Port of Newcastle Green Hydrogen Hub

Feasibility Study – Public Summary Report

August 2023

ARENA Project: 2021/ARP012

Note: "Macquarie Green Investment Group" has been re-named as "Macquarie Asset Management Green Investments"

Contents

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This Project received funding from ARENA as part of ARENA’s Advancing Renewables Program.

1. Executive Summary

The Port of Newcastle Green Hydrogen Hub Project

Port of Newcastle Green Hydrogen Hub is a green hydrogen and ammonia hub project that was expected to be developed by Macquarie's Green Investment Group ("**Macquarie GIG**")[1] and the Port of Newcastle ("**PON**") (together the "**Project Sponsors**"). The thesis behind Port of Newcastle Green Hydrogen Hub was that PON was a potentially ideal location for an early hydrogen and ammonia hub given its existing infrastructure, access to electricity and proximity to early demand. The plan for the Project was to develop an early project accessing domestic production and leveraging concessional funding from the Government that would be well positioned for an emerging export market in the coming years.

The feasibility study

The Project Sponsors with part funding from the Australian Renewable Energy Agency ("**ARENA**") progressed a concept feasibility study ("**feasibility study**"). The feasibility study was structured in two stages. The key areas that were tested as part of Stage 1 of the feasibility study included:

- The timing and feasibility of proposed hydrogen offtake cases including heavy mobility, power to gas, fertiliser, bunkering and export;
- A comparison of the different sites in and around the Port;
- The availability of services and infrastructure for a pilot (~40MW) and large scale (+1GW) facility;
- The potential options for berthing and bunkering at the Port;
- A concept design and estimated costing (class V estimate); and
- A vision for the future of hydrogen in the region and the potential benefits the industry could provide the hunter.

Feasibility study outcomes

The key outcomes of Stage 1 of the feasibility study include:

- The Kooragang Island Waste Emplacement Facility ("**KIWEF**") was the preferred site at the Port given the:
    - Availability of land (+200ha);
    - Access to services including proximity to the 330kV Transgrid power line;
    - Proximity to existing infrastructure and berthing; and
    - Proximity to other industry and hazards.

  (Other sites investigated including Walsh Point and Mayfield).
- The Project is technically feasible and there is expected to be land and services available for an electrolyser of up to 1GW and associated plant.
- The key offtake for a larger plant would be ammonia for domestic use. Newcastle is a key supply point for ammonia on the East Coast with existing distribution and storage infrastructure.
- Power to gas and hydrogen mobility use cases are emerging and potential demand from these use cases would be smaller for early plants.
- The Port has a range of berthing options that may be used for a future export operation.
- The ~40MW plant had a high cost of production as a result of the high level of fixed costs and operational staff that was included. The study determined a plant above ~150MW would provide a significantly lower per unit production cost.
- The electricity market had changed significantly since the Project was first scoped. Electricity pricing was higher and more volatile than envisaged at inception of the Project. With recent energy market events, the outlook for the Project was seeking to purchase long term electricity

1: "Macquarie Green Investment Group" has been re-named as "Macquarie Asset Management Green Investments" from a market that was in short supply (given the announced closing of existing coal-fired generators) and facing rising costs.

Economic feasibility

Given the costs of producing green hydrogen, the feasibility of the Port of Newcastle Green Hydrogen Hub project was (and is) dependent on receiving a range of Government support which at inception of the feasibility study was expected to include:

- Support for the upfront construction cost of the plant;
- Ongoing revenue support to underwrite and provide some certainty regarding the emerging green premium in different markets; and
- Access to a wholesale electricity market without Distribution Use of System ("**DUOS**")/ Transmission Use of System ("**TUOS**") charges.

Key changes to the macro environment that have impacted our initial analysis include:

- The introduction of the Inflation Reduction Act ("**IRA**") in the United States in August 2022. This has removed market expectation regarding the emergence of a green premium for markets exposed to imports; and
- Significant cost inflation as a result of COVID and the war in Ukraine amongst other factors.

These factors have meant that:

1) the amount of concessional finance required for the Project to reach a Financial Close has increased significantly; and

2) the horizon for scale up of the Project has become uncertain as without ongoing Government subsidy output from the Project will not be able to compete with the global market.

Next steps

The Project Sponsors had agreed to assess the outcome of the Stage 1 feasibility study before progressing to Stage 2 and developing a more detailed implementation plan to progress the Project to FEED stage and ultimately Financial Investment Decision ("**FID**").

However, as described in more detail in Section 5, the Project Sponsors have ultimately decided to not progress to Stage 2 feasibility study.

This does not prevent a future development of the Port of Newcastle Green Hydrogen Hub, if and when the commercial feasibility of the Project become viable and attractive for the Project Sponsors to continue to fund the development of the Project.

Important note: The Feasibility Study was conducted prior to the finalisation of the Federal Government's Hydrogen Headstart programme. The Hydrogen Headstart program is expected to support the earnings of a plant for a period of time. Subject to the final details of the Programme, this type of support is expected to help the development of Australian green hydrogen projects.

2. Project Definition

2.1 Background

Macquarie GIG and PON had been seeking to develop an integrated clean hydrogen and ammonia production and export hub at the Port of Newcastle. The Project Sponsors sought and received grant funding support from ARENA to complete the feasibility study on the Project. The Project was expected to be developed through multiple phases to meet the projected off-take demand for green ammonia and hydrogen corresponding to the forecast growth of these products.

At the start of the feasibility, the Project Sponsors were targeting to develop a pilot plant with a nominal installed electrolyser capacity of ~44MW producing hydrogen to supplement mobility trials, gas blending to the domestic natural gas network, and a 20ktpa ammonia production facility ("**Phase 1 Project**" or "**pilot plant**"). The Phase 1 Project was targeting to commence ammonia production from the pilot plant in mid-2025.

The plant was expected to be expanded in latter phases to reach a nominal installed electrolyser capacity of ~1GW and an ammonia facility of ~530ktpa by 2030 ("**Full Expansion Project**" or "**full-scale plant**"), catalysing decarbonisation of the industries within the Hunter Region and provide further opportunities for natural gas blending, mobility applications, renewable power generation and growing the export market for green ammonia.

The development of the feasibility study was planned to occur in two stages: the first stage was focussed on a desktop analysis and the second stage was intended to progress the early development of the Project and refine the costing and design assumptions from Stage 1. This Report covers the outcomes from Stage 1 of the feasibility study that commenced in November 2021 and was completed in June 2022. A summary of the feasibility study workstreams is contained in Section 1.4.

2.2 Rationale

The feasibility study allowed the Project Sponsors to test the rationale for the Project, including the expected economics and make a decision as to how to progress to full development.

The key rationale around developing the Project included:

- a broad and comprehensive range of potential use cases for a green hydrogen and ammonia production and export hub in the Hunter region, including applications across fertiliser, mobility, blending into the gas network, export and bunkering;
- the Port of Newcastle is potentially an ideal location for the Project, exhibiting favourable characteristics such as its existing deep-water port with world-class infrastructure, strong industry and skills partnerships, access to significant electricity and water infrastructure, proximity to existing demand and access to global energy export routes;
- suitable land holdings are available at the site to support both a Phase 1 Project and a Full Expansion Project;
- the Project might have the ability to provide electricity market ancillary services to assist, as well as other opportunities to provide supporting services to, the wider National Electricity Market; and
- the Project has the potential to generate significant outcomes in job creation during the construction and operation phases, develop new industries, and contribute to Australia's long-term economic and energy strategy.

2.3 Project sponsors

The Project Sponsors entered a Memorandum of Understanding ("**MoU**") in 2021 to co-develop the Port of Newcastle Green Hydrogen Hub.

Macquarie GIG is a specialist green investor within Macquarie Asset Management, and a global leader in the development of companies, assets and technologies that aim to accelerate the global transition to net zero. Initially launched by the UK Government in 2012 as the Green Investment Bank, it was the first institution of its type in the world. Acquired by Macquarie in 2017, Macquarie GIG has grown to become one of the world's largest green investors with a development pipeline of 45 GW in over 25 markets as of 30 September 2022, spanning established renewables and emerging green technologies. Macquarie GIG has development capabilities to support the development of the Project, including leveraging its expertise in: (i) securing the optimal energy solution and power purchase agreement(s); (ii) sharing lessons learnt across several hydrogen projects under development in Australia, the Americas and Europe; and (iii) raising debt for infrastructure and energy assets.

PON is Australia's deep-water global gateway and the largest port on its east coast. With trade worth ~A$37B to the national economy annually, PON is a significant enabler of Australian businesses to successfully compete in the international markets. PON currently handles 4,697 ship movements and 166Mt of cargo annually, with deep-water shipping channels operating at only 50% of its capacity. Additionally, PON has available land in a new undeveloped energy precinct with access to existing global and domestic energy supply chains with world-class infrastructure. In combination with strategic partnerships being secured with key end-market players of its import/export market, PON is positioned to further underpin the future prosperity of the Hunter, NSW and Australia through clean hydrogen and ammonia production.

2.4 Feasibility study process and other project partners

During the feasibility study, the Project Sponsors engaged specialist consultants to undertake detailed financial modelling and engaged in discussions with potential off-takers to assess the feasibility of the Project. The outcomes from this process have informed the decision-making regarding next steps.

The feasibility study has been structured in two stages:

1. **Stage 1** comprised desktop feasibility investigations, with the aim of determining whether there is a path to technical and commercial feasibility. Stage 1 considered the feasibility of both the Phase 1 Project (~44 MW) and the Full Expansion Project (1 GW+ export scale), such that a potential scale up of production is included in Phase 1 planning considerations. The Project Sponsors would need to receive sufficient evidence of technical feasibility, expected electricity costs being within an economically viable range and availability of concessional funding for the Phase 1 Project (~44 MW) prior to progressing to Stage 2.
2. **Stage 2** comprised of detailed investigations and costings, with a view to enabling an investment decision to progress to FEED for the Phase 1 Project. Preliminary design would be undertaken for this plant, including development of tender packages to receive pre-FEED costing estimates for key plant components.

The following table provides a summary of the eight workstreams that formed the feasibility study and lists the project partners that have contributed and participated in those workstreams in addition to the Project Sponsors and the consultants engaged to conduct the work.

A public version of the Element Energy / ERM report will be made available on the ARENA Knowledge Bank website[1].

[1] https://arena.gov.au/knowledge-bank/

Table 1. Feasibility study workstreams, consultants and project partners

Workstream	Deliverable	Workstream Details	Project Partner(s)	Consultant Engaged
Technical	Technical Report	Technical study to assess the feasibility of ~44MW pilot plant and ~1GW full-scale plant	• N/A	• WSP Australia
Fertiliser	Market Study Report	Market analysis to assess the demand and growth of green ammonia as a fertiliser	• Macquarie Agriculture	• Argus Consulting
Mobility	Mobility Report	Market analysis and concept design for the application of hydrogen to enable mobility use cases and building out a mobility eco-system	• Keolis Downer • Lake Macquarie City Council • Aurizon Australia	• ERM / Element Energy
Export & Bunkering	Market Study Report	Market analysis to assess demand and growth of green ammonia as an energy carrier for power generation and bunkering fuel	• Idemitsu Australia	• Argus Consulting
	Technical Report	Concept design of the export and bunkering berth for the loading of ammonia for international markets	• Idemitsu Australia	• WSP Australia
Pipeline	Pipeline Report	Feasibility and concept design of a pipeline network that enables the gas blending of hydrogen into the domestic natural gas network owned and operated by Jemena with later phase supporting hydrogen supply to the Kurri Kurri gas generator and long-term extensions to support industrial decarbonisation	• Jemena • Snowy Hydro	• GPA Engineering
Commercial	Hunter Vision Report	Impact assessment report concerning Port of Newcastle Green Hydrogen Hub's economic and decarbonisation benefits to the Hunter region	• N/A	• KPMG
Stakeholder Engagement	Stakeholder's Engagement Report	Engagement with Hunter region industry participants	• N/A	• KPMG
Energy Solution	N/A	Confirmation of net energy costs, including electricity market forecasts or retailer pricing, TUOS	• N/A	• Project Sponsors

Workstream	Deliverable	Workstream Details	Project Partner(s)	Consultant Engaged
		/ DUOS charges, and ancillary services revenue		

2.5 Process for project approval and development

The Project Sponsors agreed to assess the outcome of the Stage 1 feasibility study before progressing to Stage 2 and developing a more detailed implementation plan to progress the Project to FEED stage and ultimately a FID.

However, as described in more detail in Section 5, the Project Sponsors have ultimately decided to not progress to a Stage 2 feasibility study for the time being and therefore the Project's development journey is currently on hold.

This does not prevent the future development of the Port of Newcastle Green Hydrogen Hub, if and when the commercial feasibility of the Project becomes viable and attractive for the Project Sponsors to continue to fund the development of the Project.

3. Technical Feasibility

3.1 WSP disclaimer

The information cited here is from a report prepared by WSP Australia Pty Limited for the sole benefit of the Port of Newcastle and Macquarie Corporate Holdings Pty Limited (the "Proponents") (the "WSP Information") in accordance with the instructions of the Proponents and has only considered the interests of the Proponents. You acknowledge and agree:

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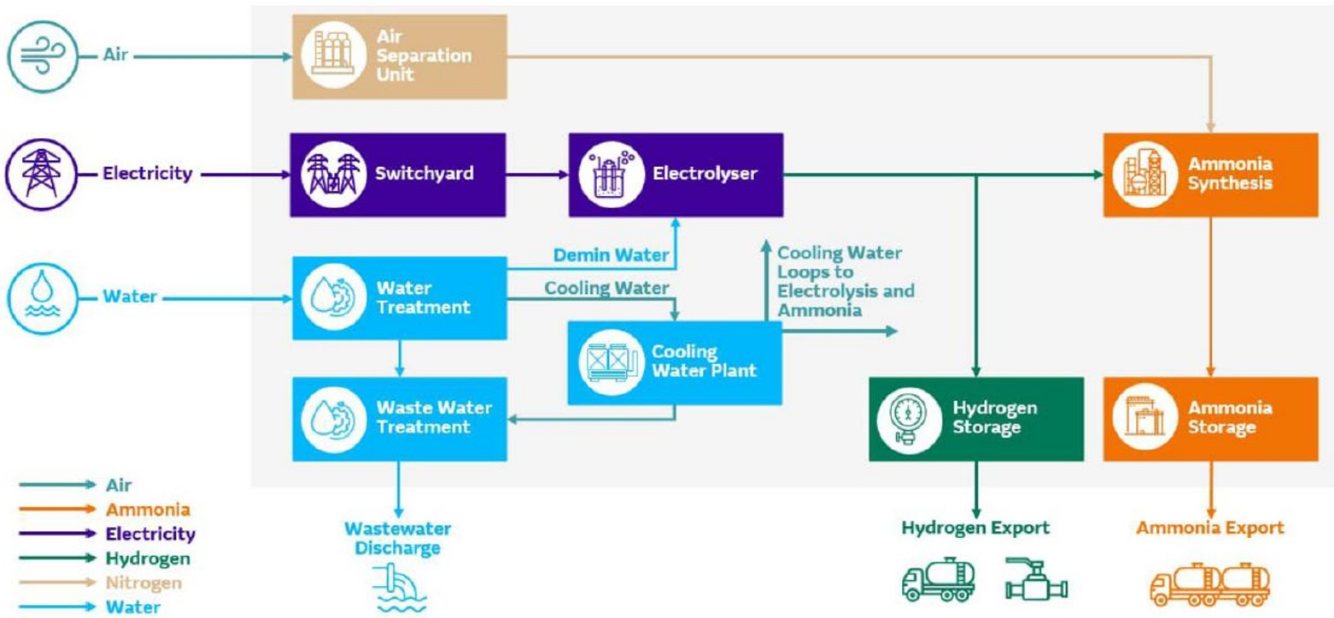
3.2 Design concept

The Project is designed to generate gaseous hydrogen and liquid ammonia with the feedstock of water, air and renewable energy (grid-connected). The process to generate these two outputs can be segregated into two main parts:

1. **Hydrogen** is obtained through the electrolysis of water, a process powered by renewable electricity. Firstly, potable water from Hunter Water Corporation or recycled wastewater from Water Utilities Australia enters the water treatment plant. Here, the water is filtered to remove suspended solids and treated with sodium bisulphite to reduce free chlorine. The filtered water is then pressurised and treated through reverse osmosis units to remove dissolved solids and other impurities. Finally, the reverse osmosis permeate is demineralised to remove the final trace quantities of the dissolved minerals. The demineralised water is then split into hydrogen and oxygen in the electrolysers, where the oxygen will be safely vented into the atmosphere. Most of the hydrogen is used as a feedstock for the ammonia synthesis process, with the leftover amount piped/trucked offsite.

2. **Ammonia** is obtained through the Haber-Bosch process, using the feedstock hydrogen and nitrogen extracted from the air as inputs. Firstly, air enters the separation plant and is dust-filtered to remove dust and pollen. It is then compressed and fed into a purification unit to remove water, carbon dioxide and hydrocarbon molecules. The air is subsequently entered into a fractional distillation chamber, where the nitrogen is separated from the oxygen and argon in the air. Within the ammonia synthesis plant, hydrogen and nitrogen gas are first mixed to form a synthetic gas ('syngas'). The syngas is then compressed and heated before entering the iron catalytic bed reactor, providing an environment that is more conducive for hydrogen and nitrogen to react. The hydrogen is then absorbed onto the nitrogen atoms, and ammonia is produced; the produced ammonia, together with the unreacted syngas, is then cooled down for ammonia condensation, separating the ammonia liquid as bleed stream from the unreacted syngas. The unreacted syngas is subsequently recycled back into the iron catalytic bed reactor alongside fresh syngas, whereas the liquid ammonia is pumped into the storage tank for distribution and export.

Figure 1. Pilot plant concept design



It is worth noting that the hydrogen will be generated using either proton electrolyte membrane ('PEM') or alkaline electrolyser technology.

The process also requires "balance of plant" components to support its production requirements. These comprise of a stable grid connection, connection to water supply, recycled water supply and sewer for water discharge, wastewater treatment plant, cooling plant, instrument air compression, chemical dosing system, ammonia vapour recovery unit, vent flare system, hydrogen compression for ISO container storage and feeding into the gas blending pipeline, and hydrogen and ammonia loading to road transport vessels.

Figure 2. Conceptual layout of the pilot plant

Electrolyser	
Capacity	150 MW
Type	Alkaline or PEM
Availability	92%
Utilisation rate	93%

Figure 3. Indicative location of the pilot plant

Note: The layout presented on the left hand side does not reflect the configuration required to optimise the plant on the proposed KIWEF footprint.

3.3 Design assumptions

During the feasibility study, the assumption for a ~44MW pilot electrolyser plant for the Phase 1 Project was proposed with key design inputs as indicated in Table 2. It is assumed that the plant would be grid-connected (i.e. the electrolyser can access required electricity freely when needed and is not constrained by the intermittent availability of behind-the-meter renewable electricity supply). The plant's operational profile assumes the electrolyser is being turned on and off daily in correspondence to periods of high energy pricing (an assumption has been made to exclude 20% of the day or 4.8 hours on average). To maintain steady-state ammonia production and cover periods when the electrolyser is turned off, the plant design includes hydrogen storage to allow the ammonia synthesis plant to operate continuously.

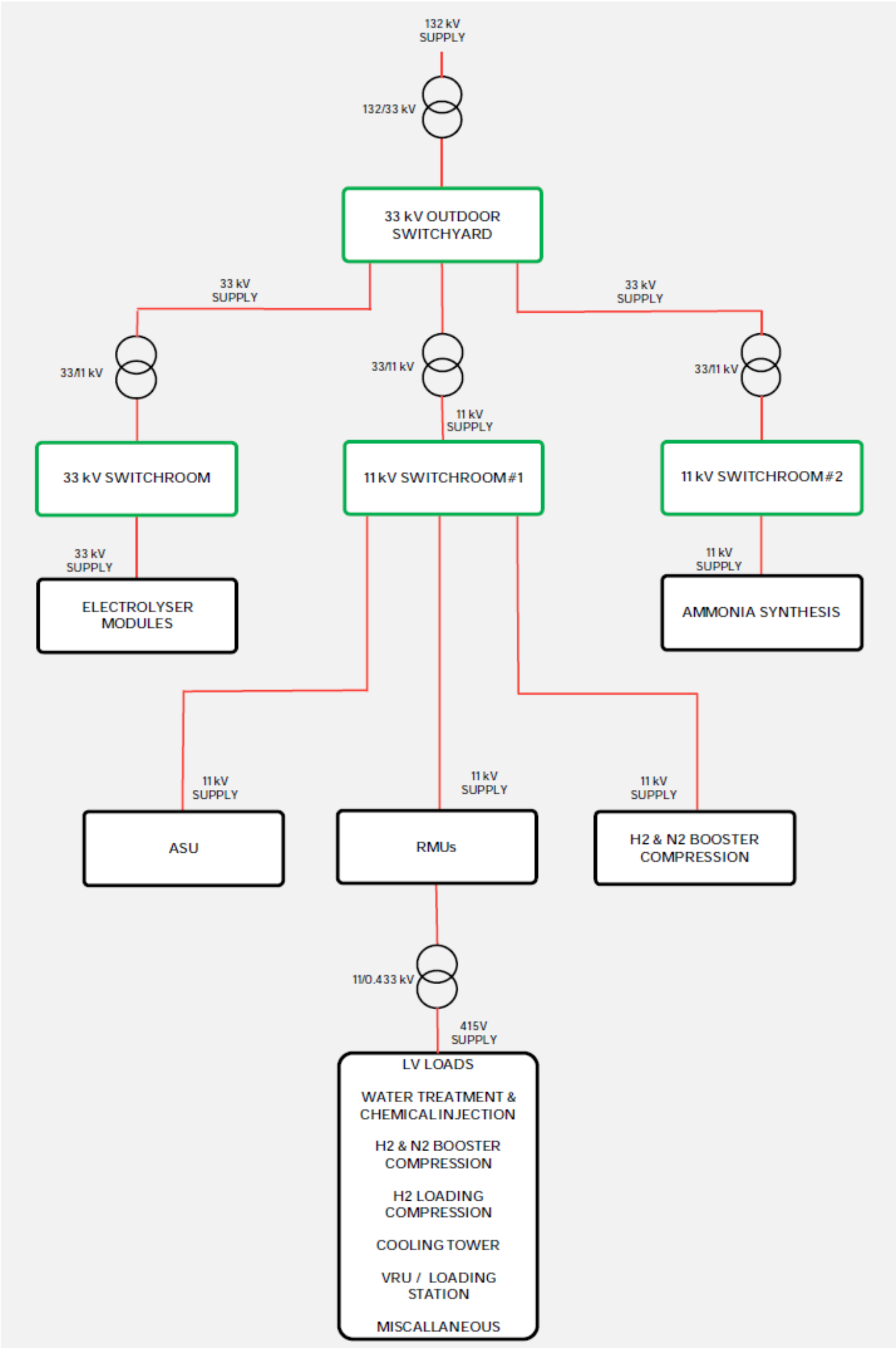
Table 2. Key design input – pilot plant

Parameter	Unit	Value	Commentary
Hydrogen Output	ktpa	5.4	Annual hydrogen production
Ammonia Output	ktpa	20.0	Annual ammonia production
Electrolyser Efficiency (Average)	kWh/kg	55.7 (alkaline)	ALK BoL – 52.59; EoL – 58.81; Average – 55.65kWh/kg PEM BoL – 51.97; EoL – 58.12; Average – 54.99kWh/kg Calculated as the midpoint of the electrolyser efficiency with a degradation of 1.25% p.a. carried across 10 years from the Beginning of Life ('BoL') efficiency to End of Life ('EoL') efficiency
Electrolyser Utilisation	Rate	80%	Annual average utilisation, noting that the electrolysers will typically operate at either 100% capacity or 10% capacity (the 80% is therefore an average). Electrolysers have flexibility to ramp down in response to high electricity prices or FCAS opportunities. 80% was chosen based on the expected volatility in the electricity markets. We expect the actual utilisation would be set based on the market pricing and activity at the time.
Annual Operational Availability	Rate	92%	Assuming 4 weeks annual maintenance and unplanned downtime. This is also the net capacity factor of the ammonia plant. The difference in net capacify factor between the electrolyser and the ammonia plant can be explained by the storage infrastructure deployed to allow the ammonia production to work based on an 80% electrolyser net capacity factor.
Balance of Plant Load (Including House Loads) Electricity Factor	Rate	20% of the electrolyser capacity	Based on market research including balance of plant and ancillary equipment

3.4 Power supply requirements, availability, and arrangements

The Phase 1 Project is expected to be supplied from Ausgrid's Waratah West Transmission network. While the Waratah West substation offers 33kV and 132kV, load demand on the former would adversely impact other 33kV customers under switching or fault events. Therefore, a 132kV supply is likely to be the most appropriate for the Project, dispensed through a single circuit overhead line. The incoming 132kV supply to the site would connect via a 132/33kV step-down transformer, feeding the 33kV outdoor switchyard. The proposed busbar arrangement is a single bus arrangement with the feeder and transformer being able to supply the full load of the entire site. The HV system can be described as radial 33kV and 11kV network which provides power supply for the entire plant. The 33kV network is used to supply the electrolysers while the 11kV network will supply the remaining electrical loads.

Figure 4. Proposed electrical system block diagram of the pilot plant



The process plant operational availability is set to 92%. The 8% downtime is expected to accommodate for 2 weeks unplanned shutdown and 2 weeks annual maintenance. However, this figure is subject to optimisation by the OEM/supplier and further maintenance planning.

Regarding engagement with utility providers, the Project Sponsors have developed a preliminary connection enquiry to Ausgrid for connection design services. Ausgrid has since issued a Design Related Services Offer and the Project Sponsors expect to engage Ausgrid to proceed with the connection studies during the Stage 2 feasibility study.

3.5 Water supply requirements and availability

The Phase 1 Project's water treatment systems have been designed based on the water quality requirements of its downstream processes. In summary, there are two principal streams that require water for hydrogen production – electrolyser feed water and balance of plant feed water. While both streams require ultra-pure quality feed water, electrolyser feed water quality is expected to be more stringently assessed due to the pilot plant preference for PEM electrolysers. Regarding balance of plant feed water, cooling tower make up is the major consumer of the water demand, and the leftover demand is for site services (i.e. wash down) and fire water requirements.

Water is expected to be readily available from two water sources – potable water from Hunter Water Corporation and recycled water from Water Utilities Australia. A dedicated desalination plant was considered, but it was discarded for the pilot plant due to the prohibitive cost of seawater intake/outfall infrastructure and the extensive environmental permits required. Potable town water supply for the plant through Hunter Water Corporation is available at all site options investigated. Additionally, Water Utilities Australia's recycled water plant is supplied from the treated effluent from Hunter Water Corporation's Shortland wastewater treatment plant. Water Utilities Australia has estimated current recycled water availability to be 33.2ML/month (annual average), which will make up the majority (i.e. 73%) of the pilot plant feed demand, but not the entire volume.

3.6 Summary of design elements for cost estimation

The Project has assumed the design elements laid out in Table 3 as a basis for the cost estimation exercise.

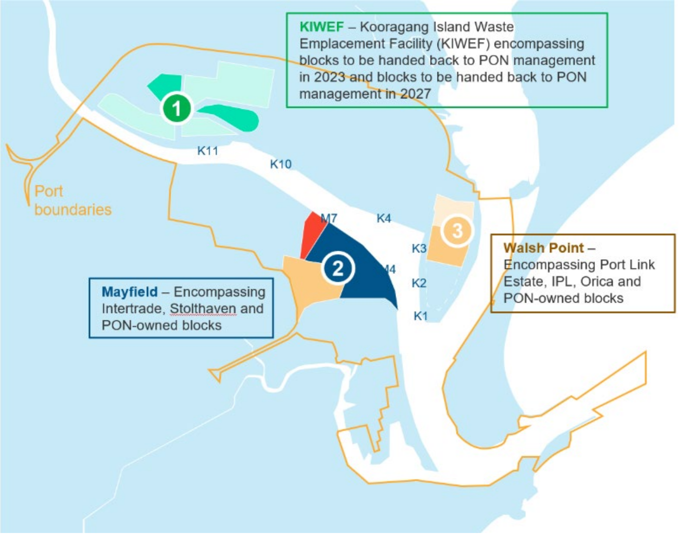
Table 3. Design Elements

A – General / Sitewide	B – Process Plant (incl. water)	C – Power Supply	D – Ancillary Facilities
• Site preparation works • General sitewide earthworks, bulk excavation, fill etc • Site access road • Site roads • Site fencing • Stormwater management • Environmental ponds, dams etc • Site services • Landscaping	• Water treatment unit • Electrolyser unit • Air separation unit • Gas booster • H_2 loading • Ammonia synthesis • Ammonia storage and vapour recovery unit • Miscellaneous	• Connection • Switchyard • 33kV distribution • 11kV distribution • LV distribution	• Gatehouse • Tube trailer staging area • Laydown area • Administration building/control room • Workshop • Warehouse/store

3.7 Production site assessment

As part of the ARENA funded feasibility study, the Project Sponsors completed a site assessment with WSP to identify the appropriate site for hydrogen and ammonia production at the Port of Newcastle. The site selection process considered three distinct precincts: (1) Kooragang Island Waste Emplacement Facility ("**KIWEF**"), (2) Mayfield and (3) Walsh Point precincts, as shown in Figure 5.

Figure 5. Potential Port of Newcastle Green Hydrogen Hub sites considered



A high-level desktop assessment of the three precincts was conducted based on criteria such as operational risk impact to surrounding land zones, environmental and planning approval pathways, geotechnical risks, contamination risks, community opposition, availability of suitable land, ease of ownership and access to resources and infrastructure. Ultimately, the KIWEF precinct was selected as the preferred site location based on these criteria. Table 4 provides a summary of advantages and disadvantages for each precinct assessed.

Table 4. Summary of key findings for the precincts assessed

Kooragang Precinct – KIWEF	Mayfield Precinct	Walsh Point Precinct
✓ Good separation from residential areas ✓ Land options and capacity for 2GW+ facility ✓ Access to Transgrid 330kV and Ausgrid 132kV networks ✓ Road and rail access ✓ Opportunity to repurpose coal infrastructure in future ✓ Access to berthing	✓ Acceptable separation from residential areas ✓ Land capacity for 2GW+ facility ✗ Constrained electrical capacity and available corridors/easements for upgrade	✓ Existing ammonia infrastructure and berthing ✗ Inadequate separation from residential areas ✗ Constrained land and utilities capacities can only support up to 250MW facility ✗ Inability to scale beyond Phase 1 ✗ Cumulative hazard risk associated with existing and adjacent industry

The KIWEF site location provides significant benefits toward the Project:

- Capped and remediated land area available for construction of both pilot and full-scale plants, with most of the land area to become PON-managed in the second half of 2023.
- KIWEF is the preferred option for both pilot and full-scale plants for grid power connection. KIWEF is in close proximity to potential Ausgrid (132kV) and Transgrid (330kV) networks.
- Good access to potable water with a 1,050mm diameter Hunter Water Corporation potable water trunk main running on the northern boundary, as well as a 400mm diameter Water Utilities Australia recycled water main running on the southern boundary. Further, the KIWEF precinct has a 600mm diameter sewer rising main running on the southern boundary.

- The site is also situated on the north side of the river which is the preferred site if desalination options are evaluated in the future (for a full-scale plant). This location also has potential to supply treated wastewater to neighbouring industries (etc. for coal dust suppression).
- The site has strong access to the Jemena pipeline easement on the north of the site (for gaseous hydrogen export) and general vehicle access to the precinct for hydrogen export by tube trailers and ammonia export by tanker.
- KIWEF provides the opportunity to co-locate the pilot and the full-scale plant, subsequently having all hydrogen infrastructure within a common port precinct.

3.8 Capacity of electrolyser technology to participate in ancillary markets

The feasibility study assessed the potential for the Project to facilitate development of a significant number of renewable projects in New South Wales, potentially leading to lower electricity prices and reduced electricity price volatility. On one hand, the Project could provide a stable load to the National Electricity Market and enable sustained renewable generation demand for new renewable generators and on the other hand the Project could deliver valuable services to the grid network by operating flexibly. Those potential benefits have been explored qualitatively and are summarised in Table 5.

Table 5. Electrolyser benefits to the energy market

Enabled Grid Services	Commentary
Voltage Control	Fluctuations in power output of intermittent renewables can cause voltage fluctuations, which reduce the power quality in the grid. An electrolyser with flexible operating capabilities has the potential to reduce voltage fluctuations.
Load Shifting and Storage	The variable load of electrolysers helps reduce volatility in the electricity market and is complementary to the build out of renewables. It also provides storage for the broader energy market and maybe used to provide low emission firming in gas fired generators. As an alternative to electrification, energy stored as hydrogen molecules is used by industry, heavy mobility, and existing gas users to decarbonise their operations.
Optimal Use of Infrastructure Capacity	The use of electrolysers and hydrogen provides an efficient energy system that delivers renewable energy to end users in the form of molecules rather than electrons. When coupled with the effect of leveraging the additional capacity in existing electrical infrastructure and gas pipelines, hydrogen used as an energy source minimises the need for construction of additional transmission infrastructure.
Marginal Loss Factor (MLF) Improvement	The Project provides additional load to the energy grid which will assist the build out of renewable generation in nearby areas. The large load has the potential to reduce energy transmission losses near the Port of Newcastle Green Hydrogen Hub, consequently improving the MLF applied to nearby developments. As a result, the financial performance of these energy generators could improve, and the region could become more attractive for renewable energy generation.
Frequency Control Ancillary Services	The electrolyser and wider plant are likely able to increase load in contingency FCAS markets to help lower network frequency in contingency events, with the potential to provide both 6 second- and 1-minute raise and lower contingency. The potential for accessing revenue streams from valuable FCAS markets will depend on the electrolyser capability to ramp up and ramp

Enabled Grid Services	Commentary
	down quickly. Whilst the Proton Exchange Membrane (“**PEM**”) and Alkaline technologies are expected to be able to operate flexibly, broadly speaking the feedback from suppliers is that PEM will be more flexible than the Alkaline technology.
Demand Response	The Project would be able to participate in the Wholesale Demand Response Mechanism provided that facility does not have direct exposure to wholesale prices. Providing demand response services can improve grid stability and minimise potential blackout events in periods of high demand/low supply.
Reliability and Emergency Reserve Trader (“**RERT**”)	The Project may be able to offer services to AEMO as a RERT panel member.

3.9 Environmental impact assessment

A preliminary assessment of the environmental impact issues and their associated risks is presented in Table 6 below:

Table 6. Key environmental planning considerations and risk for the pilot plant

Environmental Issue	Description	Pilot Plant Preliminary Risk	Specialist Reporting Required to Consider Risk
Air Quality	Potential changes in air quality levels and increases in dust at both plants, and high toxicity levels at the Main Plant. Air pollution and dust could affect surrounding residents in the suburbs of Mayfield/Mayfield West	Medium	Air quality impact assessment in line with *Protection of the Environment Operations Act 1997* and the NSW Environment Protection Authority Approved Methods for the Modelling and Assessment of Air Pollutants in NSW
Biodiversity (Terrestrial)	Potential for the Project to impact the local Green and Golden Bell Frog (listed as ‘Endangered’ in NSW and ‘Vulnerable’ under Commonwealth status). Additionally, the Project can result in habitat loss, contamination of surrounding areas and wetlands, and loss of some ecosystem	Medium to High	Impacts to the Green and Golden Bell Frog would likely require a referral under the *Environment Protection and Biodiversity Conservation Act 1999* for the Main Plant, alongside the provision of a Biodiversity Development Assessment Report (‘**BDAR**’)
Biodiversity (Marine)	The project could result in impacts to marine species in the surrounding Hunter River and estuaries. Potential for impacts to threatened species because of contamination from the plant(s)	Low	A BDAR would be required for impacts to marine species

Environmental Issue	Description	Pilot Plant Preliminary Risk	Specialist Reporting Required to Consider Risk
Coastal Wetlands North and South of the Project	There are mapped coastal wetlands to the north and south of the plant, including the Hexham Swamp nature reserve. Construction and operation of the project including potential contamination in the Hunter River is likely to impact these wetlands and local wildlife	High	A BDAR would be required for impacts to nearby coastal wetlands, to the north and south of the project. Wetlands in NSW are protected under the *Biodiversity Conservation Act 2016* (BC Act), EPBC Act and the State Environmental Planning Policy (Resilience and Hazards) 2021
Hunter River Contamination	Contaminants from the plant have the potential to run-off into the surrounding Hunter River and estuaries. The Hunter River estuary is a large barrier estuary and contains the extensive Hunter Estuary Wetlands. Contamination to these wetlands could affect wildlife including the Green and Golden Bell Frog and other threatened species	Medium	Compliance with site audit requirements and the existing remediation plans for each plant
Key Fish Habitat	The construction and operation of the plant has potential to impact nearby Key Fish Habitat (KFH), including the Hunter River and surrounding estuaries. KFH are ecologically sensitive areas and are important to the sustainability of the recreational and commercial fishing industries, the maintenance of fish populations and the survival and recovery of threatened aquatic species. Contamination can directly affect KFH and aquatic fish species in the area	Medium	A BDAR is required to assess impacts to Key Fish Habitat and determine what activities can occur and where. These areas are protected under the *Fisheries Management Act 1994* (FM Act)
Loading of Ammonia	Loading of ammonia into ships is a potential hazard onsite. This could lead to potential contamination (including the Hunter River and its estuaries) if hazardous substances/ materials are leaked	Medium	The loading of ammonia would be assessed under the SEPP (Resilience and Hazards) 2021 and would require an Export Management Plan that includes loading of hazardous substances with appropriate controls
Noise	There are potential noise impacts as a result of construction and operation of the project. This could affect local sensitive	Low	A Noise and Vibration Impact Assessment (N&VIA) would be prepared by a specialist acoustic consultant to determine likely impacts

Environmental Issue	Description	Pilot Plant Preliminary Risk	Specialist Reporting Required to Consider Risk
	receivers including residents living in nearby suburbs such as Mayfield and Mayfield West. Also, potential noise impacts to local wildlife and marine species in the Hunter River and wetlands		to sensitive receivers for both the Pilot Plant and Main plant
RAMSAR Wetland	Construction and operation of the plant has potential to impact on the nearby RAMSAR Wetland and mapped Hunter Wetlands National Park and Hexham Swamp Nature Reserve	Medium	A BDAR would be required for impacts to nearby RAMSAR wetlands. RAMSAR are Wetlands of International Importance and protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
Sea Level Rising and Flooding	The Kooragang Island area is subject to inundation under flooding or sea level rise scenarios. This could impact the design of the plant(s)	Medium	A Flood Impact Assessment would be required which considers a component of sea level rise. Mitigation measures to reduce risks from sea level rise and flooding would be implemented into project design
Traffic and Transport	Potential impacts to surrounding traffic and transport if trucks are used during operation of the plant(s). Impacts to traffic and transport could affect surrounding residents and suburbs of Newcastle including Mayfield and Mayfield West	Low	A Traffic Management plan would be required to assess potential traffic impacts during construction and operation of both plants
Visual	The project would result in visual impact from each plant, particularly at the Main Plant with the construction of two flues at around 45 metres high. This would have a visual impact on the area and local residents due its 24-hour operation	Low	A Visual Impact Assessment (VIA) would be required to assess visual impacts including impacts to surrounding properties and sensitive receivers
Waste and Wastewater	Potential impacts resulting from waste at the plant(s) and potential impacts from wastewater. Hazardous waste could impact surrounding Hunter River and estuaries and local residents in surrounding suburbs. Contaminated wastewater could contaminate Hunter River or local wetlands and impact wildlife and/or marine species	Low	A Waste Management Plan (WMP) would be required to assess and manage waste at both plants. The type and amount of waste would be assessed and an Environment Protection Licence (EPL) may be required if hazardous waste is present at the plant(s). Relevance of any requirements of the *Environmentally Hazardous Chemicals Act 1985* that apply, particularly for disposal of

Environmental Issue	Description	Pilot Plant Preliminary Risk	Specialist Reporting Required to Consider Risk
			chemical wastes, would need to be considered
Water Quality	Potential impacts to water quality of the Hunter River and surrounding rivers and estuaries. The project could contaminate nearby water bodies and this could affect local flora and fauna, marine species, and local residents	Medium	Water quality would be assessed with a Water Quality Management Plan (WQMP) to determine impacts to water quality as a result of the plant(s) and mitigation measures to be implemented

3.10 Pathway to securing all required development, environment, regulatory and land approvals

The capital investment value of the pilot plant will exceed A$100M in value and would likely follow the same planning approval pathway as the full-scale plant. However, a full-scale plant would likely require more extensive and detailed investigation. Additionally, landowner's consent is required to submit a State Significant Development ('**SSD**') application, which provides an alternative approval pathway for projects deemed to be of 'State Significance', elevating the planning assessment to a state level rather than a council level.

The proposed KIWEF site is currently leased by PON from the NSW Government. The land is currently operated by the Hunter and Central Cost Development Corporation ('**HCCDC**') and handover from HCCDC to PON is planned during the second half of 2023, subject to regulatory approval for a plan of management for the site following completion of the remediation works.

Table 7. Key approvals and permits

Approval	Key Details	Timing and Next Steps
Development and Planning Approvals	• Preparation of State Significant Development application and briefing pack (approval pathway to be finalised in feasibility) • Submission to NSW DPIE • State landowner Port Lessor (NSW Treasury) and TfNSW approvals	• Scoping Meeting with DPIE and development of Scoping Report during Stage 2 of the feasibility study • Development Approval to be submitted after completion of the feasibility phase
Environmental Permitting	• Relevant Standard Secretary's Environmental Assessment Requirements ('**SEAR**') issuance and consultation • Environmental Impact Statement ('**EIS**') preparation and submission	• Request for SEARs during Stage 2 of the feasibility study • Detailed EIS studies to be started after completion of the feasibility phase
Community Consultation	• SEARs Consultation and EIS public feedback	• Community engagement strategy to be developed during feasibility

Approval	Key Details	Timing and Next Steps
	• Project updates through the Port of Newcastle Community Liaison Group	
Other Regulatory Approvals or Licenses	• Environment Protection Licenses • Pipeline Licenses • Mine Subsidence Board • Utilities • Harbour Master	• Other required approvals or licenses to be fully identified during the feasibility phase
Land Access Arrangements	• NSW Treasury coordinating the land handover process between HCCDC and PON for KIWEF site • Current site access coordinated through HCCDC	• PON and HCCDC to engage with EPA to develop land management plan for the KIWEF site feasibility and plan is updated for development phase of the project

4. Commercial Feasibility

4.1 Pathway to commercialisation

During the feasibility study and through discussion with project partners, the Project Sponsors have identified a series of potential domestic and international use cases for the Port of Newcastle Green Hydrogen Hub that could provide offtake demand for either Phase 1 or future expansion phases.

Table 8. Identified domestic and international use cases

Use case	Commentary	Demand timing
Fertiliser	Nitrogen fertilisers are a key source of GHG emissions (>2% of global emissions) and switching from natural gas to green hydrogen to produce green ammonia is potentially one of the tools to decarbonise the fertiliser sector[5]. Green ammonia can be used for direct application but also as part of low-carbon fertilisers such as ammonium sulphate ("**AS**"), Monoammonium phosphate ("**MAP**") / Diammonium phosphate ("**DAP**") and nitrates ("**AN**"/"**CAN**")[5]. The Project is in proximity to a key Australian nitrogen fertiliser demand cluster. Heavy reliance on imports (~74% of total usage in Australia as of 2020) and expected domestic supply shortages after 2022 due to closure of a large domestic plant present a key market opportunity for a new entrant[5]. There is no significant export of ammonia abroad from the East Coast of Australia as of today[5]. In Eastern Australia, Argus has identified a potential short-term demand of green ammonia of 100kt p.a., growing to 320kt p.a. in the medium-term and to 570kt p.a. in the long-term [5]. Note however that this represents a scenario in which these volumes are achieved in part through changes in fertilizer application practices as well as product mix.	Current
Mobility	Hydrogen fuel cells provide a zero-emissions mobility solution that is particularly well suited to hard-to-abate segments such as heavy-duty transport. When compared with battery electric solutions, hydrogen has the following potential benefits: (i) much higher energy density by weight than lithium-ion batteries so great vehicle range can be achieved without compromising on payload capacity; (ii) hydrogen is much easier to dispense quickly into vehicles, with refuelling times similar to current diesel vehicles; (iii) hydrogen solutions also mitigate the impact on the electricity network that is required for significant charging infrastructure; and (iv) green hydrogen is essentially stored renewable energy that decouples the timing of renewable generation from charging / fuelling (leading to higher levels of actual renewable generation feeding the decarbonised transport systems, compared with battery-electric vehicle which often slow charge overnight and miss out on Australia's rich solar resource)[7]. Element Energy has engaged with potential vehicle and equipment suppliers to assess the ability to deliver Fuel Cell Electric Vehicles ("**FCEVs**") trial vehicles and hydrogen refuelling stations ("**HRS**") in the coming years: buses (2022+), refuse collection vehicles or RCVs (2022+), HRS (2022+), trucks	2025+

Use case	Commentary	Demand timing
	(2025+), locomotives (unconfirmed, likely post 2025)[7]. For some categories, choice of suppliers can be limited for trials occurring in the coming years. This feasibility study has considered a gradual scale-up schedule for hydrogen mobility for the Hunter region with potential short-term demand identified of 766t p.a. by 2025, increasing to 8,285t p.a. by 2030 when FCEV are used across a network linking Brisbane, Sydney and Melbourne[7].	
Power to gas	Hydrogen provides a possible route to decarbonise gas usage in the Hunter region and GPA explored the possibility of building a 100% hydrogen pipeline from an electrolyser located at Port of Newcastle to Beresfield via Hexham[6]. The proposed pipeline would provide the following benefits to the region: (i) supply green hydrogen for blending into the low-pressure gas network at Hexham assisting the NSW Government in meeting its 10% blending target by 2030 and facilitating the development of the green gas certificate market; (ii) provide a low-cost source of hydrogen supply for refuelling heavy mobility use cases at Hexham and Beresfield; (iii) provide the first dedicated hydrogen infrastructure that will enable decarbonisation of significant gas users, like Snowy Hydro's Hunter Power Project, as well as other heavy industrial users in the surrounding region; and (iv) lower the cost of developing the hydrogen economy in the region by providing a hydrogen storage asset that could be used to facilitate the build out of the different hydrogen use cases[6]. The estimated capex for the pipeline was A$69 million[6] with annual operating expenditure estimated at A$8.3 million per year.	2025+
Export	Green ammonia demand is forecast to reach close to 11Mt for power generation by 2030 and 57Mt for marine fuel bunkering by 2050 in Asia Pacific[4]. Emerging demand for green ammonia has been identified from: • South Korea – targeting to use 30% hydrogen at all its gas fired power plants by 2035 and 100% by 2040. Coal power stations to be mixed with 20% ammonia at more than half of power stations as early as 2030. • Japan – targeting domestic ammonia use for fuel of 3Mt by 2030 and 30Mt by 2050. Uses include consumption for ammonia co-firing in coal plants, marine fuel, and power generation from ammonia combustion in gas turbines.	2025+
Bunkering	Green ammonia is one of the options being explored to act as a suitable low emission fuel for shipping. Argus forecasts around 11Mt of green ammonia demand in 2030 from various sectors and if New South Wales was responsible for 20% of these volumes being exported, ammonia carriers would require more than 40kt for ammonia bunker fuel from the Port[4]. Australia has typically not been a bunkering location as it has not had a competitively priced supply of bunkering fuel to date. With green ammonia	2025+

Use case	Commentary	Demand timing
	potentially being produced in large quantities in Australia, bunkering should become a viable option given the competitive supply. The feasibility study has assessed potential paths for the Project to become a key bunkering location on the East Coast of Australia[4].	

4.2 Estimated levelised cost of hydrogen ("**LCOH**") and levelised cost of ammonia ("**LCOA**")

The LCOH and LCOA reflect the cost of producing green hydrogen and green ammonia, respectively. The boundary for LCOH and LCOA include the cost of input utilities, the plant operations and storage at the site. The cost of delivery is not included in the calculations. The costs are summed up and discounted at a 10% weighted average cost of capital to take into consideration the time value of money.

The financial modelling was based on the assumptions presented in Table 9.

Table 9. General plant assumptions

Assumption	44 MW plant	1 GW plant
Electrolyser size	~44 MW	~1,000 MW
Capacity factor electrolyser	80%	80%
Capacity factor ammonia plant	92%	92%
Total capex (electrolyser, ammonia plant, balance of plant and contingency)	AUD 287.2 million	AUD 2,708.3 million
Cost of power	AUD 90 / MWh	AUD 90 / MWh
Annual fixed operational costs	AUD 11.9 million	AUD 23.2 million
Asset life	30 years	30 years
Annual hydrogen production	5,418 tonnes per annum	20,500 tonnes per annum
Annual ammonia production	20,000 tonnes per annum	529,000 tonnes per annum

Below are the calculated outputs for the 44 MW plant:

- LCOH: AUD 10.6 per kilogram of hydrogen
- LCOA: AUD 3,155 per tonne of ammonia

4.3 Sensitivity analysis

The main economic drivers behind the LCOH and LCOA are the upfront capital costs and the cost of electricity. Table 10 assesses the impact of changes in these two parameters in the 44 MW plant case:

Table 10. Key sensitivities

Sensitivity	LCOH (AUD/kg hydrogen)	LCOA (AUD/ton ammonia)
Base case	10.6	3,155
Capex +10%	11.0 (+3.8%)	3,289 (+4.2%)
Capex -10%	10.3 (-2.8%)	3,020 (-4.3%)
Cost of electricity + AUD 10/MWh	11.2 (+5.7%)	3,289 (+4.2%)
Cost of electricity - AUD 10/MWh	10.0 (-5.7%)	3,020 (-4.3%)

4.3.1 Cost of electricity considerations

The Project Sponsors started the feasibility study in H2 2021 with a target assumption for the cost of electricity of AUD 45/MWh (nominal).

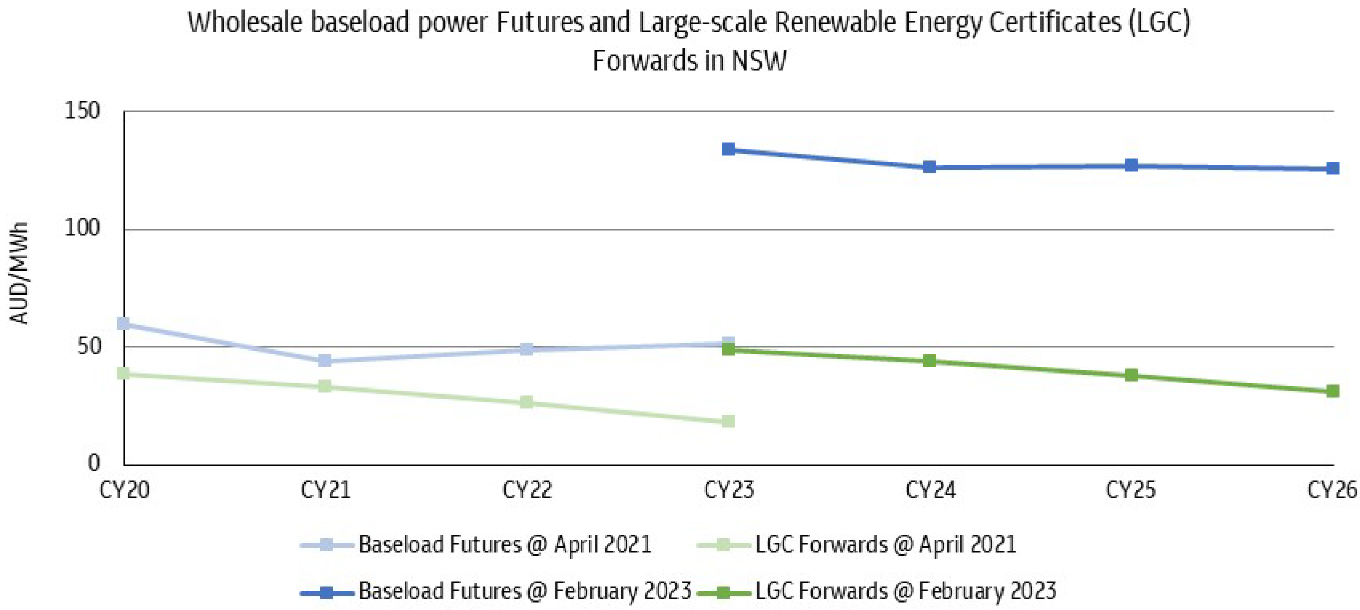
However, during the winter of 2021, volatility in gas and electricity markets increased. In August and September 2022, both electricity and gas prices reduced significantly but remained historically high when compared to previous years, and, at the time of this Report, futures indicate this could remain the case in the coming years.

Factors that have led to increased electricity prices in NSW include, but are not limited to:

- The announced closing of existing large coal-fired generators;
- Uncertain timing and scale for the build out of renewable capacity;
- Shortages resulting from supply chain disruption caused by COVID and the war in Ukraine (e.g. global constraints on natural gas and coal supplies and deliveries); and
- Uncertainty regarding the build out of infrastructure in the NEM (in relation to both transmission and generation).

Figure 5 uses public data from Mercari.com.au and ASXEnergy.com.au to show the increase in baseload Futures price. The cost of green certificates is added on top of this price to form the total cost a project like Port of Newcastle Green Hydrogen Hub would have to bear to source low-carbon electricity. In relation to the transmission and distribution costs, the NSW Government has proposed to offer a 90% discount on transmissions costs for up to 750MW for 12 years for green hydrogen projects connecting to the grid before the end of 2030. Port of Newcastle Green Hydrogen Hub could potentially be eligible to this network charges waiver.

Figure 6. Evolution of wholesale baseload power Futures and LGC Forwards in NSW



5. Strategic Feasibility

Important Note regarding IRA: The Project has the potential to be strategically important to Newcastle and the Hunter Valley. The challenge for the Project and the hydrogen industry in Australia is that post announcement of the IRA, domestic projects could struggle to compete in the international market where green hydrogen from the US is expected to be produced at a level competitive with grey markets. This change in the international landscape has altered the horizon for domestic projects as the emergence of a green premium for offtake exposed to the export market is no longer expected while product can be sourced from the US at a lower cost.

5.1 Economic impact assessment

The Project could contribute to establishing a thriving green economy for the Hunter region and position the Hunter Valley for long term prosperity.

The Hunter is Australia's largest regional economy, contributing $34.7b to the NSW economy by leveraging its strengths across mining, energy and export. As Australia and the world shift towards green energy, a number of industries that underpin the strength of the Hunter are likely to be phased out, leaving a gap for green hydrogen.

As the Project scales, the Hunter region is likely to benefit from the creation of direct construction jobs and ongoing operations jobs. Diversification of use cases will create long term employment opportunities in downstream industries, such as green product manufacturing, energy services and transport and logistics. Additional construction jobs will be created when Port of Newcastle Green Hydrogen Hub is first commissioned, as the Port is upgraded to facilitate export, and supporting infrastructure is rolled out for downstream use cases.

Additionally, the Project could catalyse development of a green hydrogen ecosystem in the Hunter. Underpinned by growing hydrogen demand, Port of Newcastle Green Hydrogen Hub is likely to encourage investment in green hydrogen R&D and innovation, stimulate development of skills and training resources, and increase participation of broader industry to position both the Hunter and NSW for sustained economic growth in a green future.

KPMG has estimated the following economic benefits based on inputs provided by the Project Sponsors (under the analysis the Full Expansion Project was assumed to have a capacity of 1.6GW):

- A$334 million economic benefit to the Hunter region growing to A$4.2 billion for the Full Expansion Project[8] (economic benefit has been calculated as increase in Gross Regional Product, expressed in present value terms over 20 years of operations, assuming the Project operates at the Phase 1 Project and Full Expansion Project capacities respectively);
- 195 average full time equivalent jobs (FTE) created for the duration of the 2-year construction period for the Phase 1 Project, growing to 1,142 average FTE for the duration of the 2-year construction period for the Full Expansion Project[8]; and
- 38 ongoing FTE created during operations for the Phase 1 Project, growing to 650 average FTE during operations for the Full Expansion Project[8].

5.2 Decarbonisation benefits analysis

When produced from renewable energy, hydrogen sourced from the Project has the potential to decarbonise significant sectors of Newcastle and the Hunter region. As the Project scales, there is the potential for it to reduce emissions by over 1.7 million tonnes CO_2-e once the Full Expansion Project is operational[8].

For the Phase 1 Project, KPMG has estimated a total of ~52,000 tonnes CO_2-e avoided per annum[8], based on the following use cases:

- 34,000tpa CO_2-e avoided supporting clean ammonia production for fertiliser[8];
- 8,400tpa CO_2-e avoided through blending into the gas network[8]; and
- 9,500tpa CO_2-e avoided by decarbonising transport[8].

The Project will contribute to the NSW Government's Net Zero by 2050 target and the establishment of a low carbon economy in the Hunter and Australia.

5.3 Analysis of key stakeholder groups

Port of Newcastle Green Hydrogen Hub received support from different types of stakeholders. A range of research, government and industry organisations from the Hunter community see the benefit of the Port of Newcastle Green Hydrogen Hub project. These benefits include:

- The creation of significant new industries being built around clean hydrogen;
- Creating new regional jobs and increased capability of local workforce;
- Development opportunities to further the applications of hydrogen;
- Reducing the cost of clean hydrogen;
- Providing community opportunities to expand its capabilities into new technologies;
- Demonstrating a regional project for bottom-up industry development and skills refinement; and
- Showcasing the Hunter region's leadership and progressive attitudes to changing economic landscapes.

The stakeholders supporting the Port of Newcastle Green Hydrogen Hub fit into the following categories:

- Research & Development (R&D) and innovation organisations (e.g. University of Newcastle, UNSW Sydney, CSIRO) that support the project through R&D in accordance with the Project's priorities;
- Industry organisations that can leverage industry and cluster networks to reduce overlaps, identify gaps to the development, deployment, and commercialisation of clean energy technologies;
- Regional and government organisations to help develop accurate policies and regulations and create a virtuous ecosystem in which information flows among key stakeholders;
- Investment and capital providers that attract business and drive commercial aspects of innovation in the Hunter region; and
- Education, skills and workforce organisations which represent a catalyst for partnerships and programmes that focus on building the critical skills for the hydrogen industry in the Hunter region through trainings including enhanced work integrated learning and postdoctoral programmes.

The Port of Newcastle Green Hydrogen Hub creates an environment in which stakeholders can share knowledge and experience which is critical for the success of such a large-scale project.

5.4 Regulatory barriers

Given the early stage of the hydrogen industry, a range of potential regulatory barriers were identified particularly with new industry use cases including hydrogen for mobility, ammonia bunkering and hydrogen into gas networks.

If the Project progressed to the next stage, a detailed understanding of the regulatory barriers would be required.

6. Conclusion

6.1 Changing international landscape

The implementation of the IRA has changed the outlook for this Project and the hydrogen industry in Australia as:

- US produced green hydrogen and derivative products are expected to influence the price of export markets; and
- The potential for the emergence of a green premium for Australian producers is reduced as buyers are likely to have access to US product at lower prices.

Given the above, post IRA Australian projects are expected to require:

1) more Government subsidy; and
2) take longer to become economically viable without Government subsidy.

Without a similar support framework to that developed in the US, we expect post IRA that early hydrogen projects in Australia will therefore be:

1) smaller; and
2) domestically focused.

6.2 Key conclusions from Stage 1 of the feasibility study

Stage 1 of the feasibility study provided the opportunity for the Project Sponsors to test the key hypotheses assumed pre-feasibility. These are presented alongside key conclusions in Table 11.

Table 11. Key conclusions

	Project Sponsors hypotheses pre-feasibility…	…key lessons from the Stage 1 feasibility study:
Project	• PON is an ideal location for an early hydrogen project that could be scaled given its existing infrastructure and links to East Coast demand	• Feasibility Study confirms our hypothesis that the Port is likely to be the leading location on the East Coast for a large-scale hydrogen project
Site	• Whilst PON has a range of site options, Walsh Point was likely the ideal site for an early project given proximity of Orica and other fertiliser distributers	• KIWEF was selected as the preferred site at PON for a hydrogen project of any size, given its available land and access to utilities. Walsh Point faces significant constraints limiting development of scale
Sizing	• A logical first stage Project was a ~40MW electrolyser and 20ktpa ammonium loop given the current state of the hydrogen industry in Australia	• Small scale plants are expensive given high proportion of fixed and scalable costs • Significant economies of scale could be achieved if a larger capacity is built during the initial phase

	Project Sponsors hypotheses pre-feasibility…	…key lessons from the Stage 1 feasibility study:
Energy solution	• The Project would be able to access an all-in power pricing at <A$50/MWh	• Given the current status of the energy market and the cost pressures in the materials and supply chains, challenges exist in the energy solution • A significant gap exists between the current expected cost of electricity and the target of <A$50/MWh that needs to be closed for private investors to consider the investment opportunity attractive
Grid connection	• Whilst a Transgrid connection would ultimately be the path for the full-scale PON Green Hydrogen Hub, Ausgrid is the likely connection option for early stages given cost	• Ausgrid connection has immediate capacity constraints, with preferred option to directly connect into TransGrid line opening up ~700MW of capacity and providing an infrastructure saving in the expansion phases
Shared infrastructure	• Early common use infrastructure could potentially be pipelines, storage or tube trailer distribution	• A larger initial plant expands potential to leverage common use infrastructure. This includes ammonia storage to facilitate early export trials (through being able to warehouse sufficient volumes for loading)
Concessional funding	• Existing concessional funding under Federal and State programs is limited to upfront grants (to fund development and / or construction)	• Significant concessional funding is required both to fund construction and operational phases of the Project that accesses the existing grants available under Federal and State programs

6.3 Project Sponsors positioning post Stage 1 of the feasibility study

Over Stage 1 of the feasibility study, several structural changes have impacted the positioning of the Project Sponsors vis-à-vis Port of Newcastle Green Hydrogen Hub. Such changes include:

- The introduction of the IRA in the United States in August 2022. This has removed market expectation regarding the emergence of a green premium for markets exposed to imports;
- Disruption to the East Coast energy market which meant that the price of electricity had increased; and
- Significant cost inflation as a result of COVID and the war in Ukraine, amongst other factors.

These factors have meant that: 1) the amount of concessional finance required for the Project to reach a Financial Close has increased significantly; and 2) the horizon for scale up of the project has become uncertain as without Government subsidy it is unlikely to be able to compete with the global market.

Given the above, the Project Sponsors have decided not to progress to stage 2 of the Feasibility Study.

7. Project Data Summary

Table 12. Project data

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Hydrogen delivered	Tonnes per annum	Calculated as the tonnes of hydrogen expected to be delivered to the point of hydrogen offtake (i.e. at the point of exit of the electrolyser to demand sources) in normal operations in the first 12 months of steady state operations	5,418	20,500	Inferred from WSP Technical Feasibility Report[1]
Ammonia delivered	Tonnes per annum	Calculated as the reasonable tolerance range of tonnes of hydrogen expected to be delivered to the point of ammonia offtake in normal operations in the first 12 months of steady state operations	20,000	529,000	Inferred from WSP Technical Feasibility Report[1]
Levelised cost of hydrogen delivered over the life of the asset	AUD per kg of H2	Takes into account all the costs related to the production of green hydrogen over the life of the asset and discounted at a certain discount rate	10.6	4.6	Internal calculations
Breakdown of levelised cost of hydrogen delivered over the life of the asset	AUD per kg of H2	Breakdown of levelised cost of hydrogen	Capex 3.4 Cost of energy (incl. network charges) 5.7 Water costs 0.2 Other operational costs 1.4	Capex 1.6 Cost of energy (incl. network charges) 2.6 Water costs 0.2 Other operational costs 0.3	Internal calculations
Levelised cost of ammonia delivered over the life of the asse	AUD per tonne of NH3	Takes into account all the costs related to the production of green ammonia over the life of the asset and discounted at a certain discount rate	3,155	1,227	Internal calculations
Breakdown of levelised cost of ammonia	AUD per ton of NH3	Breakdown of levelised cost of ammonia	H2 production 1,892 Other capex 677	H2 production 812 Other capex	Internal calculations

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
delivered over the life of the asset			Cost of energy (incl. network charges) 289 Other operational costs 297	341 Cost of energy (incl. network charges) 51 Other operational costs 23	
Ammonia product specifications	Deg C, MPa, %	Temperature, pressure, purity	- Temperature: minus 33.3 degC - Pressure: 1.00 bar - Purity: 99.8 %	- Temperature: minus 33.3 degC - Pressure: 1.00 bar - Purity: 99.8 %	Inferred from WSP Technical Feasibility Report[1]

Table 13. Electrolyser data

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Electrolyser capacity	MW	Size of the electrolyser stack capacity	44	1,000	Inferred from WSP Technical Feasibility Report[1]
Capacity factor	%	Product of the electrolyser technical availability and utilisation rate	80.0%	80.0%	Internal assumption
Energy efficiency	MWh / tonne H2	This is calculated as MWh per tonne of hydrogen delivered	55.7	55.7	Inferred from WSP Technical Feasibility Report[1]
Asset life	Years	Expected initial life of the asset	30	30	Inferred from WSP Technical Feasibility Report[1]
Stack replacement interval	Hours	The scheduled lifetime of the electrolyser equipment before significant replacement of electrolyser stacks are required (reasonable tolerance of estimation)	80,000	80,000	Inferred from WSP Technical Feasibility Report[1]

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Hydrogen purity	%	The purity of the final hydrogen product as a percentage on a (per molecule basis)	99.8% at electrolyser outlet 99.999% at dryer/deoxo outlet.	99.8% at electrolyser outlet 99.999% at dryer/deoxo outlet.	Inferred from WSP Technical Feasibility Report[1]

Table 14. Capital expenditure

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Total project cost	AUDm	The total capital expenditure to deliver the Project including all contingency	287.2	2,708.3	Inferred from WSP Technical Feasibility Report[1]
Electrolyser capital cost	AUDm	The cost of the electrolyser equipment, not including the electrolyser O&M costs	58.0	875.0	Inferred from WSP Technical Feasibility Report[1]
Ammonia capital cost	AUDm	The capital cost of the ammonia loop	67.0	432.2	Inferred from WSP Technical Feasibility Report[1]
Balance of plant capital cost	AUDm	The cost of all other equipment required to produce hydrogen at the required offtake pressure not including the electrolyser or compressors	58.1	69.9	Inferred from WSP Technical Feasibility Report[1]
Storage equipment capital cost	AUDm	Including all on-site storage for hydrogen and/or ammonia (if relevant)	24.2	386.8	Inferred from WSP Technical Feasibility Report[1]
Contingency	AUDm	Contingency added to the capital costs	44.2	404.2	Inferred from WSP Technical Feasibility Report[1]
Other capital costs	AUDm	Other capex required	35.7	540.2	Inferred from WSP Technical Feasibility Report[1]

Table 15. Operational costs

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Fixed operating and maintenance cost	AUD per year	Costs required to operate and maintain the electrolyser over the asset life, as reflected in the financial model	11,949	23,240	Inferred from WSP Technical Feasibility Report[1]
Cost of power	AUD / MWh	Cost of power required for the electrolysis and power the plant	90.0	90.0	Internal assumption
Water Cost	AUD/kL	Cost of water to operate the plant and perform the electrolysis	Potable Water: $2.46 / kL Recycled Water: $2.02 / kL	Potable Water: $2.46 / kL Recycled Water: $2.02 / kL	Inferred from WSP Technical Feasibility Report1

Table 16. Environmental costs

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Water source	None		- Potable water, provided by Hunter Water through town water pressurised mains; and - Recycled water, provided by the Kooragang Recycled Water Scheme (KRWS), which is currently operated by Water Utilities Australia (WUA)	- Potable water, provided by Hunter Water through town water pressurised mains; and - Recycled water, provided by the Kooragang Recycled Water Scheme (KRWS), which is currently operated by Water Utilities Australia (WUA)	Inferred from WSP Technical Feasibility Report[1]

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
Water intensity of production	Litres / kg H2	Quantity of water consumed per kilogram of hydrogen delivered including cooling water and water for electrolysis as well as other minor water usages	65.0	65.0	Inferred from WSP Technical Feasibility Report[1]
Water consumed annually	ML p.a.	Includes all water input to the electrolysis process, including desalination and demineralisation for example, it should not include any water required for other processing activities	492	10,000	Inferred from WSP Technical Feasibility Report[1]

Table 17. Resourcing

Data description	Units	Definitions	44 MW plant	1 GW plant	Source
FTEs required during construction period	# FTEs	Full time equivalent employees (including those working on the project under contract or other employment arrangements)	194	730	KPMG[8]
FTEs required during operations period	# FTEs	Full time equivalent employees (including those working on the project under contract or other employment arrangements)	38	650	KPMG[8]

References

1. *Port of Newcastle Green Hydrogen Hub Technical Feasibility Report (Stage 1A) – Pilot Plant*, WSP, June 2022.
2. *Port of Newcastle Green Hydrogen Hub Technical Feasibility Report (Stage 1B) – Full Scale Plant*, WSP, June 2022.
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4. *H2 Newcastle – Export and Bunker Study,* Argus, May 2022.
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6. *Stage 1 Summary Report – Hydrogen Pipeline Feasibility Study*, GPA, May 2022.
7. *Project Nobbys – Mobility Work Package*, Element Energy, March 2022.
8. *Port of Newcastle Green Hydrogen Hub – Economic Impact Assessment, 2022.*