilisers

Nickel: Significant emissions reductions in nickel refining can be achieved in the next decade by switching current electricity use to renewables and using green hydrogen for high heat processes.

As shown in Table 4, most of the major abatement opportunities identified in the Kwinana region depend on zero emissions energy and feedstocks. An estimated total of up to 9.7 TWh of renewable electricity would be needed to power the three industries of alumina refining, ammonia and ammonia nitrate production, and nickel refining, requiring WA to expand its current variable renewable energy (VRE) generation by 87 percent (Australian Energy Statistics, Table of Electricity generation by fuel type 2019-20 and 2020, 2021). A transition to a zero-emissions energy system could cost up to A\$7.3 billion to secure the necessary VRE, storage, and electrolyser capacity.

Estimated jobs opportunity

The estimated A\$3.9–A\$7.6 billion of capital investment in decarbonisation in Kwinana could support between 15,000 and 31,000 jobs; of which, 34 percent are created in Kwinana and 66 percent across Western Australia.

Activities already underway in Kwinana

The WA government has established a new ministerial taskforce to support the transformation of the Western Trade Coast into a ‘global advanced industries hub’. The taskforce will ‘oversee development of an economic framework for the hub with a focus on industry development and attraction, land and infrastructure, and skills and workforce development, among other opportunities’ (Government of Western Australia, 2021a). The economic framework is expected to align with the WA government’s commitment to net zero emissions by 2050.

The Technology and Decarbonisation Working Group set up under the WA government’s LNG Jobs Taskforce is collaborating with the Future Energy Exports Cooperative Research Centre to investigate the development of a Futures Facility called Kwinana Energy Transformation Hub (KETH), microscale research and teaching plant to allow testing of new LNG and hydrogen processes in Kwinana (The Western Australian LNG Jobs Taskforce working groups, 2021).

The Western Australian government has a strong focus on hydrogen industry development, including a 10 percent target for renewable hydrogen to be blended into WA’s existing gas pipelines and networks (Western Australian Renewable Hydrogen Strategy and Roadmap, 2019) as part of the State’s Renewable Hydrogen Strategy (2019).

Several development projects are already underway in Kwinana, many of which are highly relevant to the future decarbonisation of the region.

bp Australia and Macquarie Capital are undertaking a feasibility study into the production of green hydrogen at bp Australia’s Kwinana site, supported by A\$300k funding from the WA government’s Renewable Hydrogen Fund (Cabinet, 2021).

Woodside Petroleum plans to spend A\$1 billion to develop a hydrogen and ammonia production hub, initially consisting of one-third green hydrogen. A combination of abatements, offsets, and renewable energy certificates will aim to offset 100 percent of all emissions at the plant (Shine, 2021).

A 100MW battery storage system, located at Synergy’s Kwinana Power System, is under development and could be operational by late 2022 (Cabinet, 2021b); while BHP Nickel West has opened its new nickel sulphate plant, a key material in lithium-ion batteries (Cabinet, 2021a).

WesCEF has entered into a memorandum of understanding with Mitsui & Co to explore opportunities to export ~1 million tonnes per annum of low carbon Ammonia to Japan as a substitute for coal in power generation. The partnership combines WesCEF’s deep experience in Ammonia manufacturing and local knowledge with Mitsui’s gas assets and the prospect of using Mitsui’s depleted gas fields in the Perth Basin for carbon capture and storage.

What is needed

To date, government support has predominantly focused on capital contribution to stimulate the production of hydrogen. However, corresponding demand and offtake agreements are essential to underpin investment in clean hydrogen projects and supporting infrastructure at scale. In Kwinana, there are at least six existing users of grey hydrogen (produced from steam methane reformation without CCS). In theory, this existing domestic grey hydrogen demand provides a ready market for clean hydrogen. However, the cost differential between grey hydrogen and clean hydrogen is much higher than green premium users might be prepared to pay at this time. Lowering the cost of renewable electricity, which is a significant input cost for green hydrogen, will help reduce the gap as will falling costs in electrolyzers, but this will take time.

State and Federal governments can consider developing policies to reduce the cost differential between grey and clean hydrogen and stimulate new demand. Targeted policy incentives to encourage the development of a local hydrogen industry, like an obligation on natural gas users to procure a certain percentage of clean hydrogen (similar to how the Renewable Energy Target operates) would be one way of stimulating such demand.

Regulatory changes at both state and federal levels are also needed. These changes should enable or provide policy certainty around the production, transportation and use of hydrogen as well as the capture, handling, use and sequestration of carbon dioxide. Reviews are currently underway at both state and federal levels, but they could be accelerated to provide greater certainty sooner to industry and investors.

Developing the opportunities for regional decarbonisation at scale

Kwinana presents a unique opportunity to scale decarbonisation opportunities within an emissions-intensive industrial region. Technical and commercial barriers remain to be overcome, particularly around delivering decarbonised, firm renewable electricity as well as green hydrogen at scale to decarbonise current and potential new export-oriented industries.

Opportunities to decarbonise the Kwinana region demonstrated in Table 4 would significantly reduce emissions from the region. In aggregate, these opportunities require investment of up to A\$7.3 billion in additional renewable energy generation, hydrogen production and energy storage.

There will be limited opportunity for onsite renewable generation in the Kwinana Industrial Area given land constraints. Therefore, investment is required to facilitate the delivery of decarbonised energy into the region, either in the form of electricity or molecules such as ammonia or hydrogen.

Coordination of a complex system transition

Coordination to support industrial decarbonisation in Kwinana should focus on planning and development of multi-user infrastructure, stimulating early demand for clean hydrogen and developing offtakes, and addressing regulatory challenges to enable clean hydrogen production, transportation and use.

A key challenge to overcome in enabling the decarbonisation of the region is to deliver low-cost decarbonised energy, through both renewable electricity and clean hydrogen, into the precinct at the scale required. This is front of mind for decision making in organisations in the WTC.

Access to low-cost, clean electricity (including generation, network and any market costs) is a priority for industry. It will be particularly important for the production of competitively priced green hydrogen because electricity accounts for up to 70 percent of hydrogen production costs (World Economic Forum, 29 June 2021).

To minimise network and market costs, on-site renewable generation is typically favoured. However, there is not sufficient land available directly in Kwinana for large-scale, low-cost on-site solar and wind generation, therefore the role of networks in transporting renewable electricity is important to connect tenants with low-cost clean energy from outside of the WTC.

However, with increased demand for electricity in the vicinity of 4.8 to 9.7 TWh, there are likely to be both transmission and distribution capacity constraints in the area. The scale of investment needed to alleviate constraints is recognised as likely being cost prohibitive for a single user to fund. A coordinated approach by industry and the network operator, Western Power, would help address these grid challenges.

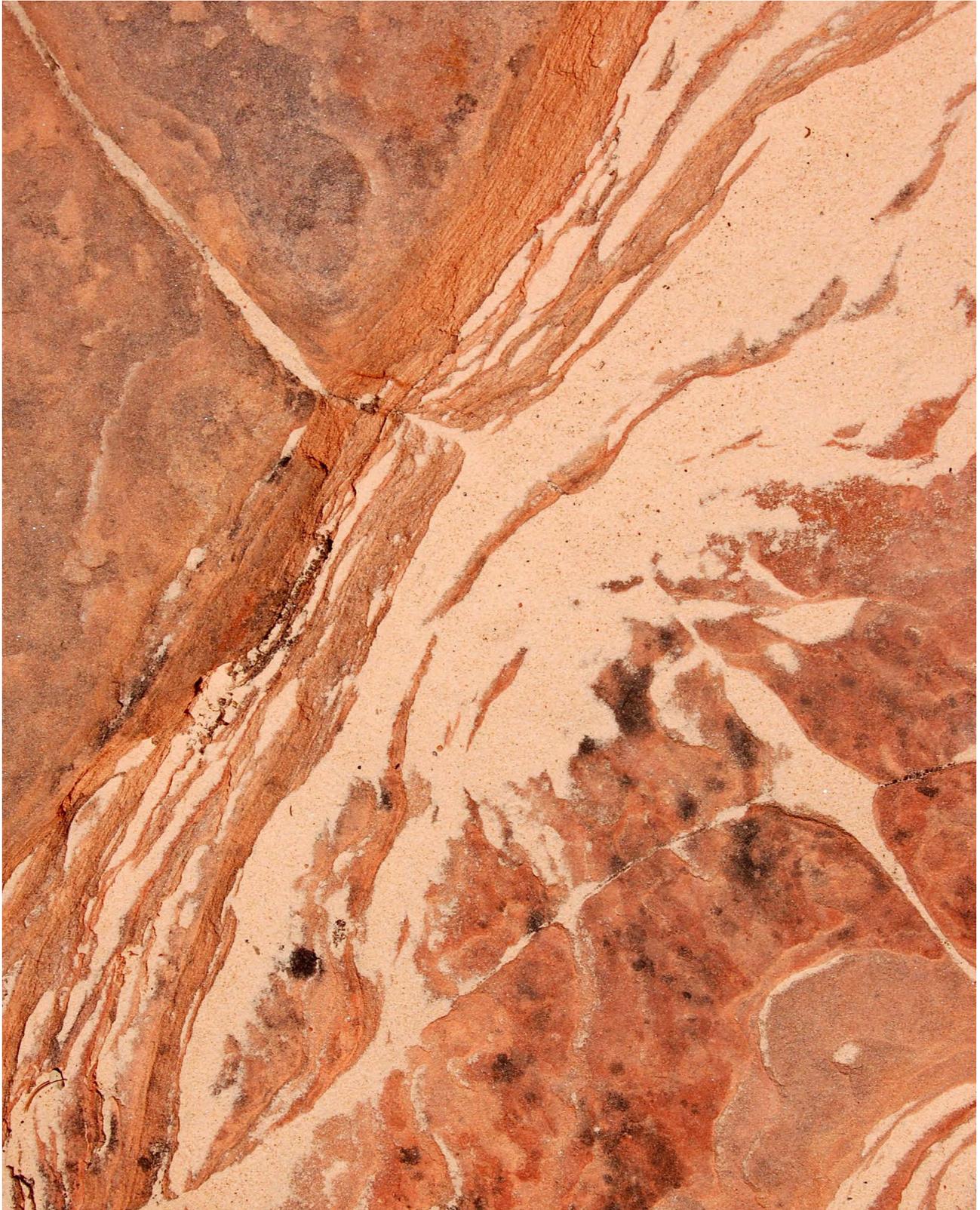
Given Kwinana is within the Perth Metropolitan area, there is the potential to benefit from the early deployment of hydrogen, leveraging Perth's natural gas and road freight networks for offtake. Action in the near term should focus on demonstrating and scaling a hydrogen network with aggregated demand, supply and multi-user infrastructure for the region to facilitate learning benefits and economies of scale as the use of hydrogen expands. Within the KIA, industries such as ammonia as well as nickel and alumina refining present near-term opportunities for the demonstration of these technologies and early offtake that can lead to the development of export-oriented industries. Leveraging the existing hydrogen demand and work undertaken by industry in the area can help gain an advantage in hydrogen market development and a deeper understanding of carbon capture and storage (CCS) and the role this might play in the area.

Collaboration across multiple stakeholders

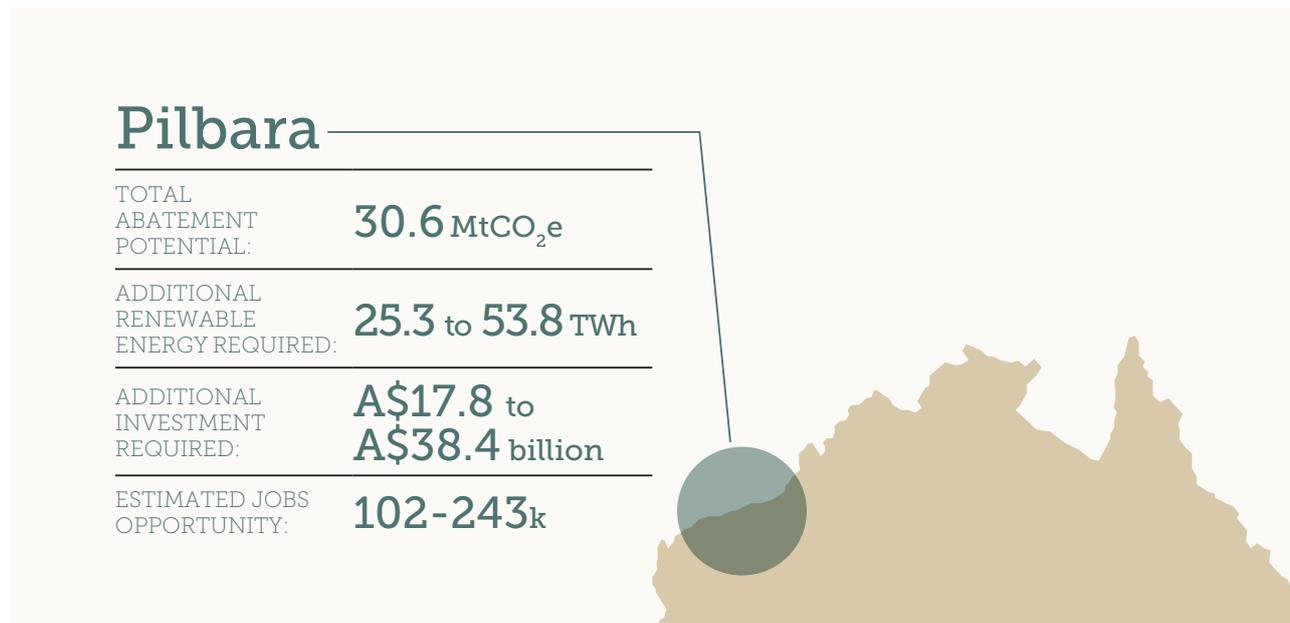
Kwinana has a high concentration of interconnected heavy industry operations, such as 'coal companies supplying fly ash to cement firms, the use of recycled carbon dioxide in the alumina process, and a pigment plant supplying hydrochloric acid to a chemical manufacturer to produce sodium hyperchloride' (Kwinana Industries Council, 2020). Collaboration between companies is at both operational and strategic levels with strong representation in joint leadership through the Kwinana Industries Council (KIC). This provides a strong basis for companies to come together to work on regional decarbonisation solutions across energy, feedstocks and infrastructure.

Collaboration in Kwinana is focused on increasing access to affordable renewable electricity and hydrogen as well as expanding transmission infrastructure and pipelines for hydrogen and CO₂ management. Joint efforts in Kwinana also focus on strengthening and formalising activities being identified through the KIC's Carbon Reduction Plan to enable large-scale emission abatement projects and planning for large-scale renewable energy and infrastructure solutions.

Collectively and individually, the KIC and industry are grappling with the limitations of land and renewable energy supply in the area. Industry can collaborate to explore solutions such as the use of hydrogen as an energy carrier to manage grid network constraints.



1.2 Focus on Pilbara



- Extensive region in northwest WA, equivalent in size to Spain.
- Responsible for a major portion of the production, value, exports and investments of extraction industries commodities.
- Annual economic output of A\$88 billion.
- Low-cost, decarbonised energy systems are needed to enable net zero emissions production and new decarbonised industries such as green iron production at scale.

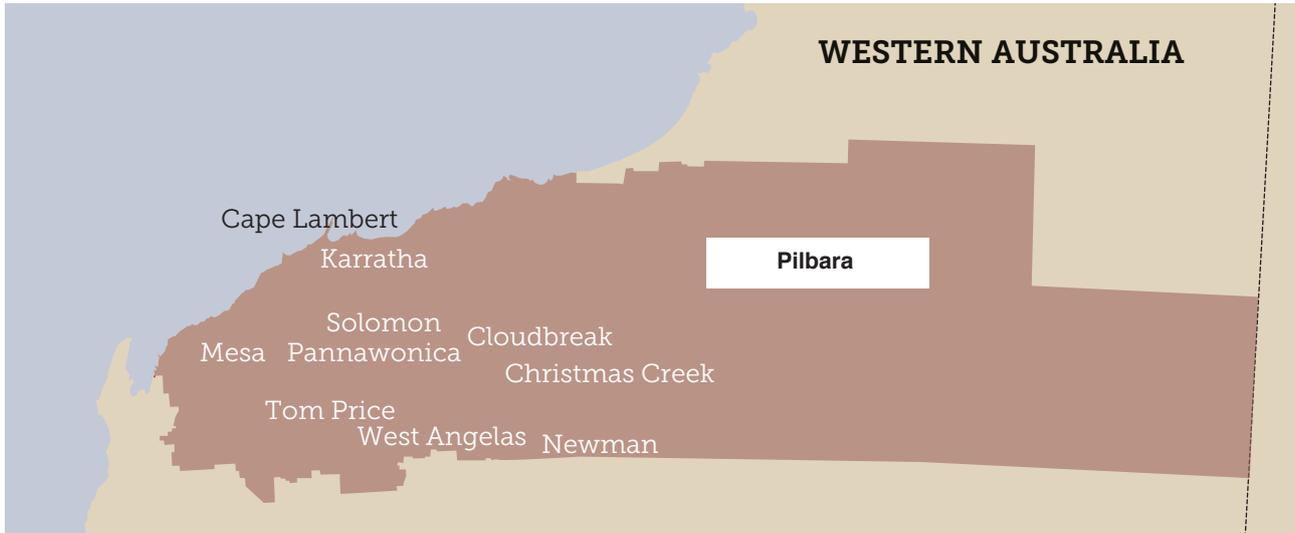
What is needed

- Leverage the region's huge renewable energy potential to support future industries.
- Coordinated regional approach to renewable electricity, hydrogen and energy infrastructure, to enable effective, large scale electrification and integrated hydrogen, supported by new multi-stakeholder models and ways of working.
- Coordinated industry and government support for new low carbon iron and steel technologies research and development and demonstrations, including post extraction processes for hematite ores for green steel manufacture.
- Industry in the region to work together with original equipment manufacturers to accelerate decarbonisation of haulage and shipping.
- Large scale development of the North-West Interconnected System, off-grid and stand-alone grids in the region at the scale needed to support large scale electrification of extraction industries.

The Pilbara is Western Australia's second most northern region and extends from the Indian Ocean in the east across to the Northern Territory border in the west. The semi-arid region has a total area of 507,896km² including offshore islands (RDA Pilbara, 2017) and is home to 62,841 people, supporting 63,850 jobs with an annual economic output of A\$87.773 billion (Economy, Jobs and Business Insights, n.d.). By 2035, the region is expected to have a resident population of more than 140,000, based on the growth and diversification of the economy (Pilbara, n.d.).

The Pilbara has four local government areas: the City of Karratha, Shire of Ashburton and Shire of East Pilbara and the town of Port Hedland. The Pilbara is on the doorstep of Asia with existing and easy access to key Asian markets. Asia accounted for 80 percent of global iron ore demand in 2020, with China (63 percent), India (8 percent), Japan (4 percent) and South Korea (3 percent) having the largest shares (Government of Western Australia, 2021a). The Pilbara region is an international gateway for trade with an existing skilled workforce, deep ports and Asian supply routes (with three major ports and two major airports), and operational centres for several global resource companies, including BHP, Rio Tinto, Fortescue, Roy Hill, Woodside Energy and Chevron.

FIGURE 08: The Pilbara



The Pilbara is a global biodiversity hotspot for subterranean fauna and includes numerous culturally significant Aboriginal heritage sites, including the Burrup Peninsula which has one of the world’s largest collections of prehistoric rock art. It is also known for its vast mineral deposits, in particular, iron ore and offshore oil and gas, with projects operated by a large fly-in-fly-out (FIFO) workforce. Indigenous communities are key stakeholders for projects, industrial clusters and transition planning especially with respect to the workforce, land use, native title and heritage.

Recently the Pilbara has also been recognised for its vast, world-class solar and wind resources: a potential catalyst for activating huge investment in decarbonising existing industries and creating new low carbon competing and complementary ones in the region (Pilbara Development Commission: Energy, n.d.).

Mining, construction and exports dominate the Pilbara’s economy. The region is the state’s mining powerhouse and makes a significant contribution to the national wealth. The iron ore and LNG industries are valued at over A\$70 billion, representing more than 70 percent of mineral and energy production in Western Australia (Regional Development Australia (RDA) Pilbara, 2020). The Pilbara is home to Australia’s most valuable export commodity, iron ore. Western Australia is the largest iron ore supplier in the world, accounting for 39 percent of global supply (government of Western Australia, 2021a) and 28 percent of the world’s crude iron ore reserves in 2020, with most of these reserves located in the Pilbara region. In 2020-21, Western Australia had an estimated 48.8 billion tonnes of economic demonstrated iron ore resource which could sustain production for 56 years (at 2020-21 production rates).

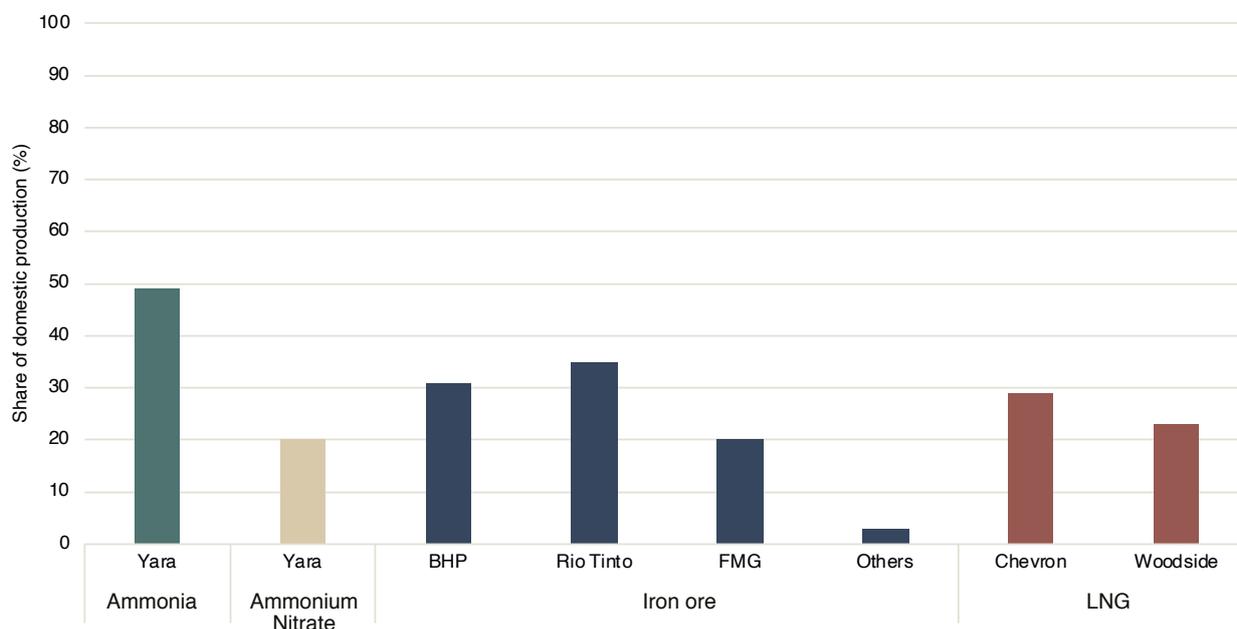
Many Pilbara companies, especially Australian Industry ETI partners, are focused on decarbonisation with clear net zero commitments and ongoing work to align strategy and governance. Organisations in the region are highly competitive with each other, with a history of duplicated energy and transport infrastructure. Coordination and collaboration in some areas (e.g. infrastructure, energy supply, equipment) is now seen as necessary, although organisations are cautious, needing to balance production risk management and competitive realities with the mutual benefit of multi-user infrastructure.

Production in the Pilbara

The Pilbara region is responsible for a major portion of the production, value, exports and investments of extraction industries commodities, particularly iron ore and LNG (The Pilbara Producing Local, Selling Global, n.d.)

In 2021, Australia was the world’s largest LNG exporter with a record 80.9 million tonnes shipped, earning an estimated A\$48 billion, according to consultancy EnergyQuest (Bethune, 2022). Western Australia is the dominant export region, accounting for 57 percent of shipments, with the Woodside Petroleum-managed North West Shelf venture the country’s single biggest exporter, followed by Chevron’s Gorgon and Wheatstone plants (Regional Development Australia (RDA) Pilbara, 2020). The Pilbara produces a combined total of 43 Mt of LNG, representing 52 percent of domestic production. Two companies contribute to this production: Chevron, with their Gorgon (18 percent) and Wheatstone (11 percent) facilities; and Woodside Energy, with their Pluto (5 percent) and North West Shelf (18 percent) facilities.

The Yara Pilbara Fertilisers plant produces 0.85 Mt of ammonia, representing just under half of Australia’s domestic production. The Yara Pilbara Nitrates plant produces 0.35 Mt and 20 percent of domestic ammonium nitrate for commercial blasting.

FIGURE 09: Share of domestic production of major industrial sub-sectors in the Pilbara

Energy in the Pilbara

The North West Interconnected System (NWIS) is in the Pilbara, extending from Karratha, south to Newman and east beyond Port Hedland. The NWIS comprises a number of interconnected electricity networks with both government and private owners. There is also a significant amount of non-connected generation. A distributed energy resource microgrid has been successfully piloted in Onslow, using solar photovoltaic (PV) (utility and rooftop) and batteries.

INFORMATION BOX 9:

\$450 million investment into Pilbara Energy Connect Program

Fortescue Metals Group

The Pilbara Generation Project complements the US\$250 million Pilbara Transmission Project announced in October 2019, and will provide low-cost power to the energy-efficient Iron Bridge Magnetite Project.

The Pilbara Transmission Project consists of 275km of high-voltage transmission lines connecting Fortescue's mine sites, while the Pilbara Generation Project will include 150MW of gas-fired generation, together with 150MW of solar photovoltaic (PV) generation. This will be supplemented by large-scale battery storage and will be constructed, owned and operated by Fortescue.

Together, the transmission and generation projects, totalling US\$700 million, form the Pilbara Energy Connect Program, providing Fortescue with a hybrid solar-gas energy solution that will enable low-cost power to be delivered to Iron Bridge. This allows Fortescue to leverage its existing energy infrastructure including the Fortescue River gas pipeline and generation capacity at the Solomon Power Station, and supports the incorporation of large-scale renewable energy.

Pilbara Energy Connect builds on Fortescue's previous energy initiatives, including the construction of the Fortescue River Gas Pipeline, the conversion of the Solomon Power Station from diesel to gas generation, as well as a partnership agreement with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to develop and commercialise hydrogen technology (Fortescue Metals Group, 2020).

Information provided by Fortescue Metals Group

The WA government has developed a light-handed access regime to facilitate third party access to ‘covered’ electricity networks in the Pilbara, which include the networks of Horizon Power (a state government trading enterprise) and Alinta Energy (Pilbara Electricity System, n.d.). To complement this reform, a Pilbara independent system operator has been created to maintain and improve system security, and facilitate network coordination and planning. There is no reserve capacity market and no central balancing market or dispatch; each network operator/retailer manages its own dispatch and own generation adequacy.

Electricity generation utilised by the key sectors is overwhelmingly supplied by gas (99 percent), while diesel and solar together make up around 0.1 percent. A significant amount (68 percent) of energy generation is self-supplied, generated and used by companies with operations in the region (Electricity sector emissions and generation data, 2021).

Infrastructure in the Pilbara

Ports are located in Ashburton (near to Onslow), Dampier and Port Hedland with an offshore port at Varanus Island. 697 million tonnes (Mt) passed through Pilbara ports in 2018–19, reaffirming the region’s status as the world’s largest bulk export port authority (Port Profile, n.d.).

There are also depleted oil and gas reservoirs that could potentially be used for greenhouse gas (GHG) storage.

There are nine water supply schemes in the Pilbara region. Alluvial aquifers are the predominant source of water for the larger schemes. Water use in mining operations and mine dewater discharge accounts for almost 90 percent (360 GL/year) of all water abstracted or produced in the Pilbara (Government of Western Australia, 2013).

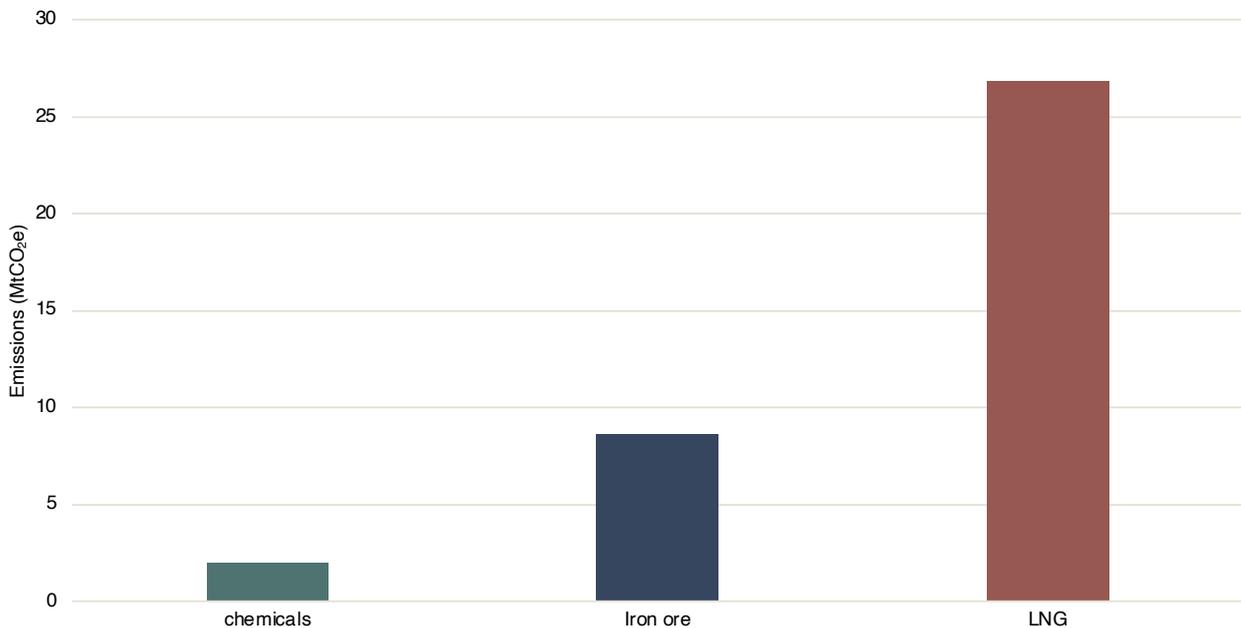
The Pilbara has about 2,300km of railways of which the majority is owned by mining companies.

Emissions in the Pilbara

The Australian Industry ETI supply chains in the Pilbara are responsible for around 41 percent of Western Australia’s emissions. The bulk of these emissions result from the production and liquefaction of gas for export. The main source of emissions in gas production is non-energy emissions from leakage, venting, and flaring; while emissions from liquefaction result from its large energy requirements. In the Pilbara, this results in 27 MtCO_{2e} being emitted annually, excluding significant additional scope 3 emissions from the end-use of exported gas.

The mining and haulage of iron ore is the second highest contributor to emissions in the Pilbara region, primarily from the use of diesel in vehicles and machinery, and electrified mining processes (9 MtCO_{2e}). Lastly, the production of ammonia and ammonium nitrate results in 2 Mt of total annual emissions.

FIGURE 10: Annual emissions by major industrial sub-sector in the Pilbara



Abatement opportunities in the Pilbara

Mature technologies are available to reduce industrial emissions in the Pilbara in the short term; however, net zero technologies that are not yet commercial are required to fully decarbonise. Table 5 below shows a number of key abatement options, including the scale of energy requirements and capital costs necessary to achieve significant emissions reductions.

TABLE 5: Major abatement opportunities for Australian Industry ETI partner supply chains in the Pilbara

Industry	Major, long-term abatement options	Readiness	Percentage identified industry abatement potential	Energy requirements	Energy capital costs (excluding infrastructure) ²³
LNG ²⁴	LDAR and vapour recovery for fugitive emissions. Waste heat recovery during liquefaction	Mature and commercially available	~12 percent = 0.9–3.2 MtCO ₂ e	-	-
	Electric drives for liquefaction ²⁵	Proven but not yet commercial	~39 percent = 2.8–10.4 MtCO ₂ e	5.8–21.4 TWh	VRE: A\$ 2.3–8.6 b Battery storage: A\$ 2.6–9.8 b
	CCS for reservoir gas	Proven but not yet commercial	~28 percent = 2.1–7.6 MtCO ₂ e	-	-
AMMONIA AND AMMONIUM NITRATE	Nitrous oxide abatement	Mature and commercially available	~25 percent = 0.5 MtCO ₂ e	-	-
	Switch current electricity use to renewables	Mature and commercially available	~5 percent = 0.1 MtCO ₂ e	0.2 TWh	VRE: A\$0.1 b Battery storage: A\$0.1 b
	Green hydrogen as feedstock and Haber Bosch electrified and powered by renewables	Proven but not yet commercial	~70 percent = 1.4 MtCO ₂ e	8.0 TWh	VRE: A\$2.5 b Electrolyser: A\$1.7 b
IRON ORE	Switch to renewable electricity for site operations (excluding haulage)	Mature and commercially available	~26 percent = 2.2 MtCO ₂ e	3.2 TWh	VRE: A\$1.8 b Battery storage: A\$0.05 b
	Battery electric trucks with trolley assists	Proven but not yet commercial	~62 percent = 5.3 MtCO ₂ e	8.2 TWh	VRE: A\$2.7 b Battery storage: A\$3.6 b
	Hydrogen fuel cell electric trucks	Proven but not yet commercial		21.0 TWh	VRE: A\$6.9 b Electrolyser: A\$6.6 b

Where technology options do not require renewable energy (and corresponding investment) energy and energy capital costs are zero.

²³ Capital costs are based on current production capacities of each supply chain in the Pilbara. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4–5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

²⁴ The lower end of the range for abatement potential, energy requirements, and capital costs represents a ~73 percent reduction in Australia's LNG production by 2050 aligned to IEA Net Zero scenario.

²⁵ Electric drives for greenfields are 'mature and commercially available' but for brownfields are considered 'proven but not yet commercial' due to various retrofitting and operational challenges.



LNG: The main focus for emissions reduction technologies for current sites is in leak detection and repair (LDAR), capture and storage of emissions from reservoirs and re-injection of venting gas. These options generate improvements in efficiency and productivity and offer abatement potentials of up to 12 percent. The largest opportunity for decarbonising natural gas liquefaction is in the transition away from gas-fired turbines to electric drives, powered by renewable electricity. Electric drives have higher capital expenditure requirements than gas turbines but have a short payback period when the value of fuel gas saved is considered (ABB, n.d.). However, the scale and complexity of works to retrofit the technology are significant and, as such, this would mainly be considered for greenfield sites.

Ammonia and ammonium nitrate: Switching to zero emissions feedstocks for ammonia production and deploying mature nitrous oxide abatement solutions in the production of ammonium nitrate are the main solutions to decarbonising chemical production, but each face different barriers to uptake. For ammonia production, technologies to switch the current gas-based hydrogen feedstock to one produced entirely from renewables does exist. However, in the absence of incentives for green ammonia production, this route is currently not cost competitive with fossil-fuel based production. The main barrier to deploying nitrous oxide abatement solutions stem from the fact that, in addition to high capital expenditure (CAPEX), there are limited commercial incentives, given that in the absence of any penalty on emissions, reducing non-energy emissions delivers no economic return for producers.

Iron ore: With diesel-based haulage accounting for more than half of emissions in iron ore production, finding zero-emissions alternatives is a primary challenge. The use of battery electric vehicles (BEV) or hydrogen fuel-cell electric vehicles (FCEV) has the potential to abate 62 percent of emissions. However, the use of BEV and FCEV in mining haul is not yet commercially available, with concerns regarding battery size, charging infrastructure and the uncertainty of green hydrogen costs.

INFORMATION BOX 10:

World first hydrogen-powered coach fleet via partnership with Hyzon

Fortescue Metals Group

A key decarbonisation goal for Fortescue is, by 2030, to replace the roughly 700 million litres of diesel it uses every year across its truck, train and shipping fleets with 15 million tonnes of green hydrogen.

Fortescue Metals Group is introducing hydrogen-powered coaches to its fleet at the Christmas Creek iron ore mine in Western Australia's Pilbara region through a collaboration with US startup Hyzon Motors (Haselgrove, 2020). Fortescue's mobile fleet represents around 400 to 450 million litres of diesel consumption per year, and a significant opportunity to decarbonise an element of their supply chain.

The collaboration will see a fleet of 10 hydrogen fuel-cell buses built to service the Pilbara region. Hyzon will supply the buses to replace a fleet of diesel vehicles and install a refuelling station that will use energy from Fortescue's solar-gas hybrid system.

The custom-built buses will initially be imported from outside Australia, but Hyzon plans to eventually manufacture them locally, leading to further economic benefits and job opportunities in the region (Hyzon, 2020).

Information provided by Fortescue Metals Group

As shown in Table 5, the vast majority of net-zero solutions depend on zero emissions energy and feedstocks, demanding a considerable expansion and transformation of the Pilbara's energy system. There is a long-term opportunity for the Pilbara to build a competitive advantage in variable renewable energy, although ensuring reliability while managing costs will be a key challenge.

Estimated jobs opportunity

The estimated A\$17.8-38.4 billion of capital investment in decarbonisation in the Pilbara could notionally support between 102,000 and 243,000 jobs; of which, 34 percent are created in the Pilbara and 66 percent across Western Australia. Short term capital investment of A\$1.8 billion to switch current electricity use to renewable energy could support 8,000 jobs.

Activities already underway in the Pilbara

The Pilbara is host to a growing number of development projects which will be highly relevant to the future decarbonisation of the region. There are plans for multiple gigawatt scale renewable energy projects like the Asian Renewable Energy Hub, Rio Tinto's 1GW renewable investment, Fortescue's 5.4GW Uaroo Renewable Energy Hub and Pilbara Energy Connect projects. Investigations into Pilbara ore processing for green steel making are underway by the Heavy Industry Low-Carbon Transition Cooperative Research Centre (HILT CRC) and the Minerals Research Institute of Western Australia (MRIWA). Rio Tinto and BlueScope Steel have partnered to explore low carbon steel making (see Box 4). Yara Pilbara and ENGIE will build a renewable hydrogen plant to produce renewable ammonia. The project is supported by a A\$42.5 million grant from the ARENA Renewable Hydrogen Deployment Funding Round (Renewable hydrogen and ammonia production (Yara International, 2021). Industry is working together on the role of CCS with Woodside and bp collaborating with Japan Australia LNG (MIMI) on a feasibility study of a multi-user CCS project near Karratha.

INFORMATION BOX 11:

Australian CCS study

Woodside, bp and MIMI

Woodside, bp, and MIMI are collaborating on a feasibility study for the first multi-user carbon capture and storage (CCS) project near Karratha in Western Australia. Japanese companies Mitsubishi and Mitsui will participate in the survey through MIMI, their Australian joint venture for LNG (Cavcic, 2021). The consortium's aim is to assess the technical, regulatory and commercial feasibility of capturing carbon emitted by multiple industries located near Karratha on the Burrup Peninsula and storing it in offshore reservoirs in the Northern Carnarvon Basin. The study aims to assess the potential to store captured carbon dioxide in depleted gas fields off the coast of Western Australia. Although nothing has been decided in terms of investment or carbon dioxide reduction. If successful, the storage facility would be expected to begin operating around 2030 (Suzuki, 2022).

Information provided by bp

What is needed

Developing opportunities for regional decarbonisation at scale

Central to the decarbonisation and transition of heavy industry to net zero in the Pilbara is scaling the use of renewables-based electricity supply and low emissions storage technologies, the coordination of enablers to make it possible, coordination on iron ore mining and processing decarbonisation, and support for the region's participation in a global green steel market.

Development of the infrastructure needed to decarbonise the region's energy system is a key first step. Electrification can only take the region so far. Many Pilbara industrial sectors, most notably the mining and energy extraction sectors have processes considered 'hard to abate'. Current electrification technologies are simply unable to meet the energy needs of the key mobile mine equipment used in today's modern mines, such as haulage and excavation vehicles. With this equipment accounting for over 60 percent of the sectors' scope 1 and 2 emissions, alternative energy solutions and the infrastructure to support their needs are to be found.

The same can also be said of the world-scale rail, marine and shipping sectors which support the regions' exports. With its unique locality and access to, or potential for, the physical resources required (land, water, low-cost gas and renewable electricity, depleted gas reservoirs), regional production of low carbon and green hydrogen, together with the use of bio-based 'drop-in' fuels has great potential to both reduce cross-sector supply chain emissions and act as a catalyst for new domestic and export market opportunities.

Coordination of a complex system transition

A coordinated approach to industrial decarbonisation in the Pilbara can result in larger scale energy systems being developed, enabling more effective and larger-scale electrification of operations and integrated hydrogen systems.

Industrial operators in the Pilbara have historically focused on developing infrastructure such as energy generation, rail and road on a single entity basis, rather than coordinating development. With the scale of transformation required for decarbonisation, coordinated efforts now will enable more effective decarbonisation of operations in existing industries and potentially enable new low carbon energy and industrial export industries such as green hydrogen, green ammonia and green iron.

A key first step is investigation of and planning for the scale-up in the actions required to decarbonise the region's existing, still largely fossil-fuel-driven energy system. Given the decarbonisation opportunities identified in analysis for this report, as much as 53 TWh of electricity would be required from renewable energy sources to enable the opportunities. This equates to 20 percent of Australia's total electricity generated in 2019–20. With such a significant build out of infrastructure needed, alongside integration, energy management and storage to ensure firm supply for large-scale industrial operations, a coordinated, planned approach to infrastructure development would enable faster uptake and more effective investment to maximise export opportunities.

Planning and coordination on an iron and steel decarbonisation roadmap for the region should consider the potential for future development of new export-focused industries in light of the shifting risks and opportunities presented by global decarbonisation. Coordinating industry and government support around the development of new low carbon iron and steel technologies can help.

Collaboration across multiple stakeholders

One of the key focus areas for companies in the Pilbara is increasing the share of renewables in their operations. This includes displacing fossil-fuel based electricity for LNG production, chemicals manufacture and mine site equipment in the short term and displacing diesel through electrification for haulage in the medium to longer term. Traditionally, Pilbara operators have deployed individual infrastructure and energy solutions. As discussed above, the scale and speed of the decarbonisation challenge has generated a growing need to collaborate on regional solutions for renewable energy and hydrogen generation, transmission, storage and firming. Collaboration may result in making this challenge achievable more quickly, with fewer resources.

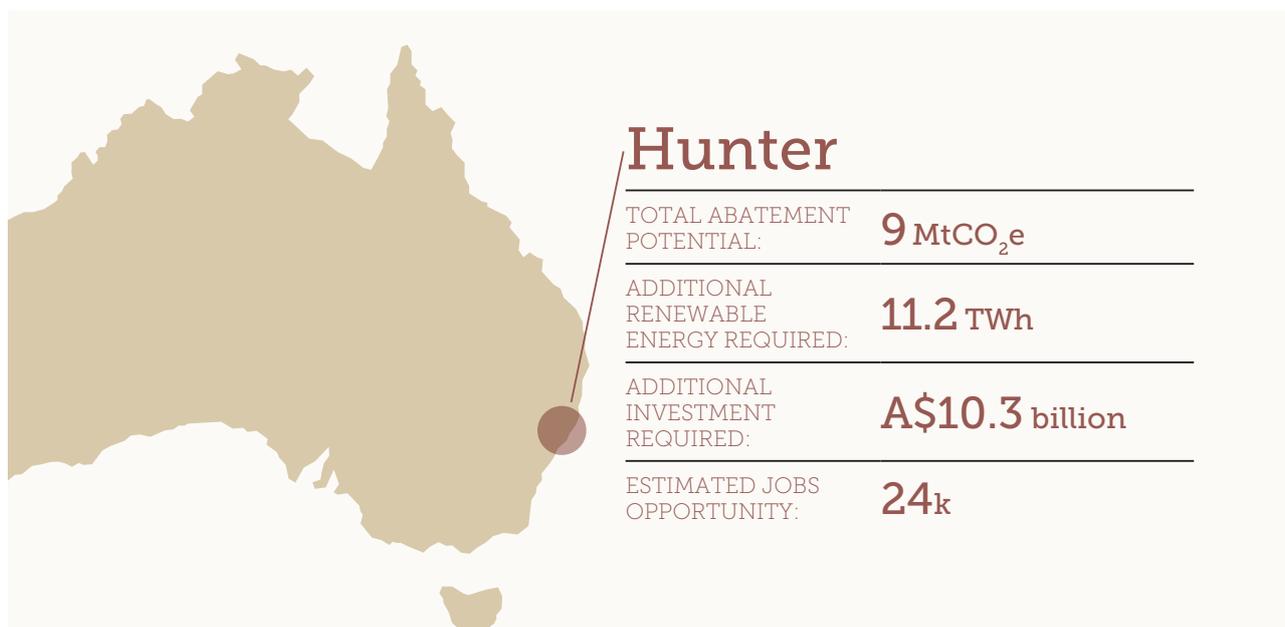
One of the key factors to navigate in any broader collaboration on energy and infrastructure in the Pilbara is the competitive nature of doing business in the region – especially for mining companies – as well as the need to closely manage operational risks. One industry in the Pilbara where a level of collaboration has been the norm is LNG, with strategic project development on joint ventures, equity investment and operations. Continuing to explore and find approaches to successfully manage competitive barriers will be key for enabling collaboration on regional solutions.

Decarbonising haulage by displacing diesel is a common challenge facing many companies in the Pilbara. Decarbonising shipping with low emissions fuels such as ammonia is another common challenge. With the solutions most likely to come from original equipment manufacturers (OEMs), greater collaboration within the region and with OEMs on accelerated development of suitable solutions for the Pilbara is a potential opportunity for mutual benefit for the region.

An area of common strategic risk and potential area for collaboration is pre-competitive and pre-commercial research on process techniques for improving processes to prepare Pilbara hematite ores for green steel manufacture. Hematite iron ore is not yet able to be used in hydrogen direct reduced iron processes which currently rely on very high concentrations of iron. Further research and development are required on affordable processing techniques that improve the grade and purity of Pilbara ores, making them suitable for hydrogen-based steel making.

Efforts are also needed on the research, development and demonstration of alternative decarbonised steelmaking approaches which may be more accommodating of Pilbara hematite ores. Given the importance of this challenge to the region, areas of collaborative research and development may accelerate learning and quicken the pace to implementation.

1.3 Focus on Hunter



- One of Australia's largest and most diverse regional economies.
- Contributes \$50 billion to NSW Gross State Product (~8 percent) indirectly driving 28 percent of state economic output.
- Diversified mix of industry spread across aluminium, steel, chemicals, manufacturing, agriculture, coal mining and energy.
- The Hunter has strong potential for competitive advantage for decarbonised industrial production through existing infrastructure, workforce, manufacturing skills, supply chains, ports, and supportive communities to enable a larger scale transition to net zero industry.

What is needed

- Build on NSW's Electricity Infrastructure Roadmap, taking into consideration new demand from decarbonisation and electrification.
- Leverage momentum from existing policy to join up existing networks, collaborations and research and development efforts. and support joint heavy industry leadership.
- Facilitation of market development to enable scale-up of green products and renewable energy with, for instance, government procurement, mandates, feed-in tariffs.
- Development of large scale electricity generation and transmission infrastructure from nearby renewable energy zones.

The Hunter region in New South Wales extends from 120km to 310km north of Sydney, with a total area of 22,694 km². The region has a population of approximately 700,000 and a workforce of 280,000, with most living in the cities of Newcastle and Lake Macquarie (Hunter Business Chamber, 2021). By 2060, one million people are expected to call the region home (Regional Development Australia, n.d.).

The Hunter is Australia's largest regional economy, contributing A\$50 billion to NSW Gross State Product (~8 percent) but indirectly driving 28 percent of state economic output (the leading regional economy in Australia, 2022). The region is characterised by a highly professional and skilled workforce and strong research, health, tourism, manufacturing and defence sectors (NSW government, n.d.). The region also offers strong research capability with the University of Newcastle and CSIRO having strong links to industry.

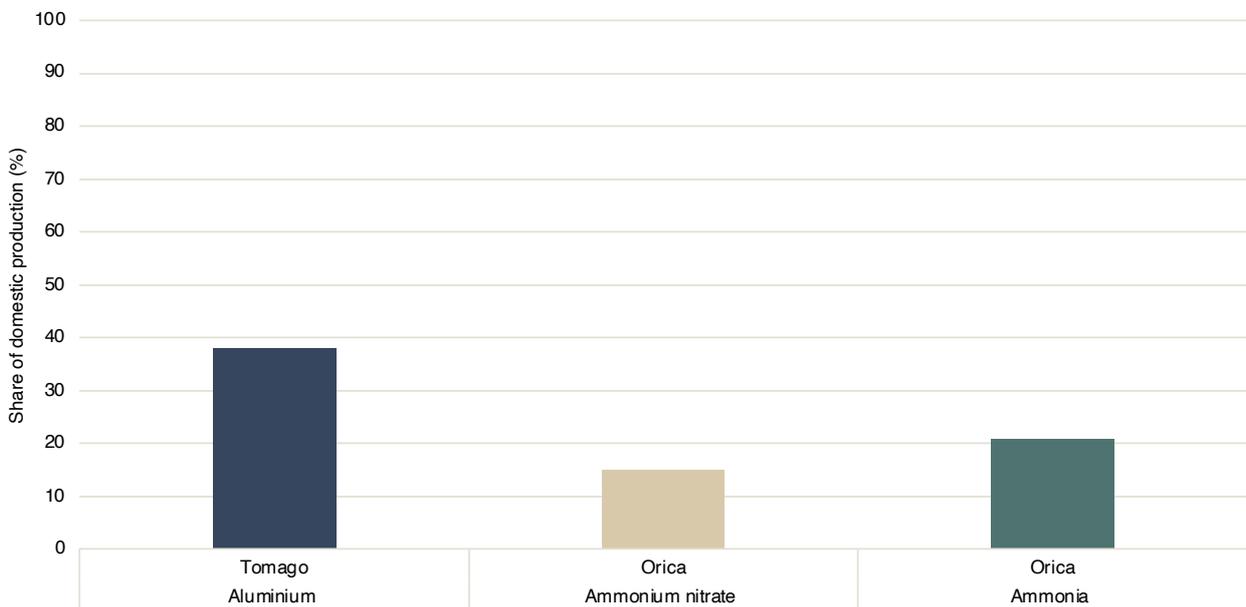
The Hunter is part of the Northern Sydney Basin bioregion which is known for its coal mining, power generation, equine and viticulture industries. The Hunter Valley is Australia's oldest wine region (NSW Regional Investment, n.d.) and about 40 percent of land in the subregion is used for agricultural production (Context statement for the Hunter subregion, 2019). The region includes two Ramsar-listed wetlands and contains part of the Greater Blue Mountains World Heritage Area. The Hunter is the major river in the region which is defined by ridge lines associated with the Hunter Range, Liverpool Range and Great Dividing Range (Bioregional Assessments, 2018).

The Hunter has a relatively diversified mix of industry spread across aluminium, steel, chemicals, manufacturing, agriculture, coal mining and energy. Hunter industries have grown around coal-fired electricity supply and the port. The transition out of coal-fired power is an important aspect of industrial energy decarbonisation with Liddell set to close in April 2023, and Bayswater in the early 2030's. The Hunter region has good wind resources, with the Hunter coast also considered suitable for offshore wind (Offshore wind potential for Australia, 2022).

Production in the Hunter

The Australian Industry ETI supply chains in the Hunter make a significant contribution to Australia's production of aluminium, ammonia and ammonium nitrate (Figure 11). Tomago's Aluminium smelter in the Hunter region is Australia's largest aluminium smelter, producing 0.59 Mt of aluminium each year, representing 38 percent of Australia's domestic production. At Orica's Kooragang Island, 21 percent of Australia's ammonia and 15 percent of Australia's ammonium nitrate are produced per year.

FIGURE 11: Share of domestic production of major industrial sub-sectors in the Hunter



Infrastructure in the Hunter

Three coalfields are located in the Hunter region: the Hunter, Newcastle and Western coalfields (Bioregional Assessments, 2018). The Hunter also contains rivers that flow into two major river basins: the Hunter River basin and the Macquarie Tuggerah basin. There are a number of dams within the Hunter region built for flood mitigation, hydro-electric power, irrigation, water supply and conservation. The Hunter Valley Alluvium aquifer is an important groundwater resource supplying up to 80.4 gigalitres of water per year under licence. The rainfed Tomago Tomaree Stockton Sandbeds, located between Newcastle and Port Stephens, are another important water resource for the Newcastle area (Hunter subregion I Bioregional Assessments, 2018).

The Hunter Valley is well serviced by infrastructure with access to national road and rail infrastructure which provides important freight connections between Sydney, Brisbane and inland NSW, with Newcastle hosting world-class transport gateways in the Port of Newcastle and Newcastle Airport (NSW government, n.d.).

The deep-water Port of Newcastle is the east coast's largest port and Australia's third largest port overall, the world's leading coal export port and the 24th largest in the world by trade volume, with commercial shipping lines to major ports throughout Asia and the Pacific (NSW Regional Investment, n.d.). The port is currently operating at 50 percent capacity indicating opportunity for further growth (Port of Newcastle, 2022). The Hunter also has established gas and oil pipelines and transmission infrastructure.

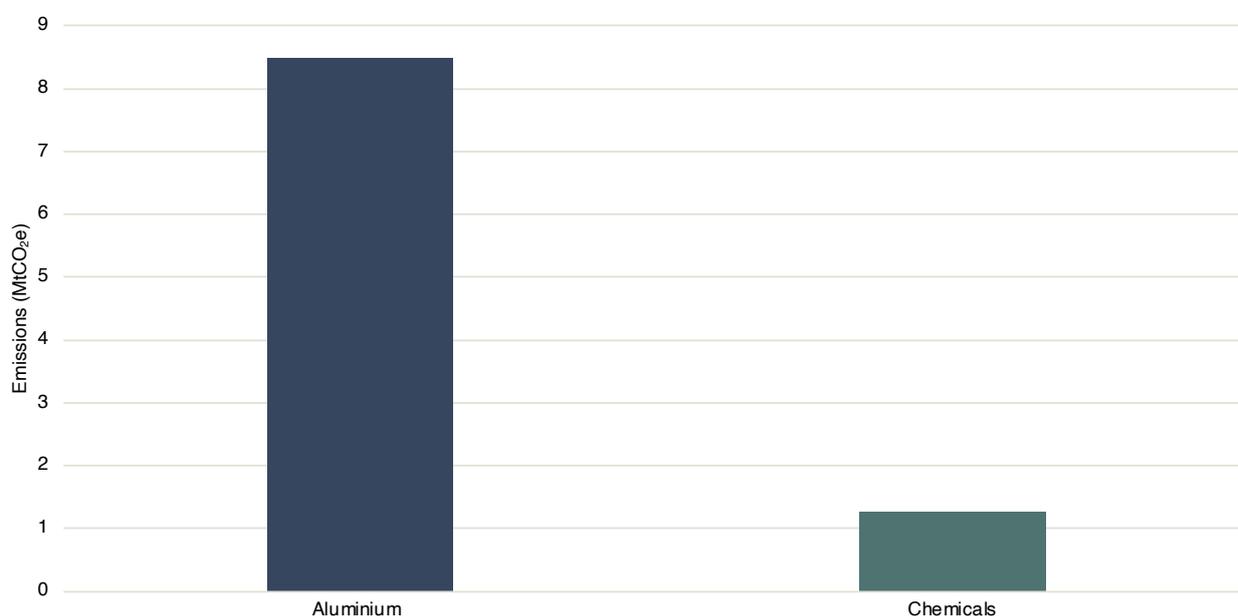
In the Hunter Valley's infrastructure capacity continues to grow with the area proximal to a future 5.5 GW renewable energy zone (REZ) in New England and the Hunter Central Coast REZ, the size of which is yet to be determined (Renewable Energy Zones, n.d.). The Hunter has also been identified as a hydrogen technology cluster.

Emissions in the Hunter

Australian Industry ETI partner supply chains in the Hunter Valley contribute 7 percent of annual emissions for NSW. The majority of these emissions result from aluminium smelting that uses electricity to extract aluminium from alumina via the Hall-Héroult process. Significant emissions also result from the release of perfluorocarbons (PFCs) during the use of carbon anodes in the aluminium reduction process (anode effect). At Tomago’s aluminium smelter plant, around 51 GJ of electricity is consumed and 14 tonnes of CO₂e released to make each tonne of aluminium.

The production of ammonia and ammonium nitrate also contributes significantly to the annual emissions of the Hunter, primarily through the use of methane as feedstock and for process heat, and through the release of nitrous oxides. For every tonne of ammonia produced, 35 GJ of energy is required and 1.87 tonnes of CO₂e are released. The subsequent conversion of ammonia to ammonium nitrate results in the release of a further 1.5 tonnes of CO₂e. Combined, the chemicals industry in the Hunter is responsible for 1.27 Mt CO₂e each year.

FIGURE 12: Annual emissions of major industrial sub-sector in the Hunter



Abatement opportunities in the Hunter

Mature technologies are available to reduce industrial emissions in the Hunter in the short term; however, technologies that are not yet commercial are required to fully decarbonise. Table 6 shows a number of key abatement options, including the necessary scale of energy requirements and capital costs to achieve significant emissions reductions.

TABLE 06: Major abatement opportunities for Australian Industry ETI partner supply chains²⁶ in the Hunter

Industry	Major, long-term abatement options	Readiness	Percentage identified industry abatement potential / year	Energy requirements	Energy capital costs ²⁷ (excluding infrastructure)
Ammonia and ammonium nitrate	Nitrous oxide abatement	Mature and commercially available	~41 percent = 0.52 MtCO ₂ e	-	-
	Switch current electricity use to renewables	Mature and commercially available	~8 percent = 0.1 MtCO ₂ e	0.1 TWh	VRE: A\$0.05 b Battery storage: A\$0.07 b
	Green hydrogen as feedstock and Haber Bosch electrified and powered by renewables	Proven but not yet commercial	~47 percent = 0.6 MtCO ₂ e	2.8 TWh	VRE: A\$1.3b Electrolyser: A\$0.7 b
Aluminium smelting	Renewable electricity for aluminium smelting ²⁸	Proven but not yet commercial	~79 percent = 6.7 MtCO ₂ e	8.3 TWh	VRE: A\$3.9 b Battery storage: A\$4.0 b
	Switch current carbon-based anodes to inert anodes	Proven but not yet commercial	~13 percent = 1.1 MtCO ₂ e	-	-

Where technology options do not require renewable energy (and corresponding investment) energy and energy capital costs are zero.

Ammonia and ammonium nitrate: As discussed previously, switching to zero emissions feedstocks for ammonia production and deploying mature nitrous oxide abatement solutions in the production of ammonium nitrate are the main solutions to decarbonising chemical production in the Hunter. Combined, these solutions could reduce emissions by 88 percent in the Hunter. While the absence of commercial incentives and high CAPEX of nitrous oxide abatement usually present barriers to uptake, Orica has recently announced its plans to install nitrous oxide abatement catalysts at its Koorangang Island manufacturing plant (see Box 12). This project – a partnership with the New South Wales government and financed by the CEFC – is set to be commissioned by 2023 and aims to reduce site emissions by up to 50 percent (Orica, 2021).

Aluminium smelting: Given aluminium smelting is completely electrified, switching to renewable generation is the primary opportunity. This represents a major transformation of the energy system given the quantity and nature (i.e. continuous flow requirements) of Tomago’s electricity use. The use of alternative electrodes presents the opportunity to reduce emissions further; however, these have not yet reached the stage of commercial deployment. Combined, these two solutions could abate 92 percent of emissions.

As shown in Table 6, most of the major abatement opportunities identified in the Hunter depend on zero emissions electricity and green hydrogen. Deploying these technologies at the scale required for deep decarbonisation will demand a significant expansion of NSW’s current renewable energy supply and associated infrastructure. An estimated total of 11 TWh of renewable electricity would be needed to power aluminium smelting and chemicals production, including the

26 This analysis does not include manufactured steel products in the Hunter due to limited data and comparatively low emissions and energy use relative to upstream processes such as metals extraction, refining, and crude steel production.

27 Capital costs are based on current production capacities of each supply chain in the Hunter. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4-5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

28 Although renewable energy technologies are mature and commercially available, constant and reliable supply of variable renewable energy for large energy users such as aluminum smelters is still not commercially viable.

necessary renewable electricity to power electrolyzers for green hydrogen production. This represents 73 percent of NSW's current VRE generation (Australian Energy Statistics, Table of Electricity generation by fuel type 2019-20 and 2020, 2021).

Estimated jobs opportunity

The estimated A\$10 billion of capital investment in decarbonisation in the Hunter could support 24,000 jobs; of which, 35 percent are created in the Hunter and 65 percent across New South Wales.

Activities already underway in the Hunter

As part of the NSW Government's Net Zero Industry and Innovation Program, throughout 2022 a Clean Manufacturing Precincts roadmap is being developed for the Hunter, to provide a pathway for the region and key industrial stakeholders to accelerate their shift to net zero emissions.²⁹

There are numerous developments centred on hydrogen, including a green hydrogen feasibility study underway in the Port of Newcastle (Port of Newcastle, 2022), AGL and Fortescue Future Industries (FFI) collaborating on green hydrogen generation (Parkinson, 2021), the Hunter Hydrogen Network (H2N) (Hunter Hydrogen Network, 2021), and the Hunter Hydrogen Technology Cluster (Home, n.d.).

The NSW and federal governments are providing funds to support a planned Hunter Hydrogen Hub (Hydrogen hub, 2021) and the Committee for Hunter's Hunter Hydrogen Taskforce has released a Hunter Hydrogen Roadmap, developed with industry, research and government to translate state and national hydrogen strategies into targeted actions for the Hunter (Hunter Hydrogen Roadmap, 2022).

There are a number of decarbonisation projects already underway in the Hunter region. Companies and organisations are participating in the NSW government's Clean Manufacturing Precinct roadmap development process. The program is in the early stages with expressions of interest (EOI) submitted in December 2021.

Efforts are also being made to reduce emissions at Orica's Kooragang Island ammonium nitrate plant through the use of nitrous oxide abatement catalysts (see Box 12). Orica has additionally invested in Mineral Carbonation International (MCI) that captures CO₂ emissions and combines them with mine waste to produce carbonate products for the construction sector (Mineral Carbonation International – Orica, 2022).



²⁹ For more information on the NSW context, see appendix 5.

INFORMATION BOX 12:**Kooragang Island Decarbonisation****Orica, CEFC, NSW Government, (Federal Government Emissions Reduction Fund)**

In November 2021 Orica announced the Kooragang Island Decarbonisation Project for its Newcastle plant to significantly reduce greenhouse gas (GHG) emissions. Orica's Kooragang Island operations play a key role in New South Wales' economy, supplying critical products to the mining and infrastructure, agriculture, water supply, food and medical sectors.

To accelerate Orica's progress towards achieving its 2030 emissions reduction target, the \$37 million Kooragang Island Decarbonisation Project will install proven nitrous oxide GHG emissions tertiary catalyst abatement technology from 2022, with commissioning in 2023.

Orica's capital contribution will be financed by a \$25 million loan from the Clean Energy Finance Corporation (CEFC) on behalf of the Australian government, together with \$13 million grant co-funding from the NSW government (NSW government, 2021b). The Kooragang Island Decarbonisation Project is the first major direct CEFC investment in the manufacturing sector and also represents one of its largest single abatement projects. Both the \$25 million CEFC debt facility and the grant under the NSW government's \$750 million Net Zero Industry and Innovation Program announced earlier this year have been instrumental in facilitating the Kooragang Island Decarbonisation Project.

The implementation of the tertiary catalyst abatement technology, EnviNOx®, at Orica's Kooragang Island manufacturing plant will be an Australian industry first. The technology is designed to deliver up to 95 percent abatement efficiency in reducing the site's total greenhouse gas emissions by almost 50 percent (\$13 million to halve Kooragang Island's emissions and support jobs, 2021).

The technology will be installed across all three nitric acid manufacturing plants used in the production of ammonium nitrate at Kooragang Island, and is designed to eliminate at least 567,000 tCO₂e per year from the site's operations. It is expected to reduce the site's total emissions by 48 percent and deliver a cumulative emissions reduction of at least 4.7 MtCO₂e by 2030 based on forecast production (Orica, 2021).

The Kooragang Island Decarbonisation Project is an example of a public-private collaboration to forge pathways towards heavy industry decarbonisation and marks a critical step in Orica achieving their 2030 emissions reduction targets and progress towards net zero emissions (Orica, 2021).

Information provided by Orica

What is needed

The Hunter represents an opportunity to leverage existing advantages such as infrastructure, workforce, manufacturing skills, supply chains, ports and supportive communities to enable a larger scale transition to net zero industry.

A significant abatement opportunity of 9.0 MtCO₂e has been identified in the Hunter region which is 7 percent of NSW's total current emissions (Greenhouse Gas Emissions, n.d.).³⁰ Achieving this level of abatement will contribute significantly to the region's and the state's transition to net zero emissions, but will require substantial investment in green and firmed renewable electricity, hydrogen electrolysers and battery storage.

Developing opportunities for regional decarbonisation in the Hunter at scale

The opportunities identified across the industrial supply chains in scope for this study would require significant investment in energy supply systems. The 11.2 TWh of electricity required to power the opportunities identified would require A\$10 billion in investment in the energy system through variable renewable energy, electrolysers and storage. Additional investment will also be required in energy infrastructure such as transmission and distribution networks.

A key for enabling these opportunities at scale is ensuring affordable, renewable, firmed electricity production and low-cost hydrogen as an energy and feedstock for industrial production. Some large industrial operations such as aluminium smelting in particular are highly exposed to energy costs and require firmed power. Large scale development of electricity

³⁰ Based on 2018-2019 emissions.

generation is needed through proximate renewable energy zones which are in planning in New England and Central West Orana with others being planned. There is also potential for offshore wind generation as costs from this technology decrease globally.

There are opportunities for industry in the Hunter to contribute to affordable, decarbonised, firming electricity for industry by sector coupling across the economy (leveraging storage solutions and demand side management), using bi-directional charging opportunities close to large population centres and transport routes, developing integrated, responsive hydrogen production systems and storage, and investigating emerging opportunities for smart grids to enable localised grid firming (both on the grid and behind the meter solutions for microgrids).

Coordination of a complex system transition

Coordination in the Hunter region is needed in five areas to reduce emissions and enable the region's economy to thrive through the transition:

- setting clear decarbonisation goals to create investment confidence;
- building on existing networks to coordinate stakeholders together around a regional roadmap;
- supporting technology solutions across the range of maturities to enable both the scale up of near-term solutions and the near-term investment needed to support emerging solutions for abatement;
- facilitating market development for early supply and demand to enable scale;
- align policy, regulation and programs across state and federal governments to make it easier for heavy industry to navigate efficiently.

Strong networks already exist in the region such as the Chamber of Commerce, business networks, and University of Newcastle research relationships. These groups are already working on their potential role in transitioning the region, connecting on decarbonisation and new industry initiatives. There is currently no joint heavy industry leadership group, which would be critical to decarbonisation in the region. These organisations and entities need government coordination to draw them together, with communities, to co-create one, coherent regional approach. The regional roadmap process should:

- Leverage assets, resources, know-how and capabilities in the region such as the skilled industrial workforce and small businesses, export know-how and relationships, existing rail networks, transmission networks, shipping infrastructure, coal loading and port facilities for new industrial opportunities such as hydrogen;
- Include infrastructure planning and land use policies as well as a focus on decarbonisation;
- Be flexible enough to support diverse solutions, changes in technology, regulation and markets and an increase in ambition from the group;
- Create a strong transition plan for the whole community, supporting the transition of the quality jobs essential for the community and sustainable industry in the region, breaking down the 'us and them' of fossil-fuels and decarbonisation; and
- Connect up other hubs and regions to share learning (e.g., Hunter and Illawarra).

A range of technologies at various levels of maturity are needed to decarbonise heavy industries in the region and make the most of new low carbon opportunities. Government, through the existing Net Zero Industry and Innovation programs, can support the scale-up and expansion of more mature solutions and integrate efforts on the emerging technology solutions needed such as low emissions steel, mineral carbonates for use in construction, and offshore wind. Key to this is fostering strong relationships between industry operators, R&D, small to medium enterprises (SME) and start-ups for pilots and demonstration of emerging technologies (alongside the larger projects with mature solutions) and to facilitate data sharing and learning.

Support for market development is needed where the solutions are not yet commercial. Government policy and procurement can play an important role in developing demand and supply together. Options include feed-in tariffs, aggregated demand including government procurement, underwriting, guaranteed purchase of hydrogen, coordination for public offtake agreements, support to develop circular solutions and sector coupling.

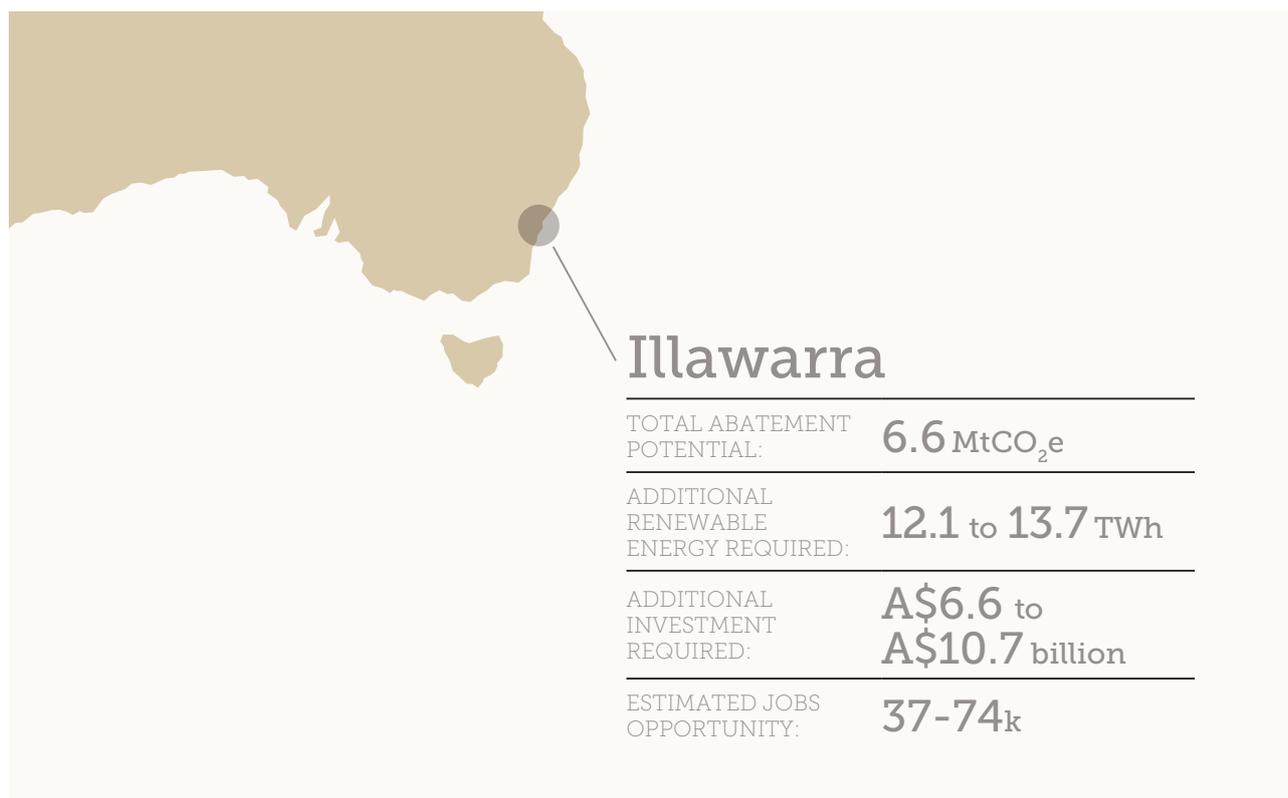
Alignment on policy, regulation and programs across state and federal governments would create more certainty and more efficient navigation of the many programs. Regulatory barriers are also hampering innovation in the region. Examples include regulatory barriers for energy networks, renewable gas, offshore wind, and 100 percent hydrogen pilots. A coordinated effort on addressing the regulatory barriers for both mature and emerging decarbonisation solutions is a critical enabler for industry.

Collaboration across multiple stakeholders

Collaboration across industry sectors is increasingly important for energy transition and decarbonisation in the Hunter region. It can build on the culture of collaboration between industrial companies, the University and other stakeholders. Multiple organisations have come together on hydrogen R&D through the National Energy Resources Australia (NERA) hydrogen cluster and the Energy Estate led hydrogen valley partnership for example. The development and demonstration of carbon capture and utilisation would benefit from collaboration with industry organisations to build on the work of Mineral Carbonation International, Orica and the University of Newcastle.

Heavy industry organisations sharing insight, challenges, common needs and collaborating to lead the transition is a critical part of the region's approach. There are a variety of leadership groups in the Hunter that bring subsets of actors together. However, currently there isn't a group for industry akin to the Kwinana Industries Council in WA or the Gladstone Industry Leadership group. Industry coming together to participate and provide leadership in the government's regional roadmap process is critical.

1.4 Focus on Illawarra



- Narrow coastal strip south of Sydney.
- Modern industry dominated by steel production.
- Significant recent economic diversification with the introduction of advanced manufacturing, ICT and professional services into the economy, as well as the defence sector.
- Emissions from steelmaking, the major heavy industry in the Illawarra, can be reduced by around 20 percent through mature and commercial technologies.

What is needed

- Coordinated efforts between industry and government on current and future energy need to plan generation and infrastructure such as transmission, storage and grid firming.
- Regional industry stakeholders, agencies and communities need to come together to develop one industry decarbonisation roadmap.
- Market development support for green products.
- Coordinated industry and government support for new low carbon iron and steel technologies research and development and demonstrations, including post extraction processes for hematite ores for green steel manufacture.
- Full decarbonisation will require the development, commercialisation and implementation of new low emissions iron and steelmaking technologies requiring a substantial increase in energy systems to deliver electricity and hydrogen for these processes.

The Illawarra region is a narrow coastal strip from the south/south-western outskirts of Sydney down to the northern boundary with the Shoalhaven and the south coast of NSW. The region includes the three local government areas of Wollongong, Shellharbour and Kiama (The Illawarra Region, 2022).

The Illawarra has undergone significant transformation in recent years. Traditionally recognised for steelmaking and coal mining industries, significant economic diversification has seen the introduction of advanced manufacturing, information communication and technology (ICT) and professional services into the economy, as well as the defence sector.

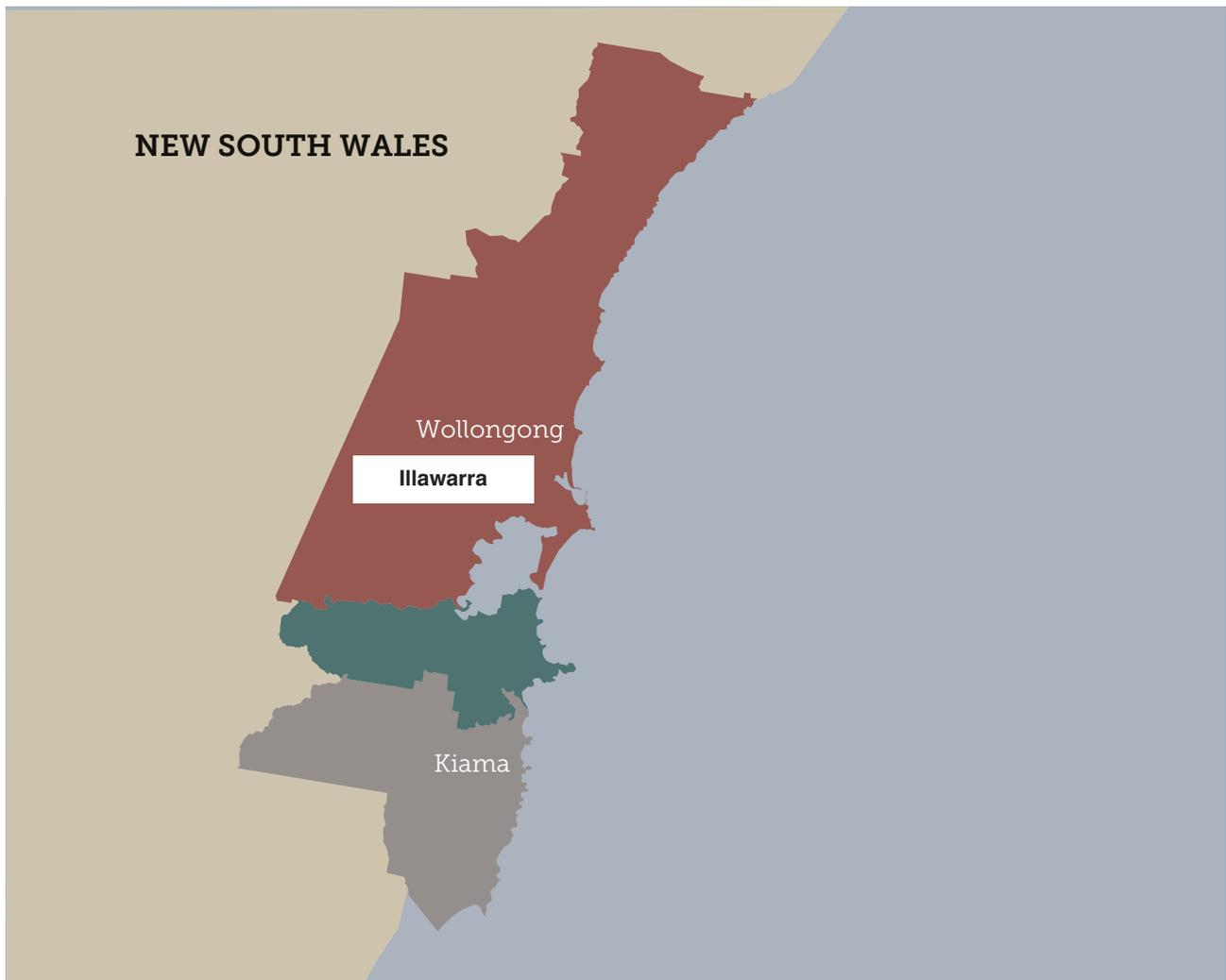
Modern industry in the Illawarra is dominated by steel production. BlueScope is the major steelmaker in Port Kembla directly employing around 3,000 people and supporting a further 10,000 jobs in the broader Illawarra region – including contractors, suppliers and other service providers. BlueScope’s operations provide 11 percent of the Gross Regional Product (A\$1.6 billion) and almost 1 percent of the Gross State Product (Inquiry into Development, 2021). The majority (nearly 80 percent) of BlueScope’s revenue is derived from the domestic market, particularly for the production of building products.

The Illawarra has a population of approximately 293,500 (mostly living in the cities of Wollongong and Shellharbour) and a labour force of approximately 136,700 (Census Illawarra, 2016). The Illawarra-Shoalhaven region contributes A\$15.5 billion to NSW annually, supporting 24,900 businesses (Illawarra-Shoalhaven, n.d.).

Strong networks are present in the region, including the i3Net business network, Regional Development Authority Illawarra, Business Illawarra and the Wollongong City Council. The University of Wollongong has excellent research facilities and high potential for R&D, and is connected with industry and government via the Energy Futures network.

Support for industry has been a strength for some time with stakeholders having a strong interest in transforming the region and engaging with the community, understanding that this is important for decarbonisation and to continue industry’s social licence.

FIGURE 13: Illawarra region



Production in the Illawarra

Steelmaker BlueScope produces more than half of the raw steel (56 percent) in the Australian domestic market in the Illawarra region, from their Port Kembla facility. BlueScope's steel production is focused on servicing the Australian domestic steel market.

INFORMATION BOX 13:

BlueScope Steel in the Illawarra

The Port Kembla Steelworks in the Illawarra region is the largest of BlueScope's global operations, currently producing 3.2 million tonnes of raw steel each year.

BlueScope directly employs around 3,000 people in the Illawarra and more broadly supports about 10,000 jobs in the Illawarra, including contractors and suppliers.

BlueScope accounts for more than \$2 billion in sales of locally produced steel each year, and the Port Kembla Steelworks covers 760 hectares (BlueScope in the Illawarra, n.d.).

Information provided by BlueScope

Infrastructure in the Illawarra

The Illawarra region is well connected to domestic and international markets through a high quality broadband network, road and rail connections into Sydney and other markets on Australia's east coast and the Illawarra Regional Airport (Illawarra-Shoalhaven, n.d.).

Port Kembla, site of BlueScope's steelworks, is a deep-water port, close to Sydney, surrounded by highly developed industrial businesses. The port enables import and export potential with good access to markets and is central to the region's industrial future.

Emissions in the Illawarra

Integrated steelmaking is highly energy and emissions intensive. The blast furnace-basic oxygen furnace (BF-BOF) process at BlueScope consumes an estimated 65 petajoules (PJ) of coal, 1 PJ of gas and 2 PJ of electricity annually, equating to roughly 23 gigajoules (GJ) of embodied energy in each tonne of crude steel. With coal being the dominant source of energy, the Port Kembla Steelworks has significant Scope 1 emissions of around 6 MtCO₂e per year, representing 5 percent of the total annual emissions of NSW in 2019.

Abatement opportunities in the Illawarra

Proven technologies are available to reduce industrial emissions in the Illawarra in the short term; however, emerging technologies are required to fully decarbonise. Table 7 shows a number of key abatement options, including the necessary scale of energy requirements and capital costs to achieve significant emissions reductions.

TABLE 07: Major abatement opportunities for the Australian Industry ETI supply chains in the Illawarra

Industry	Major, long-term abatement options	Readiness	Percent identified industry abatement potential	Energy requirements	Energy capital costs ³¹ (excluding infrastructure)
Steelmaking	Green hydrogen for DRI-EAF steel production ³²	Proven but not yet commercial	~100 percent = 6.6 MtCO ₂ e	12.3 TWh	VRE: A\$4.3 b Electrolyser: A\$4.3 b Battery storage: A\$0.8 b
	Green hydrogen for DRI-Melter-BOF steel production	Emerging technology		12.1 TWh	VRE: A\$3.8 b Electrolyser: A\$2.6 b Battery storage: A\$0.3 b
	Ore electrolysis technologies	Emerging technology		13.7 TWh	VRE: A\$4.3 b Battery storage: A\$6.4 b

Steelmaking: For steelmaking, there are opportunities to reduce emissions from the current integrated iron and steelmaking processes. The use of best available technologies or hydrogen in blast furnaces could achieve emissions reductions of 30 and 15 percent respectively, while utilising existing assets. However, to achieve low or near-zero emissions steelmaking, a complete process switch to a direct reduced iron–electric arc furnace (DRI-EAF), direct reduced iron–Melter–basic oxygen furnace (DRI-Melter-BOF), or emerging technologies such as electrolytic steelmaking will be required.

The implementation of these technologies depends on further technological developments to reach commercial scale, the availability of suitable ores, and supportive policy frameworks (BlueScope, 2021). Additionally, the need for firming renewable electricity and green hydrogen will increase the VRE demand of the Illawarra by 28 TWh; almost double the current VRE generation of NSW (Australian Energy Statistics, 2021).

Estimated jobs opportunity

The A\$6.6-10.7 billion of capital investment in decarbonisation in Illawarra could support between 37,000 to 74,000 jobs; of which, 34 percent would be in Illawarra and 66 percent across Australia.

Activities already underway in the Illawarra

Like the Hunter region, the Illawarra has the opportunity to benefit from frameworks the NSW government has put in place with renewable energy zones (REZ), clean manufacturing precincts (CMPs), the New Low Carbon Industry Foundations (NCILP), the Net Zero Industry and Innovation Program (NZIIP) and hydrogen hubs.³³

The Illawarra region is host to a number of decarbonisation projects seeking to understand low carbon iron and steel making,³⁴ dual-fuel power plants at Tallawarra B (Tallawarra B Project, n.d.) and Port Kembla (Port Kembla Energy Hub, n.d.), renewable hydrogen hub development (BlueScope Corporate, 2021) and Australia’s first hydrogen refuelling station and heavy vehicle fleet, to be located at Port Kembla (Fernandez, 2021) with offshore wind farm options being explored (Oceanex Energy, n.d.).

What is needed

Hydrogen DRI steel-making is being demonstrated internationally, although there is significant uncertainty on how these technologies will perform in commercial operations in Australia, and these will require further development in particular with regard to Pilbara hematite ores which dominate supply. The development of decarbonisation plans for the region will require significant attention to research, development, pilots and demonstration to develop viable pathways towards net zero for the region.

31 Capital costs are based on current production capacities of each supply chain in the Illawarra. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4-5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

32 Hematite is not yet able to be used in hydrogen direct reduced iron processes which currently rely on very high concentrations of iron

33 See more in NSW context at appendix 5.

34 See Box 13 on BlueScope and Rio Tinto below.

Developing opportunities for regional decarbonisation in the Illawarra at scale

Full decarbonisation of steel production from iron ore (as opposed to scrap) is not projected to be cost competitive in its own right before mid-century without more certainty on carbon in the market or a green premium. Accelerating the transition to net zero integrated iron and steel operations in the Illawarra will be dependent on:

- Access to large-scale (12 to 14 TWh) affordable, reliable renewable energy
- Accelerating technology development in new iron and steel making technologies
- Continued emissions and waste optimisation of existing operations
- Support for the deployment of mature and commercial technologies
- Availability of appropriate volumes of competitively priced hydrogen from renewable sources
- Substantial investment in energy infrastructure of A\$7 billion to A\$10 billion dollars
- Supportive policy and regulatory environment that supports investment in large scale plant and equipment.

Earlier implementation of these opportunities could be facilitated by markets that value externalities and a premium on green steel. This can be facilitated with effective coordination and collaboration across government, industry, research and investors.

Coordination of a complex system transition

Coordination in the Illawarra needs focus across several areas to support an effective transition for industries in the region, for example:

- Bring together regional industry stakeholders, agencies and community to develop one industry decarbonisation roadmap
- Build a shared understanding of current and future energy and infrastructure to support new supply and demand together
- Support emerging technology R&D, pilots, demonstrations and market development for low emissions steel
- Align government policy, programs and regulations across both state and federal levels to enable decarbonisation.

Planning for decarbonisation through the development of roadmaps can coordinate across levels of government, helping industry to de-risk investment where projects are not yet commercially viable. Examples include the Port Kembla hydrogen hub and the NSW Clean Manufacturing Precinct (CMP) roadmaps. These regional leadership and coordination efforts have seen strong engagement from a variety of organisations across industry (including steel, cement, energy), research, community groups and government coming together to accelerate learning and work together.

Consensus among stakeholders is that the CMP roadmaps with their clustered approach, while early days, are a step in the right direction. It's important that the Clean Manufacturing Precinct roadmaps process builds on existing plans that networks and agencies in the area have developed, deepens collaborations across heavy industry, amplifies existing R&D, and draws industry in with a clear value proposition.

The Illawarra is a small geographic area with close working relationships across several sectors and good community engagement. Regional processes can leverage these strengths to create alignment.

One of the most critical factors in developing a coordinated approach to decarbonisation in the Illawarra is the development of an energy system that can support decarbonised steel production. Planning for available, affordable and reliable electricity and hydrogen from renewable sources will require:

- A clear understanding of current and future energy needs to enable planning across government and energy market operators;
- Coordinated efforts between industry and government on energy infrastructure needs and ownership, such as transmission lines for increased electricity as operations electrify, and demand for renewable electricity increases and energy storage and grid firming are needed;
- Aggregating demand and identifying early offtake to build markets (and develop the infrastructure) for hydrogen across the region, enabling early supply and building critical mass. Transport in the region is a promising opportunity for this.

Support for the development of low emissions steel is needed as technology solutions are still emerging. This can include support for R&D, pilots and demonstrations, the development of supportive policies, regulations, standards and support for adoption and scale up e.g. through government procurement or mandates.

Steelmakers in a highly competitive global market face a major commercial and strategic decision, requiring a clear and consistent policy environment to unlock investment and manage risk. Government funding support for a collaborative value chain effort for low emissions steel in the Illawarra could align to BlueScope Steel's public commitment to partnerships.

Aligning government efforts across multiple departments and agencies is key to an effective transition in the Illawarra. Current programs such as the NSW government's CMP Roadmap process have the opportunity to play an important role in planning for and aligning stakeholders, including government agencies, through the transition.

INFORMATION BOX 14:

Iron ore miner and steelmaker working together to solve decarbonisation challenges in the iron ore supply chains

BlueScope Steel and Rio Tinto

In 2021, Australian steelmaker BlueScope Steel and iron ore miner, Rio Tinto announced a memorandum of understanding to undertake two important research projects. This collaboration aims to better understand decarbonisation of the iron ore supply chain (BlueScope, 2021a).

Rio Tinto and BlueScope Steel are working together to research and design low-emissions processes and technologies for the steel value chain across iron ore processing, iron and steelmaking and related technologies, using Pilbara iron ore mined by Rio Tinto. One key priority is to explore producing a low emissions iron feed for direct consumption into BlueScope's existing steelmaking process. The pilot aims to use green hydrogen to directly reduce Rio Tinto's Pilbara iron ore. The direct reduced iron (DRI) from this process will then be melted in an electrical furnace, powered with renewable electricity, to produce iron suitable for the steelmaking process. (Identified by this report as an emerging technology with abatement potential of 6.6 MtCO₂e), BlueScope and Rio Tinto are progressing important decarbonisation technologies. Until these breakthrough projects are proven, economically viable and implemented at commercial scale, Rio Tinto and BlueScope are also exploring iron ore processing and technologies directed at reducing carbon emissions from existing iron and steelmaking processes (BlueScope, 2021a).

Information provided by BlueScope

Collaboration across multiple stakeholders

Companies need new collaboration models and ways of meaningfully engaging and working together, to successfully navigate the complexity of transition. In the Illawarra, companies are actively engaging in regional transition and decarbonisation efforts such as the Port Kembla Hydrogen Hub and the Clean Manufacturing Precinct roadmap process. This needs to continue and deepen as diverse organisations from industry (including steel, cement, energy), research, community groups and government come together to accelerate learning. Businesses need a clear understanding of each other's issues, planned activities, target outcomes and potential value proposition of working together. More work is needed to mature new models for collaboration. The potential for cross-sector collaboration on green steel is a great example.

The future of low emissions iron and steel making in the Illawarra depends on the availability of large volumes of affordable renewable electricity and hydrogen, which in turn requires expansion of transmission and pipeline infrastructure. Multiple organisations collaborating and working together along the supply chain can enable this transition. New frameworks are needed for sharing plans, risk and reward. A successful multi-stakeholder collaboration on green steel in the Illawarra has the potential to closely replicate the world leading green steel pilot in Sweden known as HYBRIT – a supply chain collaboration supported by the Swedish government and the European Union, involving an iron ore miner (LK AB), a steelmaker (SS AB), energy company (Vattenfall) and steel user (Volvo Cars).

2. Key factors for decarbonising industrial regions

In the course of analysis for this report, some common themes emerged across the regions of focus. While each region is unique, cross-cutting factors that are central to the effective decarbonisation of industrial regions include:

- The need for large-**scale** investment and deployment of renewable energy, infrastructure and measures that improve energy system efficiency and flexibility, to ensure affordability and reliability of decarbonised energy systems;
- The need for enhanced **coordination** across multiple dimensions of the system;
- The need for enhanced **collaboration** between entities;
- The need to **act now**: setting transformative changes in motion now by laying the groundwork for deployment of mature, not yet commercial and emerging technologies.

Each Australian industrial region is unique, with its own assets, capabilities, possibilities and challenges. These include the energy systems that power each region, the policy and regulatory contexts, the diverse mix of industries, and physical and geographical differences such as land availability, access to ports and suitability for different types of renewable energy. There are also significant community and social differences across regions; from the vast areas of the Pilbara with its important cultural heritage to the more compact, urbanised region of Kwinana. Differences such as these must be considered when developing appropriate place-based strategies for decarbonisation.

In decarbonising these regions, particular attention is needed on the energy networks which will be vital to supplying the low-cost, decarbonised and firmed supply of energy needed for large-scale transition. Large industrial regions along the east coast of Australia such as the Hunter, Illawarra and Gladstone are connected to the NEM, Kwinana's energy system is serviced by the SWIS, while Pilbara industrial operations often generate their own electricity onsite with only loose connections to the primary network, the NWIS. Each of these networks operate under different market dynamics, capacity of supply and availability of renewable resources.

In considering what is needed for scale, coordination and collaboration, regional differences need to be front and centre. As the regions in focus have shown, the particular dynamics of each region and the diverse stakeholder perspectives within them are vitally important to creating a shared understanding of what's possible and what action is needed by industry, governments, investors and communities. This report is intended as a guide to potential opportunities at a regional level, and to align relevant actors within each region by highlighting the similarities and differences in each region as we work towards net zero emissions for Australia.

2.1 Developing opportunities for regional decarbonisation at scale

An unprecedented transformation of the energy system is needed to achieve regional decarbonisation at scale, with a priority of delivering low cost, decarbonised, firmed electricity supply and establishing a market for green hydrogen

Based on the analysis of decarbonisation opportunities in each region, it is evident that a significant increase in the development of renewable energy and investment in the energy systems of these regions will be required to unlock substantial emissions reductions.

The scale of emissions reductions from heavy industry in these five regions alone is hugely significant to Australia's overall emissions. For example, the 70 MtCO₂e of total potential abatement identified is the equivalent of removing all emissions from cars and light commercial vehicles across Australia.

TABLE 08: Technology abatement potential by region

Region	Technology abatement potential by region	Energy requirements	Energy capital costs (excluding infrastructure) ³⁵
Kwinana	2.1 MtCO ₂ e (~92 percent)	4.8–9.7 TWh	A\$ 3.9 b–7.3 b
Pilbara	30.6 MtCO ₂ e (~82 percent)	25.3–53.8 TWh	A\$ 17.8 b–38.4 b
Hunter	9.0 MtCO ₂ e (~93 percent)	11.2 TWh	A\$ 10.3 b
Illawarra	6.6 MtCO ₂ e (~100 percent)	12.1–13.7 TWh	A\$ 6.6 b–10.7 b
Gladstone	21.2 MtCO ₂ e (~93 percent)	14.8–37.5 TWh	A\$ 14.3 b–33.6 b
Total	69.5 MtCO ₂ e (~88 percent)	68.3–125.9 TWh	A\$ 52.9 b–100.3 b

The amount of renewable energy required to achieve the abatement across all five regions is equivalent to 26 percent to 47 percent of Australia’s total electricity generation and 107 percent to 197 percent of total generation from renewables currently (Australian electricity generation, 2021). The investment required in the energy system to achieve these reductions is similarly substantial, but not unachievable when compared to region building efforts elsewhere. The overall energy capital costs across these regions are estimated between A\$53 billion and A\$100 billion over the next decades.³⁶ As a point of comparison, investment in LNG over the last 15 years has been A\$300 billion in support of regional development (Mercer, 2021).

If land is available, the development of additional renewable energy capacity in proximity to industrial precincts can reduce transmission costs. Solar and wind generation each require available land but can co-exist with other land use such as agriculture. For the Pilbara, between 414 and 6,680 km² would be needed, depending on the renewable energy mix. Although this seems like a large area, covering an area around one-third of the size of Melbourne’s metropolitan area, this is only between 0.08 percent and 1 percent of the Pilbara’s total land area of 507,896km² (including offshore islands).

Land constraints are more pressing around more urban industrial precincts such as Kwinana. This may require the development of renewable energy resources around the south-west and mid-west regions of Western Australia, together with additional energy transmission infrastructure to deliver energy to where it is needed as either electricity or in molecular form (such as hydrogen or ammonia).

³⁵ Capital costs are based on current production capacities of each supply chain. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4-5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Hydrogen production costs are based on PEM electrolysis powered by variable renewable energy with a utilisation rate of 30 percent. Hydrogen storage costs are also included in the CAPEX cost. Additional capital cost assumptions are included in the appendix.

³⁶ This does not take into consideration transmission and distribution costs.



Renewable hydrogen is anticipated to play a major role in a decarbonised world, with markets emerging domestically and internationally. The development of a thriving domestic hydrogen market will facilitate the production of net zero industrial commodities and opportunities to establish industries in emerging global markets

Green hydrogen is hydrogen produced from renewable energy such as wind or solar power rather than from fossil fuels. The effort required to develop green hydrogen at scale is substantial, but momentum is building. New projects are being announced at a rapid pace, with the pipeline of the world's largest GW-scale green hydrogen projects growing from 50 GW to 137.8 GW in just four months from December 2020 (Collins, 2021).

The average size of hydrogen electrolyser projects in Australia at June 2020 was approximately 1,100 MW, but just 35 MW if the two largest projects are excluded. For comparison, international capacities (at June 2020)³⁷ were approximately 10,000 MW in Italy, 5,700 MW in the Netherlands, 1,500 MW in the USA, 900 MW in France, and 750 MW in Germany. Commercially available electrolyser modules are typically up to 5 MW, although some manufacturers are producing modules up to 20 MW (IRENA, 2020). Clearly, there needs to be rapid and profound investment in green hydrogen electrolysers to meet future needs. Efforts are underway across Australia and the world to understand hydrogen's application and to catalyse markets and demand.

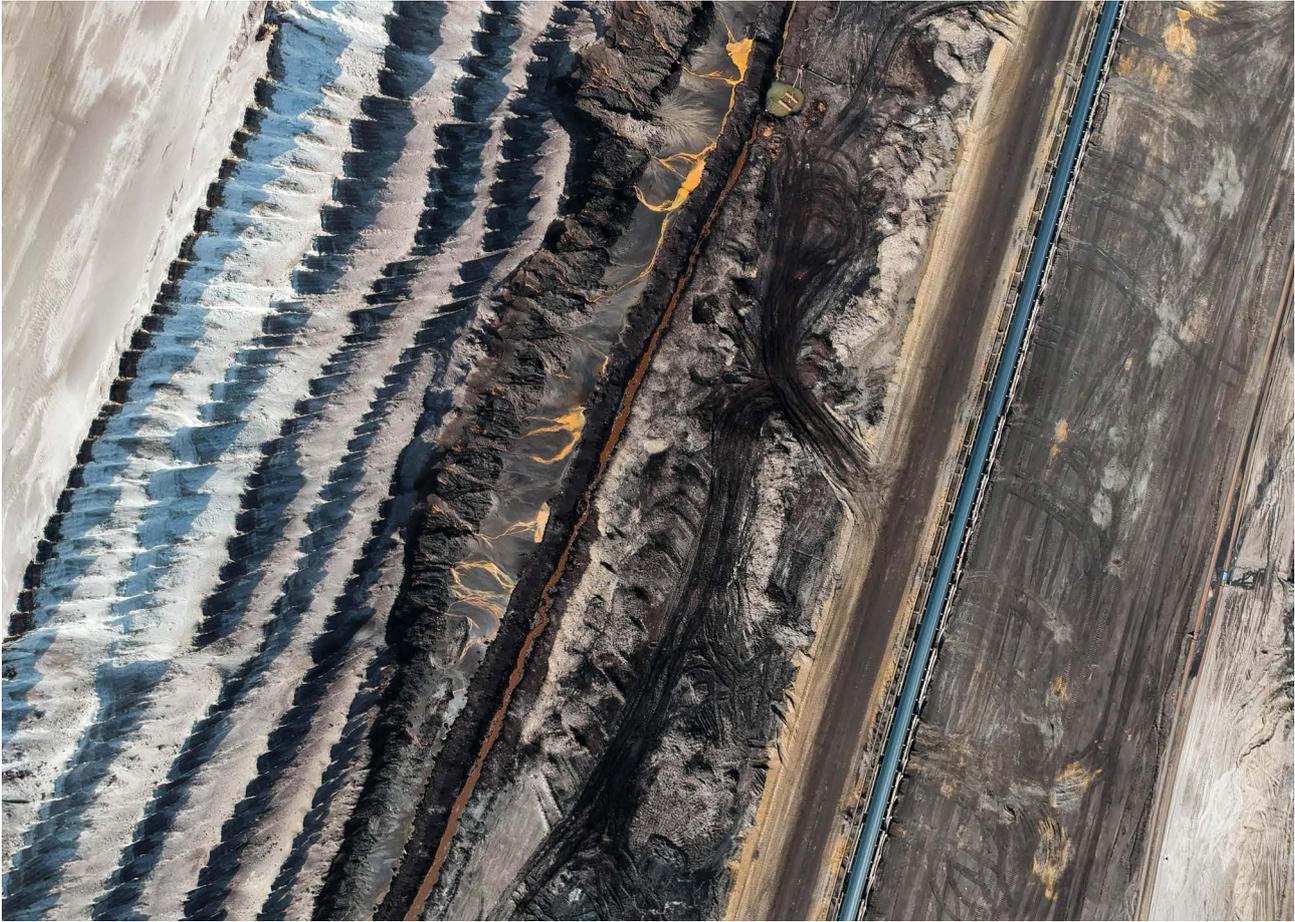
It is unclear whether hydrogen fuel cell electric or battery electric vehicles will dominate domestic and industrial transport in the future, although it is likely that renewable electricity will mostly be used for smaller vehicles and renewable hydrogen will be used for large long-haul vehicles, trains and shipping (the latter in the form of ammonia). Investing in the use and manufacture of both electric and renewable hydrogen fuelled vehicles could be one mechanism to reduce investment risks. Establishing a supply of renewable hydrogen and building refuelling stations would provide increasing emissions reductions and will help build understanding, experience and knowledge of the technology.

Recommended action: Target net zero emissions in industrial regions

A coordinated approach to policy, regulation and programs by state and federal governments can accelerate industry efforts, create investment confidence and increase the effectiveness of government action. With net zero emissions targets now set at the state and national level, planning and action to decarbonise industrial regions should be aligned to a net zero target to guide decision making for the long-term transition.

Governments have an important and valued role in providing milestones, targets and setting an overall strategic direction for the economy. Clear goals and stable policy are critical as a long-term signal to create investment confidence. The Federal Government's November 2021 net zero by 2050 announcement alongside state government targets and commitments brings some alignment across governments in Australia. Ensuring support mechanisms across levels of government are aligned to achieve the scale of decarbonisation needed is critical and can take the form of both incentives and the removal of market barriers.

³⁷ Operation and planned electrolyser capacity, but investment in hydrogen has increased dramatically since June 2020 and planned capacity is now greater than that stated here.



Recommended action: Energy system planning for rapid and accelerating transition

The Australian Energy Market Operator's (AEMO) Integrated System Plan (ISP) in the NEM and the WA government's Whole of System Plan (WOSP) in the Wholesale Energy Market³⁸ can be powerful tools to actively plan for an accelerating transition towards low-cost, firm, zero emissions electricity networks. These plans send powerful signals and help direct investment into electricity networks by indicating to the market where it is likely to be needed.

System plans should actively consider an accelerating transition towards firm, zero-emissions electricity and hydrogen networks at the scale needed. Planning should be consistent with 1.5 degree warming scenarios, including planning for energy and green metals export scenarios. In order to develop low-cost, firm, decarbonised energy systems to support industry's decarbonisation over the coming decades, a range of efforts can be deployed in industrial regions.

Energy and material efficiency: by reducing the volume of inputs required in production processes, energy and material efficiency improvements throughout the economy can help lower the overall burden of shifting to zero emissions processes and technologies. This is important in a context of finite physical and capital resources. Given challenges with deploying zero emissions energy at scale, 'no-regret' actions such as energy-efficient technology upgrades can reduce energy waste, in effect freeing up energy use in other areas of the economy. Moreover, energy efficiency upgrades often have very short payback periods on investment, where the costs are offset by energy savings.

Material efficiency improvements include the design of end products to require less input material or increase durability and recyclability, additive manufacturing to reduce unnecessary use of materials and losses in production, substituting emissions-intensive materials with low emissions alternatives, material recovery and reuse in place of primary production, and asset utilisation through sharing economies and new business practices. Industrial energy efficiency can also be improved by technological and process changes including steam, motor drives, pumping systems, compressed air systems, heating and cooling.

Demand side response: system flexibility can be enhanced by enabling demand to ramp up and down based on the supply. Large industry facilities, for example, often have the flexibility to adjust their energy demand by temporarily

³⁸ Beyond the SWIS, the Western Australian government's planned Sectoral Emissions Reduction Strategy for Energy could be used in a similar way to plan for the energy transition and help signal where investment would most appropriately be directed.

changing their operations. As major consumers of energy, large consumers like aluminium smelters could theoretically play a key role in energy system flexibility through demand side response, adjusting their operations – or load shedding – at times where energy demand exceeds supply; hydrogen electrolyzers could perform a similar role in the future. Demand response services can also be provided by non-industry energy consumers like households. It has been suggested that current energy market mechanisms are not able to fully recognise the value of demand response services, and hence there is limited incentive for energy consumers to scale up the ability to vary their energy demand.

Distributed energy generation and storage: small-scale wind, biomass, or rooftop solar can provide flexibility to the grid, especially when combined with community or household-level battery storage. In addition to meeting household power demand when distributed generation is low, this storage can be utilised to feed into the grid by aggregating multiple small household storage units (and also generations) to a virtual power plant. When connected together via smart-grid links, this distributed energy resource can be dispatched and bid into the energy market.

Utility scale energy storage: pumped hydro, solar thermal (e.g. molten salt) and front-of-meter batteries can provide various services to increase grid flexibility. These storage solutions can store excess renewable energy generation and ‘firm’ energy supply. For system operators, battery storage systems can also provide grid services like frequency response, regulation reserves and ramp rate control, along with deferring the need for investments in peak generation and grid reinforcements.

Electric vehicle integration: The rapid uptake of electric vehicles poses challenges to the grid, but could also bring opportunities. For instance, current static electric vehicle charging could be modified to respond to dynamic rates or control signals to shift charging demand into more desirable periods for the grid. Similarly, under vehicle-to-grid (V2G) and vehicle-to-home (V2H), electric vehicles act as an integral part of the grid and/or home energy system, and respond to signals through charging and discharging. Similar to distributed energy generation, there is potential for aggregators to combine a large number of electric vehicles and sell their battery capacity into the grid, charging or discharging in response to grid needs for flexibility.

Integrated hydrogen systems: as a carrier of energy, hydrogen could act as a storage option similarly to storage of existing fuels throughout Australia. Hydrogen can be stored either as gas or liquid and then used when required. It can provide a flexible, rapid source of electricity when combusted either with natural gas or in pure form in gas turbines (Wartsila, 2021). Hydrogen fuel cells might also be suitable for short-duration power back-up at specific energy-intensive sites, such as data centres. Although batteries will likely be the more competitive solution for storage durations below four hours, green hydrogen alternatives may become competitive against diesel power generators for longer durations (Energy Transitions Commission, 2021). Hydrogen can also be used to stabilise the grid, with production increasing during periods of high-power generation from renewable sources, especially when this coincides with lulls in demand.

Sector coupling: interconnecting and integrating the energy consuming sectors – heating and cooling of buildings, transport and industry – with the power sector is especially important in leveraging the benefits of the energy transition. For example, there is great potential to use renewable hydrogen produced nearby for the manufacture of green ammonia (blending into existing gas networks), and for use in transport systems.

Recommended action: Develop the energy systems of tomorrow, today

System planning for accelerated transition can provide opportunity for scale. In the NEM, identification of potential Renewable Energy Zones (REZ) seek to leverage transmission planning as a tool to enable high penetration of renewable energy and enabling technologies on the grid. REZ are an opportunity to progress development of our future energy system and should be considered for co-location with industrial regions, particularly in WA.

2.2 Coordination will facilitate system wide transitions in industrial regions

The scale, pace and importance of decarbonisation in hard to abate sectors in key regions is now clear. The transition to net zero needs a regional focus on the integrated transformation of energy systems and industrial processes in a fast-changing global context.

This complex system transition challenge will involve simultaneous shifts on multiple fronts, including: corporate strategy; technology research, development and deployment; nurturing new demand and market development; new business models, finance and investment for new solutions and changes to infrastructure; changes to regulation and policy; and shifts in workforce skills and capabilities. Transition requires coordination across the entire industrial ecosystem in these regions. Globally, cities, governments, consulting organisations, NGOs and forward-thinking corporations are taking a coordinated, place-based approach and, increasingly, an industrial cluster approach to decarbonisation (Geels, 2016).

Regional energy transitions aren't uniform, as seen in the four quite different regions across NSW and WA. Stakeholders need to be 'simultaneously aware of the 'big picture' developments while at the same time capturing the local opportunities and challenges for diversity, contestation, experimentation and failure when acknowledging the difference that regions make in energy transitions' (Coenen, 2021).

Recommended action: Strategic alignment of supporting mechanisms

State, federal and local governments can play interconnected coordination and facilitation roles by:

- Aligning and coordinating policies, regulations, and programs across all levels of government on net zero to create clear common goals and efficient engagement in programs;
- Facilitating and supporting industry, communities and other regional stakeholders to align on a shared vision and regional decarbonisation roadmaps and manage the flexible implementation of solutions for the region;
- Coordinating support for research, development, demonstration and deployment of the range technical solutions needed to decarbonise; and
- Supporting market development for new and emerging supply and demand, to enable future domestic and global opportunities.

Long-term investment signals from governments, such as the renewable energy target, and enabling policies are needed to incentivise and underpin additional, competitively priced, firmed and well-planned energy supply. Industry and regional stakeholders have stressed the importance of a more active and coordinated approach to action towards net zero emissions across different levels of government, to support industry's transition.

Recommended action: Align and coordinate federal and state government policy and programs

Greater coordination across governments to join up strategies, policies and programs is key to an effective transition. A mission approach, where government efforts are coordinated around a common goal, are gaining traction globally and could be a useful mechanism for coordination in Australia.

The many diverse programs aimed at developing and supporting decarbonisation and regional industrial clusters across federal and state governments such as hydrogen hubs, the NSW Clean Manufacturing Precincts and Minerals Research Institute WA (MRIWA's) net zero mining opportunity are welcome, but navigating them can be overwhelming. One possibility is a central navigation support service to help companies effectively engage the multitude of programs across different levels of government and jurisdictions, enabling them to better focus their efforts on those things which will support their transition. Sweden's Transition Boost program is a good example of the government meeting this challenge (Johansson, 2021). In Sweden, as in Australia 'Companies often need to spend a lot of time just understanding the support system to be helped by it, and it can be a challenge in itself just to decide (who) it's best to approach.' (Johansson, 2021).

Forward looking, coordinated thinking around regulation is also needed as new regulations are critical enablers for new or changing products (e.g., hydrogen storage and transport, 100 percent hydrogen pilots, CO₂ transport, offshore wind). In some cases, regulation is a hurdle to rapid uptake in new and emerging technologies. A coordinated approach to regulation that enables transition, with industry input, is a critical role for governments.

Recommended action: Regional decarbonisation roadmaps

Industry, investors, governments and communities can work together to align plans, develop roadmaps and regional solutions. Governments can play an important role in facilitating and supporting regional leaders to align on common goals, develop roadmaps and manage a flexible implementation of solutions for the region. Co-developed regional decarbonisation roadmaps focusing on the vision and milestones for the deployment of infrastructure, energy systems, technology solutions and the development of new opportunities in potential markets such as hydrogen, green metals and energy export.

Developing a shared transformation vision and common goals is an important aspect of the coordination role. It creates confidence in the direction, and helps stakeholders align on the long-term ambition for their region and common goals. Support for the co-creation of regional roadmaps that enable integration and shared solutions is another critical part of government coordination. Policy can support this wider system-level planning.

Collaboration between companies, government agencies, universities and research institutions, unions, and communities are, however, rarely spontaneous. In one region, industry stakeholders talked about wanting the state government

to incentivise collaboration. Regional stakeholders have shared their perspective that 'local organisations are good at synergy (for example connecting bilaterally), but strategic coordination is needed for real region transition'. Where clustering is already happening in several regions, coordination can strengthen it. In regions where agencies, research consortia and regional business associations are already working on what's needed and their potential role, the government needs to build on what's there and 'draw it all together' as one industry leader put it. Many organisations see a key role for the government in coordinating and facilitating the stakeholders coming together, not controlling or directing industrial transition in the regions, but rather, enabling regional stakeholders to address complex challenges together and make the most of opportunities in getting to net zero.

A shared vision and co-developed regional transition roadmaps can help create coherence and buy-in across industry, finance and investment, and communities, as stakeholders identify the opportunities and challenges together. These roadmaps need to be flexible, build on what's already happening, spread risk, address existing and future infrastructure needs, create investor certainty, create a social licence for the transition and incorporate multiple technology solutions. Roadmap development and evolution needs to be able to anticipate changes and adapt, allow for new technologies, changing regulations, an increase in ambition and new entrants. The roadmap development process also should consider existing infrastructure and avoid stranded assets and the lock-in of long-term emissions, especially given the long asset life cycles in heavy industry.

The La Trobe Valley Authority is an example of government coordination through a purpose-built regional authority to support the challenging transition of major industry change in the region, working in an ongoing way with communities, businesses, government, education and training organisations. The authority supports business incubation and acceleration, skills and training development, impact monitoring and shared learning.

In 2022, NSW government support for regional roadmaps, called CMPs, is stimulating conversations and connections between relevant organisations and is a good initial step. Industry in the Hunter and Illawarra regions are supportive of the cluster and roadmap approach. The expectation is that this will lead to consortia building and collaboration. Learning from the UK and Europe points to the need for strong goals and aligned policy to make this effort effective. The Kwinana Industries Council, a long-standing association with members from the Kwinana Industrial Area, is unique in that it is developing its own Carbon Reduction Plan without government support (Kwinana Industries Council, 2021a). Industry organisations in other regions are very interested in learning from Kwinana.

Recommended action: Coordinate technology demonstration and deployment

Coordination of a region's decarbonisation efforts should include support for the variety of technology solutions available, and needed, to reach net zero.

- **Stimulate emerging technologies:** stimulating R&D through funding, sharing knowledge, supporting early applications to stabilise dominant solutions. (e.g. hydrogen direct reduction iron, carbon capture and utilisation (CCU) and carbon capture and storage (CCS), melter-BOF for green steel);
- **Support diffusion of proven but not yet commercial technologies:** support market uptake of new solutions which are technically viable but not yet commercially competitive through efforts such as government procurement, targets, mandates, underwriting, contracts for difference, subsidies and feed-in tariffs, for example for green hydrogen;
- **Accelerate scale-up of proven and commercial technologies:** support faster uptake through regulation, standards and market signals as well as enabling infrastructure, business models, user and customer practices and technical skills and capabilities e.g. renewable electricity.

An approach across different technology maturities would need support for diverse solutions and project types, coordinated over time through a roadmap and implementation process. It's important to note that stimulating and accelerating technology solutions needs supportive and simultaneous action across other dimensions of the system such as policy and regulation, markets, finance and investment, leadership and strategy. Shared learning is needed across the work to develop, diffuse and scale the range of technologies. This can be facilitated by robust, open and practical knowledge sharing, linked to government funding.

Recommended action: Support market development

Building early supply, demand and the enabling infrastructure that allows new markets such as hydrogen and green metals to develop and scale is critical to decarbonisation. Coordination, especially through policy, is important in building early supply, demand and the enabling infrastructure that allows new opportunities to scale.

Potential supports to develop markets could include:

- Incentives for demand side management e.g. demand response from heavy industry;
- Large users incentivised to make public offtake commitments, and guarantee purchase of green products;
- government procurement for products like hydrogen and green steel, through concierge and matchmaking services (Collins, 2022);
- Feed-in tariffs for green hydrogen;
- Coordination of material stocks and exchanges of inputs/outputs for establishment of a circular economy;
- Sector coupling for renewable fuels, diesel replacement and firming;
- Grants and subsidies for manufacture, to spur further development;
- A 'renewable energy target (RET)' style hydrogen framework with tradable certificates or a broader renewable or zero emissions gas target, such as with NSW and WA targets of 10 percent hydrogen blending in gas networks by 2030;
- Contracts for difference (the government agrees a strike price with hydrogen producers and tops up payments when the wholesale price is below this (Judd, 2021) allowing producers to price clean hydrogen competitively with alternative fuels;
- A mandated minimum percentage blend of green hydrogen e.g. as part of government procurement requirements, or nested within existing government programs;
- Hydrogen certification to improve access to markets,
- Sector-specific public funding that de-risks private investment to attract private capital and achieve scale.

2.3 Collaboration to overcome complex challenges

Industrial organisations increasingly recognise that many decarbonisation challenges and opportunities can't be addressed by single organisations acting alone. In the UN Global Compact's 2nd CEO Study (United Nations Global Compact, 2019) 'CEOs emphasize that many of these global development challenges are bigger than any one company: to truly solve these issues, collaboration is a necessity' and 'Winning no longer (only) means besting your competitors, but working collectively to achieve lower emissions.' (Tuff, 2021).

Recommended action: Collaborate on research, development and demonstration of emerging solutions

Industry partnerships are needed for emerging supply chain solutions and working on common strategic risks and opportunities. Partnerships are important where new solutions are needed along the supply chain or where several organisations face similar strategic challenges and see an opportunity to share risk and costs. As we've seen in the analysis above, some solutions needed to decarbonise heavy industry are mature and commercially available, but many others are not. Emerging and proven but not commercial solutions require further research, development and demonstration over coming decades.

The future of steelmaking in general and the future attractiveness of Pilbara ores in particular are two topics of huge strategic importance to Australia. Domestically, BlueScope Steel is developing new partnerships for low emissions steel technology development, announcing MoU's with Rio Tinto (BlueScope, 2021a) and Shell Energy Operations (BlueScope, 2021b) which are profiled in this report. Rio Tinto and BHP have also made public announcements on research partnerships they have with customers and leading international steelmakers such as China Baowu Steel Group (Rio Tinto, 2020) in China and JFE Steel in Japan (BHP, 2021).

INFORMATION BOX 15:**Understanding the role of hydrogen in steelmaking****BlueScope Steel and Shell Energy**

Steelmaker BlueScope and Shell Energy have joined forces with a Memorandum of Understanding (MOU) to develop renewable hydrogen projects in the Illawarra region.

Shell and BlueScope will investigate the design, build and operation of a 10MW pilot renewable hydrogen electrolyser plant at the Port Kembla Steelworks to explore and test the use of green hydrogen in the blast furnace onsite. The MOU also provides for BlueScope and Shell to collaborate with other organisations to develop a hydrogen hub in the Illawarra region, exploring options for hydrogen supply and offtake, renewable energy supply and hydrogen and electricity infrastructure.

The Illawarra's diversity of sectors across industry, energy, transport infrastructure, minerals and mining, combined with research and academic partnerships, makes it well-placed for further collaborations to develop hydrogen technology and support the region's decarbonisation efforts. (BlueScope, 2021b).

Information provided by BlueScope Steel

Carbon capture and utilisation (CCU) and carbon capture and storage (CCS) are potential abatement solutions that companies are looking at across a range of industries. The complexity of these challenges is a strong catalyst for companies to collaborate on developing and demonstrating solutions together.

Recommended action: Develop new ways to collaborate

There are challenges for collaboration. Heavy industry players are traditionally highly competitive which constrains the transparency needed for effective collaboration, and there are few models and frameworks for multi-stakeholder collaboration. Enabling collaboration requires experience, knowledge and tools not previously required in a traditionally competitive environment. Government program funding that requires multiple industry partners can facilitate collaboration by requiring projects with multiple industry partners to develop collaborative models for supply and demand solutions and supply chain level initiatives. In addition, support is needed to organise ongoing connections and draw in collaboration model learning and insight into regional efforts in a timely way, linking to leading efforts in Australia and overseas. Funding is needed to support and organise ongoing connections between stakeholders. Models for collaborations should bring together demand, supply, infrastructure, government funding and/or procurement, and manage shared risk, competitive tensions and intellectual property are evolving and emerging all over the world and in Australia.

Joint cluster efforts at the regional level are critical for bringing about energy system transformation and industrial process supply chain decarbonisation. The energy system is a key enabler for decarbonisation and is interconnected at the local district and region level. Sector coupling, the process of integrating end-use sectors with power supply to enable flexibility to respond to VRE, enables a more effective energy system with a higher share of renewables. Clustering can also provide opportunities for efficiencies on energy use, reliability and by-product markets in a circular economy.

Recommended action: Active engagement in regional leadership and coordination efforts

In order to position themselves for the challenges and opportunities ahead, it is important for heavy industry companies to actively engage and work with each other in regional leadership and coordination efforts, both those being facilitated by federal and state governments as well as cluster organisations and in some cases a need to come together in new constellations. Companies increasingly understand the need to have a clear understanding of each other's issues, planned activities, target outcomes and potential value proposition of working together. This can be provided through coming together in regional leadership groups and coordination efforts and working on joint plans and roadmaps for the transition. Regional industry leadership groups and decarbonisation sub-groups should be established, where they don't already exist, to enable active industry involvement in regional decarbonisation solutions. Knowledge exchange between leadership groups domestically and internationally can accelerate learning for the transition. Examples of established regional industry leadership groups include Kwinana Industries Council (KIC) and the Gladstone Industry Leadership Group. The Kwinana Industries Council is working on a Carbon Reduction Plan which should provide a solid basis from which to build coordinated decarbonisation efforts. Regional industry leadership groups focusing on decarbonisation are in their starting phase, don't yet exist in all regions, and will need to be scaled up to support the type of change required.

Recommended action: Collaborate to align policy and regulation to net zero

Governments often seek input from industry on policy and regulation development through public consultations. Industry can work together to align and amplify messaging to government on what policy and regulation is needed to enable their decarbonisation based on operational experience. Better outcomes can be achieved for government and industry if companies work together to inform the policy and regulations needed through forums like public consultations to support decarbonisation. Companies should explore opportunities to work through existing groups and come together in new groups where coordination is not happening or is not sufficient.

2.4 The importance of acting now

While many opportunities to decarbonise industry are still emerging, it is not an option to wait. Action is needed now to ensure emissions are reduced in line with limiting warming below dangerous levels and to capture early-mover advantages and mitigate risks in the transition to a global green economy.

Urgent action is needed to avoid the worst risks of climate change and avoid the need for much steeper emissions reductions in the future

The impact of warming from CO₂ is cumulative in the Earth's atmosphere. Without further action on decarbonisation now, the global carbon budget would be exhausted by 2030, from which point emissions would need to be brought immediately to zero, to stay within a carbon budget that limits warming to 1.5°C. Action now will reduce the need to make even steeper emissions reductions in the future.

Action now will enable industries and regions to transition more effectively over the coming decades and develop world-leading capabilities that can drive competitiveness in a new economy

While much of the opportunity to decarbonise industrial regions towards net zero requires further development before being commercially ready for deployment, action is needed now to align industrial ambition, lay the policy and regulatory groundwork and enable a more efficient and effective transition.

There are opportunities to be found in the challenge of transformation by acting now. The Business Council of Australia advocates for Australia to adopt an early-mover advantage on decarbonisation, arguing regional transitions can be better planned and, as a result, less costly both economically and socially, with the potential to gain a greater share of new green export industries (Business Council of Australia, 2021).

The benefits of clustering industry and green technology are widely recognised and are being promoted in New South Wales through the state government's Clean Manufacturing Precincts. By taking a whole-of-cluster approach, governments and industry can drive new investment in these regions, helping to create new jobs and opportunities, while also supporting the regions' traditional industry and supply chains.

Fostering early demand for green hydrogen will be critical over the next decade to unlock cost reductions and develop a feasible scale-up trajectory for its widespread use in a net zero transition (Energy Transitions Commission, 2021). As major industrial centres, these regions have opportunities to develop early offtake markets at a regional, state, and potentially international scale, using their energy loads to help support system transformation.

Innovation, investment, and support by governments and industry accelerate technology development and enable commercial competitiveness sooner than anticipated

Industrial transition is challenging and takes time. Significant investment over a number of decades will be required to deploy zero carbon technologies and build infrastructure to decarbonise industry and the economy more broadly. It is anticipated that many technologies will not be commercially viable for the next five to ten years, if not longer. This leaves a development and economic gap that must be filled, as waiting until this gap has closed to implement net zero initiatives will prevent the meeting of net zero ambitions and lock Australian industry out of lucrative global markets.

The phase between proof of concept and successful innovation with positive revenue is known as the 'valley of death'. Increasingly, researchers from industry and academia are working together, often encouraged by governments, to cross this 'valley' as they seek to bring new innovations to the market. There is a clear role for governments to address the market failure which emerges from the 'valley of death'.

Governments must play a role in helping to pull new technologies through the research, development, demonstration and commercialisation pipeline. Government assistance is being provided in the form of grants and subsidies, but non-financial assistance can also be valuable. Examples include ensuring policy, regulation and standards support and do not block new solutions, providing concierge services that help to match supply and demand, identifying planning and licensing requirements, and other types of facilitation. However, much more needs to be done for Australia to keep up with the pace of spending and support provided by governments in Europe, Asia and North America.

Future developments can drive down the cost of technologies, increase their performance and uptake, and potentially lead to achieving the transition much sooner than 2050. Multiple factors could contribute to this. Technology often outperforms even the best expectations, as long as deployment is driven early to achieve positive feedback loops of continued learning effects. Similarly, breakthrough technologies can overturn timelines based on anticipated incremental improvements. Further, record low costs of renewable electricity are being regularly recorded, and there are clear synergies and positive feedback loops involving green hydrogen production, renewables and hydrogen use. Positive feedback will continue as long as Australia remains at the forefront of these industries and can capitalise on growing global demand.

While currently some green processes appear to be competitive only in the long term, effective large-scale deployment in the short term could drive the technology improvements needed to reach cost parity much sooner than expected, as has been seen with solar and wind pricing.

The development of decarbonised industrial processes has accelerated rapidly in recent years driven by increasing support and investment from governments and industry. In the last few years, green steel production using hydrogen has been demonstrated and has delivered small shipments of steel produced without fossil-fuels (The Guardian, 2021). New technologies for steelmaking are also emerging, including molten oxide electrolysis and Melt-BOF, which may address issues with ore quality that would limit application of hematite ores (Mission Possible Partnership, 2021).

3. Enabling regional transformation

The global decarbonisation transition tremendous opportunities but also presents potential trade risks for countries like Australia as the world embraces net zero compatible products such as renewable hydrogen and ammonia, and green metals. Unlike many countries, Australia has the natural resources, workforce and ability to expand infrastructure to support the development of these new industries, including in existing industrial regions such as the Pilbara, Kwinana, Hunter and Illawarra. Where these opportunities can be realised, there are clear benefits for employment within these regions as well as for the nation as a whole.

The challenges of decarbonisation cannot be underestimated. Navigating the decarbonisation of existing heavy industrial operations and associated infrastructure requires significant change and disruption. Realising decarbonisation opportunities in heavy industry will often require changes to the entire production process, as is the case in alternative steelmaking processes such as direct reduction of iron through hydrogen. The International Energy Agency describes achieving net zero emissions by 2050 as 'requiring nothing short of a complete transformation of the global energy system'. While energy is material to decarbonisation, transformation is also required in other areas. Australian Industry ETI partners are experiencing the transformation first-hand in planning and implementing changes in operations, strategy, regulatory environment, and financing.

Realising the opportunities outlined in this report will require a strong effort from industry, investors and government. An appropriate level of ambition is required; one that acknowledges the scale of the transition, as well as the fact that coordination, collaboration and urgent action will be key to the effective decarbonisation of Australia's industrial regions. A number of levers are available to address the challenges and opportunities discussed in this report. Table 9 provides recommended actions and the potential roles that government, industry and broader stakeholders can play in the effective adoption of these actions.

TABLE 09: Recommended actions that could unlock the opportunity of regional decarbonisation

		Government	Industry	Communities	Investors
Target net zero emissions in industrial regions	With net zero emissions targets now set at state and national levels, planning and action to decarbonise industrial regions should be aligned to a regional net zero target to guide decision making for the long-term transition.				
Energy system planning for rapid and accelerating transition	Ensure system plans such as the NEM's ISP and the WOSP in Western Australia's SWIS actively plan for an accelerating transition towards firm, zero-emissions electricity and hydrogen networks at the scale needed. Planning should be consistent with 1.5°C warming scenarios, including planning for energy and green metals export scenarios.				
Develop the energy systems of tomorrow, today	Develop Renewable Energy Zones (or equivalent in WA) in proximity to industrial regions at the scale needed for industrial decarbonisation.				
Strategic alignment of supporting mechanisms	Provide long term investment signals strategically aligned to the scale of decarbonisation needed to achieve net zero targets in these regions. Align enabling policies to incentivise and underpin additional, competitively priced, firm and well-planned energy supply.				
Align and coordinate federal and state government policy and programs	Effectiveness of government efforts can be increased by coordinating across multiple levels of government, and by supporting industry's efforts to engage. Missions, tasked with coordinating government efforts on a common goal, are gaining traction globally. A central navigation support service for industry is also needed to enable efficient engagement in government programs				
Regional decarbonisation roadmaps	Co-develop regional decarbonisation roadmaps to align stakeholders on the vision and milestones for the deployment of infrastructure, energy systems and technology solutions. Roadmaps should target the development of new opportunities in potential markets such as hydrogen, green metals and energy export.				
Coordinate technology development, demonstration and deployment	Stimulate emerging technologies with funds for research and development, pilot and demonstration studies. Support proven but not yet commercial technologies through government procurement, targets, mandates, discounted finance. Accelerate the deployment of proven and commercial technologies through aligned policy, regulation, standards, finance and investment, and enabling infrastructure. Shared learning should be facilitated across technology development efforts.				
Support market development	Build early supply, demand and the enabling infrastructure that allows new markets such as hydrogen and green metals to develop and scale. Levers include: facilitating offtake commitments, guaranteeing the purchase of green products through government procurement, feed-in tariffs, mandates and certification schemes for green products such as green metals and hydrogen.				
Collaborate on research, development and demonstration of emerging solutions	Industry partnerships are needed for emerging supply chain solutions and working on common strategic risks and opportunities. Government program funding that requires multiple industry partners can facilitate collaboration on supply and demand solutions and supply chain level initiatives.				
Develop new ways to collaborate	Funding is needed to support and organise ongoing connections to draw in learning and insight on collaboration models into regional efforts in a timely way. Models for collaborations should bring together demand, supply, infrastructure, government funding and/or procurement, and manage shared risk, competitive tensions and intellectual property.				
Collaborate to align policy and regulation to net zero	Better outcomes can be achieved for government and industry if companies work together to inform the policy and regulations needed through forums like public consultations to support decarbonisation. Companies should explore opportunities to work through existing groups and come together in new groups where coordination is not happening or is not sufficient.				
Active engagement in regional leadership and coordination efforts	Regional industry leadership groups and decarbonisation sub-groups should be established, where they don't already exist, to enable active industry involvement in regional decarbonisation solutions. Knowledge exchange between leadership groups domestically and internationally can accelerate learning for the transition.				

4. Next steps

From regional opportunities to decarbonisation pathways

This report provides a high-level overview of potential opportunities across key industrial regions in Australia with the goal of providing an evidence base for more informed and aligned action towards net zero emissions from industry, investors and government.

Significant action is underway across heavy industry to decarbonise, particularly in these regions. However, further efforts are needed to ensure Australia, its industries and its regions are positioned for prosperity in a decarbonising global economy and to avoid the worst impacts of climate change. Urgent actions are needed to significantly scale-up investment in industry and the energy system to reach the level of abatement required, and facilitate coordination of a complex transition and the necessary collaboration among stakeholders.

The Australian Industry ETI will continue to bring Australia's industrial economy together to focus on these challenges. The next phase of the Australian Industry ETI focuses on the development of tangible pathways and action projects to inform, enable and build momentum towards the transition.

The Australian Industry ETI and research partners are currently developing modelling of the energy system transition to understand what actions need to happen by when, to achieve decarbonisation in line with 1.5°C . This modelling will build on the analysis of the Phase 1 and 2 reports by developing techno-economic modelling of least cost pathways aligned to 1.5°C .

Industry partners will work closely with the initiative on the insights of this modelling to develop strategic pathways to net zero emissions to further inform an effective transition. They will also collaborate on tangible action projects and demonstrations to build learning and momentum.

The Australian Industry ETI's efforts will continue to focus on accelerating action towards net zero emissions by 2050. It is a challenging path, but one that provides opportunities to position Australian industry to thrive in a decarbonised global economy.

Glossary of terms

ACCU s	Australian carbon credit units
AEMO	Australian Energy Market Operator
AGIG	Australian Gas Infrastructure Group
AMC	Australian Marine Complex
ARENA	Australian Renewable Energy Agency
Australian Industry ETI	Australian Industry Energy Transitions Initiative
BEV + TA	battery electric vehicle and trolley assist
BF-BOF	Blast furnace–basic oxygen furnace
bp	British petroleum
CA100+	Climate Action 100 plus
CAPEX	Capital expenditure
CCS	carbon capture and storage
CCU	carbon capture utilisation
CEFC	Clean Energy Finance Corporation
CEIP	Clean Energy Innovation Park
CMP	Clean Manufacturing Precincts
CO₂	carbon dioxide
CRCs	cooperative research centres
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DRI-EAF	Direct reduced iron–electric arc furnace
DRI-Melter-BOF	Direct reduced iron–Melter–Basic oxygen furnace
DSR	demand side response
EOI	Expression of interest
ESG	environmental, social and governance
FCEV	fuel cell electric vehicle
FEnEX CRC	Future Energy Exports Cooperative Research Centre
FFCRC	Future Fuels Cooperative Research Centre
FFI	Fortescue Future Industries
FIFO	fly in fly out
FMG	Fortescue metals group
GDP	Gross domestic product
GFANZ	Glasgow Financial Alliance for Net Zero
GHG	greenhouse gas
GJ	Gigajoule
GW	Gigawatt
H2N	Hunter hydrogen network
HILT CRC	Heavy Industry Low-carbon Transition Cooperative Research Centre
ICT	Information, communication and technology

IEA	International energy agency
IPCC	Intergovernmental Panel on Climate Change
IPL	Incitec Pivot Limited
ISP	Integrated System Plan
KETH	Kwinana Energy Transformation Hub
KIA	Kwinana Industrial Area
KIC	Kwinana Industries Council
LDAR	leak detection and repair
LNG	Liquefied natural gas
MCI	Mineral Carbonation International
MOU	Memorandum of Understanding
MRIWA	Minerals Research Institute WA
Mt	megatonne
MtCO₂e	megatonne of carbon dioxide equivalent
MVR	mechanical vapour recompression
MWh	megawatt hour
NAIF	Northern Australia Infrastructure Facility
NCILF	New Low Carbon Industry Foundations and
NCIIP	Net Zero Industry and Innovation Program
NEM	National Electricity Market
NERA	National Energy Resources Australia
NDC	Nationally Determined Contributions
NSW	New South Wales
NWIS	North West Interconnected System
NZAOA	Net Zero Asset Owner Alliance
OEM	Original equipment manufacturer
PEM	proton exchange membrane
PFCs	perfluorocarbons
PJ	Petajoule
PPA	power purchase agreement
PV	photovoltaic
R&D	Research and development
RET	Renewable Energy Target
REZ	Renewable energy zone
RIZ	Rockingham Industrial Zone
ROI	Registration of interest
SIA	Strategic industrial area
SMR	Steam methane reforming
SWIS	South West Interconnected System
SAF	sustainable aviation fuel
TRL	Technology readiness level
TWh	Terawatt hour
UK	United Kingdom

USA	United States of America
V2G	vehicle-to-grid
V2H	vehicle-to-home
VRE	variable renewable energy
WA	Western Australia
WEM	Wholesale Electricity Market
WOSP	Whole of System Plan
WTC	Western Trade Coast

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Appendix

Appendix one - Key assumptions and methodology

In line with achieving net zero emissions supply chains, only those technologies with the most significant, long-term abatement potential for each industrial process have been presented. While alternative technologies may play a role in the transition to net zero emissions industrial supply chains, analysis of these and the timing of their deployment will be a focus of analysis in the next phase of the Australian Industry ETI program.

The abatement opportunities identified in this report are classified into three broad categories of commercial readiness. Those with a technology readiness level (TRL) of 8-9 are deemed 'mature and commercially available'; where 'commercially available' technologies are those able to be purchased and practically deployed in a commercial setting, rather than indicating cost-competitive relative to incumbent or other technologies. Those technologies with a TRL of above 6 are deemed 'proven but not yet commercial' and those with a TRL of below 6 are 'emerging', requiring further research and development.

Energy capital costs are based on current production capacities of each supply chain and do not take into consideration changes in demand or production capacity. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4-5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Hydrogen production costs are based on PEM electrolysis powered by variable renewable energy with a utilisation rate of 30 percent. Hydrogen storage costs are included in the CAPEX cost. Variable renewable electricity costs do not take into consideration transmissions and distribution costs. The following assumptions have been used in the analysis:

Year	Technology capital costs ³⁹		
	Large scale PV (A\$/kW)	Wind (A\$/kW)	12h storage (\$/kW)
2020	1408.00	1951.00	3468
2030	827.00	1895.50	2532
2040	654.50	1817.00	2220

Year	VRE capacity factor (percent)				
	Pilbara	Kwinana	Gladstone	Illawarra	Hunter
2020	35	38	37	26	30
2030	33	35	36	26	32
2040	32	34	34	26	31
2050	32	34	34	26	31

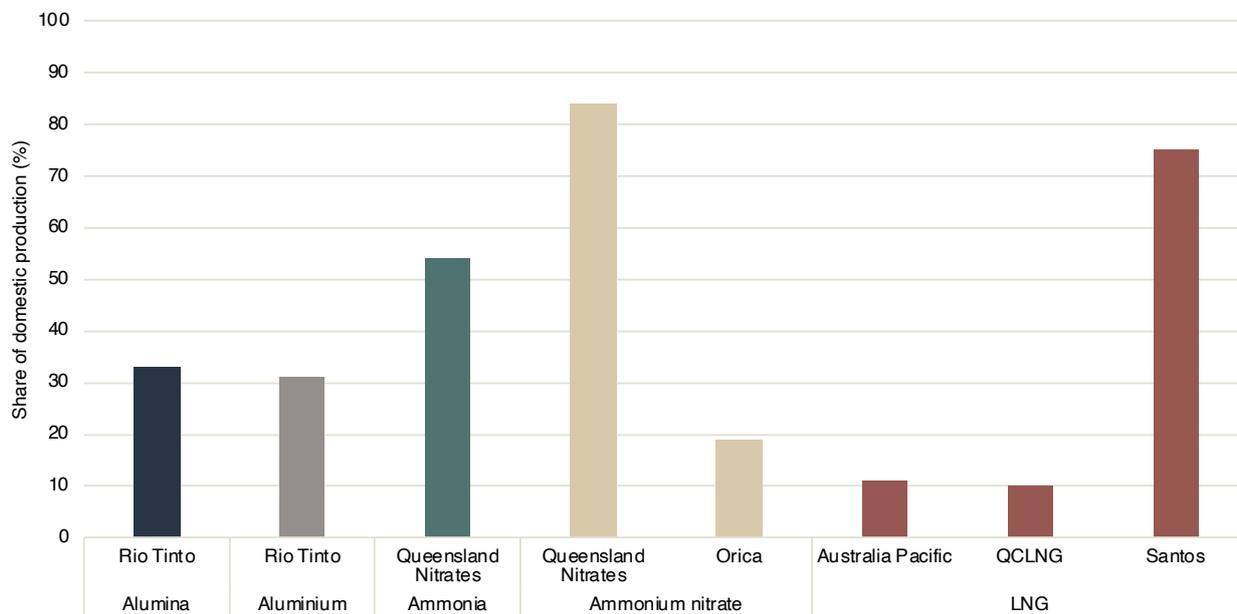
Year	PEM performance (kWh/kg)	PEM cost (A\$/kW)	Hydrogen storage (A\$/kW)
2020	52.6	1944	511.06
2030	47	949	237.21
2040	43	292	161.61
2050	43	206	161.61

³⁹ Technology capital costs are sourced from CSIRO GenCost data

Appendix two - Gladstone analysis

Production in Gladstone

FIGURE 14: Share of domestic production of major industrial sub-sectors in Gladstone



Emissions in Gladstone

FIGURE 15: Annual emissions of major industrial sub-sectors in Gladstone

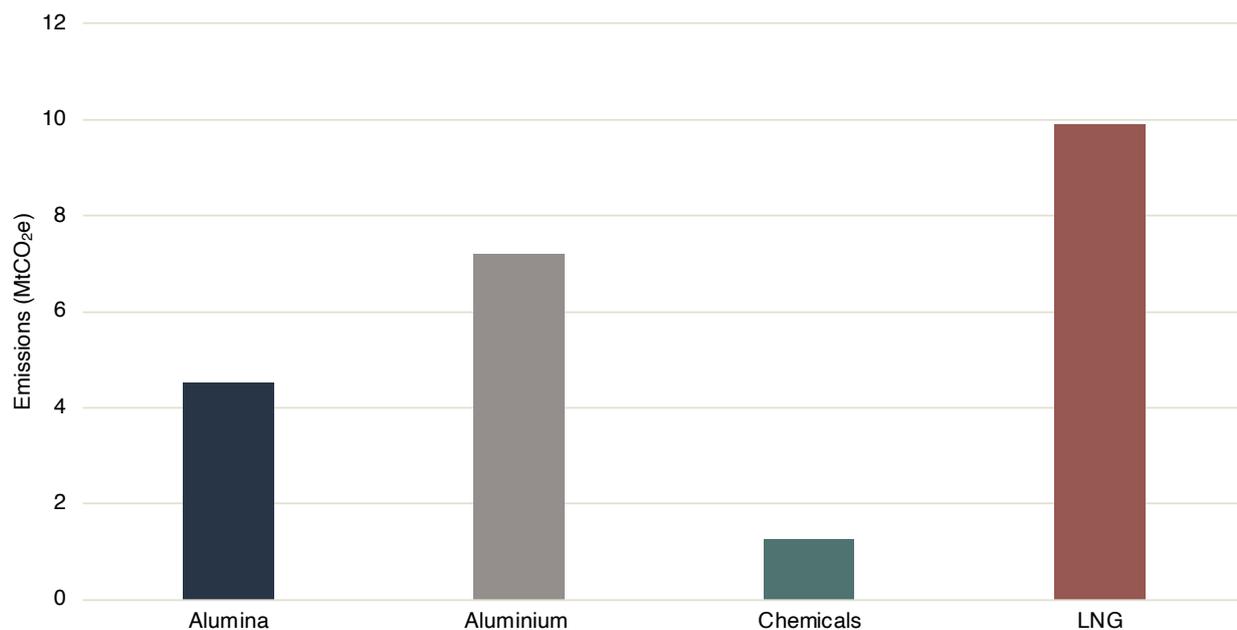


TABLE 15: Major abatement opportunities for Australian Industry ETI partner supply chains in Gladstone

Industry	Major, long-term abatement options	Readiness	Percentage identified industry abatement potential/year	Energy requirements/year	Energy capital costs (excluding infrastructure) ⁴⁰
LNG ⁴¹	LDAR and vapour recovery for fugitive emissions. Waste heat recovery during liquefaction	Mature ⁴² and commercially available	~16 percent = 1.6 MtCO ₂ e	-	-
	Electric drives for liquefaction ⁴³	Proven but not yet commercial	~61 percent = 1.62–6.0 MtCO ₂ e	2.6- 9.7 TWh	VRE: A\$ 1.4–5.2 b Battery storage: A\$ 1.1- 4.08 b
	CCS for reservoir gas	Proven but not yet commercial	~5 percent = 0.5 MtCO ₂ e	-	-
Ammonia and ammonium nitrate	Nitrous oxide abatement	Mature and commercially available	~73 percent = 0.9 MtCO ₂ e	-	-
	Switch current electricity use to renewable electricity	Mature and commercially available	~8 percent = 0.1 MtCO ₂ e	0.1 TWh	VRE: A\$0.06 b Battery storage: A\$0.05 b
	Green hydrogen as feedstock and Haber Bosch electrified and powered by renewable electricity	Proven but not yet commercial	~16 percent = 0.2 MtCO ₂ e	0.9 TWh	VRE: A\$0.4 b Electrolyser: A\$0.2 b Battery storage: A\$0.1 b
Alumina	Electric boilers for digestion heat, powered by renewable electricity	Mature and commercially available	~77 percent = 3.5 MtCO ₂ e	12.0 TWh	VRE: A\$4.8 b Battery storage: A\$5.1 b
	Mechanical vapour recompression for digestion heat	Proven but not yet commercial	~73 percent = 3.3 MtCO ₂ e	2.3 TWh	VRE: A\$1.2 b Battery storage: A\$1.0 b
	Green hydrogen for calcination	Proven but not yet commercial	~26 percent = 1.2 MtCO ₂ e	6.4 TWh	VRE: A\$3.9 b Electrolyser: A\$2.8 b
	Electrification of calcination, powered by renewable electricity	Emerging Technology		2.0 TWh	VRE: A\$1.0 b Battery storage: A\$0.8 b

40 Capital costs are based on current production capacities of each supply chain in the Pilbara. Battery storage costs assume a flat, 24/7 industrial load; but measures to improve demand flexibility in line with a typical diurnal load combined with access to customer-owned storage (such as embedded storage and electric vehicles) could reduce the amount of storage capacity by up to 70 percent and the average duration of storage from 12 hours to 4-5 hours (the latter of which are roughly 40 percent cheaper on a \$/kW basis). Electrolyser costs are based on PEM electrolysis and include costs of hydrogen storage. Additional capital cost assumptions are included in the appendix.

41 The lower end of the range for abatement potential, energy requirements, and capital costs represents a ~73 percent reduction in Australia's LNG production by 2050 aligned to IEA Net Zero scenario

42 For the purposes of this analysis, 'commercial' technologies are those able to be purchased and practically deployed in a commercial setting, rather than indicating cost-competitive relative to incumbent or other technologies.

43 Electric drives for greenfields are 'mature and commercial' but for brownfields are considered 'proven but not yet commercial' due to various retrofitting and operational challenges.

TABLE 15 continued: Major abatement opportunities for Australian Industry ETI partner supply chains in Gladstone

Industry	Major, long-term abatement options	Readiness	Percentage identified industry abatement potential/year	Energy requirements/year	Energy capital costs (excluding infrastructure) ⁴⁰
Aluminium	Switch to renewable electricity for smelting ⁴⁴	Proven but not yet commercial	~86 percent = 6.2 MtCO ₂ e	7.0 TWh	VRE: A\$3.9 b Battery storage: A\$3.0 b
	Switch carbon-based anodes to inert anodes	Proven but not yet commercial	~14 percent = 1.0 MtCO ₂ e	-	-

Where technology options do not require renewable energy (and corresponding investment) energy and energy capital costs are zero.

Estimated jobs opportunity

The estimated A\$14.2 – 33.6 billion of capital investment in decarbonisation in Gladstone could support between 34,000 to 89,000 jobs; of which, 35 percent would be in Gladstone and 65 percent across Australia.

⁴⁴ Although renewable energy technologies are mature and commercial, constant and reliable supply of variable renewable energy for large energy users such as aluminum smelters is still not commercially viable.

Appendix three - WA context for focus studies

Western Australia led the nation in exploring a variety of new low carbon industries in their 2021-22 State Budget including funding for a range of emerging sectors, including green steel, battery manufacturing, and renewable hydrogen. Western Australia is home to rich renewable energy and mineral resources and is starting to identify opportunities for advancing innovative technologies, scaling renewable energy and catalysing hydrogen as an enabler for decarbonisation. Western Australia (WA) is the world's biggest lithium producer and host to large reserves of other battery metals including nickel and cobalt and offers opportunities to participate in any and every step of the supply chain.

In 2020, the Western Australian Climate Policy was launched by the state government (Government of Western Australia, 2020), setting out actions and policy priorities, which are at varying stages of implementation including plans for net zero industrial estates; green industry transformation, and sectoral emissions reductions strategies (Government of Western Australia, 2021).

The Western Australian government has a strong focus on hydrogen industry development, with the release of the Renewable Hydrogen Strategy (2019), a Renewable Hydrogen Fund at the same time, and the Renewable Hydrogen Roadmap (2020) which brings forward hydrogen targets from 2040 to 2030, including a 10 percent target for renewable hydrogen to be blended into WA's existing gas pipelines and networks (Western Australian Renewable Hydrogen Strategy and Roadmap, 2019). The state government is involved in workstreams under the National Hydrogen Strategy and has sought funding to develop hubs in the Pilbara and Mid-West.

The state government has been pursuing significant energy reforms under the Energy Transformation Strategy (ETS). Much of the focus of this work has been on the main energy grid, the SWIS, to maintain reliability and security as it transitions to very high renewables penetration, including the inaugural WOSP modelling four scenarios with varying demand, technology, and economic conditions to help guide investments to achieve lowest-cost, lower-emissions electricity (Whole of System Plan, 2020). The next phase of ETS includes the establishment of an Energy Industry Development Team at Energy Policy WA (EPWA), which will work with local manufacturers and the mining industry to increase the uptake of locally-supplied renewable energy options for remote mine sites (Energy Transformation Strategy, 2019). Planning is also underway for the next WOSP which will this time include scenarios for renewable energy and storage penetration consistent with national and State emissions reduction goals (Government of Western Australia, 2020).

The state government has also established an LNG Jobs Taskforce (The Western Australian LNG Jobs Taskforce working groups, 2021) tasked with developing areas of opportunity for Western Australia's LNG industry. This includes a Technology and Decarbonisation Working Group and made Net Zero Emissions Mining and Green Steel research priorities for the Minerals Research Institute WA (MRIWA), setting up a Green Steel Challenge to map the pathway to maximising use of WA's magnetite and hematite iron ore resources and emerging hydrogen and renewable energy potential.

INFORMATION BOX 16:**Western Australian LNG Jobs Taskforce**

The Western Australian LNG Jobs Taskforce brings together government, industry and unions to create new opportunities, to bolster Western Australia's position as a global energy hub.

The taskforce has established a technology and decarbonisation working group which provides a forum for addressing challenges and opportunities for advancing innovative technologies, synergies between gas and renewables, and decarbonisation of the LNG sector (The Western Australian LNG Jobs Taskforce working groups, 2021).

The LNG taskforce is focused on enabling opportunities for advancing innovative technologies, better understanding the synergies between gas and renewables, and decarbonisation in the LNG sector (The Western Australian LNG Jobs Taskforce working groups, 2021).

The working group is progressing several initiatives, including support for the establishment of the Future Energy Exports Cooperative Research Centre (FEnEx CRC) (Future Energy Exports, n.d.). The centre will undertake cutting-edge, industry-led research, education and training to help sustain Australia's position as a leading LNG exporter, and enable it to become a leading global hydrogen exporter.

The WA government in collaboration with the FEnEX CRC is investigating the development of a Futures Facility, a microscale research and teaching plant to allow testing of new LNG and hydrogen processes in Kwinana.

The government has emissions regulation in place through the Greenhouse Gas Emissions Policy for Major Projects (Greenhouse Gas Emissions Policy for Major Projects, n.d.) which has a requirement for new projects or project expansions with significant emissions to set interim and long-term emissions reduction targets to support the State's aspiration of net zero emissions by 2050.

Appendix four - NSW context for focus studies

In September 2021, New South Wales increased its ambition and 2030 emissions reduction target to 50 percent of 2005 levels (up from 35 percent). The NSW government has a range of policies material to industry decarbonisation, including a recently released hydrogen strategy (Oct 2021) and is progressing energy regulation changes (Hydrogen, n.d.).

The New South Wales Government has a Net Zero Plan Stage 1 (NSW government, 2021a), as well as the industry specific Net Zero Industry and Innovation Program (NSW government, 2021), which focuses on supporting investment in regions to achieve a 50 per cent reduction in emissions by 2030, and net zero by 2050. Sitting under this program is support for the development of clean manufacturing precincts (CMPs) to set the foundation to attract and create new, low carbon industries, funding to fast track decarbonisation solutions for high emitting industry operations, and accelerate the commercialisation of clean technology.

The NSW government's Electricity Strategy (NSW government, 2019), and the Electricity Infrastructure Roadmap (Electricity Infrastructure Roadmap, n.d.) which followed, sets out a plan to transform the electricity system, coordinate investment in transmission, generation, storage and firming infrastructure as ageing coal-fired generation plants retire. It includes:

- Renewable Energy Zones (REZs) in the Central-West Orana, New England, South-West, Hunter-Central Coast, and Illawarra regions. Of these, the New England and Central-West Orana REZ around Dubbo and Wellington is the most advanced, with construction is expected to start before the end of 2022. The REZ will unlock up to 3000 MW of new electricity capacity by the mid-2020s, bringing up to A\$5.2 billion in private investment to the Central-West Orana region by 2030.
- Electricity Infrastructure Investment Safeguard to deliver an investment signal for generation, long generation storage and firming energy services. Consultation on some aspects has occurred with further insulation on competitive tender processes expected to be underway shortly,

There are other energy reforms in train currently, such as the Energy Security Safeguard (Energy Security Safeguard, n.d.) which includes a Peak Demand Reduction Scheme to support activities that reduce demand at peak times, including flexible demand response.

The NSW state government released its NSW Hydrogen Strategy (Stock, 2021) in October 2021 which includes a range of stretch goals, and three broad pillars of action: 1) Enable industry development; 2) Lay industry foundations; and 3) Drive rapid scale. There are numerous relevant actions, including:

- the establishment of a state-wide hydrogen infrastructure master plan;
- hydrogen-ready regulatory frameworks;
- A\$70 million for the development of hydrogen hubs (with the Hunter and Illawarra to be the first two hubs);
- 10 percent hydrogen blending in the gas network;
- network and electricity scheme concessions for electrolysers to incentive use of spare capacity to support hydrogen industry development;
- setting a hydrogen target (through the Energy Security Safeguard);
- market engagement to facilitate and opportunities to aggregate hydrogen demand.

Other relevant policy:

- Electric Vehicle strategy which includes rebates for new electric vehicle purchases, incentives for business to support vehicle fleets with hydrogen fuel cell and electric vehicles (NSW Electric Vehicle Strategy, n.d.)

Available funds:

- Net Zero Industry and Innovation Program and high emitting industries - A\$380m to support major plan and equipment upgrades by 2030 - combined are the Emissions Intensity Reduction Program A\$450m
- New Low Carbon Industry Foundations, including Clean Manufacturing Precinct Roadmaps and subsequent roadmap projects A\$175m, A\$70m of which will go to hydrogen hubs - confidential expression of interest (EOI) process closed December 2021

- Clean Technology Innovation A\$195m for an innovation hub, grants for R&D, commercialisation, and pilots, low emissions standards and unlocking sustainable finance.
- Hydrogen Hub Initiative A\$70m state wide (plus A\$70m from New Low Carbon Industry Foundations Program)
- Expression of interest (EOIs) for hydrogen projects and for hydrogen consumers (Developing hydrogen hubs for NSW, n.d.)
- Manufacturing efficiency funding – access up to A\$70k for metering or energy efficient equipment upgrades
- Emerging Energy Program – A\$75m for capital and pre-investment studies for large scale electricity and storage projects
- Energy Savings Scheme: financial incentives for organisations to invest in energy savings projects.

Power generation and energy markets

Electricity generation in NSW, and across the NEM, has historically been dominated by large coal-fired power stations which provide about three quarters of the State's electricity generation today. Four of the five remaining NSW coal-fired power stations are expected to close by the mid-2030s, starting with the Liddell power station in April 2023, followed by Vales Point in 2029, and Eraring and Bayswater in the early 2030s. This will remove 70 per cent of the State's generation capacity, equivalent to 9,500 MW, by the mid-2030s.

In NSW, replacement electricity supply to cover the exit of coal-fired generation is partially being planned for through the construction of several natural gas power stations (e.g. Tallawarra B in the Illawarra, the Hunter Power Project at Kurri Kurri). These power stations are intended to be hydrogen ready, however they are likely to use only small volumes of hydrogen for the short-medium term, and it is unclear how much hydrogen they will use in the longer term.

The NSW government's Electricity Strategy (Electricity Strategy, n.d.) and Electricity Infrastructure Roadmap (Electricity Infrastructure Roadmap, n.d.) set out a plan to deliver the State's first five REZs in the Central-West Orana, New England, South-West, Hunter-Central Coast, and Illawarra regions.

FURTHER INFORMATION

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