1. List of active, committed and under development hydrogen projects and hubs in Australia.

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| # | Project Name | Location | Scale | Type of Project | Domestic Market | Export Market | Project Status/Comments |
| Queensland | | | | | | | |
| 1. | **Daintree Microgrid Project**  Proposed plan for a solar energy based microgrid with intermediate storage through hydrogen generation, as a replacement of the current diesel-based power system.1  The project was provided $990k in grant funding from the Federal Government as part of the Regional and Remote Communities Reliability Fund to conduct a feasibility study. The report was originally expected to be completed by mid-2020 2, but the findings are yet to be made public3.  Recently (as of May 2021), the Federal Government has provided A$19.3 million to support stage 1 of project construction.4 | Daintree,  Qld | N.A. | Demonstration Facility | Icon  Description automatically generated |  | Under development  (Stage One Construction) |
| 2. | **Origin Energy’s Green Liquid H2 Export Project**  Origin Energy is partnering up with Kawasaki Heavy Industries (KHI) to develop a 300 MW hydrogen electrolyser project for generating and exporting liquid hydrogen to Japan.5  Recently the companies have signed an MoU with the port of Townsville to develop the facility.6 The project is now undergoing a FEED process and is expected to be operational by 2025.7 | Townsville,  Qld | 36.5 ktpa of H2  (300 MW electrolyser) | Feasibility Study  (Commercial Plant) |  | Icon  Description automatically generated | FEED study being conducted. (Operation targeted for 2025) |
| 3. | **SunHQ Project**  Sun Metals Corporation Pty Ltd is developing a 1 MW electrolyser system at their zinc processing facility. The hydrogen will be used to power fuel cell vehicles sourced by Ark Energy to replace the current diesel operated fleet used at site. The project was provided $5 million in funding as part of Qld Government’s Hydrogen industry fund development.8  Further phases of the project will include increasing capacity for domestic use and develop an export economy for green hydrogen to Korea.8 | Stuart,  Qld | 140 tpa  (1 MW electrolyser) | Commercial Plant | Icon  Description automatically generated |  | Final stages of project development. (Construction anticipated by Q1 2021 – Operation anticipated by Q2 - 2023) |
| 4. | **Abbot Point Clean Energy Hub**  The Abbot Point Clean Energy Hub has been proposed for development in the Abbot Point State Development Area by Energy Estate.  The hub is expected to host hydrogen, freshwater, and renewable electricity production facilities.  The project is expected to be built in stages, with the initial stage involving export of 20 tpd of hydrogen. The upfront cost of the infrastructure is estimated in the region of A$2.5 – 3.5 billion.9 | Bowen,  Qld. | Initial Stage Capacity:   * 260 MW solar farm + 600 MW wind farm * 20 tpd of H2   (50 MW electrolyser)   * 50 Mega liter/day desalination plant | Commercial large scale hydrogen hub development | Icon  Description automatically generated | Icon  Description automatically generated | * Energy Estate started feasibility studies in Q1, 2019.   The final investment decision is targeted by Q2,2023 with operation by 2025. The company is currently working to find project partners, securing relevant approvals and securing access to Powerlink, Queensland’s electricity transmission network.9,10 |
| 5. | **Dyno Nobel Renewable Ammonia Feasibility**  Dyno Nobel, a subsidiary of Incitec Pivot Ltd., conducted a A$2.7 million feasibility study to develop a green ammonia facility at its existing ammonia generation site.11  The proposed design includes developing a 160 MW PEM electrolyser and a 240 MW solar farm. The proposed facility at the time was expected to be the world’s largest green ammonia facility, producing 45 ktpa of ammonia.  ARENA provided $980k funding to assist the company in carrying out the feasibility study as part of the Renewable Hydrogen Development Fund.12 The study estimated that ~A$675 million would be required to construct the plant.13 | Moranbah,  Qld | 9.6 ktpa of H2 (160 MW plant + 54 t of intermediate storage)  45ktpa of NH3 | Feasibility Study  (Commercial Plant) | Icon  Description automatically generated |  | The feasibility study was completed in 2020 (final decision is still to be made) |
| 6. | **Stanwell Renewable Hydrogen Production**  A feasibility study has been conducted to develop a 10 MW (or larger) electrolyser to demonstrate hydrogen production using electricity from the Stanwell Power plant.14  The project will generate hydrogen and offset the emissions from the coal power plant sourced electricity using energy and green certificates from renewable energy projects. The study also evaluated the use of the generated hydrogen for transport, ammonia, or electricity generation.  ARENA provided grant funding of A$1.25 million to conduct the feasibility study as part of the Renewable Hydrogen Development Fund.15 | Rockhampton,  Qld | 1.6 ktpa of H2  (10 MW electrolyser) | Feasibility Study  (Demonstration facility) | Icon  Description automatically generated |  | The ~A$5 million feasibility study was completed in 2020.15  It was suggested that domestic use for hydrogen was not viable, and export should be preferred.  Stanwell Corp. has since partnered with Iwatani Corp. to explore hydrogen export options to Japan.16 |
| 7. | **Bundaberg Hydrogen Hub**  The A$300 million Bundaberg Hydrogen Hub is being developed to generate hydrogen for industrial and transportation use by the Green Hydrogen Australia Group (GHAG), a consortium comprised of Denzo Pty Ltd, Elvin Renewables Group and H2X Australia.  The proposed projects includes a 80 MW electrolyser plant with a 100 – 110 MW solar farm that will supply hydrogen to the Australian hydrogen vehicle developer H2X.17 | Bundaberg,  Qld. | 80 MW electrolyzer | Commercial plant | Icon  Description automatically generated | Icon  Description automatically generated | Early stages of development. |
| 8. | **Queensland Nitrates (QNP) Renewable Ammonia Feasibility Study**  Queensland Nitrates Pty Ltd. conducted a feasibility study of retrofitting its existing ammonium nitrate plant in Moura, Qld. The facility has a fully integrated ammonia, nitric acid, and ammonium nitrate plant.  The feasibility study investigated a 30 MW facility that will be used to generate 3.5 ktpa of hydrogen. The hydrogen will be then converted in a new 20 ktpa ammonia plant (the company currently buys this amount of ammonia from 3rd party to supplement operation). The new facility is expected to be powered through a hybrid solar and wind PPA.  The study received funding of A$1.91 million from ARENA as part of the Advancing Renewables Program to support the total cost of A$3.8 million.18 The study was completed in 2020 and estimated a total project cost of A$150 – 200 million.19 | Moura,  Qld | 3.5 ktpa of H2  (30 MW electrolyser)  20 ktpa of NH3 | Feasibility Study  (Commercial Plant) | Icon  Description automatically generated |  | The study was completed in mid-2020, recommending a 88ktpa or higher plant capacity should be targeted for viability without external subsidies.20 |
| 9. | **Bio-hydrogen Demonstration Plant**  Southern Oil Refining company is developing a hydrogen generation demonstration project at their existing Northern Oil Refinery at Gladstone.  The oil refinery currently generates crude oil from biomass-based feedstocks, which is then processed to make kerosene and diesel. The company plans to utilize a catalyst based chemical looping process (trialed at small scale in partnership with CSIRO), that will enable on site hydrogen generation by steam reforming of the waste biogas stream. 21,22 | Gladstone,  Qld | 0.017 ktpa of H2 | Demonstration  Facility | Icon  Description automatically generated |  | The facility is being developed as a demonstration plant for future scale up. |
| 10. | **H2-HubTM Gladstone**  Hydrogen Utility (H2UTM), a clean infrastructure company, is developing plans for a 3 GW electrolyser facility for green ammonia production and its subsequent export.23,24  The plant is expected to be developed and scaled in stages. The company has already purchased land (171 hectares) in Gladstone from the Queensland Government. It now plans to conduct a detailed feasibility study with a target to get approvals by 2023 and commence operations by 2025.  H2UTM is also working to secure export opportunities and have secured an agreement with Germany’s RWE Supply and Trading to export green hydrogen/ammonia to Germany.25 | Gladstone,  Qld | 3,000 MW electrolyser for H2 Generation  4.8 ktpd of ammonia   * Stage 1: 1.5 GW installation by 2023: 2.4 ktpd of ammonia. * Stage 2: Additional 1.5 GW installation by 2027: 2.4 ktpd of ammonia. | Pre-Feasibility Phase  (Commercial Plant) |  | Icon  Description automatically generated | The project is in development and is expected to be operational by 2023-2025. |
| 11. | **Hydrogen Park Gladstone (HyP Gladstone)**  The Australian Gas Networks (AGN) is establishing a 175 kW PEM electrolyser system.26  The facility will be a demonstration plant for injecting hydrogen into natural gas grid (10% by vol.) for domestic, commercial, and industrial use.  The facility is expected to cost A$4.2 million and has received a A$1.7 million in grant funding under the Qld Government’s Hydrogen Industry Development Fund.27 | Gladstone,  Qld | 20 kg pd  (0.175 MW electrolyser) | Demonstration Facility | Icon  Description automatically generated |  | The electrolyser has been ordered, and the site preparation is underway to commence construction.27  Hydrogen production is anticipated by 2022.27 |
| 12. | **APA Group and Southern Green Gas Renewable Methane Pilot Plant.**  The project commenced in March 2020 in Queensland and plans to capture CO2 from the atmosphere (using direct air capture technology) and react with H2 from electrolysis (5 kW electrolyser), producing 340 kg H2 per annum and converting it to 35 GJ of methane.28  The initial project will cost $2.2 million for the plant.29 | Wallumbilla,  Qld | 0.34 tpa of H2  (5 kW electrolyser)  35 GJ of methane p.a. | Demonstration Facility | Icon  Description automatically generated |  | Under Construction. |
| New South Wales | | | | | | | |
| 13. | **Manilla Solar Project and Renewable Energy Storage Project**  The Manila project will utilize proprietary H2 storage technology (metal hydrides) developed at UNSW as a means of storing solar energy in the form of hydrogen.  The project consists of a 4.95 MW solar farm, battery storage (4.5 MW/45 MWh), and UNSW’s H2store technology (2 MW/17 MWh). The hydrogen system on its own will enable 6 to 7 hours of energy storage for reconversion.  The project was granted A$3.5 million in grant funding by the NSW government under the Regional Community Energy Program.30 The project is expected to cost A$7.3 million. | Manilla,  NSW | N.A. | Demonstration Facility | Icon  Description automatically generated |  | In advanced stage of development. |
| 14. | **Project NEO – (Infinite Blue Energy)**  Infinite Blue Energy has developed plans to develop 1 GW of hydrogen-based electricity to provide NSW’s baseload power using solar, wind turbines and hydrogen fuel cells.  The facility is planned to be complete by 2027 in NSW’s Hunter region at a cost of A$2.7 billion.31,32 | Hunter Valley, NSW | 1,000 MW of green hydrogen based electricity | Prefeasibility Study | Icon  Description automatically generated |  | Early stage of development. |
| 15. | **Western Sydney Green Gas Project**  Jemena in combination with ARENA for the Western Sydney Green Gas Project will be using 500 kW PEM electrolysers to produce approximately 53 tpa/100 Nm3 h-1 of hydrogen using Cummins technology.33–35  This is a demonstration project, costing A$15 million. 33–35 | Sydney,  NSW | 100 Nm3 h-1 of H2  (500 kW) | Demonstration  Facility | Icon  Description automatically generated |  | Under construction |
| Canberra | | | | | | | |
| 16. | **Australia’s first hydrogen Refueling Station.**  Australia’s first public hydrogen refueling station has become operational in Canberra.36  The facility has been developed in partnership with the ACT government, Neoen, Hyundai, ActewAGL and SG Fleet. It is installed at AcetewAGL’s existing CNG refueling station.37 The facility is primarily being used to service 20 fuel cell vehicles (Nexos model) provided by Hyundai to the ACT government.38 | Canberra,  ACT | 21 kg per day  (75 kW electrolyser) | Commercial Plant | Icon  Description automatically generated |  | Operational |
| Victoria | | | | | | | |
| 17. | **Hydrogen Park Murray Valley (HyP Murray Valley)**  The HyP Murray Valley project is being planned in Wodonga. The project will be based on a 10 MW electrolyser, with the hydrogen used for blending into the natural gas pipeline (10% by volume). The electrolyser will be installed near the Wodonga Wastewater Treatment Facility. The project is being led by the Australian Gas Networks.  The project has recently secured A$32.1 million in funding from ARENA (through the Hydrogen Deployment Fund).39,40 | Wodonga,  Vic | 10 MW electrolyser | Demonstration  Facility | Icon  Description automatically generated |  | Under development  (Operations anticipated by 2023) |
| 18. | **Hydrogen Energy Supply Chain Pilot Project (HESC)**  The HESC project is a pilot project exploring the full hydrogen supply chain from Australia to Japan.  Utilizing Victorian coal from the Latrobe Valley to generate hydrogen, the project is also establishing a liquefaction unit in Port of Hastings. The project is being developed by a consortium comprising of Kawasaki Heavy Industries (KHI), J-Power, Iwatani Corporation, Marubeni Corporation , Sumitomo Corporation and AGL.41  The pilot project (which is expected to deliver 1 – 3 tonnes over 1 year) is being developed to assess the viability of an overall supply chain between Japan and Australia.42 | Latrobe Valley (generation), Vic  Port of Hastings (export), Vic | 1 – 3 tonnes over the pilot project life.  Commercial Scale up: The future proposed scaled up facility will include a large-scale coal gasification plant.  The CO2 generated from the process for the pilot phase have been accounted for using carbon credits that have been purchased form Clean Energy Regulator (Australian Carbon Credit Units – AACUs).43  For the commercial scale the CO2 is expected to be captured and stored in the CarbonNet Project. 43The CarbonNet project is being jointly developed by the Federal and Victorian Government for CO2 storage in depleted oil and gas reservoirs beneath the Bass Strait in Victoria.44 | Demonstration Plant/Future Scale Up |  | Icon  Description automatically generated | Operational  (First export shipment later this year)  Final decision on proceeding towards commercial phase will be taken after assessing the outcomes of the pilot project, hydrogen demand and successful development of CCS technology. |
| 19. | **Portland Hydrogen Export Project**  The Portland Hydrogen Export Project has been proposed by the Glenelg Shire Council, Countrywide Renewable Hydrogen and Port of Portland for generating green ammonia using the area’s rich renewable resources.45  The project will host an 80 MW wind farm to power a 50 MW electrolyser. The hydrogen will then be exported to Asian markets (potentially as ammonia or liquid H2) through the Port of Portland, with further options for local use by blending in natural gas network or for domestic fertilizer production being evaluated.46 | Portland, Vic | 10 ktpa of H2  (50 MW electrolyser) | Feasibility Study  (Commercial Plant) |  | Icon  Description automatically generated | Under development |

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| Tasmania | | | | | | | | | | | | |
| 20. | **Fortescue Metal Group Green Ammonia Plant**  Fortescue Metal Group is investigating the development of a green ammonia plant in the Bell Bay industrial precinct in Tasmania with a vision of a 250 MW green hydrogen plant capable of producing 250,000 tonnes per annum of H2.47  An investment decision is targeted for 2021 with a projected cost of up to $500 million.48 Fortescue are in partnership with the CSIRO working on a “world first membrane technology” for large scale hydrogen extraction from ammonia.47 | | Bell Bay Precinct,  Tas. | | 250ktpa of H2  (250 MW electrolyser) | | Feasibility Study  (Commercial Plant) | | Icon  Description automatically generated | Icon  Description automatically generated | | Under development |
| 21. | **ABEL Energy Bell Bay Powerfuels Project**  ABEL Energy is partnering up with Thyssenkrupp to develop a large-scale hydrogen electrolyser (100 MW) and e-methanol production facility to produce 60,000 t yr-1 methanol,.49 The CO2 feedstock will be sourced from the local wood waste or from Direct Air Capture (DAC). A further small-scale methanol to di methyl ether (DME) plant is also planned, for local industry.  The feasibility study for the project was conducted in 2020 with the support of funding from Tasmanian Government.50 The production is expected by 2024.51 | | Bell Bay Precinct,  Tas. | | 44 tpd (38 tpd for Methanol generation and 6 tpd for domestic use)  (100 MW electrolyser)  60 ktpa of Methanol | | Commercial Plant | | Icon  Description automatically generated | Icon  Description automatically generated | | Under development  Operation expected by 2024 |
| 22. | **Origin Energy Green Ammonia Project**  Origin Energy is conducting a feasibility study into >500 MW plant capable of producing 420,000 tonnes of ammonia per annum.52 The study was also funded (A$1.6 million) by the Tasmanian Government.50  The study is expected to be completed December 2021 with the first production targeted for mid-2020s.52 Current projections would see such a plant costing up to $1 billion.48 | | Bell Bay Precinct,  Tas. | | 500 MW electrolyser for H2 generation  420 ktpa of Ammonia | | Feasibility Study (Commercial Plant) | |  | Icon  Description automatically generated | | Under development |
| South Australia | | | | | | | | | | | | |
| 23. | **Hydrogen Park South Australia (HyP SA)**  Australian Gas Infrastructure Group (AGIG) in 2018 announced plans for a hydrogen production and distribution facility using a 1.25 MW Siemens (Silyzer technology) PEM electrolyser in the Tonsley Innovation District, South Australia.53  Hydrogen distribution began in Q1 2021 to industry via tube-trailer and homes by hydrogen-blended gas using existing networks.54 The facility is currently the largest operational electrolyser in Australia.  The total project has been estimated to cost A$14.5 million, which was financed by an equity investment of A$9.6 million by AGIG and A$4.9 million in grant funding by South Australia (SA Government Renewable Technology Fund).55 | | Tonsley Innovation District, SA | | 20 kg per hour of H2  (1.25 MW electrolyser) | | Demonstration Facility | | Icon  Description automatically generated | Icon  Description automatically generated | | Operational |
| 24. | **Neoen Australian Hydrogen Superhub**  The Neoen hydrogen superhub project is being developed as part of the Crystal Brook Energy Park.  The energy park will have a renewable energy generation capacity of 275 MW and 50 MW electrolyser is being proposed as a potential load.56  The SA Government provided $1 million in grant funding to Neon for carrying out a feasibility study. Additional funding of $4 million in grant and $20 million in loans have been committed for eventual construction and investment into the project. The estimated cost of the project is ~A$500 million.57 | | Crystal Brook,  SA. | | 25 tpd of H2  (50 MW electrolyser) | | Commercial Plant  (Under development) | | Icon  Description automatically generated | Icon  Description automatically generated | | * Feasibility study completed in 2018. * The company has since been provided with approvals by the SA government to proceed with developing the project facility. * The company is still assessing its options to proceed beyond the prefeasibility stage. |
| 25. | **Eyre Peninsula Gateway Project (H2UTM)**  In addition to the project in Gladstone, H2UTM is also developing another ammonia export facility in South Australia.  The project will be rolled out in two stages. The demonstrator phase of this project, due to come online in 2022, integrates a 75 MW electrolysis plant with a 120 t day-1 ammonia production facility.58  The demonstration plant is expected to cost A$240 million (The SA government has provided A$4.5 million in grants and A$7.5 million in loans to support development). The demonstration stage will be used to supply domestic markets and trail shipments of products to Asia.  The goal is to scale-up the project over time to 2,400 t day-1 for export capabilities..58 The export activities are expected by the proponent to start post 2025 (Source: Based on the information shared by the H2UTM at the Smart Energy Expo 2021). | | Eyre Peninsula, SA. | | 75 MW electrolyser of H2 generating  120 tpd of Ammonia | | Demonstration  Facility | | Icon  Description automatically generated | Icon  Description automatically generated | | Demonstration Plant, is currently in the Front-End Engineering and Design (FEED) stage (since March 2021). |
| Western Australia | | | | | | | | | | | | |
| 26. | **Western Green Energy Hub**  CWP and Intercontinental Energy, have also recently announced plans for a A$100 billion renewable hydrogen project in WA.59  The project will host a 50GW solar and wind generation capacity to generate green hydrogen for export. The committed capacity is nearly equal to the current size of the Australian National Energy Market (54 GW), which would make it the largest renewable energy project in Australia and the word.60–62  The project is expected to be developed in three phases with initial production by 2030.60 | Dundas Shire/City of Kalgoorlie-Boulder,  WA | | * 50 GW renewable capacity (30 GW wind and 20 GW solar) * 3.5 Mtpa of green H2 * 20 Mtpa of green ammonia | | Feasibility Stage  (Commercial Scale hydrogen export hub) | |  | | Icon  Description automatically generated | Early stages of development  The Final Investment Decision is targeted by 2028. | |
| 27. | **ATCO Renewable Methane Project**  ATCO is developing a demonstration plant for generating renewable methane for injection into the Albany gas network.  The WA state government has provided in $20k in funding to conduct a feasibility study.63 | Albany,  WA | | N.A. | | Feasibility Study  (Demonstration Facility) | | Icon  Description automatically generated | |  | Early stage of development. | |
| 28. | **Hazer Commercial Demonstration Plant**  The Hazer Commercial Demonstration Plant is planned to demonstrate Hazer’s proprietary hydrogen production technology, which converts biogas from sewage treatment into hydrogen and graphite.64  The plant is expected to cost $20 -22 million to build and ARENA has approved up to $9.4 million in funding for construction and operation.65 | Perth,  WA | | 100 tpa of H2 | | Demonstration  Facility | | Icon  Description automatically generated | |  | Under construction (Operations expected by the end of 2021). | |
| 29. | **Clean Energy Innovation Park**  ATCO is developing a hydrogen electrolyser facility as part of their Clean Energy Innovation Park project.  The site will host a 10 MW electrolyser, that will generate ~4 ton per day of hydrogen which will be injected into the natural gas grid. The site is co-located with the Warradarge Wind farm (180 MW) which will provide energy to drive the electrolysis plant.  The project has been provided with A$28.7 million in funding by ARENA to support the development of the project.39,40 | Warradarge,  WA | | 4 tpd of H2  (10 MW electrolyser) | | Demonstration Plant | | Icon  Description automatically generated | | Icon  Description automatically generated | Final stages of project development. | |
| 30. | **Badgingarra Renewable Hydrogen Project**  The Badgingarra Renewable Hydrogen project is proposed to generate hydrogen from local renewable resources for power generation, transport operation and industrial applications.66  Future provisions include plans to develop a pipeline for transporting the hydrogen to Perth. | Badgingarra,  WA | | N.A. | | Feasibility Study (Commercial Plant) | | Icon  Description automatically generated | |  | Early stages of development. | |
| 31. | **Arrowsmith Hydrogen Project**  Infinite Blue Energy have proposed plans to develop the Arrowsmith Hydrogen Project.  The facility is expected to be developed in 2 stages, with stage 1 acting as a small-scale plant for hydrogen utilization locally67 and stage 2 is aimed for large scale production targeted for export.68  The company conducted a prefeasibility study for a A$350 million project with Petrofac in 2020.69 The company has since secured A$300 million in investment to proceed ahead with the stage 1 of the project.70 | Dongara,  WA | | 9 ktpa of H2  (First Stage)  120 tpd of H2  (Second Stage) | | Feasibility Study (Commercial Plant) | | Icon  Description automatically generated | | Icon  Description automatically generated | The project has successfully secured investment for stage 1.  Stage 1 due in 2022  Stage 2 due by 2030 | |
| 32. | **Oakajee Hydrogen Generation Zone**  The Western Australia Government has allocated A$28 million in funding to develop the Oakajee Strategic Industrial Area to develop hydrogen export projects.  The area will have access to 1.25 GW of wind and 270 MW of solar energy for hydrogen generation. The WA government has called for expression of interest to invite prospective project partners for the zone.71 | Oakajee,  WA | | N. A | | Expression of Interest  (Commercial Plants) | | Icon  Description automatically generated | | Icon  Description automatically generated | The WA government has received several Expressions of Interest. | |
| 33. | **Project Geri Feasibility Study**  BP Australia, in combination with GHD Advisory, are conducting a feasibility study detailing a techno-economic evaluation of a pilot and commercial scale renewable ammonia plant in Geraldton, Western Australia.72  The study will evaluate different technologies for a pilot plant creating 20 ktpa of green ammonia and a commercial plant of 1000 ktpa. .  The study was granted with A$2.7 million BP funding and $1.7 million ARENA funding, commencing April 2020.73 | Geraldton,  WA | | 20 ktpa of Ammonia | | Feasibility Study  (Commercial Plant) | | Icon  Description automatically generated | | Icon  Description automatically generated | Feasibility Study in Progress | |
| 34. | **Murchison Renewable Hydrogen Project**  The Murchison Renewable Hydrogen project has been proposed by Hydrogen Renewables Australia.  The proposed project includes developing electrolyser systems with a desalination unit that will be powered using a 5 GW solar and wind farm to generate hydrogen for local use and export.74 The electrolyser for the project will be provided by Siemens.  Recently, Copenhagen Infrastructure Partners have joined the project as a secondary investor.75 | Kalbarri,  WA | | N. A | | Prefeasibility  (Commercial Plant) | | Icon  Description automatically generated | | Icon  Description automatically generated | The project is in an early stage of development. | |
| 34. | **Denham Hydrogen Demonstration Plant**  The Denham project is being developed by Horizon Power (a Western Australian Government backed company) as a remote power generation system. The hydrogen based microgrid project will include a 704 kW solar farm, a 348 kW electrolyser and a 100 kW fuel cell.  The system is expected to deliver 526 MWh of renewable energy every year to 100 residents. The project has received A$2.6 million in funding from ARENA (Advancing Renewables Program), A$5.7 million from WA government (WA Recovery Plan) and A$1 million through the WA Renewable Hydrogen Fund.76,77 | Denham,  WA | | 13 tpa of H2  (348 kW electrolyser) | | Demonstration Facility | | Icon  Description automatically generated | |  | Final stages of development (Project commissioning expected by end of 2021) | |
| 35. | **Yuri Green Ammonia Project**  Yara, one of the world’s largest ammonia and fertiliser company, owns and operates the Yara Pilbara Fertilisers facility. The plant generates 850ktpa of liquid ammonia for domestic use and export to Asia.  The current facility generates the required hydrogen using Steam Methane Reforming (which has a large environmental footprint). Yara in combination with ENGIE plan have conducted a feasibility study (with support of ARENA – A$995K funding) to replace a portion of their SMR based hydrogen production with an onsite solar PV powered electrolyser as part of a long term aim to replace 80 - 100% of the SMR hydrogen supply with green hydorgen for ammonia production.78  The feasibility study was was completed in 2020, which suggested scale up in stages. Starting with a commercial demonstration plant of 10 MW capacity at a cost of A$70 million.78 The project is still pending a final investment decision (FID), with expectation that the plant can be operational by 2023.  The project has recently secured conditional funding of A$42.5 million through ARENA’s Hydrogen Deployment Fund and A$2 million in grant funding through Western Australian Renewable Hydrogen Fund, both subject to the condition of the project reaching an FID. | Pilbara,  WA | | Demonstration Phase:  625 tpa of H2  (10 MW electrolyser)  Equivalent to 3.5ktpa of Ammonia | | Demonstration Facility  (Commercial scale pilot project with future scale up) | | Icon  Description automatically generated | | Icon  Description automatically generated | On going project development  (FDI pending with expectation of project becoming operational by 2023) | |
| 36. | **Asian Renewable Energy Hub**  The Asian Renewable Energy Hub is being developed as a large scale solar and wind hybrid renewable energy zone. Bulk of the 26 GW energy will be used to generate hydrogen and renewable ammonia for export.79  The project proponents include CWP Energy Asia, NW Interconnected Power, Intercontinental Energy, Vestas and the Pathways Investment group.  The project is expected to cost ~48 billion to develop.80 | Pilbara,  WA | | * 26 GW of hybrid solar and wind capacity. * 1.7 Mtpa of H2 * 9.9 Mtpa of green ammonia   (Based on a feasibility study conducted in 2019)80 | | Feasibility Stage  (Commercial scale hydrogen export hub) | |  | | Icon  Description automatically generated | Early stages of development  The Final Investment Decision is expected in 2025 and first export by 2027/28. | |
| 37. | **Ord Hydrogen Project**  The Ord Hydrogen project is being proposed by Pacific Hydro at their 30 MW hydroelectric power plant. A 5 – 25 MW electrolyser is planned for generating hydrogen for local use and export.81 | Kununurra,  WA | | 5 - 25 MW electrolyser | | Feasibility Stage  (Demonstration Facility) | | Icon  Description automatically generated | | Icon  Description automatically generated | Early stage of development. | |
| Northern Territroy | | | | | | | | | | | | |
| 38. | **Aqua Aerem Demonstration Project**  Aqua Aerem a developer of proprietary electrolyser systems is in advanced stages to trial their technology to generate hydrogen using water extracted from desert air and renewable energy.  The project has been backed by the NT state government.82 | Alice Springs,  NT. | | N.A. | | Demonstration Facility | | Icon  Description automatically generated | |  | Early stage of development. | |

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| Australian Hydrogen Hubs /Industrial Clusters (Note: some hubs encompass the projects outlined above) | | | | | | | |
| A. | **Hunter Region and Port Kembla Hydrogen Hubs**  The NSW government has committed to spending $70 million to develop hydrogen hubs in the state as part of the $750 million Zero Industry and Innovation Program.  As part of these plans the Hunter Region and Port Kembla have been proposed by NSW government as the state’s first hydrogen hubs.83,84  Particularly in Port Kembla, the state government has recently provided A$0.5 million in funding to Coregas to develop a hydrogen refueling station at their existing hydrogen plant at the port.83 | Hunter Region,  NSW  Port Kembla,  NSW | N.A. | Large scale hydrogen hub | Icon  Description automatically generated | Icon  Description automatically generated | Early stages of development |
| b. | **Bell Bay Hydrogen Hub**  The Bell Bay Advanced Manufacturing Zone has been established as a hydrogen hub by the Tasmanian Government. The zone is already being investigated for large hydrogen projects by Fortescue, ABEL energy and Origin Energy.  The Tasmanian Government is also proposing another hydrogen hub in Burnie, Tasmania. The state and federal governments will collaborate with stakeholders to develop hydrogen projects in these hubs.  The state government has made $20 million available in funding as part of the Tasmanian Renewable Hydrogen Fund to support potential projects.85,86 | Bell Bay,  Tas. | N.A. | Large scale hydrogen hub | Icon  Description automatically generated | Icon  Description automatically generated | Several projects are already undergoing feasibility studies. |
| C. | **South Australia Hydrogen Hub**  The Federal government has committed A$400 million in funding for high priority renewable energy projects including hydrogen as part of the A$1 billion energy deal for South Australia.87  The funding will be potentially utilized to develop hydrogen hubs identified by the South Australian Government in88:  **D.** Port Bonython: The site is already home to the Eyre Peninsula Hydrogen Project (#23).  **E.** Port Adelaide  **F.** Cape Hardy/Port Spencer: The SA government has identified that A$250 million will be required to upgrade Cape Hardy port to support hydrogen export.89  The SA government have also recently signed MoU with the Port of Rotterdam to explore hydrogen export opportunities from these hubs.90 |  | N.A. | Large scale hydrogen hubs | Icon  Description automatically generated | Icon  Description automatically generated |  |
| g. | **National Energy Resources Australia (NERA) backed Hydrogen Clusters.**  The federal government backed NERA has invested A$1.85 million in developing 13 regional hydrogen hubs and technology clusters across Australia.91  Each of the clusters will be operated by a consortium of universities, government institutions and private companies to develop and invest in projects for growing hydrogen industries. | Several locations across the states.  (1 each in, ACT, NSW, NT, SA and Tas, 4 in Victoria and 3 each in Western Australia & Queensland) | N.A. | Government led development of hydrogen hubs and technology centers. | Icon  Description automatically generated | Icon  Description automatically generated | Early stages of development |
| Additional Notes: | | | | | | | |
| Federal Government Support for Regional Hydrogen Hubs in Australia  Federal government has also committed to provide up to A$314 million in funding over 5 years to support/develop regional hydrogen hubs.92 | | | | | | | |

**Note:** This list in non-exhaustive due to the evolving hydrogen market in Australia. For more information, refer to CSIRO’s [HyResource](https://research.csiro.au/hyresource/projects/) project database.

1. Representative duration curves

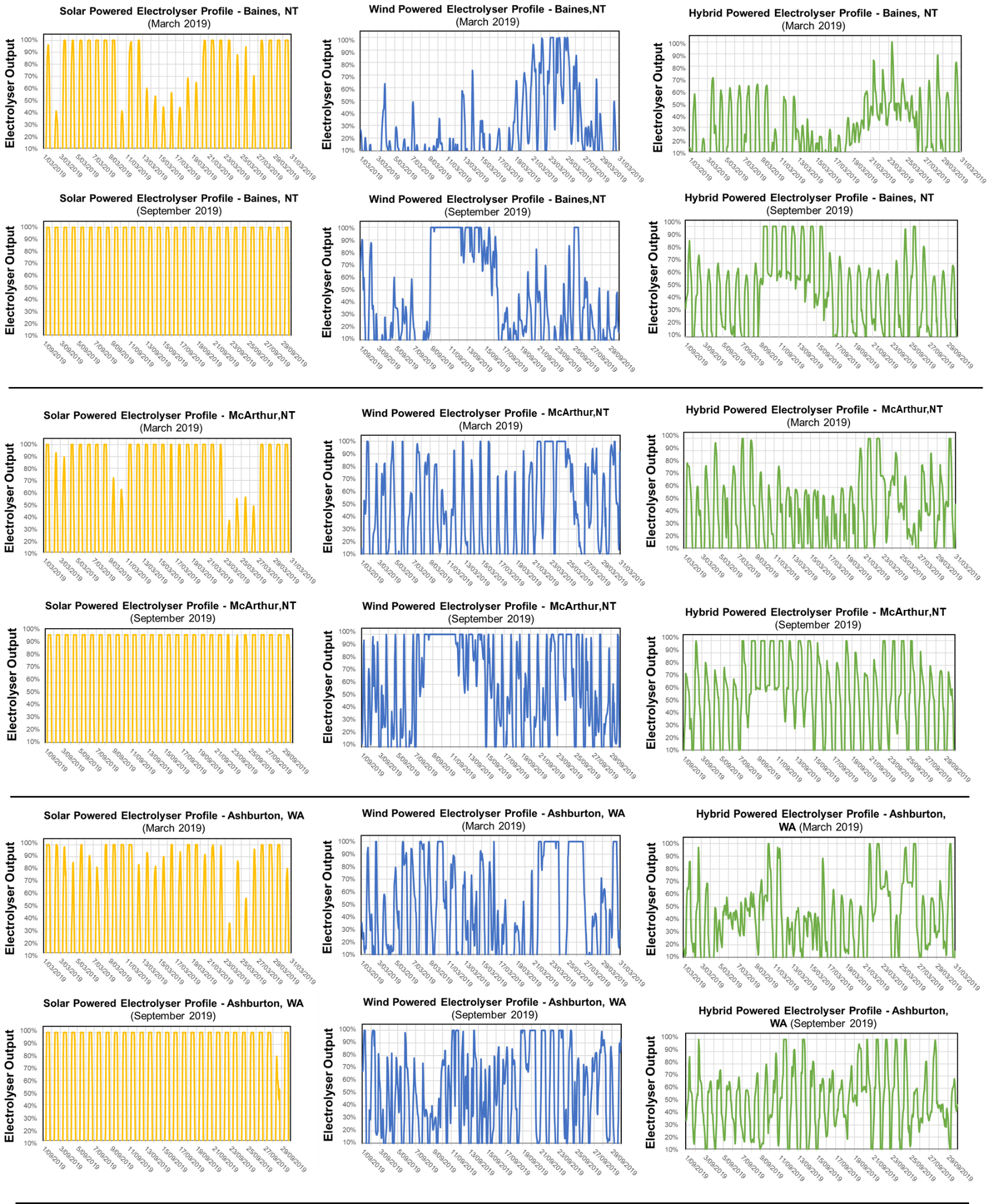


Figure B1. Monthly and daily breakdown of electrolyser duration curves for Solar PV, Wind and Hybrid (solar + wind) electricity in the chosen locations. The duration curves as a daily representation of the electrolyser output (%) over the course of the months of March and September for electrolyser facilities assumed in Baines (NT), Macarthur (NT) and Ashburton (WA)

A picture containing diagram

Description automatically generated

Figure B2. Monthly and daily breakdown of electrolyser duration curves for Solar PV, Wind and Hybrid (solar + wind) electricity in the chosen locations. The duration curves as a daily representation of the electrolyser output (%) over the course of the months of March and September for electrolyser facilities assumed in Geraldton (WA), New England (NSW) and Southern NSW Tablelands (NSW)

1. Hydrogen Carrier Assessment Tools

A multi-criteria analysis (MCA) tool was developed by HySupply Australia to provide a preliminary analysis mechanism to identify the most suitable hydrogen derivative for export between Australia and Germany. The MCA tool was developed to assess the hydrogen derivatives against key techno-economic criterion, such as commercial, hydrogen export, energy export, transportation and decarbonisation benefits. The key performance indicators used to assess each hydrogen carrier are discussed in Sections C1 – C5.

**Note that HySupply Australia recognises that the performance indicators used for the MCA analysis are subjective to the use-case in Germany. To facilitate this conversation and provide flexibility, HySupply Australia is releasing the hydrogen carrier assessment tool online.**

**C.1. Commercial Metrics**

Technical Readiness

The technical readiness level (TRL) has been used to evaluate the storage and transport of liquefied hydrogen and hydrogen carriers (ammonia, methane, methanol and other LOHCs) for an intercontinental value chain. Additionally, in the case of hydrogen carriers, the production and hydrogen retrieval technologies have been included within this assessment. For liquefaction, the technical readiness of liquefaction technology has been assessed.

An assessment of the TRL of the entirety of the value chain is made based upon technical readiness level of the individual components and not the current operational status of the value chain (**Table C1**)**.** This was performed to provide a perspective for the technical feasibility of a hydrogen export value chain. The assessment of the entire chain is taken as the minimum TRL value for each constituent of the chain (hydrogen carrier production/liquefaction, port infrastructure at source and destination country, transport and hydrogen recovery.

Ammonia, methane and methanol all have existing production, storage, export and retrieval processes which could be applied within a hydrogen value chain. As such these were evaluated as having the highest technical readiness level of 9.93–95 As previously discussed, the production and storage of liquefied hydrogen exists. However, intercontinental transport infrastructure is still being developed, with construction currently occurring within Japan, leading to a TRL assessment of 7. Furthermore, LOHCs exist within a range of TRL values, with more promising LOHCs such as DME having a TRL 7 used within this assessment.93,95

Capital Expenditure - CAPEX

To measure CAPEX for comparison between storage and transportation methods, it has been normalised to the AUD per kWh per annum across the technologies (30 years project life). This incorporates storage and transportation capital expenses. It also includes production and hydrogen retrieval facility costs for hydrogen carriers as well as liquefaction costs for methane and liquefied hydrogen. Values have been converted from the models within peer-reviewed published literature and commercial feasibility studies. These capital costs do not include the hydrogen production cost or utilisation costs.

Modelling indicates that methane has the lowest CAPEX. This is due to the existence of large-scale methane value chains and a fully developed liquefaction process and export industry. Liquefied hydrogen and methanol follow with similar CAPEX costs. Ammonia is relatively expensive with the non-existence of large-scale LOHCs export meaning economies of scale gains are unknown at this point, leading to a large CAPEX.

Operating Expenditure - OPEX

To measure OPEX for comparison between storage and transportation methods, it has been normalised to dollars per kWh per annum across the technologies. This incorporates storage and transportation operating expenses. It also includes production and hydrogen retrieval facility operating costs for hydrogen carriers as well as liquefaction operating costs for methane and liquefied hydrogen. Values have been converted from the models within peer-reviewed published literature and commercial feasibility studies.

As with CAPEX, methane has the lowest OPEX owing to the process being the most developed as an energy storage medium. However, ammonia and methanol are both similar in value. Liquefied hydrogen is more energy intensive in the cooling to cryogenic conditions and subsequent maintenance of those conditions, leading to the higher OPEX. As previously stated, LOHCs are underdeveloped technologies and as such are relatively less energy efficient, with expensive carbon-chain source materials, making them relatively more expensive.

**D.2. Hydrogen Export Metrics**

Hydrogen Storage Density

The hydrogen storage density is the measurement of weight % of hydrogen within the carrier. This reflects the actual quantity of hydrogen stored and transported, as opposed to the total energy of the carriers which is discussed with the energy export metrics (**Section C.3**). Naturally, liquefied hydrogen has the highest hydrogen storage density of 100% as it is comprised solely of hydrogen molecules. This is followed by methane and ammonia, with molecules containing a single carbon and nitrogen atom, respectively. Finally, methanol and other LOHCs contain other additional atoms which reduce the weight % of hydrogen within the carrier.

Hydrogen Conversion Efficiency

The hydrogen conversion efficiency is the energy efficiency of converting from the hydrogen carrier back into hydrogen form. This criterion is designed to facilitate decision making for German stakeholders that are primarily interested in the use of hydrogen in its pure form. Methanol was identified as the most efficient hydrogen derivative for hydrogen extraction (excluding liquified hydrogen).

**C.3. Energy Export Metrics**

Volumetric Energy Density

The volumetric energy density is the energy density per unit volume, herein we considered the volumetric energy density during storage and transport measured in MJ L-1. This metric was then used to compare the ease of energy storage, with a greater volumetric energy density indicating that less volume is required per MJ of energy delivered. This way a carrier with a higher volumetric density contains more energy per equivalent volume compared to a carrier with low volumetric density. Di-methyl Ether (DME), the LOHC used here for comparison, and methane have similarly high energy density, due to the higher energy C-H bonds. Ammonia and Methanol both had moderate densities, with liquefied hydrogen having the lowest, exemplifying the difficulties with hydrogen storage.

Gravimetric Energy Density

In comparison, the gravimetric energy density is the energy density per unit mass as opposed to volume. Herein, we represent the gravimetric energy density during storage and transportation in terms of MJ kg-1. This metric was also used to compare the ease of energy storage, with a greater volumetric energy density indicating that less mass is required per MJ of energy delivered. This way a carrier with a higher gravimetric density contains more energy per equivalent mass compared to a carrier with low gravimetric density. Higher gravimetric density means more energy can be stored and transported at the same mass, reducing the associated costs. Liquefied hydrogen and methane exhibit the highest gravimetric densities following the liquefaction process. This was followed by LOHCs, with methanol and ammonia having similarly low gravimetric density.

**C.4. Transportation Metrics**

Transportation Cost

Herein we use the shipping cost from port in Australia to destination port in Europe (**Table 15**), as the metric for comparing the transportation costs of each carrier. These transportation costs are then based on the Capital Cost (CAPEX) which represents the cost of ship/hiring the ship for intercontinental shipping and the Operating Costs (OPEX) which incorporate requirements to maintain storage conditions (such as liquification), for employee renumerations, for transport energy costs as well as other operation and maintenance costs. The source values for these costs were adopted from models within peer-reviewed published literature and commercial feasibility studies. The capital and operating costs (A$) were then levelized over the amount of carrier (kg) transported.

Overall, Ammonia incurs the lowest transportation costs as it does not require energy inputs for the maintenance of liquified conditions and has established transportation networks over time which has facilitated efficiency improvements and consequently cost reductions. Methanol and other LOHCs have less developed transportation infrastructure at smaller scale resulting in higher transportation costs. The energy requirement for maintenance of liquified conditions for methane and liquefied hydrogen result in relatively higher transportation costs.

Carrier Yield Loss During Transportation

During transportation, energy losses occur in the form of gas boil off and leaks, which reduces the yield for the importing nation. This is a key metric for determining the energy export efficiency of the export value chain. i.e., If there is a high carrier yield loss, this results in an additional energy export loss beyond conversion of renewable energy into hydrogen/ hydrogen derivatives, which may be a key consideration for German stakeholders, looking to utilise hydrogen/ hydrogen derivatives as purely an energy carrier.

Overall, Ammonia, methanol and LOHCs both have low yield losses per day owing to their higher boiling point, making transport, and handling easier as boil off is less likely to occur. Contrastingly, the liquefaction of methane for transport requires constant energy input to prevent regassification over the length of a voyage, making the yield loss higher. Furthermore, it is important to note that any methane leaks are an environmental concern due to the high greenhouse warming potential of methane. Finally, liquefied hydrogen incurs the largest yield loss owing to the much lower cryogenic conditions for liquefaction and subsequent energy requirement during transit.

**C.5. Decarbonisation Metrics**

Decarbonisation Benefit

The environmental impact was measured using the kg CO2 equivalent per kWh of energy produced. This was evaluated based upon the emissions released from the combustion of the hydrogen carrier. Methane and methanol had the most detrimental environmental impact. For the purposes of this investigation, the emissions (or lack of emissions) from energy production via LOHCs correspond to the combustion of hydrogen, as LOHCs are a transport medium for hydrogen, as opposed to an energy carrier/fuel.

Table C1. Evaluation of the technical readiness, CAPEX, OPEX, yield loss, energy efficiency, environmental impact of physical hydrogen and hydrogen carrier storage and transportation.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Storage and Transport Medium | Scenario | Technical Readiness Level | CAPEX  (A$ kWh-1 y-1) | OPEX  (A$ kWh-1 y-1) | Storage Density  (wt% hydrogen) | Reconversion Efficiency  (%) | Volumetric Energy Density  (MJ L-1) | Gravimetric Energy Density  (MJ kg-1) | Transport Cost  (A$ kg-1) | Yield Loss  (%) | Decarbonisation Benefit  (kg CO2 eq. per kg fuel) | Comments | Source |
| Liquefied Hydrogen | Production and Storage | 9 | 0.863 | 0.653 | 100 | 61 | 8.5 | 120 | 1.01 | 0.2 | 0 | Existing Small-scale production and storage Technologies | 95–98 |
| Transport | 7 | - | - | - | - | - | - | - | - | Intercontinental Vessels under development | 95,96 |
| Ammonia | Production, Storage and Transport | 9 | 0.921 | 0.318 | 17.65 | 44 | 12.7 | 18.6 | 0.104 | 0.0043 | 0 | Existing Export Industry | 20,95–100 |
| Methane | Production, Storage and Transport | 9 | 0.22 | 0.117 | 25.00 | 52.4 | 20.6 | 53.6 | 0.205 | 0.017 | 0.18 | Existing Export Industry | 93,95–98,101–103,101 |
| Methanol | Production, Storage and Transport | 8 | 0.843 | 0.367 | 12.50 | 68.1 | 16.0 | 20 | 0.073 | 0.0016 | 0.25 | Existing Export Industry, however, at smaller-scale with less developed production technology | 93–98,104,105,101 |
| LOHCs | Production Transport and Storage | 7 | 1.266 | 1.174 | 4.35 – 13.09 | 54.9 | 21.3 | 42.59-43.45 | 0.088  (DME as carrier) | 0.0053 | 0 | Dependent upon the LOHC considered (DBT assessed) | 93,95–98,106,107 |

**Note:**

* The CAPEX and OPEX values represented here include the total hydrogen value chain, hydrogen generation (electrolysis), conversion to carrier at export site, port storage and onloading to ship. The costs are based on literature analysis
* Reconversion efficiency represents the efficiency for y
* The transport costs are based on the individual shipping costs of carriers established as part of internal HySupply analysis (Table 15 of State of Play Report). The case of transporting from Geraldton to Rotterdam was used as a reference.

**C.7. Multi-Criteria Analysis**

Evaluation bands were developed as a mechanism to assess and categorise the hydrogen carriers (**Table C2**). The weighting for each carrier will be determined by the user of the MCA tool, enabling users to prioritise criterion based on their desired offtake requirements (i.e. zero emission focused or energy export focused).

Table C2. Determination of the evaluation bands for hydrogen carrier transportation and storage.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Evaluation Bands | 1 | 2 | 3 | 4 | 5 |
| TRL | 1.0 - 3.0 | 4.0 - 6.0 | 7 | 8 | 9 |
| CAPEX (A$ kWh-1 annum-1) | >1 | 1 - 0.8 | 0.8 - 0.6 | 0.6 - 0.4 | <0.4 |
| OPEX (A$ kWh-1 annum-1) | >0.8 | 0.6 - 0.8 | 0.4 - 0.6 | 0.2 - 0.4 | <0.2 |
| Hydrogen Storage Density (wt% hydrogen) | <10 | 10-15 | 15-20 | 20-25 | >25 |
| Gravimetric Energy Density (MJ kg-1) | <10 | 10 - 20 | 20 - 30 | 30 - 50 | >50 |
| Volumetric Energy Density (MJ L-1) | <10 | 10-12 | 12-14 | 14-16 | >16 |
| Carrier Yield Loss by Transportation (%) | >0.033 | 0.025-0.033 | 0.017-0.025 | 0.008-0.017 | <0.008 |
| Hydrogen Conversion Efficiency (%) | <30 | 30-40 | 40-50 | 50-60 | >60 |
| Decarbonisation Benefit (kg CO2 eq./kWh) | >0.15 | 0.1 – 0.15 | 0.05-0.1 | 0-0.05 | 0 |
| Transportation Cost (A$ kg-1) | >1 | >0.5 | >0.2 | >0.1 | <0.1 |

The MCA is provided above, with a high score indicative of better performance (**Table C2**). Methane is the best performing storage and transportation method, owing to its low CAPEX and OPEX, high energy density and technical readiness, with methane export, in the form of natural gas, a mature industry. Ammonia also is high performing with low OPEX but higher CAPEX. It also has low environmental impact and losses during transportation as well as a high level of technical readiness. Methanol performed moderately regarding all criteria, hampered by higher CAPEX and OPEX and a less mature formation and export technology. Liquefied hydrogen and the DME LOHC evaluated both performed poorly. Liquefied hydrogen suffers from high OPEX owing to the large liquefaction energy requirement. Furthermore, the requirement for maintaining cryogenic conditions causes yield losses during transport and the developing export infrastructure contributed to lower potential for application. Furthermore, the lack of technical readiness for LOHCs cause the high OPEX and CAPEX costs which currently make this an unviable method for hydrogen storage and transport.

**References**

1. CSIRO. Daintree Microgrid Project . *HyResource* https://research.csiro.au/hyresource/daintree-microgrid-project/ (2020).

2. CSIRO. Daintree Microgrid Project . *HyResource* https://research.csiro.au/hyresource/daintree-microgrid-project/ (2020).

3. What Happened To The One Million Dollar Shovel Ready Daintree Microgrid Project? | DouglasNews.Network. https://douglasnews.network/2021/04/24/what-happened-to-the-one-million-dollar-shovel-ready-daintree-microgrid-project/.

4. Warren Entsch MP. Morrison Government to invest $19.3m to support stage one construction of the Daintree microgrid project. *Media Releases* https://www.warrenentsch.com.au/morrison-government-to-invest-19-3m-to-support-stage-one-construction-of-the-daintree-microgrid-project/ (2021).

5. Origin Energy. Green hydrogen project signs port MOU. *Media Releases* https://www.originenergy.com.au/about/investors-media/media-centre/green\_hydrogen\_project\_signs\_port\_mou.html (2021).

6. Macdonald-Smith, A. Origin inks accord for hydrogen exports from Townsville. *Australian Financial Review* https://www.afr.com/companies/energy/origin-inks-accord-for-hydrogen-exports-from-townsville-20210414-p57j2c (2021).

7. Townsville Mayor Welcomes Hydrogen Agreement Between Origin Energy And Kawasaki Heavy Industries. *FuelCellsWorks* https://fuelcellsworks.com/news/townsville-mayor-welcomes-hydrogen-agreement-between-origin-energy-and-kawasaki-heavy-industries/ (2021).

8. CSIRO. Sun Metals Hydrogen Queensland SunHQ Project. *HyResource* https://research.csiro.au/hyresource/sun-metals-hydrogen-queensland-sunhq-project/ (2020).

9. Burgess, K. Developer seeks partners for Abbot Point Hydrogen Export Hub. *Inframation News* https://www.abbotpointcleanenergy.com.au/news (2021).

10. Abbot Point Clean Energy Hub. The Project — Abbot Point Clean Energy Hub. *2021* https://www.abbotpointcleanenergy.com.au/the-project.

11. Incitec Pivot Limited. Dyno Nobel conducts feasibility studies to assess renewable hydrogen at Moranbah facility. *Media Releases* https://www.incitecpivot.com.au/about-us/about-incitec-pivot-limited/media/2019-09-30-dyno-nobel-conducts-feasibility-study-for-renewable-hydrogen-option-for-moranbah-facility (2019).

12. ARENA. Dyno Nobel Renewable Hydrogen Feasibility Study . *Knowledge Bank* https://arena.gov.au/knowledge-bank/dyno-nobel-renewable-hydrogen-feasibility-study/.

13. ANT Energy Solutions & Dyno Nobel Moranbah. *DNM Renewable Hydrogen Feasibility Study*. (2020).

14. Stanwell. Hydrogen. https://www.stanwell.com/energy-assets/new-energy-initiatives/stanwell-hydrogen-project/.

15. ARENA. Stanwell Hydrogen Electrolysis Deployment Feasibility Study. *Projects* https://arena.gov.au/projects/stanwell-hydrogen-electrolysis-deployment-feasibility-study/ (2020).

16. Stanwell. Central Queensland: a future hydrogen export powerhouse. https://www.stanwell.com/our-news/media/central-queensland-a-future-hydrogen-export-powerhouse/ (2020).

17. Matich, B. Green light for the $300 million green Bundaberg Hydrogen Hub.  *pv magazine Australia* https://www.pv-magazine-australia.com/2020/09/10/green-light-for-the-300-million-green-bundaberg-hydrogen-hub/ (2020).

18. ARENA. QNP Green Ammonia Project Feasibility Study . *2020* https://arena.gov.au/knowledge-bank/qnp-green-ammonia-project-feasibility-study/.

19. CSIRO. Queensland Nitrates Renewable Hydrogen and Ammonia Project. *HyResource* https://research.csiro.au/hyresource/queensland-nitrates-renewable-hydrogen-and-ammonia-project/ (2020).

20. QNP, ARENA & Neon and Worley. QNP Green Ammonia Project Feasibility Study. (2020).

21. CSIRO. Bio-Hydrogen Demonstration Plant . *HyResource* https://research.csiro.au/hyresource/bio-hydrogen-demonstration-plant/ (2020).

22. Terzon, E. Hydrogen power plant pilot, a first for Queensland, highlights resurgence of humble chemical elements. *ABC news* https://www.abc.net.au/news/2018-07-18/hydrogen-power-pilot-concept-gladstone-refinery/10003812 (2018).

23. Brown Trevor. H2U moves forward with 3 GW green ammonia export plant . *Ammonia Energy* https://www.ammoniaenergy.org/articles/h2u-moves-forward-with-3-gw-green-ammonia-export-plant/ (2020).

24. CSIRO. H2-Hub(TM) Gladstone . *HyResource* https://research.csiro.au/hyresource/h2-hub-gladstone/ (2020).

25. RWE. RWE and H2U join forces to develop global hydrogen trading between Australia and Germany. *Press Release* https://www.rwe.com/en/press/rwe-supply-and-trading/rwe-and-h2u-join-forces-to-develop-global-hydrogen-trading-between-australia-and-germany (2021).

26. AGN expands hydrogen to QLD . *The Australian Pipeliner* https://www.pipeliner.com.au/2020/03/05/agn-expands-hydrogen-to-qld/ (2020).

27. AGIG. Hydrogen Park Gladstone . https://www.agig.com.au/hydrogen-park-gladstone (2021).

28. APA Renewable Methane Demonstration Project - Australian Renewable Energy Agency (ARENA).

29. APA to trial renewable methane in Australia’s gas pipelines – pv magazine Australia.

30. Mazengarb, M. Regional NSW town to host large-scale hydrogen energy storage project – state’s first . *RenewEconomy* https://reneweconomy.com.au/regional-nsw-town-to-host-large-scale-hydrogen-energy-storage-project-states-first-79334/ (2020).

31. Infinite Blue Energy. Project NEO 1 GW Baseload. https://infiniteblueenergy.com/project/project-neo-coming-soon/.

32. Dabas, C. New South Wales to transition to 100% green hydrogen electricity . *Energy Live News* https://www.energylivenews.com/2020/05/22/new-south-wales-to-transition-to-100-green-hydrogen-electricity/ (2020).

33. Jemena’s Western Sydney Green Gas Project - Jemena.

34. The future of hydrogen: how‌ ‌to‌ ‌build‌ ‌an‌ ‌electrolyser‌ | Energy Magazine.

35. CSIRO. Western Sydney Green Gas Project . *HyResource* https://research.csiro.au/hyresource/western-sydney-green-gas-project/ (2020).

36. Chief Minister, T. and E. D. D. Australia’s first public hydrogen refuelling station opens in Canberra . *Media Releases* https://www.cmtedd.act.gov.au/open\_government/inform/act\_government\_media\_releases/rattenbury/2021/australias-first-public-hydrogen-refuelling-station-opens-in-canberra (2021).

37. Mazengarb, M. ACT unveils Australia’s first public hydrogen refuelling station. *The Driven* https://thedriven.io/2021/03/26/act-unveils-australias-first-public-hydrogen-refuelling-station/ (2021).

38. CSIRO. Renewable Hydrogen Refuelling Pilot . *HyResource* https://research.csiro.au/hyresource/renewable-hydrogen-refuelling-pilot/ (2020).

39. Mazengarb, M. Australia’s first three commercial green hydrogen projects to share $103m ARENA funds. *RenewEconomy* https://reneweconomy.com.au/australias-first-three-commercial-green-hydrogen-projects-to-share-103m-arena-funds/ (2021).

40. Ludlow, M. & Macdonald-Smith, A. ARENA tips $100m into three hydrogen projects. *Financial Review* https://www.afr.com/companies/energy/arena-tips-100m-into-three-hydrogen-projects-20210504-p57otr (2021).

41. Construction starts on a world first liquid hydrogen project in Victoria - Invest Victoria.

42. Hydrogen Engineering Australia. Hydrogen Energy Supply Chain. https://hydrogenenergysupplychain.com/ (2020).

43. HESC. Community and sustainability - Emissions. https://hydrogenenergysupplychain.com/community-and-sustainability/.

44. Victoria Government. The CarbonNet Project - Earth Resources. https://earthresources.vic.gov.au/projects/carbonnet-project.

45. Mazengarb, M. Consortium proposes 80MW solar farm and green hydrogen facility in Victoria . *RenewEconomy* https://reneweconomy.com.au/consortium-proposes-80mw-solar-farm-and-green-hydrogen-facility-in-victoria-39922/ (2019).

46. CSIRO. Portland Renewable Hydrogen Project . *HyResource* https://research.csiro.au/hyresource/portland-renewable-hydrogen-project/ (2021).

47. Fortescue announces development study into green ammonia plant in Tasmania | Fortescue Metals Group Ltd. https://www.fmgl.com.au/in-the-news/media-releases/2020/11/17/fortescue-announces-development-study-into-green-ammonia-plant-in-tasmania.

48. Macdonald-smith, A. & Thompson, B. Origin, Fortescue in rival hydrogen projects in Tasmania. *Australian Financial Review* https://www.afr.com/companies/energy/origin-fortescue-in-rival-hydrogen-projects-in-tasmania-20201117-p56f76 (2020).

49. CSIRO. ABEL Energy Bell Bay Powerfuels Project. *HyResource* https://research.csiro.au/hyresource/abel-energy-bell-bay-powerfuels-project/ (2020).

50. S&P Global Platts. Tasmania chooses four companies for new green hydrogen studies. *Market Insights* https://www.spglobal.com/platts/en/market-insights/latest-news/metals/111720-tasmania-chooses-four-companies-for-new-green-hydrogen-studies (2020).

51. ABEL Energy. Bell Bay Power Fuels Project. https://www.abelenergy.com.au/our-projects.

52. Origin Energy. Origin to investigate export scale green hydrogen project in Tasmania. https://www.originenergy.com.au/about/investors-media/media-centre/origin\_to\_investigate\_export\_scale\_green\_hydrogen\_project\_in\_tasmania.html#:~:text=17 November 2020-,Origin to investigate export scale green hydrogen project in Tasmania,sustainable water (2020).

53. Siemens Australia. Hydrogen Demonstration Park. *Press Release* https://new.siemens.com/au/en/company/press-centre/hydrogen-demonstration-park.html (2018).

54. AGIG. Hydrogen Park South Australia - HyP SA. https://www.agig.com.au/hydrogen-park-south-australia (2018).

55. CSIRO. Hydrogen Park South Australia. *HyResource* https://research.csiro.au/hyresource/hydrogen-park-south-australia/ (2021).

56. Renewables SA & Government of South Australia. Neoen Australia Hydrogen Superhub. http://www.renewablessa.sa.gov.au/topic/hydrogen/hydrogen-projects-south-australia/neoen-australia-hydrogen-super-hub.

57. CSIRO. Neoen Australia Hydrogen Superhub (Crystal Brook Energy Park). *HyResource* https://research.csiro.au/hyresource/neoen-australia-hydrogen-superhub-crystal-brook-energy-park/.

58. The Eyre Peninsula Gateway Project - Renewables SA. http://www.renewablessa.sa.gov.au/topic/hydrogen/hydrogen-projects-south-australia/hydrogen-green-ammonia-production-facility.

59. Intercontinental Energy. Western green energy hub . https://intercontinentalenergy.com/western-green-energy-hub.

60. Goowdwin, S. T. & Dias, D. World’s biggest green energy hub proposed for south coast of Western Australia . *ABC* https://www.abc.net.au/news/2021-07-13/green-energy-hub-planned-for-south-coast-of-wa/100288734?utm\_campaign=news-article-share-control&utm\_content=linked-in&utm\_medium=content\_shared&utm\_source=abc\_news\_web (2021).

61. Parkinson, G. World’s biggest wind and solar hydrogen hub planned for south-west Australia . *RenewEconomy* https://reneweconomy.com.au/worlds-biggest-renewable-energy-hub-planned-for-south-west-australia/ (2021).

62. Readfearn, G. Plan to build world’s biggest renewable energy hub in Western Australia . *The Guardian* https://www.theguardian.com/environment/2021/jul/13/plan-to-build-worlds-biggest-renewable-energy-hub-in-western-australia (2021).

63. ATCO. ATCO investigates renewable natural gas in Albany, Western Australia. https://www.atco.com/en-au/about-us/stories/atco-renewable-natural-gas-albany.html (2020).

64. Australian Renewable Energy Agency. The Hazer Process: Commercial Demonstration Plant. https://arena.gov.au/projects/the-hazer-process-commercial-demonstration-plant/ (2020).

65. CSIRO. Hazer Commercial Demonstration Plant . *HyResource* https://research.csiro.au/hyresource/hazer-commercial-demonstration-plant/ (2020).

66. CSIRO. Badgingarra Renewable Hydrogen Project . *HyResource* https://research.csiro.au/hyresource/badgingarra-renewable-hydrogen-project/ (2020).

67. Infinite Blue Energy. Arrowsmith Hydrogen Plant stage 1. https://www.infiniteblueenergy.com/projects/arrowsmith-hydrogen-plant-stage-1/.

68. Infinite Blue Energy. Arrowsmith Hydrogen Plant stage 2 . https://www.infiniteblueenergy.com/projects/arrowsmith-hydrogen-plant-stage-2/.

69. Infinite Blue Energy. Infinite Blue Energy progresses Perth green hydrogen plant . *2020* https://www.infiniteblueenergy.com/infinite-blue-energy-progresses-perth-green-hydrogen-plant/.

70. Mazengarb, M. Massive hydrogen project gets green light after securing $300m investment . *RenewEconomy* https://reneweconomy.com.au/massive-hydrogen-project-gets-green-light-after-securing-300m-investment-68959/ (2020).

71. Vorrath, S. Call to develop 1.5GW green hydrogen hub gets ‘super major’ response . *RenewEconomy* https://reneweconomy.com.au/call-to-develop-1-5gw-green-hydrogen-hub-gets-super-major-response/ (2021).

72. Project GERI Feasibility Study - Australian Renewable Energy Agency (ARENA).

73. BP. bp Australia announces feasibility study into hydrogen energy production facility. *Press Releases* https://www.bp.com/en\_au/australia/home/who-we-are/sustainability/low-carbon-projects/feasibility-study-renewable-hydrogen-production-facility.html (2020).

74. Siemens Australia. Murchison Renewable Hydrogen Project. *Press Release* https://new.siemens.com/au/en/company/press-centre/2019/murchison-renewable-hydrogen-project.html (2019).

75. Hydrogen Renewables Australia. Hydrogen Renewables Australia and Copenhagen Infrastructure Partners announce partnership on the Murchison Renewable Hydrogen Project. *Media Release* (2020).

76. Australian Renewable Energy Agency. Horizon Power Denham Hydrogen Demonstration. *Projects* https://arena.gov.au/projects/horizon-power-denham-hydrogen-demonstration/ (2020).

77. Gascoyne Community Hydrogen Project Gets Off The Ground In Denham Australia. *Fuel Cells Works* https://fuelcellsworks.com/news/gascoyne-community-hydrogen-project-gets-off-the-ground-in-denham-australia/ (2021).

78. Yara & Engie. *ENGIE-YARA Renewable Hydrogen and Ammonia Deployment in Pilbara YURI Phase 0: Feasibility Study Knowledge Sharing Report*. (2020).

79. Mazengarb, M. Massive Asian Renewable Energy Hub grows to 26GW of wind and solar | . *RenewEconomy* https://reneweconomy.com.au/massive-asian-renewable-energy-hub-grows-to-26gw-of-wind-and-solar-49343/.

80. Intercontinental Energy. Asian renewable energy hub . https://intercontinentalenergy.com/asian-renewable-energy-hub.

81. CSIRO. Ord Hydrogen . *HyResource* https://research.csiro.au/hyresource/ord-hydrogen/ (2020).

82. Fernyhough, J. Northern Territory to trial hydrogen made with ‘water from air’ . *RenewEconomy* https://reneweconomy.com.au/northern-territory-to-trial-hydrogen-made-with-water-from-air/ (2021).

83. NSW Government. First steps towards Port Kembla’s hydrogen hub. *Invest Regional* https://www.investregional.nsw.gov.au/news/first-steps-towards-port-kemblas-hydrogen-hub/ (2021).

84. NSW Government. Hunter hydrogen hub announced. *Invest Regional* https://www.investregional.nsw.gov.au/news/hunter-hydrogen-hub/ (2021).

85. Barnett, G. & Ferguson, M. Renewable hydrogen set to take off in Tasmania - Premier of Tasmania. *Press Release* http://www.premier.tas.gov.au/site\_resources\_2015/additional\_releases/renewable\_hydrogen\_set\_to\_take\_off\_in\_tasmania (2020).

86. Howarth, C. Tasmanian Government to invest $50m in hydrogen power plan . *ABC News* https://www.abc.net.au/news/2020-03-02/hydrogen-energy-tasmania-government-to-invest-millions/12015654 (2020).

87. Scott Morrison reveals $1bn energy deal with South Australian government. *ABC News* https://www.abc.net.au/news/2021-04-18/energy-and-emissions-reduction-deal-south-australia/100077114 (2021).

88. Heynes, G. Morrison’s $1bn energy deal with South Australia includes funding for ‘priority’ areas such as hydrogen. *H2View* https://www.h2-view.com/story/morrisons-1bn-energy-deal-with-south-australia-includes-funding-for-priority-areas-such-as-hydrogen/ (2021).

89. Cape Hardy poised for major role in South Australia’s hydrogen future . *NS Energy* https://www.nsenergybusiness.com/news/cape-hardy-poised-for-major-role-in-south-australias-hydrogen-future/ (2020).

90. Port of Rotterdam. Feasibility study on export of South Australian green hydrogen to Rotterdam . *News and Press Releases* https://www.portofrotterdam.com/en/news-and-press-releases/feasibility-study-export-south-australian-green-hydrogen-rotterdam (2021).

91. Australian Hydrogen Technology Clusters : NERA National Energy Resources Australia. https://www.nera.org.au/regional-hydrogen-technology-clusters.

92. Peacock, B. Federal government commits a further $275m to regional hydrogen hubs while devoting similar sum to controversial technology . *PV Magazine Australia* https://www.pv-magazine-australia.com/2021/04/21/federal-government-commits-a-further-275m-to-regional-hydrogen-hubs-while-devoting-similar-sum-to-controversial-technology/ (2021).

93. Niermann, M., Drünert, S., Kaltschmitt, M. & Bonhoff, K. Liquid organic hydrogen carriers (LOHCs)-techno-economic analysis of LOHCs in a defined process chain. *Energy Environ. Sci.* **12**, 290–307 (2019).

94. Jarvis, S. M. & Samsatli, S. Technologies and infrastructures underpinning future CO2 value chains: A comprehensive review and comparative analysis. *Renew. Sustain. Energy Rev.* **85**, 46–68 (2018).

95. Bruce S *et al.* Pathways to an economically sustainable hydrogen industry in Australia National Hydrogen Roadmap. (2019).

96. Ishimoto, Y. *et al.* Large-scale production and transport of hydrogen from Norway to Europe and Japan: Value chain analysis and comparison of liquid hydrogen and ammonia as energy carriers. *Int. J. Hydrogen Energy* **45**, 32865–32883 (2020).

97. Al-Breiki, M. & Bicer, Y. Comparative cost assessment of sustainable energy carriers produced from natural gas accounting for boil-off gas and social cost of carbon. *Energy Reports* **6**, 1897–1909 (2020).

98. Al-Breiki, M. & Bicer, Y. Investigating the technical feasibility of various energy carriers for alternative and sustainable overseas energy transport scenarios. *Energy Convers. Manag.* **209**, (2020).

99. Zhang, H., Wang, L., Van herle, J., Maréchal, F. & Desideri, U. Techno-economic comparison of green ammonia production processes. *Appl. Energy* **259**, (2020).

100. Office of Energy Efficiency & Renewable Energy. Hydrogen Storage . *Hydrogen and Fuel Cell Technologies Office* https://www.energy.gov/eere/fuelcells/hydrogen-storage.

101. Salomone, F. *et al.* Techno-economic modelling of a Power-to-Gas system based on SOEC electrolysis and CO2 methanation in a RES-based electric grid. *Chem. Eng. J.* **377**, 120233 (2019).

102. Keipi, T., Tolvanen, H. & Konttinen, J. Economic analysis of hydrogen production by methane thermal decomposition: Comparison to competing technologies. *Energy Convers. Manag.* **159**, 264–273 (2018).

103. Hasan, M. M. F., Zheng, A. M. & Karimi, I. A. Minimizing boil-off losses in liquefied natural gas transportation. *Ind. Eng. Chem. Res.* **48**, 9571–9580 (2009).

104. Bellotti, D., Rivarolo, M., Magistri, L. & Massardo, A. F. Feasibility study of methanol production plant from hydrogen and captured carbon dioxide. (2017) doi:10.1016/j.jcou.2017.07.001.

105. Elsernagawy, O. Y. H. *et al.* Thermo-economic analysis of reverse water-gas shift process with different temperatures for green methanol production as a hydrogen carrier. *J. CO2 Util.* **41**, (2020).

106. Brigljević, B., Byun, M. & Lim, H. Design, economic evaluation, and market uncertainty analysis of LOHC-based, CO2 free, hydrogen delivery systems. *Appl. Energy* **274**, (2020).

107. Combustion of Fuels - Carbon Dioxide Emission. *The Engineering Toolbox* https://www.engineeringtoolbox.com/co2-emission-fuels-d\_1085.html.