Hunter Hydrogen Roadmap
(2021 – 2040)

Hunter Hydrogen Taskforce
November 2021

ON BEHALF OF A UNIFIED VOICE FOR THE HUNTER | COMMITTEE FOR THE HUNTER

ACKNOWLEDGMENT OF COUNTRY

The Hunter Hydrogen Taskforce respectfully acknowledges the traditional custodians of the lands upon which we work and live in the Hunter and Central Coast regions of NSW. We pay respect to the wisdom of our Elders past, present and emerging.

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MESSAGE FROM THE HUNTER HYDROGEN TASKFORCE

Newcastle and the Hunter are well positioned to harness the tremendous opportunities created by the emerging global market for hydrogen and its many applications.

The Hunter Hydrogen Taskforce (Taskforce) – an initiative led by the University of Newcastle, identified this significant opportunity for the region and has been working to outline a roadmap that will position the region, attract investment and drive economic activity into the future.

The Hunter region is an energy, research and innovation powerhouse, with the complimentary infrastructure and industrial expertise to accelerate renewable hydrogen generation, storage and use. The development of a hydrogen economy in the region is set to provide significant economic benefits including employment and industry growth.

Stakeholders in the region have come together under the Taskforce, and have worked to translate ambition into action including alignment with State and Federal Government initiatives. The Taskforce recognises the power of a collaborative and strategic approach to position and unlock the region for growth, to promote capabilities, and to attract trade and investment partnerships.

The Taskforce has an aligned vision for the region to lead the way in the hydrogen economy and to do it in a way that drives job creation, innovation and growth.

The following members are acknowledged for their generous contribution to the Taskforce and Roadmap development:

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EXECUTIVE SUMMARY

Hydrogen is receiving attention world-wide as a key to the most ambitious undertaking in industrial history – redesigning the way the world is powered to reduce carbon emissions and mitigate the impacts of climate change. Hydrogen can fuel transport and power stations, provide energy for heating and industrial processes, and supply molecular feedstock for sustainable chemicals and material. The variety of ways hydrogen can be produced and used represent a significant opportunity to prosper in the emerging low carbon economy.

Australia is fortunate to have both world-class renewable resources and extensive workforce expertise industrial and resources sectors. The Hunter region of New South Wales is at the forefront of the national advantage with existing infrastructure, a skilled and experienced workforce and proximity to domestic demand centres. With collaboration and by leveraging and strategically positioning existing assets the Hunter can strengthen its position as an international energy powerhouse to harness the opportunity of a hydrogen future.

The production of hydrogen has been part of the Hunter for decades, and with it a suite of specialised skills and expertise. Hydrogen has been produced and handled using traditional steam reforming technology to produce derivative products such as ammonia, fertilisers and explosives for the resources and associated sectors.

Critically, a large-scale green hydrogen industry provides an opportunity to enhance the ongoing economic prosperity of the Hunter, and with it, thousands of jobs including through the sustained employment of skilled workers in the manufacturing and resources sectors, and the establishment of new construction and enterprises in the region.

In 2020 the Hunter Hydrogen Taskforce was formed, an initiative led by the University of Newcastle. The Taskforce was formed to provide a platform for collaboration to navigate a pathway for the Hunter to take advantage of the rapidly emerging hydrogen opportunity.

This Roadmap is the culmination of this work and is intended to provide a shared message and vision for the region and act as a tool for communication to the community, Government and industry stakeholders. The objective of the roadmap is to articulate a strategic vision for hydrogen in the region, outline a targeted set of actions aligned to Federal and State Government priorities, and provide a practical approach to foster a role for hydrogen in the Hunter in the short, medium and longer term.

Strategic Vision: The Hunter will be Australia's leading hydrogen hub and technology cluster, demonstrated by excellence in research, innovation, technology and education, production, use, export and employment participation across the hydrogen supply chain.

We envision that by:

2025	The Hunter region has prepared the market and is recognised as a hydrogen hub and cluster underpinned by its reputation in industry collaboration, research excellence and innovation. The region will have demonstrated that it is an attractive location to pilot and invest in hydrogen production, technologies and applications such as hydrogen fuel cell buses, trucks, cars, ferries, rail, P2X solutions and injection into natural gas pipelines.
2035	The Hunter has deployed and scaled hydrogen production and a growing group of dynamic industries are confident in the use of hydrogen as feedstock for domestic use. A broad suite of applications could include green ammonia, fertilisers, steel, aluminium. The region will have advanced international export relationships and opportunities to meet the markets from countries, committed to Green Hydrogen such as Japan, Korea, Singapore, Germany and China.
2040	The thriving hydrogen economy of the Hunter region is providing jobs to thousands of skilled workers, including zero emissions equipment manufacturing and industry. The region will have achieved an enviable reputation as an international exporter of hydrogen, and hydrogen equipment, technology and services (HETS) to a global market. Assured under a Guarantee of Origin Scheme, the Hunter region will be known for reliable and quality green hydrogen supply, underpinned by a specialised HETS sector that is globally recognised.

The Hunter is well on the way to the 2025 goal however the Taskforce has recognised certain enablers and actions are required to unlock and realise the unique opportunities and advantages of the region.

This roadmap helps us to see the steps that the Hunter region will take in the years to come to achieve the strategic vision.

The Taskforce identified 7 strategic enablers that will underpin and optimise the opportunity for success for the Hunter region. Actions have been outlined for each time horizon recognising the structurally complex and dynamic production and technology environment.

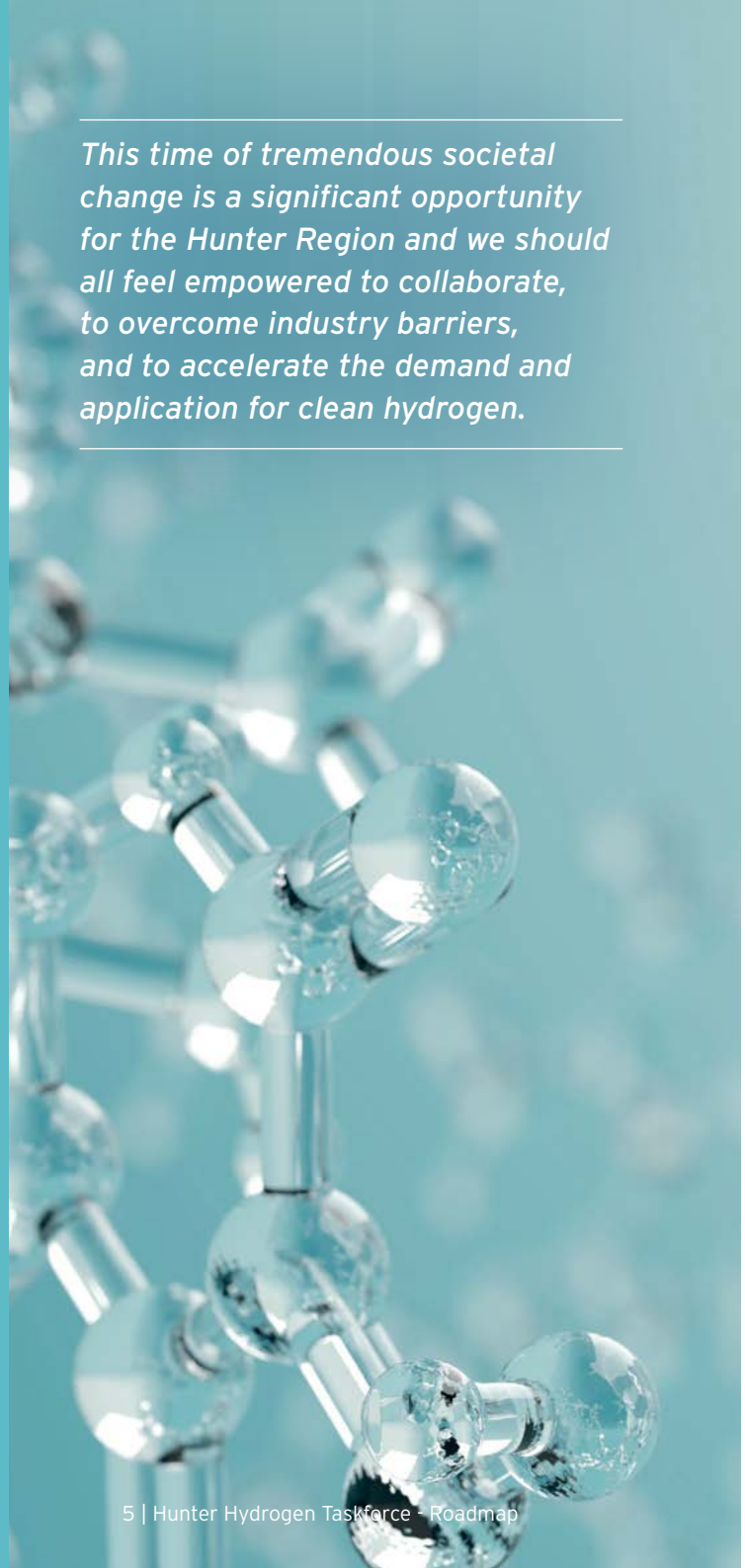
The Taskforce see a future where the Hunter will leverage its asset base and expertise and through coordinated and collaborative effort will reap the economic potential offered by the new hydrogen economy. This future will create new industries and employment growth and contribute to the regions objectives as a low emission renewable energy powerhouse across a broad spectrum of applications and industry segments.

SUMMARY OF ACTIONS

STRATEGIC ENABLERS	REGIONAL COLLABORATION	R&D AND INNOVATION	INVESTMENT ATTRACTION
2021-2025 **PREPARE AND PILOT**	• Entity to oversee Roadmap • Hunter Hydrogen Ambassador • Map stakeholders and ecosystem • A unified Hunter Hydrogen brand and narrative	• HyRIF – Phase 1 • End use demand and infrastructure assessment • Map research and innovation ecosystem • Baseline gap analysis on regional demand and capability • National and International Research MOU's • Hydrogen and HETS Doctoral Training Centre • Initiate research demonstration sites • Regional readiness education assessment • Challenge (mission) based innovation series • Scope business capability accelerator support	• Promote a shared brand and narrative for hydrogen in the region • Regional planning assessment • Advocacy to promote the Hunter as an internationally competitive location for investment • Concierge-style model • Annual Hydrogen Conference • International market assessment to determine priority markets - hydrogen exports and HETS
2025-2035 **DEPLOY AND SCALE**	• Roadmap review and adjustment • Knowledge Platform to map ecosystem and align regional demand and supply	• HyRIF – Phase 2 • Advance National and International Research MOU's • Grow the hydrogen and HETS Doctoral Training Centre • Scale demonstration sites into a sustained model • Dedicated facilities via HyRIF to support training • Cadence of innovation programs • Advancement of IP and transformative capabilities	• Active promotion of Hunter as an attractive trade and investment destination • Grow the annual Hydrogen Conference to an event of state and national significance • Deliver hydrogen specific international visitations and delegations • Foster bilateral partnerships in priority markets
2035+ **PROSPER**	• A unified Vision and Roadmap to advance the hydrogen economy for the Hunter • A shared narrative on the Hunter Hydrogen competitive position, and alignment with the participants in the ecosystem	• Cutting edge R&D, innovation and commercialisation of new technologies • The translation of research has been achieved to scale • Local research participation and demonstration has achieved a growth in education pathways	• Export success with target international markets • International relationships fostered through trade and investment initiatives • A reputation for reliable and quality HETS that can compete in the global markets

	HUMAN CAPITAL	POLICY ALIGNMENT	SAFETY AND STANDARDS	COMMUNITY ENGAGEMENT
2021–2025	• Analysis of skills requirement, map regional readiness and workforce training demand • Benchmark analysis of core competencies for participation in hydrogen supply chains • Career pathways and workforce scenarios • Establish a Hydrogen Skills Taskforce • Scope testing and training centre	• Engage with State and Federal governments, inform policy, planning and regulatory developments • Establish requirements of a Hydrogen Certification Scheme • Map opportunity for regulatory harmonisation and burdens and coordinate advocacy efforts • Disseminate relevant standards and support industry education and uptake • Map OH&S regimes and alignment to project development	• Gap analysis for industry to accelerate understanding of Standards and assurance processes • Establish a series of skills forums with industry to share industry standards relevant to hydrogen economy • Liaise and translate the development of Standards Australia, AIG and other peak Industry bodies such as Australian Hydrogen Council and Clean Energy Council	• Economic, social licence and community engagement strategy development • Develop a community and stakeholder engagement framework • Engage with entities responding to any potential risk or event aligned to Australian Standards. • Knowledge exchange, education and branding campaign
2025–2035	• Leverage demonstration projects for skills recognition • Deliver H2-specific training certification utilising demonstration sites • Deliver educational and training programs for skilling, upskilling and reskilling the region's workforce • Align a national coordinated approach to skills and training requirements	• Policy and legislative environment for larger-scale hydrogen applications, land use and export considered and consulted • World class practice in social licence • Address State and Federal policy settings that are resulting in business impacts • Regulatory and assurance aspects shared with hydrogen and HETS industry	• Through R&D initiatives and demonstration project enact a continuous improvement culture in standards adoption, safety management • Monitor global trends in evolution of industry standards/best practice • Translate assurance and certification schemes to industry preparedness programs	• Build trust for hydrogen building connection to the consumer supply chain • Track key Hunter Region economic indicators to measure impact of the hydrogen economy to the region • Tours of demonstration projects to inform STEM education and community groups
2035+	• A strategic and holistic approach to developing workforce capabilities, aligned to industry development • Attract industry and skills delivery programs beyond the region • Industrial training delivery, vocational education has met the needs of the sector and has evolved to a niche service offering from the region	• A coordinated regulatory and reform agenda to drive industry competitiveness and growth • The region has delivered best practice OH&S and risk mitigation frameworks • Hydrogen produced from the region is assured and certified under a certificate of origin scheme	• Hunter industry is abreast of standards and standard development and has established a leading position and reputation in safe production and operations across the hydrogen value chain	• A foundational framework has resulted in widespread community engagement, understanding, acceptance and support of the Hydrogen economy in the Hunter • There is evidence of a positive impact to the hunter economy across a range of economic indicators

This time of tremendous societal change is a significant opportunity for the Hunter Region and we should all feel empowered to collaborate, to overcome industry barriers, and to accelerate the demand and application for clean hydrogen.



WHY HYDROGEN?

The global energy sector is undergoing a profound and complex transformation as the shift to clean energy systems and the mitigation of climate change gathers momentum. Countries such as China, Japan, Korea, Germany and Canada - and the recommitment by the United States to the Paris Agreement – have set bold targets for net zero emissions.

To support future energy needs and climate ambition, the world needs clean, flexible and safe fuels and storage.

Hydrogen – the most abundant element in the universe has broad ranging solutions and application to meet global decarbonisation goals.

Hydrogen when produced from renewable energy does not emit any greenhouse gases when it is burned or used in fuel cells. Hydrogen can be produced as a gas and stored in high pressure vessels, and with additional energy can be liquefied and stored at very low temperatures in low pressure vessels.

Hydrogen's potential is recognised for its diversity of applications – this includes fuel for heating and transport applications, as a way to store electricity, or as a chemical feedstock in a range of industrial processes.

When hydrogen is produced using a renewable energy source, hydrogen can be utilised as a way of storing renewable energy for use at a later time when it is needed. When converted to a liquid or another suitable material such as ammonia, hydrogen can also be transported. This provides opportunities for it to be mobilised and exported, effectively making it a tradable energy commodity.

WHY NOW?

Hydrogen is shaping up to be a major enabler of the global energy revolution. Governments and industries around the world investing heavily in hydrogen technologies that will facilitate and accelerate demand in the various applications where it can be used. According the Australian Hydrogen Council, the number of announced large-scale hydrogen projects around the world have grown from 228 to 359 in less than six months.[1] HyResource[2] estimate that around AUD$1.5 billion has been awarded and/or committed by Australian Governments, industry and research institutions to clean hydrogen projects and supporting activities.

In Australia, funding and policy announcements from state and Federal governments, including the endorsement of the 2019 National Hydrogen Strategy demonstrate a clear commitment to the hydrogen economy including advancing industries in the value chain.

Hydrogen is a priority industry for the Hunter region that has the potential to anchor significant new jobs and economic growth.

The NSW Government has established a zero emission target by 2050 and announced funding to support the delivery of this target including the $750 million Net Zero Innovation program. $70 million has been allocated to support the establishment of Hydrogen Hubs in the Hunter and Illawarra.

The Hunter is an attractive and natural destination to drive the development of a clean hydrogen supply chain. This will require ongoing focus and investment in renewable energy generation, transport, storage and end-use technologies, collaboration and deployment of applications at scale.

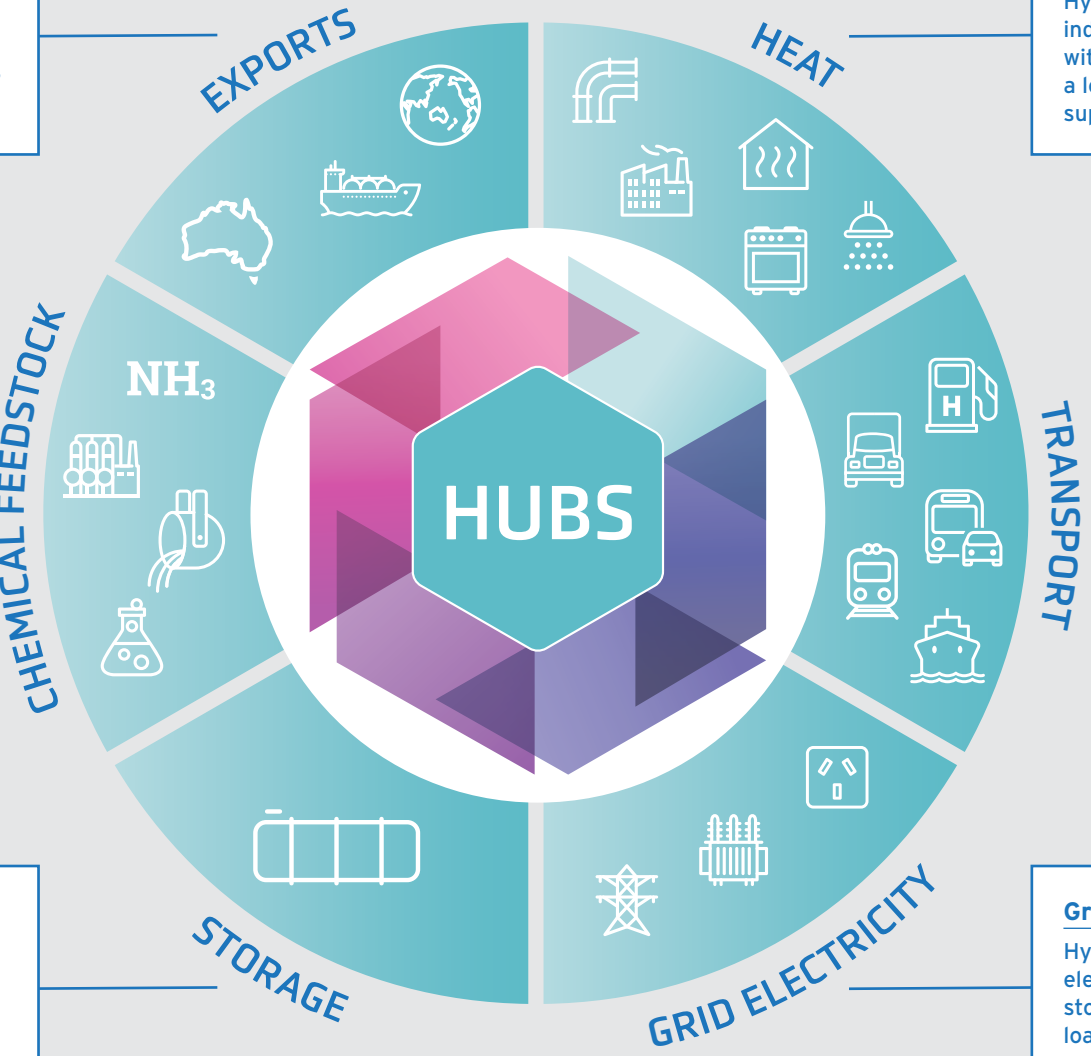
1. Hydrogen Insights 2021, July 2021 Update, Hydrogen Council, July 2021.
2. HyResource is a website collaboration between National Energy Resources Australia (NERA), CSIRO, Australian Hydrogen Council and Future Fuels CRC.

Exports

Once produced, hydrogen can be exported as liquefied hydrogen or converted to another chemical such as ammonia for shipping.

Heat

Hydrogen can be used as a fuel for industrial heating and can be blended with the natural gas network to supply a lower emission heating and cooking supply.



Chemical Feedstock

Hydrogen can be used as a chemical feedstock in low carbon industrial processes or a secondary process to produce other powerfuels, chemicals and green commodities.

Transport

Hydrogen can be used for a variety of mobility applications such as buses, cars, ships, trains and trucks. The hydrogen stored in the vehicle is converted into electricity by a fuel cell, which in turn drives an electric motor.

Storage

Hydrogen can be stored as either a gas or a liquid. Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption).

Grid Electricity

Hydrogen can be used to support electricity systems including seasonal storage or demand response, flexible load generation and frequency control services.[3]

Figure 1: Potential uses of Australian Hydrogen (Source: Adapted from Commonwealth of Australia (2019), Australia's National Hydrogen Strategy)

3. Hydrogen Strategy Group (2018), Hydrogen for Australia's Future: A briefing paper for COAG Energy Council.

WHY THE HUNTER?

The Hunter is Australia's largest regional economy, servicing a population of over one million. Contributing $60 in gross regional product, the Hunter is a mature economy of significant scale and capacity. The Hunter is Australia's Energy Capital with strong capabilities in energy extraction, processing, generation, distribution and export, storage, R&D, retail and manufacturing of renewable energy technology.

Our nation's carbon and energy transition depends on what happens in the Hunter

The region produces 63 per cent of the State's electricity. The energy and resources sectors in the region directly employ more than 16,000 people and 47,600 people indirectly. Our heavy industries comprise some of the largest energy and emissions intensive users in the nation. Newcastle is home to the east coast of Australia's largest deep water port, facilitating trade worth $26 billion including energy exports with global trading partners.[4]

The region's assets, capabilities and functions - built by and for coal industries - provide Australia and NSW with a considerable head start in the world-wide race for hydrogen.

The communities and businesses of the Hunter are optimistic about the leadership role the region can play in the world's low carbon future and hydrogen economy

We are working together to achieve this vision.

This roadmap will build, through higher level coordination and targeting gaps, the pathways to capitalise on the Hunter's unique assets and attributes and to drive the collaborative culture needed to attract and anchor business, researchers, investors, entrepreneurs and workforce.

The roadmap will help drive participation and growth across the hydrogen value chain to maximise the economic benefits for the region and beyond, leveraging key strengths including:

- **Robust Asset Base -** energy generation networks, infrastructure, land and supply chains connected to domestic and international markets – including major energy trading partners - via east coast road and rail corridors and the world class Port of Newcastle.
- **Diverse Industries -** a unique mix of upstream and downstream industries, mature manufacturing, large-scale energy generation and users, including some of Australia's most emissions intensive, largest users of energy.
- **Workforce Skills -** highly experienced human capital in energy, resources and manufacturing, including the specialised handling of dangerous goods. The workforce of the Hunter is further enhanced by excellent training and education infrastructure. Education networks work closely with regional employers to meet industry needs.
- **Research Capability -** leading energy research capabilities at CSIRO and the University of Newcastle, which have an internationally recognised record of industry-led collaboration, knowledge translation and commercialisation.
- **Innovative Culture -** a vibrant, collaborative and innovative ecosystem that connects the Hunter's large energy providers, end users, SMEs and entrepreneurs.
- **Shared Vision -** regional coordination and leadership on hydrogen innovation and commercialisation through entities such as the Hunter Hydrogen Taskforce, Hunter Hydrogen Technology Cluster (NewH2) and a well-connected network of industry stakeholders.

The opportunity for hydrogen in the Hunter is unparalleled. This opportunity extends across the whole supply chain of production, storage and exports, and participating hydrogen equipment, technology and service (HETS) providers.

Further detail and examples of the regional assets and attributes include:

Infrastructure, land, and connections with domestic and international markets

The Hunter boasts a deep water international port (Port) connected to Australia's energy trading partners. The supply chain it forms part of is widely considered to be amongst the most efficient in the world. The Port has demonstrated diversification and has plentiful land assets suitable for heavy industry and advanced manufacturing located adjacent to the facility.

The Port with its land, logistics supply chains, industrial processes and expertise is primed as a location for demonstration projects. The Port has a vital role in accelerating the domestic growth cycle by supporting innovation, evolution and deployment of new and cutting-edge hydrogen technologies with export potential.

A strong manufacturing base, skilled energy and resources workforce

This includes science, technology and engineering expertise across resources, energy, processing and fabrication, steel, transport, logistics and defence sectors. The Hunter is well positioned to harness manufacturing opportunities related to the use of hydrogen as a feedstock for a number of industrial processes, including but not limited to the manufacture of ammonia, petroleum refining, and methanol production. The region is home to deep high-tech production capabilities through advanced manufacturing that has demonstrated its ability to rapidly pivot when faced with pressing challenges.

The Hunter workforce has unique expertise and infrastructure to improve energy and fuel security and safety, and unlock further value in energy and gas sectors. Many Hunter based manufacturing and METS companies are already adept at operating with hazardous gas; the unique characteristics of hydrogen, and additional safety considerations. This expertise will provide a competitive advantage in the participation in hydrogen supply chains.

4. NSW Government's Hunter Regional Plan 2036. Available online at: planning.nsw.gov.au/plans-for-your-area/regional-plans/hunter/hunter-regional-plan

The Hunter not only has the capabilities to foster technology and innovation - we can produce it at scale and speed.

WHY THE HUNTER?

Ammonia production

Ammonia production currently occurs at Kooragang Island (KI) complex at around 350ktpa and mostly used for the manufacture of nitric acid and ammonium nitrate. The ammonia is produced through a Steam Methane Reforming (SMR) process, producing a 'grey' ammonia. Leveraging existing "know-how" will accelerate the transition to 'green' ammonia, produced using hydrogen derived from renewable energy and provide the potential to position the Hunter as a leading global producer and exporter.

Electricity and gas transmission networks

The Hunter has long been a provider of competitive energy which has supported a concentration of manufacturing and heavy industry cheaper, quicker at scale. The Hunter Region is well equipped with existing electricity and gas transmission networks along with freight and logistics infrastructure ready to be utilised for the domestic market in hydrogen. With industrial land close to international gateways, the Hunter is positioned to become an energy exporter, and a competitive trader in products and services produced from hydrogen.

Collaboration will leverage the skills and capabilities that have been developed from the Hunter's deep industrial roots to create future opportunity in the hydrogen economy

NewH2 – The Hunter Hydrogen Technology Cluster

NewH2 is emerging as vibrant collaborative ecosystem that connects the Hunter's large energy providers, end users, SMEs and entrepreneurs. NewH2 is working to accelerate local capacity, enable a dedicated forward leaning focus on hydrogen technologies, and incentivise knowledge sharing and collaboration. NewH2 provides a platform for regional business associations, government, research, and industry to work together and to support a message that the Hunter is driving industry participation in the hydrogen economy and is ready for investment.

Innovation

The Hunter's entrepreneurial and start-up culture is vibrant and aligned to clean energy technologies and sustainability. A number of incubators including but not limited to Eighteen04, Slingshot, I2N Innovation Network and Dantia provide the physical and cultural space to foster collaboration and networking for tech entrepreneurs and scalable product-based enterprises to target global markets for a new energy economy.

The commercialisation of research

The Hunter has a strong track record of industry led collaboration and research commercialisation supporting the energy and resource sector. NIER at the University of Newcastle and the CSIRO Energy Centre are nationally recognised research institutions. Large scale demonstration projects are underway that are attracting external funding with national and international partners such as:

- A partnership between the University of Newcastle and Southern Green Gas and ARENA to trial the conversion of green hydrogen into renewable methane which will be injected into existing gas infrastructure and piped to households and industrial users.
- A partnership with the University of New South Wales on the recently awarded ARC Training Centre for the Global Hydrogen Economy, and a feasibility study on Australia-Germany trade and investment in hydrogen produced from renewables.
- Early-stage R&D capability in steel technologies and the progression to 'green steel'. Steel makers are large greenhouse gas emitters globally and responsible for 5 per cent of global greenhouse gas emissions. Steelmaking is also one of the most difficult economic sectors to decarbonise, due to tough global competition, the dependence of the production process on carbon, and the need for new "breakthrough" technologies with high abatement costs and long investment cycles. The Hunter's legacy and expertise in steel have seen the University of Newcastle host the BHP's Centre for Ironmaking Materials Research (CIMR).
- At NIER, researchers are focused on next generation technologies using renewable fuels (hydrogen, electricity, biomass) or end-of-pipe capturing of CO2

Strong government partnerships

Engagement with State and Federal Government hydrogen initiatives including the national network of Hydrogen clusters and State Hydrogen Hub designation will ensure the Hunter is well positioned for the future development of the hydrogen sector (Table 1 – Alignment of Hunter Hydrogen with government policy and programs).

This includes proximity to capitalise on and support the success of the NSW Renewable Energy Zones (REZ) and Special Activation Precincts (SAP).

The Hunter Renewable Energy Industrial Precinct

A proposal that will focus on mining, mineral processing, energy and manufacturing to accelerate the zero-carbon potential of the Hunter. The precinct will support a cluster of manufacturers powered by 100 percent renewable energy, leveraging the State Renewable Energy Zones (REZ) through high voltage transmission lines or connections to renewable energy generation. The Precinct will work to accelerate access and participation to clean heat, renewable hydrogen production and infrastructure.

Table 1: Alignment of Hunter Hydrogen with government policy and programs

DATE	SIGNIFICANT MILESTONES
August 2018	CSIRO release National Hydrogen Roadmap
November 2019	COAG Energy Council endorsed and released Australia's National Hydrogen Strategy
May 2020	The Australian Technology Investment Roadmap discussion paper is released, which confirms the Government's commitment to working towards the 'H2 under 2' goal of producing hydrogen at below $2 a kilogram
September 2020	The Federal Government releases its first Low Emissions Technology Statement (the LETS) reaffirming clean hydrogen as one of five priority low emissions technologies
February 2021	The Hunter is awarded seed funding by NERA to establish NewH2 – Hunter Hydrogen Technology Cluster
March 2021	The Hunter is set to become the home of one of the State's first green hydrogen hubs with the NSW Government committing up to $70 million to hydrogen hub development
	The $750 million NSW Net Zero Industry and Innovation Program is announced to support the development of new clean technologies, create world leading centres of research and development, and industry decarbonisation
May 2021	ARENA invests $103.3m in three projects developing 10 MW electrolysers
	The $68 million Hydrogen Industry Mission launched by CSIRO
	The 2021-22 Federal Budget includes $1.2b to be invested in a Technology Co-Investment Facility for low emission technology projects over the next decade. $275.5m will support the development of four additional regional hydrogen hubs in key export regions such as the Hunter Valley, and implementation of a clean hydrogen certification scheme
August 2021	The Office of the NSW Chief Scientist & Engineer (OCSE) announces a Decarbonisation Innovation Hub under the NSW Government Net Zero Industry and Innovation Program to support researchers, industry and government stakeholders in critical sectors to collaborate, and increase the uptake of new technologies in decarbonising NSW
September 2021	As part of the NSW Government's Net Zero Plan Stage 1: 2020-2030 the NSW Government releases a new hydrogen initiative, which includes a hydrogen strategy, to help scale up the hydrogen industry in NSW
October 2021	The NSW Government launched the NSW Hydrogen Strategy and committed $3 billion to position the State as a "global hydrogen superpower" and grow the economy by more than $600 million by 2030.

CASE STUDY

Green hydrogen demonstration driving a zero emission future

An industry and research partnership led by the University of Newcastle is aimed at creating carbon-neutral energy from Australian R&D and renewable resources.

At the heart of the technology is the ability to extract pure water from air, then using electrolysis - an electrical current generated from solar panels, split the pure water into hydrogen and oxygen before storing hydrogen as a gas which can be used to power vehicles. The partnership is developing manufacturing capability across other renewable fuels, including green methane which is made by combining hydrogen with carbon dioxide from the atmosphere.

The University worked with Southern Green Gas to develop the ability to manufacture green hydrogen at a lab scale, and demonstrate the results in a Hyundai's NEXO hydrogen fuel cell SUV.

"Seeing this fuel hit the roads is a proud moment for my team, who have worked to perfect it over several years. We're now looking forward to scaling this technology, working with Southern Green Gas toward commercial rollout and a wide range of possible applications," said Professor Behdad Moghtaderi of the University of Newcastle.

THE HUNTER HYDROGEN FUTURE

There are numerous pathways that the Hunter can take to develop the hydrogen industry. The multitude of potential use cases and the extent to which they can overlap and intersect presents both a challenge and an opportunity.

The Roadmap recognises that the development of segments of the industry is not mutually exclusive but rather will be accelerated by harnessing a multi-faceted broad-based approach to alternatives, opportunities and turning points as the hydrogen industry matures.

As identified by CSIRO (2018), Figure 2 illustrates that Hydrogen must be both affordable and sustainable if it is to diversify and supersede traditional energy sources. The technical challenges and timeline for their feasibility will need to be addressed through an integrated program of development to achieve competitiveness goals.

The Hunter has both the capacity, assets and necessary frameworks to support the conditions for transformation including viable demonstration of hydrogen, opportunities to aggregate demand to achieve scale, and deliver products and services for domestic and international markets.

The process of hydrogen production and use in a complex landscape necessitates a strategic approach to identify needs, challenges, and gaps including infrastructure and workforce, and facilitate coordination across sectors and firms in a commercially sensitive environment to determine the optimal pathway to drive uptake. This coordination will be led by a symbiotic hub and cluster approach, to achieve mutual benefit for all stakeholders and the region.

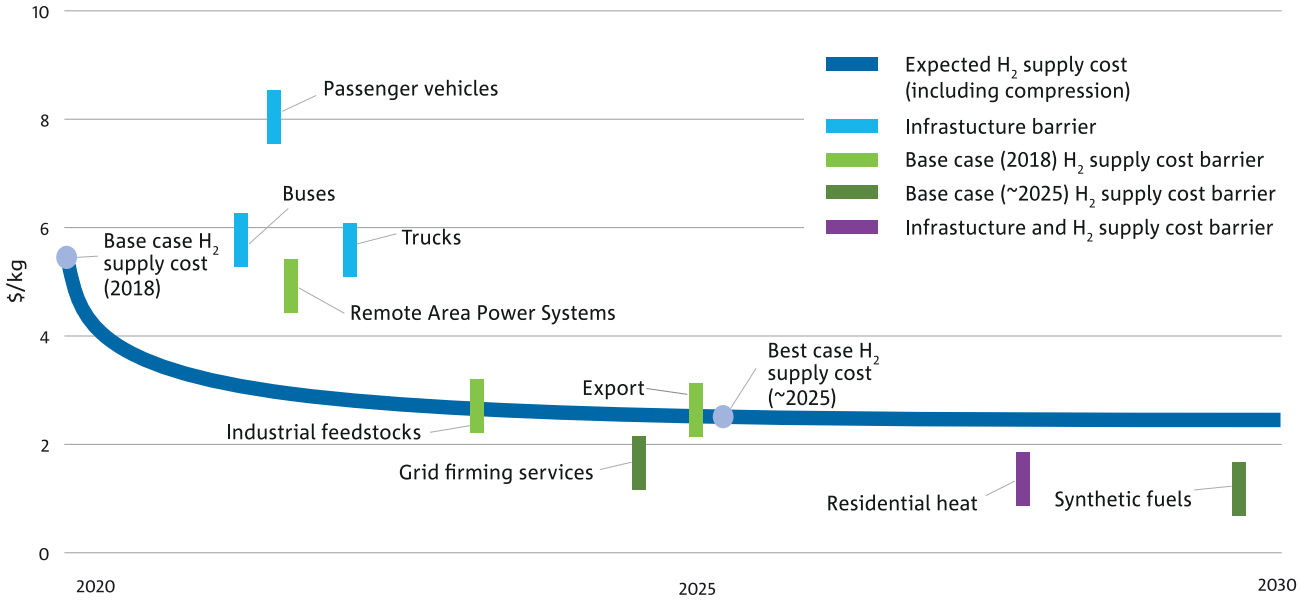


Figure 2. Hydrogen competitiveness in targeted applications. Source: CSIRO (2018) National Hydrogen Roadmap.

A Hub and Cluster approach - working together – can establish the Hunter as a leader in hydrogen-related production, use, technology and expertise.

Hydrogen Hubs

The development of a Hunter Hydrogen Hub will provide groups of hydrogen users with common infrastructure for the local production, use and distribution of hydrogen. The Hub model will work to reduce risk and costs for participants through coordination and economies of scale.

Hydrogen Cluster

A Cluster works to drive supply chain coordination, connection and development by bringing together the expertise, technologies, resources, capital and knowledge of businesses and organisations needed to support and participate in the emerging domestic and export hydrogen industry.

A Hub and Cluster Model

The full opportunity for the Hunter is to provide diversified and sustainable supply chains and networks via application of both the Hub and Cluster models, working in synergy, coordinating efforts, and leveraging both physical assets, knowledge and industry connections.

With a coordinated approach, the region is poised to support diverse opportunities and business models, recognising that the path to hydrogen deployment and industry uptake have potential to unfold in a number of ways. The Hub and Cluster model will enable Hunter's hydrogen future to be realised in stages and various formats.

THE HUNTER HYDROGEN FUTURE

2021–2025

PREPARE AND PILOT

The Roadmap recognises the "low hanging fruit" in terms of the current most competitive applications for renewable Hydrogen. In the near-term activity will include a focus on demonstrating commercially attractive uses include mobility applications, remote area power systems, ammonia production, natural gas blending and chemical feedstock applications.

Early projects will provide small to mid-scale demonstrations to better inform and enable workforce, technology and support the advancement of infrastructure planning components for larger de-risked commercial commitments.

In the short term the region will embark on feasibility assessment to inform development funding for larger scale electrolyser and export projects. Opportunities will be staged and aligned to technologies as they mature and costs decline. Prioritisation will depend on the outcomes of Hunter-specific studies into relative economic performance of gas, batteries, electrification and how these might compare to cost trajectories of hydrogen systems.

2025–2035

DEPLOY AND SCALE

STAGE 1, STAGE 2

In the Medium Term the Roadmap will leverage and further refine the efficiencies created by Hub efforts including optimisation of common use infrastructure and will focus on larger scale deployment of electrolysers aligned to industries with higher demand applications. This will be staged in parts and will include heavy industry, transport and mobility, and the demonstration of diesel replacement applications.

In this phase stakeholders will work toward local production, transportation, utilisation and export. The application for hydrogen for mobility applications will be scaled and bulk transportation of Hydrogen will be advanced. The region will have explored and tested mechanisms to drive investment and scale for the hydrogen industry and drive local industry participation. This could include the application of a certificate scheme and procurement-based incentives.

2035+

PROSPER

The short and medium-term foundations will ensure significant production scale-up in the longer term to facilitate and drive additional domestic demand, application and export opportunities.

The region will realise the uptake of domestic energy applications, have delivered into new export markets, achieved an increase in skilled jobs and industry certification from hydrogen use, and is benefiting from clean energy generation and lower carbon emissions outcomes.

The Hub and Cluster model will have achieved a rich coordination of government, research, industry to drive an aggregation of demand. Industry confidence in use could drive a diversification of industry application such as green steel manufacturing, power generation, heavy industry application and the commercialisation and participation of regional advanced technology solutions beyond the Hunter.

The Roadmap has been anchored on foundational initiatives and production outlooks that will enable the region to drive a number of target applications and use cases.

THE HUNTER HYDROGEN FUTURE

PREPARE AND PILOT – 2021-2025

- Projects that enable the advancement of hydrogen infrastructure, production, storage and delivery
- Translate emerging hub elements to promote demand and supply opportunities for industry, technology and expertise
- Validate technical and operational performance through demonstrations and pilots
- Prepare industry and workforce participation

DEPLOY AND SCALE – 2025-2035

- Advance local production, transportation, utilisation and export in two stages to scale
- Optimise common use infrastructure and focus on larger scale deployment of electrolysers aligned to industries with higher demand applications
- Drive coordinated and strategic mechanisms to accelerate investment opportunity and industry decarbonisation objectives to scale
- Communicate 'wins', scale and broaden industry, workforce and community participation elements

PROSPER 2035 +

- Further aggregate demand and supply, and increase export opportunities
- Leverage established industry confidence to drive a diverse suite of industry applications across P2X and hydrogen such as green steel manufacturing and power generation
- A thriving HETS sector delivering advanced technology solution and applications beyond the Hunter including exports

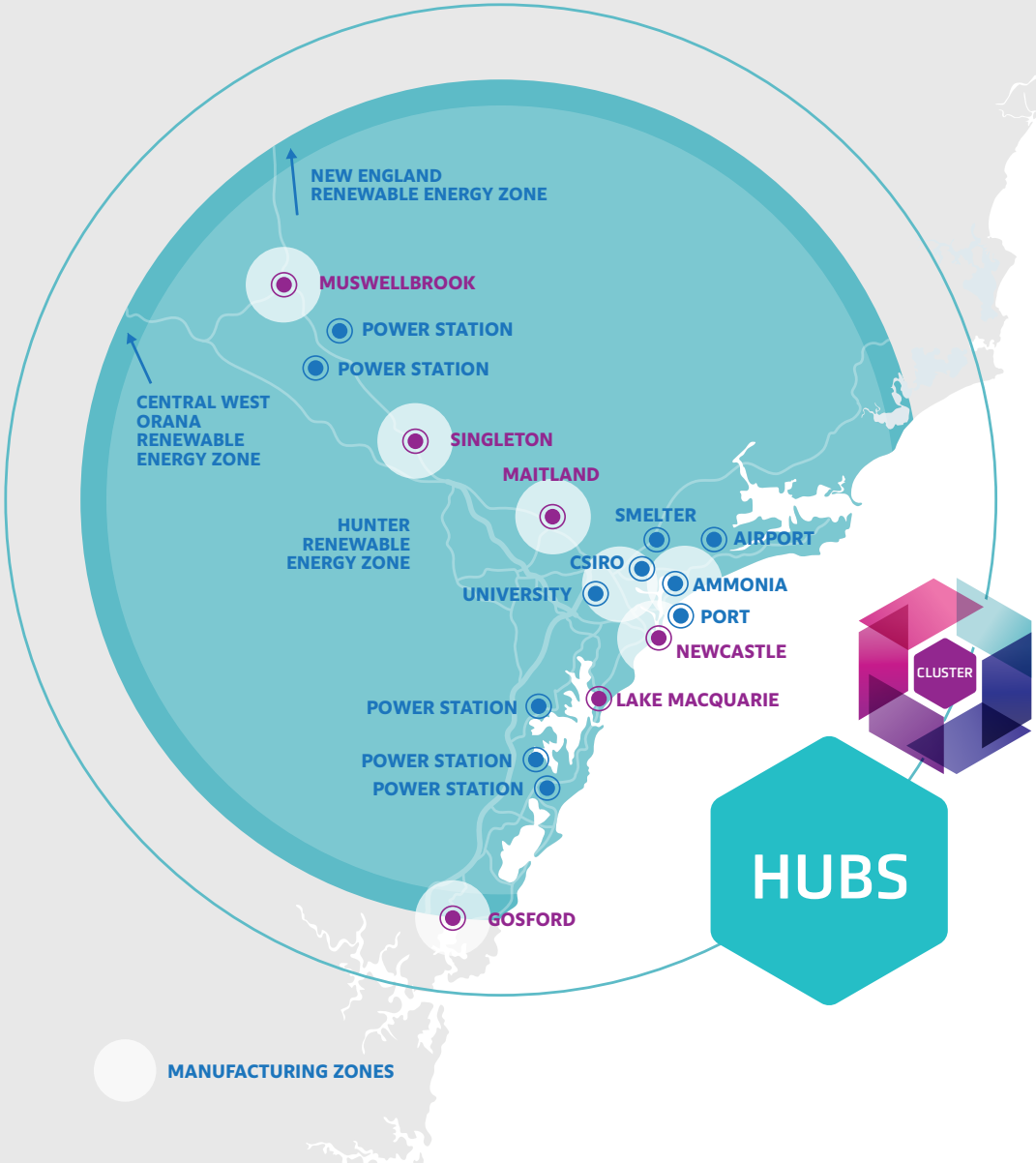


Figure 3. Hub and Cluster unlocking the potential uses of hydrogen.

PREPARE AND PILOT 2021–2025

Establish pilot and demonstration projects

Investment: (<$150M)

TARGET APPLICATIONS AND USE CASES

Pilot and Demonstration Projects

Including mobility applications, remote area power systems, ammonia production, natural gas blending and chemical feedstock applications.

Feasibility Studies

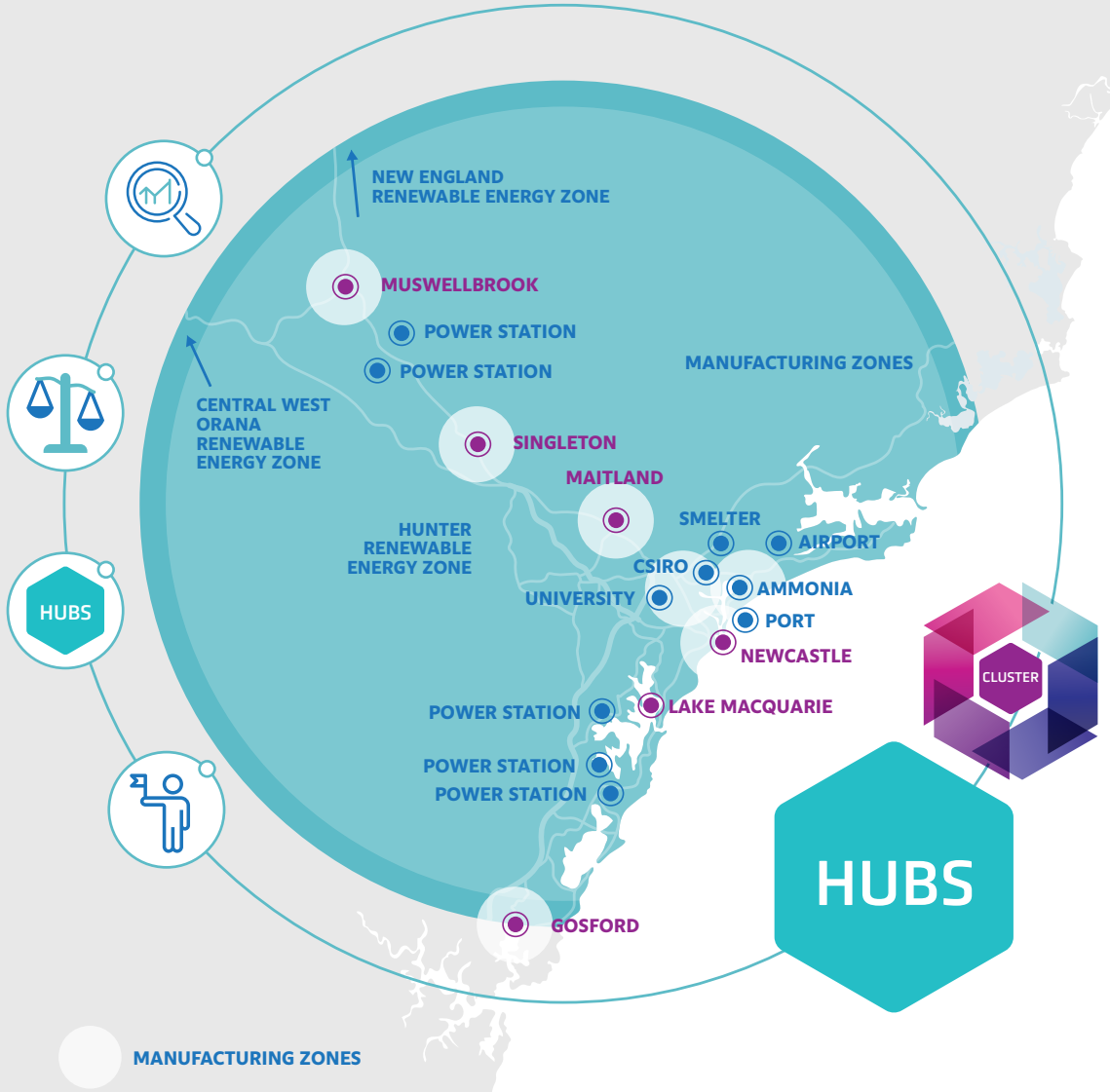
To inform development and delivery options for larger scale electrolyser and export projects.

Hunter Hydrogen Hub

Promote and broker demand and supply opportunities to attract investment, reduce project risks and costs through coordination and economies of scale.

Industry and Workforce

Map and benchmark industry and workforce preparedness, identifying development needs, new career pathways and training facilities.



DEPLOY AND SCALE 2025 – 2035

STAGE 1

Hydrogen Production from:
100 MW + Electrolyser

Investment:
($150M+)

TARGET APPLICATIONS AND USE CASES

Chemical Feedstock

Commence feasibility for green hydrogen as a feedstock for industrial production including ammonia and fertiliser manufacturing.

Gas Networks

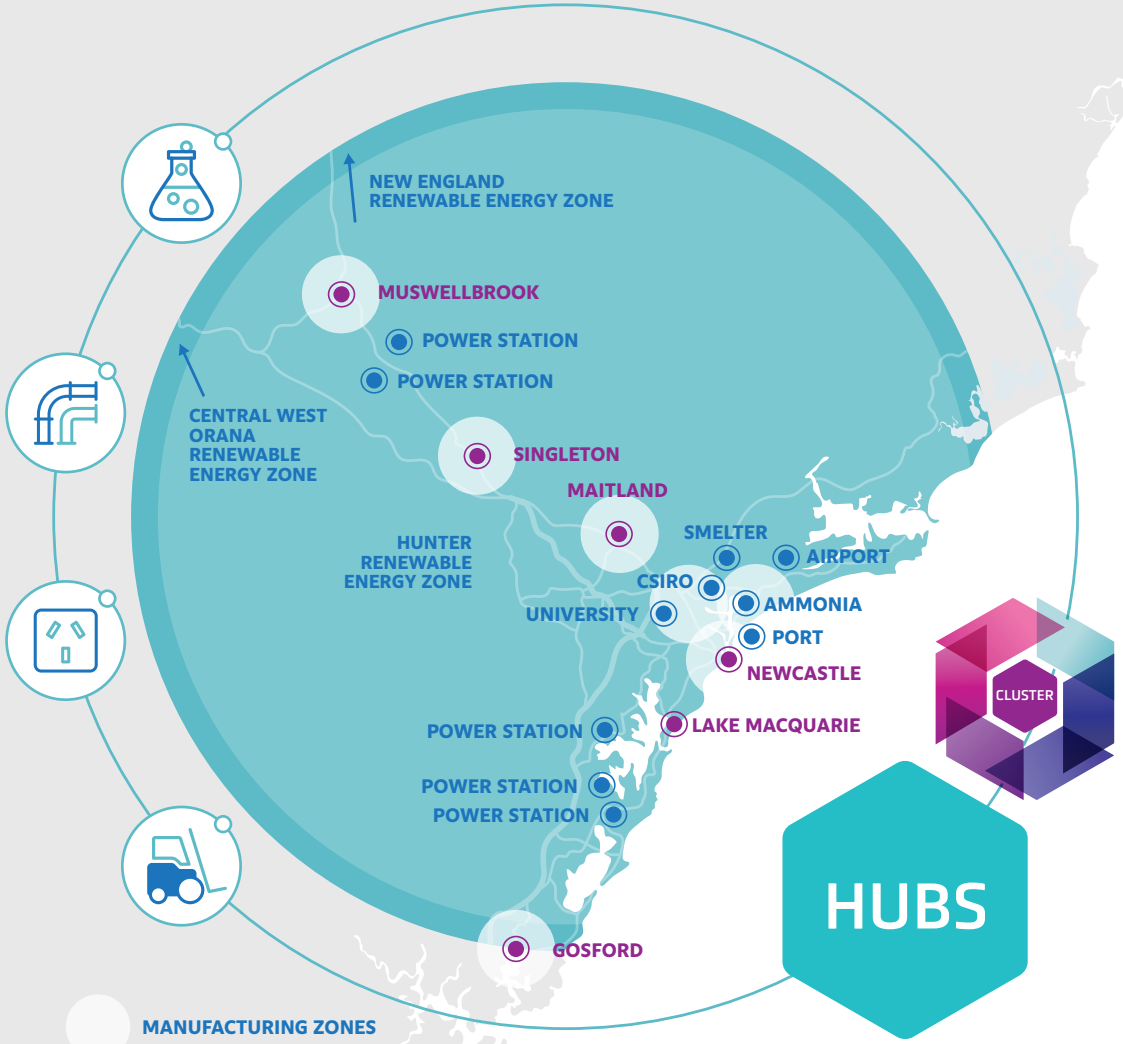
Commence feasibility to blend with natural gas for industrial use. Pilot blending of green Hydrogen from 5% to 10% into existing pipeline infrastructure.

Power Generation and Regional Opportunities

Explore and pilot remote power generation applications as a substitute to diesel.

Fuels and Mobility

Commence building "Back to Base" Green Hydrogen production and refueling infrastructure. Pilot supply applications include forklifts, public transport, heavy vehicles, and rail.



DEPLOY AND SCALE 2025-2035

STAGE 2

Hydrogen Production from:
1 GW + Electrolyser

Investment:
($1bn+)

TARGET APPLICATIONS AND USE CASES

Heavy Industry

Decarbonisation of heavy industry and manufacturing including production of locally produced green aluminium through firmed renewable electricity.

Direct use of hydrogen either as a heat source or a reductant or in ammonia and fertiliser production, industry and manufacturing.

Transport and Mobility

Expand on the Stage 1 initiatives to include shipping and additional mobility operations at the Port of Newcastle. This could include ferries, tugs, dredging equipment.

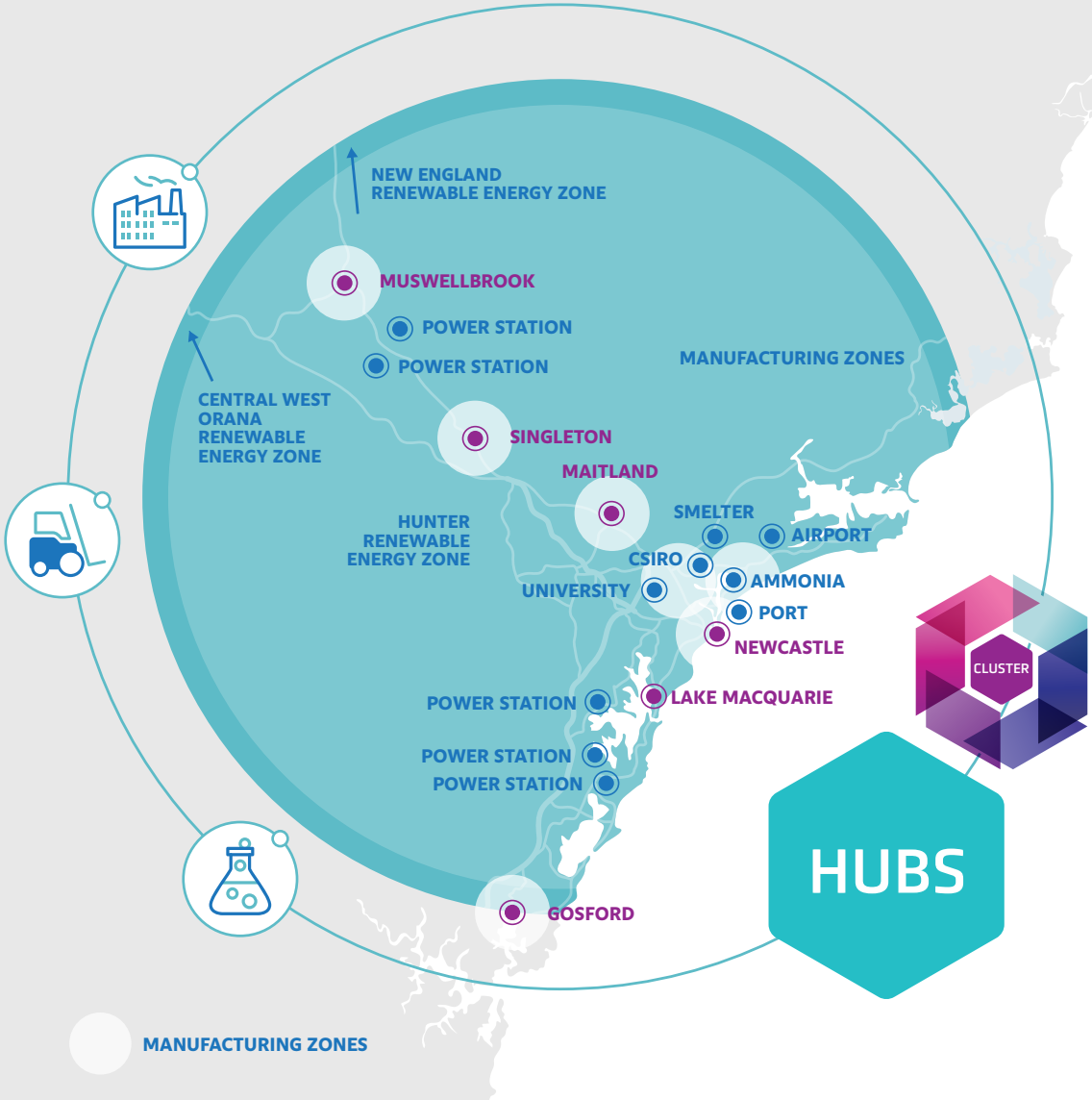
Work with ship manufacturers to develop a ammonia and/or methanol fuel based engine for the industry.

Leverage international partnerships to enable hydrogen passenger fuel cell for train services.

Collaborate with the Hunter's existing logistics operators utilising industrial transport corridors and networks to provide extensive pathways and infrastructure for transportation of large mass, high mileage vehicles.

Chemical Feedstock

P2X applications including aviation fuels, biomethane production from domestic and commercial waste converting directly to hydrogen.



PROSPER 2035 +

Hydrogen Production from:
5GW + Electrolyser

Investment:
(Approx $2.5bn+)

TARGET APPLICATIONS AND USE CASES

Technology Scaleup

Scaling up the activities underway with view towards regional economic objectives including exports of green ammonia, liquid hydrogen, fertilisers, and other green hydrogen derivatives to key markets.

Green Steel Manufacturing

Supported by large-scale renewable energy, reduced electrolyser costs and low-cost hydrogen distribution and storage enable a large domestic and export-scale, green steel manufacturing industry.

Power Generation and Regional Opportunities

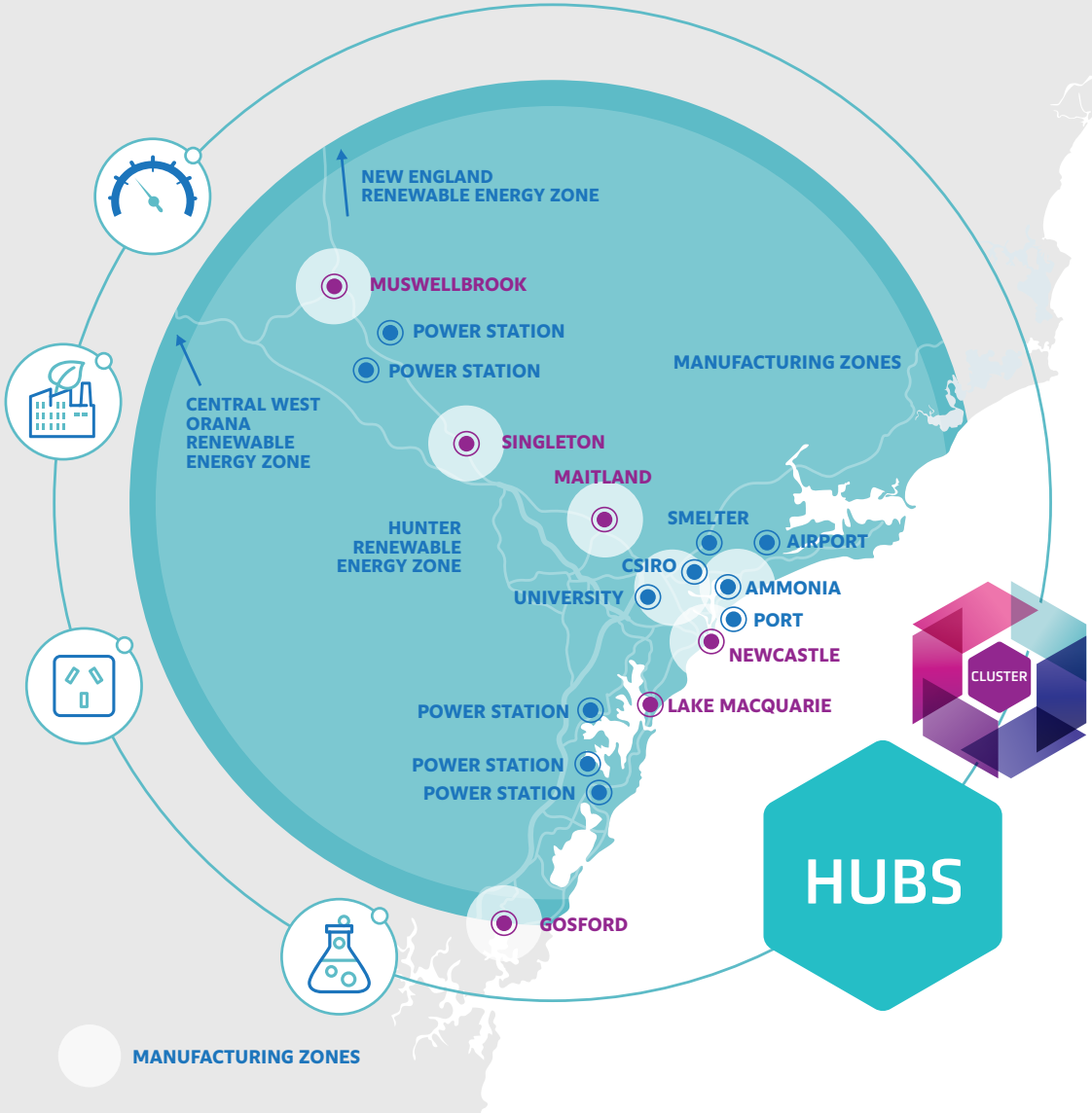
Production of renewable hydrogen close to the sources of solar, wind and potentially pumped hydro and transport via the construction of pipelines to the Port of Newcastle for export in various forms namely liquefied state, ammonia and other derivatives.

Hydrogen as stored energy for power generation and electricity grid balancing services.

Piped hydrogen to other areas in the State with offtake spurs.

Chemical Feedstock

Diverse P2X applications including aviation fuels, biomethane production from domestic and commercial waste converting directly to hydrogen.



STRATEGIC ENABLERS

The Roadmap recognises that the development of a thriving hydrogen economy in the Hunter will require a coordinated and agile approach, with actions and investments across sectors, levels of government and portfolios. This calls for dedicated oversight and adjustment as the industry evolves.

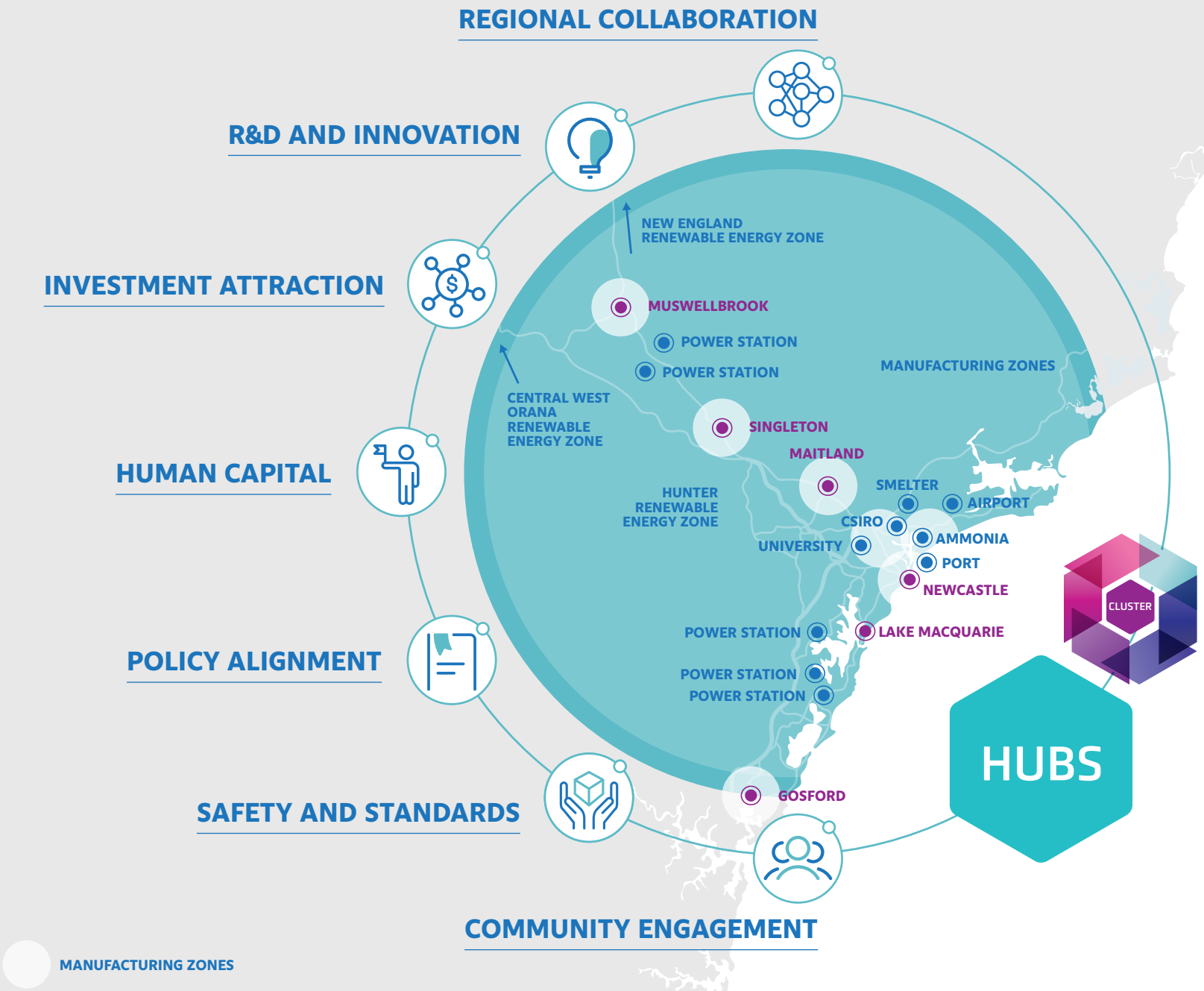
A review of regional strengths and asset base, against growth scenarios for hydrogen reveals a set of strategic enablers to continue to grow the Hunter's value proposition and support investment in hydrogen.

Enablers will work to accelerate the "quick wins", to streamline existing settings, unlock innovation and reduce barriers to project development. These include:

- **REGIONAL COLLABORATION**
- **R&D AND INNOVATION**
- **INVESTMENT ATTRACTION**
- **HUMAN CAPITAL**
- **POLICY ALIGNMENT**
- **SAFETY AND STANDARDS**
- **COMMUNITY ENGAGEMENT**

Independently and in concert the strategic enablers focus on growth along the upstream and downstream hydrogen value chain to deliver a vibrant ecosystem of investment, competitiveness, R&D and commercialisation in hydrogen production, use, manufacturing and export.

Oversight of the Roadmap will be via a coordinating body and recommends the introduction of a "Hunter Hydrogen Ambassador" to ensure governance, review, consultation and adjustment where required.


REGIONAL COLLABORATION
R&D AND INNOVATION
INVESTMENT ATTRACTION
HUMAN CAPITAL
POLICY ALIGNMENT
SAFETY AND STANDARDS
COMMUNITY ENGAGEMENT
NEW ENGLAND RENEWABLE ENERGY ZONE
CENTRAL WEST ORANA RENEWABLE ENERGY ZONE
HUNTER RENEWABLE ENERGY ZONE
MANUFACTURING ZONES
MUSWELLBROOK
POWER STATION
POWER STATION
SINGLETON
MAITLAND
SMELTER
AIRPORT
CSIRO
AMMONIA
UNIVERSITY
PORT
NEWCASTLE
POWER STATION
LAKE MACQUARIE
POWER STATION
POWER STATION
GOSFORD
CLUSTER
HUBS
MANUFACTURING ZONES

REGIONAL COLLABORATION

The development of a hydrogen industry in the Hunter will require a culture of collaboration, information sharing across sectors, and partnerships between industry, researchers, government and community. This framework will support a shared ambition, drive innovation, foster connections, accelerate technology to market and promote jobs growth. There are already significant collaborative networks and activity underway in the region with key business and industry groups that can be leveraged including:

Hunter Hydrogen Taskforce

The Taskforce is a collaborative leadership group, formed to identify and mobilise key assets (including skills and expertise) to position the Hunter competitively for the future hydrogen economy, including in the manufacturing sector.

NewH2 - Hunter Hydrogen Technology Cluster

NewH2 is a local industry consortium that was awarded funding from National Energy Resources Australia (NERA) to accelerate industry transition to the new hydrogen economy and foster an environment for investment, growth and jobs. The Hunter Hydrogen Technology Cluster (New H2) aims to build the collaborative culture needed to attract and anchor businesses, researchers, investors, entrepreneurs and a future workforce to the hydrogen economy. As the only cluster to receive funding in NSW, this Cluster works closely across a national network of 15 clusters and the national hydrogen technology cluster H2TCA.

NSW Energy & Resources Knowledge Hub

The Energy & Resources Knowledge Hub (ERKH) is a collaborative knowledge platform that supports the NSW energy and resources sector. An initiative of the NSW Government, the Hub facilitates engagement between industry, research organisations and government. It also supports NSW business by sharing knowledge, giving SMEs the resources needed to overcome challenges, thrive in their local region and be competitive in global markets.

Committee for the Hunter

The Committee for the Hunter is an independent and inclusive champion for the people of the Hunter and their enterprises, providing effective advocacy and thought leadership to help build a sustainable and prosperous future for the region. It identifies long-term strategic goals and champions these on behalf of the region with the common goal of driving growth, prosperity and diversity in the Hunter. The Committee sees a continued future for the Hunter as Australia's leading regional economy and shares a vision for enhancing the economic, social, cultural, environmental and creative assets of the region.

Hunter Joint Organisation

The Hunter Joint Organisation is a collaborative body that brings together the ten councils in the region to provide a united and local voice for the community. As the hub for local intergovernmental collaboration, the statutory mandate includes identifying key regional strategic priorities, advocating for these priorities, and building collaborations around these priorities with other levels of government, industry and community.

HunterNet Cooperative

HunterNet Cooperative is widely recognised within Australian manufacturing and academia as the most successful industry 'cluster' of its type nationally. Incorporated in 1992, HunterNet is a network of manufacturing, engineering and specialist services companies located in the Hunter and Central Coast Regions of NSW. Formed as a non-trading, not for profit Co-Operative, it involves over 200 companies, active in national and international infrastructure & asset management, energy & resources, defence and advanced manufacturing supply chains. HunterNet provides members numerous business support programs and the opportunity to take part in activities including training and development, networking, joint marketing initiatives, joint project bids, focused task forces, trade missions and tendering.

Business Hunter

Business Hunter is the largest regional peak business group in Australia, representing members across all business and industry sectors. Business Hunter is a not-for-profit member organisation dedicated to connecting people in business with what they need to succeed. Business Hunter members benefit from our strategic affiliations with Business NSW and Business Australia, which extends its reach and enhances the range of services that can be offered.

Central Coast Industry Connect

Central Coast Industry Connect (CCIC) is an umbrella organisation for manufacturing and related industry sectors on the NSW Central Coast. CCIC fosters collaboration and connection between Industry and Business. It aims to interface with all levels of government, education providers and the community to create growth opportunities in the region and add value to its social fabric. CCIC focus is on specialisations in Advanced Manufacturing, Food and Beverage production and the Circular economy with a goal to make the Central Coast a Centre of Innovation Excellence across these areas.

Australian Industry Group (AIG)

AIG Hunter responds to and represents the interests of members throughout the Hunter, Central Coast, New England, Mid North Coast and Northern Rivers regions, providing professional and timely member services, which include:

- Workplace Relations advice, advocacy and assistance
- Regional Policy advice, advocacy and representation
- Regular training courses and seminars on Employee Relations, Occupational Health & Safety and Business Improvement
- Product Standards and Compliance
- Quarterly Newsletter "Industry Matters"
- Networking events

The Regional Office actively participates with other Regional Organisations to promote local manufacturing to the world.

NSW Decarbonisation Hub

The recently announced NSW Decarbonisation Innovation Hub will coordinate research, government and industry efforts across three priority areas:

- Energy Systems and Electrification
- Land and Primary Industries
- Power Fuels including Hydrogen.

The priority areas were selected to capture the opportunities identified by the NSW Chief Scientist & Engineer's Decarbonisation Innovation Study and the Innovation Hub will adopt the 'innovation and research network model' developed by the Office of the NSW Chief Scientist & Engineer (OCSE) used to establish innovation and research networks including the NSW Smart Sensing Network, Defence Innovation Network and NSW Circular.

Beyond Zero Emissions

Beyond Zero Emissions (BZE) is an internationally recognised think tank that demonstrates through independent research and innovative solutions how Australia can prosper in a zero-emissions economy. BZE purpose is to accelerate the transition to a zero-emissions Australia. BZE has developed a zero-emissions plans for every sector of the economy, place-based transition plans for regions, and brought it all together with a critical jobs-focused narrative in The Million Jobs Plan.

BZE has a strategic plan to make the Hunter a strong manufacturing nation through the establishment of Renewable Energy Industrial Precincts - clusters of manufacturers powered by 100% renewable energy. They aim to connect industrial centres with the abundant and cheap renewable energy provided by Australia's Hydrogen Hubs and Renewable Energy Zones.

INITIATIVES

It is important that a coordinated and concerted effort is undertaken to advance and promote the hydrogen opportunity for the region as a whole.

The Roadmap recommends this effort be supported by a dedicated entity to oversight delivery and a dedicated "Hunter Hydrogen Ambassador" for the region.

2021–2025 **PREPARE AND PILOT**	Determine oversight entity to drive the Hunter Hydrogen Technology Roadmap. Appoint representation of a "Hunter Hydrogen Ambassador" to drive regional cooperation, leverage strength and complement activities. Oversee the mapping of stakeholder / ecosystem initiatives to strengthen the region as a whole.	Drive a branding and narrative effort to determine Hunter Hydrogen strengths and value proposition. Deliver joint communication and marketing effort with a shared message and narrative.
2025–2035 **DEPLOY AND SCALE**	Review and adjust Roadmap to ensure short-term delivery efforts are matched and/or adjusted to achieve longer-term objectives.	Deliver a knowledge platform to map ecosystem and points of excellence and to align renewable Hydrogen demand to large scale projects including Renewable Energy Zones (REZ) and Special Activation Precincts (SAP).
2035+ **PROSPER**	Key representative stakeholders in the region are unified in a vision to advance the hydrogen economy for the Hunter and are working together on Roadmap deliverables.	There is a shared narrative on the Hunter Hydrogen competitive position, and the participants in the ecosystem.

R&D AND INNOVATION

The R&D and Innovation enabler will work to target and strengthen collaborative research efforts and drive industry uptake via the innovation ecosystem.

Research institutes will provide linkages to national and international efforts to advance the R&D required to develop the Hydrogen economy for the region. Innovation efforts will be complimented by innovation entrepreneurship and accelerator programs to drive commercial outcomes.

The Hunter is home to an active energy research and innovation ecosystem anchored by a number of leading Centres.

- **The University of Newcastle (UON)** is a research intensive university that ranks 12th in the world for the impact of its work. The University is an established research leader in science, engineering, resources and energy and is committed to developing the next generation of resources, which will bring the world closer to a sustainable future.
- **Newcastle Institute for Energy and Resources (NIER)** is one of the University of Newcastle's flagship research institutes. NIER research teams work closely with industry to drive innovative outcomes and solutions in areas of national significance including low emission energy technologies. NIER is a Federal Government initiative representing 21 research centres and groups, 138 engaged University of Newcastle researchers with 148 active industry partners.
- **CSIRO Energy Centre** hosts CSIRO's solar field and energy research hub. The Centre focuses on pioneering low-emission technologies and intelligent energy management tools for industry and households. CSIRO is well positioned to springboard the NSW hydrogen strategy and leverage the CSIRO Hydrogen Industry Mission.
- **Integrated Innovation Network (I2N)** works to drive business growth through innovation and entrepreneurship. I2N fuels the success of innovators and entrepreneurs by connecting them to community, customers, coaching and capital. I2N helps people develop their enterprise skills and impact potential, validate ideas and accelerate to market.
- **Hunter iF's** mission is to harness the region's immense potential to help create a more innovative future. Hunter iF has been established as a not-for-profit support organisation to encourage and facilitate investment, jobs and growth as our region undergoes significant change. It does this by providing a one stop shop for innovation in the Hunter through a comprehensive, connected and cohesive package of services, programs and opportunities. Hunter iF accelerates innovative ideas to successful outcomes.
- **The Melt** is Australia's first fully-integrated accelerator and industrial prototyping lab for hardware. Launched in December 2019 it is a collaboration between Dantia, The Melt Accelerator (managed by the founders of innovation company Slingshot) and local engineering powerhouse Ampcontrol through their research and development arm ResTech. The Melt aims to grow, scale and commercialise hardware startup projects and revolutionise the way corporate research and development teams build and deliver their innovation product pipeline.
- **Eighteen04 Inc.** supports early-stage startups seeking to transform the energy economy, environment and build smart and sustainable cities with an emphasis on scalable product-based enterprises targeting global markets. Eighteen04 is a curated collaborative working space for technology startups in Newcastle and builds on regional strengths to launch scalable technology startups into a global market.
- **Hunter Angels** is a group of angel investors who invest in early-stage innovative enterprises with a proven product and a need for capital to fund expansion. Hunter Angels promote the growth of local emerging enterprises through investments and to provide a good return for investors. Hunter Angels mentor participants, serve on boards, provide contacts and assist with strategic planning.

INITIATIVES

Investment in R&D and innovation is essential to enable and accelerate the translation of research into practice and commercialisation to drive a thriving hydrogen economy. Priorities include:

- Research into emerging technologies focused on the cost of production to facilitate industrial uptake; pathways for integration of hydrogen with existing industries, novel transport and power applications
- Demonstrate approaches for integrating hydrogen into existing industrial and energy applications
- Educate to support industry transition, understanding of hydrogen technologies and community acceptance
- Catalyse including entrepreneurship and facilitated accelerators both for emerging businesses and the reorientation of existing businesses toward hydrogen

Research and innovation efforts will be underpinned by a centralised facility to drive centralised activity and provide pathways for students into the sector including close alignment to industry via a Hydrogen doctoral training centre.

Hydrogen Research Infrastructure

CSIRO and the University of Newcastle are exploring opportunities for specialised research and demonstration facilities to advance the development of technology, products and services to underpin growth in the hydrogen industry.

Purpose-built infrastructure and collaborative spaces will allow dedicated hydrogen related research teams, PhD students and industry partners to collaborate on joint projects with laboratory and demonstration scale testing facilities.

	RESEARCH		DEMONSTRATE	EDUCATE	CATALYSE
2021–2025 PREPARE AND PILOT	Complete HyRIF – Phase 1. Map Hunter end use demand and assess infrastructure. Map Hunter research and innovation ecosystem in the hydrogen value chain.	Complete a baseline gap analysis on regional demand and capability, and identify complementary regions for partnership. Identify and execute strategic National and International Research MOU's –to enhance priority research efforts. Establish a hydrogen and HETS Doctoral Training Centre.	Identify and initiate research demonstration sites in targeted hydrogen applications.	Conduct a regional readiness education assessment to meet short & long-term demand (national and international).	Commence challenge (mission) based innovation series Scope business capability accelerator support for start-ups and scale-ups linked to the Hydrogen economy.
2025–2035 DEPLOY AND SCALE	**RESEARCH** Complete HyRIF – Phase 2 including deployment and integration of R&D into new industries. Review and measure the Baseline gap analysis.	Advance National and International Research MOU's to collaboration agreements and partnerships to deliver mutual value creation in Hydrogen research and innovation. Grow the hydrogen and HETS Doctoral Training Centre.	**DEMONSTRATE** Establish demonstration sites into a sustained model to test and trial hydrogen applications.	**EDUCATE** Launch dedicated facilities via HyRIF to support training, education, community acceptance and impact.	**CATALYSE** Demonstrate a cadence of innovation programs to foster a pipeline of hydrogen related startup and scale-ups. Foster collaborative and novel business models to address supply and demand imbalance. Support the advancement of IP and transformative capabilities in Hydrogen.
2035+ PROSPER	The Hunter has led cutting edge R&D, innovation and commercialisation of new technologies across the entire renewable hydrogen supply chain.	The translation of research has been achieved to scale including cross-sector decarbonisation initiatives such as diesel replacement across port operations and the non-electric rail network.	Demonstrate local research participation and demonstration has achieved a growth in education pathways.		

INVESTMENT ATTRACTION

The Hunter region is well recognised as a dynamic, innovative, outward looking investment destination and a priority location for private and public investment in hydrogen. Regional proponents need to be supported to access the variety of funding and financial support available from the NSW and federal governments. Investment concierge support aims to promote the Hunter's value proposition for hydrogen and to steward investment into the region. It will work with business to overcome hurdles to investment and provide recommendations to streamline processes including planning and regulation.

Investment attraction efforts recognise the interdependencies of players and projects in hydrogen supply chains. This will require a local brokerage function to make connections. For example, blending hydrogen into a natural gas networks co located with hydrogen refuelling stations supplying potentially forklifts, buses, trucks and cars and other activities can spawn a variety of new industries, greater diversification and jobs in regional NSW. A remote mining site could produce green hydrogen on site for use in vehicles as well as backup power supply replacing fossil fuel sources.

The Hunter is an important gateway to national and international markets. The region's ongoing prosperity will depend on its ability to capitalise on strategic regional positioning.

Federal Government Incentives

The federal government has declared the Hunter as one of seven national hydrogen hubs. The $1.2 billion program, Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs, will deliver $464 million in grants to those seven regions for hub development and design work to advance hydrogen hub concepts. The program will provide a vehicle to broker international partnerships and initiatives that will accelerate the deployment of hydrogen and other priority low emissions technologies.

The Clean Energy Finance Corporation (CEFC) has allocated $300 million in concessional loans under the Advancing Hydrogen Fund. The financing initiative will focus on projects that align with the National Hydrogen Strategy, including projects which have state or territory government financial support. Eligible projects can include advancing hydrogen production, developing export and domestic hydrogen supply chains, including hydrogen export industry infrastructure, establishing hydrogen hubs, plus other projects that assist in building domestic demand for hydrogen. Projects seeking finance must be commercial and deliver a positive return for taxpayers.

In 2019 ARENA launched Renewable Hydrogen Develop Funding to fast track the development of a renewable hydrogen industry. Over $100 million has been conditionally approved to develop three commercial-scale renewable hydrogen projects in Australia. At 10 MW, the electrolysers in these hydrogen plants will be among the largest in the world indicating the strong investment appetite for large scale project development. In 2018 ARENA also invested in 16 hydrogen research projects that aim to deliver cost reductions and efficiency gains to drive toward a $2 per kilogram threshold. ARENA aims to connect investment, knowledge and people to deliver energy innovation, and to support the foundation of a viable hydrogen industry in Australia.

National Energy Resources Australia (NERA) funded 13 regional hydrogen technology clusters, including one in the Hunter. The Hunter cluster has received $100,000 seed funding and has established NewH2 – Hunter Hydrogen Technology Cluster.

NSW Government Incentives

In October 2021 the NSW Government launched the NSW Hydrogen Strategy. The strategy brings together the NSW Government's existing and new policies into a single framework to support the development of the State hydrogen industry. The strategy will promote development of low emissions industries selling clean fuels and products to the world by providing up to $3 billion of incentives to commercialise hydrogen supply chains and reduce the cost of green hydrogen.

The strategy helps deliver on the NSW Net Zero Industry and Innovation initiative, which is the NSW Government's flagship plan to support and partner with industry to reduce emissions and help NSW businesses prosper in a low carbon world. By accelerating the development of clean technology and decarbonisation, it aims to grow the economy, support jobs and significantly reduce emissions. The program has three areas of focus:

- Clean Technology Innovation
- New Low Carbon Industry Foundations
- High Emitting Industries

The plan identifies the Hunter as one of two NSW green hydrogen hubs. The NSW Government has committed $70 million toward the development of these hubs.

In August 2021 the Office of the NSW Chief Scientist & Engineer (OCSE) announced the establishment of a Decarbonisation Innovation Hub. The Hub will support researchers, industry and government stakeholders in critical sectors including power fuels and hydrogen to collaborate, and increase the uptake of new technologies to decarbonise NSW. The Hub will establish partnerships and enhance engagement, connect industry contacts to research expertise, assist with project plans and funding bids – national and international –and assist NSW industry and researchers to identify commercialisation pathways, cost-effective use cases and market opportunities.

Investment NSW

State government led investment support includes specific financial support such as the regional job creation fund and tailor-made skills and training packages. Concierge support is available to corporations and companies seeking to relocate to the Hunter. This includes:

- Comparative location analysis suited to business requirements.
- Identification of suitable locations
- Assistance with business planning requirements including economic and skills analysis.
- Assistance with sector specific commercial opportunities
- Coordination across key government agencies and regulatory bodies.
- Assistance in identifying business-to-business solutions and opportunities.
- Information on relocation requirements and introductions to support services.

Advice on accessing grants and other financial incentives.

Private Investment

To date there has been a number of investment and signals for future investment in the Hunter region indicating initial steps to developing a hydrogen economy. These include:

- Investment in Research via Star Scientific
- Several industry consortia that are planning or fundraising for potential projects
- Various investments supporting R&D at the University of Newcastle

INITIATIVES

A dedicated investment concierge service will help attract and facilitate investment, providing tailored support and driving a sustained investment pipeline for hydrogen for the region across the areas of infrastructure, project development, technology and services. It will augment local efforts to promote the region to prospective industry and project proponents, international partners, research organisations, suppliers and customers.

International engagement has revealed appetite and demand for hydrogen produced from the Hunter including and demand for the specialised skills and technologies offered by hunter-based HETS firms.

2021–2025 **PREPARE AND PILOT**	Regional stakeholders are consulted to define a shared brand and narrative for the region. Undertake a regional planning assessment to define infrastructure, land, and asset opportunity. Regional collaboration and advocacy to promote the Hunter region as an internationally competitive location for investment.	A Hunter Hydrogen Ambassador is engaged to drive a concierge-style model in partnership with State and Federal counterparts to drive investment to the region. Deliver an annual Hydrogen conference for the Hunter. An international market assessment is undertaken to determine priority markets for hydrogen exports and HETS.
2025–2035 **DEPLOY AND SCALE**	The Hunter is actively promoted as an attractive trade and investment destination. Grow the annual Hydrogen Conference to an annual event of regional and national significance.	Stakeholders are working collaboratively to deliver hydrogen specific International visitations and delegations to promote investment to the region. The Hunter has secured bilateral partnerships in priority markets to grow global hydrogen export supply chains.
2035+ **PROSPER**	The Hunter region has achieved export success with target international markets. International relationships have developed through tailored trade and investment initiatives, trade visits.	The region has secured a reputation as a location for reliable and quality supply for HETS that can compete in the global markets. The region has secured a reputation as a place for world class education and skills development.

HUMAN CAPITAL

The development of the hydrogen sector will require the development of new skills and capabilities across the hydrogen value chain through formal training and applied learning. Human capital investment in technical knowledge and capabilities provides the advantage of creating benefits across the broader hydrogen economy.

The Hunter is home to a highly skilled and experienced workforce, with deep expertise deep across advanced manufacturing, aerospace, defence, and resources. The region's heavy industry and mining expertise is well versed in occupational health and standards.

The Roadmap objective is to leverage this technical foundation to enable further diversification and develop the capability of firms to successfully participate in Hydrogen value chains both in the region and beyond.

Priorities for developing competitive, commercially mature industry participation is to undertake a foundational assessment of current skills and experience in the region, against the projected skills requirements for the future to determine the level of training, retraining, upskilling and competencies needed at a vocational, workplace and tertiary level.

The outlook for hydrogen-sector jobs growth is positive. According to Deloitte, the economic potential of Australia's hydrogen sector is large – up to $26 billion annually in additional GDP and 16,900 new jobs by 2050[5]. The demand generated by renewable energy including Hydrogen Hubs and the establishment of Renewable Energy industrial Precincts is estimated to create 34,000 new local jobs in new industries and $11 billion in revenue by 2032.[6]

INITIATIVES

The Hunter human capital base is well equipped in technical and industrial expertise. Specific actions to support sector growth will include engaging with Hunters industry stakeholders to understand existing capabilities and relevance to the regional, national and international hydrogen economy.

Foundational actions will help develop the skills base that is skills base that is matched to business capability and growth.

2021–2025 **PREPARE AND PILOT**	In partnership with key skills and education stakeholders, and the Institute of Regional Futures - undertake an analysis of skills requirement, map regional readiness and training requirements to meet short & long-term workforce demand (national and international). Undertake benchmark analysis to define the core competencies for participation in hydrogen supply chains, including marketing, sales and managerial.	Define career pathways and likely scenarios for a renewable hydrogen workforce. Establish a Hydrogen Skills Taskforce to work to in concert with Regional, State, and National bodies and to develop Hunter specific programs to skill, upskill and retrain. Scope the establishment of a testing and training centre for Hydrogen skill and competency development linked to demonstration sites.
2025–2035 **DEPLOY AND SCALE**	Leverage existing demonstration projects for practical skills recognition. Deliver H2-specific training certification delivered utilising demonstration sites, servicing regions beyond the Hunter.	Deliver educational and training programs for skilling, upskilling and reskilling the region's workforce, linked to national and international standards and competencies. Via the National Cluster Networks work with Federal and State jurisdictions to align a national coordinated approach to skills and training requirements for the emerging hydrogen sector.
2035+ **PROSPER**	The Hunter region has developed a strategic and holistic approach to developing workforce capabilities, aligned to industry development. The region is recognised for a concentration of expertise and skills development that can attract industry and skills delivery programs beyond the region.	The capacity in industrial training delivery, vocational education has met the needs of the sector and has evolved to a niche service offering from the region. Participating industries understand the skills and competencies required to participate in the hydrogen economy.

5. Deloitte (2019) Australian and global hydrogen demand growth scenario analysis; COAG Energy Council – National Hydrogen Strategy Taskforce. Available online at: coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/nhs-australian-and-global-hydrogen-demand-growth-scenario-analysis-report.pdf 6. Beyond Zero Emissions, Renewable Energy Industrial Precincts, Economic Analysis Summary Report, Available online at: bze.org.au

POLICY ALIGNMENT

The Roadmap acknowledges emerging policy and programs to ensure the region is well positioned to support State and Federal Government's objectives and that policy and funding relating to hydrogen are targeted and effective.

Paris Agreement & National emissions reduction strategy

The Commonwealth is committed to a 2030 emissions reduction target and delivering a long-term emissions reduction strategy before the Glasgow COP conference in November 2021. There is growing momentum to support a national goal of net-zero emissions by 2050, in line with the global community.

National Hydrogen Strategy

The COAG Energy Council endorsed and released the National Hydrogen Strategy in November 2019 through the Hydrogen Working Group chaired by the then Australian Chief Scientist, Dr Alan Finkel AO. A key element of Australia's approach is the creation of hydrogen hubs to drive large-scale supply and demand and the establishment of technology clusters. The strategy identified key application areas with specific actions for each. The broad outcome has resulted in a rapid increase in activity across the country with various local strategies and roadmaps, some including hubs.

Federal Technology Investment Roadmap

The Federal Government has not yet committed to a specific target national emissions reduction policy, instead choosing to focus on "technology, not taxes". This has led to the creation of the First Low Emission Technology Statement and Investment Roadmap 2020. The Technology Statement sets out how emerging low emissions technologies can become economically competitive with and replace current high emission practices.

Clean hydrogen and carbon capture storage (CCS) are identified as priority low emission technologies. For clean hydrogen, the key goal is to reduce its price to AU$2 per kilogram, so that it becomes competitive in applications such as producing ammonia, as a fuel for transport and for firming electricity.

NSW Electricity Infrastructure Roadmap

The NSW Government has committed to the objective of achieving net-zero emissions by 2050 and a 35 per cent reduction from 2005 levels by 2030. A central plan is the Electricity Infrastructure Roadmap, released in November 2020. Key actions include the delivery of three "Renewable Energy Zones" in the Central-West, New England, and South-West in line with retiring generators in NSW and replacement with cheaper, renewable energy in the order of 12GW of renewable investment and 4GW of storage by 2030.

NSW Net Zero Industry and Innovation Program

In March 2021, the NSW Government announced the Net Zero Industry and Innovation Program, to provide $380 million to support and re-tool existing industries with low emissions alternatives, $175 million to set up new industries such as green hydrogen and $195 million to research and develop clean technologies.[7] The Hunter was announced as one of two key regions in NSW to benefit from $75 million funding to establish a green hydrogen hub. As part of the Program's aim to establish low carbon industries, Government announced AU$70 million in funding to support the establishment of hydrogen hubs in the Hunter and Illawarra regions.

In addition to the funding released as part of the NSW Net Zero Industry and Innovation Program, the Energy and Utilities Administration Act 1987 (NSW) was amended in late 2020 to specify that AU$50 million from the Climate Change Fund established under that Act is to be directed to develop the green hydrogen sector between 2021 and 2030, including the production of hydrogen energy using renewable energy and the supply, use and export of green hydrogen.

The NSW Government released the NSW Hydrogen Strategy in October 2021.

7. energysaver.nsw.gov.au/business/reducing-emissions-nsw/net-zero-industry-and-innovation

INITIATIVES

The overarching regulatory and policy climate is dynamic and evolving and Roadmap development must align to future policy to achieve a productive and sustainable hydrogen economy.

2021–2025 **PREPARE AND PILOT**	• Engage with State and Federal Departments, inform policy, planning and regulatory developments. • Actively engage with Hydrogen Certification Scheme Developments and establish regional requirements.	• Map opportunity for regulatory harmonisation and burdens and coordinate advocacy efforts. • Disseminate relevant standards and educate industry where applicable. • Map OH&S regimes and alignment to project development.
2025–2035 **DEPLOY AND SCALE**	• Policy and legislative environment for larger-scale hydrogen applications, land use and export to be considered and consulted. • Drive world class practice in social licence to engage, drive trust and mitigate project risk impacts.	• Address State and Federal policy settings that are resulting in business impacts including emerging industry trends and hydrogen application and export. • Disseminate and share relevant regulatory and assurance aspects to hydrogen and HETS industry.
2035+ **PROSPER**	• The region is abreast of regulatory impacts and will drive a reform agenda where impacting industry competitiveness and growth.	• The region has delivered best practice OH&S frameworks and regulatory developments that have enabled an appetite for industry, and have mitigated risk. • Hydrogen produced from the region is assured and certified under a certificate of origin scheme.

SAFETY AND STANDARDS

In July 2020 Standards Australia adopted eight international standards relating to hydrogen quality, storage, transportation and usage. The standards follow the ME 093 Hydrogen Technologies Strategic work plan which commenced in 2018 that the Australian Hydrogen Council (AHC) and relevant industry stakeholders including Standards Australia worked with Australia. The standards cover:

- safety aspects of hydrogen generators
- the performance of stationary hydrogen generators for residential, commercial and industrial applications
- the quality of hydrogen fuel for vehicular and stationary applications
- the construction, safety and performance of systems to produce hydrogen by the electrolysis of water
- design and safety features of systems to purify hydrogen to meet quality standards
- design, construction and testing of portable hydrogen containers
- design, manufacture and testing of tanks for hydrogen-powered vehicles
- safety and testing of high-pressure valves used in refueling stations for hydrogen powered vehicles.

A key aspect of the Roadmap is to develop an agenda to ensure widespread understanding of applicable standards and OH&S regimes including accounting and reporting requirements. This effort works to mitigate overlap and barriers related to growth, competitiveness, productivity and investment.

INITIATIVES

Effective standards are central to the goal of developing a safe and competitive hydrogen industry in the Hunter. There is already exceptional existing expertise within the region's workforce relating to the management of risks and maintaining high standards of safety in the workplace.

The Roadmap aims to leverage Hunter strengths in the operation of hazardous gas and materials, which would lend well to ensuring the safe mitigation of risks in the production and use of hydrogen and a leadership position in industry adoption both in the region and beyond.

2021–2025
PREPARE AND PILOT

- Prepare gap analysis for industry to accelerate understanding of Standards and assurance processes.
- Via the cluster network such as NewH2 and other industry stakeholders establish a series of skills forums with industry to share industry standards relevant to hydrogen economy.
- Liaise and translate the development of Standards Australia, AIG and other peak Industry bodies such as Australian Hydrogen Council and Clean Energy Council.

2025–2035
DEPLOY AND SCALE

- Through R&D initiatives and demonstration project enact a continuous improvement culture in standards adoption, safety management.
- Monitor global trends in evolution of industry standards/best practice.
- Translate assurance and certification schemes to industry preparedness programs.

2035+
PROSPER

- Hunter industry is abreast of standards and standard development and has established a leading position and reputation in safe production and operations across the hydrogen value chain.

COMMUNITY ENGAGEMENT

The 'COAG Energy Council National Hydrogen Strategy Issues Paper Series' outlines some of the main community concerns in relation to hydrogen, which informs some of the enablers and actions needed in the future to achieve community engagement and acceptance.

Community engagement will draw from a fundamental approach to identify how the broader Hunter community will benefit from the hydrogen economy and understanding how different stakeholder groups may respond to a new and expanding industry.

The Roadmap recognise that establishing community confidence in the safety of hydrogen production processes is a critical success factor for the development and participation of a clean hydrogen industry.

Community engagement aspects will focus on key areas including:

- An increase in current understanding and knowledge
- Impact on environment, water and land use
- Safety aspects related to hydrogen production and use
- Costs, benefits, opportunities, risks in relation to existing industry settings
- Associated impacts for individuals, households, and regions.

The Hunter Research Foundation Centre and the University of Newcastle Centre for Social Research and Regional Futures (CSRRF) are examples of organisations that work across cross-cutting complex settings to establish stakeholder engagement frameworks and support planning platforms for the future.

NewH2 – Hunter Hydrogen Technology Cluster as a consortium of stakeholders offers another platform to engage across a wide network, and to provide the knowledge and communication collateral for knowledge exchange and wider community education. This can be disseminated via traditional communication channels, workshops and connection to anchor demonstration projects as examples of what can be achieved.

INITIATIVES

The Roadmap activities aim to foster community understanding and acceptance of hydrogen applications and more broadly of the opportunities hydrogen offers for the region.

2021–2025 **PREPARE AND PILOT**	• Hunter Research Foundation Centre to undertake economic, social licence and community engagement strategy development. • Develop a community and stakeholder engagement framework aligned to Roadmap strategy to engage with the community on the possibilities and benefits of hydrogen.	• Engage with emergency services entities to ensure they have the necessary information available to them for responding to any potential risk or event aligned to Australian Standards. • Support via NewH2 Cluster for the delivery of a Knowledge exchange, education and branding campaign.
2025–2035 **DEPLOY AND SCALE**	• Continue to build trust for hydrogen as connected to the consumer supply chain. • Track key Hunter Region economic indicators to measure impact of the hydrogen economy to the region.	• Continue community engagement efforts to include "tours" of demonstration projects to inform STEM education and community groups.
2035+ **PROSPER**	• Through the delivery of a foundational framework there is widespread community engagement, understanding, acceptance and support of the Hydrogen economy in the Hunter.	• There is evidence of a positive impact to the hunter economy across a range of economic indicators.

NEXT STEPS

The Hunter Hydrogen Taskforce have provided advice on regional priorities to harness the tremendous opportunities created by the emerging global economy. The roadmap acknowledges the significant activity in the region already underway, and works to coordinate efforts to scale up and accelerate hydrogen in the Hunter. It has articulated a vision for the region and sets a pathway for the Hunter to be a leading hydrogen hub and technology cluster, demonstrated by an excellence in research, innovation and education, production, use, export and employment participation across the hydrogen supply chain.

The Roadmap identifies the strategic enablers that will underpin and optimise the delivery.

- **REGIONAL COLLABORATION**
- **R&D AND INNOVATION**
- **INVESTMENT ATTRACTION**
- **HUMAN CAPITAL**
- **POLICY ALIGNMENT**
- **SAFETY AND STANDARDS**
- **COMMUNITY ENGAGEMENT**

Specific actions and deliverables have been outlined for each strategic enabler and time horizon, recognising the structurally complex and dynamic environment.

A strong Hunter hydrogen future will require collaborative efforts and targeted engagement between industry, investment, research, government and the community. Standards, assurance and safety also require careful consideration. These enablers must work in parallel to drive development forward.

The Taskforce recommend an oversight body and Hunter Hydrogen Ambassador to take recommendations forward.

As the roadmap is implemented, the Taskforce is confident that opportunity offered by hydrogen will translate into new industries, jobs and economic growth, and contribute to the region's objectives to diversify the economy and maintain our lead as Australia's Energy Capital in the low carbon future.

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ACRONYMS

AIG	Australian Industry Group
ARENA	The Australian Renewable Energy Agency
ARC	Australian Research Council
BZE	Beyond Zero Emissions
CCIC	Central Coast Industry Connect
CCS	carbon capture storage
CEFC	Clean Energy Finance Corporation
CO2	Carbon Dioxide
CIMR	Centre for Ironmaking Materials Research
COAG	The Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ERKH	Energy & Resources Knowledge Hub
HETS	Hydrogen Equipment, Technology and Services
HyRIF	Hydrogen Research and Innovation Facility
IP	Intellectual Property
KI	Kooragang Island
LETS	Low Emissions Technology Statement
MOU	Memoradum of Understanding
NERA	National Energy Resources Australia
NewH2	Hunter Hydrogen Technology Cluster
NIER	Newcastle Institute for Energy and Resources
OCSE	Office of the NSW Chief Scientist & Engineer
P2X	Power-to-X (also P2X and P2Y) is a number of electricity conversion, energy storage, and reconversion pathways
REZ	Renewable Energy Zones
R&D	Research and Development
SAP	Special Activation Precincts
SME	Small to Medium Enterprise
SMR	Steam Methane Reforming
UON	University of Newcastle