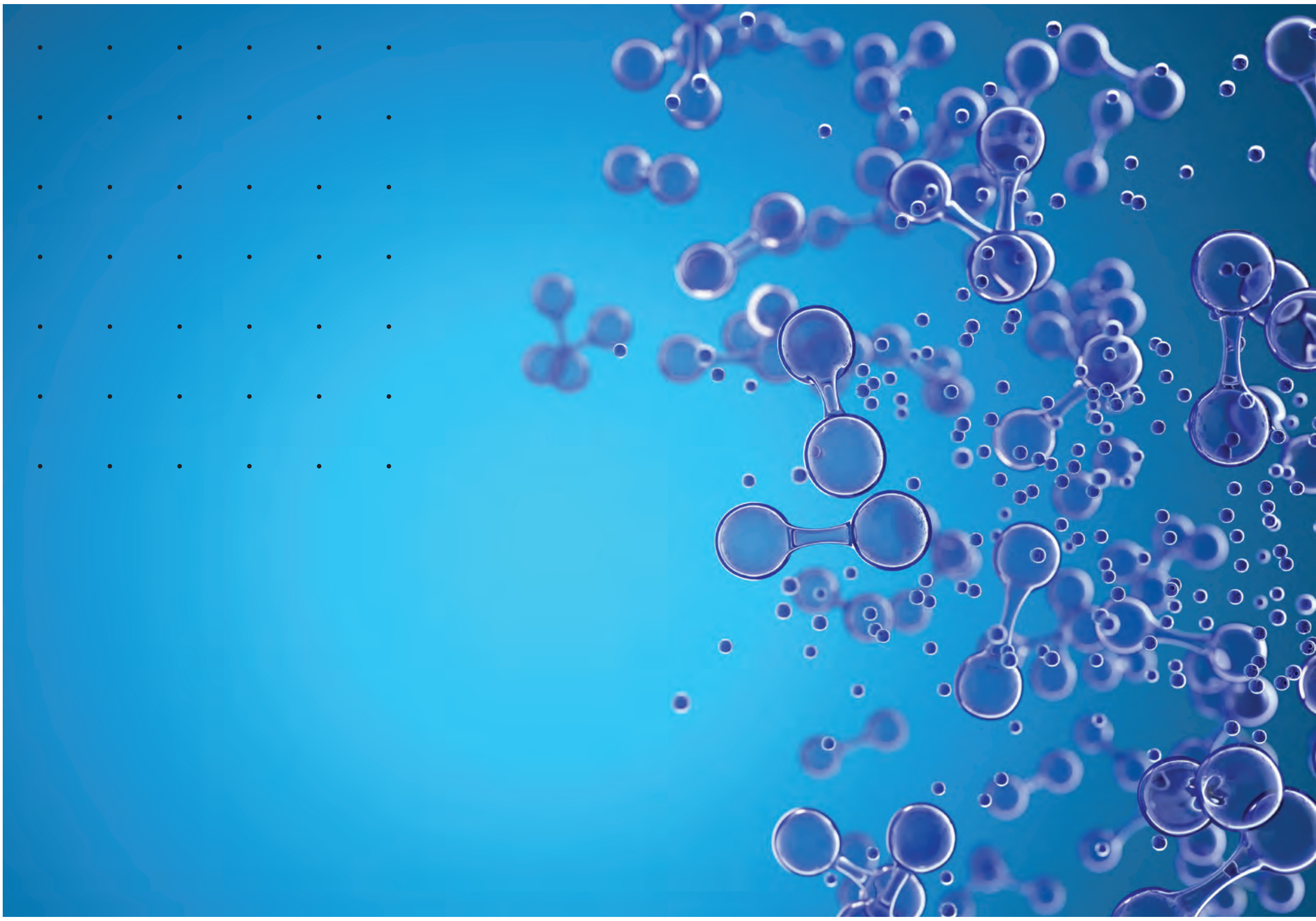
SWINBURNE UNIVERSITY OF TECHNOLOGY

VICTORIAN HYDROGEN HUB



Hydrogen Skills Roadmap

An analysis of the skills and training needs to support a future hydrogen economy

September 2022

swinburne.edu.au

Acknowledgement of Country

We respectfully acknowledge the Wurundjeri People, and their Elders past, present and emerging, who are the Traditional Owners of the land on which Swinburne's Australian campuses are located in Melbourne's east and outer-east. We are honoured to recognise their connection to Wurundjeri Country, history, culture and spirituality through these locations, and strive to ensure that we operate in a manner that respects and honours the Elders and Ancestors of these lands.

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Executive summary

Australia is experiencing a rapid shift in the implementation of environmentally sustainable practices. Through a combination of the world's most abundant substance, innovative emerging technologies, ambitious government goals, and a myriad of industries willing to drive change, the burgeoning hydrogen economy is poised to disrupt the Australian workforce on a national scale. This shift is evoking vital discussions and developments that will challenge how Australia perceives fuel and energy sources in the near future.

With potential applications of hydrogen just beginning to be unlocked, the implementation of hydrogen into the Victorian economy is a key strategy in the state government's plan to reach zero emissions by 2050[1]. In what can be understood as a call to action, the Hydrogen Skills Roadmap describes how Victoria is preparing to respond to the rapidly emerging need for a widespread transition into the anticipated hydrogen economy. This includes how the growth of hydrogen across multiple sectors will impact the need for rapid development of education and training solutions that can be implemented at both state and national level.

According to Australia's National Hydrogen strategy[2], the nation will require 7,600 domestic hydrogen-related jobs by 2050. To achieve these ambitious goals and respond to impending requirements posed by the burgeoning hydrogen economy, the nation requires a skilled and appropriately-trained workforce.

Framework for investigation

The Hydrogen Skills Roadmap addresses jobs and skills requirements that are fundamental to supporting Australia's green hydrogen economy. This Roadmap focuses on investigation and analysis informed by the following key questions:

- What industries will be impacted by the introduction of hydrogen and what hydrogen training and education are available right now?
- What skills will be in demand as the hydrogen supply chain scales up?
- How can the workforce be appropriately prepared to best meet the demands of hydrogen technologies' production, storage, distribution, export and its many uses?
- What new skills will be necessary to support the growth of a flourishing hydrogen economy in the future?

Hydrogen production is expected to become cheaper in alignment with a decrease in the cost of utilising wind and solar energy, resulting in an increased uptake of green hydrogen. Modelling predicts that heavy vehicles such as trucks and buses, then cars, will be the first to transition to hydrogen as a fuel source. This will be followed by widespread implementation of hydrogen in the ammonia, refinery, and steelmaking industries by 2040, with gas blending expected to reach scale after 2050. Prior to these anticipated timeframes, these industries will require development of training resources and upskilling opportunities related to the uses and benefits of hydrogen in their respective sectors.

Industries impacted

Research and evidence suggest that the introduction of hydrogen energy sources will impact a range of industries, including gas production, gas pipelines, storage, trades, steel and manufacturing, ammonia, transport and automotive. Higher-level workers such as executives, managers, researchers and engineers will be required to lead the way in driving these imminent changes; however, significant investment in reskilling and certification to meet newly required regulations is vital in supporting significant cross-sector change.

There are currently a number of hydrogen research hubs, projects and industry applications underway, across Victoria and nationally. Electrolysers are already producing hydrogen, five to ten percent of which is then blended with natural gas in pipelines, then distributed to residential homes. It is expected that blending with hydrogen will ramp up to one hundred percent in the coming decades. In Victoria, bus companies are exploring the acquisition of hydrogen-powered buses; this shift has been encouraged by Victoria's Zero Emissions Roadmap[3], which mandates that all new bus purchases from 2025 be zero emission vehicles. With projects such as these currently in progress and many more on the near horizon, Australia must quickly mobilise and upskill in order to ensure an adequately skilled and competent workforce.

With executives, managers, engineers, and researchers—the currently most sought-after members of the burgeoning hydrogen workforce, leadership is vital to ensuring that the hydrogen economy is successful from its relevantly early stages. These leaders must be capable of driving workforce initiatives to effect required change and will need to remain informed of hydrogen fundamentals, supply chain, and its capacity for end users. To advance cross-sector learning and practices, opportunities for businesses to collaborate on hydrogen and its potential benefits for their respective fields must be promoted more broadly.

Sector consultation

To inform this Roadmap, 37 industry representatives from the gas, plumbing, construction, transport and manufacturing sectors were consulted to provide an eclectic mix of opinions, insights and industry knowledge on how each industry perceives the potential impact and training requirements for hydrogen application.

A desktop audit and industry consultation uncovered a significant lack of relevant training and education offerings across Australian schools, industries, and vocational and higher education sectors. With Europe appearing to lead the way in this space—followed by the UK and US across most sectors—course offerings span relevant and necessary areas for hydrogen growth, including the supply chain and potential applications for end users. Industry-based training in Australia is currently limited to one program offered by Engineers Australia, original equipment manufacturers and two companies who offer various hydrogen short courses.

Skills and training gap analysis

This Roadmap looked at training offerings across the vocational education and training (VET) sector and identified crucial trade jobs that will potentially be impacted across the hydrogen supply chain. Through an investigation of each trade and their current hydrogen skills and training gaps, only one national training package was found to have successfully made revisions to introduce hydrogen-specific units of competency at this time. With the progression of national training packages stymied by a moratorium and a lack of necessary changes being made, significant developments in training offerings across Australia will need to occur quickly to appropriately respond to impending demands of the emerging hydrogen economy.

The versatility and cross-sectional nature of skills held by trades employees such as gas workers, electricians, fabricators and technicians can be leveraged to support the shift towards the production and storage of hydrogen and pipelines. However, upskilling is still necessary across the sector for existing and future workers, with targeted training opportunities spanning a variety of fields and educational offerings being vital to ensuring that the implementation of hydrogen systems and technologies is supported adequately.

With diesel mechanics and drivers likely to require the most urgent training opportunities to address identified skills gaps, further analysis of the transportation and automotive industries as well as corresponding training development must happen immediately.

Undoubtedly, there is a fundamental need for all industries to strongly develop their awareness of hydrogen to prepare workers for significant change. There is an urgent need for a suite of micro-credentials to be developed that address identified skills gaps across industries while training packages and other education and training programs are brought to scale. The following subjects are identified as the most relevant and vital areas for micro-credentials to address:

- Hydrogen fundamentals
- Hydrogen safety
- Emergency response
- Understanding regulations
- Electrolysis and compressors
- Fuel cells
- Appliance installation
- Hydrogen batteries & installation
- Transport bottles
- Hydrogen vehicle drivers
- FCEV service, maintenance and repair
- Small-bore tubing skills.

With uniform standards and regulations being absolutely vital in supporting the development of hydrogen training and education offerings, the emerging hydrogen industry has been, and will continue to be hindered by the lack of a completed Australian Hydrogen Standards framework. With hydrogen training restricted in its ability to move to scale without official standards in place, the industries working with hydrogen will experience challenges in accessing required workforce training to support expansion.

Recommendations

To meet the immediate and long-term needs of a rapidly-developing hydrogen market, a number of recommendations are outlined that involve collaboration between all stakeholders—governments, regulators, industry and academia.

1. Hydrogen content to be introduced to primary and secondary school curricula to facilitate the younger generation's engagement and preparedness.
2. Hydrogen subjects and industry engagement programs to be included in higher education and/or integrated into courses across Commerce, Law, Business and Engineering degrees.
3. Collaboration with industry to identify technical skill gaps for trades and gas-related workers to inform national training packages and future skills development.
4. National train the trainer program to be designed and implemented in collaboration with industry groups across the supply chain and hydrogen hubs.
5. A national suite of industry-informed hydrogen micro-credentials to be developed and made available that address immediate training needs.
6. Further research to be undertaken to analyse specific skill sets within the gas and hydrogen economy.
7. A Hydrogen Skills Centre to be established to leverage research and grow skills and knowledge.

To ensure that Victoria and the rest of Australia remain abreast of the burgeoning hydrogen economy, training and education opportunities must be scaled up to ensure that a skilled workforce is prepared to respond to the imminent hydrogen-related requirements of their respective industries. The implementation of hydrogen-related projects across the nation is encouraging. However, training and education offerings and opportunities will continuously remain vital to supporting the anticipated widespread development of a hydrogen economy. The Victorian Hydrogen Hub and Swinburne's Hydrogen Skills Roadmap is an important contribution to supporting the development of the emerging hydrogen economy in Australia.

Introduction

Governments and companies around the world are lifting their heads with enthusiasm to the lightest, most simple and abundant element on earth as a sustainable and ethical option for energy production. Described as a 'lifebuoy of hope'[4] in supporting the world to reduce emissions and stymie climate change, green hydrogen produced from renewable energy sources such as wind and solar has been identified as a vital agent for change amongst energy production sectors. As hydrogen produces no greenhouse gas—its only by-product being water or steam, the positive potential outcomes for mass production and the uses of this innovative and versatile element are becoming increasingly tangible.

Hydrogen was a hot topic at the Glasgow Conference of Parties in 2021 (COP26), where over 100 world leaders met following their promises made in the 2015 Paris Agreement—that each country was to hasten their actions in achieving their goals to reduce global warming. As a result of this global commitment, over forty countries have now officially confirmed their hydrogen strategies[5], which has significantly catalysed the need for global strategic movement towards the production, exportation, and consumption of hydrogen.

Australia's National Hydrogen Strategy[6] establishes a pathway to accelerate a burgeoning hydrogen industry domestically, with each of the Australian states and territories planning for increased hydrogen research and future utilisation of hydrogen. With an abundance of natural resources such as wind and solar energy, Australia is strategically positioned to be a successful producer and exporter of green hydrogen to net-zero committed nations across Asia and Europe. Exporting hydrogen has already begun in Australia, with one ship arriving from Japan in January 2022 to carry coal-produced liquified hydrogen produced in Gippsland, Victoria, back to Japan[7]. By continuously producing, exporting, and consuming hydrogen in liquid, gas or energy/electricity form, Australia will experience an increase in jobs across the whole supply chain, including in regional areas where a significant amount of hydrogen-related activity is currently occurring.

Consequently, there has been significant momentum, effort, capital, technological trialling, and research invested into hydrogen, its future energy possibilities and applications, domestically and internationally, in the early 2020s. In Australia, there are currently twenty large-scale, demonstration and pilot hydrogen projects being conducted, with 11 in the advanced stage of planning[8].

These include, but are not limited to, projects that involve hydrogen gas blending, production, industrial refining and transport. The activity occurring across Australian governments and industry is steady and optimistic, with a sense of excitement pervading the pioneering new works being carried out.

> "At a trepidatious COP26, the hydrogen revolution felt like a lifebuoy of hope, and everyone was keen to grab hold."
>
> Hans van Leeuwen
> **Financial Review**

While green, zero-emissions hydrogen is the end goal, the introduction of coal-derived hydrogen or hydrogen produced by other methods, into the Australian economy, has begun. In the two Hydrogen Park facilities located in Adelaide, South Australia and Gladstone, Queensland, hydrogen blended gas production has already commenced to reach and service domestic homes. Many more projects looking at different aspects of the hydrogen supply chain are emerging, including the Victorian Hycel and VH2 projects which focus on the testing, trialling and development of emerging hydrogen technologies and fuel cells. The implementation of electrolysers used to produce hydrogen is being set up in various places around the country, along with the introduction of hydrogen-powered car and bus fleets, and the commencement of planned hydrogen-related infrastructure projects.

Australia's National Hydrogen Strategy estimates that approximately 7,600 jobs will be generated domestically within the hydrogen industry by 2050[9]. It is anticipated that some of these jobs will be new, whereas others will need to be adapted to meet the requirements of working with hydrogen across the whole supply chain. Each of these projected jobs will require some form of training, upskilling or education as Australia develops and improves technologies to broaden our sovereign capability and applications of hydrogen. Despite the identification and awareness of hydrogen since the 1800s, the gas industry and others—who have long been aware of hydrogen—are only now showing significant interest and investment in effectively using hydrogen on a large scale.

Hydrogen is currently in use throughout Australia for the production of ammonia, carrying industrial feedstock, and cleaning and transforming crude oil into valuable fuel and chemical products. Its many versatile uses are set for expansion across industries such as steel[10], iron and aluminium.

A 2018 COAG report – *Australia's National Hydrogen Strategy* – states that 'now is the time for market activation'. This report identified three linked factors that would drive hydrogen adoption: worldwide decarbonisation motivation, emerging export markets for Australia and falling renewable electricity costs[11]. All three are occurring now. Like any emerging and quickly-developing industry full of unfamiliar trajectories, it is imperative that there is national awareness of the job roles that will be impacted, as well as a uniform understanding of what jobs will be required in both the immediate and long-term future. This involves identifying existing skills and knowledge that can be built upon now, and the skills and knowledge that could potentially be necessary for the future of the growing hydrogen industry.

With the acknowledgment that technology continues to expand and change, we need to identify the urgency in which to implement training and when certain skills will be in demand. With an understanding of these considerations, a plan can be made that considers the training and educational needs of industry, as well as essential skills and knowledge required to drive the hydrogen movement safely, consistently, sustainably and wisely.

JOBS IMPACTED
The new hydrogen economy will affect a myriad of industries, including energy production, gas networks transport and mobility, manufacturing, infrastructure and electrical supply.

Hydrogen is a novel gas that is yet untried at scale. Additionally, hydrogen technology is rushing ahead of regulatory frameworks. A leading stakeholder working in the hydrogen-powered vehicle industry who was consulted for this report said, "We need feet on the ground that know what they are doing now."

Background

As hydrogen energy production and the broader hydrogen ecosystem is rapidly emerging, it is critical that government, industry and the education and training sector are informed of the impacts on workforce skills requirements and future workforce demand.

In February 2021, Swinburne University of Technology (Swinburne) launched the Victorian Hydrogen Hub Initiative (VH2)[12], funded through the Victorian Higher Education State Investment Fund. VH2 and its founding partners—CSIRO and Germany's ARENA 2036—bring together researchers, industry partners and business to test, trial and demonstrate new technologies, pushing the boundaries of what hydrogen can deliver through sustainable manufacturing practices. The initiative is designed to provide support by conducting targeted research, exploring hydrogen usage opportunities for businesses and organisations, and generating public trust and acceptance of hydrogen as a renewable energy source for all.

A key component of VH2 is the development of a hydrogen skills and training roadmap designed to provide both government and industry with detailed analysis of sectors and job roles that will be affected, both now and in the future, by the production and use of hydrogen as an energy source. Investigation and analysis of training and education currently available in Australia and internationally will provide insight into existing training offerings and highlight skills and training gaps that need to be addressed in ensuring an adequately skilled and trained workforce. The report envisions a trajectory for future hydrogen employment growth areas with the potential to inform policy and provide a blueprint for future skills requirements.

The report casts a broad net to achieve a high-level overview with general understanding of the burgeoning knowledge and skills of the hydrogen industry across all education sectors in Australia, including school, vocational education and training, higher education and industry-based training.

Aims

The aims of this report are to:

- Identify current hydrogen training across industry and education sectors nationally and internationally.
- Identify existing hydrogen skills and future skills requirements across hydrogen-related industries.
- Capture insights for a hydrogen skills trajectory.

Methodology

To meet the aims identified throughout this project, primary and secondary data was acquired through the following sources:

- Review of hydrogen-related articles, industry and government reports relating to advancements, emerging industries and developments, impacts, future strategies and implications for the training & education sectors.
- Desktop research in current local, national, and international hydrogen training offerings.
- Online survey targeting industry professionals, industry peak bodies, local and state government representatives, and vocational education providers, with the intention to maximise ideas, thoughts and feedback across hydrogen skills and education-related industries.
- Consultations with industry practitioners with a range of experience/familiarity in the emerging hydrogen sector.
- Analysis of job advertisements seeking individuals for roles in the hydrogen sector.

Limitations of the research

The research conducted for the purposes of this report seeks to highlight current hydrogen training and education offered both nationally and internationally, as well as existing and future hydrogen jobs and skills gaps. Representatives from a wide range of industries have been consulted to identify the impacts of change on their industries. Given that the hydrogen economy is still emerging, the topic remains a challenge for some industries. Hence, researchers were unable to engage with all stakeholders. The following challenges limited the research conducted for this initiative:

- Due to the nature of continuously developing and emerging technologies, it is difficult to accurately identify and forecast defined changes in skills requirements in some industries.
- In many cases, required job skills are currently unknown, thus, identifying training needs involves interactive research combined with a job definition.
- Survey responses from industry representatives and stakeholders were limited, and therefore the survey presented in this report may not provide an adequate overview of the complex training landscape in Australia for hydrogen-related skills. To deeply understand the big picture of potential training requirements to support Australia's hydrogen economy, further research will be required.
- Employees of current and future hydrogen-impacted industries, and workplace employee safety specialists, were not consulted. Data collected through consultation with these cohorts may have better informed train-the-trainer findings.

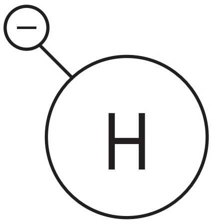
In recognising that urgent and immediate action is required, other countries have begun rapidly preparing and publishing their initial hydrogen strategy documents. Which countries have an actual, realised hydrogen strategy is not accurately known, as these documents are not necessarily published in the English language and/or may be hidden in web portals that are not freely available to the public. Therefore, only documents that have been published in the English language and that are freely available in the public domain have been collected and analysed for this report to develop and present an analysis of hydrogen applications, training, and education.

It is important to also acknowledge that given the rapid developments in the emerging hydrogen economy, some published documents that had been previously retrieved for the purpose of this report may inevitably become out of date. Likewise, countries that had not previously published their hydrogen strategy in the public domain may have since done so since this report's publication.

Understanding hydrogen

What is hydrogen?

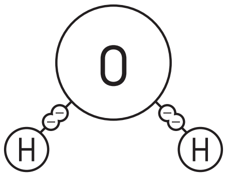
Found everywhere around us – including within the human body – hydrogen is the most abundant element in the universe.



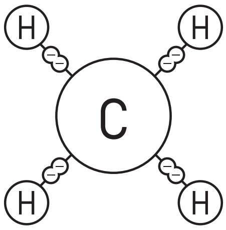
Invisible, tasteless, odourless, lighter than air and highly combustible, hydrogen was first discovered in the early 1500s. With a flame that is clear and burns significantly hotter than natural gas, hydrogen was not recognised as a discrete gas until Henry Cavendish conducted experiments with the element in 1766 .

Hydrogen packs the strongest punch of all chemical fuels; for example, a kilogram of hydrogen releases 2.6 times the energy of natural gas, and about 3.1 times the energy of petrol. Hydrogen is a flammable gas, and, like other combustible fuels, poses safety risks. Hydrogen can burn in a wide variety of concentrations in air, but its safety profile is improved significantly by its tendency to race towards the sky at great speeds when released, allowing it to rapidly dissipate and cease being a danger in the environment. Scenarios in which hydrogen poses the most significant risks involve its release in poorly ventilated spaces, where it is unable to escape to the atmosphere.

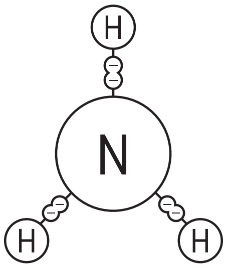
A hydrogen atom consists of one proton and one electron, which is the simplest composition an atom can be. On Earth, hydrogen atoms form part of bigger chemicals; therefore, hydrogen gas does not exist on its own, and has to be produced through other sources, such as water. Fortunately, hydrogen is part of many common chemicals around us.



Water contains two hydrogens and one oxygen [H_2O].



The main component of natural gas, methane contains one carbon and four hydrogens [CH_4]

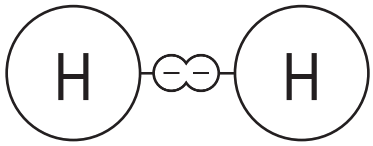


Ammonia has one nitrogen and three hydrogens [NH_3]

Figure 1. Stefan Lodewyckx, VH2

In hydrogen production, hydrogen atoms are broken off from other chemicals; as a result, free hydrogens atoms pair up to become hydrogen gas, which is then collected for use.

When a hydrogen atom is on its own, the hydrogen atoms tend to form pairs and become molecules of hydrogen gas (known as H_2).



A number of chemical processes are currently being used to produce hydrogen. Colours are often used to describe the different processes.

The colours of hydrogen

Non-renewable hydrogen	Carbon dioxide released		**Grey**	Steam reforming natural gas
			Brown	Coal or biomass gasification
			Black	Coal gasification
	Carbon dioxide captured		**Blue**	Steam reforming with carbon capture and storage
	Carbon collected as solid by-product		**Turquoise**	Pyrolysis (breakdown) of natural gas into hydrogen and solid carbon
	No carbon produced		**Pink**	Nuclear-powered electrolysis
Renewable hydrogen			**Green**	Renewable powered electrolysis

Table 1. Stefan Lodewyckx, VH2

Hydrogen production

Steam reformation and gasification

When producing hydrogen, fossil fuels, such as natural gas or coal, are heated to high temperatures and high pressure in the presence of water vapour. This causes carbon atoms in the fuel to combine with oxygen atoms in the water vapour, resulting in the creation of carbon dioxide, whilst hydrogen gas is left over and then collected. Currently, this method is the cheapest, most efficient and most common method used globally to produce hydrogen. This process, known as steam reformation, is the first step within the hydrogen supply chain in the production of hydrogen; however, through the utilisation of fossil fuels, this method is environmentally harmful. It is believed that coal and gas will power hydrogen production for some time into the future, however the production of green hydrogen remains a central, cherished goal to achieve targets of zero emissions.

JOBS IMPACTED
Gas, electrical and mechanical workers, technicians and power plant-related engineering jobs are involved throughout the hydrogen production stage.

Electrolysis

The process of electrolysis involves using an electric current to split water molecules into hydrogen and oxygen. This process is currently more expensive than steam reformation, however this method contributes to the production of green hydrogen when it is powered by renewable energy sources, such as solar or wind power. Given the high international interest in devising methods to produce zero-emissions hydrogen, electrolysis has the potential to shift towards reducing the harmful effects of global warming. Fossil fuel energy is still being used, and is consequently contributing to harmful carbonisation; however, recent technological breakthroughs have significantly increased the energy efficiency of green hydrogen production through electrolysers. Another benefit of green hydrogen is that it can be produced in appropriate locations close to where it is needed.

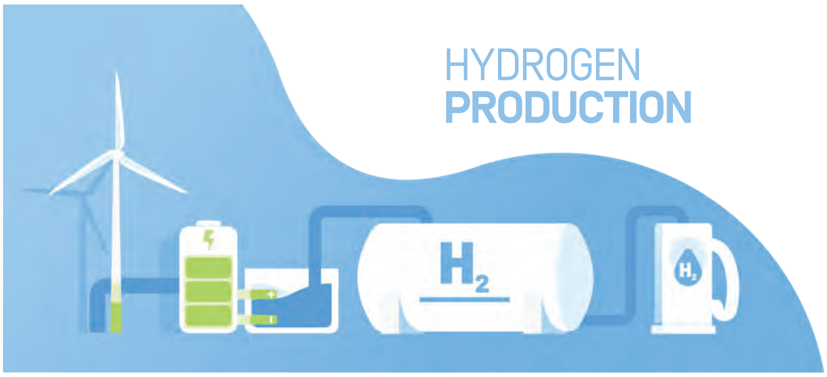


Image 1. A snapshot of hydrogen production

Current projects

As of May 2021, 18 Australian electrolysers were either operating or under construction, according to HyResource's short report on hydrogen initiatives and projects, with the largest (at 1.25 megawatts) operating at the Hydrogen Park project in South Australia. There are currently eight Australian Renewable Energy Agency (ARENA)-funded clean energy production research and development projects being undertaken in Australia[14], which will continue to significantly increase the capacity of the nation's hydrogen energy production. Three of these commercial-scale projects involve the production of three 10 megawatt electrolysers, which will be among the largest built in the world so far.

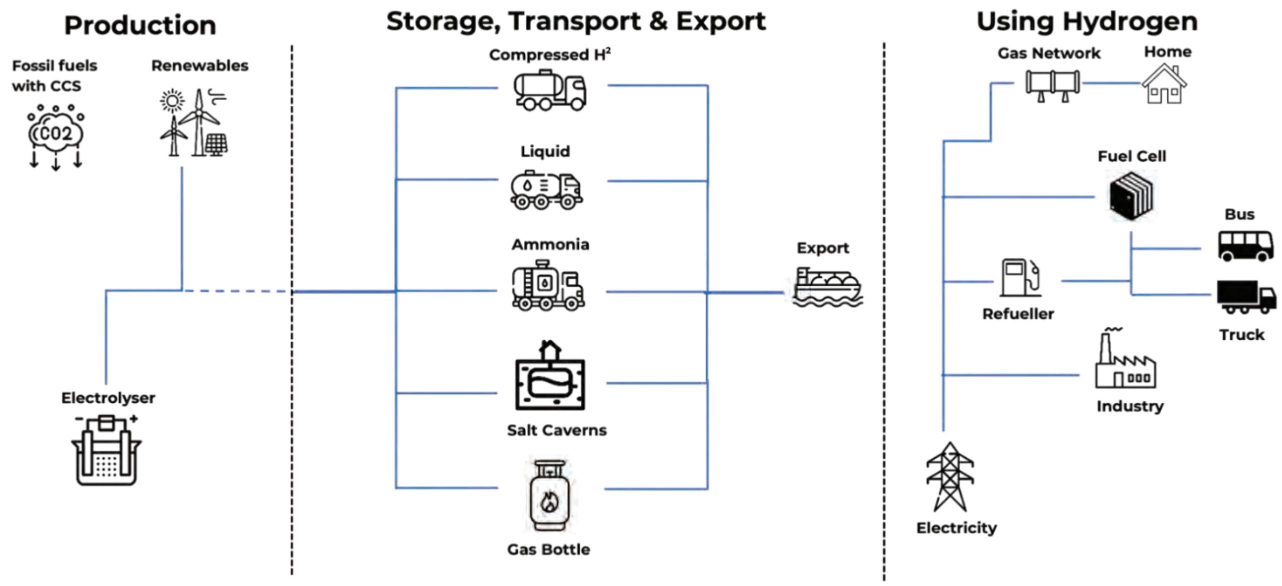
These electrolysers range from producing 20kg of hydrogen per day to 625 tonnes per annum[15], and are currently being integrated into energy production networks and infrastructure across Australia. For example, West Sydney's 500kw electrolyser is currently producing hydrogen for blending into the natural gas network[16]. The size and production capacity of electrolysers are expected to continue increasing, which will subsequently reduce electrolyser costs[17].

Recently, in 2022, Australia's University of Wollongong made a significant technological breakthrough that will support the giga-scale production of green, efficient hydrogen, as soon as 2025. This breakthrough has seen the development of the world's most efficient electrolyser, with the capacity to produce green hydrogen at a cheaper rate than traditional fossil fuels. With a staggering increase in efficiency to 98% cell energy efficiency, this electrolyser will catalyse a 50-fold increase in total renewable hydrogen production over the next 5 years[18].

The establishment of new research, development and production projects across Australia has significantly supported hydrogen production and energy generation in recent years.

JOBS IMPACTED
The increase in development and use of electrolysers will provide new jobs for gas and electrical workers, electrical engineers, technicians and manufacturers working with hydrogen generation systems, storage containers and equipment.

The hydrogen supply chain



Hydrogen costs

The future of the hydrogen economy is dependent on what has been identified as a key driving factor; the lower hydrogen production costs, the more industries will adopt hydrogen.

The following analysis of the hydrogen trajectory seeks to highlight information surrounding the future of the hydrogen economy, and to identify when it is likely that hydrogen-related jobs will be brought to scale. The general trend of the hydrogen future shown here is focused on the green hydrogen industry, with the widespread appetite for green hydrogen predicted to drive higher solar and wind energy production.

Hydrogen is anticipated to replace gas as an energy carrier and generator as the costs for using solar and wind power decrease. According to the International Renewable Energy Agency (IRENA) , the installed costs for Solar Photovoltaic (SP) panels have decreased from over $USD4000/kW in 2010 to below $USD1000/kW in 2020. Hence, over 10 years, SP panel costs have fallen by 81%. With this decrease in costs, the capacity of solar power has also increased from 13.8% in 2010 to 16.1% in 2020[20]. A similar trend can also be seen in global wind production costs, which fell 31% from 2010 to 2020; this decrease in costs has increased the capacity of production from 27% in 2010 to 36% in 2020[21].

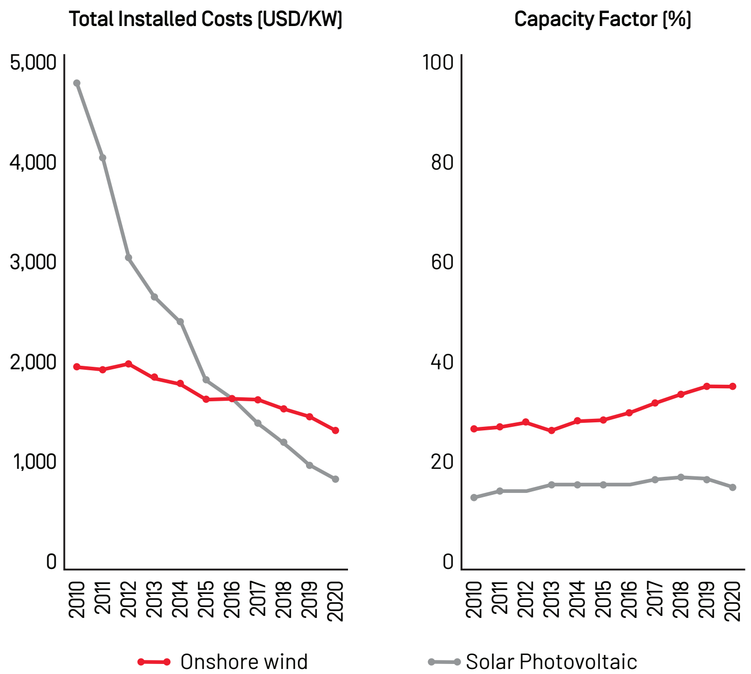


Figure 2.Variation in global solar production cost and capacity over a 10-year period, Steven Percy VH2

According to modelling developed by Steven Percy from the VH2 initiative and *Australia's National Hydrogen Strategy*, various predictions have been made surrounding hydrogen uses in the future in accordance with its lowered cost of production. With the cost of hydrogen production being currently higher than $3.50 per kilogram, the figure below predicts when hydrogen costs may lower, therefore paving the way for it to be put into more widespread use.

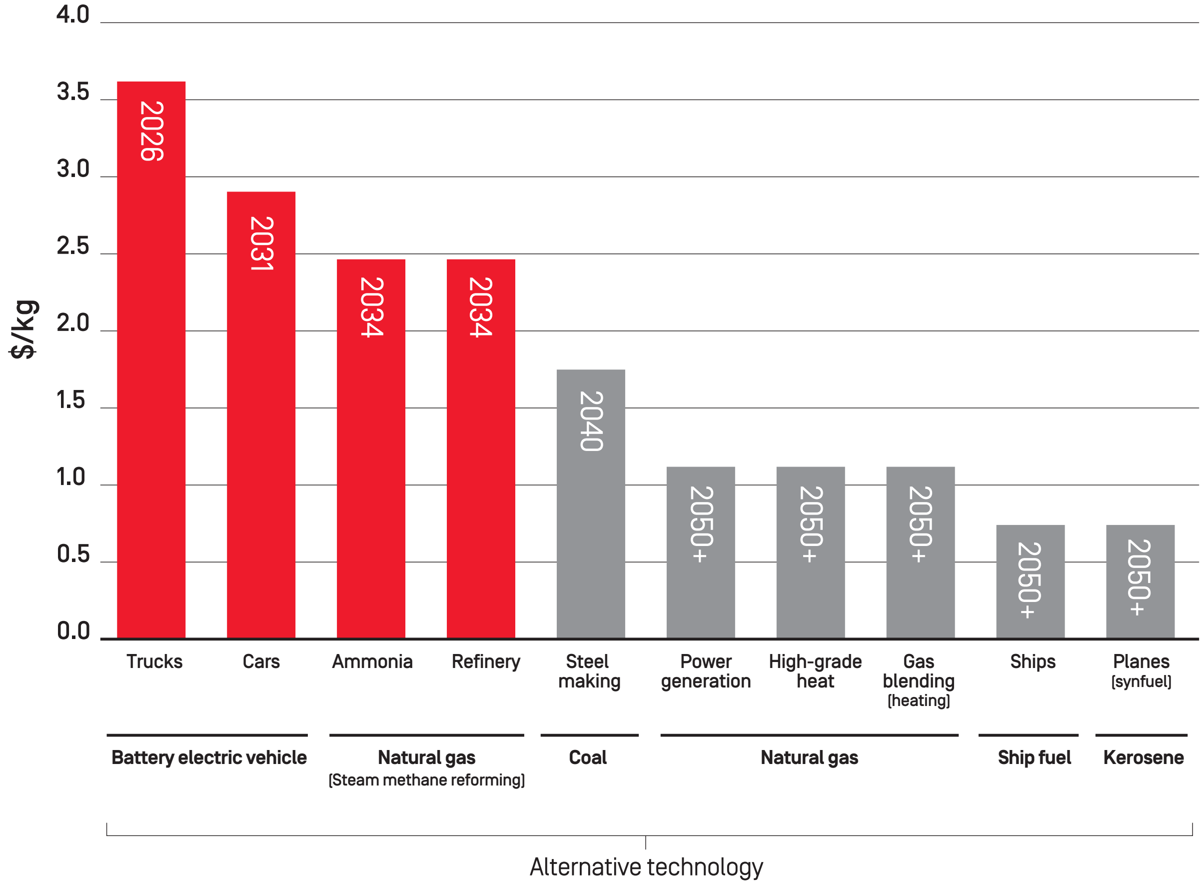


Figure 3. Predicted timeline for hydrogen to replace fossil fuels in various industries in accordance with hydrogen production cost (source: Steven Percy (VH2), Australia's National Hydrogen Strategy)

Green hydrogen production

Considering the low costs of renewable energy production, green hydrogen is a more cost-effective solution for a variety of industries than traditional methods. According to Beyond Zero Emissions , the Australian government is aiming to establish the nation as a major exporter of hydrogen, which opens up avenues for the green hydrogen market to capture a large share of the global hydrogen market by 2030[23]. This prediction is supported by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), who anticipates that by 2040, producing gas-driven hydrogen would be relatively more costly than generating it using electrolysers[24].

It is also expected that coastal regions in northern Queensland, with their abundant natural wind and solar resources, have the potential to be an Australian hydrogen powerhouse by 2040. Figure 4 below shows more regions across Australia that have strong capacity to support hydrogen production over coming decades, given their access to cheap solar and coastal ports.

Regional and transitional work

Given the number of remote and regional locations shown in Figure 4 below, it is expected that a significant amount of emerging hydrogen-related jobs will be transitional and regional. This emerging workforce is predicted to be involved in supporting the construction and set-up of hydrogen production plants, as well as assisting in developing hydrogen infrastructure such as pipes and refuelling stations.

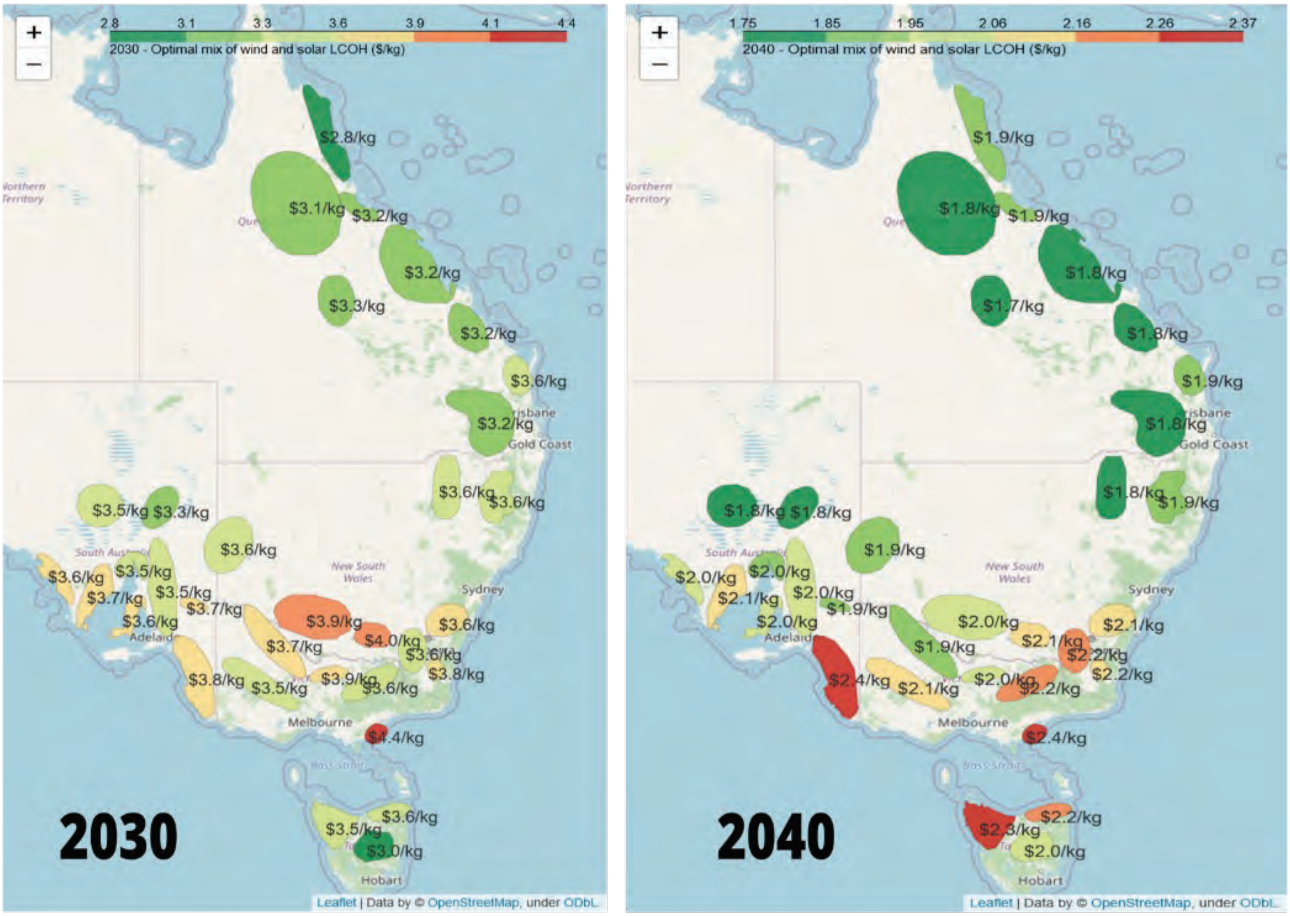


Figure 4. Renewable hydrogen energy zones in Australia for 2030 & 2040 (source: Steven Percy, Victorian Hydrogen Hub)

Storage, transport, and export

Compression

As a gas, hydrogen is capable of being compressed for storage in tanks and bottles, and for transportation in pipelines[25]. Due to the massive pressure involved in storing pressurised hydrogen, portable tanks must be heavily strengthened to carry the fuel successfully and safely, adding to their overall weight. Tanks must also be built in such a way that a rupture does not lead to the tank failing completely. Such a failure could be extremely dangerous due to the released pressure and the potential for the hydrogen to ignite; however, auto manufacturers have invested time and resources into developing these tanks to required safety levels.

JOBS IMPACTED
As hydrogen begins to replace LPG bottles, other workforces in the supply chain will be impacted; this includes but is not limited to shipping, transport and retail workers.

Liquification

Hydrogen has the capability to be cooled to low, cryogenic temperatures, to the point that it becomes a liquid. As a liquid, a litre of hydrogen has about double the energy as a litre of compressed hydrogen in gaseous form, as hydrogen can exist at far higher densities as a liquid than as a gas. Historically, this is why liquid hydrogen has been used as a rocket fuel. Liquefied hydrogen has the capacity to be transported by truck, rail or ship; workforces within these industries will need to be reskilled and upskilled in safe transportation methods. The liquification process is currently being utilised in an internationally-impacted hydrogen project being carried out in Victoria, Australia[26].

CURRENT LIQUIFICATION PROJECT

The first Australian end-to-end production and exportation of hydrogen is well under way at the AGL Loy Yang complex, located in Victoria. This project involves the conversion of brown coal into hydrogen, which is then transported to the Port of Hastings' liquification terminal before being shipped to Japan.

Salt caverns

Salt caverns are large underground structures that are typically excavated for the purposes of salt mining. Compared to other types of caves, or even cavities from which natural gas or oil are extracted, salt caverns are argued to have excellent geological properties that prevent hydrogen from leaking[27].

JOBS IMPACTED
Miners are involved in the geological storing process.

Ammonia

Ammonia is a compound element containing one atom of nitrogen and three atoms of hydrogen. This compound is commonly manufactured for agricultural uses, including as a fertiliser. However, hydrogen can be transported as ammonia in liquid form, as long as it is kept under pressure at room temperature or at a modest cool temperature. Ammonia is classed as a hazardous substance, which will require current and emerging workforce to be trained in handling procedures.

Currently, there is a high cost associated with the conversion of hydrogen to ammonia for transportation services and requirements; it involves engaging chemical engineers to perform necessary conversions to transform the substance back into hydrogen. However, it is currently seen as the best method of transporting hydrogen over long distances. The substance has been flagged as a potential green fuel source for shipping, rail, and heavy road freight, and has the capacity to support Australia's continuous engagement with and use of zero-emissions hydrogen-based energy sources.

JOBS IMPACTED
In order to assist with the transport and production requirements of utilising ammonia for hydrogen storage, marine crews and drivers are used to support the process.

Image 3. Ammonia production at a chemical plant

Using hydrogen

Australian hydrogen gas blending projects

Australian gas businesses have responded quickly to the call for decarbonisation and a shift to more widespread use of hydrogen. This has led to innovative research, studies and trials into the production and introduction of hydrogen as an energy source. Trials involving the blending of hydrogen gas and natural gas in pipelines and appliance adaption are occurring, coinciding with current research into the production of domestic appliances that have the capacity to be hydrogen-powered. Nine hydrogen blended gas network projects are expected to be operational by 2025 in Australia[28], and the gas blended hydrogen projects shown in Table 2 are currently being undertaken by various energy companies.

JOBS IMPACTED
Gas and pipeline workers will play a significant role in the transition from hydrogen gas blending to 100% hydrogen gas pipelines in the future, in addition to ongoing maintenance.

In alignment with *Australia's National Hydrogen Strategy*, all Australian state governments have implemented hydrogen gas plans and strategies, with most setting a target of 10% hydrogen gas blending throughout their respective networks by 2030. Once this goal is achieved, Australia will move towards a target of 100% hydrogen gas pipelines.

The Australian government's Future Fuel CRC will receive $26 million in grant funding to help adapt gas infrastructure and equipment[29] to support the national endeavour of using hydrogen as a replacement for natural gas and LPG.

Gas

As a combustible gas, hydrogen can be substituted as a burning fuel source in applications that currently use a flame for heat or aesthetic purposes. A short list of regularly utilised household examples through which hydrogen can be used to substitute traditional appliances include stovetops, ovens, water boilers, hot water systems, ornamental fires, and general heating. This also broadens the possibilities for hydrogen to be used as a burning fuel source in industrial applications, such as for ovens and kilns.

JOBS IMPACTED
Gas fitters and manufacturers will be required for the transition, adaption, revision and fitting of new or revised hydrogen-powered appliances once hydrogen blends are increased and gas pipelines are scaled up.

Mobility and fuel cells

Fuel cell technology converts the energy contained in hydrogen into electricity and minimal heat through two electrodes, which are separated by an electrolyte.

Fuel cell technology has been in use since 1838. In the 1960s, international focus on achieving successful space travel objectives provided the impetus for a steep upwards curve in the technological development of fuel cells, which continues to this day.

JOBS IMPACTED
Drivers, mechanics, vehicle maintenance workers and car manufacturers will be heavily involved in the widespread transition to using hydrogen-powered fuel cells.

Like electrolysers, significant research and time is being invested into the technological opportunities and innovative uses of fuel cells. Fuel cells convert hydrogen into electricity to be stored in batteries, used to support the entry into electricity grids or to power vehicles. While hydrogen can be used as a fuel in internal combustion engines, most hydrogen-powered vehicle design operates using fuel cell configurations.

JOBS IMPACTED
Builders, construction workers, architects, safety inspectors, gas workers, gas fitters and other infrastructure workers will be amongst those involved in the establishment of hydrogen refuelling stations.

COMPANY	PROJECT
The Australian Gas Infrastructure Group (AGIG)	Located in South Australia, AGIG's innovative Hydrogen Park currently supplies hydrogen blended with gas at volumes of up to 5% to Mitchell Park, Adelaide. AGIG has also commenced the development of a similar project in Victoria.
Jemena	As an Australian electricity company, Jemena begun supplying gas blended with hydrogen to 23,500 residential customers, 100 commercial customers and seven industrial customers in New South Wales in November 2021.
Australian Gas Networks (AGN)	As part of AGIG, the AGN's Hydrogen Park in Queensland plans to supply the suburb of Gladstone with 10% blended hydrogen gas in 2022.
ATCO	ATCO plans to deliver a project that will blend up to 10% hydrogen gas at approximately 2,500 connections throughout the Western Australian distribution network.
APA Group	Australia's first 100% hydrogen-ready transmission pipeline has been announced by APA Group, which will transform 43 kilometres of existing gas pipeline in Western Australia and serve the industrial precinct.

Table 2. Hydrogen gas blending projects in Australia

Hydrogen-powered fuel cell electric vehicles (FCEVs) are currently being used as government fleet cars in Canberra, with incentives for further take up within industry being offered. Significant progress has taken place with heavy vehicles, trucks, buses and coaches, with interest in expansion to ships, trains, and planes globally and domestically. There is huge potential and interest for using hydrogen-powered fuel cells in larger vehicles, supporting national strategies for decarbonisation at greater scale[30].

With this shift towards exploring the potential of hydrogen-powered fuel cells in heavier and larger vehicles, job opportunities within the current and future workforce have begun to arise. Transitioning to large-scale hydrogen-powered vehicles is already underway, with Hyzon (a global supplier of green hydrogen fuel cell powered vehicles) and the Royal Automobile Club of Victoria (RACV) recently joining forces to produce and manufacture hydrogen-powered trucks in Victoria[31].

Refuelling stations

A major barrier for the successful and quick uptake of hydrogen vehicles in Australia is a lack of refuelling infrastructure. The Toyota Mirai and Hyundai Nexo – two commercial cars powered by hydrogen fuel cells – will not be sold to the public through dealerships until hydrogen refuelling infrastructure responds to projected requirements for hydrogen-powered commercial vehicles. Infrastructure projects and planning has begun and is a major priority of the Commonwealth Government's Future Fuels and Vehicles Strategy. As of 2021, there are four hydrogen refuelling stations in Australia; Sweden also has four, England has ten, and Japan has 154 stations[32]. Hydrogen refuelling stations will be integral to the uptake of hydrogen-powered vehicles domestically.

Chemical feedstock

Hydrogen is currently in use as an important feedstock for a number of chemical processes. Estimated to take up to 20% of total electrolyser capacity[33], hydrogen as a feedstock is used in the industrial production of ammonia. Hydrogen as a chemical feedstock is also used to make cyclohexane, nylon products, and methanol, which is utilised in the process of producing plastics and pharmaceuticals. Hydrogen is also used to remove sulphur from fuels in the oil refining process, and to hydrogenate oils to form fats as in the creation of margarine[34]. Although hydrogen is consistently considered to be an incredibly innovative, world-changing element that will power the future, hydrogen is not new to the manufacturing, agricultural and ammonia industries.

JOBS IMPACTED
The introduction of hydrogen into manufacturing industries will affect industry workers, including gas fitters and engineers.

Image 4. Theoretical hydrogen refuelling station servicing a hydrogen-powered bus

Hydrogen-related job advertisements analysis

From October 2021 to April 2022, the research team conducted an analysis of hydrogen-related jobs advertised on job search websites such as Seek and Indeed.

Using the keyword "hydrogen", the most popular jobs advertised were found to be those related to leadership, executive and engineering jobs. The highest number of hydrogen-related jobs advertised are situated in Victoria, followed by New South Wales, Western Australia and Queensland. Currently, the state with the least employment opportunities is South Australia.

In Victoria, the majority of hydrogen-related job advertisements are seeking employees in managerial positions with over five years' experience and an extensive background in engineering, business, and/or consulting. Engineers and advisory/consulting jobs are the next most in-demand job roles being advertised. Hydrogen researchers were found to be sought after in Victoria only; employment opportunities for these roles require over 10 years' experience, postgraduate degrees in related fields, and a strong knowledge of hydrogen technologies.

Given the large amount of hydrogen-related research projects currently being undertaken by universities across Australia, there is a growing need for additional researchers with appropriate skills, knowledge and experience, despite the low number of positions advertised throughout the research period. Some projects that have been identified include Swinburne's VH2 initiative, Deakin University's Hycel research facility, and RMIT's SHELL research group. Researchers are also currently sought after to lead hydrogen industry projects (such as infrastructure projects designed to provide more public hydrogen refuelling stations, hydrogen plant design projects, alternative fuel processing plant projects and engine fuelling combination projects) and investigate new hydrogen perspectives and opportunities for Australian hydrogen economy. These researchers' background and expertise is often found to be in engineering.

The number of job advertisements seeking employees in the transport/mobility and gas sectors is surprisingly low given the current emerging activity. One possible explanation for such low numbers may be that hydrogen skills can be taught on the job and can be leveraged from existing skills, such as managing dangerous gases or heavy vehicle driving and maintenance. High-level jobs such as executives and managers appear to be in greater demand. These jobs require high levels of skill, with minimum qualifications sought being a bachelor's degree in areas such as STEM, economics, business, law, health and safety, or combinations of the fore-mentioned. Commonly, these job advertisements require applicants to have over five years' experience, expertise in advisory services and/or strong knowledge of emerging technologies (such as hydrogen technical, hydrogen safety, and hydrogen applications).

As an emerging economy, hydrogen and its related industries currently require researchers, engineers and top-level managers to guide the trajectory forwards. This workforce will require immediate knowledge of the new hydrogen economy as they will be responsible for making key decisions, planning for the future and mobilising the workforce.

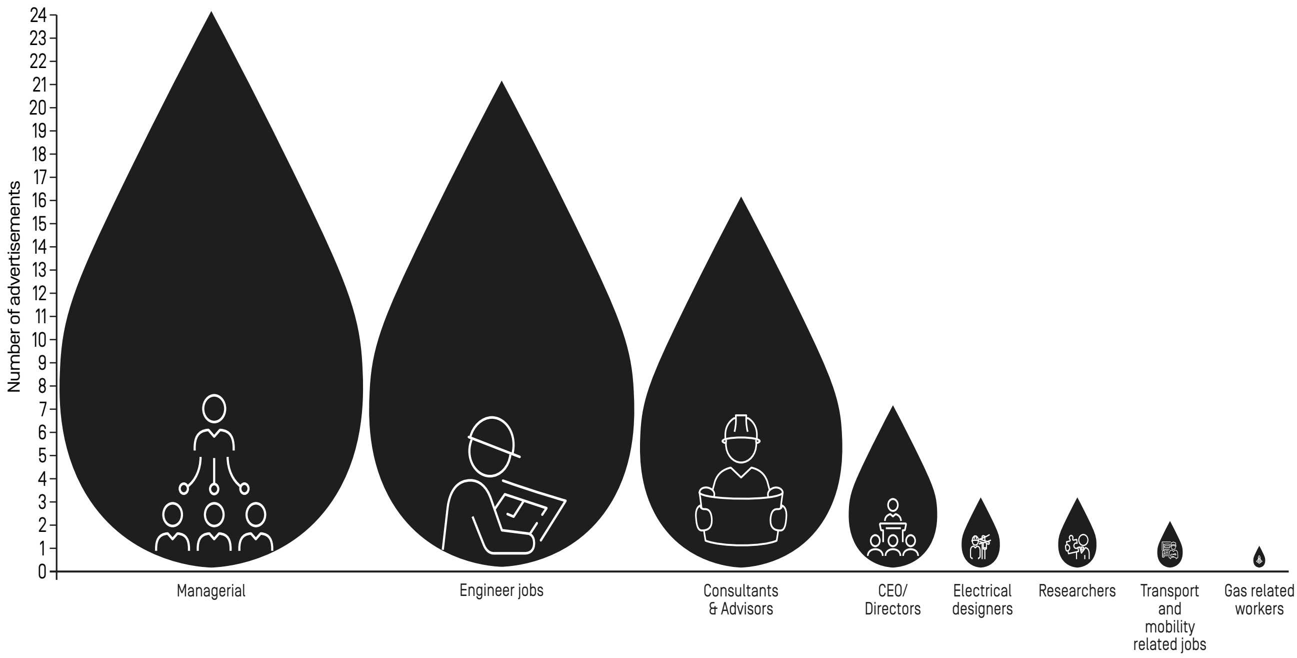


Figure 5. Job demand in the hydrogen industry

Online survey

As part of the Hydrogen Skills Roadmap initiative, an online survey was distributed to 317 contacts from various industries between October 2021 and February 2022.

The components of this online survey included relevant questions that sought to provoke insight into the future of the emerging hydrogen economy, and what training is required for Australia to maximise its hydrogen energy outputs in the coming years. Respondents were asked about the impacts of hydrogen-related changes on their organisations and workforces and were surveyed about their views on the changes required for current education and training offerings in hydrogen.

The survey attracted a total of 41 responses from a variety of industry representatives, including CEOs, Executives, Project Managers, Academic Researchers, Engineers, Government Employees, RTO Managers, Consultants, Trainers, Business Managers and an Energy & Emissions Specialist. These industry representatives operate in a total of 13 sectors, including the automotive, energy, gas, plumbing, water, infrastructure, electrotechnology, manufacturing, transport & logistics, government, higher education, storage, and training industries. CEOs and Executives comprised the highest number of respondents.

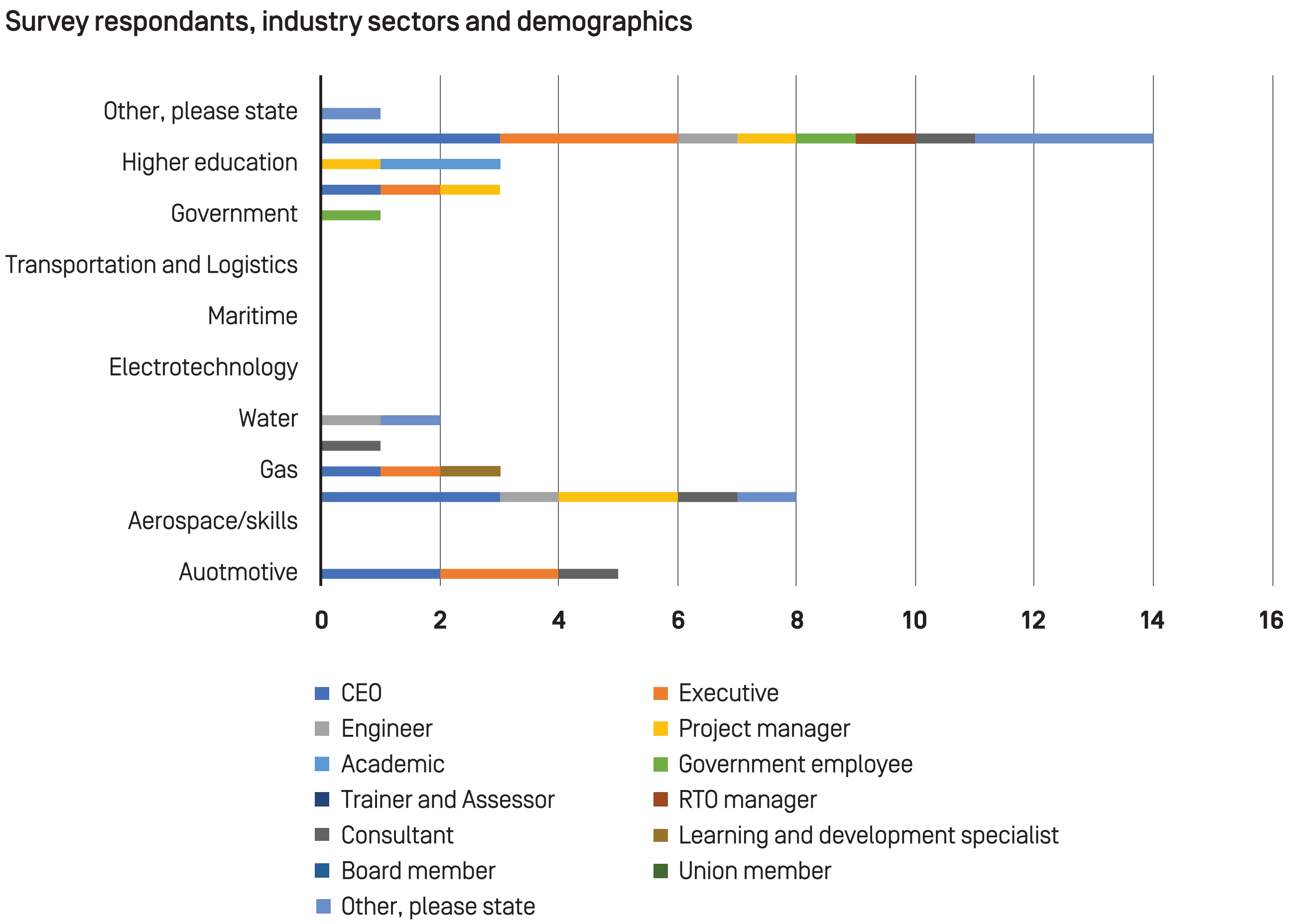


Figure 6. Survey demographics

Insights

The data resulting from this survey indicates that hydrogen is currently making significant changes and impacting workforces across industries in Australia. However, as evidenced by concerns raised by industry through their survey responses, currently there are limited training opportunities and resources to equip the existing workforce with hydrogen knowledge and training. We also identified areas with the highest hydrogen skills and knowledge gaps—fuel cells, hydrogen electrolysers, storage, refuelling stations and hydrogen systems and safety. The following figure indicates key takeaways from the survey conducted.

Skills gaps in existing hydrogen education and training

Respondents were asked to select skills which they considered to be most required in the burgeoning hydrogen economy; they were allowed to choose more than one. They rated fuel cells, electrolysers and storage rate as the most relevant, with refuelling stations and safety following closely.

73%
of respondants report a lack of training is the biggest barrier to integrating hydrogen training into workers existing knowledge

Training
should be heavily aligned with industry standards and must be industry endorsed

Most impacted
job roles include gas fitters, plumbers, drivers and mechanics

47%
of respondants claim that existing hydrogen training and education programs do not meet industry needs

50%
of companies are not currently providing hydrogen related education or training to their employees

60%
of respondants report that training is important, because hydrogen is impacting or will impact their industry

Figure 7. Key survey insights

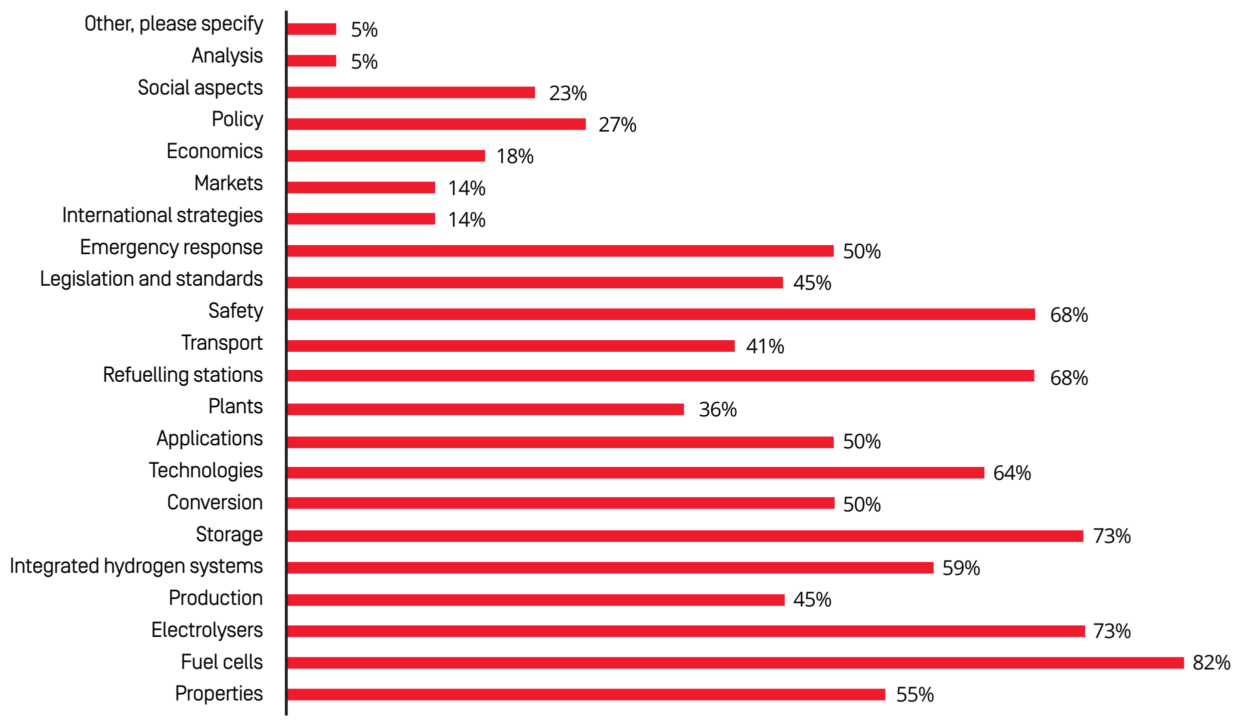


Figure 8. Skills gaps in existing hydrogen education and training programs

Consultations

One face-to-face and 28 online consultations and interviews with 37 industry representatives were undertaken to learn about current hydrogen training offerings, as well as perceived future needs for skills and training. Each of these interviews lasted from 30 minutes to over an hour.

The research team undertaking this initiative met with the Australian Pipelines and Gas Industry Association, as well as representatives from gas companies such as AGIG, BOC, Evoenergy and ATCO. Also consulted were representatives from EnergySafe (Victoria's energy safety regulator), mobility representatives from Hyzon and Dyson buses, the Plumbers Industry Climate Action Centre (PICAC), researchers from RMIT, Deakin and Future Fuels CRC, two Service Skills organisations in Australian Industry Standards and Artibus, the Victorian Builders Association, several training managers, one trainer and several hydrogen businesses. The research team were not able to engage with the electrical industry.

INDUSTRY	NUMBER OF
Gas	8
Mobility	8
Emergency Services	1
Plumbing	2
Hydrogen-based businesses (equipment/ appliances/ services)	4
Trainers and training managers	3
Researchers	2
Government	1

Table 3. Consultations with industry

Questions asked of these representatives included:

- 'What hydrogen training are you aware of?'
- 'Have you undergone any hydrogen training?'
- 'Has your staff undergone any training?'
- 'How and when will hydrogen affect your workers' jobs?'
- 'What sort of training do you think is required, and by when?'

Industry forum

In March 2022, all those who had contributed to the consultations and other key stakeholders were invited to an online forum where preliminary findings were presented. With further feedback strongly encouraged, a discussion about regulations during the forum ensued. 28 participants attended the forum.

Key themes raised by industry representatives

- **The majority of industry leaders are self-taught in hydrogen-related spaces**
- **Currently, safety and awareness training are the priority**
- **Formalisation of regulations and standards need to be prioritised for the industry to progress quickly and confidently**
- **Little to no existing hydrogen training is available across all sectors**
- **Hydrogen is not considered to be "new" across industry**
- **Industry is reliant on manufacturers' guidance for training and knowledge**
- **Gas workers, gasfitters and plumbers will leverage their newly acquired hydrogen knowledge off their existing skills base**
- **There are existing industries that have been working with hydrogen for many years, and therefore have a high familiarity with its benefits and uses**
- **Appliances will require modification once hydrogen gas blending reaches a certain percentage [a number not yet widely agreed upon]; at this point, plumber and gas fitter upskilling must occur**
- **There will be electrical knowledge gaps across industries as hydrogen continues to be more widely used**
- **Hydrogen technology [including fuel cells and electrolysers] knowledge is highly sought after**
- **Consistency in training is highly sought after**

Figure 9. Key themes raised by industry representatives

Desktop audit of current projects

As part of this research initiative, a desktop audit was undertaken to identify existing Australian research and projects that are seeking to identify and analyse hydrogen-related skills and/or development of training products.

PROJECT NAME	PROJECT DESCRIPTION
National Hydrogen Skills Analysis	A Commonwealth initiative supported by the South Australian Government to analyse and plan for the future skills and training for Australians working with hydrogen .
Interim Research Report: Hydrogen Industry-Job roles, Skills Qualification and Experience, Energy Skills Queensland	A short analysis of job roles in hydrogen
H2 Networks: Status of Vocational Hydrogen Training in Australia: A snapshot June 2021	Outlines hydrogen vocational training progress and maps existing competencies for content overlap across training packages content.
Future Fuels and RMIT plumber gas fitters	Consultation with RMIT has indicated that this research project, in collaboration with Future Fuels, is targeting plumber gas fitters and their future hydrogen training needs.
Energy Skills analysis of gas workers	Consultation with Energy Skills has revealed that they are planning to access their data base of over 38,000 gas workers to conduct a detailed skills gap analysis to identify training pathways for current CSG/LNG workers towards hydrogen skills and qualifications. The in-depth analysis of existing gas industry workers qualifications and consultation with gas stakeholder networks aims to identify whether their current qualifications/skills would suffice for the needs of the Hydrogen sector.
Future Battery Industry	The Future Battery Industry Cooperative Research Centre (FBIRC) and the South Metropolitan TAFE in Western Australia will investigate skills gaps for electrical and mechanical skills, first responders, electricians and mechanics trained in electric vehicles and battery energy systems
Upskilling diesel mechanics	A Victorian state initiative will see four bus companies work with the Australian Manufacturing Union and Bendigo Kangan Institute to upskill diesel mechanics and transport technicians to work on electric and zero-emission buses. The project aims to produce industry informed training that will be made available to all Victorian bus operators and new apprentices .
Heavy Vehicle Industry Australia-Leading the Industry Transition to Electromobility HVIA-LITE	This project will harness the experience and expertise of industry members and stakeholders
H^2 TAS001 Certificate II in Renewable Energy Pathways	This Tasmanian Artibus initiative addresses entry point training needs across a range of applicable renewables in Tasmania including hydrogen. Drawing on a number of training packages, the draft course outline also includes the newly accredited hydrogen gas units from the gas training package .

Table 4. Current hydrogen skills research and projects in Australia

Desktop audit of existing hydrogen training

National industry training

Research has shown that most Australian industries are sourcing their knowledge and skills base from Original Equipment Manufacturers (OEMs) and/or their guides, some of which provide information on operating hydrogen-powered coaches and using electrolysers. The results of this desktop audit uncovered minimal publicly accessible Australian-based industry training in hydrogen (see **Appendix B** for more details on these courses). Some of the training programs include:

- Informa and H2Advantage offer online training by well-experienced facilitators in the hydrogen and other gases sector, with relevant materials on hydrogen fundamentals, transportation, safety, and plants .
- Engineers Australia, a not-for-profit organisation and platform representing Australian engineering professionals, offer high-level hydrogen education to gas workers, engineers, managers and researchers.
- EnerTrain, an RTO specialising in gas training offer a course for existing workers on the Jemena West Sydney green gas project.
- Free webinars, such as Resources Safety & Health Queensland's Hydrogen Safety – Mobility Webinar .
- TAFESA offer an online short course called Hydrogen Fundamentals in the trades section of their website.

It is assumed that many companies already utilising hydrogen or hydrogen systems and equipment deliver in-house training to their staff or venture out as consultants in the growing hydrogen milieu. Swagelok, a large American organisation now operating in Australia, provides sales of industrial hydrogen systems and components across Australia and New Zealand and offers technical hydrogen training to those who use Swagelok products.

International industry training

Desktop research revealed that 17 international hydrogen training courses and various webinars are currently offered globally. The UK, US and other countries across Europe offer courses through government departments, partnerships between government, universities and business, and energy and engineering centres. The topics covered in these hydrogen training courses include relationships between hydrogen and ammonia, wind, the existing hydrogen economy, supply chain and hydrogen fundamentals, as well as fuel cells and related technologies – see **Appendix C** for more details.

National higher education

Universities across Australia are beginning to offer undergraduate and/or master's degrees and programs in fields such as hydrogen technologies, systems, generation, storage, transportation, and conversion. For example, Australian National University (ANU) offers the Master of Energy Change (Advanced), a multi-disciplinary coursework and research degree that provides students with a strong knowledge base in fundamental areas related to hydrogen generation, storage, transportation, conversion, and physics underlying key energy transformations. This course also allows students to undertake further learning in the existing and emerging technologies underpinning the hydrogen economy, as well as different hydrogen policy frameworks.

The University of Melbourne currently offers a Master of Energy Systems degree, which provides students with the opportunity to learn how to analyse energy systems to work on the transition to a sustainable energy future. Participants experience and take part in a real-world industry project and are guided by experts specialising in areas such as electricity generation, energy network design and transport . RMIT University and Swinburne University of Technology have also followed suit, with the introduction of hydrogen courses such as the Master of Engineering (Sustainable Energy) and Renewable Energy and Hydrogen Technologies respectively[44]. These courses also focus on learning outcomes related to the development of hydrogen, hydrogen storage and utilisation technologies . The details of these courses are explained in **Appendix D**.

International higher education

Research into international higher education hydrogen offerings found a Hydrogen Student Design Contest, based in Washington DC, which challenges multi-disciplinary teams of university students to apply their creativity and academic skills in the areas of hydrogen and fuel cell-related design, engineering, economics, environmental science and business. This theme-based challenge program includes themes such as power-to-gas (2018), residential fuelling with hydrogen (2011), designing a hydrogen community (2010), and hydrogen applications for airports (2008). The contest is open to undergraduate, graduate and PhD students worldwide; however, this contest does not run every year, with the last occasion being 2018. This is noted as a way to increase motivation, provide incentives, and promote opportunities and knowledge development in STEM graduates and engineers throughout the hydrogen space.

CURRENT COLLABORATIVE PROJECTS

Swinburne's collaboration with the VH2 hub and industry partners such as CSIRO and ARENA 2036 is an example of this shift towards domestic collaboration between universities and industry. Deakin University's Hycel initiative also exemplifies this necessary shift, with the project seeing the university collaborate with Southwest TAFE and Warrnambool Bus Lines.

In addition to the hydrogen contest, a number of hydrogen courses are being offered at universities internationally. In the UK, Newcastle University and the University of Birmingham offer a PhD program on the topic of hydrogen safety for major projects, in addition to courses focusing on the understanding of wind energy technologies in relation to hydrogen power. In Europe, where there is more advancement in topics such as hydrogen fundamentals and safety, knowledge bases relating to hydrogen storage, hydrogen energy systems, fuel cells, the hydrogen supply chain, electrolysers, legislation and technologies are covered comprehensively. These courses are offered at the Norwegian University of Science & Technology, the University of Oslo and HAN University of Applied Science (please see **Appendix E** for details).

Compared to Australia, international universities appear to be more advanced in the provision of targeted accredited hydrogen training. Research shows that the domestic relationship between industry and higher education needs to be developed in order for Australia to reach the standards that have been set for hydrogen higher education and training internationally. See **Appendix E**.

National school sector education

In Australia, primary and secondary school curricula are typically revised every four to six years, as is the case for senior secondary school curriculum. Guidance for the key knowledge and skills that are to be included within these curricula are usually drawn from a diverse group of subject specialists, academics and industry experts. A desktop analysis of the current Victorian Certificate of Education (VCE) curriculum—with subjects including VCE Chemistry, VCE Environmental Science, VCE Physics and VCE Systems Engineering—was undertaken, as was an analysis of the Australian Curriculum Chemistry and A-Level Chemistry course offered in the UK (please see **Appendix F**). While some of these accredited school curricula mention renewable energy, only the Australian Curriculum Chemistry and VCE Chemistry cover basic understanding of fuel cell technology, with the latter covering fundamentals of fuel cells as an energy source.

The most recent edition of the Australian National Curriculum (released May 2022) includes a reference to hydrogen in the year 8 science curriculum where students 'examine how proposed scientific responses to contemporary issues may impact society and explore ethical, environmental, social and economic considerations. Hydrogen is specifically mentioned in the learning outcome; 'examining how the development of hybrid and solar, electric and hydrogen-powered vehicles are applications of contemporary science responses to the depletion of fossil fuels and exploring environmental considerations.

Some STEM education providers currently offer hydrogen energy/fuel cells content within their curricula; for example, Earth Ed (Earth Sciences Centre) based in Ballarat provides a hydrogen-related STEM program to primary and secondary students, which addresses the VCE Chemistry Unit 3 key knowledge. This program offering has students exploring how proton-exchange membrane (PEM) electrolysers and PEM fuel cells work, as well as information on their current and potential uses in society while comparing their benefits and costs with other alternative energy sources. The above-mentioned courses can be found in **Appendix F**.

International school sector education

Research conducted into international school sector training has shown that education providers offer various hydrogen-related programs for primary and secondary school-aged children. For example, Horizon Hydrogen DIY Race is a European/US program introducing elementary and middle school students to basic science and engineering principles, with a focus on sustainability and renewable energy awareness. In this program, students are encouraged to design and build their own fuel cell-powered vehicles using recycled materials. Arcola Energy, another global energy provider, delivers hands-on learning to more than 100,000 young people across the United Kingdom, the United Arab Emirates, Ireland and Indonesia. One of their program offerings is their flagship Hydrogen Challenge – Design, Build, Race – team activity, which challenges students to build the most energy efficient model vehicle from LEGO components and a hydrogen fuel cell-powered electric motor (please see **Appendix F**).

KEY POINT
Most international hydrogen-related school program offerings focus on sustainability and general renewable energies.

Given that hydrogen education courses and units embedded in the Australian Curriculum and VCE are limited, it is recommended that national development in this area is prioritised to prepare the younger generation and respond to the growing employment possibilities for hydrogen in the future. Deakin University's Hycel initiative is currently designing and evaluating a series of hydrogen-related learning sequences for primary (years 4-6), high school (years 8-10) and VCE students. This evaluation also provides an opportunity for teachers to undertake professional learning on the same topics. Delivered by researchers from Deakin's School of Education alongside community and industry partners, this project will be conducted in southwest Victoria in mid-2022. This project intends to support young people and teachers in broadening their knowledge of STEM concepts across renewable energy, the production of and applications for using hydrogen, critical thinking and translating scientific research in contemporary classrooms.

Bringing these training projects to fruition will require a coordinated approach by policymakers, regulators and industry representatives for hydrogen to see much higher development levels across Australia. As little attention has been given to national and international policies on hydrogen training, industries and organisations rely heavily on current education resources, in-house training and informal learning to equip themselves with the knowledge required to respond to the quickly evolving hydrogen sphere.

Hydrogen jobs and skills summary

Based on the project team's analyses of job advertisements, desktop audits, an online survey and a range of industry consultations, a number of jobs have been identified that will potentially be impacted by changes brought about by hydrogen across the supply chain.

Figure 10 below describes different hydrogen-related jobs that will be in demand as hydrogen production, storage, transport, distribution and export advances throughout Australia. Executives, managers, emergency responders, infrastructure workers and builders are some key positions that must be filled to enable widespread transition to hydrogen across the supply chain. Research has indicated that the growing hydrogen production workforce will require additional gas workers, electricians and technicians to meet emerging demands in the near future. In the process of storing and transporting hydrogen, drivers, marine crew workers and gas workers are crucial for the transportation and delivery of compressed or liquified hydrogen, while miners are required for geological storage and will operate hydrogen-powered vehicles. The distribution of hydrogen to end users can also create a pathway for growth through the engagement of mechanics, FCEV drivers, auto electricians, manufacturing workers, and plumber gas fitters. For a detailed hydrogen job list, please see **Appendix G**.

In the following sections, we consider focus industries and job roles in detail, discuss skills requirements as well as explore various miscellaneous jobs. The sections are presented as:

- Executives and managerial roles
- Engineers
- Trades, including:
  - Gas industry workers
  - Electrical workers
  - Plumber gas fitters
  - Construction workers
- Transport and mobility
- Manufacturing
- Emergency responders
- Hydrogen trainer and assessors
- Regulators

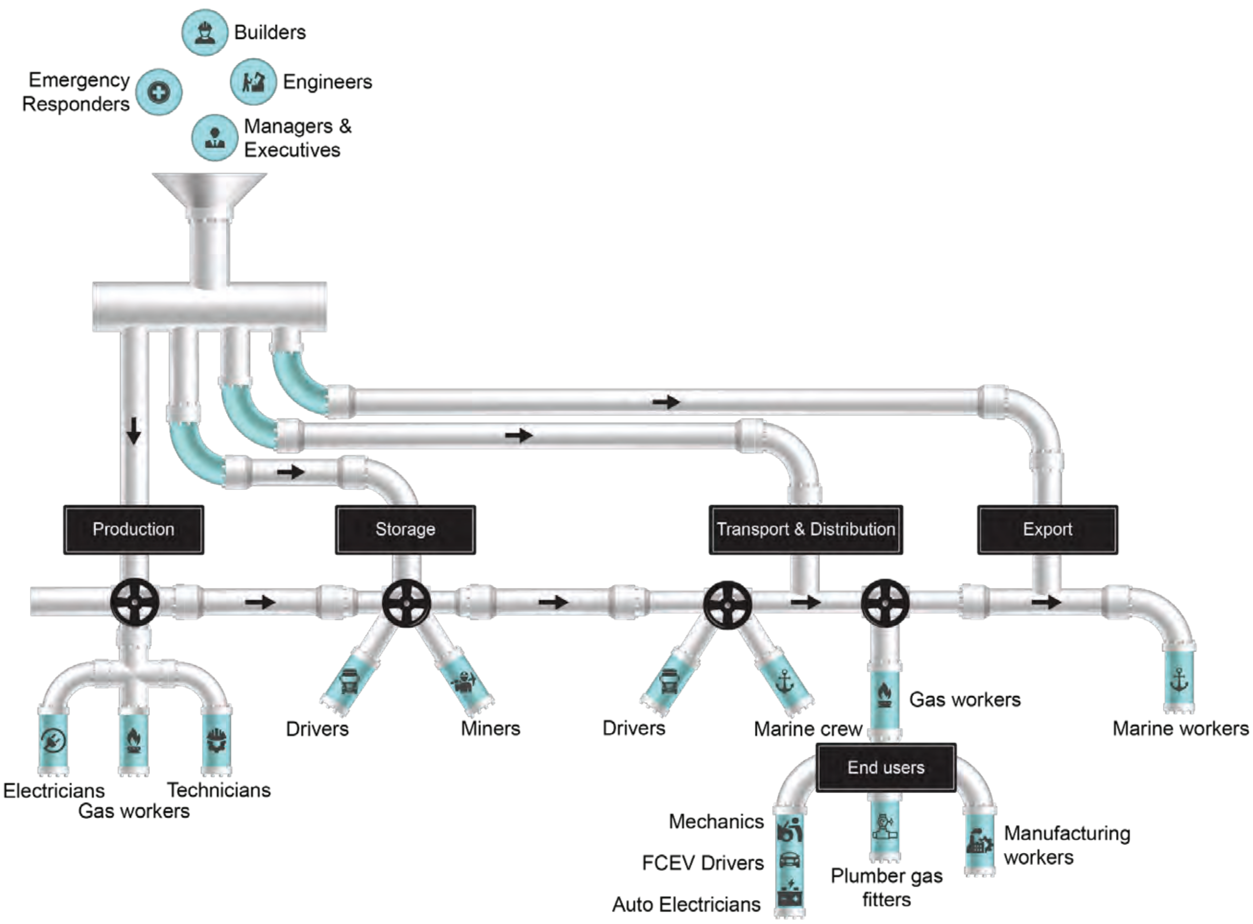


Figure 10. Hydrogen-related jobs across the supply chain

Executives and managerial roles

Across all industries in Australia, key management personnel make up a significant percentage of the corporate workforce. These personnel include top-level executives, non-executive directors and mid-level managers who have authority and responsibility for planning, managing, and controlling the activities of an organisation, whether directly or indirectly[46].

Executives and managerial personnel are required to regularly stay abreast of updates and changes to emerging systems and technologies within their industries. According to the Australian Bureau of Statistics (ABS), employment at management-level positions in Australia has increased from 1,041,200 people to 1,604,900 from February 2000 to February 2020 respectively[47].

Through consultation with industry, it has been identified that hydrogen training and education for executives and managerial roles is limited. In a report written by Deloitte in 2019, analysing the Australian and global hydrogen demand growth scenario, hydrogen sector jobs are likely to expand quickly to around 16,900 new global jobs; hence, a predicted increase in Australia's GDP to nearly $26 billion by 2050[48]. With this rate of job growth in the sector, future top-level management employees and executives will need to be aware of hydrogen fundamentals, the supply chain and how hydrogen can play an integral part in their business and production, in order to develop timely hydrogen strategies and reap the benefits of an emerging successful hydrogen sector.

Nationally, two prominent hydrogen training providers – H2 Advantage and Informa—offer hydrogen short courses that target a variety of audiences (including managers, executives, engineers, fire departments, drivers) on the topics of hydrogen fundamentals, hydrogen safety, transporting hydrogen and hydrogen power plants. However, only one CEO interviewed for the VH2 Roadmap Report was aware of these training offerings and/or had arranged delivery in their organisation. It has also been found that less than 50% of companies are offering hydrogen-related training to their employees at this time.

More than one representative of the gas network company consulted for this report emphasised that key management personnel, such as CEOs and CFOs, indicated that executives are beginning to prepare themselves with hydrogen knowledge through informal learning. Industry consultations revealed that the majority of executives, CFOs, and senior managers are hydrogen self-taught, and build on their existing knowledge of gas to strengthen their skills in and awareness of hydrogen.

KEY POINT
There is currently a high level of informal, self-initiated hydrogen learning being carried out at the executive and managerial level.

For gas workers and gas management personnel, hydrogen is not considered a 'new' innovation throughout their respective industries. Hydrogen as an energy source has been used for many years, and personnel within the gas workforce are aware of hydrogen through their experience in the industry. Gas company managers and executives currently leverage existing skills and expertise derived from their careers—dealing with all types of gas, natural gas, methane, LPG and other sources. There is a high level of self-initiated learning happening at the executive and managerial level, with gas industry executives revealing, throughout consultations, that they believe hydrogen to not be overly complex.

Job roles

Combining the data from this report's job advertisement analysis, a report by Energy Skills Queensland[49] and the information highlighted in the United States Government, Office of Energy Efficiency & Renewable Energy's hydrogen and fuel cells career map[50], we have identified and summarised required managerial jobs for the hydrogen economy in Table 5.

JOB ROLE	
Project Manager	Senior/Principal Hydrogen Consultant
Energy Advisor	Principal, Commercial Hydrogen
Hydrogen Plant Operator	Technical Director - Hydrogen Energy
Hydrogen Technologies Storage Expert	Business Development Manager
Head of Research & Development - Hydrogen	Hydrogen Deputy Director - General
Energy Transition Strategy Manager, Management Consulting	Head of Global and Safety
Logistics Manager	Hydrogen Fuels Policy Analyst & Business Sales
Depot Manager	Regulative Experts
Electrical Manager	

Table 5. Managerial Jobs

Emerging higher-level jobs

Several emerging higher-level jobs within the hydrogen industry are predicted to become more prevalent in the near future. These potential workforce opportunities have been compiled through our analysis of the existing hydrogen economy, industry consultations, and suggestions made by Bezdek[51]. Based on both US and Australian hydrogen industries, the following jobs have the potential to be expanded upon within the fuel cell, hydrogen systems and finance sectors:

- Fuel Cell Managers
  - Hydrogen/fuel cell research and development director
  - Fuel cell plant manager
  - Fuel cell quality control manager.
- Financial Managers
  - Emissions accounting & reporting consultant
  - Head of finance—project.
- Hydrogen Systems Managers
  - Director of hydrogen energy development
  - Hydrogen fuelling station manager
  - Hydrogen systems program manager
  - Hydrogen systems safety investigator cause analyst
  - Hazardous materials management specialist
  - Emissions reduction credit portfolio manager
  - Emissions reduction project developer specialist
  - Emissions reduction project manager
  - Hydrogen systems sales consultant
  - Hydrogen plant operations manager.

Skills, training, and education required

Across hydrogen-related industries, high-level managers and executives require targeted, sector-aligned training to upskill themselves with the following skills and knowledge:

- Hydrogen fundamentals and safety
- The supply chain
- The hydrogen economy
- How hydrogen can be used in their particular businesses.

Swinburne's VH2 Hydrogen Readiness Program is preparing to meet these outcomes by delivering workshops and forums to fast-track support and training for industry leaders, assisting them in developing a stronger understanding of hydrogen and its applications within their respective organisations. Through this program, companies from various industries are empowered to discover and leverage new opportunities in renewable hydrogen, in addition to:

- gaining access to comprehensive up-to-date knowledge about hydrogen and associated technologies
- strengthening their ability to confidently understand hydrogen-related information and technologies
- receiving the tools to think different about hydrogen's opportunities and challenges
- identifying how VH2 can support their industry's businesses as they transition towards a hydrogen economy.

Engineers

Apart from executive and high-level manager positions, the overwhelming majority of hydrogen-related jobs advertised were identified as those seeking engineers.

Employees working within the engineering workforce are required to hold an undergraduate degree beyond high school diploma level, in addition to long-term on-the-job training. Qualified candidates are typically expected to hold relevant qualifications in engineering, science, automation, mechanics, chemicals, electrics, technology or business. A bachelor's degree is the most common requirement for engineering jobs, however some higher-level jobs (such as project engineering managers) require at least a master's degree. For a research-related engineering position, a doctorate degree is the preferable criteria.

> "Australia is the third lowest producer of engineers as a proportion of all graduates in the OECD, a situation which has been further exacerbated by a new government funding structure for university courses."
>
> Julie Hare
> **Financial Review**

Along with these expected qualifications, the most in-demand hydrogen engineering roles are required to have advanced technical expertise and experience in hydrogen-related industrial projects, as well as a deep understanding of hydrogen technologies, safety, and systems. Proficiency in systems modelling tools (such as Python, MATLAB, and HYSYS) are also sought after within some engineering roles involving hydrogen systems. Analysis of job advertisements indicate that it is highly desirable that these skills have been acquired through over five years' experience in the gas sector or related industry.

In both hydrogen production and manufacturing, highly qualified engineers are required to design, develop, assemble, test, modify and evaluate the construction of fuel cells and electrochemical systems . Engineers are vital in the development of hydrogen technologies, particularly due to their familiarity with wiring electrical systems and high-pressure gas systems[53].

As a result of the global supply chain being severed due to closed borders resulting from the spread of COVID-19[54], Australia is currently experiencing a skills shortage of engineers and STEM graduates. Overseas-born engineers currently account for over 60% of the engineering workforce in Australia[55] with experts urging the Australian government to strengthen its 'sovereign capacity to build a sustainable engineering workforce'[56]. While there are many master's-level engineering courses available domestically, student places in Australia are largely taken up by foreign students.

Efforts are being made to provide Commonwealth-funded options to increase take-up of engineering programs by local students for local students to take up engineering programs. With engineers being crucial to the burgeoning hydrogen sector, it is imperative that Australia encourage new entrants to the domestic workforce; suggestions have been made to increase the value of engineers through increasing wages for new engineers[57]. Universities will play a vital role in achieving this goal, particularly through offering engineering courses that address the latest outcomes and developments in hydrogen technological knowledge.

TAFE-trained engineers

Whilst the majority of hydrogen-related engineering jobs advertised are targeted for higher education qualified graduates, TAFE-trained engineers are also required to work in the gas sector. TAFE trained engineers are addressed in the gas workers section.

Hydrogen-related engineering job roles

The table on the following page provides information regarding engineering job roles in demand and their respective requirements; they range from mid-level to top management roles[58].

Image 5. Engineers will be required to support hydrogen systems and infrastructure

MID-LEVEL ROLES	REQUIREMENTS
Electrical Engineers	Design, develop, test, and oversee the production of electrical equipment, including electric motors, radar and navigation systems, communication systems, and power generation equipment. Electrical engineers are also responsible for the design of vehicles, aircraft electrical systems.
Fuel Cell Engineers	Create, build, modify, and test fuel cells and other electrochemical systems that convert fuel to electricity.
Material Science Engineers	Investigate hydrogen substances at the atomic and molecular levels, as well as understand how they interact with one another. Also required to apply their expertise to create new and improved methods for producing hydrogen, as well as to evaluate the quality of hydrogen that is continuously produced.
Software Engineers	Develop the underlying systems that power hydrogen devices, to control hydrogen networks, and to create applications that allow monitoring and controlling the hydrogen blending process.
Water Treatment Engineers	Develop systems that treat water in a safe, efficient and effective manner, eliminating harmful elements and purifying the water for hydrogen production.
Smart Grid Engineers	Design and develop converters that transform electricity generated from fuel cells to be used in domestic settings.
Research Engineers	Assist with technical management of hydrogen and other energy storage technologies demonstration projects, including the design, procurement, construction, installation, and commissioning of such projects. Research Engineers are also required to overlook the research process surrounding hydrogen technology and knowledge including electrolyser knowledge.
Process Safety Engineers	Conduct quality and quantitative analysis, including the development of credible release scenarios, the measurement of scenario frequency, and the modelling of consequence development. They also perform formal safety assessment investigations, such as hazard identification studies and fire and explosion analyses, analysis of safety key elements, including emergency system survivability.
Mechanical Engineers	Analyse, design, develop, construct, and test hydrogen-related mechanical and thermal sensors and devices including tools, engines, and machines. Mechanical engineers develop and supervise the production of a wide range of items, from medical equipment to new batteries. Mechanical engineers create power-generating machinery like electric generators, internal combustion engines, and steam and gas turbines, as well as power-consuming machines like refrigeration and air-conditioning systems.
Heavy Vehicle Industry Australia-Leading the Industry Transition to Electro mobility HVIA-LITE	Solve environmental problems, in addition to applying engineering, soil science, biology, and chemistry concepts to hydrogen. This position also requires the individual to be active in implementing initiatives that promote recycling, waste disposal, public health, and the management of water and air pollution. They also deal with worldwide challenges including contaminated drinking water, climate change, and environmental sustainability.

HIGH-LEVEL ROLES	REQUIREMENTS
	Oversee multidisciplinary engineering teams in large projects, implementing design requirements and procedures. They are responsible for implementing hydrogen projects, implementing technical improvements, and executing the company's engineering functions.

Table 6. Hydrogen-related engineering job roles and requirements

Trades

Gas workers

Australian gas facts

The gas industry is a huge part of Australia's energy economy. Gas is used for heating, cooking and hot water in commercial and residential settings. An amazing 39,000 km of gas pipelines in Australia connect 70% of Australian homes to gas. It is used to produce heat and as a feedstock, to produce plastic, ammonia and other goods. Gas also provides stability across our power system by providing peak generation to back up renewable electricity. 39,000 km of gas pipelines currently connect 70% of Australian homes to gas and the industry assists in producing industrial feedstock, plastic, ammonia and other goods. From 2019 to 2020, gas contributed over $47 billion to the economy through exportation alone. The national gas industry currently employs more than 16,000 workers that work with 100,000 gas network connections[59].

Upstream/downstream gas workers

Those working with the infrastructure and appliances associated with the gas industry often categorise the workforce as either upstream or downstream workers. This distinction refers to the different levels within the supply chain that gas workers operate within.

UPSTREAM
Upstream gas workers are involved in gas production, networks, pipelines and industries prior to supplying gas to the consumer's gas meter.

DOWNSTREAM
Downstream employees work closer to the end user, such as connecting gas to appliances within the home or in commercial/ industry settings.

Hydrogen gas blending

Australia's National Hydrogen Strategy has set a strategic goal of running the national gas network exclusively using hydrogen. However, this scenario is still some time away from becoming a reality.

Image 6. Scaling up gas pipelines will significantly support decarbonisation

Continuous research and monitoring continue to increase the gas industry's understanding of the feasibility of blending renewable hydrogen with natural gas in pipelines. The majority of research and development initiatives currently focus on exploring appropriate materials for infrastructure, including pipes that are compatible with the chemical/physical properties of hydrogen at higher percentages than the currently tested 5-10% gas blends.

In alignment with the national and many state hydrogen strategies, the Australian Gas Vision for 2050 is set on achieving net zero emissions, with large gas companies (such as AGIG) promising to fully decarbonise the existing domestic distribution networks by 2040 It is intended that continuously scaling up of the use of hydrogen within gas pipelines will support the realisation of these targets, however, in doing so, green solar or wind-based hydrogen will need to overlap with brown coal-based hydrogen. During this transition period to higher blends of hydrogen within Australian gas pipelines, hydrogen gas skills across the supply chain will need to scale up.

Gas pipelines

Existing upstream transmission pipelines that carry gas long distances from production locations to storage spaces close to urban areas are mostly made of steel. Hydrogen has been reported to cause embrittlement in these steel pipes due to its small molecules and high pressure, resulting in cracks and fractures. Whether embrittlement within these steel pipes will require vital pipeline revisions and upgrade work is yet to be known.

Downstream distribution pipelines that transport gas to end users (such as homes and industry) have mainly been changed from steel to polyethylene or nylon pipes, which have been found to be more compatible with hydrogen[61]. Revising downstream transmission pipelines and attached appliances may be necessary prior to shifting towards higher hydrogen gas blends or pure hydrogen; however, varying industry sources have indicated that this requirement may not be needed and is debatable. Therefore, pipeline work forecasts are currently uncertain.

As hydrogen must be pumped at higher pressure and flows through pipes in a manner that is different to natural gas, much of the skills focus is currently on gas workers and the trades that will work with, or are a part of, gas production and electrical generation processes designed for the future grid. While gas workers have strong understanding of how to work with gas and may have learnt about hydrogen in trades school, the majority of gas workers might not have a detailed and current awareness that hydrogen behaves differently to natural gas.

The research team has identified relevant trades that have been brought to our attention through the survey conducted, industry consultations and

Image 7. Construction of a gas pipeline

desktop audits. The job roles and trades described here are not exhaustive but are currently salient in the industry's collective observance.

Gas roles and requirements

Employees working within gas-related industries and operations are found to most likely hold a Certificate II in Gas Supply Operations, a Certificate III or IV in Gas Control Operations or Gas Industry Operations, or a similar superseded qualification. If in a managerial position, an employee would be expected to hold at least a Diploma of Gas Supply Industry Operations.

Required roles within the gas supply industry include installation; maintenance; fault finding; repair; creation and implementation of pipeline infrastructure; reading gas metres; working in control centres; supporting operations of distributing and transmitting gas within pipelines; storage, handling, loading and transportation of cylinders according to relevant Australian standards; and regularity requirements, supervision, and diagnostics.

Image 8. Hydrogen gas storage is integral to the gas supply industry

KEY POINT
Upstream steel transmission pipelines have been found to experience hydrogen-caused embrittlement; however, downstream nylon and polystyrene pipes have been found to be more compatible with hydrogen.

Some identified[62] gas-related job roles may include:

- Gas Industry Worker (Transport)
- Utilities Industry Worker (Transmission Laying)
- Gas Industry Worker (Cylinder Distribution)
- Gas Meter Reader
- Gas Pipeline Worker
- Gas Service Technician
- Gas Industry Operator (Distribution/ Transmission)
- Pipeline Technician
- Inspector
- Gas Pipeline Supervisor
- Gas Industry Operator (Support Services)
- Gas Industry Operator (Systems Operations/Pressure Centre)
- Gas Industry Operations Supervisor (Control Centre)
- Gas Industry Operations Supervisor (Storage/Processing)
- Gas Industry Operations Supervisor (Transmission/Distribution)
- Gas Pipeline Supervisor.

Consultation with several gas companies has indicated that the laying down of pipes is often carried out by civil excavation workers overseen by pipeline engineers, as opposed to gas industry workers who work with these pipes once the gas is being transmitted through them. Plumber gas fitters also hold skills related to working with gas pipes and joinery and have demonstrated expertise in working with leaks in pipe systems; however, in comparison to gas workers, plumber gas fitters have been found to receive their qualifications under a different training package. These workers may have the capacity to work in hydrogen-related industries, however plumber gas fitters generally work downstream at the distribution pipe level, with appliances and other gas requirements at homes or in industry settings.

Accredited training

The majority of gas workers and technicians complete a related VET qualification at a TAFE institution. Most nationally endorsed training packages are facing a moratorium on making hydrogen-related changes due to the current Commonwealth National Hydrogen Skills Analysis and pending changes in industry clusters. However, the Gas Industry Reference Committee (Gas IRC) and Australian Industry Standards (AIS) were successful in winning their case for the endorsement of a revision of the existing gas training package. This approval for the UEG Gas Industry Training Package was fast-tracked due to the urgency for the gas industry to become more hydrogen-informed, given the activities already in action. This also occurred in response to the highlighted Australian government's and energy companies' goals of seeing carbon emission reduced and green hydrogen scaled up as soon as possible.

Consequently, the Gas IRC and AIS have produced three qualifications revised to respond to the emerging hydrogen economy- Certificates II, III and IV in Gas Supply Industry Operations – which were released for implementation in November 2021. The changes to these qualifications include:

- Six new units of competency
- 13 revised units of competency were revised for contextualisation to hydrogen and other gases
- Three skill sets.

Please see **Appendix H** for a full list of existing accredited gas training products.

New topics included in the changes to these aforementioned VET qualifications include:

- working safely in a hydrogen environment
- hydrogen characteristics
- electrolysis principles and electrical safety
- emergency response
- sustainable energy, environmental principles and practices (including different types of hydrogen)
- fault finding
- repair and operations for hydrogen storage
- handling and status of hydrogen containers
- injecting hydrogen into distribution networks
- purging injection lines, control centre systems
- hydrogen pressurisation
- compression and flow procedure
- hydrogen analysis equipment
- hydrogen-specific electrical hazard control measures and earth protection
- underground storage
- injection and withdrawal
- data logging procedures
- complying with hydrogen-specific regulations
- industry standards, legislative requirements
- codes of practice
- manufacturers' recommendations and specifications
- environmental requirements.

According to the IRC's and AIS' 'Case for Endorsement' paper[64], the new units of competency developed for hydrogen gas technology can be used by the plumbing, manufacturing, electrotechnology and other related industries wanting to work with hydrogen. Additionally, the new units of competency developed for data loggers can be used by employees working within the water industry, whilst the new units of competency developed for the storage and reinjection of gas can be used by the gas processing and manufacturing industry[65].

Non-accredited training

Hydrogen production operations at ATCO Clean Energy Innovation Park in Jandakot, WA, and Jemena's Western Sydney green gas project have found and indicated that their workers require immediate additional skills training. In Sydney, EnerTrain has designed the Western Sydney Green Gas Station Operations Program (WSGG-STOP) training course for existing workers. This 3-day course (2 days classroom-based and 1 day field-based at their facility) includes relevant training pertaining to hydrogen awareness and properties, safety and emergency response, problem solving, and injection panel/gas panel learning outcomes (see **Appendix B**).

EnerTrain have also committed to developing six of the new hydrogen-specific nationally accredited units outlined within the gas industry training package, and plan on delivering two of these units to gas workers in Sydney. It is assumed that other registered training organisations have already commenced development of materials and resources to deliver the new UEG Gas Training Package units. However, current hydrogen-specific training is mostly non-existent. Industry consultation has revealed that across all trades working in the hydrogen gas and electrical supply industry, Original Equipment Manufacturers (OEMs) are playing a significant role in upskilling existing upper- and lower-level workers on how electrolysers and other hydrogen-related equipment are operated. With intellectual property posing a concern, the sharing of these OEMs' expertise and knowledge has the potential to be sensitive. When speaking with gas industry leaders, the majority were unaware of any current hydrogen training opportunities for themselves or for their workers. Current industry training offerings can be seen in **Appendix B**.

Engineers

Mechanical fitters who undertake a preliminary level qualification, such as a Certificate III in Engineering – Mechanical Trade, are provided with hydrogen-related skills such as fitting, assembly, manufacture, installation, modification, testing, fault finding, maintenance, service of mechanical equipment, machinery and using machine tools in the gas industry. The Certificate IV in Engineering builds on these Certificate III skills and supports employees' entry into the electrotechnology and electrical generation maintenance fields of work. There are also state accredited courses relating to this skill set, such as the Western Australian Advanced Diploma of Electrical and Instrumentation Engineering for Oil and Gas Facilities, and the Advanced Diploma of Electrical and Instrumentation Engineering in Mining.

It has been identified that fabricators have experience in working with hydrogen systems that involve small-bore installations and tubing systems, in addition to working in metal, engineering and manufacturing industries. Fabricators hold a Certificate III in Engineering. Other engineering-related workers that have the potential to be involved in the hydrogen gas industry are welders and machinists.

Existing training

There are currently no revised or new hydrogen-related units in the Manufacturing and Engineering Training Package.

Additionally, it is not known if there are any current non-accredited training opportunities being offered nationally.

Swagelok, an organisation that manufactures parts and equipment for hydrogen systems, offers non-accredited training courses focusing on safe and effective tubing skills that target fabricators, as well as other engineers and technicians. As an example of an OEM offering training to the growing hydrogen workforce, training is offered only to organisations who use their products. Please see **Appendix B** for examples of the training courses and learning outcomes currently being offered by Swagelok.

JOBS IMPACTED
Engineers and related professions—including fabricators, welders, and machinists—have the capacity and some existing foundational knowledge to work with hydrogen.

Electricians

Electrotechnology is an industry that is currently playing a vital role in supporting the shift towards a renewable energy future. In 2021, there were 7,500 electricians installing solar and battery storage systems; employment growth is set to rise 7.1% by 2026[66]. It has been identified that the majority of electricians begin their career by obtaining a Certificate III in Electrotechnology and are responsible for installation, fault finding, testing, and maintenance of electrical systems. In order to practise as electricians, workers must meet state-regulated standards that can differ from state to state, in order to obtain licences.

Industry consultations have indicated that electricians often require additional training to work in the gas industry; many also hold a Certificate III in Instrumentation and Control. This qualification covers competencies that support workers in selecting, installing, setting up, testing, fault finding, repairing, and maintaining systems and devices that measure and record both physical and chemical phenomena, as well as related process control.

Electrical workers with expertise in instrumentation will be in demand as the requirement for increased levels of renewable energy and hydrogen production continues. Unlike many gas workers, electricians have a strong understanding of working with high voltage, and therefore will have existing skills and knowledge in dealing with the electrical side of hydrogen and electricity generation, and the use of fuel cells. Electricians will have the capacity to build on their existing knowledge of instrumentation and control, which can be applied within the hydrogen sector as well as on electrical systems pertaining to electrolysers and fuel cell technologies.

Existing training

AIS' electrotechnology industry reference group has formed a Technical Advisory Committee (TAC) to oversee a renewables project, designed to review and develop the UEE Electrotechnology Training Package's installation & maintenance of renewable technologies content. This involves the review of eight qualifications and 50 units for industry practices, regulations, and accreditation. However, no reference to hydrogen has been made clear, and no other formal hydrogen training for electrical workers is known.

Electrical generation workers

With gas companies in Australia announcing that they will install hydrogen-ready turbines, the national electrical generation market is poised to utilise hydrogen to generate electricity and support the power grid. Major turbine manufacturers, such as Siemens and General Electric, have also begun producing and selling 100% hydrogen-ready gas turbines[67]. Workers in the electrical generation industry may also have the potential to work alongside those in related trades, such as energy plant and systems operations, electrical and mechanical maintenance, and wind and solar power generation.

The Certificate II in Electrical Supply Industry (ESI) Generation is the base qualification required for electrical generation workers, as this qualification equips them with competencies to ensure they can operate non-critical generation plant systems, lubricate generation plants and perform minor maintenance on electrical and mechanical equipment. This role also includes cleaning power generation plants, operating mobile load-shifting equipment and observing safe working practices in the workplace.

At the Certificate III level, a worker can operate power generation plant systems, isolate power generation plant systems, and undertake routine maintenance on power generation plants and equipment in the electrical supply industry. A Certificate IV-level worker will most likely be responsible for supervisory tasks[68]. It is predicted that electricity generated from fuel cells will eventually outdate turbines. However, the hydrogen electrical generation industry is in its early stages and is not as advanced as the gas sector.

Existing training

The ESI Generation Industry Reference Committee has formed a Technical Advisory Committee for a Control Room Operations project to review materials within the UEP Electrical Supply Generation Training Package. This training package addresses critical skills requirements for control room operations relating to power generation in both fossil fuels and renewable energies. Feedback has closed and five new units have been proposed as electives in the Certificate III in ESI Generation[69]. It is unknown if any of these revisions will include hydrogen-specific content, and no other formal training is known.

Plumber gas fitters

Working downstream from the gas meter, plumber gas fitters ensure safe and effective connections between distribution gas pipes and appliances in residential, industrial and commercial workplaces. Most plumber gas fitters work in small businesses, with many being sole traders. Plumber gas fitters mostly work with Type A gas appliances in domestic settings, such as gas stove tops, barbeques and grills connected to gas cylinders, hot water systems, gas refrigerators and ducted heating. There are approximately 11 million Type A appliances in use around Australia[70]. Found mostly in industrial and production settings, Type B appliances consume significantly more energy and include gas-fired steam boilers, furnaces, and kilns. Classifications and regulations for Type A and B appliances can differ from state to state.

Plumber gas fitters will most likely have obtained a Certificate III in Gas Fitting or Certificate III in Plumbing (Gas Fitter) from the Construction, Plumbing and Services Training package. These

KEY POINT
In most states, an electrical licence is mandated; therefore, electrical skills required to work with some hydrogen-powered appliances already exist for plumber gas fitters, albeit at lower voltages than what electricians are trained to work with.

workers specialise in gas installation, testing and maintenance, in addition to repairing gas lines, meters, regulators and piping systems downstream of the billing meter. This workforce is also skilled in working with gas appliances and ancillary equipment, such as hot water systems, gas heaters and heat pumps associated with the use of fuel gases (including LPG systems[71]). In the emerging hydrogen economy, gas fitters may also be responsible for tasks such as converting appliances, adjusting gas pressures, installing gas detection systems, testing for leaks, and repairing and issuing of compliance certificates or plates. A plumber gas fitter may also undertake pressure welding tasks for water, gas, and steam for industrial processing applications.

Not only do plumber gas fitters need a Certificate-level qualification, this workforce must also secure different types of gas fitting licences. Australian states have differing regulations that make it difficult to consistently describe trade competencies in plumbing and electrotechnology across the country. For example, to become registered to work with Type A and B appliances, Victorian plumber gas fitters must hold a restricted electrical worker's license, have completed units of competency from the construction, plumbing and services training package, and meet additional criteria[72].

Existing training

In 2021, Artibus—the Skills Service Organisation (SSO) that supports industry reference groups for the CPC Construction, Plumbing and Services Training Package—released a Case for Change[73]. Noting the link between electricity and the use of electrolysers and fuel cells, the report advised that plumbers and gas fitters will require new skills with the introduction of hydrogen to the domestic gas supply. The report also indicated that these skills are different to the skills and knowledge of gas workers trained under the existing Gas Training Package and proposed 19 new units. Eleven of these units of competency are based upon traditional combustion steam units to meet current skills gaps. The remaining eight units pertain to fuel cells/electrolysis to meet emerging hydrogen skills needs. Please see **Appendix I** for more information.

The new units proposed for this training package encompass the storing and handling of hydrogen; installation, decommissioning, disconnecting, reconnecting and ventilation specifications for Type A and B appliances; vent lines; storage capacity; the commission and decommission of hydrogen combustion, fuel cells and electrolyser systems; servicing and maintaining of fuel cell electrolysers; purging; designing hydrogen systems; water treatment; flue systems; the characteristics and chemistry of hydrogen; and the compression and cooling of hydrogen. However, these changes have been referred back to the Construction and Plumbing Industry Reference Group for resubmission in 2022 pending the national analysis of the hydrogen workforce, which has been commissioned by the Commonwealth Government[74].

Currently, there are no plumber gas fitter-specific accredited or non-accredited hydrogen training offerings available.

Image 9. Gas fitters ensure safe and effective connections between distribution gas pipes and appliances

Skills for hydrogen-related trades

Gas technicians, mechanical fitters, and electrical generation workers

Energy Skills Limited is in the process of conducting a detailed gap analysis to identify training pathways for coal, steam and liquid natural gas workers. With a national database of over 38,000 workers and a strong gas stakeholder network, Energy Skills Limited aims to expedite the increased capacity and capabilities of gas industry workers. In the meantime, the first step is to increase awareness of the new hydrogen economy amongst the gas worker community.

As hydrogen is not entirely new to gas workers and technicians, it is expected that existing skills will be built upon to respond to the impending upscale of hydrogen in the near future. By building upon existing skills, this workforce may not need to learn new skills entirely; rather, their skills will become contextualised to the nature and attributes of hydrogen gas. Furthermore, the industry experienced similar disruption in the 1970s when town gas was switched to natural gas; the switch to hydrogen could potentially be based on past lessons.

The skills required to establish hydrogen gas networks already exist amongst the current gas workforce. However, working with hydrogen will be new to most workers. Hydrogen blended at low rates will not affect current practices, so current skills for pipeline gas workers will remain unchanged until pipelines are updated, and new procedures and equipment are implemented. This is expected to happen in a patchy, non-linear fashion until hydrogen gas blended pipelines and production levels are scaled up.

At the least, existing gas workers and technicians (including gas fitters) will require a refreshed understanding of hydrogen fundamentals. This will include the provision of a stronger understanding of hydrogen characteristics, the highly pressurised transport and storage of hydrogen blended gas, and the maintenance of appliances and their flammable ranges/flash points for safety and emergency response. Workers may need to contextualise their skills, for example, by using electronic hydrogen gas detection devices or monitoring equipment. However, workers will need to be trained on the job, to use devices and instruments that are hydrogen-specific. In time, gas production workers and technicians may need to acquire high voltage electrical skills and knowledge when working in green energy production plants, primarily where electrolysers and related production equipment utilise electricity.

Electricians

Electricians working in the gas industry possess knowledge of high voltage and electrical principles, however they will require appropriate upskilling on what hydrogen is and how it behaves. Working with new technologies such as electrolysers and fuel cells, and their related pipes and tubing, will require electricians to gain relevant upskilling. It is also anticipated that this workforce will need to be aware of and competent in working with hybrid systems that create and utilise hydrogen gas.

Gas fitters

Like their upstream counterparts, gas fitters are very familiar with working with all types of gas; it is the nature of hydrogen that will disrupt the familiarity they have in their current practices. Different understandings of pressure levels; hydrogen-revised manufactured products and installation equipment; joining techniques and/or threaded joints; purging; and commissioning and decommissioning hydrogen systems skills will be required. Hydrogen appliance conversion may also present changes to the way that gas fitters install and repair Type A and B appliances.

Image 10. Electricians will require hydrogen upskilling

The University of Adelaide has tested a free-standing cooker and barbeque using hydrogen gas blends of 21.7% and higher[75]. However, it is not yet known how much hydrogen in gas (let alone pure hydrogen) will impact the revision of pipes and tubing, in addition to the appliances used by gas fitters. If and when revisions and changeovers occur, these will determine the timing of greatest demand for gas fitters during the transition phase. In the coming decades, gas fitters will also need to be aware of and competent in working with hybrid systems that may require electrical and gas skills. If gas fitters are required to work with fuel cells, industry has informed this Skills Roadmap that small-bore tubing systems will be a significant skill gap. It is a highly specialised technical area, that requires a micro-credential to be developed with specialised subject matter experts.

Should industries experience a rapid hydrogen uptake, training large numbers of gas fitters in a short time frame will present significant logistical challenges[76]. Moreover, the assurance of independent sole traders meeting their upskilling responsibilities may pose both a safety challenge and a skill shortage if a response to required hydrogen awareness, new skills and emerging knowledge is not planned immediately. A current study being undertaken by RMIT and Future Fuels CRC is currently investigating hydrogen skills gaps for gas fitters[77], using Victoria and South Australia as detailed case studies. This report will assess the changes in resourcing and education required to support the gas fitting industry's transition to future fuels, including hydrogen.

KEY POINT

It is imperative that gas fitters' skills gaps be addressed in a systemic fashion, introducing new licencing requirements if deemed necessary.

The gas and electricity intersection

Research and industry consultations have revealed that there is often an unclear distinction between trades within the hydrogen supply chain, particularly in the upstream transmission and production stages. Engaging with industry representatives in the gas industry often resulted in conflicting descriptions of the qualifications required by these trades workers; this may be because workers with gas qualifications were trained on the job with electrical skills, and electricians were trained on the job with gas skills. According to gas industry leaders, workers trained under the existing gas training package can possess instrument expertise that is usually recognised under an electrical Certificate III in Instrumental and Control, without undertaking that specific qualification. Those with mechanical qualifications and gas skills also work alongside colleagues trained in the gas training package. This intersectionality of different trades and skills requirements, in conjunction with the potential for trades to leverage existing skills, is perhaps why several gas representatives we engaged with indicated that the transferral to hydrogen would not be deemed difficult or complicated. An example of this transition between intersecting trades is a worker with an electrotechnology and electrical instrumentation background upskilling on the job, to become a gas worker with a job title such as a transmission controller, pressure controller and mechanical electric instrumentation technician. Once embedded in a particular industry, workers learn on the job, become multi-skilled, or indeed specialised in the context of the industry's immediate and necessary job tasks.

Outside the realm of gas production and pipelines, organisations operating with hydrogen fuel cells and hydrogen storage systems are looking for plumbers or electricians (or both) who have received hydrogen training from relevant manufacturers (e.g. Swagelok or Hyzon). One stakeholder describes the composition of these skills as a 'hydrogen ticket'. Once hydrogen scales up, educational institutions will need to be responsible for the skills and knowledge that OEMs are currently teaching. Companies as Swagelok and Hyzon will also need to be engaged as subject matter experts to ensure that course content is accurate, consistent and relevant.

It is expected that electrical and gas skills will overlap and intersect more in the future hydrogen economy. A zero-emissions vision means all hydrogen gas is green and produced from green (renewables) electricity. The cyclical nature of hydrogen gas and electricity is evident; electrolysers use electricity to produce hydrogen gas, and fuel cells use hydrogen gas to produce electricity. Therefore, in the production and usage of both hydrogen gas and electricity, both energy sources are utilised.

AS/NZS 5601 Australian gas standards define fuel cells and electrolysers as gas appliances, yet both demand electrical skills. Other associated devices and components including piping are defined in AS/NZS 5601 as gas installations. This is not completely new as gas fitters work on cooking appliances that have stove tops that are electric and ovens that are gas-fuelled. However, the hydrogen economy will see the joining of renewable energy sources, gas and electricity in ways we haven't seen before. The LAVO energy storing system is an example of this convergence. The LAVO system takes unused solar cell energy (that would previously have been uploaded to the grid) and uses an electrolyser to create hydrogen gas which is stored. When electricity is required, the hydrogen gas is then processed through a fuel cell to become electricity.

Image 11. The gas and electricity industries often intersect, leading to an often unclear distinction between trades

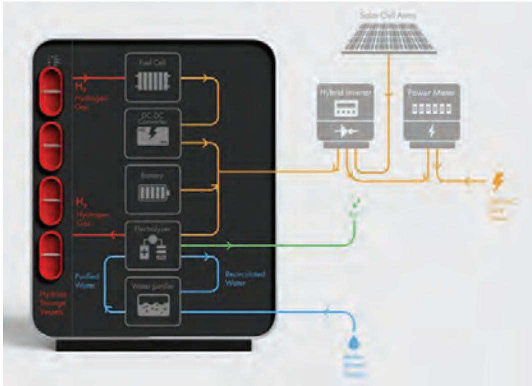


Image 11. The LAVO hydrogen energy storage system

Six demonstration sites are currently showcasing the hybrid technology. LAVO's technical director explained that a gas fitter is used to install and connect the water and gas components. An electrician or electrical engineer then tests and commissions it. Software installed on the tradesperson's laptop or electronic device guides the commissioning of the LAVO.

Skills gaps for gas industry workers

As hydrogen is tested and trialled at higher percentages, and requirements and revisions are identified for ensuring compatible pipelines, infrastructure and appliances, it is expected that gas workers, mechanical fitters, technicians, electricians and gas fitters will leverage existing skills and be exponentially upskilled. Micro-credentials can fill skills gaps as workplaces, training packages, the current training analyses and importantly, regulations and standards, catch up with the emerging hydrogen gas industry.

Basic hydrogen awareness and safety is fundamental and an immediate skills gap. In a study of first responders and hydrogen fuel cell vehicles, it was found that unless there is preparatory education and fundamental awareness, misconceptions and different opinions can emerge in the worker group[79]. The vast majority of gas workers and related trades are not yet working with hydrogen; however, an awareness of hydrogen is fundamental to worker understanding, acceptance and engagement as scaling up begins. Understanding of new technology and how gas and electricity will intersect is also crucial to addressing skills gaps for the future gas industry. Table 7 indicates the high level skills gaps that have been identified for gas industry workers.

MICRO-CREDENTIALS	GAS WORKERS AND TECHNICIANS	MECHANICAL FITTERS AND ENGINEERS	ELECTRICIANS	ELECTRICAL GENERATION	GAS FITTERS
Hydrogen fundamentals	•	•	•	•	•
Safety emergency response	•	•	•	•	•
Understanding of electrolysers and fuel cell technology	•	•	•	•	•
Electrolysis principles and electrical safety	•	•	•	•	•
Understanding regulations	•	•	•	•	•
Industry-specific operations skills such as panel and instrumentation skills	If appropriate in workplace context	If appropriate in workplace context	•	If appropriate in workplace context	•
High voltage small-bore tubing			•		

Table 7. High level skills gaps identified for gas industry workers

Construction

Supporting the development of a hydrogen economy will involve constructing hydrogen production plants, refuelling stations and other buildings that utilise hydrogen. As hydrogen is lighter than air, when leaks occur, it will float up and disperse quickly. It will also ignite more easily than natural gas due to its wider flammability limits and like most gases, can be highly explosive. It will require purpose-built facilities with adequate ventilation and leak detection infrastructure to ensure safety. For example, the Hydrogen Test Bed at the Deakin Hycel Technology Hub was required to have a 400-metre section at the top of walls for ventilation and an exclusion zone around the shed. At the time of writing, no regulations or standards exist to guide the built environment. Plans for roadside refuelling stations will be implemented in the future , requiring construction workers as well as gas and electrical workers. Bus and truck depots, councils, factories and warehouses may also need hydrogen refuelling stations for hydrogen-powered vehicles in the future.

Construction workers complete their training and apprenticeships under the same national training package as gas fitters. Job skills involved with hydrogen-related construction include but are not limited to carpentry, plumbing,

Image 12. Construction workers will be required to support the development of hydrogen buildings

bricklaying, concreting, roof tiling, swimming pool construction and heating, scaffolding, rigging, fire protection and steel fixing. An awareness of hydrogen safety and behaviours will be necessary before detailed, construction-specific analysis of training needs is undertaken. Importantly, construction workers on hydrogen fuel stations will need a mandatory safety course. Architects, drafters, builders and building inspectors will also need to be made aware of hydrogen safety principles, emergency response and hydrogen infrastructure such as compressor units and production systems.

Existing Training

CPC Construction, Plumbing and Services Training Package

No hydrogen training or projects were identified for construction workers.

Transport and mobility

Hydrogen-powered vehicles

With the transport and mobility sector currently responsible for 19% of Australia's total greenhouse gas emissions[79], the implementation of hydrogen is envisioned as playing a key role in achieving reduced transport emissions goals. In addition, Australia's greenhouse gas emissions have risen by 25% from 1990 to 2017, with heavy vehicle emissions more than doubling over the same time span. By 2030, transport emissions are expected to have risen by 82% since 1990[80]. With a continuously increasing number of vehicles on the road, relatively small carpooling numbers and a high demand for freight trucks, emissions will continue to soar unless Australians adjust behaviours towards transport and, importantly, begin to move towards low/zero emissions transport options.

Hydrogen gas-powered vehicles have the potential to support this shift, as these vehicles produce zero emissions, only emit water while driving, are quiet, and exhibit superior take-off speeds in contrast with other vehicles. In comparison to electric battery vehicles, hydrogen-powered vehicles have a longer distance range and can be refuelled in less time than it takes for an electric battery vehicle to recharge. Hydrogen-powered vehicles also avoid carrying heavy batteries like electric vehicles, which supports the use of hydrogen-powered heavy haulage vehicles.

Zero Emissions Vehicles (ZEVs) include both electric battery-powered and hydrogen-powered vehicles. Both are classified as electric vehicles; however, unlike battery electric vehicles (BEVs), hydrogen-powered vehicles use fuel cell technology and are known as fuel cell electric vehicles (FCEVs). The first mass produced FCEV car with Proton Exchange Membrane Fuel Cells (PEMFC), the Honda FCX Clarity, was announced in 2007 by Honda[81]. Since 2007, fuel cell technologies have continued to advance.

Image 14: BEVs and FCEVs are examples of ZEVs

Victoria's zero emissions energy roadmap[82] indicates that ZEVs will make up 50% of all new light vehicles sold by 2030, which will significantly contribute towards the overall state goal of reaching zero emissions by 2050. In addition, the Commonwealth Government's *Future Fuels and Vehicles Strategy*[83] highlights methods and intentions to reduce barriers that currently or have the potential to stymie the uptake of hydrogen vehicles. A complementary report—*Developing a low/zero emission transport strategy for Australia*, produced by the University of Queensland and iMove[84] - recognises the challenges and confusions presented by a coordinated transition from petrol and diesel vehicles to electric vehicles, including hydrogen. This strategy aims to clarify trajectories, build public confidence, consider infrastructure and set clear policies for Australian governments to effectively implement and navigate low and zero emissions strategies for the transport sector. These transport strategies include land, marine and air transport.

Infrastructure such as hydrogen refuelling stations are vital in supporting the uptake of hydrogen-powered vehicles; currently, there are only 4 hydrogen refuelling stations operational in Australia. A lynchpin initiative expected to be completed by 2026 is a green hydrogen freight-way for heavy vehicles that joins Queensland, New South Wales and Victoria[85]. The related joint grant initiative by Victoria and New South Wales of $10 million for the Hume Hydrogen Highway announced in July 2022 plans to open four more refuelling stations between Melbourne and Sydney with a fleet of at least 25 hydrogen-powered trucks utilising it[86].

In addition to cars and other heavy road vehicles, vehicles expected to be powered by hydrogen fuel cells include freight trains, cranes, forklifts, planes and ships. To support strong uptake of FCEVs to meet critical goals and significantly drive down carbon emissions resulting from transport, the development and implementation of more hydrogen

Image 13. Hydrogen-powered cars are becoming more and more prevalent in Australia

refuelling stations is paramount. New skills will be required for the construction and installation of stations and management of hydrogen.

A focus on heavy vehicles

While Hyundai has registered twenty hydrogen-powered cars for the ACT Government fleet[87], and government incentives are encouraging more fleet ZEVs, most current action is focused on heavy vehicles, at least until hydrogen-powered domestic and light cars become more cost effective. As heavy vehicles currently require expensive diesel fuel for long travel, hydrogen will provide a more affordable alternative. In addition, FCEV trucks and buses are lighter than their electric counterparts as they do not have a heavy battery on board. Hyzon Motors showcased their first hydrogen-powered coach in 2021, describing the benefits of hydrogen-powered heavy vehicles[88] in a virtual forum.

General Motors, Honda, Hyundai, Hyzon, Kenworth and Toyota are manufacturing or planning to manufacture medium and heavy FCEV trucks[89]. Hyzon initiatives also include the implementation of hydrogen-powered waste collection vehicles and heavy trucks for the Townsville-based Sun Metal zinc refinery. Considering that most of the Australian population's food supply is freighted by trucks and road freight, the increased inclination of consumers to have their products home-delivered, and predictions that urban freight alone will grow 60% by 2040[90], indicate that the freight industry is ripe for the implementation of more earth-friendly practices.

Hydrogen buses and coaches are advancing just as quickly as other heavy vehicles. BOC and Foton Mobility have indicated that they are collaboratively developing operational and commercial hydrogen bus models across the supply chain, including production, storage, refuelling, and leasing arrangements . Hyzon and Fortescue Metals have also announced their plan to introduce hydrogen-powered buses/coaches for use in the mining areas of the Pilbara , with each coach able to seat up to 55 adults and have an impressive range of 700 kilometres[91]. The first coach was showcased in Brisbane and on a virtual forum in 2021[94].

Bus companies will be required to shift gears, to investigate how FCEV buses and coaches will impact their business.

Image 15. Hydrogen-powered buses will support Victoria's shift towards widespread ZEVs

In consultation with a representative from Deakin and the Hycel Hydrogen hub, it has been highlighted that Warrnambool, a regional town in southwest Victoria, will introduce 12 hydrogen buses in the coming year. South West TAFE aims to work with Deakin to support training opportunities for this initiative.

Dyson bus services have indicated that they are already exploring the purchase of hydrogen buses and coaches. A representative informed the roadmap research team that there was currently little information to guide the bus line industry with the transition to hydrogen-powered buses, or to identify training opportunities. There appears to be a keen willingness to learn more. In Victoria, the interest in FCEV buses is particularly motivated by the fact that all new bus purchases are mandated to be ZEVs by 2025[95]. Whether the bus, freight and logistics sector embraces hydrogen vehicle technology by choice or regulation, training and industry preparedness will be essential to successfully implement the predicted quick uptake of FCEVs once infrastructure and manufacturing is expanded.

In the next five years, the Australian public can expect to see hydrogen-powered heavy vehicles on their highways, urban routes and in mining environments. The speed of FCEV uptake is reliant on hydrogen production, refuelling infrastructure, engagement of business, and government incentives and support. However, it is evident that the transport industry—particularly heavy vehicles—will be at the very forefront of the transition to hydrogen in Australian society. Consequently, this will significantly impact workers such as mechanics and drivers over the next five years. The transport and mobility sector is extensive; significant reskilling and upskilling is required to enable the workforce to service, maintain, manufacture and drive FCEVs, and to support their associated logistics.

Light vehicle automotive workers

The automotive service and repair industry sector encompasses a wide range of job role specialisations. Electric vehicles, water sports vehicles, motorcycles, motor sports vehicles, marine vehicles, agricultural vehicles, outdoor power equipment, and motor maintenance, as well as sales and administration, are some specialisations that may be impacted by the introduction of hydrogen by the end of the decade.

The workers most likely to be impacted in the near future are mechanics and auto electricians. Automotive workers with a Certificate III qualification in Light Vehicle Mechanical Technology have the capacity to inspect, repair and maintain cars and light trucks[96]. Those with a Certificate III or IV-level qualification in Automotive Electrical Technology have the competency to service, diagnose and repair of electrical systems and components in cars and light vehicles[97]. Both are familiar with computer diagnostics and testing equipment.

Heavy vehicle automotive workers

Large, heavy vehicles currently using diesel engines are maintained and serviced by specialised mechanics. A Certificate III in Heavy Commercial Vehicle Mechanical Technology qualifies a person to perform a broad range of tasks on a variety of heavy commercial vehicles[98]. The Certificate III in Automotive Diesel Fuel Technology specialises in diesel fuel systems and another Certificate III specialises in Diesel Engine Technology[99]. Generally, all three qualifications qualify a person to test and repair diesel motors and mechanical parts such as suspension, transmissions, brake and steering of buses, trucks and other heavy vehicles[100].

around fuel cell hydrogen-powered electrical vehicles in July 2022.

New automotive telematics units have been introduced for the marine mechanical, automotive electrical technology, and agricultural mechanical technological sectors in the national training package. These units will provide competencies to service and repair electronic management, monitoring and tracking systems, including those in heavy vehicles or mobile plant machinery. While these skills are not directly related to hydrogen, new FCEV vehicles will have the latest technology, therefore, auto electricians will need to upskill.

It appears that some FCEV knowledge can be transposed from electrical vehicle training, however fuel cells—the essential component—will not be included. The Roadmap research team could not uncover any existing training for heavy vehicle mechanics. It is unknown whether mining companies have developed or implemented any training courses for vehicle maintenance and service. Industry has stated that manufacturers are delivering training after purchase and as required.

Image 16. The automotive servicing sector will be impacted by the introduction of FCEVs

Existing Training and Skills

AUR Automotive Retail, Service and Repair Training package

No qualifications in the automotive industry currently contain any reference to hydrogen. A new qualification has been approved – called the Certificate III in Automotive Electric Vehicle Technology—along with three battery electric vehicle units of competency and a Battery Electric Vehicle Diagnose and Repair Skill Set. However, these units and qualifications do not reference fuel cells or hydrogen. In a statement from Price Waterhouse Cooper, the Automotive Skills Service Organisation had no plans to create competencies

Skills initiatives

The Future Battery Industry Cooperative Research Centre (FBIRC) and South Metropolitan TAFE in Western Australia have indicated that they plan to investigate skills gaps for electrical and mechanical technicians, first responders, electricians and mechanics trained in electric vehicles and battery energy systems[102]. Skills related to understanding high voltage batteries and fuel cell technology also encompasses automotive engineers and auto electricians.

A vital and timely Victorian state initiative will see four bus companies work with the Australian Manufacturing Union and Bendigo Kangan Institute to upskill diesel mechanics and transport technicians to work on electric and zero-emissions buses. The project aims to produce industry-informed training that will be made available to all Victorian bus operators and new apprentices[103].

Skills for FCEV mechanics and auto electricians

Both light and heavy vehicle mechanics and auto electricians work with combustion engines; however, they will require new skills to work on FCEVs. These skills will involve the ability to work with high voltage fuel systems that need to be decommissioned, installed and modified safely. A representative from Swagelok—specialists in hydrogen components and systems—informed the Roadmap report that they perceive the biggest skills gap in the hydrogen economy to be among mechanics who are new to working on fuel cells and hydrogen-powered vehicles. Mechanics will need to further their technical skills as they will be required to understand and work with electricity, gas and tubing

Image 17: Small-bore tubing (source: Swagelok)

systems, and related systems. Small-bore tubing skills will be integral for mechanics working with fuel cells. Other skills will also include coding and reprogramming vehicle software; these latter skills are mostly unfamiliar to the current workforce, while the former will be completely novel. Telematics will be built into ZEV buses and other vehicles.

The training supplied by companies such as Swagelok, Hyzon or Toyota equate to what the growing heavy FCEV industry calls a 'hydrogen ticket'. In addition to the hydrogen ticket, Hyzon recommends that technicians who work on the maintenance and service of hydrogen-powered heavy vehicles possess the following four additional skills in contrast with a traditional diesel mechanic:

- High voltage (600VDC) automotive electrical skills
- Big battery mechanic skills (e.g. 100kWh)
- Gas fitting or electrician-trained-in-gas skills
- CAN (controller area network) bus analysis skills

An FCEV industry representative informed the Roadmap report that new fuel cell trucks and coaches are currently predominantly custom-built, with required skills including computer design, engineering, project management, mechanics and fuel cell technical skills. Custom-made trucks cost approximately $4,000-$5,000 more than new diesel trucks so many are converting existing diesel engines to hydrogen fuel cell technologies. Consequently, it is likely that skills for conversion will continue to be in demand as heavy vehicles are converted to hydrogen. Overall, it is predicted that there will be a skills shortage of 6,000 electrical vehicle technicians by 2030, as ZEVs start to gain popularity[104]. There is currently an urgent need to begin upskilling and reskilling new apprentices and existing workers to prepare for this shift towards hydrogen.

As heavy diesel vehicles move towards using hydrogen and new FCEVs are utilised, there will be less demand for diesel mechanics and more for mechanics with electrical expertise. It is anticipated that there will be an overlap of need for diesel engine and fuel cell technology skills for a period of time. At an unknown point in the future, a teach-out period for the Certificate III in Diesel Technology will need to be mandated.

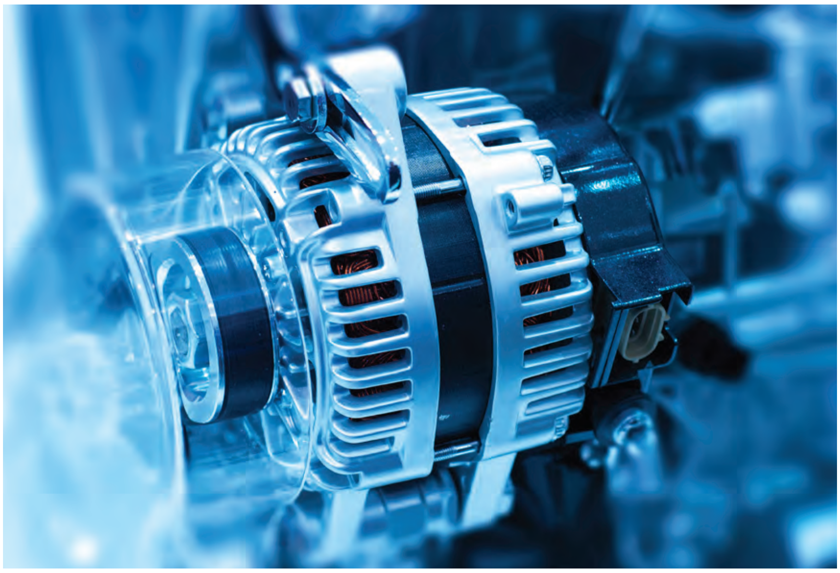


Image 18. Mechanics and automotive workers will require reskilling to work with hydrogen engines

Transport and logistics

Job requirements for employees working in transport and logistics include driving trucks and vans, working in various roles in freight rail networks, and supply chain operations (which includes logistics and transport scheduling and transport clerks). Some qualifications required for this workforce include furniture removal, traffic control, wharf operations (including stevedoring), crane operating, crane driving instructing and train driving. At 60%, road freight employment and truck drivers make up the highest percentages of occupations in the sector, followed by bus, coach and automobile drivers[105].

KEY POINT

All vehicles that currently use diesel for fuel are expected to become hydrogen-powered at some point in the future.

A Certificate III in Driving Operations will qualify an employee to work as a bus, coach, tip truck, concrete mixer, tow truck or waste vehicle driver. However, in each state, certain licenses and on-the-job training will also qualify a worker to be a professional driver. In Victoria, to drive a gross vehicle mass (GVM) vehicle greater than 4.5 tonnes or a bus that seats more than twelve people, a heavy vehicle licence is required. The licence has five categories with different criteria for licensing[106].

Existing training

TLI Transport & Logistics Training Package

In response to requests from bus and coach stakeholders who work for transport operators, two new electric units of competency have been created and are currently at the validation stage[107]. The 'Operate a battery electric bus and coach' and 'Operate a battery electric heavy vehicle' units will provide workers with the required skills and knowledge for working with and operating battery-powered electric heavy vehicles. Currently, there is no training available or FCEV awareness education for drivers or other transport workers in Australia.

Skills for FCEV transport

In the transport sector, heavy vehicle and fleet car drivers must be targeted initially due to rapid and imminent development in this sector. Hydrogen fuel cell vehicles drive differently to combustion engine vehicles, as they use a greater torque and more advanced technology. Additionally, liquid hydrogen fuel is stored under extreme pressure at -40 degrees, so the fuel pump feels cool to the touch. Hydrogen-powered vehicles are very quiet, much like their electric counterparts, however energy flow screens display whether electricity is being drawn from the battery, fuel cell, or both, when the driver accelerates. These differences are significant enough for Hyzon to offer a driver's course to experienced drivers, to teach them how to get the best performance out of hydrogen-powered vehicles.

Indirect to hydrogen but related to the technologies that will exist in FCEV heavy vehicles, digital knowledge and skills required to work with telematics in transport and logistics operations may be required. In base-to-base vehicle operations, telematics supply data about vehicle location, driving speed and distance travelled. Base workers will be able to analyse freight weight in relation to the consumption of fuel and road conditions; these skills will require the involvement of engineers and software specialists.

KEY POINT
Hydrogen is set to become be a major export in the future. It is vital that drivers who are currently driving diesel trucks have the skills and knowledge to safely transport hydrogen.

Future mobility

With developments rapidly occurring across the transport and mobility sector for light and heavy road vehicles in Australia, more opportunities for transition to FCEVs are on the horizon. The following sectors have been identified as potential areas for growth, once hydrogen costs and infrastructure allow for a feasible shift:

- **Shipping:** ammonia is a potential source of low-emissions maritime fuel, particularly for ships that spend a long time at sea, such as cargo ships[108]. The current marine training package requires updating to upskill engine drivers, mechanical workers, and related employees.
- **Rail:** a feasibility study is underway in Queensland to explore whether hydrogen fuel cells can be used in heavy freight rail operations[109].
- **Aviation:** Airbus is planning on collaborating with other stakeholders to develop the first zero-emissions commercial aircraft by 2035[110]; Andrew Forrest has signed an MOU to cooperate in the development. In coming decades, as hydrogen may be used for aviation fuel and to generate synthetic e-fuels[111], the existing aviation training package and industry training will need revision and innovation to facilitate skills training for pilots, ground crew and other workers.

Other job roles that may be impacted by hydrogen in the transport and mobility industry include:

- Mobile plant machinery workers, including those in the mining industry
- Farmers and agriculture workers
- Forklift drivers
- Logistics managers and coordinators
- Logistics administration workers
- Depot managers
- Regulative and safety experts
- Computer scientists and software specialists
- Sales managers
- Environmental, automotive, software, electric, mechanical and industrial engineers.

Skills gaps for the transport and mobility sector

The existing skills gaps for automotive service and maintenance workers and heavy vehicle drivers are identified as the most immediate and urgent. The electrical and gas components of working with hydrogen fuel cell-powered vehicles are predominantly new to diesel mechanics and unfamiliar to the industry; current automotive electricians will be capable of leveraging some skills but will need further understanding of electricity and gas working together to power an engine. Bus and truck companies will also require immediate awareness education around hydrogen, with upskilling and reskilling opportunities to follow for drivers and mechanics. Industry has informed this Roadmap that the skills of working with fuel cells and small-bore tubing systems are also a significant skill gap for mechanics and auto electricians. It is a technical area that particularly requires a micro-credential to be developed with specialised subject matter experts. It is anticipated that it may take up to two years for training packages to develop new units, and for registered training organisations to develop training and assessment materials that address skills gaps. The table below identifies the immediate skills-based topics required to address gaps in the transport and mobility sector.

MICRO-CREDENTIALS	DIESEL MECHANICS	AUTO TECHNICIANS AND MECHANICS	AUTO ELECTRICIANS	DRIVERS	LOGISTICS WORKERS
Hydrogen fundamentals	●	●	●	●	●
Safety emergency response	●	●	●	●	●
Understanding of electrolysers and fuel cell technology	●	●	●	●	●
Understanding regulations	●	●	●	●	●
High voltage small-bore tubing	●	●	●		

Table 8. Skill-based gaps in transport and mobility sector training

Manufacturing

Highlighted in Beyond Zero Emissions' Million Jobs Plan[112], Australia has strong potential to rapidly become a leading manufacturing nation in the production of renewable hydrogen. This opportunity would create thousands of jobs for the future workforce, with heavy-duty transport, ammonia and steel production expected to be three key sectors where renewable hydrogen would be predominantly used[113].

In the freight and transport industry, it is expected that hydrogen-powered trucks will be widely used once the price per kilogram for hydrogen reaches $3.50 . Additionally, it is predicted that by 2030, renewable hydrogen will be used as a feedstock for ammonia production[115], with several Australian fertiliser companies planning to use renewable hydrogen in ammonia plants. For example, a Queensland Nitrates facility near Rockhampton has pledged to produce 20,000 tonnes of green ammonia annually[116].

> "A significant part of the 'hydrogen economy' will be the use of ammonia. In many respects, this is more dangerous than hydrogen, and the lack of available training as well as a lack of hydrogen knowledge and expertise are the barriers to training and the use of ammonia."
>
> Consultant
> **VH2 Online Survey**

This predicted growth of hydrogen being utilised in these industries will create additional jobs within the manufacturing sector, resulting in an impending need for hydrogen-specific training. Additionally, with the steel manufacturing industry bringing strong potential to supporting Australia's emerging hydrogen economy, 25,000 jobs may be generated throughout the industry in the near future, predominantly throughout the identified regions of the Hunter Valley and Central Queensland[117]. In the next five years alone, 5000 jobs are expected to be created as a result of early employment potential coming from the initial emergence of a green steel industry.

As fuel cells are currently being manufactured overseas, the emerging domestic hydrogen economy will see production moved to Australian soil as FCEVs, electrolysers and other hydrogen-related products become more widespread nationally. To respond to this potential for domestic manufacturing, the Deakin Hycel Project situated in southwest Victoria will be developing and testing fuel cells to scale. As fuel cell production is a manual-intensive job, workers within the hydrogen manufacturing sector must be well-equipped with hydrogen and electrical-related knowledge.

In an analysis of the existing Automotive Manufacturing Training Package and Manufacturing and Engineering training package, there are currently no units of competency covering hydrogen information. As engineers have the skills and capabilities to repair, maintain and install electrical systems and equipment in buildings, oil and gas installations, mine sites and processing facilities, it is essential that hydrogen skills are targeted in the manufacturing training package.

Other jobs that play important roles in the manufacturing sector include technicians, manufacturing plant process workers, fuel cell and electrolyser manufacturers, manufacturing supervisors, managers & quality control inspectors. For the manufacturing industry to grow domestically, continuously and exponentially, hydrogen upskilling will need to take place.

Automotive manufacturing

In alignment with potential growth for the hydrogen manufacturing sector across Australia, the hydrogen-powered automotive manufacturing industry also has the opportunity to become a leading sector domestically. The manufacturing requirements of hydrogen automotive and related vehicles requires the workforce to draw on skills in automotive design, systems integration, and component manufacturing. This is all dependent on hydrogen production and supply.

> "Over 100 localised engineering and manufacturing jobs are expected to be generated through the new [Hyzon Motors] facility by 2025, with hundreds more indirect jobs expected through the supply chain."
>
> **Prime Mover Magazine**

One major project currently occurring in the automotive manufacturing sector is the collaborative Hyzon Motors facility currently being built. This purpose-built facility developed by Hyzon and the RACV is designed to invest in clean energy production for the hydrogen-powered vehicle manufacturing sector in Noble Park, Victoria. This shift towards renewable hydrogen-powered vehicle manufacturing will continue to generate workforce opportunities as Australia continuously strengthens its capabilities in hydrogen manufacturing and production[118].

Image 19. Manufacturing will be significantly impacted by the burgeoning hydrogen economy

Emergency responders

The Australian emergency services workforce is currently made up of 400,000 emergency services workers, including 200,000 volunteer first responders across Australia.

These professionals include firefighters, state emergency service (SES) workers, lifesavers, marine rescue personnel and volunteer rescue personnel[119] who are typically the first to arrive at a scene of crisis to perform medical and critical public services to Australians. Police, ambulance workers/paramedics, defence officers and tow truck/vehicle recovery operators are also identified as emergency workers. This workforce must have the capacity to deal with probable events or accidents involving fuel cells and hydrogen systems, vehicles, and infrastructure in a reliable, consistent, and protective manner. Their roles underpin supporting a safe and reliable transition towards using fuel cell-powered vehicles and implementing a widespread hydrogen infrastructure[120].

Existing training

In the United States, a considerable effort has already been made to train firefighters, police officers and medical personnel to respond to critical hydrogen-related situations. Many hydrogen training programmes have been designed to educate and train first responders about using electric vehicles, including hydrogen fuel cell-powered vehicles (FCEV) and hydrogen fuelling infrastructure. Existing international hydrogen training programs also include components that address hydrogen awareness, as well as the technical aspects of operating hydrogen-powered vehicles.

HyResponse, an international emergency response hydrogen training organisation, offers a program across Europe that provides first responders and site operators with technically accurate safety and emergency response information. In particular, these programs assist participants in understanding how to respond to incidents and accidents involving hydrogen and fuel cells[121]. Offered through an online training platform, this program covers three main components:

- hydrogen safety basics
- regulations, codes and standards
- the intervention strategies and tactics relevant to First Responders[122].

Image 20. Emergency services will require vital hydrogen training

The American Institute of Chemical Engineers Academy (AIChE Academy), a world-leading organisation for chemical engineering professionals, also offers multiple hydrogen safety eLearning courses for emergency responders globally[123]. These short courses focus on providing first responders with information regarding handling, storing and using hydrogen for fuel cell applications. The AIChE Academy has also developed the Centre for Hydrogen Safety (CHS), a global non-profit organisation dedicated to promoting hydrogen safety and guiding companies to use best practices as they transition into a hydrogen economy[124]. CHS is partnered with 93 worldwide companies to ensure that the delivery of hydrogen education and training offerings is widely accessible. The above hydrogen training model is referred to in the training program proposed by the Australasian Fire and Emergency Service Authorities Council (AFAC).

Details of international training offerings can be found in **Appendix J**.

Australian initiatives

In Australia, H2 Advantage offers hydrogen training courses that partially pertain to the hydrogen training requirements of emergency responders in Australia. While their training programmes are not exclusively designed for emergency workers, they cover relevant material regarding hydrogen fundamentals and safety for emergency responders[125].

> "Appropriate training for emergency services on how to deal with a hydrogen-related incident is essential to minimise the risk to themselves, others and property and equipment"
>
> **Australia's National Hydrogen Strategy**

Australia's National Hydrogen Strategy states that consultations between the Australian Industry and Skills Committee and Public Safety Industry Reference Committee will occur to 'update training packages for hydrogen safety, including the Public Safety Training Package that contains training materials and guidelines for managing emergencies'[126]. However, in consultation with the National Council for Fire and Emergency Services (AFAC) and referenced in the emergency responders' Training Needs Analysis Report, it was revealed that there will be no changes to the Public Safety Training Package.

Instead, three recommendations have been made:

- Develop a training collaborative group
- Develop a sustainable training and funding model
- Develop hydrogen training framework and portal[127].

The AFAC, along with NSW Fire and Rescue, plan to provide hydrogen skills and knowledge through segmented training offerings. Hydrogen-specific training materials will be made available in three areas[128]:

- Hydrogen awareness: to be delivered via eLearning and cover fundamental hydrogen knowledge such as physical and chemical property identification, industry and end user applications, and incident response guidelines and preparedness.
- Specialist responders: to be delivered face-to-face and cover more advanced and detailed training in hydrogen response. This program will be offered to specialist rescue and hazmat responders.
- Train-the-trainers: to be delivered face-to-face and prepare 'hydrogen trainers' within each AFAC agency.

Concerted effort has been made by the AFAC to propose training frameworks for firefighters and rescue personnel. The Roadmap is unaware of time frames for development and implementation. While many existing skills may be applicable in hydrogen-related circumstances, 'hydrogen-ready' emergency workers will need to be qualified and trained to safely work with hydrogen and respond to hydrogen-related incidents in the not-too-distant future.

The Roadmap was unable to engage the Victorian Police Force or Ambulance Victoria.

The emergence of hydrogen

Sectors likely to be affected

The following sectors are expected to be affected by the imminent introduction and emergence of hydrogen in various capacities. This list is indicative and is not exhaustive.

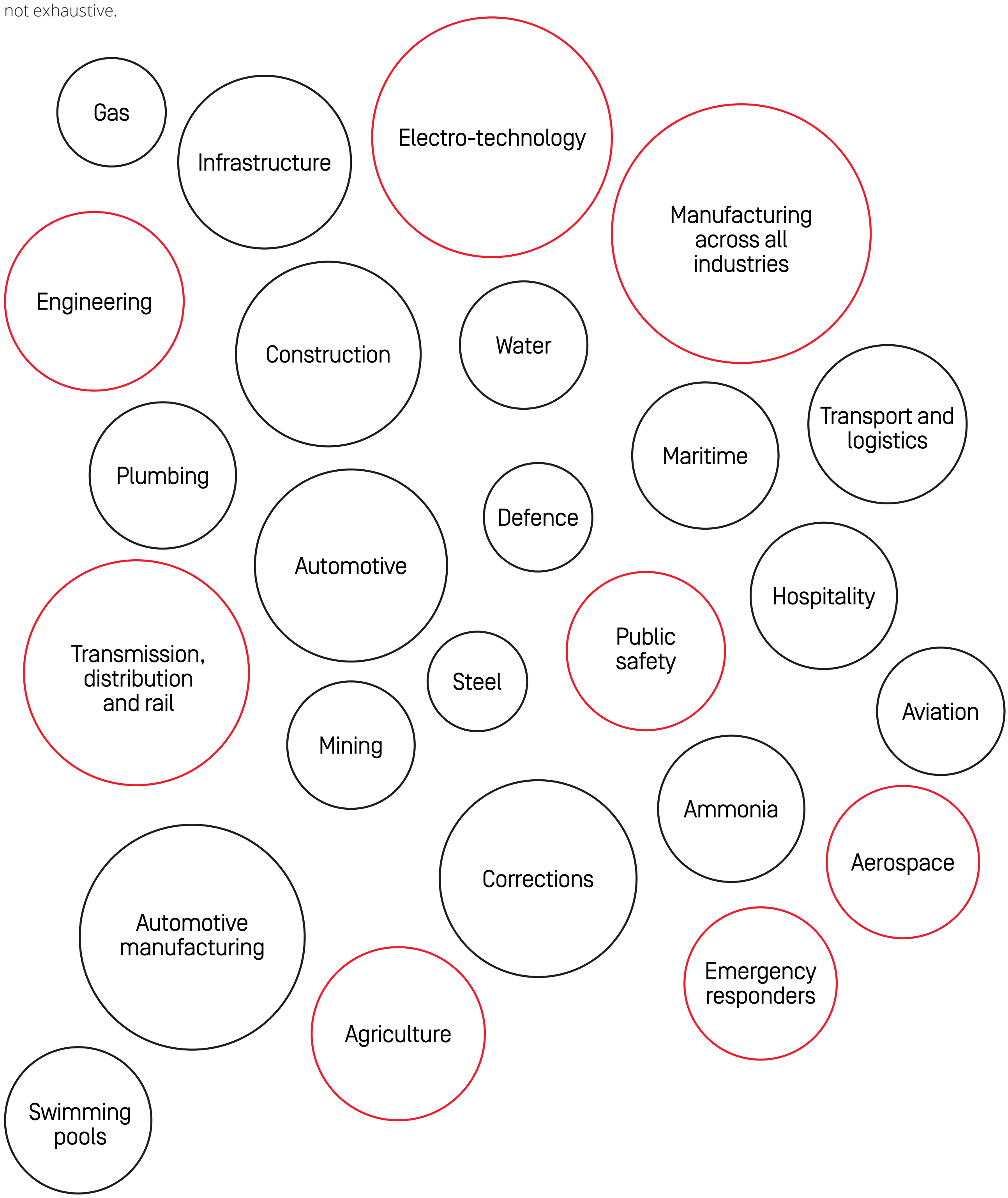


Figure 11. Sectors likely to be affected by the emergence of hydrogen

Train-the-trainer

In Australia, trainers who teach and assess nationally accredited training courses must abide by the Australian Skills Quality Authority (ASQA) Standards for Registered Training Organisations (RTOs).

These standards stipulate that trainers are required to maintain industry competencies at the level at which they are training (at the least) and must show currency in their acquired skills and knowledge in their respective areas of expertise. Furthermore, RTOs must collect evidence that demonstrates a trainer/assessor's current industry skills and knowledge, which will be hydrogen-related in this case. The evidence of this competency must directly correlate with the content of each accredited unit that the trainer teaches or assesses[129].

Demonstrating industry currency may include a variety of examples below:

- volunteering or working part-time in the industry field
- undertaking accredited training relevant to the industry field
- belonging to industry associations
- engaging with industry (for example, through discussions with employers or attending industry networking events)
- reading industry journals and subscriptions
- staying informed about changes to technology
- keeping up to date with changes to legislation[130].

Whether a trainer is teaching accredited or non-accredited short courses or workshops, it is expected they possess knowledge and skills in the subject matter at a deeper and broader level than their learners. Industry newsletters may keep trainers up to date with the latest technologies and progress, however they are not considered to be appropriate training resources. Short courses or micro-credentials focusing on hydrogen fundamentals might include content on safety and emergency response, understanding electrolysers and fuel cell technologies, following legislation, and gaining relevant and necessary knowledge. However, a range of workplace contexts as well as technical and practical knowledge must be absorbed by a quality trainer to train and assess learners confidently and before entering a classroom or workplace.

Desktop research has revealed that the two major hydrogen courses being offered to industry are delivered by trainers who have over 40 years' experience working with gases and research in hydrogen and related subjects, or, in the second case, have many years extensive experience working in hydrogen businesses and projects. With the hydrogen economy only beginning to emerge, trainers with extensive hydrogen knowledge and workplace contextualised skills will be difficult to find. As hydrogen is considered to be a young industry, skills from the ammonia, fertiliser, gas, plumbing and other related sectors will need to be leveraged to upskill trainers; however, some sectors—such as the automotive sector—are still in their infancy in terms of available transferrable hydrogen skills.

It is recommended that the development and implementation of hydrogen train-the-trainer courses include:

1. Collaboration with industry specialists in trainers' own sectors.
2. Collaboration with hydrogen gas specialists.
3. Collaboration with industry reference groups.
4. Collaboration with OEMs.
5. Identification of Hydrogen Training Champions, and the provision of incentives for mentoring opportunities.
6. Arrangement of formalised visits to hydrogen research hubs and working facilities.
7. Consideration of the kinesthetics learning style and practical applications used by trades people and the importance of demonstrations and examples of working hydrogen equipment and systems.
8. The provision of funding and manufacturing opportunities for training equipment resources be made freely available to Australian training institutions.

Available training resources

A desktop audit of available training resources revealed a limited amount of resources.

NAME OF RESOURCE	ORGANISATION/ TRAINER	WEBSITE/ CONTACT	DESCRIPTOR
Fuel cell technology **STEM resources** **Renewable energies**	Training Systems Australia	Fuel cell technology UniTrain Course trainingsystemsaustralia.com.au	Supplies training equipment blended learning solutions and courseware including: Electrical and Renewable Energies teaching equipment and courseware and offers fuel cell training resources
Hydrogen Fuel Cell Education and Training	EDQUIP Timo Wohlin-Elkovsky	Hydrogen Fuel Cell Education & Training edquip.co/en/blog/training-education-hydrogen-fuel-cell-systems	Hydrogen fuel cell training systems and equipment e.g. H2Hybrid Fuel Cell Automative Trainer, Fuel Cell Trainer (PEM fuel cell systems)

Table 9. Available hydrogen training resources

Standards and regulations

Australia's National Hydrogen Strategy has identified 730 pieces of legislation and 119 standards that will potentially impact the hydrogen industry and supply chain.

In August 2021, the ME-093 committee was formed to review international hydrogen laws and revise, integrate, and contextualise gas standards for Australian use at a national level. The ME-093 committee is currently consulting with a wide range of stakeholders; energy ministers have agreed that a draft of these regulations will be completed by mid-2022[131].

Hydrogen industry workers will also be required to work within defined state and territory rules and regulations. While the national strategy is calling for consistent regulation and a coordinated approach, some Australian states and territories have differing definitions for gas and cannot agree on definitions for Type A and Type B appliances. Some states and territories operate under a single Act that addresses gas transmission, distribution and end use. In other states, each section of the gas supply chain operates under a separate Act[132]. Adding to this complexity, most gas fitters and electricians do not have their licences recognised in other states because of differing regulations and training. At this stage, it is anticipated that state and territorial differences are likely to remain unreconciled, even if all state and territory jurisdictions use national standards and regulations suggestions to build their individual regulations.

Nine new standards for Australia have already been adopted, while the ME-093 committee are researching the following areas:

- Production, handling, and storage
- Pipeline and gas distribution networks
- End use applications
- Fuel cell applications
- Mobility use applications[133].

Energy Skills Queensland and the Gas Industry Reference Group have worked in collaboration to suggest a combination of the Australian Technical Standards for electrolysis and storage with the current standards for fuel cells to support the development of hydrogen regulation uniformity. A representative of Energy Skills Queensland indicated to the Roadmap research team that this has been suggested to the ME-093 committee, as these interim standards will allow for the development of much-needed training programs and regulations in a shorter time frame (approximately six months compared to two to four years for the development of full standards). This will help expedite informed quality training for existing workers and hydrogen trainers by providing a crucial framework for the development of hydrogen training materials. A final decision had not been made at the time of writing.

One stakeholder who was engaged in the development of this Roadmap report stated the following:

> "It is not [lack of] skills holding back the hydrogen economy from thriving in the face of climate change but a lack of clarity in standards and the regulatory environment. If hydrogen projects are to progress quickly to reduce carbon emissions, government needs to move faster with regulations."

Consultation has also highlighted the urgency in equipping regulators with relevant underpinning hydrogen knowledge to ensure that the decisions they make in designing and implementing hydrogen regulations are appropriate and realistic so that hydrogen industries can grow and prosper in accordance with the ambitious goals set by government and the gas industry.

Training for regulators

Across many sectors, regulators are not considered to be industry members; rather, they are considered to be government employees who must gain the appropriate hydrogen safety-related knowledge before developing and implementing regulations that industry members must adhere to.

Australia's National Hydrogen Strategy has enlisted the support of the South Australian government to train regulators and assess whether the initial training materials developed for emergency responders would also have application as an introductory training package for regulators. It is expected that regulators will have access to this training well before July 2023, with a further analysis of training needs conducted during this time.

All Australian state governments are continuously liaising directly with relevant state regulators in relation to hydrogen regulator training projects occurring in each jurisdiction, in addition to existing national regulatory projects that are underway. With the widespread introduction of hydrogen to Australian industries still dawning, and with pioneering regulator training projects beginning to take their first steps, all stakeholders are experiencing a learning curve. To build a comprehensive knowledge bank for the burgeoning hydrogen regulatory environment, it is vital that all stakeholders are engaging and learning from each other.

Deakin University's natural gas to hydrogen boiler conversion project is a good example of the facilitation of an environment of continuous learning and feedback. The execution of this project has prioritised safety and regulatory requirements from its early stages, with an external review committee of representatives employed to support the development and intersectional transmission of regulatory knowledge requirements. These representatives include Energy Safe Victoria, the Victorian Building Authority, Worksafe Victoria, the Australian Gas Association and industry experts including licenced plumbers, small-bore specialists and industrial hydrogen specialists. This project's aim is to demonstrate hydrogen applications whilst contributing to the development of hydrogen safety, standards and regulations, specifically in Type A gas appliances. The project model allows for the cross pollination of knowledge, problem-solving skills and ingenuity amongst industry representatives, supporting the navigation of a new regulatory pathway and thus enabling the broader uptake of new hydrogen technologies.

By involving regulatory bodies in new and planned projects, the intersectional provision of hydrogen-related knowledge will continuously allow for regulatory standards to be developed in association with industry requirements. Given the lengthy timeline to formalise training for regulators, incorporation of regulatory bodies into hydrogen projects in Victoria and across Australia needs to be encouraged.

Standards and regulation training for industry

Energy Safe Victoria, the Victorian Building Authority (VBA) and Master Plumbers have run a series of webinars for gasfitters and Type A appliance servicing gasfitters to provide updates on regulatory changes concerning AS/NZS5601.1:2022 and give an update on hydrogen. The standards related to hydrogen will be the next focus for the regulators. Therefore, industry has some time to wait before regulations are confirmed and disseminated.

Future jobs and skills trajectory

Combining the analysis and modelling of the future green hydrogen economy, the emergence of jobs being impacted by green hydrogen-related changes over the coming decades is predicted in the figure below.

As the industry rapidly evolves, these predictions are subjected to change. The introduction of new technologies, implementation of new regulations and adoption of hydrogen to scale is expected to result in jobs needing to be filled earlier than anticipated.

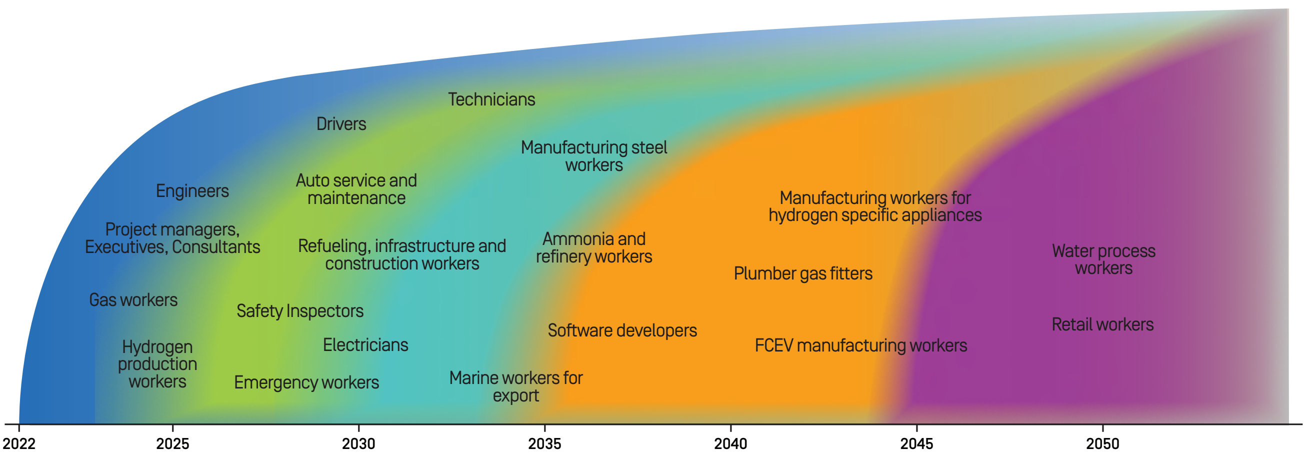


Figure 12. Predicted emerging jobs in various industries driven by green hydro

Summary and key findings

The Hydrogen Skills Roadmap Report has taken a broad approach to examining and assessing existing hydrogen-related skills and educational offerings as well as potential future opportunities in Australia.

This report outlined the basic technological uses of hydrogen and the existing supply chain throughout related industries, whilst capturing current hydrogen training on offer both internationally and across all education sectors in Australia. The research team behind this report has engaged with a range of representatives from industries currently being impacted by the introduction of hydrogen and has analysed a large collection of feedback from representatives from the gas, transport, plumbing, construction, and other hydrogen-related industries. This report also envisioned a potential trajectory for future training demands in hydrogen-related industries and education sectors, whilst also identifying existing and future jobs, skills gaps and requirements for training and education.

It was found that there is little or no current hydrogen training across school, vocational education training (VET) and higher education in Australia. International hydrogen education opportunities are more visible and advanced, particularly the United States, with their first responder training, and in Europe, where higher education and general hydrogen industry programs and resources are more abundant. In Australia, there is a currently a heavy reliance on OEMs to guide companies and deliver training.

The gas, automotive and transport sectors were found to be the most quickly and significantly impacted by the emerging hydrogen economy. FCEV buses and coaches will be utilised in the near future and plans for FCEV heavy vehicle manufacturing is well on its way. Diesel mechanics will need to learn unfamiliar skills such as fuel cell technology and high voltage work that has gas and electricity intersecting. There will be a teaching out period for diesel skills in the coming decades; the timing of which is dependent on the uptake of FCEVs. The technical skills gaps analysis and the development of training programs and resources for mechanics need to commence in earnest now, to avoid a skills shortage and to prevent hindering the growth of hydrogen fuel. Skills for infrastructure such as refuelling stations might not necessitate intensity in the upskilling of mechanics but skills and knowledge will need to be developed, nonetheless.

For the gas industry, it appears that the skilling up of workers is more of an evolution than a revolution[134] as most gas workers and plumber gas fitters will be able to leverage existing skills. Although Australia is behind the rest of the world in its advancement in hydrogen, the gas industry has set keen articulated goals. Changes to their national training package have been made and training and assessing resources are beginning to be developed, along with research, hubs and other training already in the pipeline. The gas industry appears to have made a promising start for the steady upskilling of gas workers. Industry leaders who were consulted were very aware of gas and electricity intersecting hydrogen demands for future jobs.

Engineers and researchers are currently in demand as the hydrogen economy begins its technological creep into various industries, according to the analysis of jobs advertised in the hydrogen economy. It is vital that schools prepare young workers for the future, alerting them to hydrogen-related opportunities not only for higher education jobs such as engineers and researchers, but for all jobs across the hydrogen supply chain; giving them a good grounding in hydrogen technologies and inspiring designs of the future.

National training packages, training organisations and industry bodies have traditionally always participated in a consultative process. Higher education institutions will need to liaise with industry hydrogen specialists and/or international universities to develop relevant programs. Universities will need existing hydrogen researchers and engineers to inform curriculum, and design new postgraduate courses that can continuously support a growing hydrogen economy.

The Roadmap found through its job analysis that higher-level jobs; the people who will lead the industry forward, are the first job cohort to be sought after. While gas executives may springboard off their existing knowledge, findings from the survey and consultations identified that other sectors such as manufacturing, and bus and truck companies, will need guidance and knowledge of the benefits of hydrogen and the different ways to utilise it in their business. Leadership roles are key for upskilling and building the economy.

Hydrogen knowledge and education is still in its early planning stages, and Australia is beginning to see hydrogen expertise being adapted in various industries. Currently, we are seeing a steeper curve in innovation rather than in the implementation of skills on the ground. Hydrogen skills training is not an urgent and immediate need in certain industries. However, it is anticipated that this need will grow over the next five years. It is imperative that training packages are updated to include hydrogen content as soon as possible, and that the emerging hydrogen workforce is given opportunity to gain a general awareness of hydrogen and safety to facilitate engagement and smooth transitions.

The acceleration of the need for hydrogen-skilled workers is dependent on the predicted reduction in cost of renewable energies for the production of hydrogen. Gas blends will also play a significant part in the planning and implementation skills programs. One of the major findings from this report revealed that when moving the future workforce through transition, hydrogen preparedness and awareness is perceived to be the initial priority for training. This is also supported in a report by The Reliable, Affordable, Clean Energy for 2030 Cooperative Research Centre (RACE for 2030)[135]. The best place to start is awareness.

As the hydrogen economy moves forward in the next five years, it will appear substantially different to the economy of today, requiring significant shifts in jobs and skills, as well as a larger hydrogen workforce once production scales up. There will be a growing demand for skilled and hydrogen-aware engineers, managers, gas workers, manufacturing workers (e.g. FCEVs manufacturing, electrolysers and fuel cell manufacturing, hydrogen-specific appliances manufacturing), mechanics, drivers, plumbers, emergency workers, refuelling and infrastructure workers. For a detailed list of hydrogen-related jobs, please see **Appendix G**.

With an industry still in its infancy, knowledge and skills belong to a minority. Because of this, the development of quality train-the-trainer programs will need the expertise and collaboration with industry reference groups that include OEMs and experienced hydrogen professionals. Standards and regulations are also pivotal in implementing hydrogen training and education. Industry leaders are concerned about the difficulties of designing training materials without access to appropriate standards. As such, hydrogen-related standards are viewed as a key issue that must be rapidly addressed.

It will take some years for revisions and course development of national training packages. Achieving accredited training package competency in units can often mean taking time off work to complete training that traditionally consists of classroom-based learning as well as written and practical assessment tasks. This may not be an option for full-time workers, especially those in remote or regional areas. Furthermore, while the new training packages will skill up new entrants, existing workers may not have recourse to upskilling opportunities as they require them. Existing workers will find themselves with skills gaps once hydrogen has scaled up. Therefore, a carefully planned rollout needs to be considered with education that is accessible to all. A suite of nationally available micro-credentials developed in collaboration with industry subject matter experts can address the urgent skills gaps while training packages catch up, and importantly, raise awareness for industry workers across a range of industry sectors. Topics identified are:

- Hydrogen fundamentals
- Hydrogen safety
- Emergency response
- Understanding regulations
- Electrolysis and compressors
- Fuel cells
- Appliance installation
- Hydrogen batteries & installation
- Transport bottles
- Hydrogen vehicle drivers
- FCEV service, maintenance and repair
- Small-bore tubing skills.

This report reveals a number of key findings about current skills and current and future needs for hydrogen training and education:

- Hydrogen safety and awareness is the first step.
- Hydrogen will replace current energy sources, so awareness of hydrogen management is required. This will be built on existing skills in several sectors such as gas and ammonia.
- Hydrogen is progressing most quickly in the areas of gas pipelines and heavy vehicles. Hence, heavy vehicle drivers and maintenance/services workers need upskilling as a priority.
- Gas workers and plumbers have pre-existing and transferrable knowledge and skills to be rapidly upskilled to work with hydrogen.
- Industry is relying on manufacturers' guidance for operation and maintenance of hydrogen equipment such as electrolysers, fuel cell hydrogen-powered trucks and buses.
- Electrical knowledge will need to be acquired across a number of trades and job roles (e.g. car mechanics, energy generation workers, gas workers, plumbers).
- Diesel mechanics have urgent re-skilling requirements.
- There will be a bridging time between old technologies and new. For example, in the automotive industry, existing workers and graduates will need to know and use skills related to both combustion diesel engines and fuel cell technology.
- Little training exists for trades industries at the executive/ managerial level.
- Incomplete Australian standards are a barrier to progress in projects and training development.
- High demand for engineers and high-level workers in the hydrogen sector currently.
- Engineers are identified as a job role that needs immediate hydrogen-related learning and it would be wise for universities to design hydrogen-related units as soon as possible, for inclusion in relevant undergraduate Engineering and Technician courses.
- VET sector, industry and government have a strong appetite not to overlap efforts.
- There is a great need for a train-the-trainer course.
- Schools have little hydrogen-specific curriculum and teachers may have little knowledge of hydrogen.
- Universities offer little in hydrogen-specific programs.

Recommendations

To meet the immediate and long-term needs of a rapidly developing hydrogen market, a number of recommendations are outlined below that involve collaboration between all stakeholders—governments, regulators, industry and academia:

- Hydrogen content to be introduced to primary and secondary school curricula to facilitate the younger generation's engagement and preparedness.
- Hydrogen subjects and industry engagement programs to be included in higher education and/or integrated into courses across Commerce, Law, Business and Engineering degrees.
- Collaboration with industry to identify further technical skills gaps for trades and gas-related workers to inform national training packages and future skills development.
- National hydrogen train-the-trainer program to be designed and implemented in collaboration with industry groups across the supply chain and hydrogen hubs.
- A national suite of industry-informed hydrogen micro-credentials to be developed and made available that address immediate training needs.
- Further research to be undertaken to analyse specific skill sets within the gas and hydrogen economy.
- A Hydrogen Skills Centre to be established to leverage research and grow skills and knowledge.

In conclusion, the research and findings from the Hydrogen Skills Roadmap hopes to help guide policy makers, industry and training bodies by providing consideration of the skills, training and education required for a successful transition over the next decades to a flourishing hydrogen economy.

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APPENDIX A

Abbreviations, acronyms, and definitions

AIS	Australian Industry Standards, a Skills Service Organisation that supports 11 industry reference committees including the gas industry.
Ammonia	A compound of hydrogen and nitrogen that can be used to transport hydrogen in liquid form.
ARENA	Australian Renewable Energy Agency
ATCO	An international organisation that owns, operates and distributes infrastructure assets (including gas) across Australia.
Blending	The process of adding hydrogen to natural gas pipelines, resulting in no significant impacts on gas quality, safety and risk aspects, materials and network capacity (providing the mixture is homogenous).
Blue hydrogen	Hydrogen produced using traditional production methods whilst using carbon capture, utilisation and storage to separate the carbon dioxide from the hydrogen.
Biogas	An environmentally friendly, renewable energy source produced when organic matter, such as food or animal waste, is broken down by microorganisms in the absence of oxygen. Can be used in a variety of ways (including as vehicle fuel, and for heating and electricity generation).
Brown/black hydrogen	Produced from brown/black coal, with emissions subsequently released into the atmosphere.
Brown/grey hydrogen	Most commonly derived from fossil fuels through steam reformation.
Carbon neutral	When carbon emissions are equally offset by other mechanisms and initiatives that reduce emissions, achieving a neutral state.
CCUS	Carbon capture, utilisation and storage—refers to a suite of technologies that capture carbon dioxide from large point sources, such as power generation or industrial facilities, that use either fossil fuels or biomass for fuel. The captured carbon dioxide is then compressed and transported to be used or stored.
Certification	A system in place to ensure that hydrogen purchased by a consumer is guaranteed to be produced sustainably.
CSIRO	Commonwealth Scientific and Industrial Research Organisation—Australia's national science research agency.
Decarbonisation	A process where sources of carbon emissions are reduced, resulting in lower overall emissions.
ESI	Electrical Supply Industry
Electrolyser	A device that splits water into hydrogen and oxygen using electrical energy.
Electrolysis	The process of using electricity to split water into hydrogen and oxygen using an electrolyser.
Energy carrier	A substance with the capacity to carry energy to be used later, including chemical fuels and batteries, physical devices such as capacitors or compressed air, and even hydrogen.
Energy provider	An entity that provides energy in consumable form for others, such as fuels or electricity; usually refers to companies, but can also refer to countries or regions.
FCEV	Fuel cell electric vehicle—an electric vehicle powered by a hydrogen fuel cell rather than electricity from batteries.
Fuel cell	A device that enables a fuel, such as hydrogen, to chemically react in stages, resulting in the production of an electric current.
Green hydrogen	Produced via electrolysis using an electrolyser powered by renewable energy sources such as solar or wind; whilst this method is not yet cost competitive at commercial scale, governments are placing a significant focus on it.
Grey hydrogen	Hydrogen produced from natural gas via steam reforming; the emissions are subsequently released into the atmosphere.
Heavy duty vehicle	A vehicle of over 4.5 tonnes gross vehicle mass.
Hydrogen	A colourless, odourless, tasteless, flammable substance that is the simplest chemical element in the periodic table. It is virtually non-existent in its free form on Earth, and requires energy to liberate it from the material forms in which it is found.

Hydrogen economy	A conceptualised economy where hydrogen is used as a significant fuel in a range of applications conventionally undertaken by fossil fuels and, sometimes, electricity; in a hydrogen economy, hydrogen is readily produced, bought, transported, and consumed.
Hydrogen ecosystem	A community consisting of all participants, including producers, transporters, consumers, designers, and manufacturers of hydrogen, operating in the theorised conceptualised economy.
Hydrogen embrittlement	A destructive chemical process where hydrogen reacts under special conditions with some metals (steel in particular) and causes them to become more susceptible to cracks and fractures.
IRC	Industry Reference Committee
Methane	Comprised of one carbon atom and four hydrogen atoms, methane (CH4) is the simplest hydrocarbon and is the main component of natural gas.
Methane pyrolysis	A chemical process that heats methane to very high temperatures, causing it to split into solid carbon and hydrogen gas (turquoise hydrogen); if the heating process is powered by renewable electricity, it produces no direct greenhouse gas emissions.
Natural gas	As an odourless and colourless fossil fuel formed from the decomposed remains of plants and animals, natural gas is used predominantly in residential homes for heating and cooking, as well as powering home appliances.
Net zero	An objective where greenhouse gas emissions are first reduced where practicable, then offset using verifiable offset products.
PEMFC	Proton Exchange Membrane Fuel Cells
Renewable energy	Energy that is collected from renewable resources, which are naturally replenished on a human timescale such as sunlight, wind, rain, waves, tides and geothermal heat.
Steam reforming	A chemical process where a hydrocarbon fossil fuel is stripped of hydrogen under pressure in the presence of water vapour; in addition to hydrogen gas, the process produces carbon monoxide and carbon dioxide.
Social license [to operate]	A contract between and the community indicating that an organisation and its practices are widely accepted.
Telematics	A term commonly used to refer to telecommunications, vehicle technologies, electrical engineering, and computer sciences in reference to commercial fleet vehicles, tracking, maintenance, monitoring and quality assurance.
Turquoise hydrogen	Produced when methane gas is split into hydrogen and solid carbon, and considered a clean form of hydrogen as solid carbon is a potentially valuable resource; this production method uses approximately seven times less energy than is required to release hydrogen from water.
VET	Vocational Education and Training
ZEV	Zero emissions vehicle – may be defined as motor vehicles that produce no ‘tailpipe’ emissions, such as FCEVs.

APPENDIX B

Australian hydrogen industry training (non-accredited)

Name of course	Organisation/ trainer	Website	Key learning objectives	Target audience
Hydrogen Fundamentals	TAFESA	https://www.tafesa.edu.au/xml/course/sc/sc_T533157536.aspx	• Hydrogen's advantages and challenges • Handling hydrogen • Hydrogen projects and opportunities	Building and construction; anyone interested in exploring opportunities diversifying their business or career into the hydrogen sector.
Hydrogen Industry Fundamentals	Informa, Dr Hugh Outhren	https://www.informa.com.au/	• Understanding hydrogen production methods, and costs of production • Exploring how hydrogen may be produced from renewable sources, including electrolysis, biofuels, and photolysis • Understanding hydrogen storage methods and estimated costs • Discerning possible future hydrogen transport methods—such as through compressed gas, via liquid, or through ammonia and naphthene—for an international market • Exploring how hydrogen is transported by pipeline, and the cost of transport • Learning how hydrogen is used in fuel cells for stationary and vehicle applications • Analysing the costs of different hydrogen production, storage and transport scenarios • Understanding how hydrogen will compete with conventional fuels for stationary and vehicle applications • Exploring the key barriers to overcome in developing a hydrogen economy	Managers; executives and staff from the electricity, gas, renewable energy and storage industries; regulatory bodies and government; banks; brokers; lawyers; consultants; industry advisors; major energy users and other industry professionals seeking more knowledge about the current electricity industry and future trends.
Hydrogen Safety Mobility Webinar	Petroleum Gas Inspectorate (Resources Safety & Health Queensland)	https://www.rshq.qld.gov.au/about-us/resources/presentations	• Understanding key legislative requirements and protocols for the transport and mobility sector • Strengthening knowledge of hydrogen regulatory bodies • Exploring hydrogen licencing requirements for worker authorisations in the gas sector	Gas industry workers seeking information on licencing and legislative requirements when working with hydrogen.
Hydrogen Fundamentals	H2 Advantage, Cranston Poulson	https://www.h2hadvantage.com.au/	• Analysing the properties and economics of hydrogen • Exploring hydrogen production, storage, and conversion technologies • Understanding hydrogen applications • Designing hydrogen plant and refuelling stations • Understanding hydrogen safety, standards, and emergency response requirements	Managers and executives responsible for strategic decisions about hydrogen technologies; engineers responsible for designing hydrogen systems; technicians and tradespeople responsible for building hydrogen systems and interested first responder trainers.
Hydrogen for Transportation	H2 Advantage, Cranston Poulson	https://www.h2hadvantage.com.au/	• Analysing the designs, manufacturers and maturity levels of hydrogen-powered FCEVs, buses, trucks, ships, UAVs, trains, bikes • Exploring the challenges associated with hydrogen transportation • Understanding project scoping, including siting, compliance, hydrogen supply and refuelling station design/configuration considerations	Managers and executives responsible for making strategic decisions about hydrogen technologies; engineers responsible for designing hydrogen systems; technicians and tradespeople responsible for building hydrogen systems; interested first responder trainers.
Hydrogen Safety (fire department)	H2 Advantage, Cranston Poulson	https://www.h2hadvantage.com.au/	• Developing an understanding of general hydrogen awareness, properties, and considerations for fire department employees • Understanding market movements and how the hydrogen industry is unfolding, including uses for fire departments • General emergency response complementing existing training being carried out in respective fire departments • Exploring hydrogen plant/product specifics as required	Fire department employees; managers and executives responsible for strategic decisions about hydrogen technologies; engineers responsible for designing hydrogen systems; technicians and tradespeople responsible for building hydrogen systems; interested first responder trainers.

Name of course	Organisation/ trainer	Website	Key learning objectives	Target audience
Hydrogen Plants	H2 Advantage, Cranston Poulson	https://www.h2hadvantage.com.au/	• Project development/scoping considerations • Design/configuration considerations • Plant build considerations— ner bold design, implementation, and sustainment	Managers and executives responsible for strategic decisions about hydrogen technologies; engineers responsible for designing hydrogen systems; technicians and tradespeople responsible for building hydrogen systems; interested first responder trainers.
Various hydrogen webinars and events	Engineering Education Australia,	https://www.engineersaustralia.org.au/learning-and-events/events-webinars-and-courses	• various	General audience.
Masterclass: Hydrogen – Fuel of Tomorrow	Charles Darwin University, Professor David Young (Dean of the College of Engineering, IT and Environment)	https://www.studyaustralia.gov.au/english/masterclasses/hydrogen---fuel-of-tomorrow	• Providing an introduction to hydrogen • Exploring technologies required or hydrogen to become the fuel of the future	General audience.
WSGG-STOP Western Sydney Green Gas Station Operations training course	EnerTrain, John Granat (Technical Training Manager)	www.enertrain.com.au	• Understanding the WSGG project and facilities • Gaining an awareness of hydrogen and its properties • Exploring hydrogen LELs ignition, flammability, flame & burning characteristics • Analysing hydrogen flame detection systems • Understanding hydrogen venting and purging operations • Exploring the hydrogen Joule Thomson effect • Understanding secondary main injection panels/gas panels, including: – Hydrogen rated valves, fittings, and pipework ratings – Methane process flow, pressures, and temperatures – Hydrogen process flow control, nominations, pressures, and temperatures – Methane and Hydrogen Over Pressure protection – Methane and hydrogen measurement – Methane and hydrogen leak detection, fixed and portable – SCADA interface, alarms, control philosophy, and setpoint control. • Using emergency equipment such as first aid kits, fire extinguishers, etc. • Understanding emergency response procedures • Exploring techniques to identify system faults and operational conditions • Using problem-solving techniques • Evaluating environmental site requirements • Understanding relevant workplace documentation	Existing Western Sydney green gas workers/employees.

Name of course	Organisation/ trainer	Website	Key learning objectives	Target audience
Tube Fittings Installation Essentials	Swagelok, OEM	https://ea.swagelok.com/	• Ensuring tube selection is correct, taking into account pressure and temperature variables • Preparing roper tubes, eliminating system contamination • Understanding best practice in tube preparation, care, and handling • Installing fittings correctly to ensure safe, leak-free installation	Fabricators, contractors, technicians, engineers and draftspersons working for companies that use Swagelok products.
Tube Bending Essentials	Swagelok, OEM	https://ea.swagelok.com/	• Determining the 'exact' length of tubing required to complete a job • Developing an ability to apply time-saving fabrication techniques • Reducing waste and scrape tubing through trial-and-error fabrication attempts • Saving time and resources during scheduled shutdowns or other maintenance	Fabricators, contractors and technicians working for companies that use Swagelok products.
Advanced Tube Bending	Swagelok, OEM	https://ea.swagelok.com/	• Understanding advanced tube bending, including multiple tube runs, dimensional bending, calculating angles and common offsets	Fabricators, contractors, and technicians working for companies that use Swagelok products.
Tube Fitting Installation Inspection	Swagelok, OEM	https://ea.swagelok.com/	• Understanding how to list common errors leading to tube fitting leakage • Identifying correct tube system design and practices • Installing tube fittings correctly • Identifying mixed material fittings • Understanding variables associated with proper tube selection • Identifying tube bending defects • Validating correct pipe thread usage and assembly	Fabricators, contractors, technicians, engineers and operators working for companies that use Swagelok products.
Hose Essentials	Swagelok, OEM	https://ea.swagelok.com/	• Defining common hose terms and terminology • Describing how to evaluate hose fit for purpose • Discussing hose selection variables • Following guidelines for hose installation • Understanding how to respond to common issues found in house applications	Technicians, engineers and operators working for companies that use Swagelok products.
Training for the New Hydrogen Economy (under development)	Australian Renewables Academy	https://www.renewablesacademy.com.au/training	• Development of a course that focuses on a trades skills pathway and course structure • Development of an articulation pathway from trades to tertiary qualifications • Development of courseware that addresses skills for the maintenance and operational support for Australia's emerging Fuel Cell Electric Vehicle (FCEV) heavy transport fleet	General audience.

APPENDIX C

International hydrogen industry training (non-accredited)

Name of training course(s)	Organisation/ trainer	Website/contact	Location	Learning outcomes	Target audience
Fundamentals of Green Steel	Charley Rattan, Associates & InformaConnect (Ammonia, Hydrogen and Offshore Renewables Business Advisor and Trainer)	https://www.charleyrattan.com/fundamentals-of-green-steel-3/	UK	• Understanding commercial considerations involving green steel, hydrogen and lessons learned • Gaining awareness of the Green Standards • Learning the techniques required for the production and use of green steel as part of net zero construction • Understanding practical risks and opportunities associated with the production and use of green steel, especially via the use of hydrogen • Appreciating the challenges around a net zero-aligned steel industry, support and bailouts • Exploring alternatives to green steel • Learning about real-world projects aimed at reducing CO_2 emissions in steel making • Understanding the differing perspectives of the investor, the operator, the customer and government • Recognising political and diplomatic implications of international trade in green steel including recent trends • Reviewing design, storage and hydrogen transportation considerations • Discovering the characteristics that broaden yet constrain the commercial and technical links in the 'supply chain' • Considering various options for green steel market developments	• Existing companies—particularly those who are already part of the steel supply chain and those looking to future-proof their capabilities. • Project developers seeking to decarbonise and source green • Infrastructure, financiers and the construction industry. • Construction, OEMs and plant organisations. • Engineering companies • Stakeholders from government, finance, consenting, and those wishing to understand the realities of green steel production.
Hydrogen as Energy Vector	European Multiple MOOC Aggregator (EMMA)	https://www.classcentral.com/course/emma-hydrogen-as-energy-vector-19653	USA	• Understanding the fundamentals of hydrogen technologies • Exploring how to store energy through hydrogen.	Electrical engineering students
Project development best practices for hydrogen Ensuring safe development of hydrogen economy Floating wind and hydrogen Integrating hydrogen with renewable power Hydrogen transmission in gas pipelines Hydrogen refuelling station technologies Hydrogen policy Carbon capture, utilisation, and storage Hydrogen storage, transport and distribution High-capacity underground storage Electrolysis technologies for green H_2 Blue energy islands Investment case for hydrogen Green hydrogen projects Giga-scale pathways for low-carbon hydrogen Hydrogen for power generation Biomass to green hydrogen Waste to hydrogen Technologies for turquoise hydrogen production Hydrogen business models and regulations Mineral industries and green hydrogen Wind and hydrogen Hydrogen and natural gas industry Clean hydrogen in power and heat Clean hydrogen in transport Clean hydrogen in industrial decarbonisation Clean hydrogen: key concepts Hydrogen safety master class	World Hydrogen Leaders	https://www.worldhydrogenleaders.com/courses	UK	See course titles.	Businesses, industries, and organisations currently working or planning to work with hydrogen and its systems, technologies, and infrastructure.

Name of training course(s)	Organisation/ trainer	Website/contact	Location	Learning outcomes	Target audience
Sustainable Hydrogen and Electrical Energy Storage	TUDelft OpenCourseWare, Prof. dr. Fokko Mulder, Prof.dr.ir M. Wagemaker	https://ocw.tudelft.nl/courses/sustainable-hydrogen-electrical-energy-storage/	Intl.	• Understanding the chain of hydrogen production, storage and use and the devices involved • Evaluating electrical storage in battery form • Analysing scientific advances required to bring forward hydrogen and batteries as energy carriers	• Not available
Mastering Clean Hydrogen	Infocus International	https://www.infocusinternational.com/hydrogen	Intl.	• Understanding independent perspectives on the markets and supply chain activities which will (and will not) drive demand for clean hydrogen	Renewable power developers, natural gas producers, industrial hydrogen users, electrolysis technology developers, fuel cell developers, gas distribution network owners, industrial gas providers, policymakers, low-carbon heat developers, transport OEMs, and investors (funds and project finance providers).
Renewable Training Modules	Pure Energy Centre	https://www.pureenergycentre.com/Training_courses/Hydrogen_training_course/hydrogen_course_content/hydrogen_course_content.php	UK	• Understanding hydrogen energy & storage • Identifying the current approach by industrialised countries to delivering energy security • Reducing energy insecurity • Understanding basic hydrogen technologies, production techniques and the market • Understanding electrolysers and their use • Evaluating hydrogen research and development opportunities • Complying with hydrogen safety requirements • Understanding hydrogen storage processes • Installing and understanding fuel cells	Practitioners from the renewable energy industry; engineers wishing to improve their knowledge in the hydrogen industry; community development organisations; public agency representatives; government advisors; insurance representatives; construction industry workers; undergraduate & postgraduate students; academic researchers and teachers; politicians; developers; investors; motor mechanics; international students; individuals interested in hydrogen.
Safety Training for Marine Workers **HYDIME Project** **Hydrogen Diesel Injection in a Marine Environment**	BIG HIT	https://www.bighit.eu/news/2021/2/19/new-hydrogen-maritime-safety-training-course-in-orkney	UK	• Understanding requirements for working on hydrogen-powered vessels in UK waters • Identifying existing international requirements under the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels	Marine workers.

Name of training course(s)	Organisation/ trainer	Website/contact	Location	Learning outcomes	Target audience
BRE 141 Sustainable Hydrogen Technologies **Introduction to Hydrogen Production & Process Simulation**	Bryan Research & Engineering, LLC	https://www.bre.com/Sustainable-Hydrogen-Technologies	UK	• Understanding the basics of hydrogen production technologies • Evaluating potential storage and use options for hydrogen energy • Understanding the capabilities and features of simulation software • Evaluating facility modelling techniques and methods • Understanding common process design and operational practices	Not available
Mission Hydrogen Webinar Collections	Mission Hydrogen	https://mission-hydrogen.de/webinar-collection/?gclid=EAIaIQobChMI5KOp_uW78gIV2ZpmAh2P0AD9EAMYASAAEgKRtvD_BwE	EUR	• Understanding various fuel cell technologies, systems, and infrastructure	Businesses, industries, and organisations currently working or planning to work with hydrogen and its systems, technologies, and infrastructure.
Hydrogen and Fuel Cells course	Ariema	http://www.ariema.com/en/hydrogen-solutions/ariema-education-h2	EUR	• Introducing or expanding knowledge of the hydrogen and fuel cell sector • Understanding companies, associations, finance in research and development, and the national situation associated with hydrogen	The hydrogen and fuel cell sector.
European Curriculum on Fuel Cell and Hydrogen Technology	HySafe	http://www.hysafe.org/CurriculumHFCT	EUR	• Providing an in-depth, varied, and technical insight into fuel cell and hydrogen technologies.	The hydrogen and fuel cell sector.
Hydrogen Fuel Cell Education and Training	EDQUIP Timo Wohlin-Elkovsky	https://edquip.co/en/blog/training-education-hydrogen-fuel-cell-systems	EUR	• Understanding why hydrogen and fuel cells are important • Evaluating how hydrogen and fuel cells can be applied in industry • Identifying job roles associated with hydrogen and fuel cells • Understanding hydrogen and fuel cells education and training systems • Identifying hydrogen fuel cell training systems and equipment.	The hydrogen and fuel cell sector.
Introduction to Hydrogen for Code Officials	US Department of Energy	https://www.hydrogen.energy.gov/code_official_training.html	USA	• Exploring lessons learned for offshore wind from prospecting, developing, implementing, constructing and decommissioning • Overview of hydrogen and fuel cell technologies, how these technologies are used in real-world applications, and references for related codes and standards	Not available

Name of training course(s)	Organisation/ trainer	Website/contact	Location	Learning outcomes	Target audience
Fire response and extrication of hydrogen fuel cell vehicle **Hydrogen fuelling station incident response** **Hydrogen system maintenance and inspection** **Hydrogen system operation** **Hydrogen as an energy carrier** **Introduction to hydrogen fuel cell vehicles for incident response** **Introduction to hydrogen safety for first responders** **Material compatibility design considerations for hydrogen systems** **Properties and hazards of hydrogen** **Safety considerations for hydrogen system components** **Safety considerations for liquid hydrogen systems** **Safety planning for hydrogen projects** **Transport of hydrogen fuel** **Global hydrogen safety codes and standards** **Material compatibility considerations for hydrogen** **Safety of water electrolysis** **Ventilation considerations for hydrogen safety**	AIChE The Global Home of Chemical Engineers	https://www.aiche.org/academy/	Intl.	• Safety across a wide range of hydrogen contexts	Emergency responders and hydrogen users.
Hydrogen Energy Course	European Energy Centre (EEC), The Renewable Energy Institute	https://www.renewableinstitute.org/training/hydrogen-energy-course/?gclid=EAIaIQobChMIqPnwxbi58gIVE51LBR1R9gA2EAAYAyAAEgK4xvD_BwE https://cpduk.co.uk/courses/european-energy-centre-hydrogen-energy-course	UK	Not available.	Personnel and consultants interested in learning more about the advantages and uses of different hydrogen technologies.

APPENDIX D

Australian hydrogen training (higher education)

Name of course	University/ education institution	Website	Learning outcomes	Target group	Status
Master of Energy Change (The Hydrogen Economy)	Australian National University (ANU)	https://www.anu.edu.au/study/scholarships/find-a-scholarship/global-power-generation-australia-scholarship-in-the-hydrogen	Learning outcomes sourced from H2 Networks Status of Vocational Hydrogen Training in Australia, Table 4, p13[136] include: • Appropriately describing and applying basic physics of hydrogen generation, storage, transportation, conversion and underlying key energy transformations • Evaluating and comparing the physics of existing and emerging technologies underpinning the hydrogen economy • Applying techno-economic analysis in selecting appropriate hydrogen technology for specific objectives • Critically analysing different hydrogen technologies (for example, the construction of fuel cells and electrolysers) and supply chain models • Evaluating different hydrogen policy frameworks and analysing the relative merits of alternative policy scenarios • Developing and communicating key areas of governance and safety metrology systems needed to support the hydrogen economy • Developing a personal qualified, well-argued view of possible pathways for the hydrogen economy • Using offered scholarship stipends for research projects in the field of the hydrogen economy	Students studying a Master of Energy Change (Advanced)	Current
Master of Energy Systems	University of Melbourne	https://study.unimelb.edu.au/find/courses/graduate/master-of-energy-systems/?gclid=CjwKCAiA4KaRBhBdEiwAZi1zzhdDic8A5wI2FBSpRCO9-ezKAfUgl101mqyLiY6n7N8CroNvIGnqcxoC5OwQAvD_BwE&gclsrc=aw.ds	• Analysing energy systems from technical, commercial and policy standpoints • Understanding the generation of energy, storage, and delivery • Exploring energy finance, economics, energy markets and the operation of renewable and non-renewable energy systems	Domestic and international students with an undergraduate degree in Commerce, Science, and/or Engineering	Ongoing
Master of Engineering (Sustainable Energy)	RMIT	https://www.rmit.edu.au/study-with-us/levels-of-study/postgraduate-study/masters-by-coursework/master-of-engineering-sustainable-energy-mc229	• Developing and implementing plans to improve energy efficiency and productivity to cut fuel bills, and reduce greenhouse gas/pollution emissions to meet regulatory requirements • Researching, developing, demonstrating, commercialising, designing, and evaluating innovative solar, wind and hydro, biomass, hydrogen and other sustainable energy supply, storage and utilisation technologies • Devising innovative sustainable solutions to current problems associated with adverse economic, social, and environmental problems linked to energy supply, distribution and consumption • Maintaining and optimising the performance of installed sustainable energy technologies and systems • Managing consultative processes with social groups affected by energy-related projects and developments	Domestic and international students with an undergraduate degree in Engineering, Science, Information Technology, Physics and/or Chemistry	Ongoing
Renewable Energy and Hydrogen Technologies Course - MEE40011 (short course)	Swinburne University of Technology	https://www.swinburne.edu.au/study/courses/units/Renewable-Energy-and-Hydrogen-Technologies-MEE40011/local	• Understanding the astrophysical and geophysical factors affecting the calculation of renewable energy resources • Calculating the output of renewable energy systems driven by geophysical fluid flows (such as wind and waves) • Describing and analysing how solar thermal and photovoltaic electricity systems work, including major cost issues • Analysing the thermodynamics of using solar thermal for industrial applications • Evaluating hydrogen energy storage and distribution methods and developing a technoeconomic assessment of selected energy storage systems • Identifying energy markets, marketing aspects of energy, and generating a business opportunity idea in the energy sector • Understanding the supply and demand relationship in the energy sector • Analysing and interpreting business performance in the energy sector; including application-related optimisation methods	Not available	To be implemented in 2024

Name of course	University/ education institution	Website	Learning outcomes	Target group	Status
Hydrogen Energy Program	University of Technology Sydney (UTS), Centre for Green Technology	https://www.uts.edu.au/about/faculty-engineering-and-information-technology/civil-and-environmental-engineering/cgt-hydrogen	• Developing an understanding of key hydrogen technologies • Promoting Australia as a hydrogen energy centre • Preparing skilled workers for the emerging global hydrogen economy • Connecting technology providers with Australian hydrogen producers and overseas markets	Not available	To be implemented
Master of Sustainable Energy, Master of Sustainable Energy	The University of Queensland	https://energy.uq.edu.au/Master-of-Sustainable-Energy	• Understanding the complex nature of energy generation, distribution, and supply • Evaluating the crucial role of finance, technology and regulation in hydrogen business development and project management • Understanding real-world requirements for energy professionals	Domestic and international students with an undergraduate degree.	Ongoing

APPENDIX E

International hydrogen higher education training

Name of course	University/ education institution	Website	Learning outcomes	Target group
Energy MPhil, PhD	UK Newcastle University	https://www.ncl.ac.uk/postgraduate/courses/degrees/energy-mphil-phd/#profile	• Developing and researching programs pertaining to hydrogen safety for major projects, including geo-energy, power electronics, drives and machines, and sustainable development and use of key resources • Understanding the hydrogen supply chain, including feedstocks, fuels, chemicals and engines • Undertaking original research projects relating to hydrogen as a biofuel, biowaste methanisation, CO_2 capture and storage, engine and power plant emissions monitoring and novel engine configurations	PhD students.
Hydrogen, Fuel Cells and their Applications, MRes	UK University of Birmingham	https://www.birmingham.ac.uk/postgraduate/courses/combined/chemical-engineering/hydrogen-fuel-cells-mres.aspx	• Exploring and understanding global energy problems to ensure graduates are capable of addressing interdisciplinary challenges involved in the transition to a sustainable energy future • Investigating the wide range of fuels used in fuel cells, including hydrogen, ethanol, natural gas and other biomass products	Master's students with a degree in a relevant subject (e.g. Chemical Engineering, Biology, Physics or Mathematics).
TMT4285 - Hydrogen Technology, Fuel Cells, Batteries and Solar Cells	EUR Norwegian University of Science & Technology	https://www.ntnu.edu/studies/courses/TMT4285#tab=omEmnet	• Evaluating production and storage procedures for hydrogen • Understanding water electrolysis and electrical energy from fuel cells • Investigating water electrolysis and electrical energy from fuel cells • Understanding thermodynamic and kinetic calculations for electrolysis and fuel cells • Following safety procedures for hydrogen handling • Analysing economical and energy opportunities for the introduction of energy systems based on renewable energy sources and hydrogen	University students with relevant knowledge of chemistry, thermodynamics and material science.
TEK5390- Hydrogen Technology	EUR University of Oslo	https://www.uio.no/studier/emner/matnat/its/TEK5390/	• Understanding the principles of hydrogen production and storage, as well as thermodynamics and kinetics of the processes involved • Evaluating processes and technologies related to hydrogen production, utilisation, storage, and safety • Understanding the operation, functionality and interaction among various components in the hydrogen-based energy systems • Understanding the role of electrolysers/fuel cells in energy systems with intermittent renewable energy sources • Following safety requirements for hydrogen handling • Analysing technical aspects of stationary and mobile hydrogen-based energy systems, including solutions for the heavy-duty transport sector • Understanding non-technical challenges for the adoption of hydrogen-based technologies, such as market and social factors • Gaining an awareness of national and international hydrogen-related initiatives, such as the Norwegian Hydrogen Forum, the International Energy Agency (IEA), Hydrogen Implementing Agreement, and the US Department of Energy (DOE)	Master's students. This unit credits/overlaps with TEK9393 below.
Hydrogen Course	EUR HAN University of Applied Sciences	HyMatters https://www.hymatters.com/en/services/hydrogen-course/	Understanding the following hydrogen-related functions, systems, requirements and uses: • Physical properties • Hydrogen chain • Hydrogen technology • Fuel cell • Electrolyser • E55 Compressor • Storage • Safety • Physical safety • Functional, process and environmental safety • Laws and regulations • Mobile applications • Stationary applications • Built environment • Finances and market • Calculations in hydrogen applications • National and international policy.	Not available

Name of course	University/ education institution	Website	Learning outcomes	Target group
Bachelor (BSc) Clean Energy Processes	EUR - Germany Clean Energy Processes	https://www.deutschland.de/en/topic/knowledge/first-courses-of-study-on-hydrogen-technologies Bachelor (B.Sc.) Clean Energy Processes › Clean Energy Processes (fau.eu)	• Understanding sustainable production, distribution and utilisation of renewable energy for the chemical industry, reflecting on changes to chemical processes	Bachelor's students.
Master (MSc) of Clean Energy Processes	EUR - Germany Clean Energy Processes	https://www.deutschland.de/en/topic/knowledge/first-courses-of-study-on-hydrogen-technologies Master (M.Sc.) Clean Energy Processes › Clean Energy Processes (fau.eu)	• Understanding sustainable production, distribution and utilisation of renewable energy for the chemical industry, reflecting on changes to chemical processes.	Master's students.
Diploma in Energy Technology	EUR – Germany Dresden University of Technology (TU Dresden)	https://www.deutschland.de/en/topic/knowledge/first-courses-of-study-on-hydrogen-technologies https://tu-dresden.de/ing/maschinenwesen/iet/wket/studium?set_language=en	• Understanding hydrogen as an energy carrier • Expanding knowledge of nuclear energy technology, including nuclear power plants • Analysing the production and application opportunities for hydrogen • Following safety issues relating to hydrogen technologies Note: course cannot be accessed in English.	Diploma students.
Renewable Energies - Bachelor (REB)	EUR – Germany Institute for Regenerative Energy Systems (IHRES) at Stralsund University of Applied Sciences	https://www.deutschland.de/en/topic/knowledge/first-courses-of-study-on-hydrogen-technologies https://www.hochschule-stralsund.de/en/reb/	• Following sustainable storage requirements for renewable energies • Understanding the innovative hydrogen technologies that have become available, and how they can be integrated into energy supply networks. Note: hydrogen technology is a compulsory module in the 5th semester.	Bachelor's students.
Hydrogen Technology	EUR - Germany FHWS University	https://fm.fhws.de/	• Understanding the basics of mathematics, electrical engineering, mechanics, and thermodynamics • Analysing fuel cells, hydrogen production, and hydrogen transport and storage Note: course cannot be accessed in English.	Degree students.
Hydrogen Education Program	EUR Brunel	https://www.brunel.net/en/renewables/hydrogen/hydrogen-education-program	• Assessing opportunities for worldwide energy transition and the integration of hydrogen energy into the global energy infrastructure. • The course is intended for experienced technical and legal professionals who wish to grow their knowledge in hydrogen.	Postgraduate degree students, experienced technical and legal professionals wishing to grow knowledge in hydrogen.

APPENDIX F

Australian and international hydrogen-related school subjects

Curriculum, year level(s) and accreditation period	Jurisdiction	Key knowledge and/or skills (with comments)	Comments
NATIONAL			
Chemistry (2017-present)	NSW	Module 7 (Organic Chemistry): • Comparing and contrasting fuels from organic sources to biofuels, including ethanol.	• A potential connection to this knowledge is hydrogen production from fossil fuels, but nothing explicitly is mentioned.
Australian National Curriculum	Australia	Unit 3 (Redox reactions): • Understanding how galvanic cells, including fuel cells, generate an electrical potential difference from a spontaneous redox reaction; they can be represented as cell diagrams including anode and cathode half-equations (ACSCH108). • Analysing how fuel cells use metal nanoparticles as catalysts to improve the efficiency of energy production (ACSCH109). Unit 4 (Development of molecular manufacturing processes): • Understanding how fuels (for example, biodiesel, ethanol, hydrogen) can be synthesised from organic or inorganic sources using a range of chemical reactions such as addition, oxidation and esterification (ACSCH137).	The Victorian VCE Chemistry course is the state's interpretation of this national chemistry curriculum.
VCE Chemistry (2016-2021)	Victoria	Unit 3 (Fuel cells as a source of energy): • Evaluating the common design features of fuel cells including use of porous electrodes for gaseous reactants to increase cell efficiency (details of specific cells not required). • Comparing the use of fuel cells and combustion of fuels to supply energy with reference to their energy efficiencies (qualitative), safety, fuel supply (including the storage of hydrogen), production of greenhouse gases and applications. • The comparison of fuel cells and galvanic cells with reference to their definitions, functions, design features, energy transformations, energy efficiencies (qualitative) and applications.	VCE Chemistry is Victoria's interpretation of the national curriculum and features a strong and meaningful connection to the emerging hydrogen industry.
VCE Environmental Science (2022-2026)	Victoria	Unit 4 (How can climate change and the impacts of human energy use be managed?): • Highlighting non-renewable energy sources: oil, coal, natural gas, coal seam gas and nuclear. • Identifying renewable energy sources: biomass, biofuels, solar, hydro-electric, wind, tidal and geothermal. • Understanding options for building a sustainable energy future that produces lower greenhouse gas emissions and supplies reliable and affordable energy services; improving resource efficiency; increasing the efficiency of energy conversion devices; replacing fossil fuels with non-fossil fuel energy sources and reducing personal energy consumption.	This newly-accredited study design continues a focus on renewable energy, but, unfortunately, no specific mention is made of hydrogen as an energy source.
VCE Physics (2016-2022)	Victoria	Unit 1 (Thermodynamics): • Understanding cooking alternatives such as appliance options (microwave, convection, induction) and fuel options (gas, electricity, solar, fossil fuel). • Identifying automobile efficiencies such as fuel options (diesel petrol, LPG and electric), air delivery options (naturally aspirated, supercharged, and turbocharged) and fuel delivery options (common rail, direct injection and fuel injection).	There is a clear and relevant opportunity for the explicit inclusion of hydrogen energy and/or fuel cells, but there is no specific reference to hydrogen as an energy source nor fuels. This could probably be a result of its significant inclusion in the VCE Chemistry course.
VCE Systems Engineering (2019-2024)	Victoria	Unit 3 (Clean energy technologies): • Understanding the technologies used to harness, generate, store and transmit renewable energy sources including wind turbine systems, solar systems, hybrid fuel cells, and the combinations of these technologies.	While students gain an understanding of energy sources and the application of technologies to convert energy sources into power for engineered systems, as well as considering the relevance of designing systems that are beneficial to the economy, environment and society, there is no specific focus on hydrogen as an energy source. The main focus is on solar power and wind power, where students consider the advantages/disadvantages of solar and wind power and determine the efficiency of energy conversions.

Curriculum, year level(s) and accreditation period	Jurisdiction	Key knowledge and/or skills (with comments)	Comments
		INTERNATIONAL	
DOE Hydrogen and Fuel Cells Program (Grade 5-12)	US	• Introducing the concept of hydrogen and fuel cells • Understanding the basics of hydrogen, how it is made, its component/atomic structure, its uses, and its role as a dual source.	
A-Level Chemistry (2015-present)	UK	3.1 Physical chemistry: • Understanding how cells can be non-rechargeable (irreversible), rechargeable or fuel cells. • Analysing how fuel cells are used to generate an electric current and do not need to be electrically recharged. • Understanding electrode reactions in an alkaline hydrogen–oxygen fuel cell. • Evaluating benefits and risks to society associated with using these cells.	In the UK's A-level Chemistry (valid for teaching from 2015-onwards), a brief reference is made to fuel cells under the topic 'Commercial applications of electrochemical cells'.
H_2GP Horizon Hydrogen Grand Prix Horizon Educational	International	• 6th-12th grades • Students receive a basic car kit to build a remote controlled FCEV and race them with the ultimate goal of getting to the world finals	

APPENDIX G

Australian hydrogen industry training (non-accredited)[137]

Engineers	Managers/executives	Gas industry upstream	Gas industry downstream	Transport & mobility	Automotive	Electrical	Hydrogen miscellaneous	Miscellaneous	Emergency services
• Engineers • Director of hydrogen energy development • Fuel cell engineering intern • Hydrogen energy systems designer • Hydrogen energy system operations engineer • Hydrogen fuelling station designer & project engineer • Hydrogen energy engineer • Fuel cell retrofit installer • Fuel cell power systems engineer • Hydrogen systems & retrofit designer • Fuel cell vehicle development engineer • Hydrogen lab technician • Automotive fuel cell power electronics engineer • Computer/ software engineers • Control engineers • Electrical engineers • Mechanical (HVDC) engineers • Systems engineers	• Electrical management • Hydrogen fuelling station manager • Hydrogen/fuel cell R&D director • Fuel cell plant manager • Hydrogen fuels policy analyst & business sales • Hydrogen systems program manager • Emissions accounting & reporting consultant • Fuel cell quality control manager • Hydrogen plant operations manager • Emissions reduction credit portfolio manager • Emissions reduction project developer specialist • Emissions reduction project manager • Logistic managers • Depot managers • Regulative experts • Car and heavy vehicle sales managers	• Gas pipeline worker • Gas service technician • Mechanical fitters • Gas pipeline supervisor • Gas industry operations supervisor • Gas meter reader • Energy generation plant operators • Energy generation plant technician/ operator • Hydrogen plant operator • Control centre operator • Hydrogen energy technician • Mechanical fitters • Hydrogen energy system installer • Pressure pipe welders and fabricators • Transmission controller • Pressure controller • Mechanical electrical instrumentation technician	• Plumber gas fitters • Meter readers • Safety inspectors	• Drivers • Heavy vehicle driver • Hydrogen fuel transport driver • Fuelling station operator • Telematics system operator • Logistics manager • Marine workers • Aviation workers • Train drivers • Service and repair	• Mechanic • Auto mechanic • Auto electrician • Hydrogen vehicle electrician • Vehicle inspectors • Manufacturing plant process workers • Manufacturing supervisors • Car and heavy vehicle salesperson	• High voltage electrician Note: Electrical skills and job roles will be transferra-ble across multiple industries	• Hydrogen fuel cell system technician • Fuel cell fabrication technician • Fuel cell manufacturing technician • Fuel cell fabrication and testing technician • Fuel cell retrofit manufacturer plant labourer • Fuel cell power systems operator and instructor • Fuel cell backup power system technician • Power electronics engineer • Fuel cell power systems operator and instructor • Fuel cell designer • Fuel cell and electrolysers manufacturing workers • Hydrogen systems sales consultant • Hydrogen systems safety investigator • Assemblers	• Construction workers • Architects • Builders • Building inspectors • Safety inspectors • Quality auditors • Production line workers • Fabricators • Hazardous materials management specialist • Retail workers (BBQ gas bottle exchange) • Purified water producers • Environmental, social, and corporate governance (ESG) workers (for transition from fossil to green hydrogen)	• Fire fighters • Rural fire services • Police • Ambulance • State emergency workers • Tow truck/vehicle recovery operators • Protective service officers (PSOs)

APPENDIX H

Approved new Gas Training Package 3.0 hydrogen changes

Qualifications	Status
UEG20121 Certificate II in Gas Supply Industry Operations	Updated and equivalent
UEG30121 Certificate III in Gas Supply Industry Operations	Updated and equivalent
UEG40221 Certificate IV in Gas Supply Industry Operations	Updated and equivalent

Units of competency	Area covered	Status
UEGNSG102 Prepare safe design specifications of a gas system	Hydrogen Gas Technology	Updated and equivalent
UEGNSG205 Commission or decommission gas distribution pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG206 Construct and lay copper and stainless-steel gas distribution pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG208 Construct and lay large copper gas distribution pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG209 Construct and lay polyethylene gas distribution mains	Hydrogen Gas Technology	Updated and equivalent
UEGNSG211 Construct and lay steel gas distribution pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG214 Coordinate and conduct gas distribution pipeline repair and modifications	Hydrogen Gas Technology	Updated and equivalent
UEGNSG215 Coordinate construction, laying and testing of gas distribution pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG303 Carry out transmission pipeline construction work activities	Hydrogen Gas Technology	Updated and equivalent
UEGNSG304 Commission or decommission gas transmission pipelines	Hydrogen Gas Technology	Updated and equivalent
UEGNSG307 Coordinate the operation of relevant plant and equipment for transmission pipeline construction	Hydrogen Gas Technology	Updated and equivalent
UEGNSG309 Coordinate transmission pipeline construction operations	Hydrogen Gas Technology	Updated and equivalent
UEGNSG316 Work in proximity of transmission pipeline construction plant and equipment	Hydrogen Gas Technology	Updated and equivalent
UEGNSG313 Monitor and operate flow control, pressure measuring and regulating devices for gas transmission	Storage and Reinjection of Gas	Updated and equivalent
UEGNSG509 Remotely monitor and operate gas transmission flow and pressure measuring and regulating devices	Storage and Reinjection of Gas	Updated and equivalent
UEGNSG702 Disconnect and reconnect small capacity gas meters	Data Loggers	Updated and equivalent
UEGNSG709 Process meter reading information using appropriate technology	Data Loggers	Updated and equivalent
UEGNSG710 Read and record meter readings	Data Loggers	Updated and equivalent
UEGNSG103 Install and commission stationary gas fuelled turbine engines*	Prerequisites required: • CPCCWHS1001 Prepare to work safely in the construction industry • HLTAID009 Provide cardiopulmonary resuscitation	Updated and equivalent
UEGNSG230 First on site response to gas pipeline emergencies*	Prerequisites required: • CPPFES2005 Demonstrate first attack firefighting equipment • HLTAID011 Provide first aid • UEGNSG141 Apply workplace health and safety regulations, codes and practices in the gas supply industry	Updated and equivalent
UEGNSG317 First response to a gas facility event*	Prerequisites required: • CPPFES2005 Demonstrate first attack firefighting equipment • HLTAID011 Provide first aid • UEGNSG141 Apply workplace health and safety regulations, codes and practices in the gas supply industry	Updated and equivalent
UEGNSG901 Apply safety practices, procedures, and compliance standards for handling hydrogen gas	Hydrogen Gas Technology	New

UEGNSG902 Commission, operate and maintain electrolysers	Hydrogen Gas Technology	New
UEGNSG903 Fault find and repair hydrogen storage equipment	Hydrogen Gas Technology	New
UEGNSG904 Inject hydrogen gas into distribution networks	Hydrogen Gas Technology	New
UEGNSG905 Monitor and control hydrogen in gas distribution networks	Hydrogen Gas Technology	New
UEGNSG906 Undertake routine hydrogen storage operations	Hydrogen Gas Technology	New
UEGNSG306 Control gas processing, storage or regasification operations in an LNG storage facility	Storage and Reinjection of Gas	New
UEGNSG312 Inject gas into underground storage	Storage and Reinjection of Gas	New
UEGNSG315 Withdraw gas from underground storage	Storage and Reinjection of Gas	New
UEGNSG701 Disconnect and reconnect data logging equipment	Data Loggers	New
UEGNSG703 Fault find and repair data logging equipment	Data Loggers	New
UEGNSG704 Install and commission data logging equipment	Data Loggers	New
UEGNSG707 Process data logging information	Data Loggers	New
UEGNSG715 Use data logging equipment	Data Loggers	New ¬

New skill sets

Code	Title
UEGSS00013	**Basic Hydrogen Safety Skill Set** Includes these units: • PUAFER008 Confine emergencies in a facility • UEGNSG901 Apply safety practices, procedures and compliance standards for handling hydrogen gas • UEGNSG005 Prepare to work in the gas industry
UEGSS00014	**Inject Hydrogen into Distribution Networks Skill Set** Includes these units: • PUAFER008 Confine emergencies in a facility • UEGNSG901 Apply safety practices, procedures and compliance standards for handling hydrogen gas • UEGNSG005 Prepare to work in the gas industry • UEGNSG904 Inject hydrogen gas into distribution networks
UEGSS00015	**Monitor Hydrogen using Control Systems Skills Set** Includes these units: • MSS402061 Use SCADA systems in operations • UEGNSG005 Prepare to work in the gas industry • UEGNSG906 Monitor and control hydrogen in gas distribution networks

APPENDIX I

Proposed new construction & plumbing and services training package hydrogen units

Traditional combustion stream:

- **Purpose:** this stream is designed to build on traditional plumbing skills and knowledge
- **What it covers:** the safe handling of hydrogen, understanding the different pressures and levels of condensation, jointing techniques and threaded joints, cylinder requirements, different manufacturer/product/certification requirements, commission and decommission of hydrogen-based appliances.

Fuel cell/electrolysis stream

- **Purpose:** this stream is designed to be an additional non-traditional plumbing skill set to support industry practitioners to meet emerging market needs and demands. It will have a domestic/residential focus. There are currently no competency requirements or training that cover this area of work.
- **What it covers:** emerging and predicted technology, purging against manufacture specifications, sizing and designing consumer piping, water treatment, wastewater management.

Code	Title	Stream
CPCHYD3001	Store and handle hydrogen	Traditional Combustion Stream
CPCHYD3002	Install and commission for hydrogen Type A appliances	Traditional Combustion Stream
CPCHYD3003	Maintain and service for hydrogen Type A appliances	Traditional Combustion Stream
CPCHYD3004	Disconnect and reconnect for hydrogen Type A appliances	Traditional Combustion Stream
CPCHYD3005	Calculate and install ventilation for hydrogen Type A appliances	Traditional Combustion Stream
CPCHYD3006	Install and commission for hydrogen Type B appliances	Traditional Combustion Stream
CPCHYD3007	Maintain and service for hydrogen Type B appliances	Traditional Combustion Stream
CPCHYD3008	Disconnect and reconnect for hydrogen Type B appliances	Traditional Combustion Stream
CPCHYD3009	Safe termination of vent lines for hydrogen	Traditional Combustion Stream
CPCHYD3010	Install hydrogen storage capacity up to xxxx (storage size to be determined)	Traditional Combustion Stream
CPCHYD3011	Commission and decommission hydrogen combustion systems	Traditional Combustion Stream
CPCHYD3012	Commission and decommission hydrogen fuel cell and electrolysers	Fuel Cell/Electrolysis Stream
CPCHYD3013	Inspect, service and maintain hydrogen fuel cell and electrolysers	Fuel Cell/Electrolysis Stream
CPCHYD4001	Undertake purging	Fuel Cell/ Electrolysis Stream
CPCHYD4002	Size and design consumer hydrogen systems	Fuel Cell/ Electrolysis Stream
CPCHYD4003	Water treatment and wastewater	Fuel Cell/ Electrolysis Stream
CPCHYD4004	Size and design flue systems for hydrogen appliances	Fuel Cell/ Electrolysis Stream
CPCHYD4005	Characteristics and chemistry of hydrogen	Fuel Cell/ Electrolysis Stream
CPCHYD4006	Compression and cooling/chilling of hydrogen	Fuel Cell/ Electrolysis Stream

APPENDIX J

Australian and international hydrogen training for emergency responders

Name of course	Organisation		Website	Content and objectives
An Essential Guide to Hydrogen Safety	H2 Advantage	AUS	https://www.informa.com.au/training/	• General hydrogen awareness, properties, and considerations • Market movements and how the industry is unfolding, including uses • General emergency response complementing your existing training • Plant/product specific as required
		INTERNATIONAL		
Hydrogen Emergency Response Training Programme	The Pacific Northwest National Laboratory (PNNL), the California Fuel Cell Partnership (CaFCP) and the National Fire Protection Association (NFPA)	US		• Emergency response for electric vehicles, including hydrogen fuel cell-powered vehicles (FECV) and hydrogen fuelling infrastructure • Other aspects of hydrogen awareness, operation of hydrogen and technician surrounding hydrogen vehicles
HyResponse Project	HyResponse	Europe	www.hyresponse.eu	This project has been completed, yet the web-based training platform contains information that provides first responders and site operators with technically accurate safety and emergency response information. This program helps emergency responders to deal with incidents and accidents involving hydrogen and fuel cells[139]. The training covers three components: • hydrogen safety basics • regulations, codes, and standards, • intervention strategies and tactics relevant to first responders[140].
Introduction to Hydrogen Fuel Cell Vehicles for Incident Response	AIChE[141]	US/ Global	https://www.aiche.org/academy/courses/ela261/introduction-hydrogen-fuel-cell-vehicles-incident-response	An introductory course that covers the properties of hydrogen and provides a basic understanding of fuel cell vehicles, how they operate, and emergency response.
Fire Response and Extrication of Hydrogen Fuel Cell Vehicles	AIChE	US/ Global	https://www.aiche.org/academy/courses/ela262/fire-response-extrication-hydrogen-fuel-cell-vehicle	This course covers the impact of fire on hydrogen storage and high-voltage batteries and the proper guidelines for fire response and extrication.
Transport of Hydrogen Fuel	AIChE	US/ Global	https://www.aiche.org/academy/courses/ela263/transport-hydrogen-fuel	This course looks at different methods of transporting hydrogen and how that impacts emergency operations.
Hydrogen Fuelling Station Incidents Response	AIChE	US/ Global	https://www.aiche.org/academy/courses/ela264/hydrogen-fueling-station-incident-response	The course covers how to respond to a leak or fire at a hydrogen fuelling station. Additional considerations are also discussed for stations that dispense other flammable fuels.

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