Seizing Australia's energy superpower opportunities

Assessing the outlook for Australia in a net zero world

An EY Net Zero Centre report

EY
Building a better working world

Foreword

Opportunity knocks, but will Australia answer?

Australia is well-positioned to catch a wave of opportunity, but our actions today on our pathway to net zero emissions will define our future.

Over the last 15 years, accelerating climate action has 'bent the curve' of global emissions, but much more must be done to limit climate change to 1.5°C. We're already seeing the world begin to take meaningful action on climate change, but as we increasingly shift globally towards a net zero future, we will face waves of new changes. These changes will lead to the development of new low-emissions technologies and industrial processes that will transform our energy systems to enable our wider decarbonisation. A world of new opportunities awaits, but does Australia have what it takes to be an energy superpower?

For communities, business leaders, and policymakers, understanding how to better compete and thrive globally is more critical than ever. Strong global action to reduce emissions, will inevitably impact Australia's export base. As a nation, we have advantages in raw materials and renewable energy that could underpin a re-energised export sector, helping to meet the world's needs for clean energy-intensive products. However, Australian capital and labour costs will be a watchpoint for significant investments, and our window of opportunity may be narrow.

At the heart of *Seizing Australia's energy superpower opportunities: Assessing the outlook for Australia in net zero world* lies an urgent call to action for our nation. Net zero offers an opportunity to re-energise the Australian economy and the heavy industry which underpins it. We have a conditional advantage for new heavy industry, leveraging our highly competitive renewable energy and mineral resources, but it has been some decades since Australia last invested in heavy industry at scale.

We have all the ingredients required to become a new energy superpower, with cost-competitive large-scale renewable energy, abundant minerals and natural resources, a highly skilled workforce, and deep access to capital. The real challenge, and opportunity, lie in developing competitive new low-carbon materials and energy-intensive industries and the infrastructure and manufacturing underlying these. Investment and capital flows are crucial to enable this transition, but if we move quickly, the opportunity is enormous. The earlier we, as a nation, can prepare for this change, the better placed we will be to capture our competitive advantage. Those organisations with a clear vision and roadmap for their energy transition will be best positioned for success – who accurately understand the real inhibitors to making bold steps, such as the availability of critical infrastructure and technology to support this transition– and who are prepared to move swiftly as these inhibitors dissipate.

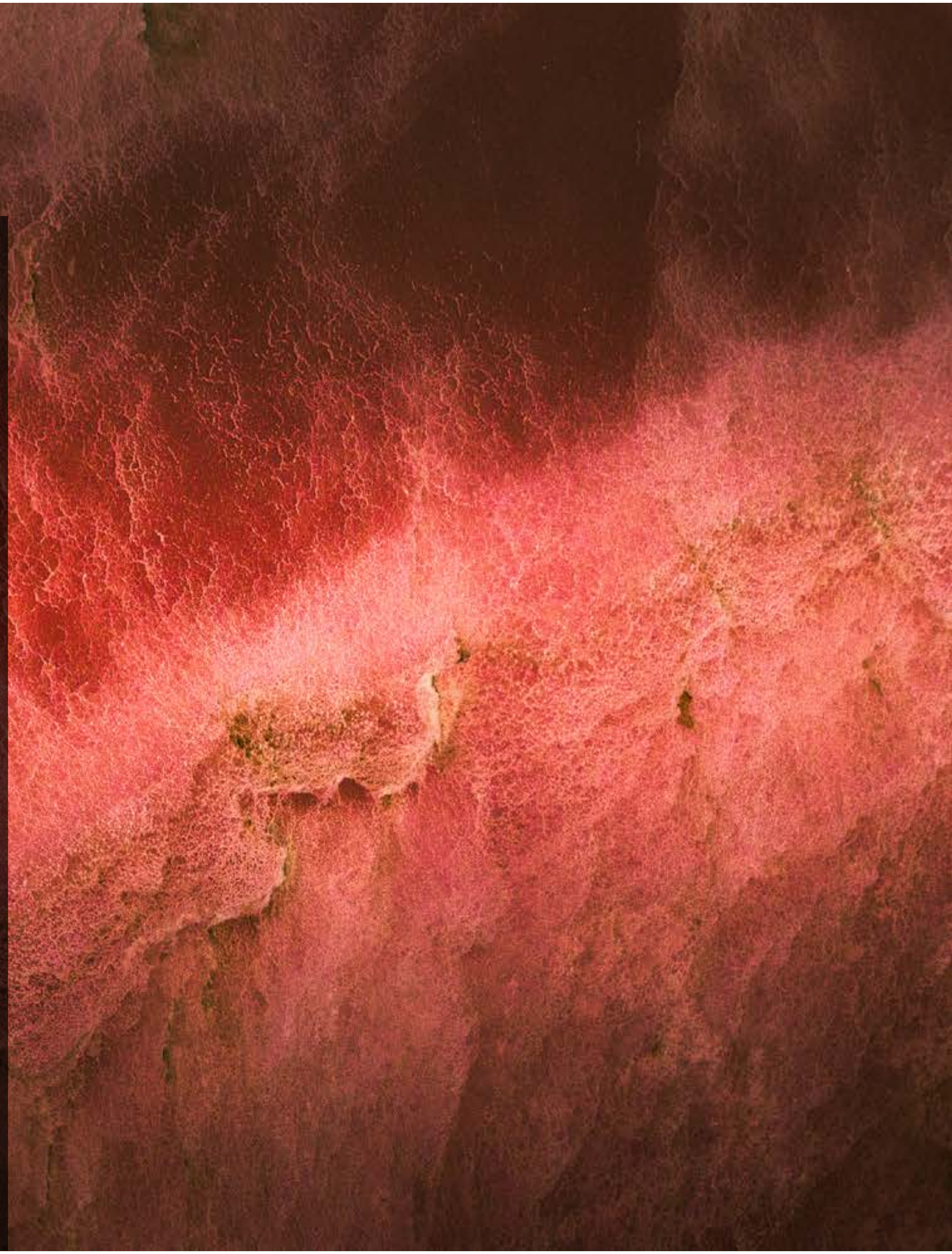
At EY, we are guided by our purpose of building a better working world, a world where economic growth is sustainable and inclusive. For the past two decades, we have been the largest and strongest Oceania advisor on climate change and sustainability strategy. EY's Net Zero Centre, led by Blair Comley, is integral to continuing this legacy, bringing the best of our deep expertise in climate change and energy transition together with the firm's strength in providing an end-to-end offering and organisational strategy to help Australian companies transition and improve their capacity to create long-term value.

Thank you to the EY Net Zero Centre team for their work to assist and accelerate the net zero transitions of our Australian and New Zealand client partners, for their strategic insight, expertise and deep knowledge in energy and climate change leadership, challenging stakeholders to solve the big problems ahead as we move towards net zero emissions by 2050.

Thank you for your interest in this report,

David Larocca

EY Oceania Chief Executive Officer and Regional Managing Partner



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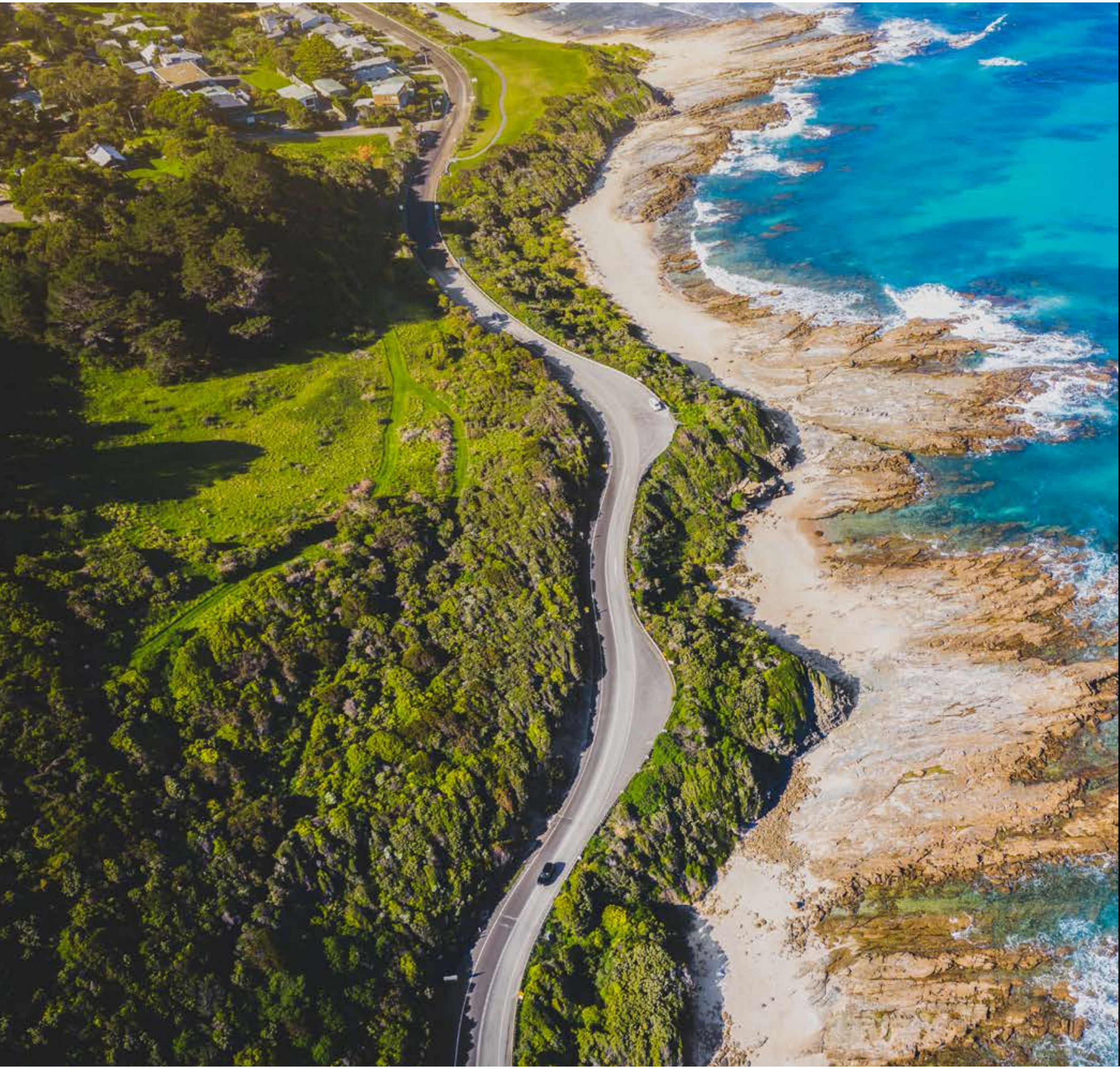
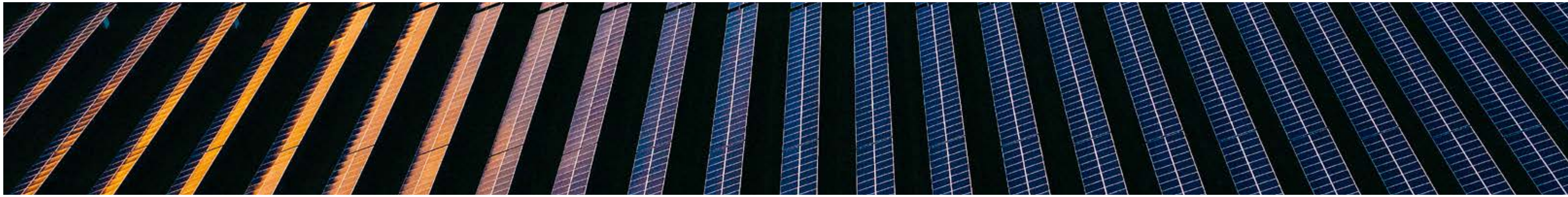


The global transition to net zero emissions opens a world of opportunity for Australia. But will the global shift create actionable and investible opportunities for Australia? And do we have what it takes to be an energy superpower?

The EY Net Zero Centre assesses this global shift and its implications for Australian materials- and energy-intensive sectors.

We find the economic opportunity is enormous, particularly for green iron and steel, and new energy minerals, and could add $40 billion to national income and $65 billion to Australian economic activity by 2050.

But urgent effort is required to capture this emerging new competitive advantage. Coordination, clarity and courage will be essential.



Global shift

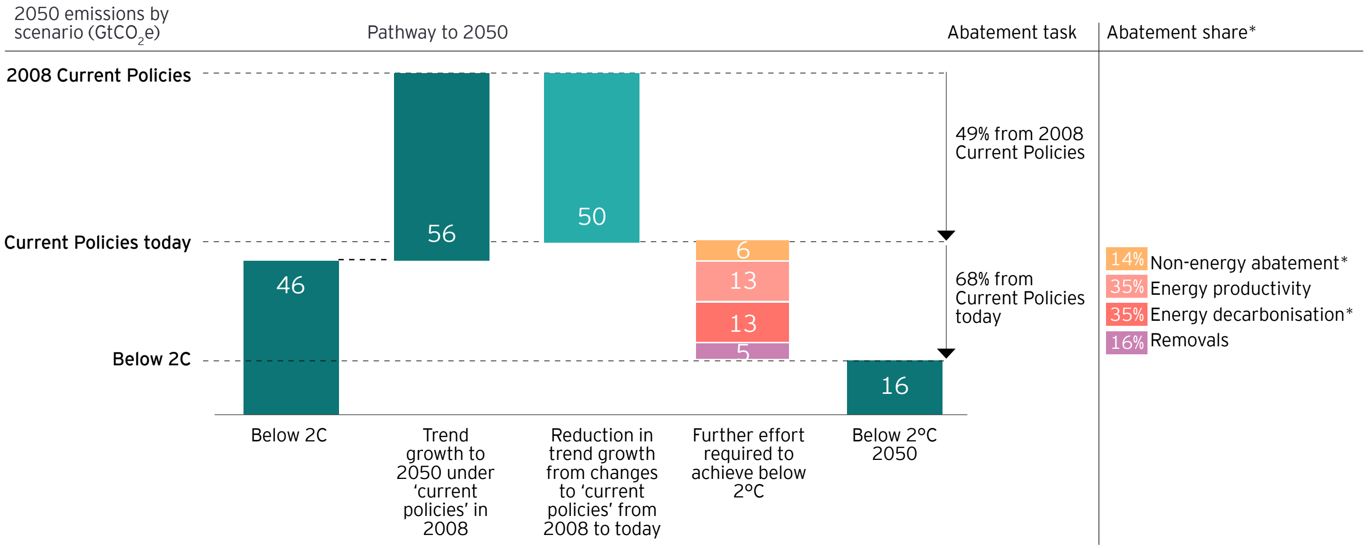
The world is already acting on climate change

A net zero world is not a low-income world. By 2050, the global economy will double while the number of people living in high-income countries will triple. This will drive demand for goods and services, and for the materials and energy that underpin them (as shown in Exhibits 05 and 06 in the main report).

Accelerating climate action over the last 15 years has already 'bent the curve' of global greenhouse gas (GHG) emissions, stabilising global emissions. But much more needs to be done to limit climate change to well below 2°C.

The analysis for this report assumes an orderly middle-of-the-road climate transition, described as strong climate action, in which advanced countries take the lead in reducing emissions. This pathway is consistent with limiting climate change to below 2°C, and involves reducing global emissions by 56% in 2050 relative to current policies, and net emissions by 68% including removals, as shown in Exhibit 01. This pathway is significantly less challenging than ambitious action, consistent with limiting climate change to 1.5°C, which requires net emissions to be reduced by around 80% by 2050 relative to current policies (as shown in Exhibit 07 in the main report).

Exhibit 01: Global action has already bent the curve, but strong additional action is required to limit global temperatures to well below 2°C



Note: * See Exhibit 08 for more detail

The global shift to net zero emissions will create waves of change

Strong global action to reduce emissions will both drive the development of new low-emissions technologies and industrial processes, and increase demand and willingness to pay for these.

This global action transforms energy systems, reducing electricity emissions by more than 90% while electricity supply increases significantly, displacing other energy sources. This enables wider decarbonisation through increased electrification and energy input switching in major end-use sectors, including transport and industry.

We find emissions reductions from energy accounts for 70% of global abatement in 2050, as shown in Exhibit 01, with reductions in industrial emissions accounting for an additional 7% of global abatement.

Heavy industry is centre stage

To limit climate change to below 2°C global emissions must fall by around 70% by 2050, even as the global population grows by 20% and the economy doubles.

The scale of this challenge means that action to reduce emissions is required by all major sectors, including heavy industry – made up of ferrous and non-ferrous metals, chemicals, and refinery products.

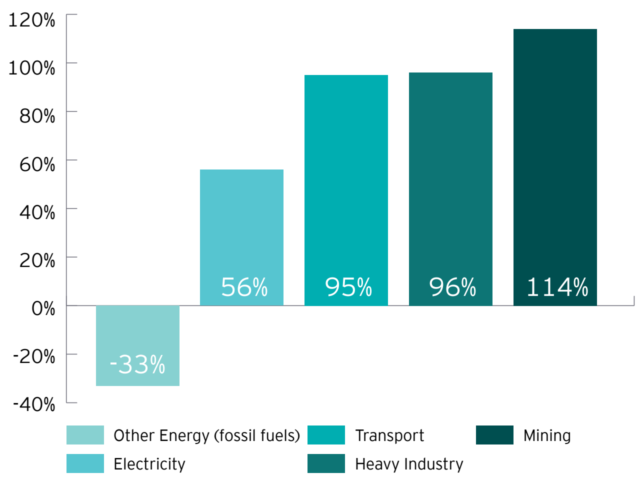
Heavy industry is central to this global transition for two reasons. First, heavy industry accounts for a large share of primary energy use and direct emissions, and so must be involved in global abatement efforts. And second, the transition to the new energy economy will require additional metals and minerals supplied by heavy industry to generate, store and distribute renewable energy in place of the old energy system based on fossil fuels.

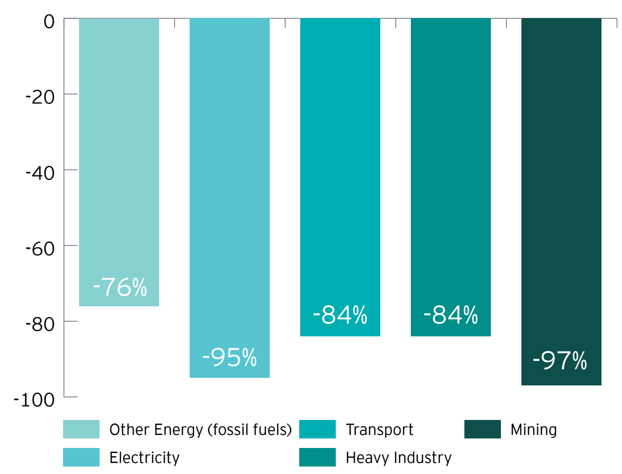
Heavy industry must find ways to reduce its emissions intensity by around 80%, while doubling its output value, as shown in Exhibit 02.

In tackling this challenge, we find heavy industry have less potential to reduce its energy intensity, relative to other sectors, as businesses in these sectors already pay close attention to energy use and energy efficiency.

However, we find material- and energy-intensive industries have more potential to reduce their emissions intensity as the world drives towards net zero, reflecting their relatively high emissions intensity today (including high non-CO_2 emissions).

Exhibit 02: Material- and energy-intensive sectors increase output 85% globally, on average, while reducing emissions intensity by 80% to 2050





Australia's opportunity

We assess Australia's potential competitive advantages in this emerging world

The analysis for this report brings together three sets of expertise and experience to understand the implications and opportunities of this global transition:

- Deep public and private sector climate change expertise from the EY Net Zero Centre
- Granular analysis of low-carbon technology and industry opportunities, drawing on EY work in business strategy and transformation
- Global economic modelling of climate transition dynamics by the EY economic modelling practice

We find Australia is well positioned to catch a wave of opportunity

Australia has a potential advantage for new heavy industry, leveraging highly competitive renewable energy and mineral resources.[1,2]

Australia's distinctive advantage is the ability to combine world-class renewable energy resources with abundant raw materials in locations connected to other inputs and key destination markets. New firmed clean energy can be positioned close to raw materials, such production of green iron from iron ore or alumina from bauxite. Emerging technologies may also see increasing demand for bio-based materials and energy products, such as biochar and liquid biofuels.

However, the vast majority of available new energy in Australia is variable renewables rather than the more reliable hydropower or geothermal. This abundance of variable renewables aligns best to sectors with higher operational flexibility, like hydrogen and iron, rather than processes requiring near 100% reliability, such as aluminium.

Our granular analysis of specific technology and industry processes identifies three highly prospective opportunities:

1. **Clean low-carbon heavy industry**, including first stage iron processing for use as an input to electric arc furnace (EAF) steel production
2. **Lithium, copper, nickel** and other critical 'new economy' minerals, metals or rare earths, including initial processing opportunities
3. **Hydrogen** for use within Australia, including as an input to other exports

However, this advantage is conditional, not automatic or absolute. While the shift to net zero creates new potential strengths, existing potential weaknesses remain. Australia has no room for complacency and project approvals processes, relative capital requirements, and labour costs will continue to be watchpoints for major investments (see Exhibit 12 and Exhibit 14 in the main report).

1. Ross Garnaut (2019) Superpower: Australia's Low-Carbon Opportunity
2. Ross Garnaut (2022) The Superpower Transformation : Building Australia's Zero-Carbon Future

Australia's energy superpower dividend could, conservatively, be worth $40 billion in additional income each year by 2050

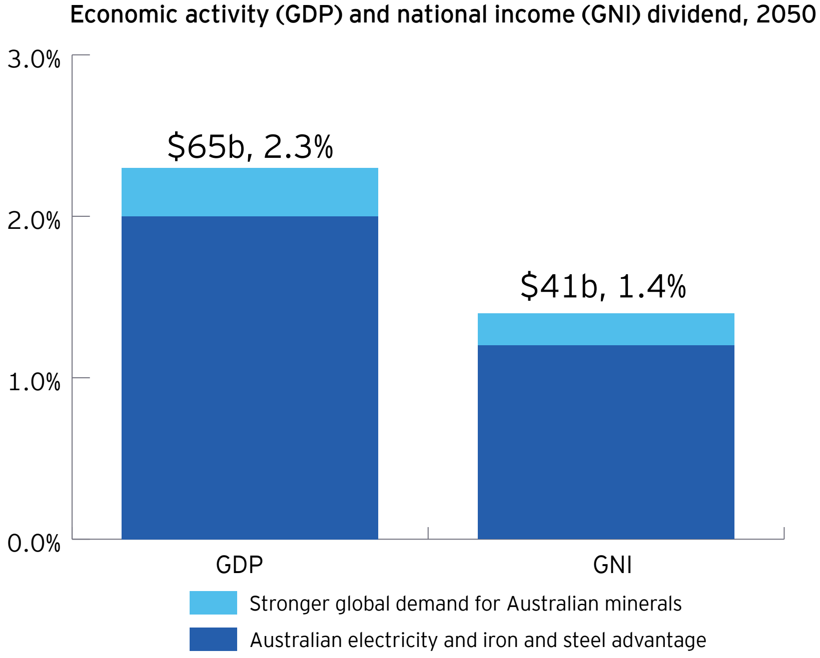
We assess the value of these emerging opportunities by modelling two alternative scenarios of Australian action, in the context of strong global climate action.

We find the energy superpower dividend adds around AUD$40 billion to national income (GNI), equal to $1,100 per person, and around $65 billion to value of economic activity (GDP) by 2050 (in real 2021 dollars). This represents a 1.4% boost to national income and a 2.3% boost to GDP, relative to the baseline scenario, as shown in Exhibit 03.

These positive impacts primarily reflect the higher productivity of advantaged Australian heavy industry sectors, driving higher margins and returns to Australian workers and investors.

We consider this assessment of the energy superpower dividend to be very conservative.

Exhibit 03: The Energy Superpower dividend lifts national income by $40 billion and economic activity by $65 billion in 2050



Australia is well positioned to grow its share of clean energy-intensive global value chains, particularly through supply of green iron

We find that iron and steel is likely to be a significant early mover in the global transition to clean, low-emissions energy-intensive products.

Global steelmaking is optimised for current costs and circumstances. Blast furnace production accounts for 60% of global production. Increasing the share of electric arc furnace (EAF) would reduce emissions from steelmaking, but is constrained by the availability of scrap metal inputs. The emergence of competitive green iron will address this constraint, decoupling production from fossil fuel inputs and enabling a global shift to low-emissions steel.

Consistent with this, we find iron and steel has the largest potential of any heavy industry sector to decouple production from emissions (see Exhibit 17 in the main report).

Green iron requires vast quantities of renewable energy and suitable iron ore. Australia is in the box seat on both.

Australia is also well positioned across transition pathways, which initially are likely to use natural gas as a reductant in the directly reduced iron (DRI) process, until this can be replaced with low-carbon green or blue hydrogen.

Australia's long term growth potential in upstream segments of iron and steel value chains is almost unlimited, as we are currently producing over a third of the world's iron ore but account for less than 1% of iron and steel production (see Exhibit 18 in the main report).

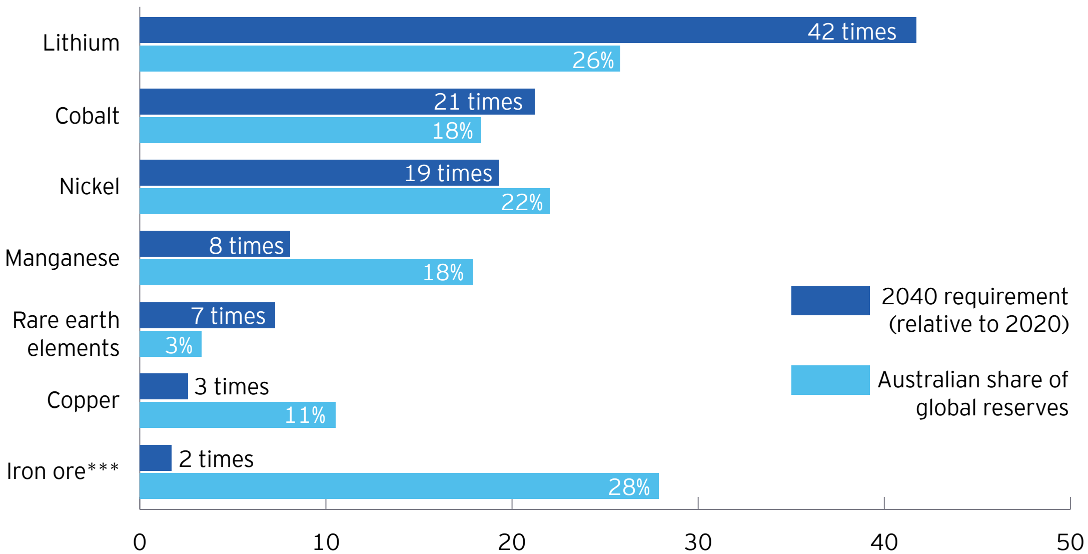
> "Green iron requires vast quantities of renewable energy and suitable iron ore. Australia is in the box seat on both.

Australia can also help meet accelerating demand for new energy minerals, through friendly supply chains

The renewable energy transition is driving almost unprecedented demand for essential mineral inputs with requirements set to increase up to 40-fold for lithium, cobalt, nickel, manganese and copper in several cases. Australia is a producer of almost all of these transition minerals, and in many cases accounts for one-tenth to one quarter of global reserves, as shown in Exhibit 04.

Exhibit 04: Global requirements are surging for energy transition minerals, along with key metals, and Australia has substantial reserves

Projected global requirements in 2040 and Australian reserves for selected minerals
Growth relative to 2020*, Australian share of global reserves**



* A multiple of five indicates a five-fold increase, or 400% change, from 2020 to 2040
** Australia's share of global production in 2021 is smaller than its share of reserves for all minerals shown except iron ore and rare earth elements.
*** Iron and steel output value growth to 2050 from EYGEM Energy Superpower scenario
Sources: 3. US Geological Survey Mineral Commodity Summary (2022). 4. IEA Global Electric Vehicle Outlook (2022). 5. Resources and Energy Quarterly (Sept 2022), and EYGEM 2023

Hydrogen will add momentum, acting as an opportunity multiplier when it comes

We find Australia can benefit from hydrogen as an input to other exports without exporting hydrogen. Australia's abundant renewable energy resources make it well-suited to large-scale production of green hydrogen.

While media coverage often focuses on the potential for Australia to establish an export-oriented industry, viability will be complicated by high conversion and transport-related losses. Using renewable hydrogen close to its source adds value in Australia and avoids the cost and technical challenges involved in seaborne transport.

This would allow Australia to export easy-to-ship products (such as steel or hydrogen-based feedstocks), rather than difficult-to-ship hydrogen. Specific domestic opportunities include green iron and steel, fertiliser and chemicals, alumina refining, and synthetic fuels.

We find the tactical and strategic importance of hydrogen to Australia's low-carbon future suggests Australia should strengthen our engagement and policy support for this cornerstone emerging technology (while recognising the challenges set out below).

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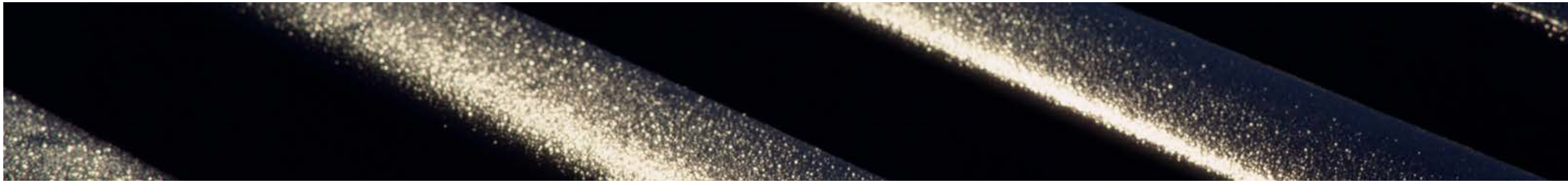
> Using renewable hydrogen close to its source adds value in Australia.



Effort required

Capturing these opportunities will require greater pace and scale of renewables deployment and low-carbon innovation

Australia's electricity system is rocketing past 'Step Change', and into the unknown. A few years ago, the Australian Energy Market Operator's (AEMO's) Step Change scenario was regarded as an unlikely outlier. Now it is the central forecast, and on the verge of being overtaken by events (see Exhibit 20 in the main report).

But planning is one thing. Doing is another. The transition to near-zero carbon is enormously disruptive for the electricity market, and so urgent action is required to deliver reliable near-zero carbon electricity.

In addition, coal generation is on a path to exit, with ageing plants under pressure from cheaper renewables and rising maintenance costs. Unanticipated exits can result in prolonged higher prices, and adverse impacts on regional communities.

Keeping the lights on, and powering industry, will require necessary firming investments to be coordinated and de-risked as the generation share of variable renewables increases. Risk sharing arrangements (such as contracts for difference) can make these projects bankable, without necessarily involving subsidies, and are already being considered by governments.

Scaling up to support growing demand, including for electrification of transport and industry, adds to these challenges.

State and federal governments are already moving (as shown in Exhibit 21 in the main report), but there is more to be done.

Thriving through the global shift will require savvy business strategy and government support

Capturing the superpower dividend will require more than cost-competitive firmed electricity.

The global transition to net zero emissions will disrupt materials and energy-intensive industry in Australia and around the world. Every sector – and every facility – will need to change its production processes, energy inputs and supply chains. Success will require large-scale investment and a healthy national innovation ecosystem.

Business will need to map commercially viable pathways for adopting technologies that are not yet demonstrated at scale, and in some cases, do not yet exist.

Business will need a dual-track strategy: competing under current conditions while positioning for agile adaptation

Capturing the renewable energy superpower opportunity will demand new and established businesses to embrace significant business risks, and widen their focus from optimising existing sources of competitive advantage to creating new ones.

Businesses with a clear vision and roadmap for their energy transition will be best positioned for success. They will accurately understand the real inhibitors to making bold steps (such as lack of appropriate carbon incentives, technology availability, infrastructure availability) and be prepared to move swiftly as these inhibitors dissipate.

Adopting this dual track posture will be uncomfortable for many in the private sector. But creating – and seizing – new opportunities will be essential for business success, and the wider transformation of Australia's industrial landscape.

"Creating – and seizing – new opportunities will be essential for business success, and the wider transformation of Australia's industrial landscape.

Government will need to lean in heavily

Australia is a small open economy, with a fifty-five year tradition of largely hands-off industry policy settings. Consistent with this, previous climate policy settings, such as the Renewable Energy Target, tend to provide incremental assistance favouring more mature technologies with lower emissions. However, it does not provide the resources or support required to develop innovations providing step-change reductions.

We can invest ahead of the curve and position Australia as a world leader in areas where we are likely to have durable advantage. Or we can allow others to develop. The risk of the first is that substantial government funds may be squandered seeking to outbid the support provided by other countries with no guarantee of developing a long-term industry that justifies the investment. The risk of the second choice is that we will not benefit from learning by doing, will not develop our skill base, and in practice will never be able to follow.

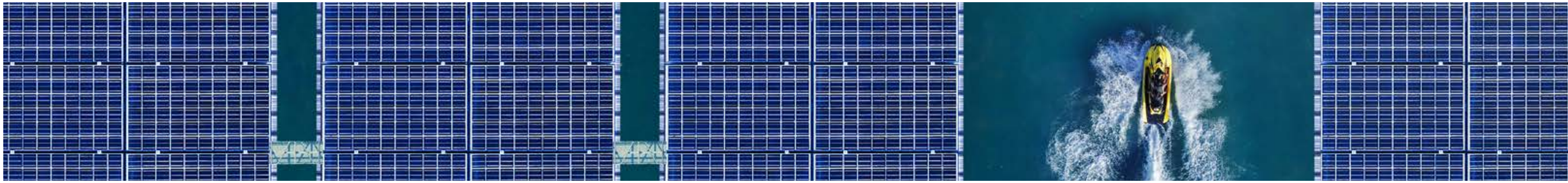
Catching the wave requires policy to travel in the right direction at the right speed

Australia can't be good at everything, and so will need to make choices and set priorities to get the best result.

Australia cannot win a bidding war against Europe or the United States. Instead we need clear-eyed policy that addresses underlying business needs, while recognising Australia's context and constraints. This implies an approach that is focused on nationally significant low-carbon opportunities, and positions Australia among 'early leaders' without seeking to be at the very front of the pack.

Government support is most likely to deliver benefits where a location has pre-existing advantages, such as natural resources, internationally competitive energy, a supportive local ecosystem, and proximity to key markets, as shown in Exhibit 23 in the main report).

"Australia cannot win a bidding war against Europe or the United States. Instead we need clear-eyed policy that addresses underlying business needs, while recognising Australia's context and constraints.



Call to action

Success will require coordination, clarity and courage

The global shift to net zero emissions provides Australia with a once-in-a-generation opportunity. What then should Australia do?

We suggest three things will be essential to long term success:

- **Coordination, coordination, coordination** – across different aspects of energy policy, wider policy processes (including climate, project approvals, industry and innovation policy), and planning by public and private actors, including all levels of government.
- **Clarity** – informed by a clear understanding of purpose and desired outcomes, and a logical and clearly articulated path to impact.
- **Courage** – to embrace the complexity, uncertainty and ambiguity associated with the global net zero transition, and its implications for Australia.

Start now to prepare your business for coming waves of change

Businesses with a clear vision and roadmap for their energy and emissions transition will be best positioned for success.

Here we suggest five questions to guide the development of a robust strategy for managing risks and realising opportunities:

1. **Evolving context:** What is your view about the evolution of the global and national economy over the next 30 years?
2. **Competitive environment:** What is your view about the evolution of your specific sector?
3. **Business position:** What is your view about the relative position of your business within your sector?
4. **Watchpoints:** If you are contemplating multiple scenarios, what indicators should you watch to identify which scenario you are in?
5. **Strategy groundwork:** Have you wargamed out what near term actions might help manage risks create options?

(See Exhibit 24 in the main report for the full set of questions.)

Opportunity knocks

This report finds the global shift to net zero emissions will create multiple competitive advantages for Australian heavy industry, but effort is required to capture these opportunities. This includes some effort that is already planned, such as to deliver secure and reliable low-carbon electricity. But it also includes additional efforts, such as to coordinate export-related energy supply and demand, leverage sentiment in favour of friendly supply chains, and – perhaps most importantly – support world-class low-carbon industrial innovation in areas aligned to Australia's economic interests.

We also find the economic benefits could be enormous. But dollars are only part of what is at stake. Australia can make a distinctive contribution to meeting global needs for heavy industry essentials, while supporting the global transition to net zero emissions. We can do well while doing good.

Opportunity knocks. How will Australia and your business respond?

Introduction

Assessing the outlook for Australia in a net zero world

The global shift to net zero emissions opens a world of opportunity for Australia

This report assesses Australia's energy superpower opportunity: the advantages that might flow from the global shift to net zero emissions, particularly for Australian metals, minerals and other heavy industry; and the efforts required to capture these potential dividends.[1,2] We find it is a world full of opportunities, offering vast economic benefits if Australia rises to the challenges ahead.

We explore the outlook for Australia in a net zero world

Navigating the net zero transition requires a clear understanding of the risks and opportunities ahead.

This report explores the business implications of this global transition, with a particular focus on the shift to low-carbon electricity, reductions in the emissions intensity of heavy industry*, and emerging demand for energy transition minerals. Our analysis also highlights the need for government action and explores the implications of alternative policy stances, as these will have a crucial role in shaping the operating environment for business.

A future report will explore opportunities for nature-based markets and sectors, leveraging climate action to deliver biodiversity and sustainability benefits alongside improved economic returns.

The world is moving towards a new trajectory

Momentum is building, with 193 countries, plus the European Union, committed to the goal of the Paris Agreement on climate change. The world is working to limit global temperatures to well below 2°C while pursuing efforts to limit the increase even further to 1.5°C.

All high income countries, including Australia, have committed to achieve net zero emissions by 2050 – where emissions that can't be eliminated are balanced by offsets or removals from the atmosphere.

More than 5,000 businesses have committed to net zero targets, globally, with a third of these committed to achieve net zero before 2035 or 2045.[6]

* Heavy industry in this report refers to ferrous and non-ferrous metals, chemicals, and refinery products. See Appendix Table 1 (page 86) for more details.

1. Ross Garnaut (2019) Superpower: Australia's Low-Carbon Opportunity
2. Ross Garnaut (2022) The Superpower Transformation: Building Australia's Zero-Carbon Future
6. EY Net Zero Centre (2022) Essential, expensive and evolving: The outlook for carbon credits and offset

We find the shift to a low-carbon world could deliver vast economic benefits for Australia

Australia has all the ingredients required to become a new energy superpower. We have cost-competitive large-scale renewable energy, abundant minerals and natural resources, a highly skilled workforce, and deep access to capital.

These set the stage for Australia to pursue jobs and growth through exports of energy-intensive commodities and the materials required for the new-energy economy.

We also find effort is required, and quickly, to capture these opportunities

To be blunt: the time for action is upon us. Delivering near-zero carbon electricity while maintaining energy system stability requires fast-paced and well-coordinated action by government, energy system managers, energy businesses and investors. Leveraging this new energy advantage by creating new low-carbon energy-intensive exports will also require a dramatic – and challenging – increase in supply.

But the real challenge – and opportunity – lies in developing competitive new low-carbon materials- and energy-intensive industries.

Major sections of this report

EY's approach to modelling and analysis of the net zero transition

This report seeks to provide a robust multi-faceted assessment of the implications of the global net zero transition for Australian heavy industry and mining. The analysis draws on three main pools of expertise and experience:

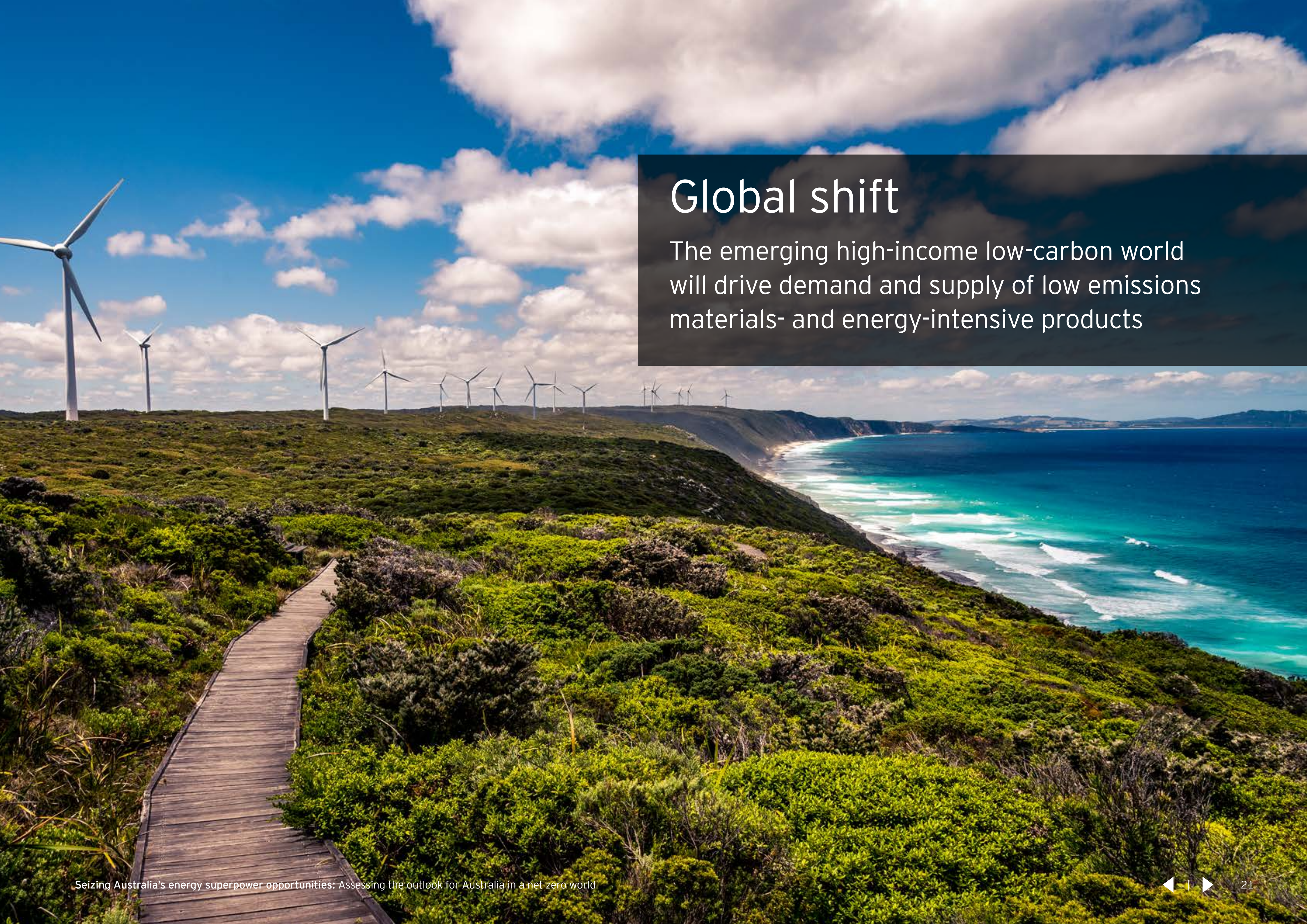
- EY Net Zero Centre expertise and engagement on climate change policy and business strategy.
- Granular analysis of low-carbon technology and industry opportunities, drawing on EY work in business strategy and transformation.
- Global economic modelling of climate transition dynamics by the EY economic modelling practice.

The economic modelling framework used for this analysis is well suited to exploring and assessing the global net zero transition, with detailed representation of the whole economy and major economies and groupings.

This economy-wide coverage is well suited to analyse fuel switching (away from fossil fuels towards renewable electricity). The modelling framework takes a stylised approach to abatement-related innovation, and does not endogenously represent development of specific breakthrough new technologies, such as the development and use of green hydrogen to replace metallurgical coal in steel making.

In framing our assessment of industry growth and the value of the 'energy superpower' opportunity, we have systematically chosen to err on the side of caution. This implies the modelling results are likely to understate emissions reductions (particularly from industrial production), overstate abatement and adjustment costs, and understate overall benefits to Australia.

More details of the modelling framework and implementation are provided in the Appendix to this report.



Global shift

The emerging high-income low-carbon world will drive demand and supply of low emissions materials- and energy-intensive products

By 2050, the global economy will double but the number of people living in high-income countries will triple

As global economic output grows, the number of people living in high-income countries grows faster. That number will triple to more than three billion people by 2050, assuming a continuation of trend wealth and productivity growth. All current 'low-income' countries will become high- or middle-income, with many of the new high-income countries being significant trading partners for Australia.

Global economic output almost doubles while population rises by 18% to 2050

We forecast that the value of global economic output will rise 92% in real terms. With output comfortably outpacing population growth, average income and gross domestic product (GDP) per capita increases by around two-thirds.

In the near term, the climate transition will boost investment, increasing productivity but perhaps putting downward pressure on consumption. But over the long run, reducing greenhouse gas (GHG) emissions will boost incomes and living standards, and promote stability, as it avoids or reduces the worst impacts of climate change and variability.

Disruption and volatility will continue

The transition to a high-income world will not necessarily be smooth. Long term economic growth involves, and is partly driven by, creative destruction: observed in disruptive technologies, shifts in consumer preferences, and the emergence of new business models. Other forms of disruption are also likely, including increasingly fractal geopolitics, global economic booms and busts, escalating natural disasters and climate events, potential pandemics, and other unforeseen events.

The number of consumers in high-income countries almost triples

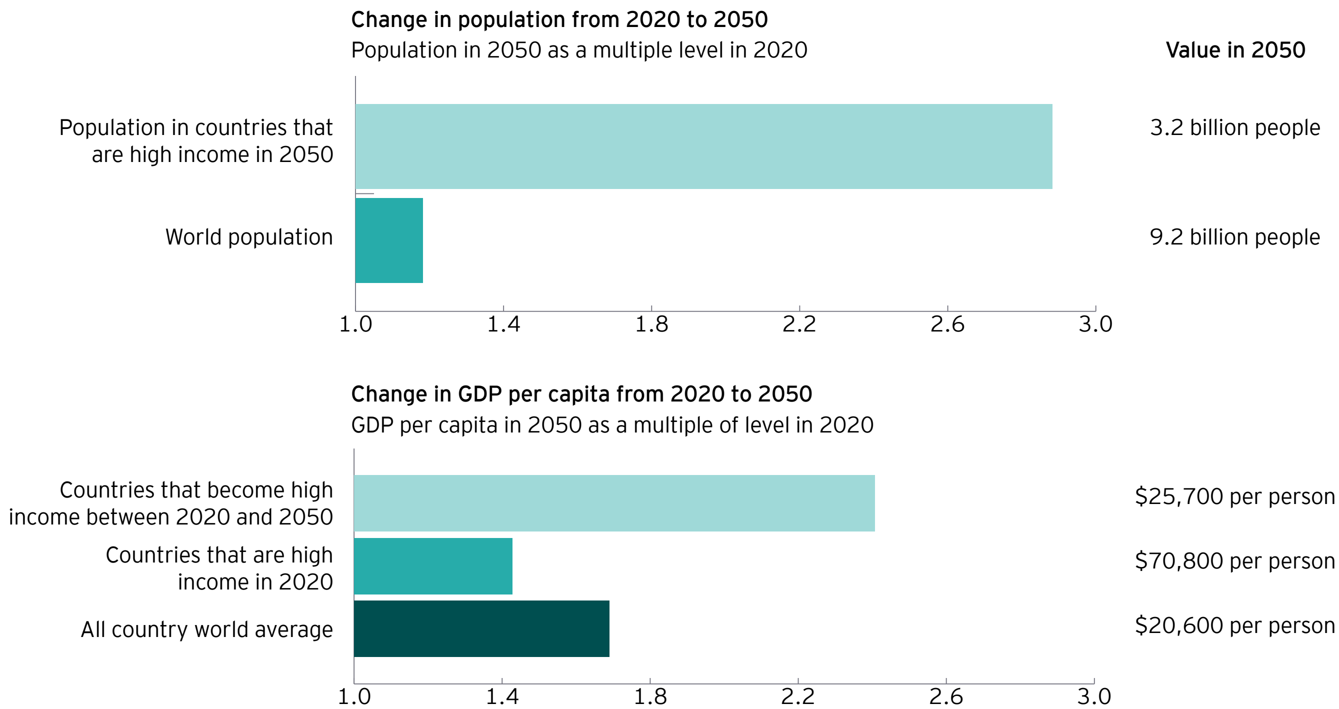
In 2020, almost two thirds (61%) of the world's people lived in low-income countries, and just over one third lived in medium- and high-income countries (27% and 14% respectively), as classified by the World Bank.

By 2050, one third of the world living in high income nations and every country will have had the opportunity to transition from poverty, although this may be blocked by conflict or governance failures.

These cohorts of new high- and middle-income consumers will experience a transformation in living standards, with average incomes increasing more than two or three-fold in a single generation.

Rising incomes drives rising expenditure, including on vehicles, housing, appliances and other goods. And consumers are also citizens, voting for roads, railways, and other infrastructure as well as schools, hospitals and other public buildings.

Exhibit 05: The number of consumers in high income countries triples to 2050



Rising income means rising global demand for energy- and material-intensive products

The increasing number of people in high-income countries sustains strong growth in global demand for goods and services. This in turn drives growth in demand for the materials and energy that underpins those goods and services: minerals, metals and related materials- and energy-intensive products.

Material-intensive demand rises with income

Heavy industry underpins all other economic activity, providing the materials for buildings, infrastructure, plant and equipment, manufacturing and logistics, and everyday products and appliances. Accordingly, output from material- and energy-intensive industries rises broadly in line with the economy-wide average.

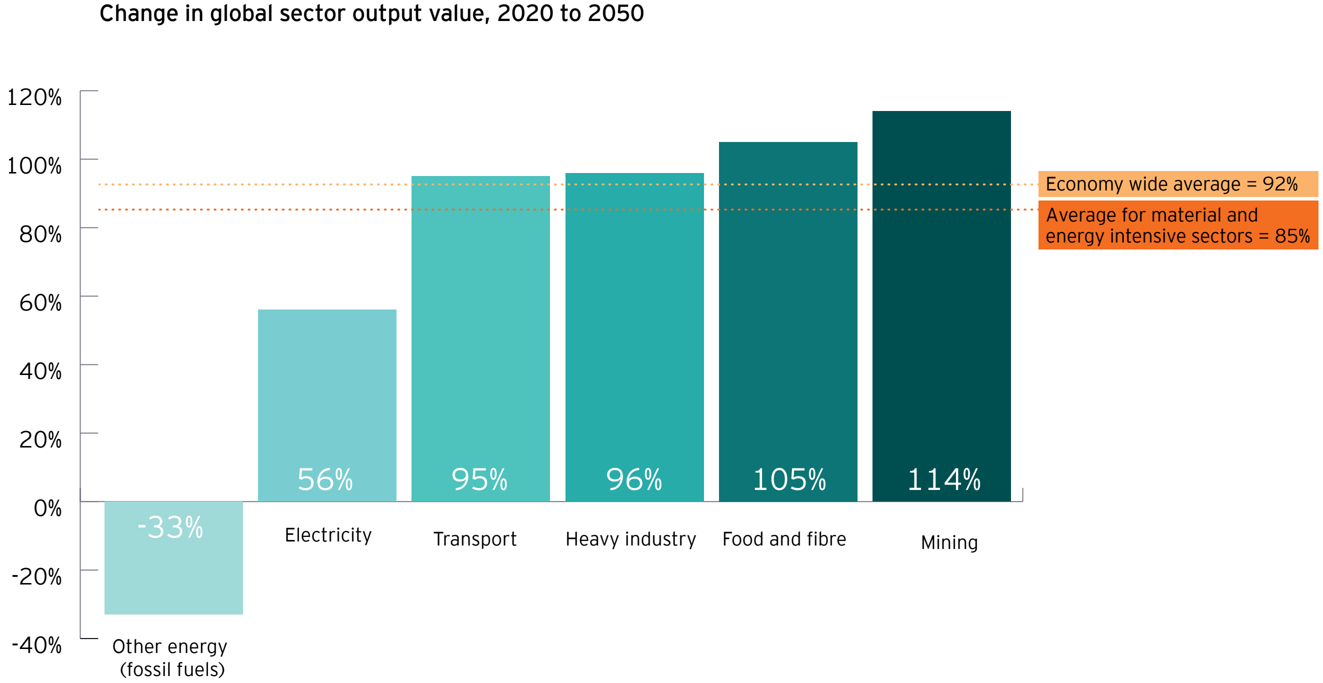
Growth rates vary across sectors

Elsewhere, the value of transport, and food and fibre (including forestry) output are projected to grow a little faster than the economy-wide average, as shown in Exhibit 06.

The value of mining is projected to increase 114%, well above the economy-wide average. This reflects the shift towards the new energy economy, which requires additional metals and critical minerals to generate, store and distribute renewable energy in place of the fossil-fuel based 'old energy' system.

The volume of electricity use expands rapidly, but this is more than offset by falling prices, resulting in global sector value growing by just 56%, well below the economy-wide average. The value of fossil fuel production shrinks by a third from 2020 to 2050 as climate commitments drive falling demand, reflected in both declining unit prices and shrinking output volumes.

Exhibit 06: Most materials and energy-intensive sectors grow strongly



Global commitments and action to reduce emissions must accelerate

Actions and commitments on climate change have already 'bent the curve' of global emissions, reducing the rate of growth. This global momentum is encouraging, but limiting climate change to well below 2°C will require global emissions to peak soon and then fall significantly.

We have 'bent the curve' since 2008

Fifteen years ago, business as usual emissions with the 'current policies' of the day were generally projected to almost triple from 2010, rising from 40Gt CO_2e per year to around 110Gt in 2050.

Today, experts project that global emissions will stabilise under 'current policies',* with renewable energy, improved energy efficiency, and deployment of low-carbon technologies offsetting population and economic growth.

Accelerating action by governments, business and households has flattened the previously rising emissions curve. This decoupling from the past trend began around 2008, indicating that countries had begun to act before formalising their commitments and ambitions in the 2015 Paris Agreement.

* Emissions projections define 'current policies' as measures that are already implemented, such as in legislation. 'Announced policies' refers to specific measures that have not been implemented. Neither of these include high level goals, such as national net zero commitments, but will include specific mechanisms to achieve these goals as they are announced and implemented.

But the world has a long way to go

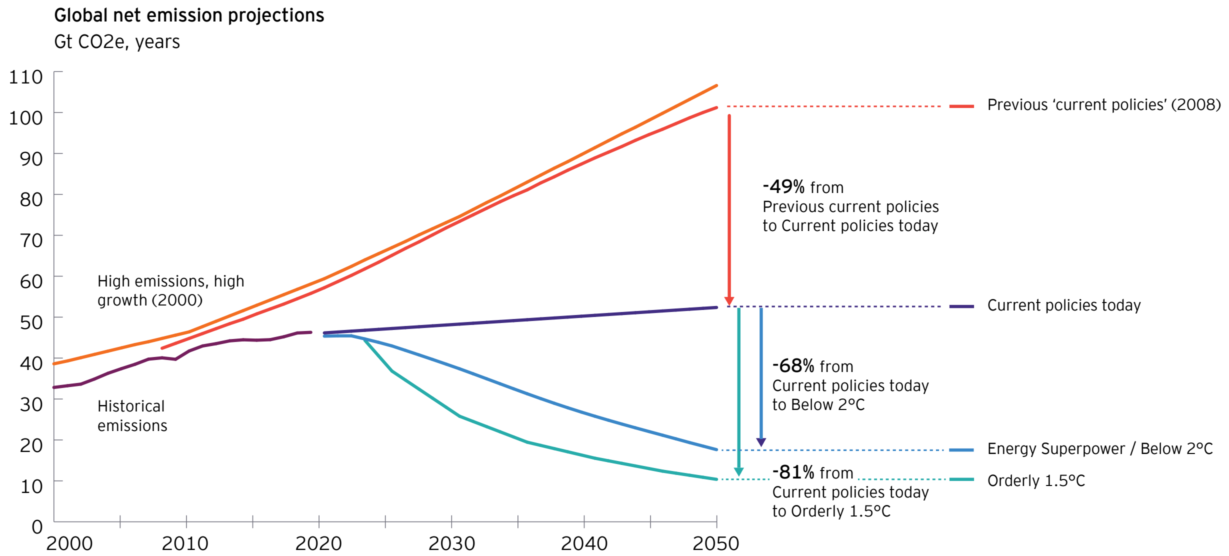
Although the projections of flat emissions are welcome, much stronger action is required to limit climate change to below 2°C. For that, emissions must fall by around 70% from current levels by 2050.

Policies that have been announced but are not yet implemented are expected to help, but will still fall well short of what is needed.

The analysis for this report assumes an orderly middle-of-the-road climate transition, described as strong climate action, in which advanced countries take the lead in reducing emissions. This pathway is consistent with limiting climate change to below 2°C, and involves reducing global emissions by 56% in 2050 relative to the projection for current policies, and reducing net emissions by 68% including removals, as shown in Exhibit 07. This is a 63% reduction from 2020 levels by 2050.

Limiting long term climate change to 1.5°C would require even more ambitious action, reducing net global emissions by around 80%, with many scenarios suggesting net zero CO_2 emissions by 2050.

Exhibit 07: Global action has already bent the curve, but limiting global temperatures to well below 2°C remains very challenging



Notes: High emissions, high growth is the A1FI scenario from IPCC (2000), Previous Current Policies is from Treasury (2008), Current policies today and Energy Superpower / Below 2°C are from EYGEM calibrated to NGFS (2021) scenarios of the same name, Orderly 1.5°C scenario from NGFS (2021

Source: 7. IPCC 2000. 8. Treasury 2008. 9. NGFS 2021 and EYGEM 2023

Reducing emissions from material- and energy-intensive sectors is crucial, but challenging

Avoiding dangerous climate change will require all sectors to significantly reduce their emissions. Heavy industry has two essential roles in supporting the low-carbon transition: reducing its own emissions intensity; and enabling the new energy revolution. While materials- and energy-intensive industries have many hard-to-abate sources of emissions, they also have access to a range of near-term abatement options.

The low-carbon transition requires emissions to be decoupled from economic value

To limit climate change to below 2°C, global emissions must fall by around 70% from current levels by 2050, even as the population grows by 20% and the economy doubles. This means that global emissions per dollar of economic activity must fall by around 83%.

The scale of this challenge means that action to reduce emissions is required by all major sectors, including heavy industry.

Heavy industry is too significant to overlook

It would be almost impossible to shift to a Paris Agreement emissions pathway without heavy industry playing its part.

The first reason for this is the calculus of global abatement: the abatement potential of each mitigation option, the costs and requirements of each, and their wider implications for emissions reductions and the global climate system.

Material and energy-intensive sectors account for around two thirds of current global emissions. Direct emissions from heavy industry account for around one sixth (16%) of global emissions, making it one of the three largest sources of emissions alongside electricity generation (one third) and transport (one sixth).

The maths of trying to achieve a below 2°C pathway without heavy industry simply does not add up.

But the second reason is more fundamental: heavy industry is an essential part of the supply chains required for decarbonisation and the new energy transition. Building the new energy economy will require a step up in global supply of metals and minerals, including steel, aluminium, copper and a variety of advanced materials that are all produced by heavy industry.

Low-carbon energy and improved energy productivity are crucial

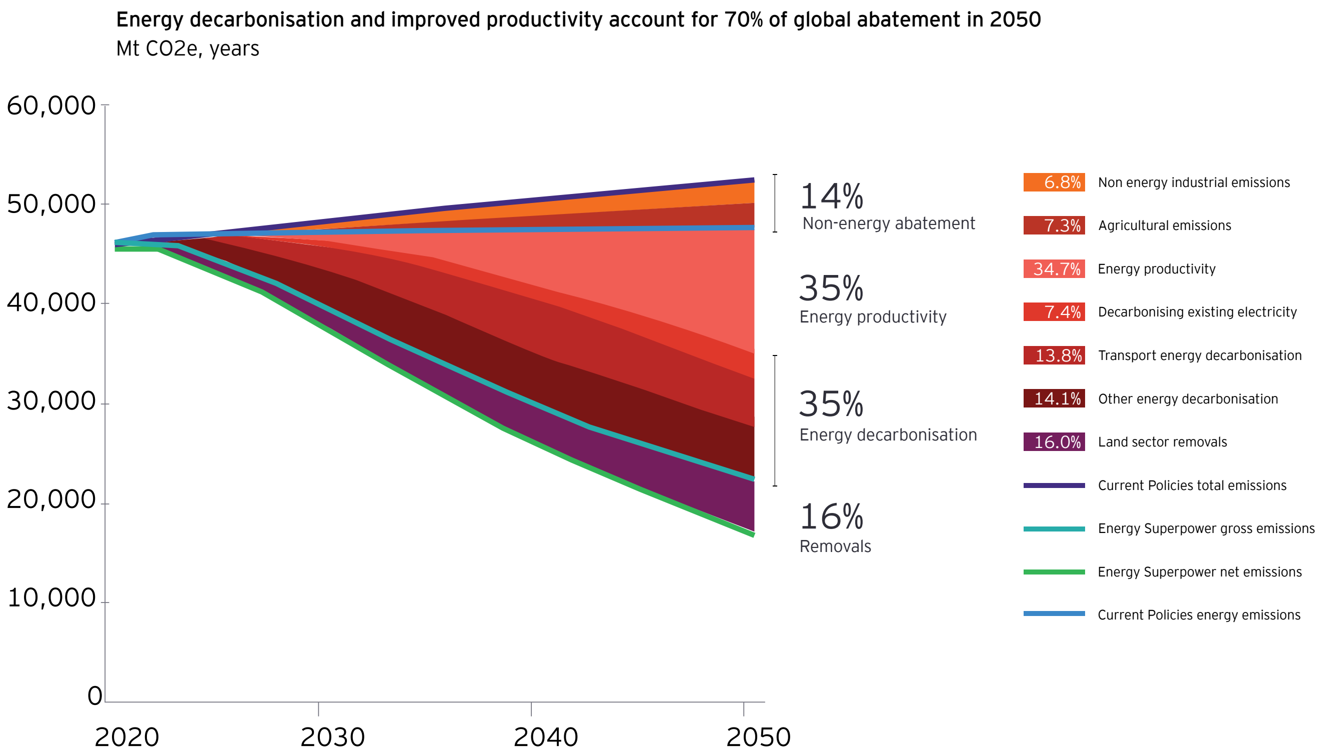
We assess the relative contributions of three broad options for reducing emissions and find that change in energy emissions and demand account for the bulk of near-term global abatement.

As shown in Exhibit 08, we find abatement in 2050 consists of:

- 35% from reducing the emissions intensity of energy, including through electrification of industry and transport.
- 35% from improving energy productivity and reducing energy use.
- 14% from reducing non-energy emissions, including a 7% contribution from reduced non-CO_2 industrial emissions and 7% from reduced livestock methane and other agricultural emissions.
- 16% from removals, particularly land sector sequestration.

In practice, reducing non-combustion emissions and developing alternative low-emissions chemical processes is likely to be particularly challenging. This is a crucial issue for heavy industry (including iron and steel, non-ferrous metals, and basic chemicals) and agriculture (particularly red meat and dairy).

Exhibit 08: Reducing emissions from material- and energy-intensive sectors is essential, but challenging



Switching to renewable electricity is essential for achieving net zero emissions

Low-carbon electricity is essential for global and Australian decarbonisation. The growth of renewables meets established electricity needs and supports decarbonisation of industry and transport through electrification, as these sectors switch away from gas and petroleum fuels. Each action stimulates further innovation and emissions reductions.

Renewable electricity is an essential enabler

Stronger global action on climate accelerates the uptake of renewables. We project global electricity emissions fall by 90% to 2050, while supply grows substantially. This switch to zero carbon renewable electricity is an essential precondition for decarbonising the wider energy system and the global economy.

The transition to low-carbon electricity contributes in multiple ways

The first contribution is to directly reduce electricity system emissions as coal and gas fired generation is replaced by renewables. Falling costs of renewable energy are already driving this switch around the world.

We find electricity emissions fall by around 90%, with high income countries taking the lead (see Exhibit 09).

We project the decarbonisation of existing electricity supply accounts for half of global energy-related abatement in 2050.

Second, the transition to renewable electricity at scale enables energy input switching in building and industry, particularly from gas to electricity. This is already attractive for building space and water heating and cooling, and a wide range of light manufacturing processes. However further innovations are required to develop cost-competitive electrification options for high-temperature industrial processes across different heavy industry segments.

We project all heavy industry sectors will increase their use of electricity over time (see Exhibit 09). We find this could account for around 20% of global energy-related abatement and 14% of total global abatement in 2050 (as shown Exhibit 08 above).

Third, scaling up renewable electricity enables the transition to low- or zero-emissions transport, including battery electric road transport and hydrogen powered heavy freight.

Battery electric vehicles for passenger transport and light freight will soon be cost competitive against traditional internal combustion engine vehicles, on a whole-of-life basis. EY research finds combined electric vehicle sales in the US, China and Europe are likely to outstrip sales of all other engine types by 2030, this is three years sooner than previously expected.[10]

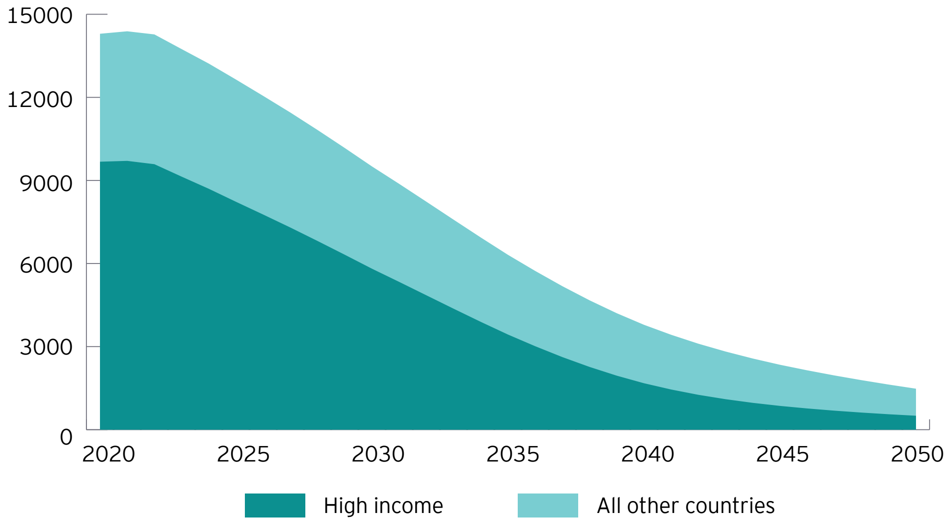
Cost competitive solutions for heavy freight and long-range remote applications, such as hydrogen fuel cells, are expected to take longer to emerge.

Concerted action creates a virtuous circle

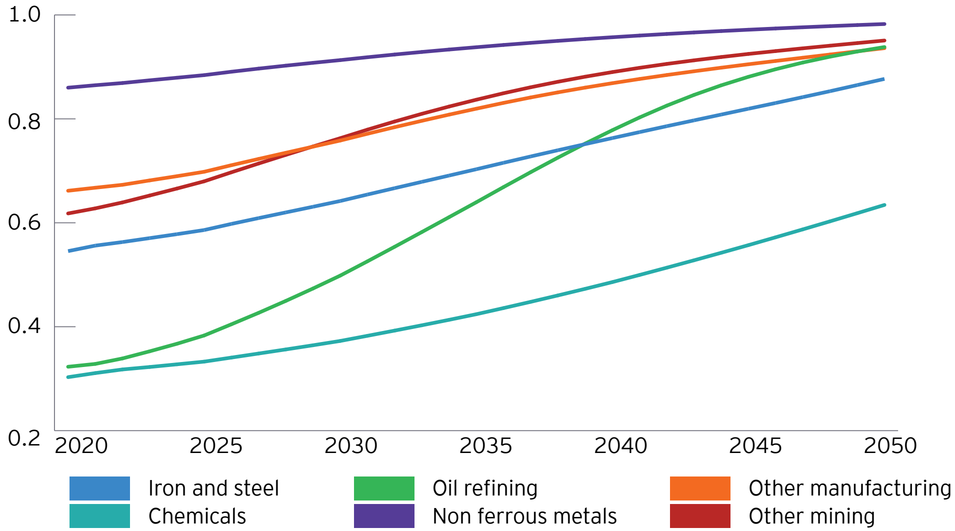
Increased deployment of renewable energy and electrification technologies promotes learning-by-doing, reducing technology costs and supporting further deployment.

Exhibit 09: Switching to renewable electricity is essential for achieving net zero emissions

Global electricity emissions fall by 90%, as supply increases
Mt CO2e, years



Heavy industry and mining increase their use of electricity over time
Mt CO2e, years



10. EY (2023) EY Mobility Lens Forecaster, 5 January 2023

While the global shift to net zero emissions leaves limited room for oil and gas in the long run, it remains a central part of the energy mix in 2050

The global transition to net zero will inevitably include a drop in demand for coal, oil and gas as economies shift to renewable sources of energy. The size and speed of this drop will depend on user preferences, government policies, and the costs of new technologies (including carbon capture, use and storage (CCUS)). We find fossil fuels play a substantial role up to and beyond 2050 in the below 2°C Paris aligned scenario we model for this report. However, the sector will be significantly smaller than it is today.

Energy systems are deeply embedded and will take time to transition

Patterns of energy supply and use are tightly woven into modern economies. Each stage of energy extraction, processing, distribution, and use involves purpose-built assets and infrastructure.

Some types of assets – such as electricity transmission systems and road networks – can transition reasonably easily to non-fossil fuel energy options, such as renewable electricity or battery electric vehicles. However, in most cases transitioning from fossil fuels will require replacement of many or most of the key components of the energy system. This takes time.

The below 2°C scenario involves strong global action to achieve net zero emissions around 2070

The report is calibrated to the most modest and gradual global transition to net zero, consistent with the Paris Agreement on climate change.

While achieving this global trajectory requires strong action – and an acceleration from current efforts – the implications for fossil fuels are less radical than in scenarios with a more rapid transition.

Fossil fuel use starts to fall before 2035 across all fuel types

Notwithstanding that we model the most gradual transition, we find that demand for fossil fuels falls within the life of existing assets.

In broad terms, global oil and gas volumes are stable or grow modestly to around 2030 and then each decline by around 30% to 2050 (measured in both physical energy units and real dollar values).

Impacts on coal are more immediate and severe, with volumes falling by 20% by 2030 and by around 70% from 2020 to 2050. Demand for coking coal (used in steelmaking) is impacted less than thermal coal (for electricity generation) in the medium term, but similar over the longer term.

Improving energy productivity is also vital, but transport and heavy industry have fewer untapped opportunities

Reducing emissions while serving the economic needs of emerging middle- and high-income consumers drives improved energy productivity by increasing sector revenues per unit of energy. However, we find material- and energy-intensive sectors have fewer opportunities to reduce their energy use.

Improved energy productivity delivers 40% of global energy-related abatement

Energy productivity is the flipside of energy efficiency. 'Productivity' refers to revenue or output value per unit of energy. 'Technical efficiency' refers to the effectiveness of a technology or process to convert energy into a useful output or 'energy service', such as driving 100 kilometres or kiln-drying timber or melting glass. 'Energy efficiency' refers to a subset of opportunities where the cost savings from reduced energy expenditure outweighs the capital and operating costs required, recognising that economic or financial attractiveness of specific opportunities will be influenced by a range of factors, including local energy costs.

We find reducing global energy use while delivering more energy services is a crucial component of the low-carbon transition. As shown in Exhibit 10, we project this could account for half of all energy-related abatement globally in 2050, and 35% of total global abatement.

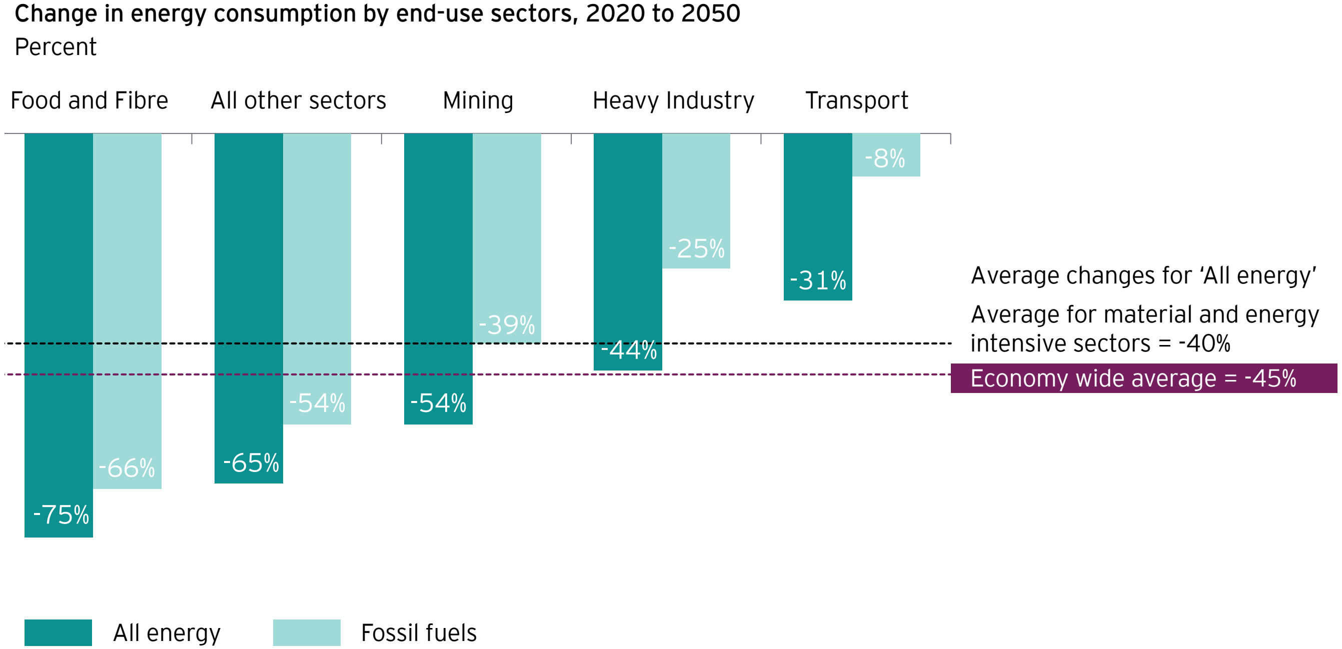
Material- and energy-intensive sectors find it harder to reduce energy use

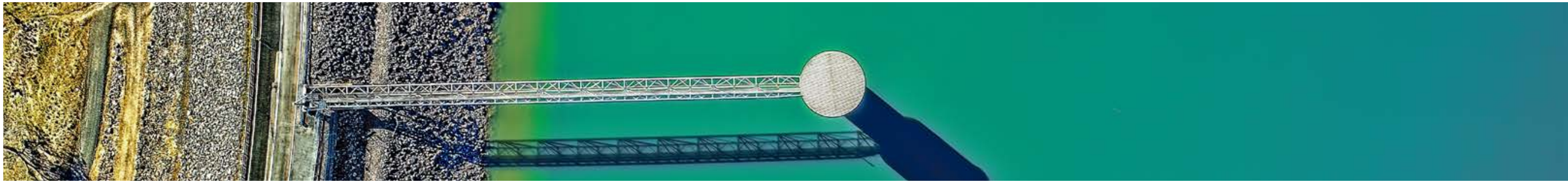
We find heavy industry and transport can reduce energy use substantially, while output value doubles (see Exhibit 10 this page and Exhibit 06 above).

However, the projected reductions in energy use for these sectors are substantially smaller than the average across the rest of the economy, particularly for fossil fuel-based energy.

This is because material- and energy-intensive industries already pay close attention to energy costs and potential improvements in energy efficiency, as energy represents a substantial share of sector input costs. Implementing energy efficiency options also typically involves longer lead times, due to relatively long asset lives of major energy using assets relative to the rest of the economy. These sectors therefore have fewer untapped near-term opportunities to reduce energy use, relative to other sectors.

Exhibit 10: Energy use falls across all end-use sectors





This global disruption will create new opportunities

The shift towards net zero will drive waves of change through the global economy, especially materials- and energy-intensive sectors. Heavy industry, more than other sectors, must solve multiple problems: reducing fossil fuel use and non-combustion emissions, replacing the chemical contributions currently met by fossil fuels, and responding to growing demand for materials essential to the new energy transition. That makes the challenge for heavy industry particularly difficult – and an immense opportunity for businesses and countries who can solve it.

Sectors with high current emissions have more abatement potential, but larger near-term challenges

We find that transport, heavy industry and mining each reduce their emissions intensity more than the economy-wide average (see Exhibit 11). This, in part, reflects their current relatively high fossil fuel use, and the potential switch to electricity and other low-carbon energy as technologies are demonstrated and become more cost competitive.

But heavy industry faces additional challenges.

Many industrial processes, such as iron and steel production, use coal or gas as both an energy source and a chemical agent. Re-engineering these processes is more complex than 'simply' swapping coal or gas for electricity. Some processes, such as aluminium smelting (powered by electricity), also have significant non-combustion emissions, which are currently difficult or impossible to abate.

Solutions to these challenges will require significant technological innovations to address difficult to abate sources of emissions.

“

Re-engineering these processes is more complex than 'simply' swapping coal or gas for electricity.

Decarbonisation options will mature over different time frames

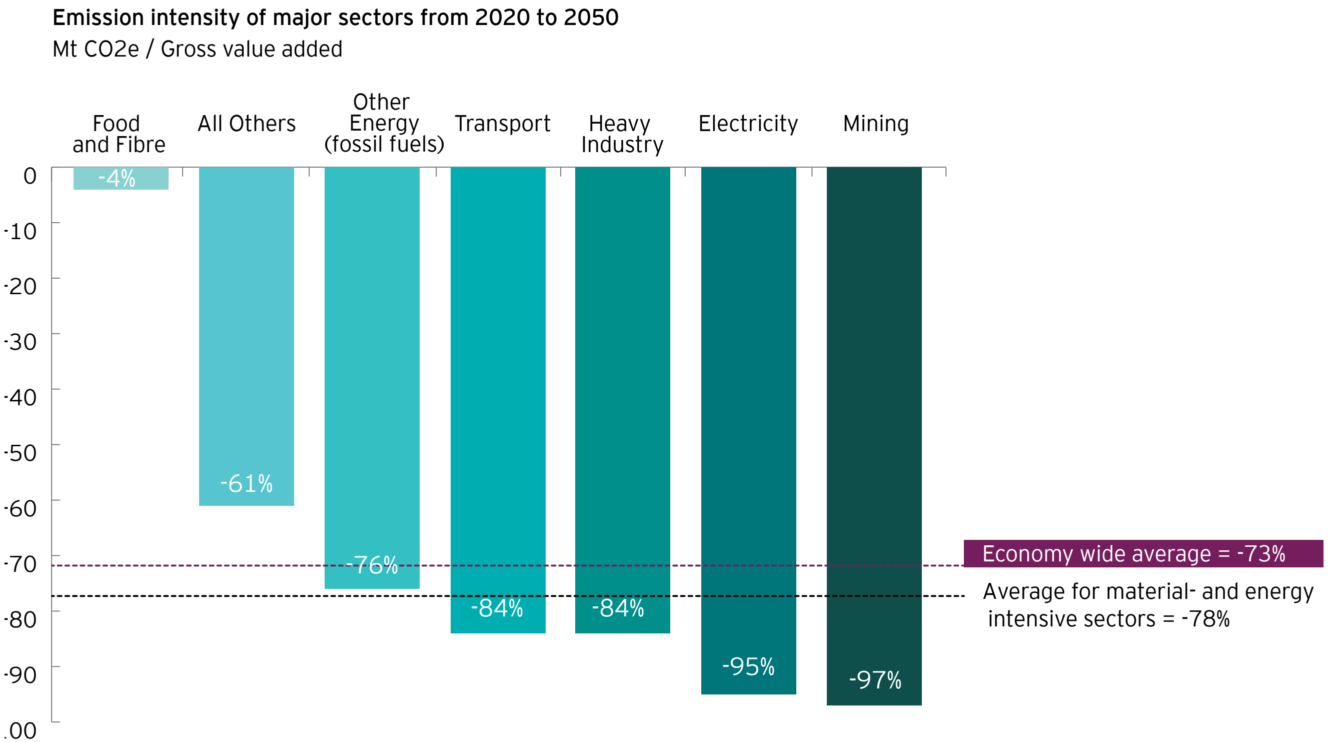
Energy switching and electrification are expected to become more accessible and attractive over time. However, near term opportunities will vary across sectors and locations, and will reflect the existing local infrastructure. In practice, energy switching will almost always involve replacing energy-using assets, and so will be most cost-effective when aligned with normal asset refurbishment and replacement cycles.

Facility-level risks may emerge when local context and circumstances delay the uptake of decarbonisation options, particularly if this erodes competitiveness or access to capital. In many cases these circumstances will relate to supply chains or infrastructure outside the control of specific facilities or businesses.

Improved energy productivity can be pursued incrementally and immediately but is unlikely to deliver step-change emissions reductions in heavy industry and transport.

Substantial resources are being directed to solving the spectrum of chemistry-related emissions, from basic research to scale-up and commercial demonstration projects. The potential – and rewards – for achieving step-change reductions in emissions intensity is large, but the pace of technology developments is uncertain for specific sectors and market niches.

Exhibit 11: Materials- and energy-intensive sectors reduce their emissions intensity more than the global average



Australia's opportunity

Assessing the sources of Australia's energy superpower dividend

Australia has a conditional advantage for new heavy industry, leveraging highly competitive energy and mineral resources while watching costs

The low-carbon transition will shift the basis of competitive advantage in some sectors. Australia has advantages in raw materials and renewable energy that could underpin a re-energised export sector, helping to meet the world's needs for clean energy-intensive products. However, Australian capital and labour costs will be a watchpoint for major investments, and our window of opportunity may be narrow.

Net zero offers an opportunity to re-energise the Australian economy

It has been some decades since Australia last invested in heavy industry at scale. When it did, major projects were often secured through significant government subsidies and support, offered to attract related investment, employment, and up- and down-stream economic opportunities. Since then, established heavy industry facilities have largely remained competitive, but most new investment has focused on mining, minerals and fossil fuel extraction.

This raises two questions: Will the global shift towards net zero create new investible opportunities for Australia? Do we have what it takes to be an energy superpower?

We find Australia could establish new durable competitive advantages – but only if we move quickly. Key factors in this assessment are summarised in Exhibit 12 (page 40) and Exhibit 14 (page 45). Our analysis is framed in terms of Australian industry's relative position against producers in other countries, typically in emerging markets, that may also have access to raw materials and clean energy.

> "Do we have what it takes to be an energy superpower?

The combination of large-scale renewable energy and abundant raw materials provide a significant potential advantage

Few, if any, countries can match Australia's access to new large-scale low-cost renewable generation, given that global opportunities for new hydropower are very limited.

Variable weather-based renewables, such as wind and solar, need to be supported by cost-effective firming technologies. This will require accelerated investment in pumped hydro, grid-scale batteries and other multi-day storage options.

Australia's distinctive advantage is that our world-class renewable energy resources can be combined with abundant raw materials and connected to key destination markets.

New energy generation and storage can be positioned close to raw materials, such as in the Pilbara, for primary ore processing and early-stage metal-making. These key raw materials will increasingly include bio-based inputs, such as biochar to provide carbon.

Australia can also create flexible and efficient industrial ecologies and networks that combine reliable access to clean energy, secondary processing plants, and shipping terminals relatively close to key destination markets, particularly in Asia.

Access to capital and skilled labour are important but neutral for Australia's competitiveness

Capital cost is neutral for Australia. We are a low-risk jurisdiction with the institutional strengths needed to keep the cost of capital low. However, capital projects have often proven to be expensive in Australia for a variety of reasons. This is likely to be a watchpoint for potential investors.

The cost of labour is neutral overall for Australia. While average labour costs are higher than those in most competitor jurisdictions, they are not so high as to be an impediment. Importantly, international cost differentials are smaller for crucial high skill roles. Australian labour costs are below the OECD average, the skill base is relatively high, and sector demand for labour will ease over time with ongoing industrial plant automation.

Exhibit 12: Australia has a conditional advantage for new heavy industry, leveraging abundant renewable energy and mineral resources

Australian green competitive advantage		
Capital	Relative capital intensity	✗ No – capital projects typically more expensive in Aus.
	Cost of capital	✓ Yes – low risk jurisdiction
Labour	Labour intensity	— Some capability in industrial plant automation
	Cost of labour	✗ No – cost disadvantaged
Energy	Energy intensity	— Process dependent
	Cost of bulk energy	✓ Yes – great availability of co-located solar/wind
	Cost of firmed energy	— Some – limited PHES co-location with renewables*
Proximity	Access to end markets	— Some – close to Asia
	Input location advantage	✓ Yes – unrivalled access to raw material inputs

* PHES refers to pumped hydropower energy storage

Australia's renewable energy advantage favours hydrogen and green iron

The advantage conferred by cost-competitive variable renewables is tempered by the need, and cost, of firming to secure consistent supply. 'Always on' energy is most competitively supplied in locations with abundant hydropower. In contrast, Australia's energy advantage could be found in processes that require energy 80-85% of the time. This is sufficient for iron and hydrogen, but not for aluminium.

Some industrial processes need near 24/7 delivery of energy

Many heavy industrial processes have limited 'operational flexibility' and need reliable energy for their operations more than 95% of the time. As shown in the top band of Exhibit 13, aluminium production is the most dependent on continuous energy. If a plant loses energy for even a few hours, the 'pot' of liquid being processed from alumina to aluminium solidifies and the pot and its contents must be discarded, incurring huge costs.

Hydrogen production is one of the most flexible and is expected to be commercially attractive in some circumstances with capacity factors as low as 50% (where electricity is only available 50% of the time).

Processes with high operational flexibility (including desalination for local use) can reduce average unit costs through demand management. By profitably using 'excess' power when the sun shines and wind blows, these processes can absorb variability at the system level.

Hydropower can firm energy for 24/7 delivery more cheaply than any other technology

Locations such as Quebec in Canada and Norway have abundant hydropower that can deliver firmed, clean energy almost continually. New large-scale hydropower opportunities are limited, however, and so the vast majority of new renewable generation will be variable.

As a relatively hot, dry and flat country, Australia has limited potential to use existing hydropower for firming. We need to invest in more expensive forms of storage such as batteries and pumped hydro to 'firm' electricity supply from variable weather-dependent renewable sources such as wind and solar.

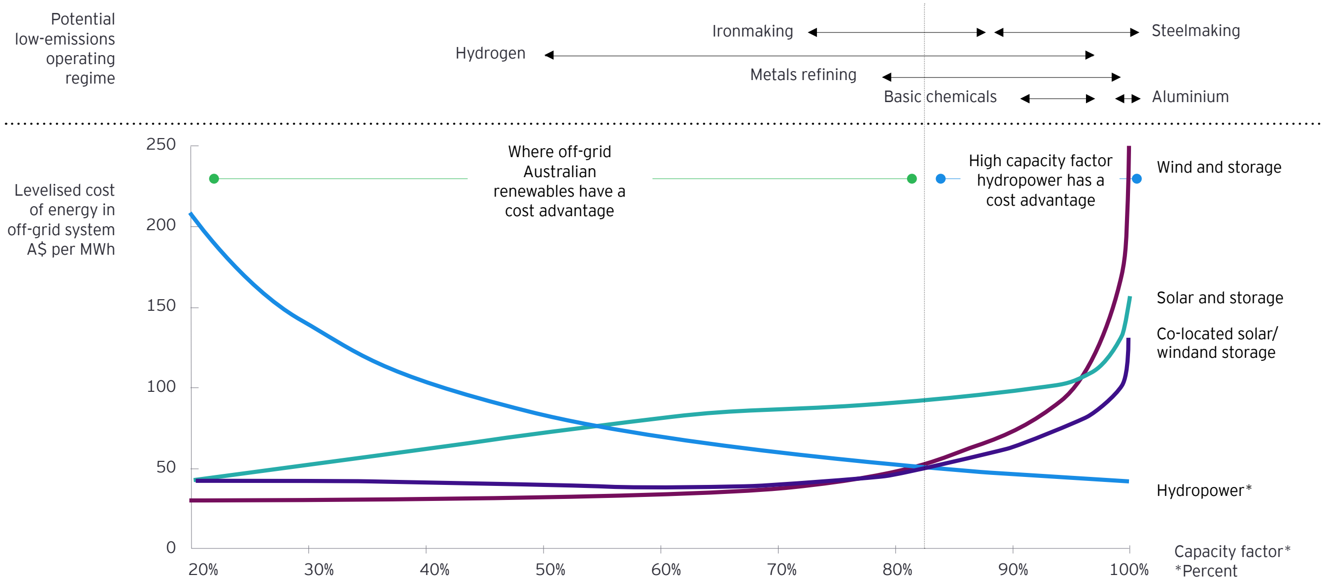
Delivering that firmed electricity becomes markedly more costly for a 90% continuous flow, and almost prohibitive beyond 98%.

Australia's energy advantage aligns best to sectors with higher operational flexibility, including hydrogen and iron production

Australia's greatest medium-term opportunity is where its abundant clean energy can serve processes with some energy flexibility, as the energy advantage cannot be undercut by countries with abundant existing hydropower. The advantage is stronger when energy can be generated cheaply close to mineral deposits, such as in the Pilbara.

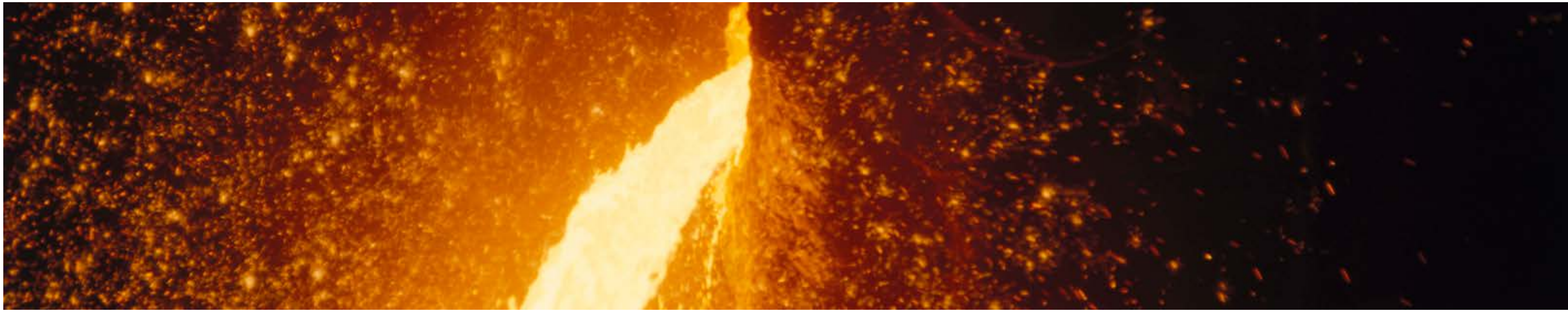
This constraint may become less binding over the longer term, as competing existing hydro resources become fully allocated and costs of pumped hydro and other storage declines.

Exhibit 13: Firming costs constrain industrial processes that have limited energy flexibility (in countries with scarce hydropower resources)



* Negative slope appears since hydropower costs are largely fixed

** Capacity factor = average output / maximum output. For variable energy sources maximum output is constrained by weather



Hydrogen can benefit Australia, and the world, in multiple ways

Green hydrogen is a crucial and multifaceted replacement for fossil fuels. Uses include providing long term chemical storage of energy; serving as an energy carrier; and contributing as a chemical agent. These uses involve different technology challenges, and offer different value propositions.

We see enormous potential to produce and use hydrogen in Australia, including as an input to other exports – adding value in Australia and avoiding the costs of technical challenges of seaborne trade (see pages 56-58 for more details).

> "These technologies are thus likely to play a crucial long-term role in the global net zero transition.

Carbon removal technologies may emerge as attractive opportunities as costs fall

Many 2°C and most 1.5°C climate scenarios reviewed by the Intergovernmental Panel on Climate Change (IPCC) assume large-scale use of carbon removal technologies such as direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS). These technologies offer permanent CO_2 storage for 10,000-plus years, in contrast to the 25-100 years of storage generally offered by nature-based removals.

These technologies are thus likely to play a crucial long-term role in the global net zero transition.

However, current deployment is very small and very high cost relative to nature-based options. This cost differential is likely to shrink as DAC and BECCS costs fall, and as nature-based costs increase (reflecting competition for land and stricter quality standards). Public and private willingness to pay for permanent storage may also increase as climate change risks and impacts become more obvious.

A broader analysis also finds big opportunities in energy transition minerals including lithium and copper

We assess a wide range of potential opportunities across metals production, minerals processing, new energy carriers, and technology-based CO_2 removals. This assessment expands the lists of prospects for Australia and confirms opportunities in iron and hydrogen. We also identify additional opportunities for energy transition metals and alumina (the key input to aluminium production). Technology-based CO_2 removals may also emerge as attractive opportunities over the long-term as costs fall and willingness to pay increases.

We assess export prospects against four foundations of heavy industry advantage

The first two of these foundations relate to the industrial process used to create the exported product: its energy intensity; and its operational flexibility (discussed above). Australia's availability of low-cost high-volume renewable energy favours processes with relatively high energy intensity. However, this advantage is undermined if a process has low operational flexibility.

The other two foundations relate to potential locations: resource input availability, including renewable energy resources and raw materials; and proximity to other inputs and destination markets (including relevant transport infrastructure). Of these, proximity to destination markets is a greater differentiator, as Australia is competitive across the board in relation to resource availability.

We find multiple attractive opportunities: three energy-intensive processes and several energy transition minerals

- Green iron and steel, particularly iron, including first stage processing that can then be used as an input to electric arc furnace (EAF) steel production.
- Alumina, processing bauxite to alumina as the first step towards aluminium (although aluminium itself would require large quantities of expensive firming and so new capacity is more likely to be located offshore).
- Lithium, copper, nickel and other critical 'new economy' minerals, metals or rare earths, with initial processing leveraging Australia's proven mining capabilities.
- Hydrogen for multiple domestic and export-oriented uses, including as an input to exported products such as green chemical feedstocks.

Our detailed assessment is summarised in Exhibit 14.

Exhibit 14: Green iron and steel and energy-related minerals are prospective

Group	Product	Production pathway	Resource input availability	Operational flexibility	Process energy intensity* GJ/t	Proximity advantage*	Overall prospect for Australia	
Energy dense processed metals	Ironmaking	H2-DRI	●	▲ Limited	● 20-25	● Positive	●	Ironmaking
	Steelmaking	EAF	●	▲ Limited	▲ 1.5	● Positive	▲	
	Alumina	Bayer process	●	● Some	▲ 10	● Positive	●	Alumina
	Aluminium	Reduction	●	■ None	● 200-250	● Positive	■	
Refined energy transition metals	Copper	Processing and refining	●	● Some	▲ 6	● Positive	●	Refined energy transition metals
	Nickel		●	● Some	▲ 13	● Positive	●	
	Lithium OH/CO3		●	● Some	▲ 5-9	● Positive	●	
	Critical metals		●	● Some	▲ 10	● Positive	●	
Industrial chemicals and energy vectors	Hydrogen (domestic)	Electrolysis	●	● Lots	● 180	● Positive	●	Hydrogen
	Ammonia (H2 export)	Haber-Bosch	●	▲ Limited	● 20	▲ Neutral	▲	
	Methanol	Methanation	●	▲ Limited	▲ 7-10	▲ Neutral	■	
	Basic chemicals	-	●	▲ Limited	▲	▲ Neutral	■	
Atmospheric carbon removals	CO_2 from DAC	Adsorption	●	▲ Limited	▲ 6-10	● Positive	●	DAC
	CO_2 from BECCS	-	●	● Lots	▲ -	▲ Neutral	▲	

*Proximity advantage reflects freight costs to destination markets

We assess a realistic 'energy superpower' scenario against a 'lost opportunity'

Australian business and governments have choices to make, and work to do, to capture our renewable energy superpower opportunity. We assess the size of this dividend by modelling two feasible pathways for Australia in a world on track to limit climate change to less than 2°C.

Australia could become a renewable energy superpower

In this scenario, Australia rolls out cost-competitive firmed renewable energy at scale, and leverage's this to grow its share of global materials- and energy-intensive production – particularly in iron and steel.

This is a significant shift from Australia's current export focus, in which fossil fuels are exported to generate energy elsewhere.

The Energy Superpower pathway sees Australia amass advantages in the production and use of energy onshore, enabling competitive exports of manufactured and refined products. Powered by Australia's abundant renewable energy, those products have high embodied energy yet low embodied emissions.

This scenario also sees Australia consolidate its existing advantages in minerals and resources. Australia is well positioned to supply the raw materials required in the rapidly expanding new global energy system, including metal ores such as copper and lithium. This scenario also sees Australia leverage growing global attention to develop friendly and secure supply chains for essential inputs.

Or Australia could fall behind and face a lost opportunity

The alternative is that policy settings and business strategies do not support the required development of cost-competitive renewables, or wider low-carbon innovations, making investment less attractive. In this scenario, Australia falls behind countries and regions with high grade renewable resources and well-coordinated new energy strategies.

Instead of becoming an energy superpower, our market share declines and our future opportunities fade.

Both scenarios are set against a backdrop of strong global climate action

Both scenarios assume a world on track to reach net zero emissions, globally, by around 2070. This involves a significant step-up in the pace and extent of global emissions reductions, sufficient to limit temperatures to below 2°C, but not consistent with limiting temperatures to 1.5°C above pre-industrial levels.

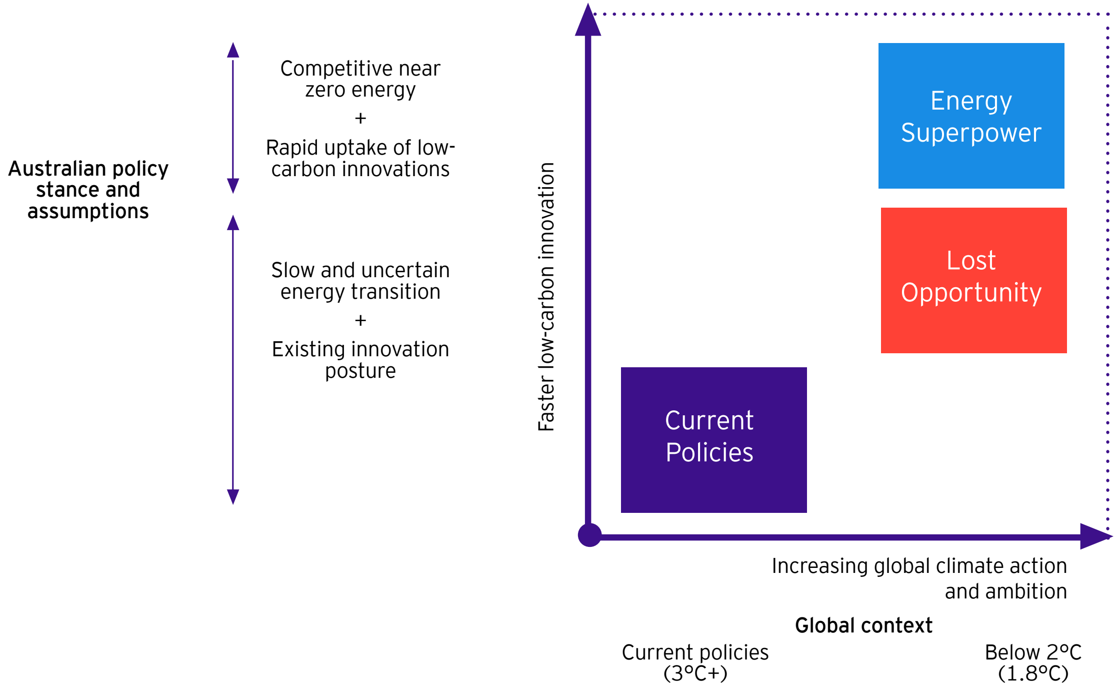
This strong global climate action drives and supports progressive decarbonisation of the global energy system, along with innovations to reduce non-energy emissions.

Australia has access to globally available technologies, with advantages or disadvantages arising from its resource endowments and technology deployment.

Australia takes advantage of land-based removal credits in both scenarios, using these to offset residual emissions and achieve net zero emissions in 2050. Additional credits are exported from around 2045.

More details on the scenarios and our modelling framework are provided in Exhibit 15 and the Appendix to this report.

Exhibit 15: We model two Australian scenarios in a world taking strong action on climate change



Note: See Appendix and Exhibit 23 for more detail.

We find Australia's potential energy superpower dividend is, conservatively, worth $40 billion in additional income every year by 2050

We find the energy superpower dividend for Australia is at least $40 billion in additional national income in 2050. This is worth $1,100 per person and represents $65 billion in additional economic activity. These gains are underpinned by the new opportunities captured, particularly in green iron and steel, and in energy transition minerals and metal ores. We consider these numbers to be a conservative estimate of the value of Australia's opportunity.

Income, wages and economic activity are all higher than in the 'Lost Opportunity' scenario

We find the energy superpower dividend adds around AUD$40 billion to national income by 2050 (in real 2021 dollars), equal to $1,100 per person. The value of economic activity (GDP) grows more than national income (GNI),* to be $65 billion larger in 2050 (see Exhibit 16).

The Energy Superpower dividends sees national income 1.4% higher and the economy 2.3% larger by 2050, relative to the 'Lost Opportunity' scenario. Real wages are up by 1.5%, around the same as national income. These positive impacts primarily reflect the higher productivity of advantaged Australian heavy industry sectors, which drive higher margins and returns to Australian workers and investors.

* Gross Domestic Product (GDP) measures the total value of economic activity located in Australia, while Gross National Income (GNI) measures the total income received by Australian residents from the use of their land, labour and capital. Foreign investment typically contributes more to Australian GDP more than it boosts GNI, as payments for the use of this capital flow back to residents in other nations.

These dividends flow from Australia leveraging its advantages in renewable energy and other resources

The key drivers of these gains in the 'Energy Superpower' scenario include:

- Australian iron and steel production grows around 33% faster than the global average to 2050 (but still slower than in India and other emerging markets), reflecting our competitive advantage in green iron.
- Australia remains an attractive investment destination and avoids the modest investment risk premium assumed in the Lost Opportunity scenario.
- Australia's global share of mining output is broadly maintained in the Energy Superpower scenario (falling by 0.5 percentage points by 2050), rather than falling 1.3 percentage points in the Lost Opportunity scenario.

More details on the modelling assumptions and implementation are provided in the Appendix to this report.

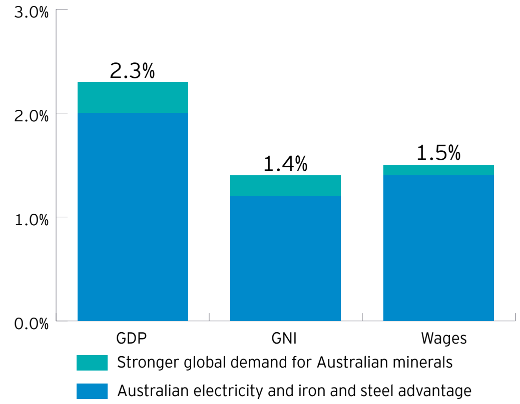
Even better economic outcomes are likely

The input assumptions for our economic modelling are deliberately more conservative than the conclusions of our more granular sector-based analysis of technology opportunities for Australia.

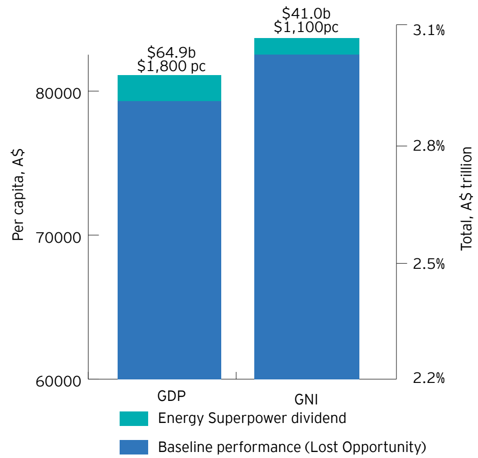
We consider the modelling provides a robust lower bound estimate of likely economic benefits. Key reasons for this include: we assume Australia's share of global iron and steel production remains very small (at less than 1% of global production in 2050); the modelling does not fully account for the emergence of hydrogen as a distinct new part of the global energy system; and abatement cost and technology assumptions are relatively conservative for a world taking strong action on climate change.

Exhibit 16: The Energy Superpower dividend lifts national income and economic activity by $40 billion, more than $1100 per person by 2050

Economic activity (GDP) and national income (GNI) dividend, 2050



Economic activity (GDP) and national income (GNI), 2050



Metals: Transitioning to green iron and steel would help drive down global emissions

Iron and steel account for a significant share of global emissions and energy use. While a variety of steelmaking technologies are available, with different emissions intensities, the bulk of global production uses emissions-intensive coking coal-based blast furnaces. Evolving climate policy settings are beginning to shift incentives, and this will increasingly drive the transition to green iron and steel. Over the longer term, development of cost-competitive hydrogen will support step-change reductions in emissions relative to current levels.

Accelerating climate action will push, and perhaps pull, the growth of green iron and steel

Iron and steel account for around 7% of global emissions, and around one quarter of direct CO_2 emissions from heavy industry.[11] This is more than the emissions from all road freight, and around five times the emissions from aluminium and other non-ferrous metals.

Shifting to low-emissions steel production is a crucial opportunity to achieve large-scale reductions in industrial emissions.

A range of technology challenges are still to be overcome. But the immediate constraints that prevent existing facilities from moving towards low-emissions steelmaking are commercial rather than technical. This is because steel is a widely traded commodity and a highly competitive industry with current facilities and processes that have been optimised without regard to emissions.

Incentives are now beginning to shift. To date, steelmaking has been largely excluded from carbon pricing schemes, but this will not last forever. Policies in advanced countries will increasingly cover steelmaking emissions, including Carbon Border Adjustment Mechanisms (CBAM) like the one that is being introduced by the European Union. This will tilt returns in favour of low-emissions steel, including in source countries that export to advanced countries, expanding global market volumes and accelerating technology development. We are already seeing initial investments being made in this direction in Europe, assisted by carrots (support) as well as sticks (emissions pricing and constraints).

Over time, a demand-side price premium may also emerge for green steel, which would accelerate this shift.

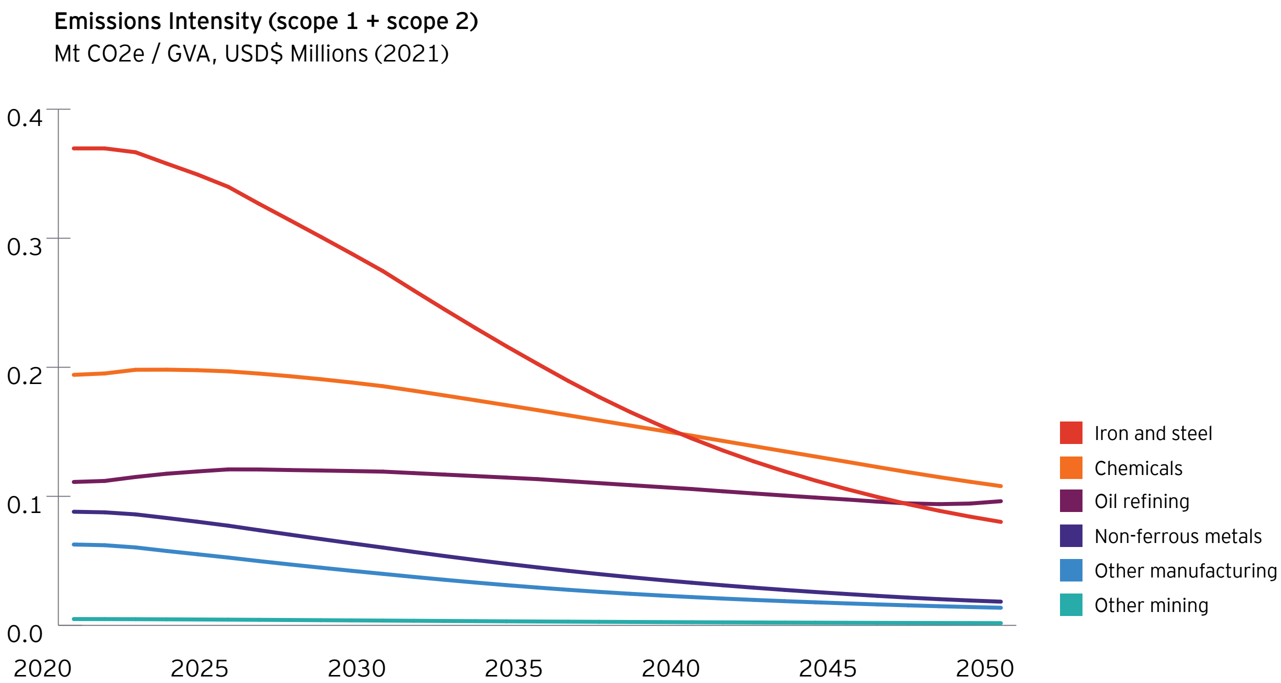
11. IEA (2020) Iron and Steel Technology Roadmap

Iron and steel have very significant decarbonisation potential within heavy industry

The immediate decarbonisation pathway for steelmaking involves shifting from coking coal to the use of natural gas to meet process requirements. Over the longer term, development of green hydrogen will decouple steelmaking from fossil fuel inputs, enabling step-change reductions in emissions intensity from current levels.

Consistent with the technology options available and under development, iron and steel have the largest decarbonisation potential of any heavy industry sector, falling by 45% from 2020 to 2035 and by around 80% by 2050 (see Exhibit 17).

Exhibit 17: We find iron and steel has the largest decarbonisation potential within heavy industry and mining, supported by electrification



Australia is well positioned to grow its share of global iron and steel production

While Australia is currently the world's largest exporter of iron ore, Australia's steelmakers process only a small fraction of this into iron and steel, largely to serve the domestic market. As greater emphasis is placed on decarbonised steel, Australia is well positioned to add value to existing ore exports, grow its share of global iron and steel production, and extend its participation in the iron and steel value chain.

Green iron enables deployment of cleaner electric furnaces needed to replace existing coal-based blast furnaces

Today, around 60% of the world's steel is produced in blast furnaces. This highly emissions-intensive process produces an average of 2.2tCO_2e per tonne of steel. Most of the remainder is produced in electric arc furnaces (EAF) with a combination of 'directly reduced iron' (DRI) and recycled scrap steel. Emissions vary with inputs used, but currently average around one third lower (~1.4tCO_2e per tonne of steel produced).

One of the key constraints enabling the transition to green steel is the availability of suitable iron units, either from virgin ores or recycled steel, in sufficient quantities and at competitive costs. Increased supply of virgin iron is essential, as the volume of scrap metal available globally falls well short of current and projected requirements.

Producing iron units suitable for green steelmaking processes requires low-carbon energy in vast quantities to support beneficiation, agglomeration and direct reduction. This plays well to Australia's renewable energy advantage.

Initially, there will also be a requirement for natural gas as a reductant in the DRI process, until this can be replaced with low-carbon green or blue hydrogen. Western Australia and South Australia, where the majority of the nation's iron ore resources exist, are both globally advantaged locations for renewable electricity and gas.

Australia is in the box seat to add value by supplying green iron

Australia has a long-established competitive advantage established in bulk iron ore mining, with global-scale mining operations, and the ability to further expand production at low incremental cost compared to alternatives.

However, Australia's participation in the global iron and steelmaking value chain is limited, with domestic steelmakers largely servicing the domestic market alongside imported steel.

Most Australian iron ore is currently exported to China, where the blast furnace steelmaking process is dominant. Almost none of these exports involve value-adding processes, such as agglomeration or pelletisation, or manufacture into pig iron using the direct reduction route.

Options to accelerate the green iron and steel transition could include deeper research into the direct reduction of haematite ores – a process used to convert iron oxides into metallic iron without the need for intermediate smelting or refining. Direct reduction of haematite has historically been considered technically unattractive due to the higher 'gangue content', or impurities, compared to purer magnetite concentrates. Technical breakthroughs in this respect could significantly increase the value of Australia's mostly haematite iron ore reserves.

Achieving cost-competitive agglomeration and direct reduction of these ores would both enable increased use of electric arc furnace steelmaking in place of blast-furnaces, allow Australia to produce a high-value feedstock for decarbonised steelmaking, rather than exporting lower-value ore to more carbon-intensive steelmakers.

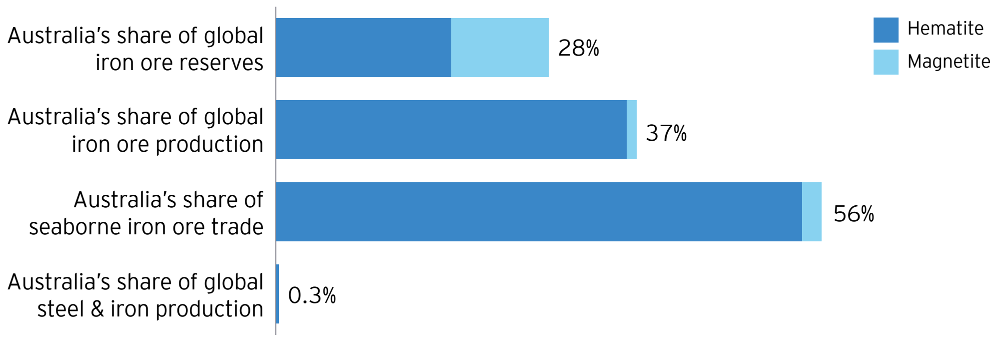
We find Australia could at least triple the value of iron and steel production over coming decades

Australia's long term growth potential for upstream iron and steel products is almost unlimited, given our vast iron ore resources and tiny share of global iron and steelmaking (see Exhibit 18).

However, we take a very conservative approach to iron and steel growth for the purposes of assessing the energy superpower dividend for Australia. This analysis does not account for the potential emergence of hydrogen. It also assumes the value of Australian iron and steel production only grows around 20% faster than the global average to 2050, implying output value increases by around a factor of three over coming decades.

Exhibit 18: Australia accounts for over a third of iron ore production globally, but only a third of one percent of iron and steel production

Australia's share of global reserves, trade and production, 2021
Percent



Minerals: Australia can help meet accelerating demand for new energy minerals, through friendly supply chains

The renewable energy transition is driving almost unprecedented demand for essential mineral inputs such as lithium, cobalt, nickel, manganese and copper. Australia has significant reserves of these minerals and is a reliable and cost-effective supplier for 'friendly' global value chains. With its own clean energy, Australia can increase our contributions to those value chains with primary ore processing.

The renewables revolution is already driving surging demand for energy transition minerals

Global demand for key minerals is set to multiply substantially over coming decades, with the International Energy Agency projecting lithium requirements will increase more than 40-fold (4100%) by 2040 (see Exhibit 19). The tripling of copper requirements is equally impressive, given current copper production is already worth more than AUD$230 billion (US$155 billion). These minerals are essential not only for batteries and grid storage, but also for renewable energy generation and the global 'rewiring' required to shift that energy from where it is produced to where it is needed.

Australia has substantial reserves of transition minerals, alumina and iron ore

Australia has significant reserves of almost all transition minerals, other than graphite and rare earth minerals, ranging from 11% to 26% of global reserves (see Exhibit 19). In addition, Australia's current share of global production is smaller than its share of reserves for these transition minerals. Rare earth elements are an exception, with Australia accounting for 8% of current production and 3% of global reserves.

The low-carbon transition – along with growing 'business as usual' demand for goods, services and infrastructure – will also drive increased global requirements for iron, steel, alumina, aluminium and other light metals and metal ores.

The pandemic and other disruptions have drawn attention to the value of friendly supply chains

If the past is any guide, global trade and supply chains will continue to be vulnerable to disruption. While causes and consequences are uncertain, likely drivers include severe weather events, accidents impacting trade routes or globally-significant facilities, pandemics, economic and financial crises, and local conflicts and wider geopolitical tensions.

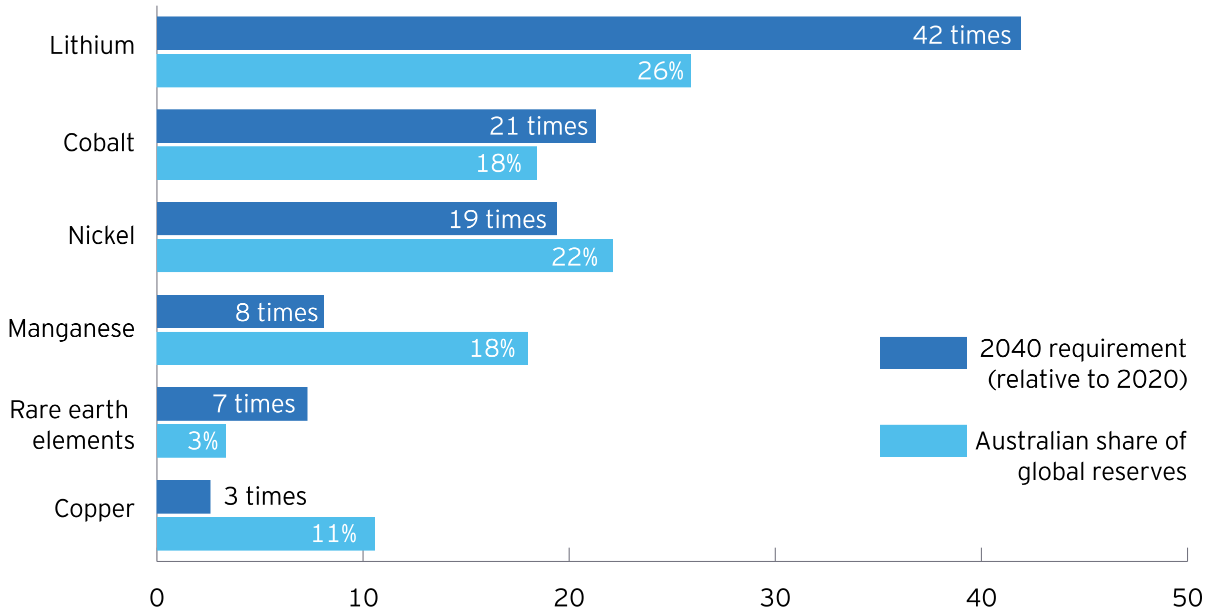
These risks highlight the value of more resilient and secure trade and supply chains.

Australia's strong trade credentials and alliances provide an additional potential advantage as a reliable and friendly supplier of essential materials including iron and steel, aluminium, chemicals, and energy transition minerals.

Trade partners may also appreciate Australia adding value in those supply chains, by delivering processed rather than raw mineral ore. Australia's abundant renewable energy, typically co-located with the mineral ore, gives it us the capacity to pursue that opportunity.

Exhibit 19: Global requirements of energy transition minerals are surging, and Australia has substantial reserves

Projected global requirements in 2040 and Australian reserves for selected minerals
Growth relative to 2020*, Australian share of global reserves**



* A multiple of five indicates a five-fold increase, or 400% change, from 2020 to 2040
** Australia's share of global production in 2021 is smaller than its share of reserves for all minerals shown except rare earth elements, with a 8% share of production.
Source: 3. US Geological Survey Mineral Commodity Summary (2022).
4. IEA Global Electric Vehicle Outlook (2022)

Momentum: Cost competitive hydrogen will be an 'opportunity multiplier' when it comes

Australia can leverage its natural advantage in green hydrogen to accelerate green industry development and amplify the benefits of the net zero transition. Australia has a strong interest in being near the front of the pack, and would benefit from 'leaning in' more strongly on government support for hydrogen innovation.

Australia is well placed to produce globally competitive clean hydrogen

Australia's abundant land and natural resources make it well-suited to large-scale production of renewable hydrogen. Vast open land areas with attractive solar and wind energy resources could host massive solar and wind farms, and supply renewable electricity to suitable locations for hydrogen production via electrolysis.

Hydrogen has multiple uses – storing and transporting energy, and working as a chemical agent

Hydrogen provides long term chemical storage of energy. Like batteries and pumped-hydro systems, hydrogen can be produced when energy is abundant, allowing energy to be stored until it is needed.

Hydrogen can also serve as an energy carrier, allowing energy generated in one location to be released and used in another location. However, it pays an increasingly severe penalty for each additional transformation step that is required to deliver to an end user further away or to store until the time it is consumed. What creates this loss is the need for a value chain which requires multiple transformations either from electricity into a chemical or between different types of chemicals and then back again.

Australia can benefit from using hydrogen to create other exports

Media coverage frequently focuses on the potential for Australia to establish a renewable energy export industry that ships hydrogen or its derivatives to energy-importing countries like Japan or Korea.

However, using renewable hydrogen close to its source adds value in Australia and avoids the cost and technical challenges involved in seaborne transport.

We therefore see production and domestic use of low-cost renewable hydrogen as the more exciting medium-term option to enable and accelerate low-carbon industries in Australia.

Unavoidable energy penalties limit the value proposition for seaborne hydrogen trade

Production and export of hydrogen involves multiple steps: using renewable energy to produce transportable hydrogen, compressing or converting hydrogen for transport, and then transforming this back into useable energy. For example, transport will typically require compression, hydrogenation (such as chemical conversion to ammonia) or liquefaction, followed by reconversion into energy (such as electricity via a fuel cell or combustion for heat). Together these steps can impose an energy penalty around 75%, depending on the process flow, technologies, and efficiencies at each step.

For many end use customers, it will be challenging to justify seaborne green hydrogen or its chemical derivatives against alternatives like pipeline transport of hydrogen at lower levels of compression, directly electrified process heat, development of onshore renewables and storage, or use of fossil-fuel based hydrogen with CCUS.

While there is an important market niche for seaborne hydrogen trade, we expect the scale of this market will be relatively limited for some time.

Australia can play in multiple end-use hydrogen markets

These technical issues draw attention to three distinct end-use markets and value propositions for green hydrogen.

1. **Industries where hydrogen is directly useful,** such as reductant in the direct reduction of iron ore.
2. **Industries that use hydrogen-based chemicals as a 'green feedstock'**, such as fertiliser production, fertiliser production, explosives, other petrochemicals.
3. **Industries that are energy constrained,** and not able to meet their energy needs through local (or grid connected) renewables, but do not require or value hydrogen or its derivatives for non-energy related needs.

Australia is well positioned across each of these end-use markets.

As set out above, Australia has a natural advantage in the first of these markets, involving production and domestic use of hydrogen. (Of course, Australia must ensure its competitive disadvantages in manufacturing (higher capital and labour input costs) do not outweigh its energy- and resource-based advantages relative to competing locations.)

The second market includes production for export as well as for domestic use. Transport and use of chemical products synthesised from green hydrogen, such as ammonia is a well-established low-cost industry. Australia already plays in this market, and could grow its market share.

However, Australia's opportunity in the third market is limited both by the size of the total market, and by the fact that Australian exports will require seaborne trade. We consider the market for hydrogen as a pure energy carrier is relatively small. However, where end-use context and circumstances give rise to demand for seaborne imports of hydrogen, Australia is likely to be well positioned to compete.

Hydrogen will create new opportunities when it comes

Cost competitive clean hydrogen will be an opportunity multiplier when it is available at scale. This could open a range of new opportunities for Australia to develop new supply chains. For example, hydrogen could be used in the production of:

- Green iron through the direct reduction process, displacing fossil natural gas (and eliminating more than half of ironmaking process emissions).
- Fertilisers and explosives through its conversion into ammonia, displacing the use of grey hydrogen from natural gas.
- Alumina refining, displacing natural gas in the calcination process and reducing emissions by around 30%.
- Producing synthetic fuels in conjunction with CO_2, particularly for use in heavy transport.

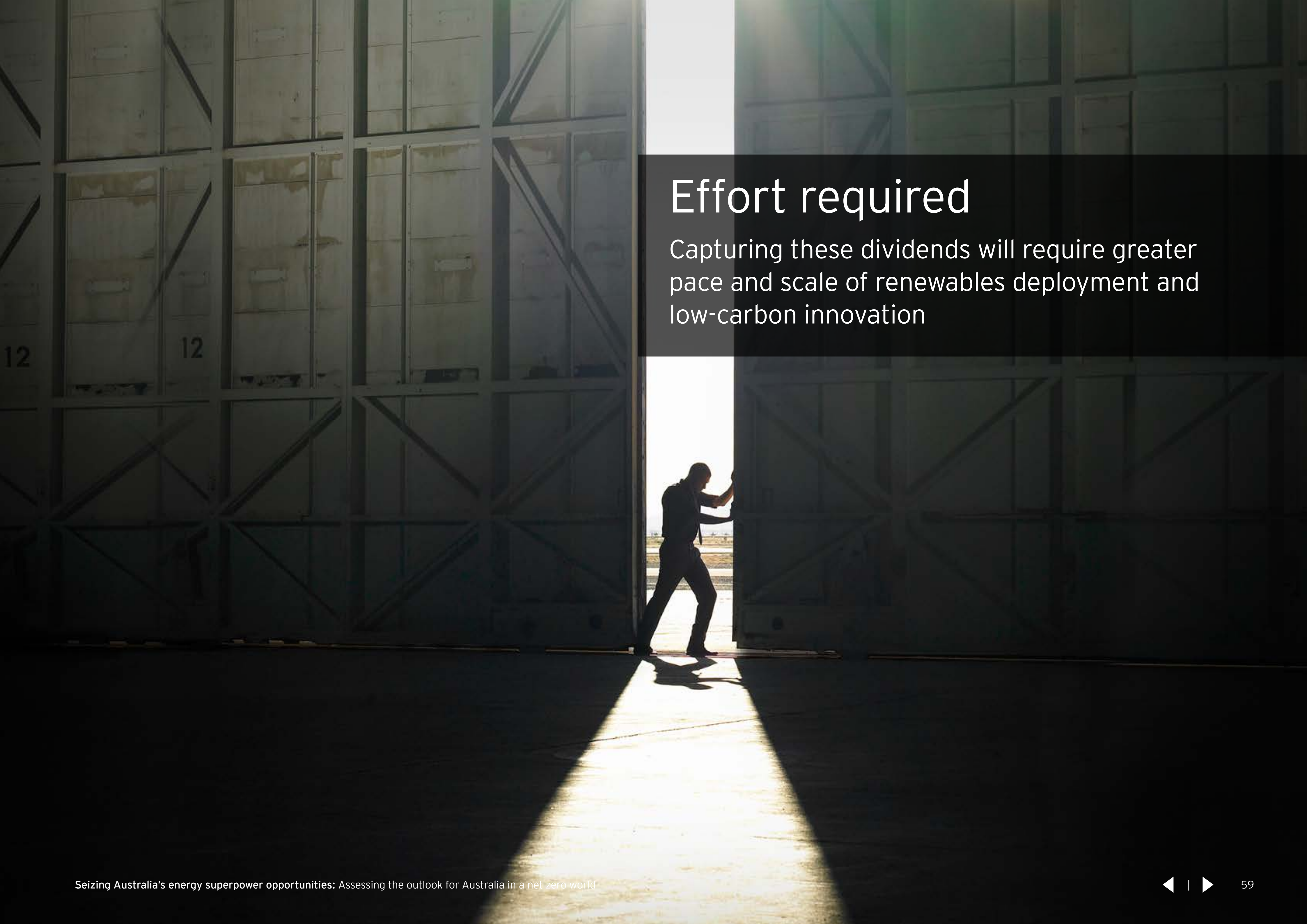
The development of hydrogen industries globally may also multiply the critical minerals opportunity for Australia, with many of these minerals needed for hydrogen production and electrolysis, storage, and end-use technologies.

'Leaning in' to hydrogen innovations and partnerships would bring benefits

The tactical and strategic importance of hydrogen to Australia's low-carbon future suggests we should strengthen our engagement. This could include:

- Increased targeted government incentives and support for the development of a domestic green hydrogen industry through grants, tax credits, and other measures to help companies build hydrogen projects and supply chains.
- Clear policy targets around hydrogen adoption to give investors confidence to invest in production, and to give customers confidence in the emergence of cost-competitive supply.
- Foster international partnerships to develop green hydrogen projects and global value chains. Joint ventures and shared investments could enhance economies of scale and scope, making green hydrogen more feasible, particularly for production inputs like electrolysers and balance of plant equipment.

These initiatives have the potential to provide significant national returns, including by enabling the development of downstream clean industries.



Effort required

Capturing these dividends will require greater pace and scale of renewables deployment and low-carbon innovation

Australia's electricity system is rocketing past 'step change' into the unknown

The Australian Energy Market Operator's (AEMO's) Step Change scenario for National Electricity Market (NEM) transformation was regarded as an unlikely outlier when it was first published in 2020. But it became the central forecast just a year later. Now, Step Change is being overtaken by events, particularly announcements bringing forward the retirement of coal. This creates urgent challenges for policy makers, planners and industry participants.

Renewables development is outpacing even recent predictions, as economic returns shift against fossil fuels

AEMO's 2020 Integrated Systems Plan (ISP) set out five possible scenarios for the future of energy planning, with the Step Change scenario being the most radical for both decarbonisation and decentralisation of the system. Just a year later, industry, government, consumers and academics all considered the Step Change scenario the most likely outlook. This was confirmed in the 2022 Final ISP.[12]

Market announcements through 2022 indicate that Australia's switch to renewables is occurring at least as fast as Step Change projected. For example, the proportion of renewable energy generation in the NEM reached a record 68.7% on 28 October 2022. The average renewable share for the quarter reached a record high of 40.2%, just shy of the 40.6% share of black coal, and the lowest in NEM history.[13]

12. AEMO (2020) 2020 Integrated System Plan for the National Electricity Market, Figure 6; AEMO (2021) Draft Integrated System Plan, Figure 9; AEMO (2022) 2022 Integrated System Plan
13. AEMO (2023) Quarterly Energy Dynamics Q4 2022

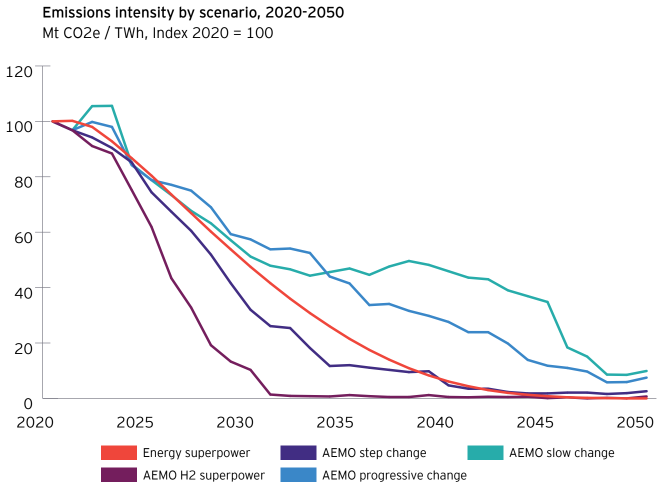
Coal generation is on a path to exit, with ageing plants under pressure from cheaper renewables, rising maintenance costs, and declining social licence. Current solar and wind generation costs are between 50 to 75% cheaper than black and brown coal generation, and these costs are forecast to decline further each year.[14] As a result of these pressures, announcements of coal-plant closures have reset the anticipated coal capacity for 2035 from 15GW down to just 3GW. All plants are now scheduled to close by 2040 (see Exhibit 20).

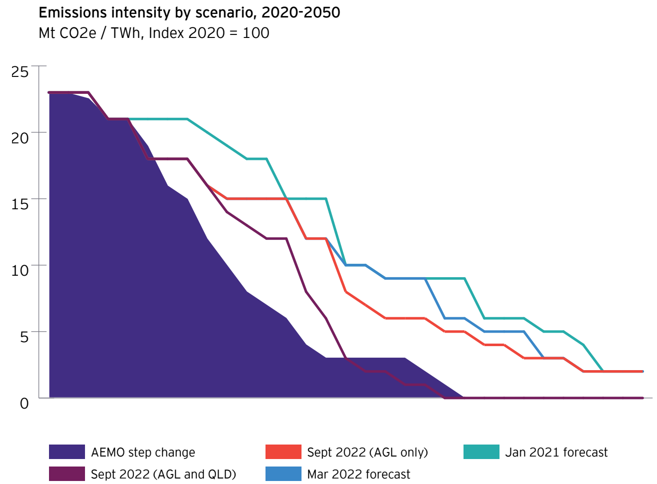
Looking ahead, Australian electricity emissions will fall by more than 90% while supply more than doubles

Consistent with this, our modelling projects changes in Australian electricity supply volumes and emissions that are broadly similar to AEMO's Step Change projections for the connected east coast market, with emissions intensity falling by 90% over coming years (see Exhibit 20).

This transition to abundant low-carbon electricity lays the groundwork for Australia's energy superpower opportunity.

Exhibit 20: We project a 90% reduction in electricity emissions intensity by 2040 and near zero by 2045





Source: 15. AEMO (2022) 2022 Integrated System Plan. 16. Reeve, A, and J. Ha (2023) coal retirement dataset, Grattan Institute (unpublished)

14. Graham et al (2022) GenCost 2021-22, CSIRO

Australian governments are driving significant change to electricity markets

Australian governments are moving to secure reliable low-carbon electricity, and support new low-carbon industries. In 2022, the federal government announced the Powering Australia plan, with policies and funding to support jobs and reduce emissions.

Action by state governments is a significant, but often overlooked, driver of the transition to low-carbon electricity. These are summarised in Exhibit 21 below.

Exhibit 21: State Governments are driving the transition to reliable low-carbon electricity

	NSW	Victoria	Queensland	Western Australia
Emissions reduction target	50% by 2030 Net zero by 2050	75-80% by 2035* Net zero by 2045	30% by 2030 Net zero by 2050	Net zero by 2050
Renewable energy target		95% by 2030*	70% by 2032 80% by 2035	
Storage and firming	2GW long duration storage by 2030	2.6GW by 2030 6.3GW by 2035	5GW pumped hydro by 2032, 7GW long term	1.1GW battery storage
Coal retirements		AGL has announced closure of Loy Yang A in 2035. The renewable energy target* implies closure of both Loy Yang A and B by 2030	No regular reliance on coal by 2035 Convert coal plants into clean energy hubs	All state government owned coal fired power retired by 2030
Other policies	$3 billion for new hydrogen projects $500m for Renewable Energy Zones	$1 billion for 4.5GW renewable energy projects 4GW offshore wind by 2035	Energy "job security guarantee"	$90 million for renewable hydrogen

* Victorian Government election commitment

Urgent additional action is required to deliver reliable near-zero carbon electricity and increase supply

Planning is one thing. Doing is another. The transition to near-zero carbon electricity is urgent. We need action now on system planning and coordination to unlock investment in firming and storage, facilitate demand management, and ensure new supply is aligned with new major sources of demand (such as hydrogen, or new heavy industry precincts). Action is also required to avoid the social and economic risks from disorderly retirement of ageing coal-fired generation. The dramatic increases in supply required to decarbonise other sectors through energy switching and to support new export-oriented industry amplifies these challenges.

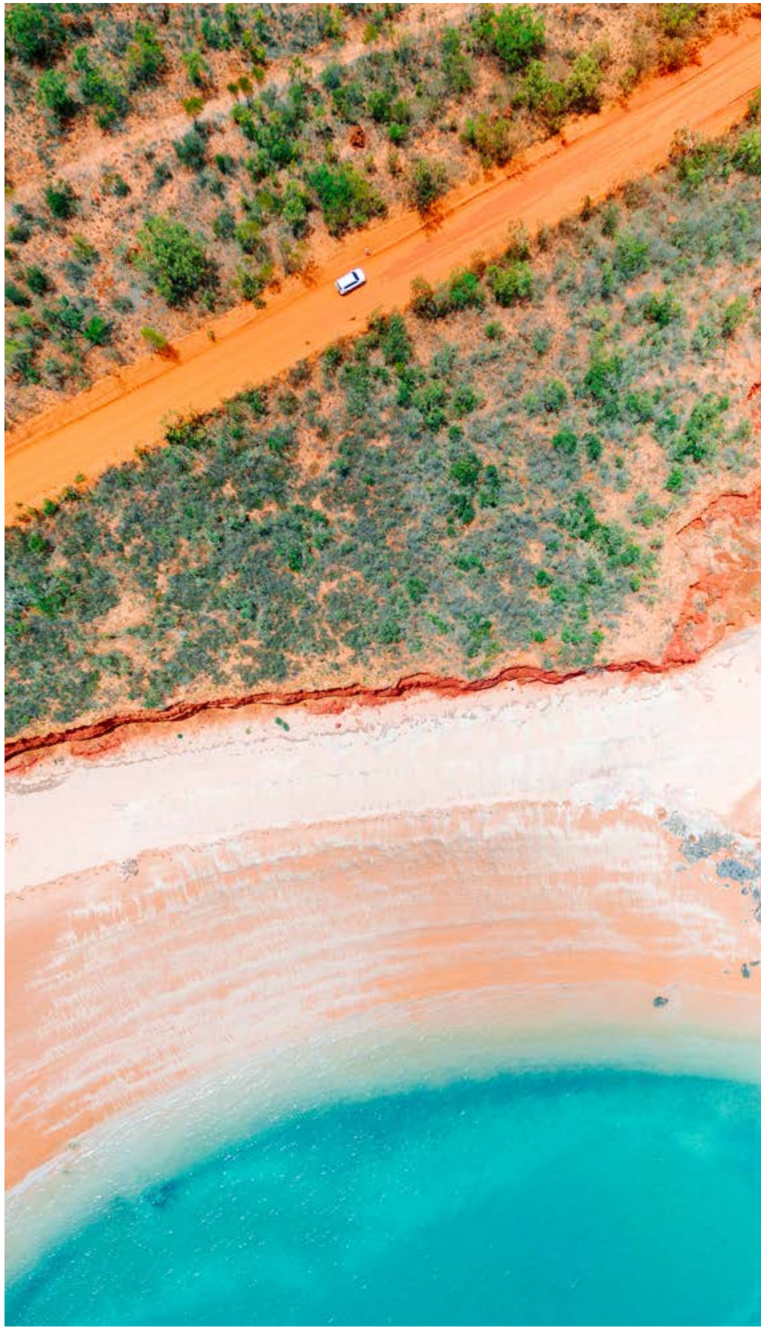
The transition to near-zero carbon is enormously disruptive for the electricity market

New grid-scale renewables have been cost competitive against new-build coal and gas generation for more than a decade.

The resulting increase in renewable generation is triggering a new tipping point in Australia's electricity system, where older coal-fired plants are not worth maintaining in a system where renewables (with zero fuel costs) set wholesale prices for an increasing share of the time.

This raises two related challenges:

- Delivering cost-effective firming as weather-dependent variable renewables increases as a share of total supply. This will require a mix of battery storage, pumped renewables, and incentives for other dispatchable energy, and should also include demand-side management.
- Avoiding disorderly retirement and replacement of coal power, to support regional adjustment and avoid the sustained high prices that occur following unanticipated closures.



Keeping the lights on, and powering industry, will require firming investments to be coordinated and de-risked

Nation-building investment of a scale reminiscent of the first Snowy Mountains Hydro-electric Scheme will be needed to decarbonise the electricity grid over the next two decades. Renewable generation, together with tens of thousands of kilometres of new transmission infrastructure, is already being planned at scale across multiple renewable energy zones.

More urgently, the deployment of firming solutions needs system-level support and coordination to be investible.

The challenge is that a project's revenue and returns are jointly determined by two aspects outside the control of project proponents: market operation rules and granular details of the system-level generation mix and transmission network (including system interconnections).

Risk sharing instruments such as contracts for difference can make these projects bankable, without necessarily involving subsidies, and are already being considered by governments.

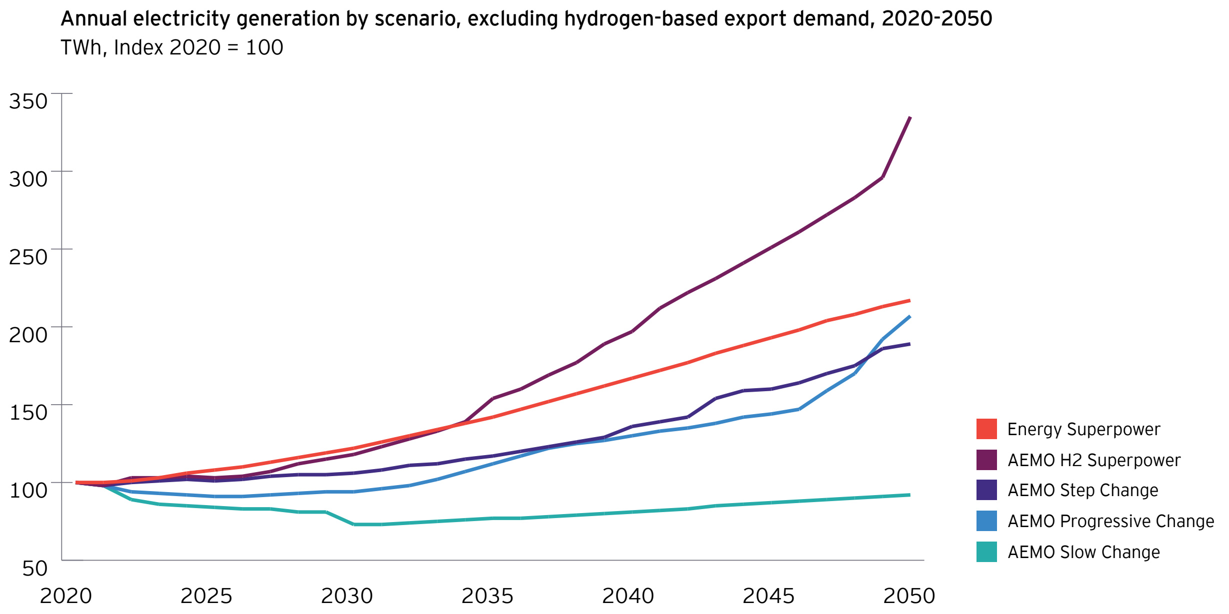
Whether subsidies will be required will depend in part in whether governments consider it appropriate to pass through higher costs to consumers and business.

Scaling up adds to the challenges

Electricity supply needs to at least double, while also decarbonising. This amplifies the challenges facing the sector but can also support aspects of the transition – particularly where increased scale helps to lower average unit costs.

Our modelling sees Australian supply volumes double (see Exhibit 22), aligning more closely to the AEMO's Step Change than to scenarios assuming high volumes of hydrogen production.

Exhibit 22: We project electricity supply more than doubles by 2050, sitting between Step Change and scenarios assuming very strong export-related demand



Thriving through the global shift will require savvy business strategy and government support

The global transition to net zero emissions will disrupt materials and energy-intensive industry in Australia and around the world. Every sector – and every facility – will need to change its production processes, energy inputs and supply chains. Business will need to map commercially viable pathways for adopting technologies that are not yet demonstrated at scale, and in some cases, do not yet exist. Government will need to act in the public interest by coordinating infrastructure, supporting innovation and fostering well-functioning markets.

Success will require large-scale investment and a healthy innovation ecosystem

This report has outlined some of the challenges involved in transitioning from coal-based electricity to a renewables-based system. These include ensuring appropriate firming, managing exits, and coordinating supply to and demand from major new facilities.

Thriving requires more investment and effort than what is required for mere surviving. Australia will perform best if we manage to stay near the commercial innovation frontier in industry niches where we have long term potential advantage. This will require both business leadership and government support for research, development and demonstration.

Business will need to succeed in the old world while preparing for the new

Successful Australian heavy industry businesses are optimised to succeed in highly competitive markets, that – with the exception of electricity generation – currently give little weight to achieving significant reductions in carbon emissions.

This context, and all its related incentives, is increasingly likely to shift, and to do so within the lifecycle of current assets.

This creates both opportunity and challenge for business: where they must continue to perform in our current 'old world', while simultaneously preparing to chart an as-yet untrodden path into the new. This will multiply risks and uncertainties, while making it harder to secure rewards.

Government will need to lean in heavily

Getting the best outcomes will also require Australia to make choices about posture and priorities, as Australia is too small to be good at everything.

Australia has a choice. At one end of the spectrum, Australia can invest ahead of the curve and position as a world leader in areas where we are likely to have a durable advantage. Or we can allow the risk of the of substantial government funds to be squandered seeking to outbid the support provided by other countries with no guarantee of developing a long-term industry that justifies the investment. The risk of the second choice is that we will not benefit from learning by doing, will not develop our skill base, and in practice will never be able to follow.

This implies Australia needs to be close enough to catch the wave, avoiding both being too far ahead and the risk of being left behind.

"Getting the best outcomes will also require Australia to make choices about posture and priorities, as Australia is too small to be good at everything.

Business needs to compete in the current 'old world' while preparing for the new

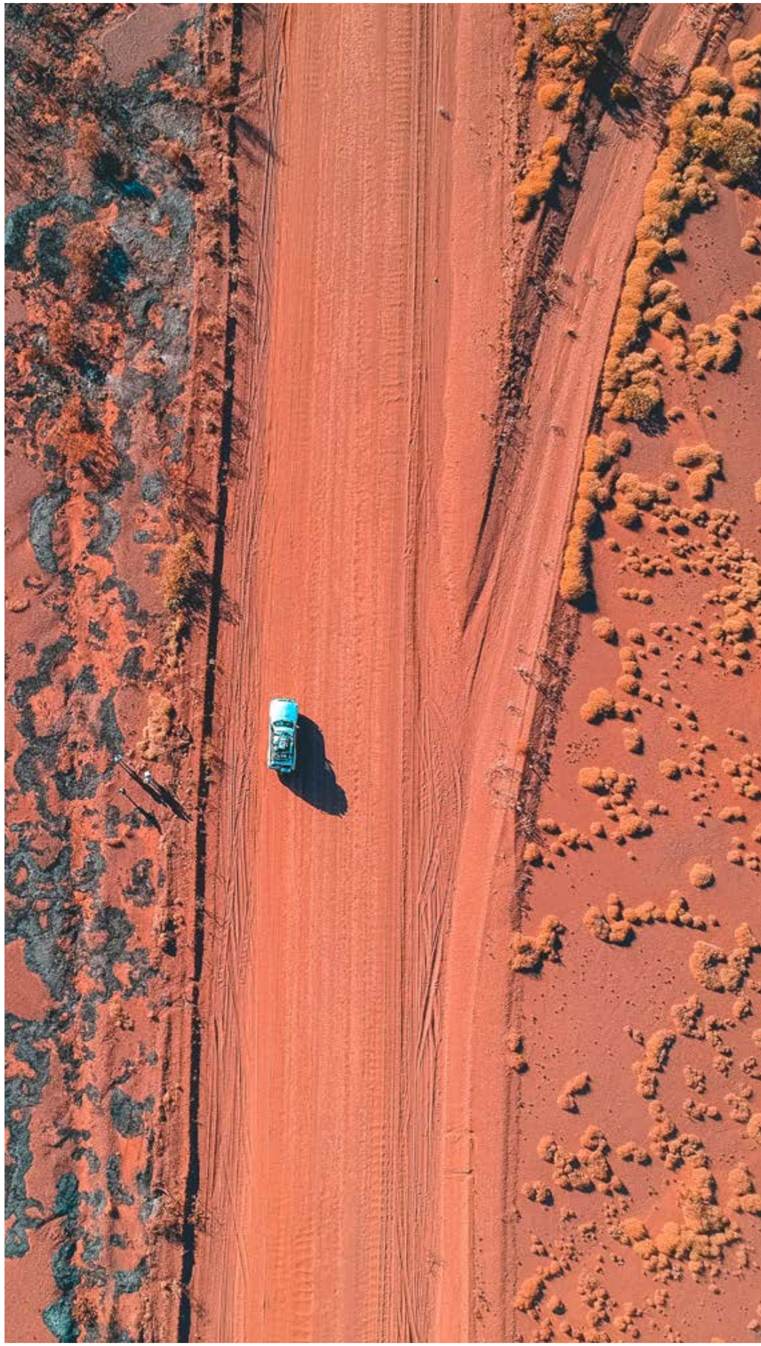
Capturing the renewable energy superpower opportunity demands the coordinated efforts of hundreds of firms, both large and small, across a wide range of sectors. These firms must respond to incentives, embrace significant business risks, widen their focus from optimising existing sources of competitive advantage to creating new ones, and reframe their relationship with government and regulation to thrive in a decarbonised world.

Change is coming, ready or not

Mature industrial firms, which face competition from both domestic and international rivals, have spent multiple generations of management concentrating on optimising their assets for efficiency, often without considering carbon emissions. These managers now face a growing demand for substantial decarbonisation, even when the incentives or enablers to do so may not be in place, or have only very recently arrived.

The challenge confronting these firms is immense. In developing decarbonisation strategies, managers must assess the impact of:

- Accelerating the obsolescence of existing carbon-intensive assets.
- Making significant investments in decarbonised processing or manufacturing plants, with highly uncertain return profiles.
- Decoupling from existing, highly optimised supply chains to establish new supplier relationships.
- Transitioning from established energy supplies to new forms of energy, such as renewable electricity over gas or potentially even green hydrogen.



Risks are multiplying, but rewards are unclear

Naturally, these bold moves may exceed the risk appetite of even the most ambitious firms. However, standing still is likely to be more problematic; the status quo is likely not as privileged as many firms believe.

Although the timing remains uncertain, decarbonised alternatives have the potential to out-compete established industrial processes, and this could even occur within the replacement cycle of currently established assets. Technology is advancing quickly, and the policy environment is becoming more favourable to bolder action.

Winners will position for agile adaptation, while competing under current conditions

For a while, carbon-intensive industrial firms will need to adopt dual-track strategies – maintaining competitiveness under present-day conditions while constantly assessing the viability and attractiveness of decarbonised business models and technologies. They must also be prepared to move quickly when these alternatives become viable or even attractive.

Businesses with a clear vision and roadmap for their energy transition will be best positioned for success. They will accurately understand the real inhibitors to making bold steps (such as a lack of appropriate carbon incentives, technology availability, infrastructure availability) and be prepared to move swiftly as these inhibitors dissipate.

Adopting this dual track posture will be uncomfortable for many in the private sector. But creating – and seizing – new opportunities will be essential for business success, and the wider transformation of Australia's industrial landscape.

Australian industrial firms can position themselves at the forefront of the global energy transition by fostering collaboration and innovation, embracing change, and seizing opportunities in a decarbonised world.

Solidifying Australia's status as a renewable energy superpower will in turn help Australian business capture the competitive advantage that comes with being a leader in sustainable and renewable practices.

Catching the wave requires policy to travel in the right direction at the right speed

Government support for research and development is essential, as effort by private agents is inhibited by the difficulties in capturing a sufficient return, as many of the benefits 'spill over' to others. Current Australian support for innovation is valuable, but modest relative to support available in other high-income nations. Success will require support for business innovation that is tactical, targeted and timely, rather than lazy, lavish and late.

Targeted and timely beats lavish and late

Australia cannot win a bidding war against Europe or the United States. Instead, we need clear-eyed tactical policy that addresses underlying business needs, while recognising Australia's context and constraints.

This implies an approach that is focused on nationally significant low-carbon opportunities, and positions Australia among 'early leaders' without seeking to be at the very front of the pack.

Policy should be cautious about positioning as a 'free rider' rather than as an 'already moving fast follower'. Moving too slowly involves several risks:

- Innovation knowledge may not be easily transferred without learning by doing, or higher costs may reduce the benefits achieved.
- Skill gaps may block or delay participation. Competition for the skilled labour required for clean technologies is likely to intensify, with the International Energy Agency (IEA) reporting that skilled labour shortages are already resulting in project delays.[17, 18]
- Solutions developed elsewhere may not be adapted to Australian needs, including environmental conditions, population density, and distinctive economic circumstances.
- Late mover reputation might discourage investment or damage Australia's standing, particularly if we are not considered a valuable regional contributor and partner.

Crucially, the quantum of support that is appropriate for Australia should flow from these considerations, and the scale of the Australian opportunity, rather than from a comparison to support provided elsewhere.

17. IEA (2022) Trends in Photovoltaic Applications 2022
18. PV Magazine, Global installed PV capacity could hit 260 GW in 2022 (October 19, 2022)

Innovation needs carrots as well as sticks

Necessity is the mother of invention.

Strong policies are required to drive global and national decarbonisation, including regulation, support and incentives. Australia is a small open economy, with a tradition of largely hands-off industry policy settings.

Consistent with this, previous climate policy settings, such as the Renewable Energy Target – tend to provide incremental assistance favouring more mature technologies with lower emissions. Proposed safeguard reforms will also drive uptake of available technologies and incremental operational changes to reduce emissions. If they continue for a prolonged period, these policies may also incentivise step changes in technology.

However, these policies do not themselves provide the resources or support required to develop innovations providing step-change reductions. Here it is widely recognised that government support for research and development is essential, to address difficulties private agents face in capturing the benefits of innovation.

Support should be focused, and aligned to Australia's economic interests

Policy is most likely to deliver benefits where a location has pre-existing advantages, such as natural resources, internationally competitively energy, a supportive local ecosystem (including suppliers and skilled workforce), and proximity to key markets.

Exhibit 23 (below) presents a framework for prioritising policy support for emerging industries.

> “Strong policies are required to drive global and national decarbonisation, including regulation, support and incentives.

Achieving long term benefits will require coherent and well targeted government support

Government support should learn from past mistakes, while recognising new challenges and opportunities. Previous attempts to support 'infant industries' sought to develop local versions of industries that were already established and mature in other locations. History has shown these attempts rarely if ever succeeded. Australia now faces a new challenge: supporting the development of local champions in industries that are not yet mature anywhere. The history of this is not yet written, but policy should still heed the lessons of experience.

Government support works best when it builds on existing advantages

Government should limit intervention to high-growth markets where Australia can develop or maintain a competitive and strategic advantage. Government support is generally only effective if there are some natural advantages for an industry to develop in a certain location such as:

- Historic concentration of suppliers, customers, and workforce.
- Natural resources (such as minerals or relatively cheap local energy sources).
- Proximity to key markets.

Government attempts around the world to create new industry clusters without at least one of these factors have almost all been unsuccessful.

This suggests government support should only be considered in areas where Australia can build a durable competitive advantage, and industry is willing to invest, as shown in Exhibit 23.

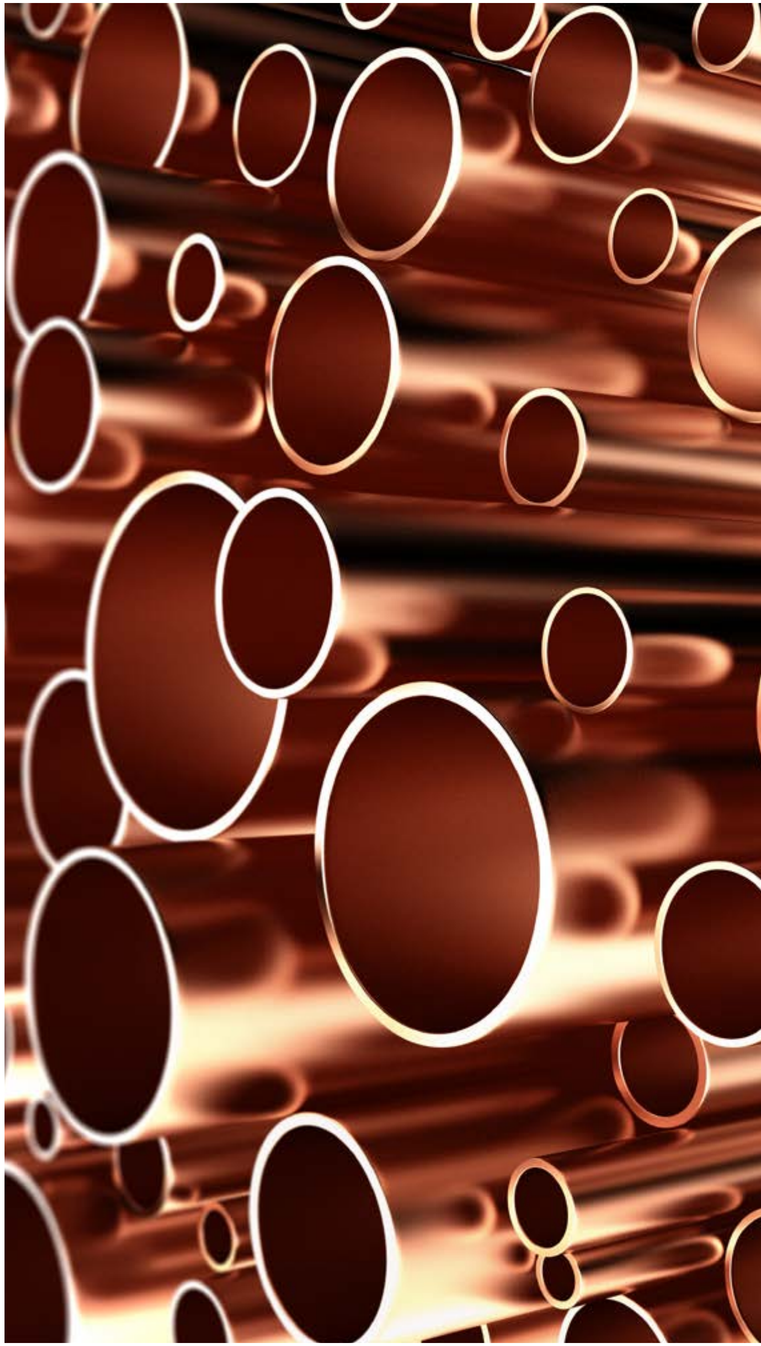
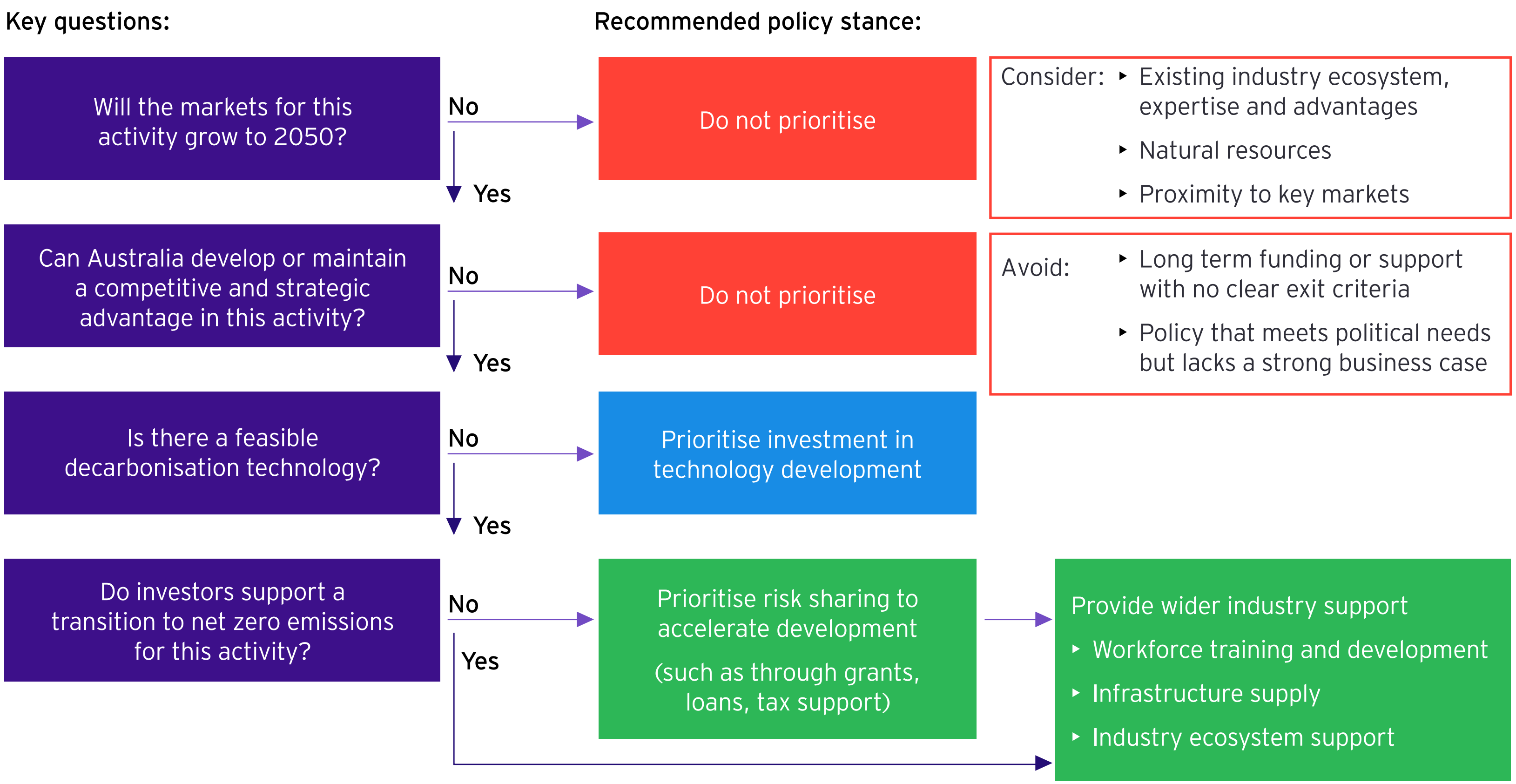


Exhibit 23: Well-targeted and tailored public support will provide better returns

Framework for prioritising policy support for emerging low-carbon industries



Source: Adapted from 19. Wood et al (2022) The next industrial revolution: Transforming Australia to flourish in a net-zero world, Grattan Institute, Melbourne

The form of support should align to underlying needs

Having established clear locational advantages for an industry, and prospective low-carbon industry niche, the government should focus addressing barriers to industry development. Key options include:

- Supporting the development of commercially viable decarbonisation technology.
- Assisting with risk sharing, particularly risks that cannot be managed by project proponents.
- Developing supporting wider innovation and value chain ecosystems.

Core enablers will always be crucial

Existing policy settings and frameworks will need to be reviewed and re-energised to ensure they support the growth of new heavy industries, while continuing to support mining and minerals processing.

Getting the basics right is always important. Project development and approvals processes should be timely and efficient, including necessary coordination with energy system planning and enabling infrastructure (including available land, servicing, energy supply, transport links). Processes should support the trust and transparency required for durable social licence, and ensure appropriate protections for heritage, natural assets and local communities.

Government can also improve the chances of successful industry transition through activities such as:

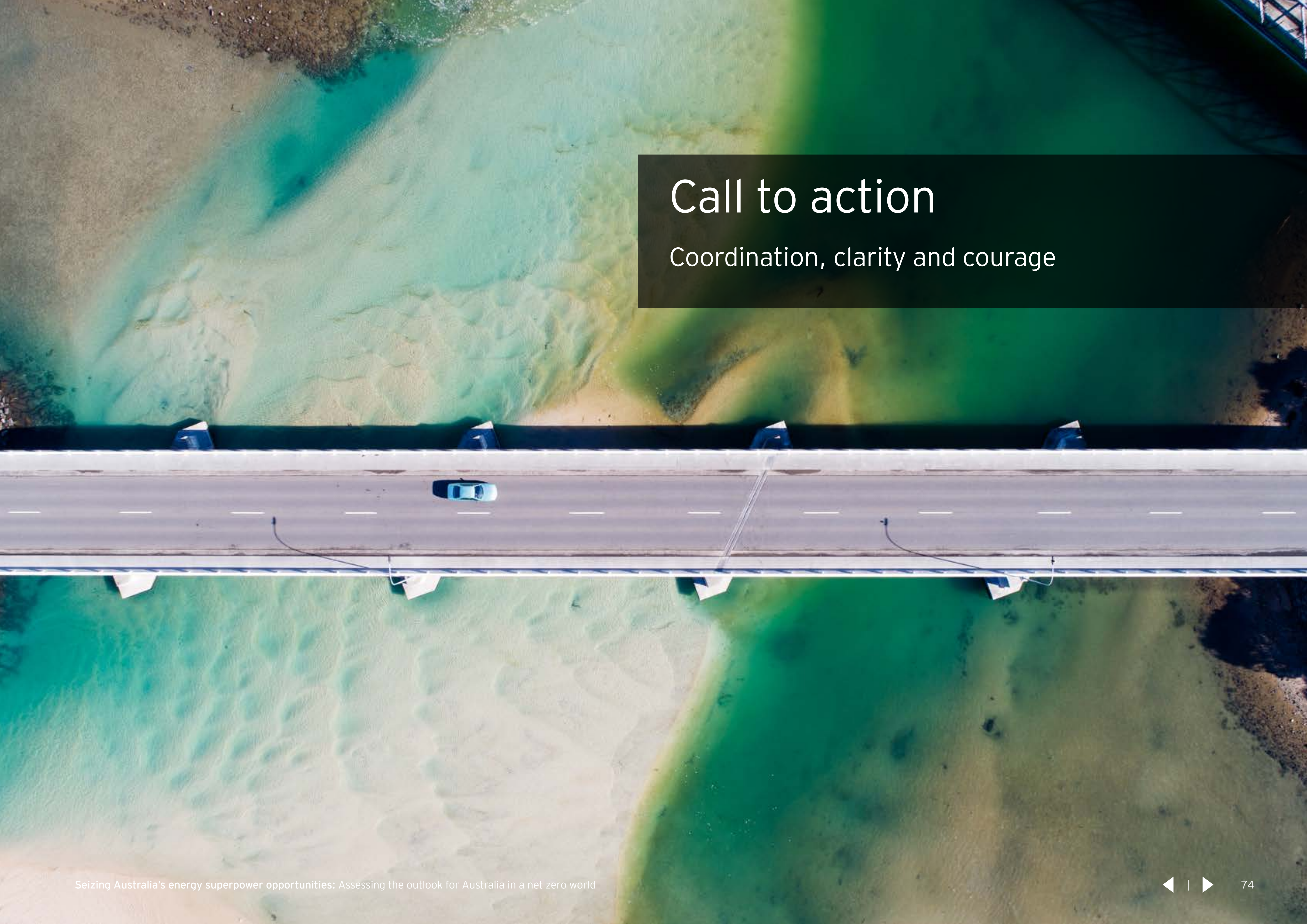
- Investment in research and development of "public goods".
- Industry support (grants and loans) and tax concessions to kick-start activity and overcome first-mover disadvantages.
- Workforce training and development.
- Promotion of industry networks and interactions.

Avoid repeating past mistakes

Governments should be wary of common traps that emerge where there is no clear policy logic or path to desired impact, or where long-term support is provided without clear exit criteria.

The risk of poor outcomes is particularly high when:

- Original investments or announcements were driven by political imperatives, rather than clear policy frameworks.
- Withdrawing support takes an active decision (due to a lack of sunset provisions or automatic review), risking reluctance to abandon poor performing projects due to sunk costs.



Call to action

Coordination, clarity and courage

Coordination, clarity and courage all necessary to capture the energy superpower dividend

The global shift to net zero emissions provides Australia with a once-in-a-generation opportunity. How will Australians respond? We suggest coordination, clarity and courage will be essential.

When life hands you lemons, make low-carbon lemonade

The transition to net zero emissions is disruptive, difficult and uncertain – for countries, industries and businesses. But in the end, it is also inevitable.

Countries, industries and businesses that engage early will be most likely to achieve a successful climate transition.

Failure is always an option, but is best avoided

This report maps some of the efforts required to capture Australia's energy superpower opportunity. These include de-risking and incentivising electricity firming and storage; avoiding disorderly coal power exits; more than doubling electricity supply; and ensuring this new supply aligns to new major demand sources.

These actions, while urgent and challenging, are also essential to keep the lights on.

We also argue that Australia should go further than delivering reliable low-carbon electricity. Actions include providing effective support for innovation aligned to Australia's durable potential advantages; attending to crucial enablers (such as project planning and approvals processes); and ensuring Australia's material and energy-intensive industries survive long enough to thrive.

We consider existing Australian support for innovation as valuable, but modest relative to other countries.

Success will require coordination, clarity and courage

What then should Australia do? We suggest three things will be essential to long term success:

1. **Coordination, coordination, coordination:** Energy policy needs to be coordinated across different instruments, jurisdictions, energy-types (including electricity and gas) and end-uses (transport, buildings, heavy industry). Wider policy must be consistent and coherent across climate policy, project and investment approvals, regional development, and industry and innovation policy. Planning and action needs to be coordinated across different actors, including investors, project proponents, energy businesses, regulators, policy makers, and different levels of government.
2. **Clarity:** Success will require choices between alternative strategies and tactics. Good choices are most likely when informed by a clear understanding of purpose and desired outcomes, and a logical and clearly articulated path to impact.
3. **Courage:** Few other areas of business and government decision-making involve as much high-stakes complexity, uncertainty and ambiguity as the net zero transition. Securing reliable zero carbon electricity will require decisive and timely policy action, business investment and R&D. Support and investment should be targeted to prospective areas where Australia has distinctive interests or advantages.

Opportunity knocks

This report finds the global shift to net zero emissions will create multiple competitive advantages for Australian heavy industry, but that effort is required to capture these opportunities. This includes some effort that is already planned, such as to deliver secure and reliable low-carbon electricity. But it also includes additional efforts, such as to coordinate export-related energy supply and demand, leverage sentiment in favour of friendly supply chains, and – perhaps most importantly – support world-class low-carbon industrial innovation in areas aligned to Australia's economic interests.

We also find the economic benefits could be enormous. But dollars are only part of what is at stake. Australia can make a distinctive contribution to meeting global needs for heavy industry essentials, while supporting the global transition to net zero emissions. We can do well while doing good.

Opportunity knocks. How will Australia respond?

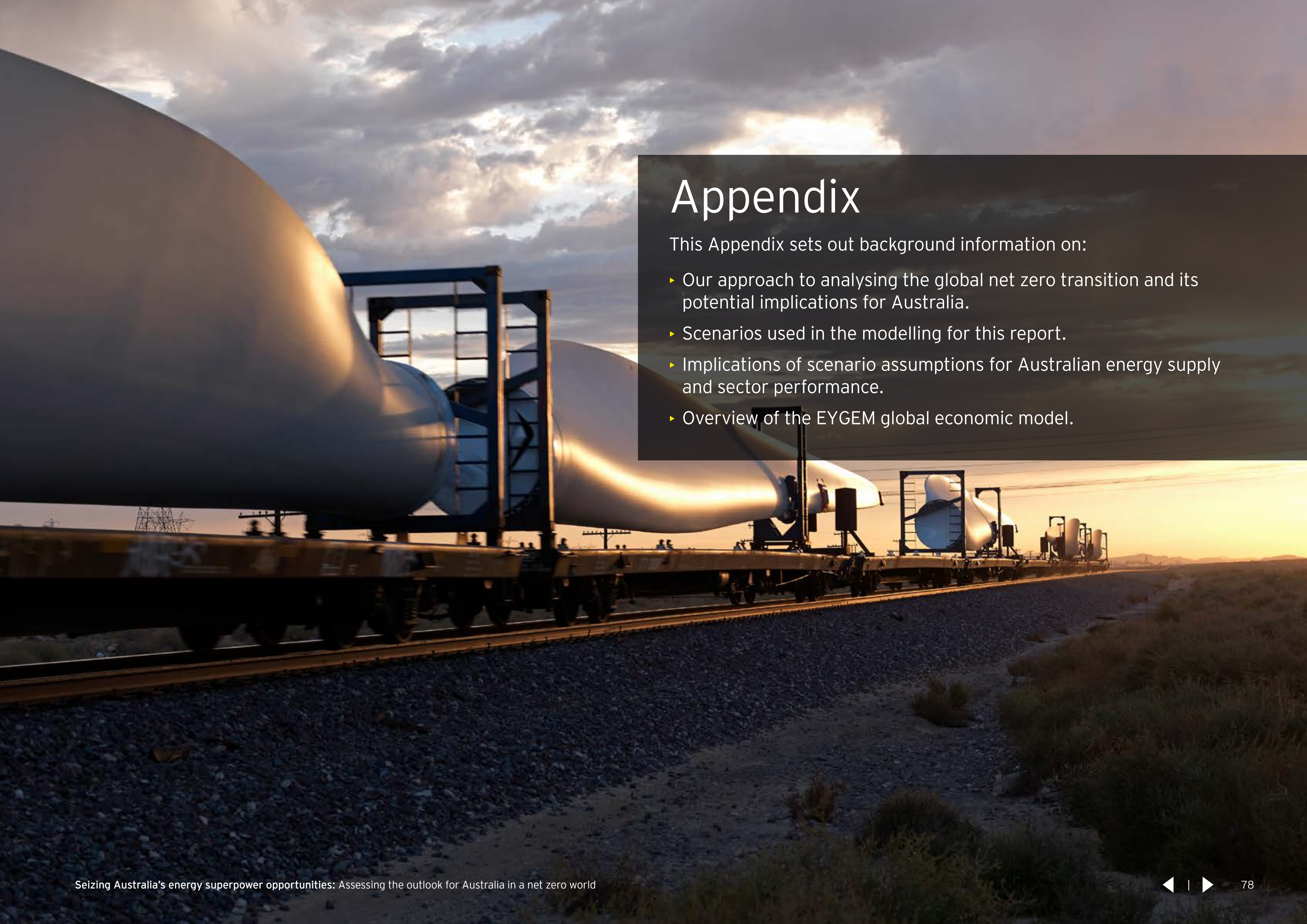
Business needs to prepare to move quickly as circumstances change

Businesses with a clear vision and roadmap for their energy transition will be best positioned for success.

> "Think about the next 30 years, but recognise you may need to act tomorrow.

Exhibit 24: Five questions to prepare your business for coming waves of change

Evolving context	1	What is your view about the evolution of the global and national economy over the next 30 years? What might change as result of accelerating climate concerns?
Competitive environment	2	What is your view about the evolution of your specific sector? What are the key uncertainties?
Business position	3	What is your view about the relative position of your business within your sector? What are your advantages and vulnerabilities, and how might these change?
Watchpoints	4	If you are contemplating multiple scenarios, what key indicators should you watch to identify which scenario you are in? Who is watching for these?
Strategy groundwork	5	Have you wargamed what you will do if you see one or more of these key indicators emerge? What near-term actions might help manage risks create options?



Appendix

This Appendix sets out background information on:

- Our approach to analysing the global net zero transition and its potential implications for Australia.
- Scenarios used in the modelling for this report.
- Implications of scenario assumptions for Australian energy supply and sector performance.
- Overview of the EYGEM global economic model.

Our approach to analysing strong global climate action and its potential implications for Australia

This report seeks to provide a robust multi-faceted assessment of the implications of the global net zero transition for Australian heavy industry and mining.

As noted in the introduction to this report, the analysis draws on three main pools of expertise and experience:

- EY Net Zero Centre expertise and engagement on climate change policy and business strategy.
- Granular analysis of low-carbon technology and industry opportunities, drawing on EY work in business strategy and transformation.
- Global economic modelling of climate transition dynamics by the EY economic modelling practice.

The economic modelling framework used for this analysis is well suited to exploring and assessing the global net zero transition, with detailed representation of the whole economy and major economies and groupings.

This economy-wide coverage is well suited to analyse fuel switching (away from fossil fuels towards renewable electricity). The modelling framework takes a stylised approach to abatement-related innovation, and does not endogenously represent development of specific breakthrough new technologies, such as the development and use of green hydrogen to replace metallurgical coal in steel making.

In framing our assessment of industry growth and the value of the 'energy superpower' opportunity we have systematically chosen to err on the side of caution. This implies the modelling results are likely to understate emissions reductions (particularly from industrial production), overstate abatement and adjustment costs, and understate overall benefits to Australia.

The rest of this Appendix details the scenario assumptions and implementation, and the EYGEM modelling framework.

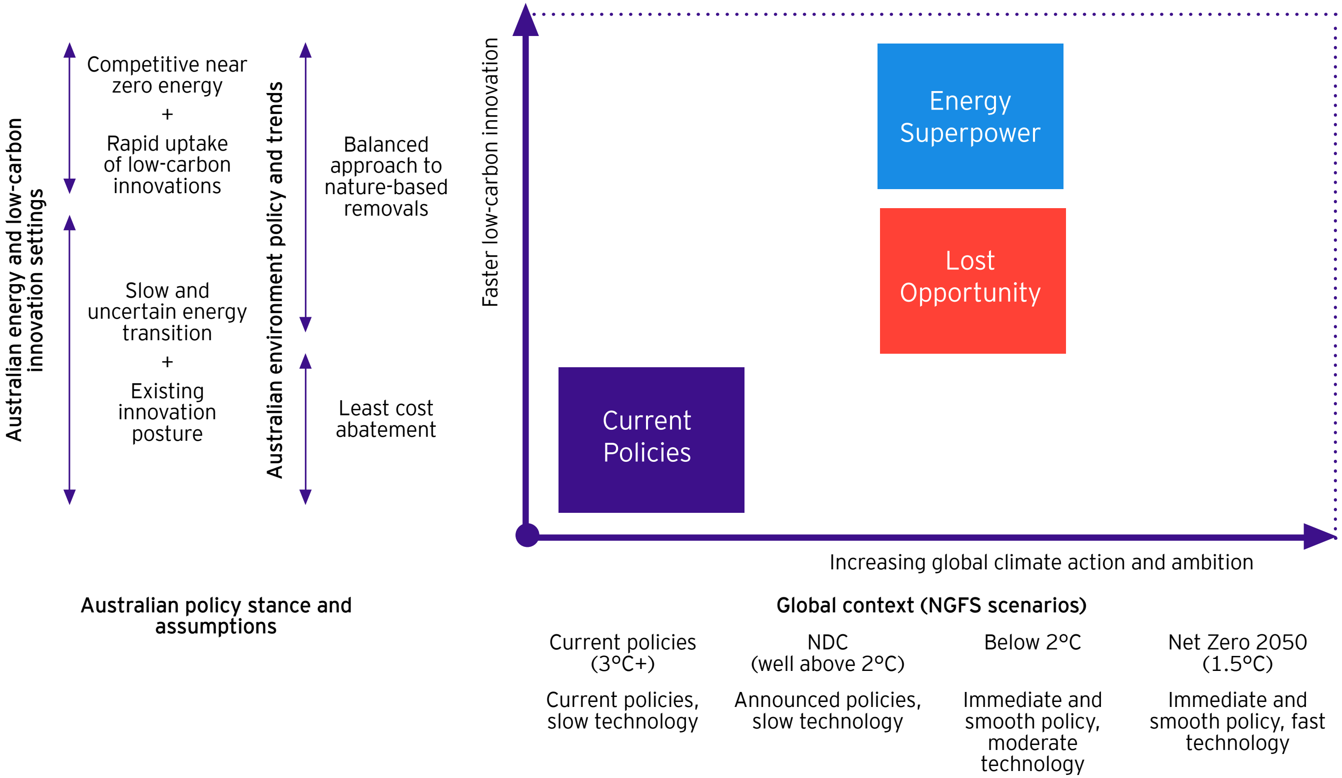
Scenarios used in the modelling for this report

The modelling and scenario analysis for this report is built up through a series of steps:

- Establish the Current Policies scenario as the underlying baseline.
- Develop an Energy Superpower scenario that assumes an orderly global transition to a below 2°C emissions pathway, with Australian industry settings based on our granular technology and industry analysis.
- Contrast this with a Lost Opportunity scenario, reflecting the consequences of Australia taking longer to establish coherent climate policy, including less timely and effective action to move to reliable near zero carbon electricity.

An overview of key scenario assumptions is shown in Exhibit 25.

Exhibit 25: Overview of key assumptions for the scenarios used in this report



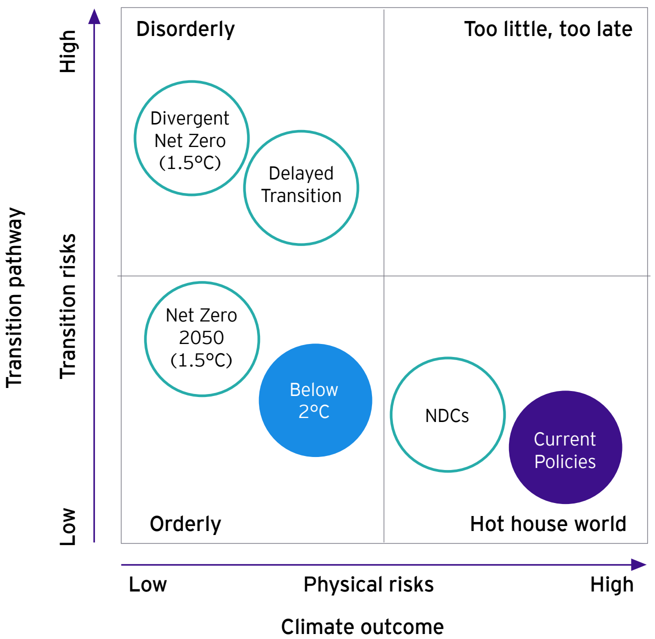
Calibration to established benchmark scenarios

Each of the scenarios draws on projections from benchmark scenarios published by the Network for the Greening of the Financial System (NGFS), as shown in Exhibit 26, along with energy detail from the International Energy Agency (IEA).

Phase II of the NGFS developed a set of six climate change scenarios, published in 2021, to act as a starting point for analysing climate risks to the economy and financial systems. The six scenarios are designed to explore a range of lower and higher risk outcomes.

The spread of scenarios reflects two distinct types of risks: physical risks associated with a changing climate, which vary systematically with long term climate outcomes, and transition risks associated with the pace and mechanisms use to limit climate change.

Exhibit 26: Network for the Greening of the Financial System (NGFS) scenarios



Current Policies underlying baseline

The Current Policies scenario reflects current market arrangements and policy settings, and is calibrated to historical data on population, GDP and emissions up to 2021. Future economic growth is determined by population growth and trend productivity or GDP per capita growth from NGFS Current Policies for each country or region.

Assumptions on energy productivity and trend electrification (increasing electricity as a share of primary energy) are aligned with International Energy Agency (IEA) stated policies projections.

Emissions intensity is calibrated so that total emissions align with regional level results from the NGFS Current Policies scenario (published in 2021). Australian land sector emission or removals are taken from the CSIRO LUTO model (assuming 'balanced' assumption in DISER 2021) with global emissions from MESSAGE-GLOBIOM model (Frank et al 2021), both assuming a zero carbon price.

General global below 2°C settings

The modelling assumes well-coordinated climate action across sectors and countries, moving quickly to a global emissions pathway consistent with a likely long-term temperature increase of 1.7°C. As shown in Exhibit 07 in the main body of the report, this involves net emissions falling by 63% from 2020 levels by 2050, and 68% relative to the Current Policies scenario.

The modelling starts from the Current Policies scenario and achieves the NGFS below 2°C global net emission trajectory through combination of three treatments:

- Each region achieves its NGFS below 2°C emission trajectory through a carbon price, accounting for the other steps below.
- Likely accelerated reductions in technology costs with strong global climate action are represented by increasing the pace of decarbonisation of electricity and enhanced industry and transport energy input switching, informed by IEA projections.
- Land sector removals are calculated off model and added to regional emissions trajectories.

The modelling assumes central estimates for technology advances and reductions in abatement costs, with particular attention to likely shifts in transport industrial energy use towards electricity.

Energy Superpower

The Energy Superpower scenario builds on these general below 2°C settings with three Australia-specific treatments:

- Advantages in renewable energy are represented through a trend increase in capital productivity in the electricity sector, relative to the general global settings.
- Advantages in iron and steel are represented through a combination of a trend increase in total factor productivity (TFP) and increased capital productivity, relative to the general global settings.
- The shift towards sourcing mineral resources through friendly supply chains is assumed to benefit Australia, and is represented by boosting other mining output to broadly maintain Australia's share of global production, with no change to Australian productivity.

Lost Opportunity

For simplicity and transparency, the contrasting Lost Opportunity scenario assumes:

- No productivity uplift for electricity or iron and steel.
- Delays in implementing timely and coherent climate and energy policies discourage investment, represented though a transitory capital risk premium. This premium is set at 25 basis points in 2022 and halves each year, falling to less than 2 basis points in 2026.
- Australia is less effective in leveraging 'friendly supply chain' sentiment, with mining output boosted by half the amount achieved in the Energy Superpower scenario.

Australian removals and land sector credits

Each region produces land-based removal credits in response to the carbon price.

For Australia, this results in surplus credits from around 2045, beyond what is required for Australia to achieve a trajectory to net zero emissions in 2050. These surplus credits are exported, with revenue included in Australia's national income (GNI). Agricultural productivity is adjusted to reflect reduced land available for livestock production.

Land sector credit supply and revenues are identical in the Energy Superpower and Lost Opportunity scenarios.

Implications of scenario assumptions for Australian energy supply and sector performance

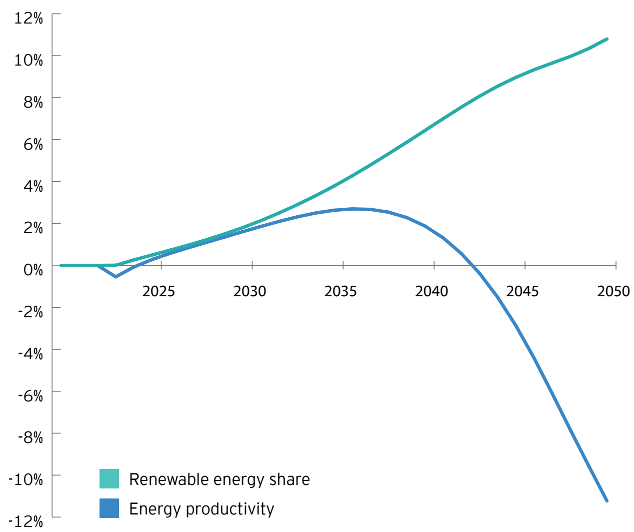
Energy Superpower sees more renewable energy and a more energy-intensive economy

Higher electricity sector productivity sees additional investment and generation, lifting renewable energy by 11% in 2050 relative to the Lost Opportunity scenario, as shown in Exhibit 27.

Energy Superpower treatments boost primary energy use more than GDP, increasing the energy intensity of the Australian economy. This sees energy productivity (GDP per unit of energy) fall below the baseline 'Lost Opportunity') scenario after 2045.

Exhibit 27: Energy Superpower sees higher renewable energy, and higher average energy intensity by 2050

Global net emission projections
Gt CO2e, years



Stronger growth in advantaged sectors is modest

The impact of these treatments on Australian advantaged sectors of electricity, iron and steel, and other mining are modest from a global perspective.

While Energy Superpower treatments lift the growth of iron and steel output, Australian production remains less than 1% of global output. Higher productivity sees Australian iron and steel output value grow 33% faster than the global average to 2050, but sector growth remains below projections for India, Rest of Asia, and Rest of America.

For other mining, the Energy Superpower assumptions result in Australia's share of global output falling from 10.1% in 2020 to 9.6% by 2050. With the weaker Lost Opportunity assumption, Australia's share falls more than twice as far, to an 8.8% global share in 2050.

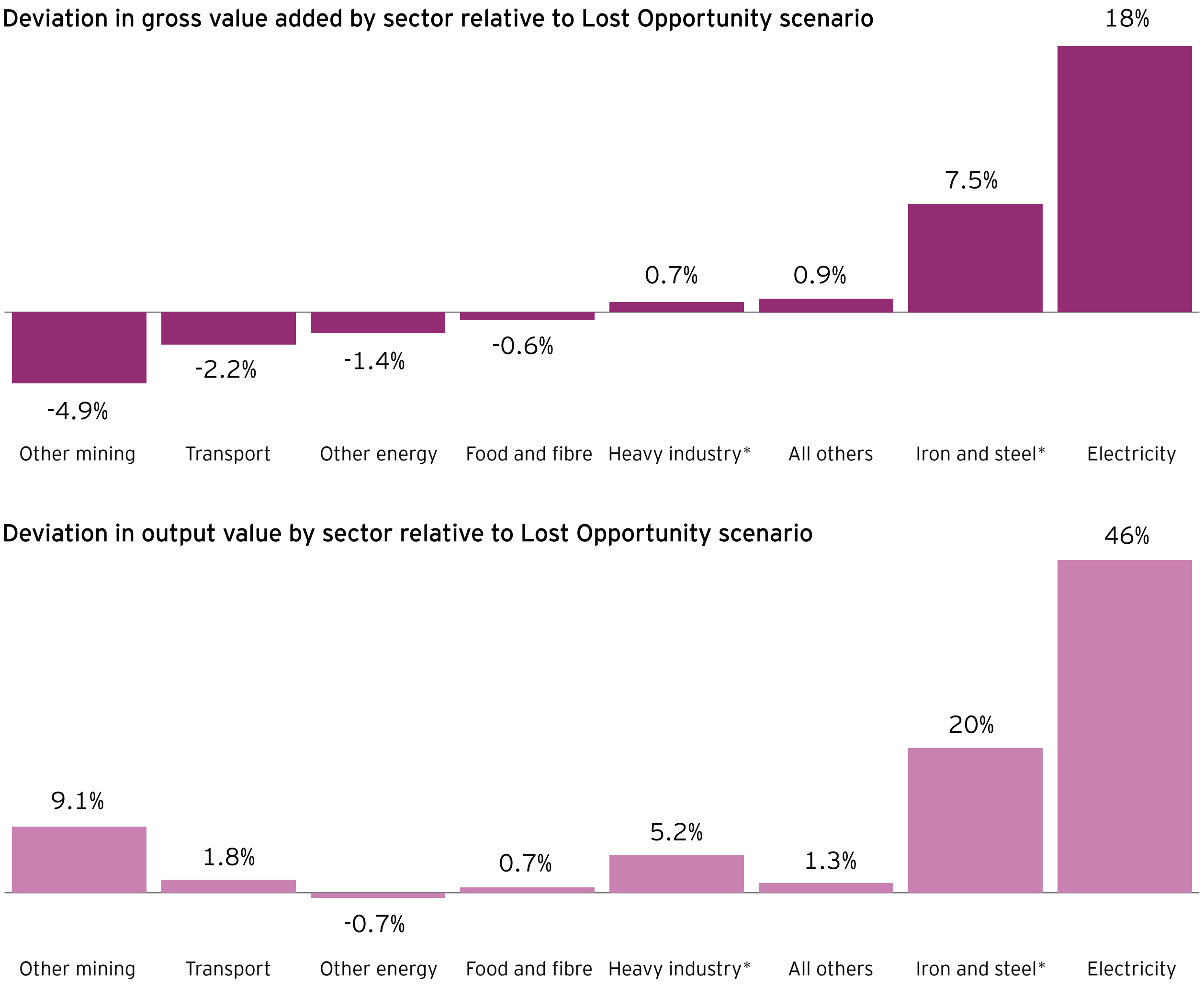
Impacts of the Energy Superpower scenario vary across major sectors

Scenario impacts can also be understood in terms of the deviation, or difference, in projected outcomes across the Energy Superpower and Lost Opportunity scenarios.

Here impacts on different sectors fall into four main groups, as shown in Exhibit 28:

- Electricity and iron and steel both benefit significantly, with 8-18% higher gross value added and 20-46% higher output value in 2050. Heavy industry includes iron and steel, and also benefits in this way.
- Other mining, by contrast, has 9% higher output value but 5% lower value added in 2050. This reflects higher demand driving higher output volumes, which requires the mining sector to push up into higher marginal supply costs. Together with exchange rate effects, this reduces unit margins and total sector value added. The same factors also impact the transport and food and fibre sectors, although to a lesser extent than other mining.
- Other energy includes coal, gas and oil extraction. These sectors are disadvantaged by increased renewable energy generation, with 1.4% lower value added and 0.7% lower output in 2050, relative to the Lost Opportunity scenario.
- All other sectors see average gains of 0.9% and 1.3% in value added and output, respectively, reflecting beneficial economy-wide spill-over effects.

Exhibit 28: Action to capture the Energy Superpower dividend impacts differently across sectors



*Heavy Industry includes Iron and Steel

Overview of the EYGEM global economic model

EYGEM is EY's in-house Computable General Equilibrium (CGE) model. EYGEM is a large scale, dynamic, multi-region, multi-commodity model. It is based on a proud academic lineage that has been applied globally across the public and private sector. The EYGEM model has significant flexibility both at the regional and sectoral level, including the capability to individually identify subregions of Australia.

CGE modelling is often used to measure the flow-on effects of changes in the economy. Changes can originate from government policies, macroeconomic trends, or industrial activities.

EYGEM draws on the global CGE modelling framework and data developed by the Global Trade Analysis Project (GTAP) based at Purdue University in the United States.

Our model is implemented in modern data science frameworks, including Python and Pandas, with a user-friendly Excel interface. These frameworks are specifically designed to improve audit and trackability of modelling processes, reduce the risk of error, and support systematic sensitivity analysis.

Model structure

EYGEM can be configured with different aggregations of sectors and global regions. For this report we used our current default structure, with 29 sectors and 11 countries or regions, as shown in Tables 1 and 2.

Table 1: EYGEM sector structure

Group	Sector
Materials- and energy-intensive sectors	
Food and fiber	Crops
	Livestock
	Forestry and fishing
Mining and fossil fuels	
‣ Other mining	Other mining
‣ Other energy (fossil fuels)	Coal
	Oil
	Gas
Heavy industry	Iron and steel
	Petroleum and coal products
	Chemical, rubber, and pharmaceutical manufacturing
	Non ferrous metals
Electricity	Electricity
Transport	Air transport
	Other transport (land)
	Water transport
All other sectors	
Construction and utilities	Construction
	Water
Light industry	Food manufacturing
	Electronics, electricals and machinery
	Other manufacturing
Services	Trade
	Accommodation, food and service activities
	Communications
	Financial services
	Real estate activities
	Other business services
	Recreational and other services
	Other government services
	Health and human technology

Table 2: EYGEM regional structure

Region/regional grouping	Countries included (based on the GTAP database)
Australia	Australia
United States of America	United States of America
Canada	Canada
European Union	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
China	China
India	India
Other European Advanced Economies	Iceland, Liechtenstein, Israel, United Kingdom, Switzerland, Norway
Other Asia-Pacific Advanced Economies	New Zealand, Hong Kong, Japan, Korea, Taiwan
Rest of Asia	Mongolia, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Bangladesh, Nepal, Pakistan, Sri Lanka, Rest of Oceania, Rest of Southeast Asia, Rest of East Asia, Rest of South Asia
Rest of the Americas	Mexico, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Costa Rica, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Caribbean, Rest of North America, Rest of South America, Rest of Central America
Rest of the World	All other countries

Overview of the modelling framework

EYGEM is based on a substantial body of accepted microeconomic theory. Key assumptions underpinning the model are:

- The model contains a 'regional consumer' that receives all income from factor payments (labour, capital, land and natural resources), taxes and net foreign income from borrowing (lending).
- Income is allocated across household consumption, government consumption and savings so as to maximise a Cobb-Douglas utility function.
- Household consumption for composite goods is determined by minimising expenditure via a CDE (Constant Differences of Elasticities) expenditure function. For most regions, households can source consumption goods only from domestic and imported sources. In the Australian regions, households can also source goods from interstate. In all cases, the choice of commodities by source is determined by a CRESH (Constant Ratios of Elasticities Substitution, Homothetic) utility function.
- Government consumption for composite goods, and goods from different sources (domestic, imported and interstate), is determined by maximising utility via a Cobb-Douglas utility function.
- All savings generated in each region are used to purchase bonds whose price movements reflect movements in the price of creating capital.
- Producers supply goods by combining aggregate intermediate inputs and primary factors in fixed proportions (the Leontief assumption). Composite intermediate inputs are also combined in fixed proportions, whereas individual primary factors are combined using a CES production function.
- Producers are cost minimisers, and in doing so choose between domestic, imported and interstate intermediate inputs via a CRESH production function.
- The supply of labour is positively influenced by movements in the real wage rate governed by an elasticity of supply. This is most often assumed to be 0.15 for central case scenarios, and 0.3 for high side scenarios, depending on the employment market conditions for the region under consideration.
- Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. A global investor ranks countries as investment destinations based on two factors: global investment and rates of return in a given region compared with global rates of return.
- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.
- Prices are determined via market-clearing conditions that require sectoral output (supply) to equal the amount sold (demand) to final users (households and government), intermediate users (firms and investors), foreigners (international exports), and other Australian regions (interstate exports).
- For internationally traded goods (imports and exports), the Armington assumption is applied whereby the same goods produced in different countries are treated as imperfect substitutes. But in relative terms imported goods from different regions are treated as closer substitutes than domestically produced goods and imported composites. Goods traded interstate within the Australian regions are assumed to be closer substitutes again.
- The model accounts for greenhouse gas emissions from fossil fuel combustion. Taxes can be applied to emissions, which are converted to good-specific sales taxes that impact on demand. Emission quotas can be set by region, and these can be traded, at a value equal to the carbon tax avoided, where a region's emissions fall below or exceed their quota.

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How can EY help?

The EY Net Zero Centre helps companies cut through the complexity, manage the uncertainty and create clear pathways to net zero emissions.

Headed by the region's leading climate change strategists, the Net Zero Centre supports EY clients to make the right decisions at the right times and set themselves on a pathway for success.

We can help you turn disruption into opportunity.

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