The economic potential of **Australia's critical minerals and energy transition minerals**

Economic impact analysis of Australia's critical minerals and energy transition minerals and downstream processing

June 2023

pwc

Australian Government
Department of Industry, Science and Resources

About this report

The Department of Industry, Science and Resources (DISR) commissioned PwC Australia to estimate the potential 'size of the prize' of Australia's critical minerals and energy transition minerals opportunity as part of understanding the impact Australia may have in supporting efforts to decarbonise the global economy.

The results quantified as part of this modelling exercise are purely informative for the Australian Government to establish how best it realises the potential of Australia's endowment of critical minerals and energy transition minerals and does not guarantee investment to be allocated to specific minerals and/or activities considered within the scenarios modelled.

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Highlights and findings

- The global energy transition is gaining momentum and demand for critical minerals and other energy transition minerals is increasing, driven by the world's ambition to achieve net zero by 2050. This includes the development of advances in clean energy technologies (i.e. solar photovoltaics, wind turbines, batteries, mobile phones, medical applications, etc.).
- Australia's abundance of critical and energy transition minerals presents an economic and strategic opportunity to service the globe with such pivotal resources. However, Australia will need to act quickly, with other countries seeking to position themselves as key producers.
- DISR commissioned PwC to undertake whole-of-economy modelling to estimate the 'size of the prize' that could be realised under four scenarios. The scenarios are based on opportunities within the critical minerals and energy transition minerals sector, and potential for value adding.
- The modelling considers the additional macroeconomic impacts each of the scenarios could generate for Australia's economy, across an analysis period from 2022 to 2040. GDP values have been reported as 2023 dollar values.
- Under the base case scenario, we maintain a current status quo. This means Australia would continue to benefit from domestic and international economies decarbonising, with no additional efforts from the government or industry.
- Under Scenario 1, Australia maintains its market position within the critical minerals sector, increasing production in line with increasing world-wide demand. In these circumstances, Australia has the potential to achieve an additional **$71.2 billion** uplift in gross domestic product (GDP) and an additional **115,100 FTE jobs,** relative to the base case scenario (Scenario 1).
- Where investment is made to develop Australia's downstream capabilities, Australia has the potential to achieve an additional **$69.9 billion** uplift in GDP and an additional **143,000 FTE jobs,** relative to the base case scenario (Scenario 2). These economic and employment benefits from increased value adding would be in addition to any benefits arising from increasing Australian mineral production to maintain global market share, such as those determined under Scenario 1.
- Where Australia maintains its market position, while also attracting a green price premium due to its capacity to influence international markets, **Australia** has the potential to achieve an additional **$72.5 billion** uplift in GDP and an additional **121,100 FTE jobs,** relative to the base case scenario (Scenario 3).
- Where policies focus on both building downstream processing capability and securing a greater share of international trade and investment, Australia has the potential to achieve an additional **$139.7 billion** uplift in GDP and an additional **262,600 FTE jobs**, relative to the base case scenario (Scenario 4).
- These results are expected to inform Government's priorities for developing the critical minerals and energy transition minerals sector and the associated economic opportunities.

Glossary

CGE model	computer-generated equilibrium model
critical minerals	A critical mineral is a metallic or non-metallic element that is essential for modern technologies, economies or national security, and has a supply chain at risk of disruption (1). Minerals that will be captured in this report are lithium, cobalt, graphite, manganese ore, high purity alumina, vanadium, silicon, rare earths, platinum group elements, nickel, copper and titanium.
DISR	Department of Industry, Science and Resources
energy transition minerals	For the purposes of this report, energy transition minerals capture both copper and nickel
FTE	full-time equivalent – all jobs are reported as the number of additional (net new, above the base case) full-time equivalent roles in the Australian economy
GDP	gross domestic product - GDP is a reference point for the health of national and global economies. GDP measures the monetary value of final goods and services produced in a country in a given period (2)
IEA	International Energy Agency
metallic ore mining	Metallic mining refers to the extraction of both ferrous metals (typically iron) and nonferrous metals (including gold, silver, copper, nickel, lead, and zinc) (3)
non-metallic ore mining	Non-metallic industrial minerals are geologic materials that are mined for their commercial value but are not fuel and are not sources of metals (metallic minerals) (4)
rare earth elements	The group of metals referred to as rare earth elements (REE) comprises the 15 elements of the lanthanide series. Metals in the lanthanide series are lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu). In addition, yttrium (Y) and scandium (Sc) are often grouped with the lanthanides and referred to as REE. Geoscience Australia assesses the lanthanides and yttrium together and has produced a separate review of scandium (5)

(1) Geoscience Australia, Critical Minerals at Geoscience Australia
(2) IMF, Gross Domestic Product: An Economy's All
(3) GLIFWC, Metallic Mineral Mining: The Process & the Price
(4) USGS, Nonmetallic Industrial Mineral Resources of the U.S.
(5) Geoscience Australia, Rare Earth Elements

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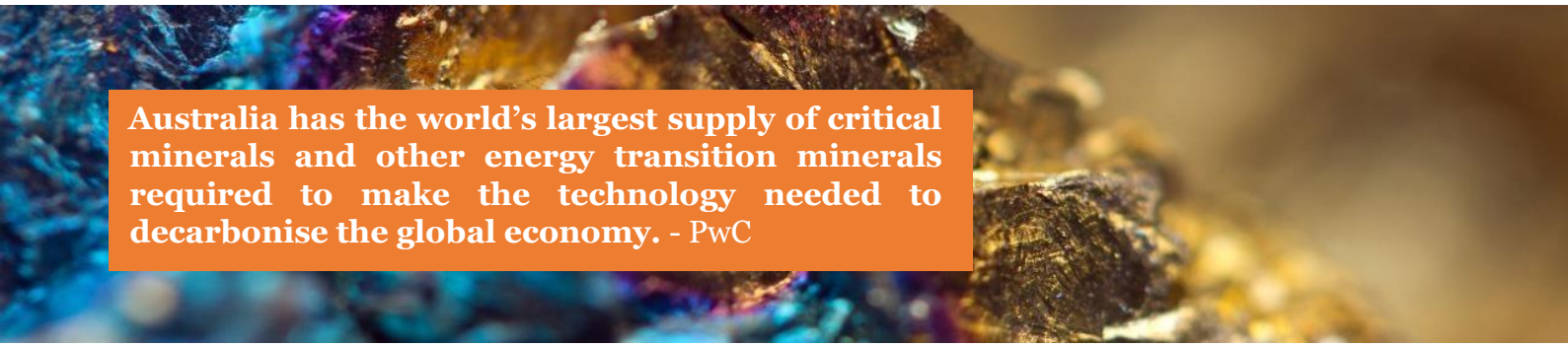
Introduction

1.1 Australia's critical minerals opportunity



Australia has the world's largest supply of critical minerals and other energy transition minerals required to make the technology needed to decarbonise the global economy. - PwC

Australia will require support to maximise the opportunity provided by its endowment of critical minerals and energy transition minerals.

Decarbonisation technology and reaching net zero

An adequate supply of critical minerals and other energy transition minerals will be pivotal to the world's path to net zero. Low-emissions technologies such as solar photovoltaics, wind turbines, batteries for energy storage and magnets for electric vehicles (EVs) rely on critical minerals and energy transition minerals for their production and performance. These minerals also have important applications in the defence, space, medical and telecommunication sectors. Importantly, as the global energy transition gains momentum, demand for these minerals is increasing and shortages are inevitable.

Australia's current position

Australia is a global 'go-to' location for critical minerals and energy transition minerals at an important time in the energy transition. Australia is already the world's number one producer of lithium, and a globally significant producer of many other resources, including nickel, cobalt, manganese ore, rare earth elements, tungsten, and vanadium.

Australia will face a significant task to meet the anticipated global demand for critical minerals and energy transition minerals over the coming decades. Factoring in development lead times, greater exploration efforts and pre-production, a concerted focus on supply will be required today to meet demand growth in the future. This will ensure Australia does not fail to capture the full value of expanding its involvement along the value chain.

If Australia does not grasp the opportunity, it risks missing out on capturing the full value of the generational opportunity the energy transition presents, and of failing to meet the expectations of its allies with respect to the supply of critical minerals that would otherwise underpin secure and reliable value chains and deliver energy independence. The good news is there's time to address this. But like so much associated with the race to net zero emissions, it's only possible if we think differently and act now.

The opportunity

In conceptualising the potential opportunity for Australia, DISR commissioned PwC to undertake whole-of-economy modelling to estimate the 'size of the prize' that could be realised where the growing demand for low-emissions technologies and an onshore value-adding capability is leveraged.

The global energy transition will be underpinned by clean energy technologies that require a broad range of minerals. Critical minerals are a subset of minerals that are metallic or non-metallic materials that are essential to our modern technologies, economies and national security, and whose supply chains are vulnerable to disruption. Minerals like nickel, copper and aluminium will also be important to the energy transition as they are also widely used in clean energy technologies.

Together, critical minerals and energy transition minerals present an opportunity to capitalise on Australia's resource endowment, and in capturing both these categories together within the modelling, demonstrates the collective economic opportunity across these minerals.

Critical minerals captured as part of this modelling have included lithium, cobalt, graphite, manganese ore, high purity alumina, vanadium, silicon, rare earths and platinum group elements. Other energy transition minerals captured as part of this modelling include nickel and copper.

The scenarios considered within this exercise include:

- *Scenario 1: maintaining market position*
- *Scenario 2: developing value-adding (downstream) capabilities*
- *Scenario 3: shaping international markets*
- *Scenario 4: building capabilities and international market share.*

The scenarios and assumptions adopted for the modelling are detailed in the next chapter, followed by the modelling results.

1.2 Scenarios examined

Scenario 1

A scenario that reflects global critical minerals and energy transition minerals demand aligned with the International Energy Agency's Net Zero Scenario, and Australia capturing a share of that global demand consistent with current levels or projected trends. Under this scenario, Australia would undertake limited additional downstream processing activities (beyond known projects already confirmed and expected to proceed) – that is, Australia will remain primarily an exporter of raw materials and undertake limited downstream processing onshore.

Scenario 2

A scenario where deliberate policy focus by governments leads to increased investment in downstream processing capabilities such that a greater share of Australia's minerals are turned into value added materials onshore.

Scenario 3

A scenario where Australia is effective in shaping international markets (e.g. by influencing standards) and progressing government-to-government and business-to-business partnerships with key countries, and in doing so, secures a greater market share of those markets. Under this scenario, Australia undertakes limited downstream processing onshore.

Scenario 4

A scenario where governments adopt a deliberate policy focus on both building downstream processing capability and securing a greater share of international trade and investment.

Two additional sensitivity tests were modelled for Scenario 4, to illustrate the implications of:

- faster than expected technology adoption rates for specified low emissions technologies (e.g. EVs)

- increased policy support and finance sector engagement leading to accelerated project development times.

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Results

2.1 Summary of results

The results shown in Table 1 summarise the economic impacts to Australia across the four modelled scenarios, from 2022 up to 2040. Using an economy-wide model, we estimated the macroeconomic and job impacts to demonstrate the 'size of the prize' that could be unlocked where Australia leverages the growing demand for low-emissions technologies and the development of more onshore value-adding capability.

The results under all scenarios reflect a global shift to net zero and the scale of change required to transform global economies to net zero emissions. This is anticipated to bring unprecedented levels of demand from private and public sectors for new markets in clean technology products, and by extension, the critical minerals and energy transition minerals these products rely on for their production and performance. As a result, the impacts are significant, but reflect the scale of demand and activity globally.

The scenarios have been assessed against a base case (i.e. the 'status quo'), which assumes some growth in the critical minerals and energy transition minerals sectors based on known activity from industry and governments. The base case reflects some impacts resulting from the decarbonisation of the Australian and global economy, however, remains agnostic as to whether this decarbonisation is in line with the Paris Agreement or Australian Government emission reduction targets.

The base case is informed by a view of the Australian economy, based on Australian Bureau of Statistics (ABS) data, as well as known and anticipated mine expansions based on current trends. It is assumed under the base case, that no further investment stimulates the economy (in addition to what has already been catered for in the model), nor the use of any other policy mechanism or levers within each of these subsequent scenarios. This also means no green price premium, no faster adoption of clean technologies and no further adoption of energy transition related policies are captured under the base case. This provides us with a genuine 'status quo' in order to capture the size of the prize of Australia's mineral endowment and the associated downstream value adding opportunity.

Importantly, the results have been quantified out to 2040, based on publicly available projections relating to foreseen demand for critical minerals and energy transition minerals captured within this modelling exercise. The specific inputs and assumptions adopted across each scenario have been captured within the subsequent sections.

Table 1: Summary of results

Scenario	**Australian GDP** *NPV from 2022 – 2040 (2023 dollar values)*	**Australian jobs** *Additional cumulative FTE 2022 - 2040*
1 – Maintaining market position	**$71.2 billion**	**115,100 jobs**
2 – Value adding (1)	**$69.9 billion**	**143,000 jobs**
3 – Shaping international markets	**$72.5 billion**	**121,100 jobs**
4 – Building capabilities and international market share	**$139.7 billion**	**262,600 jobs**
4i – Earlier consumer technology adoption	**$139.1 billion**	**257,900 jobs**
4ii – Faster project development times	**$170.8 billion**	**329,000 jobs**

(1) Note: Benefits for Scenario 2 relate only to value adding and would be in addition to any benefits arising from increasing Australian mineral production to maintain global market share.

Note: This table has been updated from a previously-published version to reflect the NPV based on 2023 dollar values for all scenarios.

2.2 Scenario 1: Maintaining market position

Scenario 1 looks to quantify the additional economic value that could be unlocked if Australia continued to capture its current share of global demand consistent with current levels or projected levels

Scenario 1 sees Australia maintaining market position within the critical minerals and energy transition minerals sector by increasing exports of critical minerals and energy transition minerals in line with increasing global demand for these minerals leading up to 2040.

Maintaining market position

Australia's market position is our share of the global market. Today, Australia is a global 'go-to' for critical minerals and energy transition minerals at an important time. Australia is the number one producer of lithium and holds a globally significant market position in minerals such as nickel, cobalt, manganese ore, rare earth elements, and vanadium.

The International Monetary Fund says Australia is in a prime position to benefit from the staggering demand for critical minerals and energy transition minerals over the next 20 years as the energy transition gathers pace. However, maintaining Australia's position against a market that is growing at a rapid pace and where supply is becoming increasingly competitive will be a significant challenge.

Scenario 1 considers the impacts of government and industry in Australia taking immediate action to maintain our market position. The current global demand is driven by the energy transition and aligns with the IEA's Net Zero Scenario and with Australia capturing a share of that global demand, consistent with current levels or projected trends. Under this scenario, Australia would undertake limited additional downstream processing activities and would remain primarily an exporter of raw materials.

This is measured against a **base case** that captures Australia's pipeline of development projects falling short of the expected surge in global demand over the coming decades. The difference between Scenario 1 and the base case reflects the economic implications of Australia missing out on capturing the full value of the generational opportunity the energy transition presents, and the risk of falling short of the expectations of our trade partners in supplying the critical minerals and energy transition minerals required for energy independence and secure reliable supply chains.

Scenario 1 reflects the significance of Australia's opportunity to supply the world with the raw materials for the energy transition and does not consider the further potential for value adding in the resources industry.

2.2 Scenario 1: Maintaining market position

Modelling shocks

To model the economy-wide impacts of Australia maintaining its current market position in the critical minerals and energy transition minerals sector, PwC employed economic 'shocks' to represent additional exports across the critical mineral and energy transition mineral commodities included within the analysis, effectively making Australia maintain its current market position as the global critical minerals and energy transition minerals sector grows over time and out to 2040.

The shocks employed have been applied to the following sectors:

I. Non-ferrous metal mining sector

- Cobalt
- Nickel
- Manganese Ore
- Copper
- High Purity Alumina
- Vanadium
- Rare Earths
- Platinum Group Elements
- Titanium

II. Non-metallic mining sector

- Lithium
- Graphite
- Silicon

This list contains both energy transition minerals and critical minerals.

(6) Geoscience Australia, Australia's Identified Mineral Resources.
(7) IEA, The Role of Critical Minerals in Clean Energy Transitions.
(8) Australia's market value for has been quantified by adopting the current commodity price across each critical mineral, times by the level of demand anticipated out to 2040.
(9) The expected production of each critical mineral from 2020 out to 2040 has been established by calculating and applying the compound annual growth rate (CAGR) for each critical mineral.

Model inputs

The main modelling inputs for this scenario were:

- **Global demand**: Global production of critical minerals in 2020 has been adopted from Geoscience Australia (6). The global demand of critical minerals and energy transition minerals captured within this report have been assumed to grow in line with the 2040 projections adopted under the IEA Stated Policies Scenario (7).
- **Australia's current market position:** According to Wood Mackenzie data, Australia's current market share in the critical minerals and energy transition minerals sector is 5.66% overall (based on Australia's 2023 market value when compared to the global equivalent). This forms the base case for the analysis period (8).
- In terms of establishing Australia's market position under a scenario where it maintains its current market position, both Geoscience Australia and IEA 2040 projections datapoints have been leveraged to establish the level of production that would be expected over the analysis period (9).
- Based on the projected demand in 2023, Australia's market position is expected to grow to 7.67% additional to the base case. This growth rate is calculated by PwC, based on data from DISR, Geoscience Australia and U.S. Department of the Interior. This percentage has been applied consistently out to 2040 to quantify the additional benefits that could be realised where Australia maintains this market position.
- The market share adopted is assumed to sustain in the absence of intervention in the form of government policies and/or investments.
- **Downstream capabilities**: Australia remains a major producer of primary raw materials with no additional investment in mining operations for downstream processing or production.

2.2 Scenario 1: Maintaining market position

Scenario 1 has the potential to achieve an additional $71.2 billion uplift in GDP (2023 dollar value) and an additional 115,100 FTE jobs between 2022 and 2040.

Economic impacts

Under Scenario 1, Australia is expected to benefit from an additional **$71.2 billion** (2023 dollar value) uplift in GDP out to 2040, relative to the base case (10).

Western Australia (WA) is expected to capture the greatest portion of the economic impact, given the state's abundance of critical minerals and energy transition minerals resources and the expectation that for Australia to maintain its market share, the greatest level of mining activity will need to occur there, alongside mining activities within the Northern Territory (NT).

The transition to clean energy alternatives is set to occur against a backdrop of surging global demand for renewable energy, which will drive a significant jump in demand for critical minerals and energy transition minerals as inputs for renewable energy sources.

Employment impacts

From a jobs perspective, the Australian economy is expected to support an additional **115,100 FTE jobs** between 2022 to 2040, relative to the base case.

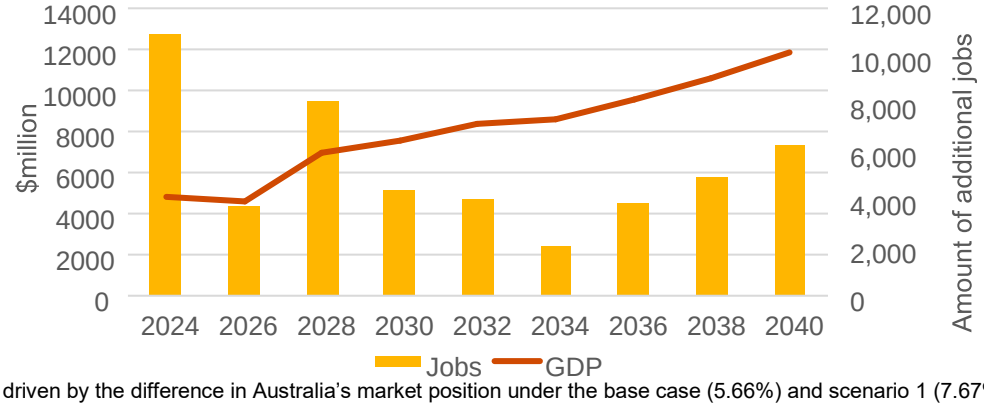
Industries captured within the non-ferrous metal mining (for instance, cobalt and nickel mining) and non-metallic mining (for instance, lithium and silicon mining) sector are expected to directly employ workers, while also stimulating employment indirectly through supply chain and flow-on impacts triggered by additional wages and salaries.

WA is expected to capture the greatest portion of these FTE jobs, given the state's high abundance of critical mineral and energy transition mineral resources and mining activities, now and into the future. The state will also attract skilled talent and jobs from other states.

As Australia increases its current export capabilities, commercial opportunities across mining, manufacturing and production of upstream supply chain inputs is set to drive growth in the Australian critical minerals and energy transition minerals industry, and therefore the job opportunities.

The gains in employment are mostly spread amongst professional, technical, community and machinery workers as extractive industries do well and those large industries which support them face increasing demand from a larger economy expand. (11)

Figure 1: Results for Scenario 1



(10) This result is driven by the difference in Australia's market position under the base case (5.66%) and scenario 1 (7.67%).
(11) The employment impacts have the potential to draw in more talent this can both be from university graduates or tradespeople.

2.3 Scenario 2: Value adding

Scenario 2 reflects the scale of change required to transform global economies to net zero, generating unprecedented levels of demand from private and public sectors for clean technology products. These clean technology products are critical to global decarbonisation, with all pathways to net zero requiring a significant increase in capital expenditure and investment in material efficiency, circular economy solutions, and renewable energy technologies.

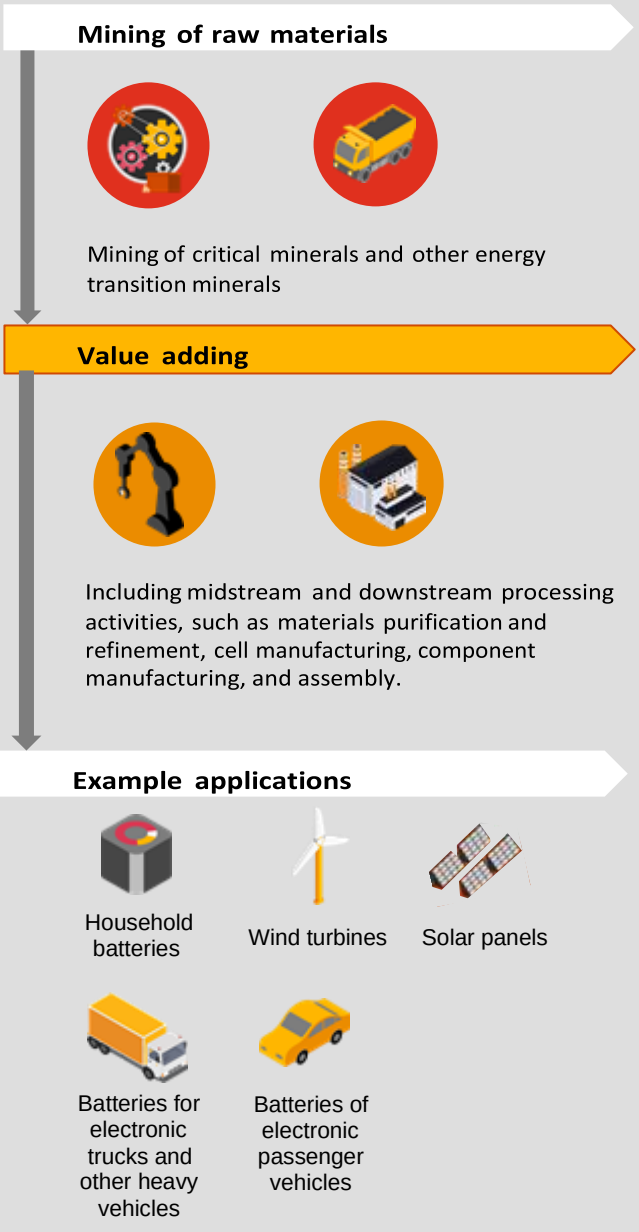
Value adding

Australia is currently well placed to benefit from this transformation, as one of the world's largest suppliers of the raw materials that underpin many of the technologies needed to decarbonise. Scenario 2 captures the opportunity for Australia to become more than a primary producer and capture the potential of developing Australia's sovereign manufacturing capability to value add to these raw materials.

It captures a concerted effort from government and industry investment in industrial capability to better position Australia to realise downstream opportunities by contributing to global supply chains for technologies such as wind turbines, electric vehicles and electricity networks. The demand for these components is expected to grow quickly as the clean energy transition gathers pace.

Scenario 2 aims to capture the value of focusing on value adding, and the hypothetical implications to the economy if Australia becomes a supplier of processed critical minerals by capturing more of the downstream processing supply chain. Unlike Scenarios 1, 3 and 4, Scenario 2 does not capture the benefits from increasing Australian mineral production to maintain market share as global demand grows. Results for this scenario only reflect the investment in developing processing capability and would be additional to any other benefits, such as those described under Scenario 1.

Illustrative examples of the critical minerals and energy transition minerals value adding



2.3 Scenario 2: Value adding

Modelling shocks

To model the economy-wide impacts of Australia possessing greater downstream capabilities, we have employed economic 'shocks' to represent construction and operation phases, effectively making Australia's downstream capabilities more productive. Sectors that were shocked contained processing of mineral products, battery manufacture, electrical equipment manufacture, metal fabrication and transport equipment manufacturing.

The shocks employed include additional investment:

- **Other metals sector,** which includes for example professional, scientific, computer and electronic equipment manufacturing and electrical equipment manufacturing.
- **Other chemicals sector,** which includes for example chemical manufacturing.
- **Other manufacturing sector,** which includes for example metal product manufacturing.

Additional investment has been adopted across these sectors given their direct use and/or input of critical minerals and energy transition minerals.

In adopting these economic shocks, it is assumed that greater productivity will be achieved within the above sectors, meaning less input will be required to deliver the same level of output.

Model inputs

The main modelling inputs for this scenario were:

- **Australia's market position with respect to critical mineral exports:** The quantum of critical minerals exported under this scenario aligns with the level of export assumed under the base case (5.66%).
- Given this assumption, the modelling does not assume that a percentage of critical mineral exports would shift to Australia's downstream capabilities.
- **Investment:** $6.94 billion in total investment is assumed from government and industry to be applied to the Australian economy (specifically to the three sectors referenced above) from now to 2035. The level of investment assumed has been based on:
    - potential government mechanisms such as the National Reconstruction Fund (NRF), Export Finance Australia (EFA) Critical Minerals Facility, the Critical Minerals Development Program and Critical Minerals R&D Hub that target the development of downstream segments of Australia's critical minerals supply chain (12)
    - level of co-investment that is expected from industry (13)

(12) Potential government mechanisms that may drive the development of downstream segments of Australia's critical minerals supply chain have been provided by DISR.
(13) The level of co-investment anticipated from industry for the following scenario has been based on information provided by DISR.

> **Aim to ensure Australia becomes a supplier of processed critical minerals and capture more of the downstream processing supply chain**
> - Action Plan for Critical Technologies

2.3 Scenario 2: Value adding

Scenario 2 has the potential to achieve an additional $69.9 billion uplift in GDP (2023 dollar value) and an additional 143,000 FTE jobs between 2022 to 2040.

Economic impacts

Additional investment from both government and industry is expected to make manufacturing cheaper and drive higher sectoral output and exports. The national GDP sees a net increase in the amount of **$69.9 billion** (2023 dollar value) relative to the base case, driven by investment in three manufacturing sectors (Non-Ferrous Metals, Other Chemicals and Other Manufacturing) from now to 2035. There are also indirect impacts of this investment which continue to be realised out to 2040 given the interconnected nature of the economy.

The additional economic impact quantified under Scenario 2 is expected to deliver the most benefit to New South Wales (NSW), Victoria and Queensland, based on Australia's current processing and chemical refining capabilities existing within those states. WA is also expected to benefit from the additional investment adopted across the relevant sectors (although at a smaller scale), until it is offset by greater economic activity occurring within the above three states from 2033.

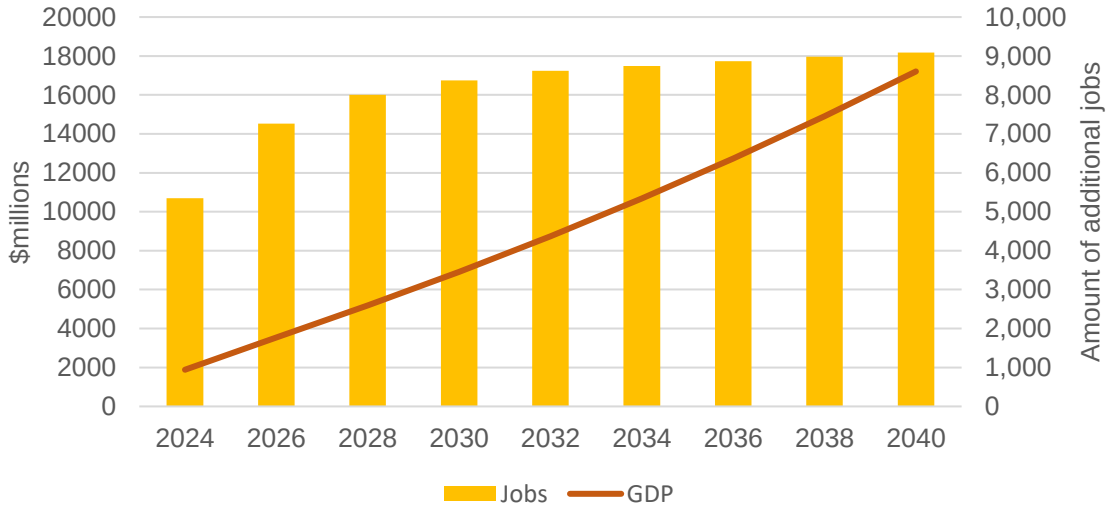
Employment impacts

Developing downstream capabilities is expected to shock three manufacturing sectors (Non-Ferrous Metals, Other Chemicals and Other Manufacturing), and directly employ skilled manufacturing workers (such as chemists, engineers and production technicians) and stimulate employment indirectly through supply chain and have flow-on impacts triggered by additional wages and salaries.

This scenario is expected to create up to **143,000 additional FTE jobs** from 2022 to 2040, relative to the base case. While the investment captured as part of this scenario is spread out from now to 2035, employment levels post 2035 do not go back to the base case as the shocks adopted within the modelling remain ongoing.

Similarly, the additional jobs expected to arise under Scenario 2 have been attributed to NSW, Victoria and Queensland, based on Australia's current processing and chemical refining capabilities existing within those states.

Figure 2: Results for Scenario 2



2.4 Scenario 3: Shaping international markets

Australia is able to maintain its market share, while attracting a green price premium on the critical minerals and energy transition minerals exported.

Scenario 3 sees Australia maintain its market position within the critical minerals and energy transition minerals sector by way of increasing exports in line with increasing global demand up to 2040 (Scenario 1). Additionally, Australian miner al exports are assumed to attract a price premium because of Australia's status as an international market leader.

Shaping international markets

The transition to a low carbon economy is accelerating, signaling an imminent change in the resource sector. Critical minerals and energy transition minerals are key resources in the shift due to their role as inputs for renewable energy technologies. Australia's resource endowment positions the country as a potential key supplier in the transition.

Maintaining Australia's current position as a key supplier of mineral resources globally into the future plays into global demand, providing the opportunity for suppliers to develop a dependency (to an extent) on Australian exports across global clean energy supply chains. However, Australia's success is highly contingent upon effective efforts to capitalise on this opportunity, whilst managing the challenge of competition from other countries.

Environmental, social and governance (ESG) frameworks are important in ensuring that organisations can manage risks and opportunities as we enter an increasingly decarbonised economy. ESG standards help to create a transparent and comparable way to demonstrate an organisation's ability to support and meet stakeholder requirements and ensure continued access to investment and global supply chains.

The need for harmonisation of existing global ESG standards across energy transition and critical mineral supply chains presents a specific opportunity for Australia. Good management across the mining industry has established Australia as a reliable and transparent supplier of geological resources. Countries that champion systems for sustainability reporting and establish mechanisms for responsibly sourcing minerals are positioned to capitalise on this opportunity by becoming market leaders in the ethical supply of minerals.

Scenario 3 considers an outcome where Australia can effectively manage competition from other countries and maintain market share, whilst also championing the ethical supply of energy transition and critical minerals. Under this scenario, Australia would charge a premium for responsibly sourced mineral exports and undertake llimited downstream processing onshore.

This scenario models the additional benefits (relative to the base case) arising from economic activity directly attributable to maintaining market share and the implementation of a price premium. In this scenario prices increase 1% from 2030 to 2035, following which prices lift by a further 1%.

Scenario 3 demonstrates the significance of the opportunity if Australia becomes a leader in the reliable and responsible supply of minerals.

2.4 Scenario 3: Shaping international markets

Modelling shocks

In combination with the shocks adopted under Scenario 1, this scenario models the economy-wide impacts of Australia attracting a green price premium by applying a marginal uplift to the price attributed to the critical minerals and energy transition minerals within the Non-ferrous metal mining and Nonmetallic mining sectors.

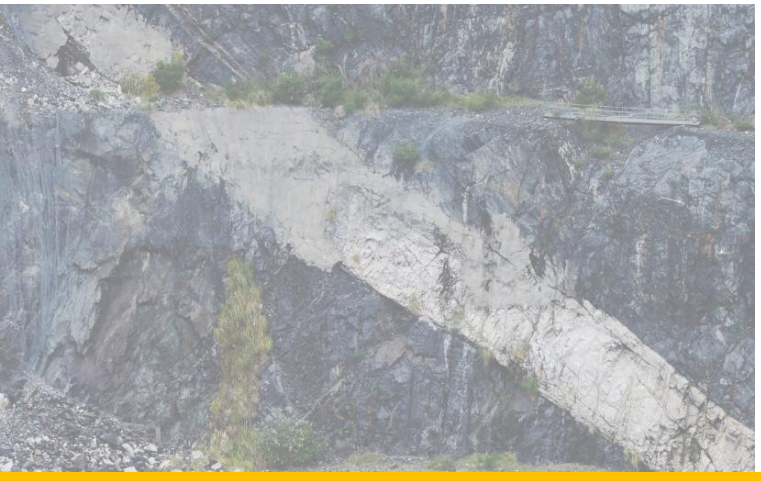
Examples of factors that allow for a price premium on ethically sourced Australian exports include:

- international partnerships that generate more favorable investment in Australia across the energy transition and critical minerals sector
- a shift towards an industry preference for ESG-conscious material sourcing
- growing momentum for ESG reporting environment where ESG disclosures are highly desirable.

Modelling inputs

In combination with the inputs outlined in Scenario 1, the main additional modelling inputs for this scenario were a:

- **Price premium:** An illustrative and conservative price premium of 1% has been adopted to understand the additional benefit that could be realised where Australia establishes itself as an international market leader and shapes international markets (particularly in respect to ESG standards).
- In terms of establishing a plausible price premium that could be applied to this scenario, the direct challenge of trying to attribute a willingness to pay value to critical minerals and energy transition minerals in the future is recognised.
- Nevertheless, a 1% price premium has been adopted in Scenario 3 to quantify the minimum additional benefit which could be unlocked at a macroeconomic level if Australia was to have an active role in shaping international markets and the standards under which they operate.
- In this scenario prices increase 1% from 2030 to 2035, following which prices lift by a further 1%. This timeframe has been adopted on the understanding that it may take some time for Australia to establish itself as an international marker leader with respect to ESG standards, and therefore will unlock the proposed price premium later within the analysis period.



A 1% price premium has been adopted to test the potential impact of a green premium on Australia's critical minerals and energy transition minerals.

2.4 Scenario 3: Shaping international markets

Scenario 3 has the potential to achieve an additional $72.5 billion uplift in GDP (2023 dollar value) and an additional 121,100 FTE jobs between 2022 to 2040.

Economic impacts

Under Scenario 3, Australia is expected to benefit from an additional **$72.5 billion** (2023 dollar value) uplift in GDP relative to the base case. This uplift in GDP also captures the additional benefit realised where Australia maintains its market position with respect to critical minerals and energy transition minerals exports.

Increasingly, broader social license issues, environmental and human-rights-related concerns are being considered as significant financial risks for mining projects as they could erode investor support, limit access to, and increase the cost of, capital, increase scrutiny from relevant stakeholders, and lead to short-term production disruptions and stark local and international resistance to mining investments.

Given this impact, capabilities in tracking and reporting on mining practices, along with the environmental impacts of mineral production, will distinguish certain suppliers over others on the global stage. In the wake of Australia's reputation as an ethical and transparent supplier of resources and raw materials, Australian critical mineral and energy transition mineral industries have the potential to capitalise on this opportunity through the introduction of a price premium.

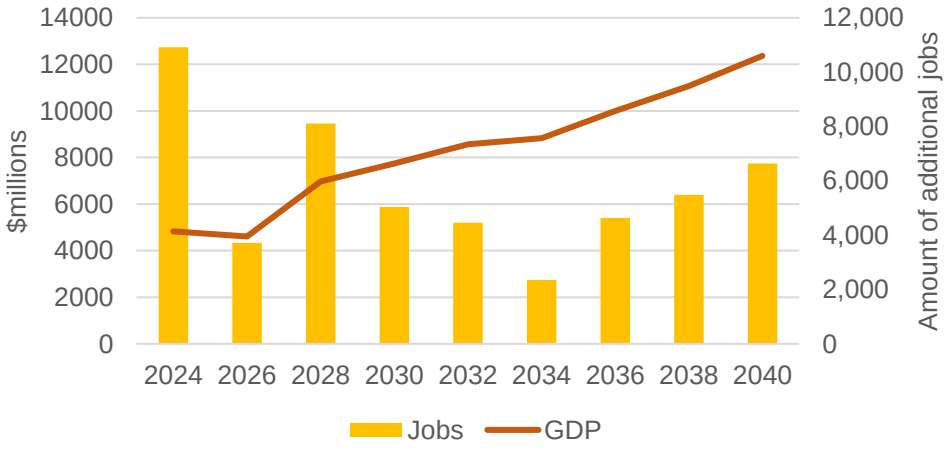
Employment impacts

Under Scenario 3, the Australian economy is expected to create an **additional 121,100 FTE jobs** between 2022 to 2040, relative to the base case. This uplift in FTE jobs also captures the additional benefit realised where Australian maintains its market position in respect to critical minerals and energy transition minerals exports.

WA is expected to capture most of these additional FTE jobs, given the state's abundance of critical minerals and energy transition minerals resources and mining activities, now and into the future. This additional employment is expected to be met by workers outside the state (in jurisdictions such as Victoria and NSW).

During the analysis period, sustained increases in employment are seen from 2030 and 2035, peaking at 2035 from the additional 1% price premium uplift.

Figure 3: Results for Scenario 3



Note: Aggregate results for this scenario include both the benefits illustrated in this chart and those in Figure 1.

2.5 Scenario 4: Building capabilities and international market share

Australia adopts a deliberate policy focus on both building downstream processing capability and securing a greater share of international trade and investment.

Scenario 4 considers the additional benefits that could be realised if Australia was to build its downstream capabilities (Scenario 2) and maintain its current market share in the critical minerals and energy transition minerals sector, while influencing international markets, which unlock a price premium (Scenario 3).

Two sensitivity tests are also included in this scenario:

- Sensitivity 1 (4i), which tests the implications of faster than expected technology adoption rates for specified low emissions technologies, specifically electric vehicles (EVs).
- Sensitivity 2 (4ii), which tests the implications of increased policy support and finance sector engagement leading to accelerated project development times.

Building capabilities and international market share

Across countries all over the world, leaders and policy makers are paying more attention to critical minerals and energy transition minerals than ever before. Due to every country's different position in the supply chain and other national circumstances, they all approach this area with different mindsets and goals. Notwithstanding this, there is an increasingly common recognition that policy intervention is unavoidable to ensure that they do not miss out on opportunities in this field to achieve their climate goals.

> Policy intervention can ensure supply safety, sustainability, resiliency and reliability.
>
> **- Critical Minerals Policy Tracker**

In **Scenario 4**, governments adopt a deliberate policy focus on both building downstream processing capability and securing a greater share of international trade and investment. To expand Australia's capability to supply processed critical minerals, as outlined under Scenario 2, it is assumed additional public capital and policy support is required. This is needed to manage early-stage risk and to facilitate coordinated investment up the value chain.

In addition to the policy and public capital support, downstream capabilities will need to be further developed, like Scenario 2. Exploring downstream capabilities in critical mineral processing in Australia can be expected to support higher volumes of currently processed minerals, and/or generate the exportation of additional critical minerals types.

In **Scenario 4i**, existing policies, tax breaks and national renewable energy targets are expected to accelerate the take-up of low-emissions technologies such as EVs. Critical minerals are materials used in the battery precursor, battery cell production and battery pack assembly industries. The adoption of these technologies are assumed to drive significant demand for critical minerals currently sourced in Australia such as lithium and cobalt.

In **Scenario 4ii**, government investment is expected to reduce the risk of expected to reduce the risk of project development across financing, obtaining resources and / or meeting industry standards for production. Accelerated project development timelines resulting from policy support and finance sector engagement can allow for earlier realisation of benefits and generate momentum for continued innovation across industries. Demand for critical minerals to support this change is assumed to increase as a result.

2.5 Scenario 4: Building capabilities and international market share

Modelling shocks

To model the economy-wide impacts of Scenario 4 and its respective sensitivities, PwC employed the following economic 'shocks':

- **Scenario 4** combines the shocks applied in Scenario 2 and 3, to understand the combined impact of maintaining Australia's market share, coupled with a price premium, while also expanding Australia's downstream capabilities
- **Scenario 4i** adopts the shocks captured under Scenario 4, in addition to shocking the domestic 'other chemicals' sector to reflect faster than expected technology adoption rates of EVs (14).
- **Scenario 4ii** adopts the shocks captured under Scenario 4, while adopting additional investment in the 'Other Metals', 'Other Chemicals' and 'Other Manufacturing' sector (above that which is adopted in Scenario 2), to test implications of increased policy support and finance sector engagement.

Modelling inputs

In combination with the inputs outlined in Scenario 2 and 3, the main additional modelling inputs for Scenario 4 and each sensitivity were:

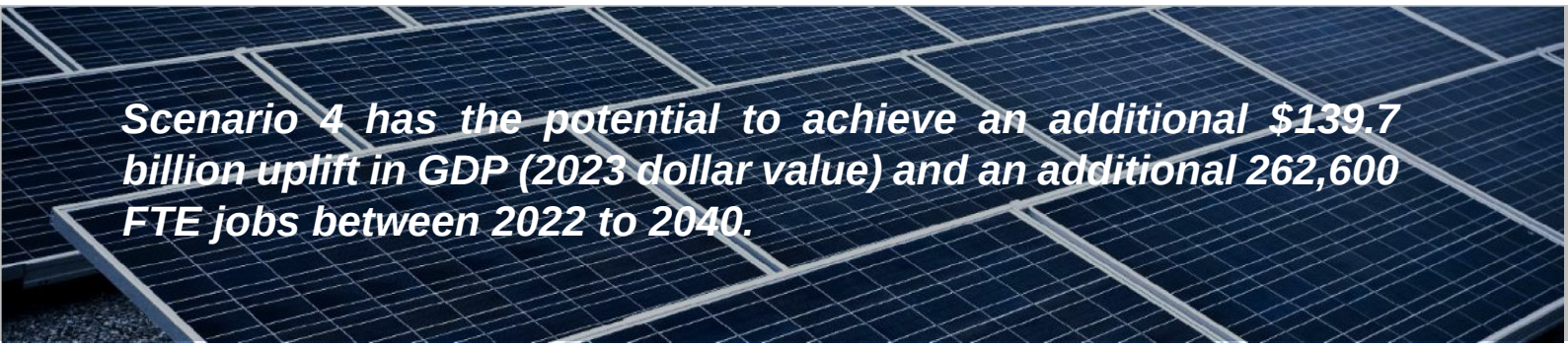
- **Scenario 4:** no further inputs.
- **Scenario 4i):** to capture a faster than expected technology adoption rate of EVs, a 'twist' towards domestic and away from imported other chemicals (5%) has been adopted.
- This has been coupled by a shift in consumer tastes towards electricity (5.78%) and away from petrol (5% - to match spending).
- **Scenario 4ii):** $10.4 billion in total investment is assumed to be applied to the Australian economy (specifically to the three sectors referenced above) from now to 2035. The level of investment assumed has been based on:
  - potential government mechanisms that may drive the development of downstream segments of Australia's critical minerals and energy transition minerals supply chain, such as the National Reconstruction Fund (NRF), Export Finance Australia (EFA) Critical Minerals Facility, the Critical Minerals Development Program and Critical Minerals R&D Hub, with an uplift factored for the investment under Scenario 2 (15)
  - level of co-investment that is expected from industry (16).

(14) Broadly, the economy will also be impacted by consumer preferences moving away from petrol refining and towards electricity. Potential government mechanisms that may drive the development of downstream segments of Australia's critical minerals supply chain have been provided by DISR.

(15) Note: the government mechanisms which have been adopted to model this sensitivity are purely illustrative and have been leveraged to establish the level of additional investment which could be applied to as increased policy support.

(16) The level of co-investment anticipated from industry for the following scenario has been based on information provided by DISR.

2.5 Scenario 4: Building capabilities and international market share



Scenario 4 has the potential to achieve an additional $139.7 billion uplift in GDP (2023 dollar value) and an additional 262,600 FTE jobs between 2022 to 2040.

Economic impacts

Under Scenario 4, Australia is expected to benefit from an additional **$139.7 billion** (2023 dollar value) uplift in GDP relative to the base case. This additional benefit is driven by capturing the shocks adopted within Scenario 2 (adoption of additional investment to develop Australia's downstream capabilities) and Scenario 3 (maintenance of Australia's current market share out to 2040 (7.67%), paired with a 1% price premium), to understand the combined impact such measures could achieve.

Given the interrelated nature of the Australian economy, the uplift in results within Scenario 4 do not see the total uplift in GDP of Scenarios 2 and 3 individually. Rather, the expansion of some sectors captured within the economy have the potential to interrupt others, leading to a smaller impact of Scenario 4, than the combined impact of Scenarios 2 and 3, for both GDP and employment.

The additional impact quantified under Scenario 4 is expected to deliver benefits across an array of states. NSW and Queensland will predominantly benefit from the additional investment leveraged from Scenario 2, based on Australia's current processing and chemical refining capabilities existing within those states.

NT is also expected to capture a sufficient share of the additional benefit quantified, given the state's critical minerals and energy transition minerals resources and mining activities, now and into the future.

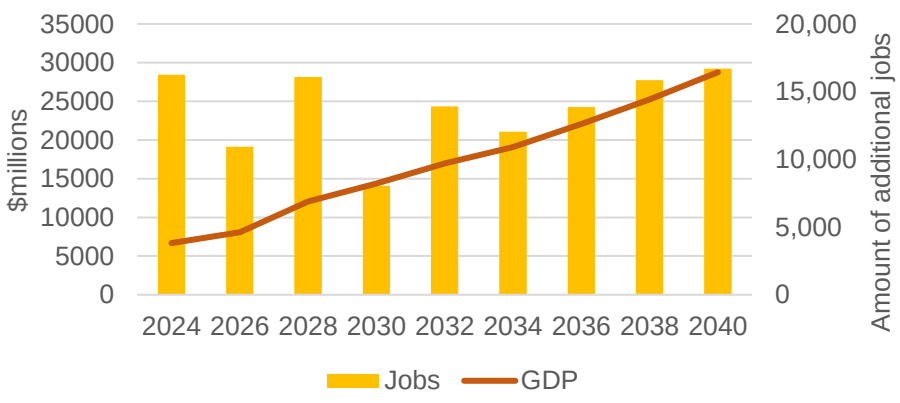
Employment impacts

Under Scenario 4, the Australian economy is expected to support the equivalent of an **additional 262,600 FTE jobs** between 2022 to 2040, relative to the base case.

WA is expected to capture the greatest portion of these FTE jobs, given the state's high abundance of critical mineral and energy transition mineral resources and mining activities, now and into the future. Such resources will be important to feed into the processing and chemical refining industry, particularly as they continue to develop. This will result in the state attracting skilled talent and jobs from other states to meet the expected demand.

As seen within Scenario 1, the gains in employment are mostly spread amongst professional, technical, community and machinery workers as extractive industries do well and those large industries which support them face increasing demand from a larger economy expand. However, as Scenario 4 captures both the shocks modelled within Scenario 2 and 3, it is important to recognise that this combination results in a need for a slightly different industrial composition. Both mining activities and refining processes will need to be catered for within the Australian economy, meaning that industries with different labour intensity will do better.

Figure 4: Results for Scenario 4



2.5 Scenario 4i: Sensitivity testing on earlier technology adoption

This sensitivity test includes the implications of faster than expected technology adoption rates for specified low emissions technologies.

Economic impacts

Under Scenario 4i), Australia is expected to benefit from an additional **$139.1 billion** (2023 dollar value) uplift in GDP relative to the base case. Importantly, this additional benefit is driven by the design of Scenario 2 (adoption of additional investment to develop Australia's downstream capabilities) and Scenario 3 (maintenance of Australia's current market share out to 2040 (7.67%), paired with a 1% price premium), while also considering the impact changes in consumer consumption from petrol to electricity have, driven by faster adoptions of EVs.

This sensitivity demonstrates that there is a marginal decline to the uplift in GDP quantified under Scenario 4 when low emission technologies, such as EVs, see faster than expected adoption rates. This is due to the interrelated nature of the Australian economy, whereby the expansion of some sectors captured have the potential to interrupt others, seen through consumer consumption changes from petrol to electricity, capturing faster adoptions of EVs.

WA is expected to capture most of the additional benefit associated with Scenario 4i, given the state's abundance of critical minerals and energy transition minerals resources and mining activities, now and into the future.

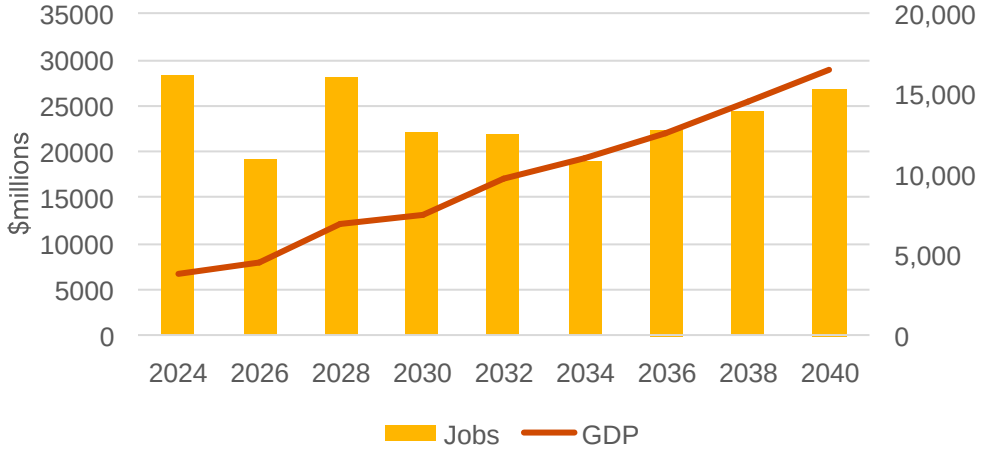
Victoria is also expected to realise a portion of the GDP uplift quantified, given a great deal of Australia's current downstream capabilities are located on the east coast. The state has approximately 26 percent of Australia's population residing within its borders, which justifies why changes in consumer consumption preferences would have a direct impact on the state GDP.

Employment impacts

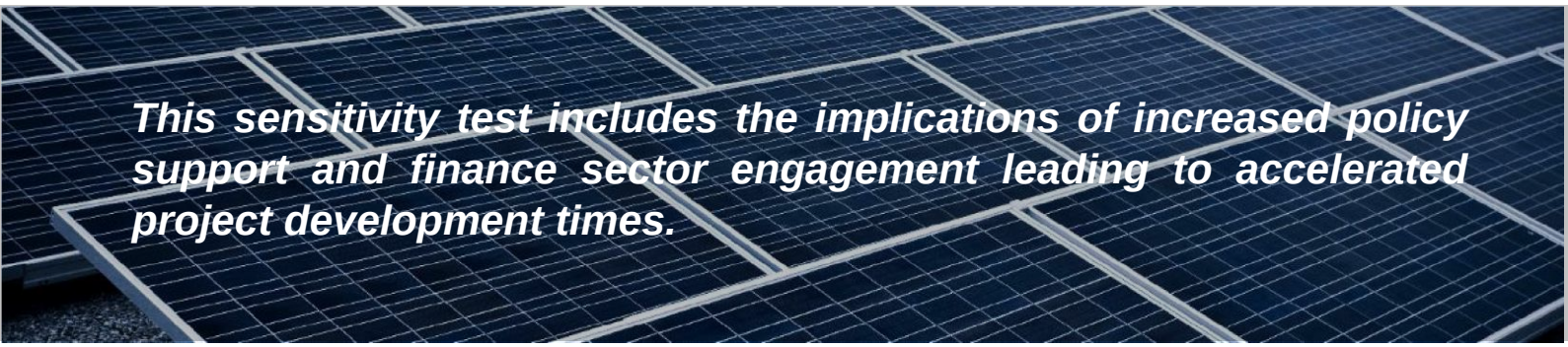
Under Scenario 4i, the Australian economy is expected to support the equivalent of an **additional 257,900 FTE jobs** between 2022 to 2040, relative to the base case.

It is expected that there will be a shift in jobs across the different sectors concerned, with a positive impact on sectors that correlate to critical minerals and energy transition minerals (i.e. the 'Other metals', 'Other chemicals' and 'Other manufacturing' sectors). A negative impact is foreseen in non-critical minerals related sectors (for example non-renewable energy industries). This means that the expansion of sectors correlating to critical minerals will also redirect investment and opportunities from other sectors.

Figure 4: Results for Scenario 4i:



2.5 Scenario 4ii: Sensitivity testing on faster project delivery times



This sensitivity test includes the implications of increased policy support and finance sector engagement leading to accelerated project development times.

Economic impacts

Under Scenario 4ii), Australia is expected to benefit from an additional **$170.8 billion** (2023 dollar value) uplift in GDP relative to the base case. This is largely driven by higher additional investment ($10.4 billion relative to $6.94 billion in Scenario 2) across Non-Ferrous Metal, Other Chemical and Other Manufacturing sectors across Australia. This benefit is also driven by maintaining current market share (7.67%) paired with a price premium (1% at 2030 and a further 1% at 2035 under Scenario 3).

Positive impacts result from productivity gains driven from increased policy support. The specific mechanisms of government investment considered in the modelling is non-specific but may be implemented through the form of grants, funding for research and financing options to support industry expansion on existing downstream capabilities and development of new capabilities. This investment, coupled with co-investment from industry, attributes to a higher magnitude of benefits relative to Scenario 4i.

The modelling indicates that international demand for Australian exports is expected to drive development across the critical minerals and energy transition minerals sector.

This leads to higher profitability and benefits for the broader economy through increases in the terms of trade, specifically an increase in the price of Australian exports.

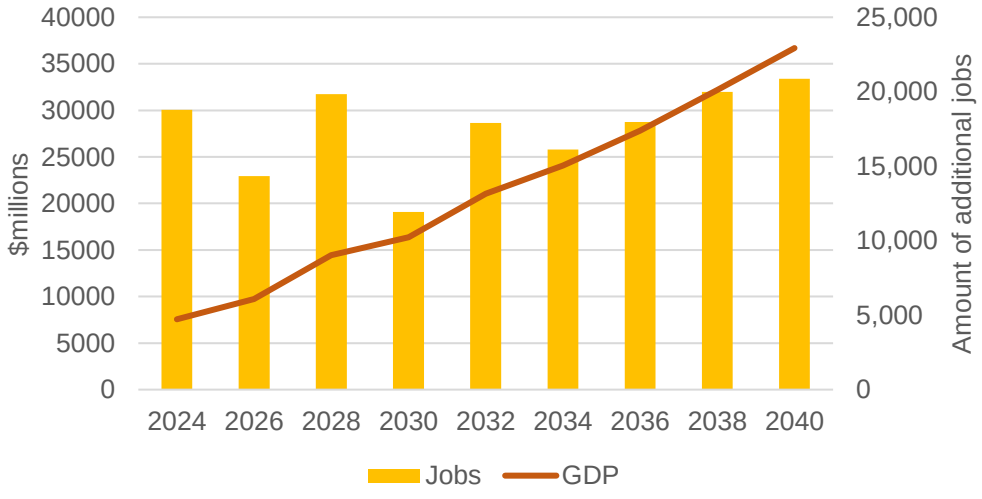
The additional economic impact is expected to deliver significant benefits to WA, NSW, Victoria and Queensland based on current resources, facilities and capabilities in the mining, refining and processing sectors within these states.

Employment impacts

Under Scenario 4ii, the Australian economy is expected to support the equivalent of an additional **329,000 FTE jobs** between 2022 to 2040, relative to the base case. The vast number of these jobs occur across WA.

Investment and productivity gains are found to improve Australia's competitiveness in manufacturing. More efficient use of resources drives improvements to profitability in local industries and leads to higher employment across the sector. This is demonstrated in the results as a significant uplift in jobs.

Figure 5: Results for Scenario 4ii:



Footnotes

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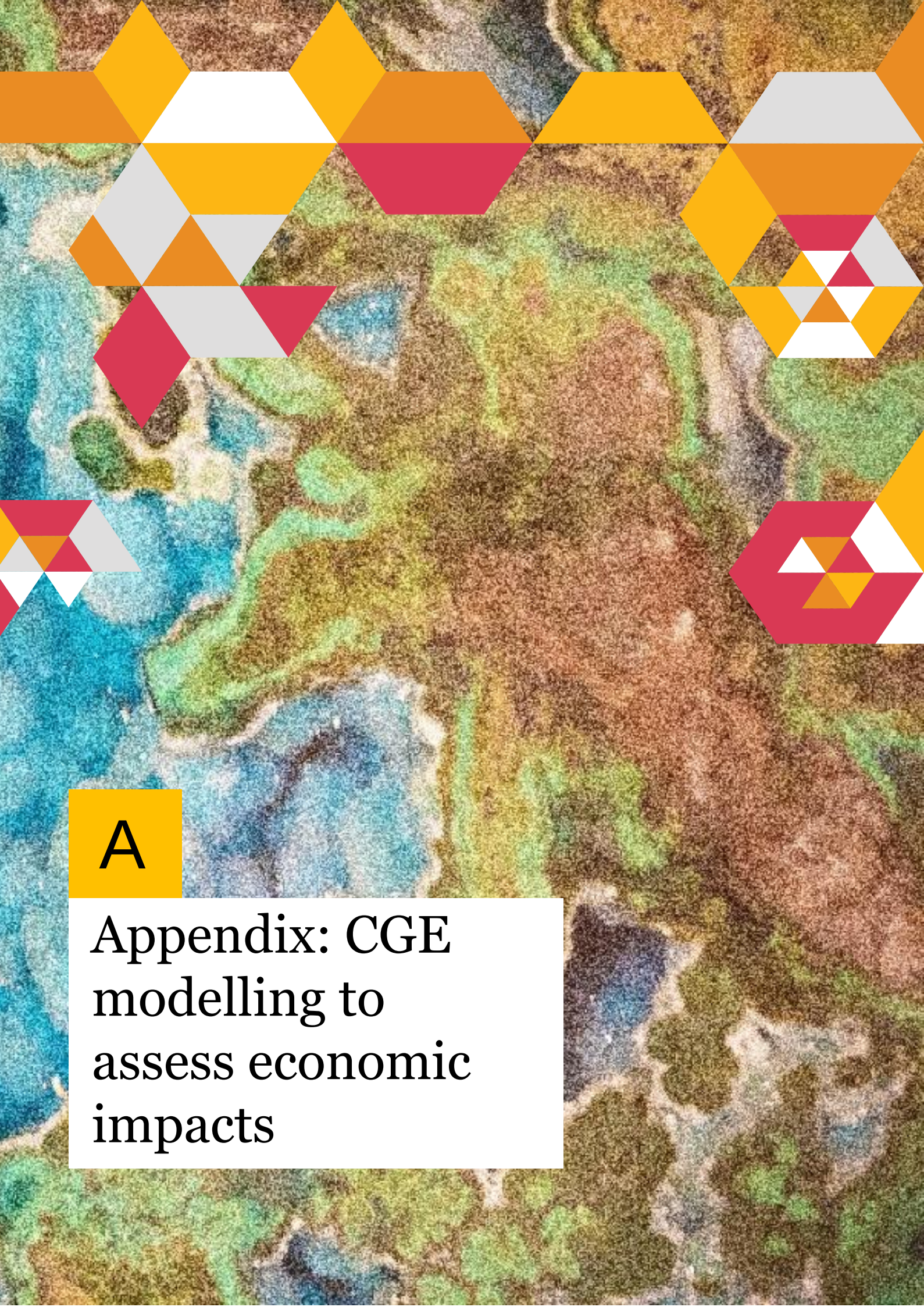

A

Appendix: CGE modelling to assess economic impacts

A1 Whole of economy analysis

The economic impact assessment of production participation has been undertaken using a computable general equilibrium (CGE) model, specifically the Victoria University Regional Model (VURM) developed by the Centre of Policy Studies (CoPS) at Victoria University.

A CGE model is a mathematical model of an economy that is capable of capturing economywide impacts and inter-sectoral reallocation of resources that may result from a 'shock' (i.e. change in the status quo) to the economy. CGE models are widely used in economic analysis of policies and projects around the world including in Australia by both government and the private sector.

What is a CGE model?

A CGE model places a change or 'shock' on a base input-output table by solving a set of equations that capture neoclassical microeconomic theory to determine the behaviour of economic agents (such as households, governments, and industries) when they are faced with changes in key economic variables, especially relative prices. The equations are solved simultaneously, where some variables are determined by the model (endogenous variables) and some are determined outside the model (exogenous variables). The classification of endogenous and exogenous variables is determined by the user based on the set of assumptions derived for the specific modelling exercise. In this way, CGE models recognise that complex macroeconomic mechanisms and inter-industry interactions exist in the economy and, in light of this, replicate how the economy will adjust to 'shocks' from significant projects and policies.

PwC uses the CGE models developed by the CoPS. These are preferred because they have been peer-reviewed, meaning the inputs and assumptions are fully and publicly documented, providing greater modelling credibility. The Victoria University models have wide use in Australia by both government and the private sector. The VURM is a multi-regional, dynamic CGE model. It distinguishes up to eight Australian regions (six States and two Territories) and up to 144 commodities/industries. The model contains explicit representations of intra-regional,

inter-regional and international trade flows based on regional input-output data developed at CoPS, and includes detailed data on state and Federal governments' budgets. As each region is modelled as a mini-economy, VURM is ideally suited to determining the impact of region-specific economic shocks. Second-round effects are captured via the model's input-output linkages and account for economy-wide and international constraints.

The results for policy or counterfactual simulations (i.e. scenarios) in VURM are of deviations from base case. The base line of the model produces a picture of Australian labour markets growing over time using population forecasts, capital accumulation and underlying productivity growth. When the model is shocked, employment in industries, regions and in the economy overall can deviate from the base case. The model uses 'sticky' wages, where wages begin to rise in response to higher than base case employment, but take time to rise sufficiently to make employment return to base case. For the following modelling exercise, simulations, the model continues to be shocked quite far into the future, so the adjustment process where employment gains gradually become increases in real wages are yet to be completed.

A1 Whole of economy analysis

Assumptions

In undertaking the modelling, PwC has assumed the following general assumptions:

- The CGE model quantifies the economic impacts resulting from the various success in building downstream capability scenarios (and sensitivities).
- PwC uses a customised version of Victoria University's Regional Model (VURM), which contains a detailed model and base case of future growth of the Australian economy.
- The model uses detailed data from the ABS and features price-driven behaviour and economywide constraints. The recursive dynamic mode of the model involves an economy changing and growing over time in response to population, capital and debt accumulation, partial adjustment mechanisms in the labour market, as well as changes in technology and patterns of international trade and growth
- While the base case captures the baseline impact that is expected by Australia as it moves to low emission technologies to support it's decarbonisation journey, it is unclear whether or not the VURM assumes Australia achieves net zero by 2050, and whether it is on the trajectory to achieve that target over the analysis period.
- We consider this to be a reasonable position to adopt within the base case as it represents Australia's current trajectory towards net zero – governments and industries are actively taking steps to support the decarbonisation of the Australian economy, but whether such measures will be enough to achieve such an extremely ambitious target, within the timeframes required, is not captured by the model.
- All results presented are additional to the growth that is expected to occur under the model base case forecast of the Australian economy.
- Jobs reported as 'additional' within the scenario results are the estimated net number of new jobs generated above the baseline, which move from non-productive industries to those which are stimulated by additional activity / investment.

A1 Whole of economy analysis

Limitations

The approach taken has the following limitations:

- The results have been quantified out to 2040, based on publicly available projections relating to foreseen demand of critical minerals.
- The modelling has been conducted using a forecast of critical mineral demand values, so would be subject to any changes in those forecasts.
- Due to data limitations, the commodity prices adopted for the following exercise have been assumed to remain consistent across the analysis period.
- The additional investment adopted under Scenario 2 is not directly associated with specific government policy mechanisms or industry players, as it remains unclear what key drivers will lead to the additional investment adopted. Notwithstanding this, key inputs from DISR have been provided to establish a total co-investment value that could be attributed to building out downstream capabilities. Given the time horizon of the analytical exercise, these inputs are necessarily illustrative, and should not be considered as indicating future government policies.
- It remains unclear what green price premium could be unlocked by Australia, where it plays an active role in shaping international standards in the future. This would require a 'willingness to pay' study to establish what premium the market would be willing to pay for Australian commodities, based on future appetite and the state of future commodity markets.
- CGE is a simplication of real-world interactions and will not definitely address all uncertainties. One of these uncertainties includes whether Australia achieves net-zero by 2050, in the absence of any targeted additional ‘shocks’.
- The results of the CGE modelling are only as robust as their inputs.
- Representative ratios for government to private sector investment provided by DISR have been used for Scenario 2 and 4. This is based on historic performance of similar or related government measures
- The scenarios do not capture the impacts of recent and notable shifts in international renewable energy and renewable energy manufacturing policy, including the U.S. Inflation Reduction Act.

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