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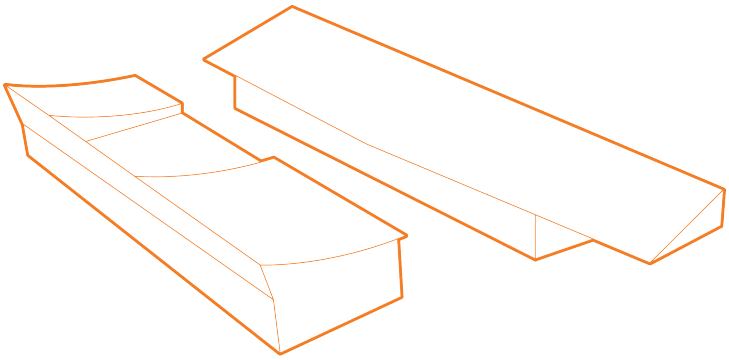

ILLAWARRA CLEAN ENERGY INDUSTRY ROADMAP

FINAL REPORT

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TABLE OF CONTENTS

Table of Contents 3

Executive Summary 8

A Clean Energy Roadmap for Illawarra Shoalhaven Industry Development 8

Chapter 1: Introduction 1

Chapter 2: Global and Australian Energy Demand – Current Trends and Outlook 3

2.1 Global Energy Outlook 3

2.1.1 Status 3

2.1.2 Future Scenarios 3

2.1.3 Global Outlook for Clean Energy Transition 6

2.1.4 Economic Impact of Clean Energy Transition 7

2.2 Australia 14

2.2.1 Current Demand 15

2.2.2 Future Demand 18

2.3 Roadmap to Green Energy Transition – Illawarra Shoalhaven 23

2.3.1 Policy 24

2.3.2 Status 28

2.3.3 Future Demand 29

2.3.4 Clean Energy Transition in the Illawarra Shoalhaven 31

2.4 Unintended Consequences from Clean Energy Transition 33

2.5 Global Supply Chain Outlook – Green Energy Transition 34

2.5.1 Structure and Bottlenecks 34

2.5.2 Investment in Clean Energy Transition 39

2.5.3 Circular Economy: End-of-Life Considerations 40

2.5.4 Australia 43

Chapter 3: Methodology 47

3.1 Scope and Assumptions 47

3.2 Stage 1: Consultation with Industry, Government, and Tertiary Education Leaders 49

3.2.1 Participant Selection and Ethical Considerations 49

3.2.2 Interview Structure and Content 50

3.3 Stage 2: Heatmap Development 50

3.3.1 Heatmap Criteria and Definitions 50
3.3.2 Steering Committee Involvement 51

Chapter 4: Findings *53*

4.1 Illawarra Clean Energy Transition Action to Date **53**

4.2 Vision for the Illawarra Shoalhaven **54**

4.3 Capability and capacity: Illawarra Shoalhaven Heat Map **55**

4.4 Opportunities for the Illawarra Shoalhaven **57**

4.4.1 Enabling Infrastructure 59
4.4.2 Clean Energy Generation 60
4.4.3 Clean Energy Storage 62
4.4.4 Alternative Industries 63

4.5 Less Desirable Opportunities for the Illawarra **64**

4.5.1 Energy Generation 64
4.5.2 Energy Storage 65
4.5.3 Energy Distribution, Enabling Opportunities, Spillover and Alternative Opportunities 66

4.6 Regional Roadmap **67**

4.6.1 Critical Success Factors Needed for a Successful Transition 70
4.6.2 Challenges Facing the Transition 78

Chapter 5: Recommendations and Conclusion *80*

References *3*

Appendices *11*

Appendix A: Total Energy Consumption (in Terawatt-Hours) **11**

Appendix B: Financial Costs and Economic Impact **11**

Appendix C: Summary of Recommendations for the Solar Supply Chains **12**

Appendix D: Summary of Recommendations for the Wind Supply Chains **13**

Appendix E: Policy Elements to Ensure Plentiful, Decent Jobs **14**

Appendix F: Consent Form **15**

Appendix G: Participant Confirmation Sheet **16**

List of Figures

Figure 1: Energy Consumption by Source
Figure 2: Share of Global Total Final Consumption by Selected Fuel and Scenario, 2022–2050
Figure 3: Global Electricity Demand, 2010–2050, and Generation Mix by Scenario, 2022 and 2050
Figure 4: Change in Global Energy Employment by Sector in the STEPS and NZE Scenarios, 2022–2030
Figure 5: Evolution of Global Renewal Energy Employment by Technology, 2012–2022
Figure 6: Investment Flows from 2015 to 2020
Figure 7: Global Solar PV and Battery Storage Capacity Additions and Power Sector CO2 emissions, 2022 and 2030
Figure 8: Average Annual Global Investment in the Power Sector by Type and Scenario, 2018–2022 and 2030
Figure 9: Investment Trends in Grids Versus Needs in the APS
Figure 10: Production, Consumption, and Export of Australia's Energy
Figure 11: End-Use of Energy by Industry, Household, and Exports
Figure 12: Renewable Energy Use at Household Level
Figure 13: Energy Consumption by Fuel Type
Figure 14: Australian Electricity Generation from Renewable Sources, by Fuel (Gigawatt hours)
Figure 15: The Australian Energy Market Operator's (AEMO) Electricity Outlook
Figure 16: Capacity, NEM (GW, 2009–10 to 2049–50)
Figure 17: Coal Capacity, NEM (GW, 2009–10 to 2049–50)
Figure 18: Percent Change in Employment 2015–2030
Figure 19: Forecast Labour Demand by Job Type
Figure 20: A Policy Framework for Accelerating Heavy Industry Clean Energy Transitions
Figure 21: Virtuous Cycle to Accelerate Energy Transition
Figure 22: International Energy Agency Policy Package
Figure 23: GHG Emissions from the Illawarra Shoalhaven Region
Figure 24: Vision for the Illawarra Shoalhaven
Figure 25: Unique Capability and Capacity: Illawarra Shoalhaven
Figure 26: Energy Distribution and Enabling Infrastructure
Figure 27: Energy Generation: Offshore Wind, Solar, Hydro, and Biogas
Figure 28: Energy Storage: Battery, Gravity, Green Hydrogen/Ammonia
Figure 29: Spillover and Alternative Opportunities in Clean Energy Industries
Figure 30. Roadmap for the Illawarra Shoalhaven

List of Tables

Table 1: Key Opportunities, Future Forecasts, and Challenges for the Transition into Clean Renewable Energy
Table 2: Economic Impact of Clean Energy Transition
Table 3: Natural Inputs of Selected Australian Energy Products
Table 4: Energy Use by Industry
Table 5: Australia's National 2020, 2030 and 2050 Energy and Climate Targets
Table 6: Application of the Policy Packaging Framework
Table 7: Summary of Current and Future Outlook for Clean Energy Industry in the Illawarra Shoalhaven
Table 8: Future Opportunities for Clean Energy Storage Infrastructure
Table 9: Summary of Unintended Consequences or Considerations Relating to Clean Energy Transition
Table 10: Scope of the Investigation
Table 11: Key Assumptions
Table 12: Clean Energy Initiatives in the Illawarra Region
Table 13: Summary of Economic Impact Projections

Table 14: List of Identified Barriers
Table 15: List of Key Recommendations

List of Appendices

Appendix A: Total Energy Consumption (in Terawatt-Hours)
Appendix B: Financial Costs and Economic Impact
Appendix C: Summary of Recommendations for the Solar Supply Chains
Appendix D: Summary of Recommendations for the Wind Supply Chains
Appendix E: Policy Elements to Ensure Plentiful, Decent Jobs
Appendix F: Consent Form
Appendix G: Participant Confirmation Sheet

Glossary

Term	Definition
AEMO	Australian Energy Market Operator
APS	Announced Pledges Scenario
ARENA	Australian Renewable Energy Agency
BOC	British Oxygen Company
BP	British Multinational Oil and Gas Company
BZE	Beyond Zero Emissions
CE	Circular Economy
CEDA	Committee for Economic Development of Australia
CO2	Carbon Dioxide
EIA	Energy Information Administration
EREC	European Renewable Energy Council
ETS	Emissions Trading Scheme
EV	Electric Vehicle
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOES	Grain-Oriented Electrical Steel
GVA	Gross Value Added
HELE	High-Efficiency, Low-Emissions
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
KWH	Kilowatt-hour
MWH	Megawatt-hour
NETP	National Energy Transformation Partnership
NEM	National Energy Market
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NZE	Net-Zero Emissions Scenario
NZT	Net-Zero Transformation
OPGGS	Offshore Petroleum and Greenhouse Gas Storage
O&M	Operation and Maintenance
PJ	Petajoule
PV	Photovoltaic
R&D	Research and Development
REE	Rare Earth Element
REZ	Regional Economic Zone
RGGI	Regional Greenhouse Gas Initiative
SPP	Solar Power Plant
STEPS	Stated Policies Scenario
TWH	Terawatt-hour
WEF	World Economic Forum
WPP	Wind power plant
5GW	Equivalent to 5,000,000 kilowatts and indicates large-scale power generation capacity

Executive Summary

A Clean Energy Roadmap for Illawarra Shoalhaven Industry Development

Australia's energy transition is rapidly advancing, with renewable energy now accounting for approximately 40% of the country's electricity use (Clean Energy Council, 2024).

The energy transition poses significant opportunities for the Illawarra regions.

In February 2023, the New South Wales government declared an Illawarra Renewable Energy Zone (REZ). In June 2024, an offshore wind zone with a capacity of 2.9GW was declared by the Australian government.

The Illawarra region now faces the challenge of harnessing major opportunities in the clean energy transition, particularly in offshore wind energy, while addressing current regional capacity and capability gaps, leveraging Government policies, workforce development and supply chain including infrastructure.

To position itself as a leading hub for offshore wind energy by 2030, and green advanced manufacturing and logistics by 2050, the region must leverage its existing regional capacities and capabilities and attract targeted investments in key supply chain/ infrastructure areas and identify the critical steps and milestones necessary to drive the region's transformation into a clean energy and manufacturing leader.

Business Illawarra commissioned this research with the University of Wollongong and supported by a Steering Committee of Illawarra Shoalhaven Industry to focus on the timely identification of clean energy transition opportunities for the Illawarra region, develop a high-level roadmap to implementation and pose critical recommendations for the successful delivery of a clean energy transition for the region.

This report reviews an appropriate mix of leveraging existing regional capabilities, expanding capabilities into adjacent areas of opportunity, and taking action to develop new renewable energy business opportunities which are a best fit for the region.

Economic Impacts of Clean Energy Transition Globally

Global energy demand has been steadily increasing over the last two decades. The increase in energy consumption has been closely matched by increasing greenhouse gas (GHG) emissions. To meet the agreed climate targets set in the Paris agreement, a large-scale transition is required to a net-zero energy system. In 2022, 82% of all primary energy originated from fossil fuel sources (Energy Institute, 2023). Whilst uptake of renewable energy generation is growing – more than 500 Gigawatts of renewable capacity was added globally in 2022 – its share of overall primary energy consumption was 7.5% in 2022. It is predicted that an 11-fold increase in global wind power capacity and a 20-fold increase in solar photovoltaic (PV) is required to achieve net-zero by 2050 (IEA, 2023). Achieving a clean energy transition requires overcoming various challenges such as substantial investments in renewable infrastructure and supply chain, grid modernisation, workforce transition and robust policy stability.

The economic impact of renewable energy, particularly wind energy, has been significant in various regions, both in terms of GDP growth and shifts in employment patterns. Table I provides a sample overview of established economic impact studies globally. Further global economic impact studies can be found in the Literature Review section of the full report.

Table I. International Clean Energy Transition Impact Studies

Country	Renewable Energy Source	Economic Impact
United States (Brunner and Schwegman, 2022)	Onshore and offshore wind installations between 1995 and 2018	• increased GDP per capita by 8.5% • increase income per capita by 6% increase home values by 7%
United States, (Greene and Geisken, 2013)	147 MW onshore wind farm in Oklahoma	• 25 million in economic benefits • 200 jobs (construction and operation phase)
Spain (Varela-Vazquez and del Carmen Sanchez-Carreira, 2015)	Onshore wind	• Adding 1.2% to the regional GDP • 0.5% of total employment • 5.3% increase in indirect employment within R&D
Morocco (de Arce et al., 2012)	Onshore wind and solar over a 30-year period	• Projected contribution of 1.2% - 2% to GDP • Up to 499,000 FTEs

Regional clean energy transition caused employment to move from traditional sectors such as farming to higher-paying industries like construction and manufacturing. This highlights the broader economic benefits of transitioning to clean energy, especially for regions that embrace these new technologies and adapt their workforce accordingly (Brunner and Schwegman, 2022).

The International Energy Agency (IEA) projects that global employment in the clean energy sector will continue to grow, with the number of new jobs created expected to surpass those lost in fossil fuel industries (IEA, 2023). The International Renewable Energy Agency (IRENA) (2023) reports significant employment growth in the renewable energy sector over the past decade (2012 to 2022), with 13.7 million people employed by the industry globally, marking an 88% increase over 11 years. The solar industry leads in employment, followed by hydro and biofuel energy. The report by IRENA (2023) aligns with the IEA (2023) in projecting that, if the Intergovernmental Panel on Climate Change targets are met, 139 million jobs in the energy sector will be created by 2030, with renewable energy areas contributing to 80 million jobs.

Australian Clean Energy Transition

The Australian Government's Clean Energy Transition Plan aims to achieve net-zero emissions by 2050 while driving economic growth and job creation. The plan focuses on investing in renewable energy sources, reducing reliance on fossil fuels, and fostering innovation in clean technologies.

Key initiatives within the plan include:

1. Powering Australia Plan: This strategy emphasizes expanding solar, wind, and battery storage projects. It sets a target of generating 82% of electricity from renewables by 2030, aiming to reduce energy costs and enhance grid reliability.
2. Rewiring the Nation: A $20 billion initiative to modernize and expand the electricity grid, enabling more renewable energy to be integrated and ensuring a stable energy supply.
3. Hydrogen and Critical Minerals: The government is investing in green hydrogen production and critical minerals, positioning Australia as a global leader in clean energy exports and new technology supply chains.
4. Support for Households and Industry: Incentives are provided for energy efficiency upgrades in homes and businesses, helping reduce emissions and energy bills.

The plan is designed to create over 600,000 jobs, particularly in regional areas, while protecting the environment. By focusing on innovation, clean energy investments, and sustainable growth, Australia aims to secure a cleaner, more resilient energy future.

Australia's **National Energy Workforce Strategy** is designed to prepare the country's workforce for the transition to a low-emission, renewable energy future. The strategy focuses on ensuring that Australia has the skilled labour needed to support the rapid expansion of clean energy projects, such as solar, wind, hydrogen, and battery storage.

Key components include:

1. **Workforce Development and Skills Training**: The plan prioritizes investments in vocational education, apprenticeships, and specialized training to equip workers with skills in emerging energy technologies. This includes reskilling workers from traditional fossil fuel industries to transition into clean energy sectors.
2. **Regional Job Creation**: As renewable energy projects are often located in regional areas, the strategy aims to create jobs and economic growth outside of major cities. This supports regional communities and ensures a just transition for workers affected by the shift away from coal and gas.
3. **Collaboration with Industry and Education Providers**: The strategy promotes partnerships between government, industry, and educational institutions to align training programs with industry needs, ensuring a pipeline of skilled workers.
4. **Diversity and Inclusion**: Encouraging a diverse workforce, including women, Indigenous Australians, and young people, is emphasized to address labor shortages and foster inclusive growth.

This strategy aligns with Australia's broader goals of achieving net-zero emissions and ensuring a sustainable, skilled workforce for the future.

Overall, these policies are supported by the **Future Made in Australia policy,** which aims to revitalise and expand the Australian manufacturing sector, focusing on boosting domestic production, creating local jobs, and reducing reliance on imports. Central to this policy is fostering a robust and sustainable manufacturing industry by leveraging Australia's strengths, including its skilled workforce and abundant natural resources.

Key components include:

1. **National Reconstruction Fund**: A $15 billion investment fund to support priority sectors like clean energy, medical technology, and transport manufacturing. The goal is to spur innovation and local production, particularly in sectors critical to national security and resilience.
2. **Buy Australian Plan**: This plan focuses on using taxpayer dollars to prioritize Australian-made products and services in government procurement. It aims to strengthen local industries, promote job creation, and ensure the benefits of public spending stay within the country.
3. **Support for SMEs**: Small and medium-sized enterprises (SMEs) are given special attention, with initiatives to improve their access to finance, technology, and export opportunities. Programs like the Australian Industry Capability (AIC) plan help integrate SMEs into larger supply chains, particularly in defence and infrastructure projects.
4. **Clean Energy Transition**: Emphasising renewable energy manufacturing, the policy supports investments in green technologies to help Australia become a leader in sustainable production.

The policy aligns with the vision of making Australia a self-reliant, high-tech, and globally competitive manufacturing hub, securing long-term economic resilience and sustainable growth.

Illawarra Clean Energy Transition Action to Date

The Illawarra region has undertaken several significant initiatives to advance its clean energy transition, leveraging both local resources and government support. These efforts are aimed to establish the region as a leading hub for renewable energy and to foster sustainable economic growth. Table II highlights significant developments within the Illawarra region established to date, noting however that the list in Table II is a summary of the major initiatives and is not a comprehensive list of all renewable activities underway in the region, nor is Table II intended to be a list of all investments. These initiatives are aiding the Illawarra region in making substantial progress towards its vision of becoming a leader in clean energy and sustainable development.

Table II. Clean Energy Initiatives in the Illawarra Region

RE Initiatives	Illawarra Shoalhaven
Renewable Energy Zone (REZ) and Offshore Energy Infrastructure Zone (OEIZ)	• The NSW Government declared the Illawarra as a REZ in February 2023 • The Australian Government declared an Offshore Energy Infrastructure Zone (OEIZ) of 2.9GW in June 2024, recognising the region's high offshore wind potential
Port Kembla Hydrogen Hub	• Committed to green hydrogen leadership, attracting investment, and creating jobs • The NSW Government awarded $28.5 million to BOC Gases from the Hydrogen Hubs program to establish a 10.5MW hydrogen electrolyser and other hydrogen infrastructure • The hub supports the production, storage, and export of green hydrogen and ammonia
Regional Transition to Low Carbon Transport	• Wollongong is being targeted as a priority area within the NSW Government's Electric Vehicle public charging masterplan • A Hydrogen heavy vehicle refuelling station has been commissioned by Coregas to service local heavy vehicle decarbonisation initiatives
Solar and Hydro Projects	•Illawarra has established rooftop solar and hydro projects
Transmission and Distribution Infrastructure	• Integrated System Plan: 10,000 km of new transmission lines needed by 2050, with 2,500 km in development. A relatively minimal volume of this is forecast to occur in the Illawarra region. • The transmission projects are estimated to (1) save consumers $18.5 billion in avoided energy costs, (2) deliver $3.3 billion in emissions reduction
Clean Energy Futures Skill Centre	• AUD 13 million commitment by the Australian government for UOW to establish a clean energy future skills centre jointly by UOW and Wollongong TAFE • Super TAFE and Clean Energy Skill Centre develop local workforce skills to support transition
Advanced Manufacturing and Start-Up Ecosystem	• Leveraging the region's steel manufacturing base to support advanced clean energy infrastructure • Establishing new clean energy businesses in the Illawarra through R&D (e.g., Hysata, Sicona, Green Gravity)
Gas projects	• Natural Gas upgrade for Tallawarra aims for long-term hydrogen application • Port Kembla Energy Terminal (PKET) established by Squadron Energy to provide gas based firming capacity in the transition to renewables in NSW. PKET has been designed to allow future fuel uses.

Vision for the Illawarra Shoalhaven

The development of clean energy industries in the Illawarra and Shoalhaven will establish the region as a leading hub for renewable energy innovation, investment, and sustainable economic growth. By leveraging its strategic geographical position, existing industrial base, and skilled workforce, the Illawarra is well placed to attract significant investment, and the further development of robust enabling infrastructure will support various established and emerging clean energy technologies. A summary of key elements of the vision is presented in Figure I.

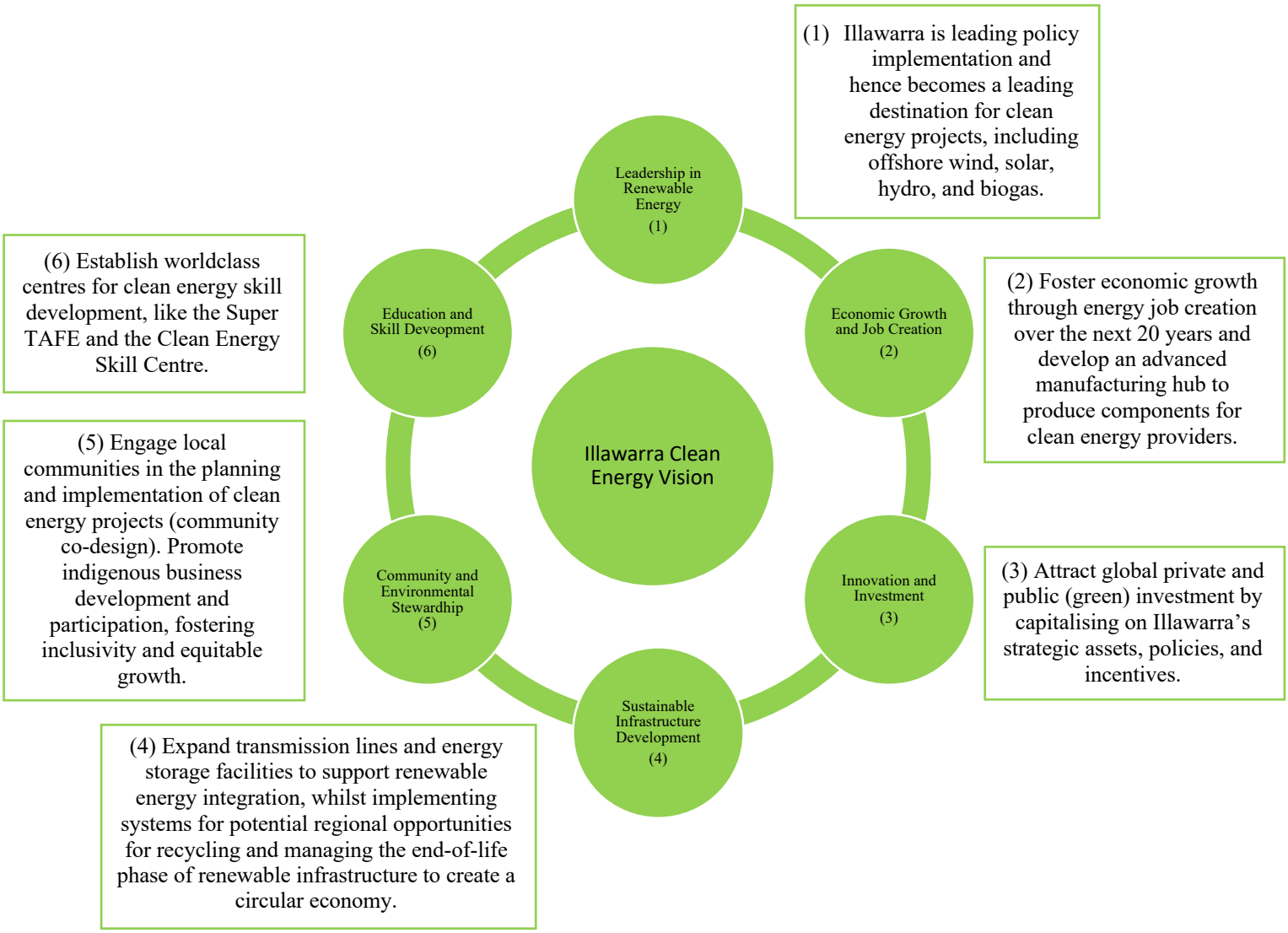


Figure I. Vision for the Illawarra Shoalhaven.

A roadmap for the implementation of the vision depicted in Figure I is presented in Figure VII, later in this report. The next section of this report takes a deep dive into specific opportunities for the region focusing on the overall desirability of engaging with an opportunity area as well as the current regional capability and capacity. The capability and capacity analysis provides qualitative guidance on potential investment areas which may have the highest potential returns.

Capability and capacity: Illawarra Shoalhaven Heat Map

Despite finite land resources, the region boasts major energy, port, and transport infrastructure, a skilled workforce with experience in heavy manufacture, oxygen and hydrogen production, storage

and use, and a strong local demand for hydrogen projects, including future green steel production. These combined assets, when leveraged to facilitate the energy transition, have the potential to transform the local economy. Figure II highlights a summary of the region's unique capability and capacity.

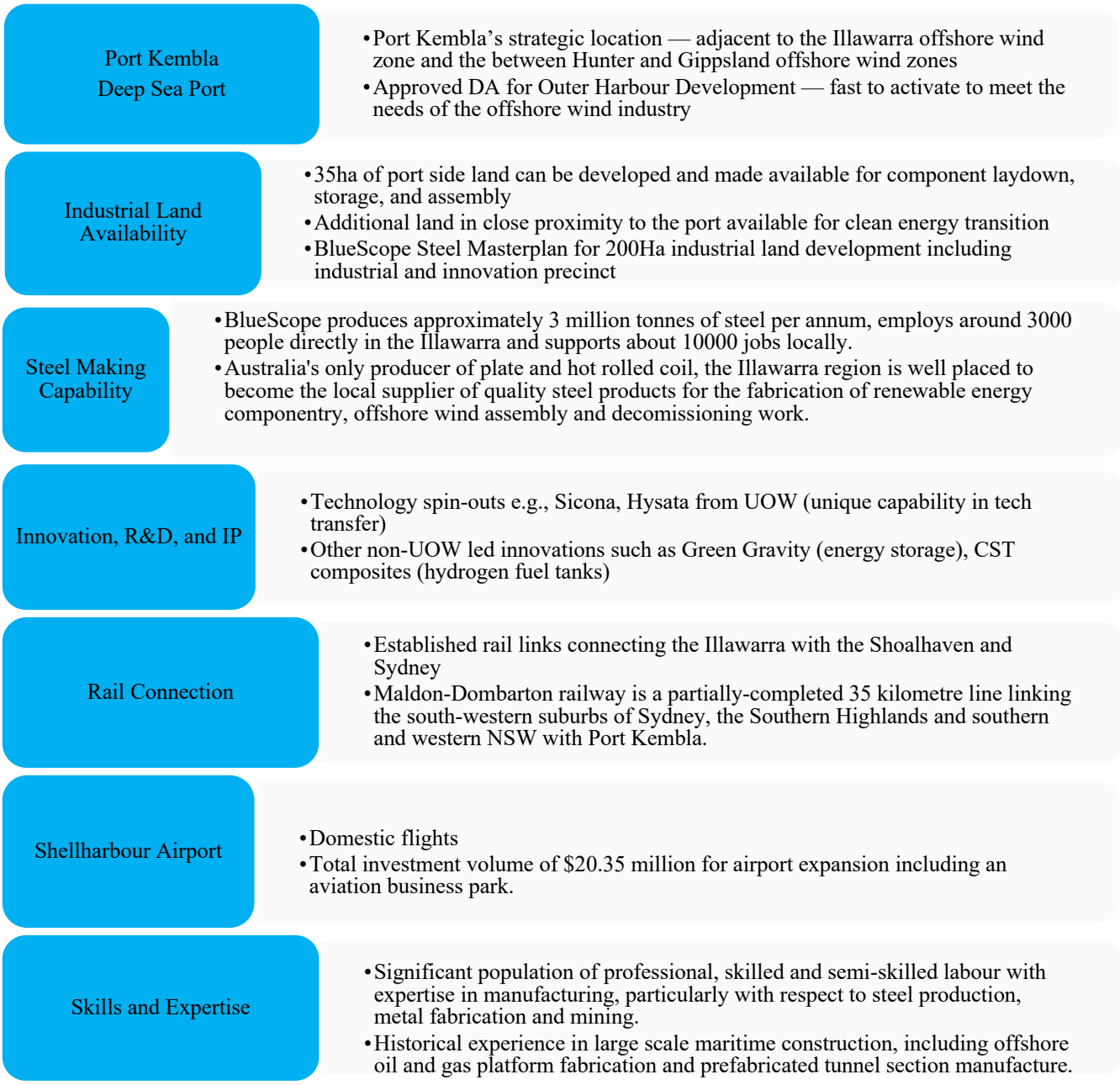


Figure II. Unique Capability and Capacity: Illawarra Shoalhaven.

The region is uniquely placed to become a leader in clean energy transition. One key aspect that sets the Illawarra REZ apart from other REZ regions is the significance of having an existing, considerable load geographically close to a potential source of generation. Considering the Illawarra's unique capabilities, the next section of this report explores and identifies opportunities for the region associated with the clean energy transition.

The clean energy transition presents significant employment opportunities for the Illawarra region, which is poised to become a major hub for renewable energy industries. The region's strategic position, existing industrial base, and government-backed initiatives such as the Illawarra Renewable Energy

Zone (REZ) and offshore wind projects make it well-positioned to support the rapid growth of green energy jobs.

The International Renewable Energy Agency (IRENA) estimates that the global renewable energy sector will generate 80 million jobs by 2030. In Australia, the clean energy sector is expected to create up to 50,000 new jobs by 2035, with the offshore wind and hydrogen industries being key drivers. The Illawarra region, with its infrastructure, skilled workforce, and educational institutions, could attract a substantial share of these opportunities. With the establishment of a 2.9 GW offshore wind zone, the Illawarra region could see the creation of approximately 4,000 to 6,000 jobs over the next decade, focusing on areas such as turbine manufacturing, assembly, installation, and maintenance. The Port Kembla Hydrogen Hub aims to create around 2,000 direct and indirect jobs, particularly in hydrogen production, storage, and export logistics. Battery and Storage Technologies: Community battery installations and microgrid projects could generate approximately 500 new jobs focused on installation, operation, and maintenance.

However, considerable gaps currently exist in regard to workforce, leveraging policy initiatives and clean energy supply chain that can position the Illawarra as a leading destination for clean energy transitions. The Illawarra has identified shortages in specific/specialised skills or talent such as electrical engineering, electrical trades, fabrication and mechanical trades, project management, WH&S and other skilled workers). The supply chain requires investment in critical infrastructure. However, uncertainty in demand due to a lack of an approved project pipeline (e.g., offshore wind projects) stalls investment. Further the electricity network infrastructure is insufficient to support electrification and decarbonisation (e.g. electric vehicle and hydrogen recharging infrastructure) including the transmission and distribution network capacity.
Finally, a lack of alignment and coordination between local, state and federal government has been identified as a gap to attract clean energy businesses to the region. Coordinated energy policy implementation is required at the local, state, and federal levels to fully unlock the regional benefits and opportunities. International policy best practice studies can be found in the Literature Review section of the full report.

Opportunities for the Illawarra Shoalhaven

The Illawarra region's unique capabilities and strategic positioning enable it to seize various clean energy opportunities, driving the local economy towards a sustainable and clean energy future.

Research conducted through a comprehensive series of interviews and national and international literature searches have been distilled into a combined qualitative and quantitative summary. This qualitative and quantitative research created Heat Maps, which are communicated in this report in the form of Venn diagrams.

The diagrams summarise the analysis of the data by focusing on the three factors of industry desirability, regional capability and regional capacity, whilst also factoring in time to implement. The intersection of all three factors (circles) in the Venn diagrams identify the elements that the research has identified as *most implementable* with the highest likelihood of success as they meet all three criteria, namely (1) industry desirability; (2) regional capability; and (3) regional capacity.

Industry desirability captures the attractiveness of a particular region, sector, or project for industrial development. It reflects the advantages that can be leveraged to make clean energy projects successful.

Regional capability includes the combined strengths, resources, and expertise within a region that enable it to effectively contribute to and benefit from the clean energy transition.

Regional capacity refers to the ability of the region to support, manage, implement, and sustain the clean energy transition.

Note that the opportunities presented here are those identified by key industry stakeholders.

Where two circles overlap, the opportunities meet the criteria of two sets but lack the third (either capacity or capability) requiring time for either capacity or capability development.

Lastly, those opportunities that are only desired by industry at this point are classified as long-term projects that are viewed as less feasible at present, and which require significant capacity and capability development to proceed.

Each opportunity is placed in one of three-time categories; A, B, & C where A focuses on 2024–2027, B focuses on mid-term initiatives between 2028–2031, and C on long-term plans out to 2050.

The research has been grouped into the categories of enabling infrastructure, clean energy generation, clean energy storage, and new or alternative industries. Thus, there are four Venn diagram heat maps, one for each of these categories.

1. Enabling Infrastructure

Figure III presents the analysis of enabling infrastructural opportunities in the Illawarra including energy distribution infrastructure.

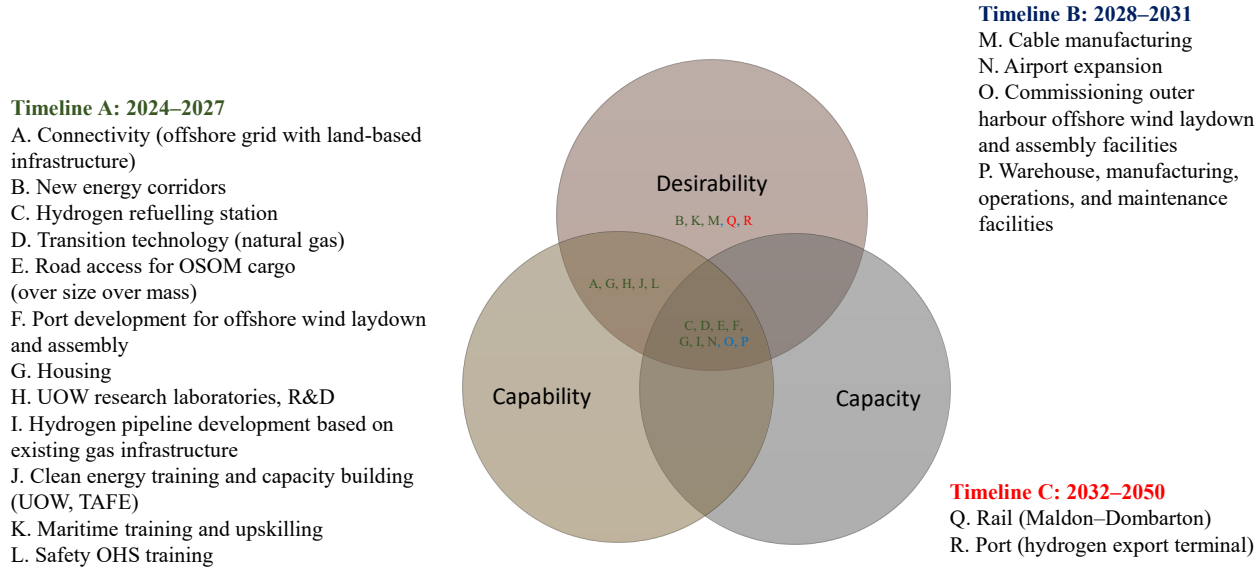


Figure *III*: Energy Distribution and Enabling Infrastructure.

Industry desirability with existing regional capacity and existing regional capability:
Developing Port Kembla to enable it to support the offshore wind industry in the Illawarra, Hunter, and Gippsland regions is critical and is an immediate priority to commence within Timeline A. In relation to onshore wind and other renewables projects, enhanced road access for Over Size/Over Mass (OSOM) components will also enable the Illawarra to supply imported and locally produced componentry to regions within the state. The Illawarra has a history of coke oven gas production (60%

of which is hydrogen) as part of making high value coke. The region has a familiarity of using hydrogen rich gases in steelmaking. Additionally, local established gas producers such as Coregas and BOC bring expertise in hydrogen production, storage, transport and liquefaction that can be leveraged to further develop hydrogen supply chains. Finally, in the medium-term airport infrastructure upgrades have also been identified.

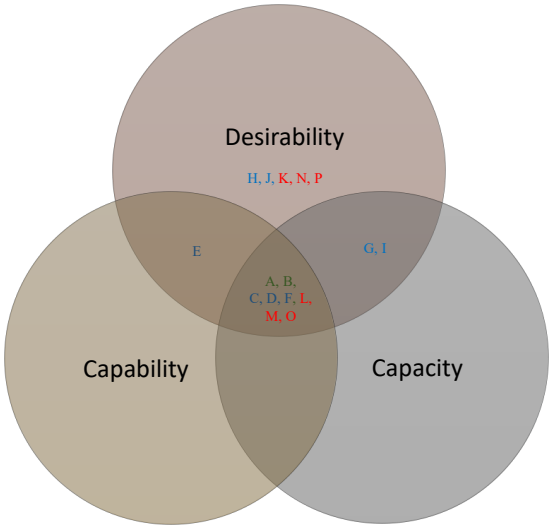
Industry desirability that requires regional capability development:
Capability gaps currently exist to tackle desired opportunities regarding grid connectivity (offshore to onshore), worker shortages worsened by housing development challenges, UOW R&D due to funding and budget constraints and human resource training and development for the clean energy transition industry.

Industry desirability that requires regional capacity and regional capability development:
The development of new transmission corridors, the establishment of a maritime skills centre, cable manufacturing (bringing back a previously established industry), rail infrastructure development and a port hydrogen export terminal have all been identified as desirable for the Illawarra but with limited capacity and capability available now.

2. Clean Energy Generation

Figure IV provides an overview of the identified opportunities in clean energy generation with most opportunities stemming from the emerging offshore wind industry.

Timeline A: 2024–2027
A. Steel sub-structures for large scale solar farms
B. Rooftop Solar



Timeline B: 2028–2031
C. Support construction of fixed bottom offshore wind turbines
D. Pre- and final assembly of turbines
E. Marine offshore support industry
F. Floating platform manufacturing
G. Fixation of turbines (seabed anchors and ropes)
H. Marine offshore support industry (offshore vessels, maintenance, inspection)
I. Main tower manufacturing
J. Mooring lines (chains, synthetics)

Timeline C: 2032–2050
K. Component manufacturing/ assembly (e.g. taper at top of wind turbine)
L. Gearbox maintenance
M. Offshore and onshore spares and maintenance excluding vessels
N. Port support during windfarm, operation and maintenance phase
O. Infrastructure upgrade hydro
P. End-of-Life (decommissioning and CE)

Figure *IV*: Energy Generation: Offshore Wind, Solar, Hydro, and Biogas.

Industry desirability with existing regional capacity and existing regional capability:
The existing heavy construction industry in the Illawarra has demonstrable capabilities and capacities in manufacturing of large infrastructure components such as offshore oil rigs. These capacities and capabilities are transferrable to the manufacturing of the sub-structures (e.g., floating windfarm components or solar farm support structures) for as well as the assembly and decommissioning (de-assembly) work. In the long-term, turbine maintenance as well as wind energy maintenance

opportunities are highly desirable. Finally, the further extension of roof top solar and the Kangaroo Valley pumped-hydro energy storage scheme have been identified as desirable opportunities long-term that can proceed with existing capability and capacity.

Industry desirability that requires regional capacity development:
The Illawarra region has existing capability in the provision of maritime services. An investment in capacity is required to unlock the opportunity to establish the region as a maritime service centre for offshore windfarm deployment and maintenance services. Here services range from marine certifications, seabed surveys and telemetry, engineering design services and environmental services, geophysical services but also vessel maintenance and offshore inspections.

Industry desirability that requires regional capability development:
Two desired opportunities have been identified for the region to participate in fixation technology for floating offshore wind infrastructure such as seabed anchors and ropes as well as the manufacturing of wind towers.

Industry desirability that requires regional capacity and regional capability development:
Larger investments are required to unlock opportunities as regards the establishment of a marine offshore supplier industry including the provision of vessels, inspection, and maintenance. In addition, manufacturing of mooring lines such as chains and synthetics would complement this emerging marine industry. Finally, long-term capabilities in taper manufacturing are desirable but lack regional capacity and capability.
Noteworthy is the opportunity for capacity and capability development around decommissioning. Here, BlueScope has key enabling infrastructure (blast furnace and electrolytic steel making) to unlock this circular economy infrastructure opportunity.

3. Clean Energy Storage

Figure V provides an overview of the identified opportunities in clean energy storage with most opportunities stemming from emerging start-up companies.

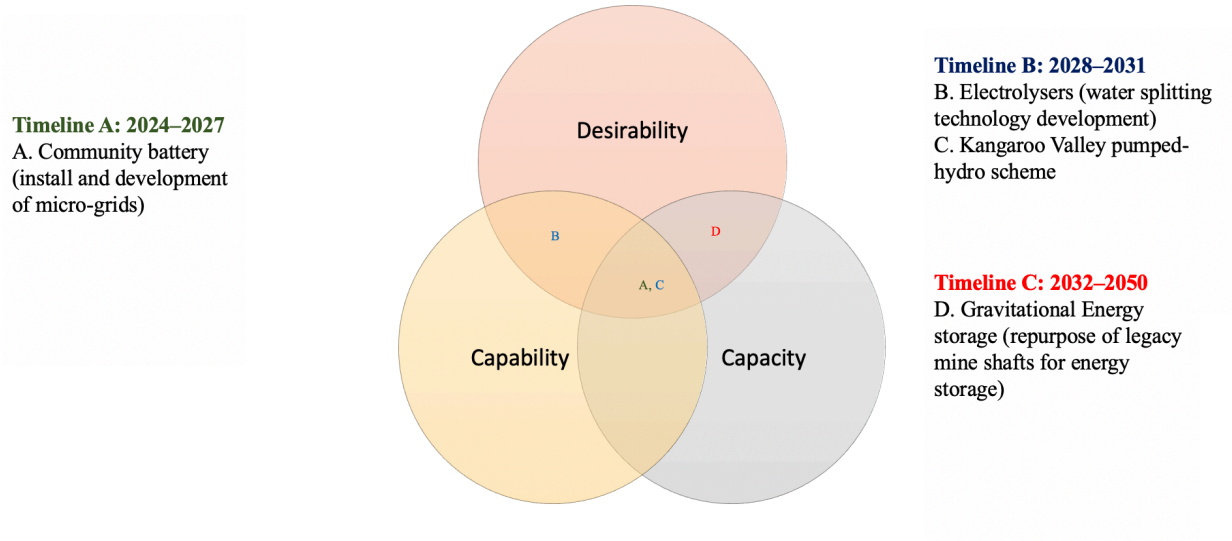


Figure *V*: Energy Storage: Battery, Gravity, Green Hydrogen/Ammonia.

Industry desirability with existing regional capacity and existing regional capability:
An opportunity within existing capacities and capabilities is the roll out of more community batteries and the establishment of micro-grids. Here, excess rooftop solar energy charges the community battery during daytime to be released during night-time. Leveraging community focussed initiatives such as Electrify 2515 into an overall regional clean energy industry for households could significantly increase local economic activity for locally based installers.

Industry desirability that requires regional capacity development:
Emerging technologies in the space of electrolysers are promising and support the growing green hydrogen industry.

Industry desirability that requires regional capability development:
This is an emerging technology with the objective to reactivate retired mineshafts and ventilation shafts for gravitational energy storage. The technology is currently being developed, simulated, and trialled. A deployment at scale is likely to occur later in this decade.

4. Alternative Industries

The clean energy transition in the Illawarra region also creates innovation spillover into alternative industries. Figure VI presents these opportunities. Interestingly, no opportunities have been identified that can be tackled with existing capacity and capability.

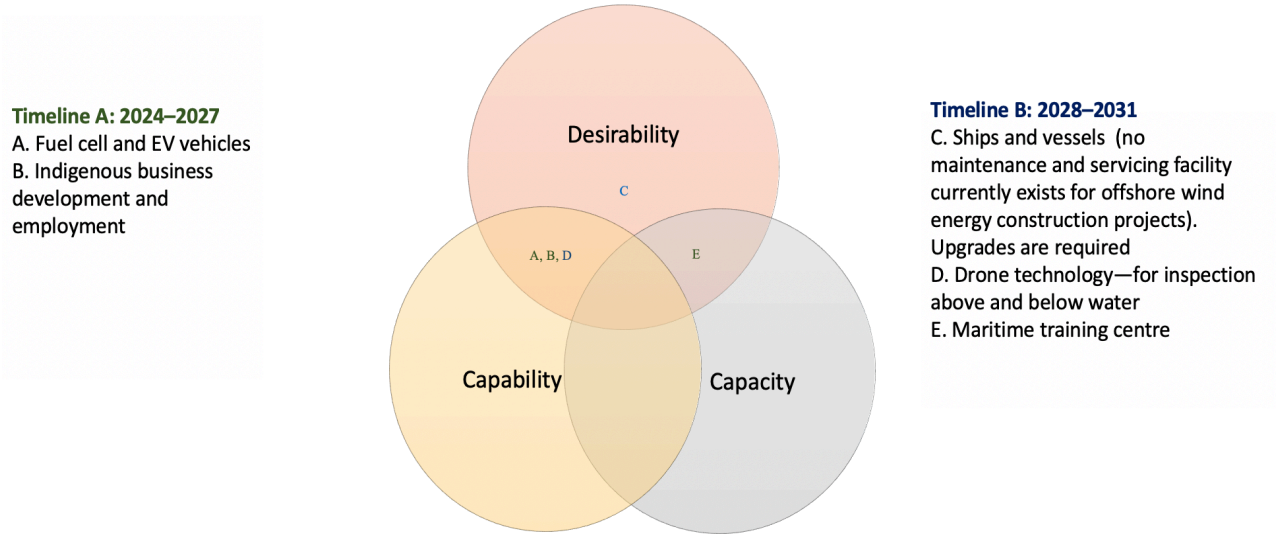


Figure *VI*: Spillover and Alternative Opportunities in Clean Energy Industries.

Industry desirability that requires regional capacity development:
Capacity development is required to enable the manufacturing of fuel cell and EV vehicles, in particular trucks, buses, planes, and ships. The same holds true for the development of various drone technology required for inspection (above and below water). Further, capacity development is required to unlock the potential amongst First Nations people. Opportunities that are ocean based are highly desired amongst First Nation people.

Industry desirability that requires regional capability development:
A maritime training centre is highly desirable in the medium term, with the roll-out of a striving wind industry and the associated offshore maritime support industry.

Industry desirability that requires regional capacity and regional capability development:
Upgrading Ships and Vessels: Necessary for offshore wind energy construction, requiring public approval, and capacity investment for successful implementation.

After unpacking and examining the significant opportunities available to the Illawarra region, the report now focuses on the next section, which outlines a strategic roadmap for guiding the region's development and realising these opportunities.

Regional Roadmap

The roadmap for implementing the identified opportunities in the clean energy sector is built upon several existing and ongoing initiatives underway in Illawarra Shoalhaven.

Five distinct stages have been identified that will position the Illawarra as Australia's leading centre in Green Advanced Manufacturing and Logistics by 2050.

Incorporating social licensing practices that engage local communities and stakeholders — giving importance to social investment and cultural sensitivity — is central to achieving long-term success and fostering sustainable, inclusive development.

Stage 1 therefore focuses on policy implementation and obtaining a social license from community to embark on the clean energy transition journey collectively.

Stage 2 puts the enabling infrastructure in place that supports the clean energy transition and the diversification of the regional economy (Stage 3).

Stage 4 focuses on the implementation of the ongoing service provision, whilst Stage 5 establishes the region as Australia's centre for a green advanced manufacturing and logistics.

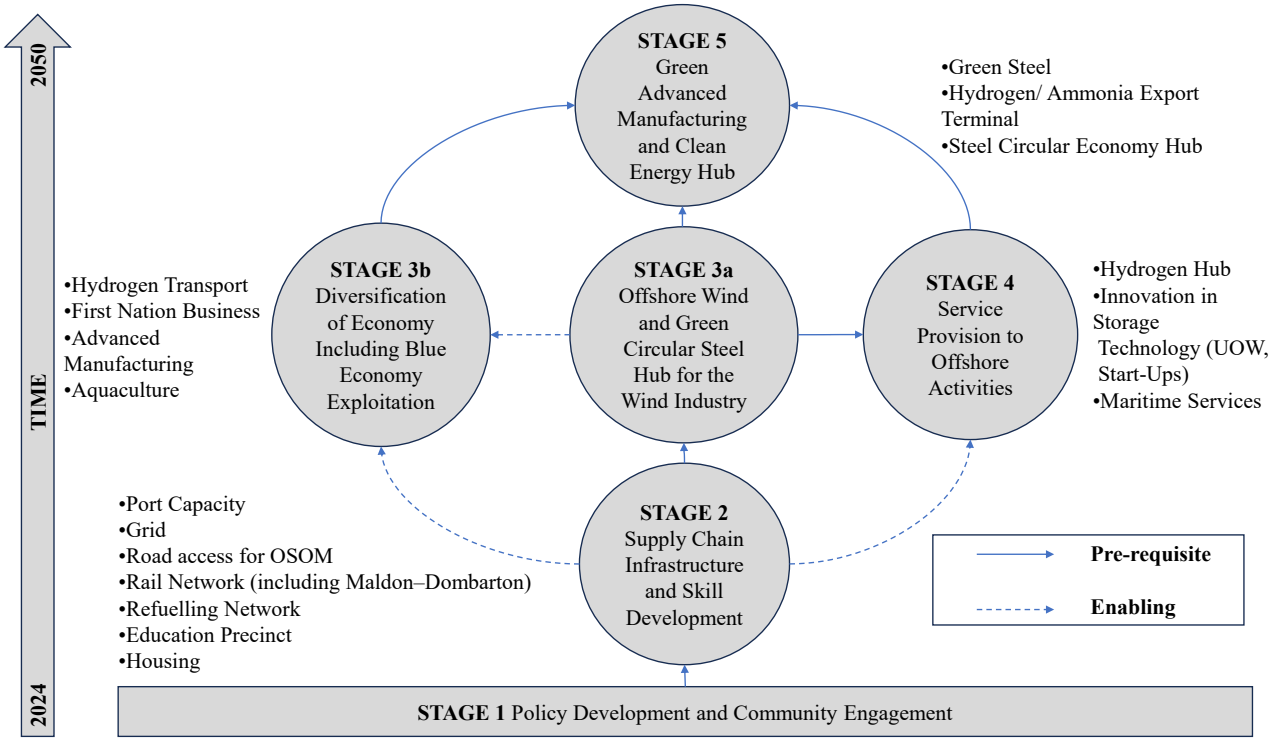


Figure VII. Roadmap for the Illawarra Shoalhaven.

Stage 1: Leveraging Policy Direction and Development and Community Engagement

- Co-designing the clean energy transition with the local community
- Align the narrative amongst critical government and industry stakeholders
- Leveraging the National and State policies to support long-term emissions reduction goals
- Develop predictable and credible implementation plans, support specific technology areas, and create enabling conditions for successful implementation

Stage 2: Supply Chain Infrastructure and Skill Development (2030+)

- Key infrastructure upgrades, particularly at Port Kembla, are necessary to support the development of offshore wind and hydrogen projects
- Educational precinct development to enable workforce development and workforce transition

Stage 3a: Offshore Wind Enabler and Green Circular Steel Hub for the Wind Industry (2030+)

- The region a major player in offshore wind energy and hydrogen production
- Manufacturing of components for offshore wind turbines, producing green hydrogen for domestic use and export, developing a green steel industry powered by renewable energy, and recycling clean energy infrastructure

Stage 3b: Diversification of Economy including Blue Economy Exploitation (2030+)

- The port and the offshore wind industry enable the Illawarra to diversify its economy through mixed-use of spatial marine zoning
- Aquaculture industries co-located with the offshore wind parks including post-harvest processing facilities
- An opportunity to strengthen the economic self-determination of Aboriginal communities.
- Connectivity to export markets by air via the Western Sydney Airport and the Maldon to Dombarton rail link are critical for the industry to take off.

Stage 4: Service Provision to Offshore Activities (2030+)

- Offshore wind industry and the aquaculture industry require marine-based maintenance and service provision.
- Positioning the Illawarra as a maintenance hub for the offshore wind industry with land available to host warehouses for spare parts (e.g. engineering consultancy, education, skill development, R&D, divers, logistics, vessel maintenance).

Stage 5: Advanced Manufacturing and Clean Energy Hub (2050+)

- Illawarra and Shoalhaven region is Australia's future hub for sustainable industries in green steel and hydrogen/ ammonia.
- Illawarra and Shoalhaven region as a producer and exporter for clean hydrogen/ammonia to international markets.

Critical Success Factors Needed for a Successful Transition

By focusing on local content, infrastructure upgrades, and targeted financing, the region can attract investment, create jobs, and drive sustainable economic growth.

Economic Benefits of Clean Energy Growth in the Illawarra Region

The Illawarra region stands to gain substantial economic benefits from investments in clean energy, particularly through the development of offshore wind, hydrogen production, and advanced energy storage solutions. These sectors are poised to transform the region into a clean energy hub, driving job creation, GDP growth, and infrastructure development.

1. Offshore Wind: A Catalyst for Regional Economic Growth

The declaration of a **2.9 GW offshore wind zone in Illawarra** is projected to bring significant economic gains. Based on studies from similar offshore wind developments globally, the economic benefits can be quantified as follows:

a) Job Creation:

- **Construction Phase (2025-2030)**: Approximately 4,000 to 6,000 direct jobs are expected during the construction phase, including roles in turbine assembly, installation, cabling, and port upgrades.
- **Operations and Maintenance (2030 onwards)**: Around 500 to 1,000 permanent jobs could be generated in long-term operations, maintenance, and logistics support for offshore wind farms.
- **Supply Chain and Indirect Jobs**: For every direct job in offshore wind, studies indicate there are typically 1.5 to 2 indirect jobs created in supporting industries (manufacturing, logistics, and professional services). This could result in an additional 6,000 to 8,000 jobs over the lifespan of the projects.

b) Economic Output:

- The construction of offshore wind farms could inject **AUD 2.5 billion to 3 billion** into the regional economy, based on investments in infrastructure, local procurement, and workforce salaries.
- Once operational, offshore wind farms are estimated to contribute **AUD 300 million to 500 million** annually to the Illawarra economy through ongoing operations, maintenance, and local spending.

c) Regional GDP Impact:

- Offshore wind developments could increase the Illawarra region's GDP by an estimated **1.5% to 2% annually** over the next decade.
- Drawing parallels from similar projects in Europe, such as the UK's Dogger Bank Wind Farm, regions with significant offshore wind investments have experienced GDP growth of up to 2.5%.

2. Hydrogen Production and Clean Energy Storage

In addition to offshore wind, the **Port Kembla Hydrogen Hub** and associated green hydrogen projects are set to boost the Illawarra region's economic landscape.

a) Hydrogen Hub Economic Benefits:

- The development of hydrogen production facilities at Port Kembla is expected to attract **$1 billion in investments** over the next five years.
- This initiative is projected to generate **2,000 direct and indirect jobs**, particularly in high-skilled areas such as chemical engineering, plant operations, and logistics.
- Hydrogen exports could bring in **$250 million to $400 million annually** by 2030, as Australia positions itself as a key player in the global hydrogen market.

b) Community Battery and Storage Solutions:

- Deployment of community batteries and microgrids could result in **$200 million to $300 million** in economic activity, with jobs focused on electrical engineering, installation, and maintenance.
- These initiatives are also expected to reduce energy costs for local communities, freeing up consumer spending and driving regional economic growth.

3. Broader Economic and Social Benefits

Beyond direct economic impacts, the growth of the clean energy sector in Illawarra will have broader social and environmental benefits:

a) Skill Development and Workforce Transition:

- The establishment of training centres, such as the Clean Energy Futures Skills Centre, is expected to upskill **3,000 to 5,000 workers** over the next decade, ensuring a sustainable workforce transition from traditional industries to clean energy sectors.
- Investment in education and training will attract younger generations to STEM fields, boosting long-term employment rates and regional talent retention.

b) Infrastructure Upgrades and Regional Revitalisation:

- Investment in grid connections, transmission lines, and port upgrades will have spillover effects, enhancing the region's attractiveness for other industries, including advanced manufacturing, logistics, and export services.
- The enhancement of infrastructure could increase property values and generate **$100 million to $200 million** in additional tax revenues for local governments.

4. Summary of Economic Impact Projections

Category	**Economic Impact**
Offshore Wind Construction	$2.5 billion to $3 billion (one-time investment)
Offshore Wind Operations	$300 million to $500 million annually
Hydrogen Production & Exports	$1 billion (investment) + $250 million annually
Community Batteries & Storage	$200 million to $300 million (one-time investment)
Total Job Creation	10,000 to 15,000 jobs (direct, indirect, and induced)
Regional GDP Growth	1.5% to 2% increase annually over the next decade
Tax Revenue Generation	$100 million to $200 million annually

By strategically investing in clean energy infrastructure and workforce development, the Illawarra region can position itself as a leader in Australia's energy transition. This approach not only supports sustainable economic growth but also drives social and environmental benefits for local communities.

For Illawarra Shoalhaven industry to fully realise this potential, three key areas of support are needed for success:

1. Policy and regulatory support:
A robust policy framework is important to drive investment and ensure long-term project security. Policy measures should focus on incentivising renewable energy investments, ensuring local content requirements in energy projects, and providing certainty for investors. Regulatory clarity, especially in areas such as offshore wind, hydrogen, and energy storage, is critical for attracting investment and fostering growth in the clean energy sector. Government incentives, such as tax breaks and grants, are also necessary to reduce the risk profiles of new clean energy ventures and encourage innovation. A stable policy environment that aligns state and federal regulations will help mitigate investor concerns and accelerate project timelines. Supportive policies are essential to create a conducive environment for clean energy investments and ensure long-term project viability.

Key Policy Recommendations:

- Long-term Clean Energy Targets: Set clear and ambitious regional clean energy targets aligned with national net-zero goals to provide certainty for investors and project developers.
- Renewable Energy Purchase Agreements (REPA): Encourage the adoption of REPAs by local industries, enabling them to source a significant portion of their energy from renewable sources, thus driving demand for clean energy projects.
- Carbon Pricing and Emissions Trading Schemes: Advocate for the introduction of carbon pricing or emissions trading schemes to incentivise the transition away from fossil fuels and promote investments in low-carbon technologies.
- Local Procurement Policies: Implement policies that prioritize local suppliers and contractors for clean energy projects to maximize economic benefits for the Illawarra community.
- Research and Development Incentives: Increase funding for R&D in clean energy technologies through grants, tax credits, and partnerships with universities and industry.

2. Workforce development:
Developing a skilled workforce capable of managing and operating advanced clean energy technologies is essential for the region's transition. Collaboration between educational institutions, government bodies, and private industry will be crucial to upskilling the current workforce and training the next generation of workers in clean energy technologies. The roadmap calls for the establishment of educational programs and training centres that focus on renewable energy, advanced manufacturing, and hydrogen technologies. This roadmap aims to implement Australia's National Energy Workforce Strategy within the region. Illawarra's workforce has a strong foundation in heavy industry, which can be leveraged for the clean energy sector. However, retraining programs and skills development will be required to equip workers with the technical expertise needed for new roles in offshore wind, hydrogen production, and advanced manufacturing. The transition to a clean energy economy requires targeted workforce development initiatives to upskill existing workers and prepare new entrants for roles in emerging industries. The Illawarra region, with its established educational institutions such as the University of Wollongong (UOW) and TAFE Illawarra, is well-positioned to deliver specialised training programs in renewable energy technologies.

Key initiatives include:

- Clean Energy Futures Skills Centre: The establishment of a skills centre dedicated to training in offshore wind, hydrogen, and battery technologies is crucial. This centre could train up to 1,000 new workers annually in critical areas like electrical engineering, fabrication, project management, and environmental services.
- Super TAFE Facility: Expanding the capabilities of the TAFE system to include certifications and apprenticeships in renewable energy technologies. Courses could cover fields such as

marine engineering, subsea cabling, and offshore platform maintenance, aligning with industry needs.

- STEM Education Initiatives: Investing in STEM education for younger students is vital to ensure a future pipeline of skilled workers. Partnerships with local schools and community organizations can promote careers in clean energy.

The clean energy transition will create jobs across a range of skill levels, from entry-level positions to highly specialised technical roles. Below is an overview of the types of jobs expected to be in demand.

Tertiary Qualified Jobs:

- Electrical Engineers: Responsible for designing and maintaining electrical systems for offshore wind turbines, hydrogen electrolysers, and battery storage systems.
- Marine and Environmental Engineers: Specializing in offshore wind infrastructure, these roles focus on the sustainable design, deployment, and maintenance of marine-based energy systems.
- Project Managers: Overseeing the planning, execution, and commissioning of large-scale renewable projects, ensuring timelines and budgets are met.

Vocational Qualified Jobs:

- Fabrication and Mechanical Trades: Involved in manufacturing components for turbines, solar panels, and hydrogen storage systems.
- Technicians: Skilled in installing, operating, and maintaining energy storage systems like community batteries and electrolysers.
- Vessel Operators and Maritime Support: Required for offshore wind farm maintenance and logistics.

Key Support Jobs:

- Construction Workers: Supporting the installation of renewable energy infrastructure, particularly in offshore wind projects.
- Logistics and Supply Chain Coordinators: Managing the transportation of components and materials for project construction.
- Administrative and Support Staff: Providing necessary back-office support for project planning and execution.

Regional Support for Workforce Development:

To support the anticipated growth in clean energy jobs, the Illawarra region can leverage several strategic initiatives:

- Public-Private Partnerships: Collaboration between government, industry, and educational institutions to fund and develop targeted training programs. These partnerships can focus on filling skills gaps, particularly in offshore wind and hydrogen sectors.
- Investment in Housing and Infrastructure: Addressing housing shortages and improving transport infrastructure will be crucial to attract talent to the region. This includes affordable housing projects and enhanced road and rail connectivity.
- Community Engagement: Building social license through community co-design initiatives ensures that local populations are engaged and benefit from clean energy projects. This approach promotes inclusivity and enhances community support for new developments.

3. Supply chain solutions:

Energy storage is essential for ensuring grid stability and managing fluctuations in renewable energy generation. There is a need for large-scale battery installations, hydrogen storage solutions, and innovative gravity storage systems that can store energy for use during periods of low renewable generation. Additionally, the development of a robust supply chain including enabling infrastructure for renewable energy components is necessary to overcome potential bottlenecks and delays in project implementation. Local manufacturing capabilities, particularly in steel production and advanced manufacturing, offer an opportunity to produce key components for the clean energy industry. Developing these capabilities will reduce reliance on imported components and create jobs within the region.

To fully leverage the significant opportunities in the Illawarra region's clean energy sector, it is crucial to establish robust governance structures, develop necessary infrastructure, and implement strategic financing mechanisms. These enablers will provide the foundation for successful project development, attract investment, and ensure community and industry stakeholders are aligned in their efforts to drive the region's clean energy transition.

1. Governance Mechanisms

Effective governance is vital to streamline project approvals, coordinate efforts across different government levels, and engage with stakeholders, ensuring that clean energy initiatives align with local priorities.

Key Governance Recommendations:

- Local Content Rules: Implement regulations that require a minimum percentage of local content for renewable energy projects. This approach will ensure that local businesses and suppliers benefit directly from investments in the sector. For example, offshore wind projects can include requirements for local fabrication, assembly, and maintenance.
- Benefit Sharing Agreements with Developers: Establish agreements with developers that ensure a portion of the profits or benefits from projects is reinvested into the local community. This can include funding for community programs, training initiatives, and infrastructure development.
- Streamlined Approvals Process: Consider creating a centralised "Clean Energy Development Office" in the Illawarra to fast-track approvals for clean energy projects, reducing bureaucratic delays. This office can coordinate with state and federal agencies to streamline processes for permits, environmental assessments, and grid connections.
- First Nations Co-Design Engagement: Engage with Indigenous communities through co-designed strategies that respect traditional knowledge and provide opportunities for direct participation in projects. Establishing a clear and transparent process for Indigenous consultation will support the social license for clean energy projects.
- Regional Clean Energy Task Force: Form a task force comprising representatives from government, industry, educational institutions, and community groups to oversee the implementation of the Illawarra Clean Energy Roadmap. This body can help align strategic initiatives, monitor progress, and adapt plans as needed.

2. Infrastructure Development

Developing the right infrastructure is crucial to support the Illawarra region’s transition into a clean energy hub. This includes upgrading existing assets, creating new facilities, and ensuring integration with the national energy grid.

Key Infrastructure Recommendations:

- Grid Connection Points and Transmission Lines: Invest in expanding grid infrastructure to connect offshore wind farms, hydrogen production facilities, and community batteries to the national electricity grid. Priority should be given to establishing new grid connection points in the Illawarra REZ to support offshore wind and green hydrogen projects.
- Port and Logistics Infrastructure: Upgrade Port Kembla to accommodate large-scale offshore wind installations, hydrogen export, and green steel manufacturing. This includes improving OSOM (Over Size Over Mass) transport routes for wind turbine components and investing in specialized maritime facilities for maintenance and decommissioning.
- Hydrogen Refuelling Stations: Develop a network of hydrogen refuelling stations to support the region's transition to low-carbon transport, particularly for heavy vehicles and public transport systems.
- Energy Storage Facilities: Support the rollout of community batteries, gravity storage solutions, and green hydrogen storage to enhance grid stability and maximize the use of locally generated renewable energy. These initiatives will reduce reliance on fossil fuel-based power during peak demand periods.

- Super TAFE and Clean Energy Skill Centres: Invest in developing world-class education and training facilities, focusing on offshore wind, hydrogen technologies, and renewable energy integration. Expanding the capabilities of TAFE and UOW to offer specialized courses will ensure a pipeline of skilled workers.

3. Financing Mechanisms

Access to capital and effective financing models are essential to attract investment in large-scale clean energy projects. The Illawarra region can benefit from a mix of public and private financing to unlock its potential as a clean energy leader.

Key Financing Recommendations:

- Green Bonds and Public-Private Partnerships (PPPs): Establish green bonds and PPPs to fund critical infrastructure projects, such as offshore wind farms, hydrogen production facilities, and grid upgrades. Green bonds can attract sustainable finance from institutional investors focused on ESG (Environmental, Social, Governance) criteria.
- Clean Energy Investment Fund: Create a dedicated regional investment fund to support clean energy startups, advanced manufacturing, and research initiatives. This fund can provide grants, low-interest loans, and equity investments to catalyse innovation and commercialization of new technologies.
- Incentives for Local Manufacturing: Offer tax incentives and grants for companies that establish manufacturing operations in the region, particularly those focused on producing components for wind turbines, electrolysers, and battery systems. This can boost job creation and enhance local supply chains.
- Benefit-Sharing Agreements: Structure financing models that include benefit-sharing clauses, where a percentage of revenue from projects is allocated to local community development funds. These funds can be used for social programs, skills training, and infrastructure improvements.
- Government Subsidies for Early-Stage Technologies: Provide subsidies and rebates for early-stage technologies, such as electrolyser manufacturing, gravitational energy storage, and offshore wind maintenance. These subsidies can reduce the financial risks for new entrants and attract international firms to the Illawarra.

Challenges facing the transition

The clean energy transition presents significant challenges in terms of supply chain, skills and policy uncertainty.

These challenges are impediments to the clean energy transition, hindering progress, and reducing the potential impact of this crucial initiative in the region.

The identified challenges highlight the critical areas that must be addressed to achieve the region's clean energy goals.

By understanding these challenges, the region can develop targeted strategies to overcome them, thereby ensuring a more successful and impactful transition.

Table III. List of Identified Barriers

Barriers	Details
Supply Chain	Bottlenecks in global critical component and equipment supply chains for clean energy transition.
Skills	Shortages in specific/specialised skills or talent (e.g., electrical engineering, WH&S and other skilled workers).
Demand	Uncertainty in demand due to a lack of an approved project pipeline (e.g., offshore wind projects). This stalls investment in critical infrastructure.
Cost of living	High cost of living in Australia/Illawarra (i.e., unaffordable and unattractive). Attracting international talent becomes increasingly difficult.
Housing	Housing and accommodation shortages.
Government	Red tape, lack of alignment and coordination between local, state and federal government.
Commercial land	Commercial lands are too expensive.
Supply Chain Infrastructure	Lack of electricity network infrastructure to support electrification and decarbonisation (e.g. electric vehicle and hydrogen recharging infrastructure). Lack of transmission and distribution network capacity.
Social licence	Inadequate early education and empowerment initiatives, leading to slower community acceptance of renewable energy projects.
Lack of awareness	Lack of Federal Hydrogen Hub coverage in the region.
First Nations	A clear, co-designed First Nations engagement strategy is lacking that is respective of key knowledge holders from the Illawarra.
Policy uncertainty	Uncertainty surrounding state and federal policies related to clean energy presents risks for investors and project developers.
End of life considerations	De-commissioning and end-of-life demands currently not considered as part of the planning and roll-out process.

Recommendations

Drawing from the challenges identified in the previous section, these recommendations are specifically designed to address and overcome the challenges to implementing the vision and roadmap for the Illawarra Shoalhaven region.

It establishes a roadmap for clean energy transition regarding supply chain, workforce and policy development over time.

Local content is of critical importance for regional clean energy transition and it requires strong government and local business support.

Each recommendation is crafted with the intent to mitigate the obstacles that currently impede the region's clean energy transition.

By directly targeting these challenges, the recommendations aim to facilitate a more seamless and accelerated shift to clean energy, ensuring that the Illawarra region can fully realise its potential and position itself as a leader in the clean energy sector.

Table IV provides a comprehensive overview of the five-stage approach highlighted in Figure VII and complements it with more detailed descriptions and recommendations.

Table IV. List of Key Recommendations

Stages: Illawarra Roadmap	Description	Recommendations
Stage 1: Policy implementation and Community Engagement	Establishing clear policy implementation programs and securing community buy-in are essential for advancing the region's clean energy ambitions. This includes engaging local stakeholders, fostering partnerships between government, industry, and community organisations, and ensuring that projects address the needs and concerns of the local population.	• Promote social license — achieving community buy-in through a collaborative co-design process. • Develop a robust local content policy by incorporating international best practices. • Align regional, state, and federal government plans to attract industry by developing a cohesive cluster strategy — create industry cluster development.
Stage 2: Supply Chain Infrastructure and Skill Development	The establishment of port infrastructure is necessary to realise the significant growth in the renewable energy sector locally and in the Hunter and Gippsland regions. The Gippsland offshore wind zone will likely be developed ahead of projects in the Hunter and Illawarra zones. While several ports may be developed over time to support offshore wind project developments, Port Kembla, with its existing planning approval for outer harbour development (requiring only minor modification), is well-positioned to be the first port with facilities available to fully support the construction of offshore wind projects. Port Kembla can be developed sooner than alternative East Coast ports to support the advance. Other enabling infrastructure projects are road infrastructure for OSOM transport, housing, grid, hydrogen refuelling networks, rail networks and education precincts. Leverage and expand existing vocational and tertiary skills and education capabilities through educational precinct development to enable workforce development and workforce transition.	• Government to support the development of Port Kembla as the first port on the East Coast to provide facilities enabling offshore wind project construction. • Enhance road infrastructure access for over-sized cargo between the Illawarra and other regions. • Develop policies and incentives that attract complementary clean energy businesses to the Illawarra including housing. • REZ – Asset/Transmission Corridors: The NSW Government, through EnergyCo, should expedite progress to unlock and accelerate the development of Renewable Energy Zones (REZ). • Promote green financing (i.e., government to attract investment). • Accelerate establishment of the UOW/TAFE Energy Futures Skills Centre • Accelerate establishment of the enhanced TAFE facility located within the BlueScope redevelopment • Invest in workforce transition training programs for existing workers in traditional industries • Invest in STEM education programs for school students to build a pipeline of STEM capable and engaged young people.
Stage 3a: Offshore Wind Enabler and Green Circular Steel Hub for the Wind Industry	The enabling infrastructure allows for the establishment of an offshore wind industry. The Illawarra is a critical hub for offshore wind floating platform manufacturing and tower assembly. The Illawarra's positioning to port, road, rail, and airport infrastructure offers the opportunity to activate assembly and	• Immediate initiation of decommissioning efforts—establish a centre for circularity.

	end-of-life treatment. Decommissioning and recycling work should also include onshore windfarms. The geographical reach for the decommissioning work can be extended to Southeast Asia to meet scrap metal demands. The Port Kembla Steelworks provides the opportunity to establish an 'Illawarra Green Circular Steel Hub' around the wind industry powered by green hydrogen beyond 2030. This offers opportunity to use existing and rehabilitated industrial sites in and around the Port Kembla area such as the BlueScope Master Plan to develop 200 Hectares (Ha) of non-steelmaking, excess landholdings adjacent to the Port Kembla Steelworks to host energy infrastructure whilst leveraging the regions highly skilled workforce and experience in manufacturing.	
Stage 3b: Diversification of Economy Including Blue Economy Exploitation	The port and the offshore wind industry enable the Illawarra to diversify its economy through mixed-use of spatial marine zoning. Aquaculture industries can be co-located with the offshore wind parks. It presents an opportunity to strengthen the economic self-determination of Aboriginal communities. The aquaculture industry would require post-harvest processing facilities and a more diverse skill set strengthening economic resilience. Connectivity to export markets by air via the Western Sydney Airport and the Maldon to Dombarton rail link are critical for the industry to take off.	• Indigenous communities are both critical stakeholders and essential members of the workforce. To unlock their potential, it is vital to invest in capacity and capability development, with a particular emphasis on ocean-based opportunities.
Stage 4: Service Provision to Offshore Activities	Both the offshore wind industry and the aquaculture industry require marine-based maintenance and service provision. The Illawarra is ideally located as a maintenance hub for the offshore wind industry with land available to host warehouses for spare parts. The service provision includes engineering consultancy, education, skill development, R&D, divers, logistics, vessel maintenance to name a few.	• Promote advanced training and skills development to prepare for future needs. • Encourage/ increase spinouts by investing in R&D within tertiary education and streamlining the process. • Establish a R&D Centre of Excellence for Clean Energy Storage (Gravity, Hydrogen, Ammonia, and others).
Stage 5: Green Advanced Manufacturing and Clean Energy Hub -	-Illawarra and Shoalhaven region is designated as Australia's future hub for sustainable industries in green steel and hydrogen/ ammonia production. The region boasts proximity to major ports and transport infrastructure, positioning it ideally for export of hydrogen/ammonia to international markets which is further enabled by the second rail link connected to the Western Sydney cargo corridor, including inland ports. This will enable the Illawarra/ Shoalhaven region to become a critical logistical node in Australia's distribution network that simultaneously unlocks the commercial potential of the NSW South Coast.	• Increase incentives to retain and attract relevant clean energy technology providers that supports the Illawarra in becoming a leading destination for clean energy. • Establish policies that will attract high-skilled individuals through migration of global talent into the Illawarra region.

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Chapter 1: Introduction

Australia is undergoing an energy transition, shifting from conventional energy production technologies (e.g., high-carbon industries like coal) to clean and sustainable energy sources such as solar, wind, and hydro. Adapting to climate change and mitigating its effects are at the forefront of policymaking. Historically, Australia has relied heavily on fossil fuels, with a thriving coal industry both domestically and internationally. The goal is straightforward – to significantly reduce global carbon emissions and make energy production and consumption more sustainable. However, whilst the goal is clear, the actions required to achieve it are complex. Combined efforts are needed to champion this pursuit whilst meeting the increasing energy demand of society.

The current global actions aim to develop measures to adapt to climate change between 2030 and 2050, disseminating these through the formation of extensive regulatory frameworks. The Paris Agreement, a legally binding treaty on climate change, has been joined by 196 countries, including Australia. It aims to limit the global average temperature increase to 1.5 degrees Celsius above pre-industrial levels. Many countries are committed to carbon neutrality by 2050 and have set a more ambitious goal of reducing emissions by at least 55% by 2030 compared to 1990 (International Energy Agency, 2021).

According to the International Energy Agency (IEA), energy efficiency and renewable energy will play important roles in preventing global temperatures from rising more than 2 degrees Celsius and reducing carbon emissions by 2050. Renewable energy is critical for decarbonising electrical systems. However, renewable energy accounts less than 25% of the world's generating capacity, with 16% hydropower and about 5% solar (SPP) and wind (WPP) power plants (Brych et al., 2023). Given these goals and the current energy mix, stronger actions and conscious participation from both public and private institutions are necessary.

To gain a comprehensive understanding of Australia's role in pursuing climate goals, as well as the potential impacts and economic opportunities that the country and the Illawarra region can realise from the energy transition, this research maps out Australia's experiences and initiatives geared towards a sustainable clean energy future. In Chapter 2, we explore global and Australian trends in

energy demand and outlook, with a particular focus on the Illawarra Shoalhaven region, recognised for its potential as a clean energy hub due to its unique resources or endowments. Moreover, Chapter 2 highlights the importance of developing a robust supply chain system and circular economy, which are crucial for positioning the region as a leader in clean energy both in the country and globally.

Given the recent declaration of Illawarra as a Renewable Energy Zone (REZ) by the NSW government and the identification of the Illawarra offshore wind zone, Chapters 3 and 4 cover the methodology, findings and discussion from the research conducted amongst stakeholders. The analysis, which draws on interviews and a critical review of both international and local literature, centres on three key aspects: desirability, capability, and capacity. Using heatmaps, the data was analysed and presented in diagrams, highlighting key findings across four topics or categories: (1) enabling infrastructure, (2) clean energy generation, (3) clean energy storage, and (4) new or alternative industries. In Chapter 5, we outline the regional roadmap for the Illawarra, whilst in Chapter 6, we discuss the barriers to implementing this vision and provide recommendations to facilitate a timely and effective transition. This chapter also highlights areas for future research and concludes the report.

Chapter 2: Global and Australian Energy Demand – Current Trends and Outlook

2.1 Global Energy Outlook

2.1.1 Status

Global energy demand has been steadily increasing over the last two decades, with smaller variations observed in 2020, and again in 2022 (Appendix A). The increase in energy consumption has been closely matched by increasing greenhouse gas (GHG) emissions. Global emissions fell in 2020 due to the Covid-19 pandemic but are already rebounding strongly as economies recover. To meet the agreed climate targets set in the Paris agreement, a large-scale transition is required to a net-zero energy system. In 2022, 82% of all primary energy originated from fossil fuel sources (Energy Institute, 2023). Whilst uptake of renewable energy generation is growing (Figure 1) – more than 500 Gigawatts of renewable capacity was added globally in 2022 – its share of overall primary energy consumption was 7.5% in 2022 (Energy Institute, 2023).

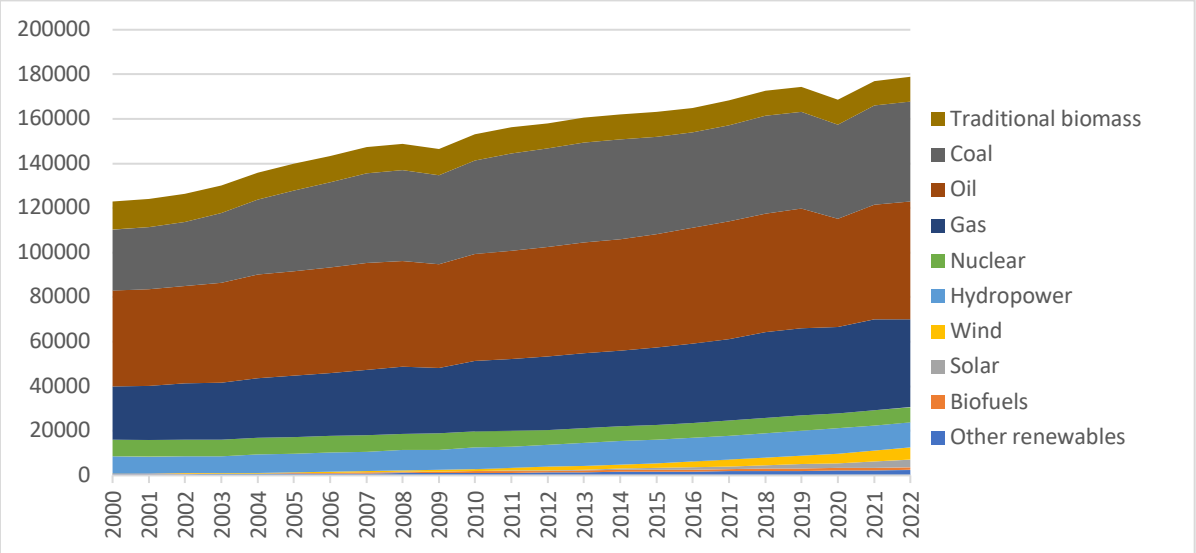


Figure 1: Energy Consumption by Source
Source: (Energy Institute, 2023); Smil (2017). Note: The unit of measurement is in TWh or Terawatt-hour.

2.1.2 Future Scenarios

Global power demand is expected to increase. This growth is driven by the rising demand from emerging markets, primarily in developing countries, the electrification of the global economy –

especially within the transportation sector – and the increasing demand for green hydrogen (McKinsey & Company, 2024). Three future trends characterise the changing composition of energy demand.

1. The role of hydrocarbons diminishes as the world transitions to lower carbon energy sources. According to an energy outlook report by BP (2023), the share of fossil fuels in primary energy is forecasted to decline from 80% in 2019 to 55–20% by 2050; a world's first in modern history.
2. Rapid growth in renewable energy offsetting the declining role of fossil fuels. Global primary energy (i.e., energy from natural resources) will increase from 10% in 2019 to 35–65% by 2050. This is assumed to be driven by the competitiveness of renewables such as wind, solar, bioenergy and geothermal power, and the increasing prevalence of policies encouraging a shift towards low-carbon energy. According to the BP (2023) report, the pace at which renewable energy grows in the global energy system is quicker than any previous fuel in history.
3. The growing trend towards global electrification, stimulated using low-carbon hydrogen in processes, activities, and industries that are challenging to electrify. The report also estimates an increase in the use and production of low-carbon hydrogen to between 13–21% by 2050.

In 2023, IEA produced its latest World Energy Outlook report. This report mapped out three future scenarios from 2022 to 2050: the stated policies scenario (STEPS), announced pledges scenario (APS), and a net-zero emissions scenario (NZE). These are shown in Figure 2.

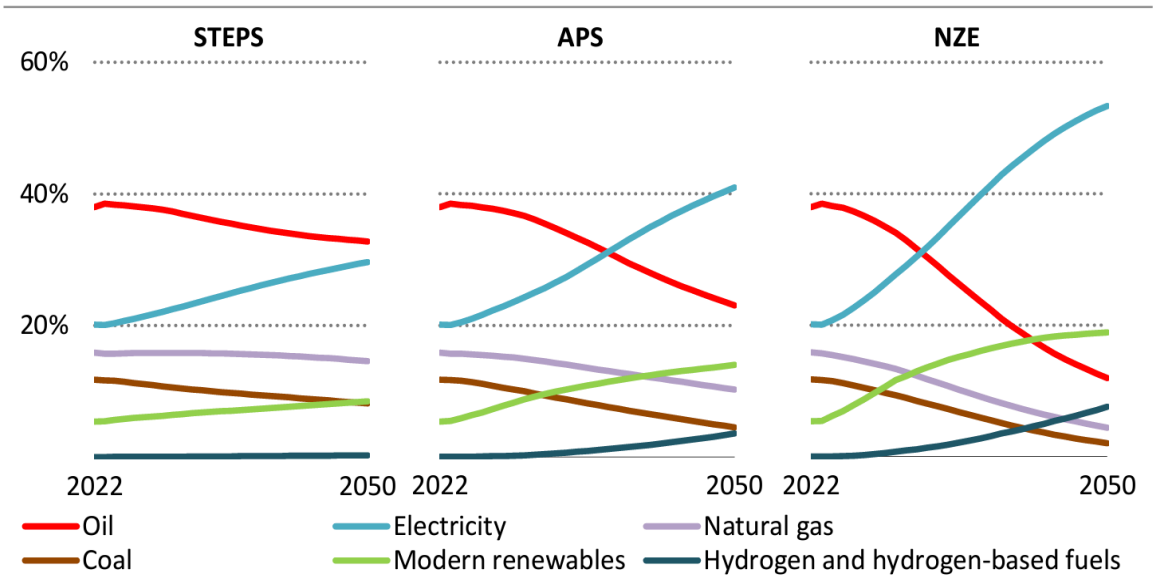


Figure 2: Share of Global Total Final Consumption by Selected Fuel and Scenario, 2022–2050
Source: Figure taken from World Energy Outlook 2023, International Energy Agency (IEA, 2023c).
Note: Modern renewables refer to renewable energy technologies that contribute to reducing greenhouse gas emissions.

The STEPS scenario provides a forecast based on the latest policy settings, including energy, climate, and industrial policies. The APS scenario considers all national energy and climate targets pledged by governments. Lastly, the NZE considers a scenario aiming to limit global warming to 1.5 degree Celsius.

These forecasts predict several key points. By 2050, the global economy will have doubled in size, and population will have increased by close to 2 billion people, yet global energy demand will be 8% less than today. A large-scale transition to renewable energy sources will have occurred, with two-thirds of energy supply coming from wind, solar, bioenergy, geothermal, and hydro power. This represents an 11-fold increase in global wind power capacity and a 20-fold increase in solar photovoltaic (PV). Conversely, to achieve net-zero will require fossil fuel input into global energy supply to fall from close to 80% to about 20%. As electrification increases across sectors to replace fossil fuels, electricity demand is projected to increase by 150% by 2050. Note that modern renewable energy sources are projected to increase by 3%, 7%, and 9% respectively for the scenarios (STEPS, APS, and NZE) by the year 2030. Therefore, the increase in energy demand will be met using low-emission sources of energy. The projected growth in renewables is accompanied by an anticipated increase in the long-run capacity of consistently available clean energy generation. Whilst a declining pattern is evident for oil and coal from Figures 2 and 3, this trend is more pronounced in the NZE scenario

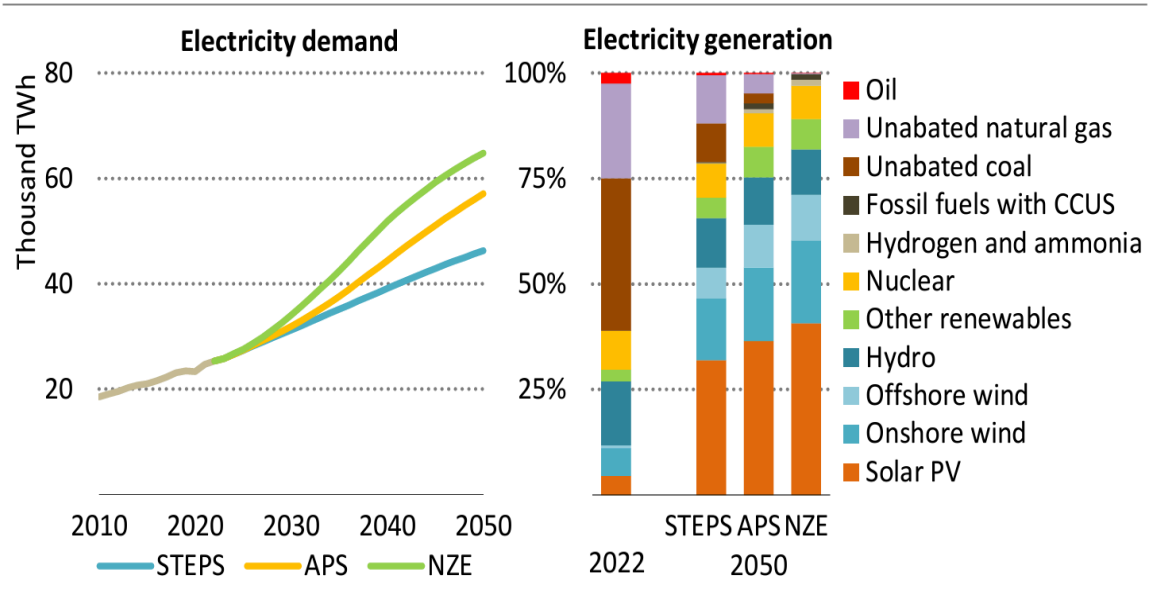


Figure 3: Global Electricity Demand, 2010–2050, and Generation Mix by Scenario, 2022 and 2050
Source: Figure taken from World Energy Outlook 2023, International Energy Agency.

The message from these projections is clear: the shift to a net-zero energy system by 2050 requires large-scale changes to the global energy system, and to achieve anything remotely like the 1.5-degree pathway, a far-reaching uptake in renewable energy generation will be required. The key technologies expected to drive this are solar PV, onshore and offshore wind, along with the storage and transmission technologies to support the uptake. Facilitating this transition requires channelling more investments into improving clean energy technology/systems and building stronger alliances and international support to overcome barriers such as substantial capital costs and challenging business environments.

2.1.3 Global Outlook for Clean Energy Transition

Achieving a clean energy transition requires overcoming various challenges such as substantial investments in renewable infrastructure, grid modernisation, and energy storage technologies to address intermittency issues. In addition, policy stability and international cooperation are crucial for enabling an environment that supports clean energy deployment, strengthens the energy market through robust supply chains, and fosters a circular economy. Table 1 identifies key opportunities, future forecasts, and challenges for the transition into clean renewable energy.

Table 1: Key Opportunities, Future Forecasts, and Challenges for the Transition Into Clean Renewable Energy

	Opportunities	Forecasts (2030 &/or 2050)	Challenges	References
Wind	Current annual deployment of 55GW scaling up to 335GW (additional capacity/year)	IRENA's 1.5°C scenario requires 10,300GW installed capacity by 2050 Required annual capacity additions of: - 390 GW in 2030 (inc. 80 GW of offshore) - 350 GW in 2050 (inc. 70 GW of offshore)	- Proximity to onshore transmission infrastructure and associated costs - Harsh conditions in marine operating environments - Expensive operation and maintenance costs of offshore sites. - Supply bottlenecks in key components due to high demand	Eisenson et al., 2024; Gibson et al., 2017; IEA, 2021
Solar	Solar manufacturing growth outpacing solar PV deployment provides opportunity to accelerate energy transitions.	Required annual capacity additions of: - 630 GW in 2030 - 630 GW in 2050	- Land requirements for large scale solar farms - Diurnal/intermittent energy generation patterns - Solar manufacturing growth outpacing solar	Eisenson et al., 2024; Gibson et al., 2017; IEA, 2021

			PV deployment, creating imbalances	
Hydro	—	—	Significant biodiversity impacts, e.g., through construction of infrastructure like roads and power lines for operations and maintenance, resulting in deforestation, forest degradation, and habitat loss and fragmentation GHG associated with hydropower reservoirs, particularly in tropical regions.	Barros et al., 2011
Other types of RE	—	Required annual capacity additions of dispatchable renewables of: - 120 GW in 2030 - 90 GW in 2050	—	IEA, 2021

Clean energy storage is predominantly focused on large-scale batteries, hydrogen/ammonia, pumped hydro, and alternative gravity storage methods. Whilst progress is underway, accelerating the clean energy transition globally will necessitate coordinated efforts from governments, industries, and society to implement the ambitious targets, foster innovation and promote sustainable energy practices.

2.1.4 Economic Impact of Clean Energy Transition

Research on the economic impacts of transitioning to clean energy reveals a mixed landscape. Whilst many studies highlight significant positive effects on employment and sustainable development, there are also drawbacks. For instance, the development of wind turbines in certain regions has been associated with a modest decrease in property prices, although this link is not statistically significant (Sunak and Madlener, 2016). However, a recently published paper concluded that in the US, the values of homes located within 1 mile of announced land-based commercial wind turbine project declined by about 11% (Brunner et al., 2024), whilst homes located more than two miles away did not experience a decline in value. Table 2 provides a summary of research investigation illustrating how the adoption and development of clean energy, along with investment in this sector, have impacted or are projected to impact the economy and the labour market in select regions/countries.

The literature is dominated by wind energy as a source. A few studies have been identified that focused on clean energy more broadly as summarised in Table 2.

Table 2: Economic Impact of Clean Energy Transition

Author/s	Country	Type of Renewable Energy	Key Results
Brunner and Schwegman (2022)	US	Wind	With an average installed capacity of 0.016MW per capita, the installation of wind energy increased GDP per capita by 8.5%, income per capita by 6%, median household income by 4 %, and home values by 7%. There was a shift in employment share from the farming sector (0.3% decrease) to the construction (0.8% increase) and manufacturing (1.6 % increase) sectors. The impact of wind energy installation on local economic growth varied based on capacity and county's level of urbanisation.
Khan et al. (2021)	International Energy Agency Countries (38)	Hydro, Geothermal, Solar, Wind, Tide/Wave/Solar Ocean Energy, Biofuels, and RE Waste Sources	The energy transition had a significant relationship with economic growth primarily in the long run, whereas economic sustainability influenced economic growth in both the short and long run. The transition was negatively correlated with the host countries' economic growth. Specifically, a 1% increase in the energy transition was associated with a reduction in the economic growth of IEA countries by 0.15% (i.e., trade-off between CO2 emission and economic growth). The index for the energy transition included renewable electricity output (percentage of total electricity output), electricity production (oil, gas, and coal sources), and energy use (kg of oil equivalent per capita). The index was constructed using principal component analysis.
Connolly (2020)	Scotland	Offshore Wind	Short-term simulations generated the highest outcomes, with a total gross value added (GVA) impact of £3.88 billion and an increase in employment of 82,393 person-years. In contrast, the long-term simulations showed a GVA impact of £2.04 billion and an employment increase of 45,181 person-years. These outcomes were based on the expenditure data for offshore wind developments, which include DEVEX (development); CAPEX (construction); OPEX (operation). An estimated £4 million per MW was used over 6 years, and considering varying offshore wind capacities ranging from 100 MW to 750 MW across different wind farms in Scotland.
Okkonen and Lehtonen (2016)	Scotland (Outer Herbrides, Shetland, and Orkney)	Community Onshore Wind Power	Analysing 11 wind farms, community-based social enterprises offered a promising solution for region-specific development in the northern periphery of Europe. Strategic reinvestments of revenues in local social services resulted in approximately ten times more employment and income impact compared to the impact of wind power production

			alone. The employment impacts of these reinvestments could be up to eight times greater than the impacts of traditional wind power production, presenting an opportunity for sustaining and growing the local economy. These outcomes were based on investment, annual turnover, and revenue data. The 11 wind farms had a combined wind power capacity of 27.6 MW, with a total investment of 52.6 million euros, from which nearly 8 million euros were channelled into the local economy. The yearly production was estimated to be 3.3 million euros, from which 2 million euros specifically went to the local economy.
Varela-Vazquez and del Carmen Sanchez-Carreira (2015)	Spain (Galicia)	Onshore Wind	The wind sector had a positive economic impact on regional GDP. The (peak) contribution of 1.2% increase in the regional GDP was attributed to the additional installation of 540MW in wind capacity. Despite requiring substantial capital investment, the sector accounted for 0.5% of the total regional employment. However, specific branches directly impacted by the stimulus saw sectoral employment rise by 6% to 18% of the total sectoral employment. In addition, there was a 5.3% increase in indirect employment in Research & Development activities within the sector.
Greene and Geisken (2013)	US (Weatherford, Oklahoma)	Onshore Wind	The 147MW wind farm generated a cumulative direct and induced impact of more than $25 million and has created a total of 200 jobs from construction to operation. In addition, the wind farm was estimated to contribute $1.7 million annually to the local economy.
De Arce, et al. (2012)	Morocco	Onshore Wind and Solar	The estimated economic impact on GDP ranged from 1.2% to 2% by 2040 (30-year period), translating to 269,252 to 499,000 jobs in full-time equivalents. The wind power investment and O&M costs per 1 MW installed (000 €): 894.5 (2010); 746.6 (2020); 701.3 (2025); 660.5 (2030); 621.9 (2040). The Photovoltaic investment and O&M costs per 1MW installed (000 €): 3661.57 (2010); 2385.31 (2020); 1993.48 (2025); 1844.24 (2030); 1647.24 (2040).
Lehr et al. (2012)	Germany	Solar	The gross employment in the renewable industries was estimated to increase from 340,000 in 2009 to around 500,000 to 600,000 by 2030, according to the Lead Scenario. This scenario included a bottom-up modelled cost structures of RE technologies aiming for 84.7% RE will be reached in electricity generation, 49.4% in heat, and 49.5% in primary energy supply by 2050. Moreover, the study examined international trade scenarios with high domestic PV increases combined with: (1) slow exports and (2) optimistic exports.
Slattery et al. (2011)	US (West Texas)	Onshore Wind	Wind power was projected to generate electricity at lower costs than biomass and solar photovoltaic (PV) in various future scenarios (EREC, 2008; De Vries et al., 2007). During the four-year

construction phase, about 4,100 full-time equivalent (FTE) jobs were sustained, with turbine supply chain impacts accounting for 58% of all jobs created. The cumulative economic activity in the state from the projects surpassed 1.8 billion, equating to 1.3 million per MW of installed capacity. The total economic activities benefiting local communities were substantial, reaching nearly 730 million over the assumed 20-year life cycle of the farms, or 53 million per MW of installed capacity.

The transition to clean energy poses challenges such as reduced profits for the coal industry and traditional car manufacturers. This situation necessitates government policies to alleviate these impacts and ensure a smooth and balanced transition. Despite these challenges, the environmental and economic benefits of clean energy have been identified as shown in Figure 4. Whilst there may be job losses in declining sectors, around 45% of energy workers today are in highly skilled occupations, compared to only one-quarter of economy-wide (IEA, 2022). Employment in the energy sector is projected to continue growing, with the number of new jobs created surpassing those lost in fossil fuel industries (IEA, 2023c). Although the jobs that are created may not be in the same place as those lost, and the required skills in many cases will be different, a cost–benefit analysis indicates that clean energy employment will significantly outweigh these losses by 2030. These estimates underscore the importance of proactive policies to navigate the transition effectively, balancing economic consideration with environmental imperatives.

Figure 4: Change in Global Energy Employment by Sector in the STEPS and NZE Scenarios, 2022–2030
Source: Figure taken from International Energy Agency (IEA)2023c, Renewable Energy and Jobs Annual Review 2023.
Notes: ICE vehicles = internal combustion engine vehicles; EVs = electric vehicles; unabated power = unabated fossil fuel power. Critical minerals include only extractive activities.

IRENA (2023) reports significant employment growth in the renewable energy sector from 2012 to 2022, with 13.7 million people employed, marking an 88% increase over 11 years. Solar and bioenergy industries lead in employment, followed by hydro and wind energy. The report aligns with the IEA (2023b) that if the IPCC targets to limit the earth's warming to 1.5 degrees Celsius rather than 2 degrees Celsius are met, 139 million jobs in the energy sector will be created by 2030, with renewable energies contributing to 80 million jobs. Figure 5 outlines the evolution of global renewable energy employment by technology between 2012 and 2022 as observed by IRENA (2023).

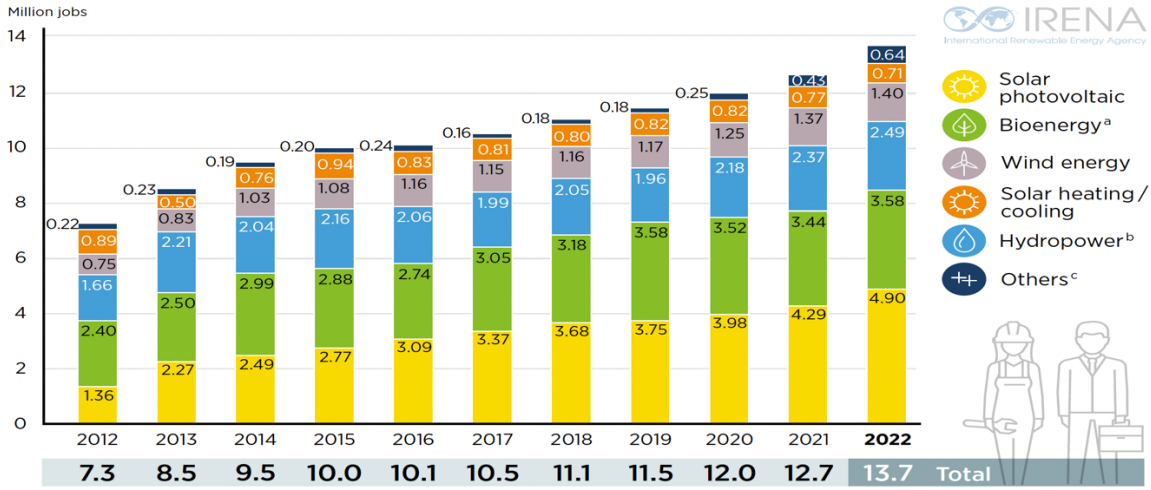


Figure 5: Evolution of Global Renewal Energy Employment by Technology, 2012–2022
Source: Figure taken from International Renewable Energy Agency (IRENA), Renewable Energy and Jobs Annual Review 2023.
Notes: a includes liquid biofuels; b indicates direct jobs only; c includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy.

Investing in storage and firming generation technologies is central to the transition of clean energy. Solar, wind, and hydro-renewable energy is positioned to dominate electricity generation by 2050. These sources' intermittent nature necessitates storage to ensure stability and reliability. Storage facilities can store excess energy generated during peak production for use during low-production periods. Addressing intermittency could enable renewable sources such as wind and solar to meet between 72% to 91% of major countries' electricity demand (Tong et al., 2021). The solar industry, identified by IEA as a major global player, requires expanded grid infrastructure and increased storage capacity to optimise its benefits. Global investment trends as illustrated in Figures 6 and 7 show a focus on enhancing grids and battery storage, with expected expansion in solar PV and battery capacity by 2030. This trend could lead to an estimated 30% reduction in power sector carbon emissions under a net-zero emissions (NZE) scenario highlighting the critical role of addressing storage gaps in the clean energy transition.

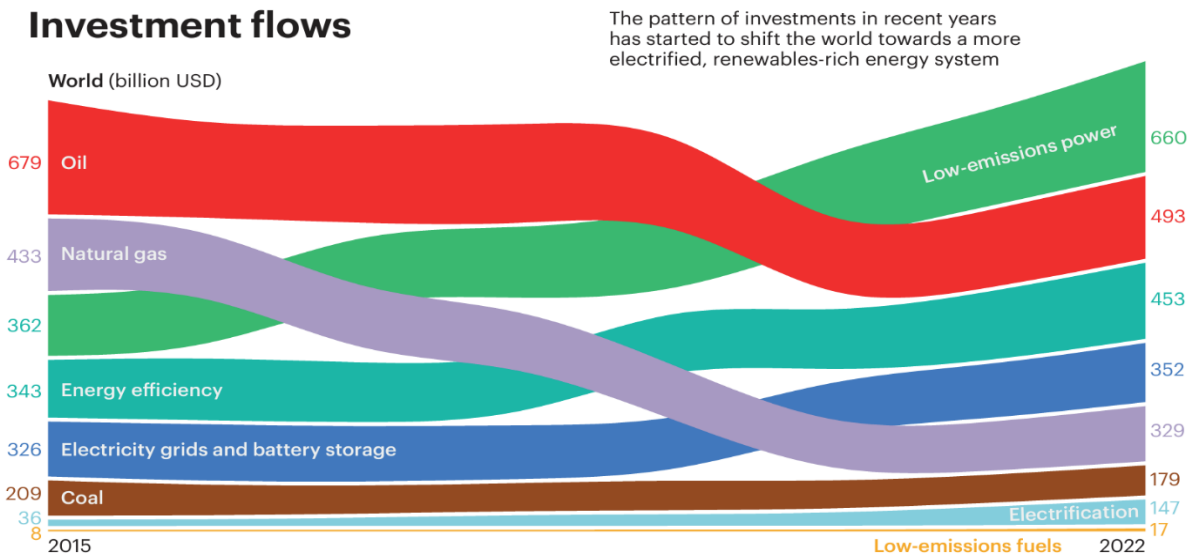


Figure 6: Investment Flows from 2015 to 2020
Source: Figure taken from World Energy Outlook 2023, International Energy Agency.

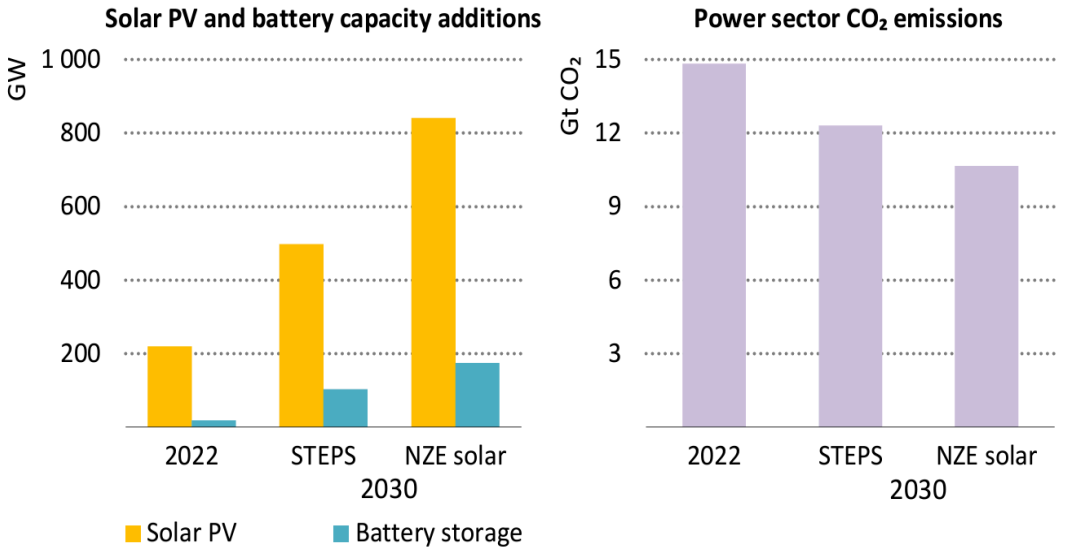


Figure 7: Global Solar PV and Battery Storage Capacity Additions and Power Sector CO2 emissions, 2022 and 2030
Source: Figure taken from World Energy Outlook 2023, International Energy Agency.
Notes: GW = gigawatts; Gt = gigatonnes; NZE solar = NZE solar case.

Advancements in sustainable energy production and storage must be complemented by substantial, modernised, and repurposed infrastructure networks (IEA, 2023c). According to the World Energy Outlook (2023) insufficient attention to transmission infrastructure slows down the transition to clean energy, causing delays in development projects (Figure 8). Currently, more investment is channelled towards solar PV and wind energy than into electricity grids.

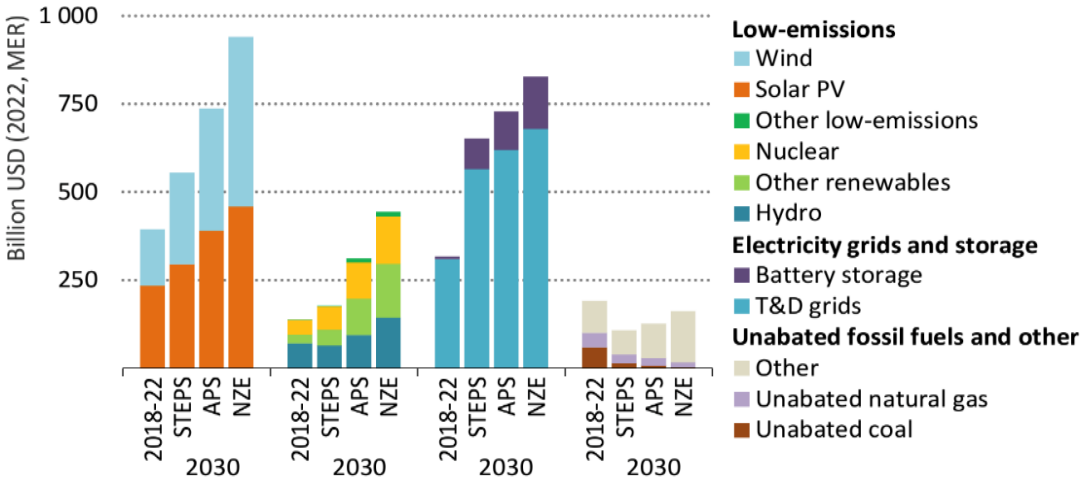


Figure 8: Average Annual Global Investment in the Power Sector by Type and Scenario, 2018–2022 and 2030
Source: Figure taken from World Energy Outlook 2023, International Energy Agency.
Notes: T&D = transmission and distribution; MER = market exchange rate.

Although, the WEO reports that there are approximately 80 million kilometres of electricity networks currently available worldwide, the current capacity needs to be increased to facilitate the transition to clean energy. More investments need to be channelled into further developing the grid connections. Economies such as Italy, Spain, the UK, and the US have not reached the targeted level – based on the APS scenario. Moreover, a larger gap is found amongst emerging and developing countries, as depicted in Figure 9.

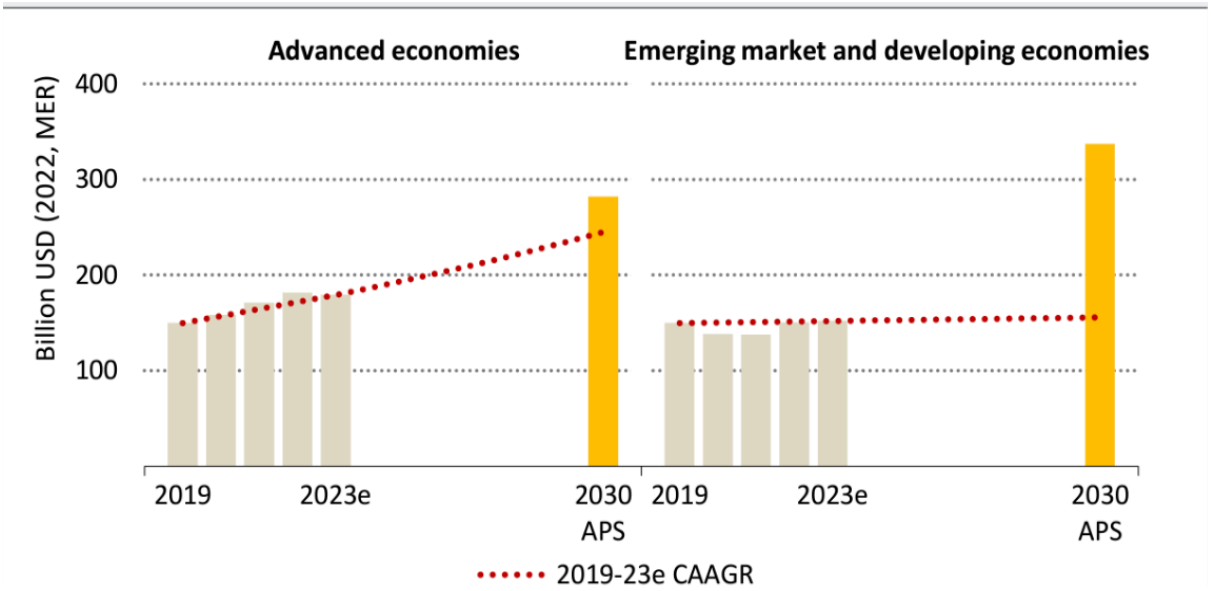


Figure 9: Investment Trends in Grids Versus Needs in the APS
Source: Figure taken from World Energy Outlook 2023, International Energy Agency.
Notes: MER = market exchange rate; CAAGR = compound average annual growth rate; 2023e = estimated values for 2023.

2.2 Australia

The Australian Government's Clean Energy Transition Plan aims to achieve net-zero emissions by 2050 while driving economic growth and job creation. The plan focuses on investing in renewable energy sources, reducing reliance on fossil fuels, and fostering innovation in clean technologies. This section examines Australia's energy outlook, including current and future demand and the projected role of clean energy. Australia's energy transformation is being shaped by multiple technologies and demands. This includes the need to integrate national energy efficiency policies and several alternative energy sources such as solar, wind, hydro and hydrogen, and to develop an energy market that supports the delivery of affordable, reliable, and clean energy (IEA, 2023a). Energy production and consumption have steadily risen over the past two decades, peaking in 2019. Australia is a significant net exporter of energy (**Error! Reference source not found.**) and the world's second-largest coal exporter (Energy Information Administration, 2022). However, energy consumption saw a dip in 2020 and 2021, likely due to the Covid-19 pandemic, mirroring global trends (see Appendix A). Despite ranking as the 7th largest energy producer globally in 2021, Australia still grapples with the challenge of transitioning to cleaner energy industries given its heavy reliance on coal exports (EIA, 2022).

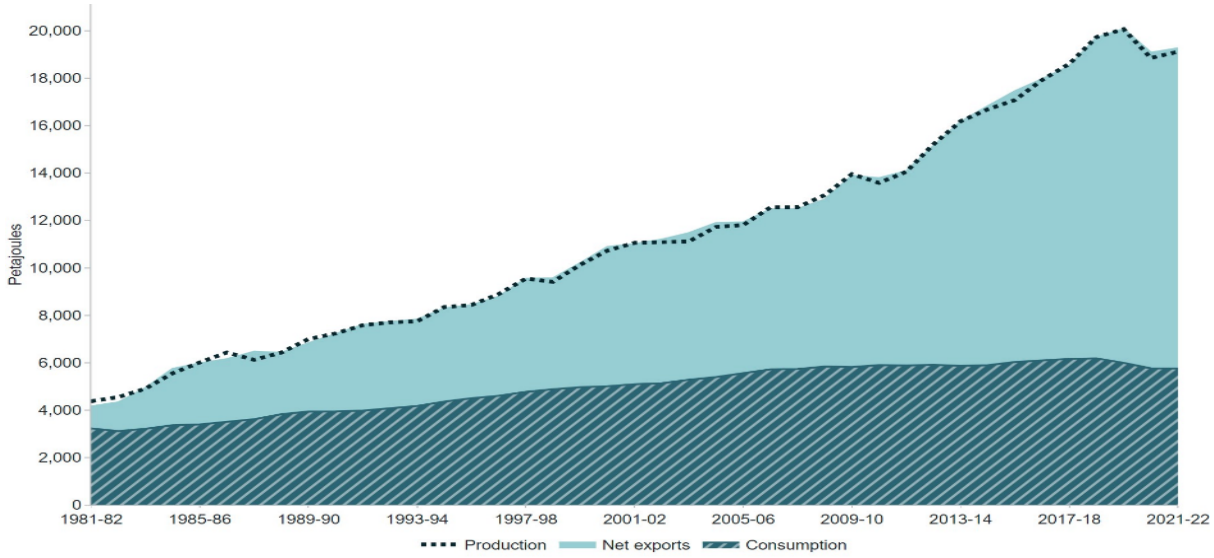


Figure 10: Production, Consumption, and Export of Australia's Energy
Source: Australian Department of Climate Change, Energy, the Environment and Water 2023; Australian Energy Statistics, Tables C and J.

2.2.1 Current Demand

As of 2024, the Australian National Energy Market (NEM) delivered 200 TWh of electricity annually. This demand is projected to double by 2050 due to increased electrification in transport, industry, and households. Australia's energy consumption decreased slightly in 2021–2022 to 5,762 PJ (a 0.1% decrease) (Department of Climate Change, Energy, the Environment and Water, 2023). Energy exports and household energy decreased by 2% and 4% respectively, whilst industry energy end use increased by 2%. Renewable energy generation including hydro, solar, and wind energy, increased by 19% (Figure 11).

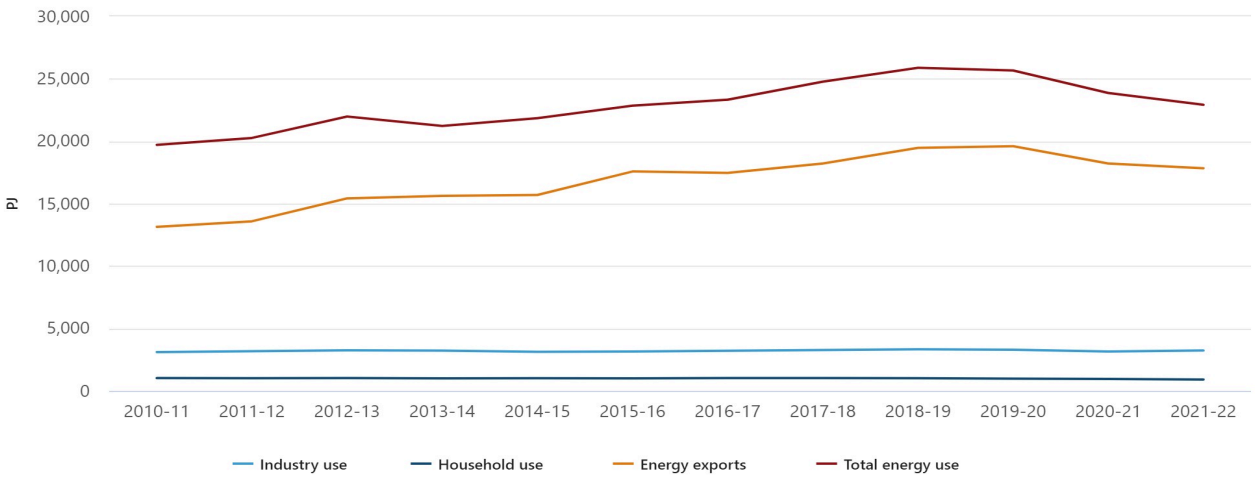


Figure 11: End-Use of Energy by Industry, Household, and Exports
Source: Australian Bureau of Statistics, Energy Account, Australia 2021-22 Financial Year.

The Australian Bureau of Statistics (ABS) (2023) attributed the energy supply of Australia's energy to domestic production, i.e., commodities extracted from the environment (20,757 PJ) and imported products (2,157 PJ). The summary of the main sources of domestic energy production are listed in Table 3.

Table 3: Natural Inputs of Selected Australian Energy Products

Source of Energy	Standard Unit (in PJ)	Percentage Exported
Black Coal	10,838	93
Natural Gas	5,842	79
Uranium	2,108	100
Crude Oil and Condensates	844	77
Brown Coal	410	Unknown (mostly used for domestic production)

Source: Australian Bureau of Statistics, Energy Account, Australia 2021-22 Financial Year.

The renewable energy sources were estimated to supply 30% of domestic electricity use and have exceeded aggregate annual household electricity demand since 2019–2020, with combined solar and wind energy supply exceeding aggregate household demand for the first time in 2021–2022. According to the ABS (2023) data, solar, wind, and hydro energy were all up by 25%, 17%, and 12%, respectively. Figure 12 further illustrates the use of renewable energy at the household level.

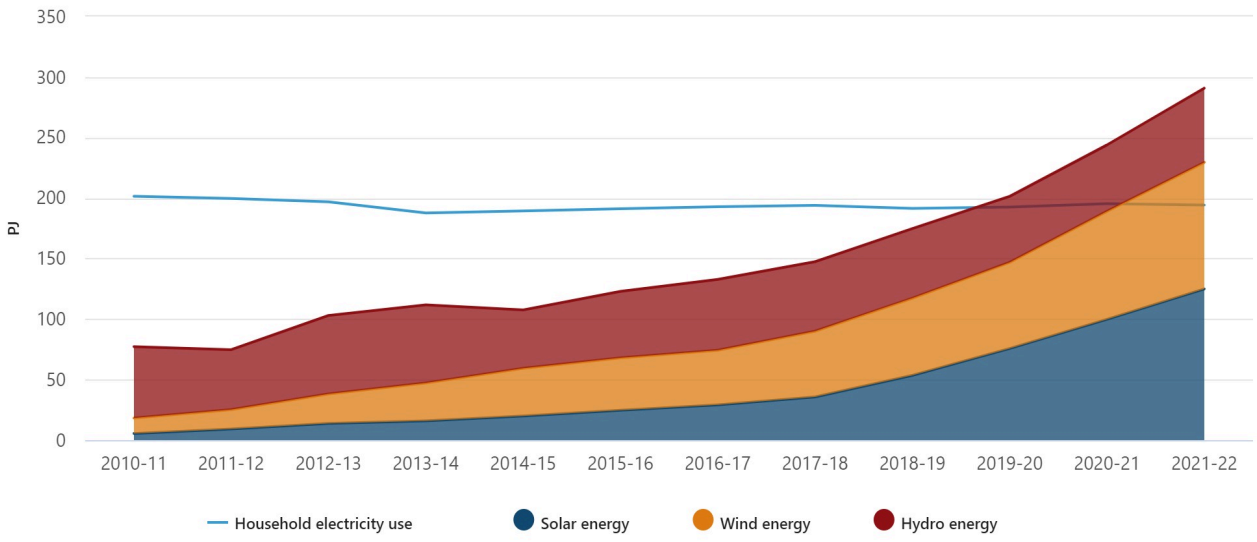


Figure 12: Renewable Energy Use at Household Level
Source: Australian Bureau of Statistics, Energy Account, Australia 2021-22 Financial Year.

Energy end use by industry was estimated to have increased by 2% to 3,232 PJ whilst energy by household decreased by 4% to 913 PJ. Table 4 below provides energy use in different industry sectors.

Table 4: Energy Use by Industry

Industry Sector Energy Use	Standard Unit (PJ)	Change (%)
Manufacturing	999	–3%
Mining	647	1%
Commercial and services	620	1%
Transport, storage, and services	512	15%
Construction	177	5%
Agriculture, forestry, and fishing	175	9%
Electricity, gas, water, and waste	102	3%

Source: Australian Bureau of Statistics, Energy Account, Australia 2021-22 Financial Year.

Oil and coal are the primary energy sources in Australia, with renewable energy contributing a smaller share as shown in Figure 13. However, there is a clear trend showing an increasing share of renewable energy adoption over time, reflecting Australia's efforts to invest more in green energy.

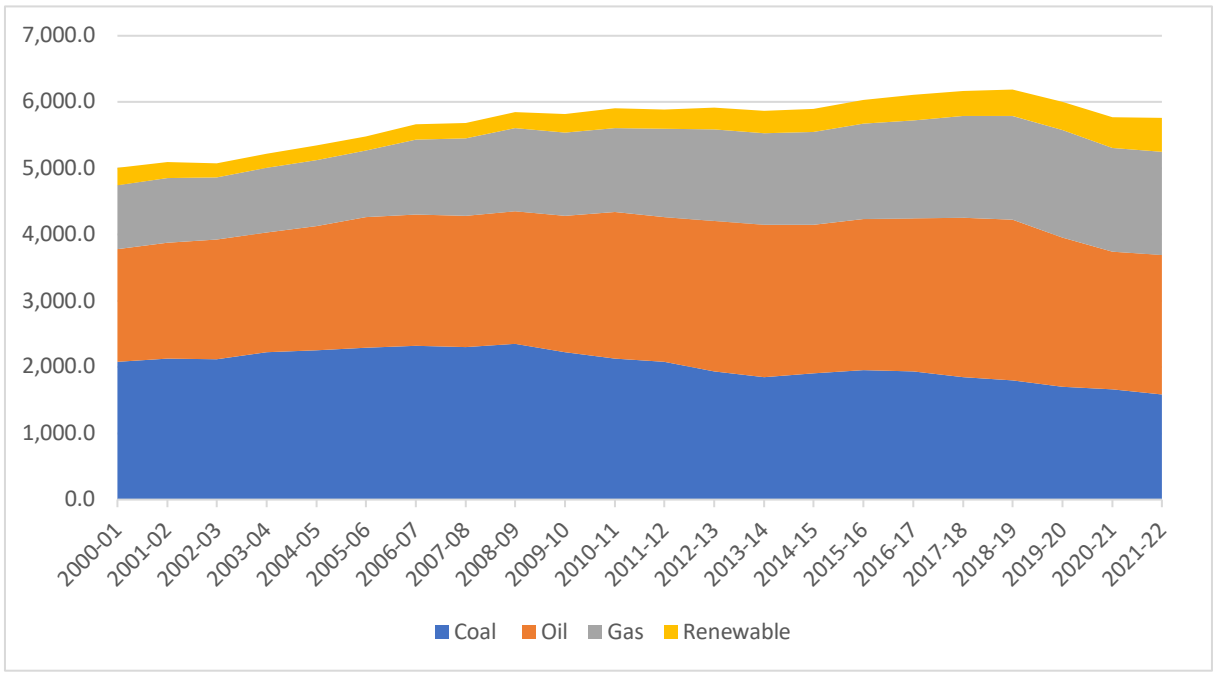


Figure 13: Energy Consumption by Fuel Type
Source: Department of Climate Change, Energy, the Environment and Water (2023), Australian Energy Statistics, Table C.

The Federal Government is focused on boosting energy efficiency through renewables and collaborating with States under the National Energy Transformation Partnership (NETP). NETP aims to create jobs, develop technology, and ensure a just and inclusive transition to cleaner energy (IEA, 2023a). In addition, the Federal Government is developing an Energy Workforce Strategy to enhance skills, create new jobs through active steps in reskilling, and promote advanced manufacturing in the energy sector.

Based on Figure 14, hydro energy has played a significant role in Australia's energy mix. The data also highlights a substantial increase in the adoption of wind energy, indicating a consistent upward trend. Solar energy has emerged as the primary form of renewable energy in recent years, with widespread adoption accelerating over the decade.

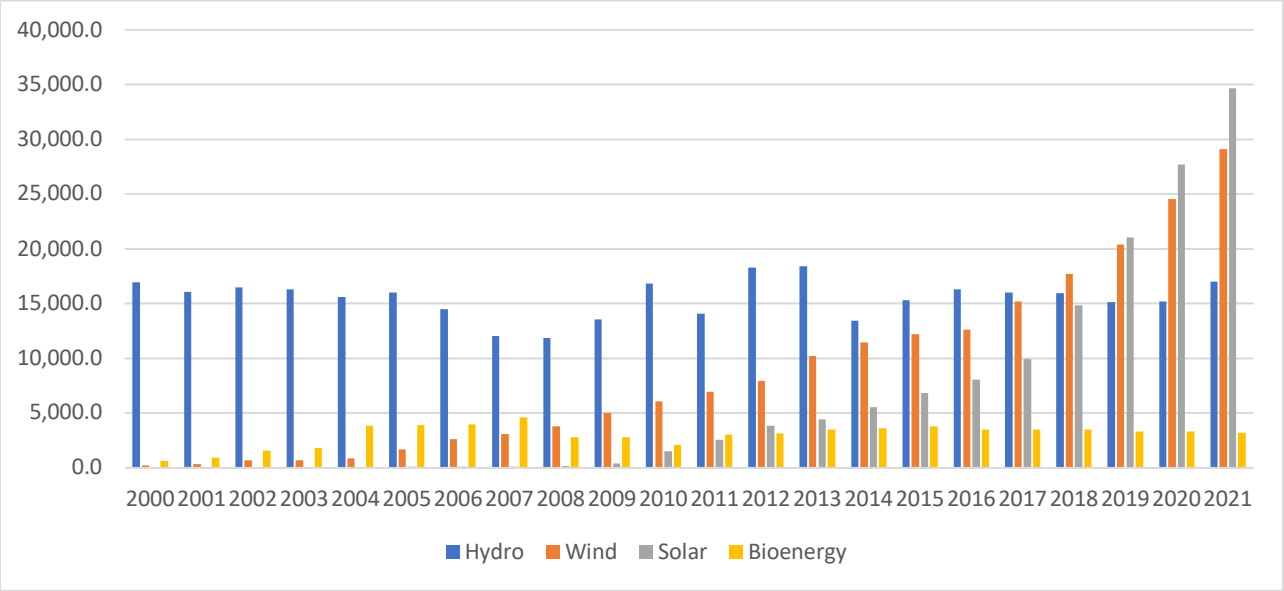


Figure 14: Australian Electricity Generation from Renewable Sources, by Fuel (Gigawatt hours)
Source: Department of Climate Change, Energy, the Environment and Water (2023), Australian Energy Statistics, Table O.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) identifies Australia's potential to be a trailblazer in the global transition to low-emission energy solutions, given its vast resources and advanced technology. CSIRO has been leveraging technology to establish and develop the Australian hydrogen industry, tackling challenges in various industries including aviation (Bruce et al., 2020). Although the commercial adoption of hydrogen in the country has faced economic and infrastructure limitations, a significant milestone was achieved in 2018, when a CSIRO pilot plant in Queensland successfully refuelled fuel cell cars for the first time (Bruce et al., 2020). There is a keen expectation regarding the potential for hydrogen utilisation in the aviation industry.

2.2.2 Future Demand

According to IEA (2023), Australia has reduced its greenhouse gas (GHG) emissions by 20% since 2005. The Federal Government has a target to reduce emissions by 43% by 2030 on the path to achieving net-zero emissions by 2050. The country's energy market is projected to expand its capacity by 40% by 2030, primarily using clean or green energy sources. Renewable energy is expected to play a significant role, covering 82% of the energy market's projected goal for the year 2030. Table 5 provides an overview of the Federal Government's energy and climate goals.

Table 5: Australia's National 2020, 2030 and 2050 Energy and Climate Targets

		2020 and 2021 Status	2020	2030	2050
GHG Emissions	GHG emissions versus 2005 (excluding removals)	–20%	—	–43%	Net Zero
Energy Productivity	Real GDP/primary energy consumption	8.5%	—	40%	—
Renewable Energy	Share of renewable generation capacity in electricity (GWh)	40 000 or 30%	33 000	82%	—

Source: IEA, Energy Policy Review Australia 2023a.
Notes: GHG = greenhouse gas; GDP = gross domestic product; GWh = gigawatt hour.

Moreover, the Australian Energy Market Operator (AEMO) has outlined its electricity outlook until 2050, as depicted in Figure 5. Aligned with the Federal Government's objective of achieving net- zero emissions, the graph indicates that the rising energy demand will primarily be met through renewable energy sources, with a total capacity reaching nearly 300 GW by 2050. Solar and wind energy are projected to constitute much of the electricity energy mix. Different modelled scenarios of renewables uptake are shown in Figure 16. Concurrently, the coal market is anticipated to face challenges, with capacity projected to decline significantly by 2050, as illustrated in Figure 17.

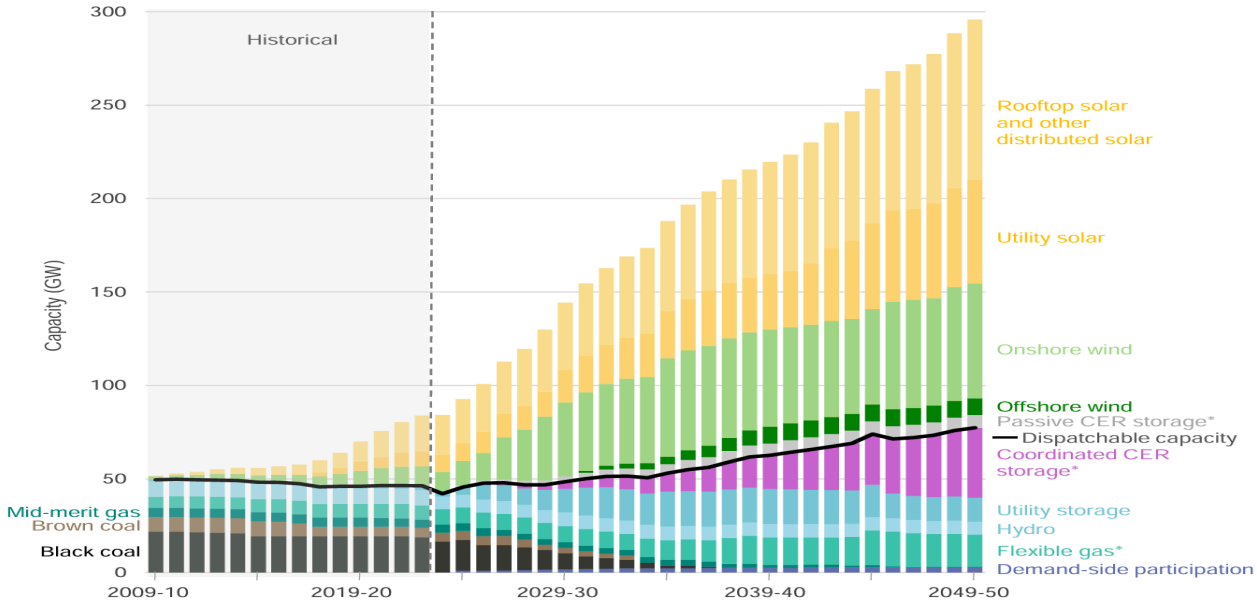


Figure 15: The Australian Energy Market Operator's (AEMO) Electricity Outlook
Source: AEMO, 2024 Integrated System Plan (ISP)
Notes: GW = gigawatt; Flexible gas includes gas-powered generation, and potential hydrogen and biomass capacity. CER storage are consumer energy resources such as batteries and electric vehicles.

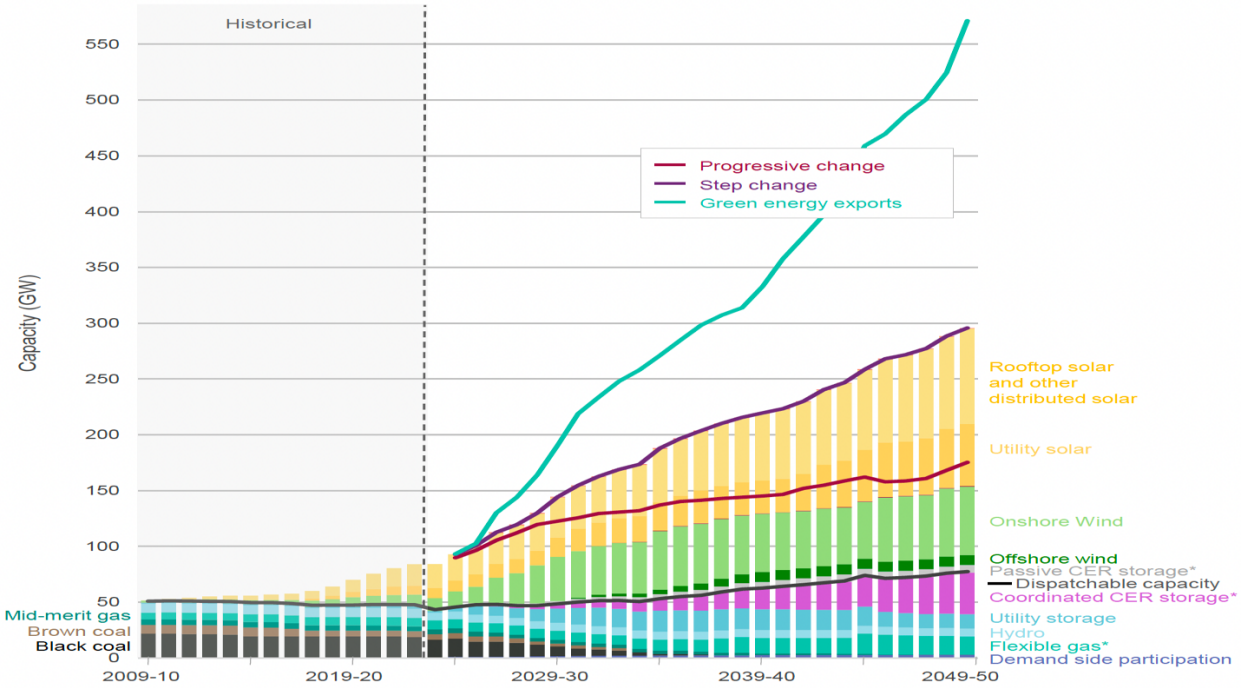


Figure 16: Capacity, NEM (GW, 2009–10 to 2049–50)
Source: AEMO, 2024 Integrated System Plan (ISP)
Notes: Flexible gas includes gas-powered generation as well as potential hydrogen and biomass capacity. CER storage are energy consumer energy resources such as batteries and electric vehicles. National Energy Market (NEM).

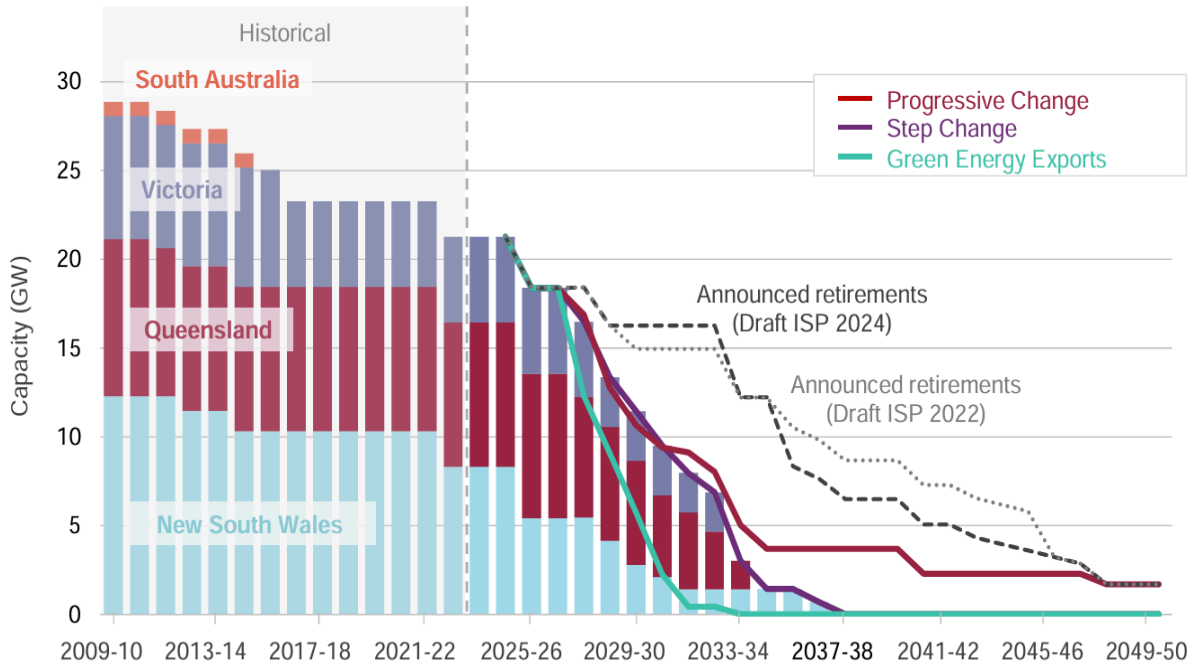


Figure 17: Coal Capacity, NEM (GW, 2009–10 to 2049–50)
Source: AEMO, 2024 Integrated System Plan (ISP).
Notes: National Energy Market (NEM).

Whilst the global transition to clean energy yields significant employment gains (Figure 18), Australia's situation is nuanced. PwC conducted an evaluation spanning from 2019 to 2040, assessing the costs, GDP benefits, and key ratios. Their findings project positive economic impacts on Australia's GDP, ranging from 6 to 15 billion dollars, depending on the scenario. The report further suggests that a renewable energy-dominant power generation mix by 2040 could offer reliable and cost-effective electricity (PwC and Jacobs, 2019). However, substituting retired coal-fired thermal plants with new high-efficiency low-emissions (HELE) coal plants may lead to less favourable economic outcomes and challenges. This analysis aids policymakers in navigating a smoother transition by addressing crucial aspects, namely affordability, reliability, and sustainability. A more detailed breakdown is presented in Appendix B.

PwC's (2019) analysis highlighted four challenges for Australia's energy sector and policymaking. These challenges are summarised as (PwC and Jacobs, 2019):

- Several major fossil-fuel-burning generators will retire over the next decade
- The large variability in our weather and demand
- Emerging energy market design challenges
- Australia's east coast has one of the world's longest transmission systems, comprising some very long 'stringy' sections with very low customer density.

Despite these challenges, Australia's market has been identified to be ideal for the initial implementation of large-scale innovative solutions. Australians Clean Energy Transition Plan is designed to prepare the country's workforce for the transition to a low-emission, renewable energy future. The Committee for Economic Development of Australia (CEDA, 2023) emphasises the importance of understanding the employment impacts of transitioning to clean energy to effectively. Forecasts suggest a minor impact on overall employment with less than a 1% reduction expected by 2030 (CEDA, 2023). In contrast, the Clean Energy Transition Plan ensures that Australia has the skilled labour needed to support the rapid expansion of clean energy projects such as solar, wind, hydrogen and battery storage. According to Nong et al. (2017) shifts in specific sectors of the Australian energy industry should be expected due to the emissions trading scheme (ETS) (see Figure 18). Whilst Australia may experience a slight constriction, the ETS could facilitate the country in achieving its climate goals and transitioning towards a low-carbon economy. Positive employment changes in renewable energy sectors are expected to outweigh reductions in other sectors, with wind

electricity forecasted for significant growth and gas electricity most adversely affected (Nong et al., 2017). Reskilling efforts could facilitate a compensatory effect allowing individuals from affected sectors to transition to sectors with increasing demand.

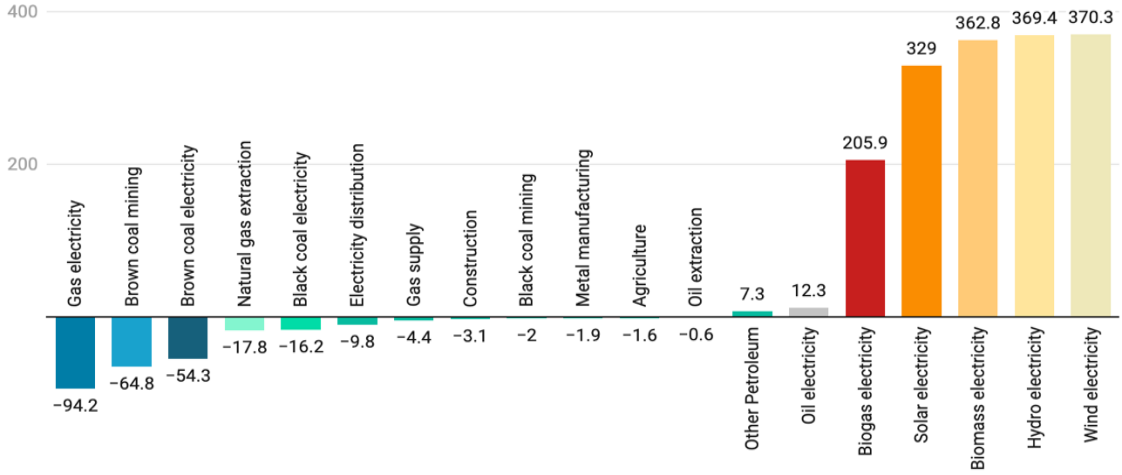


Figure 18: Percent Change in Employment 2015–2030
Source: Nong, Meng, and Siriwardana, 2017. Figure taken from Committee for Economic Development of Australia (CEDA), 2023.
Notes: Authors used the MONASH-Green model to evaluate the effect of a proposed emissions trading scheme on the Australian economy. Sector changes are relative to a business-as-usual-baseline.

Whilst the energy sector is expected to experience significant growth in the coming years, employment prospects will vary depending on the size and phase of development of the projects, from construction to operation and maintenance (O&M). More jobs are anticipated during the construction phase, with a decrease during the O&M phase. Australia's National Energy Workforce Strategy outlines these job creation opportunities in 4 key components;

1. **Workforce Development and Skills Training**: The plan prioritizes investments in vocational education, apprenticeships, and specialized training to equip workers with skills in emerging energy technologies. This includes reskilling workers from traditional fossil fuel industries to transition into clean energy sectors.
2. **Regional Job Creation**: As renewable energy projects are often located in regional areas, the strategy aims to create jobs and economic growth outside of major cities. This supports regional communities and ensures a just transition for workers affected by the shift away from coal and gas.
3. **Collaboration with Industry and Education Providers**: The strategy promotes partnerships between government, industry, and educational institutions to align training programs with industry needs, ensuring a pipeline of skilled workers.

4. **Diversity and Inclusion**: Encouraging a diverse workforce, including women, Indigenous Australians, and young people, is emphasized to address labor shortages and foster inclusive growth.

To gain a further understanding of these key sectors, Infrastructure Australia (2021) offers a labour demand forecast by job type, presented in Figure 19. The graph illustrates substantial variations in employment patterns, making this information crucial for mitigating the risks of project delays due to manpower and skill shortages and ensuring job security for workers.

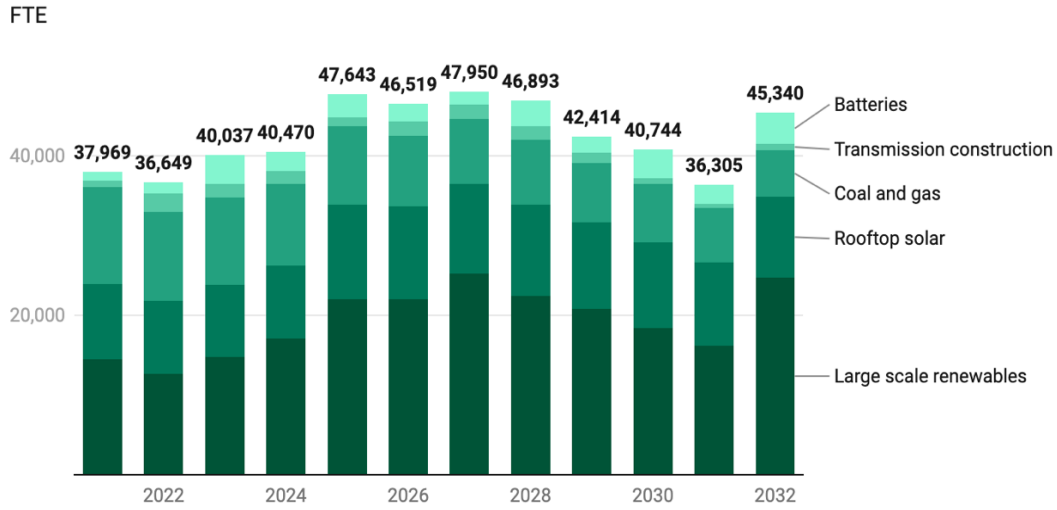


Figure 19: Forecast Labour Demand by Job Type
Source: Infrastructure Australia. Infrastructure Market Capacity 2021. Figure taken from Committee for Economic Development of Australia (CEDA), 2023.

2.3 Roadmap to Green Energy Transition – Illawarra Shoalhaven

The Illawarra Shoalhaven region is the third largest regional economy in NSW and is strategically positioned next to the rapidly expanding Western Sydney area (New South Wales Department of Planning, Industry, and Environment, 2021). This section of the report aims to shed light on the status of energy generation within the Illawarra Shoalhaven area and opportunities for sustainable energy transition. The region has been announced as a renewable energy zone by the NSW government and has embarked on a clean energy transition. Transition pathways in the region's energy system envisage energy supplied from an intelligent grid that is optimised for reliability, sustainability, and resilience to climate events, and that has ethical production and equity for access to communities in the region (New South Wales Department of Planning, Industry, and Environment, 2021). The system also needs strong community-government-business partnerships to support the strategic planning that

can foster innovation and adoption of localised clean energy generation and energy efficiencies that are scalable.

2.3.1 Policy

In the Illawarra region, transitioning to a clean energy industry necessitates robust government policies that align with global best practices and address local challenges. Governments worldwide are leveraging diverse policies to reduce emissions across various sectors. For instance, the European Union's emissions trading scheme, established in 2005, covers energy-intensive industries and power generation, expanded to include aviation in 2012 (IEA, 2020). Similarly, China is developing a scheme focused initially on the power sector, with plans to extend to other energy-intensive industries (Zhang et al., 2023). India's Perform, Achieve, Trade Scheme, introduced nearly a decade ago, targets industrial energy efficiency through a tradeable performance standard, effectively reducing energy consumption (Bureau of Energy Efficiency, 2023).

To support clean energy technology innovation, many governments have introduced programs targeting various stages of development. The United States' Advanced Research Projects Agency–Energy (APRA-E) (2024) invests in high-potential clean energy technologies that are too early for private sector funding. In the EU, the Innovation Fund supports demonstration projects, focusing on energy-intensive industries and carbon capture and storage (European Commission, 2023).

However, existing policies are insufficient for the deep emission reductions required as indicated by the International Energy Agency. The agency's analysis concludes that more ambitious and comprehensive strategies are necessary (Figure 20). For the Illawarra, this means establishing a robust policy framework that supports long-term emissions reduction goals. Such a framework should include a multi-faceted approach, addressing complex challenges and fostering collaboration among stakeholders. It must also ensure predictable and credible policies, support specific technology areas, and create enabling conditions for successful implementation. Figure 20 provides an overview of a policy framework for accelerating heavy industry clean energy transition developed by the IEA.

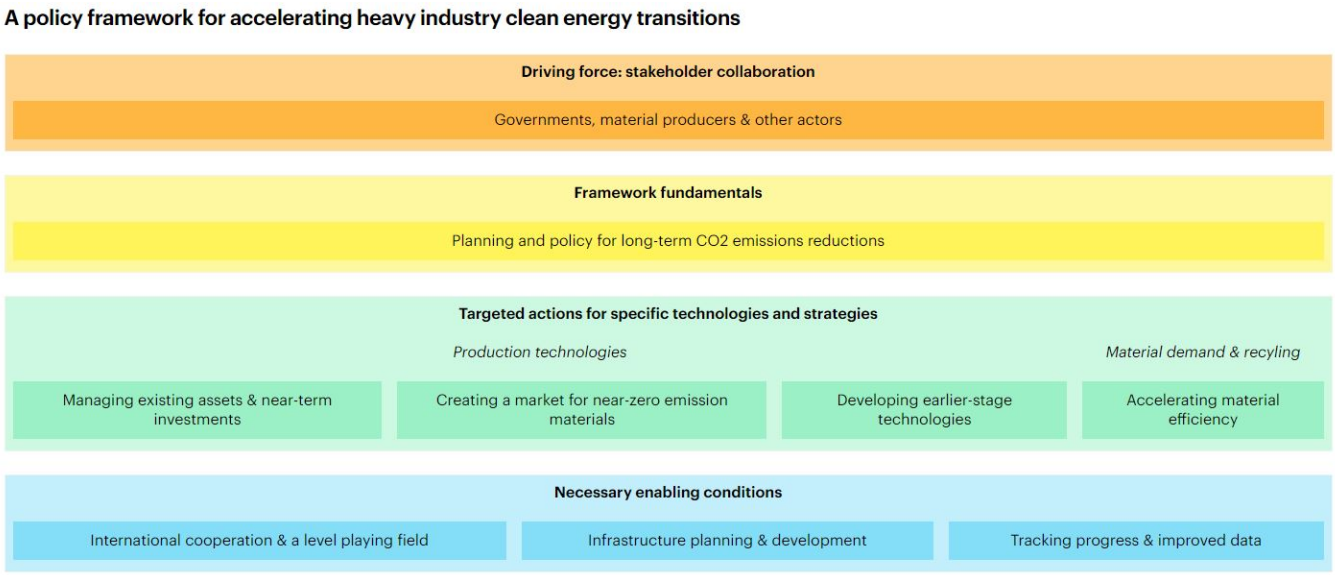


Figure 20: A Policy Framework for Accelerating Heavy Industry Clean Energy Transitions
Source: International Energy Agency, 2020.

In Australia, Federal, State, and Local Governments are poised to take decisive action to accelerate the transition to clean energy. This includes adopting ambitious policies and programs aimed at reducing energy-related emissions through key strategies: transitioning away from fossil fuels to electrified systems, enhancing energy efficiency, and expanding renewable electricity generation. However, implementing these solutions presents significant challenges for policymakers. As the energy system evolves towards electrification, there is a growing need for increased system flexibility and demand-response measures to ensure a secure, reliable, and affordable energy future.

In this context, best practice policies can guide the region towards a rapid and sustainable energy transformation. For instance, according to the World Bank's (2023) energy-transition framework (see Figure 21), governments should prioritise breaking down barriers to clean energy adoption to accelerate transition. This involves fostering a supportive regulatory environment that enhances institutional capacity and mitigates risks. By facilitating a conducive environment, governments can lower capital costs and attract private sector investments. Transparent and competitive project allocations are essential for delivering immediate benefits such as energy security, affordability, and job creation. Furthermore, scaling up clean energy infrastructure is crucial for phasing out coal-fired power in a politically and economically viable manner. This includes strategies like refinancing coal

plant liabilities, managing stranded assets through effective planning and policy clarity, and preparing just transition frameworks for affected workers and communities.

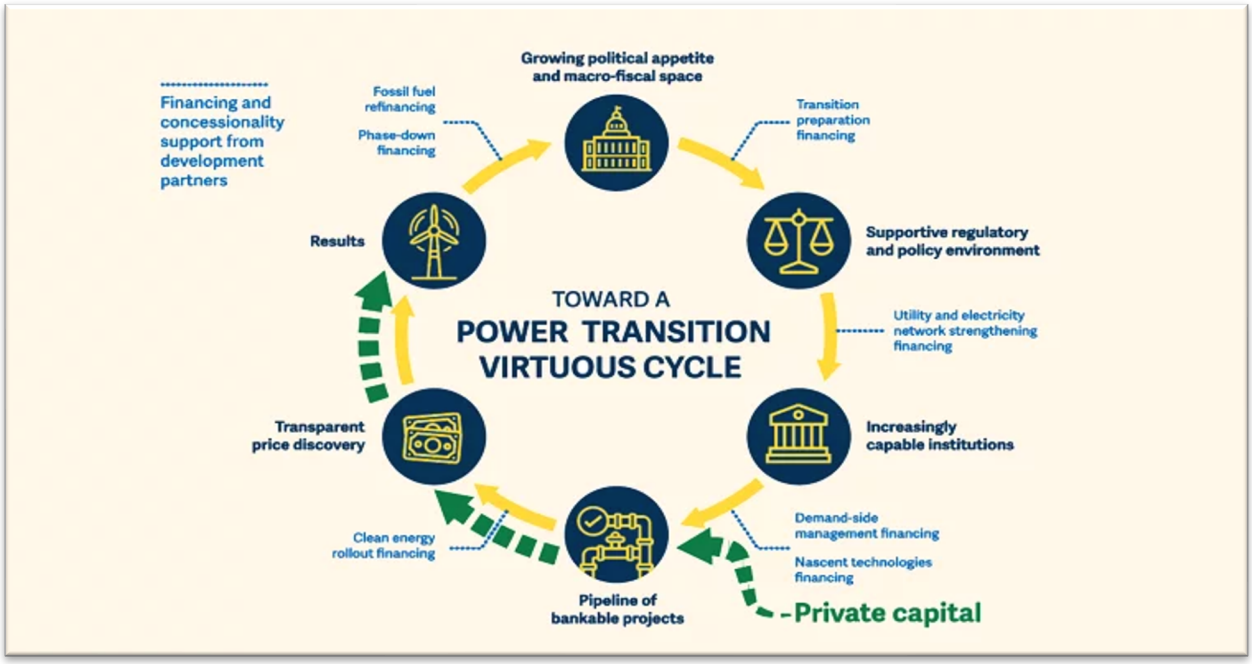


Figure 21: Virtuous Cycle to Accelerate Energy Transition
Source: World Bank, 2023.

The above approach not only supports the region's energy goals but also aligns with global imperatives for sustainable development and climate resilience.

The IEA (2023d) report complements previously discussed frameworks by providing a policy package for the evolution of energy efficiency policies to support clean energy transition. Based on the IEA framework, governments should focus on policy packaging. This is a practical approach to policy design and implementation which is built on three essential elements: regulation, information, and incentives (see Figure 22 below). For the Illawarra region, this measure supports the transition to increased energy performance levels and enhanced energy system flexibility. The report argues that using this lens of energy efficiency policy packages highlights the key policies available to government, and how they can be integrated to an effective overall coherent suit of policies and actions to deliver faster and stronger efficiency gains.

Figure 22: International Energy Agency Policy Package
Source: International Energy Agency, 2023d.

The report encourages careful design and implementation of policy packages that will deliver full efficiency potential, can enhance security, create jobs, increase living standards, cut energy bills, and reduce emissions. For example, applying the framework provided in Figure 22 above, Table 6 below highlights the evolution of energy efficiency policies to support electrification, flexibility, and demand response. Using a policy package approach, the example below serves as a foundation to further evolving policies to ramp up implementation.

Table 6: Application of the Policy Packaging Framework

	Regulation	Incentives	Information
Buildings	**Building Codes** •Solar Photovoltaic (PV) •Demand response (e.g., heat pumps) •Smart EV charging **MEPS for Appliances** •Demand response	**Energy Efficiency Obligations** •Carbon-based obligations •Peak demand targets	**Energy Performance Certificates** •Fuel to GHG
Transport	**Fuel Economy Standards** •Fuel to GHG •ICE phase-out •EV bonus •EV-to-grid bonus	**Demand Incentive Schemes** •Subsidies directed to EVs •EV charger subsidies	**Energy Label** •Fuel to GHG •EV-to-grid bonus
Industry	**Industry Agreements** •Energy to GHG •Electrification (e.g., heat pumps) •Demand response requirements	**Subsidies, Grants** •Carbon-reduction based	**Energy and Carbon Reporting** •Adding GHG reporting •Demand response reporting

Notes: MEPS = minimum energy performance standards; ICE = internal combustion engine.
Source: International Energy Agency, 2023d.

Energy efficiency is crucial for achieving net zero emissions, but its potential is not fully realised globally. To maximise its impact, energy efficiency policies in the Illawarra should be designed not only to reduce overall energy intensity but also to enhance system flexibility, asset visibility, and demand response. These elements are essential for supporting a successful transition to clean energy. Moreover, policies that emphasise inclusivity and prioritise the needs of people can strengthen the connection between energy consumers and the energy system, fostering greater engagement and support for clean energy initiatives. By integrating these principles, the Illawarra can advance its clean energy goals more effectively and equitably.

2.3.2 Status

The Illawarra Shoalhaven is responsible for an estimated 7% of the state's GHG emissions (Figure 2Figure 23). The energy and transport sectors contribute the bulk of emissions due to the region's energy-intensive heavy industry as steel manufacturing and value-added processing and the increased movements of people and goods as the population increases. A recent report by the NSW Department of Planning, Industry, and Environment (2021) stated that the region's system is centralised and vulnerable to network infrastructure failure from extreme climatic events.

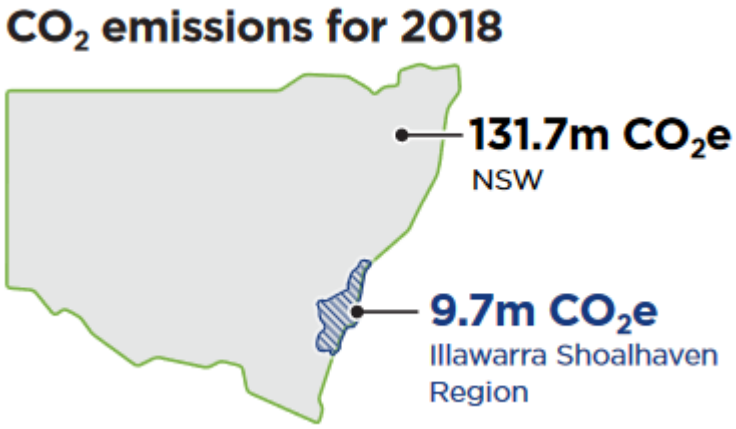


Figure 23: GHG Emissions from the Illawarra Shoalhaven Region
Source: New South Wales Department of Planning, Industry, and Environment, 2021.

The four councils in the Illawarra region (Wollongong, Shellharbour, Kiama, and Shoalhaven) participate in the Cities Power Partnership, which provides a platform for collaborative projects and knowledge sharing to combat climate change. Wollongong City Council joined the international Global Covenant of Mayors for Climate and Energy and set a target of net-zero emissions by 2050 for the LGA and a target of net-zero emissions by 2030 for its own operations (New South Wales Department of Planning, Industry, and Environment, 2021).

The Electricity Infrastructure Investment Act 2020 committed NSW to develop five REZs, including one in the Illawarra Shoalhaven region. As part of the plan developed by the region to be a net-zero region by 2050, an Illawarra Shoalhaven Sustainability Roadmap will be created, aiming to position the region as a hub for clean energy. The Illawarra Shoalhaven is emerging as a global hub for clean energy as it transitions away from a dependence on fossil fuels. Yet, many industries still rely heavily on fossil fuel. This brings opportunities to explore renewable energy sources and commit to the decarbonisation goals of the country (New South Wales Department of Planning, Industry, and Environment, 2021). In the next section, more details are presented discussing the outlook and proposed energy transition projects in the region.

2.3.3 Future Demand

The Illawarra Shoalhaven has existing clean energy generation in place and has identified opportunities to scale through offshore wind. Grid scale solar and onshore wind are limited to the geographical particularities of the region. Suitable land for deployment is not available. Tables 7 and

8 further summarise opportunities and gaps within the clean energy transition in the Illawarra Shoalhaven, accurately gauging future demand and potential opportunities (i.e., economic benefits and employment).

Table 7: Summary of Current and Future Outlook for Clean Energy Industry in the Illawarra Shoalhaven

Generation	Illawarra Shoalhaven: Current	Illawarra Shoalhaven: Outlook
Wind	No offshore wind currently in NSW, but the Federal Government has recently declared the Illawarra offshore wind zone. Closest Onshore Wind farms to the Illawarra are outside of Goulburn (e.g., Taralga) and Canberra (e.g., Capital & Woodlawn).	Offshore wind zones have been declared for the Illawarra and Hunter regions. The Illawarra zone covers an area of 1,022 km² with a potential generation capacity of 2.9 GW, whilst the Hunter zone spans 1,854 km² with a potential generation capacity of 5.2 GW. The timing of development in these zones is uncertain at this point. One feasibility licence has been awarded in the Hunter Zone and licence applications are being processed for the Illawarra Zone. Port Kembla has the capacity and potential to facilitate importation of offshore and onshore wind farm components and other equipment used for energy projects (e.g., transmission tower components, transformers, tunnel boring machines).
Solar	Currently, more than 20% of Endeavour Energy's customers have installed Solar PV systems to supplement their energy requirements.	55% of Endeavour customers with solar PV are projected by 2030. At the end of 2023, there was a total of 271,980 PV generators connected to Endeavour Energy's network with a total combined capacity of over 1,610 MW (Endeavour Energy Distribution Annual Planning Report, 2023).
Hydro	Shoalhaven Pumped Hydro consists of 240 MW of combined generation and pump capacity at two sites constructed in 1977.	The NSW Pumped Hydro Roadmap 2018 identified several sites with potential for pumped hydro including the Shoalhaven Hydro Pump Storage power plant in Kangaroo Valley. Origin Energy, in collaboration with ARENA, has investigated a proposed expansion with one unit (~235MW) of additional capacity (ARENA, 2018). Further investigation into the feasibility of the sites is required.
Biogas	In Shoalhaven, Innovative Energy is trialling a waste to energy plant from dairy manure. The proposal includes 18 dairy farms connected via a shared manure waste pipeline that can be used as a supply line back to the farms to supply treated water and residual solids which can be used as fertiliser.	It is envisioned a larger roll out in the region if trials run successful.
Other (gas as transition)	Tallawarra B upgrade resulted in 320 MW gas plant now operational in the Illawarra.	The Tallawarra B plant is expected to also run on 5% green hydrogen by 2025. In relation to liquefied natural gas (LNG), which remains a subject of debate regarding its role in the energy sector and transition, Port Kembla, through the construction of the Port Kembla Energy Terminal and gas pipeline, can facilitate its importation from Squadron Energy.

Table 8: Future Opportunities for Clean Energy Storage Infrastructure

Storage	Details	Illawarra Shoalhaven: Outlook
Battery	Community batteries provide a shared battery allowing a group of neighbours to store and share solar power, this can help manage local challenges in the grid. Electric vehicles (EV) can also be used as flexible battery storage with the network, and storage capacity is predicted to dramatically increase in the next decades.	Endeavour is trialling 10 community batteries across its network, including some locations outside of Illawarra. Participating customers rent a portion of the battery to store their excess solar or use some of other neighbours excess solar.
Gravity	Technology to raise and lower heavy weights in disused mine shafts to capture and release the gravitational energy of the weights.	Green Gravity is a start-up in the Illawarra region with the support from University of Wollongong's iAccelerate and BlueScope Steel that is developing prototypes of this technology.
Hydrogen/ Ammonia	Hydrogen production, utilisation and export could maximise Australia's energy resources and transition to a low carbon economy. Hydrogen has zero carbon emissions when consumed, and if created with renewable energy can be a zero-emission energy source. ATCO is undertaking a feasibility study for its ScaleH2 project to develop a 1 GW electrolyser and 800 ktpa ammonia facility for the export of ammonia from Port Kembla to Germany. ARENA has supported the work with $800,000 in funding through its Hygate program. The feasibility study is due for completion in early 2025.	Port Kembla identified as one of two potential green hydrogen hubs in NSW in 2021 NSW Hydrogen Strategy. The proposed hydrogen production facility at Port Kembla, estimated to be worth more than $500 million, could complement opportunities for smaller scale hydrogen plants that couple with industrial and agricultural processes that use hydrogen. Aim to have Australia's first 5GW-plus scale green hydrogen hub for domestic and export markets by 2030. British Oxygen Company (BOC) has received funding to construct 10MW electrolyser to produce green hydrogen. Project aims to produce 4,000kg/day of hydrogen to power ~40 fuel cell buses and trucks.

2.3.4 Clean Energy Transition in the Illawarra Shoalhaven

Energy transformation has regional significance to the Illawarra. With mining operations in the region investigating clean energy options, there is opportunity to transition existing workforces in these sectors towards new jobs in clean energy. Port Kembla is home to the green hydrogen hub. The Hydrogen Hub has a vision to be Australia's first 5GW-plus scale green hydrogen production facility to service domestic and export markets by 2030. BOC has been awarded funding from the NSW government to build a 10MW electrolyser.

The funds are allocated for producing green hydrogen at BOC's Port Kembla facility. The project will produce up to 4000 kg/day of green hydrogen that will be used to power some 40-fuel cell electric buses and trucks. Wollongong is also home to Energy Australia's $300 million Tallawarra B project, which will deliver Australia's first dual fuel capable power station, to be powered by a blend of gas and green hydrogen with direct emissions offset. Alongside these developments, ATCO Australia has

secured a grant from the Federal Government's ARENA to conduct a feasibility study to advance the hydrogen and ammonia facilities in the Illawarra region and understand their economic potential in the export value chain (ATCO Australia, 2023).

The region is also home to various clean energy start-up companies, including Sicona batteries and Hysata. These businesses are spin-out companies from the University of Wollongong commercialising patent protected IP generated by UOW researchers highlighting the regions research and development capabilities to help clean energy initiatives launch and grow. Other green technologies start-up companies are Green Gravity and Gridsight. Green Gravity employs a method where heavy weights are moved up and down within disused vertical mineshafts. This movement converts potential energy into electricity as the weights are lowered. Gridsight is a service provider to network operators helping with data transparency for advanced decision making. At the local government level, through its Climate Change Mitigation Plan, Wollongong City Council has set a path to achieve net-zero emissions for council operations by 2030 and net-zero community emissions by 2050. Wollongong is also home to Australia's first zero emissions, hydrogen powered garbage truck. To strengthen the initiative towards clean energy transitions through educational programs, Wollongong City Council and the NSW government have partnered with Inside Industry. This organisation is conducting clean energy tours at Port Kembla to educate the community, schools, and stakeholders about the use of renewable energy and hydrogen, whilst also showcasing the Illawarra Industry.

The growing number of local clean energy initiatives in Wollongong are opening job opportunities for locals to work in the sector, helping to position the Illawarra as a clean energy hub. The University of Wollongong (UOW) provides distinctive capability through our comprehensive approach of energy-related research. The UOW Energy Futures Network brings together a university-wide network of energy researchers who meet regularly to coordinate their activities to create a holistic energy research environment, including the behavioural and social impacts of energy solutions, the economics of transformation and new technologies for energy supply. UOW is a core partner in the Australian Research Council Research Hub for Australian Steel Innovation (the Steel Research Hub) which is focused on decarbonisation opportunities for the steel industry. As part of the Priority Community Infrastructure Program of Federal Government grants, UOW is about to receive $10 million to establish the Energy Futures Skills Centre. The centre will collaborate with local industry,

international partners, and the community to support education and training needs, as well as meet the engagement requirements of the future workforce.

2.4 Unintended Consequences from Clean Energy Transition

In evaluating renewable energy options to combat the effects of climate change, it is crucial to achieve a balance between environmental benefits and resource demands. Whilst renewable energy sources such as solar, hydro, wind power, and other forms of green energy emphasise their low greenhouse gas emissions, they can place significant demands on natural resources and affect the labour market. Moreover, as policymakers advocate for these solutions, certain policies aimed at facilitating the transition to clean energy may unintentionally lead to additional ramifications during their implementation, which are context specific. To shed light on these considerations for policymaking, Table 9 presents documented instances of these unintended repercussions.

Table 9: Summary of Unintended Consequences or Considerations Relating to Clean Energy Transition

	Unintended and Other Related Consequences or Considerations
Materials and Parts	- Wind energy uses turbine blades, which typically have a 20-year life span and are difficult to recycle due to size and material composition (Maguire, 2023). - Solar energy faces a challenge as older panels are less efficient than newer ones, making it less attractive for businesses to recycle these parts (Maguire, 2023). - The varying shapes, sizes, and configurations of batteries from electric vehicles make it challenging to automate the reclamation process, which requires machinery and automated systems for disassembling, sorting, and processing different parts, resulting in higher recycling costs (Maguire, 2023). - The unrecycled parts from renewable energy infrastructure, such as wind, solar, hydro, and other types, often end up in landfills, potentially producing toxic substances that pollute water sources (Andersen, 2013).
Land Use Conflicts and Geopolitical Pressures	- Land use conflicts arise with landowners, traditional owners (i.e., First Nations People), environmental groups due to the significant land footprint required to operate solar and wind farms, which is much larger compared to fossil fuel power stations in Australia. (Adkins, 2023). - China's production of more than 40% (and in some cases over 80%) of the world's refined copper, nickel, cobalt, lithium, and rare earth elements could lead to global supply issues due to geopolitical tensions between China and Australia (Adkins, 2023).

Rebound Effects from Policies	- In Australia, the feed-in-tariff policy has led to a 20% increase in electricity consumption amongst prosumers due to solar energy generation (Deng and Newton, 2017). Similar evidence has been observed in the US (Arizona), where the adoption of PV or solar energy has resulted in prosumers consuming an additional 0.18 kWh for every 1 kWh of solar energy generated (Qiu et al., 2019). - In Belgium, subsidies for rooftop solar photovoltaic (PV) installations encouraged households to set-up larger systems, leading to a 35% increase in energy consumption (Boccard and Gautier, 2021). - In the US, analysis of the Regional Greenhouse Gas Initiative (RGGI) (CO2 cap-and-trade program) provided evidence that trading within the RGGI region caused electricity production to move to areas where the marginal damages caused by sulphur dioxide (SO2) emissions are higher. In addition, there is some leakage or spillover of electricity generation and emissions to nearby states. The effect, however, is modest (Chan and Morrow, 2019). - In general, renewable energy subsidies, without a carbon tax or similar measures or policies, can make fossil fuels cheaper. This can lead to faster extraction of fossil fuels because companies will produce more to meet the increased demand (i.e., Green Paradox) (van den Bergh, 2013; Nachtigall and Rübbelke, 2016; Andersen, 2013).
Capacity	- In Australia (2023), 61 % of total electricity generation comes from fossil fuels, and 39% comes from renewable energy. The general estimated capacity factors of coal fired power stations when new is 70–80%, but Australia's ageing coal fired fleet has a capacity factor of 60-65% (GenCost, 2023). Large-scale solar farms have an average capacity of 22.5%, onshore wind farms have an average capacity of 30–35% and offshore wind farms have a capacity factor of 40-50%, approaching that of the ageing coal fleet (Adkins, 2023).
Footprints: Water and Land	- Some renewable resources like hydropower and biofuels require a high amount of freshwater (Mekonnen and Hoekstra, 2012; Hadian and Madani, 2015). This situation can potentially impact the food sector, which can result in increased food prices and security concerns due to competition in water use and requirements (Suckling et al., 2021; Gerbens-Leenes and Hoekstra, 2011).
Biodiversity and Wastes	- The utilisation of various forms of renewable energy typically requires the construction of infrastructure such as roads and power lines for operations and maintenance. This, in turn, leads to deforestation, degradation of natural resources, and habitat loss and fragmentation, all of which contribute to biodiversity loss and other ecological impacts (Suckling et al., 2021; Gibson et al., 2017; Andersen, 2013)

2.5 Global Supply Chain Outlook – Green Energy Transition

2.5.1 Structure and Bottlenecks

According to a study by the IEA in 2023, clean energy investment has reached USD 1.4 trillion in 2022, an increase of 10% relative to 2021 and representing 70% of the growth in total energy sector investment. It is predicted that jobs in the clean energy sector in the NZE scenario will soar from 33 to 70 million globally over 2021–2030, offsetting the loss of 8.5 million jobs in fossil fuel-related sectors. Building a large skilled workforce is critical to meeting net-zero targets, but labour and skills shortages in expanding clean energy industries are already creating bottlenecks globally (IEA, 2023b).

Fossil fuels still account for about 80% of the primary energy mix (IEA, 2023b). The transition to clean energy relies on the efficiency and effectiveness of clean energy technology supply chains.

IEA (2023b) reported that USD 1.2 trillion of cumulative investment is required to bring enough capacity online for the supply chains to be on track with the NZE scenario's 2030 targets. Currently announced investments cover around 60% of this total. Considering project lead times, most investments are required during 2023-2025, at an average of USD 270 billion per year during that period, which is nearly seven times the average rate of investment over 2016-2021.

Critical minerals like copper, lithium, cobalt, nickel, and neodymium are impacting supply chain security/certainty and clean energy transition. These minerals including bulk minerals such as steel, cement, plastics, and aluminium are required for a range of technologies and infrastructure, from wind turbines, solar panels, and batteries to electricity grids. Demand for each of the five key critical minerals increases 1.5 to 7 times by 2030. Anticipated supply expansion suggests that production could fall well short of NZE scenario requirements for 2030, with deficits of up to 35% for lithium mining and 60% for nickel sulphate production. Establishing new supply chains and expanding existing ones often involves lengthy processes or turnaround times, requiring immediate policy interventions and the adoption of appropriate strategies. For instance, deploying clean energy infrastructure can span more than 10 years. Conversely, building a factory or expanding operations for technologies that are mass-produced typically takes a relatively shorter period, specifically between one to three years.

In the IEA report (2023), it was highlighted that the geographical concentration of critical mineral production is creating supply security concerns. The production of cobalt, rare earth elements (REEs), nickel, and lithium is concentrated in specific countries, with the Democratic Republic of Congo, China, Indonesia, and Australia producing 70%, 60%, 40%, and 55% of these minerals respectively. Moreover, the processing of the minerals is also globally dominated by China, which refines 90% of REEs and 60–70% of lithium and cobalt. When it comes to bulk material supply, China also gains dominance over crude steel, cement, and aluminium output (i.e., half of the global output). Currently, China stands as the foremost global provider of clean energy technologies. The country controls the global manufacturing capacity for many mass-produced technologies – at least 60% – along with

40% of electrolyser manufacturing (IEA, 2023b). These technologies are used in solar PV, wind systems, and batteries.

In addition to potential supply security issues arising from production and processing concentration, recent global events such as the Covid-19 pandemic, political tensions between Russia and Ukraine, and increased demand have caused supply chains disruptions. These situations have led to increasing costs of materials and energy. Average prices have almost quadrupled for lithium and doubled for cobalt and nickel in 2022 compared to 2019. Moreover, the surge in battery metal prices early in 2022 resulted in a nearly 10% global increase in battery prices compared to 2021. Lastly, the prices of PV modules have risen by 25%, and wind turbines outside China have experienced a 20% increase. These price changes were driven by the twofold increases in prices of PV-grade polysilicon, copper, and steel from the first half of 2020 to that of 2022 (IEA, 2023b).

The capacity to extract essential minerals must increase rapidly to catch up and align with the objectives aimed at achieving net-zero emissions. The largest gap is for lithium, with anticipated expansions covering just two-thirds of 2030 requirements. Current anticipated mining projects point to large supply gap for some critical materials including shortfalls of 60% for nickel sulphate and 35% for lithium, relative to what is needed in the NZE scenario by 2030. One of the possible solutions to these gaps and disruptions is to diversify production, processing, and other operations, as well as to expand supply source from other countries or regions. However, current growth strategies suggest that China will continue to maintain its dominance (IEA, 2023b).

Another important aspect of the supply chain is the workforce. Workers are essential for various stages, including production, manufacturing, transportation, installation, and maintenance. Therefore, given the increasing demand for clean energy, it is necessary to significantly increase the number of people working in the clean energy sector and equip them with the skills needed for the industry. According to the data, approximately 33 million people are employed in the clean energy sector, where 24% of the workforce in the electric vehicles sector. These numbers are still insufficient given the expected growth in the sector. It is estimated that an additional 4 million workers will be necessary to meet the future demands for solar PV, wind, and heat pump systems – 75% for installation and 25% for manufacturing. (IEA, 2023b).

Together with the workforce, the availability of infrastructure for the transportation and storage of electricity, hydrogen, and CO_2 is a critical enabler. These types of infrastructure are necessary for meeting clean energy transition objectives and strengthening supply chains. According to the International Energy Agency, in relation to infrastructure, "the Net-Zero Emissions by 2050 (NZE) scenario is a useful indicator of the potential needs: in the NZE scenario, the global length of power transmission lines increases by around 185% and distribution lines by almost 165% over 2021–2050, with 85% of the additions occurring in emerging economies. Trade in low-emission hydrogen, which is almost non-existent today, covers more than 20% of global merchant hydrogen demand by 2030" (IEA, 2023b, p. 280).

The rapid expansion in clean energy infrastructure projected under the NZE scenario would place significant demands on supply chains. From 2022 to 2030, the annual use of metals for power transmission lines, distribution grids, and transformers is expected to grow by around 50% compared to current levels. In particular, the amount of copper needed for these grids and transformers is projected to reach nearly 20% of the global copper production by 2030. Moreover, the manufacturing of power transformers, which relies on grain-oriented electrical steel (GOES), faces a critical supply chain challenge. Currently, China, Japan, Korea, Russia, and the United States dominate GOES production – accounting for almost 85% of the global capacity. The NZE scenario forecasts that the demand for GOES will double to 6 Mt annually between 2022 and 2030. This surge in demand underscores the need for significant adjustments and expansions in the supply chains to support the clean energy transition effectively (IEA, 2023b).

The global annual investments in the infrastructure for low-emission hydrogen and hydrogen-derived fuel transport have surpassed USD 50 billion in the latter half of this decade (i.e., NZE scenario). This includes investments in pipelines, storage facilities, terminals, and refuelling stations, and represents nearly 40% of the current annual spending on natural gas pipelines and shipping infrastructure. As demand for hydrogen and its derived fuels continues to grow over time, the necessary infrastructure investments are expected to increase significantly, reaching more than USD 80 billion annually between 2041 and 2050. This scenario underscores the substantial financial commitment required to support the transition, highlighting the need for strategic planning and investment to build the necessary infrastructure for hydrogen transportation and storage (IEA, 2023b).

The timeline for constructing new clean energy infrastructure can be lengthy, sometimes spanning over ten years. Although the actual physical construction phase is typically efficient, lasting between two to four years, delays often occur during the planning and permitting stages. These delays can create obstacles in the process, resulting in an overall construction timeline ranging from two to seven years. The duration varies depending on the specific laws and regulations governing the project and the type of infrastructure being built. The Australian government has committed to a 43% reduction in the country's emissions by 2030 and to net-zero by 2050. The IEA (2023b) identified that the establishment of an offshore wind sector in Australia will play an important role in decarbonisation of the energy sector. In August 2022, the federal government announced the establishment of several offshore wind zones around the country (Gippsland, Hunter Valley, Illawarra, Portland, Northern Tasmania, Perth, and Bunbury). The industry has been encouraging the federal government to set national targets for offshore wind, but as of now there have been no volume targets attached to the zones (IEA, 2023b). The Global Wind Energy Council and Boston Consulting Group (2023) made several key recommendations ranging from policy and regulatory certainty for developers to fundamental reforms to power markets:

- Address policy and regulatory barriers that lead to heightened uncertainty for project investments (including complex permitting procedures, grid bottlenecks and impractical pricing signals at auction)
- Standardise and industrialise through modularisation of physical wind supply chain to gain economies of scale
- Regionalise the supply chain to support growth and resilience
- The market must provide clear and bankable demand signals to reach net zero
- Trade policies should aim to build competitive industries, not push higher costs onto end-users
- To provide the certainty needed to attract investment, power market reform should be introduced to better address the requirements of renewable generation. Long-term operating margins must be ensured through awards based on solutions with higher system value – such as a better production profile – rather than strong competition for the lowest price per MWh.

Global Wind Energy Council and Boston Consulting Group (2023) further recommend that governments should adopt a balanced approach between fostering regional supply chain security and accounting for the global interlinkages of the wind energy supply chain. Regions will need to pursue supply diversification strategies, onshore some segments and grow their own capacities. However,

this strategy does not imply that actions or policies implemented should prevent current trade activities or cause disruptions that delay the implementation of plans or specific projects.

2.5.2 Investment in Clean Energy Transition

Globally, there is increasing competition amongst countries or regions to attract international investment aimed at supporting the shift towards sustainable and clean energy practices and technologies. Governments around the world allocated USD 1.3 trillion to clean energy investment support between 2020 to 2023 (IEA). Subsidies like those offered under the United States Inflation Reduction Act and the European Green Deal have proven a big draw. Concurrently, investor appetite for infrastructure assets has risen in the face of variable economic conditions. Private equity investors appreciate the ongoing, steady returns pegged to inflation that infrastructure assets offer during market volatility. BlackRock has expressed great enthusiasm for the convergence of infrastructure and decarbonisation, eyeing opportunities in electrification and energy storage. The longer-term nature of energy transition investment suits private capital, 8 with global FDI in renewable energy investments up more than 40% since 2019. But Australia's ability to attract that foreign capital has come into question. The country's ranking in the FDI Confidence Index by Kearney has declined, moving from 7th place in 2021 to 10th place in 2024. This annual survey gauges the investment intentions of major businesses. Countries higher in the index, such as the US, Canada, Germany, France, and the United Kingdom, attracted the most investment in energy transition initiatives. Whilst Australia continues to see robust overall FDI inflows, investment from the US has declined – Australia's biggest source of foreign capital. As reported by the American Chamber of Commerce in Australia in 2021, an increasing number of American investors believe that Australia is becoming less friendly towards investments and is not an encouraging place to conduct business. Whilst these sentiments may not be ubiquitous, they do not bode well for Australia's attractiveness as a destination for green funds to capitalise on the transition opportunity and decarbonise their portfolios are funnelling capital into energy transition infrastructure faster than ever. According to S&P Global, combined public and private investment in the energy transition has almost doubled since 2020, and in the United States and Europe, it is private markets that are leading the charge (IEA, 2023b).

2.5.3 Circular Economy: End-of-Life Considerations

Considering the global shifts away from unsustainable waste management practices, notably underscored by leveraging policies such as the Paris Climate Change Agreement (IPCC, 2018), there is an urgency for an innovative circular economy (CE). The CE is defined as narrowing, slowing, and closing resource loops that can potentially generate significant economic and social benefits, promote resource security, and improve environmental performance (Ellen MacArthur 2021; Mendoza et al., 2022). Given the growing population and expanding industrial activities, the need for commercial energy is rising accordingly. Urgent action is required to slow global temperatures from rising above 1.5 and 2 degrees Celsius (IPCC, 2018). Therefore, to achieve net-zero significant changes such as phasing out the internal combustion engine or adding the equivalent of the world's largest solar farm every single day (IRENA and IEA-PVPS, 2016) are required.

The World Economic Forum (2023) reported that 35 countries improved their drive towards a low-carbon future by transitioning to clean energy industries. The report concurs with the Office of Energy and Climate Change suggesting that several countries including Australia are shifting to clean energy, pivoting away from natural gas and petroleum towards hydrogen, solar and wind power or other zero-emission technology supported by batteries. Although this is positive, these transitions trigger a massive demand for the critical minerals required for the manufacture of clean energy infrastructure (IEA, 2022). Furthermore, the installation of these large amounts of clean energy in the coming decades will have more waste in the coming years that require management. For example, it is estimated that by 2050, 78 million tons of solar panels per year will be decommissioned, and wind blades could account for 43 million tons of waste (IEA, 2023b).

The widespread implementation of the CE could decrease the need for mining and support sustainable, prolonged utilisation of rare earth materials. For example, recycling could help recover metals from the estimated 60 million tons of smartphones, laptops, hard drives, and other electronic devices that can be used in wind energy infrastructure (Pennington, 2022). Furthermore, CE initiatives can help in extension of product life, easy disassembly, and recycling. The Illawarra region already faces a significant challenge in its onshore waste management practices, which currently lack sustainable practices and result in substantial landfill accumulation (Australian Broadcasting Corporation, 2018). Moreover, the imminent disposal of decommissioned clean energy infrastructure poses a forthcoming issue, which can potentially overwhelm the existing infrastructure and public

concerns. Strategic planning is needed in advance to address these challenges, provide low-carbon materials, and avoid potential environmental impacts. For example, a recent study identified recycled aluminium or gold, copper and palladium from printed circuit boards emit up to 95% less carbon dioxide than that from virgin sources (Pennington, 2022).

Decommissioning involves the process of safely retiring or dismantling equipment, infrastructure or facilities from the clean energy area that are no longer operational often due to age, obsolescence, or regulatory requirements (NOPSEMA, 2020). According to the Australian government, there is about AUD 60 billion worth of offshore decommissioning activity that is expected to occur in Australia over the next 30–50 years (NOPSEMA, 2020). It is estimated that the fast-growing waste stream such as solar panels is expected to generate 78 million tons of cumulative waste by 2050 (IEA, 2022) whereas wind turbine blades are projected to generate 43 million tons of waste cumulatively by 2050 (Liu and Barlow 2017). In addition to the waste tonnage, The International Energy Agency (IEA, 2021) and Xue et al. (2022) estimate that the global clean energy transition will have a high demand for minerals over the next 20 years, estimating a doubling of requirements for minerals such as lithium cobalt and nickel which are pivotal in clean energy infrastructure. The Global Battery Alliance and McKinsey (2022) estimate that the market for second-use lithium-ion batteries could grow by over 30% annually from 2022 to 2030, expecting to reach a value of more than $400 billion and a market size of 4.7 TWh. The new estimates were updated from their previous report in 2019 which estimated that the second-hand market could grow by 25% by 2030, with a projected market size of 2.6TWh worth $4 billion, if standardisation and better, more flexible energy management systems are introduced (Global Battery Alliance and WEF 2019; Pennington, 2022). These scenarios provide not just a challenge but showcase opportunity for pioneering sustainable practices within the renewable energy sector, particularly in wind farm infrastructure.

According to Pennington (2022), more companies have already started to put these opportunities into action. For example, Siemens Gamesa announced the world's fully recyclable wind turbine blade using resin that is easily separated to retrieve different materials from the wind blade at end-of-life. Additionally, the Johan Cruyff Arena, the home stadium of Ajax Amsterdam in the Netherlands, uses second-hand Nissan leaf batteries to create a storage unit equivalent to the power used by 7,000 homes in an hour. The innovation has allowed the stadium to store energy on sunny days that power it during evening games and support the local grid.

Under the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act), title holders are responsible for full costs and safe removal of all offshore oil and gas infrastructure. Currently, this Act also applies to offshore clean energy industries and titleholders/developers must comply with stringent environmental and safety approval processes for the decommissioning activities including consultation with impacted communities but does not include the option to identify Circular alternatives. Countries leading in wind energy generation such as the UK, Germany, and Denmark, reveal a lack of established practices for managing the decommissioning of clean energy industries with most infrastructure crushed and buried in landfills (Xue et al., 2022). This oversight has rendered decommissioning efforts reactive rather than proactive, often relegating them to an afterthought. However, the existing regulations in Australia require offshore waste produced during decommissioning categorised and managed appropriately (NOPSEMA, 2020), this provides the opportunity to avoid cross-contamination and ensure that opportunities to recycle offshore clean energy waste streams are maximised.

Australia can begin their planning process for decommissioning offshore renewables early by borrowing from Brent Delta Topside Decommissioning Program in the UK. The project was approved on July 3, 2015, by the UK government for decommissioning, the planning process took nine years of complex engineering outcomes that resulted in 97% of the infrastructure by weight being reused or recycled (Shell UK, 2019). Based on the Brent Delta Topside project by Shell UK, adequate time is required for successful planning for the proper decommissioning industry to be set-up. This also allows for the evaluation of the potential CE initiatives that can be met and maximised in the Illawarra and Australia.

2.5.4 Australia

The University of Technology Sydney recently investigated the industry opportunities for Australia to embrace the clean energy transition (Gill et al., 2024). The report identified that Australia is already a key player in the global supply chains for clean energy technologies. However, much of its contribution comes from the mining of resources (e.g., iron ore, aluminium, and other critical minerals). The country has certain capabilities across different segments of the supply chains, but these are circulated amongst a limited number of companies or confined to research and development within universities – generally limited and there is no concentration.

Australia's expertise in solar research positions the country favourably to seize opportunities and innovations that capture the full value of its potential in the global market (Beyond Zero Emissions or BZE, 2024a). Being a leader in solar research, Australia can leverage a local supply chain to capture these potentials. Examples of these research initiatives include world leading photovoltaic cell R&D at the University of NSW, wind tower and cage manufacturing, heavy-duty vehicle manufacturing and assembly and innovation in electrolysers Hysata and University of Wollongong. Gill et al. (2024) identified several key opportunities for Australian industry to move towards becoming a key player in the renewable energy supply chain. These opportunities include:

- **Diversified battery supply chain:** Develop domestic production capability for the manufacturing of battery cells and pack assembly for both domestic and export markets and incorporate recycled materials in a circular supply chain currently going offshore.
- **High voltage cable manufacturing:** Domestic production of high voltage cables for renewable energy transmission domestically and to connect Australia to regional neighbours and unlock our potential as a net exporter of clean energy
- **Wind tower manufacturing and offshore wind port infrastructure:** Develop wind tower manufacturing capacity and the local steel supply chain for the $20 billion-plus Australian onshore market. Port infrastructure for offshore wind could unlock increased local manufacturing
- **EV (heavy vehicle) manufacturing:** Support the production of heavy EVs for domestic market and explore feasibility of developing for export
- **Solar supply chain expansion:** Building solar manufacturing based on Australian innovation to achieve Australia's net-zero targets could create up to 60,000 jobs in the manufacturing sector

Each of these align with or leverage existing core industry capabilities, fill in a supply chain gap, shore up domestic demand or unlock significant export potential for Australia. They also represent opportunities that, due to the scale of transformation, early mover risk or global competition, require some form of government support either through direct funding or in-kind support. Each of these presents as an opportunity. However, the mapping of these technologies and sectors on the following pages also highlights the possible inter-dependencies that each have that can create a compounding value proposition for Australia to realise its Renewable Energy ambitions. Three things stand out from this mapping:

1. Critical mineral refinement and green hydrogen are 'keystone' upstream opportunities, as they unlock several downstream sector opportunities
2. A concurrent focus on multiple clean energy sectoral pathways will speed up domestic ability to meet domestic clean energy demand and fasten speed to market for key components of global supply chain, creating significant export potential
3. Rapid development of clean energy increases capacity to create green hydrogen, accelerating decarbonisation efforts in global manufacturing supply chains, with Australia playing a lead role.

Transformational industry development is facing some key barrier such as:

- New or upgraded facilities have high capital expenditure and risk and require demand certainty.
- Opportunities for Australia in the clean energy sector are often regionally isolated and lack the enabling infrastructure such as energy networks, port access and even housing and community infrastructure for a growing labour force.
- The energy system is complex and has significant regulatory oversight and barriers to entry for individual businesses.
- There are established global supply chains in many technologies that make it difficult for domestic businesses to engage in. Global supply chains are linked with bilateral trade agreements.
- Domestic production capacity and higher manufacturing costs put Australia at a disadvantage compared with other countries.
- Government funding (often through grants) is often at levels too small for substantial capital investment in advanced manufacturing facilities.

Gill et al. (2024) argue that Australia requires the equivalent of the United States' Inflation Reduction Act level of funding if it wants to realise its renewable energy aspirations and to ensure that innovative companies, and value adding opportunities that directly align with existing comparative advantages can be realised. Whilst the technologies, capabilities and markets exist, the up-front capital costs and level of risk will continue to deter significant private sector co-investment without clear signals from the Commonwealth Government about their commitment to these opportunities. Australia is advised to prioritise a larger and faster deployment of utility-scale solar to notably lower electricity generation costs (i.e., economies of scale) and solidify its status as a renewable energy superpower (BZE, 2024a). The nation should harness its world-leading innovation, collaborate with global solar companies, and foster a supportive policy environment to reduce costs throughout the entire supply chain. Some recommendations for the solar and wind industries are listed in Appendix C and D.

In advanced manufacturing economies, or those that have sustained a strong manufacturing base such as the US, access to funding is more likely to be effective as a means of government intervention. This is because businesses domestic supply chains and supporting infrastructure are already established. Whilst access to significant levels of capital is vital in accelerating this transformation, it must occur within in a broader, multi-pronged policy and regulatory response. What emerged from engagement was that for Australia to be competitive in whatever sub-sector is targeted, we must have scale and to have scale, three things are required: (1) certain and consistent demand for the product, (2) underlying capability within organisations and the wider labour market, (3) a well-functioning business ecosystem.

To support and strengthen the country's economic security and foster investment, innovation, and resilience across critical sectors, The Federal Government has allocated $22.7 billion to the 'Future Made in Australia' initiative (Australian Government, n.d.), aimed at maximising the economic benefits of transitioning to net-zero emissions. The plan has five goals: (1) attracting and enabling investment, (2) making Australia a renewable energy superpower, (3) adding value to resources and strengthening economic security, (4) backing Australian ideas: innovation, digital, science; and (5) investing in people and places. In addition, a National Interest Framework will categorise priority industries into two streams: net-zero transformation (NZT), focusing on emissions reduction, and

economic security and resilience, addressing sectors vital to national resilience and supply chain stability.

In relation to the Australian workforce, the Federal Government has implemented projects and allocated significant financial resources to facilitate and speed up the transition. Some of these initiatives include the Renewable Energy Target (RET). RET aims to drive the growth of the renewable energy sector and promote sustainable energy development by providing incentives to businesses and households. In addition, the establishment of the Clean Energy Finance Corporation (CEFC) is intended to increase financial support for the country's decarbonisation efforts. For instance, CEFC invested $15 million in Hysata to help the company expand the production of its high-efficiency hydrogen electrolysers (Australian Government, 2024). Hysata is a young and innovative company located in Port Kembla – a regional area in the Illawarra region of Australia.

In the recently published government budget, funds and investments have been dedicated to support skills development and employment in key regions. The proposed budget specifically allocates financial resources and programs to support workers affected by the transition. These programs include the Energy Industry Jobs Plan (EIJP) and Regional Workforce Transition Plans (RWTP) (Australian Government, Department of Employment and Workplace Relations, n.d.). The EIJP prioritises safeguarding the welfare of workers and employers by mitigating the negative impacts of closures. It will provide tailored support to assist workers transition directly to new jobs and aid employers in recruiting and matching workers from facilities that have closed due to the transition (e.g., emission-intensive industries). The RWTP is set to inform communities about the employment and skills support available in each region and to provide guidance on accessing these resources. It aims to help individuals develop new skills, recognise existing ones, and apply for job opportunities in the clean energy industries. Furthermore, the International Renewable Energy Agency (IRENA) has provided recommendations to ensure that more (decent) jobs are available for the workforce (see Appendix E). Consequently, these programs and funding initiatives – directly or indirectly – contribute to reshaping the labour market as it moves towards a clean energy future.

Chapter 3: Methodology

3.1 Scope and Assumptions

Building on the previous discussions on how the world and Australia are moving towards a more sustainable and cleaner energy future, we explore and gather more insights on how Australia has been planning and navigating its resources to achieve climate goals. We take a step further in unpacking the potential of Australia in this green energy initiative by conducting research on the Illawarra region. Illawarra Shoalhaven, which includes Wollongong, is set for significant transformation with recent developments. It has been declared a Renewable Energy Zone, and an offshore wind zone with a capacity of 2.9 GW has also been established. This transition is crucial not only for supporting existing businesses but also for fostering new economic opportunities and job growth in the region and potentially for the country.

The scope of the investigation was clearly defined to ensure that the study remained focused on the most relevant aspects of the clean energy transition. The scope covered three main areas: generation, storage, and distribution of clean energy within the Illawarra region (Table 10).

Table 10. Scope of the Investigation

Scope	(A) Generation	(B) Storage	(C) Distribution
Within Scope	• Wind (Offshore) • Solar • Hydro • Biogas and/or Biofuel	• Battery • Gravity • Green Hydrogen/ Ammonia	• Grid • Liquid • Gas • Enabling Infrastructure (Transportation and Facilities)
Out of Scope	• Nuclear • Fossil Fuels	• Fossil Fuels • Carbon Capture and Storage	• Illawarra only and Interfacing Geographical Boundaries

Note: Onshore wind is also an opportunity for both Port Kembla to support component importation and for local manufacturers to fabricate and supply certain componentry.

The geographical boundaries of the study were confined to the Illawarra region, with specific borders defined to the south by Bomaderry, to the north by Stanwell Park, and to the west by the M31 highway, stretching from Appin to Berrima. This focus on the Illawarra region ensured that the study was tailored to the unique characteristics and needs of the local area. In addition, the research was

conducted based on several key assumptions that shaped the study's approach and findings (Table 11).

Table 11. Key Assumptions

Assumptions	Description
(1)	No large land areas will be allocated for grid-scale solar projects. This assumption recognizes the limited availability of large, undeveloped land areas in the Illawarra region and focuses the study on other renewable energy sources, such as offshore wind and biogas.
(2)	Offshore wind development will require a multi-port solution to support projects in the declared offshore zones in the Illawarra, Hunter, and Victorian regions. This assumption acknowledges the need for a coordinated approach to offshore wind development that leverages multiple ports to support construction, maintenance, and operations.
(3)	Gas will be used as a transitional fuel for decarbonizing heavy industry. This assumption reflects the current realities of energy transition, where gas is expected to play a key role in reducing emissions from heavy industry until renewable alternatives are fully scalable and viable.
(4)	Hydro-generation and storage solutions will be limited to less than 0.5GW. This assumption considers the limited potential for large-scale hydro development in the region and focuses the study on other storage solutions, such as batteries and green hydrogen.
(5)	The offshore wind development will be staged, most likely commencing with Gippsland projects, followed by projects in the Hunter and Illawarra zones. This assumption reflects the anticipated timeline and staging of offshore wind projects, with implications for the region's planning and infrastructure development.

The study also considered potential spillover effects into related industries, such as electrical cable manufacturing, pressure vessel production, and aquaculture. The potential for Port Kembla to support offshore wind project construction and development was also explored, along with the possibility of local industries providing materials and inputs for these projects.

This comprehensive methodology ensured a deep understanding of the opportunities and challenges associated with the clean energy transition in the Illawarra region. By drawing on diverse perspectives and expert insights, the study provided a clear, actionable roadmap for the region's clean energy future.

This study investigates the roadmap for the clean energy transition in the Illawarra region using a comprehensive, two-stage methodology. The approach is designed to capture in-depth insights from

key stakeholders across industry, government, and education, and to develop a strategic framework that supports the region's transition to a sustainable and clean energy future. The two stages of this process are outlined in detail below, encompassing data collection, analysis, and strategic development.

3.2 Stage 1: Consultation with Industry, Government, and Tertiary Education Leaders

The first stage of the methodology focused on conducting thorough consultations with a broad range of stakeholders to gather diverse perspectives on the current state and future potential of the clean energy industry in the Illawarra region. This stage was essential for grounding the study in real-world insights and ensuring that the findings and recommendations were informed by those with direct experience and expertise in the sector.

A total of 36 one-hour interviews were conducted, involving representatives from 23 different organisations. These interviews were carried out using both face-to-face and online formats, allowing for flexibility in participation and accommodating the varying locations and schedules of the stakeholders involved. The semi-structured interview approach was chosen to balance structure with flexibility, enabling interviewers to explore specific topics in depth while still allowing participants to share additional insights that might not have been anticipated.

3.2.1 Participant Selection and Ethical Considerations

Participants were selected through a purposive sampling technique, which ensured that the sample included a diverse cross-section of the clean energy sector. The selection criteria focused on industry experts, policymakers, leaders from tertiary education institutions, and representatives from start-up businesses within the clean energy industry. This diverse representation was crucial for capturing a wide range of views and experiences, from established industry leaders to emerging innovators.

Prior to the interviews, all participants were provided with detailed consent forms (Appendix F) and participant information sheets (Appendix G). These documents outlined the purpose of the study, the use of the data collected, and the rights of the participants, including confidentiality and the option to

withdraw from the study at any time. The process ensured that all ethical considerations were met, and that participants were fully informed and comfortable with their involvement in the research.

3.2.2 Interview Structure and Content

An interview guide was developed, featuring open-ended questions designed to elicit detailed and thoughtful responses. The guide was carefully crafted to cover key topics related to the clean energy transition, such as current industry practices, challenges, opportunities, and prospects. The open-ended nature of the questions allowed participants to provide nuanced and context-rich responses, facilitating in-depth discussions that could capture both common themes and divergent viewpoints.

The interviews were recorded and transcribed with the permission of the participants. The data from these interviews were then manually analysed to develop a codebook that identified key themes and patterns. This codebook was subsequently used in NVIVO software to conduct a more systematic analysis, enabling the researchers to quantify and visualise the themes that emerged from the discussions. The analysis was focused on identifying the most significant opportunities and challenges related to the clean energy transition in the Illawarra region, as well as capturing the various perspectives and priorities of the stakeholders involved.

3.3 Stage 2: Heatmap Development

The second stage of the methodology involved the development of a strategic heatmap, a visual tool designed to assess and prioritise the opportunities identified during the first stage of the study. This heatmap was developed with input from the Steering Committee (SteerCo), which included key stakeholders from industry, government, and academia. The involvement of the SteerCo ensured that the heatmap was informed by a broad range of expertise and that it accurately reflected the perspectives and priorities of the key players in the region's clean energy sector.

3.3.1 Heatmap Criteria and Definitions

The heatmap was designed to evaluate the identified opportunities based on three key criteria: desirability, capability, and capacity. These criteria were defined as follows:

1. Capacity: This criterion refers to the availability of the necessary resources, infrastructure, and institutional frameworks required to effectively implement and scale clean energy solutions. It

includes factors such as financial resources, technological capabilities, a skilled workforce, supportive policies, and adequate regulatory frameworks. A region or stakeholder with high capacity is well-positioned to efficiently integrate renewable energy sources, implement energy efficiency measures, and support sustainable practices across various sectors.

2. Capability: Capability refers to the technical expertise, knowledge, and innovation potential needed to develop and deploy clean energy infrastructure, technologies, and solutions. It encompasses research and development capabilities, advancements in renewable energy sources (such as solar, offshore wind, hydroelectric, and biogas), energy storage solutions, smart grid technologies, and improvements in energy efficiency. Stakeholders, governments, or businesses within the region with high capability can lead in the design, manufacturing, installation, and maintenance of clean energy infrastructure.

3. Desirability: This criterion indicates the societal, economic, and environmental motivations and support for transitioning to clean energy.

Desirability reflects a broad consensus or commitment among stakeholders, including governments, businesses, communities, and individuals, to prioritise and invest in clean energy solutions. Factors driving desirability include environmental sustainability goals, reducing carbon emissions, energy security, economic opportunities in the clean energy sector, and public demand for cleaner and more sustainable options.

The heatmap provides a visual representation of how different opportunities ranked in terms of these criteria, helping to prioritise areas where the region should focus its efforts. This tool was instrumental in highlighting key areas for potential development within the clean energy transition framework, ensuring that the study remained aligned with the overall project objectives while providing deeper, more actionable insights.

3.3.2 Steering Committee Involvement

The Steering Committee played a critical role in the development and refinement of the heatmap. Comprising representatives from industry, government, and academia, the SteerCo provided valuable feedback on the initial findings and helped to ensure that the heatmap was both comprehensive and focused on the most critical issues. The SteerCo's involvement ensured that the heatmap was not only

a theoretical tool but also one grounded in practical considerations and the real-world context of the Illawarra region.

Chapter 4: Findings

4.1 Illawarra Clean Energy Transition Action to Date

The Illawarra region has undertaken several significant initiatives to advance its clean energy transition, leveraging both local resources and government support. These efforts are aimed to establish the region as a leading hub for renewable energy and to foster sustainable economic growth. Table 12 highlights significant developments within the Illawarra region established to date, noting however that the list in Table 12 is a summary of the major initiatives and is not a comprehensive list of all renewable activities underway in the region, nor is Table 12 intended to be a list of all investments. These initiatives are aiding the Illawarra region in making substantial progress towards its vision of becoming a leader in clean energy and sustainable development.

Table 12. Clean Energy Initiatives in the Illawarra Region

RE Initiatives	Illawarra Shoalhaven
Renewable Energy Zone (REZ) and Offshore Energy Infrastructure Zone (OEIZ)	• The NSW Government declared the Illawarra as a REZ in February 2023 • The Australian Government declared an Offshore Energy Infrastructure Zone (OEIZ) of 2.9GW in June 2024, recognising the region's high offshore wind potential
Port Kembla Hydrogen Hub	• Committed to green hydrogen leadership, attracting investment, and creating jobs • The NSW Government awarded $28.5 million to BOC Gases from the Hydrogen Hubs program to establish a 10.5MW hydrogen electrolyser and other hydrogen infrastructure • The hub supports the production, storage, and export of green hydrogen and ammonia
Regional Transition to Low Carbon Transport	• Wollongong is being targeted as a priority area within the NSW Government's Electric Vehicle public charging masterplan • A Hydrogen heavy vehicle refuelling station has been commissioned by Coregas to service local heavy vehicle decarbonisation initiatives
Solar and Hydro Projects	•Illawarra has established rooftop solar and hydro projects
Transmission and Distribution Infrastructure	• Integrated System Plan: 10,000 km of new transmission lines needed by 2050, with 2,500 km in development. A relatively minimal volume of this is forecast to occur in the Illawarra region. • The transmission projects are estimated to (1) save consumers $18.5 billion in avoided energy costs, (2) deliver $3.3 billion in emissions reduction
Clean Energy Futures Skill Centre	• AUD 13 million commitment by the Australian government for UOW to establish a clean energy future skills centre jointly by UOW and Wollongong TAFE • Super TAFE and Clean Energy Skill Centre develop local workforce skills to support transition

Advanced Manufacturing and Start-Up Ecosystem	• Leveraging the region's steel manufacturing base to support advanced clean energy infrastructure • Establishing new clean energy businesses in the Illawarra through R&D (e.g., Hysata, Sicona, Green Gravity)
Gas Projects	• Natural Gas upgrade for Tallawarra aims for long-term hydrogen application • Port Kembla Energy Terminal (PKET) established by Squadron Energy to provide gas based firming capacity in the transition to renewables in NSW. PKET has been designed to allow future fuel uses

4.2 Vision for the Illawarra Shoalhaven

The development of clean energy industries in the Illawarra and Shoalhaven will establish the region as a leading hub for renewable energy innovation, investment, and sustainable economic growth. By leveraging its strategic geographical position, existing industrial base, and skilled workforce, the Illawarra is well placed to attract significant investment, and the further development of robust enabling infrastructure will support various established and emerging clean energy technologies. A summary of key elements of the vision is presented in Figure 24.

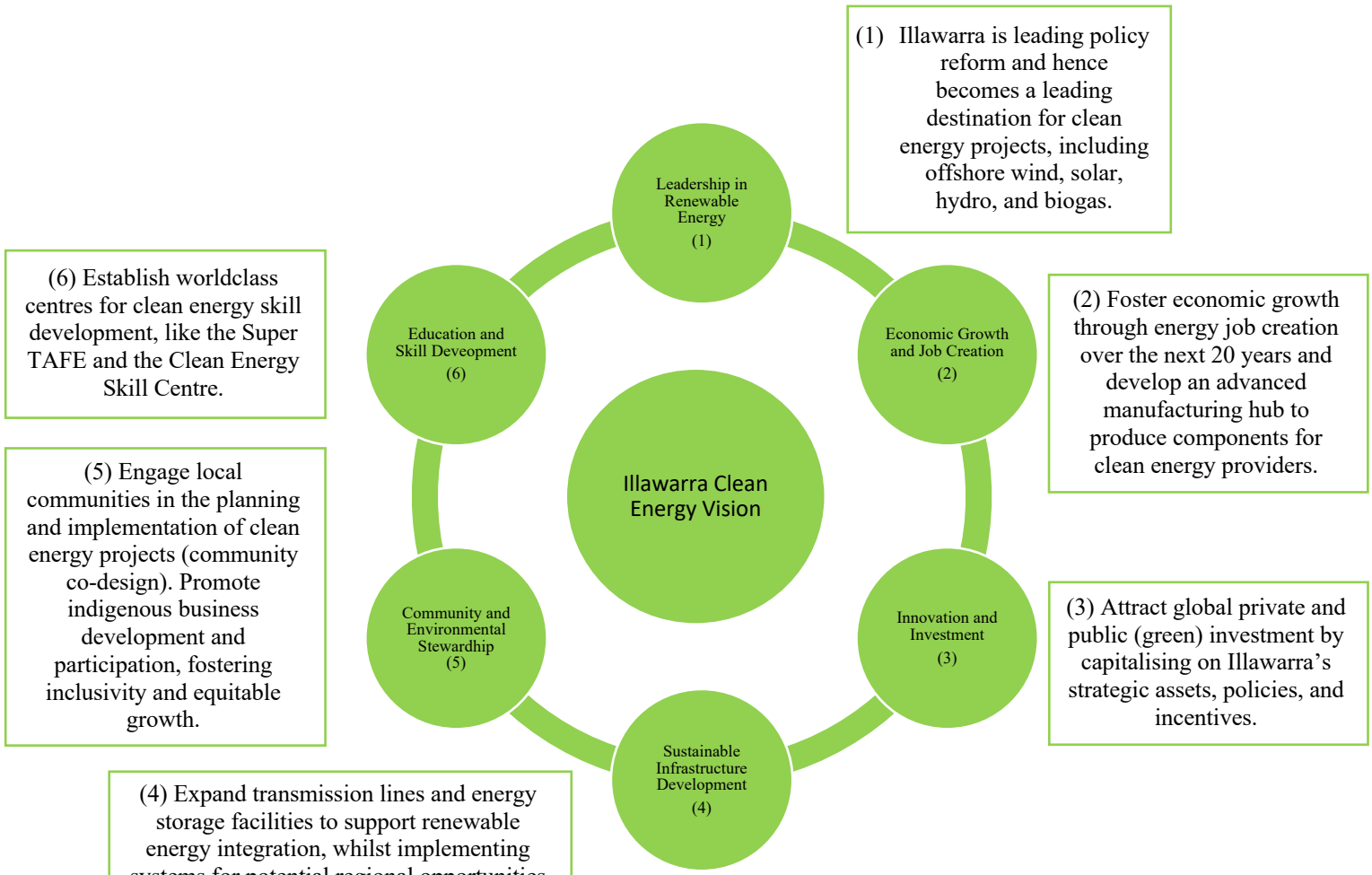


Figure 24. Vision for the Illawarra Shoalhaven.

A roadmap for the implementation of the vision depicted in Figure 24 is presented in Figure 30, later in this report. The next section of this report takes a deep dive into specific opportunities for the region focusing on the overall desirability of engaging with an opportunity area as well as the current regional capability and capacity. The capability and capacity analysis provides qualitative guidance on potential investment areas which may have the highest potential returns.

4.3 Capability and capacity: Illawarra Shoalhaven Heat Map

Despite finite land resources, the region boasts major energy, port, and transport infrastructure, a skilled workforce with experience in heavy manufacture, oxygen and hydrogen production, storage and use, and a strong local demand for hydrogen projects, including future green steel production. These combined assets, when leveraged to facilitate the energy transition, have the potential to transform the local economy. Figure 25 highlights a summary of the region's unique capability and capacity.

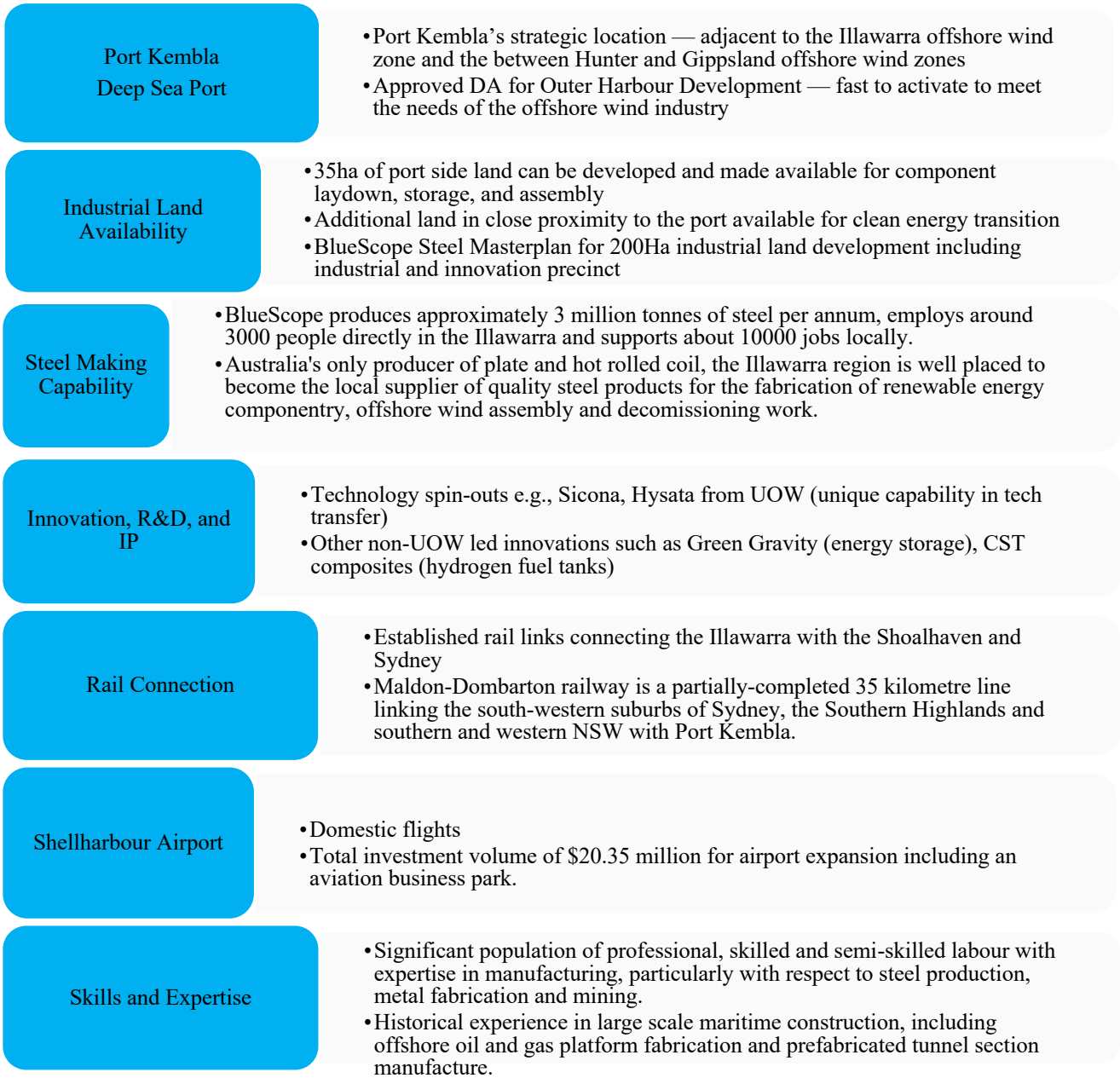


Figure 25. Unique Capability and Capacity: Illawarra Shoalhaven

The region is uniquely placed to become a leader in clean energy transition. One key aspect that sets the Illawarra REZ apart from other REZ regions is the significance of having an existing, considerable load geographically close to a potential source of generation. Considering the Illawarra's unique capabilities, the next section of this report explores and identifies opportunities for the region associated with the clean energy transition.

The clean energy transition presents significant employment opportunities for the Illawarra region, which is poised to become a major hub for renewable energy industries. The region's strategic position, existing industrial base, and government-backed initiatives such as the Illawarra Renewable

Energy Zone (REZ) and offshore wind projects make it well-positioned to support the rapid growth of green energy jobs.

The International Renewable Energy Agency (IRENA) estimates that the global renewable energy sector will generate 80 million jobs by 2030. In Australia, the clean energy sector is expected to create up to 50,000 new jobs by 2035, with the offshore wind and hydrogen industries being key drivers. The Illawarra region, with its infrastructure, skilled workforce, and educational institutions, could attract a substantial share of these opportunities. With the establishment of a 2.9 GW offshore wind zone, the Illawarra region could see the creation of approximately 4,000 to 6,000 jobs over the next decade, focusing on areas such as turbine manufacturing, assembly, installation, and maintenance. The Port Kembla Hydrogen Hub aims to create around 2,000 direct and indirect jobs, particularly in hydrogen production, storage, and export logistics. Battery and Storage Technologies: Community battery installations and microgrid projects could generate approximately 500 new jobs focused on installation, operation, and maintenance.

However, considerable gaps currently exist in regard to workforce, leveraging policy initiatives and clean energy supply chain that can position the Illawarra as a leading destination for clean energy transitions. The Illawarra has identified shortages in specific/specialised skills or talent such as electrical engineering, electrical trades, fabrication and mechanical trades, project management, WH&S and other skilled workers). The supply chain requires investment in critical infrastructure. However, uncertainty in demand due to a lack of an approved project pipeline (e.g., offshore wind projects) stalls investment. Further the electricity network infrastructure is insufficient to support electrification and decarbonisation (e.g. electric vehicle and hydrogen recharging infrastructure) including the transmission and distribution network capacity. Finally, a lack of alignment and coordination between local, state and federal government has been identified as a gap to attract clean energy businesses to the region. Coordinated energy policy implementation is required at the local, state, and federal levels to fully unlock the regional benefits and opportunities.

4.4 OPPORTUNITIES FOR THE ILLAWARRA SHOALHAVEN

The Illawarra region's unique capabilities and strategic positioning enable it to seize various clean energy opportunities, driving the local economy towards a sustainable and clean energy future.

Research conducted through a comprehensive series of interviews and national and international literature searches have been distilled into a combined qualitative and quantitative summary. This

qualitative and quantitative research created Heat Maps, which are communicated in this report in the form of Venn diagrams.

The diagrams summarise the analysis of the data by focusing on the three factors of industry desirability, regional capability and regional capacity, whilst also factoring in time to implement. The intersection of all three factors (circles) in the Venn diagrams identify the elements that the research has identified as most implementable with the highest likelihood of success as they meet all three criteria, namely (1) industry desirability; (2) regional capability; and (3) regional capacity.

Industry desirability captures the attractiveness of a particular region, sector, or project for industrial development. It reflects the advantages that can be leveraged to make clean energy projects successful. Regional capability includes the combined strengths, resources, and expertise within a region that enable it to effectively contribute to and benefit from the clean energy transition.

Regional capacity refers to the ability of the region to support, manage, implement, and sustain the clean energy transition. Note that the opportunities presented here are those identified by key industry stakeholders.

Where two circles overlap, the opportunities meet the criteria of two sets but lack the third (either capacity or capability) requiring time for either capacity or capability development. Lastly, those opportunities that are only desired by industry at this point are classified as long-term projects that are viewed as less feasible at present, and which require significant capacity and capability development to proceed. Each opportunity is placed in one of three-time categories; A, B, & C where A focuses on 2024–2027, B focuses on mid-term initiatives between 2028–2031, and C on long-term plans out to 2050.

The research has been grouped into the categories of enabling infrastructure, clean energy generation, clean energy storage, and new or alternative industries. Thus, there are four Venn diagram heat maps, one for each of these categories.

4.4.1 Enabling Infrastructure

Figure 26 presents the analysis of enabling infrastructural opportunities in the Illawarra including energy distribution infrastructure.

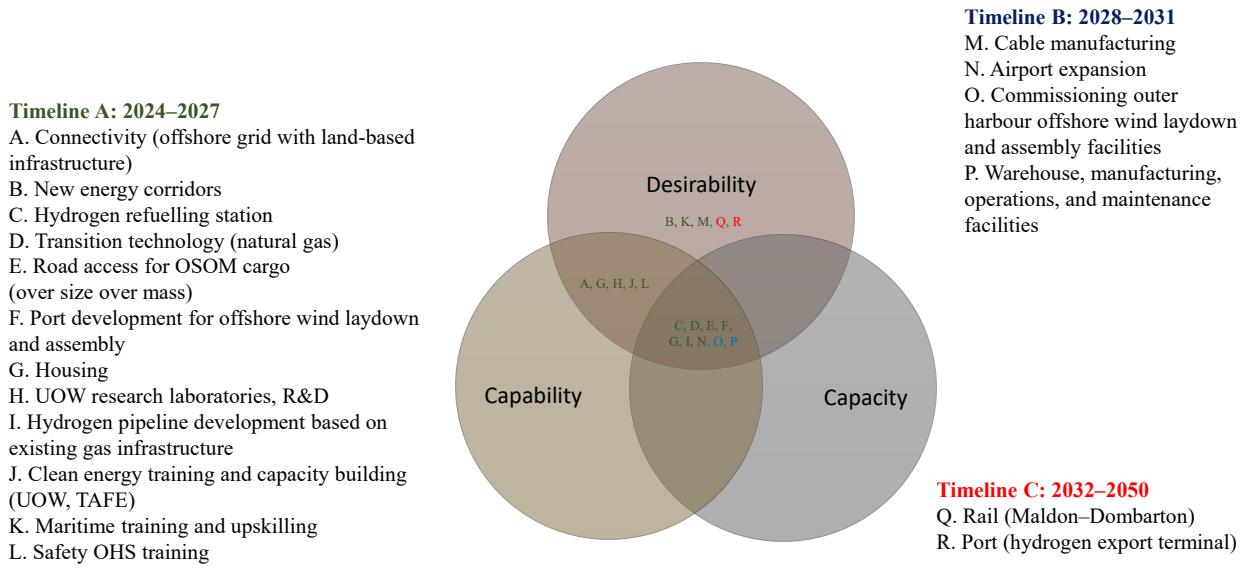


Figure 26: Energy Distribution and Enabling Infrastructure.

Industry desirability with existing regional capacity and existing regional capability:

Developing Port Kembla to enable it to support the offshore wind industry in the Illawarra, Hunter, and Gippsland regions is critical and is an immediate priority to commence within Timeline A. In relation to onshore wind and other renewables projects, enhanced road access for Over Size/Over Mass (OSOM) components will also enable the Illawarra to supply imported and locally produced componentry to regions within the state. The Illawarra has a history of coke oven gas production (60% of which is hydrogen) as part of making high value coke. The region has a familiarity of using hydrogen rich gases in steelmaking. Additionally, local established gas producers such as Coregas and BOC bring expertise in hydrogen production, storage, transport and liquefaction that can be leveraged to further develop hydrogen supply chains. Finally, in the medium-term airport infrastructure upgrades have also been identified.

Industry desirability that requires regional capability development:

Capability gaps currently exist to tackle desired opportunities regarding grid connectivity (offshore to onshore), worker shortages worsened by housing development challenges, UOW R&D due to

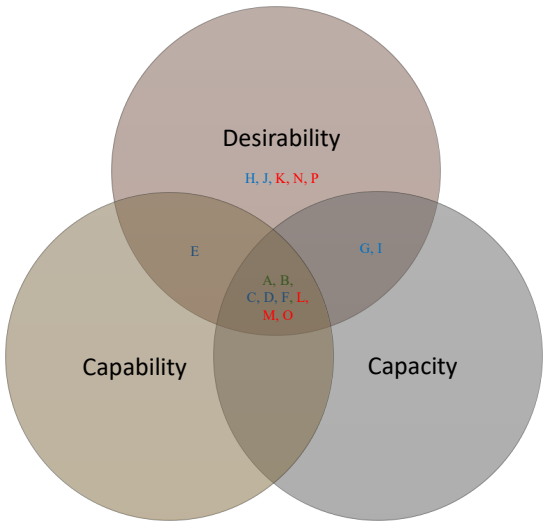
funding and budget constraints and human resource training and development for the clean energy transition industry.

Industry desirability that requires regional capacity and regional capability development:
The development of new transmission corridors, the establishment of a maritime skills centre, cable manufacturing (bringing back a previously established industry), rail infrastructure development and a port hydrogen export terminal have all been identified as desirable for the Illawarra but with limited capacity and capability available now.

4.4.2 Clean Energy Generation

Figure 27 provides an overview of the identified opportunities in clean energy generation with most opportunities stemming from the emerging offshore wind industry.

Timeline A: 2024–2027
A. Steel sub-structures for large scale solar farms
B. Rooftop Solar



Timeline B: 2028–2031
C. Support construction of fixed bottom offshore wind turbines
D. Pre- and final assembly of turbines
E. Marine offshore support industry
F. Floating platform manufacturing
G. Fixation of turbines (seabed anchors and ropes)
H. Marine offshore support industry (offshore vessels, maintenance, inspection)
I. Main tower manufacturing
J. Mooring lines (chains, synthetics)

Timeline C: 2032–2050
K. Component manufacturing/ assembly (e.g. taper at top of wind turbine)
L. Gearbox maintenance
M. Offshore and onshore spares and maintenance excluding vessels
N. Port support during windfarm, operation and maintenance phase
O. Infrastructure upgrade hydro
P. End-of-Life (decommissioning and CE)

Figure 27: Energy Generation: Offshore Wind, Solar, Hydro, and Biogas.

Industry desirability with existing regional capacity and existing regional capability:

The existing heavy construction industry in the Illawarra has demonstrable capabilities and capacities in manufacturing of large infrastructure components such as offshore oil rigs. These capacities and capabilities are transferrable to the manufacturing of the sub-structures (e.g., floating windfarm components or solar farm support structures) for as well as the assembly and decommissioning (de-assembly) work. In the long-term, turbine maintenance as well as wind energy maintenance opportunities are highly desirable. Finally, the further extension of roof top solar and the Kangaroo Valley pumped-hydro energy storage scheme have been identified as desirable opportunities long-term that can proceed with existing capability and capacity.

Industry desirability that requires regional capacity development:

The Illawarra region has existing capability in the provision of maritime services. An investment in capacity is required to unlock the opportunity to establish the region as a maritime service centre for offshore windfarm deployment and maintenance services. Here services range from marine certifications, seabed surveys and telemetry, engineering design services and environmental services, geophysical services but also vessel maintenance and offshore inspections.

Industry desirability that requires regional capability development:

Two desired opportunities have been identified that lack current capability, namely fixation technology for floating offshore wind infrastructure such as seabed anchors and ropes as well as the manufacturing of wind towers.

Industry desirability that requires regional capacity and regional capability development:

Larger investments are required to unlock opportunities as regards the establishment of a marine offshore supplier industry including the provision of vessels, inspection, and maintenance. In addition, manufacturing of mooring lines such as chains and synthetics would complement this emerging marine industry. Finally, long-term capabilities in taper manufacturing are desirable but lack regional capacity and capability. Noteworthy is the opportunity for capacity and capability development around decommissioning. Here, BlueScope has key enabling infrastructure (blast furnace and electrolytic steel making) to unlock this circular economy infrastructure opportunity.

4.4.3 Clean Energy Storage

Figure 28 provides an overview of the identified opportunities in clean energy storage with most opportunities stemming from emerging start-up companies.

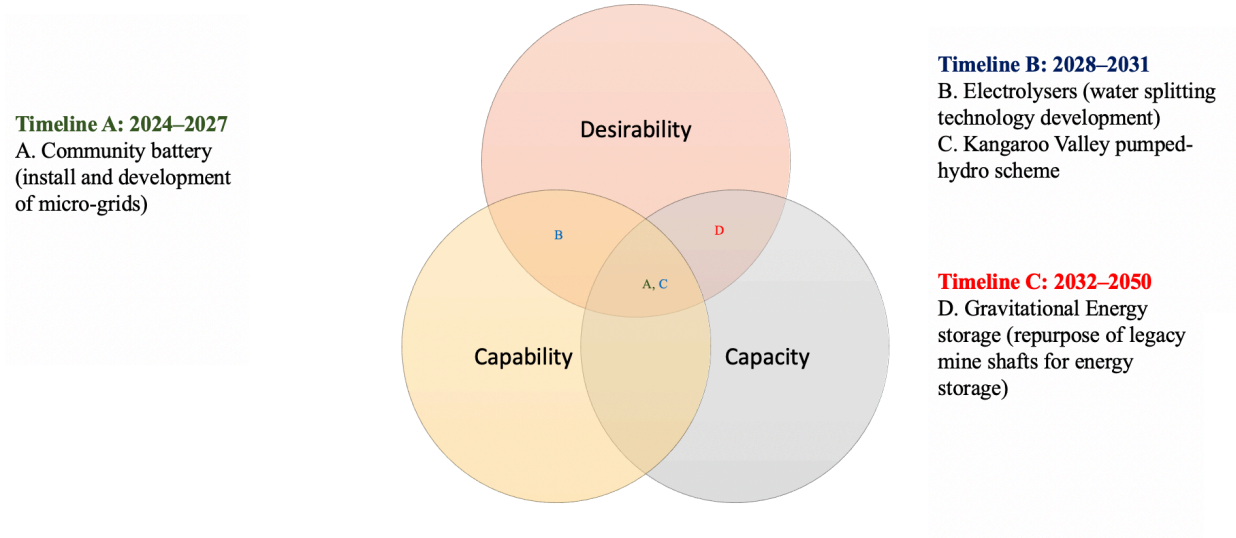


Figure 28: Energy Storage: Battery, Gravity, Green Hydrogen/Ammonia.

Industry desirability with existing regional capacity and existing regional capability:

An opportunity within existing capacities and capabilities is the roll out of more community batteries and the establishment of micro-grids. Here, excess rooftop solar energy charges the community battery during daytime to be released during night-time. Leveraging community focussed initiatives such as Electrify 2515 into an overall regional clean energy industry for households could significantly increase local economic activity for locally based installers.

Industry desirability that requires regional capacity development:

Emerging technologies in the space of electrolysers are promising and support the growing green hydrogen industry.

Industry desirability that requires regional capability development:

This is an emerging technology with the objective to reactivate retired mineshafts and ventilation shafts for gravitational energy storage. The technology is currently being developed, simulated, and trialled. A deployment at scale is likely to occur later in this decade.

4.4.4 Alternative Industries

The clean energy transition in the Illawarra region also creates innovation spillover into alternative industries. Figure 29 presents these opportunities. Interestingly, no opportunities have been identified that can be tackled with existing capacity and capability.

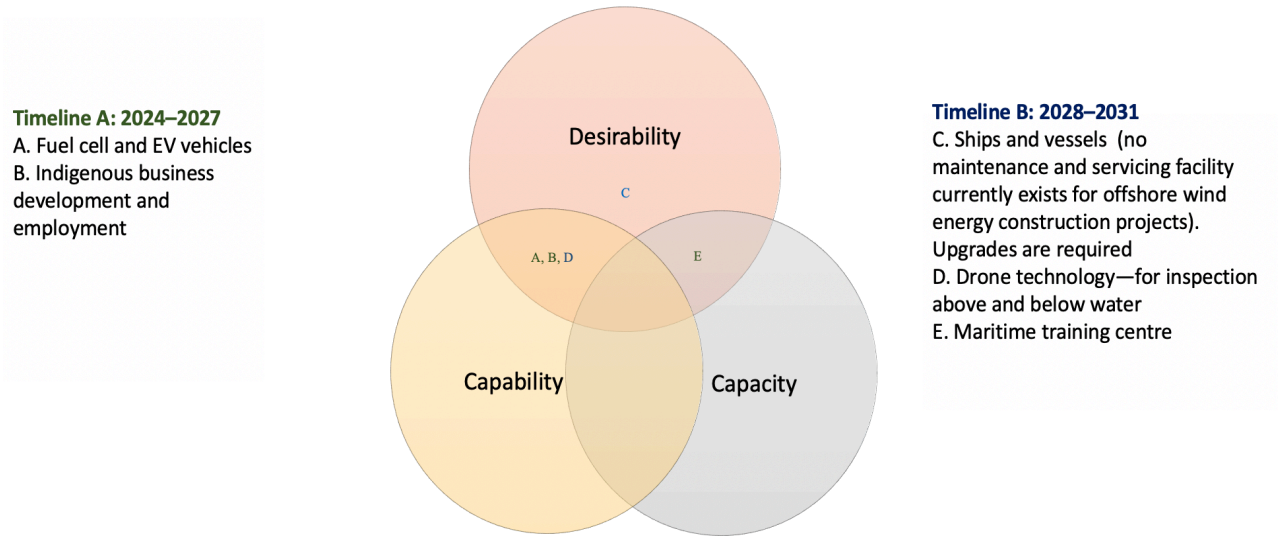


Figure 29: Spillover and Alternative Opportunities in Clean Energy Industries.

Industry desirability that requires regional capacity development:

Capacity development is required to enable the manufacturing of fuel cell and EV vehicles, in particular trucks, buses, planes, and ships. The same holds true for the development of various drone technology required for inspection (above and below water). Further, capacity development is required to unlock the potential amongst First Nations people. Opportunities that are ocean based are highly desired amongst First Nation people.

Industry desirability that requires regional capability development:

A maritime training centre is highly desirable in the medium term, with the roll-out of a striving wind industry and the associated offshore maritime support industry.

Industry desirability that requires regional capacity and regional capability development: Upgrading Ships and Vessels: Necessary for offshore wind energy construction, requiring public approval, and capacity investment for successful implementation.

After unpacking and examining the significant opportunities available to the Illawarra region, the report now focuses on the next section, which outlines a strategic roadmap for guiding the region's development and realising these opportunities.

4.5 Less Desirable Opportunities for the Illawarra

Generally, the stakeholder interviews revealed several areas within the clean energy sector that are considered less desirable for development in the Illawarra region, primarily due to economic, logistical, and environmental challenges.

4.5.1 Energy Generation

The manufacturing of gearboxes and nacelles for wind turbines was identified as economically infeasible for the Illawarra region. With all gearbox production currently based overseas and limited domestic demand in Australia, stakeholders noted that establishing local manufacturing facilities would not be viable. Similarly, nacelle production faces the same obstacles, as the global supply chain for these components is well-established, and local demand is insufficient to justify investment in this area.

The development of offshore substations was also seen as a less desirable opportunity for the region. With significant lead times of 6–7 years already established by international companies like Hitachi, and Newcastle identified as a more suitable location for this infrastructure, the Illawarra region would face stiff competition and logistical challenges in pursuing this opportunity. This diminishes the attractiveness of investing in offshore substation projects locally.

The prospect of establishing blade manufacturing for wind turbines in the Illawarra region was similarly viewed with caution. The global market for wind turbine blades is highly competitive, with established players dominating production. Given the limited local demand, the region is unlikely to sustain such operations, making it a less favourable option for investment.

While floating solar panels offer some advantages, such as reducing evaporation and cooling the panels when placed in water bodies, the technology is still in its trial phase in Europe (companies like DEME in Belgium). Moreover, the regulatory framework in Australia is unclear, adding further uncertainty and reducing the desirability of pursuing this opportunity in the Illawarra region at this time. Furthermore, the recycling of entire solar panels, including their steel infrastructure, was another area identified as less promising.
The technology for effective recycling is still developing, and the infrastructure necessary to support such an industry is better suited to regions like Victoria or the Hunter, which already have established facilities, such as aluminium smelters. This makes the Illawarra region a less ideal location for such operations.

Finally, the development of new hydro projects in the region was viewed as less desirable due to high costs, potential impacts on biodiversity, and modest energy returns. The environmental trade-offs associated with new hydro plants, combined with the limited benefits they would produce, make this option less attractive compared to other renewable energy sources.

4.5.2 Energy Storage

The stakeholder interviews reveal that certain energy storage solutions are considered less desirable for the Illawarra region, primarily due to geographic limitations and concerns about energy capacity. One of the key findings is the limited viability of pumped hydro as an energy storage option in the Illawarra (Kangaroo Valley the exception). Pumped hydro relies on suitable geological and hydrological conditions, which the region lacks. The absence of appropriate sites that meet these criteria makes the development of pumped hydro systems infeasible. Without the necessary physical conditions to support such infrastructure, the Illawarra region cannot realistically pursue this option, despite its proven effectiveness in other contexts.

Hydrogen storage infrastructure, especially for export purposes, was also identified as less desirable. Stakeholders raised concerns about the region's ability to generate enough clean energy to meet even local demand, casting doubt on the feasibility of producing surplus energy for hydrogen export. The high local energy demand, coupled with uncertainties about future clean energy generation capacity, limits the practicality of developing hydrogen storage for export. Additionally, the existing role of coking coal in hydrogen production further diminishes the urgency for new hydrogen storage infrastructure in the region, as current production methods already facilitate export.

4.5.3 Energy Distribution, Enabling Opportunities, Spillover and Alternative Opportunities

The stakeholder interviews reveal several energy distribution and enabling infrastructure opportunities in the Illawarra region that are currently considered less desirable due to practical, geographic, and technological challenges. The development of synthetic fuels, such as dimethyl ether (DME) as an alternative to diesel, was identified as less desirable for the Illawarra. The production of these fuels requires large areas of agricultural land to grow the necessary feedstocks, which the Illawarra region lacks. Without suitable land, the region is not well-positioned to support the development of synthetic fuel production facilities, making this an impractical option for the region's energy strategy.

The potential for co-locating aquaculture, such as seaweed and mussel farming, with offshore wind farms was also deemed less attractive. Stakeholders pointed to international examples, particularly in Belgium, where similar mixed-use initiatives have struggled to succeed. The complexities of managing both aquaculture and wind energy production in the same marine space pose significant operational challenges, leading to the conclusion that this approach may not be viable for the Illawarra region.

The recycling of electronics and batteries at the end of their life cycles was another area identified as less desirable. While the broader concept of establishing a centre for the circular economy in the Illawarra has potential, particularly in recycling high-value metals beyond steel, specific challenges remain. For instance, a specialised furnace would be required to recycle electronics effectively, and while there is potential in the battery recycling sector, the necessary policies and technologies are still

underdeveloped. The region's role in this area may depend on strategic investment and advances in technology and policy frameworks.

The end-of-life recycling of carbon fibre blades from wind turbines was also seen as less feasible. Currently, the technology to recover these materials is not sufficiently advanced, making it difficult to justify investment in this area. However, stakeholders acknowledged that ongoing research and development could eventually make this a more viable opportunity. As the technology and processes improve, the Illawarra region could potentially position itself as a leader in recycling and circular economy practices.

In summary, the findings suggest that while the Illawarra region has significant potential in the clean energy sector, some opportunities may not align with its current capabilities or long-term goals. Stakeholders recommend focusing resources on areas where the region can gain a competitive advantage, rather than investing in less viable options like pumped hydro, hydrogen storage for export, synthetic fuels, co-located aquaculture, and end-of-life recycling of certain materials. However, with targeted investment and advancements, the region could still play a key role in the circular economy and sustainable energy solutions.

4.6 Regional Roadmap

The roadmap for implementing the identified opportunities in the clean energy sector is built upon several existing and ongoing initiatives underway in Illawarra Shoalhaven.

Five distinct stages have been identified that will position the Illawarra as Australia’s leading centre in Green Advanced Manufacturing and Logistics by 2050.

Incorporating social licensing practices that engage local communities and stakeholders — giving importance to social investment and cultural sensitivity — is central to achieving long-term success and fostering sustainable, inclusive development.

Stage 1 therefore focuses on policy implementation and obtaining a social license from community to embark on the clean energy transition journey collectively.

Stage 2 puts the enabling infrastructure in place that supports the clean energy transition and the diversification of the regional economy (Stage 3).

Stage 4 focuses on the implementation of the ongoing service provision, whilst Stage 5 establishes the region as Australia's centre for a green advanced manufacturing and logistics.

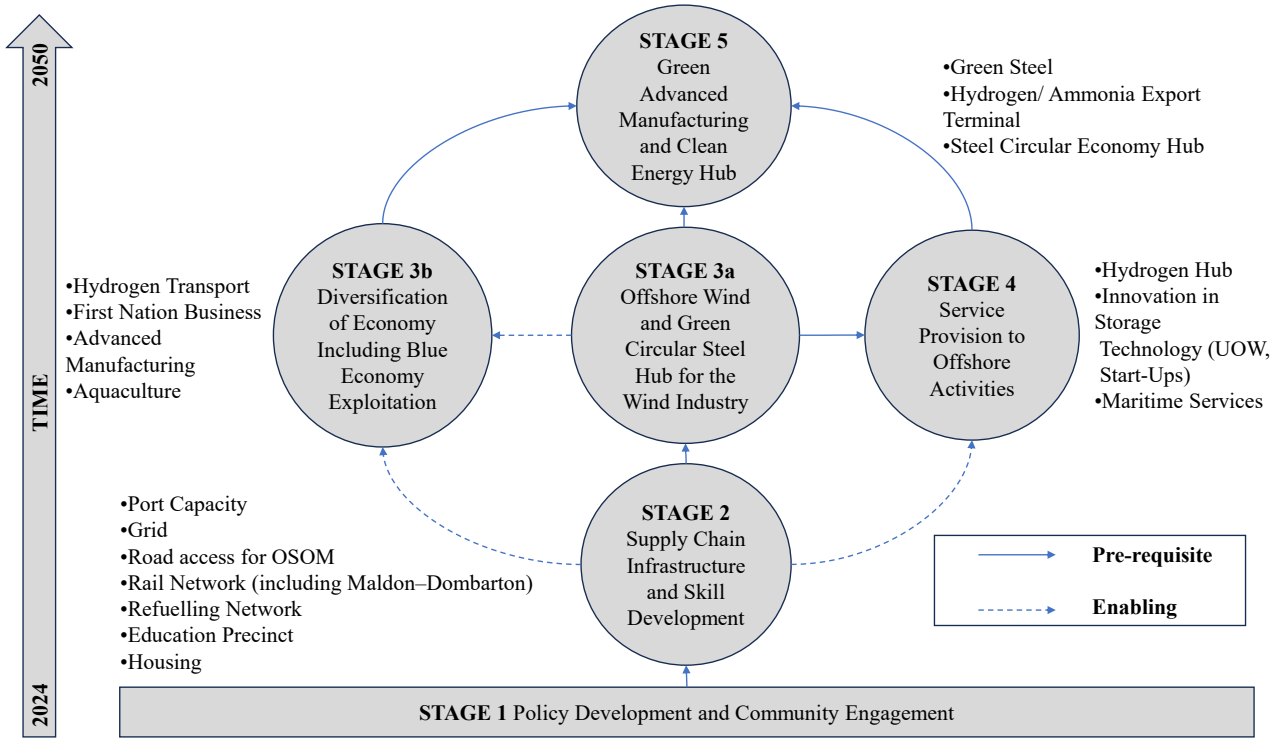


Figure VII. Roadmap for the Illawarra Shoalhaven.

Stage 1: Leveraging Policy Direction and Development and Community Engagement

- Co-designing the clean energy transition with the local community
- Align the narrative amongst critical government and industry stakeholders
- Leveraging the National and State policies to support long-term emissions reduction goals
- Develop predictable and credible implementation plans, support specific technology areas, and create enabling conditions for successful implementation

Stage 2: Supply Chain Infrastructure and Skill Development (2030+)

- Key infrastructure upgrades, particularly at Port Kembla, are necessary to support the development of offshore wind and hydrogen projects
- Educational precinct development to enable workforce development and workforce transition

Stage 3a: Offshore Wind Enabler and Green Circular Steel Hub for the Wind Industry (2030+)

- The region a major player in offshore wind energy and hydrogen production
- Manufacturing of components for offshore wind turbines, producing green hydrogen for domestic use and export, developing a green steel industry powered by renewable energy, and recycling clean energy infrastructure

Stage 3b: Diversification of Economy including Blue Economy Exploitation (2030+)

- The port and the offshore wind industry enable the Illawarra to diversify its economy through mixed-use of spatial marine zoning
- Aquaculture industries co-located with the offshore wind parks including post-harvest processing facilities
- An opportunity to strengthen the economic self-determination of Aboriginal communities.
- Connectivity to export markets by air via the Western Sydney Airport and the Maldon to Dombarton rail link are critical for the industry to take off.

Stage 4: Service Provision to Offshore Activities (2030+)

- Offshore wind industry and the aquaculture industry require marine-based maintenance and service provision.
- Positioning the Illawarra as a maintenance hub for the offshore wind industry with land available to host warehouses for spare parts (e.g. engineering consultancy, education, skill development, R&D, divers, logistics, vessel maintenance).

Stage 5: Advanced Manufacturing and Clean Energy Hub (2050+)

- Illawarra and Shoalhaven region is Australia's future hub for sustainable industries in green steel and hydrogen/ ammonia.
- Illawarra and Shoalhaven region as a producer and exporter for clean hydrogen/ammonia to international markets.

4.6.1 Critical Success Factors Needed for a Successful Transition

For Illawarra Shoalhaven industry to fully realise its potential, three key areas of support are needed for success:

By focusing on local content, infrastructure upgrades, and targeted financing, the region can attract investment, create jobs, and drive sustainable economic growth.

Economic Benefits of Clean Energy Growth in the Illawarra Region

The Illawarra region stands to gain substantial economic benefits from investments in clean energy, particularly through the development of offshore wind, hydrogen production, and advanced energy storage solutions. These sectors are poised to transform the region into a clean energy hub, driving job creation, GDP growth, and infrastructure development.

1. Offshore Wind: A Catalyst for Regional Economic Growth

The declaration of a **2.9 GW offshore wind zone in Illawarra** is projected to bring significant economic gains. Based on studies from similar offshore wind developments globally, the economic benefits can be quantified as follows:

a) Job Creation:

- **Construction Phase (2025-2030)**: Approximately 4,000 to 6,000 direct jobs are expected during the construction phase, including roles in turbine assembly, installation, cabling, and port upgrades.
- **Operations and Maintenance (2030 onwards)**: Around 500 to 1,000 permanent jobs could be generated in long-term operations, maintenance, and logistics support for offshore wind farms.
- **Supply Chain and Indirect Jobs**: For every direct job in offshore wind, studies indicate there are typically 1.5 to 2 indirect jobs created in supporting industries (manufacturing, logistics, and professional services). This could result in an additional 6,000 to 8,000 jobs over the lifespan of the projects.

b) Economic Output:

- The construction of offshore wind farms could inject **AUD 2.5 billion to 3 billion** into the regional economy, based on investments in infrastructure, local procurement, and workforce salaries.

- Once operational, offshore wind farms are estimated to contribute **AUD 300 million to 500 million** annually to the Illawarra economy through ongoing operations, maintenance, and local spending.

c) Regional GDP Impact:

- Offshore wind developments could increase the Illawarra region's GDP by an estimated **1.5% to 2% annually** over the next decade.
- Drawing parallels from similar projects in Europe, such as the UK's Dogger Bank Wind Farm, regions with significant offshore wind investments have experienced GDP growth of up to 2.5%.

2. Hydrogen Production and Clean Energy Storage

In addition to offshore wind, the **Port Kembla Hydrogen Hub** and associated green hydrogen projects are set to boost the Illawarra region's economic landscape.

a) Hydrogen Hub Economic Benefits:

- The development of hydrogen production facilities at Port Kembla is expected to attract **$1 billion in investments** over the next five years.
- This initiative is projected to generate **2,000 direct and indirect jobs**, particularly in high-skilled areas such as chemical engineering, plant operations, and logistics.
- Hydrogen exports could bring in **$250 million to $400 million annually** by 2030, as Australia positions itself as a key player in the global hydrogen market.

b) Community Battery and Storage Solutions:

- Deployment of community batteries and microgrids could result in **$200 million to $300 million** in economic activity, with jobs focused on electrical engineering, installation, and maintenance.
- These initiatives are also expected to reduce energy costs for local communities, freeing up consumer spending and driving regional economic growth.

3. Broader Economic and Social Benefits

Beyond direct economic impacts, the growth of the clean energy sector in Illawarra will have broader social and environmental benefits:

a) Skill Development and Workforce Transition:

- The establishment of training centres, such as the Clean Energy Futures Skills Centre, is expected to upskill **3,000 to 5,000 workers** over the next decade, ensuring a sustainable workforce transition from traditional industries to clean energy sectors.
- Investment in education and training will attract younger generations to STEM fields, boosting long-term employment rates and regional talent retention.

b) Infrastructure Upgrades and Regional Revitalisation:

- Investment in grid connections, transmission lines, and port upgrades will have spillover effects, enhancing the region's attractiveness for other industries, including advanced manufacturing, logistics, and export services.
- The enhancement of infrastructure could increase property values and generate **$100 million to $200 million** in additional tax revenues for local governments.

Table 13: Summary of Economic Impact Projections

Category	**Economic Impact**
Offshore Wind Construction	$2.5 billion to $3 billion (one-time investment)
Offshore Wind Operations	$300 million to $500 million annually
Hydrogen Production & Exports	$1 billion (investment) + $250 million annually
Community Batteries & Storage	$200 million to $300 million (one-time investment)
Total Job Creation	10,000 to 15,000 jobs (direct, indirect, and induced)
Regional GDP Growth	1.5% to 2% increase annually over the next decade
Tax Revenue Generation	$100 million to $200 million annually

By strategically investing in clean energy infrastructure and workforce development, the Illawarra region can position itself as a leader in Australia's energy transition. This approach not only supports sustainable economic growth but also drives social and environmental benefits for local communities. For Illawarra Shoalhaven industry to fully realise this potential, three key areas of support are needed for success:

1. Policy and regulatory support:

A robust policy framework is important to drive investment and ensure long-term project security. Policy measures should focus on incentivising renewable energy investments, ensuring local content

requirements in energy projects, and providing certainty for investors. Regulatory clarity, especially in areas such as offshore wind, hydrogen, and energy storage, is critical for attracting investment and fostering growth in the clean energy sector. Government incentives, such as tax breaks and grants, are also necessary to reduce the risk profiles of new clean energy ventures and encourage innovation. A stable policy environment that aligns state and federal regulations will help mitigate investor concerns and accelerate project timelines. Supportive policies are essential to create a conducive environment for clean energy investments and ensure long-term project viability.

Key Policy Recommendations:

- Long-term Clean Energy Targets: Set clear and ambitious regional clean energy targets aligned with national net-zero goals to provide certainty for investors and project developers.
- Renewable Energy Purchase Agreements (REPA): Encourage the adoption of REPAs by local industries, enabling them to source a significant portion of their energy from renewable sources, thus driving demand for clean energy projects.
- Carbon Pricing and Emissions Trading Schemes: Advocate for the introduction of carbon pricing or emissions trading schemes to incentivise the transition away from fossil fuels and promote investments in low-carbon technologies.
- Local Procurement Policies: Implement policies that prioritize local suppliers and contractors for clean energy projects to maximize economic benefits for the Illawarra community.
- Research and Development Incentives: Increase funding for R&D in clean energy technologies through grants, tax credits, and partnerships with universities and industry.

2. Workforce development:

Developing a skilled workforce capable of managing and operating advanced clean energy technologies is essential for the region's transition. Collaboration between educational institutions, government bodies, and private industry will be crucial to upskilling the current workforce and training the next generation of workers in clean energy technologies. The roadmap calls for the establishment of educational programs and training centres that focus on renewable energy, advanced manufacturing, and hydrogen technologies. This roadmap aims to implement Australia's National Energy Workforce Strategy within the region. Illawarra's workforce has a strong foundation in heavy industry, which can be leveraged for the clean energy sector. However, retraining programs and skills development will be required to equip workers with the technical expertise needed for new roles in

offshore wind, hydrogen production, and advanced manufacturing. The transition to a clean energy economy requires targeted workforce development initiatives to upskill existing workers and prepare new entrants for roles in emerging industries. The Illawarra region, with its established educational institutions such as the University of Wollongong (UOW) and TAFE Illawarra, is well-positioned to deliver specialised training programs in renewable energy technologies.

Key initiatives include:

- Clean Energy Futures Skills Centre: The establishment of a skills centre dedicated to training in offshore wind, hydrogen, and battery technologies is crucial. This centre could train up to 1,000 new workers annually in critical areas like electrical engineering, fabrication, project management, and environmental services.
- Super TAFE Facility: Expanding the capabilities of the TAFE system to include certifications and apprenticeships in renewable energy technologies. Courses could cover fields such as marine engineering, subsea cabling, and offshore platform maintenance, aligning with industry needs.
- STEM Education Initiatives: Investing in STEM education for younger students is vital to ensure a future pipeline of skilled workers. Partnerships with local schools and community organizations can promote careers in clean energy.

The clean energy transition will create jobs across a range of skill levels, from entry-level positions to highly specialised technical roles. Below is an overview of the types of jobs expected to be in demand.

Tertiary Qualified Jobs:

- Electrical Engineers: Responsible for designing and maintaining electrical systems for offshore wind turbines, hydrogen electrolysers, and battery storage systems.
- Marine and Environmental Engineers: Specializing in offshore wind infrastructure, these roles focus on the sustainable design, deployment, and maintenance of marine-based energy systems.
- Project Managers: Overseeing the planning, execution, and commissioning of large-scale renewable projects, ensuring timelines and budgets are met.

Vocational Qualified Jobs:

- Fabrication and Mechanical Trades: Involved in manufacturing components for turbines, solar panels, and hydrogen storage systems.

- Technicians: Skilled in installing, operating, and maintaining energy storage systems like community batteries and electrolysers.
- Vessel Operators and Maritime Support: Required for offshore wind farm maintenance and logistics.

Key Support Jobs:

- Construction Workers: Supporting the installation of renewable energy infrastructure, particularly in offshore wind projects.
- Logistics and Supply Chain Coordinators: Managing the transportation of components and materials for project construction.
- Administrative and Support Staff: Providing necessary back-office support for project planning and execution.

Regional Support for Workforce Development:

To support the anticipated growth in clean energy jobs, the Illawarra region can leverage several strategic initiatives:

- Public-Private Partnerships: Collaboration between government, industry, and educational institutions to fund and develop targeted training programs. These partnerships can focus on filling skills gaps, particularly in offshore wind and hydrogen sectors.
- Investment in Housing and Infrastructure: Addressing housing shortages and improving transport infrastructure will be crucial to attract talent to the region. This includes affordable housing projects and enhanced road and rail connectivity.
- Community Engagement: Building social license through community co-design initiatives ensures that local populations are engaged and benefit from clean energy projects. This approach promotes inclusivity and enhances community support for new developments.

3. Supply chain solutions:

Energy storage is essential for ensuring grid stability and managing fluctuations in renewable energy generation. There is a need for large-scale battery installations, hydrogen storage solutions, and innovative gravity storage systems that can store energy for use during periods of low renewable generation. Additionally, the development of a robust supply chain including enabling infrastructure for renewable energy components is necessary to overcome potential bottlenecks and delays in project implementation. Local manufacturing capabilities, particularly in steel production and

advanced manufacturing, offer an opportunity to produce key components for the clean energy industry. Developing these capabilities will reduce reliance on imported components and create jobs within the region.

To fully leverage the significant opportunities in the Illawarra region's clean energy sector, it is crucial to establish robust governance structures, develop necessary infrastructure, and implement strategic financing mechanisms. These enablers will provide the foundation for successful project development, attract investment, and ensure community and industry stakeholders are aligned in their efforts to drive the region's clean energy transition.

1. Governance Mechanisms

Effective governance is vital to streamline project approvals, coordinate efforts across different government levels, and engage with stakeholders, ensuring that clean energy initiatives align with local priorities.

Key Governance Recommendations:

- Local Content Rules: Implement regulations that require a minimum percentage of local content for renewable energy projects. This approach will ensure that local businesses and suppliers benefit directly from investments in the sector. For example, offshore wind projects can include requirements for local fabrication, assembly, and maintenance.
- Benefit Sharing Agreements with Developers: Establish agreements with developers that ensure a portion of the profits or benefits from projects is reinvested into the local community. This can include funding for community programs, training initiatives, and infrastructure development.
- Streamlined Approvals Process: Consider creating a centralised "Clean Energy Development Office" in the Illawarra to fast-track approvals for clean energy projects, reducing bureaucratic delays. This office can coordinate with state and federal agencies to streamline processes for permits, environmental assessments, and grid connections.
- First Nations Co-Design Engagement: Engage with Indigenous communities through co-designed strategies that respect traditional knowledge and provide opportunities for direct participation in projects. Establishing a clear and transparent process for Indigenous consultation will support the social license for clean energy projects.
- Regional Clean Energy Task Force: Form a task force comprising representatives from government, industry, educational institutions, and community groups to oversee the

implementation of the Illawarra Clean Energy Roadmap. This body can help align strategic initiatives, monitor progress, and adapt plans as needed.

2. Infrastructure Development

Developing the right infrastructure is crucial to support the Illawarra region's transition into a clean energy hub. This includes upgrading existing assets, creating new facilities, and ensuring integration with the national energy grid.

Key Infrastructure Recommendations:

- Grid Connection Points and Transmission Lines: Invest in expanding grid infrastructure to connect offshore wind farms, hydrogen production facilities, and community batteries to the national electricity grid. Priority should be given to establishing new grid connection points in the Illawarra REZ to support offshore wind and green hydrogen projects.
- Port and Logistics Infrastructure: Upgrade Port Kembla to accommodate large-scale offshore wind installations, hydrogen export, and green steel manufacturing. This includes improving OSOM (Over Size Over Mass) transport routes for wind turbine components and investing in specialized maritime facilities for maintenance and decommissioning.
- Hydrogen Refuelling Stations: Develop a network of hydrogen refuelling stations to support the region's transition to low-carbon transport, particularly for heavy vehicles and public transport systems.
- Energy Storage Facilities: Support the rollout of community batteries, gravity storage solutions, and green hydrogen storage to enhance grid stability and maximize the use of locally generated renewable energy. These initiatives will reduce reliance on fossil fuel-based power during peak demand periods.
- Super TAFE and Clean Energy Skill Centres: Invest in developing world-class education and training facilities, focusing on offshore wind, hydrogen technologies, and renewable energy integration. Expanding the capabilities of TAFE and UOW to offer specialized courses will ensure a pipeline of skilled workers.

3. Financing Mechanisms

Access to capital and effective financing models are essential to attract investment in large-scale clean energy projects. The Illawarra region can benefit from a mix of public and private financing to unlock its potential as a clean energy leader.

Key Financing Recommendations:

- Green Bonds and Public-Private Partnerships (PPPs): Establish green bonds and PPPs to fund critical infrastructure projects, such as offshore wind farms, hydrogen production facilities, and grid upgrades. Green bonds can attract sustainable finance from institutional investors focused on ESG (Environmental, Social, Governance) criteria.
- Clean Energy Investment Fund: Create a dedicated regional investment fund to support clean energy startups, advanced manufacturing, and research initiatives. This fund can provide grants, low-interest loans, and equity investments to catalyse innovation and commercialization of new technologies.
- Incentives for Local Manufacturing: Offer tax incentives and grants for companies that establish manufacturing operations in the region, particularly those focused on producing components for wind turbines, electrolysers, and battery systems. This can boost job creation and enhance local supply chains.
- Benefit-Sharing Agreements: Structure financing models that include benefit-sharing clauses, where a percentage of revenue from projects is allocated to local community development funds. These funds can be used for social programs, skills training, and infrastructure improvements.
- Government Subsidies for Early-Stage Technologies: Provide subsidies and rebates for early-stage technologies, such as electrolyser manufacturing, gravitational energy storage, and offshore wind maintenance. These subsidies can reduce the financial risks for new entrants and attract international firms to the Illawarra.

4.6.2 Challenges Facing the Transition

The clean energy transition presents significant challenges in terms of supply chain, skills and policy uncertainty.

These challenges are impediments to the clean energy transition, hindering progress, and reducing the potential impact of this crucial initiative in the region.

The identified challenges highlight the critical areas that must be addressed to achieve the region's clean energy goals.

By understanding these challenges, the region can develop targeted strategies to overcome them, thereby ensuring a more successful and impactful transition.

Table 14. List of Identified Barriers

Barriers	Details
Supply Chain	Bottlenecks in global critical component and equipment supply chains for clean energy transition.
Skills	Shortages in specific/specialised skills or talent (e.g., electrical engineering, WH&S and other skilled workers).
Demand	Uncertainty in demand due to a lack of an approved project pipeline (e.g., offshore wind projects). This stalls investment in critical infrastructure.
Cost of living	High cost of living in Australia/Illawarra (i.e., unaffordable and unattractive). Attracting international talent becomes increasingly difficult.
Housing	Housing and accommodation shortages.
Government	Red tape, lack of alignment and coordination between local, state and federal government.
Commercial land	Commercial lands are too expensive.
Supply Chain Infrastructure	Lack of electricity network infrastructure to support electrification and decarbonisation (e.g. electric vehicle and hydrogen recharging infrastructure). Lack of transmission and distribution network capacity.
Social licence	Inadequate early education and empowerment initiatives, leading to slower community acceptance of renewable energy projects.
Lack of awareness	Lack of Federal Hydrogen Hub coverage in the region.
First Nations	A clear, co-designed First Nations engagement strategy is lacking that is respective of key knowledge holders from the Illawarra.
Policy uncertainty	Uncertainty surrounding state and federal policies related to clean energy presents risks for investors and project developers.
End of life considerations	De-commissioning and end-of-life demands currently not considered as part of the planning and roll-out process.

Chapter 5: Recommendations and Conclusion

Drawing from the challenges identified in the previous section, these recommendations are specifically designed to address and overcome the challenges to implementing the vision and roadmap for the Illawarra Shoalhaven region.

It establishes a roadmap for clean energy transition regarding supply chain, workforce and policy development over time.

Local content is of critical importance for regional clean energy transition and it requires strong government and local business support.

Each recommendation is crafted with the intent to mitigate the obstacles that currently impede the region's clean energy transition.

By directly targeting these challenges, the recommendations aim to facilitate a more seamless and accelerated shift to clean energy, ensuring that the Illawarra region can fully realise its potential and position itself as a leader in the clean energy sector.

Table 14 provides a comprehensive overview of the five-stage approach highlighted in Figure 30 and complements it with more detailed descriptions and recommendations.

Table 15. List of Key Recommendations

Stages: Illawarra Roadmap	Description	Recommendations
Stage 1: Policy Implementation and Community Engagement	Establishing clear policies and securing community buy-in are essential for advancing the region's clean energy ambitions. This includes engaging local stakeholders, fostering partnerships between government, industry, and community organisations, and ensuring that projects address the needs and concerns of the local population.	• Promote social license — achieving community buy-in through a collaborative co-design process. • Develop a robust local content policy by incorporating international best practices. • Align regional, state, and federal governments to attract industry by developing a cohesive cluster strategy — create industry cluster development.
Stage 2: Supply Chain Infrastructure and Skill Development	The establishment of port infrastructure is necessary to realise the significant growth in the renewable energy sector locally and in the Hunter and Gippsland regions. The Gippsland offshore wind zone will likely be developed ahead of projects in the Hunter and Illawarra zones. While several ports may be developed over time to support offshore wind project developments, Port Kembla, with its existing planning approval for outer harbour development (requiring only minor modification), is well-positioned to be the first port with facilities available to fully support the construction of offshore wind projects. Port Kembla can be developed sooner than alternative East Coast ports to support the advance. Other enabling infrastructure projects are road infrastructure for OSOM transport, housing, grid, hydrogen refuelling networks, rail networks and education precincts. Leverage and expand existing vocational and tertiary skills and education capabilities through educational precinct development to enable workforce development and workforce transition.	• Government to support the development of Port Kembla as the first port on the East Coast to provide facilities enabling offshore wind project construction. • Enhance road infrastructure access for over-sized cargo between the Illawarra and other regions. • Develop policies and incentives that attract complementary clean energy businesses to the Illawarra including housing. • REZ – Asset/Transmission Corridors: The NSW Government, through EnergyCo, should expedite progress to unlock and accelerate the development of Renewable Energy Zones (REZ). • Promote green financing (i.e., government to attract investment).

		• Accelerate establishment of the UOW/TAFE Energy Futures Skills Centre • Accelerate establishment of the enhanced TAFE facility located within the BlueScope redevelopment • Invest in workforce transition training programs for existing workers in traditional industries • Invest in STEM education programs for school students to build a pipeline of STEM capable and engaged young people.
Stage 3a: Offshore Wind Enabler and Green Circular Steel Hub for the Wind Industry	The enabling infrastructure allows for the establishment of an offshore wind industry. The Illawarra is a critical hub for offshore wind floating platform manufacturing and tower assembly. The Illawarra's positioning to port, road, rail, and airport infrastructure offers the opportunity to activate assembly and end-of-life treatment. Decommissioning and recycling work should also include onshore windfarms. The geographical reach for the decommissioning work can be extended to Southeast Asia to meet scrap metal demands. The Port Kembla Steelworks provides the opportunity to establish an 'Illawarra Green Circular Steel Hub' around the wind industry powered by green hydrogen beyond 2030. This offers opportunity to use existing and rehabilitated industrial sites in and around the Port Kembla area such as the BlueScope Master Plan to develop 200 Hectares (Ha) of non-steelmaking, excess landholdings adjacent to the Port Kembla Steelworks to host energy infrastructure whilst leveraging the regions highly skilled workforce and experience in manufacturing.	• Immediate initiation of decommissioning efforts— establish a centre for circularity.

Stage 3b: Diversification of Economy Including Blue Economy Exploitation	The port and the offshore wind industry enable the Illawarra to diversify its economy through mixed-use of spatial marine zoning. Aquaculture industries can be co-located with the offshore wind parks. It presents an opportunity to strengthen the economic self-determination of Aboriginal communities. The aquaculture industry would require post-harvest processing facilities and a more diverse skill set strengthening economic resilience. Connectivity to export markets by air via the Western Sydney Airport and the Maldon to Dombarton rail link are critical for the industry to take off.	• Indigenous communities are both critical stakeholders and essential members of the workforce. To unlock their potential, it is vital to invest in capacity and capability development, with a particular emphasis on ocean-based opportunities.
Stage 4: Service Provision to Offshore Activities	Both the offshore wind industry and the aquaculture industry require marine-based maintenance and service provision. The Illawarra is ideally located as a maintenance hub for the offshore wind industry with land available to host warehouses for spare parts. The service provision includes engineering consultancy, education, skill development, R&D, divers, logistics, vessel maintenance to name a few.	• Promote advanced training and skills development to prepare for future needs. • Encourage/ increase spinouts by investing in R&D within tertiary education and streamlining the process. • Establish a R&D Centre of Excellence for Clean Energy Storage (Gravity, Hydrogen, Ammonia, and others).
Stage 5: Green Advanced Manufacturing and Logistics Hub	Illawarra and Shoalhaven region is designated as Australia's future hub for sustainable industries in green steel and hydrogen/ ammonia production. The region boasts proximity to major ports and transport infrastructure, positioning it ideally for export of hydrogen/ammonia to international markets which is further enabled by the second rail link connected to the Western Sydney cargo corridor, including inland ports. This will enable the Illawarra/ Shoalhaven region to become a critical logistical node in Australia's distribution network that simultaneously unlocks the commercial potential of the NSW South Coast.	• Increase incentives to retain and attract relevant clean energy technology providers that supports the Illawarra in becoming a leading destination for clean energy. • Establish policies that will attract high-skilled individuals through migration of global talent into the Illawarra region.

Achieving the full benefits and goals of the clean energy transition requires a gradual and sustained process. Policymakers and researchers should explore additional areas of focus to enhance this process and identify avenues for growth and development that are critical for Australia to become a leader in the clean energy space. In addition to the previously discussed recommendations for facilitating the transition in the Illawarra region, as outlined in the roadmap, we recommend future research exploring the following areas.

One limitation of this research is the inability to thoroughly discuss and analyse the energy demand of the Illawarra region due to the lack of publicly available data. To address this challenge, it is recommended to establish partnerships with local governments, energy providers, and research institutions to facilitate data sharing and access. Moreover, future research could focus on collecting primary data through surveys and interviews with key stakeholders in the region to gain a better understanding of energy demand patterns.

In the field of labour economics, understanding the impact of the green energy transition on Australia's labour market is essential for assessing how this shift will reshape employment across the country. Such analysis would examine the creation of new jobs in renewable energy sectors like solar, wind, and hydrogen production, whilst also evaluating the decline of traditional fossil fuel industries. This research should address the evolving skill requirements and the need for retraining and upskilling, particularly in regions heavily reliant on fossil fuels. Moreover, it would consider the effects on wages, job security, and the role of government policies in supporting a smooth transition for the Australian labour market. Lastly, in international trade, there is significant potential for the Illawarra region and Australia to benefit from trade partnerships with international companies and countries. Exploring these opportunities in the green energy sector could lead to the development of trade agreements that strengthen Australia’s position in global energy markets.

The conclusion of this review highlights the critical insights that can guide future policy recommendations for the successful implementation of renewable energy (RE) projects at both the regional and national levels. It underscores the importance of enhancing funding mechanisms, fostering partnerships between government, industry, and research institutions, and focusing on both domestic and international opportunities to advance the clean energy transition. Australia's energy transformation is a complex process that requires integrating diverse technologies, policies, and

market strategies. Despite challenges such as the decommissioning of fossil fuel plants and the variability of renewable resources, Australia is well-positioned to lead large-scale innovations in clean energy. By capitalising on opportunities like onshore wind and battery manufacturing, Australia can leverage its comparative advantage to attract investment, generate jobs, and create economic resilience.

Moreover, the Illawarra region exemplifies the potential for regional development through the adoption of renewable energy. Historically known for coal and steel production, the Illawarra is well-positioned to transition its industrial base towards green technologies and renewable energy projects. Through infrastructure development, research, and workforce training, the region can become a leader in clean energy advancements, offering positive employment and economic outcomes. These initiatives align with Australia's broader sustainability goals, creating opportunities for growth and job creation in both the energy and supporting industries. In the long term, a strong circular economy and well-supported clean technology supply chains will be crucial in ensuring that the benefits of the clean energy transition are fully realised, both in the Illawarra region and across Australia. The lessons learned from this research provide valuable guidance for shaping Australia's role as a global leader in the clean energy revolution.

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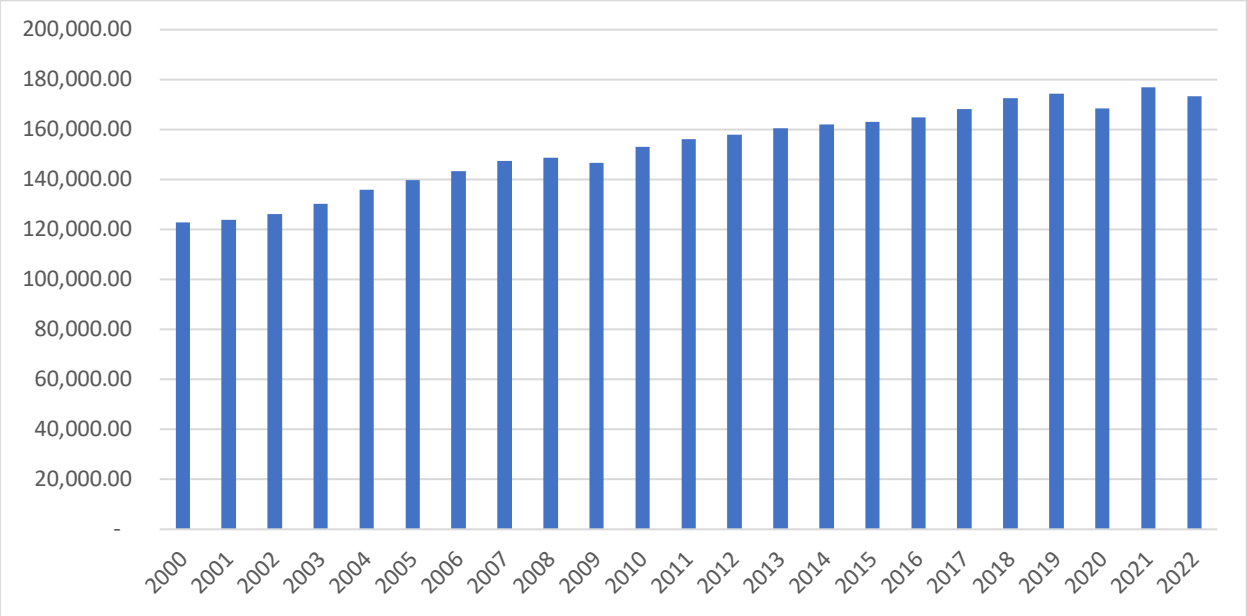
Appendices

Appendix A: Total Energy Consumption (in Terawatt-Hours)



Source: Energy Institute - Statistical Review of World Energy (2023); Smil (2017).

Appendix B: Financial Costs and Economic Impact

	Comparable scenarios			Stretch
	Reference case	Renewables case	Coal case	Accelerated renewables case
Cost 2019-2040 (NPV, $b, Dec-2018$)				
Capital	40.3	44.8	42.7	53.3
Ops & maintenance	37.9	39.0	38.6	38.8
Fuel	42.5	38.0	41.6	33.1
Total system cost	**120.7**	**121.8**	**122.9**	**125.2**
Delta v. reference case	-	*1.1*	*2.2*	*4.5*
Key ratios 2040				
Thermal capacity replaced	47% (15 GW)	47% (15 GW)	47% (15 GW)	60% (19.3 GW)
Renewable generation	65%	79%	61%	90%
Emissions reduction from power generation (vs 2005)	57%	68%	46%	84%
Unserved Energy (USE[25])	<0.002%	<0.002%	<0.002%	<0.002%
Cost of the energy system ($/MWh). *NB this not the wholesale price*[26]	65.1	66.4	67.2	71.6
Economic impact, delta to reference case (NPV, $b, Dec-2018$)				
GDP	-	+13.2	+6.2	+14.8
Consumption	-	+5.6	+0.5	+10.7

Figure 18: Financial Costs and Economic Impact
Source: PricewaterhouseCoopers (PwC), 2019.

Appendix C: Summary of Recommendations for the Solar Supply Chains

Recommendation 1: Support Supply Chain development in Australia

1a. Ensure Australian-Made solar is globally competitive through production credits.

1b. Support establishment of new manufacturing facilities with concessional finance.

Recommendation 2: Drive Demand for Australian-made solar

2a. Extend the Capacity Investment Scheme until 2035

2b. Ensure government procurement supports local industry.

Recommendation 3: Partner with international companies to establish in Australia

3. Ensure timely development of a solar supply chain by securing partnerships with world-leading companies.

Recommendation 4: manufacture zero-emissions solar in Renewable Energy Industrial Precincts (REIPS)

4a. Locate future solar manufacturing in REIPs.

4b. Pre-approve zones within REIPs to streamline establishment of new facilities.

Recommendation 5: Enable the reuse of end-of-life panels through a testing and certification scheme

5. Develop a testing and certification scheme for second hand panels.

Source: Beyond Zero Emissions, Solar Supply Chains, Briefing Paper 2024a.

Appendix D: Summary of Recommendations for the Wind Supply Chains

Recommendation 1: Ensure Volume Certainty by building a secure project pipeline

- Set National Wind Targets of at least 2 GW per annum by 2035 for wind deployment
- Establish a National Wind Strategy for Australia
- Extend the Capacity Investment Scheme until 2035
- Leverage the Capacity Investment Scheme to facilitate collaboration, underwriting demand for wind turbines and securing offtake.

Recommendation 2: Build sovereign supply chain capabilities

- Provide Advanced Manufacturing Tax (MTC) credits for domestic manufactured and sold wind components at several cents per watt for each component.
- Provide a 20% Investment Tax Credit (ITC) for Original Equipment Manufacturers (OEMs) to set up domestic manufacturing facilities.
- Introduce National Minimum Local Content Policy

Recommendation 3: Remove barriers to deployment

- Streamline a transparent permitting and approval processes
- Introduce Government guarantees
- Implement innovative financing mechanisms
- Invest in upskilling and workforce development

Recommendation 4: Ramp up deployment of wind energy

- Reduce the duplication of infrastructure and optimising resource utilisation by investing in shared ports and staging facilities
- Regulate for open data platforms to access critical information that can streamline project planning, site selection, and integration with existing grid infrastructure.
- Develop a national ports strategy to improve logistical efficiencies and reduce transportation costs
- Establish a Comprehensive Community benefit sharing model

Recommendation 5: Promote the circular economy

- End-of-life management
- Use of recycled materials and responsible sourcing practices
- Design for durability and remanufacturing

See the recommendation section for more details

Source: Beyond Zero Emissions, Wind Supply Chain, Briefing Paper 2024b.

Appendix E: Policy Elements to Ensure Plentiful, Decent Jobs

Source: International Renewable Energy Agency (IRENA), Renewable Energy and Jobs Annual Review 2023.

Appendix F: Consent Form

UNIVERSITY OF WOLLONGONG AUSTRALIA

CONSENT FORM

Project title: Illawarra Clean Energy Industry RoadMap: An assessment of the opportunities to maximise regional economic benefits for Illawarra from the transition to clean energy, providing a roadmap for implementation.

Research supervisors: Dr Tillmann Boehme, Faculty of Business and Law, Ty Christopher, Director Energy Futures Network and Dr Makrita Solitei Australian Centre for Ocean Resources and Security (ANCORS).

I have been given a copy of the Participant Information Sheet relating to this study and have had an opportunity to ask the researchers questions about my participation. I understand that if I consent to participate in this study, I will be involved in an interview and/or a focus group (either in person or on Zoom), and/or a photo elicitation exercise. I understand that if I choose to participate in the interview, it will be approximately one-hour duration and it will be recorded and transcribed.

I understand that my participation in this study is voluntary and that I am free to refuse to participate or to leave the interview at any time. I understand that I can change my mind and withdraw the information I have provided from the study for one week after my interview.

I understand that the researchers will be the only people who will have access to identifiable information about me. My name will not be used in any project publications. I also understand that the findings from this study may be published. I understand that publications will not be able to identify me. I understand that if I consent the photos that I take, and some audio/text may be used on a digital storytelling platform. I understand that I can withdraw consent from this.

If I agree, the de-identified data obtained in this project may also be shared with the other researchers so that the research findings can be published and contribute more broadly to knowledge of the social dimensions of offshore wind.

If I have any questions about the research, I can contact Freya Croft (fcroft@uow.edu.au). If I have any concerns or complaints about the way the study has been conducted, I can contact the Ethics Officer on (02) 4239 2191 or by email: uow-humanethics@uow.edu.au.

By ticking the relevant boxes and signing below, I am indicating my consent to participate in this study:

	Yes	No
I consent to participating in an interview/or focus group either online or in person	□	□
I consent to this interview being recorded for transcription purpose	□	□
I request to see a copy of the transcript of my interview prior to analysis and I understand that I must request this transcript within four weeks of my interview	□	□
I consent to participate in a photograph elicitation exercise	□	□
I consent to my photograph potentially being used on a digital storytelling platform (this will not be traced to you)	□	□
I request to review the image before it is used on a digital storytelling platform	□	□
I consent to audio of me being used on a digital storytelling platform. Please state if you have any conditions to this (such as you would like to hear it first, you would like the pitch to be change):	□	□

Consent Form v.4. 29_01_2024

Appendix G: Participant Confirmation Sheet

Participant Information Sheet

TITLE: Illawarra Clean Energy Industry RoadMap: An assessment of the opportunities to maximise regional economic benefits for Illawarra from the transition to clean energy, providing a roadmap for implementation

Purpose of the research

This is an invitation for you to participate in a research project conducted by staff at the University of Wollongong. The purpose of the research is to assess the opportunities to maximise regional economic benefits for Illawarra from the transition to clean energy, providing a roadmap for implementation. The dual focus of this project ensures a holistic approach, recognising the interdependence of economic vitality and social well-being in the sustainable development of clean energy industries. This research aims to integrate a comprehensive analysis of the Illawarra clean energy industry roadmap into an existing study on the social dimensions of emerging offshore industries and coastal community transformations. In partnership with the NSW Business Chambers (NSWBC), this project seeks to assess and harness opportunities that maximise regional economic benefits from the transition to clean energy in Illawarra crafting a detailed implementation roadmap.

Our investigation will closely align with Freya Croft's recent work emphasising the region's adaptation to emerging offshore industries and the subsequent socioeconomic transformations. This integration aims to offer a holistic view of the transition's impacts, ensuring the consideration of both the economic and social paradigms. Both these perspectives will form an understanding of the future aspirations that communities hold for the ocean and coast in this area, developers' and suppliers' supply chain processes, as well as their attitudes to and perceptions of emerging offshore industries. The industry that this research is largely interested in at this stage is offshore wind (Illawarra).

Participant Criteria

To be involved in this project we just ask that you are over the age of 18, have fluent English and work in the clean energy industry.

We have approached you as someone within your organisation with relevant expertise and an appropriate level of authority to provide organisational consent for your participation in the research. If additional approval is needed for participation please forward this information to the appropriate person.

Method and demand on participants

If you choose to be involved in this study, your participation will be informed of semi-structured interviews or focus groups conducted by the researchers for 45-60 minutes. The semi-structured interviews can be done in person or online (on a platform such as Teams or Zoom). Examples of the kinds of questions you will be asked in the interview include:

- Can you please provide us with an overview of yourself, the organisation, and the role within the organisation you are a part of??
- Where in your opinion lies the biggest economic opportunity for the region along the supply chain and in the various stages?
- Where are the biggest bottlenecks in the system (e.g., infrastructure, capability, capacity etc) at this point?
- Where in the supply chain would you see adverse effects?
- Are there any considerations, or plans to incorporate a circular economy within the supply chain to extend the end-of-life of the infrastructure, and direct the waste output?
- Where would you anticipate innovation spillovers alongside the windfarm supply chain to other industries/economies?

The interview will then be used to design a roadmap to the NSW BC in preparation for the transition to clean energy in the Illawarra.

Your Privacy

The interview/or focus group will be recorded on a digital recording device and will later be transcribed. You may request a copy of your interview transcription to review prior to analysis (to do so please email Dr Tillmann Boehme within 4 weeks of the completed interview). All data including the interview recordings, transcripts, and photographs will be de-identified (following analysis) and securely stored according to the UOW Data Management Policies for a minimum of 5 years. Raw data will only be seen by the research team.

Participant Information Sheet (RoadMap)_v.1_19_03_2024