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Opportunities for prosperity in a decarbonised and resilient NSW

Decarbonisation Innovation Study

August 2020

Disclaimer

Third Party Reliance

This report is solely for the purpose set out in the Executive Summary and Introduction, and for the NSW Government's information. It has been prepared in accordance with the Terms of Reference (Appendix 2).

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Executive summary

Climate change presents environmental and economic challenges, but also economic opportunities through the development and adoption of new decarbonised technologies and services.[1] The commercialisation and adoption of these technologies and services can increase economic productivity, create new industries and jobs, attract new investment and grow exports. They can also help NSW to adapt to the environmental impacts of climate change – by improving energy security and affordability, food and water security, disaster resilience, natural ecosystems, and regional prosperity.

Governments, investors and businesses have recognised these opportunities and are making commitments to reduce emissions and adapt to climate change. In 2019 the World Economic Forum reported that 67 countries had committed to a target of 'net zero emissions'[2] by 2050.[3] All Australian states and territories have committed to a net zero emissions target.[4] The NSW government has announced the *Net Zero Plan Stage 1: 2020-2030* as the first phase of its approach to reach the target.

The purpose of this report is to provide guidance to the NSW Government, businesses, investors and communities on the major prosperity and economic opportunities for NSW that arise from decarbonisation and climate change adaptation. It identifies opportunities that:

- Are the most technically feasible based on current or foreseeable future technologies,
- Are the most economically feasible without long term dependence on external incentives, and
- Have the potential to increase economic productivity and incomes, create jobs, and grow industries and exports.

This report is not an exhaustive survey of all decarbonisation technologies and services, but focuses on commercially attractive solutions that are more likely to be widely adopted. This is important because solutions that are widely adopted will generally deliver greater emissions reductions and economic benefits than those that struggle to compete in the market.

Some economic opportunities are immediately actionable, whereas other require further development of technologies, markets and industries. The opportunities have been grouped into three phases of a pathway to a decarbonised and climate resilient NSW by 2050:

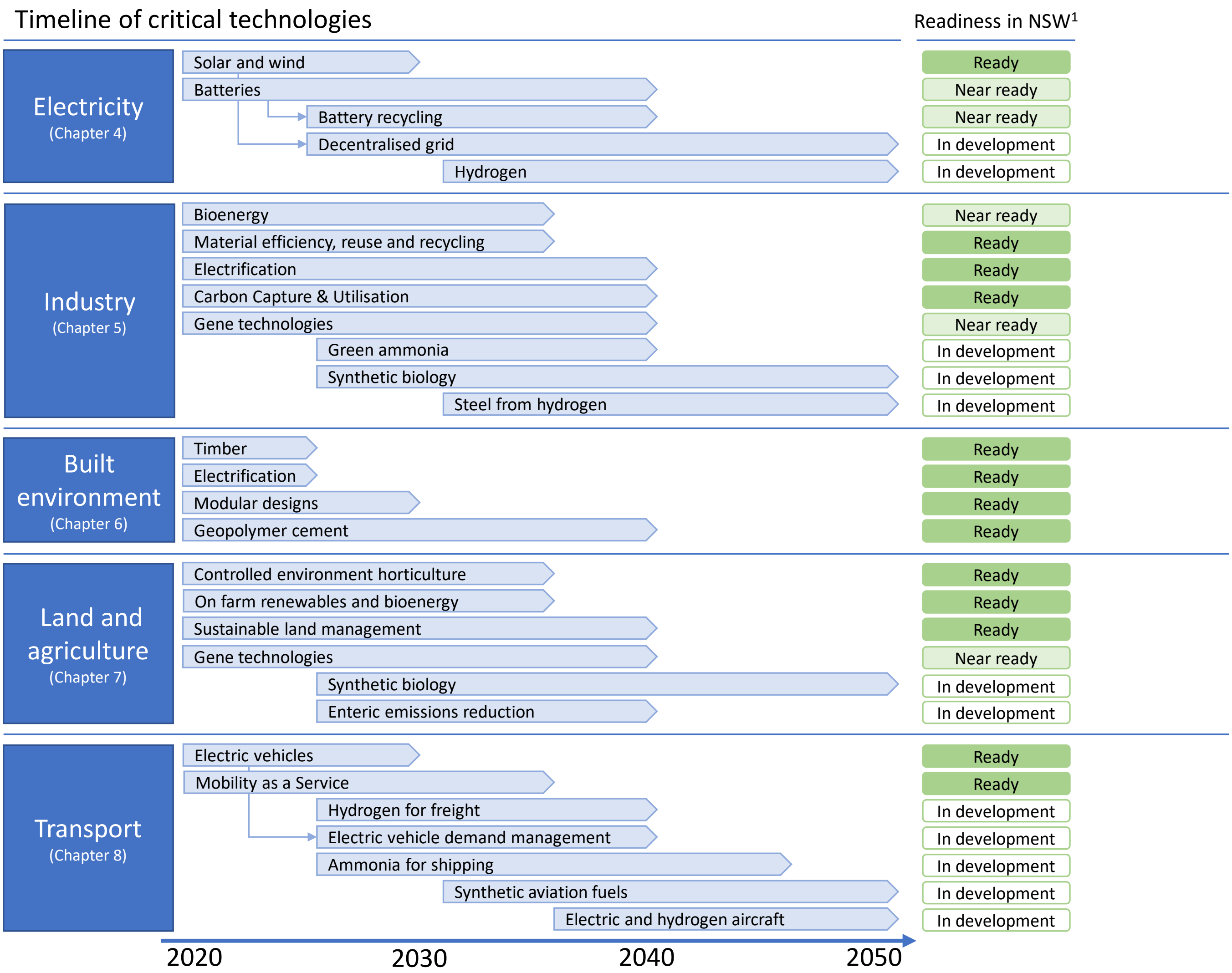
1. **Prepare the Market**: Opportunities to create the market conditions necessary for economic and technically feasible deployment of technologies and services for decarbonisation and climate change adaptation.
2. **Deploy technologies**: Opportunities to develop, commercialise and deploy new technologies and services for decarbonisation and climate change adaptation.
3. **Accelerate**: Opportunities that leverage healthy local markets for demonstrated decarbonisation and adaptation technologies and services to grow local industries and exports.

[1] Decarbonisation is the shift from activities that are greenhouse gas (GHG) emissions-intensive to activities with low or no GHG emissions or that capture, remove or offset carbon emissions.
[2] 'Net zero emissions' means balancing carbon emissions produced with carbon emissions taken out of the atmosphere. For example, through technologies or actions that eliminate, capture, remove or offset emissions.
[3] World Economic Forum, 2019, *The Net-Zero Challenge: Global Climate Action at a Crossroads (Part 1)*.
[4] Allens Linklaters, In search of consistency: state schemes and policies, accessed 3 August 2020, https://www.allens.com.au/insights-news/insights/2020/05/climate-change-guide/in-search-of-consistency-state-schemes-and-policies.

65 economic opportunities have been identified within the following sectors:

Sector	Summary of key opportunities for NSW
Services: *Global services powerhouse*	• Becoming a major global sustainable finance hub. • Attracting local and international capital, and directing it towards promising sustainable industries and infrastructure in NSW. • Improving investment practice by encouraging the widespread adoption of climate change risk management initiatives. • Growing jobs in carbon, resilience and sustainability services.
Electricity: *A distributed and low emission electricity system*	• Deploying low cost renewables and storage to lower electricity costs for businesses and households. • Developing and deploying innovative electricity generation, storage, grid and management technologies and services for a future low cost, low emissions, distributed, reliable, secure, digital and flexible electricity system. • Improving consumer confidence, participation in new electricity markets and adoption of low cost energy technologies.
Industry: *Low carbon industrial transformation*	• Developing and deploying new technologies and services to increase energy productivity, electrification and material efficiency in industrial processes. • Leveraging low cost renewable energy and energy productivity technologies to grow new and expanded energy-intensive industries in precincts and regions. • Reusing, recycling and repurposing materials in industrial supply chains. • Growing industries in hydrogen, alternative heat and bioenergy, and deploying these energy platforms across other industrial processes and economic sectors.
Built environment: *A sustainable built environment*	• Developing and deploying new technologies and services to increase energy productivity, electrification and material efficiency in the built environment. • Growing the market for efficient and modular designs that incorporate sustainable materials, energy generation and storage, and efficiency improvements. • Growing local supply chains in sustainable, reused and recycled construction materials. • Building net zero industrial, commercial and residential precincts and public infrastructure that showcases best practice design, construction and operation.
Land: *Sustainable agriculture and land use*	• Promoting best practice sustainable land management, and growing sustainability markets and ecosystem services to provide complementary decarbonised income sources for landholders, including indigenous landholders. • Improving agricultural productivity and resilience through technologies including controlled environmental horticulture, renewables, bioenergy, water efficiency and recycling, gene technologies and synthetic biology. • Growing local demand and supply chains in agricultural goods and tourism services.
Transport: *Electrified and efficient mobility*	• Increasing productivity in transport through digital connectivity, automation and new decarbonised modes of transport. • Growing availability and uptake of decarbonised energy sources in transport, including renewable electricity, green hydrogen and synthetic fuels. • Increasing awareness and uptake of Mobility as a Service solutions.

This report also assesses the technical and commercial readiness, cost-effectiveness and potential timeframe to adoption of a range of critical technologies that underpin the economic opportunities. Some of these technologies are already technically and commercially ready and cost-effective in NSW, but are not adopted to their maximum potential; some require some incremental progress before entering in the NSW market; and others require further research, development, demonstration and commercialisation. NSW needs to be proactive in developing and/or adopting these critical technologies and services to realise many of the identified economic opportunities.



Timeline of critical technologies underpinning the economic opportunities identified in the report

Note 1: 'Readiness in NSW' refers to NSW's capability and preparedness to deploy the technologies.

Many of the economic opportunities require NSW Government leadership in areas such as policy and regulation, procurement, market development and strategic transitions. Other opportunities are best led by local and international businesses, investors and communities. However, almost all the opportunities require collaboration between stakeholders. To assist the NSW Government in moving forward on these opportunities, this report provides a set of 'next steps' to realise many of these opportunities. For business, investor and community stakeholders, this report provides guidance on the potential economic opportunities that they could choose to focus on and how to go about this.

Contents

1. Introduction

1.1 Decarbonisation and climate adaptation

The changing climate is one of the most significant global megatrends of the 21st century. Anthropogenic climate change, due to emissions of greenhouse gases (GHG) by human activity, presents risks to people, economic prosperity and the environment. Globally, governments, industries, investors, and communities are recognising these risks and are making commitments to reduce emissions, including through the Paris Agreement.[5] In 2019 the World Economic Forum reported that 67 countries had gone further than the Paris Agreement, committing to a target of 'net zero emissions'[6] by 2050.[7] These include the United Kingdom, Japan, New Zealand, the European Union and 8 US states. All Australian states and territories have committed to a net zero target.[8] The NSW government has also committed to a target of net zero emissions by 2050 and announced the *Net Zero Plan Stage 1: 2020-2030* (the 'NZP') as the first phase of its approach to reach that target.[9]

To achieve these commitments and targets, jurisdictions are moving to decarbonise their economies and improve their resilience to climate change. Decarbonisation is the shift from activities that are GHG emissions-intensive to activities with low or no GHG emissions or that capture, remove or offset carbon emissions. Decarbonisation is driving increasing demand for innovative technologies and services that have low or zero emissions, low waste, and support climate change adaptation.

If appropriately managed, decarbonisation presents significant economic opportunities for NSW to develop and advance decarbonised technologies, services and skills. The economic opportunities for Australia include:[10]

- Leveraging its competitive advantages to fulfil increasing local and international demand for innovative technologies and services that enable decarbonisation and climate change resilience,
- Deploying new decarbonised products and services, including technologies to reduce or capture emissions, that can service the domestic economy and be exported,
- Attracting private and sovereign investment, for decarbonised and climate change resilient infrastructure, technology and businesses,
- Growing climate change resilient industries, communities and ecosystems that support the efficient transition of the NSW economy while adapting to a changing climate.

Many of these new technologies and services also provide secondary benefits for NSW in improved energy security and affordability, food and water security, disaster resilience, natural ecosystems, and regional prosperity.

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[5] Through the Paris Agreement, international governments have committed to taking and encouraging action to address climate change through decarbonisation and climate change adaptation. United Nations, 2015, *Paris Agreement*.
[6] 'Net zero emissions' means balancing carbon emissions produced with carbon emissions taken out of the atmosphere. For example, through technologies or actions that eliminate, capture, remove or offset emissions.
[7] World Economic Forum, 2019, The Net-Zero Challenge: Global Climate Action at a Crossroads (Part 1).
[8] Allens Linklaters, In search of consistency: state schemes and policies, accessed 3 August 2020, https://www.allens.com.au/insights-news/insights/2020/05/climate-change-guide/in-search-of-consistency-state-schemes-and-policies.
[9] The Plan aims cut emissions by 35% by 2030 compared to 2005 levels. Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[10] Garnaut, R, 2019, *Superpower, Australia's low-carbon opportunity*, La Trobe University Press.

1.2 Background to study

In September 2019, the Minister for Energy and Environment, the Hon. Matt Kean MP, requested the NSW Chief Scientist & Engineer (CSE) undertake a Decarbonisation Innovation Study ('the Study') to assess and provide advice on the challenges and opportunities for meeting emissions targets and adapting to climate change. The Terms of Reference for the Study include examining the benefits of decarbonisation and climate adaptation in generating economic development, prosperity and jobs growth in NSW, as well as considering best practice approaches to transitioning industry, including skills development and market access (Appendix 1). To assist with addressing the Terms of Reference, the CSE established an expert panel with experience in areas including energy, infrastructure, innovation, sustainability and economics (Appendix 2).

In March 2020, the CSE published a scoping paper, which was developed in consultation with an expert panel and some targeted consultation. The scoping paper provided some context on the pathways and challenges for decarbonisation and climate resilience, and a preliminary survey of potential economic opportunities for sectors of the NSW economy.

Following the release of the scoping paper, further consultation and discussions were held with a broader set of stakeholders, with the aim of seeking feedback on the potential opportunities, including understanding the challenges and actions necessary to realise the opportunities. As a result of this consultation and further research, this Final Report sets out the outcomes of the Study: a refined list of economic opportunities for NSW, and actions that may assist with realising these opportunities.

This Study has identified technologies and services offer the greatest economic and emissions reduction benefits based on factors including current maturity and competitiveness, research capabilities, investment priorities, and policy frameworks. These factors are expected to change over time, with transition outcomes and timelines likely to be highly sensitive to technology breakthroughs, adoption curves, technology interdependences, and network and ecosystem effects. Given this uncertainty, the NZP recommends that the CSE regularly review and report every two years on emerging technologies that reduce emissions and are commercially competitive.[11]

1.3 Policy context

International, Federal and State agreements and policies provide a framework for decarbonisation and climate resilience in the NSW economy. The Paris Agreement is the central international agreement governing the global response to the threat of climate change. Key elements of the Agreement are:[12]

- The long term goal to keep the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels,
- Pursuing efforts to limit the global temperature increase to 1.5 degrees Celsius,
- Near-term pledges by all countries for climate action, with quantitative emissions targets put forward by many countries including all developed countries, and
- Strengthening the ability of countries to deal with the impacts of climate change and support them in their efforts.

Australia has committed to an emissions reduction target of 26 to 28% below 2005 levels by 2030 under the Paris Climate Agreement.

[11] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[12] United Nations, 2015, *Paris Agreement*.

The NSW Government has committed to a target of net zero emissions by 2050 under the NSW Climate Change Policy Framework.[13] In 2018, NSW's net GHG emissions were 131.7 Mt CO_2-e representing 24.5 per cent of Australian GHG emissions.[14] Electricity generation followed by transport, agriculture, and fugitive emissions were responsible for most emissions – largely consistent with Australia's overall emissions profile.

To meet the net zero emissions target, the NSW Government has released the NZP. The NZP outlines the actions to deliver a 35% reduction in NSW emissions by 2030 (compared to 2005 levels).[15] Further stages of the NZP will be developed in the lead-up to 2030 and 2040 respectively. The NZP complements other NSW Government sector-specific policies relevant to decarbonisation including: the NSW Electricity Strategy (released in 2019), the NSW Electric and Hybrid Vehicle Plan (released in 2019), and the NSW Government Resource Efficiency Policy (GREP) (released in 2014). This Decarbonisation Innovation Study, conducted by the CSE, is one of the initiatives under the NZP.

[13] NSW Government, 2016, *NSW Climate Change Policy Framework*.
[14] Department of Industry, Science, Energy and Resources (Australian Government), 2020, *State and Territory Greenhouse Gas Inventories 2018.*
[15] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.

2. Economic opportunities of decarbonisation and climate adaptation

Climate change is not only an environmental and economic challenge, but also an economic opportunity. New technologies and services that enable decarbonisation and climate adaptation, also present economic opportunities across all sectors to increase economic productivity, create new industries and jobs, attract new investment and grow exports.[16]

This report identifies prosperity and economic opportunities for NSW that arise from decarbonisation and climate change adaptation. It identifies opportunities that:

- Are the most technically feasible based on current or foreseeable future technologies,
- Are the most economically feasible without long term dependence on external incentives, and
- Have the potential to increase economic productivity and incomes, create jobs, and grow industries and exports.

This report is not an exhaustive survey of all decarbonisation technologies and services, nor does it attempt to map a lowest cost pathway to a decarbonised economy. In addition to technologies and services identified in this report, other technologies and services may be technically viable or develop as a lower cost means of decarbonising particular economic sectors. Some of these technologies and services examined were not considered economically feasible without long term dependence on external incentives. This is an important factor to consider as economically attractive solutions are more likely to be rapidly and widely adopted, therefore delivering and therefore deliver greater emissions reductions, than technologies which struggle to compete the market.

For example, the report recognises that carbon capture and storage (CCS) is a potential decarbonisation technology but not significant economic opportunity because it is a pure cost and relies on a financial incentive for emissions reduction. In contrast, carbon capture and utilisation (CCU) is a significant economic opportunity because it could be commercially and economically feasible without external incentives, through development of self-sustaining markets for products manufactured with captured carbon. This does not mean that affordable CCS technologies should not be pursued – as they could be viable for some processes with financial incentives and appropriate storage identified.

2.1 Categorisation of opportunities

Economic opportunities have been identified within the following sectors:

- **Services**: Global services powerhouse
- **Electricity**: A distributed and low emission electricity system
- **Industry**: Low carbon industrial transformation
- **Built environment**: A sustainable built environment
- **Land**: Sustainable agriculture and land use
- **Transport**: Electrified and efficient mobility.

[16] Garnaut, R, 2019, Superpower, *Australia's low-carbon opportunity*, La Trobe University Press.

The economic opportunities have been defined based on type of intervention that can help realise them:

Policy & procurement	Opportunities to support the development and deployment of new technologies and services using mechanisms such government procurement, policies, regulations, and standards.
Technology & services	Opportunities to research, develop, commercialise and deploy new technologies and services for decarbonisation and climate resilience.
Education & skills	Opportunities to improve skills in, and understanding of, decarbonisation and climate resilience.

Some economic opportunities are conditional on, or support the delivery of, other opportunities:

Prepare the Market	Deploy technologies	Accelerate
Opportunities to create the market conditions necessary for economic and technically feasible deployment of technologies and services for decarbonisation and climate change adaptation	Opportunities to develop, commercialise and deploy new technologies and services for decarbonisation and climate change adaptation	Opportunities that leverage healthy local markets for demonstrated decarbonisation and adaptation technologies and services to grow local industries and exports

2.2 Assessment of opportunities

The report identifies opportunities and assesses the potential economic benefit and emissions reduction qualitatively based on scientific literature, stakeholder consultations and expert advice.

	Low	Medium	High
Economic benefits	🪙	🪙🪙	🪙🪙🪙
Emissions reduction	🍃	🍃🍃	🍃🍃🍃

The emissions reduction potential of each opportunity is assessed broadly to include: [17]

- Emissions from activities in NSW (known as 'direct' or 'scope 1' emissions),
- Indirect emissions from the generation of purchased energy ('scope 2' emissions),
- Indirect emissions (excluding scope 2 emissions) that occur in the upstream and downstream value chain of NSW economic activity ('scope 3' emissions).

The economic benefit of each opportunity is defined by its potential to increase economic productivity and incomes, create jobs, and grow industries and exports. An important qualification is that this assessment is conducted at a single point of time. Disruption due to changes in economies, industries, technologies, the environment, trade, and domestic and international policies may impact the outlook for these opportunities and may indeed create new opportunities.

Many of the opportunities identified also provide secondary benefits. These include improving energy security and affordability, food and water security, disaster resilience, natural ecosystems, and regional prosperity, as well as in reducing air and environmental pollution. Some opportunities

[17] See further the National Greenhouse and Energy Reporting Act 2007 (Cth).

may also have trade-offs, where pursuing a decarbonisation industry pathway may displace other activities or use more resources – this leads to consideration about issues such as preferred locations.

2.3 Sector diagrams

The economic opportunities identified are summarised in the following sector diagrams and discussed in Chapters 3 to 8 below. The diagrams summarise:

- The high-level supply chain in each sector,
- The status and trends within each part of the supply chain,
- The decarbonisation and climate resilience needs of each part of the supply chain, and
- The major economic opportunities within each sector and the parts of the supply chain each relates to.

Electricity – A distributed and low emission electricity system

Generation

Status and trends:
- Renewable technologies can generate electricity at low cost and without emissions.
- Renewables are forecast to reach 35 to 58% of NSW generation by 2030.

Decarbonisation and resilience requires:
- Investment in transmission and distribution infrastructure.
- Expansion of short and long duration energy storage capacity.
- Technologies and services to support security of a grid with high penetration of renewables.

Storage

Status and trends:
- Energy storage capacity enables increased penetration of renewable solar and wind generation and support grid security.
- AEMO expects that by 2040, 6 to 19 GW of new dispatchable resources will be needed to firm up renewable generation.

Decarbonisation and resilience requires:
- Investment in utility scale storage and system security services.
- Technologies and services to integrate and operate distributed storage at scale in the grid.
- Technologies for storage, demand management and rapid response.

Transmission and Distribution

Status and trends:
- The existing networks have limited capacity to connect new renewable energy projects and require strategic upgrades.
- In future, the network will support more decentralised grids, generation and storage.

Decarbonisation and resilience requires:
- Strategic investment in transmission and distribution to support renewable generation, including the Renewable Energy Zones.
- Smart grid systems and services, including Stand Alone Power Systems and microgrids.
- Technologies and services to increase grid security and resilience.

Energy users

Status and trends:
- Consumers are becoming more active in the market through behind-the-meter generation, storage, and demand response.
- In future, innovative business models for energy users will proliferate, including peer-to-peer trading and virtual power plants.

Decarbonisation and resilience requires:
- Technologies to control energy resources at the household, town and grid level.
- Pricing mechanisms that recognise the value of storage and system security services.
- Education to build consumer confidence in energy market participation.
- Technologies for energy efficiency, demand management and response.

Economic opportunities for NSW

Policy & procurement | Technology & services | Education & skills

	Low	Medium	High
Economic benefits			
Emissions reduction			

Prepare the market

1. Renewable Energy Zones – leveraging abundant low cost renewable energy in the Renewable Energy Zones to grow co-located regional industries, and increase the amount of low cost, firmed renewable energy available across NSW

2. Future energy market design – supporting the update of energy market rules and policies to increase investment in centralised and distributed renewable energy and storage, improve energy security and affordability, and increase consumer participation in the market

3. Government procurement – increasing government procurement of zero-emissions energy generation, storage and system security improvements

4. Consumer education and engagement – improving consumer confidence in participating in energy markets

Deploy technologies

5. Solar generation – developing and deploying new solar technologies

6. Energy storage – developing and deploying new storage technologies, including for power, control and grid integration, EV and battery storage, hydrogen storage, pumped hydro storage

7. Decentralised grids – deploying Stand Alone Power Systems and microgrids in regional communities to reduce network infrastructure costs and improve energy security and resilience

8. Energy efficiency and demand management – developing and deploying energy efficiency and demand response technologies and services to reduce energy costs for customers

Accelerate

9. Digitalised and distributed energy markets – developing and deploying new technologies to optimise future digital energy markets with two-way energy flows, virtual power plants, peer-to-peer trading, high penetrations of distributed and renewable energy and storage, microgrids and large demand response resources

10. Battery repurposing – developing a battery repurposing and recycling industry

11. Future energy systems and markets skills – growing and exporting skills and experience in technologies and services to enable modern energy systems and markets

Industry – Low carbon industrial transformation

Resources

Status and trends:
- Resources are a major industry and export for NSW, and the industry is highly productive.
- Demand for sustainably sourced resources is increasing.

Decarbonisation and resilience requires:
- Technologies and services to increase extraction and processing productivity, and enable electrification.
- Investment in onsite processing using low cost renewables.
- Technologies and services to measure and reduce fugitive emissions.

Industrial processes

Status and trends:
- NSW has a significant industrial footprint with manufacturing contributing $30B to NSW.
- Energy and material productivity could be significantly improved (Australian energy productivity is 15% below the OECD average).

Decarbonisation and resilience requires:
- Technologies and services to improve energy and material efficiency and increase industrial productivity.
- Integration of low cost renewable energy, decarbonised feedstocks and carbon capture in industrial processes.
- New industrial processes based on novel technologies such as synthetic biology.

Consumers

Status and trends:
- Demand for technologies to make supply chains sustainable and decarbonised is increasing.
- Businesses and governments are setting decarbonisation targets, consumers are choosing more sustainable products.

Decarbonisation and resilience requires:
- Growth in industries producing sustainable and decarbonised products and services to meet rising demand.
- Transparency and certification of decarbonised supply chains, products and services.

Reuse and recycling

Status and trends:
- Prioritising the best use of resources can maximise productivity and while minimising negative environmental externalities.
- Demand for better use of materials through resource recovery, substitution, repurposing and recycling is increasing.

Decarbonisation and resilience requires:
- Design approaches to improve material efficiency and reduce waste.
- Technologies and services for reuse and recycling of energy, water, and raw and processed materials.

Economic opportunities for NSW

Policy & procurement | Technology & services | Education & skills

	Low	Medium	High
Economic benefits	1	2	3
Emissions reduction	1	2	3

Prepare the market

1. Eco-industrial precincts – attracting industry with cooperative decarbonisation strategies in precincts (Policy & procurement; Economic benefits: Medium; Emissions reduction: Medium)

2. Government procurement – increasing government procurement of zero-emissions products and services from NSW suppliers (Policy & procurement; Economic benefits: Low; Emissions reduction: Low)

3. Certification and standards – establishing, supporting and promoting standards for certification of decarbonisation and climate resilience in industry in NSW (Policy & procurement; Economic benefits: Low; Emissions reduction: Low)

4. Decarbonisation and climate resilience skills – growing skills to support decarbonisation and climate resilience of industry (Education & skills; Economic benefits: Medium; Emissions reduction: Low)

Deploy technologies

5. Energy productivity – improving industrial productivity by developing and deploying novel and mature energy efficiency technologies (Technology & services; Economic benefits: High; Emissions reduction: High)

6. Material efficiency, reuse and recycling – developing and deploying technologies and services to increase material efficiency, substitution and durability; and reuse, repurposing, recycling in supply chains (Technology & services; Economic benefits: Medium; Emissions reduction: Medium)

7. Electrification, alternative heat and bioenergy – improving industrial productivity by developing and deploying electrification and renewable energy technologies (Technology & services; Economic benefits: Medium; Emissions reduction: High)

8. Hydrogen – developing and deploying technologies for green hydrogen in industry through hydrogen hubs (Technology & services; Economic benefits: Medium; Emissions reduction: High)

9. Carbon capture and utilisation – capturing and transforming carbon emissions to produce value-added products such as building materials, fuels and plastics (Technology & services; Economic benefits: Medium; Emissions reduction: Medium)

Accelerate

10. Critical resources – growing the critical minerals industry for decarbonised technologies (Technology & services; Economic benefits: Medium; Emissions reduction: Low)

11. Grow local production – leveraging energy productivity improvements to increase local production (Technology & services; Economic benefits: High; Emissions reduction: Medium)

12. Export industrial productivity and sustainability services – export services in industrial productivity, decarbonisation and climate resilience (Technology & services; Economic benefits: Medium; Emissions reduction: Medium)

Built environment – A sustainable built environment

Planning and design

Status and trends:
- Infrastructure and buildings under construction now will need to be net-zero ready to achieve 2050 targets.
- Regulations set minimum sustainability standards for buildings in NSW.

Decarbonisation and resilience requires:
- Planning rules to encourage and support a decarbonised and climate-resilient built environment.
- Government leadership in procurement of decarbonised public infrastructure.
- Designs that incorporate embodied and low emissions materials, extend building life, and are modular and reusable.

Construction

Status and trends:
- NSW has a large pipeline of public infrastructure construction to support population growth of 2 million by 2035.
- Productivity in the construction sector has not grown since 1990.

Decarbonisation and resilience requires:
- Technologies and services to improve energy and material efficiency, and productivity in construction.
- Increased use of materials with sequestered carbon, durable and recycled materials.
- New supply chains in sustainable construction materials such as 'green' steel and cements.

Operation

Status and trends:
- NSW has competitive advantages in world leading commercial building sustainability performance.
- Continued operational efficiency improvements can drive economic productivity while reducing energy consumption and waste.

Decarbonisation and resilience requires:
- New technologies and services to improve energy, heating, cooling and material efficiency.
- Digital technologies to optimise asset management throughout infrastructure and building lifecycles.

Precincts

Status and trends:
- NSW is investing in precincts across NSW.
- Precincts can mobilise stakeholders for joint technology development and innovation, and increase productivity from shared infrastructure and investment.
- Successful precincts can guide decarbonisation transitions across NSW.

Decarbonisation and resilience requires:
- 'Hubs' to catalyse supply chains in new technologies and services such as hydrogen.
- Cooperative place-based approaches to improve energy efficiency and reduce waste.
- Technologies and services for recycling and reuse of energy, heat, water, and materials.

Economic opportunities for NSW

Policy & procurement | Technology & services | Education & skills

	Minor	Moderate	Major
Economic benefits			
Emissions reduction			

Prepare the market

- **1. Climate risk assessment** – considering carbon and climate risks in the planning process
- **2. Sustainable precincts** – attracting industry to net-zero ready precincts with cooperative decarbonisation strategies for infrastructure and buildings
- **3. Government procurement** – increasing government procurement of net-zero ready infrastructure and buildings
- **4. Building sustainability standards** – enhancing building sustainability standards across NSW, and supporting cities and regional towns to lead in building sustainability and environmentally friendly public spaces
- **5. Decarbonisation and climate resilience skills** – growing skills to support decarbonisation and climate resilience of infrastructure and the built environment

Deploy technologies

- **6. Efficient, modular designs** – increasing efficiency and modularity in building design
- **7. Energy productivity** – improving energy productivity by deploying mature technologies for heating, lighting, appliance and motor efficiency
- **8. Low emission construction materials** – substituting high-emission construction materials with cost-effective low emission materials, and developing novel decarbonised materials
- **9. Digital technologies** – optimising infrastructure and building performance through novel digital technologies and services such as advanced sensors, digital twins and AI
- **10. Electrification** – improving energy productivity in construction and operation of infrastructure and building through cost-effective electrification and low cost onsite renewable generation
- **11. Hydrogen hubs** – establishing green hydrogen hubs to grow new domestic supply chains

Accelerate

- **12. Grow supply chains in sustainable construction materials** – leveraging increased local and international demand to grow sustainable construction material industries in NSW
- **13. Reuse and recycling** – developing and deploying technologies and services to increase material reuse, repurposing and recycling in infrastructure and buildings
- **14. Export infrastructure productivity services** – exporting services in infrastructure decarbonisation and climate resilience

Land – Sustainable agriculture and land use

Management

Status and trends:
- NSW's environmental assets face physical risks from climate change, such as rising seas and extreme weather.
- These assets also have particular cultural significance for indigenous peoples.

Decarbonisation and resilience requires:
- Monitoring of terrestrial, marine and atmospheric conditions.
- Accurate forecasting of environmental changes and impacts on ecosystems.
- Incorporating indigenous knowledge in land management.
- Sustainable land management practices.

Agriculture

Status and trends:
- Agriculture is a major export and economic driver, contributing $13.3 billion in 2018.
- Agriculture is dependent on adaptive farming responding to variable conditions, and demand for Australian agricultural products.

Decarbonisation and resilience requires:
- Approaches to reduce emissions from livestock and soils, and increase sequestration.
- Sustainable land management to improve ecosystem health and productivity.
- Technologies and services to improve economic productivity and resilience on both prime agricultural and marginal lands.

Natural Resources

Status and trends:
- The natural environment supports important social and economic outcomes, including community health and regional industries.
- The natural environment offers carbon sequestration opportunities.

Decarbonisation and resilience requires:
- Technologies, data and expertise to support sustainable management, adaptation and use of NSW's environmental assets.
- New financial approaches that incentivise carbon storage, and protection and reestablishment of ecosystems and biodiversity.

Consumers and Tourists

Status and trends:
- There is strong interest from consumers in the sustainability and 'carbon footprint' of products and services – increasing demand for sustainable foods and ecotourism.
- NSW tourism industry is reliant on maintaining our natural resources.

Decarbonisation and resilience requires:
- Growth in sustainable agriculture and ecotourism to meet rising demand.
- Transparency and certification of decarbonised agricultural supply chains and products, and ecotourism services.

Economic opportunities for NSW

Policy & procurement | Technology & services | Education & skills

	Low	Medium	High
Economic benefits			
Emissions reduction			

Prepare the market

1. Knowledge sharing – curating open data sets and expertise in climate and environment

2. Sustainability markets – growing and facilitating access to premium sustainability markets, including linking land users and industry to carbon and biodiversity markets

3. Consumer education – promoting sustainable products and services from NSW in local and international markets

4. Decarbonisation and climate resilience skills – growing skills to support decarbonisation and climate resilience of agriculture and tourism industries, and land management

5. Sustainable certification – establishing standards for certification of decarbonisation and climate resilience in NSW's agriculture products and ecotourism services

Deploy technologies

6. Sustainable land management – promoting best practice sustainable land management and complementary decarbonised income sources for landholders, including indigenous landholders (e.g. carbon farming and regenerative agriculture)

7. Ecosystem services – developing the ecosystem services industry to assist land users better manage their lands and improve their climate resilience

8. Controlled environment horticulture – improving agricultural productivity, sustainability and resilience through controlled environment horticulture

9. Renewables and bioenergy – improving energy affordability and security by developing and deploying cost effective on-farm renewable and bioenergy

10. Water efficiency and recycling – improving water efficiency and productivity by deploying water efficiency technologies and services

Accelerate

11. Gene technologies and synthetic biology – developing and cultivating highly productive and resilient crops

12. Enteric emissions reduction – developing and deploying vaccinations, feed supplements and breeding

13. Local supply chains – promoting local consumption of tourism services and agricultural products

Transport – Electrified and efficient mobility

Transport infrastructure

Status and trends:
- Modernised transport infrastructure can support decarbonised mobility while improving network efficiency.
- NSW has a large pipeline of transport infrastructure projects.

Decarbonisation and resilience requires:
- Technology and services to manage demand and improve network efficiency.
- Grid and charging infrastructure to support electrification of transport.
- Supply chains for low-emissions fuels.

Light vehicles

Status and trends:
- Mature emissions reduction technologies exist for light vehicles.
- EVs are becoming cost-competitive and can reduce net emissions if coupled with low emission electricity.

Decarbonisation and resilience requires:
- Increased fuel efficiency and quality.
- Increased uptake of EVs combined with decarbonisation of electricity.
- Accessible EV charging services and smart charging business models.
- Increases in shared ownership.
- Improved connectivity with public transport.

Public transport

Status and trends:
- NSW has an extensive mixed-mode public transport system.
- NSW is making major investments in public transport infrastructure that will need to be net-zero ready to achieve 2050 targets.

Decarbonisation and resilience requires:
- Use of electric and hydrogen public transport vehicles.
- Increased utilisation through improved operational efficiency, customer experience, and connectivity.
- Effective integration to support Mobility as a Service.

Freight and heavy modes

Status and trends:
- Freight and heavy vehicle emissions continue to rise.
- Technologies to reduce freight, heavy vehicle, maritime and aviation emissions exist but require further development.

Decarbonisation and resilience requires:
- Technology and systems to optimise logistics supply chains, vehicle routing and loads.
- Low emission energy storage and power systems for trucks, trains, ships and aircraft such as synthetic fuels, ammonia, hydrogen, and batteries.

Transport users

Status and trends:
- Private vehicle transport and ownership in NSW is relatively high.
- However, consumers are increasingly adopting Mobility as a Service (MaaS) and public transport options.

Decarbonisation and resilience requires:
- Technologies, services, infrastructure and policy to support increased uptake of cost-effective MaaS and public transport services in urban and regional communities.

Economic opportunities for NSW

Policy & procurement | Technology & services | Education & skills

	Low	Medium	High
Economic benefits	1	2	3
Emissions reduction	1	2	3

Prepare the market

- **1. Government procurement** – increasing government procurement of decarbonised and climate-resilient transport infrastructure, public transport and fleet EVs
- **2. Consumer education and research** – improving consumer understanding of the benefits and costs of transport choices
- **3. Transport funding approaches** – updating transport funding approaches to incentivise Mobility as a Service, optimise asset utilisation, reduce congestion, and improve network efficiency and flexibility
- **4. Policy and regulatory guidance** – providing a framework to incentivise and streamline technology development, and to build investor and consumer confidence in new modes of transport, including automated and hydrogen vehicles

Deploy technologies

- **5. Transport productivity** – developing and deploying technologies and services to improve operational and energy efficiency
- **6. Mobility services** – developing and deploying Mobility as a Service to improve efficiency, flexibility, and affordability in low emission transport
- **7. EV charging** – deploying technologies to manage EV charging
- **8. Electrification** – deploying EVs and other electric transport modes in cost-effective applications
- **9. Strategic hydrogen and electrification hubs and routes** – developing and deploying hydrogen, low emission fuel and EV charging infrastructure to logistics hubs and along critical road and rail routes

Accelerate

- **10. New skills and services** – developing workforce skills and capabilities to support maintenance and servicing of new transport vehicles, infrastructure and services
- **11. New components and systems** – developing and deploying new components and systems for novel decarbonised vehicles and infrastructure
- **12. Future EV battery services** – developing and deploying technologies and services to integrate EVs into the grid, and for recycling, reuse and repurposing of EV batteries

2.4 Critical technologies

A number of critical technologies underpin the economic opportunities identified in this report (Figure 1). To realise many of the economic opportunities identified, NSW businesses, researchers and government should contribute to global efforts to increase the technical and commercial readiness, cost-effectiveness and adoption of these critical technologies. If NSW is late in adopting these critical technologies and services, it risks becoming uncompetitive and losing market share in key industries that underpin NSW's economic performance.

Many of these technologies are already technically and commercially ready and cost-effective in NSW, but are not adopted to their maximum potential. There are economic opportunities in encouragement and widespread rollout of these 'ready' technologies. Other technologies are 'near ready' (requiring some incremental progress before entering in the NSW market), and others are still 'in development' (requiring further research and commercialisation).

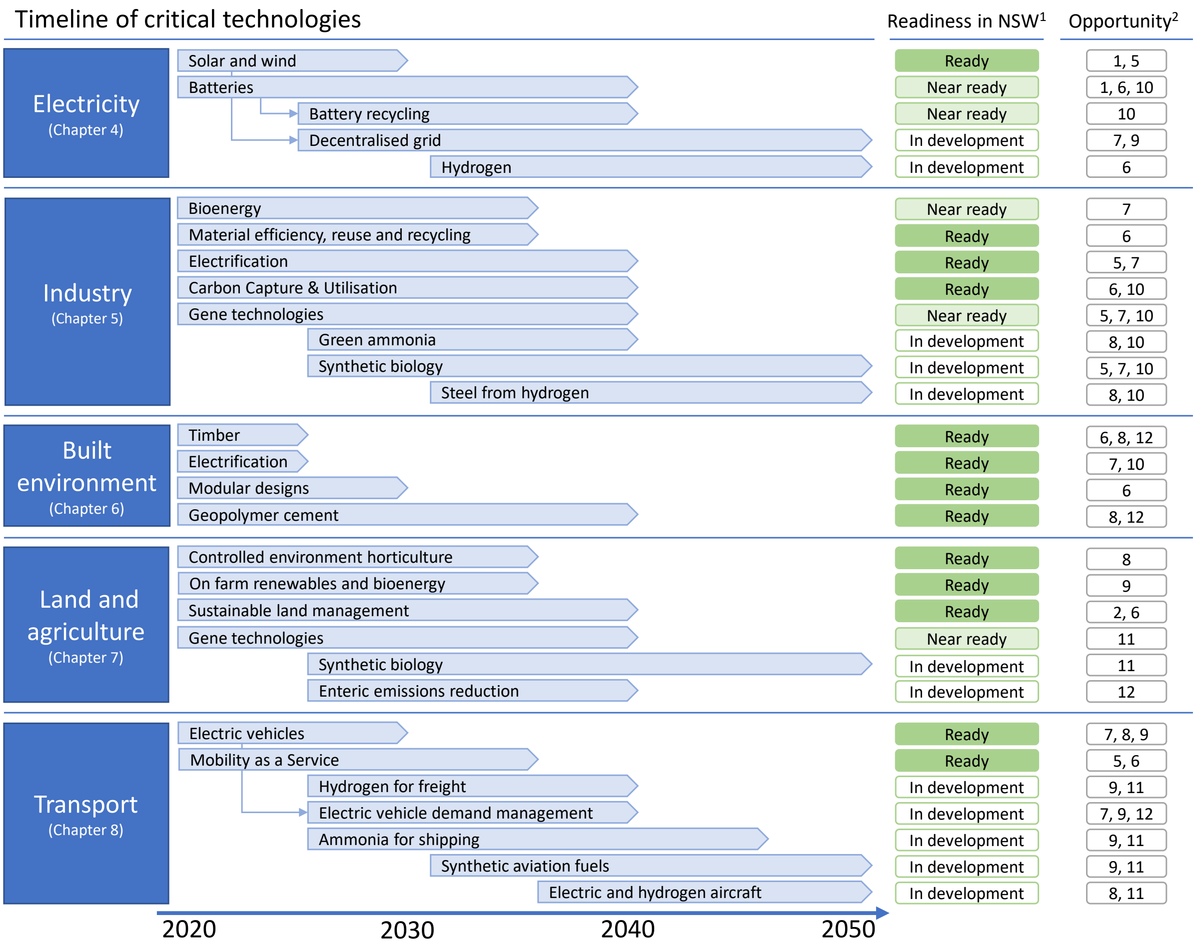

Figure 1: Timeline of critical technologies underpinning the economic opportunities identified in the report

Note 1: 'Readiness in NSW' refers to NSW's capability and preparedness to deploy the technologies.

Note 2: 'Opportunity' refers to the economic opportunities within each sector that will leverage this technology.

Further detail on the technical and commercial readiness, cost-competitiveness, interdependences and deployment timeframe of these critical technologies and some other decarbonisation technologies is at Appendix 3. This analysis is based on an extensive literature review and targeted consultations, and can be read alongside the Australian Government's Technology Investment Roadmap and the Low Emissions Technology Statements (yet to be released), which articulate the

Australian Government's decarbonisation technology priorities.[18] A summary of NSW's research and development capabilities that are relevant to the economic opportunities and critical technologies is at Appendix 4.

2.5 Common themes

A number of common themes arise across the economic opportunities identified.

2.5.1 Critical sectors and technologies can enable economy-wide opportunities

The most significant opportunities are generally interdependent. Transformation of critical sectors, in particular energy, can enable decarbonisation across the economy and grow new industries. For example, the energy system will transition as coal power stations reach the end of their technical life, with low cost renewable energy sources (firmed with storage for reliability and with ancillary services to ensure security) becoming an increasingly large component of the generation profile of the NSW grid and the National Electricity Market (NEM).[19]

This low cost and low emissions energy provides new opportunities to grow industries may have been uneconomic due to energy prices. A large land mass, attractive solar and wind profiles and a substantial mining and manufacturing industrial base also gives NSW a competitive advantage in generating renewable energy for use, storage, or export in the form of energy carriers (e.g. hydrogen), or as energy embedded in energy-intensive products (e.g. chemicals and metals). This could lead to significant industry development and jobs opportunities across NSW. It would also contribute to growth in the electricity sector, providing more jobs in industries related to energy generation, distribution and storage.

2.5.2 Opportunities rely on understanding and valuing new technologies and services

The extent to which NSW is able to successfully capture potential economic opportunities from technologies and services that address decarbonisation, depends upon governments, businesses and consumers, valuing decarbonisation and recognising the economic imperatives of adopting and building markets for decarbonised technologies and services.

If NSW businesses, consumers and government recognise the inherent and increased value of decarbonised products and services due to their environmental and social benefits, this will accelerate the uptake of new technologies and services, incentivise industries and governments to decarbonise, and open new economic opportunities. Failure to recognise this increased value could lead to missed economic opportunities. Accordingly, there is a role for businesses and governments to provide information to other businesses and consumers to assist them to make informed decisions in the market, as well as to promote these technologies and services and the opportunities they present for the NSW economy and individual consumers.

Many stakeholders consulted emphasised that businesses, consumers and governments should also be encouraged to consider the sustainability of the full lifecycle of the products they purchase. Responsible local businesses, particularly in resources and manufacturing industries, operate in a stricter regulatory environment compared to some overseas jurisdictions – with greater regard given to ensuring positive social and environmental impacts. Clear market signals from businesses, consumers and governments that sustainability is valued will encourage international manufacturers to raise their supply chain standards, making local production of many products more cost competitive, and helping to attract more investment to NSW.

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[18] Department of Industry, Science, Energy and Resources (Australian Government), 2020, *Technology Roadmap Discussion Paper*.
[19] AEMO, 2020, *Final 2020 Integrated System Plan*.

2.5.3 Government leadership can drive opportunities

During consultations many stakeholders emphasised the important leadership role of government in realising the economic opportunities of decarbonisation, accelerating technologies development and deployment, and building climate resilience. Government is a critical customer that can accelerate demand for sustainable or decarbonised products and services through procurement. For example, through leasing of buildings and cars, and purchase of consumables, technology, and digital and professional services. This purchasing power can grow markets – driving down prices through economies of scale. For example, some stakeholders raised the issue of electric vehicles (EVs), where government procurement would assist in growing the primary and secondary EV market, and infrastructure, where government procurement of sustainable designs and materials would support the sustainable building industry.

Procurement is also an effective driver of local industry development. Some stakeholders consulted identified that in addition to value for money, procurement processes across government should also recognise small, medium and large companies that invest decarbonised production facilities, supply chains and jobs in NSW. Further, some stakeholders identified the important roles of government to invest in research and accelerate commercialisation of new technologies; developing policy and regulatory frameworks to encourage decarbonisation and climate adaptation; educating and promoting decarbonisation and climate resilience; and investing in sustainable and resilient infrastructure.

2.5.4 International developments impact local opportunities

Many of the economic opportunities identified rely on NSW having access to international markets and supply chains. This presents both risks and opportunities. As global markets and international standards for decarbonised products and services expand, it is important that NSW leverages its advantages to maintain its competitive position in growing markets. This could support existing major export industries, open up significant new opportunities in decarbonised products and services, and assist our trading partners to decarbonise. For example, NSW could leverage large low cost renewable energy resources of solar and wind to grow new export industries in 'green' chemicals and metals, including exporting these products to countries with less favourable renewable energy conditions.

Conversely, NSW's emissions-intensive exports are exposed to trade and carbon risks arising from international businesses transitioning to sustainable feedstocks in their supply chains, and international investors divesting from carbon intensive industries and economies. For example, Apple has committed to make its entire business, manufacturing supply chain and product life cycle carbon neutral by 2030,[20] and Microsoft has committed to become carbon negative by 2030 and remove all its historical carbon emissions by 2050.[21] To date, over 900 major global corporations have joined the Science Based Targets initiative, which helps companies set targets that are consistent with the goals of the Paris Agreement.[22] Further trade risks include international trading partners potentially imposing carbon penalties on imports. For example, the European Council, representing the heads of state or government of all European Union countries, has agreed that the

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[20] Apple, *Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030*, accessed 27 July 2020, https://www.apple.com/newsroom/2020/07/apple-commits-to-be-100-percent-carbon-neutral-for-its-supply-chain-and-products-by-2030.

[21] Microsoft, *Microsoft will be carbon negative by 2030*, accessed 27 July 2020, https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030.

[22] Science Based Targets initiative, *Companies taking action*, accessed 27 July 2020, https://sciencebasedtargets.org/companies-taking-action.

European Commission "will put forward … proposals on a carbon border adjustment mechanism … with a view to their introduction at the latest by 1 January 2023."[23]

2.5.5 Co-location can facilitate collaborative opportunities

Some of the economic opportunities arise from inter- and intra-industry collaboration. Initiatives such as the Renewable Energy Zones (REZs),[24] the Special Activation Precincts (SAPs),[25] and the Western Sydney Aerotropolis[26] have the potential to co-locate businesses that can realise mutual economic benefits from decarbonisation. For example:

- The REZs will enable large-scale renewable energy generation and storage projects, which could attract new energy-intensive industries to regional areas seeking low cost and reliable electricity.
- The SAPs are regional industrial hubs that will facilitate collaborative approaches to decarbonisation and economic development.[27] For example, the Parkes SAP will be Australia's first United Nations Industrial Development Organisation 'Eco-Industrial Park' embedding the principles of circular economy and sustainability in the precinct.[28] The precinct is looking to attract investment and businesses in renewable energy, freight and logistics, value-added agriculture, and resource recovery and reuse.[29]
- The Western Sydney Aerotropolis and the Wagga SAP have considerations around sustainability through energy, waste and water management synergies and low-carbon approaches to transport and infrastructure embedded in the planning process.[30,31]

These place-based initiatives provide opportunities to pilot and scale new and emerging decarbonisation and climate adaptation technologies, including those that rely on businesses sharing equipment, and reusing and recycling energy, heat, water and materials to improve productivity.

2.5.6 Skills and training in decarbonisation and climate adaptation

Decarbonisation and climate adaptation present emerging and new job opportunities in new technologies and services. For example, a hydrogen industry, the renewable energy sector, the acceleration of sustainable housing, and a local and export industry in energy efficiency services and products could create thousands of new jobs in Australia.[32,33,34,35] Substantial future job opportunities exist across the whole economy, including in agriculture, land management, industrial

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[23] European Council, 2020, Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020) – Conclusions.
[24] The Renewable Energy Zones are areas that strategically coordinate the development of new grid infrastructure and generation in energy rich areas to efficiently connect multiple generators to the NEM.
[25] The Special Activation Precincts are regional areas designed by the NSW Government to become business hubs in line with the competitive advantages and economic strengths of the area. SAPs have streamlined planning and targeted investment to activate significant economic development in the area.
[26] The Western Sydney Aerotropolis is a planned high-skilled jobs hub around the Western Sydney International (Nancy-Bird Walton) Airport, specialising in aerospace and defence, manufacturing, healthcare, freight and logistics, agribusiness, education and research industries.
[27] NSW Government, 2020, *Special Activation Precincts*, accessed 21 July 2020, https://www.nsw.gov.au/snowy-hydro-legacy-fund/special-activation-precincts.
[28] Department of Planning, Industry and Environment (NSW Government), 2020, *Parkes Special Activation Precinct Master Plan.*
[29] NSW Government, 2020, *Parkes Special Activation Precinct*, accessed 21 July 2020, https://www.nsw.gov.au/snowy-hydro-legacy-fund/special-activation-precincts/parkes-special-activation-precinct.
[30] Regional Growth NSW Development Corporation (NSW Government), 2019, *Special Activation Precincts Supercharging Regional Economies through Innovative Planning*.
[31] Department of Planning, Industry and Environment (NSW Government), 2019, *Western Sydney Aerotropolis Plan*.
[32] COAG Energy Council, 2019, Australia's National Hydrogen Strategy.
[33] Clean Energy Council, 2020, *Clean Energy at Work*.
[34] Australian Sustainable Built Environment Council, 2020, *Tomorrow's Homes: A policy framework to transition to sustainable homes for all Australians*.
[35] Energy Efficiency Council, 2016, *Australian Energy Efficiency Policy Handbook*.

processing and advanced manufacturing. Under some transition scenarios, these job growth projections are even higher.[36]

These job opportunities require a broad set of new skills for decarbonisation and climate adaptation across a range of professions. Students need to understand the impact of decarbonisation and climate change adaptation on their sector, and have the skills necessary to implement solutions in theory and practice. Many of these skills build on existing workforce capabilities. This presents an opportunity to reskill existing workers and upskill existing workforces in related industries. For example, there are opportunities to upskill existing workforces in the gas and petroleum industries in hydrogen technologies, and workforces in vehicle maintenance and servicing in EV technologies. Sector-specific skills and training opportunities are discussed in opportunities under each sector (Chapters 3 to 8). Training packages already exist for some decarbonisation skills, such as courses in solar design9 and installation, and carbon farming. Decarbonisation and climate adaptation will require further training needs, and coordination between industry, the education sector and government in responding to these needs.

The NSW education sector works within a national system where training packages are developed through consultation with industry, to match qualifications and the supply of skills with demand. Industry has an important role in training. Industry bodies and businesses need to be proactive in forecasting what decarbonisation and climate adaptation skills may be required in all parts of their business (including technology, management, strategy, compliance and communications) and communicating these requirements to government. This includes specifically through Skills Service Organisations that support Industry Reference Committees in the development and review of training packages, as well as the NSW Industry Training Advisory Bodies and the NSW Skills Board. Further, businesses need to be proactive in ensuring their current and future employees have internal or external training opportunities to upskill in these areas. For example, through internal training, accredited external training, and internships and cadetships, or blended models such as the NSW Tertiary Pathways Project and the new STEM-focused multiversity and Advanced Manufacturing Research Facility being developed at the Western Sydney Aerotropolis.[37]

To meet these job and skills needs, students will need to see attractive education and career pathways in decarbonisation and climate adaptation. Incentives, such as through the Smart and Skilled Program which provides subsidised government courses and training where there is strong evidence of current or future industry training needs, can assist in attracting students to high quality programs. In addition, education and training is an existing major export industry, and developing high quality programs in emerging growth sectors related to decarbonisation and climate resilience could revitalise high value education exports.

2.5.7 Circular economy and reuse of resources

There is growing international recognition of the economic opportunities and emissions reduction potential of circular economies, including the reuse of materials, heat, and by-products.[38,39,40] For example, one company's waste materials, water, heat and emissions (including carbon dioxide) are potentially another company's feedstock. Designing out waste and embedding circular economy principles in the development of technologies for decarbonisation and climate change will create

[36] Beyond Zero Emissions, 2020, *Million Jobs Plan Briefing Paper 1*.
[37] The proposed model for the multiversity and Advanced Manufacturing Research Facility at the Western Sydney Aerotropolis integrates higher education, VET and industry training.
[38] Ellen MacArthur Foundation, 2019, *Completing the Picture: How the Circular Economy Tackles Climate Change*.
[39] Ecologic, 2020, *Decarbonisation Benefits of Sectoral Circular Economy Actions* (for European Environment Agency).
[40] ARUP, 2020, *Waste: What future do we want?*

new markets.[41] A circular economy values resources by designing out waste and pollution, substituting materials, and keeping products and materials in use for as long as possible. It contributes to innovation, growth and job creation, while reducing negative impacts on the environment.

The NSW Government is developing a 20-Year Waste Strategy to improve the state's approach to waste and resource recovery. This includes partnering with industry, local government and communities to create supply chains and markets for sustainably designed and recycled materials, adding value through recovery and re-manufacture of higher quality materials, eliminating avoidable waste and managing residual waste safely for the benefit of the environment and human health.

This report also identifies economic opportunities associated with circular economy, reuse and recycling, for example:

- End-of-life EV batteries for energy storage to support the grid,
- Wastewater and waste biomass to produce biomethane,
- Recycled wastewater as an input into other processes (e.g. hydrogen production, controlled environmental horticulture),
- Waste heat to augment heating in industry,
- Industrial by-products such as fly ash and blast furnace slag to replace cement in concrete,
- Recycling concrete and asphalt for new construction.

Maximising value from materials, waste, by-products and outputs will need to address current barriers to adoption including policy and regulatory issues and community acceptance. For example, recycled water is currently being used in some industrial and agricultural settings including cooling towers, boilers and on farms and gardens including for produce.[42] Current technology for recycling water can also deliver water of potable quality, but its uptake is low in Australia compared to other countries, largely due to community acceptance.[43]

2.5.8 Implications of COVID-19 for decarbonisation and climate resilience

On 11 March 2020 the World Health Organisation declared the novel coronavirus, COVID-19, as a global pandemic. COVID-19 is causing major economic disruption. In June 2020, the International Monetary Fund (IMF) estimated that Australia would experience a 4.5 per cent decrease in GDP in 2020, with growth of 4.0 per cent in 2021 partially compensating for this loss.[44] However, the impacts of COVID-19 will remain uncertain in the short term, with the potential to escalate in intensity and scale. In response, governments have announced large fiscal stimulus to offset worse economic impacts.

Large scale stimulus provides an opportunity to direct investment into economic development and employment initiatives that align with the transition to a low carbon economy. International organisations, such as the IMF and the International Energy Agency (IEA), are recommending that governments and policymakers consider decarbonisation and sustainability as part of their stimulus.[45] Considering decarbonisation and building climate resilience in stimulus would also support the long term value of those investments – critical to maximise the economic benefits of the

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[41] The NSW Government has established NSW Circular (https://www.nswcircular.org), an innovation network to support the transition to a Circular Economy.

[42] Sydney Water, *Using recycled water*, accessed 21 July 2020, https://www.sydneywater.com.au/SW/water-the-environment/what-we-re-doing/recycling-and-reuse/using-recycled-water/index.htm.

[43] Radcliffe, J.C. and Page, D. 2020, *Water reuse and recycling in Australia – history, current situation and future perspectives*, Water Cycle, Volume 1, Pages 19-40.

[44] International Monetary Fund, 2020, *World Economic Outlook Update (June 2020).*

[45] International Energy Agency, 2020, *Sustainable Recovery*.

stimulus. The European Union, as well as Germany and other European national countries, have made green investments a central part of their recovery plans and investment commitments.[46]

In NSW, targeted public and private investments in fast tracked projects could provide economic and employment opportunities while accelerating the transition to a more productive, economically competitive, decarbonised and resilient economy.[47] For example, accelerated REZ development could address structural issues faced by the grid, and bring more low cost renewable energy to the market – ensuring reliable and affordable power supply for households and businesses under economic pressure from COVID-19, and industries seeking to grow as the economic impacts subside.

To assist with the COVID-19 response, The NSW Government has announced a COVID-19 Recovery Plan which focuses on:[48]

- Investing in a substantial infrastructure pipeline,
- Undertaking planning reforms and investing in precincts (including the Western Sydney Aerotropolis and the SAPs),[49]
- Improving education and skills,
- Increasing digitisation,
- Growing advanced manufacturing and local supply chains, and
- Reforming federal-state relations.

In addition to a range of emergency financial relief measures for individuals and businesses, the Australian Government response includes fast-tracked funding for several large infrastructure projects,[50] including the Sydney Metro – Western Sydney Airport link,[51] as well as financial support for some specific industries, such as the construction,[52] transport and freight industries.[53]

COVID-19 has also had a disruptive impact on global supply chains for a wide variety of manufactured goods. Adoption of decarbonisation technologies and services in NSW is sensitive to these global supply chains. This creates impetus for governments and businesses to consider their industrial capabilities. Governments need to assess if sufficient local manufacturing capabilities exist to manage risks to international trade and supply chains, and invest in building local capabilities where necessary to manage those risks. Individual businesses need to assess their global footprint, improve supply chain transparency and build flexibility and resiliency in their operations.[54]

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[46] European Council, 2020, *Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020) – Conclusions*.
[47] WWF, *Securing Australia's Future: Renewable Recovery from COVID-19*, accessed 21 July 2020, https://www.wwf.org.au/what-we-do/climate/renewables/renewable-export-covid-19-recovery-package#gs.ard5yv.
[48] NSW Government, 2020, *COVID-19 Recovery Plan.*
[49] The NSW Government has established a Planning System Acceleration Program to support the creation of jobs and channel investment into the local economy by bringing forward projects already in the planning system. It specifies jobs, timing and public benefit as its three essential criteria for fast-tracked approvals. Projects brought forward under Tranche One of assessments include the Snowy 2.0 main works, the Powering Sydney's Future project and over 4000 residential dwellings. Department of Planning, Industry and Environment (NSW Government), *Fast-tracked assessments: Tranche One projects, 21 May 2020*.
[50] Infrastructure Magazine, *'PM commits $1.5n to fast-track 15 major* projects', 15 June 2020, accessed 3 August 2020, https://infrastructuremagazine.com.au/2020/06/15/pm-commits-1-5-billion-to-infrastructure-including-fast-tracking-15-major-projects/.
[51] Prime Minister, Premier of New South Wales, Minister for Population, Minister for Population Cities and Urban Infrastructure, NSW Minister for Investment, Tourism and Western Sydney, NSW Minister for Transport and Roads, *New agreement keeps Sydney Metro (Western Sydney Airport) JobMaker project on-track*, 2 June 2020, accessed 3 August 2020, https://www.pm.gov.au/media/new-agreement-keeps-sydney-metro-western-sydney-airport-jobmaker-project-track.
[52] The Treasury (Australian Government), *HomeBuilder*, accessed 3 August 2020, https://treasury.gov.au/coronavirus/homebuilder.
[53] The Treasury (Australian Government), *Severely affected regions and sectors – COVID-19 Relief and Recovery Fund*, accessed 3 August 2020, https://treasury.gov.au/coronavirus/businesses/sectors-and-regions.
[54] McKinsey & Company, *Reckoning with supply-chain disruptions from COVID-19,* accessed 30 July 2020, https://www.mckinsey.com/about-us/covid-response-center/leadership-mindsets/podcasts/reckoning-with-supply-chain-disruptions-from-covid-19.

2.6 Structure of the report

The following Chapters 3 to 8 provide further analysis of each of the economic opportunities presented in the sector diagrams. To assist the NSW Government in moving forward on these opportunities, this report provides a set of ‘next steps’ to realise many of these opportunities. For other business, investor and community stakeholders, this report provides guidance as to the potential economic opportunities that they could choose to focus on and how to go about this.

3. Services: Global services powerhouse

The economic transformations of decarbonisation and climate resilience will require significant investment. Public investment has an important role. For example, the NSW and Commonwealth governments have committed over $2 billion in investment in energy and emissions reduction infrastructure and technologies through the Memorandum of Understanding for the NSW Energy Package.[55] However, public investment is only part of the picture, and as with other economies, this transformation to successfully decarbonise the NSW economy is reliant on private investment to drive future growth in industry and infrastructure.

International capital markets are increasingly valuing decarbonisation and climate change resilience in investment decisions. How the finance sector prices and directs capital to particular industries and activities across the economy, and manages risk are significant determinants of the pace and costs of decarbonisation and the realisation of future economic growth in a globalised market where many countries and sectors are decarbonising.[56] Access to this sustainable private capital will be increasingly conditional on businesses and governments implementing policies, strategies and technologies to reduce climate risk through decarbonisation and climate resilience.[57]

Attracting this sustainable private capital can fund growth, decarbonisation and climate change resilience of NSW businesses and public infrastructure. This presents economic opportunities for NSW to provide the sustainable finance services necessary to attract this capital, direct it towards promising local and international sustainable industries and infrastructure, and provide the professional services to manage these investments. Sydney is already Australia's dominant financial centre and a financial services hub in the Asia-Pacific region. Leveraging this advantage and existing capabilities in sustainable finance would strengthen our competitive advantage to capture more of the global market for sustainable finance.

In response to the growth in sustainable finance, the NSW Government has committed to develop a Green Investment Strategy, with the aims of: [58]

- Diversifying revenue and funding to support public environmental outcomes,
- Building and stewarding markets to grow our environmental goods and services sector,
- Mobilising new partnerships to fund and deliver shared environmental values,
- Attracting new investors and help our economy align with global trends, and
- Establishing Sydney as a world leading carbon services hub by 2030.

The economic opportunities for NSW which arise in the services sector are discussed below.

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[55] NSW Government and Australian Government, 2020, *Memorandum of Understanding – NSW Energy Package*.
[56] De Hass, R. and Popov, A. '*Finance and decarbonisation: why equity markets do it better*', European Central Bank, Eurosystem, 27 November 2019, accessed 24 July 2020, https://www.ecb.europa.eu/pub/economic-research/resbull/2019/html/ecb.rb191127~79fa1d3b70.en.html.
[57] Task Force on Climate-related Financial Disclosures, 2019, *Task Force on Climate-related Financial Disclosure: Status Report*.
[58] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.

Prepare the market

3.1 Climate change risk management initiatives

1. Climate change risk management initiatives – increasing adoption of best practice climate change risk management by governments and businesses in NSW

Investors and financial regulators have identified that climate change presents risks and opportunities for investments in companies, industries, property, and infrastructure assets.[59,60] These risks include rising sea levels and increasing frequency, duration and intensity of extreme weather, changes in market demand for carbon intensive goods and services like fossil fuels and tourism, disruptive technology and skills transitions, and potential reputational risks. However, investors are also aware of the investment opportunities in growing markets, for example, EVs, decarbonised infrastructure and sustainable agriculture. Decision making that does not incorporate the risks and opportunities of climate change may lead to misdirected investment, vulnerable assets and future economic loss.

This presents an economic opportunity to encourage the widespread adoption of climate change risk management initiatives by the NSW Government and businesses to ensure public and private investment decisions consider the risks of climate change and opportunities of decarbonisation and climate resilience. Investors are already moving towards 'sustainable finance' – financial services that consider ESG reporting as an important factor during the investment process. Sustainable investments under management in Australia were $980 billion in 2018, representing 44 per cent of professionally managed assets in Australia.[61,62]

ESG reporting frameworks improve investment practice and reduce systemic future risks.[63] The results are a reorientation of businesses' efforts and investments to solutions, products and processes that have fewer emissions. Further, ESG reporting frameworks provide secondary benefits in meeting shareholder needs for reporting, improving organisational resilience and meeting community expectations.[64] In Australia, the Australian Securities and Investments Commission, Australian Prudential Regulation Authority and the Reserve Bank of Australia have encouraged adoption of these frameworks, for example, the Task Force on Climate Related Disclosures.[65]

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[59] Investor Group on Climate Change, 2019, *IGCC Policy Update: Climate Risk and Fiduciary Duties*.
[60] Network for Greening the Financial System, 2020, *NGFS Climate Scenarios for Central Banks and Supervisors*.
[61] Responsible Investment Association Australasia, 2019, *Responsible Investment Benchmark Report: 2019 Australia*.
[62] This is also reflected in the growth of financial institutions specifically focused on climate change solutions (for example green banks or green funds, in Australia the Australian Renewable Energy Agency (ARENA) and Clean Energy Finance Corporation (CEFC)), and climate finance instruments (for example 'green' or 'climate' bonds and loans).
[63] To date, most industry and investor action has been voluntary. However, these activities are now starting to be formalised in regulatory frameworks, systems and standards for sustainable finance and managing climate risks. Norton Rose Fulbright, 2019, *Global and EU sustainable finance initiatives*.
[64] There are multiple ESG frameworks, including the recommendation of the Task Force on Climate-related Financial Disclosures (TCFD). The TCFD recommendations assist companies and other organisations to make effective climate-related financial disclosures – focusing on transparency on governance, strategies and risk management. Implementation of the TCFD varies globally and has been mostly driven by the private sector. ASIC, APRA and the RBA have supported the TCFD. Australian Security & Investments Commission, 2018, *Climate Change: Check Against Delivery, Keynote address by John Price, Commissioner, Australian Securities and Investment Commission, Centre for Policy Development: Financing a Sustainable Economy Sydney, Australia,* accessed 24 July 2020, https://asic.gov.au/about-asic/news-centre/speeches/climate-change/.
[65] Australian Security & Investments Commission, 2018, *Climate Change: Check Against Delivery, Keynote address by John Price, Commissioner, Australian Securities and Investment Commission, Centre for Policy Development: Financing a Sustainable Economy Sydney*, Australia, accessed 24 July 2020, https://asic.gov.au/about-asic/news-centre/speeches/climate-change/.

The broader impact of sustainability being incorporated into risk-planning and business strategy, is that the finance industry will increasingly direct capital into businesses developing technologies, products, services and infrastructure that are viable in a decarbonised economy and resilient to the effects of climate change.[66] NSW businesses that respond to these trends in investor expectations can attract this increasing pool of sustainable capital. These capital flows present whole-of-economy productivity and growth opportunities for NSW: to finance development and deployment of new high value technologies and services, to transition and grow future advanced industries, and to build new decarbonised, resilient and efficient infrastructure. This in turn also creates substantial opportunities for NSW's services industry to provide the skills, tools and advice to realise these opportunities.

Finance sector stakeholders consulted indicated that government has an important role in encouraging and supporting NSW businesses to adopt these reporting requirements and investment protocols. This could include supporting knowledge and data sharing amongst businesses and investors, development of benchmarks and taxonomies to validate decarbonisation and climate resilience performance, and market transparency to improve decision making. For example, clarity over the trajectory of future regulation assists businesses in investment decision making, reducing perverse incentives such as delaying investment decisions in the face of uncertainty.

As a major investor, NSW Government also has a role as participant in sustainable finance markets. For example, NSW Government could accelerate adoption of best practice climate risk disclosures in its financing and management of all public assets. This would help to preserve the long term value of those assets, while also growing the NSW sustainable finance sector. Importantly, as these markets are global, NSW should seek to align with international approaches, as this improves the consistency and efficacy of approaches used to attract international sustainable capital.

Next steps:

- In developing the Green Investment Strategy, consider initiatives to:
    - Improve knowledge and data sharing amongst businesses and investors,
    - Create benchmarks and taxonomies to validate decarbonisation and climate adaptation performance,
    - Improve market transparency with respect to sustainability, and
    - Make the NSW Government a major customer of sustainable finance services.
- NSW Government adopts best practice climate risk disclosures in financing and management across all public assets.
- When undertaking climate risk management, seek to align with international standards, for example, the Taskforce on Climate-related Financial Disclosures.
- To assist businesses investing in long life assets, the NSW Government seeks to provide direction, at a high level, on decarbonisation pathways from 2030 to 2050.

[66] Task Force on Climate-related Financial Disclosures, 2017, *Recommendations of the Task Force on Climate-related Financial Disclosure: Final Report*.

3.2 Carbon, resilience and sustainability services

2. Carbon, resilience and sustainability services – growing the pool of decarbonisation and climate resilience expertise available to NSW Government and businesses

Businesses and governments will need access to a wide range of expertise to help design and implement decarbonisation and climate resilience plans. This expertise will often need to be sourced from outside the organisation, being new knowledge on practices not currently used. Businesses will be seeking to decarbonise a range of processes and assets, including office facilities, fleet, distribution channels, production lines, feedstocks or other systems. This will require services, from what is currently a small pool of qualified experts and advisory businesses. The growing need will require a similarly growing pool of experienced people available to provide this expert advice.

Growing access to appropriately skilled and equipped experts presents economic opportunities not only for growth in this sector of the services industry but, importantly, for the growth of client businesses – to realise spill-over benefits and growth opportunities from de-risking those businesses from future climate impacts on their staff, supply chains, assets, share prices or cost structures.

A number of short and medium-term avenues to realise this opportunity are available. Much of this capability could be delivered by growing the existing advisory services sector. In the short term, expertise and capabilities within universities and other organisations such as CSIRO could also be leveraged to provide advice to businesses on best practice and implementable approaches for decarbonisation and climate resilience. This could be provided through various channels, including direct assistance and advice, spin out companies, and collaborative partnerships such as research consortia. In a rapidly growing sector, sharing of skills and market insights is important, to ensure that clients receive advice based on the most practical, cost-effective and reliable technology and systems to meet future needs.

Next steps:

- The NSW Government works with NSW universities to promote collaboration between businesses and universities to expand the pool of expertise in decarbonisation and climate adaptation available to the private and public sectors.

3.3 Establish Sydney as a major global sustainable finance hub

3. Establish Sydney as a major global sustainable finance hub

Investment trends in sustainable finance present an opportunity for NSW to establish Sydney as a major global sustainable finance hub, attracting significant inbound and outbound capital flows. Major capital investment is in demand globally to fund decarbonisation and climate resilience in the public and private sectors.[67] This demand is also accompanied by demand for investment to enable growth in our region. In Asia, investment of US$1.7 trillion per year to 2030 is necessary to enable continued growth, poverty reduction and for climate change solutions.[68]

This presents an economic opportunity for NSW to capture more of a growing and sustainability-orientated investment market. Financial and insurance services are already NSW's largest industry, contributing over $70 billion and 200,000 jobs to the NSW economy in 2019.[69,70] NSW could grow this industry further – positioning Sydney as a leading regional and global sustainable finance hub – by leveraging its competitive advantages in:

- **Sydney being a major global financial centre in Asia** – for example, Sydney is ranked as 10th on the Z/Yen Global Financial Centres Index 26, scoring particularly high in factors such as depth and breadth of industry clusters, the availability of capital and market liquidity, and physical and digital infrastructure,[71]
- **Deep capital markets** – for example, Australia has the third largest pool of funds under management in the world, and the largest in Asia.[72] Australian superannuation funds invest more than $2.9 trillion in assets as at June 2019,[73]
- **Large number of major financial institutions** – for example, Sydney is home to the Australian Securities Exchange, along with the headquarters of most foreign banks with a presence in Australia and many of Australia's largest fund managers,
- **Best practice in investment management practices and standards** – for example sustainable investment representing 44 per cent of professionally managed assets in Australia,[74] and 83 per cent of green bonds issued in Australia are certified under the Climate Bonds Standard, a leading share globally,[75]

[67] Climate finance is expressly encouraged under the Paris Agreement and the European Union estimates that investment of €180 billion per year is necessary to meet its Paris Agreement targets. European Commission, *What is sustainable finance*, accessed 27 July 2020, https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/what-sustainable-finance_en.
[68] Asian Development Bank, 2017, *Meeting Asia's Infrastructure Needs*.
[69] Australian Bureau of Statistics, 2019, *Australian National Accounts: National income, expenditure and product, Sep 2019*, cat. no. 5206.0, accessed 22 June 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Sep%202019?OpenDocument.
70 Australian Bureau of Statistics, 2020, Labour Force, Australian Detailed Feb 2020, cat no. 6291.0.55.003 accessed 24 July 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6291.0.55.003Feb%202020?OpenDocument.
[71] Financial Centre Futures, 2019, *The Global Financial Centres Index 26*.
[72] Department of Planning, Industry and Environment (NSW Government), 2014, *'Chinese banks choose NSW'*, accessed 20 December 2019, https://www.industry.nsw.gov.au/development/why-sydney-and-nsw/invest-case-studies/chinese-banks-choose-nsw.
[73] Investor Group on Climate Change, 2019, *IGCC Policy Update: Climate risk and fiduciary duties*.
[74] Responsible Investment Association Australasia, 2019, *Responsible Investment Benchmark Report: 2019 Australia*.
[75] Climate Bonds Initiative, 2019, *Green Finance State of the Market 2019 – Australia*.

- **Strength in financial and regulation technology ('fintech' and 'regtech')** – for example, Australia has been identified as an "up and coming" fintech hub with a high level of collaboration,[76] and Sydney is home to the Sydney Startup Hub,
- **Strength in professional services, in particular environmental services necessary to accredit, manage and operate these investments** – for example NSW has demonstrated strength in environmental services, including applying energy rating schemes such as the Building Sustainability Index (BASIX), Green Star and the National Australian Built Environment Rating Scheme (NABERS).[77]

A strong sustainable finance industry would also have tangential benefits for related professional, scientific and technical services industries in providing the analytics and certification tools, services and standards, and strategies to support investors and businesses to assess and manage the sustainability of their portfolios and operations. Professional, scientific and technical services contributed over $50 billion and 400,000 jobs to the NSW economy in 2019[78]

Investors and industry have recognised this opportunity and in 2019, established the Australian Sustainable Finance Initiative (ASFI) to recommend policies and frameworks to ensure the financial sector effectively contributes to ESG goals,[79] including by increasing capital investment into addressing climate change solutions. ASFI is currently consulting with stakeholders and expects to deliver a report in 2020.[80]

The development of Sydney as a preeminent regional and global financial hub is also well aligned with Australia's foreign policy objectives for foreign investment, in particular the Pacific Step-up and the Australian Infrastructure Financing Facility for the Pacific.[81]

Next steps:

- In developing the Green Investment Strategy, consider initiatives to:
    - Promote NSW's capabilities in sustainable finance internationally,
    - Increase the number of domestic and foreign companies and funds in NSW that adopt ESG principles.

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[76] EY, 2016, *UK FinTech: On the cutting edge, an evaluation of the International FinTech sector*.
[77] Johnson, P, '*Green building ratings are part of the drivers for Australia's green bonds*', The Fifth Estate, 1 November 2018, accessed 24 July 2020, https://www.thefifthestate.com.au/business/finance/green-building-australias-green-bonds/.
[78] Australian Bureau of Statistics, 2019, *Australian National Accounts: National Income, Expenditure and Product*, Sept 2019, cat. no. 5260.0, accessed 24 July 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Sep%202019?OpenDocument.
[79] Including ESG goals under the Paris Climate Agreement and the UN Sustainable Development Goals.
[80] Australian Sustainable Finance Initiative, *Developing an Australian Sustainable Finance Roadmap: Project Report*.
[81] Australian Government, 2017, *2017 Foreign Policy White Paper*.

4. Electricity: A distributed and low emission electricity system

The NEM is in transition, moving away from centralised systems built for fossil-fuel power generation towards a more decentralised and diverse generation mix dominated by renewable sources. This decarbonisation presents economic opportunities in low cost renewable generation, storage and grid technologies. The future distributed and low emission energy system will likely exhibit the following features:

Renewable-dominated generation supported by firming technologies

- Wind and solar are already the lowest cost new built power generation technologies on a Levelised Cost of Electricity (LCOE) basis and coupled with storage or other dispatchable technologies are cost-competitive with fossil fuels.[82]
- The Australian Energy Market Operator (AEMO) found that beyond 2025, wind and solar penetration over 75 per cent is readily achievable while maintaining operating security for the NEM, given certain targeted actions. Further, there could be periods where 90% of electricity is provided by variable renewable energy (VRE) such as wind and solar by 2035.[83] In the short term, the NSW Central-West Orana REZ Pilot is expected to bring an additional 3 GW of capacity to the NEM, which already has 11 GW of utility scale wind and solar generation.[84]
- However, high penetration of intermittent solar and wind requires firming technologies for dispatchable electricity. Depending on the rate of the change in the market, the NEM could need as much as 19 GW of new flexible, dispatchable resources, including utility scale storage, to firm up VRE.[85] Investors have signalled interest addressing these storage requirements largely through pumped hydro storage (PHS) and utility-scale batteries.[86]

Rapid uptake of Distributed Energy Resource (DER) and two-way energy market

- Australia has one of world's highest installation rates of distributed solar photovoltaics (PVs), with one in every five NSW households having rooftop solar panels. This distributed solar generation capacity could support uptake of other DERs including home batteries and EVs.
- AEMO modelling suggests that DER could contribute 13 to 22 per cent of NEM consumption by 2040.[87]
- Enabled by DER and digitalisation technologies, the two-way flows of energy will likely change the behaviours of energy consumers and offer financial benefits through energy self-sufficiency, efficiency, trading and demand management.

Decentralised, digitalised and smarter grids

- Geographically dispersed VRE and DER technologies will accelerate the deployment of microgrids to maximise local renewable energy. In some cases, these microgrids could defer the need for high cost upgrades to transmission and distribution infrastructure.
- Microgrids are particularly attractive for remote communities to improve their energy reliability and affordability, and to increase their resilience to extreme weather events by reducing reliance on long distance transmission lines.

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[82] CSIRO, 2019, *GenCost 2019-20: preliminary results for stakeholder review (draft for review)*.
[83] AEMO, 2020, *Final 2020 Integrated System Plan*.
[84] AEMO, *Generation Information*, accessed 21 July 2020, https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information#:~:text=This%20generation%20information%20page%20has,National%20Electricity%20Market%20(NEM).
[85] AEMO, 2020, *Final 2020 Integrated System Plan*.
[86] NSW Government, *Emerging Energy Program*, accessed 21 July 2020, https://energy.nsw.gov.au/renewables/clean-energy-initiatives/emerging-energy-program.
[87] AEMO, 2020, *Final 2020 Integrated System Plan*.

- Enabling-technologies such as Internet-of-Things (IoT) and artificial intelligence (AI) will enable future grids to become more digitally-connected, automated and more intelligent.

In addition, many of the economic opportunities to decarbonise other energy-intensive sectors of the economy will rely on a stable, low cost and low emissions electricity supply. For example, low cost and low emission electricity could improve the international cost-competitiveness of NSW in green hydrogen, aluminium, metal and chemical processing, mining and other energy-intensive industries.

The main challenge and opportunity for NSW is to bring more low cost renewable generation to the market, while ensuring the grid remains stable, reliable and resilient. This Chapter will discuss the economic opportunities that arise from a modern, distributed and low emission electricity system. The specific benefits of such a system for each sector are further detailed in Chapters 5 to 8.

Prepare the market

Prepare the Market | Deploy technologies | Accelerate

4.1 Renewable Energy Zones

1. Renewable Energy Zones – leveraging abundant low cost renewable energy in the Renewable Energy Zones to grow co-located regional industries, and increase the amount of low cost, firmed renewable energy available across NSW

The REZs are a model for future NEM planning and investment that coordinates renewable generation, energy storage, system security services and network infrastructure. The REZs will improve conditions for generators by reducing curtailment and network congestion risks.[88] The model will provide investment and operational certainty for generators and lower the total system cost of the NEM by optimising new generator and transmission investments. Lower overall transmission cost, and increased wholesale market competition through the introduction of low cost generation, will benefit energy consumers through lower prices.

The REZs are expected to deliver economic benefits for business and residential energy consumers. Low cost and reliable electricity provided by firmed renewable generation could attract regional investment to co-locate some energy-intensive industries in REZs, including minerals processing, data centres, controlled environment agriculture, manufacturing, metal and chemical processing, and potential future hydrogen production. This opportunity is discussed in further detail in Industry Opportunity 11 in Chapter 5. In addition, the planning and construction works for renewable generation and transmission infrastructure, as well as the other businesses clustered in the REZ, will support local businesses and provide opportunities for employment.

Three NSW REZs have been prioritised in the Central-West, New England and South-West regions, as part of the NSW Government's 2019 NSW Electricity Strategy.[89] These three NSW REZs are expected to attract $23 billion of private investment and 2,000 construction jobs each year. The deployment of these REZs would bring down electricity bills for NSW consumers, with estimated savings of $10 per household per year.[90] The NSW Electricity Strategy indicates that the NSW Government will support the development of the REZs with a range of actions, including possible transmission upgrades, ensuring regulatory changes to facilitate grid connection, and establishing a dedicated

[88] Department of Planning, Industry and Environment (NSW Government), *Renewable Energy Zones (factsheet)*, accessed 21 July 2020, https://energy.nsw.gov.au/media/1941/download.
[89] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed)*.
[90] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed)*.

government body to coordinate planning and investment. The NSW REZs are also supported by funding under the Memorandum of Understanding for the NSW Energy Package between the NSW Government and the Commonwealth.[91]

Development of the first 3 GW REZ pilot located in the Central-West Orana region is now underway for market engagement. AEMO's 2020 Integrated System Plan (ISP) notes that the transmission link required for the Central-West Orana REZ under the optimal development path would be delivered by the mid-2020s.[92] The first REZ presents opportunities for NSW to test and optimise the REZ delivery model, regulatory reforms, as well as various energy generation, storage, transmission and technologies. The 8 GW New England REZ has been announced and now is at early stages of planning.[93]

Next steps

- The NSW Government works with businesses and investors to identify and pursue opportunities to co-locate new and expanded energy-intensive industries in the REZs.

4.2 Future energy market design

2. Future energy market design – supporting the update of energy market rules and policies to increase investment in centralised and distributed renewable energy and storage, improve energy security and affordability, and increase consumer participation in the market

The basic framework for the NEM has remained relatively unchanged since the market was designed in the late 1990s. At present, the energy sector is experiencing a transition with significant change in the mix of generation technologies and patterns of energy consumption. The NEM has, at times, struggled to meet the expectations of supplying reliable, affordable and sustainable electricity with the current market design and rules. A direct result has been increasing electricity prices, where households have seen their bills rise by 56% in real terms over the last ten years in Australia, largely on account of higher network costs.[94] Market reforms could assist in managing the transition towards a low emissions electricity system and providing affordable and reliable electricity to consumers.

A future market design could incorporate efficient mechanisms to coordinate VRE generation and transmission investment to integrate large-scale renewables with improved investment certainty. The rapid pace of investment in renewables, driven by their low LCOEs, and the fact that some optimal locations for VRE are not close to existing network infrastructure raises challenges in efficiently connecting new generation and upgrading transmission. Further, the market needs to better reward firming services such as batteries (e.g. through faster settlements), to attract investment in those services.

Further improvements are needed in market design and pricing mechanisms to support the aggregation and integration of DER, and reflect the full value of small scale DER to the electricity system. A DER-enabled market design could encourage additional DER supply to the wholesale market, lower the costs of network services and provide system security services. Increased uptake of DER and actively engaged energy consumers could also support the emergence of innovative

[91] NSW Government and Australian Government, 2020, *Memorandum of Understanding – NSW Energy Package*.
[92] AEMO, 2020, Final 2020 Integrated System Plan.
[93] NSW Government, *Renewable Energy Zones-New England Renewable Energy Zone*, accessed 5 August 2020, https://energy.nsw.gov.au/renewables/renewable-energy-zones#-new-england-renewable-energy-zone-
[94] COAG Energy Council, 2019, *Energy Security Board Post 2025 Market Design (Issues Paper)*.

technologies, services and business models, for example new retail models like peer-to-peer trading.[95]

The Council of Australian Governments (COAG) Energy Council[96] tasked the Energy Security Board (ESB) with developing advice to government on a post-2025 market design for the NEM for a long term, fit-for-purpose market framework to enable a reliable lower emissions electricity system at lowest cost.[97] The ESB is progressing work to action AEMO's ISP, including to streamline regulatory processes for key projects identified in the ISP.[98] The NSW Government has committed to work with COAG Energy Council and the ESB to review the National Electricity Law and market rules to identify regulatory burdens that can be removed, streamlined or clarified. Further, the REZs present opportunities to trial new infrastructure investment mechanisms or regulatory changes.[99]

Next steps

- The NSW Government continues to work with NEM bodies and the National Cabinet Reform Committee for Energy to achieve NEM reform that encourages rapid and efficient investment in new low carbon and climate change resilient electricity infrastructure.

4.3 Government procurement

3. Government procurement – increasing government procurement of zero-emissions energy generation, storage and system security improvements

The NSW Government is one of the state's largest energy consumers, spending around $400 million on 1.8 TWh electricity per year (excluding electricity for transport).[100] This presents opportunities for the NSW Government to leverage its procurement power to increase the supply of firmed zero-emissions electricity. This could be achieved by direct procurement of firming renewable electricity through a Power Purchase Agreement (PPA) or other financial mechanisms. Entering long term contracts such as PPAs to purchase electricity directly from energy generators and suppliers will lock in agreed pricing over contract years and provide financial certainty to both government and investors. This approach enables NSW Government to support the growth in the financial viability of renewable energy projects and to send a demand signal to the market for low emissions electricity generation.

The NSW Government's current electricity retail contracts expire in June 2022. Under the new PPA, the NSW Government is seeking to combine the entire electricity load for schools, hospitals and all other state government facilities (except transportation).[101] NSW Government is undertaking assessment of an Expressions of Interest for a new contract for an integrated solution to deliver dispatchable electricity; with a total value of approximately $3.5 billion over the next 10 years.[102]

Many NSW local councils have also committed to ambitious renewable energy targets. Local government can develop renewable energy opportunities through PPAs and by installing solar PV

[95] COAG Energy Council, 2019, *Energy Security Board Post 2025 Market Design (Issues Paper)*.
[96] Note that the COAG Council has been replaced by a new National Federation Reform Council (NFRC) effective from 2 June 2020. Australian Government, *COAG becomes National Cabinet,* accessed 30 July 2020, https://www.pmc.gov.au/news-centre/government/coag-becomes-national-cabinet).
[97] COAG Energy Council, 2019, *Energy Security Board Post 2025 Market Design (Issues Paper).*
[98] COAG Energy Council, 2020, *Actionable ISP Final Rule Recommendation, accessed 11 August 2020*, http://www.coagenergycouncil.gov.au/publications/actionable-isp-final-rule-recommendation.
[99] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed).*
[100] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[101] Macdonald-Smith, A., 2019, '*NSW opens door to low-emissions power*', Financial Review, 22 Nov 2019, accessed 24 July 2020, https://www.afr.com/companies/energy/nsw-opens-door-to-low-emissions-power-20191122-p53d01.
[102] NSW Government, '*NSW Government Seeking Expressions of Interest for Retail Electricity Supply*', 20 November 2019, accessed 24 July 2020, https://www.treasury.nsw.gov.au/news/media-release-tudehope-kean-nsw-government-seeking-expressions-interest-its-retail-electricity.

across their properties. For example, the City of Sydney has concluded a PPA agreement, matching 75% of their electricity demand with a mixture of wind from the Sapphire Wind Farm and solar from the Bomen Solar Farm in NSW.[103] Solar PV is suited to many council operations with high daytime demand for electricity.[104]

NSW Government could also consider seeking PPAs with large-scale dispatchable renewable projects for major transport and infrastructure projects that are not included in the whole-of-government contract. This would further offset electricity emissions from the transport sector and support new renewable generation and storage in the state. This could continue the approach taken for the Sydney Metro Northwest railway which meets its operational electricity needs of 134,000 MWh per year through a PPA with the Beryl Solar Farm in central western NSW.[105] Another example is future desalination facilities which are energy-intensive and could also supply water for hydrogen production. At present, the Sydney Desalination Plant offsets its entire energy consumption through a renewable PPA.[106]

NSW Government manages approximately 15% of the state's landmass, much of which has high quality natural energy sources and potential to develop renewable and energy storage projects. There is opportunity for NSW Government to provide access to state-owned properties and assets for installation of rooftop solar PV, energy storage, EV charging and other emerging firming technologies. For example, there is significant solar potential in the NSW Government property portfolio.[107] The NSW NZP also proposes offering rooftops and other spaces on NSW Government for third parties to install solar PV systems.[108]

Next steps

- The NSW Government increases the amount of dispatchable and low emissions electricity it purchases from the grid (including through PPAs), and generates and stores on its own facilities.

4.4 Consumer education and engagement

4. Consumer education and engagement – improving consumer confidence in participating in energy markets

Education and engagement can assist consumers to access lower cost energy through DER, energy efficiency and demand management technologies. This can also provide benefits for energy service companies who can better engage with more informed customers to aggregate, manage and distribute DER-derived energy to the market.

NSW energy consumers are willing to adopt new energy technologies: NSW has a large uptake of solar PV, and of the households who do not have solar PV, 29 per cent say they intend to install it.[109] 30 per cent of NSW households without battery storage plan to purchase a system.[110] NSW households and small businesses are also generally confident in the future development of the energy market noting that there is still space to improve. For example, the proportion who think the

[103] Institute for Energy Economics and Financial Analysis, 2019, *Electricity Power Agreements in the Australian Corporate Market.*
[104] Department of Planning, Industry and Environment (NSW Government), 2019, *Northern NSW Renewable Energy Blueprint for Local Government Final Report.*
[105] NSW Government, *NSW Renewable Energy Action Plan – Implementation Summary 2013-2018*.
[106] Sydney Desalination Plant, '*How much carbon dioxide is emitted by the energy needed to power the plant at full production?*', accessed 5 August 2020, https://www.sydneydesal.com.au/faqs/#carbon
[107] Australian PV Institute, 2017, Spatial analysis of solar potential in Sydney.
[108] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[109] Energy Consumers Australia (Australian Government), 2019, *Energy Consumer Sentiment Survey December 2019*.
[110] Energy Consumers Australia (Australian Government), 2019, *Energy Consumer Sentiment Survey December 2019*.

overall market is working in the long term interests of consumers is increasing, but is still at a low base of 38%.[111]

The uptake of DER is shifting the balance of power in the energy sector towards consumers. However, with rapid changes in the energy market, consumers need trusted channels to deliver information and tools that they can rely on to manage their energy usage and reduce their energy costs. Well informed consumers could influence the success of emerging technologies and services by driving roll-out and capitalising on the potential cost benefits.

For example, the aggregation and management of distributed behind-the-meter assets is a feasible and economically compelling initiative, which could lower stress on the network and reduce costs for consumers. New business models for solar could also allow more customers, who may not own a rooftop solar system, to access the economic benefits of low cost solar PV.[112] However, these opportunities rely on better engagement and education programs for consumers so that they understand the impact of this technology on their energy use behaviours and potential economic benefits through lower energy prices. This information needs to be tailored for consumers with diverse levels of understanding, preferences, personal circumstances and lifestyles, and requirements for energy reliability and affordability. The Australian Energy Foundation has scoped a voluntary industry guideline to help households better manage their energy use and bills, with consumer-focused recommendations.[113] The NSW Government could work with industry bodies such as the Energy Charter to deliver industry guidelines to build trust and improve confidence in the energy market.[114]

The Power Shift Study commissioned by Energy Consumers Australia suggests that another barrier to the uptake of technologies to reduce energy costs for consumers is a lack of energy management services to connect and package these new technologies in a way that works for consumers. Improved consumer understanding would increase demand and support the growth of these firms, by expanding the supply of interested customers.[115]

Next steps

- The NSW Government works with organisations to develop consumer-facing energy audit tools that provide tailored, easily accessible and reliable information on the economic and environmental benefits of new energy technologies for individual households and businesses.
- The NSW Government provides up-to-date information on new electricity business models and opportunities for businesses and households.

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[111] Energy Consumers Australia (Australian Government), 2019, *Energy Consumer Sentiment Survey December 2019*.
[112] For example, models to overcome split-incentive situations between property owners and tenants, rooftop leasing arrangements and peer-to-peer trading.
[113] Energy Consumers Australia (Australian Government), 2019, *Scoping an Effective Voluntary Industry Guideline for Helping Households Manage Their Energy Usage and Bills*.
[114] Energy Charter is a charter signed up to by Australian energy companies to promote a customer centred approach to energy – affordability, safety, sustainability, reliability and customer experience. https://www.theenergycharter.com.au/
[115] Energy Consumers Australia (Australian Government), 2020, *Power Shift Final Report.*

4.5 Solar generation

5. Solar generation – developing and deploying new solar technologies

Solar is one of the most widely deployed renewable generation technologies in NSW, with rapidly declining costs of production and improving efficiencies of PV technologies. At the utility scale, there are 16 major operating large-scale solar farms in NSW, with a total capacity of 950 MW. In addition, there are 10 solar farms under construction amounting to about 1340 MW with $1.8 billion investment. As at July 2020, 49 solar farms representing capacity of 4.5 GW and investment of $5.9 billion that have received planning approval.[116]

NSW has the highest rooftop solar PV energy production potential in Australia with an estimated total capacity of 49 GW and output of 65 TWh per year.[117] Around 490,000 houses and small businesses in NSW have a rooftop solar PV system.[118] With the support of energy storage and other firming technologies, this significant amount of solar generation can supply reliable, low cost and low emissions electricity to support economic growth. For example, distributed solar PV can lower residential and business energy costs – a typical 4-kilowatt rooftop PV system can save up to $900 a year and could be paid off in less than five years for the average Sydney household at current system prices, tariffs and feed-in opportunities.[119]

Although solar has one of the lowest LCOEs for new-build power generation, further improving efficiency and costs improvements can be made through research and development in solar PV, a research field where NSW has world leading capability. Incremental efficiency improvements will result in lower solar PV module costs for consumers, for example, a one percentage point efficiency increase will reduce the cost of the module by approximately five per cent.[120] Higher efficiencies mean that the same electricity output can be achieved from a smaller number of modules with a smaller footprint.[121] This further reduces the capital costs which makes solar projects more cost-efficient at both utility-scale and household level. Other solar technologies, such as concentrated solar thermal, offer additional benefits, including some storage and grid services capacity.

New and improved solar cell technologies, developed in NSW, could be competitive in the global PV market over the next decade. For example, the Passivated Emitter and Rear Cell (PERC) technology developed at UNSW Sydney contributes to more than 60 per cent of commercial PV cell sales in the global market. PERC cells generated US$10 billion in revenue in 2017 and are estimated to deliver solar productivity improvements worth $750 million in Australia over 10 years.[122] Next-generation silicon wafer cells, developed by UNSW and the Australian National University (ANU), offer further potential to lower module costs and generate royalties.[123]

[116] NSW Government, Energy Infrastructure and Zones, *personal communication*, 10 August 2020.
[117] The Institute for Sustainable Futures, 2019, *How much rooftop solar can be installed in Australia?*
[118] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (overview).*
[119] NSW Government, *Solar Panels and systems*, accessed 24 July 2020, https://energysaver.nsw.gov.au/households/solar-and-battery-power/solar-panels-and-systems.
[120] Australian Government, 2020, *Technology Investment Roadmap Discussion Paper*.
[121] Australian Government, 2020, *Technology Investment Roadmap Discussion Paper*.
[122] Australian Government, 2020, *Technology Investment Roadmap Discussion Paper*.
[123] Australian Government, 2020, *Technology Investment Roadmap Discussion Paper*.

Although solar PV panels are largely manufactured overseas, there is an economic opportunity for NSW to develop value-added products and services such as software for data collection and performance optimisation for PV panels. This can build upon NSW's strength in digitalisation technology, data analytics and modelling, to focus on improving solar PV aggregation and real-time response.

Other economic opportunities include improving local system costs (e.g. costs of solar farm finance and construction), deepening construction supply chain and in PV panel recycling. The International Renewable Energy Agency (IRENA) estimated global value of materials to be recovered from solar panels by the year 2050 at around US$15 billion.[124] Extracting valuable metals and reusing silicon from waste panel presents opportunities to grow local manufacturing (both PV panel and lithium-ion battery manufacturing)[125] and down cycling civil construction projects.

The NSW Government has a range of policies, targets and programs in place that aim to further accelerate the uptake of solar technologies, especially higher penetration of rooftop PV in residential and commercial buildings. For example, the NZP has expanded the NSW Government solar target to 126,000 MWh by 2024, and committed to offering rooftops and other available spaces for third parties owned PV systems.[126]

Next steps

- The Clean Technology Program consider supporting more efficient and lower cost solar technologies.

4.6 Energy storage

6. Energy storage – developing and deploying new storage technologies, including for power, control and grid integration, EV and battery storage, hydrogen storage, pumped hydro storage

Since 2012-13, more than 93 per cent of investment in the NEM's new generation capacity has been in wind and solar.[127] This investment is forecast to continue, with new investment in renewable generation replacing 15 GW of fossil fuel generation that is likely to retire as it reaches the end of its technical life by 2040.[128] The intermittent nature of solar and wind generation requires firming technologies, such as energy storage, to ensure reliable and flexible supply of electricity to consumers. AEMO expects that by 2040, 6 to 19 GW of new dispatchable resources will be needed to firm up renewable generation.[129]

Analysis undertaken at ANU suggests that Australia could achieve 100 per cent renewable electricity from wind, solar and PHS.[130] PHS is a mature and cost-effective technology that can offer the lowest cost bulk energy storage solution over longer-durations (often more than 6 hours at maximum capacity).[131] PHS could address generation curtailment and grid congestion issues caused by high penetration of VRE in the NEM, allowing for deferral of costly transmission and distribution investments.

[124] International Renewable Energy Agency, 2016, *End of Life Management of Solar Photovoltaic Panels*.
[125] Shaibani, M., *'Solar panel recycling'*, PV Magazine, 27 May 2020, accessed 30 July 2020, https://www.pv-magazine-australia.com/2020/05/27/solar-panel-recycling-turning-ticking-time-bombs-into-opportunities/
[126] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[127] Australia Energy Regulator, *State of the Energy Market 2020*.
[128] AEMO, 2020, *Final 2020 Integrated System Plan*.
[129] AEMO, 2020, Final 2020 *Integrated System Plan*.
[130] Blakers, A., Lu, B. and Stocks, M., 2017, *100% Renewable Electricity in Australia*.
[131] ITP Energised Group, the Institute for Sustainable Futures and ITK Consulting, 2018, *Comparison of Dispatchable Renewable Electricity Options* (prepared for ARENA).

NSW's two largest PHS schemes, Snowy and Shoalhaven, both have investment plans for expansion.[132] The Snowy expansion, Snowy 2.0 and Transmission Project, could add 2000 MW dispatchable generation capacity and 350 GWh of energy storage to the NSW grid.[133] The project has received planning approval from NSW Government for the main works including the construction of a network of tunnels connecting reservoirs, underground PHS power station and supporting infrastructure.[134] The total capital costs for Snowy 2.0 are estimated at $3.8 billion to $4.5 billion with commissioning phase in 2024-25.[135]

There are further opportunities for PHS facilities across NSW with 98,000 potential sites identified representing 50 TW of capacity.[136] Many of these potential sites are within and proximate to the three proposed REZs and could support their development. For example, a feasibility study is currently underway to assess how a proposed 7200 MWh PHS project at Oven Mountain could support the New England REZ.[137] The NSW Pumped Hydro Roadmap also identifies opportunities for brownfield hydro developments at mining sites in NSW, including in the Central West, Riverina and Shoalhaven regions.[138]

As a fast-response and flexible energy storage option, utility-scale batteries can provide a wide range of services to the energy systems including load shifting, Frequency Control Ancillary Service (FCAS), voltage support services, backup power supply and system restart services. These services can yield technical, commercial and economic value to the market, however some of them are not bankable within the current framework. Moving towards a renewable dominated future generation mix, services provided by batteries including fast frequency response and simulated inertia could be better recognised and valued through market structures and incentive mechanisms.[139] Utility-scale battery storage also can support the value of PPAs by firming or increasing the dispatchability of the renewable generation that is contracted. This could provide certainty for organisations entering into PPAs and reduce the risk premiums paid to third party providers of 'firming services'.[140]

Currently, there is no grid-connected utility scale battery storage connected in NSW, with small-scale systems generally used for back-up power rather than supporting renewable generation or energy market services. There is also a new but growing market in behind-the-meter home storage batteries. Increasing investment in large scale battery projects in NSW should be underpinned by clear energy policy and strategy to help these projects improve bankability of revenue streams, in particular by providing them with certainty around how battery services will be valued over the lifetime of the batteries (typically around 10 years).

Given the expected large future demand for energy storage from batteries, it is also worth assessing the whole battery storage market and value chain and whether NSW has the potential to establish a local manufacturing industry in battery technologies if sufficient scale or a niche can be established. The large scale and industry concentration of battery manufacturing overseas would make the economics of local battery manufacturing highly challenging. Some industry stakeholders indicated that significant Australian deposits of critical materials (lithium, cobalt, nickel and copper), and

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132 NSW Government, 2018, *NSW Pumped Hydro Roadmap*.
133 NSW Government, *NSW Planning Portal – Snowy 2.0*, accessed 6 August 2020, https://www.planning.nsw.gov.au/Assess-and-Regulate/State-Significant-Projects/Snowy-2-0
134 NSW Government, '*Snowy 2.0 Approved: multi-billion dollar boost for regional NSW*', 21 May 2020, accessed 6 August 2020, https://www.planning.nsw.gov.au/-/media/Files/DPE/Media-Releases/2020/May/media-release-snowy-2-0-approved-multi-billion-dollar-boost-for-regional-nsw-2020-05-21.pdf
135 Snowy Hydro Limited, 2017, *Snowy 2.0 feasibility study report*.
136 NSW Government, 2018, *NSW Pumped Hydro Roadmap*.
137 ARENA, *Oven Mountain Pumped Hydro Planned for Future Renewable Energy Zone*, accessed 24 July 2020.
138 NSW Government, 2018, *NSW Pumped Hydro Roadmap*.
139 ARENA, 2019, *Large-Scale Battery Storage Knowledge Sharing Report*.
140 PWC, 2019, *Energy Storage – Financing Speed Bumps and Opportunities*.

potentially low energy costs through increased renewables and REZs could possibly make a manufacturing facility viable in Australia. A local facility of this kind would also be more competitive if it could leverage local capabilities in development and commercialisation of next generation battery technologies.[141] Austrade has identified Newcastle as one potential location for a lithium-ion battery cell manufacturing facility based on the logistics and technology capabilities in the area.[142]

New and emerging energy storage technologies have an important role to play in firming intermittent renewable and supplying dispatchable electricity. For example, hydrogen has potential as seasonal energy storage,[143] while grid-connected electrolysis units could provide system support services.[144] Further, hydrogen production and other Power to X processes,[145] could act as energy carriers for export of renewable resources to overseas markets. Other novel technologies, including compressed air energy storage, Virtual Power Plant (VPP) and concentrated solar thermal have investment interests in NSW under the $75 million Emerging Energy Program.[146]

Next steps

- The Clean Technology Program and Hydrogen Technology Program consider supporting more efficient, lower cost and safe hydrogen and battery storage technologies.
- The NSW Government works with industry to support the development of local battery manufacturing facilities, and to grow the market in utility-scale and behind-the-meter batteries.

4.7 Decentralised grids

7. Decentralised grids – deploying Stand Alone Power Systems and microgrids in regional communities to reduce network infrastructure costs and improve energy security and resilience

Decentralised grids offer a cost-effective model to facilitate the widespread deployment of geological dispersed renewable energy. Rather than a centralised transmission and distribution system from centralised coal-fired power stations, small and modular decentralised grids could connect consumers to utilise cost-effective solar and wind resources available locally, at lower transmission and distribution costs. There are two main types of decentralised grids:

- **Microgrids:** small autonomous grids that can be connected to larger grids and the NEM, but have the ability to operate independently (in an 'island' mode).
- **Stand-alone power systems (SAPS):** an electricity supply arrangement that is not physically connected to a larger grid, and are primarily employed due to remoteness (such as Regional Area Power System (RAPS)) or a desire for energy independence.

About 47 per cent of total energy costs paid by all NSW consumers are related to the network, including transmission, distribution and metering costs.[147] Decentralised grid technologies could reduce these total network costs, as a more cost-effective method of delivering reliable electricity in

[141] For example, new battery chemistries, such as a new type of zinc-bromine battery developed at the University of Sydney. The University of Sydney, *Gelion Technologies*, accessed 31 July 2020, https://www.sydney.edu.au/nano/industry-and-innovation/case-studies/gelion-technologies.html.
[142] Austrade, *the Lithium-Ion Battery Value Chain – New Economic Opportunities for Australia*.
[143] ITP Energised Group, the Institute for Sustainable Futures and ITK Consulting, 2018, *Comparison of Dispatchable Renewable Electricity Options* (prepared for ARENA).
[144] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
[145] Power to X is a cluster of technologies that produce hydrogen via electrolysis and other chemicals such as ammonia, synthetic fuels (methane, methanol and kerosene etc). https://www.frontier-economics.com/media/2642/frontier-int-ptx-roadmap-stc-12-10-18-final-report.pdf
[146] NSW Government, *Emerging Energy Program*, accessed 24 July 2020, https://energy.nsw.gov.au/renewables/clean-energy-initiatives/emerging-energy-program.
[147] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed)*.

situations where traditional centralised grid infrastructure is cost prohibitive – generally in regional and remote areas. This could translate into savings for all consumers through reduced total network costs.

Most of NSW is well connected to the NEM. However, some remote communities have limited access to electricity networks, facing high connection costs and fixed charges per capita, and supply reliability and quality issues. SAPS could provide these communities with more reliable and affordable electricity services, and allow expansion of local supply capacity without costly upgrades to long distance transmission lines. SAPS would also improve resilience to incidents that affect transmission infrastructure and electricity supply, such as bushfires and flooding. The SAPS include renewable generation, energy storage or other firming technologies, to provide dispatchable energy to local communities and businesses, and can be managed and operated by new service providers.

Distribution businesses could also achieve savings from SAPS, through avoided costs of distribution network maintenance, vegetation clearance and expensive equipment such as insulted overhead conductors or underground cables. Essential Energy, a NSW distribution service provider, has identified potential savings of more than $200 million by deploying SAPS in its network.[148] For example, a SAPS trial replacing transmission lines for two remote NSW consumers alone has provided $250,000 cost-savings per year from reduced network maintenance needs.[149] The Australian Energy Market Commission's (AEMC) recent rule changes to allow distribution service providers to use SAPS when economically efficient (while maintaining consumer protections and services standards) should assist the deployment of SAPS in Australia.[150]

SAPS with stable and low cost generation could also lower energy costs and improve reliability for major agriculture businesses and mining operations, attracting more businesses and investment to regional NSW. The NSW Government has established the NSW Regional Community Energy Fund to provide grants to innovative community energy projects in regional communities.[151]

Unlike SAPS, a microgrid is connected to the main grid. However, microgrids can also operate in an 'islanded' mode using its own local energy generation and storage. The advantage of maintaining a grid connection allows the microgrid community to have access to the competitive pricing benefits of importing and exporting energy to and from the NEM where advantageous. The autonomous capability of microgrids also provides resilience and reliability by avoiding power outages in the main grid. Microgrids, managed and operated by distributors, service providers, local communities or major energy users, provide direct access to local renewable resources. This can lower energy transmission losses as the electricity is consumed closer to the generation. Furthermore, aggregated DER and interconnected microgrids could enable new business models for distribution networks, retailers and other service providers, unlocking additional value for DER owners ahead of any wider NEM reform and redesign. For example, peer-to-peer energy trading using block-chain is feasible within microgrids under the current regulatory framework.[152]

Microgrids and SAPS also offer a range of secondary benefits beyond energy security, affordability and reliability for consumers. For example, for some energy users such as universities and military

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[148] Australian Energy Storage Alliance, *Emergence of Stand-Alone Power Systems In Australia*, accessed 24 July 2020, https://energystoragealliance.com.au/power.

[149] AEMC, *New and Cheaper Options to Power Remote Communities*, accessed 24 July 2020, https://www.aemc.gov.au/news-centre/media-releases/new-cheaper-options-power-remote-communities.

[150] AEMC, 2019, *Review of the Regulatory Frameworks for Stand-Alone Power Systems (Priority 2) Final Report*.

[151] NSW Government, *Regional Community Energy*, accessed 24 July 2020, https://energy.nsw.gov.au/renewables/clean-energy-initiatives/regional-community-energy.

[152] NSW Government, *Case Study: Business Share Solar Power to Save Money and Reduce Emissions*, accessed 24 July 2020, https://energy.nsw.gov.au/media/1896/download.

bases, microgrids and SAPS could support smart grid technology testing platforms and improve cybersecurity.

Next steps

- The NSW Government continues to work with distributors, decentralised grid providers, and regional and remote communities and businesses, through initiatives like the NSW Regional Community Energy Fund, to support the development of SAPS.
- The NSW Government encourages developers to deploy low-carbon microgrids in industrial and urban development precincts.

4.8 Energy efficiency and demand management

8. Energy efficiency and demand management – developing and deploying energy efficiency and demand response technologies and services to reduce energy costs for customers

The IEA describes energy efficiency as the 'first fuel' which could deliver more energy capacity than any other source and at a lower cost. Australia has begun to recognise the importance of energy efficiency however its energy efficiency performance has been slower than comparable developed countries. For example, Australia's annual energy efficiency improvement of about 0.5 per cent between 1990 and 2008 was behind the IEA average of 1 per cent for a range of developed countries including the United States, United Kingdom, Germany and Canada.[153] Australia's energy productivity still lags the Organization for Economic Cooperation and Development (OECD) average.[154] The untapped potential of adopting better energy management policies, practices and technologies is significant, and could deliver over $7.7 billion in savings each year for Australian households and businesses through lower energy bills and could create 120,000 new jobs.[155] Energy efficiency could enhance the productivity of the energy sector as a whole, and have particular benefits for the electricity system, including:

- Helping to balance new energy demand with new generation capacity,
- Reducing pressure on the electricity supply system and deferring transmission and distribution infrastructure upgrades,
- Improving energy reliability by reducing peak demand and maximum demand,
- Shifting energy loads to match generation profiles of low cost renewables, and
- Increasing grid security through better demand response from large industrial consumers or aggregated residential and business consumers.

Deploying energy efficient appliances at home and in businesses presents an opportunity for consumers to reduce their electricity costs without impacting quality of life. The Australian government sets Minimum Energy Performance Standards (MEPS) for some important appliances and equipment including refrigerators, televisions, air conditioners and electric motors through the Greenhouse and Energy Minimum Standards (GEMS). The Energy Efficiency Council suggests that the GEMS program may be Australia's most significant climate change program, delivering between nine and 15 per cent of Australia's 2020 emissions reduction target, and net savings of between $1.13 and $2.15 billion in 2018.[156] The MEPS list has 23 products, fewer than other countries including the US and China, and there is an economic opportunity to expand the product list or

[153] The Climate Institute, 2018, *Boosting Australia's Energy Productivity*.
[154] The World Bank, *World Development Indicators*, accessed 24 July 2020, https://datacatalog.worldbank.org/dataset/world-development-indicators.
[155] Energy Efficiency Council, 2019, *the World's First Fuel*.
[156] Australian Government, 2019, *Independent Review of the Greenhouse and Energy Minimum Standards (GEMS) ACT 2012 Final Report.*

raising standards for existing appliances. This could prevent less-efficient appliances, which are unable to be sold in jurisdictions with higher international efficiency standards, being imported into the local market and would assist the competitiveness of local products being exported into those markets.[157] Enabling-technologies such as automation, advanced metering, and customer side smart systems (for example, smart appliances, thermostat and energy generation and weather forecasting with solar panels) could accelerate the deployment of energy efficient appliances and equipment and attract more consumers in the market.

An advanced energy efficiency opportunity exists in improving demand response. Demand response involves deliberate actions to shift electricity consumption in response to changes in electricity supply or prices. For the peak demand periods, demand response can avoid the need for additional generation, reducing wholesale energy costs, lower transmission and distribution charges, and reduce pressure on ancillary services or system reserves.[158] For example, large industrial electricity consumers (such as the Tomago Aluminium smelter) have been directed by energy market operators to curtail operation to reduce their demand during peak period to avoid load shedding at large scale.[159] As part of the demand response protocol, large load shifting enhances grid security and reliability during extreme conditions however, business disruption it causes is not compensated for within current market framework. However, improved demand response and flexibility with technology solutions could offer economic opportunities for industrial users of energy, for example, to increase production at low-price off-peak periods.

AI and IoT technologies can further enhance the efficiency and effectiveness of demand response. For example, there are potential economic opportunities for large commercial retailers to act simultaneously across hundreds of locations via cloud technology to reduce energy use across their business, generating large total reductions.[160] NSW has capability in digitalisation technologies, software development and energy management services that could capitalise on the potential of energy efficiency and demand management. Large businesses could achieve further electricity cost reductions by coupling demand response with cooperation PPAs.[161]

In NSW, up to 28 per cent of all energy use could be avoided through improving energy efficiency, equivalent to savings of up to $1.4 billion in 2011.[162] NSW already has an energy efficiency market created by the Energy Savings Scheme (ESS) where providers of energy efficiency products and services can create certificates from energy savings activities and sell them to electricity retailers. Since its launch in 2009, the ESS has supported energy efficiency projects equivalent to savings of 27,000 GWh and $5.6 billion for households and businesses.[163] The ESS has recently been extended to 2050, with gradually increased targets, and expanded energy savings products and services under the NSW Electricity Strategy.

Next steps

- The Clean Technology Program and Energy Efficiency Program consider supporting more efficient, lower cost and safe energy efficiency and demand management technologies.

[157] Energy Efficiency Council, 2019, *the World's First Fuel*.
[158] The Institute for Sustainable Futures UTS, 2018, *Best of Both Worlds – Renewable Energy and Load Flexibility for Australian Business Customers*.
[159] NSW Chief Scientist & Engineer Office, 2019, *Assessment of Summer Preparedness for the NSW Energy Market 2019/20*.
[160] ARENA, *How is Demand Response Working in Australia*, accessed 24 July 2020, https://arena.gov.au/blog/how-is-demand-response-working-in-australia/
[161] The Institute for Sustainable Futures UTS, 2018, *Best of Both Worlds – Renewable Energy and Load Flexibility for Australian Business Customers*.
[162] NSW Government, 2013, *NSW Energy Efficiency Action Plan*.
[163] Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed)*.

4.9 Digitalised and distributed energy markets

9. Digitalised and distributed energy markets – developing and deploying new technologies to optimise future digital energy markets with two-way energy flows, virtual power plants, peer-to-peer trading, high penetrations of distributed and renewable energy and storage, microgrids and large demand response resources

Distributed energy resources (DER) are changing how electricity is produced and managed by creating two-way flows in the distribution network. Australia has experienced a rapid uptake of DER, and this demand for DER is expected to continue to grow with the deployment of home batteries, EV charging, smart appliances and energy management systems. The Electricity Network Transformation Roadmap estimates that 45 per cent of Australia's electricity generation capacity could come from DER by 2050.[164] DER offers energy cost savings and flexibility for consumers. However, the ESB's DER Integration Workplan notes that DER also offers value to the energy supply chain, some of which is not captured, including:

- providing backup generation and energy flexibility to non-DER owners,
- increasing hosting capacity, planning flexibility and supporting voltage and frequency, deferring infrastructure investment, and
- providing ancillary services, relieving network congestion and improving system security and resilience.[165]

There are economic opportunities from DER for all energy consumers and distribution businesses through efficient integration of DER into energy networks. Energy Networks Australia and CSIRO estimated that this could deliver $16 billion by 2050 for Australia.[166] As a first step, technical and operational challenges associated with DER integration require improved visibility and predictability for power systems operators and distribution service providers.[167] Adopting uniform technical standards for solar PV and smart inverters will allow more DER to be better integrated – enhancing grid stability. DER with improved interoperability enables consumers to earn extra revenue by responding to the needs of the power system, or to engage in future energy trading markets. For example, better managing EV charging time and deployment of charging infrastructure geographically will benefit the grid through reducing peak demand and congestion. The economic opportunities of EV integration into the electricity system are detailed further in Chapter 8.

Digitalisation technologies such as AI, IoT, blockchain, digital twins, 5G and remote sensing can support the visibility and interoperability of DER within the energy system. For example, digital and smarter grids support increased remote communication, control and automation of consumer devices. Further, enhanced digital connectivity and communication will support new electricity retail models such as peer-to-peer trading.[168]

NSW is well-positioned to capitalise on the value of DER because of its high penetration of distributed solar generation, digital capabilities and skills, and innovative financial services sector. New low-carbon microgrids or smart grids are well suited to developing, testing and deploying new

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[164] Australia Energy Networks, 2017, *Electricity Network Transformation Roadmap Final Report*.
[165] COAG Council, 2019, *ESB DER Integration Workplan*.
[166] Australia Energy Networks, 2017, *Electricity Network Transformation Roadmap Final Report*.
[167] AEMO, 2019, *Technical Integration of Distributed Energy Resources*.
[168] AEMC, 2019, *How Digitalisation is Changing the NEM*.

systems and markets. For example, the Byron Bay Arts & Industry Estate microgrid pilot project involves businesses generating energy from rooftop solar to power their own buildings, with excess electricity sold to others in the estate or back to NEM for additional revenue.[169]

4.10 Battery repurposing

10. Battery repurposing – developing a battery repurposing and recycling industry

Increasing demand for batteries, for electricity supply and EVs, presents an economic opportunity for reuse and recycling of batteries.[170] Batteries can be repurposed, for example from EVs to provide utility scale storage. Further, batteries can be recycled to recover critical minerals, lower battery feedstock costs, and reduce environmental impacts and dependence on high risk global supply chains in critical minerals.

Australian lithium ion battery waste is growing at a rate of over 20 per cent per annum.[171] Currently, only 2 per cent of Australia's annual 3,300 tonnes of lithium battery waste is recycled. However, 95 per cent of a lithium ion battery can be recycled or repurposed, including critical resources such as cobalt and lithium.[172] This is equivalent to a potential economic loss of between $813 million and $3 billion in recoverable value based on current commodity prices.[173]

Recycling rates of batteries can be increased through better consumer understanding of the value of recycling, improved collection processes and availability of facilities, and implementing efficient recycling supply chains. Recycling supply chains face technical constraints, economic barriers, logistic issues, and regulatory gaps.[174] Battery manufacturers have not historically focused on improving recyclability due to the lack of clear and large-scale economical recycling supply chains. Instead, manufacturers have focused on reducing the battery cost, and increasing longevity and capacity.

Local battery recycling also has several competitive advantages. Recent disruption to the recycling sector in Australia following China's "National Sword" policy and some restrictions on international shipping company of waste batteries (due to fire risk) support local recycling to improve supply chain certainty.[175] In addition, large batteries are heavy and expensive to ship. Further, local recycling can also support local battery manufacturing. In many types of lithium batteries, the concentrations of critical materials such as lithium and manganese, exceed the concentrations in natural ores. If those materials can be recovered from used batteries at a large scale and more economically than from natural ore, this will lower the price and improve the stability of the supply of those feedstocks for local manufacturers.

A recent report by CSIRO identified key findings from industry stakeholders on the feasibility of a battery recycling industry in Australia.[176] Stakeholders suggested several actions including:

- Developing dedicated product stewardship programs and providing consumer education to encourage recycling and resource recovery,

[169] NSW Government, *Case Study: Business Share Solar Power to Save Money and Reduce Emissions, accessed 24 July 2020*, https://energy.nsw.gov.au/media/1896/download.
[170] Australian Battery Recycling Initiative, *About ABRI*, accessed 24 July 2020, https://batteryrecycling.org.au/about-abri/our-vision.
[171] King, S., Boxall, N.J. and Bhatt, A. 2018, *Lithium battery recycling in Australia*, CSIRO, Australia.
[172] CSIRO, *Lithium-Ion Battery Recycling*, accessed 24 July 2020, https://www.csiro.au/en/Research/EF/Areas/Grids-and-storage/Energy-storage/Battery-recycling.
[173] King, S., Boxall, N.J. and Bhatt, A. 2018, *Lithium battery recycling in Australia*, CSIRO, Australia.
[174] Jacoby, M., '*It's time to get serious about recycling lithium-ion batteries*', Chemical & Engineering News, accessed 24 July 2020, https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28
[175] King, S., Boxall, N.J. and Bhatt, A. 2018, *Lithium battery recycling in Australia*, CSIRO, Australia.
[176] King, S., Boxall, N.J. and Bhatt, A. 2018, *Lithium battery recycling in Australia*, CSIRO, Australia.

- Increasing the availability of facilities and infrastructure for safe collection, processing and reuse,
- Increasing skills in safe battery handling and recycling, and
- Establishing standards and best practice guidelines for battery recycling.

There are initiatives underway that could be leveraged to develop and expand the battery repurposing and recycling industry. For example, the Australian Battery Recycling Institute (ABRI) includes membership from battery manufacturers, recyclers, retailers, government and environment groups to promote the collection, recycling and safe disposal of all batteries. The NSW Circular, a circular economy network supported by the NSW Government, also presents an opportunity to further develop partnerships and supply chains for new industry opportunities for end-of-life battery repurposing.

Next steps

- The Clean Technology Program considers supporting battery repurposing and recycling technologies.
- The NSW Government works with battery manufacturers, recyclers, investors, NSW Circular, and ABRI to:
    - Support a nationally-coordinated strategy and integrated supply chain in battery manufacturing and recycling, and
    - Promote safe battery recycling to businesses and consumers.

4.11 Future energy systems and markets skills

11. Future energy systems and markets skills – growing and exporting skills and experience in technologies and services to enable modern energy systems and markets

The energy system and markets are increasingly underpinned by digital technologies. Digitalisation is essential for the increasingly decarbonised, decentralised energy system to run in a stable and affordable way. This presents an opportunity to grow a range of digital skills and experience available to the energy sector, from basic AI and modelling skills to specialised expertise in solar PV optimisation and smarter inverters. The widespread deployment of DER and smart appliances will generate large volumes of data, increasing opportunities for data analytics specialists to manipulate and interpret data and optimise energy systems. For example, in buildings, digitalisation is enabling new energy services, such as smart thermostats, occupancy sensors, remote control and enhanced safety features all of which can increase energy consumption and reduce emissions (further information in Opportunity 9 in Chapter 6).

Training and upskilling in all areas of digital literacy is essential to realise the full breadth of this economic opportunity. This includes new graduates, as well as opportunities for existing workforce in an evolving energy industry. Cybersecurity for a digital, automated and interconnected energy system is key priority, and digital skills and capabilities will be in increasing demand to secure this expanding and sensitive digital environment against cybersecurity threats.[177] Once local capabilities are established in critical industries, these skills and services can be exported to other markets facing similar challenges.

Large investment in new renewable generation and storage assets will also increase demand for skills. At present, Australia's renewable energy sector is a major employer with 26,850 full-time

[177] Australian Industry Standards, 2019, *Skills Forecast 2019 – Electrotechnology*.

workers in 2019.[178] A skilled workforce is essential to ensure the delivery of major renewable projects and capture the full economic opportunities of the future energy market. This sector is experiencing difficulties in recruiting certain skills and experienced staff. Some of these skills could be transferred from the current fossil fuel workforce, for example, construction managers, electricians, mechanical trades and drivers.[179] An expanded hydrogen industry and energy-intensive manufacturing could also offer employment opportunities. An orderly transition of workforces to future energy market skills can be supported by targeted upskilling courses and apprenticeships.

Next steps

- Skills development is considered in the implementation of the NZP, for example initiatives under the NZP engaging with relevant skills advisory bodies (such as relevant Skills Service Organisations and NSW Industry Training Advisory Bodies) to identify potential future skills needs in decarbonisation and climate adaptation.

[178] Australian Bureau of Statistics, 2019, *Employment in Renewable Energy Activities, Australia 2018-19, cat. no. 4631.0*, accessed 24 July 2020.
[179] Clean Energy Council, 2020, *Clean Energy at Work*.

5. Industry: Low carbon industrial transformation

Decarbonisation of local and global markets presents economic opportunities for NSW businesses to leverage new technologies and services to reduce energy and materials, to produce more products and services for larger and higher value markets more efficiently. These opportunities are enabled by several trends in global industry, including:

- The commercialisation of technologies and services to improve industrial productivity through more efficient use of energy and materials,
- New technologies or processes that utilise less carbon-intensive chemistries, or that capture emissions,
- A growing appetite from consumers and businesses to use more sustainable and decarbonised goods and services,
- Establishment of circular economies in industrial commodities including energy, heat and materials,
- Rapid reductions in the costs of renewable energy generation and storage, and
- Interest in new energy carriers such as hydrogen.

Adoption of technology and services in response to these trends could significantly improve the competitiveness of NSW industry and create jobs in a range of sectors. Successful implementation would represent a competitive advantage for NSW to grow local production, and export goods and services to international markets.

Prepare the market

Prepare the Market › Deploy technologies › Accelerate

5.1 Eco-industrial precincts

1. Eco-industrial precincts – attracting industry with cooperative decarbonisation strategies in precincts

Eco-industrial precincts present an economic opportunity for cost-effective decarbonisation of industry by lowering capital, infrastructure and skills barriers, and providing a cooperative network of companies interested in developing and deploying decarbonisation technologies. While incremental technology upgrades can often be managed by individual businesses, precincts can reduce the transition risks associated with major new technology platforms, such as hydrogen and recycled water, energy and materials. Digitalisation is also opening up a wider range of opportunities to link industrial businesses to their surroundings. For example, producers connected can facilitate the reuse and recycling of materials. Connecting industrial equipment to the network can also help to identify and provide real-time information on the availability of local waste streams (e.g. excess heat, off-gases or organic waste), which can be captured and used to displace other energy use.

Precincts present an opportunity to pilot these new platforms on a smaller scale with a group of interested businesses, share knowledge and skills between businesses, coordinate and optimise complex supply chains, and manage investment risk. Successful decarbonised precincts can then provide a core of experience and skills that businesses and supply chains across NSW can connect to, to expand these platforms across NSW.

For example, the National Hydrogen Strategy indicates that the establishment of hydrogen hubs will accelerate the hydrogen industry in Australia by aggregating various users of hydrogen within an area.[180] NSW has locations that could become hydrogen hubs, such as the SAPs and other industrial-export hubs (for example, Newcastle and Port Kembla). These locations have significant advantages, including existing transport infrastructure (in particular ports and rail), current large industry gas users, greenfield sites where hydrogen could be readily adopted in new builds, and potential for a variety of hydrogen production pathways, facilities and end-users. Co-location of hydrogen hubs with the new REZs would also be attractive, providing access to low cost renewable electricity for hydrogen production.

The NSW Government has adopted a precincts approach to economic development and is investing in a number of precincts including regionally located SAPs and the Western Sydney Aerotropolis.[181] These developments are of sufficient scale to mobilise stakeholders to invest in shared energy, transport and waste infrastructure to create economically viable decarbonised and climate-resilient precincts.

Next steps

- Programs under the NSW Government's NZP Stage 1: 2020-2030, such as the Clean Technology and Hydrogen Programs, encourage precinct-based approaches to the development and piloting of industrial decarbonisation technologies and services.
- Future eco-industrial precincts in NSW implement measures to achieve carbon neutrality in both operation and construction.

5.2 Government procurement

2. Government procurement – increasing government procurement of zero-emissions products and services from NSW suppliers

Increasing government procurement of zero-emissions products and services from NSW suppliers supports the growth of decarbonised value-added goods and services industries in NSW. The NSW Government is a major purchaser of goods, services and infrastructure. In the 2019-20 budget, NSW government allocated:

- $20.8 billion to the delivery of government services and programs,[182]
- $15.6 billion to other government sectors, local government, community groups and non-profit organisations for the delivery of services and infrastructure projects, and
- $22.3 billion to capital expenditure.[183]

Directing that this annual expenditure of $58.7 billion preference decarbonised and climate resilience infrastructure, goods and services would provide certainty of demand for NSW industries to develop and expand their supply chains. This would reward local businesses that invest in advanced technology and improve business practices to value sustainability. NSW Government has adopted the GREP which requires government agencies to incorporate resource efficiency into all major decisions, and to leverage their purchasing power when procuring resource efficient

[180] COAG Energy Council, 2019, Australia's National Hydrogen Strategy.
[181] NSW Government, 2019, *Special Activation Precincts*, accessed 19 December 2019, https://www.nsw.gov.au/improving-nsw/regional-nsw/snowy-hydro-legacy-fund/activation-precincts/.
[182] Operating expenses excluding employee expenses.
[183] NSW Government, 2019, *2019-20 Budget Paper No. 1 - Budget Statement - Chapter 5 - Expenditure*.

technology and services.[184] Further, the NSW Procurement Policy identifies sustainability as a key objective in government procurement.[185]

Government procurement policy for office space has already been highly effective in improving commercial building efficiency and growing the building management services industry in NSW. As a result, Australia's commercial building sector has led the Global Real Estate Sustainability Benchmark (GRESB) for the past 8 years.[186]

Decarbonisation and climate resilience targets for energy efficiency and to drive the transition to a circular economy are being adopted in public infrastructure projects. For example, the Sustainability Strategy for the Sydney Metro Project aims to offset 100 per cent of its operational energy needs and 25 per cent of its construction energy needs.[187,188] There are opportunities to take these targets further across all government infrastructure. This includes decarbonising construction where feasible by using fewer emissions intensive materials, more carbon-sequestering materials such as engineered wood products and low emission steel and cement. For example, the Sydney Metro Project replaced 42 per cent of Portland cement with supplementary cementitious material.[189] There are also opportunities to apply stricter decarbonisation criteria to the purchase of goods and services including consumables, technology, and digital and professional services. The NSW Government could also strengthen conditions on grants and subsidies to ensure that recipients are meeting decarbonisation and climate resilience objectives in their delivery of services and infrastructure projects.

Using public procurement to catalyse improved supply chains for decarbonised goods and services also delivers economic benefits for consumers. For example, increased procurement of EVs for government fleets can improve the availability, affordability and utility of new and used EVs as manufacturers are encouraged to bring EVs into the local market, fleet EVs are on-sold, and charging infrastructure grows.[190]

Industry has indicated that decarbonisation and climate resilience targets for public procurement should be specific and public, to provide certainty and support business cases for the investments and transformations necessary to decarbonise goods and services.

Next steps

- The NSW Government develops a detailed strategy that sets out the NSW's Government's approach and trajectory for all government assets and procurement to meet the state's net zero target by 2050.

[184] NSW Government, 2019, *NSW Government Resource Efficiency Policy*.
[185] NSW Government, 2020, *NSW Government Procurement Policy Framework*.
[186] ASBEC, 2019, *Growing the Market for Sustainable Homes, (for Low Carbon Living CRC)*.
[187] Sydney Metro, 2019. *City and Southwest Sustainability strategy 2017-2024*.
[188] Another example is the Environmentally Sustainable Development Plan for the Parkes SAP, which sets an objective for the Parkes SAP to be carbon neutral.
[189] Sydney Metro, 2018, *Sustainability Report 2018*.
[190] Energeia, 2018, *Australian Electric Vehicle Market Study*.

5.3 Certification and standards

3. Certification and standards – establishing, supporting and promoting standards for certification of decarbonisation and climate resilience in industry in NSW

Robust and trusted certification and standards incentivise the adoption of sustainability practices in business. This presents an economic opportunity for NSW businesses to use these standards to market their products, to invest in producing value added products and services that grow revenues, and to offset additional costs of decarbonisation and climate resilience.

Demand for sustainable products and services is increasing in response to business and consumer interest in reducing emissions and saving on energy costs.[191,192] Some producers of sustainable products and services may only decarbonise their own operations, however some will also seek to decarbonise their upstream and downstream suppliers and customers. This is important for many non-vertically integrated businesses where their supply chain emissions exceed emissions from direct operations.[193]

Some trusted products and services can charge a sustainability premium. One prominent example is that producers of 'green' aluminium in Canada, Russia and Norway using hydro power are able to charge a premium for a low emission industrial aluminium.[194] Other examples of value-added products include organic produce and higher animal welfare meats. In tourism services, operators such as Qantas allow customers to pay an extra charge to offset their emissions.[195] Markets are also responding, for example, the London Metal Exchange plans to set up a spot trading platform in 'low carbon' aluminium.[196] Consumers indicate that they are often willing to pay a premium for more sustainable goods.[197] For example, minimum standards for appliances save Australian households $140 to $220 each year on average.[198] These premiums can offset business investment in decarbonised supply chains or carbon offsets, improve the value-add of exports, and the financial viability of local industry against international competitors.

Effective regulatory frameworks, including standards and quality assurance, are essential to maintain consumer trust in sustainable products and services.[199] Government has a role in participating in the development of standards, monitoring them, and educating consumers to improve awareness and trust. Government also has a role in encouraging standards that are internationally relevant: at a minimum, understood and trusted by overseas consumers, and preferably consistent across

[191] Smith, P. *'Start-up behind Qantas' carbon offsets raises $9m'*, Australian Financial Review, 11 November 2019, accessed 18 June 2020, https://www.afr.com/technology/start-up-behind-qantas-carbon-offsets-raises-9m-20191106-p5382u.
[192] For example, to date over 900 major global companies have committed joined the Science Based Targets initiative (SBTi), which helps companies set emissions reduction targets for their own emissions and their supply chain emissions that are consistent with the goals of the Paris Agreement. Science Based Targets initiative, *Companies taking action*, accessed 27 July 2020, https://sciencebasedtargets.org/companies-taking-action.
[193] Energy Transition Hub, 2019, From mining to making: Australia's future in zero-emissions metal.
[194] Hobson, P. '*Hydro-powered smelters charge premium prices for 'green' aluminum*', Reuters, 2 August 2017, accessed 27 July 2020, https://www.reuters.com/article/us-aluminium-sales-environment/hydro-powered-smelters-charge-premium-prices-for-green-aluminum-idUSKBN1AI1CF.
[195] Qantas, *'Qantas Group to Slash Carbon Emissions'*, 11 November 2019, accessed 18 June 2020, https://www.qantasnewsroom.com.au/media-releases/qantas-group-to-slash-carbon-emissions/#:~:text=The%20Qantas%20Group%20will%20reach,number%20of%20flights%20being%20offset.
[196] Desai, P. '*London Metal Exchange looking into low-carbon aluminium trading*', Reuters, 5 June 2020, accessed 27 July 2020, https://www.reuters.com/article/metals-aluminium-carbon/london-metal-exchange-looking-into-low-carbon-aluminium-trading-idUSL8N2DI2YX.
[197] Accenture, *More than Half of Consumers Would Pay More for Sustainable Products Designed to Be Reused or Recycled, Accenture Survey Finds*, accessed 27 July 2020, https://newsroom.accenture.com/news/more-than-half-of-consumers-would-pay-more-for-sustainable-products-designed-to-be-reused-or-recycled-accenture-survey-finds.htm.
[198] Energy Efficiency Council, 2019, *The World's First Fuel.*
[199] Australian Competition & Consumer Commission (Australian Government), 2011, *Green marketing and the Australian Consumer Law.*

jurisdictions. For example, a National Carbon Offset Standard is in place for emissions offsetting schemes used in the private sector.[200]

Once established, a robust regulatory framework and standards can accelerate growth in local value-add industries. For example, some industry stakeholders commented that the Commonwealth Therapeutic Goods Administration's regulation of the production of complementary medicines has contributed to the brand reputation of Australian complementary medicines.[201] They reported that this reputation has led to increased demand in overseas markets for premium Australian products and significant local industry growth. NSW has an opportunity to leverage Australia's reputation for high quality products and services to set standards for sustainability in products and services that can support growth in NSW exports.

5.4 Decarbonisation and climate resilience skills

4. Decarbonisation and climate resilience skills – growing skills to support decarbonisation and climate resilience of industry

Decarbonising and improving the climate resilience of industry requires skilled engineers and technicians to modify existing emissions intensive industrial processes to incorporate new lower emissions processes. Industrial processes are often capital intensive and integrated into complex supply chains. Cost-effective decarbonisation often requires process modification rather than simple substitution of technologies.[202] However, this process modification adds complexity, and can raise transition risks for businesses if inappropriately implemented.

There is an economic opportunity, through universities and VET, to upskill the current and future workforce to develop and deploy technologies into existing and new industrial processes. This skilled workforce is essential to managing these transition risks.[203] Skills in areas such as mechanical, electrical, chemical and process engineering are required, with a focus on building capabilities in novel decarbonised technologies and processes, and their application across all industrial processes. Other important skills are in enablers of technology transitions – for example, in areas such as digital and information technology, analytics and optimisation, and gene technology. Other business units, responsible for management, regulation, finance and communications, also need new skills in understanding and supporting these transitions. For example, a domestic hydrogen industry would require a broad range of new skills across a range of professions including:

- **Engineering and technical skills** – renewable generation, electrical, plumbing, liquefaction, materials, maintenance and servicing, digitalisation, and plant and equipment operation,
- **Management and business skills** – business development, market analysis and forecasting, Environmental, Social and Governance (ESG) reporting, supply chain transitions, collaborative innovation, networking and sales,
- **Regulatory and policy skills** – regulation setting, policy development, monitoring and reporting, ESG compliance,
- **Communications and outreach skills** – networking, business to business collaboration, community engagement skills.

[200] IP Australia (Australian Government), *National Carbon Offset Standard*, accessed 27 July 2020, https://www.ipaustralia.gov.au/tools-resources/certification-rules/1369520.
[201] Complementary Medicines Australia, 2017, *Complementary Medicines Australia 2017/18 Federal pre-Budget Submission*.
[202] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).
[203] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.

It is essential that these skills are embedded across industry. Businesses know their own processes well so although there is a role for these capabilities to be provided by third parties (contractors and consultants), businesses consulted in this report indicated that they would be more willing to invest in process modification for productivity and decarbonisation benefits where these transitions are led by their own skilled workforce. However, they also emphasised the important role of industry networks in sharing skills, knowledge and best practice.

Growing the skills to support this industrial transition presents an opportunity to grow the services sector and create jobs in industrial productivity and decarbonisation. For example, in California, it is estimated that there are over 300,000 jobs in energy efficiency alone.[204] However, there is significant employment potential in NSW beyond energy efficiency, with opportunities in areas such as industrial productivity, material productivity, hydrogen, critical mineral resources, product and service certification, and process optimisation etc.

Next steps

- Refer to next step for Opportunity 4.11.

Deploy technologies

Prepare the Market | **Deploy technologies** | Accelerate

5.5 Energy productivity

5. Energy productivity – improving industrial productivity by developing and deploying novel and mature energy efficiency technologies

Mature and emerging energy efficiency improvements can increase industrial productivity by lowering energy costs for businesses and consumers while maintaining or even increasing industrial output. For example, energy efficiency measures resulted in an estimated increase in global GDP of $2.8 trillion in 2017.[205] A one per cent increase in the level of a country's energy efficiency can contribute to a 0.1 per cent increase in the rate of per capita economic growth.[206] Widespread adoption of energy efficiency can also reduce demand for emissions intensive energy generation, as well as delaying expenditure on distribution and transmission upgrades.

Industrial processes are often energy intensive when using high temperatures and pressures, and fossil fuel feedstocks. For example, in raw material, metal and chemical processing, coal and gas are commonly used. A range of incremental energy productivity improvements are possible in the industrial sector through:

- **Product design** – substituting sustainable materials, reducing material use and manufacturing time,
- **Equipment to optimise industrial processes** – using advanced sensors, materials and insulation, industrial heat pumps,
- **Business practices** – applying circular and eco-industrial approaches to energy, water and other resources to achieve efficiencies and reduce waste.[207]

[204] Energy Efficiency Council, 2019, *The World's First Fuel.*
[205] Energy Efficiency Council, 2019, *The World's First Fuel.*
[206] Vivid Economics, 2013, *Energy efficiency and economic growth*, (prepared for The Climate Institute).
[207] In some industrial processes and infrastructure, more heat is produced than is required. Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., and Deverell, J. 2017, *Low Emissions Technology Roadmap, Technical Report*, CSIRO, Australia.

Many improvements are also cost effective through energy cost savings offsetting the capital costs of new equipment or process upgrades. However, industry stakeholders indicate that even short payback cycles of 3 to 5 years are barriers for some small and medium businesses with tight cashflows.

Australia's energy productivity is 15 per cent below the OECD average.[208] This offers a significant opportunity to make measurable improvements through implementing existing international best practice in industrial energy efficiency. Even in sectors of the Australian economy where best practice has been adopted, further technology development can continue to improve energy efficiency. For example, Australia has strong expertise in the technology translation in mining and operates some of the world's most efficient mining operations. However, greater energy efficiencies can be achieved in extraction and processing, and through the use of electrified autonomous haulage systems and conveyors.[209]

The NSW Government has implemented the ESS as an important tool to improve energy efficiency. The ESS creates a market in Energy Savings Certificates to provide financial incentives for households and businesses to invest in energy efficiency measures. The ESS has been effective in reducing energy consumption and costs, as well in deferring some additional generation and network investment in NSW.[210] Under the NSW Electricity Strategy, the ESS is being extended and expanded as the Energy Security Safeguard, with a target of 13% energy savings by 2030.[211] The Energy Security Safeguard will be extended to 2050 is forecast to deliver savings to consumers as well as emissions reduction benefits.[212]

5.6 Material efficiency, reuse and recycling

6. Material efficiency, reuse and recycling – developing and deploying technologies and services to increase material efficiency, substitution and durability; and reuse, repurposing, recycling in supply chains

Significant emissions are associated with the production and disposal of materials for products, infrastructure and buildings. However, increasing the material efficiency, longevity and residual value of materials can reduce these emissions while offering significant productivity benefits for industry and consumers, by maintaining the highest value and best use of materials for much longer lifespans. Effective approaches include:

- Applying novel design and manufacturing approaches to reduce unnecessary material use in products – additive manufacturing and advanced machining,
- Substituting carbon intensive materials for cost effective low carbon materials, materials with stored carbon, and recycled materials – concrete can be substituted with geopolymer cements or manufactured wood products (including in larger commercial and residential

[208] Australia's energy productivity, measured by GDP per unit of energy consumed, is 15 per cent below the average energy productivity of other OECD countries. The World Bank, *World Development Indicators*, accessed 27 July 2020, https://datacatalog.worldbank.org/dataset/world-development-indicators.

[209] For example, Rio Tinto has announced planned investment in more efficient production processes which will reduce GHG emissions from its Pilbara iron ore mine. Rio Tinto, *'Rio Tinto approves $749 million investment in Pilbara iron ore mine'*, 27 November 2019, accessed 10 July 2020, https://otp.tools.investis.com/clients/uk/rio_tinto1/rns/regulatory-story.aspx?cid=507&newsid=1347732.

[210] Department of Planning, Industry & Environment (NSW Government), 2020, *NSW Energy Savings Scheme -Draft Statutory Review Report*.

[211] Department of Planning, Industry & Environment (NSW Government), 2020, *Energy Security Target and Safeguard – Consultation paper*.

[212] ACIL Allen Consulting, 2020, *Energy Security Safeguard Scenario Projections – Modelling Report* (prepared for the Department of Planning, Industry & Environment.

buildings) and downcycled for roads, and concrete blocks and unused cement can be recycled,

- Improved designs and materials to increase the durability and longevity, reuse and recycling potential, and residual value of products – modern engineering approaches using manufactured wood products can improve energy efficiency in construction, and enable end of life applications including re-use, recycling and bioenergy,
- Increasing asset utilisation – sharing economies in underutilised assets such as vehicles, property and equipment can reduce costs for consumers and businesses.[213]

Industry can use these approaches to lower manufacturing costs, while also increasing the value of their products. The compounding effect of using lower emissions materials, fewer materials overall, and using materials for longer can also significantly reduce industrial process emissions. For example, emissions from the most intensive industrial emissions sectors (steel, aluminium, cement and plastics) could be reduced by 40 per cent globally (and more in developed economies) by 2050 through increased materials efficiency and application of the waste hierarchy and circular principles.[214] This also has secondary benefits in reducing demand for emissions intensive resource extraction and pressure on climate-sensitive lands.

These approaches rely on a mix of new technologies, improved knowledge of material flows, new business models and financial products, and changes in behaviours and business practices. A coordinated and more integrated approach across the supply chain is needed to create new markets and provide the critical mass necessary to support new industries and products. This requires engagement by materials producers, product manufacturers, logistics and transport companies, retailers, service providers, consumers, and waste and recycling authorities.[215]

Next steps

- The Clean Technology Program considers supporting more efficient, lower cost and safe material efficiency, reuse and recycling technologies, including technologies to improve asset utilisation, material durability and longevity.

5.7 Electrification, alternative heat and bioenergy

7. Electrification, alternative heat and bioenergy – improving industrial productivity by developing and deploying electrification and renewable energy technologies

Electrification, alternative heat and bioenergy can improve productivity for many industrial processes, particularly where industrial users have access to low cost renewable generation. For example, higher efficiency electrical heaters and motors can optimise the conversion of energy into heat and motion – and are already suitable for many industrial applications. Electrification using decarbonised electricity, alternative heat and bioenergy for industrial infrastructure and processes would also reduce fossil fuel consumption. For example, using biomass in blast furnace steel production.

Technical challenges exist for electrification of some high energy processes, for example extreme temperature heating applications such as clinker production in cement manufacturing. Where

[213] Ramage, M.H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D.U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J. et al. 2017, *'The wood from the trees: The use of timber in construction*', Renewable and Sustainable Energy Reviews, Volume 68, Pages 333-359.
[214] Energy Transitions Commission, 2017, *Mission Possible*.
[215] The NSW Government has a Circular Economy Policy which sets an ambition, approach and principles for a circular economy in NSW, and is developing a 20 Year Waste Strategy and Plastics Plan. NSW Environment Protection Authority, 2019, *Circular Economy Policy Statement: Too Good To Waste*.

complete electrification is not possible, even partially augmenting direct-fired heating equipment with renewable sources can improve efficiency while reducing emissions. Bioenergy and alternative heat offer potential as cost-effective decarbonisation technologies in some applications and locations; however, challenges can arise in securing a steady supply chain of stable bioenergy feedstock or renewable heat source at a competitive cost.

A range of cost-effective electrification, alternative heat and bioenergy technologies are already commercially available or under development. In many cases, direct substitution is not cost-effective, however process modification improves their cost-effectiveness. For example, where centralised boiler facilities are distributing heat around a manufacturing facility, the actual efficiency of process heat use can be low and improved by electrification of heat at point of use.[216]

Mature and emerging electrification, alternative heat and bioenergy technologies include:[217]

- **Electric boilers and furnaces** – already commercially available and used in some industrial applications.
- **Industrial electric heat pumps** – commercially available and particularly cost effective compared to gas for lower temperature heating applications (under 160°C). They can be combined with recycling of waste heat to reduce costs further. For higher temperature applications, pre-heating of direct-fired heating equipment with electric heating from renewable sources can reduce overall system emissions.
- **Concentrated solar thermal technologies** – emerging technologies are under development to supply heat at ~800 - 1000°C at a cost of $10/GJ.[218] These technologies are yet to be demonstrated at scale but have the potential to compete with natural gas at its present prices.
- **Bioenergy** – primarily derived from waste biomass, bioenergy is already commercially used for heating or electricity generation in some applications. It also offers an opportunity for potential value-add for landholders to generate income from waste feedstock and underutilised land. However further development of the waste market is required to establish a sustainable and reliable supply chain, and to expand the range of uses for which it is competitive with current fossil fuel feedstocks (e.g. coal and natural gas).
- **Synthetic fuels** – green hydrogen and synthetic fuels produced from renewable energy offer potential but require significant economies of scale and further technology development to reduce cost of production to compete with common industrial fossil fuels such as coal and natural gas. A range of thermochemical, electrochemical, and biological processes are being explored for production.
- **Geothermal heat sources** – highly location dependent, but where geothermal heat is naturally available, they can offer cost-effective heating, compared to gas, for large scale applications.

As the cost of renewable generation declines, the cost-effectiveness of electrification technologies will increase. However, engineering solutions are required to improve process flexibility in some continuous flow processes so electrification can leverage low cost intermittent renewables such as solar and wind. For example, energy intensive industrial facilities (e.g. desalination plants and metal smelters) can be upgraded to enable variable production capabilities – increased production during

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[216] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA), Page 75.
[217] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).
[218] Nathan, G.J., Suenaga, M., Kodama, T., Yourbier, D., Zughbi, H., Dally, B.B., Stechel, E.B., Sattler, C., Cochrane, D., DeGaris, R., Lovegrove, K., et al. 2019, *HiTemp Outlook 2018. Transforming High Temperature Minerals Processing: A multi-stakeholder perspective on pathways to high value, net zero C02 products in the new economy*, University of Adelaide.

times of abundant and low cost renewable electricity, and decreased production during peak demand and low supply periods.[219]

However, these flexible processes must be cost-competitive against firmed renewables elsewhere. For example, productors of 'green' aluminium in NSW would need to compete against 'green' aluminium produced in Canada, Russia and Norway which can be produced without having to alter the current continuous flow aluminium smelting process as abundant hydro power can provide constant generation day and night.[220]

Energy storage provides an alternative to process modification in some cases. The range of electricity storage solutions, combined with their availability to industrial users, means that industrial users have access to a range of potentially cost-effective approaches to integration of renewables, for example:

- Purchase of firmed renewables from the grid,
- Onsite renewable generation and process modification to increase flexibility in line with renewable generation intermittency,
- Onsite renewable generation and storage.

The most cost-effective approach will be context dependent, with blended approaches also suitable.

Next steps

- The Clean Technology Program and Energy Efficiency Program consider supporting more efficient, lower cost and safe electrification, alternative heat and bioenergy technologies.

5.8 Hydrogen

8. Hydrogen – developing and deploying technologies for green hydrogen in industry through hydrogen hubs

Hydrogen has the potential to increase industrial productivity while also decarbonising industrial processes that cannot be electrified. Low renewable energy costs will make Australia one of the most cost-competitive locations to produce hydrogen, potentially for example, at a lower cost than in China and Japan.[221] At present, for some industrial processes, using green hydrogen for decarbonisation is more expensive than using biomass and biogas, or CCS.[222] In future however, using green hydrogen produced from low cost renewable energy could offer a lower cost approach to decarbonisation.[223] While 'blue' hydrogen can also be produced from coal and gas with CCS – applying CCS to these processes does not capture all carbon emissions. Furthermore, green hydrogen does not face the same challenges of limited supply of resources for biomass and biogas,

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[219] For example, a controllable heat exchanger for alumina smelting is being trialled in Germany. This flexible electrolysis technology allows for greater variability in power consumption without production lines freezing.
Djukanovic, G. *'Why Trimet Aluminium is betting on EnPot's virtual* battery', Aluminium Insider, 25 October 2017, accessed 18 June 2020, https://aluminiuminsider.com/trimet-aluminium-betting-enpots-virtual-battery/.; Trimet, *'Energy revolution: TRIMET starts trial operation of its "virtual battery"*, 16 May 2019, accessed 18 June 2020, https://www.trimet.eu/en/presse/pressemitteilungen/2019/2019-05-16-energy-revolution-trimet-starts-trial-operation-of-its-virtual-battery-.
[220] Hobson, P. '*Hydro-powered smelters charge premium prices for 'green' aluminum*', Reuters, 2 August 2017, accessed 27 July 2020, https://www.reuters.com/article/us-aluminium-sales-environment/hydro-powered-smelters-charge-premium-prices-for-green-aluminum-idUSKBN1AI1CF.
[221] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).
[222] For example, use of up to 30 per cent bio-char has been demonstrated in blast furnaces. Nathan, G.J., Suenaga, M., Kodama, T., Yourbier, D., Zughbi, H., Dally, B.B., Stechel, E.B., Sattler, C., Cochrane, D., DeGaris, R., Lovegrove, K., et al. 2019, *HiTemp Outlook 2018. Transforming High Temperature Minerals Processing: A multi-stakeholder perspective on pathways to high value, net zero C02 products in the new economy*, University of Adelaide.
[223] McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.

and finding sufficient end markets for carbon products, and viable storage locations for captured carbon.

With significant future reductions in the costs of green hydrogen, hydrogen-based industrial processes may even become more cost effective than some traditional industrial processes *without* CCS.[224,225] For example, green hydrogen could be used as a more cost-effective reducing agent and heat source than coal in the steel making process.[226] Green hydrogen also could reduce costs for ammonia production and industrial heating applications compared to natural gas.[227] These industrial productivity benefits of hydrogen are dependent on technology development driving significant future reductions in the costs of renewable energy and hydrogen from electrolysis, the establishment of a local hydrogen supply, and investment in production and storage facilities.[228,229]

The adoption of cost-effective green hydrogen could catalyse a new domestic hydrogen industry in NSW. Increased demand for hydrogen would drive growth in hydrogen production, leading to lower hydrogen costs. Lower hydrogen costs would improve productivity and competitiveness of local industries, leading to increasing demand for hydrogen. However, as a hydrogen supply chain will require significant investment in production, transport, storage and end-use infrastructure, development of this industry will need to be well coordinated. For example, hydrogen hubs with co-located hydrogen production, low cost renewable energy (for example through the REZs), and multiple end-use industries could be developed to initiate a stable supply of low cost green hydrogen.[230] Co-location minimises transport costs and encourages sharing of infrastructure and knowledge which is important for uptake of new technology platforms like hydrogen.

NSW has a number of locations that could become hydrogen hubs, such as the SAPs, industrial-export hubs (for example, Newcastle and Port Kembla) and locations proximate to the REZs. These locations can leverage competitive advantages in existing or planned transport, industrial, water and renewable energy infrastructure and workforce capacity and skills.[231] As demand grows these hubs can be scaled and integrated into a state- or nation-wide supply chain. Hydrogen production can also be exported to meet future demand from major trading partners that are transitioning to hydrogen as a major energy source, such as Japan and South Korea.[232]

A domestic green hydrogen market could create significant economic and employment growth opportunities. For example, the National Hydrogen Strategy models one potential future scenario where an Australian hydrogen industry creates between 7,000 to 17,000 jobs, and $11 to $26 billion to GDP each year by 2050.[233] Further, it would also offer opportunities to develop markets in related energy carriers. For example, ammonia and synthetic fuels, both produced using green hydrogen as a feedstock, have potential as low carbon fuels in the maritime and aviation sectors respectively. Further research is required to develop these technology platforms. However, a domestic market in low cost hydrogen would also support cost effective production of these fuels for domestic consumption and export.

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224 McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.
225 BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.
226 McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.
227 McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.
228 Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.
229 COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
230 COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
231 COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
232 COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
233 COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.

Next steps

- The Hydrogen Technology Program preferences hydrogen technology development and commercialisation in a hydrogen hub model, where production, storage and use are co-located alongside transport, industrial, water and renewable energy infrastructure.

5.9 Carbon Capture and Utilisation

9. Carbon capture and utilisation – capturing and transforming carbon emissions to produce value-added products such as building materials, fuels and plastics

At present, carbon capture is one of the most feasible and cost-effective method to eliminate residual emissions in some hard-to-abate sectors, such as steel manufacturing.[234] Carbon capture involves the capture and storage of carbon dioxide or utilisation of carbon dioxide in the manufacture of carbon dioxide-based products, such as solid carbonates. CCS and CCU may either capture carbon from emissions at the point of creation (e.g. from flue gases or as a concentrated by-product), or they may capture them directly emissions from the air (direct air capture (DAC)).

While CCS is technically viable and (at present) lower cost for some applications than some other potential emissions reduction technologies, it is a pure cost and reliant on a financial incentive for emissions reduction. Emitters bear the costs of identifying and securing storage locations, and establishment of the infrastructure to capture, transport and store the carbon. This makes the economics of CCS challenging, with economic opportunities likely to be small and highly sensitive to domestic and international policy and market dynamics that incentivise emissions reduction (e.g. carbon pricing, or a viable price premium for decarbonised products).

In contrast, CCU presents a significant economic opportunity because it could be economically feasible without external incentives, through a market for products manufactured with captured carbon. Further, any domestic or international policy and market dynamics that incentivise emissions reduction would provide an additional tailwind. The total addressable market for CCU products is large: US$5.91 trillion globally each year; with fuels (US$3.82 trillion), building materials (US$1.37 trillion) and plastics (US$0.31 trillion) representing the largest opportunities.[235]

CCU has potential across a range of emissions sources in different sectors including, fossil fuel electricity generation, natural gas processing, hydrogen production from coal gasification and some emission-intensive industrial processes (production of iron and steel, cement, fertilisers, chemicals and plastics). Examples of potential carbon sources and products include:

- Ammonia production, where high purity carbon dioxide emissions are partially captured for use in food and beverage production,[236]
- Waste management, where biomethane emissions can be captured to produce hydrogen and solid carbon (graphite),[237]
- Industrial processes such as steel and cement manufacture or power generation, where carbon dioxide emissions can be captured to produce magnesium carbonate, for building and construction materials,[238]

[234] Energy Transitions Commission, 2017, *Mission Possible*.
[235] Carbon180, 2018, *A Review of Global and US Total Available Markets for Carbontech*.
[236] Orica, *Operations*, accessed 22 July 2020, https://www.orica.com/Locations/Asia-Pacific/Australia/Kooragang-Island/Operations.
[237] Australian Renewable Energy Agency (ARENA), *The Hazer Process: Commercial Demonstration Plant*, accessed 22 July 2020, https://arena.gov.au/projects/the-hazer-process-commercial-demonstration-plant.
[238] Schiffman, R. '*Pilot plant to turn CO_2 into house parts and paving stones*', New Scientist, 23 March 2016, accessed 22 July 2020, https://www.newscientist.com/article/2082112-pilot-plant-to-turn-co2-into-house-parts-and-paving-stones.

- Synthetic fuel production, where carbon dioxide can be captured directly from the atmosphere (DAC) and combined with green hydrogen to produce carbon-neutral efuels for aviation (kerosene) and other industries.[239]

The viability of CCU processes vary depending on the source of the emissions, policy and market incentives to reduce emissions, the utility of emissions captured, and the cost competitiveness of alternative decarbonisation approaches and the products produced from the captured carbon. At present, CCU is already viable and used in the manufacture of ammonia (partial CCU), enhanced oil recovery, and to produce some building materials.[240] As technology improves, further applications will likely become more feasible. For example, with sufficiently low cost hydrogen and renewable energy, an industry could be established to use DAC in the production of synthetic kerosene for aviation – a US$200 billion market.[241]

Next steps

- The Clean Technology Program considers supporting CCU technologies and processes that have the potential of becoming commercially viable without financial incentives to reduce emissions.

Accelerate

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5.10 Critical resources

10. Critical resources – growing the critical minerals industry for decarbonised technologies

Australia is already a major resources exporter with significant exports of iron ore, coal, natural gas, gold, bauxite, copper, zinc, lead, manganese.[242] NSW's three largest goods exports are coal, copper and gold.[243] However, as global demand for decarbonisation and climate resilience technologies expands, the demand profile for resources will change. This is particularly the case for the energy, transport and industry sectors, where increased renewable generation and electrification will grow demand for resources used in solar PVs, batteries, electric motors and generators, and other electronics.[244] For example, neodymium for electric motors and generators, lithium and cobalt for batteries, and copper for electronics. Some of these are critical resources: well suited to a particular function with few cost-effective alternatives, and subject to supply risk due to geopolitical, market or economic instability, or geographic scarcity.[245]

NSW's largest export, coal, is reliant on demand from major overseas economies, in particular India, Japan, China and South Korea, which comprised over 75 per cent of demand for Australian coal exports in 2018.[246] These economies use coal for electric generation and industrial processes (such as steelmaking). While the lifecycles of coal power stations and industrial facilities are long,

[239] The Royal Society, 2019, *Sustainable synthetic carbon based fuels for transport*.
[240] Carbon180, 2018, *Supporting Information: A Review of Global and US Total Available Markets for Carbontech*.
[241] Carbon180, 2018, *A Review of Global and US Total Available Markets for Carbontech*.
[242] Geoscience Australia, *Critical Minerals*, accessed 24 July 2020, https://www.ga.gov.au/about/projects/resources/critical-minerals.
[243] Department of Foreign Affairs and Trade (Australian Government), 2018, *Trade in Services: Australia, 2018*.
[244] Skirrow, R, Huston, D, Mernagh, T, Thorne, J, Dulfer, H, Senior, A, 2013, *Critical commodities for a high-tech world: Australia's potential to supply global demand*, Geoscience Australia.
[245] Skirrow, R, Huston, D, Mernagh, T, Thorne, J, Dulfer, H, Senior, A, 2013, *Critical commodities for a high-tech world: Australia's potential to supply global demand*, Geoscience Australia.
[246] Observatory of Economic Complexity, *Australia (AUD) Exports, Imports and Trade Partners*, accessed 24 July 2020, https://oec.world/en/profile/country/aus.

increased uptake of renewables is likely in these economies, presenting a headwind for continued growth in coal exports.[247] For example, China has large regions which are well suited to solar and wind,[248,249] India is well suited to solar, while Japan and South Korea have signalled their intention to transition to hydrogen as a major energy source.[250,251,252]

As a major resources producer, with an internationally competitive resources industry and large and diverse mineral deposits, there is an economic opportunity for NSW to diversify its resources industry into critical resources to address these future demands. Promising NSW mineral deposits with important applications in decarbonised energy, transport and industry include cobalt, nickel, copper, gold, and rare earth elements.[253,254] Increasing energy productivity and resilience, sustainability, and automation in the NSW resources industry, as well as enabling access to resilient and cost-effective transport and logistics networks will support the competitiveness of the NSW exports of critical resources.

5.11 Grow local production

11. Grow local production – leveraging energy productivity improvements to increase local production

NSW has an economic opportunity to leverage low cost renewable energy to grow local industry by supplying cost-competitive clean energy and goods to local and international markets. Australia is a significant exporter of fossil fuel energy (e.g. coal and natural gas) and raw materials for manufacturing (e.g. iron and other ores, aluminium oxide). At present, low production costs, and employment and environmental standards in other economies incentivise processing of these raw materials and energy offshore. However, renewable energy and environmental standards are growing globally due to rapidly reducing costs and policy incentives. Australia and NSW have a natural competitive advantage in low cost renewable energy compared to most other economies, due to the abundance of sun and wind resources and existing renewable capabilities (particularly in solar PV). These trends will make the export of raw materials and energy for secondary producton overseas less economically advantageous compared to local processing.

While renewable energy is cost effective for local generation compared to fossil fuel energy, it is more cost prohibitive to export. For example, transport of coal costs approximately 10% of its value, whereas long distance transmission of renewable electricity would more than double its cost.[255] Further, liquefaction, transport and regasification of natural gas is substantially cheaper than hydrogen – even at scale.[256] The cost competitiveness of local production of renewable energy in NSW, and the challenges of exporting that renewable energy, mean that the future economics of manufacturing will generally favour local energy intensive processing industries versus overseas

[247] Cunningham, M, Van Uffelen, L, Chambers M, 2019, *The Changing Global Market for Australian Coal*, Reserve Bank of Australia.
[248] The World Bank, *Global Solar Atlas*, accessed 24 July 2020, https://globalsolaratlas.info.
[249] The World Bank, *Global Wind Atlas*, accessed 24 July 2020, https://globalwindatlas.info.
[250] Ministry of Economy, Trade and Industry (Government of Japan), 2017, *Basic Hydrogen Strategy*.
[251] Kan, S, 2018, *South Korea's Hydrogen Strategy and Industrial Perspectives*, French Institute of International Relations.
[252] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
[253] Skirrow, R, Huston, D, Mernagh, T, Thorne, J, Dulfer, H, Senior, A, 2013, *Critical commodities for a high-tech world: Australia's potential to supply global demand*, Geoscience Australia.
[254] Australian Trade and Investment Commission (Australian Government), 2019, *Australia's Critical Minerals Strategy*.
[255] Garnaut, R, 2019, Superpower, *Australia's low-carbon opportunity*, La Trobe University Press, ch 5.
[256] Garnaut, R, 2019, Superpower, *Australia's low-carbon opportunity*, La Trobe University Press, ch 5.

processing. However, where energy is to be exported, nations will increasingly preference clean energy, for example hydrogen.[257]

As energy, transport and labour represent significant industrial costs, low cost renewable energy, proximity to raw materials and automation will improve the competitiveness of local industries. This is especially the case for industries that are energy intensive, highly automated, and use resources extracted in Australia. Metal, chemical and food production, and mining and agriculture are good examples, and industries in which NSW already has existing supply chain infrastructure and skilled workforces. Decarbonisation and climate resilience will also expand demand for products which are compatible with those objectives, for example hydrogen, green steel, aluminium, ammonia and synthetic fuels. This competitiveness and demand growth present an economic opportunity to grow local processing and manufacturing industries (Table 1).

Table 1: Examples of industries which can be accelerated by low cost renewables in NSW

Industry	Potential
Hydrogen	Green hydrogen has potential as a clean combustion fuel for transport and heating, and as an industrial feedstock.[258] Low renewable energy costs will make Australia one of the most cost-competitive locations to produce hydrogen.[259] Many countries are investing in future hydrogen economies, and if this continues, demand for hydrogen could reach 696 million metric tons or US$700 billion by 2050, supplying 24% of global energy needs and attracting over US$11 trillion of investment.[260] Australia's National Hydrogen Strategy forecasts a hydrogen industry potentially creating between 7,000 to 17,000 jobs, and $11 to $26 billion to GDP each year by 2050.[261]
Steel	Green steel, produced from green hydrogen, could be used as a cost-effective reducing agent and heat source in the steel making process (as an alternative to coal or natural gas).[262] At $1.5 to 2/kg, green hydrogen starts to become competitive with steel made using coal,[263,264] with higher coal prices and carbon prices or tariffs making hydrogen even more competitive. Total global steel production is forecasted to grow by 30% by 2050.[265] A green steel industry in one NSW region could create up to 10,000 jobs in that region.[266] The Australian Research Council (ARC) Research Hub for Australian Steel Innovation at the University of Wollongong recently received an additional $28.4 million in funding from industry, government and the research sector.[267]

[257] The International Energy Agency, 2019, *The Future of Hydrogen: Seizing today's opportunities*. Harding, R. *'Japan's hydrogen dream: game-changer or a lot of hot air?'*, Financial Times, 17 June 2019, accessed 27 July 2020, https://www.ft.com/content/c586475e-7260-11e9-bf5c-6eeb837566c5.
[258] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
[259] BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.
[260] BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.
[261] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
[262] McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.
[263] BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.
[264] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.
[265] Energy Transitions Commission, 2018, *Mission Possible Sectoral Focus: Steel*.
[266] Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.
[267] Australian Research Council (Australian Government), *New ARC Research Hub to strengthen steel industry*, accessed 30 July 2020, https://www.arc.gov.au/news-publications/media/media-releases/new-arc-research-hub-strengthen-steel-industry.

Industry	Potential
Aluminium	Green aluminium, produced from low cost renewable energy, could be cost competitive with aluminium produced using traditional energy sources. However, as this is a continuous flow industrial process, low cost storage for intermittent renewables is necessary to compete against green aluminium produced using hydro power in countries including Canada, Russia, Norway and Iceland. For example, in Iceland and Canada, prices can be as low as US$25 to 30/MWh.[268] New flexible pot-cell electrolysis technology can also assist by potentially allowing demand to be reduced by up to 25% during high priced periods.[269] Demand for aluminium is expected to remain strong in a decarbonised economy, as it is an infinitely recyclable, lightweight material critical to many technologies.[270]
Ammonia	Green ammonia, produced from green hydrogen, has potential as a clean combustion fuel in hard to decarbonise sectors such as shipping,[271] and global ammonia production is forecast to grow by 65 per cent to 2050 as population increases and transport and agriculture decarbonises.[272] If NSW captured 6.5 per cent market share of a future ammonia shipping fuel market this could create an additional 15,000 jobs.[273]
Synthetic kerosene	Synthetic kerosene, produced from green hydrogen and carbon dioxide, could be used to decarbonise aviation.[274,275] Synthetic kerosene could be used in existing aircraft engines with little modification, including in a blended approach with traditional kerosene. While currently uncompetitive at prices four times greater than existing aviation fuels, synthetic kerosene could be competitive with aviation fuels by 2050,[276] and earlier if renewable energy or processing costs fall faster than expected or carbon prices or tariffs are imposed in the international aviation market.[277] Despite, short term disruption due to COVID, the International Air Transport Association forecasts aviation passenger volumes to continue to strongly increase in the medium to long term due to global economic development,[278] and airlines have signalled that synthetic fuels are a critical part of meeting their decarbonisation targets.[279]
Mineral beneficiation	Mineral beneficiation is a process that improves the quality of mined ore. Access to low cost renewable energy at the mine site can improve the competitiveness of mineral beneficiation in Australia, through reduced energy and transport costs. An ARC Centre for Excellence for Enabling Eco-efficient Beneficiation of Minerals has been established at the University of Newcastle.[280]

[268] Askja Energy, *New power tariffs to Aluminium smelters,* accessed 27 July 2020, https://askjaenergy.com/2017/03/01/new-tariffs-to-aluminum-smelters.
[269] Djukanovic, G. *'Why Trimet Aluminium is betting on EnPot's virtual battery',* Aluminum Insider, 25 October 2017, accessed 27 July 2020, https://aluminiuminsider.com/trimet-aluminium-betting-enpots-virtual-battery.
[270] Barker, G. and Hobley, R., *'Aluminium can help to build the circular economy. Here's how',* World Economic Forum, 30 June 2020, accessed 27 July 2020, https://www.weforum.org/agenda/2020/06/heres-how-aluminium-can-help-to-build-a-green-recovery.
[271] International Chamber of Shipping, 2018, *Reducing CO_2 Emissions to Zero: The 'Paris Agreement for Shipping'*.
[272] McKinsey & Company, 2018, *Decarbonization of industrial sectors: the next frontier*.
[273] Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.
[274] Note that other types of synthetic fuels could be also be used to decarbonise other combustion engine processes in road transport and shipping.
[275] Pavlenko, N., Searle, S., Christensen, A. 2019, *The cost of supporting alternative jet fuels in the European Union*, The International Council on Clean Transportation.
[276] The Royal Society, 2019, *Sustainable synthetic carbon based fuels for transport*.
[277] Department of Industry, Science, Energy and Resources (Australian Government), 2020, *Technology Roadmap Discussion Paper.*
[278] Pearce, B. 2020, *COVID-19: Outlook for air travel in the next 5 years,* International Air Transport Association.
[279] Lufthansa Group, *Sustainable Aviation Fuel,* accessed 27 July 2020, https://www.lufthansagroup.com/en/responsibility/climate-environment/fuel-consumption-and-emissions/sustainable-aviation-fuel.html.
[280] Australian Research Council (Australian Government), *2020 ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals*, accessed 27 July 2020, https://www.arc.gov.au/2020-arc-centre-excellence-enabling-eco-efficient-beneficiation-minerals.

Industry	Potential
Controlled environment horticulture	Controlled environment horticulture is energy intensive. For example, greenhouse farming can consume up to 10 to 20 times the amount of energy per kilogram as broad-acre farming.[281] However, controlled environment horticulture can improve water efficiency, overall farm productivity and the viability of agriculture in harsh climates. Renewable generation onsite can supply sufficiently low cost energy for competitive intensive agricultural facilities.[282]

The scope to increase processing industries is substantial, given Australia is already a large conventional producer of raw materials for many of these industrial processes.[283]

The viability of renewable powered processing industries will be highly location dependant. Factors such as proximity to raw materials, logistics hubs, skilled workforces and low cost renewable energy will vary between locations, with particular locations likely favouring different industries depending on the specific input requirements of various industries.[284] Customer operated onsite generation may be appropriate in some cases, whereas in others connection to the grid may be preferred. Significant capital investment will be required, to develop, build and integrate intermittent renewable generation and hydrogen into decarbonised processes. However, precinct models such as SAPs and REZs could lower costs for some businesses by aggregated demand and reducing capital barriers.

In addition to substantial economic and employment opportunities, increased local production would also support NSW's industrial capabilities and energy security, and reduce NSW's reliance on imported fuels and other critical commodities.[285]

Next steps

- The NSW Government works with businesses and investors to identify and pursue opportunities to co-locate new and expanded energy-intensive industries in the REZs or in other regional areas with significant renewable energy potential.

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[281] Chen, G., Maraseni, T., Banhazi, T. and Bundschuh, J. 2015, *Benchmarking Energy Use on Farm*, Rural Industries Research and Development Corporation.
[282] Martin, P. *'Futuristic renewable-energy agribusiness Sundrop Farms sells to trans-Tasman investment firm',* Australian Broadcasting Corporation, 15 May 2019, accessed 27 July 2020, https://www.abc.net.au/news/rural/2019-05-15/port-augusta-sundrop-farms-sold-to-investment-fund-morrison-co/11108046.
[283] For example, Australia has approximately 29 per cent of the world's total economic resources of iron ore, 36 per cent of world's total production of iron ore, but 0.3 per cent of world total steel production. Geoscience Australia (Australian Government), *Iron Ore,* accessed 27 July 2020, https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/australian-resource-reviews/iron-ore. Anti-Dumping Commission (Australian Government), 2017, *Analysis of Australia's steel manufacturing and fabricating markets report to the commissioner of the Anti-Dumping Commission*.
[284] Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.
[285] COAG Energy Council, 2019, *Australia's National Hydrogen Strategy*.

5.12 Export industrial productivity and sustainability services

12. Export industrial productivity and sustainability services – export services in industrial productivity, decarbonisation and climate resilience

NSW can leverage its services expertise to improve NSW's industrial productivity and climate resilience to an internationally competitive standard. This expertise also presents an economic opportunity for NSW to become a leading exporter of industrial productivity and sustainability services.

Global demand for services that improve sustainability and productivity is rising.[286] This is being driven by global policy incentives in favour of decarbonisation and climate resilience, major public and private investment flows, and growing business and consumer demand for sustainable products and services. For example, the international market for energy efficiency and management is over $470 billion per annum.[287]

NSW is already a leading services exporter in some areas. For example, NSW already has internationally competitive services in commercial building efficiency and management.[288] These services have been effective in disseminating best practice and new technologies to improve energy efficiency across the commercial building sector in Australia. These services are now being exported internationally.

There is the potential to further expand this capability to export productivity services for industrial processes and facilities. Services required to manage and optimise industrial productivity, for example digital services such as machine learning and process automation, that can be successfully demonstrated in NSW could then potentially be exported. Development of the industry ecosystem of decarbonisation and climate resilience expertise, and expanding the demand for industrial productivity services from government and industry, are essential to establishing an internationally competitive industrial productivity and sustainability services industry. Critical skills include areas such as applied engineering, specifically mechatronics, mechanical, electrical, process and chemical engineering.

Initially, this economic opportunity is best suited to sectors in which NSW has a local industry of sufficient scale. For example, in areas such as food manufacturing, medical technologies, agribusiness, resources, the built environment and infrastructure.[289] As energy productivity improvements grow other local industries, for example in metal and chemical manufacturing, these services could also target these sectors.

[286] Climateworks Australia, 2018, *Decarbonisation Futures: Industry, Can we decarbonise and grow by transforming the way we extract, make and supply goods?*
[287] Energy Efficiency Council, 2016, *Australian Energy Efficiency Policy Handbook*.
[288] For example, applying NABERS in management of building efficiency.
[289] NSW Treasury (NSW Government), 2019, *NSW 2040 Economic Blueprint*.

6. Built environment: A sustainable built environment

Infrastructure is a major driver of economic growth. However, the built environment is also emissions intensive; with infrastructure projects associated with 70 per cent of emissions in Australia.[290] These emissions levels are largely driven by emissions from construction activities, use of energy and emissions intensive materials, and operations, for example heating, ventilation and cooling (HVAC) systems. However, modern trends in building design, technology and operations are enabling buildings and infrastructure that are more sustainable and productive through improved materials, energy efficiency, utilisation and flexibility.

At present, significant public and private investment is being directed into infrastructure and building construction in NSW, including major projects such as the Western Sydney Airport and Aerotropolis, the Western Harbour Tunnel and Beaches Link, and Sydney Metro. The NSW Government has committed $97.3 billion to public infrastructure over four years from financial year 2019-20.[291] From 2018 to 2035, the population of NSW is forecast to grow from 7.9 million to between 9.6 million and 10.2 million.[292] Over the same period, the population of Sydney is forecast to grow from 5.1 million to between 6.6 million and 7.1 million. This represents the delivery of around 800,000 homes and places to work for around 350,000 people as well as the associated physical and social infrastructure to support this growth.[293]

The major growth in population and public and private investment, presents economic opportunities for NSW, including an opportunity to design, develop and deploy buildings, technologies and services that increase the energy and material efficiency, utilisation and flexibility, and use of decarbonised materials in, the built environment at a world leading standard. There are also economic opportunities for government to lead, including to incorporate sustainability and climate resilience considerations into the public infrastructure pipeline, channel investment into sustainable infrastructure and precincts, and improve skills and building standards across NSW. The market signals and additional demand from such efforts would drive further investment in decarbonised and low emissions products and services, create economies of scale, and potentially open up export opportunities.

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[290] ISOA, ClimateWorks and ASBEC, 2020, *Reshaping Infrastructure: For a Net Zero Emissions Future*, (for CEFC).
[291] NSW Treasury (NSW Government), 2019, *The NSW Budget 2019-2020: Half-yearly Report*.
[292] Australian Bureau of Statistics, 2018, *Population Projections, Australia, 2017 (base) – 2066*, cat. no. 3222.0, accessed 23 July 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/0/5A9C0859C5F50C30CA25718C0015182F?Opendocument.
[293] Australian Bureau of Statistics, 2017, *2016 Census QuickStats New South Wales*, accessed 29 July 2020, https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/1.

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6.1 Climate risk assessment

1. Climate risk assessment – considering carbon and climate risks in the planning process

As discussed in Services Opportunity 3.1, climate change presents physical and economic risks for property and infrastructure assets.[294,295] However, buildings and infrastructure can also help to grow new markets and industries, for example, by increasing demand and creating local economies in green hydrogen and sustainable building materials. The planning process should consider these carbon and climate risks and opportunities to preserve and enhance the long term value of investments in public and private buildings and infrastructure assets.

The Infrastructure Sustainability Council of Australia has developed a number of tools to assist organisations in infrastructure planning and operations manage sustainability and risk, including ratings tools, score cards, materials calculators and guidelines.[296] These can cover the lifecycle of infrastructure and roads, bridges and water supply. NSW Government agencies including Transport for NSW (TfNSW), NSW Treasury and the Department of Planning, Industry and Environment have also developed various guides and tools for use in assessing the impacts of climate change and extreme events on infrastructure.

TfNSW, which owns and operates both public transport and road assets across NSW has in place a number of guidelines and tools to facilitate the construction and operation of infrastructure that reduces emissions intensity, and also assess climate risk. For example, the TfNSW Climate Risk Assessment Guideline is publicly available and provides guidance to contractors on how to undertake climate risk assessments in accordance with the Department's Sustainable Design Guidelines.[297] This expertise can be shared across government and with the private sector. Empowering consumers and businesses to make sustainable purchases is identified as a priority under the NZP, with actions focused on the transport, electricity and building sectors.[298]

Next steps

- The NSW Government considers expanding Priority 2: 'to empower consumers and businesses to make sustainable choices' under the NZP, to also cover information about the energy performance of residential properties.

[294] Investor Group on Climate Change, 2019, *IGCC Policy Update: Climate Risk and Fiduciary Duties*.
[295] Network for Greening the Financial System, 2020, *NGFS Climate Scenarios for Central Banks and Supervisors*.
[296] ISCA, 2020, *Tools & Resources*, accessed 23 July 2020, https://isca.org.au/Tools-and-Resources.
[297] Transport for NSW (NSW Government), 2017, *Transport for NSW Climate Risk Assessment Guidelines*.
[298] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.

6.2 Sustainable precincts

2. Sustainable precincts – attracting industry to net zero ready precincts with cooperative decarbonisation strategies for infrastructure and buildings

Sustainable precincts provide a test bed for innovative technologies and services, supported by policy intervention and financial mechanisms. It is well established that different areas exhibit different levels of environmental performance due to a range of factors including geography, climate, history, population and economy. Implementation of a suite of decarbonisation initiatives at the precinct-scale allows for flexibility in pursuing decarbonisation opportunities based on the unique features and competitive strengths of each area.[299] Each precinct can also function as a catalyst, to assist the transition of neighbouring areas and the state. [300]

The NSW Government has adopted a place-based approach to economic development and urban planning. This includes building a 'metropolis of three cities' for the Greater Sydney Region, and developing the SAPs for the regions with a diverse industry focus on sectors such as agriculture, logistics, manufacturing, defence and tourism. Many of these new precincts have adopted sustainable development frameworks. For example, the Greater Sydney Commission has included reducing carbon emissions and managing energy, water and waste efficiently as one of the planning priorities for Greater Sydney,[301] and the Western Sydney Aerotropolis and the SAPs have considerations around sustainability, net zero and circular economy embedded in the planning process.[302,303,304] The Parkes SAP will be Australia's first United Nations Industrial Development Organisation 'Eco-Industrial Park'.[305] The SAPs are being developed under a new *State Environmental Planning Policy (Activation Precincts) 2020 (Activation Precincts SEPP)* which commenced in June 2020.[306]

NSW has demonstrated capability in delivering sustainable precincts. For example, Barangaroo South will be Australia's first large scale carbon neutral precinct.[307] NSW Government can play a wider leadership role, by encouraging these sustainable precinct models in new districts and urban renewal projects. Successful implementation of sustainability in these precincts can support growth in skills and supply chains necessary to catalyse decarbonised and climate-resilient infrastructure across NSW.

Next steps

- The proposed clean technology innovation hub, under the NZP, demonstrates and communicates:
  - Best practice in energy, water and material efficiency and low carbon materials, and
  - Costs and benefits for developers and providers of sustainable finance.

[299] ACT Climate Change Council, *Net Zero Precincts: Summary*.
[300] Thomson, G., Newton, P., Newman, P. and Byrne, J. 2018, *Guide to Low Carbon Precincts*, (for Low Carbon Living CRC).
[301] Greater Sydney Commission, *Reducing carbon emissions and managing energy, water and waste efficiently*, accessed 23 July 2020, https://www.greater.sydney/eastern-city-district-plan/sustainability/efficient-city/reducing-carbon-emissions-and-managing.
[302] Regional Growth NSW Development Corporation (NSW Government), 2019, *Special Activation Precincts Supercharging Regional Economies through Innovative Planning*.
[303] Department of Planning, Industry and Environment (NSW Government), 2019, *Western Sydney Aerotropolis Plan*.
[304] WSP, 2019, *Environmentally Sustainable Development (ESD) Plan: Special Activation Precinct, Parkes*, (for NSW Department of Planning, Industry and Environment).
[305] Department of Planning, Industry and Environment (NSW Government), 2020, *Parkes Special Activation Precinct Master Plan.*
[306] NSW Department of Planning, Industry and Environment (NSW Government), 2020, *Activation Precincts SEPP*, accessed 23 July 2020, https://www.planning.nsw.gov.au/Plans-for-your-area/Special-Activation-Precincts/Activation-Precincts-SEPP.
[307] Sustainable Development Goals, *Barangaroo South*, accessed 23 July 2020, https://sdgs.org.au/project/barangaroo-south.

6.3 Government procurement

3. Government procurement – increasing government procurement of net zero ready infrastructure and buildings

In many economic sectors, there is a role for government, as a major purchaser of goods and services, to send market signals through its choices, which increases supply, leading to a greater decarbonised product range and lower prices due to economies of scale. This is also the case for the built environment, where there is an economic opportunity for NSW Government to drive construction of net zero ready buildings and public infrastructure. This would also increase the quality of NSW building stock and produce long term cost savings in energy and water efficiency. As decarbonisation of heavy industry and manufacturing progresses, potential capacity for green construction materials will increase, but will require an end market. Developers can be encouraged to deliver new buildings and infrastructure that incorporate decarbonised materials and deliver high sustainability ratings through procurement policies that preference higher sustainability standards (including in materials, energy and water).

Current NSW Government procurement policy requires that all new government offices should be of a minimum 4.5-star energy performance and 4-star water efficiency rating, reflecting current best practice under the Green Building Council of Australia Green Star scheme.[308] A 5-star rating recognises 'Australian excellence', and a 6-star rating recognises 'World Leading' innovation in sustainability.[309] Stakeholders consulted estimated that the construction premium differential for a 6-star building compared to a 5-star build is approximately 1.5 per cent. This represents a small fraction of the upfront cost, and in many cases could be fully recovered by the developer over the long duration of a government lease.[310] Given the limited cost premium involved, the NSW Government has an opportunity to encourage delivery of ratings above the required minimum, increasing the stock of highly sustainable buildings in the state.

NSW is regarded as an international leader in sustainable commercial office buildings, with expertise from the implementation of NABERS being sought internationally.[311,312] Government procurement can support the development of businesses and a workforce skilled in the use of new construction materials and sustainable design principles. This could grow a competitive advantage for NSW in developing infrastructure with green or carbon-sequestering materials. For example, procurement of building monitoring technologies creates local business opportunities for installation and monitoring services. For existing buildings, Property NSW is expanding a data-driven approach to operational upgrades and efficiency improvements for lighting, air conditioning and energy generation. Public schools have been identified as an opportunity for profitable solar infrastructure procurement as operational hours closely match the solar generation profile, and premises are non-operational for one quarter of the year presenting a good opportunity for export.

In addition to building the local market and supply chains for sustainable building construction, government will receive the benefit of operational cost savings due to design-embedded energy and water-efficiency in procured buildings. There are also tangential benefits for other sectors, for

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308 Premier & Cabinet (NSW Government), 2014, *M2014-08 NSW Government Resource Efficiency Policy*, accessed 23 July 2002, https://arp.nsw.gov.au/m2014-08-nsw-government-resource-efficiency-policy.
309 Green Building Council of Australia, *Introducing Green Star: Inspiring innovation, Encouraging environmental leadership, Building a sustainable future*.
310 Property NSW, *personal communication*, 21 April 2020.
311 NSW Department of Planning, Industry and Environment (NSW Government), 2019, *Eco building program to create UK business opportunity*, accessed 23 July 2020, https://www.environment.nsw.gov.au/news/eco-buildings-program-to-create-uk-business-opportunities.
312 ASBEC, 2019, *Growing the Market for Sustainable Homes*, (for Low Carbon Living CRC).

example, by providing EV charging facilities in public infrastructure, the incentives to purchase EVs would increase, as would the incentives for car manufacturers to bring more EVs to market in NSW, creating industry opportunities and decreasing prices due to economies of scale and competition.

Under the NZP, the NSW has committed to grow the market for sustainable building materials by embedding sustainable building materials standards and targets into the design and construction of major NSW Government infrastructure projects.[313] The Sydney Metro Project provides a case study of a sustainable procurement approach for major public infrastructure in NSW. For example, Sydney Metro has identified and implemented approaches to reducing or offsetting energy-related emissions in both the construction phase (25 per cent) and operational phase (100 per cent).[314] The project has also adopted solutions to reduce the emissions impacts of concrete used, for example, through optimisation of the cementitious content in the concrete to meet sufficient functional strength requirements while increasing the proportion of substitute materials. Targets for green cement substitution are currently being exceeded on the City and Southwest Metro projects across a range of applications, with an average of 42 per cent of Portland cement being replaced with supplementary cementitious material over the 2018 reporting period.[315]

More broadly with respect to procurement of transport infrastructure, the TfNSW Sustainable Design Guidelines Version 4.0 from May 2017 require that:

- All projects with a capital expenditure greater than $15 million reduce construction related GHG emissions by a minimum 5% from the project baseline GHG footprint which is established using the Carbon Estimate and Reporting Tool,[316]
- Buildings be designed and built to reduce energy consumption.

Next steps

- Refer to next step for Opportunity 5.2.

6.4 Building sustainability standards

4. Building sustainability standards – enhancing building sustainability standards across NSW, and supporting cities and regional towns to lead in building sustainability and environmentally friendly public spaces

Improved building sustainability standards present an opportunity to incentivise and increase the energy efficiency, emissions-intensity, resilience and affordability of the built environment. Building sustainability standards are set through a variety of mechanisms, including the National Construction Code, the Building Code of Australia, BASIX and in some cases local council development approvals. These standards incorporate a number of minimum sustainability requirements for new homes and renovations. NSW already has a leading position in commercial office building sustainability, through programs such as NABERS.[317] However, the sustainability of NSW residential housing stock could be substantially improved. Industry stakeholders predict that across Australia, this could deliver more than half a billion dollars of extra investment into the construction industry, 7,000 jobs, and $600 billion of household energy savings.[318]

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[313] Department of Planning, Industry and Environment (NSW Government), 2020, *Net Zero Plan, Stage 1: 2020-2030*.
[314] Sydney Metro, 2019. *City and Southwest Sustainability strategy 2017-2024*.
[315] Sydney Metro, 2018, *Sustainability Report 2018*.
[316] Transport for NSW, *Sustainability at Transport,* accessed 30 June, https://www.transport.nsw.gov.au/industry/doing-business-transport/sustainability-at-transport.
[317] ASBEC, 2019, *Growing the Market for Sustainable Homes*, (for Low Carbon Living CRC).
[318] ASBEC, 2019, *Growing the Market for Sustainable Homes*, (for Low Carbon Living CRC).

NSW's strong forecast population growth is likely to lead to large growth in housing construction over the medium to long term. To meet this demand, an estimated one million additional homes will be needed in the Greater Sydney region by 2041.[319] Most new buildings constructed today will still be in use by 2050 – when NSW has committed to reach a net zero emissions target.

Research by the CSIRO and Low Carbon Living Cooperative Research Centre (CRC) for indicates that two thirds of home buyers prefer energy efficient homes when given a choice, and that buildings with 'sustainability' features have on average, 8.6 per cent higher purchase preference than the same design without those features.[320] However, industry stakeholders commented that although many consumers were interested in the affordability and environmental benefits of sustainable buildings, and many developers and builders were proactive in offering sustainability options, residential consumers in particular were unfamiliar with the terminology and choices available, and financiers were not yet sufficiently incentivising sustainable residential buildings.[321]

BASIX provides the minimum standards for residential homes in NSW (for example, with respect to energy, water and thermal efficiency).[322] As the bulk of new home construction is driven by private finance and construction, building standards are an essential tool in driving higher performance across new housing stock in NSW. While upfront cost is also cited by some stakeholders as a perceived barrier, the cost impacts of building to higher sustainability standards are not large. For example, in a CSIRO study of a sample of homes constructed after the 2006 transition in the Australian Building Code from a 3.5 to 5-star energy efficiency standard under Nationwide House Energy Rating Scheme (NatHERS), no cost increase was observed – likely due to other cost and energy efficiencies achieved through design changes.[323]

Industry stakeholders commented that the affordability, decarbonisation and resilience benefits of increased residential building sustainability could be realised by:

- Regular upgrading of existing sustainability performance rating schemes such as BASIX,
- Mandatory home energy performance and sustainability disclosure obligations for sales and tenancies,[324]
- Upskilling for architects, designers, builders and developers (currently only 20% of homes are constructed above minimum standard),[325]
- Connecting the sustainable finance sector to transparent investment opportunities in growing sustainable housing stock,
- Increasing scrutiny of actual performance of housing stock to improve market transparency.

These measures would also support economic opportunities beyond savings to the homeowner. These include growing service industry jobs in building design and performance management, an additional pool of investment opportunities for the sustainable finance sector, greater market efficiency through improved transparency over climate risk and operating costs, demand for locally produced sustainable building materials and innovative appliances.

[319] Department of Planning, Industry and Environment (NSW Government), 2020, *A Housing Strategy for NSW*.
[320] ASBEC, 2019, *Growing the Market for Sustainable Homes*, (for Low Carbon Living CRC).
[321] With some limited exceptions being 'green' home loans offered by some banks.
[322] Department of Planning, Industry and Environment (NSW Government), *BASIX Snapshot 2017/2018.*
[323] Ambrose M.D., James, M., Osman, P. and White, S. 2013, *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings*, CSIRO Australia.
[324] Department of Industry, Science, Energy and Resources (Australian Government), 2020, *Report of the Expert Panel examining additional sources of low cost abatement*.
[325] Moore, T., Berry, S. and Ambrose, M. 2019, *'Aiming for mediocrity: The case of Australian housing thermal performance,'* Energy Policy, Volume 132, Pages 602-210.

Next steps

- The NSW Government considers rewarding net zero ready developments with planning incentives, for example increased floor areas.

6.5 Decarbonisation and climate resilience skills

5. Decarbonisation and climate resilience skills – growing skills to support decarbonisation and climate resilience of infrastructure and the built environment

A broad range of professions, skills and trades will be required to support growing demand for decarbonised and climate resilient infrastructure. Climate change will subject infrastructure to a wider range of extreme weather events that may be more frequent and intense. Designing and constructing infrastructure and buildings that are resilient to such events will grow skills in construction engineering and materials science to design and build structures that will withstand added environmental pressures.

Expansion of the market in energy efficiency and building management services could also support workers in transition from declining industries. Coordination between government, industry and the providers of education and training can assist in the development of courses and training packages that prepare or upskill workers for employment in sustainable building and energy efficiency related careers.

Due to the labour intensity of construction projects and building upgrades, there is potential to generate significant skilled employment and apprenticeship opportunities in the short to medium term through government-led programs to promote the use of energy efficiency technology in the design and construction industry. This could unlock the dual benefits of economic stimulus and reduced emissions from the building sector, with enduring long term benefits in cost savings from increased efficiency and increased workforce skills.

The Energy Efficiency Council has estimated that approximately 120,000 job years[326] of work, could be generated in Australia from the implementation of a range of efficiency upgrade projects in residential buildings, commercial buildings and industries through to 2030.[327] These include jobs created from efficiency upgrades in water and waste services (approximately 600 job years), transport (approximately 1,000 job years), and commercial buildings (approximately 48,000 job years).[328] These employment opportunities would exist in a broad range of fields, including planning, architecture, various branches of engineering, process design, materials science, digital services and information technology, air conditioning, electrical, plumbing and construction.

Government also has a role in working with industry organisations to identify and address current and future skills shortages. Some of these shortfalls may be more pronounced in areas that are new, have a faster growth trajectory, or that a cyclical – with a small number of large projects over a long timeframe (such as hydroelectric power construction).[329]

Next steps

- Refer to next step for Opportunity 4.11.

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[326] This is equivalent to 120,000 full time equivalent jobs for a period 12 months.
[327] Some of these strategies included replacement of inefficient heating systems for building and water, replacement of halogen downlights with LED alternatives, improving home insulation and draught sealing, mid-tier office upgrades and efficiency upgrades in industrial, mining and transport applications.
[328] Energy Efficiency Council, 2020, *Energy Efficient Employment in Australia*.
[329] UTS Institute for Sustainable Futures, 2020, *Clean Energy at Work*, (for Clean Energy Council).

6.6 Efficient and modular designs

6. Efficient, modular designs – increasing efficiency and modularity in building design

Economic opportunities exist in improving the material efficiency of the build environment – lowering material volumes, costs and associated emissions. Specific approaches include:

- Factory based manufacturing approaches for prefabricated and modular construction to reduce material waste, reduce build times and energy, and improve building flexibility, utilisation and ease of refurbishment,
- Innovative manufacturing approaches, such as additive manufacturing, to reduce waste and raw material inputs, and improve material strength and durability,
- Sensing and AI to provide predictive maintenance and sustainment,
- Novel and traditional zero-carbon materials (e.g. manufactured wood) to replace emissions-intensive materials (see Built Environment Opportunity 8 below),
- Whole-of-life design repurposing and recycling for deconstruction, refurbishment and longevity to reduce building waste, maximise reuse of construction materials, and extend the lifecycle of infrastructure (see Built Environment Opportunity 13 below).[330]

Prefabricated and modular construction approaches have several advantages over traditional construction methods and can lift productivity in the sector. Construction productivity has not significantly increased since 1990.[331] However, there is a growing transition towards an industrialised, product-based, specialisation model for construction businesses driven by factors including client expectations and budgets, workforce composition, safety and sustainability regulations, new materials and digitalisation. This transition could lift construction productivity by US$265 billion globally by 2035.[332] This model is also likely to drive uptake of factory-based manufacturing approaches such as prefabrication and modular construction.

Factory-based manufacturing using a controlled production system can:[333,334,335]

- Standardise the quality of builds and take advantage of innovative manufacturing technologies, such as additive manufacturing, at scale
- Improve the safety, speed and resilience of construction, by increased automation, reduced exposure to site-related delays (such as weather delays), and simultaneous site preparation and off-site construction
- Enable inputs to be monitored and optimised, reducing unnecessary construction wastage and allowing visibility over material segregation for recycling

330 ARUP, 2018, *From Principles to Practices: First steps towards a circular built environment.*
331 Australian Bureau of Statistics, 2019, *Estimates of Industry Multifactor Productivity, 2018-19*, cat. no. 5260.0.55.002, accessed 25 June 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5260.0.55.002Main+Features12018-19?OpenDocument.
332 McKinsey & Company, 2020, *The next normal in construction*.
333 prefabAUS, *What is Prefab,* accessed 25 June 2020, https://www.prefabaus.org.au/what-is-prefab.
334 Bertram, N., Fuchs, S., Mischke, J., Palter, R., Strube, G. and Woetzel, G. 2019, *Modular construction: From projects to products*, McKinsey & Company.
335 McGraw-Hill Construction, 2011, *Prefabrication and Modularization: Increasing Productivity in the Construction Industry Smart Market Report*.

- Deliver cost savings to clients through reduced construction time, labour and materials costs, more certain timeframes to occupancy, and faster return on investment.

Prefabricated and modular designs are well-suited to hotels, healthcare facilities, residential apartments and facilities requiring identical repeated spaces and have already been used in cost-effective procurement of new public buildings including schools, hospitals and social housing.[336] A number of recent Australian projects have demonstrated the quality and versatility of modular techniques. For example, the construction of a 60-storey residential apartment block in Melbourne,[337] and fast completion of a new NSW primary school.[338]

Modular builds can be either permanent or temporary, providing future flexibility for disassembly, relocation, extensions and refurbishment. This can extend the life of existing buildings, reducing the need to demolish and rebuild as user requirements change. Protection of the structure from weather during construction enables improved sealing and insulation to be undertaken with flow on effects for improved energy efficiency, operational cost savings and reduced emissions.[339]

While the majority of Australian integrated manufacturer/builders in the prefabricated housing market use a module-based approach,[340] another economic opportunity in material efficiency is in prefabricated efficient construction materials with longer lifespans. For example, energy efficient innovative manufacturing approaches that create little waste in manufacture, and use low emission materials including engineered timber, green steel and precast green concrete panels. Prefabricated construction materials provide some of the same productivity benefits as prefabricated buildings in accelerating build times, but are more flexible and can be used for non-prefabricated designs.

For both prefabricated buildings and materials, additional productivity and decarbonisation benefits can be realised through extending their durability and lifespans. For example, even a minor extension in the lifespan of a material can reduce demand for emissions intensive materials by delaying replacement or refurbishment.

The prefabricated housing sector is estimated to represent 3 per cent ($4.5 billion) of the $150 billion Australian building and construction industry.[341] While this represents a relatively small market size, increased demand for these buildings could address many challenges in the construction industry including improving construction productivity, housing affordability, and climate and environmental concerns. Countries such as Sweden and Japan offer examples of successful approaches to increasing market penetration of affordable prefabricated housing.[342]

While some major market players in the prefabricated and modular construction sector are based outside of NSW, there are many smaller builders and manufacturers operating in the local market. There is also local research expertise in this area, for example, the University of Sydney is a

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336 USG Corp and US Chamber of Commerce, 2018, *Commercial Construction Index Q1 2018*.
337 Whittle, K. 2016, *'A Case Study on Designing Superslim in Melbourne*', Council on Tall Buildings and Urban Habitat 2016 Shenzen – Guangzhou – Hong Kong Conference.
338 Richard Crookes Constructions, *Jordan Springs Public School*, accessed 25 June 2020, https://richardcrookes.com.au/project/jordan-springs-public-school/.
339 Turner, A. *'Modular housing the Building blocks of a smart home',* Australian Financial Review,11 July 2019, accessed 25 June 2020, https://www.afr.com/property/residential/modular-housing-the-building-blocks-of-a-smart-home-20190711-p526dx.
340 A case study comparing the Swedish and Australian prefabricated housing sectors identified 86 Australian integrated manufacturer/builders, of which 83 focused on producing modules or complete houses and 3 focused on panel production. Steinhardt, D., Manley, K., Bildsten, L. and Widen, K. 2020, *'The structure of emergent prefabricated housing industries: a comparative case study of Australia and Sweden',* Construction Management and Economics, Volume 38, Pages 483-501.
341 Quezada, G., Bratanova, A., Boughen, N. and Hajkowicz, S. 2016, *Farsight for construction: Exploratory scenarios for Queensland's construction industry to 2036*, CSIRO Australia.
342 Sweet, R. 2015, *'Why Sweden beats the world hands down on prefab housing'*. Global Construction Review, 28 May 2015, accessed 25 June 2020, https://www.globalconstructionreview.com/trends/why-sweden-beats-world-h8an0ds-4d2own0-6p4r2e0f8ab/.

collaborative partner in the ARC Training Centre for Prefabricated Housing Research which is seeking to attract investment and grow the industry in Australia.[343]

Next steps

- The Clean Technology Program considers supporting more efficient, lower cost and safe modular building designs and construction approaches.

6.7 Energy productivity

7. Energy productivity – improving energy productivity by deploying mature technologies for heating, lighting, appliance and motor efficiency

Infrastructure and buildings consume more than 50 per cent of electricity in NSW.[344] Enhancing energy productivity in the built environment presents an economic opportunity to reduce costs for owners and tenants, while also reducing the emissions impacts of buildings and infrastructure. Improvements can be made in productivity during construction and operation.

Improving construction productivity could offer significant economic benefits in reducing building costs. Construction productivity has not significantly increased since 1990.[345] One source of inefficiency is construction waste, which can increase project costs by up to 25 per cent, with a total economic impact of over $30 billion per year.[346] Construction productivity also has a significant impact on emissions due to increased use of energy and emissions-intensive materials. Areas for improvement include addressing lost time, rework, design mistakes, site inefficiencies and lifecycle performance failure.

Improving operational productivity of buildings and infrastructure also offers significant economic benefits for owners and tenants. For example, there is a range of mature and cost-effective technologies to improve the energy efficiency of buildings and infrastructure, including:

- Urban heat mitigation through combined use of greenery, water features, cool materials and passive cooling designs,[347]
- Interior climate control through improved HVAC designs and control systems, increased use of distributed energy efficient and electrified heating systems (e.g. heat pumps), designs and materials for passive heating and cooling, recycling of waste heat, and thermal storage,[348]
- Lighting efficiency through improved lighting controls, materials and design, as well as improved use of natural light,
- Appliance efficiency through innovation in design, materials and efficient systems,
- Integrated onsite renewable generation and storage, including solar PV and batteries.

These energy efficiency technologies can support the move towards a decarbonised built environment, with secondary benefits in reduced energy consumption and costs. This can be

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[343] ARC Training Centre for Advanced Manufacturing of Prefabricated Housing, *Partners*, accessed 25 June 2020, https://camph.eng.unimelb.edu.au/#partners.

[344] Department of Industry, Science, Energy and Resources (Australian Government), *Australian Greenhouse Emissions System Scope 2 emissions – Indirect emissions from purchased electricity 2018*, accessed 30June 2018, https://ageis.climatechange.gov.au/Electricity.aspx.

[345] Australian Bureau of Statistics, 2019, *Estimate of Industry Multifactor Productivity, 2018-19,* cat. no. 5260.0.55.002, accessed 25 June 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5260.0.55.002Main+Features12018-19?OpenDocument.

[346] The Warren Centre, *About This Project*, accessed 18 June 2020, https://thewarrencentre.org.au/project/infrastructure-productivity-ip30/.

[347] Sydney Water, UNSW and Low Carbon Living CRC, 2017, *Cooling Western Sydney: A strategic study on the role of water in mitigating urban heat in Western Sydney*.

[348] Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., & Deverell, J. 2017. *Low Emissions Technology Roadmap, Technical Report*. CSIRO, Australia, Report No. EP167885

supported by other actions, including designing flexible infrastructure that can be shared to improve utilisation rates and reduce demand for new infrastructure.[349] Industry stakeholders report that cost-effective energy efficiency measures could reduce household and business energy bills by up to $4.8 billion per annum while also freeing up gas supply for essential manufacturing processes, and significantly reducing carbon emissions.[350]

NSW already has capability in energy productivity, with existing programs such as the Energy Saving Scheme,[351] the NSW Energy Efficiency Action Plan,[352] and BASIX. The NSW and Commonwealth governments have announced additional energy efficiency initiatives under the Memorandum of Understanding for the NSW Energy Package,[353] and the NZP.[354] Industry stakeholders reported that NSW has world leading performance in commercial building energy efficiency through programs such as the NABERS.[355] NABERS has been effective in disseminating best practice, and new technologies and management approaches, across the commercial building sector in Australia.[356] This capability has the potential to be expanded to other building types across the built environment sector.

Next steps

- The Energy Efficiency Program considers supporting deployment of more efficient and lower cost technologies for heating, lighting, appliance and motor efficiency and energy demand flexibility and adaptability in the built environment.

6.8 Low emission construction materials

8. Low emission construction materials – substituting high emission construction materials with cost-effective low emission materials, and developing novel decarbonised materials

Australia's existing building stock embodies energy equivalent to ten years of the nation's energy consumption.[357] Increasing the use of low emission construction materials could grow new industries in construction materials to meet the future demand for infrastructure and buildings in NSW, while decarbonising the built environment. This could be achieved by growing supply and transitioning demand to:

- Traditional materials that store carbon (e.g. timber and engineered wood products),
- Low emission conventional materials (e.g. 'green' steel),
- New low emission or carbon storage materials (e.g. new geopolymer cements).

Substituting steel and concrete with timber and engineered wood products for new buildings can reduce the emissions intensity of construction. Timber and wood products contain embodied carbon, and approximately half of the carbon in the wood is stored beyond its useable life.[358]

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[349] ARUP, 2018, *From Principles to Practices: First steps towards a circular built environment.*
[350] ASBEC, Energy Efficiency Council, Green Building Council Australia and Property Council of Australia, *'Building efficiency for jobs and growth: Why every building counts in the post-COVID recovery'*, 12 June 2020, accessed 26 June 2020, https://gbca-web.s3.amazonaws.com/media/documents/building-efficiency-for-jobs-and-growth-final-12062020.pdf.
[351] The ESS provides financial incentives to install energy-efficient equipment and appliances in households and business.
[352] The NSW Energy Efficiency Action Plan sets targets of 16 TWh of energy savings per year and 50 per cent of NSW commercial floor space achieves a four-star energy rating of the NABERS by 2020.
[353] NSW Government and Australian Government, 2020, *Memorandum of Understanding – NSW Energy Package*.
[354] Department of Planning, Industry and Environment (NSW Government), 2020, *Net Zero Plan, Stage 1: 2020-2030*.
[355] ASBEC, 2019, *Growing the Market for Sustainable Homes*, (for Low Carbon Living CRC).
[356] NABERS, 2019, *NABERS Annual Report 2018/19*.
[357] Edge Environment Pty. Ltd. 2012, *Construction and Demolition Waste Guide - Recycling and re-use across the supply chain*, (for the Department of Sustainability, Environment, Water, Population and Communities (Australian Government)).
[358] Hepburn, C., Adlen, E., Beddington, J., Carter, E.A., Fuss, S., Mac Dowell, N.I, Minx, J.C., Smith, P, and Williams, C.K. 2019, *'The technological and economic prospects for CO_2 utilization and removal'*, Nature, Volume 575, Pages 87-97.

Engineered wood products include plywood, particleboard, laminated timber etc. There is a mature market and supply chain for these materials in product manufacturing and low-rise residential housing construction. Through advancements in wood engineering technologies to improve the durability and consistency, engineered wood products are now suitable to replace concrete and steel in medium rise commercial and residential buildings.[359] Increased use of timber and engineered wood products in construction offers multiple economic benefits, including faster construction times, greater potential for prefabrication, and supporting a sustainable plantation forestry, wood processing and manufacturing industry in NSW. Furthermore, modern engineering approaches using engineered wood products can improve energy efficiency, and increase lifecycle value through greater potential for re-use, recycling and bioenergy (as compared to concrete).[360] Industry stakeholders indicated that major construction companies in NSW are investing in their skills and supply chains to deliver medium and high rise timber buildings in response to client interest and as part of their sustainability strategies. Two medium rise commercial buildings constructed in the Barangaroo precinct with locally engineered products have been recognised with industry awards.[361,362] A 40 story hybrid timber, concrete and steel tower has been proposed for the Sydney Innovation and Technology Precinct and is due to be completed in 2025.[363]

Traditional construction materials, such as steel and concrete, could also be made more sustainable by reducing their embodied-emissions through novel feedstocks, chemistries and advanced production processes. For example, green steel produced from direct reduction with hydrogen could decarbonise steel production, with a global market estimated at potentially US$590 billion by 2050.[364] Some low emission alternative cements have the potential to replace traditional Portland cement. For example, geopolymer cement, made from by-products (e.g. fly ash from coal-fired power stations and slag from steel furnaces) could reduce cement-related emissions and waste from other industries. Sydney City Council has commenced a five-year trial project partnered with UNSW and Low Carbon Living CRC replacing a section of roadway with geopolymer concrete and monitoring its performance. The Sydney Metro Project has used flexible approaches to concrete to replace 42 per cent of Portland cement with supplementary cementitious material.[365] Other novel decarbonised building materials are in development, and could sequestrate carbon emissions during their production process to act as permanent carbon sinks (similar to timber).[366]

Under the NZP, the NSW has committed a range of initiatives to improve transparency in the construction supply chain and grow the market for sustainable building materials.[367] The NZP includes initiatives for the NSW Government to support industry led targets and certification schemes for low emission materials, lead a national strategy to achieve net zero embodied carbon in building materials, and work with large developers and infrastructure providers to drive uptake of low emission materials.

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[359] Ramage, M.H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D.U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., et al. 2017, *'The wood from the trees: The use of timber in construction*', Renewable and Sustainable Energy Reviews, Volume 68, Pages 333-359.
[360] Ramage, M.H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D.U., Wu, G., Yu, L., Fleming, P., Densley-Tingley, D., Allwood, J., et al. 2017, *'The wood from the trees: The use of timber in construction*', Renewable and Sustainable Energy Reviews, Volume 68, Pages 333-359.
[361] Wood Solutions, *2017 ATDA Winner: International House Sydney,* accessed 31 July 2020, https://www.woodsolutions.com.au/inspiration-case-study/2017-atda-winner-international-house-sydney.
[362] Tzannes, *Daramu House, Barangaroo Sydney,* accessed 31 July 2020, https://tzannes.com.au/projects/daramu-house.
[363] Bleby, M. *'Atlassian's $1b timber Sydney tower'*, Australian Financial Review, 18 February 2020, accessed 26 June 2020, https://www.afr.com/property/commercial/atlassian-s-1b-timber-sydney-tower-20200217-p541ey.
[364] Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.
[365] Sydney Metro, 2018, *Sustainability Report 2018*.
[366] Mineral Carbonation International, *Mineral Carbonation International*, accessed 20 June 2020, https://www.mineralcarbonation.com.
[367] Department of Planning, Industry and Environment (NSW Government), 2020, *Net Zero Plan, Stage 1: 2020-2030*.

Next steps

- The Clean Technology Program considers supporting innovative and cost-effective low emission construction materials.

6.9 Digital technologies

9. Digital technologies – optimising infrastructure and building performance through novel digital technologies and services such as advanced sensors, digital twins and AI

Digital innovation is an important enabler of economic growth which could generate benefits of $315 billion to Australia by improving the productivity of existing industries, and growing new products and services.[368] Digitalisation and digital-enabled technologies also offer economic opportunities for the building and construction sector in greater efficiency and sustainability, from design, planning and construction through to building operation. Integrated city systems are forecast to be a $400 billion per annum market by 2030.[369]

Digital innovation has the capacity to improve the design, planning and cost of new and existing infrastructure and buildings through optimisation of management and performance. For example, IoT enabled integrated management systems could monitor and alter parameters according to functional, cost and sustainability targets to achieve improved energy, heat and water efficiency, and space utilisation.

The NSW Government is the largest infrastructure and building asset owner in NSW, and a major purchaser of telecommunication services (approximately $500 million per annum).[370] This presents an economic opportunity for the NSW Government to ensure that new and upgraded infrastructure and buildings will be enabled for digital connectivity and smart technologies. Existing infrastructure and buildings can also be retrofitted. For example, technology out of Macquarie University has been developed to enable the low cost upgrades of legacy optical fibre cable in buildings, without the need to install new cabling.[371]

The construction industry represents around 7.5 per cent of NSW GSP ($45 billion per annum).[372] However, construction productivity has not significantly increased since 1990,[373] and it is among the least digitalised sectors (with less than 1 per cent of revenue spending on information technology).[374]

Examples of opportunities for digital technologies to improve construction productivity include:

- Digital mapping and estimating techniques to create new integrate high-definition photography, 3-D laser scanning, geographic information systems, AI, and unmanned autonomous vehicles, to deliver accurate and rapid survey information.
- Building Information Modelling (BIM) could optimise physical and functional characteristics of construction projects to improve project planning and management. Given the benefits of

[368] AlphaBeta Advisors, 2018, *Digital Innovation: Australia's $315B Opportunity*, (for CSIRO's Data61).
[369] Aurecon, *The role of Smart ICT in the design and planning of infrastructure*, accessed 19 June 2020, https://www.aurecongroup.com/thinking/thinking-papers/smart-ict-in-the-design-and-planning-of-infrastructure.
[370] Infrastructure NSW, 2018, Building Momentum: State Infrastructure Strategy 2018-2038.
[371] Modular Photonics, *Modular Photonics*, accessed 2 July 2020, https://www.modularphotonics.com/.
[372] Australian Bureau of Statistics, 2019, *Australian National Accounts: State Accounts, 2018-19*, cat. no. 5220.0, accessed 3 July 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5220.0Main+Features22018-19?OpenDocument.
[373] Australian Bureau of Statistics, 2019, *Estimates of Industry Multifactor Productivity, 2018-19*, cat. no. 5260.0.55.002, accessed 25 June 2020, https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5260.0.55.002Main+Features12018-19?OpenDocument.
[374] Agarwal, R., Chandrasekaran, S. and Sridhar, M. *'Imagining construction's digital future'*, McKinsey & Company, 24 June 2016, accessed 19 June 2020, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future.

BIM in delivering shorter project lift cycles and cost savings, a number of governments, including UK, Singapore and Finland have mandated the use of BIM for public infrastructure projects.[375] NSW Government has adopted BIM for health infrastructure and mandated the use of BIM for Sydney Metro Northwest.[376] There are further opportunities to expand the use of BIM across NSW infrastructure and building projects, including next generation 5-D BIM, to improve productivity and efficiency.

Digital technologies also have significant potential to improve operational productivity of infrastructure and buildings, and to seed additional industries and businesses. For example, providing access to high quality data could accelerate the development and commercialisation of innovative service delivery models. In the transport sector, the TfNSW Open Data Hub provides open access to static and real-time data, which businesses can leverage to create innovative services for customers. To date, this has enabled the creation of 1,500 real-time customer applications.[377] The NSW government collects data in energy, transport and other industries. Working with industry to continue to increase access to high quality data, could catalyse more innovative services and generate additional economic value.

Next steps

- The Clean Technology Program considers supporting innovative digital technologies for optimising infrastructure and building performance, for example advanced sensors, digital twins and AI.

6.10 Electrification

10. Electrification – improving energy productivity in construction and operation of infrastructure and building through cost-effective electrification and low cost onsite renewable generation

Electrification presents economic opportunities to substantially reduce the energy consumption, costs and emissions of buildings. Electrification technologies are discussed in detail in Chapter 5. Buildings are well suited to highly efficient electrified HVAC systems such as heat pumps as they generally only require small changes in temperature – minor heating and cooling. A 2015 Melbourne Energy Institute report found that households in Orange, NSW could save $421 per year in heating costs by using heat pumps (reverse-cycle air conditioners) rather than gas heating.[378] Unlike gas heating, these systems can provide both heating and cooling functionality. Although electricity is typically more expensive than gas as an energy source, electrified heating systems such as heat pumps are cost competitive because they:

- Are highly efficient at room temperatures, reducing total energy consumption required to achieve necessary heating or cooling,
- Can be distributed to avoid energy losses associated with centralised heating systems,
- Can be flexibly optimised to leverage low cost renewable electricity during peak daytime periods.[379]

[375] Agarwal, R., Chandrasekaran, S. and Sridhar, M. *'Imagining construction's digital future'*, McKinsey & Company, 24 June 2016, accessed 19 June 2020, https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future.
[376] Morrissey Law, 2019, *Future use of Building Information Modelling (BIM) in Australia*, accessed 19 June 2020, https://morrisseylaw.com.au/future-of-bim-in-australia.
[377] Infrastructure NSW, 2018, *Building Momentum: State Infrastructure Strategy 2018-2038*.
[378] Forcey, T. 2015, *Switching off gas – An examination of declining gas demand in Eastern Australia*, (for Melbourne Energy Institute).
[379] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).

These technologies are mature and already commercially available for commercial and residential buildings. They could offer secondary economic benefits (lower gas prices) for manufacturing industries that rely on gas for industrial process heat by reducing demand for gas for building heating. They also offer decarbonisation benefits if electricity is produced from renewable sources, and safety benefits versus gas heating.

To reduce costs further, electrified heating and cooling can be combined with electricity offtake agreements for large systems or onsite renewable generation and storage, which are often cheaper than average wholesale electricity prices.[380] The energy demand profile of most commercial buildings is well aligned with peak solar generation and could be largely met through solar PV, potentially combined with some battery storage. Residential building demand is generally less well aligned, however the application of digital technologies for demand control and improved energy efficiency can address this. For example, discretionary appliances and electrified heating and cooling (water and air) can be adjusted to match daytime solar peaks, while improved insulation can reduce demand for heating and cooling at night.

6.11 Hydrogen hubs

11. Hydrogen hubs – establishing green hydrogen hubs to grow new domestic supply chains

New infrastructure, including upgrades to existing gas networks and hydrogen-specific networks, may be required (depending on the application) to establish the supply chain for a local hydrogen industry. Hub-based development is being explored as an approach, with key economic advantages for both producers and users. Early users of local hydrogen are likely to include transport operators and industrial users that can replace some process uses of natural gas. Co-location of infrastructure in 'hydrogen hubs' can reduce transmission and storage costs, and risks of disrupted supplies. NSW is also working towards a blending target of up to 10% hydrogen in the existing gas network by 2030.[381]

As the infrastructure requirements for 'green', 'blue' and 'grey' or 'brown' hydrogen differ,[382] options for potential production sites must be carefully considered. Key conditions for green hydrogen production infrastructure include sufficient sources of water, renewable electricity, as well as a site appropriate for electrolysis or a thermo-chemical splitting system, and hydrogen storage.[383] While industry stakeholders expect that a mixture of production methods will be required to enable initial market growth, a policy preference for green hydrogen production will encourage investment from the sustainable finance sector, and will direct efforts towards the maximum decarbonisation potential of hydrogen. Bloomberg New Energy Finance forecasts that by 2030, that green hydrogen will be more significantly cost-effective than other hydrogen production technologies that use fossil fuels.[384]

[380] ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).
[381] Department of Planning, Industry and Environment (NSW Government), 2020, *Net Zero Plan, Stage 1: 2020-2030*.
[382] Hydrogen is categorised based on its method of production. 'Green' hydrogen is produced by electrolysis powered using renewable sources of electricity. 'Blue' hydrogen comes from processes that have zero net emissions, for example using nuclear energy or through steam methane reforming of natural gas with CCS/U or purchased offsets to mitigate carbon emissions. 'Grey' and 'brown' hydrogen are produced from natural gas and brown coal, respectively, with no mitigation of emissions. Hamilton, S. '*Australian made hydrogen must be green, or it will have no export market*,' Renew Economy, 22 June 2020, accessed 10 July 2020, https://reneweconomy.com.au/australian-made-hydrogen-must-be-green-or-it-will-have-no-export-market-99222.
[383] ARUP, 2019, *Australian Hydrogen Hubs Study: Technical Study, Issue 2*, (for COAG Energy Council Hydrogen Working Group).
[384] BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.

The Commonwealth's National Hydrogen Strategy aims to position Australia as a major exporter of renewable hydrogen to international markets, with three NSW ports identified as potential export sites (Newcastle, Port Kembla and Port Botany).[385] Significant investment from government and industry will be required to develop a range of supporting infrastructure including appropriately specified berths, delivery channels from the producer by road, rail or pipeline, and bulk handling technology. Skills and expertise developed through smaller scale hub developments, potentially co-located with these prospective export sites, will provide value in development of a larger domestic industrial market with export optionality.

ARENA and Jemena are co-funding a $15 million trial of a green hydrogen production facility in Western Sydney.[386] The Western Sydney Green Gas Project will use solar and wind generation to power a 500 kW electrolyser to produce green hydrogen. This green hydrogen will be stored for use across the gas network as well as for a hydrogen vehicle refuelling station. The project received a fast-tracked planning approval under the NSW Government's Planning System Acceleration Program in response to COVID-19.

Next steps

- Refer to next step under opportunity 5.8.

Accelerate

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6.12 Grow local supply chains in sustainable construction materials

12. Grow supply chains in sustainable construction materials – leveraging increased local and international demand to grow sustainable construction material industries in NSW

Growing demand for sustainable buildings and infrastructure presents economic opportunities to establish and grow new and existing industries in the supply chain for sustainable construction materials.[387] NSW already has well-established assets, supply chains and skilled workforces in key construction materials, including steel, cement, aluminium and timber. All of these industries have technology pathways to decarbonise their processes and produce sustainable construction materials. Some already have export supply chains, which can be used to export higher value sustainable materials (for example, steel at Port Kembla and aluminium near Newcastle). For example, engineered wood products for buildings can be locally manufactured, using timber from sustainable NSW forestry, and used for high value construction applications or exported.[388] The future markets for these technologies are expected to be large. For example, the market for green steel produced by hydrogen is forecast to reach US$590 billion by 2050.[389]

A local supply chain in sustainable construction materials will also have secondary economic and sustainability benefits. For example, these materials can be used to support the construction of new local renewable generation infrastructure to assist transition of the electricity system, or recycle waste materials from other industries (such as fly ash from coal-fired power stations in NSW).

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[385] ARUP, 2019, *Australian Hydrogen Hubs Study: Technical Study, Issue 2*, (for COAG Energy Council Hydrogen Working Group).
[386] Jemena, *Gearing up for a green gas future*, accessed 12 August 2020, https://jemena.com.au/about/newsroom/media-release/2019/gearing-up-for-a-green-gas-future.
[387] United Nations Environment Programme, 2014, *Greening the Building Supply Chain*.
[388] Industry Edge, 2020 *Australia's growing CLT market*, accessed 23 July 2020, https://industryedge.com.au/new-cross-laminated-timber-facility-in-australia.
[389] Wood, T., Dundas, G. and Ha, J. 2020, *Start with steel*, Grattan Institute.

Certification could support investment in local supply chains for sustainable materials, by incentivising and valuing responsible sourcing.[390] Reward mechanisms for responsible sourcing could be integrated into the supply chain system to incentivise projects to purchase more sustainable construction materials. At present, Green Star Rating Tools provide two credit points for responsible building materials, and three points for structural timber.[391] The NZP has a range of initiatives to encourage uptake of sustainable building materials in public and private construction, as well as growth in the supply chain for sustainable building materials in NSW.

Limited supply chain capacity is a short term barrier for NSW in realising economic benefits from sustainable construction materials. For example, NSW Sydney Metro has identified the use of geopolymer cement (a substitute for Portland cement), as a feasible opportunity for decarbonising their construction.[392] However, at present, suppliers of sufficient scale are based in Queensland and Victoria. The long-distance transportation of substantial amounts of geopolymer concrete for major construction projects undermines the financial feasibility and some of the decarbonisation benefits of using geopolymer cement.

6.13 Reuse and recycling

13. Reuse and recycling – developing and deploying technologies and services to increase material reuse, repurposing and recycling in infrastructure and buildings

Construction and demolition is a significant source of landfill waste,[393] however a high proportion of discarded materials are recoverable or recyclable.[394] There is an opportunity to create economic and decarbonisation benefits from the application of circular economy principles to construction and demolition by reducing resource wastage in construction and increasing the rate of reuse, recycling and recovery of building resources when a building is demolished. The NSW Waste Avoidance and Resource Recovery Strategy 2014-21 sets a target recycling rate of 80% for construction and demolition waste, with circular economy principles to be embedded in NSW's 20-year Waste Strategy.[395,396]

To increase the recyclable proportion of buildings when they reach end-of-life, material efficiency must be considered from the design phase. To reduce wastage, construction processes should be optimised to reduce the production of off-cuts and over ordering of materials. Current lack of visibility over construction site wastage can prevent architects and builders from receiving the feedback that can inform optimisation of processes. Some skip bin companies are now reporting to construction businesses on their recycling efficiency.[397] Increased information around waste will help builders to assess and act on potential savings. Other approaches to improve reuse and recycling include the establishment of online networks and supply chain alliances for trading in construction waste materials.[398]

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[390] University of Wollongong, *'UOW home to Australia's most sustainable building'*, 26 November 2019, accessed 22 June 2020, https://www.uow.edu.au/media/2019/uow-home-to-australias-most-sustainable-building.php.
[391] Green Building Council Australia, 2019, *Green Star and Responsible Sourcing of Timber*.
[392] Sydney Metro, 2019, *City and Southwest Sustainability strategy 2017-2024*.
[393] In 2017-18, a total of 12.8 Mt of waste (60% of NSW total waste) was generated from the construction and demolition sector. PwC. 2019, *NSW Waste Sector Volume I: Key Findings*, (for NSW Environment Protection Authority).
[394] Weiner, S. *'Building without the waste'*, Renew Magazine, 1 October 2019, accessed 18 June 2020, https://renew.org.au/renew-magazine/reuse-recycling/building-without-the-waste.
[395] NSW Environment Protection Authority, 2019, *Waste Avoidance and Resource Recovery Strategy 2014-21*.
[396] NSW Environment Protection Authority, 2019, *Circular Economy Policy Statement: Too Good To Waste*.
[397] Weiner, S. *'Building without the waste'*, Renew Magazine, 1 October 2019, accessed 18 June 2020, https://renew.org.au/renew-magazine/reuse-recycling/building-without-the-waste.
[398] matX, *Goods and Materials Exchange*, accessed 18 June 2020, https://www.matx.com.au.

Applying robotics, sensors and AI, there is potential to accelerate the development of smart demolition and processing approaches that improved segregation of materials at construction sites, and redirect material streams to appropriate processing, reuse and recycling.[399] Opportunities exist in growing feedstocks such as crushed concrete for recycled material manufacturing.[400] For example, 200,000 tonnes of concrete from old road surfaces has been recycled into a new road surface material as part of the M1 Pacific Motorway Upgrade.[401]

Other examples combining "printable" recycled materials, such as concrete waste and fly ash, with additives to develop additive (3D printing) construction methods. Such methods have potential to be highly precise, reduce construction waste and utilise recycled material, but need further development to build confidence in the quality of the materials produced.

Government has an important role to play in working with industry and other stakeholders to develop strategies and targets to deliver sustainable design and improve material recovery, reuse and recycling in buildings and other developments. Government can utilise its procurement power combined with guidance, regulation and incentives. Other interventions include supporting knowledge and material exchange networks, product stewardship and building material passport programs, encouraging segregation of materials for recycling on building sites, management of materials contamination and standards to certify product quality Internationally, challenge-style programs have been used to promote innovation in sustainable construction.[402] Publication of data on the water, energy and material efficiency and sustainability of infrastructure builds could also help drive change.

Next steps

- Refer to next step under opportunity 5.6.

[399] Ghaffar, S., Buman, M. and Braimah, N. 2020, '*Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery*', Journal of Cleaner Production, Volume 244, Article 118710.
[400] Ghaffar, S. 2019, *'How we can recycle more buildings'*, The Conversation, 4 December 2019, accessed 18 June 2020, https://theconversation.com/how-we-can-recycle-more-buildings-126563.
[401] Transport for NSW, *'Concrete recycling on M1 turns rubble into road',* 26 May 2020, accessed 3 July 2020, https://www.rms.nsw.gov.au/about/news-events/news/ministerial/2020/200526-concrete-recycling-on-m1-turns-rubble-into-road.html.
[402] Examples include the Danish Business Authority Circular Construction Challenge 2018 (https://challenges.dk/en/challenge/circularconstructionchallenge), Construction Climate Challenge hosted by Volvo Construction Equipment (https://constructionclimatechallenge.com) and the City of Melbourne Open Innovation 2020 Waste and the Circular Economy Challenge (https://participate.melbourne.vic.gov.au/open-innovation/waste-and-circular-economy).

6.14 Export infrastructure productivity services

14. Export infrastructure productivity services – exporting services in infrastructure decarbonisation and climate resilience

Infrastructure projects are long term assets with significant public and private investment to provide essential services to industry and communities. Infrastructure productivity services are critical to maximum the economic benefits, sustainability and climate resilience of these assets. Developing local supply chains in sustainable construction materials, high productivity in infrastructure and building construction and operations, and circular economies, will support a strong infrastructure productivity services industry.

For example, the new electricity system (renewable generation, storage, transmission, distribution, REZs) offers an opportunity to build a leading capability in infrastructure services for future sustainable, low cost and reliable electricity networks with high renewable penetration. The knowledge and expertise generated from design, construction and management of this infrastructure is valuable to other economies that will also undergo a similar energy transition.

As demand for low-carbon infrastructure and building increases rapidly in global markets, NSW has an opportunity to leverage local capabilities in decarbonised built environments, to export these services. These services exports can also be packaged with exports of sustainable construction materials, to offer easily deployable solutions. This requires NSW to leverage its competitive advantages in:

- **Research and development** – leveraging capabilities in energy and material efficiency, chemistry and novel materials, sensing for predictive maintenance, and applications of circular economy principles, including capabilities in embodied carbon materials, sensing, self-healing concrete and novel concrete.[403] In addition to physical sciences, behavioural insights into consumer and business drivers will be important to support the development and successful transition of new business models.
- **Supportive standards and regulatory environment** – leveraging capabilities in energy efficiency standards for buildings including BASIX and NABERS, regulatory environments and incentives to support the take-up and use of novel sustainable materials, recycling, and more efficient maintenance.
- **Procurement power** – leveraging the procurement power of the NSW Government and local government to encourage the development, commercialisation and demonstration of energy efficiency and materials technologies in NSW infrastructure.
- **Sustainable finance** – leveraging NSW's capabilities in sustainable finance (as discussed Chapter 4), NSW could develop innovative financing approaches for local and international green infrastructure and buildings.
- **Skilled workforce** – leveraging NSW's broader decarbonisation and climate resilience skills in civil, mechanical, materials, systems and electrical engineering, and sustainable finance.

[403] For example, the CRC for Low Carbon Living based at UNSW Sydney; NSW Circular; the Centre for Sustainable Materials Research and Technology (SMaRT) Centre at UNSW (home to Green Steel and Green Microfactories technologies); the ARC Research Industrial Transformation Research Hub for Microrecycling of Battery and Consumer Wastes (also headquartered at UNSW); the Newcastle institute for Energy and Resources (NIER at the University of Newcastle, undertaking work in energy and resource sustainability); the Institute for Sustainable Futures at UTS; the SMART Infrastructure Facility at the University of Wollongong; the University of New England Smart Farm; and infrastructure research at Western Sydney University.

7. Land: Sustainable agriculture and land use

The agriculture and land use sector cover agriculture, forestry, conservation land, protected areas (including indigenous uses) and other natural environments. Decarbonisation and climate resilience provide users of land with economic opportunities to diversify income sources, improve the productivity of land-based industries, improve the resilience of production to climate change and to access affordable, reliable and low emission energy. Further, as a country with large areas of land, Australia has an advantage in carbon sequestration, and Australia's rural land could offset up to 20% of Australian emissions over the next 40 years.[404]

During consultation, stakeholders identified a range of potential initiatives associated with these economic opportunities, including:

- Increasing access and uptake of sustainable land management practices by NSW landholders, including through participation in sustainability markets,
- Increasing the rollout of technologies in areas of controlled environment horticulture, renewables, bioenergy and water efficiency and recycling,
- Investing in research in gene technology (including synthetic biology) and enteric emissions reductions,
- Promoting NSW's credentials in sustainable management practices, services and goods.

Many of the economic opportunities associated with decarbonisation and climate resilience rely on the adoption of sustainable land management practices (including activities to support carbon sequestration and biodiversity). Sustainable land management is the use of land resources for producing goods while ensuring the long term productivity and resilience of the land and the environment.[405] Stakeholders consulted were each of the view that these practices need to be supported by data and knowledge, skills capability and capacity, and trusted certification systems. These opportunities are discussed further below.

Prepare the market

Prepare the Market | Deploy technologies | Accelerate

7.1 Knowledge sharing

1. Knowledge sharing – curating open data sets and expertise in climate and environment

To realise the economic opportunities of sustainable land management, landowners and users need to have access to data and knowledge. In particular, data related to climate and carbon measurements, forecasts and impacts. For example, the Clean Energy Regulator, through the Emissions Reduction Fund (ERF), has published a number of tools that can assist with calculating potential carbon abatement of land uses (e.g. FullCAM).[406] Data is also available through data repositories, such as the CSIRO Data Access Portal and the NSW Government's SEED[407] initiative. The NSW and ACT Regional Climate Modelling (NARCliM) Project also provides data that can assist with

[404] Battaglia, M. 2011, *Greenhouse gas mitigation: sources and sinks in agriculture and forestry*, in H. Cleugh, M. Stafford Smith, M. Battaglia and P. Graham (Eds.), *Climate Change: Science and Solutions for Australia*, (pp. 97-108), CSIRO Australia.
[405] Food and Agriculture Organization of the United Nations, *Sustainable Land Management*, accessed 20 June 2020, http://www.fao.org/land-water/land/sustainable-land-management/en/.
[406] Clean Energy Regulator (Australian Government), *Methods*, accessed 22 June 2020, http://www.cleanenergyregulator.gov.au/ERF/Forms-and-resources/methods.
[407] The Central Resource for Sharing and Enabling Environmental Data in NSW.

adaptation planning.[408] Many individual landholders, including indigenous landowners, also have significant knowledge of their land, and have local networks that can provide further knowledge, such as Landcare, local Aboriginal Land Councils, and NSW Local Land Services.

The NSW Government's NZP under the Primary Industries Productivity and Abatement Program proposes to prioritise assisting small landholders, including Aboriginal landowners, to participate in carbon markets.[409] To understand the full carbon sequestration potential in primary industries, NSW Department of Primary Industries (NSW DPI) is undertaking a state-wide study to identify the carbon abatement potential across the state.[410] This work will provide valuable information and data on how landowners can incorporate carbon sequestration activities into their operations while maintaining productivity and adapting to climate change.

This report does not undertake a full review and assessment of data that may be available to assist with calculating the potential carbon abatement or biodiversity, although some stakeholders indicated that there may be other data not available publicly. For success it is important that knowledge and data is accessible and open and that all parties are encouraged to share through common data repositories.

The NSW Government's SEED initiative contains a considerable amount of data from several government agencies and other organisations, some of which is relevant to sustainable land management. The SEED initiative provides an opportunity for NSW to further develop and curate open data for use in sustainable land management.

Next steps

- The NSW Government facilitates the availability and quality of open data to support the greater adoption of sustainable and low carbon land management practices.

7.2 Sustainability markets

2. Sustainability markets – growing and facilitating access to premium sustainability markets, including linking land users and industry to carbon and biodiversity markets

Sustainability markets provide economic opportunities for landowners whose use of land contributes to positive environmental outcomes and protects the natural capital of the land. A range of sustainability markets are possible. For example, carbon and biodiversity markets that seek to incentivise positive emissions reduction and biodiversity outcomes through activities such as carbon farming, regenerative agriculture, native forest regeneration.

At present in NSW, sustainability markets include schemes such as the Australian Government's ERF and the NSW Biodiversity Offsets Program (BOP), as well as some voluntary carbon-offset and green investment programs. The ERF and BOP are formal government programs and have certain requirements for participation, including eligibility criteria. Voluntary schemes allow businesses (and in some cases individuals) with opportunities to voluntarily offset their environmental impacts, and are often more flexible in permitting landholders, who may not be eligible for participation in the ERF or BOP, to participate in carbon abatement or biodiversity projects. The voluntary schemes are operated through philanthropic organisations, non-government organisations and in some cases private corporations.

[408] NCCARF, 2016, *NARCLiM: Downscaled climate projections to support adaptation in NSW and the ACT*.
[409] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[410] Department of Primary Industries (NSW Government), *Project 4: Emissions reduction pathways*, accessed 22 June 2020, https://www.dpi.nsw.gov.au/climate-and-emergencies/climate-change-research-strategy/emissions-reduction-pathways.

Sustainability markets that encompass both carbon and biodiversity can provide greater economic and environmental benefits than separate markets. These markets can also decrease the risk of unintended consequences such as monoculture environments and land use conflicts, and provide greater capacity for protecting the natural capital of the land. A collaboration between the Centre for Advanced Analytics and Economics and the Climate Change and Sustainability Division, both within the NSW Department of Planning, Industry and Environment are investigating a Natural Capital Assessment Methodology to support financial and non-financial decision making associated with natural capital to better support sustainability markets.[411]

This multi-focus approach also has the potential to expand the type of landholders who could access the sustainable markets. Currently, farmers, indigenous landowners and forestry managers are typical participants in the Australian Government's ERF. A program that encourages biodiversity as well as carbon sequestration potentially increases the attractiveness of the scheme to landholders or land managers of other land types including native reserve areas, vegetation or natural resources within the built environment. While there are current government programs that provide credits through either carbon or biodiversity markets, there is currently no government program that includes both in one market mechanism. This is also being considered by the New Zealand Minister for Climate Change.[412]

The economic benefits for landholders participating in sustainability markets will differ. Holders of large parcels of lands will gain the greatest economic benefits. Smaller landholders may need to group within regions to improve economic benefits, for example aggregating services.[413] Government can also assist landholders to participate in sustainability markets. For example, through advisory services, acting as a liaison between landholders and service providers, and further development of tools to support uptake.

Next steps

- The NSW Government works with landholders and service providers to assist them to navigate and participate in sustainability markets.
- The NSW Government continues working with the federal government and stakeholders in the finance and sustainability markets sectors, on a Natural Capital Assessment Methodology to integrate natural capital into government investment and financial markets.

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[411] NSW Department of Planning, Industry & Environment, *personal communication*, 9 July 2020.
[412] Reymer, L. *'James Shaw will consider biodiversity credits for farmers planting trees on their land'*, Newshub, 22 June 2020, accessed 22 June 2020, https://www.newshub.co.nz/home/rural/2020/06/james-shaw-will-consider-biodiversity-credits-for-farmers-planting-trees-on-their-land.html.
[413] Carbon Farmers of Australia, *Aggregation – Putting together smaller farms to implement carbon projects*, accessed 3 July 2020, https://carbonfarmersofaustralia.com.au/carbon-farming/small-farm-aggregation/.

7.3 Consumer education

3. Consumer education – promoting sustainable products and services from NSW in local and international markets

To maximise the economic opportunities associated with sustainable agriculture and tourism services, consumers need to value sustainability in the products and services they purchase. Sustainable products and services are higher value, due to their reduced environmental and social costs.[414] This value can be captured and reflected through government and industry-led mechanisms such as carbon and biodiversity markets. However, if consumers recognise and are willing to pay a premium for these sustainable products and services, this will encourage business to make the investments necessary to provide them.

Australian consumers express a desire to purchase more sustainable products and services. A survey of Australians aged between 22 and 53 years old found that 9 in 10 were concerned about sustainability and 71 per cent of individuals and 77 per cent of businesses were willing to pay premium for sustainable products.[415] Another survey of Australian shoppers found 34 per cent would buy sustainable products and 31 per cent would not purchase products that did not follow their ethical and sustainability values.[416] This same survey found that 72 per cent of shoppers ranked ethical behaviour important when shopping for products. International interest for sustainable products is similar. For example, in the United States, consumer packaged goods marketed as sustainable were responsible for 50 per cent of growth in sales for this product group from 2013 to 2018, and a survey of 25,000 consumers from 25 countries found the living "environmentally-friendly" was a priority for 54 per cent of respondents, although only 37 per cent are following through with environmentally sound purchases.[417]

This demand for sustainable goods also extends to services, especially in support of nature-based tourism for domestic and international visitors. In 2018, there were 31.1 million 'nature-based' visitors to NSW spending $21.3 billion, and 'nature-based' visitors accounted for 81 per cent of all international visitors.[418] Activities undertaken by 'nature-based' visitors include going to the beach, visiting national and state parks, visiting botanical or other public gardens and bushwalking. This demand for nature experiences presents an opportunity to promote ecotourism businesses that also value and protect these same natural assets.

Often noted is the difference between consumers expressing willingness to make sustainable choices, versus their actual purchasing behaviour. Studies have indicated that some consumers misperceive sustainable products as being of lower efficacy, less aesthetically pleasing and more expensive.[419] However, several effective strategies to encourage sustainable purchasing decisions have been identified including using social influence,[420] encouraging sustainable habits, encouraging

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[414] Grigg, A. *'The path to zero emissions is expensive – but not impossible'*, Australian Financial Review, 18 January 2020, accessed 7 July 2020, https://www.afr.com/policy/energy-and-climate/the-path-to-zero-emissions-is-expensive-but-not-impossible-20200116-p53s7d.
[415] Sustainability Matters, *'Nine in 10 Australians concerned about sustainability: survey'*, 14 September 2018, accessed 21 June 2020, https://www.sustainabilitymatters.net.au/content/sustainability/news/nine-in-10-australians-concerned-about-sustainability-survey-698649130.
[416] Lucio, R. *'Aussies will pay more for sustainable products'*, Inside FMCG, 29 August 2019, accessed 21 June 2020, https://insidefmcg.com.au/2019/08/29/aussies-pay-more-for-sustainable-products/.
[417] SustainAbility, *Sustainable Consumption: From aspiration to behaviour change*, accessed 21 June 2020, https://trends.sustainability.com/2020/sustainable-consumption/.
[418] Destination NSW (NSW Government), *Nature Based Tourism to NSW Year ended December 2018*.
[419] White, K., Hardisty, D.J. and Habib, R. *'The Elusive Green Consumer'*, Harvard Business Review, July-August 2019, accessed 8 July 2020, https://hbr.org/2019/07/the-elusive-green-consumer.
[420] For example, by making others' sustainable behaviours more evident to a consumer making a purchasing decision, by making a consumers' purchasing decision more visible to others, and by using healthy competition between social groups.

small behaviour changes to seed larger behaviour changes, promoting the benefits of sustainability rather than the negatives of non-sustainable products.[421] There is a role for government in promoting sustainable products and services, and providing information to assist consumers to make informed decisions in the market. The NZP has identified empowering consumers and businesses to make sustainable purchases as a priority, with actions focused on the transport, electricity and building sectors.[422] However, there also similar opportunities in agriculture and tourism.

7.4 Decarbonisation and climate resilience skills

4. Decarbonisation and climate resilience skills – growing skills to support decarbonisation and climate resilience of agriculture and tourism industries, and land management

Improving decarbonisation and climate resilience in the land sector, will require landholders to build skills in assessing the risks and opportunities of climate change for their land and businesses. Landholders must also build skills in the adoption of technologies and services that improve their productivity and resilience while reducing their emissions. For example, landholders require skills in implementing comprehensive sustainable land management practices. Building these skills is a particular challenge in the land sector, which has a large number of smaller scale operators and a diverse range of land uses and geographies.

At present, there are some resources and advisory services that able to assist landholders to grow and use these skills. For example, the marketplace section of the Carbon Market Institute website provides a directory of organisations that can assist businesses and landholders to access the carbon market.[423] There are also several environmental restoration services organisations and resources that can assist with the implementation of sustainable land management practices.

Upskilling landholders will also grow the workforce, predominantly in regional areas, as landholders require staff to implement technologies and services for climate resilience. This could also create more employment and skills opportunities for workers in regional areas in the management private and public lands. For example, one approach, carbon farming, could create between 10,500 and 21,000 rural and regional jobs in Australia by 2030.[424] Further technologies and services could offer more employment opportunities.

This could also lead to opportunities for indigenous communities. In 2019, Greening Australia created 117 indigenous trainees across their environmental programs and aims to expand this to 3,000 by 2030.[425] The Indigenous Land and Sea Corporation which assists indigenous people to acquire and manage land of cultural and environmental significance has created 7206 jobs across Australia for indigenous people, some of which are in land restoration and sustainable indigenous agribusinesses.[426]

Next steps

- Refer to next step for Opportunity 4.11.

[421] White, K., Hardisty, D.J. and Habib, R. *'The Elusive Green Consumer'*, Harvard Business Review, July-August 2019, accessed 8 July 2020, https://hbr.org/2019/07/the-elusive-green-consumer.
[422] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[423] Carbon Market Institute, *Australian Carbon Market Directory*, accessed 21 June 2020, http://marketplace.carbonmarketinstitute.org/market-directory-2/.
[424] Carbon Market Institute, *'Australia's Carbon Farming Industry Roadmap to Deliver Emissions Reductions Rural Jobs Value for Regions'*, 1 November 2017, accessed 24 June 2020, http://carbonmarketinstitute.org/australias-carbon-farming-industry-roadmap-to-deliver-emissions-reductions-rural-jobs-value-for-regions/.
[425] Greening Australia, *Year in review 2019*.
[426] Indigenous Land and Sea Corporation (Australian Government), South East Australia: Regional Indigenous Land and Sea Strategy 2019-2022.

7.5 Sustainable certification

5. Sustainable certification – establishing standards for certification of decarbonisation and climate resilience in NSW's agriculture products and ecotourism services

Sustainable certification protects the value of sustainable products, encouraging businesses to make investments to improve their sustainability. Certification is particularly important in providing transparency and education to consumers, including through justifying price premiums on sustainable products, and avoiding perceptions of 'greenwashing'.[427] Certification usually requires independent testing or assessment against national or international standards. Within Australia, the Australian Competition & Consumer Commission is responsible for approving certification trademarks.

There are close to 60 "ecolabels" in Australia for a variety of products and services.[428] Some of these relate to imported products with overseas certification, while others are Australian based "ecolabels". Around a dozen of these relate to products and services associated with sustainable land practices including organic farming and products, sustainable forestry, carbon-offsetting certification and general environmentally sustainable certifications for services and products. It should be noted that not all of these "ecolabels" have been certified within Australia, some may be certified using international sustainability standards (e.g. ISEAL Alliance).

The Australian Government is providing the National Farmers' Federation with funding to develop and trial an Australian Farm Biodiversity Certification Scheme Trial.[429] The Trial will undertake a stocktake of sustainability frameworks available to the agricultural sector, propose a scheme suitable for small to medium size farmers and conduct a trial. The trial aims to integrate productivity, sustainability and biodiversity on farms and showcase best practice sustainability and biodiversity in agriculture.

Government programs such as the Commonwealth's ERF and NSW's BOP require auditing which provides a level of transparency over the program. Ecotourism Australia is a not-for-profit organisation that promotes and supports ecotourism in Australia.[430] Their "ECO Certification" provides the ability for tourism operators and destinations to obtain ecological certification, their destination standard includes sustainable land practices. The Australian Farm Biodiversity Certification Scheme Trial will assist agriculture obtain biodiversity certification and there are a number of existing sustainability certification schemes appropriate for other land-based practices, particularly in forestry. There are opportunities to extend and encourage certification for all landholders undertaking sustainable land practices.

[427] Greenwashing is a process where false or misleading claims are made about the sustainability of a product or service.
[428] Ecolabel Index, *All ecolabels in Australia*, accessed 21June 2020, http://www.ecolabelindex.com/ecolabels/?st=country,au.
[429] National Farmers Federation, *Australian Farm Biodiversity Certification Scheme Trial*, accessed 16 June 2020, https://nff.org.au/programs/australian-farm-biodiversity-certification-scheme-trial/.
[430] Ecotourism Australia, 2019, *Ecotourism Australia Business Plan*, accessed 21 June 2020, https://www.ecotourism.org.au/about/2019-2021-business-plan/.

7.6 Sustainable land management

6. Sustainable land management – promoting best practice sustainable land management and complementary decarbonised income sources for landholders, including indigenous landholders (e.g. carbon farming and regenerative agriculture)

Sustainable land management, while not a new concept, is one which has been used for many years to describe land management that ensures ongoing productive uses of land, while also protecting its economic, environmental and social value into the future. Sustainable land management is increasing in importance and complexity, as landholders consider factors such as climate resilience, biodiversity conservation, and new markets for carbon and biodiversity, in managing their lands and businesses.

Sustainable land management offers economic and emissions reduction opportunities for landholders through a variety of different activities. For example, carbon farming has the potential to abate 360-480 $MtCO_2e$, deliver between $11 and $24 billion in revenue for rural and regional communities in Australia by 2030.[431] Adopting a variety of balanced sustainable land management activities is also beneficial. For example, a study of vegetation-based carbon sequestration projects in Western NSW found financial advantages for landholders having projects with medium to low levels of livestock carrying capacity with medium to high woody vegetation biomass potential.[432] Some biodiverse carbon sequestration projects are already being undertaken in NSW. For example, Greening Australia through their Biodiverse Carbon Conservation arm and NSW Local Land Services are trialling a multi-region biodiverse carbon project on NSW farmland.[433]

The NSW Government has announced a Primary Industries Productivity and Abatement Program under the NZP to assist farms and land managers to reduce emissions.[434] NSW public, private and university researchers are also active in the further research and development of sustainable agricultural practices, including through participation in CRCs such as the Food Agility CRC and the Future Food Systems CRC. These programs will assist with promoting and increasing the uptake of sustainable land management practices, including from areas of land not suitable for other uses or marginal agricultural land.

Next steps

- Refer to next steps under opportunity 7.2.

[431] Carbon Market Institute, *'Australia's Carbon Farming Industry Roadmap to Deliver Emissions Reductions Rural Jobs Value for Regions'*, 1 November 2017, accessed 24 June 2020, http://carbonmarketinstitute.org/australias-carbon-farming-industry-roadmap-to-deliver-emissions-reductions-rural-jobs-value-for-regions/.
[432] Cockfield, G., Shrestha, U. and Waters, C. 2019, *Evaluating the potential financial contributions of carbon farming to grazing enterprises in Western NSW*, The Rangeland Journal, Volume 41, Pages 211-223.
[433] Greening Australia, *personal communication*, 15 June 2020.
[434] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.

7.7 Ecosystem services

7. Ecosystem services – developing the ecosystem services industry to assist land users better manage their lands and improve their climate resilience

As more landholders look to decarbonise and participate in sustainability markets to create income, there will be a greater demand for providers of ecosystem services to assist with sustainable land management practices and projects. Most landowners will likely need assistance with designing projects that provide access to sustainability markets, their implementation and certification and auditing of the projects. Landowners may need assistance with accessing renewable energy systems including solar PV, wind turbine, storage and microgrids, as well technology for water recycling.

The ecosystem services sector already has a strong presence in regional NSW.[435] Further uptake of these services can support additional job creation in rural and regional areas. The ecosystem services sector within NSW is recognised for its innovation and has strong research and industry capability, and already has healthy export markets in Japan, South Korea, China and India.[436]

Many of these professional services require accreditation with industry bodies, with practitioners needing to meet certain standards. For example, the Certified Environmental Practitioner Scheme, an initiative of the Environment Institute of Australia and New Zealand, provides accreditation to climate change specialists.[437] These accreditation schemes provides a level of assurance to clients that the practitioners have the skills need to provide the services and can assist with increasing market access.

Next steps

- Refer to next steps under opportunity 7.2.

7.8 Controlled environment horticulture

8. Controlled environment horticulture – improving agricultural productivity, sustainability and resilience through controlled environment horticulture

Controlled environment horticulture presents an economic opportunity to improve the productivity of NSW horticulture, its climate resilience and the viability of agriculture in harsh, dry climates. Controlled environment horticulture is the use of advanced greenhouses with hydroponic growing systems to grow produce (including fruits, vegetables, herbs) consistently and reliably all year round.[438] As a predominately closed system, it uses significantly less water than broad-acre horticulture, and minimises the risks of some pests, the impacts of extreme climates and weather, and waste volumes.[439] However, energy usage for controlled environment horticulture can be 10 to 20 times higher than broadacre farming for the same crops.[440] Therefore, access to reliable and low cost renewable energy is essential to achieve the productivity and decarbonisation benefits this technology offers.

[435] NSW Innovation and Productivity Council, 2019, *Innovation in the NSW environmental goods and services sector* (for NSW Government).
[436] NSW Innovation and Productivity Council, 2019, *Innovation in the NSW environmental goods and services sector* (for NSW Government).
[437] Certified Environmental Practitioner Scheme, *About Us,* accessed 24 June 2020, https://www.cenvp.org/about-us/.
[438] Department of Primary Industries (NSW Government), *Protected Cropping*, accessed 17 June 2020, https://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse.
[439] Hadley, D. 2017, *Controlled Environment Horticulture Industry Potential in NSW* (for NSW Department of Industry).
[440] Chen, G., Maraseni, T., Banhazi, T. and Bundschuh, J. 2015, *Benchmarking Energy Use on Farm*, Rural Industries Research and Development Corporation.

The pressure on water resources due to a changing climate, the decreasing cost of energy infrastructure (in particular, renewable energy systems) and advances in technology, are increasing the economic potential of controlled environment horticulture systems. These systems have the potential to greatly improve the productivity and resilience of the agricultural industry in a changing climate, as well as to create long term, viable agricultural industries in regional communities that have previously struggled to sustain large agricultural industries due to drought. The relatively low land requirements of controlled environment horticulture (versus broadacre farming) also means there is a potential to co-locate facilities near food processing facilities, to decrease transport costs.

NSW has several competitive advantages in controlled environment horticulture compared to other states, including:

- Favourable climate conditions on the Great Dividing Range and east to the coast,
- Good logistics networks, including roads, rail, maritime and air freight,
- Average annual rainfall providing sufficient water for these systems, supplemented with recycled water in some areas.[441]

Large-scale, self-sufficient greenhouses integrating solar generation, freshwater production (desalination) or water recycling, temperature control and hydroponics are already operating in Australia and internationally. The roll-out of the REZs, with access to low cost renewable electricity presents an opportunity to further grow the controlled environment horticulture sector in NSW, creating economic and job creation opportunities. Controlled environment horticulture also presents a number of circular economy opportunities. For example, controlled environment horticulture facilities also require water, and often carbon dioxide.[442] By locating these facilities within SAPs and the Western Sydney Aerotropolis, there is also the potential to take advantage of recycled wastewater and carbon dioxide from other industrial facilities. Analysis undertaken for the Western Sydney Aerotropolis found that by locating large-scale greenhouses at the Aerotropolis connected to renewable energy sources has the benefit of deceasing energy cost, improves access to labour and reduces transport costs making production costs more competitive in international markets.[443]

NSW also has research capability in this area. For example, the Future Food Systems CRC, headquartered at UNSW Sydney, and including Western Sydney University and University of New England, is developing advanced environmentally controlled indoor farming using automation, informatics and facility design to optimise energy and water inputs, and increase output volumes and consistency.[444]

7.9 Renewables and bioenergy

9. Renewables and bioenergy – improving energy affordability and security by developing and deploying cost effective on-farm renewable and bioenergy

Renewables and bioenergy present economic opportunities for agricultural producers to reduce their energy costs and improve their self-sufficiency. Farmlands are well suited to using renewable energy onsite, including from solar PV, micro wind turbines and small-scale run-of-river hydro.[445] Onsite generation, can lower electricity costs for landowners in regional and remote areas. This is

[441] Hadley, D. 2017, *Controlled Environment Horticulture Industry Potential in NSW* (for NSW Department of Industry).
[442] Li, Y., Ding, Y., Li, D. and Miao, Z. 2018, *'Automatic carbon dioxide enrichment strategies in the greenhouse: A review'*, Biosystems Engineering, Volume 171, Pages 101-119.
[443] Agrology, 2019, *Cost of Production Analysis: Hightech Glasshouse Production in Australia* (for NSW Government).
[444] Future Food Systems, *Future food hubs*, accessed 17 June 2020, https://www.futurefoodsystems.com.au/future-food-hubs/.
[445] Clean Energy Finance Corporation and National Farmers' Federation, 2019, *Transforming Australian Agriculture with Clean Energy: A practical guide to lowering on-farm energy use and carbon emissions.*

particularly the case for remote areas, where transmission and distribution costs are higher, and local generation and storage can be operated through a SAPS. This low cost electricity can also be used to more cost-effectively operate critical (electrified) farm machinery, reducing demand for fossil fuel.

Co-locating generation and agriculture is feasible on most agricultural lands. This practice (an 'agrivoltaic' system) can also offer mutual benefits for both generation and agriculture productivity. For example, the shade of solar PV panels can assist the cultivation of high-value herbs and other species which require partial sun, while solar PV performance is improved through evaporative cooling from the crops.[446] Co-locating sheep with solar panels is mutually beneficial, as the panels increase the moisture content of soil below the panels, improving drought resilience and promoting grass growth, which can be controlled by grazing sheep.[447,448,449]

On-farm bioenergy production and consumption also present economic opportunities to replace fossil fuels (particularly diesel) currently used for agriculture operations. Bioenergy also offers secondary benefits, such as by-products (for example, organic digestates produced from anaerobic digestion can be used as a fertiliser or soil enhancer) and potentially as a more economic and sustainable technique than prescribed burning to reduce hazardous fuel levels in areas where the cost and risks associated with prescribed burning are high.[450]

The NSW DPI Climate Change Research Strategy is investigating opportunities for bioenergy,[451] and is aiming to identify optimal biomass sources, challenges, barriers and viability for adoption in NSW, including using demonstrated case studies of the facility of the technology. Further, the NSW Government has established the Regional Community Energy Fund that provides grants to community energy projects in regional areas.[452] The NSW Government is also supporting low emissions energy solutions through the Emissions Intensity Reduction Program[453] and the Clean Energy Solutions Project.[454]

Next steps

- The Clean Technology Program, the Energy Efficiency Program and the Primary Industries Productivity and Abatement Program consider supporting more efficient, lower cost and safe renewable and bioenergy technologies and services for landowners, including farmers.

7.10 Water efficiency and recycling

10. Water efficiency and recycling – improving water efficiency and productivity by deploying water efficiency technologies and services

[446] Macknick, J., Beatty, B. and Hill, G. 2013, *Overview of Opportunities for Co-Location of Solar Energy Technologies and Vegetation*, National Renewable Energy Laboratory.
[447] Hannam, P. *'The surprising way renewables can help farmers cope'*, The Sydney Morning Herald, 24 June 2020, accessed 24 June 2020, https://www.smh.com.au/environment/climate-change/the-surprising-way-renewables-can-help-farmers-cope-20200623-p555ba.html.
[448] Hassanpour Adeh, E., Selker, J.S. and Higgins, C.W. 2018, *'Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency'*, PLoS ONE, Volume 13, Article e0203256.
[449] ARENA, *'Why sheep could be good for your solar farm'*, ARENAWIRE, 17 November 2016, accessed 24 June 2020, https://arena.gov.au/blog/why-sheep-could-be/.
[450] Department of Environment, Land, Water and Planning (Victoria State Government), *Benefits of bioenergy*, accessed 24 June 2020, https://www.energy.vic.gov.au/renewable-energy/bioenergy/benefits-of-bioenergy.
[451] For example, one study is investigating the productivity of woody biomass crops grown under a variety of conditions, and should the current field trial be successful further work will investigate their productivity on marginal or unproductive mining and farmland sites. Department of Primary Industries (NSW Government), *'Innovative research on woody biomass crops for bioenergy in NSW'*, 9 October 2019, accessed 9 July 2020, https://www.dpi.nsw.gov.au/about-us/media-centre/releases/2019/innovative-research-on-woody-biomass-crops-for-bioenergy-in-nsw.
[452] Energy NSW (NSW Government), *Regional Community Energy*, accessed 2 July 2020, https://energy.nsw.gov.au/renewables/clean-energy-initiatives/regional-community-energy.
[453] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[454] Department of Primary Industries (NSW Government), '*Project 1: Clean energy solutions*', accessed 10 August 2020, https://www.dpi.nsw.gov.au/climate-and-emergencies/climate-change-research-strategy/clean-energy-solutions.

Water security (security of supply and quality) is critical to the economic, social and environmental health of regional communities and agricultural industries. Water is a feedstock across multiple industries, not only agriculture, and is helpful for decarbonising some industrial processes. Climate change, increasing the risk of droughts, poses a risk to water security. Technologies and services to improve water efficiency can improve resilience to these risks, for example, through more economically productive uses of water, reducing system losses, and recycling of wastewater.

There are numerous technologies to improve water efficiency and recycling – from simple drip irrigation systems through to more complex water recycling systems that incorporate a range of technologies such as membrane bioreactors, ultrafiltration, reverse-osmosis and disinfection. [455,456] Some of these technologies are energy intensive. Energy requirements for water systems can vary significantly depending on the water requirements and technology, for example:[457]

- Conventional water treatment systems consume 0.01 to 0.02 kWh per m^3 of water, whereas treatment systems for water reuse in agricultural settings can consume 0.38 kW h per m^3,
- Agricultural irrigation systems consume from 130 to 800 kWh/ha per year depending on system and crops,
- Desalination of seawater by reverse osmosis consume 2.5 to 7 kWh per m^3 of water.

However, in most water-scarce regions, renewable energy resources are in abundance, and widespread use of low cost renewable generation could mitigate the cost impacts of increased energy use.

Another approach to water efficiency that offers economic benefits, is the use of alternative water use pathways and 'fit-for-purpose' water quality, whereby water quality is managed on a more case-by-case basis, to increase the utilisation of lower quality water for appropriate processes where more stringent water quality is not necessary. This could enable reduced costs for treatment and distribution of water in certain applications.

Accelerate

Prepare the Market → Deploy technologies → **Accelerate**

7.11 Gene technologies and synthetic biology

11. Gene technologies and synthetic biology – developing and cultivating highly productive and resilient crops

Gene technologies have delivered productivity improvements in multiple sectors. A new wave of gene technologies, including synthetic biology and CRISPR, will accelerate economic opportunities for improved productivity and climate change resilience, and decarbonisation in multiple sectors, including agriculture, industrial processing and manufacturing. Within agriculture, these technologies have potential to increase productivity through greater yields, with fewer inputs (e.g. water, fertiliser, energy) and greater resilience to extreme climate conditions.

[455] O'Connor, N. and Mehta, K. 2019, *Modes of greenhouse water savings*, Procedia Engineering, Volume 159, Pages 259-266.
[456] Lovely, L. '*Water Reuse Technology*', WaterWorld, 4 April 2018, accessed 29 July 2020, https://www.waterworld.com/drinking-water/treatment/article/14070801/water-reuse-technology.
[457] Plappally, J.H. and Lienhard, V. 2012, *Energy requirements for water production, treatment, end use, reclamation and disposal*, Renewable and Sustainable Energy Reviews, Volume 16, Pages 4818-4848.

Gene technologies includes a range of techniques that allow for genetic changes to be made to an organism (for example, genetic engineering and genetic modification). This can range from marker assisted selection of plants or animals for breeding, to the modification or introduction of genes. In agricultural production this is used to increase crop yields, provide resistance to pests and disease, reduce pesticide and herbicide usage, improve nutritional composition and increase resilience to climate.

Synthetic biology is a rapidly advancing interdisciplinary field that applies engineering to life sciences to design and build novel biological systems. It involves the design and manufacture of novel biological structures and biologically based parts, devices and systems to perform biological functions for useful applications and draws on biology (including gene technology), biochemistry, engineering and computer science. Synthetic biology allows users to specify desired functional requirements for organisms and then develop the structures (for example genetic sequences) to meet those requirements.

Gene technologies and synthetic biology are regulated through Australia's National Gene Technology Scheme, which is highly regarded internationally, and is the joint responsibility of the states, territories and Commonwealth governments.

Gene technologies and synthetic biology present economic opportunities in:

- **Agriculture**: to create productive and climate resilient crops suited to the unique Australian conditions, animal feed by synthetic microbes (e.g. reducing methane emissions), biosensors for the detection of disease, and to create biological mechanisms to control agricultural pests.
- **Industrial processing**: to optimise the activity, yield and quality of industrial enzymes to produce better food and chemicals, with less waste and energy; to create novel bio-based chemicals from biological, renewable and waste materials (e.g. agricultural biomass) for plastics, low emission fuels (including, hydrogen and biofuels) and textiles
- **Manufacturing**: to create bioelectronic devices which exploit biology for information processing systems, sensors, motors and molecular manufacturing.

NSW has strong capabilities in gene technologies and synthetic biology. This includes the National Collaborative Research Infrastructure Strategy (NCRIS) Bioplatforms Australia facilities and Australian Proteome Analysis Facility at Macquarie University, the Ramaciotti Centre for Genomics at UNSW Sydney and the Garvan Institute genomics facilities as well as Southern Cross Plant Science at Southern Cross University. Macquarie University has established a biofoundry (or genome foundry) with co-investment from the NSW Government. This biofoundry is one of the 13 internationally recognised biofoundries in the international Synthetic Biology BioFoundry Network. A biofoundry is a high-throughput facility that provides integrated infrastructure to enable the rapid design, construction, and testing of genetically reprogrammed organisms for biotechnology applications and research.

In addition, Macquarie University is the headquarters of the ARC Centre of Excellence in Synthetic Biology (CoESB), with NSW partners at the University of Newcastle, UNSW Sydney and NSW DPI. The objective of the CoESB is to engineer synthetic microbes to enable a new bio-based economy. This includes the development of microbial strains that use agricultural biomass and waste streams to create biochemicals, biofuels and biomaterials. This set of research capabilities and infrastructure can be leveraged to develop and implement technologies to improve the productivity of NSW agriculture and industry.

Next step

- The Clean Technology Program and the Primary Industries Productivity and Abatement Program consider supporting applications of gene technologies and synthetic biology that aim to improve productivity and climate change resilience, and reduce emissions, in the agriculture and industry sectors.
- The NSW Government continues to work with other Australian jurisdictions on updating regulatory frameworks for gene technologies and synthetic biology.

7.12 Enteric emissions reductions

12. Enteric emissions reduction – developing and deploying vaccinations, feed supplements and breeding

Enteric emissions from cattle and sheep are the highest non-energy contributor to greenhouse gas emissions in Australia. Under the ERF there are four eligible methods for receiving funding for enteric methane emissions reduction: nitrate supplements and herd management for beef cattle; and dietary additives and effluent management for milking cows.[458] If deemed eligible, new and emerging technologies that assist in decreasing enteric emissions could also provide additional income for farmers under the ERF. Further, with more countries implementing emissions reduction strategies for their livestock herds,[459] if NSW were able to market low emission livestock products (e.g. meat, dairy and wool), this would provide a competitive advantage for NSW farmers in high value exports.

Research is continuing both within Australia and overseas to address enteric emissions from livestock through interventions such as feed supplements, breeding and vaccinations. For example, grape marc as a feed supplement has been shown to reduce emissions, although processing is required to remove chemical residues and alcohol.[460] Other feedstock supplements currently being progressed through to commercialisation include:

- Algae-based feed supplements are being progressed through a collaboration between CSIRO, Meat and Livestock Australia and James Cook University.[461] Trials of the feed supplement have demonstrated that it has the potential to decrease methane emissions from livestock by greater than 80 per cent. An independent company, FutureFeed, has been established to commercialise the product with the company currently looking for investors.[462]
- A feed supplement, 3-nitrooxypropanol, has been shown to reduce enteric methane emissions from cows. The company is currently undertaking internationally trials of the supplement to study interactions between diets and dosages and methane reduction to support previous trials that proved safety and effectiveness.[463]

[458] Clean Energy Regulator (Australian Government), *Agricultural Methods*, accessed 2 July 2020, http://www.cleanenergyregulator.gov.au/ERF/Choosing-a-project-type/Opportunities-for-the-land-sector/Agricultural-methods.
[459] Kahn, D. *'California Adopts Strict Rules for Methane Emissions'*, Scientific American, 24 March 2017, accessed 8 July 2020, https://www.scientificamerican.com/article/california-adopts-strict-rules-for-methane-emissions/.
[460] Littler, B. *'Grape marc – friend or foe?'*, Town & Country Magazine, 10 March 2014, accessed 24 June 2020, https://www.townandcountrymagazine.com.au/story/2135284/grape-marc-friend-or-foe/.
[461] CSIRO FutureFeed, *Commercialisation*, accessed 18 June 2020, https://research.csiro.au/futurefeed/growth-opportunities-ip/.
[462] CSIRO FutureFeed, *Commercialisation*, accessed 18 June 2020, https://research.csiro.au/futurefeed/growth-opportunities-ip/.
[463] Heerlen, N.L. *'DSM take next step towards implementation of its methane inhibitor Bovaer in the Netherlands'*, DSM, 30 September 2019, accessed 2 July 2020, https://www.dsm.com/corporate/news/news-archive/2019/2019-09-30-dsm-takes-next-step-towards-implementation-of-its-methane-inhibitor-bovaer-in-the-netherlands.html.

As many of these new technologies are dependent on reliable delivery of sufficient feed supplements, there are opportunities in developing feedlot and grazing systems. Further opportunities exist to decrease emissions through breeding approaches, and potentially vaccinations.

Lowering emissions from red meat industries has been identified as a priority and will be included in the NSW Government's Primary Industries Productivity and Abatement Program.[464] The Meat and Livestock Association has set a target for Australian beef, lamb and goat production becoming carbon neutral by 2030, and has established a research and development program for investing in methane reduction technologies and delivery technologies.[465] Cost-effective vaccinations, feed supplements, breeding and other technologies could present economic opportunities through commercialisation and export of the technology, and deployment to add value to the Australian red meat products.[466]

Next steps

- The Primary Industries Productivity and Abatement Program considers supporting commercialisation of cost effective feed supplements and feeding systems.

7.13 Local supply chains

13. Local supply chains – promoting local consumption of tourism services and agricultural products

Australia is a net importer of manufactured food products, and in 2018 Australians spent close to $US34 billion on overseas travel. [467,468] However, NSW has a competitive food production industry with a wide variety of high-quality products, and a diverse natural environment with a range of local tourism experiences. This presents an economic opportunity to increase consumption of local food products and tourism services and services to support local agriculture, food and tourism businesses. Local goods and services also reduce the emissions impacts of shipping and aviation, and bring more income to the regional communities that manage and protect many of NSW's critical environmental assets.

The recent bushfires and COVID-19 have had a major impact on the tourism sector. However, the COVID-19 pandemic in particular, offers an opportunity to encourage local tourism as international travel remains inactive. NSW consumers should be encouraged to purchase local food products and tourism services, for example, through promotional campaigns that increase awareness of local tourism experiences and leverage goodwill towards local businesses and regional economies that have been impacted by the bushfires and COVID-19.

[464] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[465] Meat & Livestock Australia, *CN30*, accessed 8 July 2020, https://www.mla.com.au/research-and-development/Environment-sustainability/cn30/#.
[466] Mayberry, D. 2019, *'Raising the steaks: reducing GHG emissions from red meat'*, 2019: Weathering the 'Perfect Storm' – Addressing the Agriculture, Energy, Water, Climate Change Nexus, 12-13 August 2019.
[467] The World Bank, *Australia Products by Sector exports and imports 2018,* accessed 29 July 2020, https://wits.worldbank.org/CountryProfile/en/AUS.
[468] OEC, *Australia*, accessed 29 July 2020, https://oec.world/en/profile/country/aus#trade-services.

8. Transport: Electrified and efficient mobility

Decarbonisation of the transport sector presents opportunities for organisations and consumers to maximise value from their mobility options while simultaneously improving environmental and health outcomes. Transport in NSW is expected to:

- **Become increasingly electrified** – modelling predicts that, under a scenario with moderate policy intervention, EV purchase price parity will be achieved in the mid-2020s and EVs could account for 50% of new car sales as soon as 2030.[469] Transport for NSW (TfNSW) is currently undertaking a project to convert the state bus fleet to net zero emissions, which will include a mixture of battery and fuel cell electric vehicles.[470] Industry is also preparing for increased electrification of freight vehicles.[471,472]
- **Become increasingly digitally connected and automated** – transport networks already contain intelligent sensing and communication technologies which can increase system productivity. For example, Sydney Northwest Metro operates driverless trains, and the M4 Smart Motorway has embedded technologies for improved traffic control.[473,474] Other examples include trials of community-based autonomous shuttles, and investigations into vehicle-to-infrastructure communication technologies.[475,476,477]
- **Have improved access to shared mobility networks** – NSW public transport networks utilise electronic ticketing and support real-time trip planning apps. More extensive mobility service platforms are becoming established internationally, with local businesses and researchers developing the Mobility as a Service (MaaS) model further.[478]
- **Incorporate new low emissions approaches to travel and logistics** – in the freight sector, telematics and data analytics can improve productivity and emissions-intensity while electric, hydrogen and alternative fuels are further developed. Clean fuel technology is emerging, with hydrogen buses being trialled and implemented internationally.[479] An Australian trial is expected to be delivered in the next 12 to 18 months.[480]

A potential impact of distributed approaches to urban development in Sydney, and COVID-19, is that communities will increasingly adopt distributed places of work and leisure, reducing the need for regular long-distance commuting. Innovative approaches to land-use planning and provision of local infrastructure combined with use of existing communications technology can support this transition through remote working and local employment opportunities. This has other benefits for communities, including reducing household travel costs and increasing time for leisure. Planning for

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469 Energeia, 2018, Australian Electric Vehicle Market Study.
470 Transport for NSW, *'Expressions of interest sought for zero emissions bus trials'*, 4 May 2020, accessed 11 June 2020, https://www.transport.nsw.gov.au/news-and-events/media-releases/expressions-of-interest-sought-for-zero-emission-bus-trials.
471 Australian Logistics Council*, Electric Vehicle Working Group*, accessed 11 June 2020, http://www.austlogistics.com.au/about-us/electric-vehicles-working-group/.
472 Costello, M. *'EV van sales poised for massive growth, says research firm'*, Car Advice, 28 February 2020, accessed 11 June 2020, https://www.caradvice.com.au/831594/ev-van-sales-poised-for-massive-growth-says-research-firm/.
473 Sydney Metro (NSW Government), *Sydney's new train*, accessed 11 June 2020, https://www.sydneymetro.info/metro-trains.
474 Transport for NSW, *M4 Smart Motorway – intelligent technology*, accessed 11 June 2020, https://future.transport.nsw.gov.au/projects/m4-smart-motorway-intelligent-technology.
475 Transport for NSW, *NSW Smart Shuttle*, accessed 11 June 2020, https://www.transport.nsw.gov.au/projects/programs/smart-innovation-centre/projects-0/nsw-automated-shuttle-trial.
476 Transport for NSW, *Regional Automated Vehicle Trials*, accessed 11 June 2020, https://www.transport.nsw.gov.au/projects/programs/smart-innovation-centre/regional-automated-vehicle-trials.
477 Intelligent Transport Systems Australia, *'ITS Australia: Putting the Connectivity in C-ITS',* 25 March 2020, accessed 11 June 2020, https://its-australia.com.au/news/putting-the-connectivity-in-c-its/.
478 iMove Australia, *'Mobility as a Service: Progress and new insights from an Australian trial*', 1 May 2020, accessed 10 June 2020, https://imoveaustralia.com/news-articles/personal-public-mobility/2020-maas-webinar-video-v2/.
479 Hydrogen Europe, *Cleaner Urban Transport with Hydrogen Buses*, accessed 11 June 2020, https://hydrogeneurope.eu/cleaner-urban-transport-hydrogen-buses.
480 Transit Systems, *'Transit Systems Charges Ahead with Global H2OzBus Project'*, 22 May 2020, accessed 11 June 2020, https://www.transitsystems.com.au/news/2020/5/22/transit-systems-charges-ahead-with-global-h2ozbus-project.

the Aerotropolis region presents an opportunity to achieve these goals for growing communities in Western Sydney.

Prepare the market

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8.1 Government procurement

1. Government procurement – increasing government procurement of decarbonised and climate-resilient transport infrastructure, public transport and fleet EVs

The NSW Government is a major purchaser of transport infrastructure and vehicles. This presents an economic opportunity for the NSW Government to leverage its procurement power, to expand markets in EVs, mobility services and low emissions climate-resilient construction materials for transport infrastructure. This can also support smaller purchasers (including businesses and households) by decreasing prices and increasing choice through economies of scale. Government procurement of low or net zero emissions electricity for public transport systems is also an opportunity to support growth of the renewable energy sector in NSW.

Clear procurement policies can also attract investment, by increasing certainty of uptake of technology and services. Transport and energy stakeholders consulted reported that there is value in government signalling to the market through: procurement policies that prefer or set targets, state-wide targets, and strategies for investment in necessary infrastructure (e.g. for the installation of EV charging infrastructure). For example, embedding decarbonisation and low emissions evaluation into procurement procedures for transport infrastructure, fleet vehicles, but also in approaches to staff travel.

TfNSW has a range of tools and guidelines for estimating and reporting on emissions as well as climate risk,[481] with guidelines in place to reduce the embedded carbon in infrastructure construction or operations for buildings.[482] A Future Energy strategy is currently being developed to support the transition of the transport sector to net zero emissions. This includes actions such as the transition of the NSW bus fleet to zero emissions technology, transitioning the electric rail network to net zero electricity, and the procurement of low emissions vehicles for the transport fleet. These initiatives will support the development of renewable energy generation in NSW and create opportunities for local operators and businesses to take advantage of new low emissions technology.[483]

While NSW is still in the early stages of EV uptake,[484] the scale of procurement that could be initiated by the NSW Government will have a signalling influence on local markets.[485] Through the NSW Electric and Hybrid Vehicle Plan, and the NZP, the NSW Government has initiatives to improve fleet EV uptake, model availability and fast charging infrastructure. A target of 30% electric and hybrid

[481] Transport for NSW, *Sustainability at Transport,* accessed 1 July 2020, https://www.transport.nsw.gov.au/industry/doing-business-transport/sustainability-at-transport.
[482] Transport for NSW, 2017, *Sustainable Design Guidelines Version 4.0*.
[483] Transport for NSW, *'Expressions of interest sought for zero emissions bus trials'*, 4 May 2020, accessed 11 June 2020, https://www.transport.nsw.gov.au/news-and-events/media-releases/expressions-of-interest-sought-for-zero-emission-bus-trials.
[484] As at 31 March 2020, 0.07% of the registered NSW vehicle fleet was fully electric and 0.68% was hybrid electric. Roads and Maritime Services, 2020. *'Table 1.1.4 Motive Power by vehicle type – registered vehicles as at 31 March 2020'*, accessed 8 June 2020, https://www.rms.nsw.gov.au/about/corporate-publications/statistics/registrationandlicensing/tables/table114_2020q1.html.
[485] Various levels of government policy action can modify the predicted trajectories for uptake of EVs according to modelling of scenarios with no, moderate and accelerated policy interventions. Energeia, 2018. *Australian Electric Vehicle Market Study*.

vehicles by 2023 has been set for the NSW Government fleet, with 10% to be fully electric.[486] TfNSW and Treasury are also developing strategies to elevate decarbonisation and low emissions mobility in procurement.

Next steps

- Refer to next step under opportunity 5.2.
- NSW Government agencies increase uptake of low emission Mobility as a Service for internal travel needs.

8.2 Consumer education and research

2. Consumer education and research – improving consumer understanding of the benefits and costs of transport choices

Consumers who can access and understand the benefits of future mobility options, such as electrification, shared mobility and future modes of transport, will value and drive demand for emerging technologies and services, and can reap benefits through lower transport costs. There is opportunity to extend access and awareness to other consumers to realise similar benefits. Information provided by an authoritative source can assist consumers to try new lower emission transport technologies. Ongoing evaluation of consumer attitudes towards new technologies and services is also required to ensure they will be well-received by their intended audience. NSW has social research capability within government, industry and academic institutions that could be leveraged to provide some of these consumer and behavioural insights for effective program design and delivery. These strengths could be combined with expertise that currently delivers existing transport survey programs.[487]

Clear communication around long term financial benefits of EVs will also assist other government policy actions to increase EV uptake. Many consumers already consider environmental benefits to be the most important benefit that EVs can offer.[488] However, improved knowledge of the lower operational costs of EVs and cost savings will encourage consumer uptake of EVs as upfront purchase prices are become competitive in the short and medium term. This aligns with an initiative under the NZP to require additional consumer information on running costs and environmental impacts at the point-of-sale to assist model comparison.[489] NSW vehicle owners will also be offered the opportunity to offset their vehicle emissions when they register their car each year.

As access to shared mobility networks improves, the benefits of owning a car are reduced, particularly in metropolitan centres. Clear comparisons of the costs and benefits of various transport options can assist consumer decision-making around private vehicle ownership. Private vehicle ownership comprises a large percentage of household transport expenditure,[490] and is heavily relied

[486] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[487] Examples include the Transport Opinion Survey delivered by the Institute of Transport Studies and Logistics at the University of Sydney, Transport Affordability Index conducted by the Australian Automobile Association and others conducted by motoring organisations such as the NRMA.
[488] Results of a consumer survey conducted by the NRMA showed that reducing vehicle emissions for environmental benefits was the most highly valued benefit of EVs (34% of respondents), followed by decreasing Australia's reliance on imported liquid fuels (14%). Electric Vehicle Council, 2019, *State of Electric Vehicles.*
[489] Department of Planning, Industry and Environment (NSW Government), *Net Zero Plan, Stage 1: 2020-2030*.
[490] Car-related costs rank as the top 3 transport costs for typical households in every Australian state according to the Australian Automobile Association's Transport Affordability Index. For a typical Sydney household, car loan repayments, fuel and toll charges represented 69 per cent of the average weekly expenditure of $427.90 in the November 2019 report. Australasian Automobile Association, 2020. *Transport Affordability Index: December 2019.*

upon for transport in the suburbs and regions,[491] however, it is not cost-effective for all consumers – particularly where low cost shared mobility options are readily available. Communication strategies may involve benchmarking mobility options and savings in a manner that enables comparison of benefits and costs faced by similar consumers. Mobility apps that also estimate emissions impact could be used to collect and present aggregated data about consumer choices and savings.

Consumer insights can also assist innovators and regulators to improve novel transport technologies and services. For example, in the first Australian trial of drone delivery services conducted in the ACT, noise produced by the drones had an unforeseen impact on acceptance of the technology by some residents. Improvement in regulatory control of the noise was subsequently recommended by an ACT Assembly Inquiry into the matter.[492] Several initiatives will be required to prepare the market for future acceptance of autonomous mobility. Increased exposure will build consumer trust through familiarity with community-based pilots such as the TfNSW autonomous shuttle trials in Sydney Olympic Park, Armidale and Coffs Harbour.[493] Consumer uncertainties around data security, technology safety and liability will also need to be addressed through government regulation and standards.[494]

8.3 Transport funding approaches

3. Transport funding approaches - updating transport funding approaches to incentivise Mobility as a Service, optimise asset utilisation, reduce congestion, and improve network efficiency and flexibility

Efficient and well-maintained transport networks are essential for social connection and economic productivity. New funding approaches, that consider traditional and future transport modes, could be explored to improve productivity across the transport network. Road charge reform was recommended as part of the Henry Tax Review of 2009,[495] with mass-distance-location pricing put forward as a key strategy. In 2017, the Productivity Commission also recommended the importance of providing a pricing structure that enables motorists to appropriately value roads as a shared resource and make cost-effective decisions about usage.[496] Such a scheme could encourage users to make travel decisions with cost, efficiency and environmental outcomes in mind, provided there are viable alternative options for travel. Consideration must also be given to social equity issues to prevent disproportionate impacts on a range of users who have high dependency on roads and long-distance travel. It is important to integrate protections for genuinely disadvantaged groups and accommodate the different usage patterns across the state as part of any user-pays system.[497]

[491] 77 per cent of passenger kilometres in the Sydney region were travelled in a private vehicle either as the driver or passenger on a typical weekday in 2018/19. Figures for the Hunter and Illawarra regions were 86 and 92 per cent respectively. Transport for NSW, *Household Travel Survey (HTS) – Data by Region*, accessed 8 June 2020, https://www.transport.nsw.gov.au/data-and-research/passenger-travel/surveys/household-travel-survey-hts/household-travel-survey-0.

[492] Jervis-Bardy, D. *'Anti-drone activists' concerns vindicated by ACT Assembly inquiry, deputy prime minister'*, Canberra Times, 1 August 2019, accessed 11 June 2020, https://www.canberratimes.com.au/story/6305091/you-were-right-anti-drone-activists-vindicated-by-act-assembly-inquiry/.

[493] Transport for NSW, *Autonomous Vehicle Trials,* accessed 25 May 2020, https://www.transport.nsw.gov.au/projects/programs/smart-innovation-centre/projects.

[494] Aspects of autonomous vehicle operation that cause high levels of concern include independent movement of unoccupied cars, unsupervised travel of children and the ability of vehicles to perform safely in all conditions. 91 per cent of respondents to an Australian public opinion survey on driverless vehicles had concerns about legal and financial responsibility in the case of accidents or mistakes. Concerns also exist around trip data privacy and location tracking for digitally connected vehicles. Australia & New Zealand Driverless Vehicle Initiative, 2017, *Preliminary findings from the first Australian National Survey of Public Opinion about Automated and Driverless Vehicles*.

[495] Department of the Treasury, 2009, *Australia's future tax system: Report to the Treasurer. Part Two, Detailed analysis, volume 2 of 2*.

[496] Productivity Commission, 2017, *Funding and Investment for Better Roads, Shifting the Dial: 5 year Productivity Review, Supporting Paper No. 9*.

[497] Terrill, M., Moran, G., and Ha, J. 2019, *Right time, right place, right price.* Grattan Institute.

Time and location-based strategies have proven effective in some international jurisdictions such as Singapore, London and Stockholm.[498] In Sydney, public transport prices under the Opal card system encourage travel during off peak times for buses, trains and light rail. These have also temporarily been decreased outside of peak hours, to encourage people to change their travel patterns through the day and reduce density of patrons on transport due to the COVID-19 response.[499]

Schemes have also been used to address other social and environmental impacts of transport behaviours, including to improve air quality and health outcomes for those living in high traffic localities. For example, London has Low and Ultra Low Emission Zones where users are charged additional fees to operate a vehicle that does not comply with low emissions standards.[500] Other areas that could be explored include additional rental and advertising opportunities on assets, monetising network data, and value capture around new developments.[501] The move towards app-based mobility also creates an opportunity for new pricing mechanisms through combined trip fees.[502]

Various stakeholders across government and industry have been exploring options for transport network charging reform. Funding approaches that spread the cost of infrastructure more equitably among users and opportunities for value sharing are being looked at by TfNSW in the Future Transport Strategy.[503] NSW has strengths in digital services that could be leveraged to produce supporting technology for consumers to make choices on the mode and route of transport based on emissions impacts, prices and duration.

Another impetus for exploring opportunities in this area are the expected changes in fuel consumption of the vehicle fleet. As the proportion of vehicles with internal combustion engines (ICEs) decreases, along with efficiency increasing, the fuel excise revenue that is gained from petrol sales will decrease relatively, reducing the availability of Commonwealth funding. This could ultimately impact delivery of transport infrastructure and require increased trade-offs with other parts of government budgets.

A transparent and sustainable funding model will be a key enabler to the realisation of the transport infrastructure and technology opportunities of the future, also creating opportunities for digital service and infrastructure businesses to deliver supporting systems.

Next steps

- The NSW Government continues to explore transport funding and pricing options, and develops a pathway to a funding and pricing model for a net zero transport system by 2050 that considers trends in future transport technologies and services.

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[498] U.S. Department of Transportation, 2017, *Lessons Learned From International Experience in Congestion Pricing,* accessed 9 June 2020, https://ops.fhwa.dot.gov/publications/fhwahop08047/02summ.htm.
[499] Casben, L. *'NSW Government slashes public transport prices on off-peak services by half, but there's a catch',* ABC News, 19 June 2020, accessed 1 July 2020, https://ops.fhwa.dot.gov/publications/fhwahop08047/02summ.htm.
[500] Transport for London, *Why we need the ULEZ,* accessed 9 June 2020, https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/why-we-need-ulez.
[501] Infrastructure Australia, 2019, *Australian Infrastructure Audit 2019*.
[502] Hensher, D. 2018, *'Road pricing reform: a thorny issue',* iMove, 28 February 2018, accessed 26 May 2020, https://imoveaustralia.com/news-articles/intelligent-transport-systems/road-pricing-reform/.
[503] Transport for NSW, 2019, *Future Transport Strategy*.

8.4 Policy and regulatory guidance

4. Policy and regulatory guidance – providing a framework to incentivise and streamline technology development, and to build investor and consumer confidence in new modes of transport, including automated and hydrogen vehicles

In order to realise economic benefits from decarbonisation, transport developers must have freedom to innovate and commercialise export-ready products and services. Consumers, investors and insurers must also have assurance that safety, privacy and liability issues have been considered in new-to-market technologies, such as hydrogen vehicles, autonomous driving systems and new air mobility modes. Achieving these outcomes will require policy and regulations that enable flexible approaches to research and trials, while also aligning with international standards that enable rapid technology uptake and export potential for local products and services. Regulation for safety and privacy can also give investors and consumers increased confidence and willingness to test and adopt novel technologies.

There is an economic opportunity to continue working on outcome-based, adaptive policy approaches following a recent review into the state of the NSW regulatory framework.[504] Outcome-focused regulation and standards can assist with the challenge of anticipating future technology that does not yet exist,[505] with embedded metrics for progress monitoring enabling policies to adapt in response to new developments.[506] This approach improves the ability of government to influence developments in the mobility landscape for the public good through direct responsibility for state legislation or through advocacy and collaboration with relevant agencies at the Commonwealth level.

Stakeholders raised some of the following decarbonisation-related transport policy and regulatory areas:

- Permissions for controlled and managed charging of EVs,
- Participant interactions in a distributed and two-way energy market,
- Australian Design Rules for vehicles, including emissions standards,
- Data security and privacy in mobility apps and autonomous vehicle networks,
- Standards for infrastructure-to-vehicle and vehicle-to-vehicle communications,
- Safety and liability in autonomous vehicle operation, batteries and hydrogen fuel cells,
- Licensing requirements for autonomous vehicle owners and operators,
- Heavy vehicle productivity and energy efficiency standards,
- Hydrogen as a fuel for transport,
- Air mobility,
- Battery stewardship.

There are several industry bodies and research centres in NSW who are actively interested and willing to collaborate with government on transport policy and regulatory issues, to achieve both industry development and decarbonisation objectives. The National Cabinet Reform Committee for

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[504] The Independent Review of the NSW Regulatory Framework (Greiner Review) of 2017 outlined a need to reduce unnecessary requirements or burdens on regulated activities and commit to improving the quality of the regulatory framework in NSW. Stakeholder collaboration and data utilisation were identified as key components of a reformed regulatory design process. Greiner, N., McCluskey, S. and Stewart-Weeks, M. 2017, *NSW Regulatory Policy Framework: Independent Review, August 2017.*

[505] Witter, L. and Samant, J. *'These 10 tips for tech regulators will drive innovation'*, World Economic Forum, 31 January 2020, accessed 15 May 2020, https://www.weforum.org/agenda/2020/01/regulation-for-the-fourth-industrial-revolution-in-2020/.

[506] Pankratz, D., Nuttall, K., Eggers, W. and Turley, M. *'Regulating the future of mobility'*, Deloitte Insights, 20 December 2018, accessed on 15 May 2020 https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/regulating-transportation-new-mobility-ecosystem.html.

Infrastructure and Transport (previously the COAG Transport and Infrastructure Council) also provides a forum for NSW Government to raise issues that are a matter of Commonwealth policy and regulation.

Next steps

- The NSW Government continues to work with national transport bodies and the National Cabinet Reform Committee for Infrastructure and Transport to achieve policy and regulatory reform that accelerates the development, uptake and export of new transport technologies and services.

Deploy technology

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8.5 Transport productivity

5. Transport productivity – developing and deploying technologies and services to improve operational and energy efficiency

Decarbonisation initiatives, including increased energy efficiency, optimised asset utilisation and reduced congestion, can also deliver economic benefits for consumers, businesses and network operators through reduced operational costs and improved productivity. For example, some decarbonisation strategies that leverage commercially available solutions to reduce operational costs include:

- Replacement of older energy-intensive technology with newer energy-efficient, low emissions alternatives in infrastructure and vehicles. For example, upgrading older vehicles to new low emissions technologies, such as electric and hydrogen, and efficiency upgrades for infrastructure.
- Movement of passengers and freight transportation to more efficient modes. For example, mode shifting from heavy road vehicles and air modes to rail.
- Utilisation of telematics and data analytics to optimise routing and service delivery.

As passenger and freight tasks increase due to population growth, a mode shift from road to rail can improve transport network productivity through alleviated congestion and provide further benefits such as cost and time savings, reduced carbon emissions and improved air quality. These benefits have been recognised internationally, with the European Union pursuing rail network improvements to support strategic mode shift in passenger and freight movements to rail.[507] In NSW, several projects to expand capacity of the Sydney metropolitan network are already underway including light rail, metro and fleet upgrades.[508] For example, a fleet of hybrid diesel-electric trains is also to be delivered by 2023.[509] Each train that runs during peak hour is estimated to reduce road traffic by 800 cars, with up to $9 in congestion costs saved per person that moves from car to rail.[510]

In NSW, freight volumes are expected to increase with projected growth of 28 per cent (excluding coal transport) over the period 2016 to 2036, reaching a total task of 618 million tonnes per annum.

[507] Shift2Rail Joint Undertaking, *Mission and Objectives*, accessed July 8 2020, https://shift2rail.org/about-shift2rail/mission-and-objectives/.
[508] Transport for NSW, *Major Projects Hub*, accessed 8 July 2020, https://www.transport.nsw.gov.au/projects/major-projects-hub.
[509] Transport for NSW, *'Hybrid trains on the right track'*, 12 Nov 2019, accessed 2 July 2020, https://www.transport.nsw.gov.au/news-and-events/media-releases/hybrid-trains-on-right-track-0.
[510] Deloitte Access Economics, 2017, *Value of Rail: The contribution of rail in Australia*, (for Australasian Railway Association).

In the Greater Sydney region, volumes are expected to double in the same time period[511]. About 80 per cent of the NSW freight task is moved by road and is affected by growing congestion around ports, producing an estimated 16 times more carbon pollution than rail freight per tonne kilometre.[512] TfNSW has identified mode shift from road to rail as an opportunity to increase freight productivity, particularly for long-distance transport of containerised goods. For example, it is estimated that the use of a 600m rail shuttle into Port Botany has potential to remove 54 trucks from the surrounding road network.[513]

Stakeholders in the NSW freight sector identified that to achieve the full decarbonisation potential of rail there are issues to be addressed with an ageing diesel freight rail fleet, track load specifications for transportation of heavy goods, and port access for the transfer of goods from rail.[514] Increasing the freight task share for rail will be supported by the delivery of the Commonwealth Inland Rail project which will improve interstate rail connections and provide an alternative north-south corridor that avoids metropolitan networks. The project is estimated to deliver rail cost savings of $10 per tonne for freight transport between Melbourne and Brisbane and prevent 750,000 tonnes of carbon emissions per year from 2050.[515]

Real time information flows assist network operators and emergency services to respond more rapidly and efficiently to events that impact the network. They also advise users of incidents, and can propose immediate action, for example rerouting to avoiding congestion. New major roads can be fitted with technologies for sensing and communication, responsive speed and lane management, travel time displays and ramp meters to control joining vehicles. The Smart M4 Motorway project is a demonstration of this technology in NSW.[516]

For the heavy vehicle and logistics sector especially, operational efficiency and demand management has been identified as an important initiative delivering economic productivity and emissions reductions benefits.[517] Stakeholders in the industry have highlighted that vehicle telematics for optimisation of freight loads and routes can deliver these operational efficiency benefits, and that improved participation by smaller operators should be encouraged through incentives or improved access programs, such as those being considered under the National Heavy Vehicle Law reform.[518,519] Increased information about road use by freight operators will also assist network analysts with capacity planning.

The NSW Government has committed to invest $55.6 billion in road and public transport projects through to 2022-23 providing many opportunities to invest in cost-effective and commercially available technology for transport productivity improvements through strategic programs such as the Future Energy program currently being developed by TfNSW.[520]

[511] Transport for NSW, 2018, Freight and Ports Plan 2018-2023.
[512] Deloitte Access Economics, 2017, *Value of Rail: The contribution of rail in Australia*, (for Australasian Railway Association).
[513] Transport for NSW, 2018, *Freight and Ports Plan 2018-2023*.
[514] Transport for NSW, *personal communication*, 21 May 2020.
[515] Australian Rail Track Corporation, 2015, *The Case for Inland Rail.*
[516] Transport for NSW, *M4 Smart Motorway – intelligent technology*, accessed 11 June 2020, https://future.transport.nsw.gov.au/projects/m4-smart-motorway-intelligent-technology.
[517] Modelling by the Energy Transitions Commission estimates global heavy-road transport emissions can be reduced by approximately 30% using demand management strategies. Energy Transitions Commission, 2018, *Mission Possible Sectoral Focus: Heavy Road Transport*.
[518] National Transport Commission, 2019, *Easy access to sustainable routes: Issues paper*.
[519] National Transport Commission, 2020, *Summary of consultation outcomes: Heavy Vehicle National Law Review*.
[520] NSW Government, 2019, *Infrastructure Statement 2019-20: Budget Paper No. 2*.

8.6 Mobility services

6. Mobility services – developing and deploying Mobility as a Service to improve efficiency, flexibility, and affordability in low emission transport

MaaS is a concept for transport ecosystems that enables consumers to access multimodal travel services provided through mobile app-brokered bundled subscriptions or a pay-as-you-go service. A fully developed MaaS model, that incorporates reliable first and last mile connections with the existing public transport network, offers economic benefits for some consumers by reducing or removing the expenses associated with private vehicle ownership, while offering multiple, flexible transport options at a lower cost. Under MaaS, consumers are able to access a variety of private, shared, and public transport options, at different price points, depending on the particular mobility needs of each trip (for example, capacity, speed, cost). MaaS also offers decarbonisation benefits, mainly through improved transport asset utilisation, which reduces demand for carbon intensive products (for example, cars) and improves the incentives for electrification.[521]

NSW consumers have responded rapidly to recent mobility developments in MaaS, such as ride- and car-sharing platforms, indicating a willingness to exchange private car trips for alternative shared modes given alternate, cost-effective options.[522] Opportunities to increase the availability and uptake of affordable, low emissions MaaS options, including micromobility[523] and community-based on-demand services, for connections to main public transport corridors in NSW should be prioritised.

The Sydney region has an extensive multi-modal electronically-ticketed transport network and ride-sharing economy with an open real-time data service, providing competitive advantages for development of a MaaS ecosystem. MaaS solutions were explored through the TfNSW Digital Accelerator in 2018 with several companies trialling various apps and data platforms.[524] Trip planning apps are currently available for the Sydney network however, there is an opportunity for development of a new business model and integrated ticketing platform across these different services, as no single platform is yet able to facilitate payment across all modes and operators. Preliminary analysis from a recent MaaS model trial in Sydney has shown that bundled transport services may have an ability to attract active car users who have relatively lower reliance on their vehicles. However, more work needs to be undertaken to optimise bundle offerings, make provision of the service economically viable for the broker and to invest in MaaS infrastructure (vehicles, depots, routes) in order to unlock the full potential and benefits of MaaS.[525,526]

Next steps

- The Clean Technology Program considers supporting more efficient, lower cost and safe Mobility as a Service technologies.

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[521] Total cost of ownership calculations become more attractive for EVs versus ICE vehicles where utilisation is higher as EVs have a lower cost per km due to better engine efficiency, reduced maintenance, and cost of electricity versus petrol and diesel.
[522] 56 per cent of Sydney respondents to the national Transport Opinion Survey in March 2020 would replace a car trip with public transport if offered a flat fare for a home-to-station on-demand service, indicating that improved connectivity to public transport networks will assist consumers to make the switch. NSW respondents were most likely to take up the offer, compared to respondents from other states. Institute for Transport and Logistics Studies, 2020, *Transport Opinion Survey, March 2020.*
[523] Micromobility refers to small devices operated at low speeds for short distances. For example, bicycles and scooters.
[524] Transport for NSW, *Challenge 1: Mobility as a Service*, accessed 28 May 2020, https://future.transport.nsw.gov.au/technology/roadmap-in-delivery/challenge-1-mobility-as-a-service.
[525] The iMove CRC recently partnered with the Institute for Transport and Logistics Studies, IAG and Skedgo to run a MaaS Trial in Sydney which began in November 2019 but was cut short mid-March by the COVID-19 pandemic. The app developed was called Tripi, and enabled users to book and coordinate trips through integration with existing operators apps. iMove Australia, *MaaS trial in Sydney*, accessed 29 May 2020, https://imoveaustralia.com/project/maas-trial-sydney/.
[526] Hensher, D. *'What Does Intelligent Mobility Add to Sustainability?* iMove Webinar, 1 May 2020, accessed 29 May 2020, https://imoveaustralia.com/news-articles/personal-public-mobility/2020-maas-webinar-video-v2/.

8.7 EV charging

7. EV charging – deploying technologies to manage EV charging

Access to affordable charging and demand response technology to deliver managed EV charging will benefit EV users and electricity grid operators. This technology can reduce charging costs for EV users, provide additional flexibility about when and where EVs can be charged, and can manage charging demand to support stability of the grid (rather than exacerbating peak loads). At present, NSW has a charging network sufficient for the small number of EVs currently on the road.[527] However, as EV uptake increases it will be important to ensure proactive expansion of available charging stations.

The NSW Government has already made changes to planning rules to enable fast-tracked development of EV charging infrastructure.[528] In addition to new grants that will be available through the NZP, the NSW Government could further unlock private investment by providing strategy that outlines the desired asset mixture and required locations in alignment with development goals for metropolitan and regional NSW. TfNSW is undertaking some of this work through the NSW Electric vehicle and hybrid plan, which could be further strengthened by incorporating strategy for hydrogen vehicle infrastructure.[529]

A strategy for grid stability is also required to mitigate issues with localised demand spikes during periods of peak charging. Energy companies have already been considering how to accommodate extra load from EVs. Demand response technology is being deployed across a variety of applications including residential water heating, pool pumps and air conditioners.[530] New developments in active load management specifically for vehicle charging are being implemented, with a local company recently engaged to provide a scalable installation at a TfNSW site.[531] In addition to driving deployment through procurement, there is a role for government to collaborate at the national level to ensure consistency across technologies deployed throughout the NEM. Simultaneously increasing renewable penetration into the grid will also be important to achieve the full decarbonisation benefits of electrified transport.

Next steps

- The Energy Efficiency Program and the Electric Vehicle Infrastructure and Model Availability Program considers supporting load management technologies for EV charging.
- The NSW Government works with national transport and energy bodies and the National Cabinet Reform Committees for Infrastructure and Transport, and Energy to consider a mandate for load management technologies in new EV charging infrastructure.

[527] Guthrie, S. *'NSW the most EV-friendly state, says major charging provider'*, Drive, 14 April 2020, accessed 1 June 2020, https://www.drive.com.au/news/nsw-the-most-ev-friendly-state-says-major-charging-provider-123492.html?trackLink=SMH1.
[528] State Environmental Planning Policy (Infrastructure) 2007 (NSW) pt III div 17 sub-div 3.
[529] Transport for NSW, 2019, *NSW Electric vehicle and hybrid plan*.
[530] AEMO, 2018, *'How demand response is shaping our global energy future'*, 1 February 2018, accessed 11 June 2020, https://aemo.com.au/en/news/how-demand-response-is-shaping-our-global-energy-future.
[531] EVSE, *'Transport NSW Electric Vehicle Charging'*, 18 March 2020, accessed 12 June 2020, https://evse.com.au/blog/transport-nsw-electric-vehicle-charging/.

8.8 Electrification

8. Electrification – deploying EVs and other electric transport modes in cost effective applications

Falling battery costs have already reduced the total cost of ownership of some EVs in Australia, to equivalent to that of some ICE vehicles.[532] However, as purchase price parity is reached with ICE vehicles in the 2020s,[533] the up-front economics of purchasing an EV will accelerate uptake, enabling business and private consumers to access the economic benefits of electrification (for example, lower costs per km in fuel and maintenance for EVs versus ICE vehicles). Internationally, EVs are available across a range of vehicle classes, and improving model availability in NSW will support uptake.

While NSW is likely to adopt overseas EV technology for cars in the short to medium term, there is an opportunity to explore options for local manufacturing of EV components and assembly, particularly if a local battery manufacturing industry were to be established. For example, EV manufacturing is expected to play a role in the Latrobe Valley transition from coal towards a renewable energy future.[534]

Transport industry stakeholders mentioned a variety of fleet electrification initiatives being taken by some businesses as part of their sustainability and corporate responsibility goals.[535] However, they noted that as the total cost of ownership of EVs and hydrogen vehicles continue to decline, these transitions will also be increasingly driven by cost reduction opportunities. Furthermore, stakeholders noted that state and Commonwealth Government leadership in defining clear strategy and policy for EV uptake, and in particular, Federal-level action on vehicle emissions standards and EV uptake targets, were critical signals to validate industry bringing more models to the Australian market. In addition, the NSW Government is co-designing an EV model availability program through the NZP which will provide co-investment opportunities for private fleet operators to increase procurement of EVs.

Electrification opportunities also exist for a range of other transport modes, including farm, mine and factory vehicles, trains and ferries. Electric vertical take-off and landing (eVTOL) aircraft and electric, hybrid and hydrogen short haul aircraft are also currently being developed and could be commercially available post 2030 (potentially earlier for eVTOL).[536,537,538] However, the impact of COVID-19 on the aviation sector has delayed development of some major electric aircraft programs.[539]

Next steps

- The NSW Government continues to work with the other jurisdictions and the Australian Government to advocate for increased vehicle emissions standards and EV targets at the Federal-level.

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532 Royal Automobile Club of Queensland, 2019, *Private vehicle expenses 2019*.
533 BloombergNEF, 2020, *Electric Vehicle Outlook 2020 Executive Summary*.
534 Latrobe Valley Authority, *SEA Project Update*, accessed 11 June 2020, https://lva.vic.gov.au/news/sea-project-update.
535 Australian Logistics Council, *personal communication*, 30 April 2020.
536 Aviation Week, *MTU, DLR to flight test hydrogen fuel-cell propulsion*, accessed 14 August 2020, https://aviationweek.com/air-transport/aircraft-propulsion/mtu-dlr-flight-test-hydrogen-fuel-cell-propulsion.
537 Clean Sky 2 JU, 2020, *Hydrogen-powered aviation: A fact-based study of hydrogen technology, economics, and climate impact by 2050*.
538 Uber Elevate, 2016, *Fast-forwarding to a future of on-demand urban air transportation*.
539 Kaminski-Morrow, D, *Airbus and Rolls-Royce cancel E-Fan X hybrid-electric RJ100* experiment, FlightGlobal, 25 April 2020, accessed 14 August 2020, https://www.flightglobal.com/air-transport/airbus-and-rolls-royce-cancel-e-fan-x-hybrid-electric-rj100-experiment/138067.article.

8.9 Strategic hydrogen and electrification hubs and routes

9. Strategic hydrogen and electrification hubs and routes – developing and deploying hydrogen, low emission fuel and EV charging infrastructure to logistics hubs and along critical road and rail routes

Hubs and strategic transport corridors provide an opportunity to maximise the utility of early investments in new transport infrastructure for hydrogen, low emission fuels, and EV charging. These developments provide a strategic approach to balance the challenges of investing in distributed, capital intensive infrastructure to support emerging technologies in an existing industry. For example, heavy road transport (such as trucks and buses) are potential early use cases for a domestic hydrogen industry. This industry could benefit from co-locating hydrogen producers with the depot locations and along critical transport corridors, reducing the cost of transport of hydrogen to the end-user (fewer refuelling stations required and shorter hydrogen transport networks). These approaches would support both point-to-point and hub-and-spoke transport and logistics networks.

In addition to hydrogen, investment in infrastructure for new low emission fuels and EV charging could benefit from this approach. For example, depots for EVs could be co-located with renewable energy and storage facilities such as near the planned REZs or a large-scale commercial rooftop installation.

This opportunity can be pursued through collaborations between interested businesses, supported by government and research organisations, to test and establish the required infrastructure and services for a hydrogen, electric and new low emission fuel supply chains. For example, a recently formed industry consortium plans to introduce 100 hydrogen buses around Australia with up to 10 hub-style projects.[540] The first phase of the project aims to identify infrastructure and practical requirements for hydrogen bus operations.

The Office of the NSW Chief Scientist & Engineer is also aware of work being undertaken to incorporate infrastructure for hydrogen storage and refuelling in the Parkes SAP.[541] There are also opportunities at other regional freight and logistics hubs with existing infrastructure. For example, as discussed in Built Environment Opportunity 6.11, Port Kembla, Port Botany and Newcastle are potential hubs that possess strategic access to shipping infrastructure that will be required to realise future export opportunities.

Next steps

- Refer to next step under opportunity 5.8.

[540] Transit Systems, *'Transit Systems Charges Ahead with Global H2OzBus Project'*, 22 May 2020, accessed 11 June 2020, https://www.transitsystems.com.au/news/2020/5/22/transit-systems-charges-ahead-with-global-h2ozbus-project.
[541] Department of Planning, Industry and Environment (NSW Government), 2019, *Environmentally Sustainable Development (ESD) Plan: Special Activation Precinct, Parkes*.

8.10 New skills and services

10. New skills and services – developing workforce skills and capabilities to support maintenance and servicing of new transport vehicles, infrastructure and services

The future transport network will require new skills to develop, maintain and service new transport technologies including EVs, hydrogen vehicles and digital services. For example, digital literacy has been identified as a priority skill for workers in a range of transport and logistics areas to prepare for increased automation and technological advancement within the sector.[542] Increasing use of digital and communications technologies will require a larger workforce with specialist capabilities in networking, data analytics and software engineering. Furthermore, transport electrification at scale will require a growing workforce with the skills to maintain, service and recycle batteries and fuel-cell EVs, as well as refuelling and charging infrastructure. Industry stakeholders report that this skills opportunity through increased EV uptake has the potential to increase Australian GDP by $2.9 billion and create 13,400 jobs by 2030.[543]

Other potential skills and employment opportunities are in the manufacture, storage, distribution, retail and export of decarbonised fuels, including hydrogen, ammonia and synthetic kerosene. Skilled labour shortages in the Australian rail sector have also been identified.[544]

NSW has capabilities in vocational education which can be leveraged to deliver local training in partnership with operators and manufacturers. There is a role for NSW government to collaborate on the development of priority skills for the state through the National Cabinet Reform Committee for Skills (previously COAG Skills Council) and Australian Industry Standards. Development of training packages that will prepare automobile, transport and logistics industry workers for increased electrification, automated and digitised work environments and the material handling and safety requirements for batteries and new fuel industries (e.g. hydrogen) are essential to support technology uptake in these sectors (and the associated economic benefits), as well as to grow employment through these technology transitions.

Next steps

- Refer to next step for Opportunity 4.11.

[542] Australian Industry and Skills Committee, 2020, *Transport*, accessed 11 June 2020, https://nationalindustryinsights.aisc.net.au/industries/transport.
[543] PwC, 2018, *Recharging the economy: The economic impact of accelerating electric vehicle adoption*, (for Electric Vehicle Council, NRMA and St Baker Energy Innovation Fund).
[544] Global Railway Review, *'Australian Government addresses skills shortage across rail industry'*, Global Railway Review, 7 August 2019, accessed 2 July 2020, https://www.globalrailwayreview.com/news/86695/autralian-government-skills-shortage-rail/.

8.11 New components and systems

11. New components and systems – developing and deploying new components and systems for novel decarbonised vehicles and infrastructure

Trends in the future transport landscape, such as automation, electrification and sharing, present economic opportunities for NSW businesses to develop and commercialise new components and systems for vehicles and transport infrastructure. This range of technologies is broad, and many approaches will be highly speculative. However, some will prove feasible, and create new supply chains. Two speculative future transport technologies, and how they could support local component manufacturing industry, are discussed below (solar PV technologies for EVs, and drone delivery). However, there are also many other emerging transport technologies which could provide similar opportunities, such as autonomous vehicles and eVTOL aircraft.

Heavy competition amongst EV manufacturers, will increase demand for technologies to increase EV range and reduce charging times and cost. One potential technology of interest is the integration of solar PVs into the body of the vehicle, to reduce demand for charging from the grid. NSW possesses leading expertise in PV engineering, with research into solar paints and perovskite skins currently being advanced.[545] The additional range provided by PV on a car is only approximately 20-30 km using currently available technology, but further research could increase this by focusing on increased vehicle efficiency, PV coatings and improved cell efficiency.[546] Successful approaches can be commercialised in partnership with EV manufacturers.

Commercial drone delivery systems are being explored internationally, and small trials of unmanned battery-powered drone delivery systems have been started in Australia.[547] At the same time, the COVID-19 pandemic has increased pressure on logistics networks with the rapid growth of online purchasing.[548] Given the right regulatory framework and level of community acceptance, use of electric drones for delivery has potential to disrupt and decarbonise traditional approaches to 'last-mile delivery'. NSW has competitive advantages in this technology, including leading expertise in robotics and autonomous systems and a supportive federal regulatory authority (the Civil Aviation Safety Authority), and could develop and commercialise this technology at scale, with export potential.

Increasing demands for zero-emissions, reliable, congestion-reducing, low cost transport solutions are likely to encourage innovation in a variety of other areas. TfNSW already has a strong technology focus, with their Digital Accelerator and Smart Innovation Centre established to accelerate innovative digital technologies and trial future vehicles. For example, they have been involved in trialling autonomous shuttle services for first- and last-mile connections along dedicated routes and in campus-based applications like retirement villages, regional towns and the Sydney Olympic Park precinct.

New transport technologies also require supportive infrastructure and regulations, and community education and acceptance. For example, autonomous road vehicles will require machine-readable signage, road-markings, standardised communication platforms and public trust. All these present

[545] Mazengard, M. *'Australian 'Solar Skin' invention could power cities and vehicles of the future',* Renew Economy, 13 February 2020, accessed 3 June 2020, https://reneweconomy.com.au/australian-solar-skin-invention-could-power-cities-and-vehicles-of-the-future-49259/.

[546] Ekins-Daukes, N. 2020, *'The opportunity for vehicle integrated PV in Australia',* UNSW SPREE, 11 February 2020, accessed 3 June 2020, https://youtu.be/CAjEDZTWSwI.

[547] Civil Aviation Safety Authority (Australian Government), *Drone Delivery Systems*, accessed 11 June 2020, https://www.casa.gov.au/drones/industry-initiatives/drone-delivery-systems.

[548] Usher, O. *'Coronavirus: medical drones could soon be helping to beat the crisis',* The Conversation, 1 May 2020, accessed 3 June 2020, https://theconversation.com/coronavirus-medical-drones-could-soon-be-helping-to-beat-the-crisis-137640.

opportunities for local development and commercialisation of technologies themselves, but also in regtech to support their effective monitoring and control. Further acceleration of this technology development, commercialisation and potential local manufacturing, can be assisted by support for innovation through initiatives such as the Clean Technology Program under the NZP. Depending on the technology and application, this might include the provision of conditional grants or co-investment to accelerate commercialisation.

Next steps

- The Clean Technology Program considers supporting new components and systems for novel decarbonised vehicles and infrastructure.

8.12 Future EV battery services

12. Future EV battery services – developing and deploying technologies and services to integrate EVs into the grid, and for recycling, reuse and repurposing of EV batteries

Wide uptake of EVs presents an opportunity for EV batteries, when connected to the grid, to provide dispatchable storage and network stability services in a two-way enabled grid. This service could provide economic benefits for EV owners through additional income that offsets the costs of owning and operating an EV. Network operators may also gain benefits through the potential for vehicle-to-grid (V2G) services to reduce peak electricity generation demand, increase security of both system-wide supply and in local distribution networks, reduced need for investment in large scale storage, and to lower costs of the electricity system overall.

End-of-life EV batteries, with a typical capacity of 70% at retirement, also have potential as repurposed stationery storage units for the grid or behind-the-meter.[549] These batteries also contain highly value recyclable materials, including cobalt.[550] In the long term, the full economic value of EV batteries can be unlocked by working towards development of a V2G framework (where EV batteries can be used to provide energy to the home or the grid), and the establishment of a local industry for battery repurpose and recycling in NSW.

Research, development and commercialisation for V2G technologies is currently ongoing with several issues to be addressed including: the impacts of bi-directional charging on EV battery life; development and optimisation of algorithms that optimise battery life and value to the grid; business models for users, manufacturers and energy utilities; and regulations and incentives that incentivise EV owners to participate in the energy market.[551] Successful deployment of more basic managed charging technology for avoiding EV charging peaks, as discussed above in Transport Opportunity 8.7, will serve as a foundation for the future implementation of V2G services once EV uptake reaches sufficient scale. Improved maturity of V2G technology will increase competitiveness against smart charging and other flexible storage solutions, enabling broader uptake and benefits to be unlocked in the long term.

A range of stationery storage repurposing options exist for end-of-life EV batteries. For example, a European battery recycler is using repurposed EV batteries to power the processing line in their factory.[552] Key opportunities for NSW include residential storage of solar generation for home use

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[549] Neubauer, J., Smith, K., Wood, E., and Pesaran, A. 2015, *Identifying and Overcoming Critical Barriers to Widespread Second Use of PEV Batteries*.

[550] A 2018 estimate suggested approximately $4,500 to $17,000 of value could be recovered from 1 tonne of battery waste. King, S., Boxall, N.J. and Bhatt, A. 2018, *Lithium battery recycling in Australia*, CSIRO, Australia.

[551] Uddin, K., Dubarry, M. and Glick, M.B. 2018, *The viability of vehicle-to-grid operations from a battery technology and policy perspective*, Energy Policy, Volume 113, Pages 342-347.

[552] Duesenfeld, *Ecofriendly recycling of lithium-ion batteries*, accessed 3 July 2020, https://www.duesenfeld.com/recycling_en.html.

and grid-side storage to provide firming energy. NSW is particularly well suited to benefiting from this additional storage, as it has large and rapidly growing renewable energy generation that is increasingly reliant on dispatchable storage. Studies in the United States have estimated that repurposed EV batteries could operate for a further 10 years under the cycling conditions required to provide grid firming services, with cost savings of up to 10-20% from reduced peak generation requirements.[553] While the technology for EV battery repurposing is mature, some logistical challenges need to be addressed. For example, the establishment of battery repurposing facilities, battery handling skills and diagnostic tools for assessment of battery life and quality.

Once batteries undergo dramatic capacity loss, there is less value in repurposing the batteries, and more value in reclaiming high value materials such as cobalt, lithium, nickel and copper. A local battery recycling industry could create skilled employment opportunities for extracting and processing these materials, while avoiding the cost and regulatory burden of shipping batteries to international recyclers. These reclaimed materials could also supplement local feedstocks of these critical materials, and supply local battery manufacturing facilities. Current technical challenges for development of an advanced recycling process include the skills, experience and labour required to disassemble battery packs due to non-standardised shapes and chemistries which hinder process automation.[554]

NSW needs to prepare for the economic opportunities of repurposing and recycling end-of-life EV batteries. Development of a battery stewardship policy, alongside targets around increased EV uptake, would provide certainty for businesses to integrate repurposing and recycling into their business models, and for investors to support research and development of the technologies required. Precincts such as the NSW SAPs, that are being established with embedded principles of circular economy, energy from waste and resilience, could play host to some future repurposing and recycling facilities.

Next steps

- The Clean Technology Program and the Electric Vehicle Infrastructure and Model Availability Program consider supporting V2G technologies and services.
- The NSW Government works with national transport and energy bodies and the National Cabinet Reform Committees for Infrastructure and Transport, and Energy to consider pathways for future deployment of V2G technologies and services.

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553 Neubauer, J., Smith, K., Wood, E., and Pesaran, A. 2015, *Identifying and Overcoming Critical Barriers to Widespread Second Use of PEV Batteries*.
554 Engel, H., Hertzke, P. and Siccardo, G. 2019, *Second-life EV batteries: The newest value pool in energy storage*, McKinsey Center for Future Mobility.

9. Transition

The global economy is undergoing a systemic transformation which is accelerating; driven by benefits of increased productivity and prosperity. These benefits are often widely spread. However, unless effectively managed, the costs can be highly localised – falling on local workers, communities and traditional industries.[555]

Communities and individuals have experience in transitioning to new technologies and industries. For example, Australian households have been strong adopters of new energy generation solutions including solar PVs and more recently battery storage. Some communities have also effectively navigated industry changes that disrupted traditional sectors. For example, the growth in medical, education and aerospace industries in Newcastle as the steel industry wound down, and the Latrobe Valley which has seen overall jobs increase since the Hazelwood power station and mine closed.[556]

Aspects of transition best practice are already being applied to future planning for resource heavy regions of the Hunter and Illawarra, with regional Joint Organisations and branches of Regional Development Australia outlining plans for social and economic growth with a focus on key regional strengths, delivery of quality living spaces and educational opportunities. In the near term, it will be important for the NSW Government to consider timeframes, roles, communication methods and possibly funding required to support planning and implementation of transition initiatives.

9.1 Outcomes of effective transitions

Effective workforce and community transition approaches not only protect communities by making them more resilient to change, but lead to increased prosperity through growing industries, upskilling local workers, attracting investment and increasing environmental sustainability. Several case studies of industrial transitions have been explored, including:

- closure of Hazelwood Power Station in 2017 (Latrobe Valley, Victoria)
- closure of BHP Mayfield steelworks in 1999 (Newcastle, NSW)
- phased closure of the German black coal industry 1980s to 2018 (Ruhr Valley, Germany)
- Singaporean industrialisation from the 1970s to 1990s.

The case studies showcase a variety of successful outcomes, including employment transitions and job creation, strategies for long term regional prospects, expansion of new industries and economic growth. For example:

- The Latrobe Valley transition successfully prevented large job losses through worker transfer schemes and has even seen a rise in regional employment through actions undertaken to enhance local strengths and attract new businesses to the region.
- Forward planning of the BHP Newcastle steel works closure allowed two years for workers to identify and undertake company-sponsored training to access transition opportunities.
- The decades-long German black coal industry shutdown has provided a model for navigating an extensive large-scale closure. Building on existing strengths, the Ruhr Valley transition has delivered competitive advantages for the region in industrial detoxification services, wind turbine component manufacturing and ecotourism. One sixth of Germany's renewable energy jobs are located in the Ruhr Valley region.[557]

[555] European Commission, 2019, *Regions in Industrial Transition: No region left behind*.
[556] Whittaker, J. *'Latrobe Valley optimistic two years after Hazelwood power station closure, but coal attachment remains'*, ABC News,18 December 2019, accessed 19 June 2020, https://www.abc.net.au/news/2019-03-18/hazelwood-power-station-closure-two-years-on/10908866.
[557] Ciobanu, C. *'A Herculean success: Managing the death of coal mining in the Ruhr region'*, Just Transition, accessed 20 July 2020, http://www.just-transition.info/a-herculean-success.

- Singapore has experienced transformative industrialisation and sustained economic growth leveraging its port location and human capital.

Decarbonisation, as another driver of economic transition, has the potential to create jobs through the roll out of low-carbon technologies and services. Investment in low-carbon technologies and services is likely to be as effective, or even more effective, than in environmentally neutral or harmful technologies.[558] For example, it is estimated that more than 11,000 net additional jobs in renewable energy construction and operational roles could be created in Australia under a 50% renewable energy scenario, with 41 per cent of those new jobs in NSW.[559]

9.2 Common features of effective transitions

An outline of some common features of successful transition approaches is provided below. Please refer to Appendix 5 for more detailed information on each of the cases.

Proactive

Adequate time is required to plan and transition regions and workers from declining industries while protecting communities from the shock of a sudden closure. In the Ruhr Valley, closure of the black coal industry was conducted over several decades allowing time for retirement of older workers, transferring and retraining younger workers as new technology industries were established.[560] Efforts to transition Germany's brown coal industry are beginning. In Newcastle, the closure date of the BHP steelworks was fixed and announced two years prior, providing certainty about the shutdown timeframe.[561] By contrast, the closure of the Hazelwood Power Station in 2017 was decided suddenly, allowing only five months for a response to be coordinated. In all these cases, communities had already been affected by major structural adjustments in the preceding years or decades, elevating the importance of a well-managed final closure. A clear timeline assists better anticipation and planning for transitions.

Local, collaborative and responsive

Leveraging local leadership and community knowledge is important in developing successful transition plans. Local organisations such as the Latrobe Valley Authority established in the Hazelwood community provide an accessible interface with the transition program and employed local staff.[562] Similar municipal bodies were established during the Ruhr transition to coordinate resources from several agencies for local delivery of services and programs such as in the Emscher Park area. Local business and university networks were also developed in the Ruhr Valley to encourage innovation for the region.[563] In Singapore, the national scale of transition from the 1970s through to the 1990s required strong government action to achieve the vision through policy and regulatory reform, with union and employer views sought.

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[558] Engel, H., Hamilton, A., Hieronimus, A., Naucler, T., Fine, D., Pinner, D., Rogers, M., Bertreaus, S., Cooper, P. and Leger, S. *'How a post-pandemic stimulus can both create jobs and help the climate',* McKinsey & Company, 27 May 2020, accessed 20 July 2020, https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate.

[559] Climate Council of Australia, 2016, *Renewable Energy Jobs: Future Growth in Australia*.

[560] O'Malley, N. 2019, *'How Germany closed its coal industry without sacking a single miner'*, The Sydney Morning Herald, 14 July 2019, accessed 22 June 2020, https://www.smh.com.au/environment/climate-change/how-germany-closed-its-coal-industry-without-sacking-a-single-miner-20190711-p526ez.html.

[561] Commentary from a worker at the Newcastle plant suggested that workers appreciated having a certain and fixed closure date to work towards. Murray, J. 2019, *'How to transition out of mining: former BHP superintendent and Greens candidate Janet Murray',* Cessnock Advertiser, 28 February 2019, accessed 22 June 2020, https://www.cessnockadvertiser.com.au/story/5924722/how-to-transition-out-of-mining-former-bhp-boss-and-greens-candidate/.

[562] Latrobe Valley Authority, *About*, accessed 22 June 2020, https://lva.vic.gov.au/about.

[563] Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.

Established communication channels for cooperation between government, employers and unions have been a feature of successful transitions in the Ruhr Valley and Singapore. The German "social partnership" model involves collaboration between all parties with compromises agreed upon to maximise mutual benefits.[564] A "tripartism" approach used to navigate Singapore's early industrial transition through structural wage adjustments remains a strength of industrial relations management in Singapore today.[565,566] In the lead up to the closure of Hazelwood, union representatives drew on these collaborative consensus models to negotiate a pooled redundancy and worker transfer plan amongst several employers, mitigating a severe loss of employment.[567]

There is a role for government to establish improved mechanisms for ongoing dialogue with unions and employers in the coming transitional decades and to require that employers share in the responsibility for social impacts of industry transitions.[568] In 2018 in Germany, a Commission on Growth, Structural Change and Employment was established to ensure that recent legislation that commits to a complete national phase out of remaining coal mining and power generation by 2038, does not inflict economic damage on regions that have been dependant on coal for decades.[569,570] The Commission had representation from stakeholders from political and regional leaders, industry, trade unions, environmental groups and scientific experts and delivered its final report in January 2019.[571]

When transitions are underway, measures to encourage local businesses from the impacted community to tender for supply contracts is also a mechanism to lift activity and employment in the region. This can lead to a double or triple benefit, with the delivery of a local project (building, infrastructure, service etc), that has emerged from local employment in its delivery, and that provides ongoing employment in its operation.

Rigorous and strategic

A strategy to identify and maximise strengths, draw on the natural assets of the region, can build competitive advantage in new industries. For example, leaders of the Ruhr transition recognised that strengths from mining and site remediation could be applied to develop strengths in transport and logistics, renewable energy, environmental services, recycling and waste management.[572] Today the region has strengths in technology and ecotourism, with one former mine listed as a UNESCO World Heritage site.[573]

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564 Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.
565 Lee, C.T. 2013, *The Story of NWC: 40 years of tripartite commitment and partnership*. Straits Times Press Pte Ltd.
566 Ministry of Manpower (Singapore Government), *What is tripartism,* accessed 22 June 2020, https://www.mom.gov.sg/employment-practices/tripartism-in-singapore/what-is-tripartism.
567 Maher, T. *'A New Approach in Australia to Just Transition*', World Resources Institute, accessed 22 June 2020, https://www.wri.org/climate/expert-perspective/new-approach-australia-just-transition.
568 Jakob, M., Steckel, J.C., Jotzo, F., Sovacool, B.K., Cornelsen, L., Chandra, R., Edenhofer, O., Holden, C., Löschel, A., Nace, T. and Robins, N., 2020. *The future of coal in a carbon-constrained climate*, Nature Climate Change, Volume 10, Pages 1-3.
569 Jordans, F. *'Germany is first major economy to phase out coal and nuclear',* American Broadcasting Company News, 4 July 2020, accessed 10 August 2020, https://abcnews.go.com/International/wireStory/germany-finalizing-plan-phase-coal-energy-71591216.
570 Wehrman, B. *'Germany's coal exit commission'*, Clean Energy Wire, 13 December 2018, accessed 10 August 2020, https://www.cleanenergywire.org/factsheets/germanys-coal-exit-commission.
571 Wehrman, B. *'Germany's coal exit commission'*, Clean Energy Wire, 13 December 2018, accessed 10 August 2020, https://www.cleanenergywire.org/factsheets/germanys-coal-exit-commission.
572 Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.
573 Zollverein, *The heritage of mankind, the cultural heart of the Ruhr area*, accessed 22 June 2020, https://www.zollverein.de/zollverein-unesco-world-heritage-site.

The European Commission has developed a "Smart Specialisation" framework for assessment of regional strengths.[574] Regional Development Australia Committees are applying this to future planning for transitioning communities including the Gippsland and Hunter regions.[575] For example, the Smart Specialisation Strategy for the Hunter region identifies competitive advantages that include:

- Advanced manufacturing
- Food and agribusiness
- Oil, gas and energy resources
- Mining equipment, technology and services
- Medical technologies and pharmaceuticals.[576]

These are identified to build on the region's existing knowledge base in mining, energy, agriculture and medical research. For example, the Hunter:

- Has a manufacturing industry that could be reinvigorated by increasing expansion of the local clean energy sector,
- Has strong agricultural strengths in wine, beef production and grains,
- Possesses research strengths in energy and mining through the Newcastle Institute for Energy and Resources (NIER) and the ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals,
- Has medical and veterinary health research strengths supported by the Hunter Medical Research Institute and local veterinary pharmaceutical manufacturers and facilities, and
- Has access to air and seaports which enable connection to global supply chains.

Once regional strengths are identified, worker education and skills development are essential for the realisation of economic goals. In Singapore, education was key to lifting the workforce from a low-wage, low-skills model to one of high wages and skills – with the government established a Skills Development Council to coordinate the achievement of this transformation.[577] Education was also a feature of the Ruhr transition with significant expansion of the tertiary education system seen throughout the region.[578] Skilled workers can feed into new regional industries as jobs are created through expansion of local business and attraction of new opportunities. In the Latrobe Valley, a range of transition initiatives are credited with an employment increase of more than 10,000 compared to the period prior to the closure of Hazelwood.[579]

Comprehensive and committed

A range of worker and community support programs have been incorporated into successful transition strategies. These include financial, health and wellbeing services, education and retraining, schemes to boost and attract local business and innovation, and investment in social housing, cultural and recreational facilities. In Newcastle, BHP established a "Pathways Programme" to assist steel workers with post-employment options with investment of $7 million. Of this total, $2.32

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[574] European Commission, *What is Smart Specialisation?*, accessed 22 June 2020, https://s3platform.jrc.ec.europa.eu/what-is-smart-specialisation.
[575] Latrobe Valley Authority, *Gippsland's Smart Specialisation Strategy,* accessed 22 June 2020, https://lva.vic.gov.au/business/gippslands-smart-specialisation-strategy.
[576] RDA Hunter, 2019, *Smart Specialisation Strategy [S3] for the Hunter Region*.
[577] Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.
[578] The region went from having no local universities to having 22 by the end of the black coal shut down. Brauers, H., Herpich, P., von Hirschhausen, C., Jürgens, I., Neuhoff, K., Oei, P.Y., and Richstein, J. 2018, *Coal transition in Germany - Learning from past transitions to build phase-out pathways*, IDDRI and Climate Strategies.
[579] Employment figures at October 2019, compared to September 2016. Latrobe Valley Authority, 2019, *Transitioning to a strong future: Latrobe Valley Community Report November 2016-November 2019.*

million was spent on retraining for approximately 1000 workers for movement into other industries or other areas of the business.[580] In Singapore, significant investments were made to improve living quality through provision of public housing.[581] In the Ruhr Valley, public and private co-investment in innovation has led to the success of Dortmund Technology Park which is now comprised of more than 300 businesses and start-ups.[582] A wide variety of initiatives will require a firm commitment from government and industry to fund and sustain projects over several years, if not decades. For example, the German government has committed €40 billion to support affected regions through its national phase out of coal mining and coal fired power generation by 2038.[583]

When transitions are underway, measures to encourage local businesses from the impacted community to tender for supply contracts, can also lift activity and employment in the region. This can lead to a double or triple benefit, with the delivery of a local project (building, infrastructure, service etc), that creates local employment in its delivery, and that provides ongoing employment in its operation.

[580] Connors, E. and Long, S. *'When downsizing becomes risky business',* Australian Financial Review, 4 June 2002, accessed 22 June 2020, https://www.afr.com/policy/economy/when-downsizing-becomes-risky-business-20020604-k1k0b.

[581] Housing & Development Board (Singapore Government*). Public Housing – A Singapore Icon*, accessed 22 June 2020, https://www.hdb.gov.sg/cs/infoweb/about-us/our-role/public-housing--a-singapore-icon.

[582] Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.

[583] Jordans, F. *'Germany is first major economy to phase out coal and nuclear',* American Broadcasting Company News, 4 July 2020, accessed 10 August 2020, https://abcnews.go.com/International/wireStory/germany-finalizing-plan-phase-coal-energy-71591216.

10. Next steps

Many of the economic opportunities require NSW Government leadership in areas such as policy and regulation, procurement, market development and strategic transitions. Other opportunities are best led by local and international businesses, investors and communities. However, almost all the opportunities require collaboration between stakeholders. The below 'next steps' are intended to provide guidance to the NSW Government in moving forward on these opportunities.

Next steps	Opportunities
Sector specific	
Services	
In developing the Green Investment Strategy, consider initiatives to: • Improve knowledge and data sharing amongst businesses and investors, • Create benchmarks and taxonomies to validate decarbonisation and climate adaptation performance, • Improve market transparency with respect to sustainability, • Make the NSW Government a major customer of sustainable finance services, • Promote NSW's capabilities in sustainable finance internationally, • Increase the number of domestic and foreign companies and funds in NSW that adopt ESG principles.	3.1 Climate change risk management initiatives 3.3 Establish Sydney as a major global sustainable finance hub
NSW Government adopts best practice climate risk disclosures in financing and management across all public assets. When undertaking climate risk management, seek to align with international standards, for example, the Taskforce on Climate-related Financial Disclosures. To assist businesses investing in long life assets, the NSW Government seeks to provide direction, at a high level, on decarbonisation pathways from 2030 to 2050.	3.1 Climate change risk management initiatives
The NSW Government works with NSW universities to promote collaboration between businesses and universities to expand the pool of expertise in decarbonisation and climate adaptation available to the private and public sectors.	3.2 Carbon, resilience and sustainability services
Electricity	
The NSW Government continues to work with NEM bodies and the National Cabinet Reform Committee for Energy to achieve NEM reform that encourages rapid and efficient investment in new low carbon and climate change resilient electricity infrastructure.	4.2 Future energy market design
The NSW Government increases the amount of dispatchable and low emissions electricity it purchases from the grid (including through PPAs), and generates and stores on its own facilities.	4.3 Government procurement

Next steps	Opportunities
The NSW Government works with organisations to develop consumer-facing energy audit tools that provide tailored, easily accessible and reliable information on the economic and environmental benefits of new energy technologies for individual households and businesses. The NSW Government provides up-to-date information on new electricity business models and opportunities for businesses and households.	4.4 Consumer education and engagement
The NSW Government works with industry to support the development of local battery manufacturing facilities, and to grow the market in utility-scale and behind-the-meter batteries.	4.6 Energy storage
The NSW Government continues to work with distributors, decentralised grid providers, and regional and remote communities and businesses, through initiatives like the NSW Regional Community Energy Fund, to support the development of SAPS. The NSW Government encourages developers to deploy low-carbon microgrids in industrial and urban development precincts.	4.7 Decentralised grids
The NSW Government works with battery manufacturers, recyclers, investors, NSW Circular, and ABRI to: • Support a nationally-coordinated strategy and integrated supply chain in battery manufacturing and recycling, • Promote safe battery recycling to businesses and consumers.	4.10 Battery repurposing
Industry	
The NSW Government works with businesses and investors to identify and pursue opportunities to co-locate new and expanded energy-intensive industries in the REZs or in other regional areas with significant renewable energy potential.	4.1 Renewable Energy Zones 5.12 Export industrial productivity and sustainability services
Built Environment	
The NSW Government considers expanding Priority 2: 'to empower consumers and businesses to make sustainable choices' under the NZP, to also cover information about the energy performance of residential properties.	6.1 Climate risk assessment
The NSW Government considers rewarding net zero ready developments with planning incentives, for example increased floor areas.	6.4 Building sustainability standards
Land	
The NSW Government facilitates the availability and quality of open data to support the greater adoption of sustainable and low carbon land management practices.	7.1 Knowledge sharing
The NSW Government works with landholders and service providers to assist them to navigate and participate in sustainability markets. The NSW Government continues working with the federal government and stakeholders in the finance and sustainability markets sectors, on a Natural Capital Assessment Methodology to integrate natural capital into government investment and financial markets.	3.3 Establish Sydney as a major global sustainable finance hub 7.2 Sustainability markets 7.6 Sustainable land management 7.7 Ecosystem services

Next steps	Opportunities
The NSW Government continues to work with other Australian jurisdictions on updating regulatory frameworks for gene technologies and synthetic biology.	7.11 Gene technologies and synthetic biology
Transport	
NSW Government agencies increase uptake of low emission Mobility as a Service for internal travel needs.	8.1 Government procurement
The NSW Government continues to explore transport funding and pricing options, and develops a pathway to a funding and pricing model for a net zero transport system by 2050 that considers trends in future transport technologies and services.	8.3 Transport funding approaches
The NSW Government continues to work with national transport bodies and the National Cabinet Reform Committee for Infrastructure and Transport to achieve policy and regulatory reform that accelerates the development, uptake and export of new transport technologies and services.	8.4 Policy and regulatory guidance
The NSW Government works with national transport and energy bodies and the National Cabinet Reform Committees for Infrastructure and Transport, and Energy to consider: • A mandate for load management technologies in new EV charging infrastructure, • Pathways for future deployment of V2G technologies and services.	8.7 EV charging 8.12 Future EV battery services
The NSW Government continues to work with the other jurisdictions and the Australian Government to advocate for increased vehicle emissions standards and EV targets at the Federal-level.	8.8 Electrification
Cross sectoral	
Procurement	
The NSW Government develops a detailed strategy that sets out the NSW's Government's approach and trajectory for all government assets and procurement to meet the state's net zero target by 2050.	5.2 Government procurement 6.3 Government procurement 8.1 Government procurement
Precincts	
Programs under the NSW Government's NZP Stage 1: 2020-2030, such as the Clean Technology and Hydrogen Programs, encourage precinct-based approaches to the development and piloting of industrial decarbonisation technologies and services. Future eco-industrial precincts in NSW implement measures to achieve carbon neutrality in both operation and construction.	5.1 Eco-industrial precincts
The proposed clean technology innovation hub, under the NZP, demonstrates and communicates: • Best practice in energy, water and material efficiency and low carbon materials, • Costs and benefits for developers and providers of sustainable finance.	6.2 Sustainable precincts

<table>
<tr><th>Next steps</th><th>Opportunities</th></tr>
<tr><td colspan="2">Skills</td></tr>
<tr><td>Skills development is considered in the implementation of the NZP, for example initiatives under the NZP engaging with relevant skills advisory bodies (such as relevant Skills Service Organisations and NSW Industry Training Advisory Bodies) to identify potential future skills needs in decarbonisation and climate adaptation.</td><td>4.11 Future energy systems and markets skills
5.4 Decarbonisation and climate resilience skills
6.5 Decarbonisation and climate resilience skills
7.4 Decarbonisation and climate resilience skills
8.10 New skills and services</td></tr>
<tr><td colspan="2">Clean Technology Program</td></tr>
<tr><td>The Clean Technology Program considers supporting more efficient, lower cost and safe:
Solar technologies,
Hydrogen and battery storage technologies,
Energy efficiency and demand management technologies,
Material efficiency, reuse and recycling technologies, including technologies to improve asset utilisation, material durability and longevity,
Electrification, alternative heat and bioenergy technologies,
Modular building designs and construction approaches,
Renewable and bioenergy technologies and services for landowners, including farmers,
Mobility as a Service technologies.</td><td>4.5 Solar generation
4.6 Energy storage
4.8 Energy efficiency and demand management
5.6 Material efficiency, reuse and recycling
5.7 Electrification, alternative heat and bioenergy
6.6 Efficient and modular designs
7.9 Renewables and bioenergy
8.6 Mobility services</td></tr>
<tr><td>The Clean Technology Program also considers supporting:
Battery repurposing and recycling technologies,
CCU technologies and processes that have the potential of becoming commercially viable without financial incentives to reduce emissions,
Innovative and cost-effective low emission construction materials,
Innovative digital technologies for optimising infrastructure and building performance, for example advanced sensors, digital twins and AI,
Applications of gene technologies and synthetic biology that aim to improve productivity and climate change resilience, and reduce emissions, in the agriculture and industry sectors,
New components and systems for novel decarbonised vehicles and infrastructure,
V2G technologies and services.</td><td>4.10 Battery repurposing
5.9 Carbon Capture and Utilisation
6.8 Low emission construction materials
6.9 Digital technologies
7.11 Gene technologies and synthetic biology
8.11 New components and systems
8.12 Future EV battery services</td></tr>
<tr><td colspan="2">Hydrogen Technology Program</td></tr>
<tr><td>The Hydrogen Technology Program preferences hydrogen technology development and commercialisation in a hydrogen hub model, where production, storage and use are co-located alongside transport, industrial, water and renewable energy infrastructure.</td><td>5.8 Hydrogen
6.11 Hydrogen hubs
8.9 Strategic hydrogen and electrification hubs and routes</td></tr>
</table>

<table>
<tr><th>Next steps</th><th>Opportunities</th></tr>
<tr><td>The Hydrogen Technology Program considers supporting more efficient, lower cost and safe hydrogen storage technologies.</td><td>4.6 Energy storage</td></tr>
<tr><td colspan="2">Energy Efficiency Program</td></tr>
<tr><td>The Energy Efficiency Program considers supporting more efficient and lower cost:
Energy efficiency and demand management technologies,
Electrification, alternative heat and bioenergy technologies,
Technologies for heating, lighting, appliance and motor efficiency and energy demand flexibility and adaptability in the built environment,
Renewable and bioenergy technologies and services for landowners, including farmers.</td><td>4.8 Energy efficiency and demand management
5.7 Electrification, alternative heat and bioenergy
6.7 Energy productivity
7.9 Renewables and bioenergy</td></tr>
<tr><td>The Energy Efficiency Program also considers supporting load management technologies for EV charging.</td><td>8.7 EV charging</td></tr>
<tr><td colspan="2">The Primary Industries Productivity and Abatement Program</td></tr>
<tr><td>The Primary Industries Productivity and Abatement Program considers supporting:
Renewable and bioenergy technologies and services for landowners, including farmers,
Applications of gene technologies and synthetic biology that aim to improve productivity and climate change resilience, and reduce emissions, in the agriculture and industry sectors,
Commercialisation of cost effective feed supplements and feeding systems.</td><td>7.9 Renewables and bioenergy
7.11 Gene technologies and synthetic biology
7.12 Enteric emissions reductions</td></tr>
<tr><td colspan="2">Electric Vehicle Infrastructure and Model Availability Program</td></tr>
<tr><td>The Electric Vehicle Infrastructure and Model Availability Program considers supporting:
Load management technologies for EV charging,
V2G technologies and services.</td><td>8.7 EV charging
8.12 Future EV battery services</td></tr>
</table>

Acknowledgements

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Australian Logistics Council
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Australian Sustainable Built Environment Council
Australian Sustainable Finance Initiative
BlueScope Steel
Clean Energy Finance Corporation
Climate Change Council
ClimateWorks Australia
Coal Innovation NSW
Commonwealth Department of Energy and Environment
CoreGas
CSIRO
Data61
Electric Vehicle Council
Engineers Australia
Farmers for Climate Action
Future Food Systems CRC
Global Product Stewardship Council
Greening Australia
Infrastructure NSW
Infrastructure Australia
ITP Renewables
Jemena
Western Local Land Services
Meat and Livestock Association
NABERS
National Australian Built Environment Rating System
Newcastle City Council
NSW Department of Education, Skills and Higher Education
NSW Department of Planning, Industry and Environment – Energy, Climate Change and Sustainability
NSW Department of Planning, Industry and Environment – Environment, Energy and Science
NSW Department of Primary Industries, Forestry Science

NSW Department of Primary Industries, Climate Research & Development

NSW Minerals Council

Planet Ark Power

Property NSW

RACE for 2030 CRC

Regional Growth NSW Development Corporation

Responsible Investors Association of Australia

Standards Australia

Sustainability Advantage

The SEED Data Initiative (Sharing and Enabling Environmental Data)

Think Brick

Transgrid

Transport for NSW, Customer Strategy ad Technology

Transport for NSW, Freight Strategy

Transport for NSW, Safety, Environment and Regulation

Transport for NSW – Smart Innovation Centre

Treasury NSW, NSW Investment Attraction

Treasury NSW, NSW Procurement

Treasury NSW, Sustainable Finance

The University of Sydney

UNSW Energy Institute

UNSW Photovoltaics & Renewable Energy

UTS Institute for Sustainable Futures

Acronyms

ABRI	Australian Battery Recycling Institute
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AI	Artificial intelligence
ANU	Australian National University
ARC	Australian Research Council
ARENA	Australian Renewable Energy Agency
ASFI	Australian Sustainable Finance Initiative
BASIX	Building Sustainability Index
BIM	Building Information Management
BOP	Biodiversity Offsets Program
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CEFC	Clean Energy Finance Corporation
COAG	Council of Australian Governments
CoESB	Centre of Excellence in Synthetic Biology
CRC	Cooperative Research Centre
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSE	NSW Chief Scientist & Engineer
DAC	Direct Air Capture
DER	Distributed Energy Resource
ERF	Emissions Reduction Fund
ESB	Energy Security Board
ESG	Environmental, Social and Governance
ESS	Energy Savings Scheme
EV	Electric vehicle
eVTOL	Electric vertical take-off and landing
FCAS	Frequency Control Ancillary Service
GEMS	Greenhouse and Energy Minimum Standards
GHG	Greenhouse gases
GREP	Government Resource Efficiency Policy
GRESB	Global Real Estate Sustainability Benchmark
HVAC	Heat, ventilation and cooling
ICE	Internal combustion engine
IEA	International Energy Agency
IMF	International Monetary Fund
IoT	Internet-of-Things
IRENA	International Renewable Energy Agency
ISP	Integrated System Plan
LCOE	Levelised cost of electricity
MaaS	Mobility as a Service
MEPS	Minimum Energy Performance Standards
NABERS	National Australian Built Environment Rating Scheme
NARCliM	NSW and ACT Regional Climate Model
NatHERS	Nationwide House Energy Rating Scheme

NCRIS	National Collaborative Research Infrastructure Strategy
NEM	National Electricity Market
NSW DPI	NSW Department of Primary Industries
NZP	Net Zero Plan Stage 1: 2020-2030
OECD	Organization for Economic Cooperation and Development
PERC	Passivated Emitter and Rear Cell
PHS	Pumped Hydro Storage
PPA	Power Purchase Agreement
PV	Photovoltaic
RAPS	Regional Area Power Systems
REZ	Renewable Energy Zone
SAP	Special Activation Precinct
SAPS	Stand-alone-Power Systems
TCFD	Taskforce on Climate-related Financial Disclosures
TfNSW	Transport for NSW
V2G	Vehicle-to-grid
VET	Vocational Education and Training
VRE	Variable renewable energy

Appendix 1

Terms of Reference

Terms of Reference for a study into the challenges and opportunities for NSW innovation to support decarbonisation of the economy

Background and context

The NSW Government has a target of achieving net zero emissions by 2050 and to make NSW more resilient to a changing climate. One of the five policy directions in the NSW Climate Change Policy Framework is "Take advantage of opportunities to grow new industries in NSW". The shift to a net-zero emissions economy can create new opportunities in sectors where NSW has a competitive advantage, such as professional services, agriculture, advanced energy technology, property management and financial services.

However, such a shift will affect established sectors of the NSW economy such as resources and commodities.

There may be an opportunity for NSW to become a global leader in innovative technologies and services that enable decarbonisation and adaptation to climate change. A decarbonisation innovation strategy could deliver economic and job growth, improve energy affordability and support a managed transition of the energy market from high to low emission energy sources. It could also catalyse change in the emissions profile of all major industry sectors. Innovation in decarbonisation and adaptation technologies and services could serve the dual purpose of addressing the NSW emissions and adaptation challenge and growing the NSW economy through economic diversification and export opportunities.

Scope of Review

The NSW Chief Scientist & Engineer is to assess and provide advice on the challenges and opportunities for meeting emissions targets and adapting to climate change. This work will examine the benefits of decarbonisation and climate adaptation in generating economic development, prosperity and jobs growth in NSW, including a discussion of best practice approaches to transitioning industry, including skills development and market access.

The NSW Chief Scientist & Engineer will report on:

1. Technologies and services to reduce carbon emissions, adapt to or mitigate the impact of climate change in which NSW could have a competitive advantage;
2. The net-value of these technologies and services for NSW in terms of both emissions reduction and economic growth;
3. Any barriers to the development of the technologies and services in NSW;
4. The role of the NSW Government in:
    a. Addressing any of the identified barriers;
    b. Supporting the acceleration of the development/commercialisation of these opportunities; and
    c. Ensuring that NSW takes advantage of carbon emission reduction technologies to maximise economic opportunities.

The Chief Scientist & Engineer will convene a panel with expertise in science and technology, business, economic and social insights. The Department of Planning, Industry and Environment will provide support to the study as required.

As needed, the Chief Scientist & Engineer will:

- draw on additional sources of advice and expertise
- commission or recommend papers or studies.

The Chief Scientist & Engineer will:

- undertake targeted consultations with stakeholders
- provide an initial report by end December 2019
- provide a final report by early April 2020.

Appendix 2

Expert Panel members

Professor Hugh Durrant-Whyte, NSW Chief Scientist & Engineer and Panel Chair

Professor Michael Dureau

Professor Frank Jotzo

Ms Meg McDonald

Mr Roger Swinbourne

Appendix 3

Decarbonisation Technology Mapping

The following set of tables provide a summary of the technological and commercial readiness, cost-competitiveness, interdependences and deployment timeframe of some decarbonisation and climate adaptation technologies. This summary reflects the conclusions of some academic research and industry stakeholders with expert knowledge of these technologies. However, the costs and timeframes of future technologies are inherently uncertain, and other sources may come to reasonable alternative conclusions.

The Technology Readiness Level (TRL) and Commercial Readiness Index (CRI) reflect the progression of a technology through the phases of research, development, demonstration and commercial deployment (Figure A.1). There is some overlap between the TRL and CRI.

The TRL is a globally accepted technology benchmarking tool. It is a scale that encompasses all phases from blue sky research (TRL 1) to actual system demonstration over the full range of expected conditions (TRL 9).[584]

The CRI has been developed by ARENA as a tool for assessing the "commercial readiness" of renewable energy solutions. It is a scale that encompasses all stages from hypothetical commercial proposition (CRI 1) to a technology becoming a bankable asset class (CRI 6).[585]

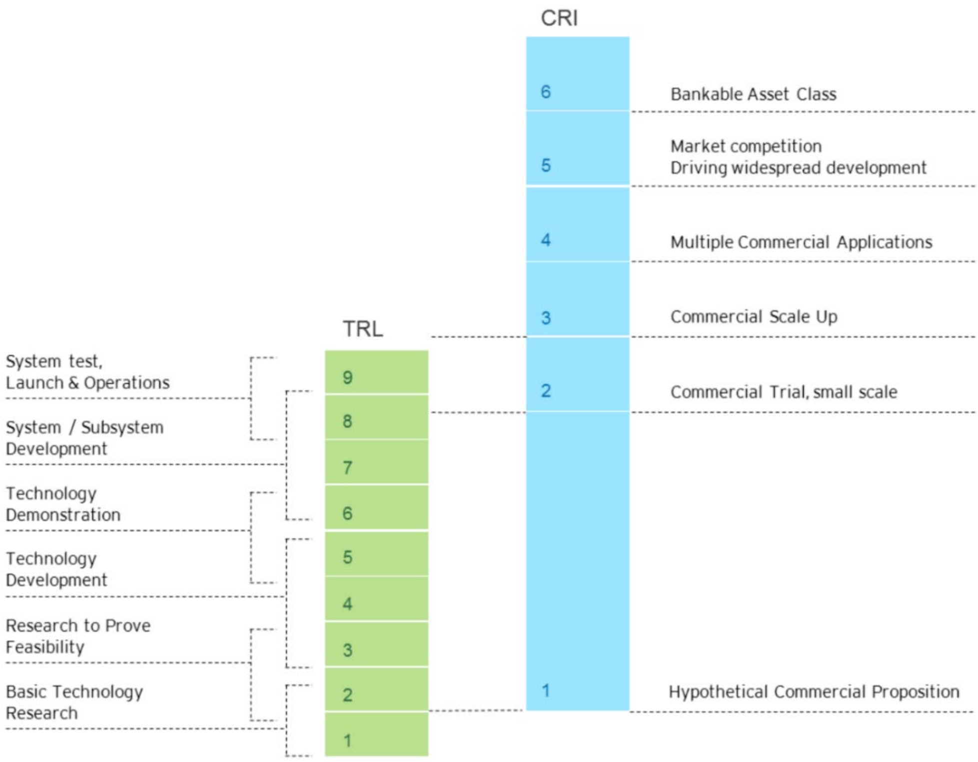

Figure A.2 The Technology Readiness Level and Commercial Readiness Indicator benchmarking tools

Source: Commonwealth of Australia (Australian Renewable Energy Agency), 2014.

[584] Commonwealth of Australia (Australian Renewable Energy Agency), 2014, *Technology Readiness Levels for Renewable Energy Sectors*.

[585] Commonwealth of Australia (Australian Renewable Energy Agency), 2014, *Commercial Readiness Index for Renewable Energy Sectors*.

Electricity

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Solar photovoltaics and wind generation	Utility scale solar and wind farms, distributed solar generation (e.g. rooftop solar PV)	Mature and commercialised technology, CRI 6	Lowest LCOE (without firming technologies) Large scale solar and wind ~$50/MWh (compared to black coal ~$150/MWh)	Available to the market	• Firming technologies include large-scale batteries and pumped hydro • Demand-side flexibility to balance intermittency	• Low-cost new generation technologies based on LCOE • Non-dispatchable without firming technologies • There is potential for further efficiency and cost reduction • Concentrated Solar Thermal is less mature (CRI 3) but has potential as a more 'firmed' form of solar generation.
Renewable Energy Zone (solar and wind)	Deployment of large solar and wind projects within REZs	Mature and commercialised technology, CRI 6	Lowest LCOE for REZs in NSW (without firming technologies) Central West and New England with <$40/MWh for solar and ~$65/MWh for wind	Available to the market, depends on REZ deployment timeline	• Firming technologies similar to above • New transmission & distribution infrastructure to connect to NEM backbone	
Energy Storage	Batteries, pumped hydro storage (PHS) and other emerging technologies such as compressed air	Batteries, CRI 4 PHS, CRI 6	Cheapest dispatchable firming generation, solar + storage $125/MWh	Available to the market	• Renewable generation	• PHS is preferred for longer duration bulk energy storage, while batteries are preferred for short-period storage to provide load-shifting and grid services.
Decentralised grids	Micro-grids, Standalone power systems and remote area power systems	CRI 4		Available to the market	• Large-scale generation and integrated DER	• Either grid connected or off grid.
Integrated grid	Digital systems to better manage the grid, such as demand response, virtual power plants, and grid models.	TRL 8		Available to the market	• Digitalisation • IoT • AI	

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
DER integration	Technologies for integrating DER such as rooftop solar, batteries and EV to electricity systems	CRI 6		Available to the market	• DER technologies	• DER integration technologies will support aggregated distributed energy generation and storage for secure and reliable operation of the grid.

Industry, Building and Infrastructure

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Industrial process heat with renewable technologies	Technologies for renewable process heat generation, including bioenergy, geothermal, renewable electric heating and solar thermal	TRL 9 and above	Alumina refinery: low temperature heating from solar thermal or renewable electric-driven mechanical vapour close to current gas costs Food and beverage: many renewable solutions are already (or close to) economic, Ammonia: short term solar thermal driven SMR close to economic Cement and Steel: biomass already demonstrated in facilities	Alumina: 2030 Food and beverage: 2020 Ammonia: 2030 Cement: 2025 Steel: 2025	• Renewable energy technologies • Industrial process and raw materials production & distribution e.g. bioenergy	• The ARENA 2019 *Renewable energy options for industrial process heat report* provides a comprehensive analysis on Australia's opportunities of renewable technologies with their deployment timeframe, heat generation potential and barriers for different industrial processes • Medium to long term opportunities require major structural change with support of R&D, policy and funding to create the value chain.
Heat pumps	Electric low temperature heating from renewables	TRL 7-9	Economic for some low temperature applications	Available to the market	• Renewable generation	
Green steel	Direct reduced iron and electric arc furnace (DRI-EAF) with hydrogen replacing natural gas	TRL 5-7	Breakeven €34-68/tonne CO_2-e & €40/MWh	2030-2050	• Low-emission hydrogen production (green, or brown/grey hydrogen with CCS)	• OECD report has a comprehensive review of low-emission steel production on hydrogen-based and CCS • Deployment of partial replacement of natural gas by hydrogen could in early 2025 and full replacement are in pilot phase and to be commercialised in 2030.

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Green cement	High-blend cement, geopolymer cement, mineral carbonisation and other negative-emission cements	High blend and geopolymer are commercially available, CRI 6 Magnesium-based cements and other carbon-sequestration cement, TRL 4-6		Available to the market	• Carbon capture technology for mineral carbonisation • Low emissions production process for blending feedstock	• Retrofitting cement plants with best available technology could increase efficiency by up to 7% • Setting up a new geopolymer cement plant is 10% cheaper than Portland cement. • NSW has research capability of mineral carbonisation in Newcastle • Geopolymer has local producer in Australia (Qld and Vic based).
Timber and engineered wood product	Cross-laminated timber, glued laminated timber, plywood etc.	Commercially available, CRI 6	Cost-competitive with concrete structures	Available to the market	• Hybrid buildings would require other sustainable construction materials e.g. green steel, geopolymer cement as low-emissions alternatives	• Case studies find engineered timber superstructures create cost savings of up to 10% compared to complete reinforced concrete structures.
Modular design	Buildings constructed as modules in a factory setting and transported to the work site for final assembly	Commercially available, CRI 6	Cost-competitive with onsite construction approaches, often more cost-effective	Available to the market	• Green building materials • Energy and water efficient technology • Digital technology • Process electrification • Transport and logistics	• Versatility of modular approaches is being showcased in a range of projects including high rise apartments and schools • Commonly cited as reducing project schedules and reducing costs by up to 20% • Australian prefabricated building market segment is small – estimated at only 3% of total construction sector.

Agriculture and Land Use

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Controlled Environment Horticulture	Production of crops within an enclosed growing structure (i.e. greenhouse) to provide protection and maintain optimal growing conditions	CRI 6		Available in the market	• Water efficiency and recycling • Renewables and bioenergy	• Technologies already exist, further advances in technology will improve efficiency and productivity.
Renewables and bioenergy	Bioenergy production includes biodiesel from oil-producing grains and ethanol and high-sugar grains can be used Bioenergy may be produced from crop residues, wood residues and energy crops.	CRI 6		Already in overseas markets and there is a mandate in NSW for 4% of ethanol in unleaded petrol	• Water efficiency	• Technologies already exist, further advances in technology will improve efficiency and productivity • Australian RD&E could adapt technologies being developed and commercialised overseas to suit local conditions and feedstocks.
Water efficiency and recycling		CRI 6			• Renewables and bioenergy	• Technologies already exist, further advances in technology will improve efficiency and productivity.
Gene technologies	Changing an organism gene to express positive attributes	TRL 9	Depends on application	From inception to market takes 10 to 13 years		• Currently 38 crop trials are taking place across Australia – each for different crops and attributes • Each application requires regulatory approval.
Synthetic biology	Designing and building novel biological systems to express positive attributes (e.g. drought resistant crops)	TRL 4-6		2025-2030		• Regulatory issues need to be addressed.

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Enteric emissions reduction – FutureFeed	Algae-based, chemical-based, and plant-based feed supplements	TRL 6-9		Currently on the market, supplies expected to rapidly expand by 2025.		• FutureFeed (TRL 6-9) is an independent company commercialising the supplement developed by CSIRO, Meat and Livestock Australia and James Cook University. • 3NOP (TRL 6-8) is being commercialised by DSM in the Netherlands. • Mootral (TRL 8-9) is being commercialised by a Swiss-based company.

Transport

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
BEV – passenger vehicle	Car	CRI 1-2	Competitive at purchase prices $20-30k	Available technology	• Batteries • EV charging infrastructure	• Purchase price of BEV car starts at around $45,000 • Emissions reduction cost: $1000NPV/tonne CO_2-e (2020-2022).
BEV – heavy road transport	Garbage trucks, buses, light commercial	CRI 1-2	Competitive compared to diesel ICE at electricity price point of US$0.14/kWh.	Available technology	• Batteries • EV charging infrastructure	• Approximate purchase prices 2020: Renault Kangoo $46,000 BEV garbage truck approx.$550,000 BEV bus $700,000-$800,000 vs. diesel bus $500,000-$800,000.
Hydrogen FCEV – passenger and light vehicles	Cars, small trucks	TRL 7	Can become competitive at H2 production costs of US$2/kg	SUVs, large passenger vehicles, taxi fleet: mid 2020s Urban delivery van: late 2020s	• Hydrogen production and storage • Refuelling infrastructure	• Hyundai Nexo approximate purchase price of $60,000, first commercially available in Australian market from late 2020 • Emissions reduction cost: $1000 NPV/tonne CO_2-e (2031-2050) • Requires a lower hydrogen production price to be cost-effective than heavy road transport, especially in areas where electricity production in cheap. Note that compact urban cars will not be competitive out to 2050 for this reason.

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Hydrogen FCEV – heavy road transport	Bus, light commercial	TRL 7	Competitive compared to diesel ICE with electricity price of US$0.04/kWh Can become competitive at H2 production cost of US$3/kg for commercial vehicles (trucks)	Medium and heavy-duty trucks, coach, long-distance bus: mid-2020s	• Hydrogen production and storage • Refuelling infrastructure	• Estimated purchase price of FCEV bus approx. $2m / €1m • Access to vehicles was identified as a major barrier for the Australian market in the 2019 COAG *Hydrogen for Transport* report.

Hydrogen FCEV – regional train	Passenger train	TRL 9
		CRI 2-3
			FCEV multiple unit trains are cost-competitive with catenary electric, particularly over long-distances. Cost-competitiveness against diesel is possible where cost of electricity production to produce hydrogen is cheap.	Available technology	• Hydrogen production and storage
					• Refuelling infrastructure
						• Hydrogen trains are operational in Germany with replacement of a diesel fleet expected in 2022
						• Key levers to increasing competitiveness against diesel are:
						  ○ H_2 consumption/km
						  ○ Price of diesel
						  ○ Price of electricity
						  ○ Purchase price.

Hydrogen FCEV - ferry	Ferry	TRL8-9 CRI 1-2		Small ferry: 2030 Large ferry: mid-2030s	• Hydrogen production and storage • Refuelling infrastructure	• Commercial hydrogen ferries are in development to be delivered early 2020s (USA, France, Norway) • COAG Energy Council grades the overall opportunity for hydrogen ferries as moderate and does not recommend investment at this stage • Suitable ferries may become available for purchase in 5-10 years.

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Telematics and optimised logistics	Vehicle monitoring and analytics to assist route and load optimisation	CRI 4		Already available		• Installation costs approx. $2000, plus $500/year to run • Emissions reduction cost -$50 NPV/tonne CO_2-e.
Micromobility	e-bikes, e-scooters	CRI 4		Available	• Batteries • Infrastructure	• Application in shared fleets • At present, motorised scooters are not able to be registered in NSW and may only be legally operated on private land.
Mobility as a Service	Brokerage apps for trip planning and payment across multiple service providers	TRL 8-9 in Sydney		Establishing in several countries, pilot in Sydney 2020	• Public transport • Rideshare and car share services • Digital services and infrastructure	• While more established overseas, MaaS is emerging in the Australian market
EV charging demand management	Technology to modulate EV charging based on grid/system capacities	TRL 9 CRI 2 Integrated grid technology: TRL 8		Available technology, scaling up Integrated grid technology: 2023-30	• Electricity sector • Renewable energy • Digital technology and analytics	• TfNSW has procured systems for fleet charging management at its Macquarie Park site.
Electric short-haul aircraft	Small passenger planes	TRL 8-9		Mid-2030s to 2050	• Charging infrastructure at airports	• Good potential for regional flights. A 30-minute trial flight consumes $6 worth of electricity compared to $300-400 worth of aviation fuel • A range of sizes are in development, including for >100 passengers.
V2X	Technology that enables two-way energy flow from EV batteries	TRL 8-9 CRI 1-2		First commercial device expected in Australian market late 2020	• Electricity sector • Two-way enabled EV batteries	• Inverters are currently in the $10-20k price range compared to more basic "smart chargers" which are <$10k • V2H technology is a potential competitor with home battery storage technology.

Technology	Brief description	TRL/CRI	Price points	Time to market	Interdependencies (technologies)	Comments
Solar PV vehicles	Vehicles that can be directly powered by solar energy in addition to battery stored electricity	TRL 2-8 Various solutions are at different stages of development		2030	• PV technology • EV technology	• Several car manufacturers are investigating integration of solar PV technology into vehicles, including Toyota and Hyundai • Sono Motors produces a hybrid solar electric car with range up to 250 km.
Drone delivery systems	Remotely or autonomously operated drones capable of providing short distance delivery services	CRI 2-3		Commercial-scale trials being undertaken in Australia	• Communications • Digital technology • Electricity	• A number of corporations are trialling commercial drone delivery systems internationally • Drone delivery systems are being trialled in the ACT and QLD.

Energy conversion technology cluster

Technology and brief description	TRL/CRI	Price points	Technology deployment timeframe	Interdependencies and conditions e.g. other technologies or feedstock prices	Comments
Power to Hydrogen					
Green hydrogen production from water electrolysis	Demonstration, CRI 2-3	Production at $2/kg (national target by 2030)	2030	• End user application technologies for transport, electricity generation/energy storage and gas network blending • Safety around transportation and storage • Feedstock treatment (seawater and wastewater treatment)	• The national economic target of 'H2 under 2' is the production cost when hydrogen becomes competitive with alternatives for large scale deployment • The price point for each sector depends on end-user applications e.g. FCEV vs ICE
Blue hydrogen through steam methane reforming (SMR) is the current bulk hydrogen production for industry	Deployment CRI 2-3 (with carbon capture) Deployment CRI 5- 6 (without carbon capture)	Price - competitive with green hydrogen production and low-emission	2040-2050 (as low emissions hydrogen production)	• Energy input and price • Carbon price or other emissions restrictions • Carbon capture and geological sequestration or utilisation technologies (Refer to *Industry Table* for CCS technology readiness)	• Cheapest production method with existing industry infrastructure and assets • Guarantees of origin for clean hydrogen production and possible certification scheme in Australia
Grey hydrogen production through coal gasification	Demonstration, CRI 2-3 (without carbon capture) Deployment CRI 2-3 (with carbon capture)	Competitive with green hydrogen production	2040-2050 (as low emissions hydrogen production)	• Energy input and price • Carbon price or other emission restrictions • Carbon capture and geological sequestration or utilisation technologies	• Cost higher than SMR (1.4-2.6 times) • Guarantees of origin for clean hydrogen production and possible certification scheme in Australia
Power to hydrocarbon fuels and chemicals					
Synthetic electrofuels (efuels) in general and includes synthetic methane and liquid fuels listed below	See below for each efuel	Efuel €$1.00/L in 2030 and close to fossil fuel price (€$0.50/L) in 2050	2030-40 (Various deployment timeframes based on fuels and chemicals)	• Electricity at low price (grid/dedicated plant at $30-40/MWh for Australia). The low electricity price can be subsidised through innovation in reusing waste	• Projected prices are based on point carbon source via direct carbon capture technologies • Lower production is expected in Australia with cheaper renewable electricity compared to EU prices.

Technology and brief description	TRL/CRI	Price points	Technology deployment timeframe	Interdependencies and conditions e.g. other technologies or feedstock prices	Comments
Synthetic methane can be directly blended into existing gas networks or for transport, chemical industry	R&D and demonstration, CRI 2-3	€0.14/kWh in 2030 and €0.11/kWh in 2050	2022-2025	heat and system engineering • Carbon source and capture technologies (no geological storage required) • Alternative water supply with treatment process • More complex hydrocarbons (e.g. kerosene) require secondary synthetic process and plants	
Synthetic liquid organics (e.g. methanol and formic acid) that can be directly used in the same application as fossil fuels for chemical manufacturing and other industry	R&D, TRL 5-6 for CO_2 electrolyser to make formic acid CRI 3-4 for methanol production	€1.26/L in 2030 and €1.00/L in 2050	2025-2030		• PV and PV/wind systems in North Africa and Middle East • Final product cost without network charges and distributions costs
Direct conversion to syngas (mixture of H2 and CO) then can be converted into formic acid, methanol, aviation fuel, methane.	R&D, TRL 4-5 for CO_2 electrolyser. Demonstration, CRI 2-3 for thermal CO_2 conversion to syngas using dry reforming		2030-2050		
Power To Ammonia					
Ammonia can be used for fertiliser industry directly or as hydrogen carrier for transportation	R&D, TRL 1-4	Competitive with SMR for hydrogen production	2030-2040 for large scale and decentralised production 2040-2050 as energy carrier	• Energy input for conversion • Air separation for nitrogen supply • Hydrogen production and transportation costs	• Ammonia cracking at high temperature has high TRL level (TRL 7-9) for hydrogen reproduction
Secondary ammonia products such as Urea DAP, ammonia nitride and nitrite as chemical feedstock or other industries	R&D, TRL 1-4	Competitive with SMR production.	2040-2050	Production of hydrogen and ammonia	

Platform technologies

Technology	Brief description	Enabling technologies, services and products in each sector				
		Electricity	Industry	Building and Infrastructure	Agriculture and land	Transport
Renewable energy	Direct use of renewable energy, through electrification or clean fuels	Low-emissions electricity grid, production of clean fuels (e.g. hydrogen, ammonia or synthetic hydrocarbon)	Electrified industrial processes, alternative heating and energy sources (e.g. bioenergy or geothermal)	Electricity generation (building integrated solar PV), passive design and solar for heating, hot water systems with solar thermal and heat pumps	Bioenergy production and use at farm, agrivoltaics and other co-located renewables	EV and other electric transportation, FCEV and hydrogen powered transport
Digitalisation	Digital technologies, AI, IoT, digital twins, big data technology, quantum computing, and block-chain	Digital appliance, digital control for DER owners, visibility and interoperability of DER to grid operator, peer to peer energy trading, VPP, smart grids	Digitalised industry process, digital twins and simulations for new services and models, centralised and autonomous control of manufacturing execution system	Digital mapping, building information modelling, digital twins of buildings with real time data,		Digitalised EV charging
Robotics and autonomous systems	Advanced automation, robotics, machine learning, sensor technology	Smart appliances, smart grid, automation in demand response and energy management, advanced solar inverter	Autonomous haulage systems and conveyor for mining process, autonomous manufacturing process	Unmanned autonomous vehicles for digital mapping, smart building environments with sensors for energy consumption and lighting	Automation for controlled environment farming	Autonomous vehicles, and shuttle services
Circular Economy	Material efficiency, waste material recycling, repurposing and reuse, energy generation, value-added manufacturing, sustainable products from waste materials	Solar PV recycling (silicon for battery manufacturing), battery recycling	Reduced use of high-emissions materials and substitution with low-emissions materials, waste material recycling	Sustainable construction materials (e.g. green steel, novel concrete), recycled construction materials	Improve agriculture productivity with controlled environment horticulture for maximising water, carbon and heat utilisation	EV battery recycling and reuse for grid

Technology	Brief description	Enabling technologies, services and products in each sector				
		Electricity	Industry	Building and Infrastructure	Agriculture and land	Transport
Efficiency and productivity improvement	Technologies, processes and innovative approach to improve resources (e.g. mineral, energy and water) efficiency and productivity	Energy efficiency and management (e.g. generation output efficiency improvement through retrofit or software), less energy lost from transmission (microgrid or generate onsite) and energy from waste	Technologies to improve industrial process energy productivity (e.g. heat pumps), better materials efficiency and utilisation	Building material recycling, home energy efficiency improvement (e.g. insulation materials)	Water efficiency and recycling	Fast charging for EV and local management for energy efficiency improvement

Sources:

AEMO, 2020, *Draft 2020 Integrated System Plan*.

Agora Verkehrswende, Agora Energiewende and Frontier Economics, 2018, *The Future Cost of Electricity-Based Synthetic Fuels*.

Agrology, 2019, *Cost of Production Analysis: Hightech Glasshouse Production in Australia*, (for Western City & Aerotropolis Authority).

Approximate estimate provided by stakeholder in logistics industry.

Australian Government, 2020, Technology Investment Roadmap Discussion Paper.

Bataille, C. 2019, *Issue Paper: Low and zero emissions in the steel and cement industries, Barriers, technologies and policies,* Green Growth and Sustainable Development Forum 2019: Greening heavy and extractive industries, 26-27 November 2019.

Beyond Zero Emissions, 2017, *Zero Carbon Industry Plan: Rethinking Cement*.

BloombergNEF, 2020, *Hydrogen Economy Outlook: Key messages*.

Charnock S., Temminghoff M., Srinivasan V., Burke N., Munnings C. and Hartley P. 2019, *Hydrogen Research, Development and Demonstration: Technical Repository*, CSIRO.

Civil Aviation Safety Authority, 2020, *Drone Delivery Systems*, accessed 28 July 2020, https://www.casa.gov.au/drones/industry-initiatives/drone-delivery-systems.

COAG Energy Council, 2019, *Hydrogen for transport: Prospective Australian Use Cases*.

Cockroft, C.J. and Owen, A.D. 2008, *'The Economics of Hydrogen Fuel Cell Buses'*, The Economic Record, Volume 83, Pages 359-370.

Colmar Brunton, 2019, *Queensland Household Energy Survey 2019. Insights Report.*

CSIRO, *FutureFeed Pty Ltd*, accessed 28 July 2020, https://research.csiro.au/futurefeed/.

Department of Planning, Industry and Environment (NSW Government), 2019, *NSW Electricity Strategy (detailed).*

Drone Industry Insights, 2019, *The Drone Delivery Market Map 2019*, accessed 28 July 2020, https://dronelife.com/wp-content/uploads/2019/11/The-Drone-Delivery-Market-Infographic.png.

DSM, *Farm wise, climate friendly: Significant reduction of methane emissions from cattle*, accessed 28 July 2020, https://www.dsm.com/corporate/solutions/climate-energy/minimizing-methane-from-cattle.html.

DSM, *Summary of scientific research how 3-NOP effectively reduces enteric methane emissions from cows*.

Energy Transitions Commission, 2019, *Mission Possible Sectoral Focus – Heavy Road Transport*.

Global Railway Review, *'World's first two hydrogen trains successfully complete passenger service'*, 19 May 2020, accessed 28 July 2020, https://www.globalrailwayreview.com/news/100802/hydrogen-trains-alstom-complete-trial-passenger-service/.

Graham, P., Hayward, J., Foster, J. and Havas, L. 2019, *GenCost 2019-20: preliminary results for stakeholder review*, CSIRO, Australia.

Hadley, D. 2017, *Controlled Environment Horticulture Industry Potential in NSW*, (for NSW Department of Industry).

Halvorson, B. 2018, *'2019 Hyundai Nexo hydrogen fuel-cell pricing: Puzzling economics'*, Green Car Reports, 11 December 2018, accessed 28 July 2020, https://www.greencarreports.com/news/1120389_2019-hyundai-nexo-hydrogen-fuel-cell-vehicle-pricing-puzzling-economics.

Heerlen, N.L. *'DSM take next step towards implementation of its methane inhibitor Bovaer in the Netherlands'*, DSM, 30 September 2019, accessed 28 July 2020, https://www.dsm.com/corporate/news/news-archive/2019/2019-09-30-dsm-takes-next-step-towards-implementation-of-its-methane-inhibitor-bovaer-in-the-netherlands.html.

Hydrogen Council, 2020, *Path to Hydrogen Competitiveness*.

Hydrogen Europe, *Hydrogen Buses*, accessed 28 July 2020, https://www.hydrogeneurope.eu/hydrogen-buses.

ITP Energised Group, the Institute for Sustainable Futures and ITK Consulting, 2018, *Comparison of Dispatchable Renewable Electricity Options*, (Prepared for ARENA).

ITP Thermal, 2019, *Renewable energy options for industrial process heat*, (for ARENA).

Jet Charge, *Vehicle to grid,* accessed 28 July 2020, https://jetcharge.com.au/services/vehicle-to-grid.

Jutsen, J., Pears, A., Hutton, L. 2017, *High temperature heat pumps for the Australian food industry: Opportunities assessment*, Australian Alliance for Energy Productivity.

KPMG, 2019, *World-class intensive integrated production hub in the Western Sydney Aerotropolis*, (for NSW Department of Industry).

Martin, T. *'Light Commercial Vehicle Market Turns Electric'*, Electrical Connection, 6 August 2018, accessed 28 July 2020, https://electricalconnection.com.au/light-commercial-vehicle-market-turns-electric/.

Mineral Carbonation International, accessed 28 July 2020, https://www.mineralcarbonation.com/.

Mootral, *The Science*, accessed 28 July 2020, https://www.mootral.com/science/.

National Energy Technology Laboratory (U.S. Department of Energy), *7.3 Technologies for Hydrogen Production*, accessed 28 July 2020, https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/technologies-hydrogen.

Nectar Farms, accessed 28 July 2020, https://www.nectarfarms.com.au/.

Office of the Gene Technology Regulator (Australian Government), 2020, *Genetically Modified Organisms – Crop Field Trial Sites,* accessed 28 July 2020, http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/map.

Quezada, G., Bratanova, A., Boughen, N. and Hajkowicz, S. 2016, *Farsight for construction: Exploratory scenarios for Queensland's construction industry to 2036, CSIRO Australia*.

Ritchie, L. and Stephan, A. 2018, *Engineered timber for apartment building in Melbourne, Australia: A construction cost comparison with traditional concrete systems*, in P. Rajagopalan and M.M Andamon (Eds.), *Engaging Architectural Science: Meeting the Challenges of Higher Density: 52nd International Conference of the Architectural Science Association 2018*, (pp. 161–168).

Roque, B.M., Van Lingen, H.J., Vrancken, H. and Kebreab, E. 2019, *Effect of Mootral – a garlic-and-citrus-based feed additive – on enteric methane emissions in feedlot cattle*, Translational Animal Science, Volume 3, Pages 1383-1388.

SEA Electric, *'SA's First Electric Garbage Truck Doing The Rounds'*, 25 February 2020, accessed 28 July 2020, https://www.sea-electric.com/sas-first-electric-garbage-truck-doing-the-rounds/.

Shift2Rail Joint Undertaking and Hydrogen Joint Undertaking, 2019, *Study on the use of fuel cells and hydrogen in the rail environment*.

Sono Motors, *Sion*, accessed 28 July 2020, https://sonomotors.com/en/sion/.

Srinivasan, V., Temminghoff, M., Charnock, S. and Hartley, P. 2019, *Hydrogen Research, Development and Demonstration: Priorities and Opportunities for Australia*, CSIRO.

Sundrop Farms, accessed 28 July 2020, https://www.sundropfarms.com/.

The Maritime Executive, *'Hydrogen Fuel Cell Vessels Destined for France and Norway'*, 13 May 2019, accessed 28 July 2020, https://www.maritime-executive.com/article/hydrogen-fuel-cell-vessels-destined-for-france-and-norway.

The Royal Society, 2019, *Sustainable synthetic carbon based duels for transport: Policy briefing*.

The Royal Society, 2020, *Ammonia: zero-carbon fertiliser, fuel and energy store.*

Transport for NSW (NSW Government), *Skateboards, foot scooters and rollerblades*, Centre for Road Safety, accessed 31 July 2020, https://roadsafety.transport.nsw.gov.au/stayingsafe/pedestrians/skateboardsfootscootersandrollerblades/index.html.

Water-Go-Round, *Golden Gate Zero Emission Marine Water-Go-Round Project,* accessed 28 July 2020, https://watergoround.com/.

Wright, M. *'Victoria needs to get on electric bus if it's serious about emissions and health'*, Renew Economy, 20 September 2019, accessed 28 July 2020, https://reneweconomy.com.au/victoria-needs-to-get-on-electric-bus-if-its-serious-about-emissions-and-health-44153/#:~:text=Electric%20buses%20are%20just%20a,as%20on%20their%20cabin%20rooftops.

Other decarbonisation technologies

The technology mapping exercise aims to identify decarbonisation technologies that have the most economic potential for NSW. It is not a survey of all low-emissions technologies for the least-cost net zero pathways for NSW. In addition to prioritised technologies under each sector and cross-cutting enablers, there are other emerging or proven technologies that could have important roles in emissions reduction. For example:

Carbon Capture and Storage – Carbon Capture and Storage (CCS) captures emissions from the flue gases of coal-fired power generators or emissions-intensive industry such as steel and cement production. The capture, transportation and storage and conversion of emissions imposes additional costs for industry – making the technologies uneconomic unless offset by external financial incentives. Further, anticipated carbon emission sources and sinks are uncertain, with a forecast retiring of coal-fleet power stations by 2042 and unexplored geological storage basins.[586] The cost of large-scale CCS in NSW could be informed by the final findings of a cost benefit analysis commissioned by Coal Innovation NSW which is currently ongoing.[587]

Nuclear – Nuclear power generation is currently prohibited under Australian and NSW law and the adoption of the technology would require legislative reform. [588] A report by the South Australian Nuclear Fuel Cycle Royal Commission found that the establishment of the regulatory framework, procurement process and construction and commission of the first nuclear plant in Australia could take at least 14 years.[589] Recent inquiries by the Commonwealth and NSW parliaments have acknowledged that the deployment of nuclear power generation technology will face substantial engineering, environmental and social challenges in Australia.[590,591] There are potential improvements in nuclear power generation technologies, for example small modular reactors (SMR), which could have the potential to lower capital costs. However, SMRs still require substantial further development and demonstration to reduce costs to be competitive with other mature low emissions energy generation technologies. For example, CSIRO forecasts SMR's CAPEX of $16000/kW compared to $6,000/kW for black coal with CCS.[592]

Fugitive Emissions Abatement – At present, there are fugitive emissions abatement technologies available, such as drainage, flaring and power generation from captured methane gas. Some opportunities exist to deploy these technologies commercially, where it is possible to utilise them for electricity generation that could offset electricity demand from mining activities by combusting pre-drained fugitive emissions from underground mines. This could also reduce fugitive emissions from mining, by converting methane to carbon dioxide.[593] NSW currently has five of these power stations with a total capacity of 120 MW.[594] The largest, Appin and Tower Power Stations, are

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[586] Resources & Geoscience (NSW Government), *NSW CO2 Storage Assessment Project*, accessed 10 July 2020, https://www.resourcesandgeoscience.nsw.gov.au/investors/coal-innovation-nsw/geological-storage/nsw-co2-storage-assessment-project.

[587] Department of Planning, Industry and Environment (NSW Government), 2019, *Annual Report Coal Innovation NSW Fund 2018/19*.

[588] Nuclear power is prohibited under the *Australian Radiation Protection and Nuclear Safety Agency Act 1998* and the *Environment Protection and Biodiversity Conservation Act 1999*. The *Uranium Mining and Nuclear Facilities (Prohibitions) Act 1986* (NSW) prohibits NSW from constructing or operating nuclear reactors for the production of electricity.

[589] Nuclear Fuel Cycle Royal Commission (Government of South Australia), 2016, *Nuclear Fuel Cycle Royal Commission Report*.

[590] Standing Committee on the Environment and Energy (House of Representatives, The Parliament of the Commonwealth of Australia), 2019, *Not without your approval: a way forward for nuclear technology in Australia*.

[591] Standing Committee on State Development (Legislative Council, New South Wales Parliament), 2020, *Report no. 46: Uranium Mining and Nuclear Facilities (Prohibitions) Repeal Bill 2019*.

[592] CSIRO, 2018. GenCost Report - Updated projections of electricity generation technology costs.

[593] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

[594] https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information

capable of generating approximately 654 GWh of electricity annually.[595] New technologies have been piloted in NSW coal mines to prove their technical viability and safety for capturing and combusting ventilation air methane (VAM) at low concentrations (less than one per cent) and high temperatures.[596]

Refrigerants – Refrigeration and air-conditioning have significant emissions impacts due to the use of refrigerant gases with very high GWP. The loss of these refrigerants to the atmosphere accounts for approximately 6.4 Mt CO2-e per annum in Australia.[597] In accordance with the Kigali Amendment to the Montreal Protocol, Australia and other countries have committed to reduce production and importation of HFCs by 85 per cent by 2036.[598] The intent of the ratified phase-down is to promote a transition to alternative technologies.[599] Alternative technologies using lower-GWP synthetic refrigerants and natural refrigerants (e.g. CO2, ammonia and hydrocarbons) are already available in Australia for some applications. Adoption of these technologies is forecast to reduce the emissions impact of the Australian bank of refrigerant from 2020 onwards.[600] However, further development of these technologies is necessary to enable adoption in some applications, for example, supermarket systems, refrigerated cold food chain transport, small air conditioning split systems, medium air conditioning systems and some large air conditioning systems.[601]

[595] https://edlenergy.com/wp-content/uploads/2019/02/EDL-Fact-Sheet-Appin-and-Tower_Final.pdf
[596] https://www.globalmethane.org/documents/res_coal_VAM_Dialogue_Report_20181025.pdf
[597] Expert Group, 2018, *Cold Hard Facts 3,* (for Department of the Environment and Energy, Australian Government).
[598] Department of the Environment and Energy (Australian Government), *PFC Phase Down – Frequently asked questions,* accessed 11 December 2019, https://www.environment.gov.au/protection/ozone/hfc-phase-down/hfc-phase-down-faqs.
[599] Department of the Environment and Energy (Australian Government), *PFC Phase Down – Frequently asked questions,* accessed 11 December 2019, https://www.environment.gov.au/protection/ozone/hfc-phase-down/hfc-phase-down-faqs.
[600] Expert Group, 2018, *Cold Hard Facts 3,* (for Department of the Environment and Energy, Australian Government).
[601] Expert Group, 2018, *Cold Hard Facts 3,* (for Department of the Environment and Energy, Australian Government).

Appendix 4

NSW's research and development capabilities

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
ARC	ARC Centre of Excellence for Australian Biodiversity and Heritage	University of Wollongong, Australian Museum, Bioplatforms Australia, State Library NSW, UNSW Sydney				✓				✓
ARC	ARC Centre of Excellence for Climate Extremes	UNSW Sydney, NSW Office of Environment and Heritage				✓	✓		✓	✓
ARC	ARC Centre of Excellence for Electromaterials Science (ACES)	UNSW Sydney, University of Wollongong		✓					✓	✓
ARC	ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals	University of Newcastle, UNSW Sydney				✓			✓	✓
ARC	ARC Centre of Excellence for Quantum Computation and Communication Technology	UNSW Sydney, University of Technology Sydney								✓
ARC	ARC Centre of Excellence in Synthetic Biology	Macquarie University, Bioplatforms Australia, NSW Department of Primary Industries, University of Newcastle, UNSW Sydney, Western Sydney University				✓				✓
ARC	ARC Research Hub for Advanced Technologies for Australian Iron Ore	University of Newcastle	✓						✓	✓
ARC	ARC Research Hub for Australian Steel Manufacturing	University of Wollongong	✓				✓		✓	
ARC	ARC Research Hub for Basin GEodyNamics and Evolution of Sedimentary Systems (GENESIS)	University of Sydney				✓				✓
ARC	ARC Research Hub for Integrated Energy Storage Solutions	University of Technology Sydney, University of Sydney		✓					✓	
ARC	ARC Research Hub for Legumes for Sustainable Agriculture	University of Sydney				✓				
ARC	ARC Research Hub for Microrecycling of battery and consumer wastes	UNSW Sydney		✓		✓			✓	
ARC	ARC Research Hub for Transforming Waste Directly in Cost-Effective Green Manufacturing	UNSW Sydney				✓			✓	
ARC	ARC Research Hub for Australian Steel Innovation	University of Wollongong, University of Newcastle	✓				✓		✓	

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
ARC	ARC Training Centre for Advanced Technologies in Food Manufacture	University of Sydney				✓			✓	
ARC	ARC Training Centre for Advanced Technologies in Rail Track Infrastructure	University of Wollongong, University of Sydney, Western Sydney University, University of Newcastle	✓		✓		✓			
ARC	ARC Training Centre for Automated Manufacture of Advanced Composites	UNSW Sydney			✓				✓	
ARC	ARC Training Centre for Cubesats, UAVs, and Their Applications	University of Sydney, Macquarie University, UNSW Sydney			✓	✓	✓	✓	✓	
ARC	ARC Training Centre for Food and Beverage Supply Chain Optimisation	University of Newcastle, NSW Department of Primary Industries, University of Sydney	✓		✓	✓				
ARC	ARC Training Centre for Functional Grains	Charles Sturt University	✓			✓				
ARC	ARC Training Centre for Innovative Bioengineering	University of Sydney, University of Technology Sydney, Royal Prince Alfred Hospital								✓
ARC	ARC Training Centre in Data Analytics for Resources and Environments (DARE)	University of Sydney, UNSW Sydney								✓
ARC	ARC Training Centre in Fire Retardant Materials and Safety Technologies	UNSW Sydney								✓
ARC	ARC Training Centre in Food Safety in the Fresh Produce Industry	University of Sydney, NSW Food Authority				✓				
ARC	ARC Training Centre for The Global Hydrogen Economy	UNSW Sydney, University of Newcastle (through NUW Alliance), University of Sydney		✓			✓		✓	
CRC-NSW	CRC CARE	University of Newcastle, University of Technology Sydney, University of Western Sydney	✓							✓
CRC-NSW	CRC for High Performance Soils	University of Newcastle, Charles Sturt University, NSW Department of Primary Industries	✓			✓				
CRC-NSW	Food Agility CRC	University of Technology Sydney, Charles Sturt University, University of New England, NSW Department of Primary Industries				✓				
CRC-NSW	Future Food Systems CRC	UNSW Sydney, Western Sydney University, University of New England, NSW Farmers, NSW Department of Primary Industries				✓				
CRC-NSW	Future Fuels CRC	University of Wollongong			✓					
CRC-NSW	RACE for 2030 CRC	University of Technology Sydney, UNSW Sydney		✓						

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
CRC-NSW	SmartCrete CRC	Macquarie University, Western Sydney University, University of Newcastle, University of Wollongong, University of Technology Sydney, University of Sydney, TAFE NSW, Transport for NSW					✓		✓	
CSIRO	Energy Hub, University of Newcastle		✓	✓			✓	✓	✓	
CSIRO	Critical Energy Metals Mission		✓	✓			✓		✓	
CSIRO	CO_2 Industry roadmap			✓			✓		✓	
CSIRO	Net Zero Emissions Mission		✓			✓	✓	✓	✓	
CSIRO	Ending Plastic Waste Missions				✓	✓	✓	✓	✓	
CSIRO	Hydrogen Industry Mission		✓	✓	✓	✓	✓	✓	✓	
KNOW HUB	NSW Energy & Resources Knowledge Hub		✓	✓					✓	
KNOW HUB	Transport and Logistics Knowledge Hub	Data61			✓					
NCRIS	Australian Urban Research Infrastructure Network (AURIN)	University of Newcastle, University of Sydney, University of Wollongong, UNSW Sydney					✓			
Network	NSW Smart Sensing Network	UNSW Sydney; University of Sydney; Macquarie University; University; University of Newcastle; University of Technology, Sydney; Western Sydney University								✓
PFRA	ANSTO								✓	✓
RDC	CRSPI (the Climate Research Strategy for Primary Industries)		✓							✓
University	Charles Sturt University	Graham Centre for Agricultural Innovation	✓			✓				
University	Charles Sturt University	Institute for Land, Water and Society	✓			✓				
University	Charles Sturt University	The Graham Centre for Agricultural Innovation	✓			✓				
University	Charles Sturt University	Institute for Land, Water & Society	✓			✓				
University	Macquarie University	Centre for Corporate Sustainability and Environmental Finance						✓		
University	Macquarie University	Smart Green Cities					✓			
University	Macquarie University	Centre for Workforce Futures							✓	
University	Macquarie University	Climate Futures								✓
University	Macquarie University	The National Climate Change Adaptation Research Facility								✓

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
University	Newcastle University	Environmental and Climate Change Research Group	✓							✓
University	Newcastle University	Newcastle Institute for Energy and Resources	✓	✓						
University	Newcastle University	Priority Research Centre for Frontier Energy Technologies & Utilisation	✓	✓						
University	Newcastle University	Priority Research Centre for Organic Electronics	✓	✓						
University	Newcastle University	Hunter Research Foundation Centre	✓						✓	✓
University	Newcastle University	International Collaborative Centre for Carbon Futures	✓	✓						
University	Newcastle University	Centre for Social Research and Regional Futures	✓							✓
University	Newcastle University	Centre for Urban and Regional Studies	✓							✓
University	Newcastle University	Centre for Water Security and Environmental Sustainability	✓			✓				✓
University	Newcastle University	Centre for Water, Climate and Land	✓			✓				✓
University	University of New England	Institute for Rural Futures	✓			✓				✓
University	University of New England	National Centre of Science, ICT and Maths Education for Rural and Regional Australia	✓							✓
University	University of New England	The Australian Centre for Agriculture and Law	✓			✓				✓
University	University of New England	Centre for Agribusiness	✓			✓				
University	University of New England	Centre for Local Government	✓							
University	University of New England	The Australian Centre for Agriculture and Law	✓			✓				
University	University of New England	Sustainable Management Accessible Rural Technologies (SMART) Farm	✓			✓				
University	University of New England	Institute for Rural Futures	✓			✓				
University	University of Newcastle	Priority Research Centre for Frontier Energy Technologies and Utilisation	✓	✓						✓
University	University of Newcastle	Priority Research Centre for Advanced Particle Processing and Transport	✓			✓				
University	University of Newcastle	International Centre for Balanced Land Use	✓	✓		✓				✓
University	University of Newcastle	Newcastle Institute for Energy and Resources (NIER)	✓	✓						
University	University of Sydney	Sydney Environment Institute				✓		✓		✓
University	University of Sydney	Climate change, human health and social impacts node								✓

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
University	University of Sydney	Australian Centre for Climate and Environmental Law				✓	✓			✓
University	University of Sydney	Centre for Translational Data Science								✓
University	University of Sydney	Institute of Agriculture				✓				✓
University	University of Sydney	Institute of Transport and Logistics Studies			✓					✓
University	University of Sydney	Australian Centre for Field Robotics								✓
University	University of Sydney	Centre for Advanced Food Enginomics			✓					
University	University of Sydney	Centre for Advanced Materials Technology (CAMT)							✓	✓
University	University of Sydney	Centre for Advanced Structural Engineering (CASE)					✓		✓	
University	University of Sydney	Centre for Future Energy Networks (CFEN)		✓						
University	University of Sydney	Centre for Sustainable Energy Development		✓					✓	✓
University	University of Sydney	Sydney Environment Institute (SEI)								✓
University	University of Sydney	Planning Research Centre (PRC)					✓			
University	University of Sydney	The Warren Centre for Advanced Engineering								✓
University	University of Technology, Sydney	Climate Change Cluster				✓				✓
University	University of Technology, Sydney	Centre for Clean Energy Technology		✓			✓			✓
University	University of Technology, Sydney	Centre for Technology in Water and Wastewater				✓	✓		✓	✓
University	University of Technology, Sydney	Climate Justice Research Centre								✓
University	University of Technology, Sydney	Institute for Sustainable Futures		✓	✓	✓	✓			✓
University	University of Technology, Sydney	Australian Centre of Excellence for Local Government								
University	University of Technology, Sydney	Centre for Built Infrastructure Research					✓			
University	University of Technology, Sydney	Centre for Clean Energy Technology		✓						
University	University of Technology, Sydney	Institute for Sustainable Futures (ISF)							✓	✓
University	University of Technology, Sydney	Materials and Technology for Energy Efficiency (MTEE)		✓					✓	
University	University of Wollongong	Sustainable Buildings Research Centre	✓				✓			
University	University of Wollongong	SMART Infrastructure Facility	✓				✓			
University	University of Wollongong	Australian Institute for Innovative Materials	✓				✓			
University	University of Wollongong	Global Challenges Program	✓							✓

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
University	University of Wollongong	Advanced Manufacturing Technologies (AMT)	✓	✓						
University	University of Wollongong	Australian Institute for Innovative Materials (AIIM)	✓						✓	✓
University	University of Wollongong	Sustainable Buildings Research Centre (SBRC)	✓				✓			
University	University of Wollongong	Institute for Superconducting and Electronic Materials (ISEM)	✓	✓	✓				✓	
University	University of Wollongong	Engineering Materials Research Strength (EMRS)	✓						✓	✓
Other	University of Wollongong	Innovation Campus (iC)	✓	✓						✓
Other	University of Wollongong	SMART Infrastructure Facility	✓				✓			
Other	University of Wollongong	Intelligent Polymer Research Institute (IPRI)	✓						✓	
University	UNSW Sydney	Australian Centre For Advanced Photovoltaics		✓						✓
University	UNSW Sydney	Australian Energy Research Institute (AERI)		✓						
University	UNSW Sydney	Centre for Infrastructure Engineering and Safety (CIES)					✓			✓
University	UNSW Sydney	Centre for Sustainable Materials Research and Technology					✓		✓	✓
University	UNSW Sydney	City Futures Research Centre (CFRC)					✓			
University	UNSW Sydney	Climate Change Research Centre (CCRC)								✓
University	UNSW Sydney	Research Centre for Integrated Transport Innovation (rCITI)			✓					
University	UNSW Sydney	Institute of Global Finance (IGF)								✓
University	UNSW Sydney	Australian Climate Change Adaptation Research Network for Settlements and Infrastructure					✓			
University	UNSW Sydney	International Universities Climate Alliance								✓
University	UNSW Sydney	Centre for Energy and Environmental Markets						✓		
University	UNSW Sydney	Global Water Institute				✓				
University	UNSW Sydney	UNSW Engineering		✓			✓		✓	✓
University	UNSW Sydney	Geospatial Research Innovation Development (Fac of Built Env)					✓			
University	UNSW Sydney	City Analytics Labs (Fac of Built Env)					✓			
University	UNSW Sydney	The Allens Hub for Technology, Law & Innovation								✓
University	UNSW Sydney	Centre for Law, Markets & Regulation								✓

Sector	University/ Organisation	NSW Centres / Nodes / Major Collaborations	Regional	Electricity	Transport	Land	Built environment	Services	Industry	Other
University	UNSW Sydney	Centre for Sustainable Material Research & Technology (SMaRT)					✓		✓	
University	UNSW Sydney	Climate Change Research Centre								✓
University	UNSW Sydney	Transport and Road Safety Research			✓					
University	Western Sydney University	Environment and Sustainability								✓
University	Western Sydney University	National Vegetable Protected Cropping Centre				✓				
University	Western Sydney University	Hawkesbury Institute for the Environment								✓
University	Western Sydney University	Greenhouse Research Education Training Facility							✓	
University	Western Sydney University	Global Centre for Land-Based Innovation				✓				
University	Western Sydney University	Centre for Infrastructure Engineering					✓			
University	Western Sydney University	Institute for Infrastructure Engineering					✓			✓
University	Western Sydney University	Centre for Smart Modern Construction					✓			

Appendix 5

Transition Case Studies

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Transition status	Steel complete	Ongoing	Complete	Complete
Context	Coal mining and power generation currently comprises a significant proportion of the Hunter region economy. Steelmaking was also a major industry in Newcastle until the closure of a major BHP processing and manufacturing site in 1999. With the city having already experienced major transition from steelmaking, there is a vision to transform the region into a hub for renewable energy expertise.	Closure of the Hazelwood Power Station was announced in November 2016, five months prior to shut down in March 2017. The region had already experienced structural adjustment during the 1990s due to privatisation of the region's power stations. The region is also anticipating future closures of Yallourn and Loy Yang A & B.	The Ruhr Valley economy was heavily dependent on black coal mining. In 1957, employment in the mining, iron and steel accounted for 70% of total regional employment.[602] Profitability of the black coal industry declined in the 1970s with the cost of deep extraction becoming economically unfeasible. Closure of the industry was actively managed with community involvement from the 1980s until 2018.	Singapore gained independence in August 1965 and had high unemployment and a housing crisis with no natural resources for trade and export. Government intervention delivered economic and social reforms that enabled Singapore to leverage its human resources and strategic location as a trade hub.

[602] Sheldon, P., Junankar, R. and De Rosa Pontello, A., 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities*, Industrial Relations Research Centre.

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Outcomes	The BHP shutdown is cited as a successful case study for large-scale restructuring, particularly the "Pathways" program which was established to assist employees in their transition to post-BHP life. About 90 per cent of participants from the program were employed or in the process of retraining 15 months after the closure. However, some reports suggested that older workers found the transition more difficult.[603]	By October 2019, the Gippsland region employment had increased by 10,600 (versus Sep 2016) and 74 per cent of the former Hazelwood workforce were in current employment or not looking for work (including retirement).[604] However, the relatively short timeframe from announcement to closure placed pressure on government and communities to react quickly. Further mine closures are expected in the future.[605]	The Ruhr Valley example is widely cited as a case study for successful regional transition away from a resource-based economy. The process was conducted gradually with time to avoid forced redundancies.[606] Unemployment rates for the region are high but lower than peak unemployment for 1978-1988 which was 15.1%. In 2013, unemployment in the Ruhr district was 12.1%.[607] Strengths of the region now include technology industry and ecotourism. However, there are concerns over rising unemployment and poverty levels in the region.[608]	Achieved a successful transition from low-tech, low-wage economy to high-tech, high-wage economy with strengths in manufacturing, technology and global connections (from 1979 onwards).[609] In 1965, GDP per capita was US$516. By 1990, GDP per capita was close to US$12,000.[610] Significant improvements were achieved in increasing quality of living through public housing. Today around 80% of Singaporeans live in public flats.[611]

[603] Murphy, D. '*Newcastle's steely resolve masks painful scars from BHP shutdown*', The Sydney Morning Herald, 19 February 2014, accessed 22 June 2020, https://www.smh.com.au/national/nsw/newcastles-steely-resolve-masks-painful-scars-from-bhp-shutdown-20140219-330y9.html.
[604] Latrobe Valley Authority, 2019, *Transitioning to a strong future: Latrobe Valley Community Report November 2016-November 2019.*
[605] Whittaker, J. *'Latrobe Valley optimistic two years after Hazelwood power station closure, but coal attachment remains',* ABC News, 18 March 2019, accessed 22 June 2020, https://www.abc.net.au/news/2019-03-18/hazelwood-power-station-closure-two-years-on/10908866.
[606] O'Malley, N. '*How Germany closed its coal industry without sacking a single miner*', The Sydney Morning Herald, 14 July 2019, accessed 22 June 2020, https://www.smh.com.au/environment/climate-change/how-germany-closed-its-coal-industry-without-sacking-a-single-miner-20190711-p526ez.html.
[607] Sheldon, P., Junankar, R. and De Rosa Pontello, A. 2018, *The Ruhr or Appalachia? Deciding the future of Australia's coal power workers and communities,* Industrial Relations Research Centre.
[608] TheLocal.de, *'Poverty rising in Germany's industrial Ruhr region: study',* The Local, 3 April 2019, accessed 22 June 2020, https://www.thelocal.de/20190403/poverty-on-the-rise-in-german-cities.
[609] Zhou, P. 2020, *The History of Singapore's Economic Development*, accessed 22 June 2020, https://www.thoughtco.com/singapores-economic-development-1434565.
[610] The World Bank, *GDP per capita (current $US) – Singapore*, accessed 22 June 2020, https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=1990&locations=SG&start=1965.
[611] Housing Development Board (Singapore Government), *HDB History and Towns,* accessed 22 June 2020, https://www.hdb.gov.sg/cs/infoweb/about-us/history#:~:text=Many%20people%20were%20living%20in,to%20solve%20Singapore's%20housing%20crisis.

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Element 1: Proactive Anticipating transition in communities, preparing agile responses in advance, developing and refining strategies for recovery	Closure of the steelworks was planned and announced two years prior to the shutdown, allowing time for workers to take stock and prepare for closure. The company set up a program to assist workers with their transition.	The Latrobe Valley Authority was established in November 2016 in response to the sudden announcement of Hazelwood's closure. The first stage of the response was to react to and manage the impending crisis. An adaptive and evolving approach is now being applied to guide the region through recovery, capability building and strategic growth for the future.	Government engagement at federal and state level began prior to the mine closures in anticipation of the significant transitions required for the industry and workers. Initially, this was not received well by industry. Long term forward planning was utilised to stagger mine closures over a period of decades. A large amount of funding in the billions of dollars was allocated over several years.	A legislative approach was undertaken by government to manage employment and industrial reforms that attracted foreign investment to Singapore. Structural wage adjustments were used to influence the mix of foreign investment into Singapore, with the objective of lowering the supply and demand of unskilled labour.

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Element 2: Local and collaborative Engaging local people and communities in development and delivery of services. Bringing together local communities, industry, educational institutions, and local, state and national agencies;	A number of local groups are working towards economic and social development of the Hunter Region, including the Hunter branch of Regional Development Australia and the Hunter Joint Organisation. The HRJO is a coalition of ten local councils and the NSW State Government formed to advance a regional strategy while seeking to acknowledge the diversity and individual character of their localities. The RDA Hunter acts as a neutral broker for collaboration across all levels of government, community, industry and business.	The LVA office was established in the local town of Morwell, providing a central point of contact for affected workers. It is staffed by locals and informed by community needs and priorities. Partners in the transition include Victorian government agencies, Gippsland region local councils, local businesses and educational institutions including TAFE Gippsland, Federation University, Melbourne University and local colleges. Examples: • Federation University delivered strategic education courses for growth of Gippsland allied health industry. • Local business Good Shepherd Microfinance used to deliver low-cost financial services to affected workers.	The German "social partnership" model enabled a culture of cooperation between workers, unions, employers and government. While transition programs were initially led and coordinated at the federal level, local coordination was increased for better integration of community initiatives. Examples: • Emscher Park Planning Company was established for a 10-year period to coordinate locally-initiated projects including business networks and a new technology park linked to the local university. • A private sector business consortium, Initiativkreis Ruhr, organised inter-municipality innovation competitions for environmental and social housing solutions in Bottrop.	In contrast to the success of bottom-up approaches, national government leadership is seen as central to the success of Singapore's industrial transition. However, tripartite collaboration that enables cooperative discourse between unions, employers and the government is seen as a competitive advantage for Singapore's economic development.[612] The non-adversarial unionism approach was forged in the early days of Singapore's independence from Malaysia post-1965. In the early years of industrialisation, the National Wages Council invited feedback and input from the public, providing opportunities for in-person consultation.[613]

[612] Ministry of Manpower (Singapore Government), *What is tripartism*, accessed 22 June 2020, https://www.mom.gov.sg/employment-practices/tripartism-in-singapore/what-is-tripartism.
[613] Lee, C.T. 2013, The Story of NWC: 40 years of tripartite commitment and partnership. Straits Times Press Pte Ltd.

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Element 3: Rigorous and strategic Identifying and investing in genuine local capabilities and competitive advantages	The European Commission's Smart Specialisation framework has been used to identify strengths for the region: [614] • Advanced manufacturing • Creative industries • Defence • Food and agribusiness • Medical technologies and pharmaceuticals • Mining equipment • Technology and services • Oil, gas and energy resources	The region is utilising "Smart Specialisation Strategy" based on best practice developed by the European Commission.[615] Focus is on developing Gippsland strengths in:[616] • Horticulture and food • Health • New energy • Advanced manufacturing • Logistics	Investment was provided to build a new service sector industry based on existing regional strengths in commodities transportation, plant closure regulation, site remediation, and mining equipment manufacturing. These include: • Packaging and transport logistics • Environmental services and technology • Renewable resources, recycling and waste • Renewable energy systems manufacturing	In the absence of natural resources for export, the government developed capabilities around the country's strategic location as a port, and human capital. Multinational companies were engaged to transfer skills and technical knowledge to the local workforce through migration which attracted skilled foreign workers.
Element 4: Comprehensive Providing a suite of programs that support workers and their families, businesses, and communities	The BHP steelworks closure was announced in 1997, with two years to prepare for a fixed closure date in 1999. The company ran a Pathways Employment Services to assist worker transitions to new industries and professions, other roles in the steel industry or retirement. Investment of A$7m was provided, of which A$2.32m was spent on retraining of workers for movement into other industries or other areas of the business.[617]	A range of transition programs and initiatives included: • Worker transfer scheme and transition service • Financial and counselling services • Grants for local business to hire and train unemployed workers • Transition planning for businesses in the supply chain for the power station • Upgrades to community infrastructure • Funds for major event attraction to boost tourism •	Programs and initiatives included: • Worker transfer and retirement schemes, retraining and on-the-job certification opportunities • Cross-sector transfer schemes • Upgrades to public infrastructure • University and technical education • Ecotourism, leisure and cultural initiatives • University-supported incubation programs to support local start-ups and innovation	Significant investment was put into lifting quality of living standards through development of a public housing system, education and industrial relations strategies. A number of agencies were established to deliver these outcomes including the: • Housing Development Board (HDB) • Economic Development Board (EDB) • Skills Development Fund (SDF) • National Wages Council Tourism was also identified as a key opportunity, with efforts put into improving tourism infrastructure and promotion.[618]

[614] RDA Hunter, 2019, Smart Specialisation Strategy [S3] for the Hunter Region.
[615] European Commission, *What is Smart Specialisation?*, accessed 22 June 2020, https://s3platform.jrc.ec.europa.eu/what-is-smart-specialisation-.
[616] Melbourne Sustainable Society Institute. *Gippsland Smart Specialisation Strategy*, accessed 22 June 2020, https://sustainable.unimelb.edu.au/research/research-projects/gippsland-smart-specialisation-strategy.
[617] Connors, E. and Long, S. 2002, *'When downsizing becomes risky business'*, Australian Financial Review, 4 June 2002, accessed 22 June 2020, https://www.afr.com/policy/economy/when-downsizing-becomes-risky-business-20020604-k1k0b.
[618] Singapore Tourism Board, 2019, *Overview*, accessed 22 June 2020, https://www.stb.gov.sg/content/stb/en/about-stb/overview.html#:~:text=History,a%20staff%20strength%20of%2025.

	Newcastle and Hunter region, NSW	Latrobe Valley, VIC	Ruhr Valley, Germany	Singapore's Industrial Revolution
Element 5: Committed Investing in workers, industry and communities to deliver transition strategies.	Education and community infrastructure are being incorporated into development plans for the region, including housing supply and availability.	Many long term programs have been established including: • Collaborations to increase use of local and Aboriginal businesses, and social and disability enterprises • Training programs to build skills in health, transportation, disability services, solar installations and construction • Gippsland hi-tech precinct development • International student attraction • Industry and education partnerships • Relocation of state government services • 10-year plan for tourism growth	Education was a key strategy for delivery of the skills transition required for development of new service industries. The area now has more than 20 universities in the region, with a flow-on effect in the growth of technology innovation. More than 300 science and technology companies are based at the Dortmund Technology Park. Focus on enhancing environmental and cultural aspects has enabled the region to become strong in ecotourism. The Zeche Zollverein mine is a UNESCO-listed world heritage site. A fund has also been set up to finance "perpetual obligations" to manage regional water quality which has been negatively impacted by mining activities over many decades.[619]	Many of the statutory bodies established in the early phase of Singapore's industrialisation continue to evolve to meet ongoing needs of the Singaporean economy. For example, the Housing Development Board still operates a successful public housing model.[620] The EDB was tasked with developing local industry through provision of infrastructure and attraction of foreign businesses.[621] They also administered the SDF[622] which was intended to provide a sustainable funding source for employee training, retraining and upgrades to business capital.[623] Both EDB and SDF continue to support economic growth and development of human capital in Singapore today.

619 RAG Stiftung. *The perpetual obligations: a never-ending task*, accessed 22 June 2020, https://www.rag-stiftung.de/en/perpetual-obligations.
620 Bryson, J. 2019, *'A century of public housing: lessons from Singapore, where housing is a social, not financial, asset*', The Conversation, 31 July 2019, accessed 22 June 2020, https://theconversation.com/a-century-of-public-housing-lessons-from-singapore-where-housing-is-a-social-not-financial-asset-121141.
621 Zhou, P. 2020, '*The History of Singapore's Economic Development*', ThoughtCo, 10 July 2019, accessed 22 June 2020, https://www.thoughtco.com/singapores-economic-development-1434565.
622 Pek, S. 2017, *Economic Development Board*, Singapore Infopedia, accessed 22 June 2020, https://eresources.nlb.gov.sg/infopedia/articles/SIP_2018-01-08_135544.html.
623 History SG, 2019, *Skills Development Fund is Established Oct 1979*, accessed 22 June 2020, http://eresources.nlb.gov.sg/history/events/98e1b55f-093d-4d44-b219-d51f6a38c313#:~:text=The%20Skills%20Development%20Fund%20was,by%20all%20employers%20in%20Singapore.