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Mapping the current and forecasted hydrogen skills landscape

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1 Executive summary

Scotland has committed to achieving net zero emissions of all greenhouse gases by 2045. The use of hydrogen as an energy carrier is one of the emerging technologies that is expected to support the reduction in emissions in sectors traditionally reliant on fossil fuels. In 2022, through the Hydrogen Action Plan, Scotland announced its ambition to become a leading producer and exporter of hydrogen, particularly green hydrogen, which is produced using electricity from renewable sources. The plan defines ambitions of 5GW of installed hydrogen production capacity by 2030 and 25GW by 2045.

A skilled workforce is at the core of any process industry. To enable rapid acceleration of an emerging hydrogen economy, it is important to understand what skills are required in the hydrogen value chain. This study focuses on skills requirements for the upstream part of the supply chain, which includes hydrogen production facility installation, commissioning and operations, as well as storage, transportation and export. End-user sectors (i.e. those who would use the hydrogen) were excluded from this study. Methods included literature and online reviews, and stakeholder interviews across the industry, skills providers and other relevant organisations.

1.1. Aims

The aim of this study was to provide a comprehensive understanding of the current and forecasted jobs and skills demands in the hydrogen economy as assuming it meets the ambitions defined by the Hydrogen Action Plan. Key objectives of the research were: to define the scope of the sector and the scale of the opportunity for Scotland as a result of growth in the hydrogen economy; assess current and future skills demand within the sector; and identify key skills requirements and issues.

1.2. Findings

Our research produced several important findings regarding the upstream hydrogen value chain and its contribution to the economy. These can be summarised as follows:

- Hydrogen has potential to be a valuable part of the Scottish economy. Sector growth models to deliver the hydrogen production capacity ambitions specified in the Scottish Hydrogen Action Plan predict that the upstream hydrogen economy will have an estimated cumulative turnover of £7.6bn by 2030 and £22.9bn between 2031 and 2035. This translates to cumulative gross value added (GVA) figures of £3.9bn over the period to 2030 and £11.9bn from 2030 to 2035.
- A large number of new jobs will be created in the hydrogen economy as it grows. Direct annual employment will be, on average, 6614 (full-time equivalent) over the 2025-2030 period and an average of 18,535 in 2030-2035.
- The people we interviewed as part of this study predict that the skills to enable the hydrogen economy are not fundamentally different from the skills required in other process industries. Therefore, we suggest that the hydrogen economy will increase the demand on the existing skilled workforce rather than create job roles that have not been used in process industries before. The demand for science, technology, engineering, mathematics and digital and data science skills will be high across the energy sector as a whole, as well as other related sectors. The majority of the skills required will be at college and graduate levels. This highlights that a talent shortage is a key concern for the hydrogen economy.
- A skilled and experienced technical workforce will be required in different areas of Scotland, including rural and remote areas such as the islands. Larger hydrogen hubs could be located closer to the key export sites and end users, such as cities (Aberdeen) or energy-intensive process sites (Grangemouth). Stakeholders agree that steps should be taken to ensure the early pilot projects in the rural and remote regions are adequately supplied with technical talent because these sites provide crucial learning experiences for the rest of the future hydrogen economy. The geographical location of skilled workers and skills provision will be a lesser concern when hydrogen production scales up because, in stakeholder experience from the oil and gas sector, the skilled workforce is mobile.

1.3. Recommendations

Based on the work carried out in this study we recommend that the Scottish Government examines the following options for action:

- Work with skills provision bodies, industry and further education institutions to design and specify relevant hydrogen-specific courses. This process should include representatives from industry, education and the public sector that are committed to delivering the required changes to skills provision. It should set out a series of short (1-2 years) and medium-term (2-5 years) actions.
- Skills development provision should be available at a regional level to support the expected development of several regional hydrogen hubs.
- The concept of 'skills passports', which the Offshore Petroleum Industry Training Organisation (OPITO) is pursuing in the energy sector, should be considered in sectors relevant to hydrogen, such as the chemical and process industries, to facilitate the mobility of individuals.
- Strategies to promote the hydrogen sector and attract new entrants could be developed and implemented. These should highlight the net zero and sustainability credentials of the hydrogen sector and be designed for primary, secondary, further

and higher education students, as well as individuals already in the workforce. These should clearly illustrate the potential career pathways for individuals, recognising that younger members of the workforce, in particular, are far more mobile.

- More research should be carried out to understand the demand and provision of skilled STEM workers across future energy, transport and industry sectors.

Contents

2 Glossary / abbreviations

AU$ Australian dollars

BEIS UK Department of Business, Energy and Industrial Strategy (now known as the Department for Energy Security and Net Zero)

bn Billion

CESAP Climate Emergency Skills Action Plan

CO_2 Carbon Dioxide

EMEC European Marine Energy Centre

ESP Energy Skills Partnership

EU European Union

FEED Front-end engineering design

FTE Full Time Equivalent

GVA Gross Value Added

GW GigaWatt, a unit of power

H_2 Hydrogen

HSE Health and Safety Executive

IFPEN Institut Français du Pétrole & Energies Nouvelles

INTOG Innovation and Targeted Oil & Gas

LOHC Liquid organic hydrogen carriers

MISP Michelin Scotland Innovation Parc

MW MegaWatt, a unit of power

NESA National Energy Skills Accelerator

NSTD North Sea Transition Deal

OPITO Offshore Petroleum Industry Training Organisation

R&D Research and Development

SQCF Scottish Credit and Qualifications Framework

STEM Science, technology, engineering and mathematics

T-skills A set of skilled worker competencies where the worker has deep expertise in one technical vocation and a broad base of supporting knowledge and skills

TWh TeraWatt hour, a unit of energy

UHI University of Highlands and Islands

UK United Kingdom

3 Introduction

3.1 Background

Hydrogen has a long history of use in industrial applications, such as ammonia and methanol production, oil refining and in the food industries. In the transition to net zero, hydrogen is predicted to have several new applications and be a key energy technology. It is expected to enable countries worldwide to mitigate the global climate emergency by reducing their over-reliance on fossil fuels, with forecasts that hydrogen will represent 20-35% of total energy consumption in 2050 (UK Government 2021). Hydrogen is a versatile energy carrier that can address the intermittency of renewable energy generation. It can also help decarbonise sectors whose energy needs cannot be efficiently addressed by other approaches, such as increased electrification.

Hydrogen is routinely produced for many industrial applications. However, insufficient volumes of hydrogen are produced for it also to be used as an energy carrier. Current production is consumed in other applications. Additionally, almost all hydrogen is currently produced using non-renewable feedstocks, typically natural gas, with significant carbon emissions. This does not align with global net zero strategies. However, it is possible to remove some of these emissions using carbon capture and storage technologies. Hydrogen produced in this way is described as 'blue' or low-carbon hydrogen.

Hydrogen can also be produced from water using electrolysis. Electricity is used to break the chemical bonds between oxygen and hydrogen. When this process is carried out using renewable electricity, the hydrogen is referred to as 'green' or renewable hydrogen. Companies worldwide are developing large-scale electrolysis facilities that will provide enough hydrogen to enable its widespread and effective use as an energy carrier (Hydrogen Projects database, no date).

Water electrolysis at this scale has not been carried out before. It will require a significant number of skilled workers to design, install, commission and operate such production facilities. There will also be a need for individuals with hydrogen transport, storage and export capabilities and competencies. Data-informed skills strategies are required to support skills providers, the next generation of skilled workers, and experienced workers, as well as to identify how existing skillsets can be adapted to support this transition to a hydrogen economy.

3.2 Purpose of this study

In 2022, the Scottish Government published its Hydrogen Action Plan outlining hydrogen production capacity ambitions of 5GW by 2030 and 25GW by 2045. The 2045 ambition, presented in the Scottish Hydrogen Assessment as the 'Green Export Scenario', aims to establish Scotland as one of Europe's leading hydrogen producers and exporters (Scottish Government 2020). A skilled workforce will play a crucial part in enabling this scale of activity. However, the identification of skills that will be required in the upstream hydrogen supply chain (i.e. production, transportation, and storage) is in its early stages. It is, therefore, critical that any skills gaps within the workforce are identified, so that skills providers and policymakers can develop actionable strategies to close these gaps and support Scotland's hydrogen economy aspirations.

This study aims to investigate the skills needs for the emerging hydrogen economy in Scotland, based on the Hydrogen Action Plan's ambitions to establish 5GW of hydrogen production capacity by 2030 and 25GW by 2045.

The objectives were to:

- Estimate the size and growth of the Scottish hydrogen economy from 2023 to 2035.
- Use these models to estimate the number of skilled workers in the upstream hydrogen value chain.
- Analyse skills gaps in the next decade.
- Identify geographical locations with potential skills requirements.

The report concludes with common themes highlighted by stakeholder consultations and a list of recommendations for future research.

The methodology used in this study is detailed in Appendix 1.

4 Hydrogen economy and skills strategies

This section summarises global trends in the hydrogen sector and details skills development assessments and initiatives in the two regions with the most mature activities: Europe and Australia. In the UK, energy and utility skills were identified as leaders in hydrogen skills development.

4.1 Global sector trends

According to the hydrogen industry knowledge sharing resource CSIRO HyResource, more than 50 national and regional hydrogen strategies have been announced as of March 2023. The 2022 Hydrogen Council report identifies almost 700 large-scale hydrogen production projects worldwide, with 530 planned to be partially or fully commissioned by 2030. However, around 170 of these projects are currently at a feasibility or front-end engineering design (FEED) stage, and only 10% of all hydrogen projects have reached a final investment decision (Mckinsey and Company, 2022). It has been highlighted by the Hydrogen Council that whilst the increase in early-stage development projects has exceeded forecasts, the progression of hydrogen production projects from feasibility and FEED stages to final investment decision, construction, and operation is slower than predicted (European Commission 2020).

4.2 Skills strategy development

An understanding of the skills needs for the future hydrogen economy is evolving rapidly. At the broadest level, many policies mention skills as a critical part of sector development, including the Climate Emergency Skills Action Plan 2020-2025 (Skills Development Scotland, 2020) and the North Sea Transition Deal (NSTD) (Department for Business, Energy and Industrial Strategy and Offshore Energies, 2022)

Several forecasts are available that estimate the number of skilled jobs that will be created in the energy sector, as a whole. For example, the NSTD Integrated People and Skills strategy predicts that a total of 211,250 jobs will be created in the offshore energy sector by 2030.

Despite these developments, the level of understanding of the types of skills, skills gaps and new and emerging job roles is relatively low. In 2021, the UK Green Jobs Task Force Report highlighted that science, technology, engineering and mathematics (STEM), as well as data and digital skills, will underpin all jobs in the delivery of net zero (including hydrogen) (UK Government, 2021). The International Energy Agency also recently provided a summary of hydrogen skills activity in the UK (IEA, 2022). However, detailed skills needs and gaps are hard to define because renewable and low carbon hydrogen have never been produced at a very large scale.

Consequently, the strategies for the delivery of these skills are currently fragmented. Several initiatives in the UK and globally are seeking to provide a unified direction to hydrogen skills strategy development, thus aiming to ensure a consistently high quality of skills provision.

4.3 Skills strategy development – Europe

The EU hydrogen strategy and the subsequent REPowerEU plan, developed to reduce the EU's dependence on Russian fossil fuels, outline the ambition to produce 10 million tonnes per annum of renewable hydrogen and to import a further 10 million tonnes per annum by 2030 (European Commission, 2020; 2022). This emerging economy is supported by the European Clean Energy Alliance. This includes over 840 projects across the hydrogen value chain with almost 450 projects focused on production. It is estimated that this scale of activity will require 1 million skilled jobs by 2030, rising to 5.4 million by 2050 (Green Skills for Hydrogen EU, no date).

The skills strategy for Europe is currently in development. It is led by the European Hydrogen Skills Alliance, which launched a high-level, hydrogen awareness masterclass for policymakers and innovation advisors in February 2023 (ibid).

Presently, graduate and postgraduate programmes remain the key providers of hydrogen skills to the industry. For example:

- Germany launched a dedicated graduate programme for hydrogen, named ‘Trustworthy Hydrogen’ (Science Business, 2022)
- The engineering graduate programme of the Institut Français du Pétrole & Energies Nouvelles (IFPEN) has integrated hydrogen skills into existing programmes. It also provides short modules with a focus on fuel cell modelling, salt cavity storage, hydrogen energy system modelling and lifecycle analyses (European Commission, 2021).

HySkills, funded by Erasmus+ and launched in 2020, is an important Europe-wide project to deliver technical and practical knowledge in hydrogen. The project is currently focusing on defining learning outcomes and units that will be most relevant to the hydrogen workforce, in preparation for the development of training courses to European Qualifications Framework Level 5. This will be followed by a ‘train the trainer’ programme. In parallel, HySkills will develop a guidance document on course accreditation and other toolkits for hydrogen skills delivery across the EU. The project has five partners: Dublin City University (Ireland), South West College (UK), the Arctic University of Norway, the European Institute for Innovation – Technology (Germany), and the Hellenic Society for the Promotion of Research and Development Methodologies (Greece).

HySkills highlighted that skills shortages are already evident across most engineering and manufacturing sectors, and the emerging hydrogen sector is at risk of a skilled worker shortage (European Commission 2021). Therefore, the need for a data-informed, agile and industrially relevant skills development strategy is universal throughout the hydrogen value chain. At the time of publication, this HySkills report found that companies with hydrogen skills needs generally upskill their workers via internal training and various short courses. These are predominantly focused on the regulatory and safety aspects of hydrogen. Less than 20% of companies relied on graduate-level courses to upskill their staff. One of the report's recommendations is that skills programmes should be co-created by industry and training providers to ensure their content is relevant. This collaborative approach is expected to enable the delivery of so-called 'T-skills'. These are a set of skilled worker competencies where the worker has deep expertise in one technical vocation (provided by the industrial counterpart) and a broad base of supporting knowledge and skills (typically enabled by training providers).

4.4 Skills strategy development - Australia

The Australian hydrogen economy strategy was announced in 2019. Since then hydrogen investment has reached AU$ 127bn across 119 industrial-scale projects (Australian Government, 2021; HyResource, no date). Of these projects, 22 are operational or under construction. The existing strategy is strongly focused on export to neighbouring economies that have publicly announced hydrogen import targets, such as South Korea, Japan, and China. Further, Australian federated states have all communicated regional hydrogen strategies. New South Wales, however, is the only state that has announced a hydrogen production target: 700MW electrolyser capacity and 110,000 tonnes of annual renewable hydrogen production by 2030 (NSW Department of Planning, Industry and Environment, 2021).

'Developing Australia's Hydrogen Workforce', published in 2022 is one of the most comprehensive publicly available national-level hydrogen skills gap studies (PWC, 2022). It focuses on the required workforce for three hydrogen production scenarios (23, 101 and 189 TWh). It highlights that most jobs in the hydrogen economy will be technician, tradesperson and engineering roles.

A key finding of this report is that the hydrogen economy will produce a significant number of jobs. This demand, however, will be focused on existing job roles, and there is no expectation that the hydrogen economy will demand new job roles, based on new capabilities, which have not been seen in the industry before. The report asserts that most will be based on existing job roles with minor levels of augmentation and upskilling. This report features a detailed 'augmentation analysis' predicting how much existing skilled jobs will change to accommodate hydrogen activities.

A significant limitation of this study is that the forecasts excluded job roles required for the construction of hydrogen production facilities or various secondary and support roles within the sector.

Australian researchers have also identified that hydrogen skills will need to be assessed in the context of increasing demand in the broader energy sector, including wind and solar energy generation (Rutovitz et al, 2022).

5 The current scale of the Scottish hydrogen economy

5.1 Ongoing activity

Scotland is actively developing its hydrogen economy project pipeline with over 60 projects outlined in the Hydrogen Action Plan. A significant number of previous and current projects are focused on end-user applications, including Aberdeen Bus Fleet, HyLaddie and Eden Mill (the Green Distilleries project) and HyFlyer hydrogen-electric powered aircraft. Also, the Hydrogen Accelerator, a collaboration between the University of Strathclyde and the University of St Andrews, established in 2020, has led the development of the Zero Emission Train Project and several heavy fleet vehicle decarbonisation projects. Numerous smaller projects are looking at hydrogen production and its integration into remote and off-grid communities, including the Pure Energy Centre and ReFLEX Orkney.

Upstream, the hydrogen production project pipeline maturity varies across low carbon hydrogen and electrolytic production projects. The Acorn low carbon hydrogen production project is considered the most well developed and, dependent on positive announcement from the UK government on the Scottish Cluster, is expected to reach the final investment decision by mid-2023 (House of Commons Scottish Affairs Committee, 2022). Most large-scale electrolytic hydrogen production projects are at concept or early design stages. These include Hy2Go, a site that has obtained planning permission in the central belt; and the Vattenfall HT1 project in the North East that is seeking to develop the world's first integrated hydrogen production site with an offshore wind turbine.

Gas transmission projects are also under development. These prioritise low-carbon hydrogen and hydrogen-natural gas blending. SGN's Aberdeen Vision project plans to develop a dedicated hydrogen pipeline from St Fergus to Aberdeen for blending into the gas network. Other SGN hydrogen transmission projects include a local hydrogen transmission trial (Grangemouth to Granton), and H100 Fife that will use electrolytic hydrogen for domestic heating. Other companies, such as Eneus Energy and the Floating Wind Company, have expressed their interest in the production of green ammonia and synthetic fuels from green and blue hydrogen.[1]

Overall, most Scottish hydrogen projects, several of which are expected to lead to large scale projects, are at early design, feasibility or FEED stages. In addition, several successful small-scale demonstrator sites have been established that illustrate the potential of hydrogen uptake in various end user sectors. It is important, therefore, that the pipeline of hydrogen production projects continues to mature and reach final investment decisions.

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[1] For more information about the projects mentioned in this section, please visit:
https://www.hydrock.com/projects/hy2go-south-lanarkshire
https://group.vattenfall.com/uk/what-we-do/our-projects/european-offshore-wind-deployment-centre/aberdeen-hydrogen
https://www.sgn.co.uk/H100Fife
https://www.eneusenergy.com/technology/
https://www.floatingpowerplant.com/power-to-x-projects/
https://www.sgn.co.uk/sites/default/files/media-entities/documents/2020-11/SGN-Aberdeen-Vision-Project_Final-Report_0520.pdf
https://www.sgn.co.uk/news/sgn-deliver-ps299m-national-strategic-hydrogen-transmission-and-storage-project
https://h2-accelerator.org/.

5.2 Scottish hydrogen value chain

A simplified hydrogen value chain is presented in Figure 1 and a more detailed version included in Appendix 2. By searching relevant directories including Scottish Industries Directory – Green Hydrogen, the One North Sea database (Net Zero Technology Centre) and the Scottish Hydrogen and Fuel Cell Association's Member Directory, and verifying with searching of published information, we identified 133 companies with a presence in Scotland, that have demonstrated commercial interest in one or more aspects of the hydrogen value chain. 44 of these companies are in support functions (including 12 universities and four colleges with identifiable hydrogen-related activities). It is important to note that each education institution can host a number of campuses, research centres, individual research groups, academics, training courses and modules, each of which could be interpreted as an individual value chain element. In addition, it is unknown how many skills providers include hydrogen skills as an integrated element in their existing courses such as chemical engineering. Therefore, more research is required to define an integrated Scottish hydrogen education value chain.

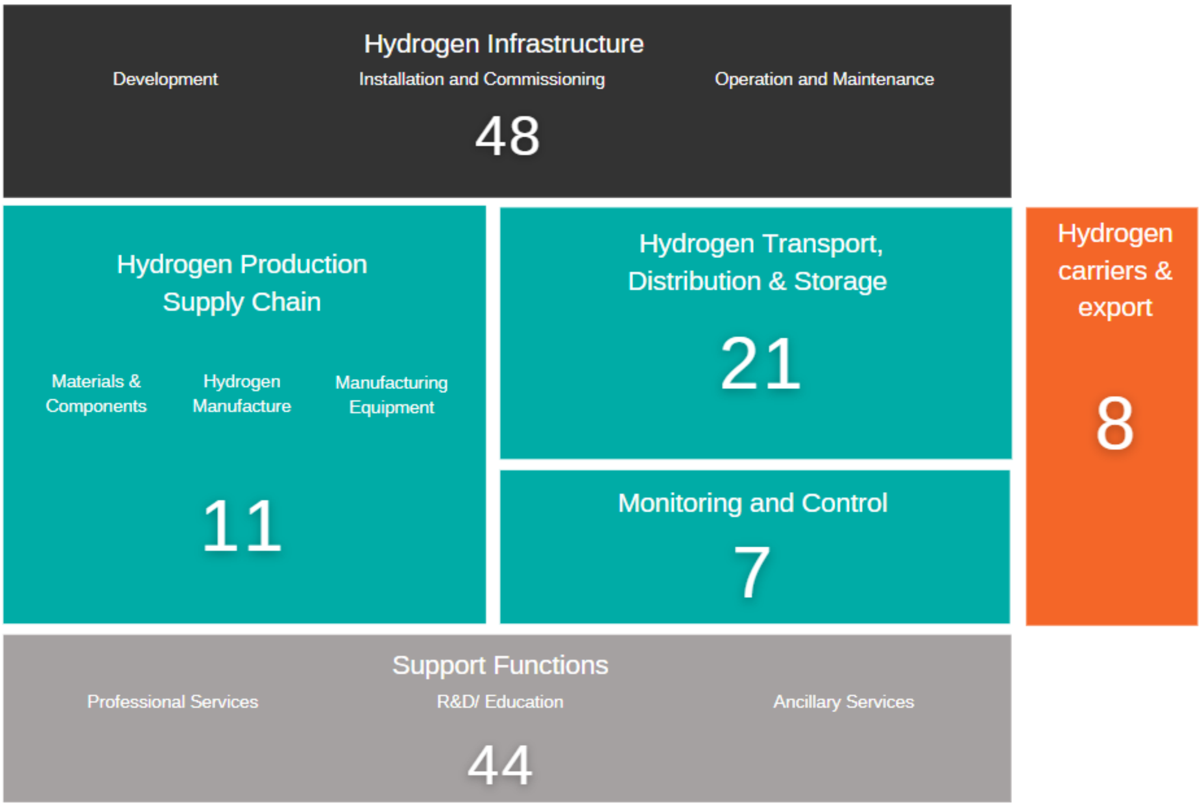

Figure 1: Scottish hydrogen value chain

Notes:

- The numbers denote the number of companies.
- In some instances, a company represents more than one value chain element. The model contains 133 individual companies.

Scotland's heritage in the oil and gas industry is recognised as a considerable enabler of the hydrogen economy. This is due to the presence of large, world-leading industrial energy players, as well as a highly skilled and experienced energy sector workforce. There are several established companies that are diversifying their service offering to include hydrogen-related activity, and several new players that have entered the sector. These developments are building the foundations of an innovation-driven and internationally competitive hydrogen economy in Scotland.

The most strongly represented aspect of the current Scottish hydrogen value chain is within the development, installation and maintenance of hydrogen infrastructure. This is considered to be a direct legacy of expertise from the oil & gas industry. Most engineering consultancy companies in that sector have extended their service offering(s) to include the development of hydrogen facilities. Stakeholder consultations revealed that most major companies have assembled their hydrogen teams from in-house expertise, further highlighting the transferability of skills across energy sectors.

6 Current and future economic activity of the hydrogen value chain

6.1 Economic activity

Most hydrogen-related companies in Scotland are established multinationals with multiple service offerings across the energy sector. As such, it was not possible to determine the percentage of their economic activity that relates to hydrogen. We identified 17 companies that focus exclusively on hydrogen but only three of them show business activity of over £1M per annum. This further suggests that hydrogen activity in the commercial environment is embryonic in nature, even though there are a number of large-scale projects at an early stage of development.

We, therefore, used the specified ambitions of 5GW by 2030 and 25GW by 2045 in the Scottish Hydrogen Action Plan and modelled the associated activities that would enable industry to achieve these ambitions. There is significant uncertainty regarding the locations of future hydrogen production and the exact amounts of hydrogen that will be transported, stored, and exported, so we made research-informed assumptions to broadly describe activities surrounding each element of the simplified hydrogen value chain. In this analysis we only considered those elements with a presence in Scotland. For example, our analysis excludes the impact of electrolyser manufacturing as this capability is currently not present in Scotland. The model is supported by data from the Scottish Hydrogen Assessment (Scottish Government, 2020). It also includes assumptions regarding hydrogen production plant capacities and the number required, land pipeline length, amount of hydrogen that will require transport and long-term storage, and the expected methods for hydrogen exports.

We estimate that total expenditure in the hydrogen economy will reach £7.6 bn by 2030 to meet Scottish Hydrogen Action Plan ambitions (see Figure 2, below) (Scottish Government, 2022a). By this date industry will be beginning to rapidly scale-up its hydrogen production capacity. Thereafter, total expenditure will be £22.9 bn between 2031 and 2035. Stakeholders expect very high levels of standardisation within operations and plants, as well as a high degree of automation, which will significantly reduce the operational costs of hydrogen production and storage. However, the costs of facility design, installation, and commissioning remain high.

In line with assumptions from BEIS Hydrogen Production Costs (2021), we calculated the capital and operational expenditure of seasonal storage of hydrogen assuming 1TWh storage capacity in 2030 and 2TWh in 2035 (BEIS, 2021a). This is based on current UK models that assume that the most likely mass hydrogen storage solution will be in salt caverns. As these caverns are in England, alternative strategies are likely to be required in Scotland, but details of these are not yet available. It is also likely that some hydrogen will be stored as methanol and ammonia, in liquid organic hydrogen carriers (LOHC) and as synthetic fuels. These latter solutions, however, are expected to be used in export activities, rather than in seasonal hydrogen storage strategies, where other alternatives such as line-packing or repurposing of legacy oil and gas infrastructure may be considered.

Further, in alignment with the Green Export Scenario in the Scottish hydrogen assessment, we have included estimates for hydrogen exports (Scottish Government, 2020). According to forecasts from the International Renewable Energy Agency, in the period to 2035 the most likely form of hydrogen for export from Scotland to Europe (roughly 1,000km distance) will be using LOHC or repurposed pipelines (IRENA, 2022). In this study, we assumed that LOHC will be the preferred form of hydrogen export due to the activity of the Hydrogen Transport from Scotland (LHyTS) project that seeks to ship LOHC from Aberdeen to Rotterdam (ERM, 2022). After 2035, bespoke hydrogen pipelines are expected to become the preferred way to export hydrogen to mainland Europe, through purpose-built North Sea pipelines such as those being explored by Aquaductus. Therefore, we have modelled pipeline construction CAPEX in 2035.

In this model, export represents over half of all hydrogen economic activity, representing a very high-value opportunity.

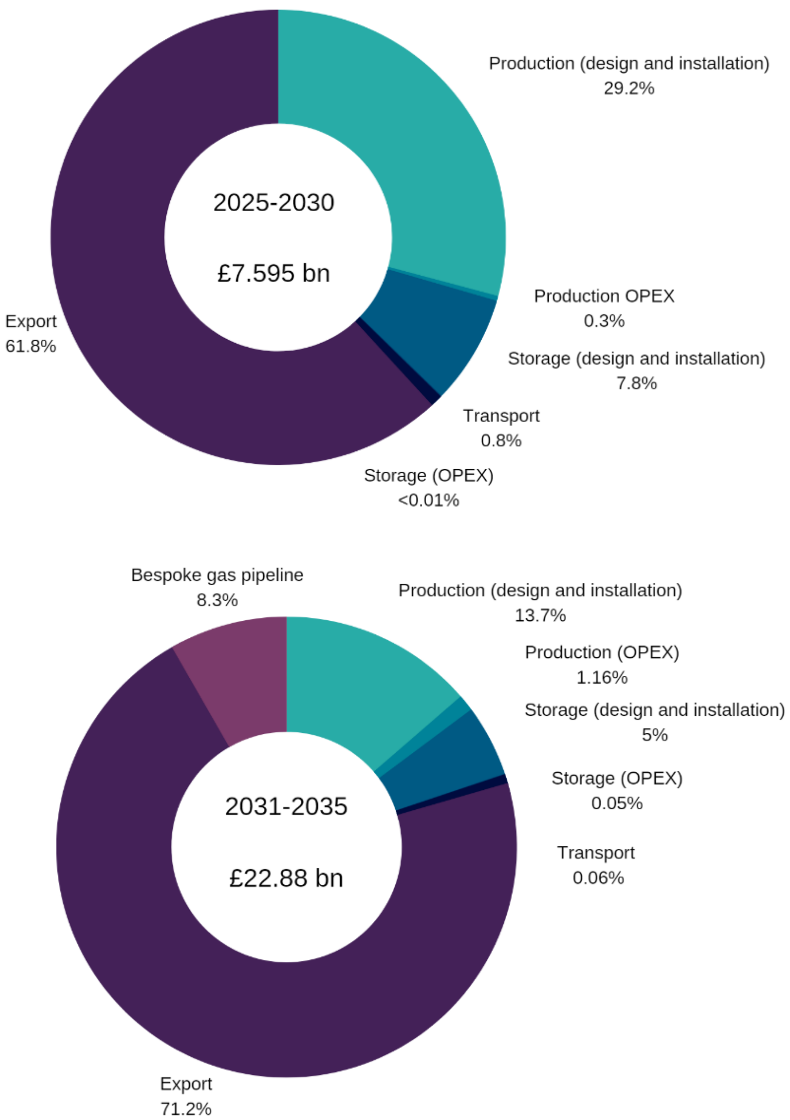

Figure 2: Estimated size of the hydrogen economy (expenditure) in 2030 and 2035

6.2 Hydrogen economy jobs

We used appropriate sectoral data in the Scottish Annual Business Statistics, to calculate employment and GVA figures for each segment of the hydrogen supply chain over the period to 2035. Some supply chain segments (e.g., design, installation and commissioning of hydrogen production plant) were based on achieving specific capacity ambitions, so the calculated employment and GVA figures are averaged over a five-year period (Scottish Government, 2022b).

Our model shows that over the 2025 to 2030 period, the Scottish hydrogen economy will require an average of 6,614 skilled jobs per annum (Figure 3). Most jobs will be dedicated to hydrogen production facility design, installation and commissioning and will involve around 40% (2,677) of all hydrogen economy jobs. It should be noted that these figures do not include the installation and commissioning of renewable electricity facilities that will provide energy to run the electrolysers, as this is beyond the scope of the current study. Operation of hydrogen production facilities, as well as transport will create a minor fraction of jobs (1-2% each). This is in line with the expectation that production will occur at decentralised sites geographically close to end users.

A similar number (39%, 2,560) of jobs will be created in the hydrogen export sector. The export value chain is likely to involve numerous activities, from liquid organic hydrogen carrier production (via hydrogenation), transport and loading of LOHC onto ships and dehydrogenation of LOHC by the importer. Due to the international nature of export, a portion of these jobs will be realised abroad. Therefore, we have excluded capital expenditure of LOHC (de)hydrogenation facilities to avoid allocating jobs from importer countries into the calculations that estimate Scottish jobs.

The third largest area by employment are activities responsible for hydrogen storage (18%, 1,169). This will include activities such as gas compression, pipeline design and installation, design and construction of storage facilities, wellheads, subsurface structures and drilling equipment. These activities are likely to build on the outcomes of projects such as HYSECURE (UK) and HyPSTER (France) that are currently at the construction stage[2].

Hydrogen economy employment in the 2030 to 2035 period will increase to an average of 18,535 jobs per annum. This includes an almost quadruple increase in export-related activities (49% of all hydrogen economy jobs) in a scenario where LOHC remain the preferred medium (Figure 3). Similarly, the number of jobs in hydrogen production operations will increase by a factor of three, as an increasing number of sites are commissioned. Due to automation, these sites will have low staff numbers and thus production operations represent approximately 1% of hydrogen economy jobs. It is expected that around 2035, a purpose-built hydrogen pipeline will be established creating a significant number of jobs in construction and installation (21%, 3,854). This could occur via projects such as Project Union (UK Hydrogen Backbone) or extensions towards AquaDuctus (National Grid, 2021). Hydrogen transport will create a further 296 jobs (2%).

[2] For more information about HYSECURE and HyPSTER, please visit:
https://www.storengy.de/sites/default/files/mediateque/pdf/2021-11/HySecure%20EN.pdf
https://hypster-project.eu/

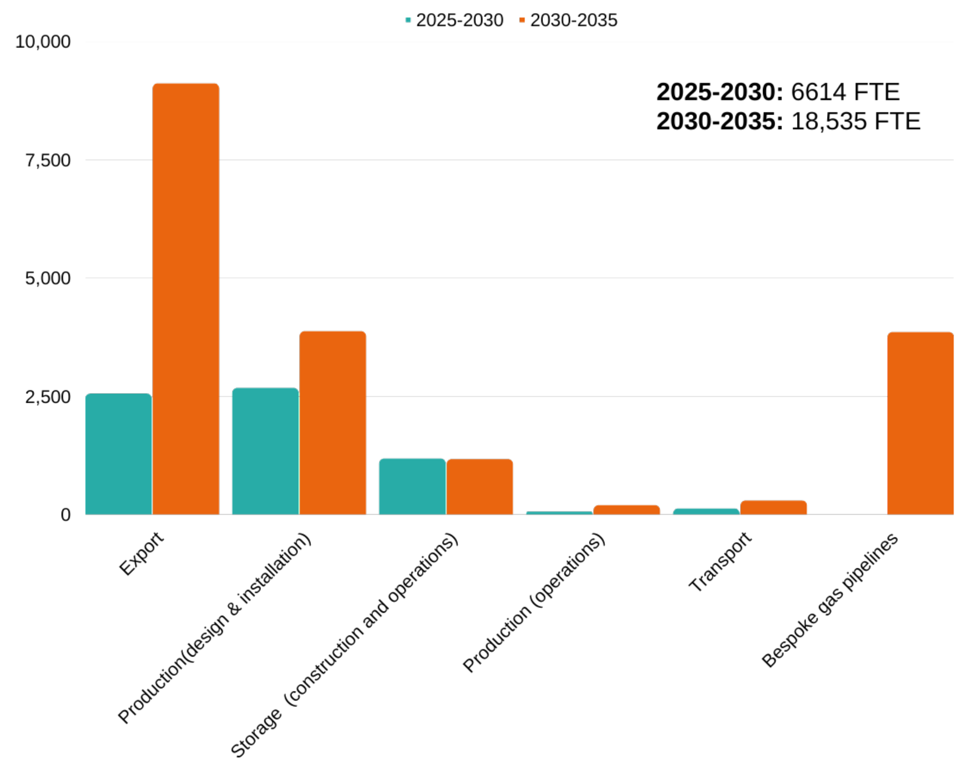

Figure 3: The average number of hydrogen economy jobs per annum in 2025-2030 and 2030-2035.

We note that our predictions are broadly comparable to those of the North Sea Transition Deal's 'Integrated People and Skills Strategy' that estimates between 13,500 and 29,250 direct and indirect hydrogen jobs in the UK in 2030 (North sea Transition Deal, 2022).

7 Hydrogen skills in Scotland

7.1 Hydrogen industry skills demand and current provision

The hydrogen economy is in the early stages of feasibility and engineering design - described as a 'nascent industry' by some stakeholders. As such, specialist hydrogen skills are either transferred from other process industries, particularly the oil and gas sector, or acquired in postgraduate research. Hydrogen technology research is carried out at most Scottish universities and several other institutions, including the National Manufacturing Institute Scotland (within their Manufacturing Skills Academy), the National Subsea Centre and the Net Zero Technology Centre.

Several awareness-level courses have already been launched to introduce the concept of hydrogen to the energy industry. At college level, for example, the 'Hydrogen Awareness' Course and 'Hydrogen for Transport' course have been developed by the Energy Skills Partnership. The Offshore Petroleum Industry Training Organisation (OPITO) has developed an entry-level 'Introduction to Hydrogen' course for technical apprentices that contains 80 guided learning hours across eight modules. This course is a part of the All Energy Apprenticeship programme that further includes introductory level modules on wind power, carbon capture, usage and storage, and oil and gas. These introductory level courses are the beginning of hydrogen skills delivery at college and graduate levels. However, stakeholders state that the awareness level courses are not designed to enable people to work hands-on with hydrogen.

Several organisations include hydrogen skills as a part of the wider energy transition theme. For example, in 2021, the National Energy Skills Accelerator (NESA) was founded in Aberdeen as a collaborative initiative between the Robert Gordon University, the University of Aberdeen and North East Scotland College. NESA has signed a Hydrogen Skills Partnership Memorandum of Understanding with Scottish Power and IMT Power (National Energy Skills Accelerator, 2022). This collaboration aims to understand the skills need and develop strategies for skills delivery across energy sector transition themes.

The University of Highlands and Islands (UHI), Outer Hebrides hosts a part-time course 'Hydrogen: An Introduction for Technicians'. This course is at the Scottish Credit and Qualifications Framework (SCQF) Level 7 professional development award. It is aimed at upskilling and reskilling existing technicians. The modules in this course include safe hydrogen gas handling; operating principles of an electrolytic hydrogen facility; and design principles of a hydrogen system. Currently, it is the only hydrogen-focused nationally recognised qualification in Scotland.

Other centres are in development, for example the PowerHouse project (hosted by the University of Highlands and Islands) that is a part of North of Scotland Hydrogen Programme. PowerHouse will be a centre focused on research and development, education and continuous skills development in the green hydrogen and floating wind sectors. The geographical location of this site will greatly support rural and remote region needs for skilled hydrogen workforce.

Hands-on technical skills will be critical for the development of hydrogen economy in Scotland. Four Scottish colleges (Edinburgh, Fife, North East Scotland College and Dundee & Angus) deliver online learning content focused on fuel cells in motor vehicles. In addition, the Energy Skills Partnership (ESP), with support from Transport Scotland, plans to install fuel cell trainer equipment at Michelin Scotland Innovation Parc (MSIP). MSIP has announced a bespoke Skills Academy focusing on sustainable mobility and decarbonisation, including hydrogen[3].

Overall, hydrogen skills provision is making rapid progress, but hands-on skills provision is generally at the planning or early trial stage. It is likely that other skills provision includes hydrogen as a discussion topic, however the details of hydrogen skills integration into the existing curricula are unknown and should be investigated further.

Stakeholders agreed that a nationwide hands-on hydrogen skills training needs to commence soon.

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[3] For more information on the courses mentioned in this section, please visit:
https://esp-scotland.ac.uk/hydrogen-resources/
https://opito.com/standards-and-qualifications/global-qualifications/global-qualifications-library/introduction-to-hydrogen
https://www.msipskillsacademy.com/future-focussed/
https://www.uhi.ac.uk/en/courses/ pda-hydrogen-an-introduction-for-technicians-scqf-level-7/#tabanchor
https://opportunitycromartyfirth.co.uk/powerhouse/
https://www.lucas-nuelle.com/1004/pid/33216/apg/17801/Course:-Fuel-cells-in-motor-vehicles.htm
https://esp-scotland.ac.uk/energy-transition/

As part of this study, we sought to elucidate what skills and job roles will be in demand as the industry evolves.

In consultation with stakeholders, we developed a matrix that broadly outlines skills needs in individual supply chain segments and identifies the current skills base that supports these sectors (Figure 4). A timeline of industry maturation was considered to predict the points of increased skills demand. For example, the matrix indicates that the development of hydrogen infrastructure currently has a low skills demand, and it is served by a skills base from the existing engineering consultancy sector. This observation was supported by stakeholder feedback that most hydrogen teams in large engineering consultancies are composed of internal staff with experience in other energy sectors (predominantly oil and gas). However, industry expects a rapid acceleration within the next five years and therefore the demand for these skills will rapidly increase. In addition, the need for data and digital skills within the identified job roles will rapidly increase to facilitate, for example, remote monitoring of hydrogen production, metering, and other automated processes.

Current skills needs are low in most hydrogen supply segments and can be covered by skills transfer from other industries and the R&D knowledge base. The expectation is that demand will begin to grow in the medium term and rapidly accelerate thereafter.

A key message from stakeholder consultations is that aligning industry maturation time with talent pipeline development will be critical for development of the hydrogen economy. Some skills transfer from relevant industries will occur and this will be able to facilitate the early steps in the development of most supply chain segments. However, the hydrogen industry will be unable to recruit the number of workers required to scale up from the existing workforce. Accessing new skilled talent is, therefore, essential.

Stakeholders estimate that the talent pipeline will take approximately three to five years to fill. Therefore, for the delivery of the 5GW installed production capacity ambition in 2030, a strategy for hands-on hydrogen skills delivery needs to be fully established in the next two to three years. Central to this is development of knowledge and capabilities within educators / skills providers, i.e. ‘training the trainers’. This has been identified as a key short-term priority.

Supply Chain Segment	Existing Source(s) of Relevant Skills	Key Development Areas	Level of Future Demand			Comment
			Short Term (0-5 Years)	Medium Term (5 - 10 Years)	Long Term (Over 10 Years)	
Development of Hydrogen Infrastructure	Engineering Consultancy Sector	Specific hydrogen issues, especially safety				Already commenced with high growth expected
Installation and Commissioning of Hydrogen Infrastructure	Oil&Gas and Process Plant Sectors	Specific hydrogen issues, especially safety				Will follow infrastructure development with a lag of 2 - 3 years
Operation and Maintenance of Hydrogen Infrastructure	Oil&Gas and Process Plant Sectors	Specific hydrogen issues, especially safety				Will follow installation and commissioning with a lag of 2 - 3 years
Green Hydrogen Production	Water Electrolysis at Scale is a New Process	Understanding the electrolysis process				Growth dependent on offshore wind generation
Blue Hydrogen Production	Existing Hydrogen Production	Linking with carbon capture				Will be overtaken by green hydrogen production
CO_2 Capture	Early Examples of Post Combustion CO_2 Capture	Understanding the carbon capture process				Directly linked to blue hydrogen production
Compressors and Liquifiers	Process Industry Sectors	Specific hydrogen issues, especially safety				Directly linked to hydrogen production capacilty
Monitoring and Control	Process Industry Sectors	Specific hydrogen issues, especially safety				Directly linked to hydrogen production, storage and transport capacilty
Pipeline Transport	Gas Transmission Sector	Materials and processes that ensure integrity of systems				Dependent on regional supply and demand and export strategy
Bulk Storage	Small Scale Examples / Gas Sector	Materials and processes that ensure integrity of systems				Dependent on regional supply and demand and export strategy
H_2 Carriers	Chemical Sector	Use of innovative carriers				Dependent on regional supply and demand and export strategy
Fuelling Facilities	Small Scale Examples in Transport Sector	Materials and processes that ensure integrity of systems				Directly linked to hydrogen production, storage and transport capacilty

Key:
- Strong
- Moderate
- Weak

Key:
- **Negligible**
- Low
- Medium
- High

Figure 4: Skills needs in the hydrogen value chain

This matrix considers the timeline of skills demand increase and the industries where existing job roles means that suitably skilled workers in the workforce.

Notes:

1. Existing source of relevant skills: the strong, moderate or weak rankings are based on an assessment of the same (or similar) skills needs in other sectors. It identifies where these skills are available but does not reflect on the number of skilled individuals within these sectors.
2. Level of future demand: the rankings here are based on our interpretation of when, and how quickly, the different parts of the hydrogen supply chain will develop over the short, medium and long term.

Our research and consultations revealed that the hydrogen economy is predicted to have a significant requirement for skilled workers (a large number of jobs), however it is not expected that these will be in new job roles that the industry has not seen before. Instead, an expansion in existing job role descriptions is forecasted.

Stakeholder's estimated that there will be a 90% transferability of skills from related sectors and that hydrogen skills development is necessary to address the other 10%. For example, one stakeholder commented: "I am not convinced that the types of skills are materially different for hydrogen manufacture, transport and storage versus those already around today in the oil and gas industry".

This is consistent with the work carried out in Australia, as summarised in Section 3, above. Therefore, existing skills provision and the workforce in existing skilled jobs already have the capabilities to address the vast majority of the needs of the hydrogen sector.

Digital, data and metaskills (such as self-management and innovation), as highlighted in the CESAP, are considered very important for development of the hydrogen sector (Skills Development Scotland, 2020). The concerns expressed regarding access to such expertise in other sectors means that this is likely to be a significant issue for hydrogen (Optimat, 2021).

Similar to stakeholder experiences in other process industries, engineering graduates are predicted to become the most highly sought-after skilled workers as the hydrogen economy grows. A selection of hydrogen production job roles that are expected to be in high demand, at different stages of industry maturity, is presented in Figure 5. This is based on analysis of the expected composition of hydrogen supply chains and their core activities, published information and evidence from stakeholder consultations.

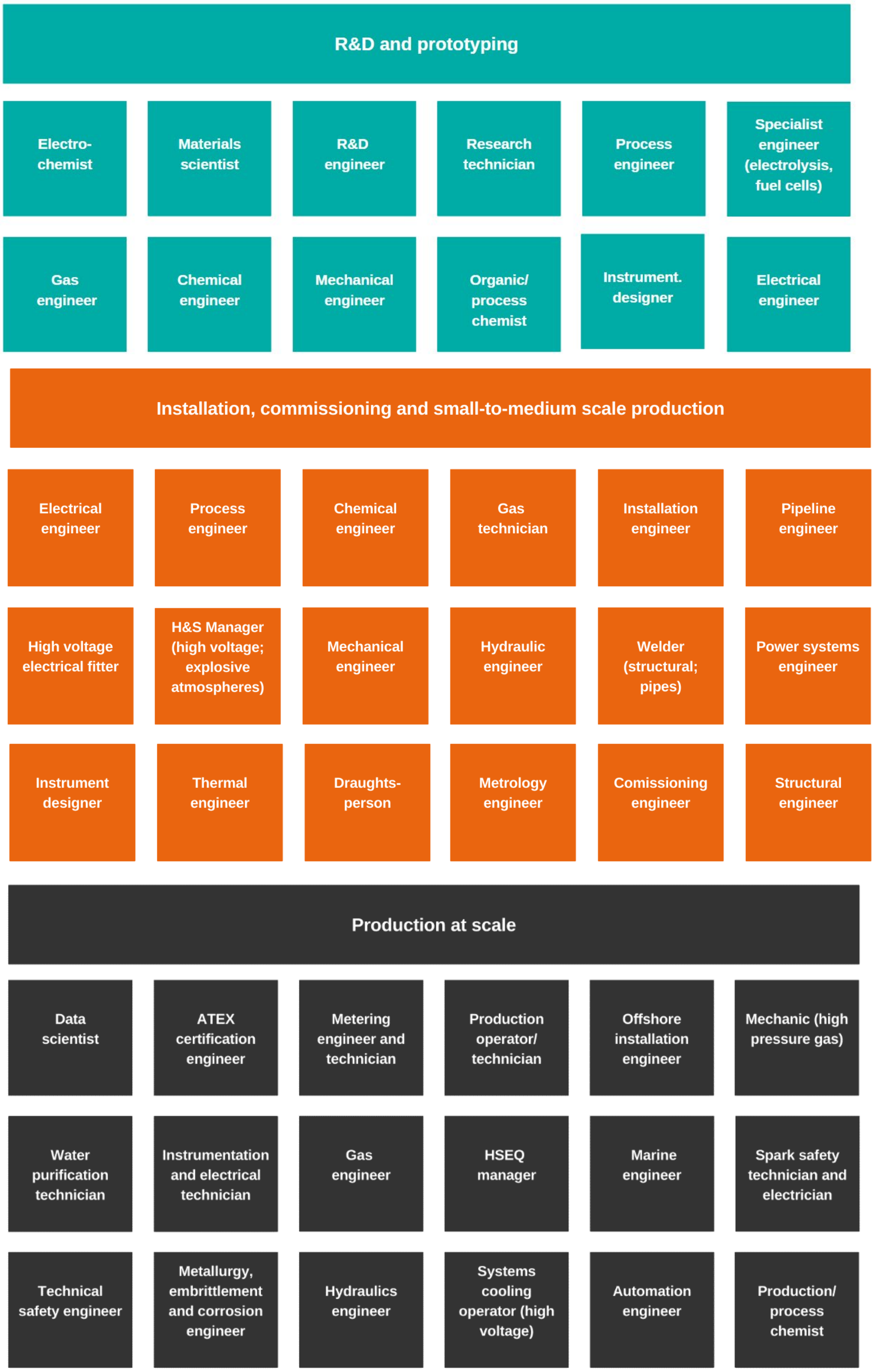

Figure 5: A matrix of predicted high-demand roles in the upstream hydrogen value chain at different stages of industry maturity

Several interesting points were identified in the stakeholder consultations regarding the level of education that will be required for the hydrogen economy. Firstly, there is a concern that industry's self-reported appetite for graduate engineers (SCQF Level 9) will in practice turn out to be a need for workers at SCQF Levels 5-8 (e.g. National Certificate, Higher National Certificate and Higher National Diploma). This could, in practice, exacerbate the lack of technicians and operators in hydrogen process industries, as well as decrease worker satisfaction and impact worker retention in a scenario of an overqualified engineering workforce being employed at a technician/operator level.

Secondly, industry is concerned about the lack of practical skills that graduates have. Some stakeholders believe that engineering graduate training at university is too strongly theory-based and research-focused and does not include enough technical hands-on skills that are needed in the industry. This means that a company that hires a graduate might need to deliver, not only company-specific training, but also basic in-house and on the job training that they feel should have been provided elsewhere. This time investment is seen as a barrier to entry into skilled jobs. One stakeholder indicated that this is a long-standing concern in the industry, potentially caused by poor communication between skills providers (teachers, trainers and curricula designers) and industry.

Both of these concerns highlight the need for industry involvement in curricula design and training.

With this in mind, apprenticeships are expected to become a key source of skilled workers for the hydrogen industry. Industry could play a further role in this respect by training the trainers to ensure that the content delivered by educators is highly applicable to modern processes and operations.

7.2 Enablers of hydrogen skills provision in Scotland

Consultations revealed that stakeholders had several actionable insights that could support hydrogen skills strategy development.

Health and safety of hydrogen handling was identified as fundamentally important to all stakeholder groups. All technical workers, regardless of their level of expertise in process industries, will be expected to require some level of upskilling and re-certification to enable them to operate with hydrogen at scale and in novel applications.

Key developments to date are:

- Health and Safety Executive (HSE) guidance relating to hydrogen was created in 2009, and, more recently, a Fundamentals of Hydrogen course was launched to introduce workers to the properties of hydrogen, material effects and system design in the context of Dangerous Substances and Explosive Atmospheres (ATEX) Regulations and Hazardous Area Classification (HSE, no date).
- The Institution of Gas Engineers and Managers released the Reference Standard for Low Pressure Hydrogen Utilisation in 2022 (IGEM, 2022).
- Energy and Utility Skills are working on an Interim Hydrogen Technical Standard as a part of their Hydrogen Competency Framework (EUS, 2021).
- Cogent Skills is facilitating the development of the UK's first National Occupational Standards for hydrogen production, storage, and transportation (Cogent Skills, 2022).
- Energy Skills Partnership (ESP) are building a Hydrogen Network across further education colleges, thus enabling a unified approach to skills development in the hydrogen economy.

However, stakeholders felt that prescriptive standards (and thus certifications) do not yet exist. For example, there is no formalised route for the approval of a hydrogen and fuel cell stationary installation. Therefore, a significant element of hydrogen project development revolves around interpretation of existing guidance and best practices. This, in turn, affects the development and delivery of training courses as curricula developers await prescriptive guidance that can serve as a base for course content development. Collaboration between industry, the HSE, and skills providers could deliver the first generation of a technical workforce that has an appropriate understanding of hydrogen regulatory compliance, hydrogen explosive atmosphere area design and operations, innovative project certification basis and safety assessments. In the UK, this approach has been pioneered by Hydrasun, which is developing a bespoke hydrogen skills academy focused on delivering a suite of competency-based hydrogen courses (Hydrasun, 2022). Soon, more skills providers are likely to consider health and safety as their first step in preparing the hydrogen workforce as this will be applicable to workers across the whole hydrogen value chain. Standardisation and internationally recognised training quality assurance schemes will further support this process. CompEx, an international scheme for competency validation and certification of staff working in explosive atmospheres, is developing a new global hydrogen safety training programme due to be fully accredited and launched in summer 2023 (Hydrogen Central, 2023).

As industry continues to innovate and create precedent and best practices, there is an expectation that various relevant standards will rapidly evolve, and workers will acquire the additional competency elements via modular courses. For example:

- The Department for Energy Security and Net Zero is working on the development of a targeted set of standards in domestic and non-domestic heating which includes hydrogen enabling standards, hydrogen installation and training standards, ancillary device standards and technical evidence research (BEIS, 2021b).
- The National Grid Hydrogen Skills and Competencies project, aims to develop methodologies for skills training and hydrogen competencies in transmission and distribution, and is expected to conclude in September 2023.

A clear definition and understanding of these technical standards will enable skills providers to respond by developing courses that address these standards and integrate them into existing training programmes.

Development of standards for hydrogen production could, however, be significantly more challenging. Stakeholders interviewed for this research suggest that to overcome this, standardisation of layouts and instrumentation within a hydrogen production facility could be used to streamline the delivery of skills that will be required for operations and maintenance.

Stakeholders expressed strong opinions that the emerging hydrogen industry cannot rely solely on skills transfer from the oil and gas industry. This is despite the highly transferable skills of workers and evident cross-project activity of the existing energy industry players. In the timeframe considered by this study, there is no expectation of a reduction in oil and gas activities that would release a sufficiently large skilled workforce from their current jobs. Additionally, caution should be exercised in the assumption that workers can be moved from other process industries into the hydrogen industry without some additional training. There are numerous technical nuances that can affect some job roles more than others. An example of such a situation is in gas metrology, where the equipment has a significantly larger error when working with hydrogen, compared to working with natural gas.

In the energy sector, the demand for a skilled workforce in existing and emerging sectors is expected to increase sharply. This was estimated by OPITO in the North Sea Transition Deal's 'Integrated People and Skills Strategy' that indicates a requirement of 154,000 jobs in 2022, 211,250 in 2030, and 350,500 in 2050. This overarching energy skills demand offers the opportunity to develop a cross-skilled energy workforce that is capable of working across a range of energy sectors. This concept of a fluid and agile workforce is being developed via projects such as OPITO's Energy Skills Passport, part of the North Sea Transition Deal (OPITO, 2022). This passport will work as a key enabler of workforce movement into areas of high demand. This approach could be employed in skills delivery across colleges and universities where it will allow the upcoming workforce to remain agile in the energy job market. However, the OPITO data highlights the significant need to attract new staff into the energy sector, as well as developing the transferability of existing staff.

7.3 Predicting the geographical distribution of hydrogen skills demands

To enable successful expansion of the hydrogen economy, relevant technical skills need to be provided in the right place as well as at the right time. Therefore, it is important to understand geographical areas that have the potential to become hydrogen hotspots to ensure that skills delivery mechanisms are in place to support industry demand.

The first hydrogen production facilities are likely to be small, de-centralised sites close to the end user. The European Marine Energy Centre (EMEC) hosts a 670kW electrolyser that uses renewable electricity and is supplemented by flow batteries (tidal energy), thus operating as a continuous production demonstrator site (EMEC, no date). Other examples include Glensaugh Farm project at the James Hutton Institute, Cloffrickland Farm in Aberdeenshire, and the Pure Energy Centre in Shetland. These sites are likely to require a small number of dedicated staff or (in case of farms) be maintained by workers alongside their other responsibilities. It is predicted that in these cases, electrolysers will operate as modular units that will be installed and connected to the electricity supply by the original equipment manufacturers (OEM) followed by periodic site visits for maintenance. In this situation, stakeholders suggest that OEMs or service companies could deliver the basic skills needed for safe day-to-day operations to the site workers via their field service technicians and equipment engineers. Pure Energy Centre, for example, currently offers a five-year maintenance contract and remote monitoring of their electrolysers.

Large hydrogen production sites will likely require dedicated operators and technicians. However, as discussed before, stakeholders expect a large degree of automation and the capability for remote control and monitoring of the hydrogen production facilities. For example, the Danish company Green Hydrogen Systems offer remote monitoring as part of service agreements (Offshore Energy, 2023). Therefore, the facilities might not require a lot of staff to operate.

It is likely that production facilities will be geographically closer to locations that have connections to offshore wind projects. In this way, the projects will have access to renewable electricity and local talent. Larger cities also provide access to end-users, thus representing significant supply chain aggregation. One such example is Aberdeen where twelve of the thirteen successful bidders to the recent INTOG leasing round are located in the North Sea off Aberdeen.

Similarly, low carbon hydrogen plants are expected be built in the locations with access to natural gas, such as St Fergus and Grangemouth.

Industry stakeholders expressed an opinion that the location is not a concern to their operations because, in their experience, the workforce is mobile. However, it is important to note that a lack of regional skills could have a detrimental effect on the early stages of the hydrogen economy that is predicted to kickstart at remote and decentralised off-grid sites. Therefore, development of a skilled regional workforce could facilitate regional hydrogen sector growth.

In the timeframe beyond 2035, when most of the hydrogen activity will occur at large, centralised sites and possibly offshore, stakeholders predict that geographical locations of skilled workers and skills providers will become less of a concern. As the offshore oil and gas sector precedent shows, skilled workers across the country can arrive at muster points for transport to the offshore sites for shift work, and this set-up is likely to be translated into hydrogen operations at scale.

7.4 Other insights

Overall, industry seems confident that it can impart on-the-job, hydrogen-specific operational skills to its workforce. The key limitation, however, is the number of people with good core technical education to which hydrogen skills can be added. Technical skills shortages are long-standing issues, with a reported shortfall of over 173,000 workers in science, technology, engineering and maths disciplines in 2021 (IET, 2021).

In summary, stakeholder feedback on the discussion document, which was based on publicly available evidence, was extremely consistent and their views are incorporated in this report.

Further, some industry stakeholders report that around 15 to 20% of their engineering staff are over 55 years old, and as this generation of skilled workers reaches retirement, the talent pipeline is insufficient to replace them. Several initiatives have been launched to raise interest in STEM career paths in schools to encourage young people to pursue more technical career paths, however, it is unclear how insufficient numbers in the current talent pipeline will affect process industries in general, and hydrogen, in particular. Industry feels that the government needs to play a more active role in encouraging young people into STEM, and especially engineering, through revisiting science curricula and ensuring that the students can study all desired STEM subjects in parallel. Stakeholders repeatedly highlighted that the hydrogen economy, as a sustainable industry, could be more appealing to the younger workforce than the oil and gas and chemicals industries. Therefore, the hydrogen industry needs to become more engaged with schools and young people to support the development of the future workforce.

Industry reported challenges with staff retention and turnover, and this is another global phenomenon across a range of industries. To that end, skills development via long-term courses, such as degree apprenticeships, can work as an employee retention strategy.

Overall, these insights suggest that the hydrogen economy faces a unique combination of global workforce attitude changes and ageing workforce challenges. These can, however, be addressed by pursuing sector-specific opportunities to secure a young technical workforce that has climate-conscious industry preferences.

8 Conclusions

Based on the work carried out, we conclude that:

- Delivering the ambitions specified in the Scottish Hydrogen Action Plan will result in the development of a significant new sector in Scotland. Average annual employment levels over the 2025-2030 and 2030-2035 periods are estimated at 6,614 and 18,525, respectively.
- Scotland is in a strong position to develop its hydrogen economy, initially by using transferable skills from the oil and gas and process industries and, in the longer term, adapting the existing skills provision so that it can support the hydrogen sector as it grows.
- This sector is currently emerging, with a focus on project development, feasibility studies and pre-FEED studies. These activities are being delivered by actors with in-depth experience in the oil and gas, utilities and process industry sectors.
- Globally, the development of sector skills strategies is at an early stage, despite the predictions for significant growth of the hydrogen sector over the period to 2030.
- The hydrogen sector will require a significant number of staff at all levels, ranging from skilled tradespeople to graduates.
- The demand for a skilled, technical workforce will rapidly increase. It is expected that existing job roles in other sectors can be adapted to service the hydrogen sector. Therefore, the industry does not expect that new job roles, with never-before seen job descriptions, will be created as an hydrogen economy evolves, instead these job roles will be familiar to organisations in related, existing sectors.
- Data and digital skills will become important in most hydrogen economy job roles as an underpinning capability.
- These needs will require adaptation of existing courses, a portfolio of appropriate modular courses and on-the-job training. It is noted that there is an appetite within industry to contribute to the specification and development of training provision. However, development of hydrogen-specific course content is dependent on hydrogen standards and specifications, which are not yet available.
- The availability of staff will be affected by competition with other energy-related sectors and existing skills shortages in technology and engineering. It is, therefore, critical that there is investment in activities to attract new entrants to the sector.
- Achieving the ambition of 5GW of hydrogen production capacity by 2030, requires the delivery of hands-on hydrogen skills to be fully established in the next two to three years. Central to this is development of knowledge and capabilities within educators / skills providers, which has been identified as a key short-term priority.
- Hydrogen activity is likely to be widespread across Scotland's urban, rural and island regions. Skills provision and development will be required across a number of Scottish regions to support the expected development of several regional hydrogen hubs.

9 Recommendations

Based on our findings in this study, we recommend that:

- An initiative to design and specify relevant hydrogen-specific course content is established. This should include representatives from industry, education and the public sector that are committed to delivering the changes to skills provision that will be needed by the sector. It should set out a series of short (1-2 years) and medium-term (2-5 years) actions to do so.
- Skills development provision is available at a regional level to support the expected development of several regional hydrogen hubs
- The concept of 'skills passports', which OPITO is pursuing in the energy sector, is considered in other sectors relevant to hydrogen, such as the chemical and process industries
- Strategies to promote the hydrogen sector and attract new entrants are developed and implemented. These should highlight the net zero and sustainability credentials of the hydrogen sector and be designed for primary, secondary, further and higher education students, as well as individuals already in the workforce. These should clearly illustrate the potential career pathways for individuals, recognising that younger generations, in particular, are far more mobile in the workforce.
- More research is carried out to understand the demand and provision of skilled STEM workers across future energy, transport and industry sectors.

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11 Appendix 1: Methodology

The research commenced with in-depth desk research, focusing on global hydrogen strategies with a focus on complementary skills strategies. We researched the current hydrogen-specific skills provision and used publicly available information to summarise forecasted skills gaps.

Based on previous research for the Department for the Business, Energy & Industrial Strategy (Optimat and Wood, 2022), we developed a value chain model describing core aspects of the hydrogen economy. This model was used to categorise Scottish-based companies with identifiable activity or interest in the hydrogen economy. For the purposes of this study, the company's activity or interest in hydrogen was defined as one or both criteria below:

- Participation in hydrogen-related projects.
- Publicly available information regarding company services in the hydrogen sector (for example, on their website).

Companies were identified by searching publicly available platforms, such as Scottish Industry Directories, the One North Sea database (Net Zero Technology Centre) and the Scottish Hydrogen Fuel Cell Association members directory. Company activities in the hydrogen sector were recorded and classified by broad supply chain activity.

Using the outputs from the desk research, we created a discussion document for semi-structured stakeholder interviews. The discussion document contained research-informed statements on existing and forecasted skills demands, existing hydrogen skills provision, and identification of potential skills gaps. It is included below. Additionally, workforce movement within energy industries and the Just Transition were discussed. The programme included 16 stakeholder interviews across the industry, skills providers and other relevant organisations. We carried out a thematic content analysis of interviews based on the stakeholders' opinions of the discussion document statements. This was supplemented by a narrative analysis that outlined stakeholders' opinions on topics not included in the discussion document.

The organisations that contributed to the study were:

- BP
- EMEC
- ESS Recruit
- ETZ Ltd
- Energy and Utility Skills

- Green Cat Hydrogen
- Hydrasun
- Ineos
- The Net Zero Technology Centre
- OPITO
- Scottish Enterprise
- Scottish Hydrogen and Fuel Cell Association
- SGN
- Skills Development Scotland
- SOAS
- TUV-NEL

To predict the growth of the hydrogen economy in the next decade, we modelled the expected increase in scale and scope of the hydrogen supply chain using the Scottish Hydrogen Action Plan ambitions of 5GW production capacity by 2030 and 25GW by 2045. We used assumptions from Optimat and Wood study for BEIS to estimate the expenditure associated with the design, installation, commissioning and operation of hydrogen production, transport and storage facilities, as well as export of hydrogen (using liquid organic hydrogen carrier as a predicted medium for export). The gross value added (GVA) and jobs (full-time equivalent) were calculated from these estimates using Scottish Government economic data using the recommended procedure by the Scottish Enterprise Impact Appraisal and Evaluation Guidance[4]. The forecasted hydrogen economy expenditure was then multiplied by the sector specific GVA: turnover ratio to identify the direct GVA. The direct GVA was then divided by the corresponding industry sector GVA: turnover ratio to calculate direct employment. Finally, we multiplied direct employment by a sector-matched FTE multiplier to investigate the broader economic impact of the hydrogen economy activity.

The report includes a list of evidence-based conclusions and highlights areas of further research needs.

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[4] https://www.evaluationsonline.org.uk/evaluations/help/guidance.htm

Discussion Document - Current and Future Skills Needs in the Scottish Hydrogen Sector

The Scottish Hydrogen Action Plan targets 5 GW of hydrogen production capacity by 2030 and 25 GW by 2045. This equates to an annual production of more than 450,000 tonnes by 2030 and around 3.3 million tonnes by 2045, with the potential to export around 75% of this output. It is expected that the output will predominantly be renewable (green) hydrogen. These figures reflect the birth, growth and development of a significant new industry sector. As a result, it is important that the skills required to support this embryonic, high growth industry are identified.

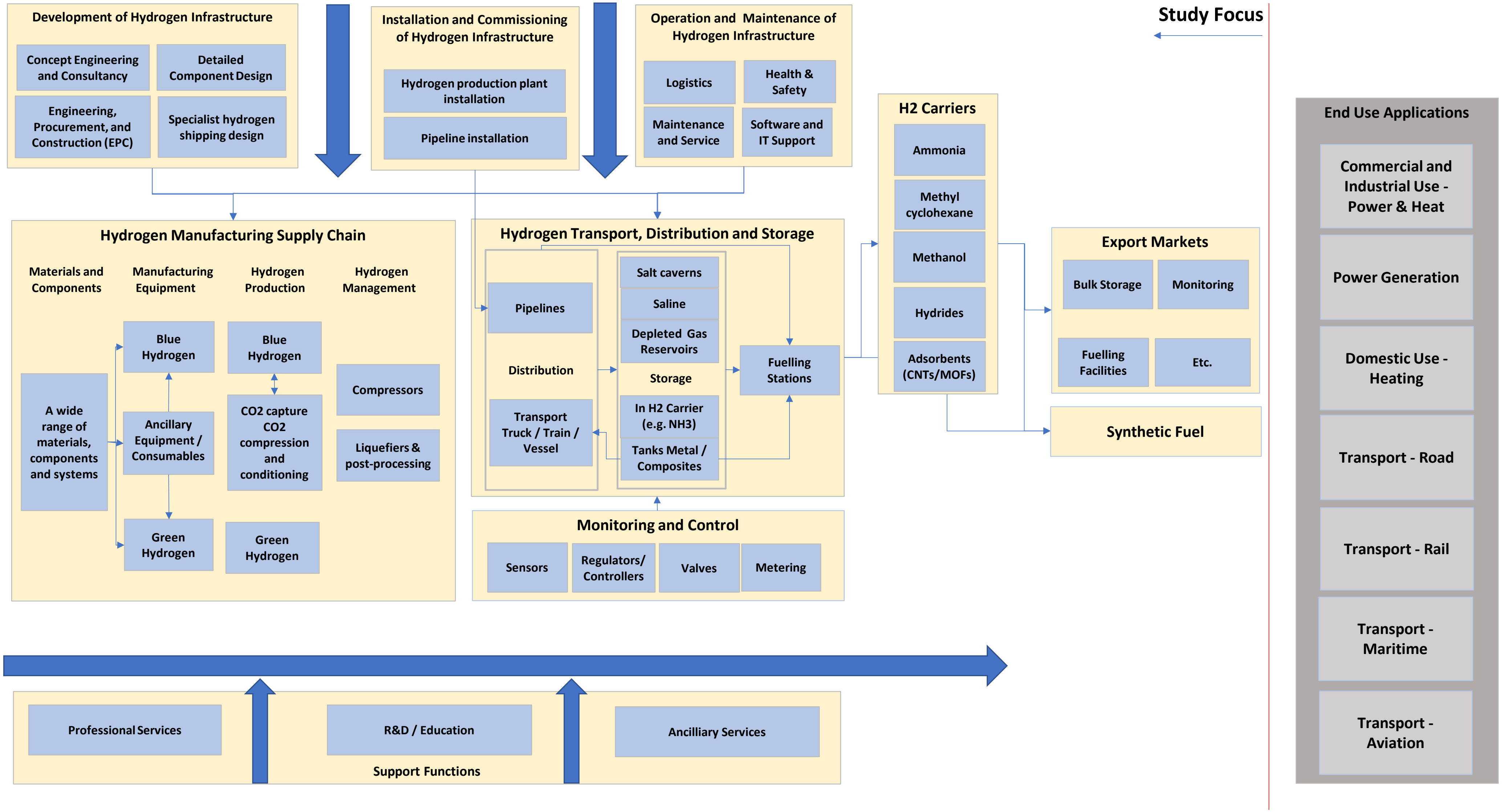
Our work, commissioned by ClimateXChange on behalf of the Scottish Government, focuses on the manufacturing, storage, transport and export of hydrogen. We have assessed existing published information on the skills needs to support a hydrogen economy and have made the following observations, which we would like to discuss with you.

1. Currently, most hydrogen-related manufacturing, storage, transport and export activities are focused on research and development and early-stage engineering design.
2. These research and development and early engineering roles are being filled by graduate level staff with relevant experience in related sectors (e.g. from the oil and gas, petrochemical and other process industries).
3. Operational hydrogen activities and related skills needs will be required at a later date.
4. As the sector develops there will be a significant need for hydrogen-specific skills.
5. There will be significant demand for engineers, technicians, tradespeople and health and safety specialists who can work on hydrogen-related equipment.
6. The majority of these roles can be filled by reskilling qualified staff from related industries and current educational backgrounds, via short course and on-the job learning.
7. It is expected that there will be a lot of skilled workforce transfer from the oil and gas, petrochemical and other process industries.
8. Thus the hydrogen economy will not create many new job roles. Existing job roles will be required for hydrogen-specific operations, adapted to meet the specific characteristics of hydrogen.
9. The exceptions to this relate to the operation of processes not seen to date in industry at scale, particularly electrolysis and carbon capture. It is expected that original equipment manufacturers (OEMs) will have a significant role to play in skills development for such process equipment.
10. The most urgently needed hydrogen-related skills relate to health and safety and hydrogen gas handling. These skills will continually be very important.
11. It is important that there is accredited training provision for hydrogen health and safety and gas handling staff to ensure that their capabilities meet required industry standards.
12. Industry standards and professional competence models need to be updated in order to include hydrogen operations where it is relevant.
13. Colleges and universities will be key providers of qualified staff for future hydrogen manufacturing, storage, transport and export.
14. Apprenticeships will be a key sources of tradespeople for building and operating hydrogen manufacturing, storage, transport and export facilities.
15. It is important that relevant university and college courses and apprenticeships are revised to include content relevant to hydrogen manufacturing, storage, transport and export.
16. Skills will need to be available across Scotland to link to the proposed Hydrogen Hubs.

Of course we will be pleased to discuss additional points raised.

Discussion Document - Current and Future Skills Needs in the Scottish Hydrogen Sector   Page 1 of 1

12 Appendix 2: Detailed supply chain structure


Development of Hydrogen Infrastructure
Concept Engineering and Consultancy
Detailed Component Design
Engineering, Procurement, and Construction (EPC)
Specialist hydrogen shipping design
Installation and Commissioning of Hydrogen Infrastructure
Hydrogen production plant installation
Pipeline installation
Operation and Maintenance of Hydrogen Infrastructure
Logistics
Health & Safety
Maintenance and Service
Software and IT Support
Study Focus
H2 Carriers
Ammonia
Methyl cyclohexane
Methanol
Hydrides
Adsorbents (CNTs/MOFs)
End Use Applications
Commercial and Industrial Use - Power & Heat
Power Generation
Domestic Use - Heating
Transport - Road
Transport - Rail
Transport - Maritime
Transport - Aviation
Hydrogen Manufacturing Supply Chain
Materials and Components
Manufacturing Equipment
Hydrogen Production
Hydrogen Management
A wide range of materials, components and systems
Blue Hydrogen
Ancillary Equipment / Consumables
Green Hydrogen
Blue Hydrogen
CO2 capture CO2 compression and conditioning
Green Hydrogen
Compressors
Liquefiers & post-processing
Hydrogen Transport, Distribution and Storage
Pipelines
Distribution
Transport Truck / Train / Vessel
Salt caverns
Saline
Depleted Gas Reservoirs
Storage
In H2 Carrier (e.g. NH3)
Tanks Metal / Composites
Fuelling Stations
Export Markets
Bulk Storage
Monitoring
Fuelling Facilities
Etc.
Synthetic Fuel
Monitoring and Control
Sensors
Regulators/ Controllers
Valves
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Professional Services
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