PwC Consulting

# Developing Australia's hydrogen workforce

## Final report

October 2022

pwc

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# Executive summary

# Developing Australia's hydrogen workforce (1/4)

**Hydrogen presents a significant opportunity for the Australian economy. With the increasing global momentum towards clean hydrogen – as seen in the discussions at the 2021 United Nations Climate Change Conference (COP26) – the 2019 Australian National Hydrogen Strategy outlined a plan for Australia to draw on its resources and establish a robust hydrogen supply chain that focuses on producing, moving and using hydrogen. However, in order to support an effective and efficient hydrogen supply chain in Australia, a skilled and capable workforce must be established.**

Hydrogen is gathering significant momentum globally as it shifts to becoming an economically viable and flexible fuel and energy carrier. It is a key part of the rapid and widespread deployment and international trade of renewable energy. Decreasing electrolyser and renewable energy costs, as well as increasing demand for widespread decarbonisation, has grown the appetite for hydrogen within industries such as automotive, power, gas and water utilities, manufacturing, refining and other industrial markets.

The last five years has seen the release of a significant number of international hydrogen strategies by countries around the world, all of which outline the economic and clean energy benefits of hydrogen and detail funding commitments and plans to implement hydrogen projects and initiatives. As at August 2022, there were 26 countries which had published a hydrogen strategy, 24 countries which were preparing national strategies, and 17 countries that were in initial policy discussions.[1]

With its natural resources, established industries and geographical proximity to major markets, there is an opportunity for Australia to become a world leader across the hydrogen supply chain. This includes producing, transporting, distributing and storing hydrogen, blending it into gas networks, and using it as a transport and export fuel. Establishing Australia as a "major player" in the global hydrogen economy and building a robust and effective hydrogen supply chain in Australia was the aspiration outlined in the 2019 Australian National Hydrogen Strategy. Achievement of this aspiration and the desired hydrogen economy will drive significant economic benefits for Australia, as well as support clean energy targets.

However, realising this opportunity will require a workforce that is skilled and capable of engaging effectively and safely with hydrogen.

Drawing on substantial consultation and research, this report builds an understanding of the workforce needed to support a safe and effective hydrogen economy in Australia in 2030 across six key supply chain areas. This includes:

1. Identifying the type and number job roles needed to support the desired hydrogen activities across the supply chain;
2. Determining the hydrogen-specific capabilities (skills and knowledge) these job roles will require to undertake hydrogen-related activities safely and effectively, including whether the job will fundamentally change in scope or only be augmented to undertaken hydrogen tasks; and
3. Establishing whether the hydrogen-specific capabilities needed by the identified job roles are already catered for within the education and training system, or whether training gaps exist that must be filled to support a pipeline of current and future workers for the industry.

This analysis leads to the overarching finding that the establishment of a hydrogen economy in Australia will create a significant number of jobs (between 13,150 and 16,050 under a forecast medium demand scenario). These jobs will be created in job roles that already exist in the economy, for example, plumbers and electrical engineers. These job roles will primarily draw on their base qualifications and some hydrogen-specific upskilling in order to undertake hydrogen activities. However, the level of hydrogen upskilling required will differ across job roles. The job roles that will experience greater changes to daily tasks and responsibilities will require more upskilling. For example, automotive light vehicle technicians. Whilst some of the identified hydrogen-specific capabilities required by job roles are already catered for in the Australian education and training system, there are key gaps that must be filled to ensure the workforce is appropriately prepared to engage with hydrogen.

1 World Energy Council, 'Hydrogen on the Horizon: National Hydrogen Strategies' accessed at https://www.worldenergy.org/publications/entry/working-paper-hydrogen-on-the-horizon-national-hydrogen-strategies, with additional research used to identify hydrogen strategies and policies released between June 2021 (publication of the World Energy Council report) and August 2022.

# Developing Australia's hydrogen workforce (2/4)

**Consultation and research found that 46 job roles are needed to support the desired activities across the six hydrogen supply chain areas in-scope for this report. All of these job roles are existing roles that will be augmented to undertake hydrogen activities and it is not expected that many job roles will require significant upskilling or retraining in order to engage in the hydrogen economy. Based on a medium hydrogen production scenario (2.6 megatonnes [MT]), between 13,150 and 16,050 Full Time Employees across the 46 job roles will be required.**

To inform the analysis of the job roles, they have been grouped into six occupational clusters, 1. Engineers, 2. Tradespersons and Technicians, 3. Logistics, 4. Management, 5. Safety and Quality Control, and 6. Specialists. This demonstrates the demand for a breadth of job role types, experiences, and skills to support and enable the target hydrogen supply chain. All the identified job roles are existing job roles, for example, electrical fitters, mechanical engineers and Occupational Health & Safety officers. No 'new' job roles were identified as being required to support the hydrogen supply chain.

Analysis of the tasks that the job roles will undertake in the hydrogen economy demonstrates that the job roles will not significantly change in regard to day-to-day tasks, responsibilities and skill/knowledge requirements. Plotting of the job roles on an 'augmentation scale' demonstrates that most job roles fall into 'insignificant', 'low' and 'moderate' augmentation categories. Logistics workers and Technicians and Tradespersons are likely to experience greater job role augmentation than Engineers, Specialists, Management, and Safety and Quality Control job roles.

To support further understanding of this workforce profile, quantitative analysis was undertaken to model how many jobs in each occupational cluster will be needed to support the hydrogen economy. Given the uncertainty of hydrogen production and the evolution of the hydrogen industry since the 2019 Australian National Hydrogen Strategy was developed, job role estimates for each occupational cluster in 2030 were developed under three hydrogen production scenarios (low, medium and high). Total employment projections under the three scenarios are as follows (rounded to the nearest 50):

| Demand scenario | Lower limit jobs | Upper limit jobs |
|---|---|---|
| Low | 3,900 | 4,600 |
| Medium | 13,150 | 16,050 |
| High | 22,650 | 27,950 |

Across all three scenarios, the majority of jobs required will be for Technician and Tradesperson and Engineering job roles, whilst Specialists will require the lowest number of jobs.

**Estimated number of jobs across each occupational cluster required to support the hydrogen economy in 2030 under a medium demand scenario**

| | |
|---|---|
| **Engineers** | 2,750 – 3,400 jobs |
| **Technicians and Tradespersons** | 7,900 – 9,650 jobs |
| **Logistics** | 650 – 800 jobs |
| **Management** | 900 – 1,050 jobs |
| **Safety and Quality Control** | 800 – 950 jobs |
| **Specialists** | 150 – 200 jobs |
| **Total** | **13,150 – 16,050 jobs** |

# Developing Australia's hydrogen workforce (3/4)

**In order to support a safe and effective hydrogen economy in Australia, the 46 job roles identified as required to support the economy must be appropriately skilled. Twenty-six hydrogen-specific capabilities were identified as being required by the relevant job roles supporting the hydrogen supply chain. These hydrogen-specific capabilities take the form of different skill and knowledge requirements.**

Research and consultation found that the 46 job roles will not require a fundamental reskilling in order to engage in hydrogen activities. Rather, the job roles will continue to rely on their base education and training for their relevant job role, but will need targeted, hydrogen-specific upskilling in key areas. For example, electrical engineers participating in hydrogen activities will already have the majority of relevant skills from their previous education (Bachelor of Engineering) and work experiences to do these activities, though the exact number of skills will depend on their background (e.g. those from an oil and gas background will likely transition more easily than those from water infrastructure). Most will only require specific skills and knowledge in order to engage safely and effectively with hydrogen. For example, an understanding of hydrogen's unique property risks (e.g. flammability and lightness).

This finding was consistent across all occupational clusters, however, it was noted that the 'hydrogen skills and knowledge gap' would likely be larger for some job roles and for some individuals transitioning between industries.

On the assumption that individuals in job roles will continue to draw on their base skill set gathered through occupation and/or field specific education and work experiences, analysis focused on understanding the hydrogen-specific capabilities that the workforce will need to engage in hydrogen activities. Consultation and research identified 26 hydrogen-specific capabilities as required by the relevant job roles supporting the hydrogen supply chain. These hydrogen-specific capabilities take the form of different skill and knowledge requirements.

A capability matrix was developed to map the 46 job roles to the 26 capabilities and identify whether the capability is a core or specialist requirement for the job role operating in that supply chain area, or not relevant. The matrix demonstrates that job roles will not require all the identified capabilities, however, all the identified skill and knowledge requirements are relevant to multiple job roles.

Education and training pathways must be available across the 26 hydrogen-specific capabilities in order to support a capable and effective hydrogen workforce.

**Figure 1. Summary of the 26 hydrogen-specific capability requirements for the identified job roles**

| | |
|---|---|
| 5 | Identified capability requirements relating to **hydrogen's fundamental properties and its material reactions** (e.g. property risks of handling hydrogen) |
| 4 | Identified capability requirements relating to **hydrogen safety and regulation** (e.g. handling hydrogen materials) |
| 10 | Identified capability requirements relating to **hydrogen production and storage techniques** (e.g. electrolysis) |
| 3 | Identified capability requirements relating to **integrating** assemblies or components into a larger system (e.g. replacing fuel cells) |
| 4 | Identified capability requirements relating to understanding factors influencing **hydrogen market architecture** (e.g. ensuring social license) |

# Developing Australia's hydrogen workforce (4/4)

**The findings of this report indicate that the job roles needed to support and enable the hydrogen economy and supply chain in Australia are not substantially different in tasks and scope to current job roles. However, the capability matrix demonstrates that there are a number of hydrogen-specific skills and knowledge requirements that the hydrogen workforce will need. The education and training system needs to be equipped to train the current and future workforce in these skills.**

Analysis found that limited Vocational Education and Training (VET) and higher education training pathways for hydrogen-specific capabilities exist in Australia. For example, there are only six dedicated hydrogen training products in the VET system. Where hydrogen-specific content does exist in the education and training system, research indicates it is woven into products with other similar content and requires contextualisation.

Of the 26 hydrogen-specific capabilities identified in this report, only 15% were assessed as having sufficient coverage within the education and training system.

There are training gaps for the remaining 85%. These training gaps need to be filled in order to support a safe, efficient and effective hydrogen workforce.

Given the potential size of the hydrogen workforce (13,150 – 16,050 job roles in a medium demand scenario), the need for a holistic education and training approach in Australia is essential to ensure a supply of appropriately skilled workers across relevant job roles. Failure to create the relevant hydrogen education and training pathways and solutions will result in an under-skilled workforce that is potentially unsafe and cannot support the desired supply chain scope and size.

## Figure 2. Key report findings

1. **No new job roles are required**. 46 existing job roles will be augmented to undertake hydrogen activities.
2. **Some job roles will augment more than others**, but most will only experience low-moderate changes to day-to-day tasks and skill needs. Logistics workers and Technicians and Tradespersons are likely to experience the greatest amount of job role augmentation.
3. **Incremental hydrogen-specific upskilling** will complement workers' existing base of education and training.
4. **The estimated demand for job roles will be greatest for Engineers and Technicians and Tradespersons**, under a medium demand scenario.
5. **There are limited existing hydrogen education and training pathways.** For example, there are only six dedicated hydrogen training products in the VET system.
6. **A whole-of-system education and training approach is required** to support the required pipeline of workers for the desired hydrogen economy.

# 2

# Background and context

# Scope of PwC engagement

**The Federal Department of Employment and Workplace Relations engaged PwC to perform a range of activities to support the skills and training actions in the National Hydrogen Strategy.**

## Scope of work

This report is part of a broader set of activities PwC was engaged to undertake. The report addresses deliverable 7 in the scope of work:

- **Deliverable 7** – provision of a final report to the Commonwealth.

This final report combines all the outputs from the broader suite of activities produced in deliverables 1-6. It integrates the findings and analysis in interim reports 1 and 2 (delivered in December 2021), interim report 3 (delivered in February 2022), and the capability matrix and report (delivered in April 2022), but is intended to be read as a standalone document.

## Out-of-scope elements

In discussion with the Department over the course of this project, several elements were agreed to be out-of-scope in this report:

- **Quantitative analysis/job role forecasts on a job-role level**: The analysis in this report was undertaken at an occupational cluster level due to modelling limitations. Analysis undertaken at an occupational cluster level included consideration of all 46 job roles in this report.
- **Quantitative analysis/job role forecasts to 2030:** This report did not attempt to quantify the number of skilled workers required to meet the growth targets of the hydrogen economy to 2050, as longer forecasting periods can significantly increase variability in the model. The intention of the job role forecasts was to inform an understanding of the number of Full Time Employees needed in 2030 for the six identified supply chain areas, as per the scenarios in the National Hydrogen Strategy.
- **No recommendations or next steps have been provided:** The report is intended to present an analysis of the workforce needed to support the six areas of the hydrogen supply chain in 2030, an identification of the skills and training this workforce would need to carry out relevant activities, and an assessment of whether there is sufficient and appropriate education and training pathways to support the delivery of these skills.
- **Supply chain areas outside the six in-scope supply chain areas:** The six in-scope supply chain areas do not cover the entirety of the hydrogen supply chain. This resulted in some elements being out of scope of the project.

# The hydrogen supply chain

## Analysis in this report is focused on six areas of the hydrogen supply chain.

### Building a view of the hydrogen supply chain

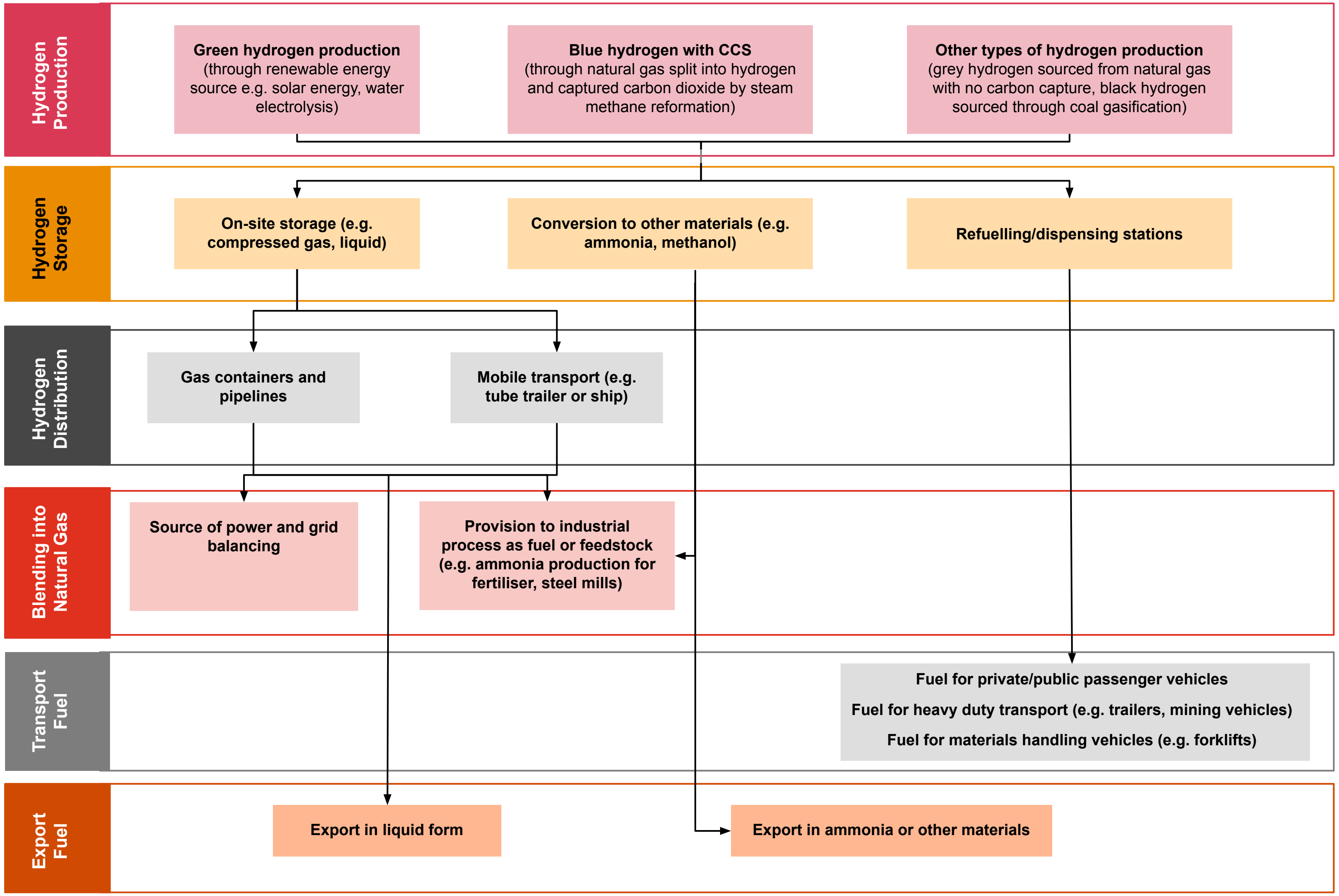
The scope of work in this report was determined by the Department in the activity order and was informed by pre-existing research and consultation as to the breadth of activities within the hydrogen market. Using this research, working definitions of the supply chain were developed and a map was built to describe activities within these provided areas.

This supply chain described at a high level the generic, current activities and contexts in which hydrogen is utilised throughout the Australian economy, from the various types of hydrogen production through to its various end uses (e.g. as a feedstock in ammonia plants and steel mills, as a source of power for the electricity grid, etc).

### The supply chain's benefit in defining scope

This supply chain was used as a check throughout research and consultation to confirm that all areas of the supply chain were being examined and that no major gaps were left outstanding upon completion of the report.

The chain was also tested with stakeholders in consultation to confirm our understanding of the current hydrogen market.

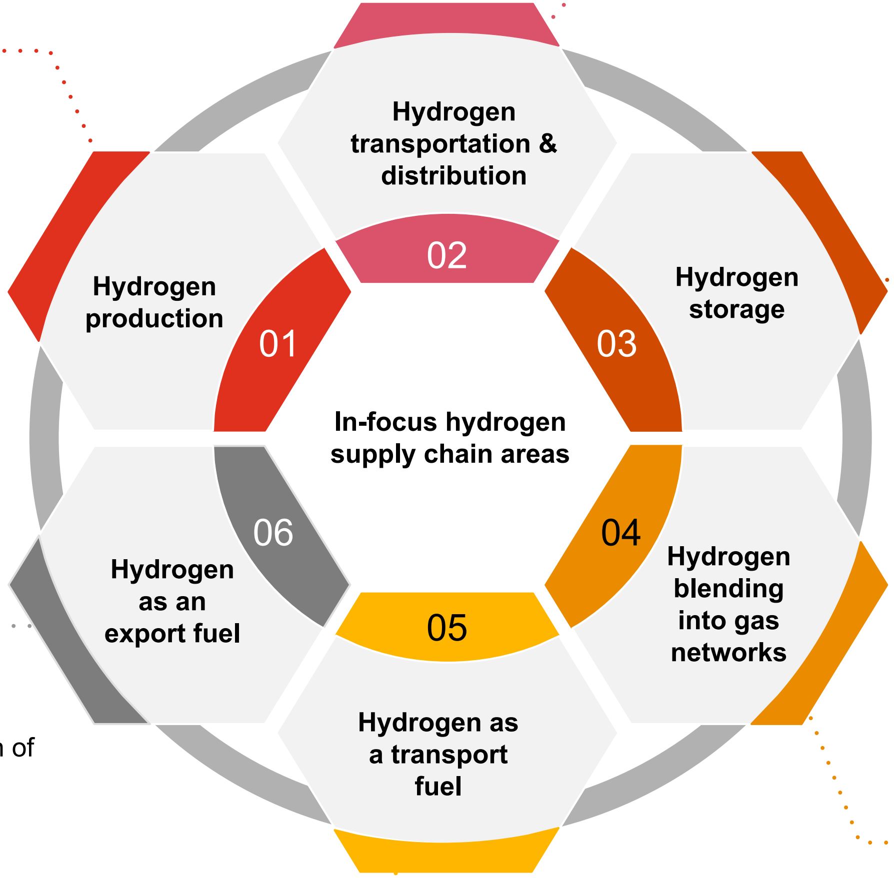


# Overview of the six key supply chain areas

**The scope of our analysis is defined by six distinct, priority supply chain areas. By examining the activities undertaken across the supply chain in all six of these areas, we built a view of the job roles that would be needed to 2030, and the capabilities these job roles would need to perform hydrogen-related activities effectively and safely. It is noted that the identified areas do not encompass the entirety of the hydrogen supply chain and that some elements fall outside the scope of the project.**

## Hydrogen production

This area concerns the production of hydrogen by any means (such as with renewable technologies or fossil fuels with carbon capture solutions).




## Hydrogen transportation & distribution

This area concerns all the labour activities required to physically compress, transport and distribute hydrogen or its derivatives between locations. This includes through pipelines in gaseous form, as well as through logistics activities including road transport and shipping.

## Hydrogen storage

This area concerns the activities needed to hold hydrogen or any derivatives in a single location for any period of time, such as conversion into a compound (e.g. ammonia), and the physical infrastructure needed, such as tankers and refuelling stations.

## Hydrogen blending into gas networks

This area addresses the activities needed to blend hydrogen into the existing or a new natural gas network within Australia, including the impacts to consumer appliances, gas turbines and maintenance arising from replacing natural gas with hydrogen.

## Hydrogen as a transport fuel

This area addresses the activities supporting the introduction of hydrogen as a fuel in mobility applications, including both commercial passenger vehicles and mobile plant equipment utilised in industrial/commercial settings.

## Hydrogen as an export fuel

This area addresses all of the activities supporting the export of hydrogen at scale from Australia's ports, whether in a gaseous/liquid form or converted into a hydrogen carrier (e.g. ammonia).

# 3

# Methodology

# Methodology (1/4)

**To understand the demand that will be required on the Australian education and training system to support the future hydrogen workforce, a six stage methodology was used. Each stage of the methodology was cumulative, with the findings from each section building on one another. The below presents a high-level view of the inputs into the project, with detailed summaries presented on the subsequent pages.**

## Figure 3. Overarching project methodology

**Job roles**
Using consultation and desktop research, the job roles that will be required to support and enable the six areas of the hydrogen supply chain were identified.

**Capability matrix**
Consultation was used to map the identified job roles to the hydrogen-specific capabilities. This supported an understanding of which job roles require each skill/knowledge requirement, including whether it is a core or specialist capability of the job role.

**Job role forecasts**
Quantitative research and analysis was used to develop a model that identifies the number of jobs in each occupational cluster required by 2030 under three hydrogen production scenarios.

**Hydrogen-specific capabilities**
Detailed consultation was used to identify the hydrogen-specific capabilities (skills/knowledge) required by job roles to safely and effectively engage in hydrogen activities.

**Existing training pathways**
The hydrogen-specific capabilities were mapped against existing training pathways in Australia to understand existing hydrogen training pathways and potential training gaps that need to be filled.

**Output**
The various inputs were collated together to develop a view of what the hydrogen workforce in Australia will look like in 2030 and what is currently available in the education and training system to support and enable this workforce.

Please refer to **Appendix F** for the list of stakeholders consulted.

# Methodology (2/4)

**A. Job roles:** Using consultation and desktop research, the job roles that will be required to support and enable the six areas of the hydrogen supply chain were identified.

**B. Hydrogen-specific capabilities:** Detailed consultation was used to identify the hydrogen-specific capabilities (skills/knowledge) required by job roles to safely and effectively engage in hydrogen activities.

A combined approach was undertaken to identify the different types of job roles needed to support the hydrogen economy and the underpinning capabilities (skills and knowledge) that these job roles would require to perform their tasks and activities. Broadly, this consisted of three main processes:

## A. International and domestic desktop research

- **Literature review**: A broad range of domestic and international literature was used to inform an understanding of the current local and global hydrogen trends and practices, and to identify current and emerging job roles required to support a hydrogen economy. This included review and analysis of national and international reports and policy documents, academic articles, skills frameworks, and training curriculum.
- **Skills and job role frameworks review**: Various skills and job role frameworks were assessed to understand how identified job roles and skill needs fit within pre-existing structures, e.g. the Australian Skills Classification (ASC). To ensure that 'like' job roles were being considered, the Australian and New Zealand Standard Classification of Occupations (ANZSCO) taxonomy was adopted to identify a common level of job role. For the purposes of this report, job roles have primarily been detailed at ANZSCO Level 2 and Level 1 – Unit Group and Occupation (four and six-digit codes).
- **Domestic and international job board and professional networking site review**: Job boards and professional networking sites were reviewed to gather data on current job role advertisements. Sites included: LinkedIn, Seek, Indeed and Glassdoor.

## B. Stakeholder consultation

- **1:1 consultations and focus groups**: Held with key stakeholders from September 2021 to January, 2022. This allowed us to capture specific and deep insights required for analysis. The scope of questions included: what job roles do you have engaging in hydrogen activities, what skills and knowledge do they need to do this, do you foresee any new job roles emerging in this space, and what education and training pathways are available to support workers in this area.
- **IRC/SSO Working Group**: Comprised of members from Industry Reference Committees (IRCs) and established to provide feedback on the relationship between hydrogen and their various industries. Several meetings were held to support the identification of relevant job roles and capabilities.

## C. Stakeholder validation

- **Testing and validation**: Key findings and insights, including the list of 46 job roles and 26 hydrogen-specific capabilities, were tested and validated with priority stakeholders (including operational organisations and the IRC/SSO Working Group).

# Methodology (3/4)

**C. Capability matrix:** Consultation was used to map the identified job roles to the hydrogen-specific capabilities. This supported an understanding of which job roles require each skill/knowledge requirement, including whether it is a core or specialist capability of the job role.

A capability matrix was developed to assist in providing the next level of analysis of the previous inputs (i.e. job roles and capabilities) by determining if a hydrogen-specific capability is a 'core' or 'specialist' capability for an identified job role in a specific supply chain area. For example, determining if 'handling cryogenic materials') is a 'core' or 'specialist' capability for Chemical Engineers in the hydrogen production supply chain area.

In the capability matrix, each hydrogen capability was mapped to every job role in each supply chain area and assigned one of the following four categorisations:

- **Core capability**: Indicates that the hydrogen-specific capability will be expected by all individuals working in this job role in this supply chain area, to some degree.
- **Specialist capability**: Indicates that the hydrogen-specific capability will only be expected by some individuals working in this job role in this supply chain area.
- **N/A**: Indicates that the hydrogen-specific capability will not be expected of this job role in this supply chain area.
- - : Indicates that the job role is not required in this supply chain area.

The capability matrix was developed using desktop research and consultation insights, including substantial subject matter expert validation using the excel tool. Please see **Appendix B** for additional information on the capability matrix methodology.

**D. Current training offerings:** The hydrogen-specific capabilities were mapped against existing training pathways in Australia to understand existing hydrogen training pathways and potential training gaps that need to be filled.

A training pathway review was undertaken to develop a complete picture of hydrogen education and training across Australia. This involved reviewing different education and training systems and formats across Australia and identifying if a training product touches on one of the 26 hydrogen capabilities.

This analysis was developed to consider whether any of the identified hydrogen capabilities are already catered for within the existing education and training system. It considers hydrogen training pathways and products across the following three areas:

**Vocational Education and Training (VET).** This includes hydrogen skills and knowledge within Units of Competency, Skill Sets and Qualifications.

**Higher Education.** This includes all higher education programs delivered by Universities and Non-University Higher Education Providers (NUHEPs).

**Non-accredited training.** This includes non-accredited training that is delivered by peak bodies, unions, and businesses/organisations.

Based on this analysis undertaken, the 26 hydrogen-specific capabilities were grouped into three categories:

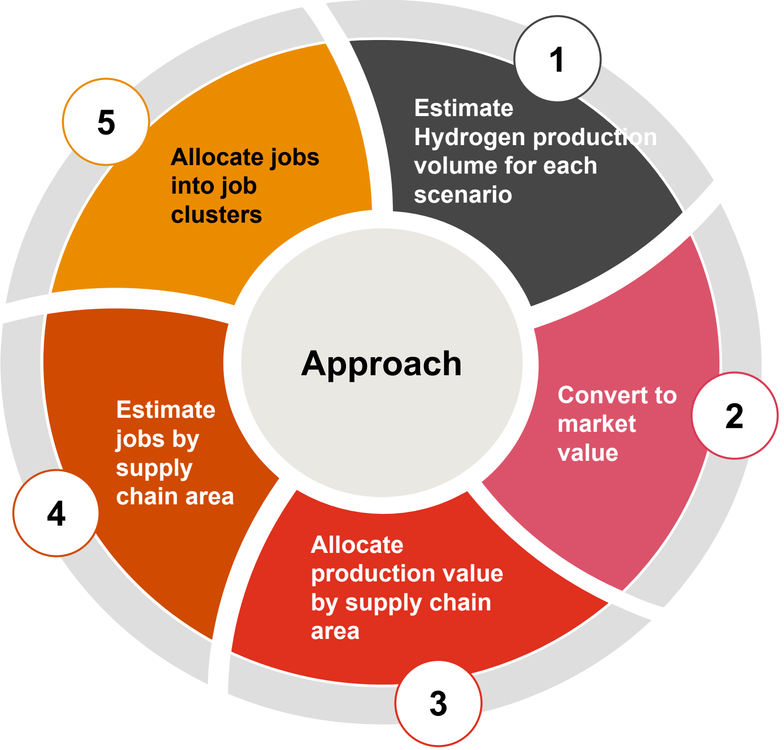
1. **Sufficient hydrogen training coverage**
2. **Some hydrogen training coverage, but additional contextualisation or development required**
3. **Minimal/no hydrogen training coverage.**

# Methodology (4/4)

**E. Job role forecasts:** Quantitative research and analysis was used to develop a model that identifies the number of jobs in each occupational cluster required by 2030 under three hydrogen production scenarios. This informed an understanding of the number of job roles that will require each capability and the subsequent demand on the education and training system.

Five steps outlined in **Figure 4** were undertaken to determine the additional jobs that may be generated within the six occupational clusters where all 46 job roles are mapped across the six in-scope areas of the supply chain. Please see **Appendix C** for a more detailed description of the methodology undertaken.

## Figure 4. Quantitative modelling approach




**Estimate Hydrogen production volume for each scenario**

A PwC proprietary dataset includes expected hydrogen production from each initiative earmarked to 2028.

The three hydrogen production scenarios were inferred from this spreadsheet by capturing a) All planned and constructed initiatives, b) All planned and constructed initiatives plus 25% of proposed projects, c) All planned and constructed initiatives plus 50% of proposed projects.

The dataset includes projects to 2028, noting that projects post-2028 are assumed to not contribute to Hydrogen production in 2030.

**Convert to market value**

Hydrogen production volumes converted to market value based on the estimated market value per kilogram of hydrogen for different end uses.

**Allocate production value by supply chain area**

Hydrogen production allocated into the relevant supply chain area based on the intended end use of the hydrogen produced by each initiative.

**Estimate jobs by supply chain area**

Employment per supply chain area obtained by applying the relevant input-output employment multiplier (IO multipliers) to the market value of hydrogen produced in each supply chain area.

IO multipliers are a government-approved method to estimate the input (in this case, jobs) per $1m output produced in a given sector.

**Allocate jobs into job clusters**

Distribute jobs by supply chain area into employment clusters using the workforce composition of comparable industries.

Workforce composition – Oil and gas industry workforce composition data was utilised to estimate the future allocation of jobs in Hydrogen for 2030.

# Report limitations (1/2)

It is noted that there are some limitations to the work undertaken in this final report. These limitations and their impact on the findings presented in this report are described below.

| | Limitation: | Description: | Future considerations: |
|---|---|---|---|
| 1 | **Occupational taxonomies (e.g. ANZSCO) do not provide coverage for all job roles required.** | This report has sought to map the identified job roles to the ANZSCO occupational taxonomy. However, given that the hydrogen industry continues to develop and emerge, some job roles are not currently reflected in these frameworks. Job roles identified by stakeholders without an ANZSCO code have been noted in **Appendix D**. In some instances, the most similar ANZSCO code for a job role has been provided for context. | Future updates to the ANZSCO taxonomy undertaken by the Australian Bureau of Statistics should consider emerging job roles in hydrogen. |
| 2 | **Job role identification and analysis was limited to ~40 job roles.** | Given the large number of job roles and job role specialisations that could proliferate within the hydrogen industry, this report targeted its investigation at ~40 job roles (and settling on 46 job roles) that are most likely to be in demand in 2030. | Further analysis of secondary job roles should be undertaken. Essential job roles, such as emergency service workers, will need to have the sufficient knowledge and skills required to safely work in the hydrogen economy. |
| 3 | **The infancy of the Australian hydrogen sector means some insights on key skills and knowledge had to be sourced from international stakeholders.** | Though Australia has had established hydrogen producers operating in its economy for many decades, some production methods (e.g. electrolysers) and hydrogen applications (e.g. fuel cell vehicles) are limited, and key skills and knowledge regarding these are located overseas in more mature markets. Consequently, some domestic consultations have provided largely speculative views, which this report has sought to rectify through consultation with international stakeholders. | As Australia's hydrogen economy matures, drawing upon future insights and findings from national stakeholders would be the preferred method of insight and data collection. |
| 4 | **The report does not have a state/territory based geographical lens to any analysis or insights.** | The purpose of this report was to analyse skills and knowledge shortages, as well as identifying job roles to support a thriving hydrogen economy. The lens taken was high-level, from a national perspective, excluding specific state-based analysis. | Identifying any state/territory associated gaps in the hydrogen workforce can potentially reduce any future work shortages that may arise and support current and future hydrogen related projects. |
| 5 | **Job role forecasts excluded job roles required for construction of hydrogen-related production facilities.** | Job roles related to the construction of hydrogen-related production facilities or related operations, were not included as part of the job role forecasts in this report. For example, planner or scheduler, surveyors, and builders. | Further analysis of job roles from the construction industry needed during the development of hydrogen-related production facilities will support future hydrogen related projects to ensure that there is a workforce ready to meet demand. |

# Report limitations (2/2)

It is noted that there are some limitations to the work undertaken in this final report. These limitations and their impact on the findings presented in this report are described below.

| | Limitation: | Description: | Future considerations: |
|---|---|---|---|
| 6 | **The hydrogen production dataset used for job role forecasts only included hydrogen initiatives and projects until 2028.** | The dataset used for job role forecasts based on hydrogen production contains a recent (2022) view of the 78 planned and committed hydrogen initiatives to 2028. There is limited data and information available for hydrogen initiatives and projects predicted to 2030 and beyond. | Updating the list of hydrogen initiatives as they are announced would enable an up-to-date view on future production volumes that can better inform government initiatives and policy over the next 10-20 years. |
| 7 | **Job role forecasts are sensitive to changes in the market price of hydrogen (both in absolute terms and relative to other renewable energy fuel sources), which can be expected to change over time.** | As the hydrogen industry continues to develop and emerge, forecasting the timing and flow on effect of future production efficiencies to the market price of hydrogen is challenging. To mitigate risk, a more simplified and conservative approach to estimating the market price of hydrogen has been employed. | A detailed investigation into the expected market value of hydrogen will strengthen future job role forecasts and analysis. |
| 8 | **Proxies have been used in place of hydrogen industry-specific data to determine the future workforce composition.** | Data on the workforce composition of the oil and gas industry has been utilised to estimate the expected distribution of the workforce across identified occupational clusters. Although the oil and gas industry is a comparable industry to the hydrogen industry, particularly with regards to natural gas, the future composition of the hydrogen workforce may not be homogenous to other industries. | As the hydrogen industry continues to develop and emerge, leveraging hydrogen project specific datasets will strengthen future insights and findings on the future workforce composition. |
| 9 | **Limited access to non-accredited training materials.** | A significant amount of training and training materials for hydrogen projects are taught by individual manufacturers or suppliers. These are typically non-accredited training materials that are conducted in-house with few organisations making them publicly available. Therefore, the discussion of non-accredited training materials in this report is more general than with accredited training materials which are publicly available. | Training developers should engage and consult with key hydrogen manufacturers and suppliers to ensure high quality, robust, and vendor agnostic training solutions. |

# 4

# The global hydrogen landscape

# Demand for a global hydrogen economy

**There has been an increasing global demand for hydrogen in recent years. To make the most of this growing demand, governments and companies have been taking actions to establish hydrogen supply chains by advancing technology, removing regulatory barriers, reducing costs, creating international trade relationships, and establishing long-term strategies to guide the industry.**

Hydrogen is gathering significant momentum globally as it shifts to becoming an economically-viable and flexible fuel energy carrier, and one of the important enablers for the global energy transition. Appetite for hydrogen within industries such as automotive, power, gas and water utilities, manufacturing, refining and other industrial markets has grown due to decreasing electrolyser and renewable energy costs, as well as increasing demand for widespread decarbonisation.

In this environment there have been a range of national hydrogen strategies, announcements and investments.[2] For example:

- **Germany** announced up to EUR 1.4 billion of government funding and subsidies for projects promoting hydrogen, with a particular focus on the transport sector.
- **The United States** announced the implementation and extension of the section 45Q tax credit in the Internal Revenue Code (that rewards carbon capture and disposal in secure geological storage sites), and targets of 1,000 hydrogen refuelling stations and 1,000,000 fuel cell electric vehicles by 2030.
- **Japan** announced the development of 80 hydrogen refuelling stations by the end of 2022.

## Global hydrogen economy snapshot

Global **demand for hydrogen is projected to increase** to 100m tonnes by 2030 and just over 500m tonnes by 2050.[3]

75 countries currently have **net zero carbon ambitions**.[4]

**Australia's hydrogen industry could generate $11 billion** in additional GDP by 2050.[5]

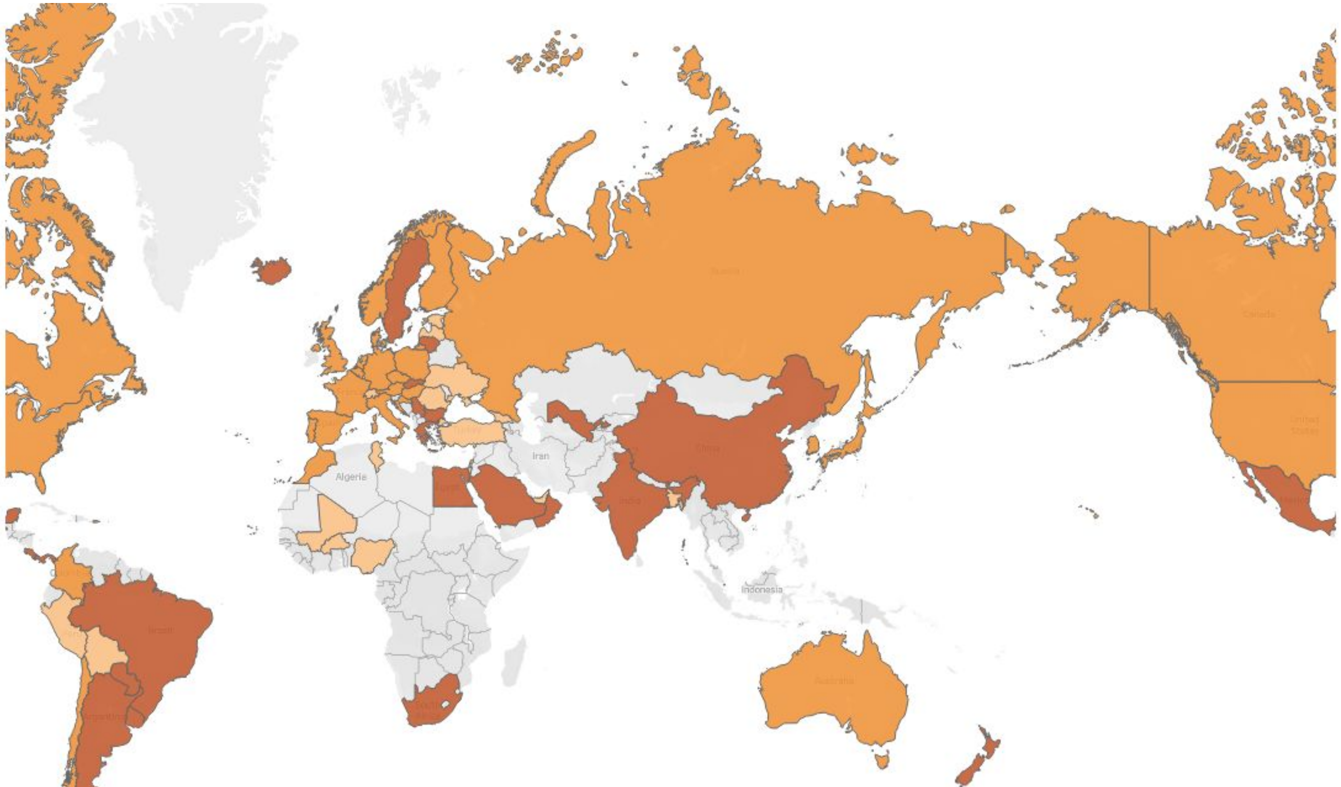
**The Asia Pacific hydrogen market** is accelerating faster than any other and is estimated to reach a value of **$52 billion by 2030**.[6]

2 H2 Bulletin, 'Which countries are backing the hydrogen economy?' accessed at https://www.h2bulletin.com/countries-hydrogen-economy-goals-policies/
3 PwC, 'Embracing clean hydrogen for Australia: How the journey towards decarbonisation can be fuelled by Hydrogen' accessed at https://www.pwc.com.au/infrastructure/embracing-clean-hydrogen-for-australia-270320.pdf
4 Hydrogen Council, 'Hydrogen Insights: A perspective on hydrogen investment, market development and cost competitiveness' accessed at https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021-Report.pdf
5 COAG Energy Council, 'Australia's National Hydrogen Strategy' accessed at https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf
6 PwC, 'The Hydrogen Sector & Our Involvement', internal documentation.

# International hydrogen initiatives and strategies

**With demand for hydrogen increasing across the international stage, the last five years has seen the release of targeted hydrogen strategies by a multitude of nations. All of these strategies identify an increased use of hydrogen to meet emissions targets and most of which include calls to action for the development of a skilled workforce to establish and enable the desired hydrogen economy.**

### Figure 5. Countries with a current or progressing national hydrogen strategy[7]




**Key:**

- Published national strategy
- National strategy in preparation (as at August 2022)
- Initial strategy discussion (as at August 2022)
- N/A (August 2022)

7 World Energy Council, 'Hydrogen on the Horizon: National Hydrogen Strategies' accessed at https://www.worldenergy.org/publications/entry/working-paper-hydrogen-on-the-horizon-national-hydrogen-strategies, with additional research used to identify hydrogen strategies and policies released between June 2021 (publication of the World Energy Council report) and August 2022.

Whilst the development of a global 'hydrogen economy' is still in its preliminary stages, the high level of activity in **Figure 5** shows the global momentum to implement country-specific hydrogen strategies and policies. To date, there are 26 countries which have published a hydrogen strategy, 24 countries which are preparing national strategies, and 17 countries that are in initial policy discussions.

Most of the strategies and policies include a focus on lowering the cost of hydrogen, reducing carbon footprints, using existing gas infrastructure to spur new clean energy supplies, supporting the transport and export of hydrogen, encouraging the development of fuel cell electric vehicles and re-charging stations, and establishing international shipping routes to promote international trade.

# Areas of international hydrogen focus

**A comparison of the core focus areas of six international hydrogen strategies demonstrates that there are varying areas of interest. However, there are common themes across several countries, particularly in technology development and emissions reduction. Interestingly, this comparative analysis shows the unique focus of the Australian hydrogen economy to develop hydrogen for export.**

## Figure 6. Focus areas of six international hydrogen strategies[8]

**Australia***
- Develop hydrogen for export
- Support technology development
- Foster economic growth

**Japan**
- Reduce emissions
- Support technology development
- Foster economic growth
- Integration of renewables
- Diversify energy supply

**The Netherlands**
- Reduce emissions
- Support technology development
- Foster economic growth
- Integration of renewables

**Germany**
- Reduce emissions
- Support technology development
- Foster economic growth
- Integration of renewables
- Diversify energy supply

**United Kingdom**
- Reduce emissions
- Support technology development
- Integration of renewables

**California, USA**
- Reduce emissions
- Support technology development
- Foster economic growth
- Integration of renewables

8 U, Albrecht et al, 'International Hydrogen Strategies' accessed at https://www.weltenergierat.de/wp-content/uploads/2020/09/WEC_H2_Strategies_finalreport_200922.pdf

* It is recognised that the new Australian Government (as of May 2022) may change these areas of focus, particularly relating to emissions reductions.

# Skills and training commitments in international strategies

**Research suggests that most of the international strategies focus on strategic initiatives to drive economic growth and the need for the production of clean hydrogen. However, some strategies include commentary on workforce development and the need for skills and training, notably the United Kingdom and France.**

## Figure 7. Examples of skills and training commitments in international strategies

### Germany[9]

The strategy outlines an aim to foster science and mobilise a skilled labour workforce. In order to facilitate the scale up in hydrogen production, there is a push to train, recruit and develop scientists and newly skilled staff. The government aims to support research companies and institutes. It places a strong focus on education and training capacity in regions working with hydrogen.

This was outlined as part of measure 29 of the 38-step action plan included as part of their national strategy.

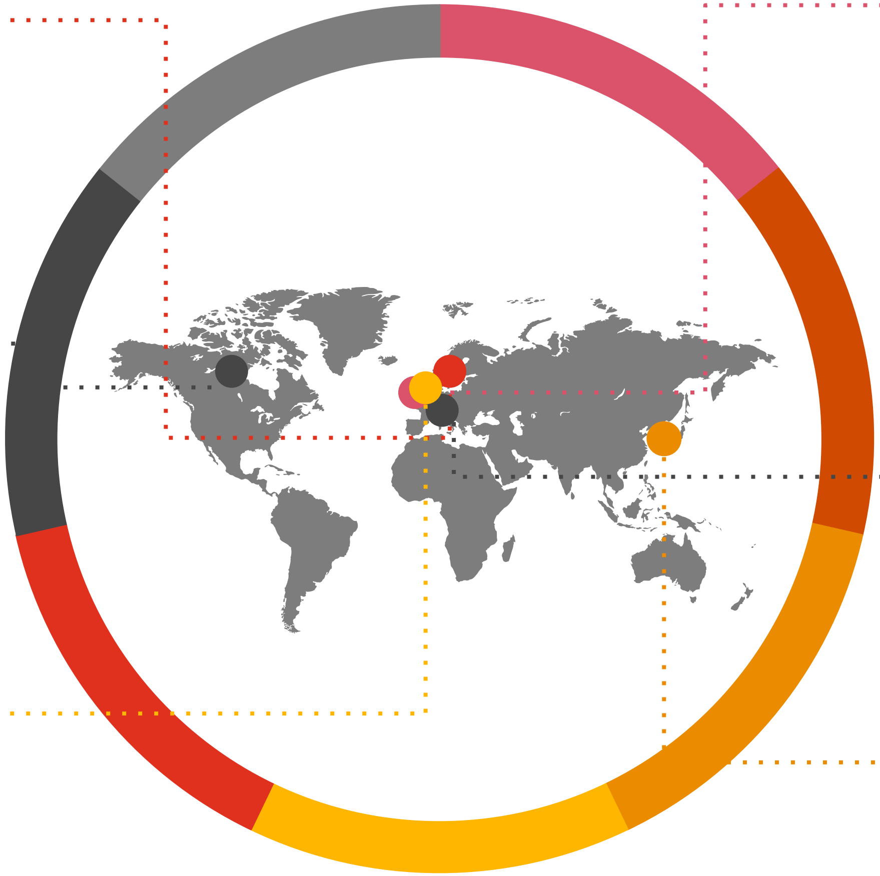
### USA[10]

The United States' primary focus is on Hydrogen production, cost, demand, emerging markets and initiatives, transportation, storage and safety.

The strategy provides limited mention of plans to upskill and support the current and future workforce. The hydrogen strategy also makes no mention of a commitment to formulating a plan for workforce development. See **Appendix A** for a detailed Case study on US hydrogen initiatives.

### The Netherlands[11]

The Netherlands plans to focus on attracting foreign investment to encourage the development of hydrogen supply chains. The benefit for attracting foreign investment is believed to improve the level of skills and knowledge for national citizens, increasing employment and global knowledge sharing. However, beyond this, there was no plan in the Strategy on how to upskill their existing workforce to support the demand of hydrogen between now and 2030/50.



### United Kingdom[12]

In order to develop a low carbon hydrogen sector, the strategy assesses opportunities for hydrogen employment across the UK and seeks to understand the profile of skills required over 2020 and 2030. To facilitate this assessment, the government aims to:

- Work with industry, education providers and unions to explore opportunities for relevant skills programs
- Ensure the UK has immediate skills to kick-start and deliver a green economy
- Develop a long-term plan to chart out skill requirements
- Ensure jobs in the green economy are of a high quality and inclusive
- Support opportunities for workers to transition from high carbon sectors to net zero sectors.

### France[13]

The France Hydrogène strategy has a strong focus on the strengthening of existing skills, knowledge, and capabilities in order to meet the increased demand for job roles in this area. To meet this need, the French government will support the development of new courses (primarily vocational) with educational establishments and higher education partnerships with companies in the sector. This will support the development of careers for new and existing individuals seeking to upskill and retrain. Please see **Appendix A** for a detailed Case study on French hydrogen initiatives.

### Japan[14]

Japan's Hydrogen Strategy does not mention strategic priorities to upskill and mobilise a hydrogen workforce, however, it notes the importance of achieving a "hydrogen society" by way of promoting the use of hydrogen and obtaining social licence.

9 German Federal Ministry for Economic Affairs and Energy, 'The National Hydrogen Strategy' accessed at https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6
10 U.S. Department of Energy, 'Hydrogen Strategy' accessed at https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf
11 Government of Netherlands, 'Government Strategy on Hydrogen' accessed at https://www.government.nl/documents/publications/2020/04/06/government-strategy-on-hydrogen
12 United Kingdom, Secretary of State for Business, Energy and Industrial Strategy, 'UK Hydrogen Strategy' accessed at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
13 France-Hydrogene, 'National Strategy For the development carbon-free hydrogen in France' accessed at https://minefi.hosting.augure.com/Augure_Minefi/r/ContenuEnLigne/Download?id=5C30E7B2-2092-4339-8B92-FE24984E8E42&filename=DP%20-%20Strat%C3%A9gie%20nationale%20pour%20le%20d%C3%A9veloppement%20de%20l%27hydrog%C3%A8ne%20d%C3%A9carbon%C3%A9%20en%20France.pdf
14 Centre for Strategic and International Studies, 'Japan's Hydrogen Industrial Strategy' accessed at https://www.csis.org/analysis/japans-hydrogen-industrial-strategy

# Landscape of international hydrogen policy initiatives

**Research suggests that governments around the world are making progress towards the goals set in national hydrogen strategies. The scale of policy activity and types of decisions being made demonstrates the international commitment to pursuing hydrogen goals.**

### Table 1. Summary of recent international hydrogen policy initiatives[15]

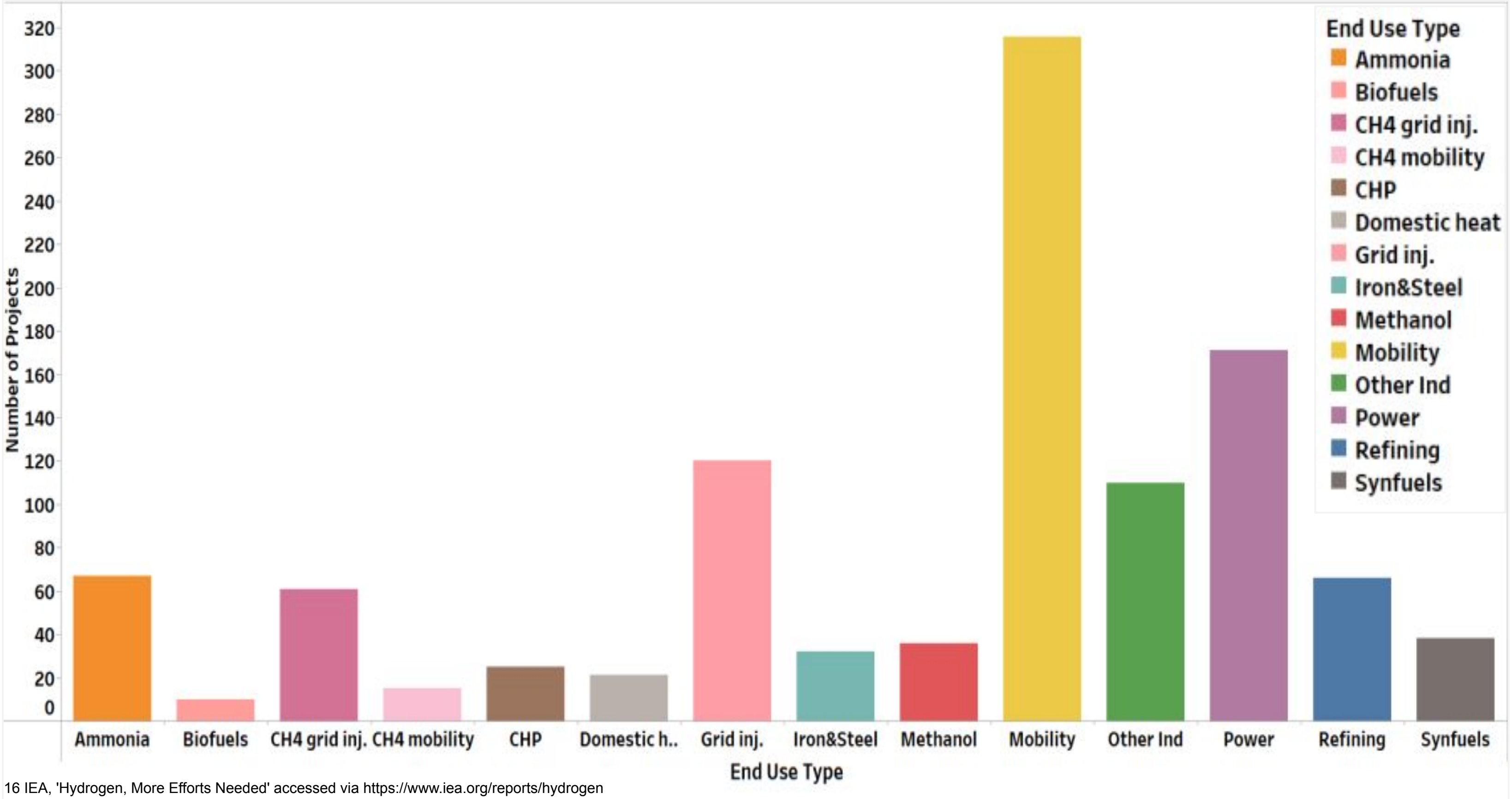
| Government | Policy type | Description | Status |
|---|---|---|---|
| **Austria** | Quota | Approximately EUR 500 million is planned to be invested in green hydrogen for those in industries willing to become CO2 neutral e.g. steel production. | Proposed |
| **Chile** | Project Approval | The Regional Environmental Commission of Magallanes approved the Environmental Impact Statement to approve the green hydrogen project Haru Oni. The initiative, led by Highly Innovative Fuels (HIF), will build a hydrogen-based fuel production plant in Magallanes (South Chile). | In Progress |
| **China** | Financial reward | China has announced a Fuel Cell Electric Vehicle (FCEV) pilot program, whereby financial reward is given if cities deploy more than 1000 FCEVs. There are a number of requirements needed to collect these incentives, these include: FCEVS to meet technical standards, achieve a maximum delivered hydrogen price of CNY 35/kg (~USD 5/kg) and establish at least 15 operational HRSs. | In Progress |
| **Denmark** | Project Approval | Denmark has planned to invest 400 million DKK in green technology to reach a 70% emissions reductions target by 2030. This green technology includes investing in technology that captures and stores CO2 and a hydrogen production plant that will convert green electricity from wind to green hydrogen. | Proposed |
| **Germany** | Tender | The German government announced the launch of a hydrogen global program (H2 global) designed to commit to releasing tenders for ten-year purchase agreements on hydrogen-based products. | In Progress |
| **India** | Mandate | The Indian government announced that from 2023/24, oil refineries and fertiliser manufacturers will be expected to implement a new policy which requires 10% of refinery hydrogen demand (increasing to 25% in the following five years) and 5% of hydrogen demand for fertiliser production (increasing to 20% in the following five years) be produced using green hydrogen. | Proposed |
| **Japan** | Conditional Agreement | A memorandum of cooperation on hydrogen was established between Japan and the UAE to facilitate the exchange of hydrogen policy and standard development. This memorandum is designed to build an international supply chain which includes production and transportation to Japan. | In Progress |
| **Norway** | Tender | The Norwegian government has announced a tender for a hydrogen fuelled ferry connection to begin operation in 2024. | In Progress |
| **Portugal** | Quota | The national hydrogen strategy outlines targets for blending 10-15 vol% of hydrogen into natural gas by 2030. | Proposed |

15 IEA, 'Hydrogen, More Efforts Needed' accessed at https://www.iea.org/policies/about. Please note that this IEA report was deleted between the data gathering phase for this project and publication of the final report. The contents of the original IEA report have been amalgamated into this 2021 IEA report: IEA, 'Global Hydrogen Review 2021' accessed at https://www.iea.org/reports/global-hydrogen-review-2021

# End use of global hydrogen projects

**Within this context of international government activity, there have been an increasing number of hydrogen projects around the world.**

**Figure 8. Quantification of global hydrogen projects mapped against end-use of hydrogen[16]**




Analysis of these projects shows that there is a particularly strong focus on projects that support the following four end uses of hydrogen:

- Mobility
- Power
- Grid Injection (hydrogen into the natural gas grid)
- Other industries (e.g. oil refining, ammonia production, methanol production and steelmaking).

Germany and France, for example, are leading the way in their investment in hydrogen mobility (use of hydrogen in vehicles: road, off-road, rail, maritime or aviation). Some examples of mobility projects include the announcement of the German project 'Hyways for Future'[17], which focuses on the development of electrolysis capacity, hydrogen fuel stations, investment in fleets of buses, fuel cell vehicles, trucks and cars. Similarly, in France, the 'Hyport – Toulouse-Blagnac Airport'[18] project has been announced with the installation of two hydrogen stations at the Toulouse-Blagnac.

16 IEA, 'Hydrogen, More Efforts Needed' accessed via https://www.iea.org/reports/hydrogen
17 FCH, 'Hyways for Future' accessed at https://www.h2v.eu/analysis/best-practices/hyways-future
18 McPhy, 'A first hydrogen production and distribution system to be implemented in an airport area' accessed at https://mcphy.com/en/achievements/hyport-3/

# 5

# The future Australian hydrogen economy

# The Australian hydrogen economy

**Amidst this international momentum, in 2019 the Australian Government released a National Hydrogen Strategy and committed funding to hydrogen initiatives. Research and consultation suggests that hydrogen presents a significant opportunity for Australia, and that Australia has the building blocks to become a global leader across the hydrogen supply chain.**

There is an opportunity for Australia to become a world leader across the global hydrogen supply chain, including in:

- **Hydrogen production**
- **Blending hydrogen into natural gas**
- **Hydrogen distribution**
- **Hydrogen as a transport fuel**
- **Hydrogen storage**
- **Hydrogen as an export fuel**

Growth in these areas would drive significant economic benefits for Australia, as well as support clean energy targets. As hydrogen infrastructure scales up in Australia, its potential use cases will expand and grow to cover increasingly advanced applications, such as combined heat and power systems and long-distance passenger transportation.

Australia aims to become a “major player” in global hydrogen production and trade by 2030 and has produced a thorough policy roadmap in support of this ambition.[19] With strong renewable energy resources, trade relationships and proximity to key markets, Australia has the potential to be a significant global producer and exporter. Hydrogen production is seen as an opportunity to diversify the economy, attract investment, and reach new export markets.

To achieve this, Australia is investing heavily in demonstration projects, emerging technologies and ‘hydrogen hubs’ to take advantage of a global market that is expected to boom between 2030 and 2050. As of late 2021, Australia had the second largest amount of zero-carbon hydrogen projects in development globally.[20]

Additionally, Federal and State Governments have committed billions to hydrogen projects across the supply chain. There have also been recent financial commitments of $300 million from the Clean Energy Finance Corporation’s (CEFC) Advancing Hydrogen Fund and $103 million from ARENA to support the development and demonstration of electrolyser technologies. The new Australian Government (as of May 2022) indicated that emissions reduction is one of their Government's priorities. For example, an election commitment of $100 million was promised to support new energy apprenticeships, including hydrogen apprenticeships.[21]

The pursuit for hydrogen in Australia is primarily driven by economic goals. Whilst reducing carbon emissions and meeting Paris Agreement commitments are included as goals in the National Hydrogen Strategy, its primary motivation for a hydrogen industrial strategy is to create jobs, attract investment, and open new export markets, especially as demand for its fossil fuel exports falls over time.

Whilst Australia has become a global leader in renewable energy installation, hydrogen provides a further opportunity to decarbonise its molecular fuel use, but also as a means of energy storage and eventual transportation to international markets, with Japan, South Korea, Singapore and China having set (or in the process of setting) ambitious hydrogen deployment targets.

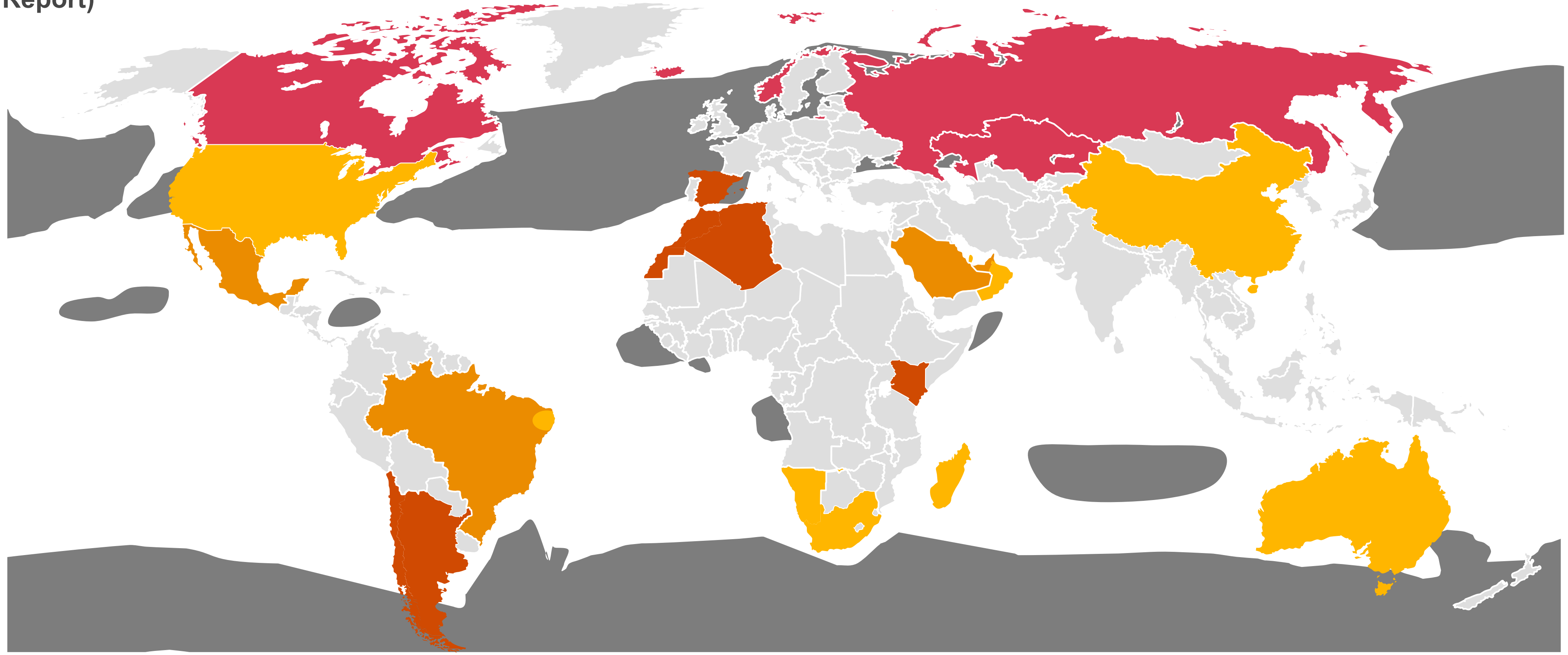
Australia has already entered into Government-to-Government agreements with Japan, Germany, Singapore, Republic of Korea, United Kingdom and India to build strong trade relationships, setting the foundation to become a major international exporter of hydrogen. By setting a hydrogen policy agenda, clear and regular progress reporting, and measurable targets for success, Australia can provide partner nations with the confidence that progress is being made towards establishing Australia as a global leader in hydrogen production.

19 Centre for Strategic and International Studies, ‘Australia’s Hydrogen Industrial Strategy’ accessed via https://www.csis.org/analysis/australias-hydrogen-industrial-strategy
20 Ibid.
21 Labor, ‘New Energy Apprenticeships’ accessed at https://www.alp.org.au/policies/new-energy-apprenticeships#:~:text=Apprentices%20who%20choose%20to%20train,boost%20retention%20and%20improve%20completions

# The opportunity for Australia as a hydrogen leader

**The hydrogen economy depends on a global production network. However, there is a limited potential in many developed regions to produce hydrogen and many countries will not be able to generate hydrogen from renewable sources to satisfy decarbonisation targets and will, therefore, become reliant on hydrogen imports.**

## Figure 9. Representation of countries with high hydrogen production potential (analysis drawn from World Energy Council Report)[22]



As a country with significant hydrogen production potential, Australia is in a position to become a key player in the global hydrogen export market. This is particularly relevant given that the Asia-Pacific hydrogen market is accelerating faster than any other.

**Key:**

- Wind
- Photovoltaic (PV)
- Primarily PV, in parts combination
- Combination
- Wind offshore >10 m/s in 100 m

Note: Illustrative presentation of the strongest renewable energy source potential only. It is not an extensive list of all countries. Only strong wind zones offshore shown.

22 World Energy Council, 'INTERNATIONAL ASPECTS OF A POWER-TO-X ROADMAP' accessed at https://www.frontier-economics.com/media/2642/frontier-int-ptx-roadmap-stc-12-10-18-final-report.pdf

# The Australian National Hydrogen Strategy

**Australia joined the international hydrogen momentum in 2019 with the release of the National Hydrogen Strategy. It sets a vision for a clean, innovative, safe, and competitive hydrogen industry that benefits all Australians. It also aims to position the Australian hydrogen industry as a major global player by 2030 and, importantly, recognises the need for an effective and skilled workforce to support this ambition.**

The National Hydrogen Strategy (Strategy) outlines the actions needed for Australia to build a large-scale hydrogen supply chain.[23] It states that the benefits of a clean hydrogen industry in Australia could be as high as $11 billion a year in additional GDP by 2050, and lead to the creation of thousands of new jobs across various areas of the economy, **including energy, transport and heavy manufacturing (such as steel).**

The 57 joint actions agreed to by the Council of Australian Governments in the Strategy are themed around seven priority areas:

1. National coordination
2. Developing production capacity
3. Responsive regulation
4. International engagement
5. Innovation and R&D
6. Skills and workforce
7. Community confidence

## Skills and workforce

Importantly, the Strategy articulates the need for a skilled Australian workforce to drive the goals set out in the Strategy. It notes:

- *Governments, industry, educational institutions and registered training organisations will need to work together to develop and deliver quality education and training. Courses and qualifications will need to take account of standards and codes as they are developed and reviewed over time, both internationally and domestically.*
- *Governments will develop nationally consistent training materials and guidelines for procedures to do with the production, handling, transport and use of hydrogen. The South Australian Government will work with relevant agencies and industries from other states and territories to develop these guidelines and training materials and facilitate knowledge sharing on safe work practices.*[24]

As such, whilst economic growth and innovation is a core aim of the Strategy, there is a clear recognition that realising the opportunities associated with hydrogen will require a workforce that is skilled and capable of engaging effectively and safely with hydrogen.

In the longer-term (2025 – 2030), the Strategy identifies the need for Australian governments and industry to work together to support:

- IRCs [Industry Reference Committees]* reviewing, updating and developing units of competency and qualifications which are hydrogen relevant.
- Clear hydrogen related education, training and employment, including recognition of prior learning.
- Clear and accurate information available for anyone interested in pursuing hydrogen-related education, training and careers.

* Note – From 1 January 2023, Industry Clusters will be responsible for reviewing, updating and developing training products in the new system.

23 COAG Energy Council, 'Australia's National Hydrogen Strategy' accessed at https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf
24 Ibid.

# State and territory support for hydrogen initiatives

**Investment in Australia's hydrogen future is receiving strong support across all levels of government, with all Australian states and territories launching policies and initiatives to support the growth of the hydrogen economy.[25] However, there are few state-based programs that relate to workforce development and, to realise the value of these projects, a workforce that is skilled and capable of engaging effectively and safely with hydrogen is required.**

## Western Australia (WA)

- Published an expression of interest to produce and export renewable energy in the industrial area of Oakajee.
- Established a $15m renewable hydrogen fund in support of the renewable hydrogen strategy.

## Queensland (QLD)

- Fleet Trial of Hydrogen Fuel Cell Vehicles.
- The announcement of a $35m Hydrogen Industry Development Fund.
- The establishment of a Hydrogen Export Task Force.
- The release of a 5-year hydrogen strategy.
- $53.6 million to renewable energy and hydrogen industry training and skills development.

## Victoria (VIC)

- Released the Renewable Hydrogen Industry Development Plan, including $10m to accelerate Victoria's hydrogen industry.
- Established the Swinburne University of Technology Hydrogen Hub.
- Announced the Climate Change Strategy and Zero Emissions Vehicle Roadmap.

## Northern Territory (NT)

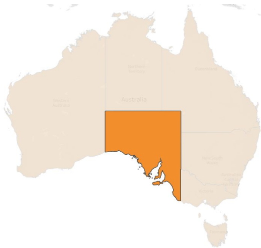
- Released a renewable hydrogen strategy.
- Remote Hydrogen Program.
- The announcement of the 'Desert Bloom Hydrogen Project'.
- The announcement of the 'Tiwi Green Hydrogen Export Project'.

## New South Wales (NSW)

- The announcement of a 'Net Zero Industry and Innovation Program'.
- Illawarra and Hunter Regions Hydrogen Hubs Development.
- The development of the Tallawarra B Dual Fuel Capable Power Station.
- A commitment to source 10% of NSW's gas requirements from green hydrogen by 2030.

## Tasmania (TAS)

- Established the Renewable Hydrogen Industry Development program:
- i) The release of the Renewable Hydrogen Action Plan, which includes details of the Renewable Hydrogen Fund.
- ii) acquirement of concessional loans and support services.



## South Australia (SA)

- 'Memorandum of Understanding' with Port of Rotterdam Authority.
- Energy and Emissions Reduction Agreement with the Australian Government.
- $18.1m contributed by the SA Government to 3 renewable hydrogen projects.
- Released the Hydrogen Action Plan with $1m committed to develop a Hydrogen Export Modelling Tool.

## Australian Capital Territory (ACT)

- Australia's first operating renewable hydrogen refuelling pilot.
- Announced target of zero emissions by 2040.
- Established a dedicated electric and hydrogen vehicle workshop run at the Canberra Institute of Technology.

Note – this is a snapshot of activities and initiatives across the states and territories, it is not a comprehensive summary

25 CSIRO HyResource, 'A short report on hydrogen industry policy initiatives and the status of hydrogen projects in Australia' accessed at https://research.csiro.au/hyresource/wp-content/uploads/sites/378/2021/05/Short-Report-on-Hydrogen-Policy-and-Projects-Status-in-Australia-May-2021-v0.pdf

# 6

# Understanding the job roles needed to support the hydrogen economy

# Overview

**Consultation and research identified 46 existing job roles across six occupational clusters that will be required to support the Australian hydrogen industry.**

## Job roles

Consultation and research were undertaken to determine what job roles are required now, and in the future, to support and enable hydrogen activities across the six areas of the supply chain. This analysis identified **46 job roles.** For the purposes of this report and, as outlined in the methodology (see **Page 14**), job roles have been defined at Level 1 or Level 2 of the Australian and New Zealand Standard Classification of Occupations (ANZSCO) taxonomy, also known as unit groups and occupations (see **Appendix G** for additional information on the ANZSCO mapping and taxonomy). Analysis found that most of the identified job roles will participate in hydrogen activities across multiple areas of the supply chain.

## Occupational clusters

Drawing on ANZSCO mapping, the 46 job roles have been grouped into 'occupational clusters' to support an analysis of the skill and knowledge requirements across major occupation groups. The occupational clusters are groupings of job roles based on shared transferable skills and the sectorial position in the wider economy (e.g. Logistics). This aligns to Level 4 groupings within the ANZSCO taxonomy, also known as sub-major groups. The six occupational clusters have been utilised to group job roles in order to understand the fundamental similarities that may occur in different industries or sectors. They are in themselves mutually exclusive (a job role can only sit in one occupational cluster). Analysis of job role placement across the supply chain indicates that, for many roles, there are opportunities for individuals to move and adapt to different sectors of the economy and supply chain (e.g. electricians). Some occupational clusters (e.g. Engineers) are anticipated to be particularly well-prepared for a transition into the hydrogen workforce in contrast to other occupational clusters (e.g. Logistics) that will require some technical knowledge of hydrogen in order to work effectively on hydrogen projects.

## New job roles and specialisations

Each of the identified 46 job roles is an existing job role that already exists in the labour market, for example, plumbers, welders and truck drivers. These job roles will be augmented to undertake relevant hydrogen activities, however, their base job role will remain the same. Whilst some international hydrogen markets and economies are reporting the emergence of new job roles in the hydrogen economy, analysis suggests that they are likely specialisations of existing job roles rather than new job roles. This suggests that Australia is unlikely to see the emergence of standalone new hydrogen-job roles.

## Six occupational clusters that will support the Australian hydrogen supply chain:

- **Engineers**
- **Technicians and Tradespersons**
- **Logistics**
- **Management**
- **Safety and Quality Control**
- **Specialists**

# Job roles: Mapped to the hydrogen supply chain (1/2)

**Analysis found that most of the identified job roles will participate in hydrogen activities across multiple areas of the supply chain. The table below maps each job role within an occupational cluster to the relevant areas of the supply chain. If a job role will be required to support hydrogen activities in the supply chain area, it is marked with an 'x'.**

| Job Roles | Supply Chain Area #1 Production | Supply Chain Area #2 Transport and distribution | Supply Chain Area #3 Storage | Supply Chain Area #4 Blending into gas networks | Supply Chain Area #5 Transport fuel | Supply Chain Area #6 Export fuel |
|---|---|---|---|---|---|---|
| **Occupational Cluster: Engineers** | | | | | | |
| Chemical Engineer | X | X | X | X | | X |
| Civil Engineer | X | X | | X | | |
| Commissioning Engineer | X | X | X | X | | |
| Electrical Engineer | X | X | | X | X | |
| Electronics Engineer | X | X | | X | | |
| Grid Connection Engineer | X | X | | X | | |
| Marine Engineer | | X | X | | X | X |
| Mechanical Engineer | | X | X | X | X | |
| **Occupational Cluster: Technicians and Tradespersons** | | | | | | |
| Automotive Electric Vehicle Technician | | | | | X | |
| Automotive Electrician | | | | | X | |
| Control Room Officer | X | | | X | | |
| Electrical Fitter | X | X | X | X | | X |
| Electrical Instrumentation Technician | X | X | X | | X | X |
| Electrician | X | X | X | | | X |
| Fitter and Turner | X | X | X | | X | X |
| Gas Fitter (general) | | | | X | X | |
| Gas Fitter (industrial) | X | X | X | X | | |
| Gas Industry Operator | | | | X | | |
| Heavy Duty Fitter | | | | | X | X |
| Heavy Vehicle Mechanical Technician | | | | | X | |
| Light Vehicle Mechanical Technician | | | | | X | |
| Plumber | | X | | | | |
| Process Control Technician | X | | | X | | |
| Refuelling Technician | | X | | | X | |
| Vehicle Body Repair Technician | | | | | X | |
| Welder | | X | | X | | |

# Job roles: Mapped to the hydrogen supply chain (2/2)

**Analysis found that most of the identified job roles will participate in hydrogen activities across multiple areas of the supply chain. The table below maps each job role within an occupational cluster to the relevant areas of the supply chain. If a job role will be required to support hydrogen activities in the supply chain area, it is marked with an 'x'.**

| Job Roles | Supply Chain Area #1 Production | Supply Chain Area #2 Transport and distribution | Supply Chain Area #3 Storage | Supply Chain Area #4 Blending into gas networks | Supply Chain Area #5 Transport fuel | Supply Chain Area #6 Export fuel |
|---|---|---|---|---|---|---|
| **Occupational Cluster: Specialists** | | | | | | |
| Fuel Cell Fabrication and Testing Technician | x | | x | x | | |
| Integration Specialist | x | | | | x | |
| Loading Master | | | | | | x |
| Power Production Plant Operator | | | | x | | |
| Technical Sales Representative | | | | | | x |
| Water Treatment Plant Operator | x | | x | | | |
| **Occupational Cluster: Logistics** | | | | | | |
| Heavy Vehicle Operator | | x | | | x | |
| Marine Master/Operator | | | | | | x |
| Plant Machinery Operator | | | | | x | |
| Stevedore | | x | | | x | x |
| Truck Driver | | x | | | x | |
| **Occupational Cluster: Management** | | | | | | |
| Engineering Manager | x | | x | x | | |
| Maintenance Manager | x | | | x | x | |
| Operations Manager | x | | | x | x | |
| Planner and Scheduler | x | | | x | | |
| Relationship and Community Manager | | | x | | x | |
| Research and Technology Manager | x | | x | | x | |
| **Occupational Cluster: Safety and Quality Control** | | | | | | |
| Gas Inspector | x | x | x | x | x | x |
| Quality Assurance Technician | x | x | x | x | x | x |
| Work Health and Safety Officer | x | x | x | x | x | x |

# Job roles: Specialisations in advanced hydrogen economies

**Analysis of job role adverts from advanced hydrogen economies suggests that hydrogen-specific job specialisations are common, however, standalone new job roles are unlikely. This was supported by international stakeholder consultation, which confirmed that job roles such as "Hydrogen Systems and Retrofit Engineer" are only specialisations of existing job roles and they are not new job roles. This suggests that Australia is unlikely to see the emergence of standalone new hydrogen-job roles.**

## Examples of future job role specialisations:

- Electrolysis Engineer
- Fuel Cell Vehicle Development Engineer
- Fuelling Station Designer
- Hydrogen Refuelling Station Console Operator
- Hydrogen Systems and Retrofit Engineer
- Liquid Hydrogen/Cryogenic Systems Engineer
- Power Electronics Specialist

## Identifying specialisations in advanced hydrogen economies

Research and consultation into international hydrogen economies found that some job role listings that appear to be new job roles are existing job roles with a change in title. In this report, we have referred to these as future job role “specialisations” and not “new” job roles. This indicates that, although new job titles are sometimes presented in the international discourse, they do not always constitute new job roles in themselves. Companies often seek established job roles certified through existing pathways but augmented with practical hydrogen experience. In many cases, advertisements for these job roles specify the requirement for education in existing disciplines such as chemical engineering, or project experience in similar industries, such as chemical processing and/or oil and gas.

For example, the job role “electrolysis engineer” is commonly cited in job ads and in hydrogen industry commentary. However, individuals in these roles undertake roles like chemical, electrical and mechanical engineers, but have years of project experience designing and optimising electrolysers (sometimes with manufacturer proprietary technology). They may also have a deep understanding of the key characteristics and operations of rare fuel cell types (e.g. solid oxide or alkaline). Additionally, “fuelling station designers” hold roles like controls engineers who are expected to work with process control infrastructure and other software, but are also required to have an understanding of the specificities of hydrogen performance. As such, these job roles are not new job roles, rather, they are specialisations of existing roles.

The list on the left provides examples of job role specialisations that could potentially emerge in Australia in the near future. Noting that these new job role specialisations are not currently present in the Australian market, due to a lack of consumer demand for the service, relevant infrastructure, technology, and/or industry experience.

## Analysis of the new specialisations

As these specialisations are not yet present within the Australian market and the role that they will fill in the domestic hydrogen economy is not yet confirmed, they have not been subject to a full skills and knowledge augmentation analysis.

# Job roles: Determining the required level of augmentation

**Consultation insights indicated that the hydrogen economy will affect 46 existing job roles, with the job roles augmented to undertake hydrogen related activities. In order to understand the level of augmentation that a particular job role would likely experience, and the corresponding training required to support them with these changes, a scale of augmentation was created.**

## Figure 10. Augmentation scale

**Increasing changes to work tasks and level of up/re-skilling required**

**Significant –** Many new responsibilities, new and unfamiliar areas of expertise assumed, and a significant need for up/re-skilling.

**High –** Some new responsibilities are assumed, up/re-skilling needed to address new tasks.

**Moderate –** Limited changes to responsibilities, skill levels are higher and tasks more complex.

**Low –** No task changes, but some domain knowledge may be needed.

**Insignificant –** No changes to responsibilities, skill levels or expected tasks.

The job roles identified as required to support the hydrogen economy are not unique nor specific to the hydrogen industry. They are existing roles that are already present in Australia's workforce and may already be expected to work in similar industries, such as chemical processing or natural gas, where their day-to-day tasks have already brought them into contact with hydrogen. However, the transition to producing, handling, storing or consuming hydrogen on a wider scale means that for some roles, their duties will change, and additional hydrogen-specific capabilities must be developed.

A scale was needed in order to build an understanding of the level of change each job role would experience when transitioning to hydrogen activities. This report has sought to assess and understand this change through the creation of a five-point scale that each job role can be positioned on. The scale was validated in consultation with industry and education/training specialists. In order to position job roles on the scale (see **Page 38**), each job role was first plotted on a matrix that considered the following:

1. **Whether new skills and knowledge would be expected of the role; and**
2. **Whether the responsibilities and day-to-day tasks of the job role would change**.

Analysis of the output of the plotting exercises found that many job roles that are either already expected to interact with hydrogen (e.g. chemical engineers) or undertake work on supporting systems without directly handling hydrogen (e.g. fitters and turners) will face very little to no augmentation in their daily tasks and skills and knowledge needs. In both cases, these roles will not go beyond the tasks and duties regularly anticipated in their job role. They may need some new domain knowledge to understand hydrogen's specific properties (e.g. its range of flammability) or they may need to execute their work tasks at a more complex level, however, the level of change will be minor.

The job roles that will be most augmented will be those where workers must learn to undertake new tasks and responsibilities, often working with unfamiliar systems. For example, automotive light and heavy vehicle technicians accustomed to internal combustion engines will need to learn how high voltage electrical and fuel cell systems work and how they can be safely serviced.

# Job roles: Augmentation scale

**In order to determine the level of augmentation experienced by each job role when transitioning to hydrogen activities, stakeholders were asked the extent to which each existing job role would face a change to their skills and knowledge, as well as to their day-to-day tasks and regular responsibilities. These insights were used to plot each job role on the following augmentation scale. Note, this augmentation scale assumes that individuals in these job roles have no prior experience with hydrogen projects.**

## Scale of Augmentation for Job Roles

**Increasing change to role responsibility and level of up/re-skilling required →**

| | **Insignificant –** No changes to responsibilities, skill levels or expected tasks. | **Low –** No task changes, but some domain knowledge may be needed. | **Moderate –** Limited changes to responsibilities, skill levels are higher and tasks more complex. | **High –** Some new responsibilities are assumed, up/reskilling needed to address new tasks. | **Significant –** Many new responsibilities, new and unfamiliar areas of expertise assumed, and a significant need for up/re-skilling. |
|---|---|---|---|---|---|
| **Technicians and tradespersons** | | • Fitter & turner<br>• Gas fitter (general)<br>• Electrician<br>• Electrical fitter<br>• Refuelling technician<br>• Plumber | • Welder<br>• Process control technician<br>• Automotive electric vehicle technician<br>• Control room officer<br>• Electrical instrumentation technician<br>• Gas fitter (industrial)<br>• Gas industry operator | • Heavy duty fitter<br>• Automotive electrician<br>• Light vehicle technician<br>• Heavy vehicle technician<br>• Vehicle body repair technician | |
| **Engineers** | • Chemical engineer<br>• Civil engineer<br>• Electrical engineer<br>• Grid connection engineer | • Electronics engineer<br>• Mechanical engineer<br>• Marine engineer<br>• Commissioning engineer | | | |
| **Specialists** | • Fuel cell fabrication and testing technician | • Power production plant operator<br>• Water treatment plant operator<br>• Loading master | • Integration specialist<br>• Technical sales representative | | |
| **Safety and Quality Control** | | • Gas inspector<br>• Quality assurance technician<br>• Work Health & Safety officer | | | |
| **Logistics** | | | • Truck driver<br>• Marine master/operator<br>• Heavy vehicle operator<br>• Plant machinery operator | • Stevedore | |
| **Management** | | • Engineering manager<br>• Operations manager<br>• Maintenance manager<br>• Planner and scheduler<br>• Relationship and community manager<br>• Research and technology manager | | | |

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# Occupational clusters: Level of augmentation required (1/3)

**Engineers are anticipated to be particularly well-prepared for a transition into the hydrogen workforce. This contrasts to some technicians and tradespersons where, depending on their trade and industry background, they will face a more significant gap in the transition to the hydrogen industry.**

## Engineers

### Job role augmentation

Engineering job roles are anticipated to face relatively low levels of augmentation in the transition into the hydrogen economy, as the fundamental tasks and responsibilities engineers undertake will largely remain consistent with current job roles.

### Impact on skill and knowledge needs

Given the limited changes to engineering tasks and responsibilities, skill and knowledge requirements won't change significantly. Some hydrogen domain knowledge may be needed and could be incorporated into education programs, however, where there are minor changes to tasks and responsibilities, current engineering training pathways will likely have already prepared individuals for the changes, for example, in the design, planning, operation and maintenance of a hydrogen project.

Engineers from disciplines such as mechanical and chemical engineering, or from industries where hydrogen is already commonly used, such as chemical processing, will be particularly well prepared for the hydrogen economy. They will face minimal upskilling and capability development requirements and will have high transferability between various hydrogen projects. These engineers will most likely be familiar with hydrogen's basic characteristics, handling properties, and safety principles, and will be equipped with the problem-solving skills to address the fundamental parameters of any project.

Stakeholder consultation noted hydrogen engineering projects tended to be multi-disciplinary, often bringing together teams with varied backgrounds in civil, mechanical, electrical and chemical engineering. While some of these engineers occasionally need to deepen their technical knowledge of hydrogen or systems unfamiliar to them (e.g. gas pipelines), it was acknowledged this knowledge was a minor gap that could often be rectified through on-the-job learning.

## Technicians and Tradespersons

### Job role augmentation

The level of augmentation expected of technician and tradesperson job roles will vary greatly depending on the specific role. The most significant job role change will be faced by automotive mechanical and electrical technicians. These job roles will need to adapt to the unfamiliarity and complexity of hydrogen fuel cell vehicles and their associated systems.

### Impact on skill and knowledge needs

Hydrogen will affect a range of well-established and highly skilled technician and tradesperson roles in the gas and electrical sectors (e.g. gas fitter, electrical fitter, electrical instrumentation technician). These job roles may already work with natural gas or other gas fuel substitutes, and they will not assume new tasks or responsibilities from hydrogen. For many of these job roles, hydrogen projects will require either a more complex execution of day-to-day tasks or background knowledge about its chemical properties. For example, welders may be expected to be proficient in working with stainless steel with consideration and management of hydrogen chemical properties, but will not undertake any new tasks.

All automotive technicians, regardless of specialisations (i.e. light or heavy vehicles), will face a high skill and knowledge gap in responding to fuel cell vehicles. The lack of access to manufacturer repair procedures, high consumer expectations, and the unfamiliarity with fuel cell systems were all cited by stakeholders as a major driver for this gap. Stakeholders stressed the importance of familiarising not only technicians, but also first responders, with basic depowering and reinitialising procedures to ensure safe work practices around dangerous high voltage systems.

# Occupational clusters: Level of augmentation required (2/3)

**On the whole, specialists and safety and quality control personnel are not anticipated to face significant skills and knowledge gaps in their transition into the hydrogen workforce.**

## Safety and Quality Control

### Job role augmentation

Safety & Quality Control (QC) job roles will undergo limited augmentation in the hydrogen economy.

### Impact on skill and knowledge needs

Safety & QC personnel will face limited skill and knowledge changes when transitioning to work with hydrogen, particularly considering that many existing Safety & QC job roles in the gas and chemical processing sectors work with natural gas and other materials broadly comparable to hydrogen in their day-to-day tasks.

Individuals in these job roles will primarily need to understand the fundamentals of hydrogen, for example, they may need to supplement their knowledge of handling gases with an understanding of hydrogen's unique qualities (such as its lightness and its implications in a explosion, its range of flammability, etc). Gas inspectors and work health & safety inspectors will only face minor changes to knowledge requirements in order to understand how hydrogen's properties differ from other gases. This could include its potential chemical reactivity and its implications on material selection, such as the need for stainless steel or high-density polyethylene (HDPE). For gas inspectors, this knowledge may inform how they carry out some of their regular duties but will not change what is expected of them (e.g. inspectors will seek to recognise the particular signs of crack propagation in hydrogen vessels and assess their safety on the basis of their knowledge of hydrogen properties).

## Specialists

### Job role augmentation

Specialist job roles will undergo limited augmentation in the hydrogen economy.

Specialists working in power generation and chemical processing (e.g. water treatment plant operators for electrolysers, power production plant operators, etc.) will experience little to no change in their expected tasks and responsibilities.

Integration specialists will see a moderate impact to their job role, as integrating fuel cells and components from different suppliers may present some complexities in adapting to the operations of hydrogen gas systems.

### Impact on skill and knowledge needs

Specialists will generally face minor skills and knowledge changes and will be expected to obtain some domain knowledge on hydrogen and its chemical properties.

Loading masters and other freight handling personnel will have more significant skill and knowledge augmentation needs as they may need familiarity with hazardous area identification and hydrogen handling operations. They will also need to understand the factors that cause a loss of containment and what practices they must undertake in order handle and store hydrogen safely.

# Occupational clusters: Level of augmentation required (3/3)

**Management job roles will need some technical knowledge of hydrogen in order to work effectively on hydrogen projects. In contrast, logistics workers may be expected to execute some of their tasks and responsibilities differently as part of the hydrogen workforce.**

## Management

### Job role augmentation

The management job roles identified in this report are all expected to carry leadership and decision making responsibilities in their respective areas and for their respective teams (e.g. engineering managers and relationship and community managers). As such, their day-to-day tasks will largely be unaffected by working on hydrogen projects, but additional knowledge requirements may be needed to effectively deploy their team members.

### Impact on skill and knowledge needs

Management job roles will face minor skill and knowledge changes, and will primarily be expected to develop domain knowledge so that they can coordinate the efforts of different roles/disciplines within their teams for successful project execution.

Consultees involved in the planning, design and construction of hydrogen production plants and appliances noted the tendency for projects to rely on multidisciplinary teams with different skills and academic backgrounds (e.g. engineering managers coordinating those with electrical and gas expertise, and technology managers coordinating sales and product design teams). With an effective understanding of hydrogen, the challenge of knowledge sharing and cooperating between team members can be easily addressed by management job roles.

Other management job roles are expected to oversee communications to stakeholders, address safety concerns on the job site, and enable the operation of hydrogen facilities with an understanding of production and storage methods.

## Logistics

### Job role augmentation

In some industries, existing logistics job roles may already transport hydrogen and be certified to handle it safely (e.g. truck drivers who are dangerous goods certified and operate tube trailers). However, increases in hydrogen production and export will mean that additional warehousing and stevedoring job roles will be exposed to hydrogen for the first time. This will result in the need for more job roles and workers to have skills and knowledge in hydrogen, and also to become dangerous goods certified. Working with specialised storage technology for liquid hydrogen, such as cryogenic systems, will require these job roles to execute some more complex day-to-day tasks, develop their hazard identification, and increase their material handling safety knowledge.

Other job roles (such as heavy vehicle operators and plant machinery operators) will be expected to adopt some new responsibilities as they utilise hydrogen fuel cell technology in their vehicles. This will present some complexities, as operators will need to be conscious of safety zones and evacuation procedures in the event of an emergency, as well as the proper maintenance procedures to recognise signs of malfunction.

### Impact on skill and knowledge needs

Logistics workers' skills and knowledge will require moderate augmentation to work with hydrogen, as some roles may be unfamiliar with hydrogen and will be exposed to hydrogen technology directly for the first time.

# Sizing the required Australian hydrogen workforce

**Employment estimates have been undertaken for each occupational cluster in 2030 under three hydrogen production scenarios (low, medium or high megatonnes of hydrogen produced). All three production scenarios are equal or greater than the 'high' scenario for job roles estimated in the National Hydrogen Strategy, indicating the growth of the industry and urgent need for education and training initiatives.**

## Scale of employment required

Job role estimates have been undertaken for each occupational cluster in 2030 under three hydrogen production scenarios (low, medium or high megatonnes of hydrogen produced) and are outlined in **Table 2**.

Across all three scenarios, the majority of jobs required will be for Technician and Tradesperson and Engineering job roles and the least amount of job roles that will be required are Specialists. Some key drivers influencing the job role estimates include:

- **The in-demand supply chains in 2030**: The underpinning dataset supporting the analysis undertaken is based on a recent view of 78 of planned and committed hydrogen initiatives to 2028. The majority of these announced hydrogen initiatives are in hydrogen production, which is reflected in the total number of jobs required in this supply chain area. The other supply chain areas will mature as more hydrogen is produced in Australia.
- **The job roles required in each scenario is influenced by the supply chain area maturity:** The analysis indicates that some occupational clusters will be more or less prevalent in some scenarios in contrast to others. For example, Engineering job roles are more prevalent in the 'low' scenario than the 'medium' and 'high' scenarios because these scenarios have more initiatives in the hydrogen as an export fuel supply chain, which does not require many Engineering job roles.
- **The intensity of labour required**: Technician and Tradesperson job roles are typically more labour intensive and in-demand. This is particularly evident in the hydrogen production, hydrogen as a transport fuel, and hydrogen as an export fuel supply chain areas.

See **Appendix C** for the detailed methodology and underlying assumptions used to estimate hydrogen production volume, convert this to a market value, allocate production by supply chain area and to estimate jobs by supply chain area.

**Table 2. Estimated 2030 hydrogen employment in each occupational cluster (2030, FTE, rounded to the nearest 50)**

| | Low | Medium | High |
|---|---|---|---|
| *Estimated hydrogen production (MT)* | *0.6* | *2.6* | *4.6* |
| Engineering | 650 – 750 | 2,750 – 3,400 | 4,900 – 6,150 |
| Technician and Tradesperson | 2,350 – 2,750 | 7,900 – 9,650 | 13,600 – 16,750 |
| Specialist | 50 – 100 | 150 – 200 | 300 – 350 |
| Logistics | 300 – 350 | 650 – 800 | 1,100 – 1,250 |
| Management | 250 – 300 | 900 – 1,050 | 1,500 – 1,850 |
| Safety and Quality Control | 350 – 400 | 800 – 950 | 1,300 – 1,550 |
| **Total jobs** | **3,950 – 4,650** | **13,150 – 16,050** | **22,700 – 27,900** |

# 7

# Identifying the upskilling needed for the hydrogen workforce

# Overview

**To support a safe and effective hydrogen economy in Australia, the 46 job roles identified in Section 6 must be appropriately skilled in relevant hydrogen capabilities. Through consultation and research, it was established that there are 26 hydrogen-specific capabilities that the 46 job roles require to support the hydrogen supply chain.**

## Hydrogen capabilities

The list of hydrogen-specific capabilities was developed through consultation and research. Each capability is articulated as a defined hydrogen skill or knowledge requirement, however, the capabilities are job role agnostic and it is assumed that all skill and knowledge requirements will be contextualised to the specific job role and work context.

**Pages 45 – 47** provide an overview of the 26 identified hydrogen capabilities required to support current and future job roles in the Australian hydrogen economy.

For each capability, the following is identified:

- **Statement of the capability**: Tasks or knowledge in a hydrogen topic that will be required by someone to interact with hydrogen in a job role.
- **Definition of the skill/knowledge requirement**: Details what is expected of an individual that has the skill and/or knowledge. For example, someone with the skill would be able to complete certain activities and work tasks.

## Understanding the hydrogen capability gap

Commentary from stakeholders suggested that job roles will not require a fundamental reskilling to engage in hydrogen activities. Rather, all job roles will combine their pre-existing skill base with new skills and knowledge specific to relevant hydrogen activities (called ‘capabilities’ in this report). This reflects the finding that the job roles required for the hydrogen economy are existing job roles that will be augmented by undertaking new hydrogen work tasks, and that, while job roles will be augmented to undertake hydrogen activities, they won’t be fundamentally changed.

For example, most stakeholders agreed that engineers participating in hydrogen activities will already have the majority of relevant skills from their previous education and work experiences to do these activities, though the exact quantity will depend on their background (e.g. those from an oil and gas background will likely transition more easily than those from water infrastructure). Most will only require specific skills and knowledge in order to engage safely and effectively with hydrogen. For example, an understanding of hydrogen’s unique property risks (e.g. flammability, lightness).

This feedback was consistent across all occupational clusters, however, it was noted that the ‘hydrogen skills and knowledge gap’ would likely be larger for some job roles and for some individuals transitioning between industries.

On the assumption that job roles will continue to draw on their base skill set gathered through occupation and/or field specific education and work experiences, the focus of this capability analysis is on the additional capability requirements that the workforce will need to engage in hydrogen activities. For workers already in these roles it would be a matter of upskilling, however, for future workers, these identified capabilities should be built into the relevant base qualifications and specialisations.

# Hydrogen-specific capabilities (1/3)

**Analysis of job roles involved in the hydrogen supply chain and the activities that these job roles undertake has identified 26 discrete hydrogen-specific capability requirements. Job roles will not require all the identified capabilities, rather, it will depend on the area of the supply chain they are engaged in and the hydrogen activities being undertaken.**

| # | Statement of the capability | Definition |
|---|---|---|
| 1 | Understanding hydrogen properties | General knowledge of hydrogen's chemical properties, its forms, structure, volumetric and energy density, how it differs to other gases, how it interacts with other materials, and its property risks (including how it affects handling e.g. odourless, leaks quietly, rises quickly due to lightness). |
| 2 | Calibrating, testing and maintaining hydrogen equipment | The ability to monitor, measure and test maintenance equipment in a hydrogen process to ensure it is functioning properly (e.g. checking vessels for signs of fracture, cracks, leakage). |
| 3 | Handling cryogenic materials | The ability to use cryogenics or related systems to maintain hydrogen in a stable form for transportation. |
| 4 | Identifying and managing hydrogen hazardous areas (safety & risk) | An understanding of the hazardous areas that arise from using hydrogen (e.g. explosive or flammable zones, spill), and which environmental/material factors may contribute to these (e.g. ignition factors, loss of containment factors), as well as the appropriate safety zones and emergency procedures. This also includes the ability to select appropriate materials that will reduce the risk of hydrogen hazards (e.g. corrosion, loss of containment, flammability, explosion). |
| 5 | Understanding hydrogen market trends and drivers | An understanding of the wider factors affecting market demand and supply for hydrogen, including technological developments, trends, and government policy/regulation that shapes industry growth. |
| 6 | Knowledge of high pressure gas systems and vessels | An understanding of the considerably higher pressures hydrogen is piped and tubed through in gas systems relative to other gases, and the impact on pipeline design, operation and safety in planning and construction, particularly relative to current natural gas systems (e.g. what materials are likely to be used for hydrogen pipes, the sizing and density of pipes etc). |
| 7 | Fuel cells – Operating and maintaining fuel cells | Knowledge of how the different types of hydrogen fuel cells function, their components, chemical and electrical processes, and advantages/disadvantages relative to other fuel cells that impact the contexts they are utilised in (e.g. operating measure, waste, temperatures). This includes proton exchange membrane (PEM), molten carbonate (MCFC), phosphoric acid (PAFC), solid oxide (SOFC), and alkaline (AFC) fuel cells. |
| 8 | Fuel cells – Diagnosing and replacing fuel cells | The ability to identify fuel cells that have degraded and arrange for/undertake unit replacement. |
| 9 | Reading and interpreting technical drawings with hydrogen equipment | The ability to interpret technical drawings of systems or components incorporating hydrogen (inc. plans, diagrams, drawings and resources, graphs and tables), accurately apply standards or regulations in tables, and understand the material implications and hazardous area requirements in operation. |
| 10 | Producing hydrogen – Understanding of cooling systems | Knowledge of the cooling systems required in hydrogen production plants, such as electrolysers, their benefits and how they operate. |

# Hydrogen-specific capabilities (2/3)

**Analysis of job roles involved in the hydrogen supply chain and the activities these job roles undertake has identified 26 discrete hydrogen-specific capability requirements. Job roles won't require all the identified capabilities, rather, it will depend on the area of the supply chain they are engaged in and the hydrogen activities being undertaken.**

| # | Statement of the capability | Definition |
|---|---|---|
| 11 | Hydrogen production techniques – SMR (steam methane reforming) | Knowledge of the technological process required to produce hydrogen through steam methane reforming and natural gas. |
| 12 | Hydrogen production techniques – Coal gasification | Knowledge of the technological process required to produce hydrogen through coal gasification. |
| 13 | Hydrogen storage techniques – Compressed hydrogen | Knowledge of how hydrogen can be converted into a compressed gas form, its material properties, and the activities required to store it in this state. |
| 14 | Hydrogen storage techniques – Liquid hydrogen | Knowledge of how hydrogen can be converted into a liquid form, its material properties, and the activities required to store it in this state. |
| 15 | Hydrogen storage techniques – Conversion to hydrogen carriers | Knowledge of how hydrogen can be converted into another chemical compound as a carrier (e.g. ammonia, methane), the selected compound's material properties, and the activities required to store it in this state, including safety considerations for these hazardous chemicals. |
| 16 | Hydrogen production techniques – Electrolysis, biofuels, photolysis | Knowledge of the production processes available to undertake hydrogen production, their processes and the technology they require, such as the water quality and H2 purity requirements required for electrolysis, and the processes required to ensure access to these. |
| 17 | Knowledge of conversion requirements for gases and their interchangeability | An understanding of the processes required to convert particular gases into others, and indicators of the interchangeability of various gases (in terms of heating or calorific value, e.g. the Wobbe index). |
| 18 | Knowledge of hydrogen embrittlement | An understanding of how hydrogen may interact with steel, plastics or composite materials at a molecular level to cause embrittlement of materials, and the testing required to address this (e.g. fracture mechanics testing for components to evaluate crack propagation). |
| 19 | Oversight of control modules for hydrogen processes | The ability to program and monitor control modules in a system undertaking a chemical process with hydrogen, so that the process occurs safely and efficiently. |
| 20 | Inspect, maintain and modify hydrogen vehicles | The ability to apply inspection and maintenance procedures to hydrogen fuel cell electric vehicles, including safely depowering and inspection of H2 gas cylinders, as well as any modifications that may be required for these systems. |

# Hydrogen-specific capabilities (3/3)

**Analysis of job roles involved in the hydrogen supply chain and the activities these job roles undertake has identified 26 discrete hydrogen-specific capability requirements. Job roles won't require all the identified capabilities, rather, it will depend on the area of the supply chain they are engaged in and the hydrogen activities being undertaken.**

| # | Statement of the capability | Definition |
|---|---|---|
| 21 | Knowledge of power electronics | Knowledge of the high-voltage power electronics that provide large energy inputs into hydrogen production (e.g. transformers, substations, capacitors). |
| 22 | Managing hydrogen logistical movement across a supply chain | The ability to oversee and manage the logistical movement of hydrogen materials across a supply chain, including ensuring a consistent even flow of supply, managing logistical bottlenecks, and reducing carrying costs and idle time where possible. |
| 23 | Recognition of hydrogen and waste product interchangeability in other industries | An understanding of how hydrogen and any associated waste products in its production process (e.g. oxygen, carbon) can be repurposed and provided to use cases (i.e. chemical processes) in other industries. |
| 24 | Integrating hydrogen equipment from various OEMs into a process | The ability to integrate components sourced from various suppliers so that they function as intended within a single system. In hydrogen contexts this may include integrating fuel cells into electric vehicles (whether they are built to purpose or involving the certification, homologation and retrofitting of powertrains into an existing vehicle) or integrating subassemblies into an electrolyser. |
| 25 | Understanding of co-firing in natural gas and hydrogen fuelled gas turbines | An understanding of the operations and processes involved in co-firing power plants where hydrogen and natural gas may be burned at the same time in specific proportions. |
| 26 | Communicating the risks, benefits and safety considerations of hydrogen | The ability to communicate to a wide range of community stakeholders the risks and benefits of hydrogen in Australia's broader energy mix (including environmental impact and safety considerations) so that new hydrogen sites are accepted. |

# Hydrogen capability matrix (1/2)

**Following the identification of the hydrogen-specific capabilities, a capability matrix was developed to map the capabilities to each of the 46 job roles. Using the capability matrix, insights about the frequency and distribution of different hydrogen-specific capabilities across job roles and supply chain areas can be drawn. This can inform an understanding of the demand for specific capabilities and the associated demand for education and training pathways.**

The capability matrix has been developed to assist in providing a detailed analysis of the specific hydrogen skills that each job role will need across each supply chain area. The matrix does this by first determining if a hydrogen-specific capability is required by a job role operating in a particular supply chain area and then determining if the hydrogen-specific capability (e.g. 'handling cryogenic materials') is a 'core' or 'specialist' capability for the identified job role (e.g. chemical engineer) in that a specific supply chain area (e.g. hydrogen production).

This analysis supports an understanding of whether all workers in a particular job role will need a particular hydrogen-specific capability, or if it is a capability that will only be relevant to workers undertaking particular activities (e.g. Specialists). This will inform the scale of workers that will require the particular capability and, therefore, the demand for education and training pathways.

In the matrix, each hydrogen capability was mapped to every job role in each supply chain area and assigned one of the following four categorisations:

- **Core capability:** Indicates that the hydrogen-specific capability will be expected by all individuals working in this job role in this supply chain area, to some degree.
- **Specialist capability:** Indicates that the hydrogen-specific capability will only be expected by some individuals working in this job role in this supply chain area.
- **N/A**: Indicates that the hydrogen-specific capability will not be expected of this job role in this supply chain area.
- - : Indicates that the job role is not required in this supply chain area.

## Purpose of the hydrogen capability matrix

The hydrogen capability matrix has been developed to:

- Articulate the hydrogen-specific capabilities required by each job role;
- Identify which job roles will require each capability in order to undertake hydrogen related activities, noting that this analysis has been done for each supply chain area;
- Identify whether a capability required by a job role is needed by all individuals in that job role operating in the hydrogen economy (e.g. it is a core skill of all electrical engineers undertaking hydrogen activities), or only required by some individuals operating in that job role (e.g. it is a specialist skill for electrical engineers undertaking certain activities); and
- Support analysis of capabilities that will be in-demand across job roles and supply chain areas, and inform considerations about education and training priorities.

# Hydrogen capability matrix (2/2)

**The capability matrix indicates that all 26 hydrogen specific capabilities are core in at least one job role. Analysis of findings at an occupational cluster level indicates that most of the demand for hydrogen capabilities is in Engineering and Safety and Quality Control job roles. These areas should be prioritised when considering the development of education and training pathways.**

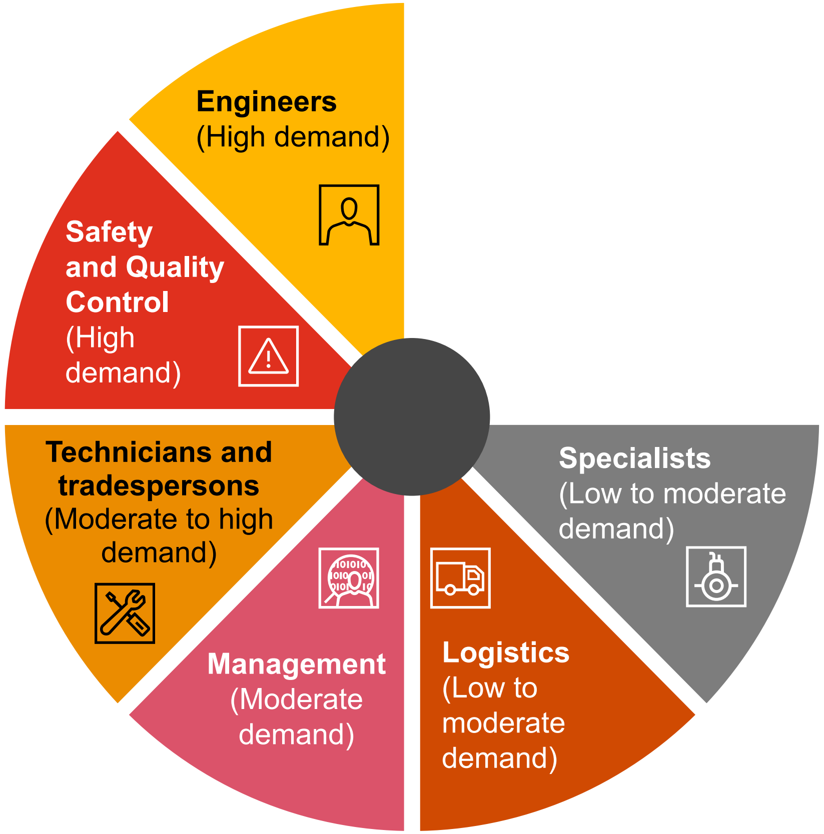
## Capability Matrix: Core and specialist capability analysis

Analysis of the capability matrix shows that all 26 hydrogen specific capabilities are a core skill/knowledge requirement in at least one job role. Half of capabilities (16) are core requirements for less than 15 job roles, indicating that the capabilities that have a more specialised subject matter are typically required in fewer job roles. This is supported by analysis of specialist capabilities that shows that 25 of the 26 hydrogen specific capabilities are a specialist skill/knowledge requirement in at least one job role (with the capability 'understanding hydrogen properties' being the only outlier).

## Capability Matrix: Occupational cluster analysis

Bringing together the analysis in the capability matrix, heat maps were developed to understand the demand for hydrogen-specific capabilities across the different job roles, occupational clusters, and supply chain areas. **Figure 11** provides a breakdown of the demand for capabilities in each occupational cluster as the Australian hydrogen economy matures.

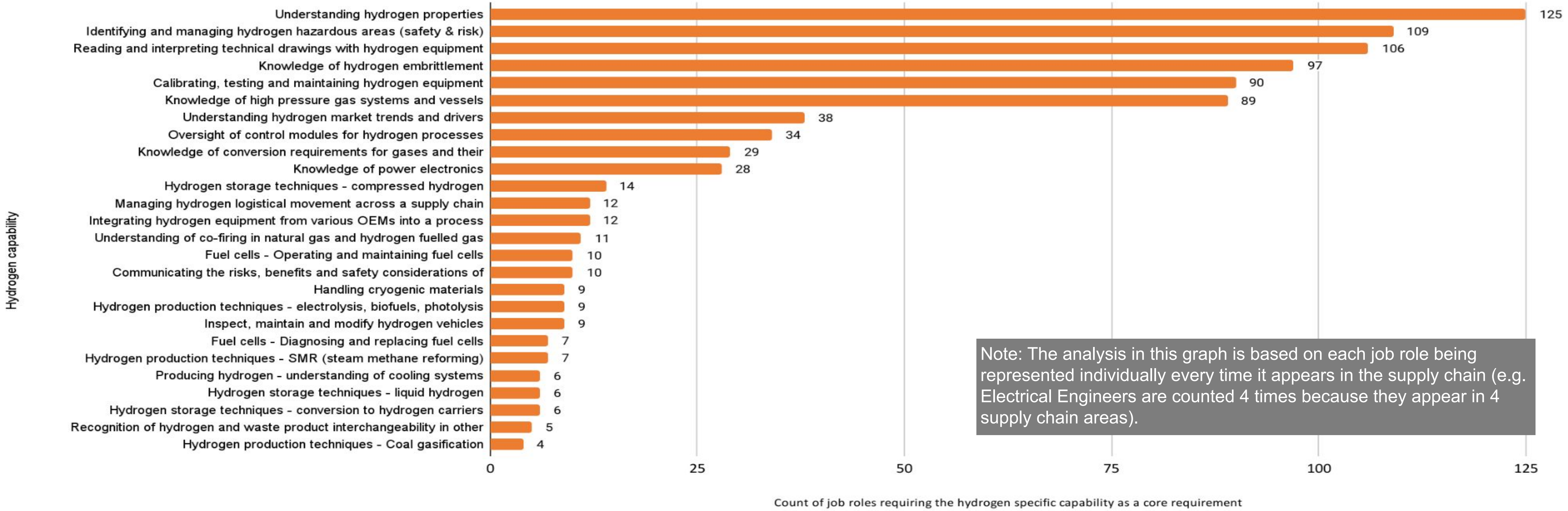
**Figure 11. Scale of demand for hydrogen-specific capabilities across occupational clusters**



# Capability matrix: Analysis of core capabilities

**Analysis of the capability matrix shows that all 26 hydrogen specific capabilities are a core skill/knowledge requirement in at least one job role. However, there are six capabilities that are core requirements across a significant number of job roles (>80), suggesting that they are capabilities fundamental to all hydrogen activities. Conversely, half of the capabilities (16) are core requirements for less than 15 job roles, indicating that the capabilities that have a more specialised subject matter are typically required in fewer job roles. The graph below presents a count of the number of job roles that require each hydrogen capability as a core requirement.**

## Figure 12. Count of job roles requiring hydrogen-specific capabilities as a core requirement

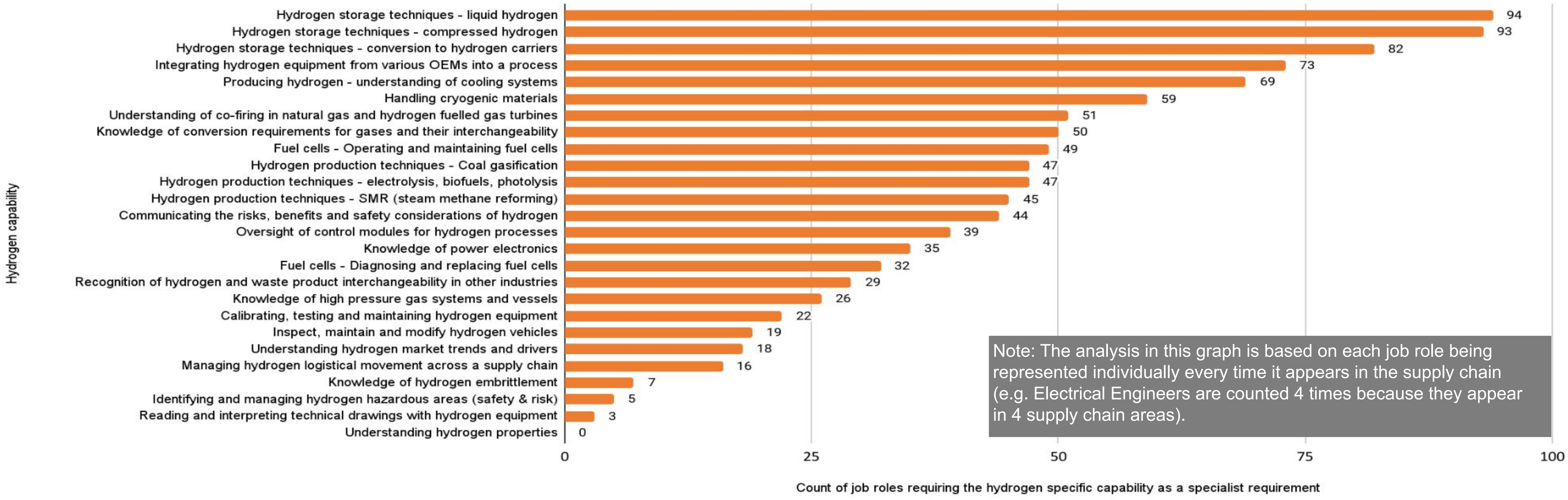



Note: The analysis in this graph is based on each job role being represented individually every time it appears in the supply chain (e.g. Electrical Engineers are counted 4 times because they appear in 4 supply chain areas).

# Capability matrix: Analysis of specialist capabilities

**Analysis of the capability matrix shows that 25 of the 26 hydrogen specific capabilities are a specialist skill/knowledge requirement in at least one job role. The capability 'understanding hydrogen properties' is an outlier as it is not a specialist requirement for any job role. However, this outcome is expected as it has the highest count of job roles using it as a core requirement. The graph below presents a count of the number of job roles which require each hydrogen capability as a specialist requirement.**

## Figure 13. Count of job roles requiring hydrogen-specific capabilities as a specialist skill and/or knowledge requirement



# Capability matrix: Analysis of occupational clusters

**Analysis of findings at an occupational cluster level indicates that there is the most demand for hydrogen capabilities in Engineering and Safety and Quality Control job roles. These areas should be prioritised when considering the development of education and training pathways.**

This section presents a summary of the hydrogen-specific capability requirements of each occupational cluster. The analysis is presented in a capability matrix heat map (see **Pages 53 – 59**) for each occupational cluster to support a comparison of like-job roles across supply chain areas. Key findings for each occupational cluster include:

## Engineers

- There is a high demand for hydrogen-specific capabilities across Engineering job roles. However, this does not mean that Engineering job roles will significantly change in the hydrogen economy. It is expected that Engineering job role augmentation will be limited as most Engineering job roles will already have most of the skills and knowledge that they will need to engage in hydrogen activities.
- The matrix shows that there are some Engineering job roles that will have a greater demand for hydrogen-specific capabilities, for example, Commissioning Engineers, Marine Engineers and Grid Connection Engineers.

## Management

- There is a moderate demand for hydrogen-specific capabilities across Management job roles.
- Most Management job roles will require a small base of core hydrogen capabilities and a large group of specialist skills.

## Safety and Quality Control

- There is a strong demand for hydrogen-specific capabilities across Safety and Quality Control job roles.
- Most supply chain areas will have a greater demand for specialist capabilities.

## Technicians and tradespersons

- Analysis of the capability matrix demonstrates that there is a moderate-strong demand for hydrogen-specific capabilities across Technician and Tradesperson job roles.
- Despite the diversity of job roles that fall in the Technician and Tradespersons occupational cluster, the quantum of required core and specialist capabilities is relatively consistent.

## Specialists

- There is a low-moderate demand for hydrogen-specific capabilities across Specialist job roles. These job roles are tailored and specific to a supply chain area. This results in these job roles typically requiring higher amounts of specialist capabilities.

## Logistics

- There is a low-medium demand for hydrogen-specific capabilities across Logistics job roles, specifically in three supply chain areas (distribution, transport fuel and export fuel).
- In contrast to this low-medium demand, moderate or high levels of job role augmentation are typically expected for Logistics job roles. This variance is due to instances when capabilities represent significant work functions of the job roles. For example, the capability, 'managing hydrogen logistical movement across a supply chain', is a significant part of the job function for Stevedore's who are responsible for managing the logistics of goods between ships. Thus, the introduction of the capability will present a substantive change to the job role.

# Capability matrix: Engineering occupational cluster

**Analysis of the heat map demonstrates that there is a high demand for hydrogen-specific capabilities across Engineering job roles. The heat map indicates that there are some Engineering job roles that will have a particularly high demand for hydrogen-specific capabilities, for example, Commissioning Engineers, Marine Engineers and Grid Connection Engineers.**

## Figure 14. Capability matrix heat map extract on Engineering job roles

| Job Role | Cluster | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| | | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Chemical Engineer | Engineering | 10 | 9 | 5 | 6 | 8 | 7 | 7 | 10 | 0 | 0 | 8 | 7 |
| Civil Engineer | Engineering | 4 | 1 | 4 | 3 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 |
| Commissioning Engineer | Engineering | 12 | 13 | 8 | 16 | 11 | 15 | 10 | 12 | 0 | 0 | 0 | 0 |
| Electrical Engineer | Engineering | 7 | 2 | 7 | 4 | 0 | 0 | 5 | 5 | 12 | 12 | 0 | 0 |
| Electronics Engineer | Engineering | 7 | 2 | 6 | 3 | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 |
| Grid Connection Engineer | Engineering | 11 | 11 | 0 | 0 | 10 | 15 | 10 | 13 | 0 | 0 | 0 | 0 |
| Marine Engineer | Engineering | 0 | 0 | 9 | 13 | 11 | 15 | 0 | 0 | 10 | 2 | 16 | 3 |
| Mechanical Engineer | Engineering | 0 | 0 | 6 | 9 | 8 | 5 | 6 | 7 | 3 | 12 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

Mapping in the matrix shows that all Engineering job roles will require core and specialist hydrogen-capabilities across relevant areas of the supply chain. The most in-demand core capability across Engineering job roles is, 'understanding hydrogen properties', and the most in-demand specialist capability is, 'communicating the risks, benefits and safety considerations of hydrogen'.

There are two Engineering job roles that will require all 26 capabilities: Marine Engineers and Commissioning Engineers operating in the storage supply chain area. The storage supply chain area has a number of job roles with a substantial number of capabilities identified as core or specialist, suggesting that this is an area of operation in which additional hydrogen skills and knowledge are critical.

Whilst the analysis in the capability matrix demonstrates that most Engineering job roles operating in the hydrogen supply chain will require a number of hydrogen-specific capabilities, stakeholder feedback suggests that the vast majority of these skill and knowledge requirements will already be held by engineers as they are built into engineering education pathways and/or are developed on-the-job. As such, whilst the number of hydrogen-specific capabilities that an engineer will require to engage in the hydrogen economy is substantial, as they already hold these skills and undertake these activities, the job roles are not expected to change significantly. This accounts for the augmentation scale mapping in **Section 6** which identified most engineering job roles as falling into the insignificant or low augmentation categories.

# Capability matrix: Management occupational cluster

**The heat map shows that there is a moderate demand for hydrogen-specific capabilities across Management job roles, with most Management roles requiring a small base of core hydrogen capabilities and large group of specialist skills.**

## Figure 15. Capability matrix heat map extract on Management job roles

| | | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| Job Role | Cluster | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Engineering Manager | Management | 7 | 10 | 0 | 0 | 6 | 12 | 7 | 10 | 0 | 0 | 0 | 0 |
| Maintenance Manager | Management | 5 | 13 | 0 | 0 | 0 | 0 | 5 | 13 | 5 | 13 | 0 | 0 |
| Operations Manager | Management | 6 | 12 | 0 | 0 | 0 | 0 | 6 | 12 | 6 | 12 | 0 | 0 |
| Planner and Scheduler | Management | 5 | 2 | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 |
| Relationship and Community Manager | Management | 0 | 0 | 0 | 0 | 3 | 11 | 0 | 0 | 3 | 11 | 0 | 0 |
| Research and Technology Manager | Management | 1 | 10 | 0 | 0 | 1 | 9 | 0 | 0 | 1 | 10 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

Analysis of the matrix shows that there is a strong demand for specialist hydrogen capabilities across Management job roles, a factor that is consistent across supply chain areas. This likely stems from the broad applicability of Management job roles and reflects the finding from **Section 6** that the day-to-day tasks of managers will be largely unaffected by working on hydrogen projects, however, additional knowledge requirements may be needed to effectively deploy their team members.

The most in-demand core capability across management job roles is, 'understanding hydrogen properties', and the most in-demand specialist capability is, 'knowledge of conversion requirements for gases and their interchangeability'.

# Capability matrix: Safety & Quality Control occupational cluster

**Analysis of the heat map demonstrates that there is a strong demand for hydrogen-specific capabilities across Safety and Quality Control job roles. The heat map shows that, regardless of the type of job role, if they are required to operate in the hydrogen economy, the quantum of hydrogen specific capabilities that they will require is substantial. This is consistent across all supply chain areas in which Safety and Quality Control job roles will be required.**

## Figure 16. Capability matrix heat map extract on Safety & Quality Control job roles

| | | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| Job Role | Cluster | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Gas Inspector | Safety & QC | 14 | 6 | 7 | 9 | 12 | 4 | 7 | 7 | 9 | 10 | 8 | 12 |
| Quality Assurance Technician | Safety & QC | 13 | 11 | 8 | 16 | 5 | 13 | 7 | 17 | 6 | 11 | 9 | 12 |
| Work Health and Safety Officer | Safety & QC | 11 | 10 | 8 | 15 | 9 | 8 | 8 | 18 | 8 | 10 | 9 | 10 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

All Safety and Quality Control job roles will require a relatively equal mix of core and specialist capabilities. However, it is noted that, in the production supply chain area, there will be a greater reliance on core hydrogen capabilities, suggesting there are a number of foundational hydrogen capability requirements to operate in this area. This compares to the distribution, blending, transport fuel and export fuel hydrogen supply chain areas where there is a greater reliance on specialist skills.

The most in-demand core capabilities across Safety and Quality Control job roles are ‘reading and interpreting technical drawings with hydrogen equipment’ and ‘understanding hydrogen market trends and drivers’. The most in-demand specialist capabilities are ‘producing hydrogen – understanding of cooling systems’, ‘hydrogen production techniques – SMR (steam methane reforming)’, ‘hydrogen production techniques – coal gasification’, and ‘hydrogen production techniques – electrolysis, biofuels, photolysis’.

It is noted that **Section 6** identified the three Safety and Quality Control job roles as falling into the low category on the augmentation scale. The outputs of the heat map are consistent with this finding as: (1) it is recognised that, whilst the day-to-day activities of the job roles won’t change, additional domain knowledge will be required, and (2) a number of the capabilities will already be held by the job roles as they will be operating in analogous areas. For example, many existing Safety and Quality Control job roles in the gas and chemical processing sectors work with natural gas and other materials broadly comparable to hydrogen in their day-to-day tasks. However, it is recognised that variances will apply across the supply chain areas in regards to the level of knowledge required by job roles (for example, a ‘Work Health and Safety Officer’).

# Capability matrix: Technician and Tradesperson cluster (1/2)

**Analysis of the capability matrix demonstrates that there is a moderate-strong demand for hydrogen-specific capabilities across Technician and Tradesperson job roles. Interestingly, despite the diversity of job roles that fall in the Technician and Tradesperson occupational cluster, the quantum of required core and specialist capabilities is relatively consistent. There are, however, some outliers (e.g. Gas Industry Operators) that have a greater demand for specialist skills.**

## Figure 17. Capability matrix heat map extract on Technician and Tradesperson job roles

| | | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| Job Role | Cluster | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Automotive Electric Vehicle Technician | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 8 | 0 | 0 |
| Automotive Electrician | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 8 | 0 | 0 |
| Control Room Officer | Tradespersons | 5 | 11 | 0 | 0 | 0 | 0 | 6 | 10 | 0 | 0 | 0 | 0 |
| Electrical Fitter | Tradespersons | 6 | 8 | 6 | 8 | 6 | 8 | 7 | 7 | 0 | 0 | 6 | 7 |
| Electrical Instrumentation Technician | Tradespersons | 6 | 7 | 6 | 7 | 6 | 7 | 0 | 0 | 6 | 10 | 6 | 6 |
| Electrician | Tradespersons | 7 | 7 | 7 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 7 | 6 |
| Fitter and Turner | Tradespersons | 6 | 9 | 6 | 8 | 5 | 7 | 0 | 0 | 5 | 7 | 6 | 7 |
| Gas Fitter (general) | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 9 | 7 | 9 | 0 | 0 |
| Gas Fitter (industrial) | Tradespersons | 10 | 2 | 6 | 9 | 6 | 8 | 6 | 9 | 0 | 0 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

Mapping in the matrix shows that all Technician and Tradesperson job roles will require core and specialist hydrogen-capabilities across relevant areas of the supply chain. The mix of core and specialist skills required in job roles is relatively consistent across supply chain areas, suggesting that the quantum of hydrogen skills and knowledge required by Technician and Tradesperson job roles will not experience much fluctuation between supply chain areas. For example, the quantum of core and specialist hydrogen capabilities required by an Electrician is consistent across the production, distribution and storage hydrogen supply chain areas.

The most in-demand core capabilities across Technician and Tradesperson job roles are ‘understanding hydrogen properties’ and ‘identifying and managing hydrogen hazardous areas (safety & risk)’. The most in-demand specialist capabilities are ‘hydrogen storage techniques – compressed hydrogen’ and ‘hydrogen storage techniques – liquid hydrogen’.

Noting the quantum of capabilities identified in the matrix, stakeholder feedback indicates Technician and Tradesperson job roles are expected to experience low to high levels of augmentation as they move towards participation in the hydrogen economy (as reflected in **Section 6**). High augmentation levels are expected for job roles where their job functions are significantly impacted by hydrogen capability requirements. For example, the capability ‘inspect, maintain and modify hydrogen vehicles’ is a significant part of the job functions undertaken by Light and Heavy Vehicle Mechanical Technicians in the transport fuel supply chain area, as they are responsible for maintaining, testing and repairing vehicles. Therefore, the addition of this capability to the Light and Heavy Vehicle Mechanical Technician job roles will significantly change their day-to-day tasks.

# Capability matrix: Technician and Tradesperson cluster (2/2)

**Analysis of the capability matrix demonstrates that there is a moderate-strong demand for hydrogen-specific capabilities across Technician and Tradesperson job roles. Interestingly, despite the diversity of job roles that fall in the Technician and Tradesperson occupational cluster, the quantum of required core and specialist capabilities is relatively consistent. There are, however, some outliers (e.g. Gas Industry Operators) that have a greater demand for specialist skills.**

## Figure 18. Capability matrix heat map extract on Technician and Tradesperson job roles

| Job Role | Cluster | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| | | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Gas Industry Operator | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 14 | 0 | 0 | 0 | 0 |
| Heavy Duty Fitter | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 8 | 8 | 7 |
| Heavy Vehicle Mechanical Technician | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 8 | 0 | 0 |
| Light Vehicle Mechanical Technician | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 8 | 0 | 0 |
| Plumber | Tradespersons | 0 | 0 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Process Control Technician | Tradespersons | 8 | 14 | 0 | 0 | 0 | 0 | 7 | 14 | 0 | 0 | 0 | 0 |
| Refuelling Technician | Tradespersons | 0 | 0 | 7 | 13 | 0 | 0 | 0 | 0 | 7 | 13 | 0 | 0 |
| Vehicle Body Repair Technician | Tradespersons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 2 | 0 | 0 |
| Welder | Tradespersons | 0 | 0 | 6 | 4 | 0 | 0 | 7 | 9 | 0 | 0 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

# Capability matrix: Specialist occupational cluster

**Analysis of the heat map demonstrates that there is a low-moderate demand for hydrogen-specific capabilities across Specialist job roles. These job roles are typically tailored and specific to a supply chain area and require higher amounts of specialist capabilities.**

## Figure 19. Capability matrix heat map extract on Specialist job roles

| Job Role | Cluster | Supply Chain Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| | | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Fuel Cell Fabrication and Testing Technician | Specialists | 9 | 8 | 0 | 0 | 10 | 5 | 10 | 5 | 0 | 0 | 0 | 0 |
| Integration Specialist | Specialists | 8 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 5 | 0 | 0 |
| Loading Master | Specialists | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 |
| Power Production Plant Operator | Specialists | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 9 | 0 | 0 | 0 | 0 |
| Technical Sales Representative | Specialists | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 12 |
| Water Treatment Plant Operator | Specialists | 5 | 6 | 0 | 0 | 5 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

The mix of core and specialist capabilities in Specialist job roles is very specific to the type of job role and supply chain area. Each job role is highly tailored and contextualised to the specific supply chain area. Typically, this correlates to more specialist capabilities being required across Specialist job roles.

The most in-demand core capabilities across Specialist job roles are ‘understanding hydrogen properties’ and ‘identifying and managing hydrogen hazardous areas (safety & risk)’. The most in-demand specialist capabilities are ‘hydrogen storage techniques – compressed hydrogen’ and ‘hydrogen storage techniques – liquid hydrogen’. Interestingly, this demand profile reflects that of the Technician and Tradesperson occupational cluster.

# Capability matrix: Logistics occupational cluster

**Analysis of the heat map demonstrates that there is a low-moderate demand for hydrogen-specific capabilities across Logistics job roles in the three relevant hydrogen supply chain areas. In some job roles, variances have occurred between the demand for hydrogen-specific capabilities and the level of job role augmentation required when capabilities represent significant work functions of job roles.**

## Figure 20. Capability matrix heat map extract on Logistics job roles

| Job Role | Cluster | Supply Chain Area: Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending hydrogen into natural gas | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist | Core | Specialist |
| Heavy Vehicle Operator | Logistics | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 4 | 3 | 0 | 0 |
| Marine Master/Operator | Logistics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 4 |
| Plant Machinery Operator | Logistics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 0 |
| Stevedore | Logistics | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 6 | 5 | 5 | 4 |
| Truck Driver | Logistics | 0 | 0 | 5 | 4 | 0 | 0 | 0 | 0 | 5 | 8 | 0 | 0 |

***The darker the shade of orange, the higher the need for core and specialist capabilities within that particular job role and supply chain area.**

The core capabilities required in Logistics job roles typically focus on a broad understanding of hydrogen properties and key safety considerations, as opposed to the specialist capabilities that are typically tailored to the specific job roles. For example, in the transport fuel supply chain area, all Logistics job roles require 'knowledge of hydrogen embrittlement' as a core capability, whereas 'fuel cells – operating and maintaining fuel cells' is a specialist capability for Truck Drivers only.

The most in-demand core capabilities across Logistics job roles are 'understanding hydrogen properties' and 'identifying and managing hydrogen hazardous areas (safety & risk)'. The most in-demand specialist capabilities all relate to hydrogen storage techniques.

Noting the quantum of capabilities identified in the matrix, stakeholder feedback indicates Logistics job roles are expected to experience moderate to high levels of augmentation as they move towards participation in the hydrogen economy (as reflected in **Section 6**). This is an outcome in job roles where their job functions are significantly impacted by hydrogen capability requirements. For example, the capability 'managing hydrogen logistical movement across a supply chain' is a significant part of the job function undertaken by Stevedore's in the Distribution supply chain area, as they are responsible for managing the logistics of goods on and off ships. Therefore, the addition of this capability to the Stevedore job role will significantly change the day-to-day tasks of the job role.

# 8

# Education and training pathways to support the hydrogen workforce

# Overview

**Each of the 26 identified hydrogen-specific capabilities have been mapped against existing accredited and non-accredited training pathways in Australia. This analysis supports an understanding of the quantum and characteristics of existing hydrogen-specific skills within the Australian education and training system, as well as enabling the identification of training gaps. This process assists in determining and prioritising proposed training solutions.**

To support job roles develop the underpinning hydrogen-specific skills and knowledge requirements, education and training pathways must be available. These education and training pathways could take a variety of formats, including VET training products, higher education courses, and non-accredited professional development.

However, before new education and training pathways are created, consideration should be given to whether any of the identified hydrogen capabilities are already catered for within the existing education and training system. If so, the existing training components should be used, rather than creating new products and promoting proliferation of products within the system.

In order to develop a complete picture of hydrogen education and training across Australia, a training pathway review was undertaken, as outlined in **Appendix E**. This involved reviewing different education and training systems and formats across Australia and identifying if and when a training product touches on one of the 26 hydrogen capabilities.

Our analysis identified the extent to which existing hydrogen education and training content is relevant and fit-for-purpose, and resulted in the 26 hydrogen-specific capabilities being grouped into one of three categories:

- Sufficient hydrogen training coverage
- Some hydrogen training coverage, but additional contextualisation or development required
- Minimal/no hydrogen training coverage.

The breakdown of capabilities across these three groupings is outlined on **Page 62**. These categorisations assist in informing training pathway priorities and proposed training solutions.

## Scope of the education and training system reviewed*

**Vocational Education and Training (VET).** This includes all accredited VET regulated by the Australian Skills Quality Authority (ASQA), with the National Register of VET (training.gov.au) reviewed to identify hydrogen skills and knowledge within Units of Competency, Skill Sets and Qualifications.

**Higher Education.** This includes all higher education programs delivered by Universities and Non-University Higher Education Providers (NUHEPs) and regulated by the Tertiary Education Quality and Standards Agency (TEQSA). Provider websites and Course Seeker were reviewed to identify hydrogen degrees and courses/units.

**Non-accredited training.** This includes non-accredited training that is delivered by peak bodies, unions and businesses/organisations. This training can take a variety of formats, including online modules, seminars, workshops and face-to-face delivery. It has been included in this analysis given that original equipment manufacturer (OEMs) and industry bodies (particularly those with international connections) are leaders in hydrogen training solutions. Provider websites were reviewed to identify hydrogen courses and offerings.

* Mentions of specific providers in this section are anonymised.

# Current training pathways (1/3)

**Only 15% (4/26) of the identified hydrogen-specific capabilities were deemed to have 'sufficient hydrogen training coverage' when mapped against existing accredited and non-accredited training pathways in Australia. This analysis indicates that training gaps exist, in some form, for 85% (22/26) of the identified hydrogen-specific capabilities. This analysis assists in determining and prioritising proposed training solutions.**

## Figure 21. Training pathway analysis

| Sufficient hydrogen training coverage | Some hydrogen training coverage, but additional contextualisation or development required | | Minimal/no hydrogen training coverage |
|---|---|---|---|
| Capability #2: Calibrating, testing and maintaining hydrogen equipment | Capability #1: Understanding hydrogen properties | Capability #13: Hydrogen storage techniques – Compressed hydrogen | Capability #5: Understanding hydrogen market trends and drivers |
| Capability #4: Identifying and managing hydrogen hazardous areas (safety & risk) | Capability #3: Handling cryogenic materials | Capability #14: Hydrogen storage techniques – Liquid hydrogen | Capability #7: Fuel cells – Operating and maintaining fuel cells |
| Capability #19: Oversight of control modules for hydrogen processes | Capability #6: Knowledge of high pressure gas systems and vessels | Capability #15: Hydrogen storage techniques – Conversion to hydrogen carriers | Capability #8: Fuel cells – Diagnosing and replacing fuel cells |
| Capability #21: Knowledge of power electronics | Capability #9: Reading and interpreting technical drawings with hydrogen equipment | Capability #16: Hydrogen production techniques – Electrolysis, biofuels, photolysis | Capability #20: Inspect, maintain and modify hydrogen vehicles |
| | Capability #10: Producing hydrogen – Understanding of cooling systems | Capability #17: Knowledge of conversion requirements for gases and their interchangeability | Capability #23: Recognition of hydrogen and waste product interchangeability in other industries |
| | Capability #11: Hydrogen production techniques – SMR (steam methane reforming) | Capability #18: Knowledge of hydrogen embrittlement | Capability #24: Integrating hydrogen equipment from various original equipment manufacturers (OEMs) into a process |
| | Capability #12: Hydrogen production techniques – Coal gasification | Capability #22: Managing hydrogen logistical movement across a supply chain | Capability #25: Understanding of co-firing in natural gas and hydrogen fuelled gas turbines |
| | | | Capability #26: Communicating the risks, benefits and safety considerations of hydrogen |

# Current training pathways (2/3)

**Analysis of current education and training pathways in Australia for hydrogen-specific capabilities found that limited VET and higher education training pathways exist. Hydrogen-specific capabilities are broadly covered by non-accredited training pathways that are typically developed for private and in-house purposes.**

## Figure 22. Findings from training pathway analysis

**There are few dedicated hydrogen training products in the VET and higher education training systems in Australia.** For example, there are only six hydrogen specific VET training products and no dedicated higher education degrees (excluding degrees in renewables). The six hydrogen specific VET training products are new units of competency created for the UEG Gas Industry Training Package that address various aspects of commissioning and maintaining electrolysers, and working with hydrogen gas storage systems. This reflects the growing popularity of electrolyser technology.

**Where hydrogen-specific content does exist in the education and training system, it is woven into products with other similar content and will require additional contextualisation to support a large scale hydrogen workforce and economy**. For example, higher education degrees typically cover hydrogen capabilities as foundational knowledge for engineering degrees or other related disciplines. This is particularly the case for many professionals working in chemical processing and the energy sector more broadly. Tradespersons may find that their pre-requisite skills and knowledge are already largely serviced by existing training packages and qualifications (e.g. the PMA Chemicals, Hydrocarbons and Refining Training Package).

**Private provider (non-accredited) training offerings cover a broad range of hydrogen capabilities.** These are typically delivered as forms of in-house or safety training by established organisations who work in gas contexts. For example, some organisations have developed 'Hydrogen 101' materials to upskill their employees who are unfamiliar with the key characteristics and properties of hydrogen.

**Private provider (non-accredited) training offerings may be subject to intellectual property considerations and not available for public consumption.** For example, organisations with proprietary technology (e.g. fuel cell manufacturers) may be reluctant to share their knowledge and products more widely with training providers in order to maintain their intellectual property. This may pose a challenge to using these training offerings to help develop national training pathways.

# Current training pathways (3/3)

**Analysis of current education and training pathways in Australia for hydrogen-specific capabilities found that limited VET and higher education training pathways exist. Hydrogen-specific capabilities are broadly covered by non-accredited training pathways that are typically developed for private and in-house purposes.**

## Figure 23. Findings from training pathway analysis

**Although greater awareness of both is needed, existing training products in the accredited training system in Australia prioritise technical skills over broader hydrogen commercial and social considerations.** Consultation and research noted there was a strong need for hydrogen experts with business acumen skills that would allow them to build commercial business cases and communicate the social and environmental benefits of the hydrogen technology that their organisation had developed. This may impact the social acceptance and uptake of hydrogen as stakeholders in the broader public (e.g. local residents, regulators) may be unaware of its benefits.

**International case studies provide examples of best practice hydrogen education and training pathways.** Learnings from these offerings should be considered and utilised when developing hydrogen-specific capabilities in Australia. For example, the Renewable Energy Institute: European Energy Centre – *Hydrogen Energy Course* could be drawn on to develop a training solution for understanding hydrogen properties (capability #1). Other offerings provide strong examples of how partnerships between industry and training providers can speed up the workforce's familiarity with hydrogen technologies, such as the North East Scotland College (NESCOL) and its work with hydrogen fuel cell vehicles.

**Fuel cell technologies differ to existing technologies and will require new training solutions**, particularly in the VET system where very limited fuel cell training solutions exist. Stakeholders have noted that fuel cells pose a large augmentation challenge to existing automotive technicians and that Australia currently does not have a strong domestic manufacturing presence for fuel cell technologies. Given the reliance on overseas supply chains to source fuel cell replacements for vehicles, the lack of practical domestic knowledge in servicing and working with fuel cells may pose a challenge to the development of training solutions.

# Identified training gaps and proposed solutions (1/4)

**Drawing on the analysis in Section 7 of the report, the following hydrogen training gaps are noted in the VET system and in Higher Education programs. Provisional training solutions have been proposed for each gap. Non-accredited training solutions are not within the remit of this project.**

| Identified training gap | Proposed training solution |
|---|---|
| Understanding hydrogen properties<br>*Hydrogen capabilities #1, 10 & 18* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Develop multiple cross-sector training products on hydrogen chemical properties, forms, structures, risks and uses.<br>**Accredited (Higher Education):** Support providers to develop subject(s) on hydrogen chemical properties, forms, structures, risks and uses for incorporation into relevant degrees (e.g. engineering bachelor's degree) and short courses. |
| Handling and transporting cryogenic materials<br>*Hydrogen capability #3* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Develop a training product on handling and transporting cryogenic materials OR update/contextualise *PMAOPS341 Operate and troubleshoot cryogenic processes* with an emphasis on transportation considerations for hydrogen.<br>**Accredited (Higher Education):** Support providers to develop a subject on handling and transporting cryogenic materials for incorporation into relevant degrees (e.g. engineering bachelor's degree). |
| Market trends and drivers<br>*Hydrogen capability #5* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop a cross-sector training product on industry trends, regulation and developments.<br>**Accredited (Higher Education):** Support providers to develop a subject on industry trends, regulation and developments for all disciplines impacted by hydrogen for incorporation into relevant degrees (e.g. research master's degree). |
| High pressure gas systems and conversion requirements<br>*Hydrogen capability #6 & 17* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Update/contextualise *UEGNSG313 Monitor and operate flow control, pressure measuring and regulating devices for gas transmission* and *UEGNSG806 Maintain SCADA controlled flow and pressure equipment and electronic gas measurement equipment* with an emphasis on conversion requirements OR develop a training product on high pressure gas systems and conversion requirements.<br>**Accredited (Higher Education):** N/A – typically the remit of gas fitters and plumbers. |

# Identified training gaps and proposed solutions (2/4)

**Drawing on the analysis in Section 7 of the report, the following hydrogen training gaps are noted in the VET system and in Higher Education programs. Provisional training solutions have been proposed for each gap. Non-accredited training solutions are not within the remit of this project.**

| Identified training gap | Proposed training solution |
|---|---|
| Fuel Cells: Operation and maintenance<br>*Hydrogen capability #7* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** *(i)* Develop a cross-sector training product(s) on hydrogen fuel cell function, components and properties; and *(ii)* Develop a training product(s) on hydrogen fuel cell operation and maintenance.<br>**Accredited (Higher Education):** Support providers to develop a fuel cell subject (including operation, maintenance, diagnosis and replacement) for incorporation into relevant degrees (e.g. engineering bachelor's degree). |
| Fuel Cells: Diagnosis and replacement<br>*Hydrogen capability #8* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop training product(s) on hydrogen fuel cell diagnosis and replacement.<br>**Accredited (Higher Education):** Support providers to develop a fuel cell subject (including operation, maintenance, diagnosis and replacement) for incorporation into relevant degrees (e.g. engineering bachelor's degree). |
| Interpreting technical drawings<br>*Hydrogen capability #9* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Develop a training product on interpreting technical drawings *OR* update/contextualise *UEGNSG229 Prepare simple drawings of as laid gas mains and services* with an emphasis on interpreting technical plans for components that incorporate hydrogen.<br>**Accredited (Higher Education):** N/A – Foundational skill in all engineering disciplines. |
| Production techniques<br>*Hydrogen capabilities #11, 12 & 16* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Develop training product(s) on respective hydrogen production techniques *OR* update/contextualise *UEGNSG902 Commission, operate and maintain electrolysers* with an emphasis on other production techniques (the current focus is on electrolysis).<br>**Accredited (Higher Education):** Support providers to develop a subject on hydrogen production techniques for incorporation into relevant degrees (e.g. engineering bachelor's degree). |

# Identified training gaps and proposed solutions (3/4)

**Drawing on the analysis in Section 7 of the report, the following hydrogen training gaps are noted in the VET system and in Higher Education programs. Provisional training solutions have been proposed for each gap. Non-accredited training solutions are not within the remit of this project.**

| Identified training gap | Proposed training solution |
|---|---|
| Storage techniques<br>*Hydrogen capabilities #13, 14 & 15* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Develop a training product on each respective hydrogen storage technique OR update/contextualise *UEGNSG906 Undertake routine hydrogen storage operations* and/or *PMAOPS240 Store fluids in bulk* with an emphasis on hydrogen storage techniques and conversion to hydrogen carriers.<br>**Accredited (Higher Education):** Support providers to develop a hydrogen storage and conversion to carriers subject for incorporation into relevant degrees (e.g. engineering bachelor's degree). |
| Vehicles<br>*Hydrogen capability #20* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop multiple cross-sector training products on the inspection, maintenance and modification of hydrogen vehicles (including light vehicles, heavy vehicles, buses/coaches and marine vessels).<br>**Accredited (Higher Education):** Support providers to develop hydrogen vehicle subjects for incorporation into relevant degrees (e.g. engineering bachelor's degree). |
| Supply chain<br>*Hydrogen capability #22* | **Categorisation**: Some hydrogen training coverage, but additional contextualisation or development required.<br>**Accredited (VET):** Update/contextualise the cross-sector Transport and Logistics training products (including *TLIX0015X Manage fundamental aspects of supply chains*, *TLIX0021X Work with global supply chains* and *TLIX0034X Undertake supply support in integrated logistics*) with an emphasis on the hydrogen supply chain.<br>**Accredited (Higher Education):** Support providers to develop a subject on hydrogen supply chain considerations for incorporation into relevant degrees (e.g. logistics and supply chain bachelor's and master's degree). |
| Waste products<br>*Hydrogen capability #23* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop training product(s) on hydrogen and waste product interchangeability.<br>**Accredited (Higher Education):** Support providers to develop a hydrogen and waste product interchangeability subject for incorporation into relevant degrees (e.g. engineering bachelor's degree). |

# Identified training gaps and proposed solutions (4/4)

**Drawing on the analysis in Section 7 of the report, the following hydrogen training gaps are noted in the VET system and in Higher Education programs. Provisional training solutions have been proposed for each gap. Non-accredited training solutions are not within the remit of this project.**

| Identified training gap | Proposed training solution |
|---|---|
| Equipment integration<br>*Hydrogen capability #24* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop training product(s) on integrating hydrogen equipment from various original equipment manufacturers into a single system.<br>**Accredited (Higher Education):** Support providers to develop a subject on integrating hydrogen equipment into a single system for incorporation into relevant degrees (e.g. computer science or engineering bachelor's degree). |
| Co-firing gases<br>*Hydrogen capability #25* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop training product(s) on understanding co-firing in natural gas and hydrogen fuelled gas turbines.<br>**Accredited (Higher Education):** N/A – typically the remit of gas fitters and plumbers. |
| Social licence<br>*Hydrogen capability #26* | **Categorisation**: Minimal/no hydrogen training coverage.<br>**Accredited (VET):** Develop a cross-sector training product on communicating the benefits and risks of hydrogen to garner community acceptance.<br>**Accredited (Higher Education):** Support providers to develop a hydrogen social licence subject for incorporation into relevant degrees (e.g. engineering, business and marketing bachelor's degrees). |

# Sufficient hydrogen training coverage

**Drawing on the analysis in Section 7 of the report, the following hydrogen capabilities have sufficient coverage in the VET system through existing training products, noting that minor updates or contextualisation may be required. Higher Education programs have not been considered noting the practical considerations in these hydrogen capabilities.**

| Hydrogen capability | Existing training solution |
|---|---|
| Calibrating, testing and maintaining equipment<br>*Hydrogen capability #2* | **Categorisation**: Sufficient hydrogen training coverage.<br>**Existing training examples:** Covered in *UEGNSG903 Fault find and repair hydrogen storage equipment* in the Performance Evidence section. |
| Hazardous areas<br>*Hydrogen capability #4* | **Categorisation**: Sufficient hydrogen training coverage.<br>**Existing training examples:** Covered in *UEGNSG901 Apply safety practices, procedures, and compliance standards for handling hydrogen gas* in the Performance Evidence section. |
| Control modules<br>*Hydrogen capability #19* | **Categorisation**: Sufficient hydrogen training coverage.<br>**Existing training examples:** Covered in *UEGNSG905 Monitor and control hydrogen in gas distribution networks* in the Performance Evidence and Knowledge Evidence sections. |
| Power electronics<br>*Hydrogen capability #21* | **Categorisation**: Sufficient hydrogen training coverage.<br>**Existing training examples:** Covered in *UETTDRSB25 Maintain high voltage power and instrument transformers* & *UEPOPS512 Manage high voltage network system* in the Performance Evidence and Knowledge Evidence sections. |

# Training pathway prioritisation (1/3)

**Analysis indicates that 80% (16/20) of the top ten core and specialist capability requirements in job roles required to grow the hydrogen industry within Australia have either 'some' or 'minimal to no' training coverage. Development of training and education pathways for these critical areas must be prioritised to support a large-scale, safe, and effective hydrogen supply chain in Australia.**

## Overview

The 46 job roles identified as required to support a safe and effective hydrogen economy in Australia must be appropriately skilled in relevant hydrogen-specific capabilities (as identified in the hydrogen capability matrix in **Section 7**).

To understand the training pathways that should be prioritised, mapping has been undertaken to determine the core and specialist capabilities required for each job role across each supply chain area. To undertake this analysis, the following factors have been considered:

- The frequency of hydrogen capabilities that are core requirements in job roles;
- The frequency of hydrogen capabilities that are specialist requirements in job roles; and
- The availability of existing education and training pathways for the most in-demand core and specialist capabilities, and the impact of training gaps.

Analysis of the top ten most required core and specialist capabilities outlined in **Figure 24** indicates which capabilities require education and training pathway prioritisation, as 80% of the top ten core and specialist capabilities have either 'some' or 'minimal to no' training coverage.

## Figure 24. Training coverage for the top ten core and specialist capabilities

**Core capabilities**

| Sufficient training coverage | Some training coverage | Minimal to no training coverage |
|---|---|---|
| 4 capabilities | 5 capabilities | 1 capability |

**Specialist capabilities**

| Sufficient training coverage | Some training coverage | Minimal to no training coverage |
|---|---|---|
| 0 capabilities | 7 capabilities | 3 capability |

# Training pathway prioritisation – core capabilities (2/3)

**Analysis of current education and training pathways in Australia for the top ten core capabilities required in job roles indicates that six of the ten core capabilities have either 'some' or 'minimal to no' training coverage. Training pathways for these core capabilities must be prioritised as they are core to the largest amount of job roles required to grow and support the hydrogen industry within Australia.**

## Figure 25. Core capability training pathway analysis

| Capability | Count of job roles in which it is a core capability | Existing training pathway analysis: Sufficient hydrogen training coverage | Existing training pathway analysis: Some hydrogen training coverage, but additional contextualisation or development required | Existing training pathway analysis: Minimal to no hydrogen training coverage |
|---|---|---|---|---|
| Understanding hydrogen properties | 125 | | X | |
| Identifying and managing hydrogen hazardous areas (safety & risk) | 109 | X | | |
| Reading and interpreting technical drawings with hydrogen equipment | 106 | | X | |
| Knowledge of hydrogen embrittlement | 97 | | X | |
| Calibrating, testing and maintaining hydrogen equipment | 90 | X | | |
| Knowledge of high pressure gas systems and vessels | 89 | | X | |
| Understanding hydrogen market trends and drivers | 38 | | | X |
| Oversight of control modules for hydrogen processes | 34 | X | | |
| Knowledge of conversion requirements for gases and their interchangeability | 29 | | X | |
| Knowledge of power electronics | 28 | X | | |

## Analysis

**Figure 25** shows that, whilst a number of the core hydrogen capabilities are already catered for within the education and training system, there are some training gaps.

For example, of the ten top hydrogen core capabilities, there is one capability which currently has minimal to no training coverage:

- ‘Understanding hydrogen market trends and drivers’.

Additionally, there are five capabilities that provide some hydrogen training coverage but require additional contextualisation or development.

Without education and training development activity, this would result in core hydrogen capabilities required across a significant number of job roles being insufficiently and/or inappropriately delivered. This would impact the capacity of workers to undertake hydrogen activities safely and effectively.

The hydrogen capabilities outlined in **Figure 25** should be given priority in training pathway development, noting that they are core capabilities across all job roles that will support a large-scale, safe, and effective hydrogen supply chain in Australia.

# Training pathway prioritisation – specialist capabilities (3/3)

**Analysis of current education and training pathways in Australia demonstrates that the top ten specialist capabilities required by job roles in the hydrogen economy only have 'some' or 'minimal to no' training coverage. This indicates that the education and training pathways may not be sufficiently ready to cater for specialist roles in the hydrogen workforce and will need significant training pathway development and prioritisation.**

## Figure 26. Specialist capability training pathway analysis

| Capability | Count of job roles in which it is a specialist capability | Existing training pathway analysis | | |
|---|---|---|---|---|
| | | Sufficient hydrogen training coverage | Some hydrogen training coverage, but additional contextualisation or development required | Minimal to no hydrogen training coverage |
| Hydrogen storage techniques – liquid hydrogen | 94 | | X | |
| Hydrogen storage techniques - compressed hydrogen | 93 | | X | |
| Hydrogen storage techniques – conversion to hydrogen carriers | 82 | | X | |
| Integrating hydrogen equipment from various OEMs into a process | 73 | | | X |
| Producing hydrogen – understanding o cooling systems | 69 | | X | |
| Handling cryogenic materials | 59 | | X | |
| Understanding of co-firing in natural gas and hydrogen fuelled gas turbines | 51 | | | X |
| Knowledge of conversion requirements for gases and their interchangeability | 50 | | X | |
| Fuel cells – Operating and maintaining fuel cells | 49 | | | X |
| Hydrogen production techniques – Coal gasification | 47 | | X | |
| Hydrogen production techniques – electrolysis, biofuels, photolysis | 47 | | X | |

## Analysis

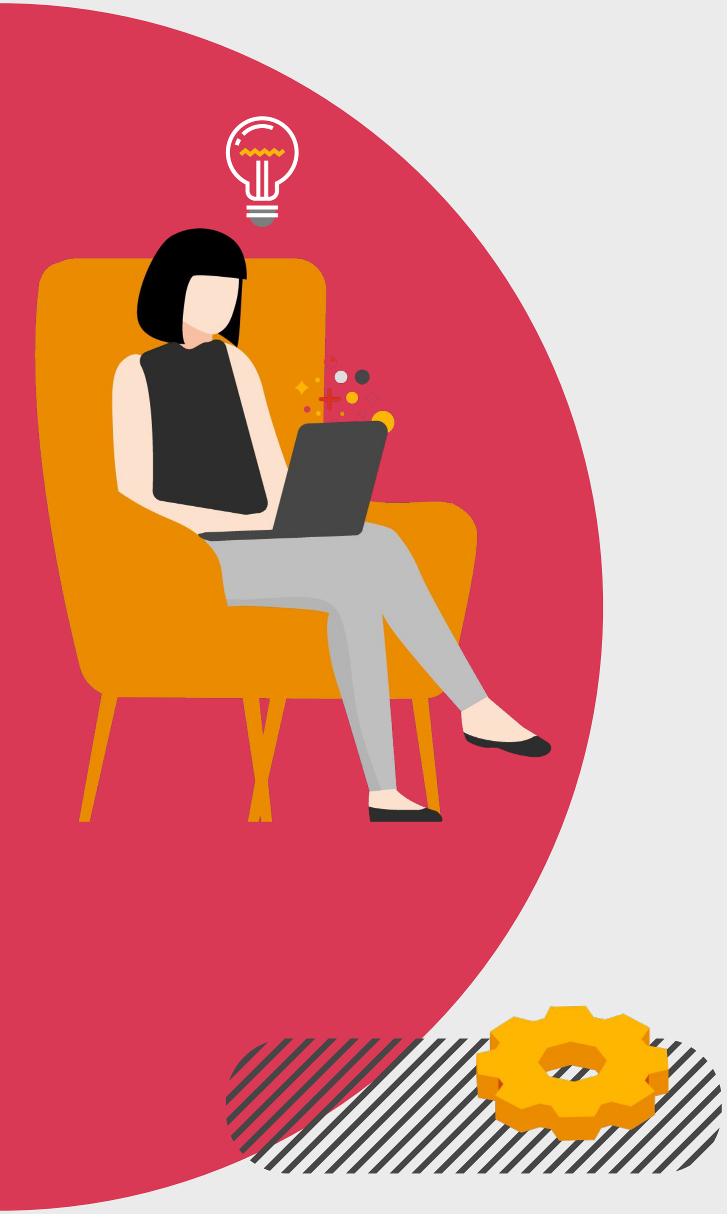
**Figure 26** shows that none of the top specialist hydrogen capabilities have sufficient training coverage in the current education and training system. Whilst some are partially addressed, they will still require additional contextualisation and/or development.

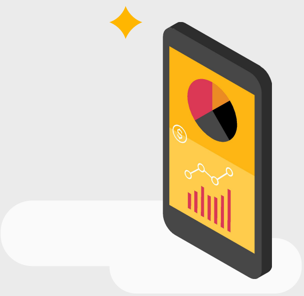
For example, of the ten top hydrogen specialist capabilities, there are three capabilities which currently have minimal to no training coverage:

- ‘Integrating hydrogen equipment from various OEMs into a process’
- ‘Understanding of co-firing in natural gas and hydrogen fuelled gas turbines’
- ‘Fuel cells – Operating and maintaining fuel cells’.

It is likely that this lack of coverage stems from the capabilities being relatively new and/or niche job role requirements and, therefore, national education and training pathways have not kept abreast with the rate of change occurring in the hydrogen industry (e.g. fuel cells). As a result, these capabilities are currently delivered through in-house training and/or on-the-job experience.

Education and training development must be prioritised to create training pathways for specialist hydrogen capabilities to adequately cater for job roles in the hydrogen workforce.





# Appendix

A. Case studies
B. Capability matrix methodology
C. Full quantitative modelling methodology
D. Occupational cluster augmentation analysis
E. Detailed training pathways analysis
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# A

# Case studies

# Case study | France (1/2)

## Overview

The French National Hydrogen Strategy (France Hydrogene[31]) outlines the skills, job roles and training required to support a thriving French hydrogen industry by 2030. The French National Hydrogen Strategy indicates that, in 2020, there were only 2,000 hydrogen job roles in France. It is estimated that by 2030, there will be 100,000 hydrogen job roles. The report developed a skills framework that indicated 14 major areas of technical skills and five areas of soft skills that are required in the 84 job roles to support a thriving hydrogen economy. Using the 84 job roles, a breakdown is provided of the required levels of training required in each job role. To ensure the current training offered is in line with the demand of the hydrogen sector, a number of strategies are proposed, such as developing hydrogen specific training modules and the creation of hybrid training courses.

## Job Roles

The French National Hydrogen Strategy identifies 84 existing job roles that are required to develop the French hydrogen industry. These jobs range from technical hydrogen job roles (e.g. Electromechanic) to more non-technical hydrogen job roles (e.g. Chief Operating Officer). The report also observes that:

- 27 professions will require hydrogen expertise
- 41 profession will require basic hydrogen knowledge
- 16 professions do not require specific knowledge of hydrogen.

**Table 3** outlines 17 job roles that were identified as being in short supply. These job roles were identified as having a significant shortage of skills and knowledge. Many of these job roles operate in highly competitive environments where the skills are sought in several industrial sectors.

## Table 3. Key job roles with significant shortages

| Job Roles | |
|---|---|
| Assembly Technician | Mechatronics Engineer |
| Certifier | Modelling Engineer of Dangerous Phenomena |
| Commissioning Technician | Pipe Fitter |
| Conformity Assessment Officer | Power Electronics |
| Electrical Technician | Test Technician |
| Electromechanic | Test Technician (Product Evaluation) |
| Truck Driver | Welder |
| Industrial Maintenance Technician | Work Operator |
| Locksmith/Metal Worker | |

31 France Hydrogene, 'Compétences-métiers de la filière Hydrogène' accessed at https://www.gouvernement.fr/sites/default/files/contenu/piece-jointe/2021/12/cma_france_hydrogene_livre_blanc_competences-metiers.pdf
(Please note, this document was translated to English using a document translator. Some translation errors may have arisen due to this process)

# Case study | France (2/2)

## Skills

The French National Hydrogen Strategy developed a skills framework that indicated 14 major areas of technical skills and five areas of soft skills that are required across the 84 job roles to support a thriving hydrogen economy.

All 14 technical skills are split by scientific or occupational competency. They represent how hydrogen systems require cross-disciplinary fields and are required in each of the 84 job roles. The five soft skills relate to areas of competence that have not been specified but are expected by a profession. Examples of each skill include:

- **Technical skills:** Electrical engineering, materials engineering, fluid mechanics
- **Soft skills:** Team management, negotiation, project management.

The most in-demand skills include: electrical engineering, industrial computing, mechanical engineering, fluid mechanics, metrology, QSE (quality, safety and environment), and English proficiency.

## Education and Training Pathways

Analysis has identified the level of training required to undertake each job role (as outlined in **Figure 27**). This identification of training needs is based on prior identification of training levels for each job role. With 58% of job roles requiring a five-year degree, the current priority training areas are centred on engineers and doctors. These figures are taking into account the trend towards the industrialisation of hydrogen solutions and projects. Hence, the need for technician (40%) and operator job roles (16%) are lower.

## Figure 27. Levels of education/training required

14 job roles require a secondary diploma

33 job roles (technicians) require a bachelor degree of two or more years training

48 job roles need five or more years of higher education training.

## Education and Training Pathways (cont.)

Currently, the number of students graduating with relevant skills compared to the number of workers required in the hydrogen sector is not sustainable. It is believed this is due to:

1. Lack of visibility of existing training courses, and;
2. Lack of training courses dedicated to hydrogen.

Strategies are being put in place to ensure that current training offerings are in line with the demand of the hydrogen sector. Some of these strategies include developing hydrogen specific training modules, creating hybrid training courses and undertaking internal skill development for employees. There is an appetite for market leaders in hydrogen to collaborate with schools, higher education and universities to improve the current training materials and the visibility of the hydrogen industry.

# Case study | United States of America (USA)[32] (1/2)

## Overview

The United States (US) Government has indicated a strong commitment to advancing technology that will assist in generating an efficient and sustainable hydrogen and fuel cell industry. They recently announced a $35 US billion dollar investment to achieve renewable technological breakthroughs to solve the climate crisis, innovate in clean energy technology and stimulate the clean energy workforce. Therefore, supporting the workforce to sustain the hydrogen industry is a key priority. Career mapping has been undertaken and identified 45 job roles required to support the hydrogen economy.

## Job Roles

The career mapping undertaken defines each of the 45 job roles by their career level and occupational clusters. The hydrogen and fuel cell workforce is split into three clusters:

- R&D, Engineering and Manufacturing
- Operations and Management
- Communications, Training and Outreach.

These three categories of the workforce are then separated into career levels (e.g. Entry, Mid-level and Advanced). The levels are classified by experience, level of education and career profiling. They do not indicate a level of responsibility.

**Figure 28** provides an overview of how the 45 job roles are quantified by career level and occupational clusters.

## Figure 28. Mapping of job roles required to support the hydrogen economy*

| | R&D, Engineering & Manufacturing | Operations & Management | Communications, Training & Outreach |
|---|---|---|---|
| Advanced | 1 | 8 | 2 |
| Mid-Level | 9 | 9 | 3 |
| Entry | 7 | 5 | 1 |

* Numbers quantified in each section are the job roles found under each classification by level and workforce category.

32 Office of Energy Efficiency & Renewable Energy, 'Hydrogen and Fuel Cells Career Map' accessed at https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cells-career-map

# Case study | United States of America (USA) (2/2)

## Overview

The career mapping splits out skills into two categories:

- **Job Skills:** These are typically non-technical skills that are required in specific job roles. For example, analytical skills, creativity, problem solving skills, ingenuity, and math skills.
- **Job Duties:** These are typically technical skills that are contextualised to the specific job role. For example, a chemical engineer typically develops safety procedures for those working with dangerous chemicals, and design and plan the layout of equipment.

For each job role, the career mapping tailors the specific job skills and job duties that are typically expected to be performed. The complexity of the skills and duties are influenced by the level of education, experience and responsibility required within that job role.

## Education and Training Pathways

The US economy has invested heavily in hydrogen training. Many resources and initiatives have been developed that are widely available for use. **Table 4** provides some examples of educational resources for students, teachers and those who are wanting to pursue a career in the clean energy sector.

With continued efforts to support the training sector, the hydrogen industry will continue to move in an upward trajectory, positively impacting job creation and supporting the US government to support their growing workforce needs.

## Table 4. Overview of existing training initiatives

| Current clean energy and hydrogen training initiatives for target cohorts |
|---|
| **School (Grades 5-12):** Resources for teachers including: lesson plans, visual aids, laboratory experiments, videos, and teacher workshops. Students have the opportunity to participate in opportunities that promote awareness about energy technologies and issues. |
| **College/Universities:** Resources for students include: textbooks, reading materials, scholarships, internships, and competitions. Colleges/universities offer the ability to map degree programs of specialisations to clean energy fields. |
| **Industry:** Funding opportunities for teachers and students to pursue energy-related studies or careers. Offering resources and internships to upskill individuals on the hydrogen economy and technologies. |


# B

# Capability matrix methodology

# Approach for developing the capability matrix (1/2)

**Drawing on research and consultation insights, a capability matrix was developed to articulate the hydrogen-specific capabilities (skill and knowledge) needed for the job roles identified as required to support the hydrogen economy.**

## Overview

A capability matrix (also known as 'skills matrix') is a tool used to map the required and/or desired capabilities (skills and knowledge) needed for a job role within a specific work context. For an individual to meet the performance expectations of their job role, they will need to have most, if not all, of the relevant skills and capabilities identified in a matrix.

Capability matrices can serve a range of purposes but are most frequently used to articulate the functional capabilities required of a particular job role and support the identification of where skill gaps of an individual/cohort may exist, and the associated education and training requirements.

## Purpose of the hydrogen capability matrix

The hydrogen capability matrix has been developed to:

- Articulate the hydrogen-specific capabilities required by each job role;
- Identify which job roles will require each capability in order to undertake hydrogen related activities, noting that this analysis has been done for each supply chain area;
- Identify whether a capability required by a job role is needed by all individuals in that job role operating in the hydrogen economy (e.g. it is a core skill of all electrical engineers undertaking hydrogen activities), or only required by some individuals operating in that job role (e.g. it is a specialist skill for electrical engineers undertaking certain activities); and
- Support analysis of capabilities that will be in-demand across job roles and supply chain areas, and inform considerations about education and training priorities.

### Key terminology

**Capability matrix:** A framework used to map the skill and knowledge requirements of a specific job role.

**Supply chain area:** A specified area in the process of developing and selling commercial goods. In this project, six hydrogen supply chain areas have been identified.

**Occupational cluster:** Groupings of like-occupations/job roles. In this project, six occupational clusters have been identified.

**Job role:** A paid position of regular employment. 46 job roles have been identified as required to support the desired activities across the in-scope hydrogen supply chain areas.

**Hydrogen-specific capability:** The underpinning skills and knowledge required by the identified job roles to engage effectively and safely in hydrogen activities. This project has identified 26 hydrogen-specific capabilities.

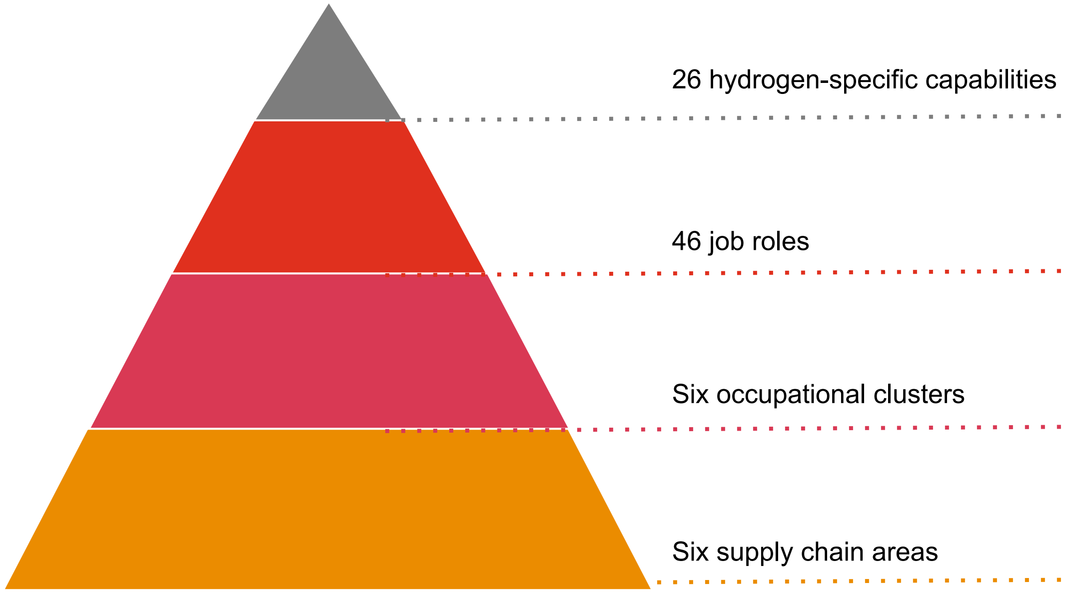
# Approach for developing the capability matrix (2/2)

**Drawing on research and consultation insights, a capability matrix was developed to articulate the hydrogen-specific capabilities (skill and knowledge) needed for the job roles identified as required to support the hydrogen economy.**

## Development process

The capability matrix builds on the findings in earlier reports that identified the in-scope supply chain areas, occupational clusters, job roles, and underpinning hydrogen-specific capabilities required to undertake relevant hydrogen related activities safely and effectively to support a large-scale hydrogen supply chain and economy in Australia.

## Inputs into the capability matrix




Previous analysis had mapped the hydrogen-specific capabilities to the 46 job roles to identify the scale of hydrogen skills and knowledge that each job role would require. The capability matrix has been developed to assist in providing the next level of analysis by determining if a hydrogen-specific capability (e.g. ‘handling cryogenic materials’) is a ‘core’ or ‘specialist’ capability for an identified job role (e.g. Chemical Engineers) in a specific supply chain area (e.g. hydrogen production). This analysis will support an understanding of whether all workers in a particular job role will need a particular hydrogen-specific capability, or if it is a capability that will only be relevant to workers undertaking particular activities (e.g. Specialists). This will inform the scale of workers that will require the particular capability and, therefore, the demand for education and training pathways.

In the matrix, each hydrogen capability was mapped to every job role in each supply chain area and assigned one of the following four categorisations:

- **Core capability:** Indicates that the hydrogen-specific capability will be expected by all individuals working in this job role in this supply chain area, to some degree.
- **Specialist capability:** Indicates that the hydrogen-specific capability will only be expected by some individuals working in this job role in this supply chain area.
- **N/A**: Indicates that the hydrogen-specific capability will not be expected of this job role in this supply chain area.
- **-** : Indicates that the job role is not required in this supply chain area.

A capability matrix for each supply chain area was developed using research and previous consultation insights. The matrices were then shared with subject matter experts for review and feedback.

# Approach for analysing the capability matrix (1/2)

**The capability matrix is comprised of six individual matrices, one for each area of the supply chain.**

Analysis of the requirements for core and specialist hydrogen-specific capabilities across job roles was done at the supply chain level to ensure that nuances between job roles operating in different contexts are appropriately captured. For example, a core capability requirement of a Commissioning Engineer in the production supply chain area may be a specialist capability requirement in the storage supply chain area, or potentially a capability that is not required. The use of six individual matrices allows analysis of these differences to take place.

An individual capability matrix has been developed for each of the following supply chain areas:

- Hydrogen production;
- Hydrogen transport and distribution;
- Hydrogen storage;
- Blending into natural gas;
- Hydrogen as a transport fuel; and
- Hydrogen as an export fuel.

**Figure 29. Extract of the capability matrix for the blending into natural gas supply chain area**

Occupational cluster that the relevant job role falls into

Hydrogen-specific capability

Identification that the particular job role does not need this capability in this supply chain area

Flag that the capability has been identified as a core capability for the particular job role in this supply chain area

| Job Role | Cluster | Understanding hydrogen properties | Calibrating, testing and maintaining hydrogen equipment | Handling cryogenic materials | Identifying hydrogen hazardous areas | Interpreting hydrogen market trends and regulation | Knowledge of high pressure gas systems and vessels |
|---|---|---|---|---|---|---|---|
| Chemical Engineer | Engineering | C | C | N/A | C | N/A | C |
| Civil Engineer | Engineering | C | S | N/A | C | N/A | C |
| Commissioning Engineer | Engineering | C | C | S | C | C | C |
| Electrical Engineer | Engineering | C | C | N/A | C | N/A | C |
| Electronics Engineer | Engineering | C | C | N/A | N/A | N/A | C |
| Grid Connection Engineer | Engineering | C | C | S | C | N/A | C |
| Marine Engineer | Engineering | - | - | - | - | - | - |
| Mechanical Engineer | Engineering | C | C | N/A | N/A | N/A | C |

Relevant job role

Indication that the job role is not relevant to the particular supply chain area

Flag that the capability has been identified as a specialist capability for the particular job role in this supply chain area

# Approach for analysing the capability matrix (2/2)

**An aggregate view of the individual supply chain capability matrices was developed to support comparative analysis of the demand for hydrogen-specific capabilities across the job roles.**

The heat map presented in the capability matrix presents a summary of the six individual supply chain matrices. It combines the data from the individual supply chain mapping assessments and allows for a comparison of the capabilities required by a job role across each supply chain area. It provides a relative indicator of whether the count of capabilities required is high or low.

This supports the assessment of:

- The job roles that, comparatively, require the most hydrogen capabilities;
- The supply chain areas in which hydrogen-specific capabilities will play a critical role; and
- The most in-demand hydrogen capabilities across job roles and supply chain areas. This will have implications on the demand for education and training.

## Methodology used to develop the heat map

The heat map counts the hydrogen-specific capabilities required for each job role (either core or specialist) across each supply chain area. The data for the map is pulled directly from the six individual supply chain matrices. A colour scale formula has been applied to the numbers in each cell to provide a visual representation of the comparative amount – the higher the number, the darker the shade of orange.

## Figure 30. Extract of the capability matrix heat map

Occupational cluster that the relevant job role falls into

Applicable area of the supply chain for the analysis

Identification of whether the count of capabilities is core or specialist

| Job Role | Cluster | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | |
|---|---|---|---|---|---|---|---|
| | | Core | Specialist | Core | Specialist | Core | Specialist |
| Relationship and Community Ma | Management | 0 | 0 | 0 | 0 | 3 | 11 |
| Research and Technology Manag | Management | 1 | 10 | 0 | 0 | 1 | 9 |
| Gas Inspector | Safety & QC | 14 | 6 | 7 | 9 | 12 | 4 |
| Quality Assurance Technician | Safety & QC | 13 | 11 | 8 | 16 | 5 | 13 |
| Work Health and Safety Officer | Safety & QC | 11 | 10 | 8 | 15 | 9 | 8 |
| Fuel Cell Fabrication and Testing | Specialists | 9 | 8 | 0 | 0 | 10 | 5 |
| Integration Specialist | Specialists | 8 | 14 | 0 | 0 | | |
| Loading Master | Specialists | 0 | 0 | 0 | 0 | | |
| Power Production Plant Operator | Specialists | 0 | 0 | 0 | 0 | | |

Relevant job role

The shade of orange is used as a visual representation of the quantum of capabilities. The darker the shade of orange, the greater the capability demand

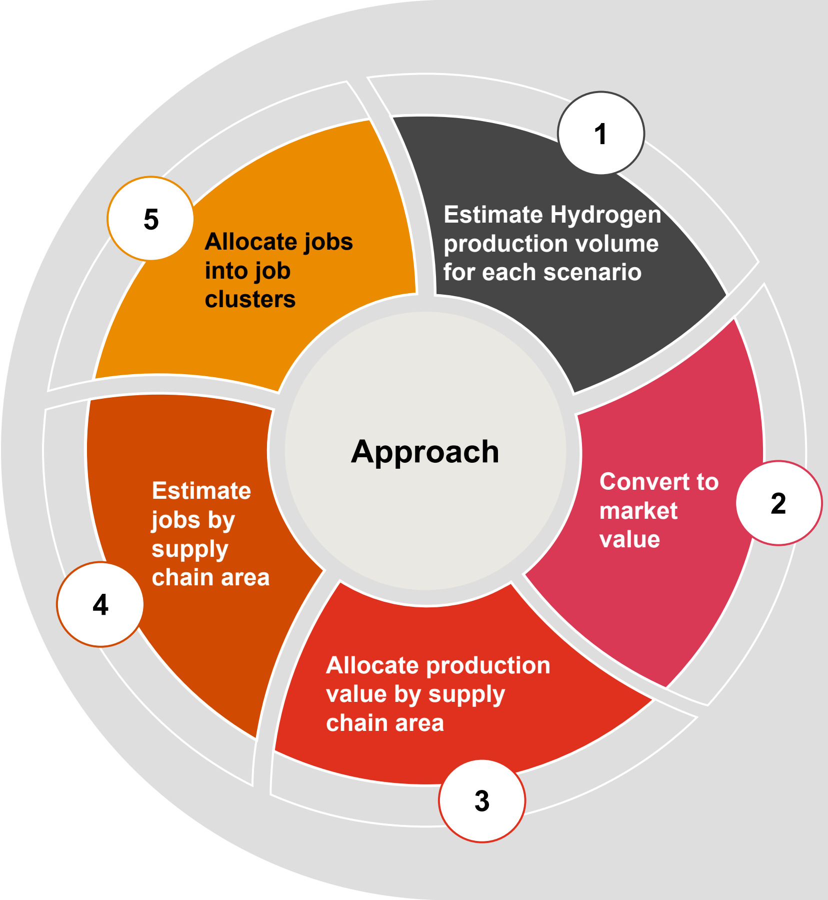
Count of capabilities that have been identified as core or specialist requirements for this job role in this supply chain area. If the numeral is 0, this means no capabilities are mapped to the job role for the supply chain area


# C

# Full quantitative modelling methodology

# Approach

**A five step approach has been used to estimate the number of hydrogen jobs in 2030 under different production scenarios. This approach estimates the additional jobs generated in the six employment clusters into which all 46 job roles are mapped to, across the six parts of the Hydrogen supply chain identified in this analysis.**




**Estimate Hydrogen production volume for each scenario**

A PwC proprietary dataset includes expected hydrogen production from each initiative earmarked to 2028.

The three hydrogen production scenarios were inferred from this spreadsheet by capturing a) All planned and constructed initiatives, b) All planned and constructed initiatives plus 25% of proposed projects, c) All planned and constructed initiatives plus 50% of proposed projects.
The dataset includes projects to 2028, noting that projects post-2028 are assumed to not contribute to Hydrogen production in 2030.

**Convert to market value**

Hydrogen production volumes converted to market value based on the estimated market value per kilogram of hydrogen for different end uses.

**Allocate production value by supply chain area**

Hydrogen production allocated into the relevant supply chain area based on the intended end use of the hydrogen produced by each initiative.

**Estimate jobs by supply chain area**

Employment per supply chain area obtained by applying the relevant input-output employment multiplier (IO multipliers) to the market value of hydrogen produced in each supply chain area.

IO multipliers are a government-approved method to estimate the input (in this case, jobs) per $1m output produced in a given sector.

**Allocate jobs into job clusters**

Distribute jobs by supply chain area into employment clusters using the workforce composition of comparable industries.

Workforce composition – Oil and gas industry workforce composition data was utilised to estimate the future allocation of jobs in Hydrogen for 2030.

# Step One | Estimate hydrogen production volume

## A. Infer hydrogen production (tonnes per annum)

Estimated annual hydrogen production was obtained from a PwC dataset that contains a 2022 view of 78 planned and committed hydrogen initiatives to 2028. This dataset was created to support PwC's *Getting H2 Right* report and a presentation by PwC Partner Lachy Haynes at the 2022 Australian Hydrogen Conference.[33]

For the purpose of estimating hydrogen production volumes, the dataset:

- includes the estimated annual hydrogen production from each initiative in megatonnes
- classifies each initiative into project categories based on the expected end-use of hydrogen production.

The project categories included in the dataset are:

- **Derivatives export** – Hydrogen that is converted into its compounds for export
- **H2 export** – Hydrogen that is exported overseas
- **Derivatives domestic** – Hydrogen that is converted into compounds for domestic use
- **Mobility** – Hydrogen that is used as a fuel source for transport vehicles
- **Industrial** – Hydrogen that is used as a feedstock to produce other material
- **Gas blending** – Hydrogen that is integrated into existing natural gas pipelines.

The dataset includes projects to 2028, noting that projects post-2028 are assumed to not contribute to hydrogen production in 2030.

33 PwC, 'Getting H2 Right' accessed at https://www.pwc.com.au/important-problems/integrated-infrastructure/PwCAU-Getting-H2-Right.pdf
34 CSIRO HyResource, 'A short report on hydrogen industry policy initiatives and the status of hydrogen projects in Australia' accessed at https://research.csiro.au/hyresource/wp-content/uploads/sites/378/2021/05/Short-Report-on-Hydrogen-Policy-and-Projects-Status-in-Australia-May-2021-v0.pdf

## B. Formulate hydrogen scenarios based on project status

The dataset also includes information on project status based on CSIRO's HyResource classifications:[34]

- **Advanced Development** – initiatives which are likely to be invested in
- **In Development –** initiatives undergoing preliminary feasibility studies
- **Under construction –** initiatives with proposed facilities being constructed
- **Operating/Operational** – initiatives which are operated, maintained and modified.

The three hydrogen production scenarios were inferred from this information by capturing:

- **Low scenario –** includes all advanced development, under construction and operating and operational initiatives
- **Medium scenario –** includes all advanced development, under construction and operating and operational initiatives plus 25% of in development initiatives
- **High scenario –** includes all advanced development, under construction and operating and operational initiatives plus 50% of in development initiatives.

The initiative types include in each scenario is shown in more detail in **Table 5** below.

### Table 5. Scenario Formulation Method

| Project status | Scenarios | | |
|---|---|---|---|
| | Low | Medium | High |
| Advanced Development | 100% | 100% | 100% |
| In development | 0% | 25% | 50% |
| Under construction | 100% | 100% | 100% |
| Operating | 100% | 100% | 100% |
| Operational | 100% | 100% | 100% |
| Unknown | 0% | 0% | 100% |

# Step Two | Convert to market value

## A. Estimate the market price of hydrogen

The market value of hydrogen was determined based on the market price of hydrogen traded for the purposes assumed by each project category.

These market prices for hydrogen are presented as dollars per kilogram and are estimated based on findings from Advisian's Australian Hydrogen Market Study report (2021) for each project category.[35] The outcome is shown in **Table 6** below.

Note that a lower bound and upper bound price has been used for each project category to account for uncertainty and market volatility.

### Table 6. Lower-bound and upper-bound market prices

| Project category | Lower bound market price ($/kg) | Upper bound market price ($/kg) |
|---|---|---|
| Derivatives domestic | $3 | $4 |
| Derivatives export | $4.50 | $5.50 |
| H2 export | $8.5 | $9.50 |
| Gas blending | $4.5 | $7.50 |
| Mobility | $5 | $6 |
| Industrial | $3.5 | $6 |

## B. Convert output (megatonnes per annum) to the market value of hydrogen (dollars per annum) based on market price

Applying the estimates for lower-bound and upper-bound market price to the estimated hydrogen production by project category gives the market value (dollars per annum) across each project category for each scenario. The results are shown below:

### Table 7a. Market value of hydrogen for project categories in a low scenario

| Low scenario | | | |
|---|---|---|---|
| Project category | Output (Mt/yr) | Market value ($m/yr) | |
| | | Lower bound | Upper bound |
| Derivatives domestic | - | - | - |
| Derivatives export | 0.4 Mt | $1,845 | $2,255 |
| H2 export | 0.2 Mt | $1,913 | $2,138 |
| Gas blending | 0.0 Mt | $3 | $4 |
| Mobility | 0.0 Mt | $2 | $2 |
| Industrial | 0.0 Mt | $0 | $0 |
| **Total** | **0.6 Mt** | **$3,762** | **$4,399** |

### Table 7b. Market value of hydrogen for project categories in a medium scenario

| Medium scenario | | | |
|---|---|---|---|
| Project category | Output (Mt/yr) | Market value ($m/yr) | |
| | | Lower bound | Upper bound |
| Derivatives domestic | 0.9 Mt | $2,785 | $3,713 |
| Derivatives export | 1.1 Mt | $4,741 | $5,794 |
| H2 export | 0.4 Mt | $3,504 | $3,916 |
| Gas blending | 0.1 Mt | $299 | $498 |
| Mobility | 0.1 Mt | $513 | $615 |
| Industrial | 0.0 Mt | $104 | $178 |
| **Total** | **2.6 Mt** | **$11,945** | **$14,715** |

### Table 7c. Market value of hydrogen for project categories in a high scenario

| High scenario | | | |
|---|---|---|---|
| Project category | Output (Mt/yr) | Market value ($m/yr) | |
| | | Lower bound | Upper bound |
| Derivatives domestic | 1.9 Mt | $5,583 | $7,445 |
| Derivatives export | 1.7 Mt | $7,809 | $9,544 |
| H2 export | 0.6 Mt | $5,173 | $5,781 |
| Gas blending | 0.1 Mt | $595 | $991 |
| Mobility | 0.2 Mt | $1,024 | $1,229 |
| Industrial | 0.1 Mt | $208 | $357 |
| **Total** | **4.6 Mt** | **$20,391** | **$25,346** |

35 Advisian, 'Australian hydrogen market study' accessed at https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf

# Step Three | Allocate production value by supply chain area

## A. Map project categories to supply chain areas

To map the project categories to the supply chain used throughout this analysis, we have developed a spend profile of each project category.

Advisian's Australian Hydrogen Market Study report (2021) forecasts how the cost or price of hydrogen may be broken down across each supply chain area depending on its end use (classified as project category in the PwC dataset).[36] In other words, the break down explains how a typical dollar generated from the sale of hydrogen may be spent across the supply chain areas in the future. This information is used to map project categories to supply chain areas – shown in **Table 8** below.

For example, a 'Derivatives domestic' initiative or project will spend 75% of the revenue generated from the sale of hydrogen produced on further hydrogen production, 25% on distributing hydrogen and 0% on storage, blending into natural gas, hydrogen as a transport fuel and on hydrogen as an export fuel.

### Table 8. Supply chain mapping to each project category (applied consistently across all scenarios)

| | Supply chain areas (% of cost) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project category** | Hydrogen production | Hydrogen distribution | Hydrogen storage | Blending hydrogen into natural gas | Hydrogen as a transport fuel | Hydrogen as an export fuel | **Total** |
| Derivatives domestic | 75% | 25% | 0% | 0% | 0% | 0% | **100%** |
| Derivatives export | 55% | 9% | 9% | 0% | 0% | 27% | **100%** |
| H2 export | 32% | 11% | 11% | 0% | 0% | 47% | **100%** |
| Gas blending | 27% | 0% | 0% | 73% | 0% | 0% | **100%** |
| Mobility | 33% | 8% | 0% | 0% | 58% | 0% | **100%** |
| Industrial | 50% | 50% | 0% | 0% | 0% | 0% | **100%** |

36 Advisian, 'Australian hydrogen market study' accessed at https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf

## B. Apply mapping to estimate production value by supply chain area

The supply chain mapping is applied to the total market value (upper and lower bound) of each project category calculated in step two (see **Table 7a to 7c**). The results are shown in the **Table 9a to 9c** below.

### Table 9a. Market value of hydrogen across supply chain areas in a low scenario

| Low scenario | | |
|---|---|---|
| **Project category** | **Market value ($m/yr)** | |
| | Lower bound | Upper bound |
| Hydrogen production | $1,612 | $1,907 |
| Hydrogen distribution | $369 | $430 |
| Hydrogen storage | $369 | $430 |
| Blending hydrogen into natural gas | $2 | $3 |
| Hydrogen as a transport fuel | $1 | $1 |
| Hydrogen as an export fuel | $1,409 | $1,627 |
| **Total** | **$3,762** | **$4,399** |

### Table 9b. Market value of hydrogen across supply chain areas in a medium scenario

| Medium scenario | | |
|---|---|---|
| **Project category** | **Market value ($m/yr)** | |
| | Lower bound | Upper bound |
| Hydrogen production | $6,084 | $7,609 |
| Hydrogen distribution | $1,591 | $2,008 |
| Hydrogen storage | $800 | $939 |
| Blending hydrogen into natural gas | $219 | $365 |
| Hydrogen as a transport fuel | $299 | $359 |
| Hydrogen as an export fuel | $2,952 | $3,435 |
| **Total** | **$11,945** | **$14,715** |

### Table 9c. Market value of hydrogen across supply chain areas in a high scenario

| High scenario | | |
|---|---|---|
| **Project category** | **Market value ($m/yr)** | |
| | Lower bound | Upper bound |
| Hydrogen production | $10,685 | $13,468 |
| Hydrogen distribution | $2,840 | $3,618 |
| Hydrogen storage | $1,254 | $1,476 |
| Blending hydrogen into natural gas | $436 | $727 |
| Hydrogen as a transport fuel | $597 | $717 |
| Hydrogen as an export fuel | $4,579 | $5,341 |
| **Total** | **$20,391** | **$25,346** |

# Step Four | Estimate jobs by supply chain area

## A. Map hydrogen supply chain areas to a jobs multiplier

Input-output (IO) multipliers are a method that can be used to estimate the input (in this case, jobs) per $1m output produced in a given sector, represented by Input-Output Industry Group (IOIG) descriptors.[37]

The jobs multiplier most relevant to a hydrogen supply chain area has been determined by mapping each supply chain area to IOIGs, shown in **Table 10** below.

### Table 10. Mapping hydrogen supply chain areas to IO multipliers

| **Supply chain area** | Hydrogen production | Hydrogen distribution | Hydrogen storage | Blending hydrogen into natural gas | Hydrogen as a transport fuel | Hydrogen as an export fuel |
|---|---|---|---|---|---|---|
| **IOIG Descriptor** | Basic Chemical Manufacturing | Gas Supply | Gas Supply | Gas Supply | Automotive Repair and Maintenance | Water Pipeline and Other Transport |
| **Jobs Multiplier** | 1.6 | 0.8 | 0.8 | 0.8 | 6.7 | 1.7 |

37 ABS 5209.0 Australian National Accounts Input-Output Tables 5 and 20 (2018-19)

## B. Estimate the total number of jobs in hydrogen supply chain areas

The supply chain mapping is applied to the total market value (upper and lower bound) of each project category calculated in step two (see **Table 7a to 7c**). The results are shown in the **Table 11a to 11c** below.

### Table 11a. Number of jobs in hydrogen across supply chain areas in a low scenario

| Low scenario | | |
|---|---|---|
| **Supply chain areas** | **Number of jobs (#) (FTE)** | |
| | Lower bound | Upper bound |
| Hydrogen production | 1,791 | 2,119 |
| Hydrogen distribution | 199 | 232 |
| Hydrogen storage | 199 | 232 |
| Blending hydrogen into natural gas | 1 | 35 |
| Hydrogen as a transport fuel | 4 | 35 |
| Hydrogen as an export fuel | 1,702 | 1,966 |
| **Total** | **3,896** | **4,619** |

### Table 11b. Number of jobs in hydrogen across supply chain areas in a medium scenario

| Medium scenario | | |
|---|---|---|
| **Supply chain areas** | **Number of jobs (#) (FTE)** | |
| | Lower bound | Upper bound |
| Hydrogen production | 6,761 | 8,457 |
| Hydrogen distribution | 857 | 1,082 |
| Hydrogen storage | 432 | 506 |
| Blending hydrogen into natural gas | 118 | 197 |
| Hydrogen as a transport fuel | 1,410 | 1,692 |
| Hydrogen as an export fuel | 3,566 | 4,148 |
| **Total** | **13,144** | **16,082** |

### Table 11c. Number of jobs in hydrogen across supply chain areas in a high scenario

| High scenario | | |
|---|---|---|
| **Supply chain areas** | **Number of jobs (#) (FTE)** | |
| | Lower bound | Upper bound |
| Hydrogen production | 11,875 | 14,967 |
| Hydrogen distribution | 1,530 | 1,949 |
| Hydrogen storage | 676 | 795 |
| Blending hydrogen into natural gas | 235 | 392 |
| Hydrogen as a transport fuel | 2,816 | 3,379 |
| Hydrogen as an export fuel | 5,530 | 6,450 |
| **Total** | **22,662** | **27,933** |

# Step Five | Allocate jobs into job clusters (1/2)

## A. Map supply chains to job clusters

Workforce composition is the distribution of jobs within an industry across categories such as skill, job nature and expertise. Given hydrogen is still an emerging energy source, we looked at the workforce composition of a more established industry (oil and gas) to estimate the future jobs by job cluster for the industry.

National Energy Resources Australia (NERA) published the Preparing Australia's Future Oil and Gas Workforce Report (2018) which outlines the workforce composition of the oil and gas industry based on 2016 ABS Census data.[38]

Allocating each part of the hydrogen supply chain to the component parts of the oil and gas industry allows us to understand the expected number of jobs available under each job cluster based on need. This is shown in **Table 12** below.

For example, storing hydrogen does not require for logistics personnel, therefore, 0% of jobs made available across the 'hydrogen storage' supply chain area are expected to be in the 'Logistics' job cluster.

### Table 12. Distribution of jobs across job clusters for all scenario

| | Supply chain area | | | | | |
|---|---|---|---|---|---|---|
| **Job cluster (% of jobs)** | Hydrogen production | Hydrogen distribution | Hydrogen storage | Blending Hydrogen into gas networks | Hydrogen as a transport fuel | Hydrogen as an export fuel |
| Engineering | 20% | 20% | 20% | 20% | 20% | - |
| Tradesperson and technician | 42% | 42% | 42% | 42% | 42% | 42% |
| Specialist | 1% | - | 1% | 1% | 1% | 1% |
| Logistics | - | 7% | - | - | 1% | 11% |
| Management | 5% | - | 5% | 5% | 5% | 5% |
| Safety and quality control | 2% | 1% | 2% | 2% | 1% | 11% |
| *Corporate (not included)* | *30%* | *30%* | *30%* | *30%* | *30%* | *30%* |
| **Total** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

38 NERA, 'Preparing Australia's future oil and gas workforce Report' accessed at https://www.nera.org.au/Featured-workforce-report

## B. Estimate the number of jobs in job clusters

The supply chain mapping is applied to the total market value (upper and lower bound) of each project category calculated in step two (see **Table 7a to 7c**). The results are shown in **Table 13** below.

### Table 13. Number of jobs in hydrogen across job clusters by scenario (rounded to the nearest 50 jobs)

| | Low | Medium | High |
|---|---|---|---|
| Estimated hydrogen production (Mt) | 0.6 | 2.6 | 4.6 |
| **Job Cluster** | **Number of jobs (FTE) (# in lower bound – # in upper bound)** | | |
| Engineering | 650 – 750 | 2,750 – 3,400 | 4,900 – 6,150 |
| Tradesperson and technician | 2,350 – 2,750 | 7,900 – 9,650 | 13,600 – 16,750 |
| Specialist | 50 – 100 | 150 – 200 | 300 – 350 |
| Logistics | 300 – 350 | 650 – 800 | 1,100 – 1,250 |
| Management | 250 – 300 | 900 – 1,050 | 1,500 – 1,850 |
| Safety and quality control | 350 – 400 | 800 – 950 | 1,300 – 1,550 |
| Total jobs | 3,950 – 4,650 | 13,150 – 16,050 | 22,700 – 27,900 |

The distribution of jobs across job clusters for all supply chain areas is also estimated (see **Table 14a to 14c** on **Page 92**).

# Step Five | Allocate jobs into job clusters (2/2)

## Table 14a. Number of jobs in hydrogen across job clusters and supply chain areas for the low scenario

| | Low scenario | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of jobs (FTE) per supply chain area (#) | | | | | | | | | | | |
| | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending into gas networks | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| **Job cluster** | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound |
| Engineering | 512 | 606 | 57 | 66 | 57 | 66 | 0 | 10 | 1 | 10 | - | - |
| Tradesperson and technician | 1,075 | 1,272 | 119 | 139 | 119 | 139 | 1 | 21 | 3 | 21 | 1,021 | 1,179 |
| Specialist | 26 | 30 | - | - | 3 | 3 | 0 | 1 | 0 | 1 | 24 | 28 |
| Logistics | - | - | 20 | 23 | - | - | - | - | 0 | 1 | 267 | 309 |
| Management | 128 | 151 | - | - | 14 | 17 | 0 | 3 | 0 | 3 | 122 | 140 |
| Safety and quality control | 51 | 61 | 3 | 3 | 6 | 7 | 0 | 1 | 0 | 1 | 267 | 309 |
| **Total jobs** | **1,791** | **2,119** | **199** | **232** | **199** | **232** | **1** | **35** | **4** | **35** | **1,702** | **1,966** |

## Table 14b. Number of jobs in hydrogen across job clusters and supply chain areas for the medium scenario

| | Medium scenario | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of jobs (FTE) per supply chain area (#) | | | | | | | | | | | |
| | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending into gas networks | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| **Job cluster** | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound |
| Engineering | 1,932 | 2,416 | 245 | 309 | 123 | 145 | 34 | 56 | 403 | 484 | - | - |
| Tradesperson and technician | 4,057 | 5,074 | 514 | 649 | 259 | 304 | 71 | 118 | 846 | 1,015 | 2,139 | 2,489 |
| Specialist | 97 | 121 | - | - | 6 | 7 | 2 | 3 | 20 | 24 | 51 | 59 |
| Logistics | - | - | 86 | 108 | - | - | - | - | 20 | 24 | 560 | 652 |
| Management | 483 | 604 | - | - | 31 | 36 | 8 | 14 | 101 | 121 | 255 | 296 |
| Safety and quality control | 193 | 242 | 12 | 15 | 12 | 14 | 3 | 6 | 20 | 24 | 560 | 652 |
| **Total jobs** | **6,761** | **8,457** | **857** | **1,082** | **431** | **506** | **118** | **197** | **1,410** | **1,692** | **3,566** | **4,148** |

## Table 14c. Number of jobs in hydrogen across job clusters and supply chain areas for the high scenario

| | High scenario | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of jobs (FTE) per supply chain area (#) | | | | | | | | | | | |
| | Hydrogen production | | Hydrogen distribution | | Hydrogen storage | | Blending into gas networks | | Hydrogen as a transport fuel | | Hydrogen as an export fuel | |
| **Job cluster** | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound | Lower bound | Upper bound |
| Engineering | 3,393 | 4,276 | 437 | 557 | 193 | 227 | 67 | 112 | 805 | 966 | - | - |
| Tradesperson and technician | 7,125 | 8,980 | 918 | 1,170 | 406 | 477 | 141 | 235 | 1,690 | 2,028 | 3,318 | 3,870 |
| Specialist | 170 | 214 | - | - | 10 | 11 | 3 | 6 | 40 | 48 | 79 | 92 |
| Logistics | - | - | 153 | 195 | - | - | - | - | 40 | 48 | 869 | 1,014 |
| Management | 848 | 1,069 | - | - | 48 | 57 | 17 | 28 | 201 | 241 | 395 | 461 |
| Safety and quality control | 339 | 428 | 22 | 28 | 19 | 23 | 7 | 11 | 40 | 48 | 869 | 1,014 |
| **Total jobs** | **11,875** | **14,967** | **1,530** | **1,949** | **676** | **795** | **235** | **392** | **2,816** | **3,379** | **5,530** | **6,450** |


# D

# Occupational cluster augmentation analysis

# Engineers: Augmentation analysis (1/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Chemical engineer (ANZSCO code: 233111)** | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in Chemical Engineering<br>• At least five years experience in related projects. | Chemical engineers are expected to design and develop chemical production processes that transform raw materials in a range of contexts. Their work includes designing and preparing specifications for chemical processes, and the construction and planning of chemical plants. They may also be expected to supervise industrial processing and the fabricating of project materials.<br><br>*Note: This job role is also seen as encapsulating materials sciences engineers and related specialisations.* | • Knowledge of hydrogen's property risks and interactions with various materials will be an expected part of a chemical engineers' work<br>• Embrittlement and crack propagation caused by molecular interaction between steel and hydrogen will influence the materials that chemical engineers select on their project<br>• Business needs to find more efficient methods of storing, transporting and converting hydrogen to other forms or compounds will require chemical engineers to advise others on the relative advantages and disadvantages of hydrogen's various states in terms of calorific and heating content, and its interchangeability with other chemicals (e.g. gases). |
| **Civil engineer (ANZSCO Code: 233211)** | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in Civil Engineering<br>• At least five years experience in related projects. | Civil engineers oversee the planning, design and construction of large structures such as plants, pipelines, and gas supply schemes. They also examine the operations of these structures, and test their materials for durability and integrity. They are responsible for project management activities, including ensuring activities run according to schedule, cost and labour constraints. | • When planning structures that will house hydrogen and consider their environmental impact, civil engineers will need familiarity with hydrogen's property risks and the various production and storage methods available for hydrogen<br>• Knowledge of high pressure gas systems will be critical to fully account for all safety considerations inherent to working with hydrogen<br>• A familiarity with power electronics may also be needed in hydrogen plant design. |
| **Commissioning engineer (ANZSCO code: 233512)** | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in an Engineering discipline or Computer Science<br>• At least five years experience in related projects. | Commissioning engineers are those who oversee the installation and testing of equipment near the conclusion of a project. They inspect the functioning of facilities and plants to confirm they meet project specifications and the broader compliance environment. They verify these elements and give final approval to a project. | • Commissioning engineers will need to understand the breadth of production and storage methods for hydrogen, such as electrolysis, steam methane reformation, and in the short term, coal gasification<br>• Liquefaction of hydrogen and storage in this liquefied form will change the material handling systems and processes<br>• They will also need an understanding of high pressure gas systems and vessels, as these are necessary when storing or transporting hydrogen. |
| **Electrical engineer (ANZSCO Code: 233311)**<br><br>Note: We have also used this ANZSCO code for Grid Connection Engineer job roles | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in Electrical Engineering<br>• At least five years experience in related projects. | Electrical engineers design and develop equipment and systems necessary for the generation and distribution of electrical power. They oversee the construction, installation and operation of these systems and equipment, and analyse the data arising from them. They may also be responsible for their ongoing maintenance and any problem solving required to ensure optimal performance. | • In some cases, electrical engineers will be expected to work with large high voltage power electronics used to supply energy to hydrogen production plants (e.g. substations, transformers)<br>• In design and planning, electrical engineers will need to recognise the importance of hazardous areas and the danger of ignition sources when designing hydrogen production and storage facilities<br>• Integration of electric vehicle drivetrains with hydrogen fuel cells will also be critical in certain sectors of industry, though this expertise may take some years to fully build within the market given the overseas location of the majority of fuel cell manufacturers. |

# Engineers: Augmentation analysis (2/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Electronics engineer (ANZSCO code: 233411)**<br><br>Note: We have also used this ANZSCO code for integration specialist job roles. | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in an Engineering discipline or Information Systems<br>• At least five years experience in related projects<br>• Prior experience with programming languages and automation suites. | Electronics engineers plan, design and monitor equipment that helps maintain manufacturing or operating processes within a set of parameters. They ensure that processes and finished work continuously remains within specifications and, in some instances, may design ways for this monitoring to be undertaken remotely.<br><br>*Note: This job role is also seen as encapsulating mechatronics and robotics engineers and related specialisations.* | • Electronics engineers will need to factor in hydrogen's specific properties when they design and program control modules that will ensure chemical processes occur safely and efficiently<br>• This programming may also demand integrating specific components from various suppliers who specialise in hydrogen production<br>• They will also need an understanding of high pressure gas systems and vessels, as these are necessary when storing or transporting hydrogen. |
| **Grid connection engineer**<br><br>Note: No ANZSCO code is currently available for this job role. The best match is 233311 – Electrical Engineer | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in Electrical Engineering<br>• At least five years' experience in related projects. | Grid connection engineers plan, design and monitor the connection of energy projects with the wider electrical grid in a region. They are responsible for ensuring that the connection is technically feasible, collaborate with national service providers, and undertake network analysis of the generation, transmission and distribution systems. | • Grid connection engineers will need to have an understanding of the power electronics systems that may be used in conjunction with some hydrogen production facilities, but this is typically expected knowledge of the job<br>• Depending on the number of industry participants in their project and the regulatory environment that they operate within, they may also need experience with navigating and managing social considerations to operate for their projects. |
| **Marine engineer (ANZSCO code: 231213)**<br><br>Note: We have also used this ANZSCO code for Marine master/operator job roles | • Certificate III in Maritime Operations (Master up to 24 metres Near Coastal) or higher<br>• Medical health standards for a seagoing career as prescribed by the Australian Maritime Safety Authority<br>• Completion of relevant sea service requirements depending on licence class. | Marine engineers are those who install, operate, and maintain machinery and equipment on ships and vessels. They inspect the functioning of vessels and in some cases undertake servicing activities to correct faults or damage to parts of a vessel. | • Marine engineers will require an understanding of fuel cell technology, how it functions, and what components in the propulsion system may be safely handled for repair<br>• Marine engineers will need an understanding of hydrogen's property risks. Knowledge of hazardous areas is also required when dealing with containment issues (e.g. leakages, crack propagation in materials)<br>• They will also need an understanding of high pressure gas systems and vessels and how they function, as these are necessary when storing or transporting hydrogen. |
| **Mechanical engineer (ANZSCO Code: 233512)** | • Engineers Australia membership (inc. accredited degree as specified)<br>• Bachelor's Degree or higher in Mechanical Engineering<br>• At least five years' experience in related projects. | The typical tasks of a mechanical engineer involve designing and planning mechanical products and systems in a range of contexts. They oversee the construction, installation and operation of these components and systems, and analyse the data arising from them. They may also be responsible for their ongoing maintenance and any problem solving required to ensure optimal performance. | • Knowledge of hydrogen's property risks and interactions with various materials will be critical domain knowledge for mechanical engineers designing systems and components<br>• Embrittlement and crack propagation caused by molecular interaction between steel and hydrogen will influence the materials that mechanical engineers select on their project<br>• Understanding hydrogen's flammability and ignition factors will also be important to designing processes safely. |

# Technicians and tradespersons: Augmentation analysis (1/5)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Automotive electrician (ANZSCO Code: 321111)** | • *Certificate IV in Automotive Electrical Technology*<br>• Experience with Original Equipment Manufacturers (OEMs) may be required. | Automotive electricians install, maintain and repair electrical wiring and electronic components in motor vehicles. They dismantle and remove electrical/electronic components and assemblies. They test, repair and replace faulty components, and connect power-operated vehicle equipment and accessories to a power supply. | • They will need a basic understanding of the operations and functions of proton exchange membrane fuel cells, including their limitations and when replacement may be necessary<br>• Automotive electricians will need to work with high voltage systems, including learning how to depower them so that repair or maintenance work can be undertaken<br>• In some cases, automotive electricians may need to have a familiarity of different supplier parts that have been integrated into the electric vehicle's assemblies. This may assist with diagnostic fault-finding and testing. |
| **Automotive electric vehicle technician**<br><br>Note: No ANZSCO code is available for this job role. The best match is 321211 – Motor Mechanic (General) | • *Certificate III in Heavy Commercial Vehicle Mechanical Technology*, *Certificate III in Light Vehicle Mechanical Technology*, or *Certificate III in Automotive Electric Vehicle Technology*<br>• Experience with OEMs may be required. | Automotive electric vehicle technicians are an emerging job role who specialise in maintaining, testing and repairing electrical vehicles and their mechanical systems, such as their transmission, suspension, steering and braking. They may also be expected to work with software and undertake diagnostic activity on vehicles to synthesise and interpret data from a number of electronic systems. | • They will need a basic understanding of the operations and functions of proton exchange membrane fuel cells but also their limitations and when replacement is necessary (e.g. due to the cell's degradation over time)<br>• They will need to work with high voltage systems, including learning how to depower them so that repair or maintenance work can be undertaken<br>• A knowledge of fuel cell cooling systems within the vehicle and how they maintain temperature homogeneity will also be needed. |
| **Control room officer (ANZSCO code: 399213)**<br><br>Note: We have also used this ANZSCO code for the Power production plant operator job role | • *Certificate IV in ESI Generation – Operations*<br>• At least three years post-trade experience in related projects. | Control room officers monitor operations within a power plant to ensure they function as intended. They identify abnormal plant operating conditions and equipment, track and log data for all operational systems, and communicate to other operators recommended changes to improve plant performance, reliability and overall output. | • Control room officers will face little to no change to their responsibilities, as the fundamental tasks and processes of their work will remain unaltered<br>• However, they may need to build domain knowledge in order to understand the interchangeability of hydrogen with other gases (in this case natural gas) and the properties on which it differs, such as its calorific content<br>• They would also need knowledge of hydrogen storage techniques and the risks that come with handling it in its various forms, (e.g. its flammability and high compression when stored as a gas, and the need for low temperatures for storage when it is liquefied). |
| **Electrical fitter (ANZSCO Code: 341111)**<br><br>Note: We have also used this ANZSCO code for Electrician job roles | • *Certificate III in Electrical Fitting*<br>• Electrical Equipment in Hazardous Areas certification<br>• Restricted Electrical Licence in relevant jurisdiction<br>• Occupational Health and Safety white card. | Electrical fitters manufacture, assemble, test, alter and repair electrical equipment, wiring and other components in a plant or machinery context. This equipment is above extra-low voltage and fitters are not authorised to install any electrical wiring systems in accordance with the Australian/New Zealand Wiring Rules. They examine wiring diagrams and specifications and use electrical/electronic equipment to analyse and find faults in systems. | • Electrical fitters will need to build an understanding of the gas trades, as well as hydrogen's unique properties and risks<br>• Depending on the type of plant being constructed, they may need certification to engage with high voltage power electronics (e.g. substations, transformers)<br>• Stakeholder consultations with engineering, procurement and construction firms noted that, given the multidisciplinary nature of hydrogen projects, a mutual understanding of electrical and gas fitting systems is needed. |

# Technicians and tradespersons: Augmentation analysis (2/5)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Electrical instrumentation technician (ANZSCO Code: 342315)** | • *Certificate III in Instrumentation and Control*<br>• Electrical Equipment in Hazardous Areas certification<br>• Occupational Health and Safety white card<br>• Relevant licence depending on state/territory jurisdiction. | Electrical instrumentation technicians examine and test machines, equipment and control systems to diagnose faults. They replace defective parts, install, wire and maintain machines and equipment. They are expected to hold knowledge of electrical, electronic, mechanical and pneumatic systems in undertaking this work. | • Electrical instrumentation technicians will need to be prepared for high pressure gas systems, particularly as hydrogen's lightness poses a risk to small bore tubing and other vessels' ability to keep the gas contained<br>• Installation and inspection of these components will require a high skill level and familiarity with degradation mechanisms, such as vibration, pitting corrosion and chloride induced stress corrosion cracking<br>• A key hydrogen property risk that they will need to consider is hydrogen's ignition sources and flammable areas<br>• In consultation, hydrogen producers noted that Electrical Equipment in Hazardous Areas (EEHA) certification is critical to working with hydrogen. |
| **Electrician (ANZSCO Code: 341111)**<br><br>Note: We have also used this ANZSCO code for Electrical Fitter job roles | • *Certificate III in Instrumentation and Control*<br>• Electrical Equipment in Hazardous Areas certification<br>• Occupational Health and Safety white card<br>• Relevant licence depending on state/territory jurisdiction. | Electricians install, test, connect, commission, maintain and modify electrical equipment, wiring and control systems. They examine wiring diagrams and specifications, connect wire and cable to terminals and connectors, and use electrical/electronic equipment to analyse and find faults in systems. They may also be expected to service and repair some complex electronic circuitry. | • Electricians working on hydrogen production plants may need certification to engage with high voltage power electronics (e.g. substations, transformers) that supply power to electrolysers, for example<br>• They may also need a general understanding of hydrogen fuel cells and their operating principles<br>• A key hydrogen property risk that they will need to consider is hydrogen's ignition sources and flammable areas<br>• In consultation, hydrogen producers noted that EEHA certification is critical to working with hydrogen. |
| **Fitter and turner (ANZSCO Code: 322311)** | • *Certificate III in Engineering – Mechanical Trade*<br>• Electrical Equipment in Hazardous Areas certification<br>• Occupational Health and Safety white card<br>• Relevant licence depending on state/territory jurisdiction. | Fitters and turners grind, shape, fit and assemble metal parts to fabricate production machines and other equipment. They check the fabricated parts for conformance to specifications, and determine suitable materials, methods and sequences of operation for these machines. They assemble and fit both plant machinery and vehicle components depending on the configuration of the hydrogen project. | • They will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas)<br>• They will also need to know the chemical reactions that hydrogen has with steel and other materials, which frequently contributes to pipeline embrittlement and crack propagation. This may influence the materials fitter and turners select in their work<br>• Depending on the type of plant being constructed, they may need knowledge of electrical systems and how those will interface with the plant's processes. |
| **Gas fitter (industrial) (ANZSCO Code: 334114)**<br><br>Note: We have also used this ANZSCO code for Gas Fitter (general) & Gas Industry Operator job roles. | • *Certificate III in Gas Supply Industry Operations*<br>• Electrical Equipment in Hazardous Areas certification<br>• Confined space entry permit<br>• Relevant licence depending on state/territory jurisdiction. | Industrial gas fitters install, maintain and service gas mains, piping systems, and any appliances and ancillary equipment typically in industrial environments upstream of the gas meter, where the gas is used as a fuel or feedstock for another process. | • As most gas fitters in industrial contexts likely already work with high pressure gases, they may only need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas)<br>• While already assumed knowledge in their role, high pressure gas systems and the potential consequences of a loss of gas containment are critical to safe work in this job role<br>• They will also need to know the chemical reactions that hydrogen has with steel and other materials to maintain containment, given that reactions contribute to pipeline embrittlement and crack propagation. |

# Technicians and tradespersons: Augmentation analysis (3/5)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Gas fitter (general) (ANZSCO Code: 334114)**<br><br>Note: We have also used this ANZSCO code for Gas Fitter (general) & Gas Industry Operator job roles. | • *Certificate III in Gas Fitting*<br>• Electrical Equipment in Hazardous Areas certification<br>• Confined space entry permit<br>• Relevant licence depending on state/territory jurisdiction. | Gas fitters install, maintain and repair gas mains, piping systems, and any appliances and ancillary equipment associated with the use of fuel gases, including liquefied petroleum gas systems. They also install gas appliances and any pressure regulating devices. | • They will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas)<br>• They will also need to know the chemical reactions that hydrogen has with steel and other materials to maintain containment, given that reactions contribute to pipeline embrittlement and crack propagation<br>• Consultation noted that fitters may need retraining to work with differences in the fundamental materials and larger sizing of pipes utilising hydrogen<br>• Knowledge of how electrical systems work would assist gas fitters in understanding the hydrogen appliances that may arrive in the market in the near future (e.g. LAVO appliances). |
| **Gas industry operator (ANZSCO Code: 334114)**<br><br>Note: We have also used this ANZSCO code for Gas Fitter (general & industrial) job roles. This role amalgamates a number of identified occupations, including gas distribution officer, gas transmission officer, mains layer, service layer, and pipe layer. | • *Certificate III in Gas Industry Supply Operations*<br>• Electrical Equipment in Hazardous Areas certification<br>• Confined space entry permit<br>• Relevant licence depending on state/territory jurisdiction. | Gas industry operators coordinate the distribution and transmission of gas by undertaking repair, maintenance and commissioning/decommissioning work on gas pipelines. They review components and materials to specifications and may seal cracks to repair pipelines. | • Gas industry operators will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas), as well as the faults that may arise from hydrogen's chemical reactions with steel (e.g. embrittlement and crack propagation)<br>• Given that hydrogen gas appliances occasionally interface with electrical systems, consultations noted that an awareness of both low and high voltage systems would be necessary as well. |
| **Heavy duty fitter (ANZSCO code: 323211)** | • *Certificate III in Heavy Commercial Vehicle Mechanical Technology*, *Certificate III in Mobile Plant Technology*, or *Certificate III in Engineering – Fixed or Mobile Plant Mechanic* with at least two years of on the job experience<br>• Experience with OEMs may be required<br>• Hazardous Area Certification may be required. | Heavy duty fitters fit and assemble metal parts and subassemblies to heavy vehicles and plant equipment (e.g. trucks, buses, some earthmoving equipment). They assemble these parts to form large pieces of equipment, fit them using precision measuring instruments, diagnose faults, and undertake operational maintenance of this equipment. In some workplaces, they may also be expected to service power generation units utilising hydrogen. | • Hydrogen fuel cell electric vehicles utilise compressed gas tanks of hydrogen to hold the fuel. Heavy duty fitters will need an understanding of high pressure gas vessels and how these systems work in order to operate safely around these vehicles<br>• An understanding of hydrogen's hazardous areas and potential ignition sources will be critical if the fitter undertakes any work with electrical equipment<br>• In consultation, hydrogen transport fuel operators noted fitters with previous experience working with hydraulic systems (e.g. experience working in the oil and gas industries) would be well suited in the transition to working with hydrogen. |

# Technicians and tradespersons: Augmentation analysis (4/5)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Light vehicle technician (ANZSCO Code: 321211)**<br><br>Note: We have also used this ANZSCO code for Automotive electric vehicle technician job roles | • *Certificate III in Light Vehicle Mechanical Technology* with at least two years of on the job experience<br>• Experience with OEMs may be required. | Light vehicle technicians maintain, test and repair engines and the mechanical parts of lightweight motor vehicles (e.g. commercial passenger cars, motorcycles), such as their transmission, suspension, steering and braking systems. They diagnose and repair mechanical and electrical faults in vehicles, undertake scheduled maintenance checks, and undertake some electronic testing of vehicle systems with the assistance of computers. | • Automotive light vehicle technicians will need a basic understanding of the operations and functions of proton exchange membrane fuel cells and the differences they present in comparison to vehicles with internal combustion engines<br>• They may generally need to develop problem-solving and analytical skills to diagnose some of the unique electrical faults that arise with fuel cells<br>• They will need to safely work with high voltage systems, including learning how to depower them so that any further repair or maintenance work can be undertaken. |
| **Heavy vehicle technician (ANZSCO Code: 321212)** | • *Certificate III in Heavy Commercial Vehicle Mechanical Technology*, *Certificate III in Mobile Plant Technology*, or *Certificate III in Engineering – Fixed or Mobile Plant Mechanic* with at least two years of on the job experience<br>• Experience with OEMs may be required. | Heavy vehicle technicians maintain, test and repair heavy vehicles and their mechanical systems, such as their transmission, suspension, steering and braking. Heavy vehicles include trucks, coaches and buses. Technicians diagnose and repair mechanical and electrical faults in vehicles, undertake scheduled maintenance checks, and undertake some electronic testing of vehicle systems with the assistance of computers. | • Heavy vehicle technicians will need a basic understanding of the operations and functions of proton exchange membrane fuel cells and the differences they present in comparison to vehicles with internal combustion engines<br>• They may generally need to develop problem-solving and analytical skills to diagnose some of the unique electrical faults that arise with fuel cells, and issues that may arise with built-for-purpose vehicle components (e.g. fuel connectors)<br>• They will need to safely work with high voltage systems, including learning how to depower them so that repairs or maintenance work can be undertaken<br>• Knowledge of cryogenics may be required as heavy vehicles may also require additional cooling systems. |
| **Process control technician (ANZSCO Code: 312412)** | • *Diploma of Instrumentation and Control Engineering* or a Bachelor's Degree in a related Engineering discipline or Information Systems<br>• Up to five years experience in related projects. | Process control technicians conduct tests of electronic systems, collect and analyse data and assemble circuitry. They may support electronics engineers in their work. They develop, construct, test and maintain electronic equipment on the site. | • They will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas), as these will affect their programming of control modules and how they moderate its chemical processes<br>• They will also need an understanding of the interchangeability of hydrogen with other gases in terms of its heating and calorific value, and what processes result in these transformations. |
| **Refuelling technician (ANZSCO Code: 399212)** | • *Certificate III in Gas Industry Supply Operations*<br>• Up to five years experience in related projects in gas or oil processing. | Refuelling technicians operate equipment to pump gas from storage tanks to gas vehicles. They set automated operating controls, inspect equipment for malfunctions and arrange for maintenance, and control records of production, including quantities transferred and other operational details. | • They will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas), as these will affect how they operate the control modules and components that moderate its chemical processes<br>• They will also need a recognition of the high pressure gas vessels that transport and hold hydrogen as well as the faults that may arise from hydrogen reactions with steel (e.g. embrittlement and crack propagation). |

# Technicians and tradespersons: Augmentation analysis (5/5)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Plumber (ANZSCO Code: 334111)** | • *Certificate III in Plumbing* alongside two years of the on-the-job experience<br>• Confined space entry permit<br>• Relevant licence depending on state/territory jurisdiction. | Plumbers install and repair water, drainage, gas and sewerage pipes and systems. They study blueprints and technical drawings to determine the layout of plumbing systems and the required materials and design of water supply systems and pipes, and install sewage and effluent pumping systems. | • Plumbers will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas), as well as the faults that may arise from hydrogen's chemical reactions with steel (e.g. embrittlement and crack propagation)<br>• Plumbers will also need familiarity with the different materials used in hydrogen piping, such as high-density polyethylene. |
| **Vehicle body repair technician (ANZSCO Code: 324111)** | • *Certificate III in Automotive Vehicle Body Repair Technology* with at least two years of on the job experience<br>• Experience with individual OEMs may be required. | Vehicle body repair technicians repair damage to motor vehicle bodies, fit and replace interior trim, and paint vehicles. Vehicle body repair technicians may also be expected to construct new purpose-built bodies for vehicles, and to use mechanical and hydraulic equipment in order to remove, replace and repair damaged panels and parts. | • Vehicle body repair technicians will need a basic understanding of the operations and functions of fuel cell powertrains and the different components they present compared to vehicles with internal combustion engines<br>• They will generally need to safely work with high voltage systems, including learning how to depower them so that repairs or maintenance work can be undertaken.<br>• They will also need to be familiar with gas systems and the work health and safety procedures required in their workshops to work around gases. |
| **Welder (ANZSCO Code: 322313)** | • *Certificate IV in ESI Generation Maintenance (Fabrication)* or *Certificate III in Engineering – Fabrication Trade*<br>• Electrical Equipment in Hazardous Areas certification<br>• Confined space entry permit<br>• Occupational health and safety white card. | Welders assemble, weld and repair pressure vessels and pipes to relevant standards. They shape and bend metal sections with machine and hand tools, cut metal sections and shapes with flame and machine tools, and finish products through cleaning with acidic solutions. | • They will need a basic understanding of hydrogen and its property risks (including its flammability, odour, appearance, and hazardous areas)<br>• They will also need to know the chemical reactions that hydrogen has with steel and other materials to maintain containment, given that reactions contribute to pipeline embrittlement and crack propagation. For this reason, welders will most likely be expected to work with materials such as stainless steel or high density polyurethane. |

# Specialists: Augmentation analysis (1/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Fuel cell fabrication and testing technician**<br><br>Note: No ANZSCO code is currently available for this job role. The best match is 312312 – Electrical Engineering Technician | • Bachelor's Degree or higher in Mechanical or Chemical Engineering, *Advanced Diploma of Manufacturing Technology* or *Advanced Diploma of Engineering*. | Hydrogen fuel cell fabrication and testing technicians specialise in the installation, operation and maintenance of fuel cells or their prototypes and the equipment used to test them. They test fuel cells for degradation and may fabricate the metal casing that is used to house the cell within the vehicle or plant. | • Fuel cell fabrication and testing technicians will need to understand the operations and functions of proton exchange membrane and alkaline fuel cells, the two most currently widespread fuel cells in the wider market, as well as their relative advantages and disadvantages. Alkaline fuel cells for instance, have lower operating temperatures and are quick to start-up, but are sensitive to carbon dioxide presence in fuel and air<br>• Fuel cell technicians will also need to understand the ongoing technological developments in rarer fuel cell types that are still being prototyped for different application, such as molten carbonate and solid oxide fuel cells. |
| **Integration specialist**<br><br>Note: No ANZSCO code is currently available for this job role. The best match is 233411 – Electronics Engineer | • Bachelor's Degree or higher in Information Systems or Electrical Engineering. | Integration specialists implement solutions which coordinate electronic systems within a project into a larger whole. They evaluate existing components or systems to determine integration requirements and ensure that the final solutions meet product or workplace needs. They also perform information technology system troubleshooting when needed. | • Integration specialists will need to understand how electrolysis functions as a hydrogen production method and what controls and instrumentation are needed to ensure electrolysers function effectively<br>• They will need familiarity with some of the non-electrical systems they may encounter in electrolysers, including high pressure gas systems and water treatment systems<br>• In mobility and materials handling contexts, they will need an understanding of fuel cell technologies (particularly proton exchange membrane and alkaline fuel cells) and how to combine them together within the other systems of a vehicle. |
| **Loading master (ANZSCO code: 5912)**<br><br>Note: No ANZSCO code is currently available for this job role. The best match is a 4-digit ANZSCO code 5912 – Transport and Despatch Clerks. The 6-digit ANZSCO codes were too specialised for this job role | • *Certificate III in Stevedoring*<br>• Relevant licence depending on state/territory jurisdiction. | Loading masters are logistics personnel who work on marine docks and supervise the handling and movement of gas and petroleum products from the terminal to a marine vessel while it is berthed. They organise the dispatch of the products and ensure there is no leakage or contamination into the environment. | • Loading masters will need to understand the basic chemical properties of hydrogen and how it differs from natural gas, most notably in its flammability and the higher pressures it is frequently transported in<br>• This will influence the material handling processes they have in place and they will need to educate all team members on hydrogen's hazardous areas and safety zones<br>• Loading masters will need familiarity with the various forms in which hydrogen can be stored, particularly liquefied hydrogen, which requires cryogenics and extremely low temperatures in order to maintain in a stable form. |

# Specialists: Augmentation analysis (2/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Power production plant operator (ANZSCO code: 399213)**<br><br>Note: We have also used this ANZSCO code for the Control Room Officer job role | • *Certificate III in ESI Generation – Operations*, including at least two years of on-the-job training<br>• At least three years post-trade experience in related projects. | Power production plant operators control boilers, turbo-generators and other associated plant equipment to generate electrical power. They operate plant controls to produce the required load, monitor operations and interpret instrument readings, and undertake authorised procedures to isolate low and high voltage electrical apparatus. | • Power production plant operators will need to understand the interchangeability of hydrogen with other gases (in this case natural gas) and the properties on which it differs, such as its calorific content<br>• They would also need knowledge of hydrogen storage techniques and the risks that come with handling it in its various forms, (e.g. its flammability and high compression when stored as a gas, and the need for low temperatures for storage when it is liquefied). |
| **Technical sales representative (ANZSCO code: 225499)** | • Bachelor's Degree or higher in Business Studies, Marketing or Commerce, or *Certificate III, IV and/or Diploma of Business*. | Technical sales representatives are company representatives who sell the company's goods or services to a range of other industrial and business entities. They market goods to their customers and maintain relationships by anticipating their clients' needs. They acquire knowledge of market conditions and competitor activities, and visit prospective client businesses to act on selling opportunities. | • Technical sales representatives will need to understand the basic chemical properties of hydrogen and be able to speak to the key safety considerations arising from its properties. These considerations could include its flammability, high pressure storage in industrial contexts, and environmental impact<br>• Depending on their company, they may need to demonstrate knowledge of the various production and storage methods available for hydrogen, such as how electrolysers function and the equipment required to store hydrogen as a gas. |
| **Water treatment plant operator (ANZSCO code: 712921)** | • *Certificate III in Plumbing* or *Certificate III in Water Industry Operations*<br>• Confined space entry permit<br>• Chlorine gas handling certification<br>• Working at heights certification. | Water treatment plant operators use plant equipment to store, distribute and treat water, including purification where a high quality is needed for electrolysers. They also maintain and calibrate field equipment (such as pH meters), and undertake testing of water samples for quality. | • Water treatment plant operators will need to understand the electrolysis process and how it produces hydrogen<br>• They will also need an understanding of the basic hydrogen property risks that come with working with hydrogen in its gaseous form, such as its high compression, flammability, and the potential for leakage in pipes and canisters<br>• Alongside this knowledge of hydrogen as a gas, their knowledge of high pressure gas systems generally may need to be augmented. |

# Safety and Quality Control: Augmentation analysis

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Gas inspector (ANZSCO code: 312999)** | • *Certificate III in Gas Supply Industry Operations* or higher<br>• *Diploma of Government Investigations* may be required in some regulatory positions<br>• At least three years of work experience may substitute for formal qualifications<br>• On-the-job training may also be required in addition to formal qualifications. | A gas inspector is responsible for assessing the safety of all gas appliances and ensuring the systems are working safely and properly. This may involve checking safety devices and their efficiencies, ensuring no harmful gases are leaking and appliances are set up properly. | • Knowledge of hydrogen properties, its risks and interactions with various materials will be expected skills to ensure safe hydrogen processes and that pipelines are in safe physical conditions<br>• In addition, gas inspectors will need to recognise the faults in vessels that may arise from hydrogen chemical reactions (e.g. crack propagation) and the impacts this may have from a safety perspective. |
| **Quality assurance technician (ANZSCO code: 139914)** | • *Diploma of Engineering* or *Diploma of Manufacturing Technology* or higher education degree in these areas<br>• *Certificate IV in Hazardous Areas – Electrical* in some industries<br>• At least five years of work experience may substitute for formal qualifications<br>• On-the-job training may also be required in addition to formal qualifications. | Quality assurance technicians are required to plan, organise, direct, control and coordinate the deployment of quality systems and certification processes within an organisation. These technicians may have specialist or technical expertise in a particular regulatory framework or industrial process that allows them to conduct audits and examinations of specific environmental factors or workplace tasks (e.g. certificates of origin, energy audits, sustainability checks, material purity tests etc.). | • Knowledge of hydrogen's property risks and interactions with various materials will be an expected skill, coupled with ensuring quality and environmental standards are met<br>• In addition, quality assurance technicians will need to have a sound knowledge of the various hydrogen production techniques such as electrolysis, steam methane reforming and compressed hydrogen so they can conduct tests to ensure quality. |
| **Work Health and Safety officer (ANZSCO code: 251312)** | • *Certificate IV in Work Health and Safety* or *Bachelor's Degree in Occupational Health & Safety* or higher<br>• Specialisations in Occupational Hygienist or Workplace Rehabilitation Officer<br>• On-the-job training may also be required in addition to formal qualifications. | Work, Health and Safety (WHS) officers are required to develop, implement and evaluate risk management policies and programs and train employees in WHS procedures. They also monitor and audit the workplace and record and investigate incidents to ensure safe and healthy working conditions. These officers may also have specialist or technical expertise in an industrial process that enables them to have oversight of particular safety systems and standards depending on the workplace (e.g. Electrical Inspectors overseeing high voltage systems), | • Knowledge of hydrogen properties, its risks, and interactions with various materials will be expected skills to ensure safe hydrogen processes are adhered to and employees are working in a safe environment<br>• In addition, WHS officers will need to have a sound knowledge of the various hydrogen production techniques such as electrolysis, steam methane reforming and compressed hydrogen so they can conduct and implement relevant risk management policies and procedures. |

# Management: Augmentation analysis (1/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Engineering manager (ANZSCO code: 133211)** | • Membership of Engineers Australia and registration as a Chartered Professional Engineer<br>• Bachelor's Degree or higher in the relevant discipline (e.g. Chemical Engineering)<br>• At least six years' work experience in related projects. | Engineering managers plan, organise, direct, control and coordinate the engineering and technical operations of organisations. They establish project schedules and budgets, and also ensure compliance with laws, regulations and safety standards. | • Engineering managers will need a base understanding of hydrogen's chemical properties and any property risks. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will also need to understand which materials may be selected for different hydrogen processes (e.g. stainless steel as a model for transporting hydrogen)<br>• Depending on previous experience, their skills in designing and interpreting plans for either power electronics or high pressure gas systems may need some augmentation to understand how they interact in hydrogen production plants<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |
| **Maintenance manager (ANZSCO code: 323211)** | • *Certificate IV* or higher in the relevant trade (e.g. Automotive Electrical Technology)<br>• At least 10 years' work experience in related projects. | Maintenance managers direct, coordinate and advise team members on the maintenance and repair activities required for plant/production machinery and other pieces of mechanical equipment. They ensure that all team members follow correct and safe procedures for the servicing and maintenance of equipment. | • Depending on previous experience, additional familiarity with hydrogen's property risks will be needed. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• Those working with hydrogen fuel cell vehicles will need an awareness of the high voltage systems within the vehicles and a basic understanding of how proton exchange membrane fuel cells operate<br>• In some cases, maintenance managers may also be expected to retrofit hydrogen sub-assemblies or components into a larger system<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |
| **Operations manager (ANZSCO code: 133512)** | • *Diploma of Production Management* or higher<br>• At least 10 years work experience in related projects. | Operations managers plan, organise, direct and coordinate the activities of an organisation, including its physical and human resources. They control plant operations through planning of operating hours and maintenance, and oversee the acquisition and installation of new plant equipment. | • Depending on previous experience, additional familiarity with hydrogen's property risks will be needed. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will also need a general understanding of the market trends that will affect the demand and supply of hydrogen in the long term, including the progress of new technologies, potential applications and use cases of new materials, and developments in Australia's regulatory framework that will affect how hydrogen is treated and handled<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |

# Management: Augmentation analysis (2/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Planner and scheduler (ANZSCO code: 591112)** | • *Certificate III in Gas Supply Industry Operations*<br>• Electrical Equipment in Hazardous Areas certification<br>• Confined space entry permit<br>• Relevant licence depending on state/territory jurisdiction. | Planners and schedulers arrange the release of oil or gas into pipeline systems within their network. They analyse the storage levels available and adjust distribution levels to meet demand, report on the gas flow and ensure that distribution occurs according to schedule. | • Planners and schedulers will need to understand the basic chemical properties of hydrogen and how it differs from natural gas, most notably in its flammability, heating, calorific value and the higher pressures it is frequently transported in<br>• In their logistical roles as schedulers, they will need an understanding of hydrogen and any associated waste products' interchangeability with other industries, such as oxygen or carbon, and how they can be supplied to chemical processing facilities. |
| **Relationship and community manager (ANZSCO code: 131114)** | • Bachelor's Degree or higher in Media and Communications, Marketing, Commerce or a related field<br>• At least five years work experience in the relevant industry. | Relationship and community managers plan, organise, direct, control and coordinate public relations and community outreach activities within an organisation. They direct development and implementation of strategies that build a company's public image and reputation with clients, investors, regulators and the wider public. | • Relationship and community managers will need to familiarise themselves with hydrogen's chemical properties if they are new to the industry. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will need to understand how the various hydrogen production and storage technologies function, and be able to explain their operations to government and regulatory groups (e.g. clarifying what emissions arise from operations, or how fuel cells differ from combustion engines)<br>• They will need an awareness of the changing market architecture of hydrogen and how regulation is being developed as this will shape consumer interactions with hydrogen technologies. |
| **Research and technology manager (ANZSCO code: 132511)** | • Bachelor's Degree or higher in an Engineering discipline or field of Science<br>• At least five years work experience in the relevant industry. | Research and technology managers plan, organise, direct, control and coordinate the research and development activities within an organisation. They lead major research operations and also monitor leading-edge developments in related disciplines to determine how they will impact the organisation. | • Research and technology managers will need to familiarise themselves with hydrogen's chemical properties if they are new to the industry. This includes developing an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will need to understand how the various hydrogen production and storage technologies function, and what chemical properties limit their various applications (e.g. molten carbonate fuel cells have a long start-up time that makes them suitable only in some contexts)<br>• They will need an awareness of the changing market architecture of hydrogen and how regulation is developing to shape consumer interactions with hydrogen technologies. |

# Logistics: Augmentation analysis (1/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Heavy vehicle operator (ANZSCO code: 7331)**<br><br>Note: No ANZSCO code is currently available for this job role. The best match is a 4-digit ANZSCO code 7331 – Truck Drivers, which encompasses multiple job roles holding the responsibilities described in this entry. | • Various Certificate III qualifications depending on field (e.g. *Certificate III in Surface Extraction Operations* or *Certificate III in Driving Operations*)<br>• Dangerous goods drivers' licence. | Heavy vehicle operators are logistics workers who handle and operate large vehicles needed to transport goods and materials between destinations. For instance, on mining sites where mineral extraction takes place, or in road freight applications where trucks are needed to carry goods. | • Heavy vehicle operators will need an understanding of fuel cell systems to enable the safe and proper handling of the vehicle<br>• They will need to understand factors that can cause a lack of hydrogen containment and prepare the proper evacuation and safety procedures in the event of a incident, such as a fire<br>• They may also need to recognise the signs of cracking or leakage in vessels storing hydrogen<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |
| **Marine master/operator (ANZSCO code: 231213)**<br><br>**Note: We have also used this ANZSCO code for the Marine engineer job role** | • A Master certificate of competency from the Australian Maritime Safety Authority<br>• Valid certificate of medical fitness as specified by the Australian Maritime Safety Authority<br>• Any other relevant international seafarer certificates. | Marine master/operators are those workers who control and manage the operations of a ship, which includes navigating a ship's course. They also control and direct shipping operations in order to ensure goods are shipped and transported safely. | • A familiarity with hydrogen's property risks is needed. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will also need to recognise the signs of cracking or leakage in vessels storing hydrogen in order to address containment issues<br>• In some cases where liquefied hydrogen is being transported, there needs to be an understanding of the cryogenics systems required to store these materials at the required low temperatures<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |
| **Plant machinery operator (ANZSCO code: 721211)** | • *Certificate III in Mobile Plant Technology* or a combination of relevant units of competency<br>• Relevant licence depending on state/territory jurisdiction. | Plant machinery operators are logistics workers who operate mobile plant machinery such as excavators, cranes and forklifts, often to physically move or shift materials between locations. They also monitor and report on the condition of the plant to ensure it is operating as intended. | • Plant machinery operators will need an understanding of fuel cell systems to enable the safe and proper handling of the vehicle<br>• They will need to understand factors that can cause a lack of hydrogen containment and prepare the proper evacuation and safety procedures in the event of an incident, such as a fire<br>• They may also need to recognise the signs of cracking or leakage in vessels storing hydrogen<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |

# Logistics: Augmentation analysis (2/2)

| Job role | Qualifications, memberships & workplace experiences | Base/current job role | Expected changes to job role from hydrogen activities (i.e. how the job role will be augmented) |
|---|---|---|---|
| **Stevedore (ANZSCO code: 891113)** | • *Certificate III in Stevedoring*<br>• Relevant licence depending on state/territory jurisdiction. | Stevedores are logistics workers who undertake the activities needed in marine terminals to secure and anchor a ship to transfer goods on and off the ship. | • A familiarity with hydrogen's property risks is needed. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• They will also need to recognise the signs of cracking or leakage in vessels storing hydrogen in order to address containment issues<br>• In some cases where liquefied hydrogen is being transported, there needs to be an understanding of the cryogenics systems required to store these materials at the required low temperatures<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |
| **Truck driver (ANZSCO code: 733111)**<br><br>**Note: It is assumed that this job role does not have any prior experience or skills required to work on a hydrogen project relative to their current job role.** | • *Certificate III in Driving Operations, Certificate IV in Specialist Driving Operations* or a higher-level qualification<br>• Dangerous goods drivers' licence. | Truck drivers can transport hydrogen in a compressed gaseous form in high pressure tubes between different locations. They will need certification to be a dangerous goods driver and will need to observe safety requirements when loading or unloading their vehicles. | • A familiarity with hydrogen's property risks is needed. This includes an understanding of hydrogen's lack of odour and invisibility when ignited, as well as its flammability<br>• Truck drivers will also need to have general awareness of the high pressure gas systems that pipes hydrogen<br>• They will also need to recognise the signs of cracking or leakage in transported tubes to address containment issues<br>• Safety considerations such as knowledge of hazardous areas and safety zones is paramount. |


E

# Detailed training pathways analysis

# VET: Hydrogen pathways matrix (1/3)

**Analysis of the National Register of VET (training.gov.au) was undertaken to identify whether hydrogen-specific capabilities are already catered for within the training system. The table below identifies where each capability is referenced or addressed within a training product.**

| Hydrogen capability | Units of Competency (UoCs) | Skill Sets | Qualifications |
|---|---|---|---|
| **Understanding hydrogen properties** | *UEGNSG901 Apply safety practices, procedures, and compliance standards for handling hydrogen gas* includes parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge Evidence section. | *UEGSS00013 Basic Hydrogen Safety Skill Set* includes parts of this capability but gaps still exist. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG20121 Certificate II in Gas Supply Industry Operations* & *UEG30121 Certificate III in Gas Supply Industry Operations*. |
| **Calibrating, testing and maintaining hydrogen equipment** | *UEGNSG903 Fault find and repair hydrogen storage equipment* includes this capability in the Performance Evidence section. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG30121 Certificate III in Gas Supply Industry Operations* & *UEG40221 Certificate IV in Gas Supply Industry Operations*. |
| **Handling cryogenic materials** | Several Chemical, Hydrocarbons and Refining (PMA) units (*PMAOPS341* & *PMAOPS343*) include parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge Evidence section. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, four qualifications in the *PMA* training package include relevant UoCs in the electives. |
| **Identifying and managing hydrogen hazardous areas (safety & risk)** | *UEGNSG901 Apply safety practices, procedures, and compliance standards for handling hydrogen gas* includes this capability in the Performance Evidence section. | *UEGSS00013 Basic Hydrogen Safety Skill Set* includes parts of this capability but gaps still exist. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG20121 Certificate II in Gas Supply Industry Operations* & *UEG30121 Certificate III in Gas Supply Industry Operations*. |
| **Understanding hydrogen market trends and drivers** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Knowledge of high pressure gas systems and vessels** | Several Gas industry (UEG) units (*UEGNSG313* & *UEGNSG904*) include this capability in the Performance and Knowledge Evidence sections. | *UEGSS00014 Inject Hydrogen into Distribution Networks Skill Set* includes parts of this capability but gaps still exist. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG30121 Certificate III in Gas Supply Industry Operations* & *UEG40221 Certificate IV in Gas Supply Industry Operations*. |
| **Fuel cells – operating and maintaining fuel cells** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Fuel cell – diagnosing and replacing fuel cells** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Reading and interpreting technical drawings with hydrogen equipment** | *UEGNSG229 Prepare simple drawings of as laid gas mains and services* includes parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge and Performance Evidence sections. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG30121 Certificate III in Gas Supply Industry Operations* & *UEG40221 Certificate IV in Gas Supply Industry Operations*. |

# VET: Hydrogen pathways matrix (2/3)

**Analysis of the National Register of VET (training.gov.au) was undertaken to identify whether hydrogen-specific capabilities are already catered for within the training system. The table below identifies where each capability is referenced or addressed within a training product.**

| Hydrogen capability | Units of Competency (UoCs) | Skill Sets | Qualifications |
|---|---|---|---|
| **Producing hydrogen – understanding of cooling systems** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Hydrogen production techniques – SMR (steam methane reforming)** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Hydrogen production techniques – Coal gasification** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Hydrogen storage techniques – compressed hydrogen** | Several units of competency (*UEGNSG906, UEPOPS318* & *PMAOPS240*) include parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge and Performance Evidence sections. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, ten qualifications in the *PMA, UEG* & *UEP* training packages include relevant UoCs in the electives. |
| **Hydrogen storage techniques – liquid hydrogen** | Several units of competency *(UEGNSG906* & *PMAOPS240*) include parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge and Performance Evidence sections. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, ten qualifications in the *PMA* & *UEG* training packages include relevant UoCs in the electives. |
| **Hydrogen storage techniques – conversion to hydrogen carriers** | Several units of competency *(UEGNSG906, UEPOPS318* & *PMAOPS343*) include parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge and Performance Evidence sections. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, 11 qualifications in the *PMA, UEG* & *UEP* training packages include relevant UoCs in the electives. |
| **Hydrogen production techniques – electrolysis, biofuels, photolysis** | *UEGNSG902 Commission, operate and maintain electrolysers* includes parts of this capability but gaps still exist. Relevant parts of this capability are built into the Knowledge Evidence section. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, a number of qualifications include relevant UoCs in the electives. E.g. *UEG30121 Certificate III in Gas Supply Industry Operations* & *UEG40221 Certificate IV in Gas Supply Industry Operations*. |
| **Knowledge of conversion requirements for gases and their interchangeability** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Knowledge of hydrogen embrittlement** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |

# VET: Hydrogen pathways matrix (3/3)

**Analysis of the National Register of VET (training.gov.au) was undertaken to identify whether hydrogen-specific capabilities are already catered for within the training system. The table below identifies where each capability is referenced or addressed within a training product.**

| Hydrogen capability | Units of Competency (UoCs) | Skill Sets | Qualifications |
|---|---|---|---|
| **Oversight of control modules for hydrogen processes** | *UEGNSG905 Monitor and control hydrogen in gas distribution networks* includes this capability in the Performance Evidence section. | *UEGSS00015 Monitor Hydrogen using Control Systems Skill Set* includes this capability. | There are no qualifications that specifically address this capability, however, *UEG30121 Certificate III in Gas Supply Industry Operations* includes relevant UoCs in the electives. |
| **Inspect, maintain and modify hydrogen vehicles** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Knowledge of power electronics** | Several units of competency *(UETTDRSB25* & *UEPOPS512*) include parts of this capability. Relevant parts of this capability are built into the Knowledge Evidence section. | No skill sets identified touch on this capability. | There are no qualifications that specifically address this capability, however, one qualification has relevant content in the core and four qualifications in the *UEP* & *UET* training packages include relevant UoCs in the electives. |
| **Managing hydrogen logistical movement across a supply chain** | Several units of competency *(TLIX0015X, TLIX0021X* & *TLIX0034X*) include parts of this capability. Relevant parts of this capability are built into the Knowledge and Performance Evidence sections. | *TLISS00195 Manage Supply Chains Skill Set* & *TLISS00192 Global Supply Chain Operations Skill Set* include this capability. | There are no qualifications that specifically address this capability, however, five qualifications in the *TLI* training package include relevant UoCs in the electives. |
| **Recognition of hydrogen and waste product interchangeability in other industries** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Integrating hydrogen equipment from various OEMs into a process** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Understanding of co-firing in natural gas and hydrogen fuelled gas turbines** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |
| **Communicating the risks, benefits and safety considerations of hydrogen** | No UoCs identified touch on this capability. | No skill sets identified touch on this capability. | No qualifications identified touch on this capability. |


# F

# Stakeholder list

# Stakeholder register (1/5)

**The below provides an overview of the stakeholders that were engaged in consultations to inform this report.**

| Name | Organisation | Role | Location | Stakeholder type |
|---|---|---|---|---|
| Aaron Smith | H2 Energy | Founding Director | Western Australia, Australia | Industry |
| Adrian Panow | University of Melbourne | Director Major Projects | Victoria, Australia | Education and Training |
| Ana Goelden | TUV SUD | International Business Development Manager | Munich, Germany | Industry |
| Andrew Dicks | Griffith University | Adjunct Principal Research Fellow | Queensland, Australia | Education and Training |
| Dr Anita Talberg | Clean Energy Council | Director, Workforce Development | Victoria, Australia | Peak Body/Industry Association |
| Anna Freeman | Clean Energy Council | Policy Director | Victoria, Australia | Peak Body/Industry Association |
| Anthony O'Brien | CNH Industrial and IVECO Trucks | Director | Victoria, Australia | Industry |
| Behnoud Tahmaseby | Chevron | Skills and Training Developer | Queensland, Australia | Industry |
| Billy Chan | BOC Limited | Senior Engineer | New South Wales, Australia | Industry |
| Brian Inglis | Inglis Consulting | CEO | Queensland, Australia | Industry |
| Chris Briggs | University of Technology Sydney | Research Director | New South Wales, Australia | Education and Training |
| Chris Dolman | BOC Limited | Business Development Manager | New South Wales, Australia | Industry |
| Chris Lamb | Zinfra | Delivery Manager | Australian Capital Territory, Australia | Industry |
| Chris Rouse | Coregas | Senior Engineering Manager | New South Wales, Australia | Industry |
| David Morgan | Artibus Innovation | - | Tasmania, Australia | IRC/SSO Working Group Member & Education and Training |
| David Norman | Future Fuels CRC | CEO | Victoria, Australia | Peak Body/Industry Association |
| Dr Neil Thompson | ITM Power | Managing Director | Queensland, Australia | Industry |
| Dr Orana Sandri | Royal Melbourne Institute of Technology | Senior Research Fellow | Victoria, Australia | Education and Training |
| Elizabeth Gibson | Construction Material Processors Association | Extractive IRC – Member | Victoria, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Erin Richards | BOC Limited (South Pacific) | Quality Change Lead | New Zealand | Industry |
| Filippa Ross | Department of Employment, Small Business and Training | Industry Engagement Team | Queensland, Australia | Government |

# Stakeholder register (2/5)

**The below provides an overview of the stakeholders that were engaged in consultations to inform this report.**

| Name | Organisation | Role | Location | Stakeholder type |
|---|---|---|---|---|
| Fiona Mitchell-Corbett | Gexcon Australia | Team Lead and Principal Engineer | Western Australia, Australia | Industry |
| Dr Fiona Simon | Australian Hydrogen Council | CEO | Victoria, Australia | Peak Body/Industry Association |
| Frank De Pasquale | Air Liquide Australia | Business Unit Manager – CO2 & H2 | Victoria, Australia | Industry |
| Frank Hobson | Ricochet Yachting | Director | Queensland, Australia | Industry |
| Gareth Phillips | AMPTO | CEO | Queensland, Australia | Peak Body/Industry Association |
| Geirmund Vislie | Gexcon | Vice President Hydrogen Safety | Norway | Industry |
| Geoff Gwilym | VACC | Strategic Automotive IRC – Chair | Victoria, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Greg Mitchell | TAFE Qld | Institute Director (Mt Isa campus) | Queensland, Australia | Education and Training |
| Herman Ng | Office of Industrial Relations | Senior Advisor (Hazardous Chemicals) | Queensland, Australia | Government |
| Jacques Markgraaff | LAVO | Chief Operating Officer | New South Wales, Australia | Industry |
| Jakes Jacobs | Energy Skills Queensland | Industry Skills Advisor – Energy | Queensland, Australia | Government |
| James Scotland | Ai Group | - | Queensland, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Jan Hempel | TUV SUD | Project Manager | Berlin, Germany | Industry |
| Jason Millford | GPA Engineering | Principal Process Engineer | Victoria, Australia | Industry |
| Jodie Badcock | Resources and Engineering Skills Alliance | Metalliferous IRC – Chair<br>Coal Mining IRC – Member<br>Drilling IRC – Member | Adelaide, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| John Khoury | VACC | Industry Policy Advisor | Victoria, Australia | Peak Body/Industry Association |
| Kate Morrison | National Skills Commission | Director, Skills Policy and Intelligence | Australian Capital Territory, Australia | Government |
| Keith Monaghan | Keith Monaghan Consulting | Process Manufacturing, Recreational Vehicle and Laboratory IRC – Member | New South Wales, Australia | IRC/SSO Working Group Member & Industry |
| Kellie Hall | BOC Limited | Key Customer Executive | Queensland, Australia | Industry |
| Ken Gardner | Master Plumbers | Construction, Plumbing and Services IRC – Member | Victoria, Australia | IRC/SSO Working Group Member & Industry |
| Kerrin Pryor | Swinburne University | Project Manager | Victoria, Australia | Education and Training |

# Stakeholder register (3/5)

**The below provides an overview of the stakeholders that were engaged in consultations to inform this report.**

| Name | Organisation | Role | Location | Stakeholder type |
|---|---|---|---|---|
| Kevin Boyle | Zinfra | Principal Mechanical Engineer | New South Wales, Australia | Industry |
| Larry Moore | NECA | Electrotechnology IRC – Chair | Adelaide, Australia | IRC/SSO Working Group Member & Industry |
| Leigh Kennedy | NERA | National Cluster Development Manager | Victoria, Australia | Peak Body/Industry Association |
| Loren Tuck | Hycel Hub – Deakin University | Education, Training and Industry Coordinator, Hycel Technology Hub | Victoria, Australia | Education and Training |
| Luc Kox | Hazer Group Limited | Commercial Manager | Western Australia, Australia | Industry |
| Luke Miller | Transtegic | Managing Director | Tasmania, Australia | Industry |
| Lynette Day | South Australian Department for Energy and Mining | Manager Strategic Projects, Energy and Technical Regulation | South Australia, Australia | Government |
| Mark Burgess | Electrical Trades Union | Electrotechnology IRC – Member | Victoria, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Mark Kirby | Canadian Hydrogen and Fuel Cell Association | President and CEO | Canada | Peak Body/Industry Association |
| Mark McKenzie | Australasian Convenience and Petroleum Marketers Association | Transport and Logistics IRC – Member | New South Wales, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Mark Shaddock | IBSA | - | New South Wales, Australia | IRC/SSO Working Group Member & Education and Training |
| Martin Hablutzel | Siemens Energy | Business Unit Manager Transmission Solutions and Hydrogen | Victoria, Australia | Industry |
| Michael Broomhead | ATCO, Gas Division | Gas IRC – Member | Western Australia, Australia | IRC/SSO Working Group Member & Industry |
| Michael Magelakis | SSMI Group | Business Services IRC – Member | Victoria, Australia | IRC/SSO Working Group Member & Industry |
| Michael Pereira | Deakin University | Lecturer | Victoria, Australia | Education and Training |
| Nancy Norton | Resources Safety and Health Queensland | Senior Inspector | Queensland, Australia | Government |
| Nathan Tukuafu | Thiess | Manager | Queensland, Australia | IRC/SSO Working Group Member & Industry |
| Neil Thompson | ITM Power | Managing Director | Queensland, Australia | Industry |
| Nicholas Wing | Department of Employment, Small Business and Training | Industry Engagement Team | Queensland, Australia | Government |
| Nick Sutton | Brunel Energy Australia | General Manager | Western Australia, Australia | Industry |

# Stakeholder register (4/5)

**The below provides an overview of the stakeholders that were engaged in consultations to inform this report.**

| Name | Organisation | Role | Location | Stakeholder type |
|---|---|---|---|---|
| Nigel Haywood | Australian Minerals and Energy Skills Alliance | General Manager, Strategy and Engagement | Western Australia, Australia | Peak Body/Industry Association |
| Paolo Damante | Ai Group | Education IRC – Member | Victoria, Australia | IRC/SSO Working Group Member & Industry Association |
| Peter Eastment | Department of Employment, Small Business and Training | Industry Engagement Team | Queensland, Australia | Government |
| Rebecca Yee | GPA Engineering | Senior Project Engineer | Northern Territory, Australia | Industry |
| Rebekah Jensen | Department of Employment, Small Business and Training | Industry Engagement Team | Queensland, Australia | Government |
| Rob Langridge | Federal Chamber of Automotive Industries | Director, Emerging Technologies | New South Wales, Australia | Peak Body/Industry Association |
| Rob McHenry | Deakin University | Lecturer | Victoria, Australia | Education and Training |
| Rob Nyhuis | Swagelok | Training Manager | Victoria, Australia | Education and Training |
| Robert Edwards | H2 Networks | Director | Australian Capital Territory, Australia | Peak Body/Industry Association |
| Romesh Rodrigo | Daimler Truck and Bus Australia | Senior Manager | Victoria, Australia | Industry |
| Roz Chivers | Bus Industry Confederation | Executive Director | Australia Capital Territory, Australia | Peak Body/Industry Association |
| Scott Sharbanee | Enscope Pty Ltd | Technical Manager – Energy Systems | Western Australia, Australia | Industry |
| Scott Walsh | Sun Metals | Training Advisor | Queensland, Australia | Industry |
| Shane Lewis | Hydroheat Supplies | Chief Commercial Officer | Victoria, Australia | Industry |
| Shane Roulstone | AWU | Agriculture and Production Horticulture IRC – Member | New South Wales, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Shaun Thomas | Australian Industry Standards | - | Victoria, Australia | IRC/SSO Working Group Member & Education and Training |
| Shayne Le Combre | Plumbing Industry Climate Action Centre | CEO | Victoria, Australia | Peak Body/Industry Association |
| Simon Coburn | Hyzon Motors Australia | Head of Special Projects | Victoria, Australia | Industry |
| Simon White | Downer | Supervisor | Victoria, Australia | Industry |
| Simone Pettorino | Gexcon Australia | General Manager | Western Australia, Australia | Industry |
| Stacey Ozolins | Office of Industrial Relations | Acting Director, Network and Supply | Queensland, Australia | Government |
| Stephen Lucas | Warrnambool Bus Lines | Managing Director | Victoria, Australia | Industry |
| Stephen McGrail | Future Fuels CRC | Research and Education Program Coordinator | Victoria, Australia | Peak Body/Industry Association |

# Stakeholder register (5/5)

**The below provides an overview of the stakeholders that were engaged in consultations to inform this report.**

| Name | Organisation | Role | Location | Stakeholder type |
|---|---|---|---|---|
| Stephen Watts | Construction, Forestry, Maritime, Mining and Energy Union | Coal Mining IRC – Member | Queensland, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Steve Moon | Association of Marine Park Tourism Operators | Maritime IRC – Member | Queensland, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |
| Tania Urmee | Murdoch University | Associate Professor, Discipline of Engineering and Energy | Western Australia, Australia | Education and Training |
| Trent Humphrys | H2 Hauler | Director and COO | Queensland, Australia | Industry |
| Tyson Cooney | H2 Hauler | Co-Founder | Queensland, Australia | Industry |
| Vera Piotrovskaya | Brunel Energy Australia | National Business Manager | Australia | Industry |
| Victoria Munro | H2X Global | Manager – Hydrogen and Advanced Development | Victoria, Australia | Industry |
| Wayne Lee | Ai Group | Industry Skills Advisor – Manufacturing | Queensland, Australia | Peak Body/Industry Association |
| Yvonne Webb | ISACNT | Culture and Related Industries IRC – Chair | Northern Territory, Australia | IRC/SSO Working Group Member & Peak Body/Industry Association |


G

# Approach to using the ANZSCO taxonomy

# Approach to identifying and mapping job roles

**To ensure that 'like' job roles were considered, the ANZSCO taxonomy was adopted to identify a common level of job role. For the purposes of this report, job roles have primarily been detailed at ANZSCO Level 1 – Occupation level (six-digit codes)**

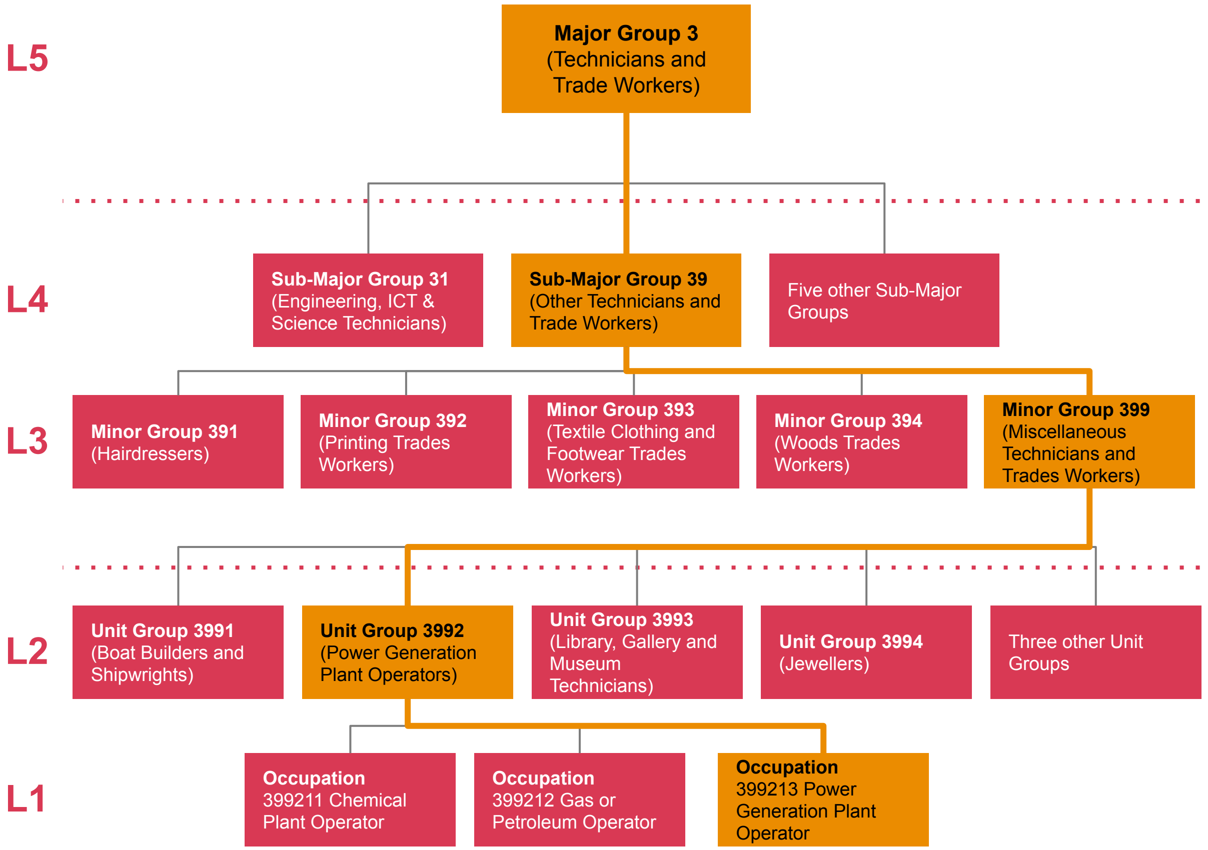
The example on the right illustrates how the ANZSCO taxonomy works. The taxonomy begins at the highest level (L) with the broadest aggregate of skilled workers in an economy, before narrowing down into progressively specialised groups that share distinct underlying skills and knowledge. There are five levels to the ANZSCO taxonomy:

- L5 is the Major Group of Technicians and Trade Workers in all sectors broadly. This level is the broadest grouping of workers on specialisation and skill level.
- L4 and L3 break this Major Group down into Sub-Major and Minor Groups, with increasingly specific areas of specialisation and subdivision (e.g. Other and Miscellaneous Technicians).
- L2 and L1 are the most specific area of detailed skill specialisation and application. The entries at these levels include individual paying job roles in the market (e.g. Power Generation Plant Operator), and the assumed educational qualifications and skills required to execute these roles.

**For this report, we have sought to map all identified job roles to an L1 tier (six digit code), with the sole exception of heavy vehicle operators and loading masters which are mapped at an L2 (four digit code).** This approach has been adopted to ensure a consistent approach to identifying job roles and a common framework for stakeholders interpreting the outputs of the report.

It is noted, however, that in this report there are several occasions where multiple job roles have been mapped to the same ANZSCO code. While conformance to the current ANZSCO taxonomy was sought in identifying job roles, stakeholders advised us that some occupations were not reflected in the taxonomy. In these cases, the underlying skills and tasks were examined and they have been mapped to the 'best match' in the taxonomy.

**Figure 31. Example mapping of the Power Generation Plant Operator job role to the ANZSCO taxonomy**

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