Cogent Skills
for science and technology

A GREENPRINT FOR SKILLS FOR THE LOW-CARBON INDUSTRIES

UNLOCKING THE SKILLS NEEDED FOR OUR LOW-CARBON FUTURE

About Cogent Skills

Cogent Skills is the UK's leading strategic body for skills in the science and technology sector. We are a not-for-profit enterprise dedicated to supporting the skills needs and ambitions of employers and their employees. We are sector-based, working with companies from across the science industries embracing Life Sciences (pharmaceuticals, medical technology, R&D), Industrial Sciences (downstream, chemicals, polymers) and Nuclear.

Our expertise in employer led facilitation enables us to support industry leading skills groups including, Nuclear Skills Strategy Group (NSSG) and The Science Industry Partnership (SIP). We actively support collaborative employer led action on skills, working hard to improve the skills landscape for all. We are owned by key trade associations in our sector who actively support us in return for expertise and skills solutions that support the long term growth and development of skills in our sector.

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About Gemserv

Gemserv specialises in complex and highly regulated energy and environmental sectors at the forefront of a changing world, offering a comprehensive range of services for organisations in both the public and private sectors. This includes experience in the green skills transition, working with organisations to outline the growing need for green skills and developing strategies for meeting this.

For the purposes of this report, Gemserv have been using their experience in green skills to work in partnership with Cogent Skills to draft the report content.

Gemserv

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Foreword

I'm proud to say we've been at the forefront of the skills agenda, working on behalf of UK science-based companies for more than two decades. From safety training standard setting to working with policy-makers to create the skills environment employers need to thrive. As a charity committed to supporting employers in our sector, everything we do is focused on raising the bar on skills in science and technology.

Yet, as employers embark on their own net zero journey neither the skills required nor their availability are known – at least with any certainty. Therefore the size of any 'green skills' gap is not known. Indeed, the term green skills (sometimes unhelpfully applied) is a broad descriptor that applies to a range of technical skills needed to support the transition. What is clear is unless our industry can access the next generation of talent – including engineers, scientists, technicians, and operators – any plan for a just transition is destined to fall short.

The rapid growth and development of these industries necessitate an agile and adaptive skills system capable of meeting the demands of an evolving workforce. The ability to train enough people in the right areas and at the right levels in time for when they are needed is critical for success.

Understanding the maturity of each sector, expected job roles, and qualification levels is essential for the UK to fulfil its climate commitments and maintain its position as a global leader in innovation. Science engineering such as chemical processing in particular, is indispensable in reaching net zero, as it provides the expertise needed to design, build and optimise new technologies whilst ensuring efficient maintenance of plants. This key discipline will ensure new low-carbon technologies are efficient, cost-effective and reliable.

Transitioning industries – such as downstream petroleum, chemicals and polymers – must also attract a workforce which can maintain operational resilience while simultaneously advancing strategies for long-term sustainability. If these industries are not viewed as part of the solution, employers may struggle to recruit the staff they need to deliver the transformative innovations crucial for achieving net zero.

While the existing workforce has an important role to play, the next generation of talent will be absolutely critical. Research shows young people are highly motivated to combat climate change; the challenge lies in raising awareness of the available job opportunities and encouraging them to pursue careers in these fields.

Our journey towards a more sustainable future is one that demands the combined efforts of all employers and stakeholders. By fostering a spirit of collaboration, strategic thinking, and–most importantly–action, we can rise to the challenge and unlock the vast potential of our emerging low-carbon industries.

At Cogent Skills, we are committed to playing our part in this national effort. This report concludes with a list of next steps we will undertake to support the growth and development of our low-carbon industries. I am confident this report will inspire both optimism and determination as we work together in building a skilled workforce which will lead us towards a sustainable, prosperous future.

Justine Fosh, Chief Executive
Cogent Skills

Foreword

The transition to a low-carbon economy is a once-in-a-generation opportunity to enhance our resilience to the impact of seismic global events and spearhead a new chapter of green growth.

Data from the Office for National Statistics suggests the low-carbon and renewable energy sector was worth almost £55 billion to the UK in 2021 – up nearly a third from the previous year. This striking financial indicator is only part of the broader picture, as green skills become increasingly important in science businesses and across the economy as a whole.

Technical skills will be instrumental in driving this transformation. Businesses across the science sector are rightly keen to understand their future skills requirements and fill any gaps, whether by attracting new and emerging talent or through upskilling the existing workforce. Developing these skills is critical for the successful implementation and integration of low-carbon technologies and solutions.

This report serves as an invaluable source of information and insight to anyone involved in or able to influence the hiring and training of staff across a range of industries. It sheds light on the unique characteristics and skills needs of each industry, providing cross-cutting insights to help cultivate a skilled and adaptable future workforce ready to meet the demands of a rapidly changing landscape.

By focusing on the specific roles and skills needed to support these emerging industries, we can more effectively invest in the development of our human capital and ensure the workforce is equipped to face the challenges ahead. This includes the importance of assessing the current workforce's transferable skills, identifying gaps, and developing specialist courses.

The report highlights the need for a proactive approach to skills development, acknowledging that only through concerted action can we truly deliver on our commitment to net zero.

In light of this, embedding green skills across the economy must become a national priority if we are to preserve our current way of life and ensure a sustainable future. We hope this report provides a catalyst for developing the workforce capable of realising this vision in the years to come.

Professor Joe Howe, Academic lead for the Humber Industrial Cluster, University of Lincoln

Study Approach

This report aims to identify the specific skills and occupations required to advance and grow a range of emerging low-carbon industries needed to support the UK's net zero transition. It draws upon insights from several stakeholder workshops, a comprehensive desk-based research exercise, and Cogent Skills and Gemserv's combined experience and expertise in this area.

Over the course of three days, Cogent Skills hosted more than 40 industry experts from over 25 organisations. The insights from these workshops are used throughout the report to evidence the findings. To wrap up the report, recommendations are provided to steer how industry and its stakeholders can work collaboratively to help manage the transition.

Extensive desk research on the green skills landscape

Gemserv's knowledge on low-carbon technology and green skills

Stakeholder engagement with over 40 industry experts

Cogent's insight on skills development for the science sector

Figure 1: Research process to arrive at recommendations

Introduction

In response to the UK Government's commitment to reach net zero emissions by 2050, industries across the economy are beginning to recognise and confront the profound shifts needed within their operational structures. Standing at the vanguard of this transformation are companies within the science and technology sectors. Their ground-breaking work will not only fuel the UK's future economic growth and prosperity but also drive forward the development of new industries and processes to deliver decarbonisation.

The scale of this challenge has prompted significant investments in a range of potential solutions for the many complex challenges facing our low-carbon transition. And while progress is being made, many promising technologies still depend on high-level R&D and scientific breakthroughs to establish their safety, reliability, and scalability. This creates a landscape that's constantly evolving—where some innovations may surpass expectations while others encounter unforeseen challenges. From a skills development perspective, the challenge lies in ensuring that each industry has a workforce that is adequately trained and sufficiently numerous to meet its changing demands.

A significant challenge we face is a lack of clarity regarding the specific skills and job roles needed to grow these emerging industries. Stakeholders, including policymakers and training providers, need accurate data that inspires confidence in the size and direction of travel within industry, particularly within new and emerging markets. And while some workforce projections exist in individual areas, a holistic view of the landscape is lacking. What is clear, however, is that there is substantial overlap across a range of low-carbon industries, underscored by an increased demand for engineering and technical skills. This situation implies that unexpected growth in one area could inadvertently constrain skills availability in another.

The conventional model of skills development, typically reactive to industry demand, no longer provides an adequate solution in the face of our urgent climate goals. Instead, we must be proactive and design a robust yet agile framework, one that considers the broader perspective and captures the intricate interplay of skills across a range of emerging industries. For the UK to realise its climate ambitions, we must be able to articulate and respond to the skills needed across different sector maturity stages, the potential job roles emerging, and the associated qualification requirements. In this context, agility is about more than preparedness — it also means being capable of capitalising on sudden opportunities and adjusting strategy when necessary.

This report explores the following low-carbon industries, given their close ties to the science and technology sectors. Detailed sections on the importance of engineering skills and the future of transitioning industries are also provided. Engineering is a key enabling discipline that is crucial throughout the sector, so its cross-cutting importance is examined separately. The focus on transitioning industries reflects the need to understand the skills requirements of more mature parts of the sector that are also evolving and must find new ways of working to secure their place in a net zero economy. And although there is still much unknown, industry recognises the need for strategic joined-up thinking and is keen to develop its understanding of the future skills demand.

- Hydrogen
- Carbon Capture
- Batteries
- Fuel Cells
- Nuclear
- Transitioning Industries

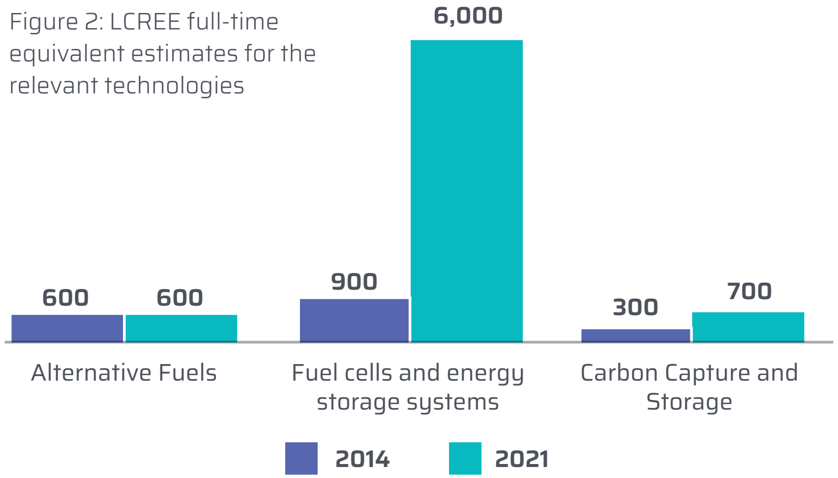
Commercialising and building these emerging industries in the UK presents a unique opportunity to provide well-paid, rewarding careers while underpinning long-term energy security and independence. While these changes won't happen overnight, several milestone targets have been set by Government, and demand is expected to grow quickly with significant investments already taking place.

Figure 2 shows the historical and current FTE footprint of these industries*, taken from the ONS Low Carbon and Renewable Energy Economy (LCREE) statistics released in February 2023.[1] While these statistics don't perfectly overlap with the report's definitions of the segments, it demonstrates each sector's relative maturity and current contribution to the UK workforce.[2]

Our ability to grow these industries from where they are today will depend upon the UK's capacity to train enough people in the right areas, at the right level, in time for when they are needed. And while future workforce demand projections do vary, it is now clear that technical skills will form the cornerstone of the transition, with increased demand for engineers, scientists, technicians, and operators across a range of low-carbon industries. As a result, developing the next generation of scientific talent across all skill levels should be considered a national priority.

*The LCREE statistics also provide an estimated employment figure for the nuclear power sector of approximately 14,500 in 2021. This is significantly lower than estimates provided by the Nuclear Skills Strategy Group (58,000) and the Nuclear Industry Association (64,000).[3] This discrepancy is in large part due to the narrow definition of the sector within the LCREE datasets, which excludes important decommissioning

Figure 2: LCREE full-time equivalent estimates for the relevant technologies



1. Office for National Statistics: Low carbon and renewable energy economy estimates, 2023.
2. Transitioning industries aren't included in the LCREE statistics. Carbon capture and storage maps well onto the report definitions. Fuel cells and energy storage maps fairly well onto fuel cells and batteries. However, energy storage encompasses a wide range of batteries beyond lithium ion and includes flywheels, thermal energy storage and pumped hydro. Alternative fuels is a catch all term that includes low-carbon hydrogen as well as synthetic fuels, e-fuels and fuels derived from waste. A full definition of each segment is provided in Appendix 2.
3. Nuclear Industry Association: Jobs Map 2022.

Cross-Cutting Insights

While each industry explored in this report has unique characteristics, several cross-cutting insights and trends emerged during the stakeholder workshops and wider literature review. This section provides an overview of these findings, accompanied by commentary that draws upon the key themes from the sector-specific analysis.

THE RELATIVE MATURITY OF EACH TECHNOLOGY IMPACTS THE GRANULARITY AND ACCURACY OF FUTURE WORKFORCE PROJECTIONS.

As **Figure 3** shows, the stage of development across these sectors heavily influences the skills requirement, manufacturing maturity and demand signals. For established technologies, the skills requirements, manufacturing processes, and future demand are relatively well-known, such as in nuclear and batteries. This makes it easier to forecast the number and types of jobs required based on the expected increase in demand in these areas.

Mature sectors also tend to have more intermediate-skilled workers, with highly skilled engineering jobs representing a smaller share of total employment. For emerging sectors, such as parts of the hydrogen economy and carbon capture, uncertain manufacturing routes and weak demand signals mean that the number and type of jobs required still need to be clarified. However, industries in the earlier stages of technology development tend to be dominated by highly skilled workers who are subject matter experts.

Research → Proof of Concept → Application Readiness → Industrialisation at Scale

Skills Requirement	High levels of skill dominate as fundamental scientific principles of how a technology work are being explored	As technologies move from the pilot phase to market entry, a balance of entry level skills and advanced skills are needed	Entry level skills are prominent due to enhanced manufacturing & maintenance positions. Highly skilled roles are focused on incremental improvements or discovering new technology
Manufacturing Maturity	The manufacturing process is not defined as there could be multiple routes for manufacturing a technology	The potential manufacturing routes are narrowed down as pilot production occurs with high typically high levels of manual assembly	Manufacturing processes are established and well defined. This is due to a sector focus on continuous improvement and enhanced levels of automation
Demand Signals	Demand signals are weak as it's uncertain whether the technology will be commercially viable	A range of different demand signals emerge from the market. There's confidence a technology will be commercialised but the scale of adoption is uncertain	Demand signals are stronger as the industry is confident the technology will grow or sustain it's position in the market

Figure 3: How technology maturity impacts skills requirement, manufacturing maturity and demand signals

DIFFICULTY IN QUANTIFYING HOW MUCH OF THE CURRENT WORKFORCE HAVE GENUINELY TRANSFERABLE SKILLS

It is often predicted that a significant proportion of the future low-carbon workforce will be workers transferring from the more carbon-intensive transitioning industries. While it is generally accepted that there will be reduced demand for jobs and skills in some areas, there will still be an important role for these critical industries. At the same time, while the types of low-carbon technologies that will be important are generally well understood, the exact composition required to best achieve net zero is still unclear.

Analysis of the supply chains and technology areas suggests substantial overlap between the skills needs of both transitioning and emerging low-carbon industries. For example, the chemicals sector will play an important role in battery manufacturing, while downstream companies are investing in hydrogen production and carbon capture technology. However, further work needs to be done to quantify how much of the current workforce has genuinely transferable skills, if they could enter the same types of job roles at similar salary levels and the extent to which an ageing workforce limits the number of transfers.

It is also important to note that some sectors may experience a faster decline in employment opportunities than the new low-carbon sectors can create. This can lead to a situation where workers are not able to find new employment opportunities in a timely manner, which can result in a range of issues such as unemployment, underemployment, and loss of skills from the economy.

LACK OF CLARITY OVER WHICH ROLES WILL NEED DEDICATED COURSES AND TRAINING

As a technology moves closer to the 'Industrialisation at Scale' phase, the need for specialist courses becomes more apparent. For example, many bespoke nuclear apprenticeships have been created to support the build-up of nuclear power, while a Battery Manufacturing Technician Level 3 apprenticeship has been developed to help meet the anticipated demand for skilled battery manufacturing personnel. While our initial analysis suggests emerging industries like hydrogen, carbon capture, and fuel cells may require bespoke courses, the types of courses and specific roles that require dedicated apprenticeships or short courses still need to be identified. Engaging with industry to understand their views will be critical to ensuring that the right qualifications and skills are developed in time to support the ramp-up.

CHANNELING YOUNG PEOPLE'S MOTIVATION TO SOLVE CLIMATE CHANGE INTO PURSUING CAREERS IN LOW-CARBON INDUSTRIES

The literature review and stakeholder workshops have consistently highlighted the trend that young people are highly motivated to solve climate change. However, while some studies report high awareness of climate change, there is currently a lack of understanding regarding the available job roles and courses that can effectively contribute to addressing the issues.[4] [5] [6] This gap indicates a need for the sector to clearly articulate future job roles and promote STEM skills to inspire future generations to enter the sector.

Projections in the wider UK skills literature and historical trends reveal a long-term decline in demand for intermediate skills, such as process, plant, and machine operators. However, workshop participants repeatedly emphasised the importance of these roles and their current difficulties in recruiting technicians, operators, and maintenance staff who are typically trained to Level 3 or 4 equivalent. A key issue raised was the perceived attractiveness of manufacturing environments compared to other career pathways for the new generation of workers.

The growth of low-carbon presents an opportunity to reposition these roles by harnessing the motivation of young people in relation to sustainability. These roles often serve as an entry point into an emerging industry with opportunities for growth, making them crucial for social mobility and providing a pathway to a fulfilling career. By focusing on the communication of available job roles and courses, promoting STEM skills, and addressing the perception of manufacturing environments, we can better engage young people and develop a skilled workforce capable of delivering the transition.

THE DEPLOYMENT OF LOW CARBON ENGINEERING AND SCIENCE ROLES IS HIGHLY DEPENDENT ON THE CONSTRUCTION SECTOR MEETING EXPECTED DEMAND

Many of the technologies discussed in this report are still emerging industries that require billions of pounds worth of capital expenditure to be realised. The estimated land needed for a gigafactory is 2-3 million square feet, which, if one was constructed at that size, would make it one of the largest buildings by footprint in the UK.[7] Similarly, constructing nuclear power plants are large capital infrastructure projects that take years to complete and need many civil and construction engineers. While carbon capture and hydrogen projects are smaller, they are still capital-intensive projects, requiring a frontloading of labour in the construction phase. Transitioning industries like downstream, chemicals, and polymers have built up their UK physical assets over many decades. Greater understanding is needed of how the scale-up of new low-carbon industries will create jobs across the entire project life cycle. This needs to take into consideration the design and construction of facilities, as well as the operational, maintenance and R&D staff required to operate them.

THE IMPORTANCE OF FORGING PARTNERSHIPS WITH ADJACENT ORGANISATIONS IN THE SKILLS AGENDA

The areas discussed in this report span multiple primary and secondary manufacturing industries in the UK as well as scientific service industries. Even for one technology area like hydrogen, it has a vast value chain compromising production, storage, transportation and end use. Significant coordination will need to occur across multiple organisations representing different industry segments to accurately quantify the number of future roles and qualifications required for these low-carbon industries. Strategic partnerships with industry, training providers, and trade associations will be needed to reduce the duplication of activities and focus efforts on the most pressing challenges.

4. National Grid: Building the net zero energy workforce, 2020.
5. WorldSkills UK & Learning and Work Institute: Skills for a net zero economy: insights from employers and young people, 2022.
6. Education and Employers: Disconnected: Career aspirations and jobs in the UK, 2020.
7. Savills: What are the real estate implications of Gigafactory development in the UK? 2021.

Recommendations

The research and stakeholder engagement process identified four key themes that have been used to help structure the recommendations. Under each theme, specific recommendations are provided, and a priority level is assigned for each of the six sectors. Evidence from the stakeholder workshops and wider literature review has been used to validate the priorities levels. Factors considered when assigning a priority ranking include the timescales of technology ramp-up, the required level of sector-specific expertise, and the existing levels of analysis and strategy.

Skills Strategy
A comprehensive, strategic plan that instils confidence and stability in both industry and government, supporting long-term investment in skills development planning.

Skills System
The methods and precise mechanisms utilised by industry to address the current skills demand.

Future Workforce
Activities that aim to create a sustainable talent pipeline to meet future skills demand.

Enabling the Transition
Short-term measures to facilitate the UK's transition

Figure 4: Key themes emerging from the research

Skills Strategy

A comprehensive, strategic plan that instils confidence and stability in both industry and government, supporting long-term investment in skills development planning.

Recommendations	Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Establish clearly defined role profiles for key positions.	Medium ●●	Low ●	High ●●●	High ●●●	Medium ●●	Medium ●●
Deliver an industry-led low-carbon skills strategy for each technology area.	Medium ●●	Medium ●●	High ●●●	Medium ●●	High ●●●	Medium ●●
Develop workforce projections to anticipate future skills demand in different growth scenarios.	High ●●●	Medium ●●	High ●●●	High ●●●	Medium ●●	High ●●●

Skills System

The methods and precise mechanisms utilised by industry to address the current skills demand.

Recommendations	Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Enable a stable and consistent policy environment that fosters employer engagement on skills and encourages long-term strategic planning.	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●
Develop and maintain a diverse range of apprenticeship standards that reflect modern technological developments and industry needs.	High ●●●	Medium ●●	High ●●●	Medium ●●	High ●●●	Medium ●●
Ensure the UK visa system facilitates the flow of workers into the sector to meet urgent and crucial skills requirements.	High ●●●	Medium ●●	Medium ●●	Medium ●●	High ●●●	Medium ●●

Future Workforce

Activities that aim to create a sustainable talent pipeline to meet future skills demand.

Recommendations	Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Promote Careers Outreach programmes to educate and inspire young people to enter the sector.	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●
Raise awareness of the sector's importance in securing the net zero transition.	High ●●●	High ●●●	Medium ●●	High ●●●	Medium ●●	Low ●
Undertake research to understand the Equality, Diversity & Inclusion (ED&I) issues of the workforce and identify best practices to inform the action plan.	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●

Enabling the Transition

Short-term measures to facilitate the UK's transition towards a net zero economy.

Recommendations	Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Promote a culture of lifelong learning and Continuing Professional Development (CPD) to ensure a skilled and committed workforce capable of delivering the transition.	Medium ●●	High ●●●	Medium ●●	Medium ●●	Medium ●●	Low ●
Develop clearly defined pathways to facilitate the transition of workers from adjacent industries to bring cross-sector learning.	High ●●●	Medium ●●	High ●●●	High ●●●	High ●●●	Medium ●●
Understand and define regional skills requirements, connecting economic hubs and industrial clusters to deliver nationally for industry.	High ●●●	Medium ●●	Medium ●●	High ●●●	Medium ●●	Low ●

The Importance of Engineering

Overview of the UK Engineering Sector.

Although engineering and science are closely linked, they are not interchangeable. Engineering involves the practical application of scientific principles and mathematical methods to design, develop, and enhance technology, products, and systems that address real-world issues. Science, on the other hand, is a systematic and empirical approach to discovering new knowledge about the natural world through observation, experimentation, and analysis. And so, while engineering draws upon scientific discovery, it also incorporates other factors, including design, economics, and practical constraints. In other words, it focuses on the practical implementation of scientific knowledge to create tangible solutions. Engineering is, therefore, essential to achieving net zero because it provides the knowledge and skills required to design, build and optimise the performance of new technologies. It is a key discipline that will be critical to ensuring that emerging low-carbon technologies are efficient, cost-effective, and reliable.

Engineering fields like chemical and materials engineering rely extensively on scientific knowledge to improve existing technologies and develop new ones. As technology becomes more complex, interdisciplinary collaboration between engineers and scientists is crucial. Consequently, engineers with a strong foundation in science will become increasingly important and continue to be in high demand. However, this does not necessarily mean that all engineers will need to have a formal science background, as interdisciplinary teams can also provide the necessary scientific expertise.

The pervasiveness and importance of engineering skills (particularly chemical/ process engineering) in the new low-carbon industries emerged consistently during the occupation and skills mapping exercise and was reinforced in the stakeholder workshops. As engineering is an established and foundational sector, detailed statistics and insights on the existing workforce, future needs, and skills development trends are relatively well established.

The Royal Academy of Engineering estimates that more than 8 million people are currently employed in the engineering economy, contributing approximately £645 billion in Gross Value Added (GVA), equivalent to 32% of the UK economy.(8) (9) Even when focusing just on engineering occupations, analysis conducted by EngineeringUK suggests that in 2021 around 5.6 million jobs in the UK were engineering-focused, representing 19% of the total UK workforce.(10) The influence of engineers and the broader engineering sector is evident across multiple industries. This ranges from primary industries such as refining, mining and chemicals to secondary industries such as manufacturing, transportation and, more recently, the emerging low-carbon sector. But despite its importance to a range of industries, the engineering sector is facing several skills-related issues. While the UK's "persistent technical skills shortage" is not a new issue, the compounding challenges of inflationary pressure, the post-COVID recovery, and net zero transition are creating a perfect storm for the sector.(11) Three broad issues were identified during the research: quantifying the scale of engineers needed for the future; the changing composition of engineer-related jobs, and the difficulties in attracting new talent.

The first challenge is that no recent analysis has been conducted to quantify the estimated supply shortage of engineers. Despite an abundance of qualitative insight and industry surveys, the latest quantitative estimates from EngineeringUK, derived from FutureWorks 2014-2024, stated an annual demand for 124,000 engineers and technicians with core engineering skills.(12) (13) Based on existing apprenticeship and degree achievements at the time, the analysis estimated there was likely to be a shortfall of between 37,000 and 59,000 engineers each year. However, these estimates are now outdated, given that FutureWorks has been significantly updated and external shocks such as the coronavirus pandemic and cost of living crisis have exerted considerable pressure on the UK economy.

8. The engineering economy is a joint definition created by the Engineering Council, Engineering UK and The Royal Academy of Engineering. Their definition includes engineers working in engineering industries; engineers working in non-engineering industries; non-engineers working in engineering industries.
9. Royal Academy of Engineering: A hotbed of innovation: New research reveals engineering adds up to an estimated £645bn to the UK's economy annually, 2022.
10. Engineering UK: Trends in the engineering workforce: Between 2010 and 2021, 2022.
11. HM Treasury: Build Back Better, 2021.
12. Engineering and Technology: Engineering skills crisis: a multi-pronged problem, 2023.
13. Engineering UK: Key facts & figures: Highlights from the 2019 update to the Engineering UK report, 2019.

A more pertinent point is that there is no single authoritative estimate on the number of engineers and technicians required to support the UK's low-carbon transition. Separate research by EngineeringUK analysed 28 recent reports from different government departments and trade associations across multiple net zero sectors.[14] All had used different methodologies and analysed the skills market at differing levels of detail. This has resulted in a disjointed estimate of the required low-carbon jobs with an inconsistent understanding of the engineering specialisms needed from electrical, chemical, or mechanical engineering graduates and higher-level apprentices. In addition, the research found no UK-level assessment of the required number of annual A level, T level students and apprentices in STEM subjects. Only one report considered the number of students currently taking STEM A levels. The lack of centralised projections, especially in relation to low-carbon technologies, impacts the confidence of training providers and universities to run dedicated courses as there's a perceived risk of lack of demand.

The second challenge is the changing composition of occupations within the engineering sector, as illustrated by **Figure 5.** [15] Research by EngineeringUK describes how the COVID-19 pandemic "led to a rapid loss of employment in engineering". It shows that between 2019 and 2021, the number of people employed as "process, plant, and machine operatives" decreased by approximately -14.8%, while "skilled metal, electrical, and electronics trades" experienced a similar decline of -20.2%. In contrast, there had been a significant increase of around +15.1% in highly skilled "science, research, engineering, and technology professionals", typically working in R&D environments. However, it is important to note that growth in these higher-level occupations has been a long-term trend and is as high as +53.1% when compared to 2010 levels.

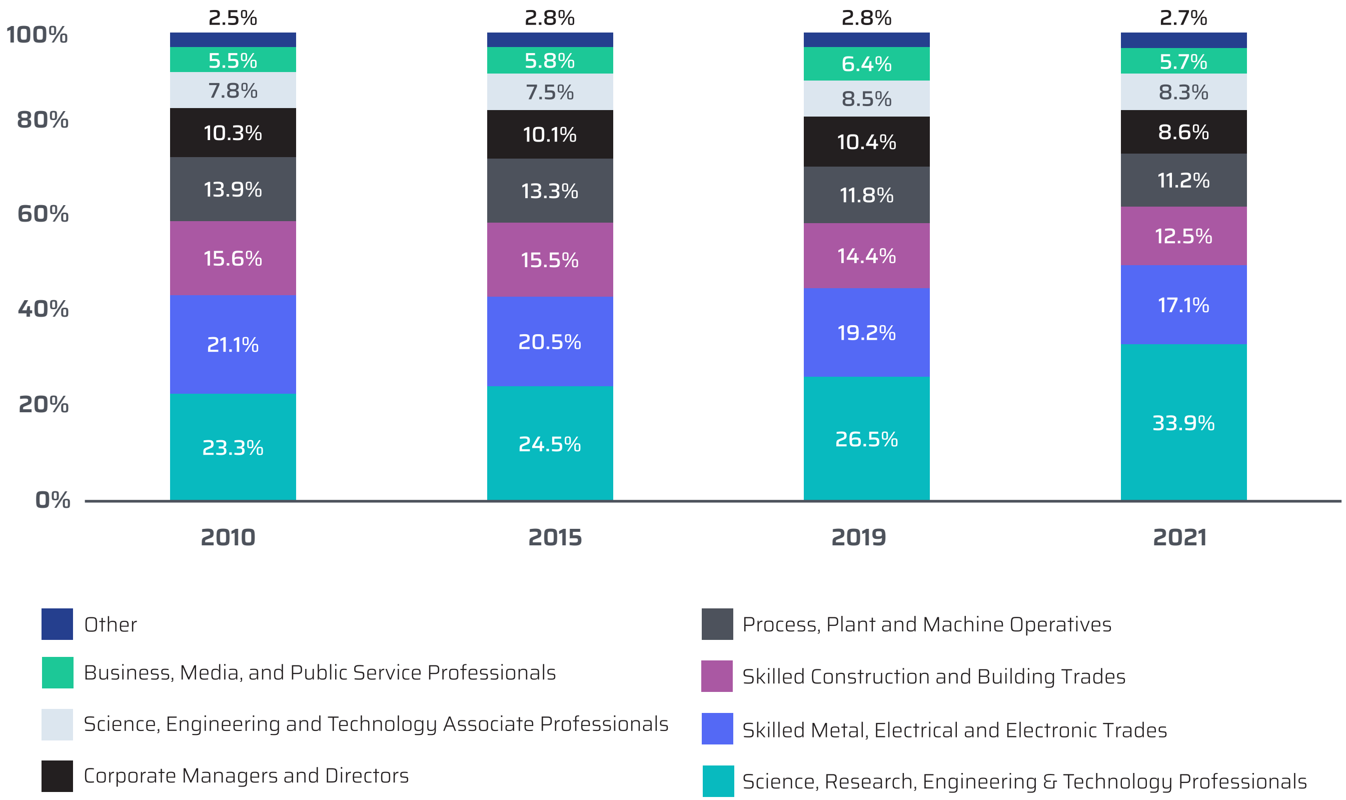


Figure 5: Breakdown of engineering occupations for workers in the UK engineering industry, 2010 to 2021

14. Engineering UK: Net zero workforce: An analysis of existing research, 2022.
15. Engineering UK: Trends in the engineering workforce: Between 2010 and 2021, 2022.

Figure 6 shows a macroeconomic analysis of the UK skills market conducted by the University of Warwick and Cambridge Econometrics that reinforces this trend.[16] Across a range of different scenarios, even factoring in varying levels of automation, 'professional occupations' are anticipated to have strong growth rates across all date periods.[17]

This suggests that despite the impact of disruptive technology, such as enhanced automation and AI, highly skilled engineering and science related jobs will still be in high demand. While this activity is undoubtedly vital for the UK economy, this trend could have more profound repercussions in the engineering and science sectors where manufacturing of low-carbon technologies is a priority.

Although the projections show an increase in demand for "process, plant and machine operatives" between 2020-2025, a subsequent decline is predicted between 2025-2035. However, the research also states, "there will be significant job openings and requirements for skills even in areas which are expected to see significant job losses."[18] Recruiting for intermediate skilled roles, such as operators and maintenance staff, is already a challenge in sectors facing immediate ramp-ups, such as batteries. This emphasises the need for a proactive approach to developing a robust talent pipeline across all levels.

The third challenge identified for the engineering sector is attracting a robust pipeline of talent. This is typically achieved through apprenticeships, graduate schemes, or by using the immigration system to supplement occupations that are experiencing acute shortages. The UK Skilled Worker visa Shortage Occupations List currently includes a range of engineering roles and disciplines, including 'mechanical' and 'production and process' engineers.[19]

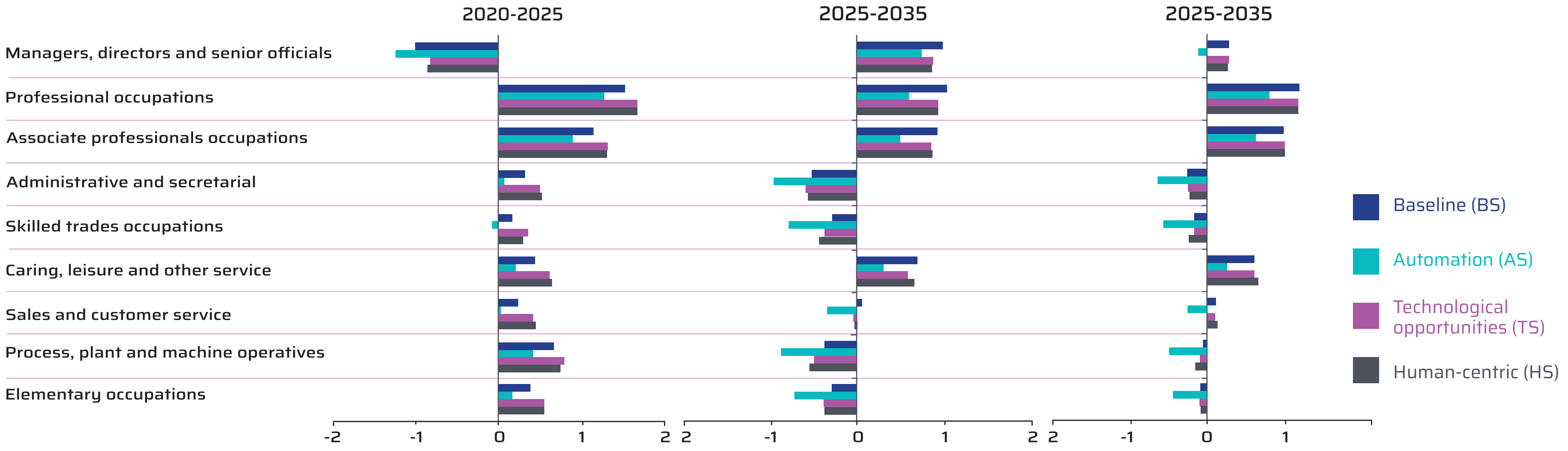


Figure 6: Net changes in employment, major employment groups, all scenarios 2020-2035

16. National Foundation for Educational Research, 2022. The Skills Imperative 2035: Occupational Outlook – Long-run employment prospects for the UK, Alternative Scenarios
17. Professional occupations' defined as science, research, engineering and technology professionals.
18. National Foundation for Educational Research, 2022. The Skills Imperative 2035: Occupational Outlook – Long-run employment prospects for the UK, Alternative Scenarios
19. Home Office: Skilled Worker visa: shortage occupations

Over the past few years, there has been a worrying decline in the total number of apprenticeships taking place in England. This includes starts within the 'Engineering and Manufacturing Technologies' Sector Subject Area (SSA) which fell by 35%, from approximately 75,050 in 2016/17 to 49,110 in 2021/22.[20] This fall was predominantly driven by a 39.2% drop in engineering-related apprenticeships at SMEs (0-249 employees). If we look specifically at starts at small businesses (0-49 employees), the data shows a significant 56% drop. This compares to a more modest 13.6% drop in starts at large organisations (250+ employees) over the same period.

Interestingly, the data shows that apprenticeships taking place at SMEs are more likely to be at lower levels. And so, the decline in engineering-related apprenticeships at SMEs has undoubtedly contributed to the 39% fall in starts at Levels 2 and 3, while starts at Levels 4+ experienced strong growth (albeit starting from a comparatively low base). This fall in lower-level starts presents a challenge to the sector's social mobility ambitions, with the data showing that learners from deprived areas are much less likely to attain an apprenticeship at higher levels. A fall in the number of apprentices being trained at science sector SMEs harms the talent pipeline for all companies by weakening an important entry point to a career in the sector. This results in fewer people with training and experience in the sector, while many companies continue to suffer from skills shortages.

The most likely explanation as to why large organisations are performing better than SMEs is the Apprenticeship Levy. Levy payers have a greater incentive to engage with the apprenticeship system. If they do not, they lose access to the often-substantial funds they have contributed. Despite access to public 'co-investment' funding that covers up to 95% of apprenticeship training costs, smaller organisations are not incentivised in the same way; the money is not 'theirs' to lose. It is also worth stating that SMEs often lack the dedicated internal staff resource needed to understand the different aspects of the technical education system and to set up and manage an effective apprenticeship programme. This is especially true given the constantly evolving nature of skills policy in recent years, which discourages engagement, particularly from time-poor SMEs that simply can't keep up.

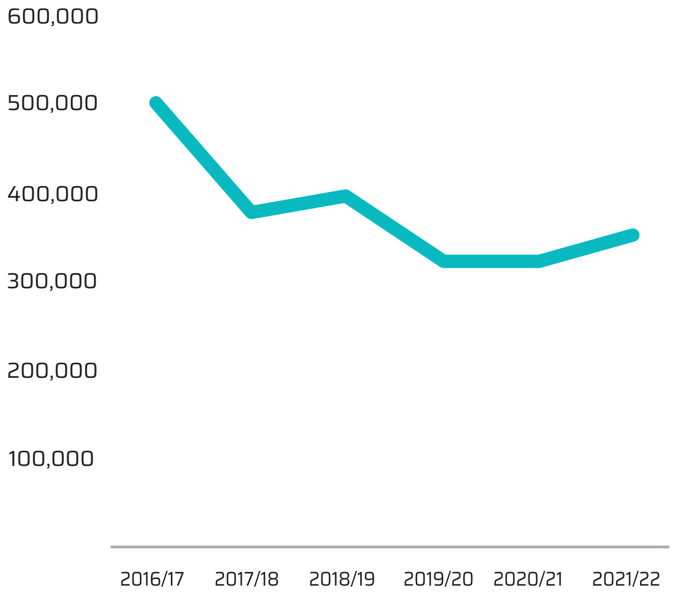


Figure 7: Apprenticeship starts in all subject areas (England)

20. Department for Education: Apprenticeships and traineeships, Academic Year 2021/22

Despite the overall trend of falling starts, the number of engineering-related apprenticeship starts showed a significant rebound in 2021/22 compared to the previous year, with a 24% increase. This compares to only a 9% increase across all sector subject areas. This suggests that despite broader issues within the UK apprenticeship system, engineering-related apprenticeships are faring relatively well in the post-COVID recovery.

According to data from the Higher Education Statistics Agency (HESA), higher education enrollments in engineering and technology related subjects increased from approximately 175,000 in 2019/20 to just under 186,000 in 2021/22.[21] [22] This places engineering and technology courses fifth in overall enrollments, above other popular broad subject areas like law and computing but below social sciences and subjects allied to medicine. Mechanical engineering was the most enrolled engineering-related course in 2021/22, with 35,000 enrollments.

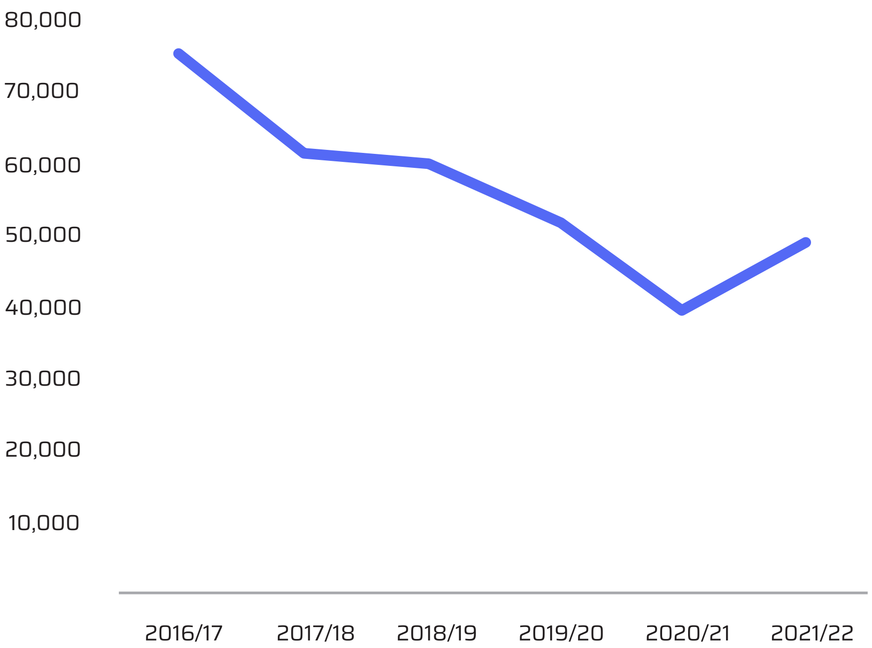


Figure 8: Apprenticeship Starts in Engineering & Manufacturing Technologies (England)

21. HESA captures "enrollments" across all different degree areas (undergrad, post grad, PhD) across all years of study. Therefore, the data provides a "stock" of the engineering pipeline at a given time across the university system.
22. HESA: What do HE students study? 2023

Important engineering job roles for low-carbon industries

Several engineering disciplines consistently emerged across the different technology areas during the occupation and skills mapping exercise. These tend to be broad engineering disciplines that are applicable across multiple sectors and range from highly skilled roles that require a degree level qualification to more intermediate roles that are typically apprenticeship-led. **Figure 9** below lists the most common roles found during the mapping exercise.

Skill level	Subject Area	Commentary
High skill level	Chemical Engineering	Highly relevant for low-carbon industries. Innovations and improvements in fuel cell and battery electro-chemistry are continuously occurring; hydrogen storage and carbon capture are reliant on innovations in chemical storage to enhance viability.
High skill level	Electrical / Electronic Engineering	Relevant for green hydrogen production given the links to renewable energy and power system. Highly relevant for batteries and fuel cells, especially when integrating them into systems. Also relevant for CCUS and nuclear sectors as they are situated in large sites.
High skill level	Software Engineering	Highly relevant across all technologies as most technologies and monitoring systems rely on electronic control units which need complicated software. Most technologies also rely on digital engineering for prototyping, virtual testing, and cloud-based monitoring software.
High skill level	Mechanical Engineering	Fundamental engineering discipline that's a core building block for all the six technology areas.
High skill level	Civil Engineering	Highly relevant for carbon capture, nuclear and hydrogen sectors as these involve large capital infrastructure projects that require an understanding of designing and constructing facilities and buildings.
	Manufacturing & Production Engineering	Straddles both high and intermediate skill levels as both degree and apprenticeship routes can lead learners to manufacturing and production engineering roles. Highly relevant for batteries and fuel cells which are mass manufactured products. Less relevant for carbon capture, nuclear and hydrogen as these are more capital/construction projects.
Intermediate skill level	Maintenance Technician	Highly relevant across all disciplines as manufacturing production lines and operations at carbon capture, hydrogen, and nuclear facilities require regular maintenance and operation.
Intermediate skill level	Quality Control Specialist	Highly relevant for batteries and fuel cells which are mass manufactured products and need to meet high customer specifications. Also relevant to hydrogen production in ensuring the purity of green/blue hydrogen and the quality of hydrogen coming from pipelines or refuelling stations. Relevant for nuclear in terms of safety and quality assessment and would be relevant for carbon capture in terms of inspection/monitoring of storage facilities.
Intermediate skill level	Production Line Operator	Highly relevant for batteries and fuel cells which are mass manufactured products. Less relevant for carbon capture, nuclear and hydrogen as these are more capital/construction projects.

Figure 9: Cross-cutting engineering roles and courses for low-carbon industries

Transitioning Industries

Figure 10: The technology maturity of transitioning industries

Beyond the growth of low-carbon industries, many established industries will also be required to transition their products and manufacturing processes to align with the UK's net zero ambitions. While all sectors need to change their business models and activity to some degree, transitioning industries in this report primarily focuses on downstream petroleum, chemicals, and polymers. Companies operating within these sectors are highly mature, with large infrastructure assets, high-volume production routes and highly skilled workforces. These industries also possess the capabilities and capital to pivot to new technologies. A brief overview of each of the core segments is given here.

DOWNSTREAM PETROLEUM

The oil and gas industry is usually divided into three major sectors: upstream, midstream and downstream. The downstream manages the import, refining, storage, distribution and retail of petrol, diesel, aviation, heating fuels and other petroleum products and ensures that supplies are available across the UK. The downstream sector comprises over 200 companies involved in the refining, importing, distribution and marketing of petroleum products. The sector plays a key role in the UK's energy security, supplying products that are essential to our way of life.[23] According to a study commissioned by the UK Petroleum Industry Association (UKPIA) in 2019, the downstream sector supports around 24,000 direct jobs with an associated UK GDP contribution of £4.5bn.[24] The dominant refiners in the UK are BP, Esso, and Shell. Other medium-sized refiners with a key hold on the downstream sector are Phillips 66, Petroineos, Essar, Valero, and Prax.

Sustainability is undoubtedly a priority for the sector, and companies are already investing considerable time and resources to plot their way forward. There are, in fact, a variety of potential pathways for the sector, including new technologies and processes to improve efficiency, lowering the carbon footprint of energy usage, production of lower-carbon fuels, and carbon capture. Companies such as Phillips 66 and Essar are leading the way with transformational carbon capture projects, as well as investing in biofuels to support the energy transition. Research by Deloitte underscores that this is a general trend in the industry, with global clean energy investments by the oil and gas industry rising by an average of 12% each year since 2020.[25] Regardless of the shape these changes may take, the fact remains that there will still be an essential role for liquid hydrocarbons in the short, medium and long term. However, it is highly likely that the hydrocarbons used in the future will be produced far less, potentially not at all, from fossil sources.

23. Department for Business, Energy and Industrial Strategy: Downstream Oil Supply Resilience, 2017.
24. Oxford Economics: The economic contribution of the UK downstream oil sector, 2019.
25. Deloitte: 2023 Oil and Gas Industry Outlook, 2022.

Nonetheless, a net zero future represents significant change for the downstream sector. Companies will increasingly need to find innovative ways to improve process efficiency and introduce new technologies to help them decarbonise. At the same time, scenarios looking at the energy transition required to achieve a net zero economy show a marked reduction in demand for liquid hydrocarbons in the decades ahead. The recent high commodity prices and growing concerns over energy security are creating urgency for many end-users to diversify supply away from oil and natural gas.

To ensure an orderly transition, it is vital to maintain secure supplies of fuel for the people and businesses whose livelihoods depend on it. To achieve this, the sector must have access to the essential skills it needs to minimise disruption and deliver the innovation required to improve efficiency and reduce carbon emissions. This period of change, therefore, also presents an opportunity to transform the sector as forward-looking with a unique and critical role in helping to deliver the nation's clean energy transition.

CHEMICALS

The chemicals industry is responsible for producing industrial chemicals and is a critical player in the global economy. It transforms raw materials such as oil, natural gas, air, water, metals, and minerals into useful products. Chemical production in the UK is mainly concentrated in 4 main clusters, connected by a pipeline to the key input feedstock, ethylene. The clusters are in the Northwest, Teesside, the Humber, and Grangemouth. The sector is hugely important to the UK economy, contributing just over £30bn worth of Gross Value Added (GVA). The latest statistical bulletin released by the Chemical Industries Association (CIA) shows that approximately 4,415 businesses are operating in the sector, directly employing over 150,000 people. It's also an incredibly productive segment of the economy with a GVA per employee of £203,000, which is 280% higher than the wider economy and 148% higher than the manufacturing sector.

The importance of sustainability is already deeply ingrained throughout much of the UK chemicals industry. Recent analysis shows an 82% reduction in direct emissions across the sector between 1990 and 2018, while at the same time, production increased by 40%.[26] Having said that, a significant proportion of this progress was achieved before 2010, and most abatement and efficiency measures that are currently available and affordable have now been exhausted. For this reason, achieving and maintaining net zero remains a formidable undertaking for many sector companies.

The same analysis referenced above also shows that for every one tonne of CO_2 emitted directly, the products and solutions produced deliver a saving of at least two tonnes in the sector's customer industries. As such, the chemicals industry will play a critical role in decarbonising the UK's economy, and as one of the nation's largest manufacturing exporters, the chemicals industry is well placed to help deliver the Government's clean growth agenda. The UK Government explicitly highlight the chemicals sector's potential contribution to net zero via being a supplier for hydrogen, batteries, and synthetic fuel sectors.[27]

26. Chemical Industries Association: Accelerating Britain's Net-Zero Economy, 2020
27. Department for Business and Trade: Chemicals, 2023.

POLYMERS

Polymers are a widely used foundational material that's usage ranges from packaging plastics to carbon fibre composites used in wind turbines and hydrogen storage tanks. The British Plastics Federation estimates that the wider plastics and polymers industry employs around 162,000 people with a turnover of £27bn. The UK currently produces around half as much polymer as it consumes (1.67m tonnes produced in 2020 vs 3.3m tonnes consumed) and is therefore heavily reliant on imports of raw material. The major manufacturers tend to be large companies such as Ineos, Basell Polyolefins, Sabic, Inovyn and Lotte Chemicals. These companies all engage in advanced R&D alongside their production facilities, so they require a broad range of highly skilled workers qualified at a degree level, as well as lower-level operations and maintenance staff.

Research is increasingly focussed on the development of natural polymers, biodegradable polymers, and bio-based plastics. These materials are derived from renewable sources such as plants and can reduce dependence on fossil fuels, lower greenhouse gas emissions, and help address plastic waste issues. Innovations in the production of bio-based plastics, such as polylactic acid (PLA) and polyhydroxyalkanoates (PHAs), have already gained traction, offering performance characteristics similar to traditional petroleum-based plastics while being biodegradable or compostable. This area is likely to experience significant growth in the coming years as industries and consumers seek more sustainable solutions.

At the same time, the industry is embracing the circular economy model to reduce waste, increase recycling rates, and optimise the use of resources. Companies are investing in innovative recycling technologies and infrastructure to promote a closed-loop system, where plastics are reused, remanufactured, or recycled instead of being discarded. This includes working to engage consumers and raise awareness about the responsible use and disposal of plastics, encouraging more sustainable choices and behaviours. Further efforts are being made to minimise the carbon footprint by improving energy efficiency, adopting cleaner energy sources, and exploring carbon capture technologies. By implementing these measures, the polymers industry aims to align with national and global climate goals, ensuring a more sustainable and environmentally responsible future.

As **Figure 11** shows, polymer manufacturing is strategically placed around industrial clusters such as Teesside, the Northwest and Scotland. These locations map well onto the initial rollout of carbon capture and hydrogen for heavy industry, so are well placed to tap into the wider industry networks.

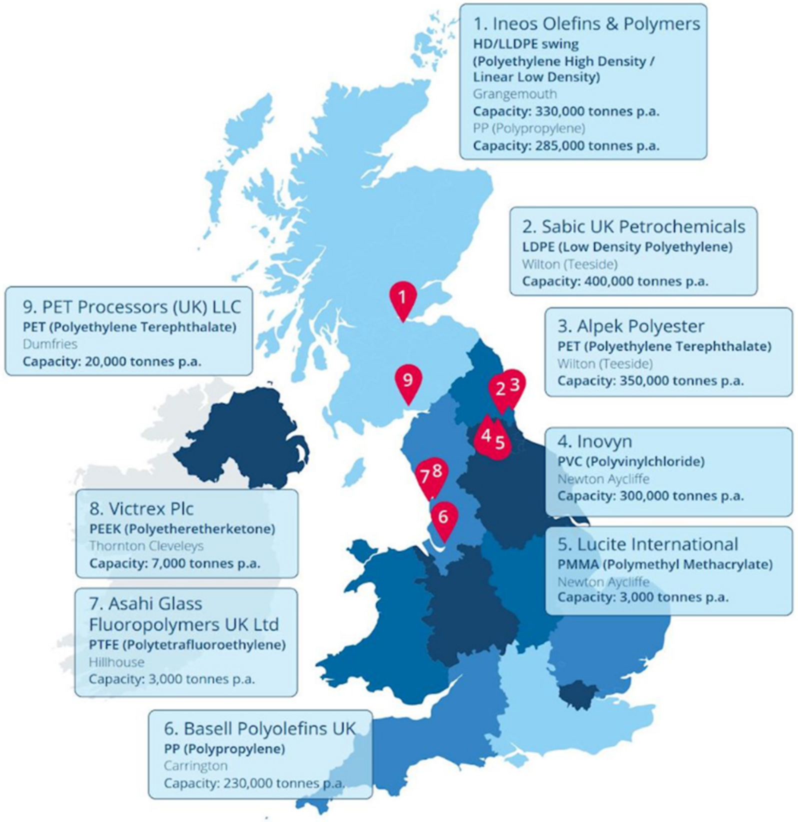


Figure 11: Map of major UK polymer manufacturers[28]

28. British Plastics Federation: About the British Plastics Industry, 2022.

OCCUPATIONAL AND SKILLS MAPPING

Given the extensive scale and scope of decarbonising downstream, chemical production, and polymers, mapping out the future skills requirements for these transitioning industries remains in its early stages. Nevertheless, their maturity has led to a well-developed ecosystem and analysis supporting skills development, with a wealth of literature available on existing roles and necessary qualifications.

Figure 12 offers an overview of the indicative job roles and qualifications for various aspects of transitioning industries. While current courses play a crucial role in supporting these industries' ongoing activities, additional courses will likely be needed to facilitate the net zero transition. As the transition progresses, continuous monitoring and evaluation of the skills landscape within these industries will be essential. This will ensure that workforce development efforts remain aligned with the changing requirements of these crucial sectors.

What's evident from this table is that the existing apprenticeships and degrees on offer broadly cater for these industries. As demonstrated in later sections, the occupations and skills required aren't drastically different from those needed for the low-carbon industries. For example, the polymers and chemicals industries have significant knowledge overlaps with both batteries and fuel cells, whereas downstream has similarities with hydrogen and carbon capture.

	Role	Skills / Qualifications Required
Downstream Petroleum	Project Manager	Accredited degree or global equivalent in relevant field of study. Chartered Engineering Status Ceng. Experience as project manager.
	System Engineer	HNC or equivalent in Engineering Systems
	Piping Design Engineering	BSc / BEng / HNC
	Cost Estimator	Degree in Quantity Surveying or Engineering.
	Regulatory Expert	Law degree plus Legal Practice Course / Bar Vocational Course
	Finance Manager	ACCA or CIMA qualifications
	Safety & Occupational Health Specialist	Bachelors degree

Figure 12: Roles and skills / qualifications required for transitioning industries

	Role	Skills / Qualifications Required
Chemicals	Product Developer	Degree (or equivalent) in mechanical engineering or chemical engineering
	New Product Introduction Manager	Chemistry degree
	Plant / Production Manager	Chemicals background
	Senior Process Engineer	Master's degree in chemical engineering
	Chemical Engineer	BEng in chemical engineering
	Senior Gas Laboratory Technician	Science or Chemistry Higher Education Qualification
	Building Maintenance Technician	Professional degree/designations/certifications/licenses legally required (i.e., RN, MD, VDM etc.)
	Production Technician	N/A
	Electrical Technician	NVQ, in an Electrical engineering discipline
	Manufacturing Technician	Diploma of Higher Education
	Chemical Process Operator	Secondary School Education to include a good standard of English and Maths Science Manufacturing Process Operative
	HQSE Manager / Assistant	Health & Safety and/or Environmental experience from a manufacturing environment
Polymers[29]	Engineering & Maintenance	Process Leader Apprenticeship Mechanical Engineering Materials Science Chemical Engineering Manufacturing Engineer Product Design
	Machine Operator	Science Manufacturing Technician Lean Manufacturing Operative Science Manufacturing Process Operative
	Operations & Management	Manufacturing Manager
	Process & Setting	Science Manufacturing Technician Lean Manufacturing Operative Science Manufacturing Process Operative Polymer Processing Technician

Figure 12: Roles and skills / qualifications required for transitioning industries cont'd

29. British Plastics Federation: Relevant Polymer Apprentice Standards, 2017.

CURRENT SKILLS SUPPLY

Broadly speaking, there are two parallel strategies that transitioning industries are taking to manage the transition. The first involves modifying existing feedstock products to support the low-carbon sector. The second involves broadening the scope of their operations to incorporate new low-carbon technologies. **Figure 13** offers a brief description of each strategy. It is worth noting that these strategies are not mutually exclusive, and most companies will utilise both to fully capitalise on the transition to net zero. At the same time, some overarching principles apply regardless of the chosen strategy, such as adopting environmentally friendly supply chain and procurement practices and making efforts to improve resource efficiency, reduce waste, and maximise productivity.

Tweaking existing products to support the low-carbon sector would have a less profound impact on reskilling the workforce. This is because the strategy leverages existing capital assets and know-how to divert activity away from carbon intensive products to more sustainable ones. There will be some adjustments in terms of quality control to meet different end use standards, but this strategy represents a less drastic reorientation of skills.

A key question that hasn't yet been answered is the scale at which transitioning industries' current products will still be needed and the corresponding level of employment, qualifications, and job roles necessary to support demand. Cogent Skills and the CIA conducted some qualitative research to gauge the scale of the transition.[30] Insights from the CIA's membership indicate the scale of job role change won't be drastic. One interviewee claimed, "The roles that are operating the plant, and the support roles all around that, will use different equipment or software, but actually, I don't see a fundamental difference in the required skill sets.". Of the new roles mentioned in the report, these tended to be in more strategic / engineering jobs that require an oversight on how sustainability and low-carbon technologies will influence multiple areas of the business.

The second strategy of expanding operational activity has a much more profound impact on skills in the transitioning industries. Developing new capabilities, either via acquisition or prolonged internal R&D, requires a more concerted effort to upskill and retrain a workforce. More data on the scale of demand and skills is therefore vital as it will aid transitioning industries in mapping out future labour requirements. Once the future workforce pinch points have been identified, transitioning industries can work towards planning recruitment and the creation of new roles for the low-carbon economy.

Transition strategy	Description
Tweak existing products to support a low-carbon transition	Redirect and ramp-up the production of existing feedstock products to support the low-carbon sector. Examples include needle coke for battery anodes, advanced polymers for fuel cell electrolytes or novel chemicals for hydrogen storage.
Expand the scope of activities to include low-carbon technologies	Expand the scope of business activities to enter new value chains. Examples would include downstream companies acquiring CCUS related technology capability or chemical companies developing capability in battery chemicals.

Figure 13: Brief overview of the two identified transition strategies

30 Chemical Industries Association & Cogent Skills: Future Skills for the Chemical Industries, 2022.

A key challenge for companies within these transitioning industries will be attracting the workforce needed to maintain operational resilience while they advance their strategies for long-term sustainability. **Figure 14** shows a breakdown of apprenticeship starts taking place at science companies in England since 2015/16. The data show a significant fall in the number of apprentices being trained at Chemicals companies (-48%), Downstream Petroleum companies (-52%), and in the Polymers industry (-70%). In comparison, there has been some modest growth in apprenticeship use in the Pharmaceuticals industry (+4%) and strong growth in Scientific R&D (+42%).[31]

This may be influenced by several factors, including the size and makeup of companies within the industry. The data show that apprenticeship starts at SMEs have dropped significantly compared to starts at large Apprenticeship Levy paying organisations. It is, therefore, unsurprising that industries with a high prevalence of large employers (e.g. Pharmaceuticals) have fared better than those where the majority of employees work for SMEs (e.g. Polymers). Equally, the number of starts in an industry is influenced by the range and quality of apprenticeships on offer.

Growth in the number of Pharmaceuticals starts is helped by the availability of an appropriate range of degree-level apprenticeship standards, such as L6 Clinical Trials Specialist and L7 Bioinformatics Scientist. If there is a lack of appropriate options available to serve a particular industry, the number of apprenticeship starts will likely fall. It remains critical that employers continue to support the development of both new and existing apprenticeship standards to ensure they are up-to-date and fit for purpose.

A report by WorkSkills UK and the Learning and Work Institute on young people's attitudes towards green skills and net zero reported that 80% of young people believe it is very (28%) or quite (51%) important to work for an organisation that is committed to tackling climate change.[32] However, a consistent theme across the stakeholder workshops was that a potential lack of understanding means there is a perception that these industries are not always viewed as being integral to the transition to net zero. This problem is especially true of new entrants into the labour market and the impact of this is already being felt within industry. Research by Cogent Skills and UKPIA reports that 62% of downstream companies believe it will become increasingly difficult to recruit staff with the right skill set in the future, despite them being central to an orderly transition to a low-carbon economy.[33]

However, this problem is not just confined to new entrants with the same report highlighting that retaining existing talent will also become increasingly difficult in the future. When asked what the main challenges were in retaining their existing staff, 62% of employers said competition from other sectors was a factor, while over 50% said some employees see no compelling future for the sector beyond what it does now. This was reinforced in the workshops, with one downstream employer anecdotally referring to younger members of their workforce moving into other areas of the low-carbon economy. If the transitioning industries aren't viewed as being part of the solution, they will struggle to attract the workforce required to deliver the large disruptive technological improvements that are so important to the national effort for net zero.

Industry	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
Chemicals	1,048	1,023	650	838	813	550
Downstream Petroleum	111	55	43	86	96	53
Pharmaceuticals	357	275	336	322	417	370
Polymers	3,176	3,928	2,145	1,783	1,391	963
Scientific Research& Development	398	387	597	749	577	546
Total	**5,090**	**5,668**	**3,771**	**3,778**	**3,294**	**2,482**

Figure 14: Breakdown of apprenticeship starts at science companies in England by industry.

31. Science Industry Partnership: Building tomorrow's workforce, Insights into the adoption of apprenticeships in the science sector, 2023
32 WorldSkills UK & Learning and Work Institute: Skills for a net zero economy: insights from employers and young people, 2022.
33. UK Petroleum Industry Association & Cogent Skills: Future Skills for the Downstream Sector, 2022.

Hydrogen

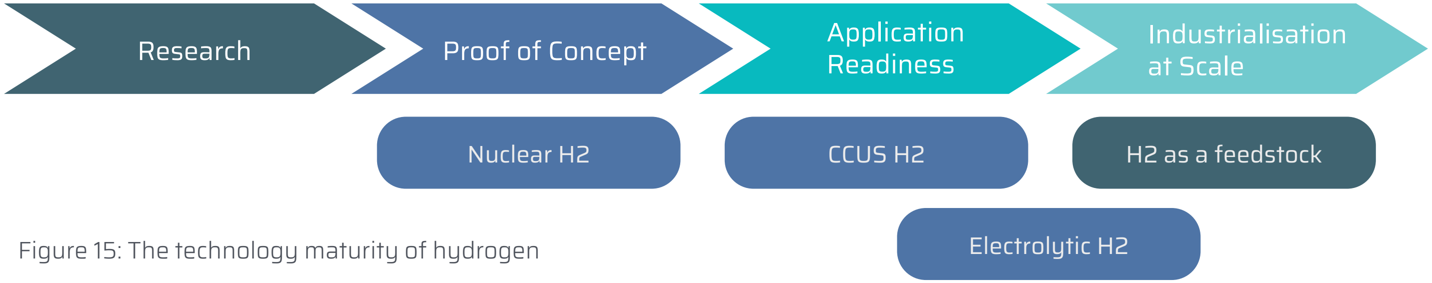


Figure 15: The technology maturity of hydrogen

SUMMARY OF TECHNOLOGY AREA

Hydrogen has been used for many years as an input into industrial processes such as ammonia production and within oil refineries, which is why it is categorised as 'Industrialisation at Scale'. It has been produced in the UK for more than 100 years, notably at INOVYN's manufacturing site in the Northwest via the chlor-alkali process. Other forms of hydrogen production, such as electrolytic, carbon capture, and nuclear, are being explored but are all further behind the development curve than industrial use.

As the global race to decarbonisation accelerates, hard-to-treat and hard-to-electrify sectors including industrial processes such as steel, cement and chemicals, require addressing. As a versatile replacement for high-carbon fuels, hydrogen is an ideal low-carbon energy vector for those sectors that require flexible energy for power, heat, and transport. It is a useful alternative because it can be combusted in boilers, turbines, or engines. The versatility is further evident in its ability to be stored in various forms such as pressurised gas, liquid or via a carrier like ammonia.

Domestic production and use of hydrogen in the UK presents a significant opportunity to deliver economic growth and both retain and create thousands of new jobs. The Hydrogen Sector Development Action Plan highlighted evidence to suggest that a UK hydrogen economy could support over 12,000 jobs by 2030 and up to 100,000 jobs by 2050.[34] A key route to achieve this was championing localised production. The Hydrogen Strategy committed the UK to a 'twin track' approach to domestic hydrogen production, supporting both 'green' (electrolytic) and 'blue' (carbon capture-enabled) production methods. Initially setting a target of 5GW, modelling referenced in the Strategy showed that such a production capacity has the potential to deliver total emission savings of around 41MT CO_2 equivalent between 2023 and 2032.[35] In response to the conflict in Ukraine, the production target was doubled in the British Energy Security Strategy to 10GW by 2030, with at least half of this to be from electrolytic. Achieving this would materially contribute to the UK's Nationally Determined Contribution (NDC) and Paris Agreement target of reducing emissions by 68% compared to 1990 levels by 2030.[36]

Despite the ideal characteristics of hydrogen, production and distribution have only recently started globally and more recently in the UK. As IEA reports, the global momentum behind hydrogen has been strong over the past year, however, developments are still below what is needed to achieve net zero emissions by 2050.[37] Compared to the UK, some countries possess a competitive advantage in adapting to producing hydrogen due to the larger domestic oil and gas sectors (carbon capture-enabled production) and/or access to renewable energy (electrolytic production). While the UK is showing an increasing ambition to accelerate hydrogen deployment, it lags behind countries like Canada and Australia in terms of its workforce strategy and understanding of potential skills shortages.[38] The following sections offer a brief description of the main elements of the hydrogen value chain. This includes production, distribution, storage and end use applications.

34. Department for Business, Energy and Industrial Strategy: Hydrogen Sector Development Action Plan, 2022.
35. Department for Business, Energy and Industrial Strategy: UK Hydrogen Strategy, 2021.
36. Department for Business, Energy and Industrial Strategy: British Energy Security Strategy, 2022.
37. International Energy Agency: Hydrogen: Energy System Overview, 2022.
38. Resources and Engineering Skills Alliance: Hydrogen and Fuel Cell Career Guide, 2021.

PRODUCTION

The predominant form of hydrogen production in the UK is 'grey' hydrogen, which is commonly produced through steam methane reforming. In this process, methane reacts with steam in the presence of a catalyst, generating hydrogen, carbon monoxide, and carbon dioxide. To convert this into a low-carbon hydrogen product, carbon capture and storage (CCS) technology is used to capture the emissions during the production process. Methane can also be pyrolised to produce hydrogen and solid carbon, commonly called 'turquoise' hydrogen. This method does not produce carbon dioxide as a by-product, which makes it a more environmentally friendly option compared to steam methane reforming.

Another method of hydrogen production involves electrolysis of water; a process which uses an electric current to split water into its constituent elements—hydrogen and oxygen. When the electricity is supplied through renewable sources, the hydrogen generated is often referred to as 'green' hydrogen. This type of hydrogen is considered low or zero carbon because it does not produce any associated greenhouse gas emissions during its production. Where low-carbon hydrogen is produced from nuclear sources (thermally or via electrolysis), it is known as pink hydrogen. The decarbonisation of transport and industry will likely require a significant increase in nuclear sourced hydrogen to complement green production if the net zero target is to be reached.

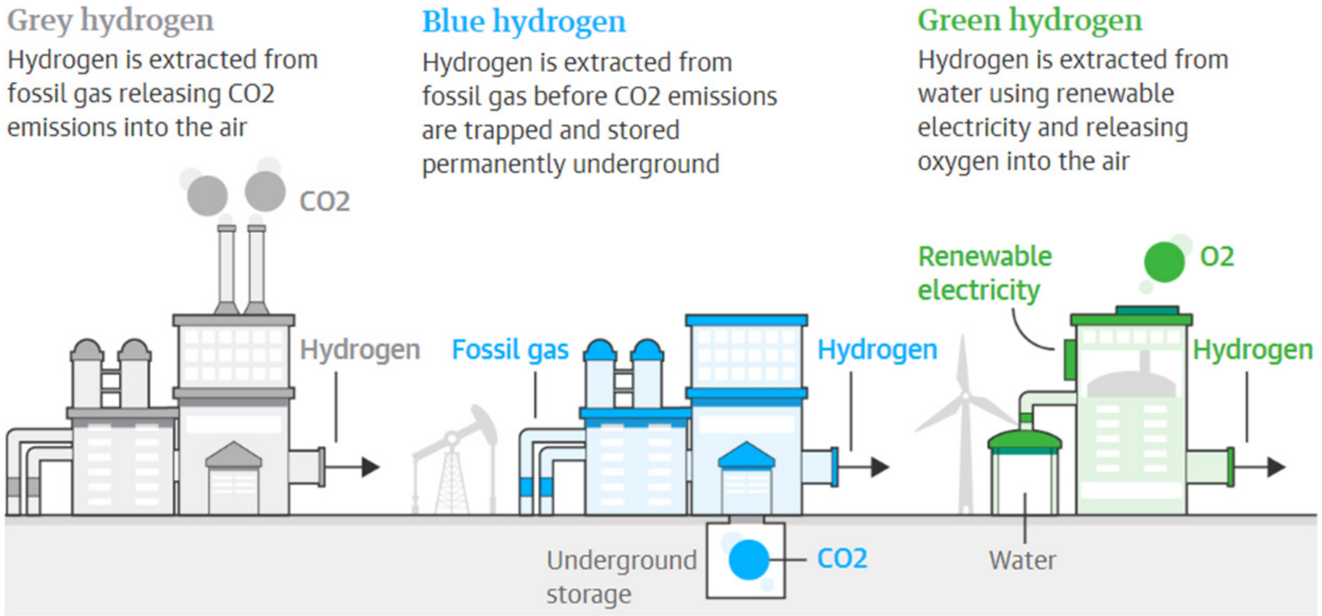


Figure 16: Three different types of hydrogen production[39]

39. The Guardian: 'We've got no choice': Locals Fear Life as Lab Rats in UK Hydrogen Heating Pilot, 2022.

DISTRIBUTION & STORAGE

Where hydrogen is not utilised immediately, it is distributed and stored as a gas, liquid or bound in a solid storage medium. Hydrogen is largely distributed in two ways. The first is via pipelines in cases where there is a concentrated demand and/or a significant distance between supply and demand. The second is via trucks or boats in cryogenic liquid tankers or gaseous tube trailers. Hydrogen can be stored in high pressure tanks, or on an industrial scale it can be stored underground in salt caverns, oil and gas fields or aquifers. Hydrogen can also be stored on the surfaces of solids through adsorption or within solids via absorption. Alternatively, where possible, surplus hydrogen can be injected into natural gas networks to create a hydrogen-enriched natural gas blend.

USE CASES

Hydrogen can be used in four broad sectors: industry, transport, power and heat. **Figure 17** taken from the UK's Hydrogen Strategy, shows the expected demand for hydrogen across these four sectors in 2030 and 2050.

Industrial clusters will form the largest consumers of hydrogen in the short to medium term. These clusters can take advantage of the existing hydrogen infrastructure to transition from carbon intensive to low-carbon hydrogen. This initial uptake provides confidence in the emerging hydrogen supply market while sharing costs for investment in infrastructure such as pipelines and storage facilities. The types of industrial users include industries where electrification may not be a cost effective or feasible option due to electricity grid constraints or the high grade of heat required. Outside of industrial clusters, smaller industrial users and heavy transport are looking to use electrolytic hydrogen, which can be deployed at a smaller scale to match individual/local requirements.

Hydrogen to power is another potentially large application, ranging from small, decentralised units to large grid-scale units. This can be coupled with hydrogen storage to act as a long duration energy storage medium. There is also the potential for hydrogen to play a role in space heating for both domestic and non-domestic buildings, using standalone hydrogen boilers, a hybrid system with heat pumps or in district heating.

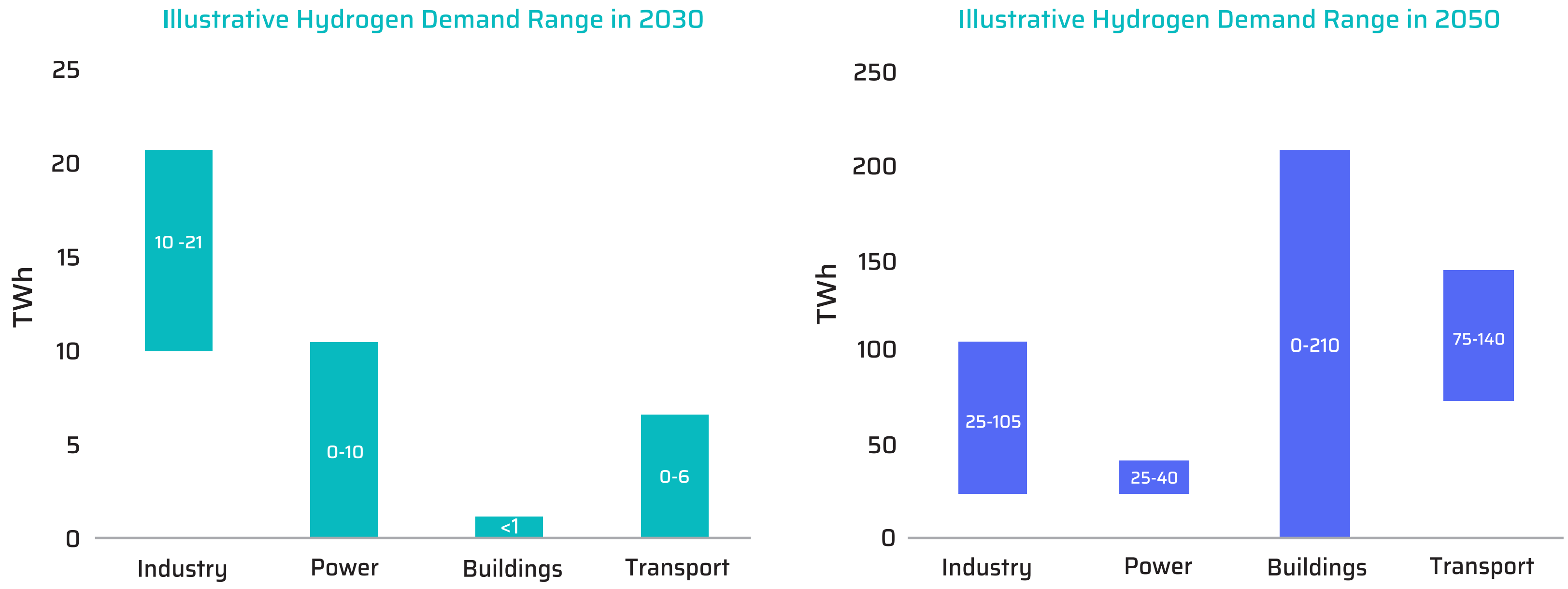


Figure 17: Demand scenarios in 2030 and 2050 from the UK Hydrogen Strategy[40]

40. Department for Business, Energy and Industrial Strategy: UK Hydrogen Strategy, 2021.

OCCUPATION AND SKILLS MAPPING

To realise the ambitions of the emerging hydrogen sector, a workforce with the right proportion of skills in each area, level, and location must be built. For this to happen, industry must come together to more accurately and thoroughly map the jobs required, including the relevant skills and training, across all project phases and sectors to meet the hydrogen production and demand projections. This is a role for the newly created Hydrogen Skills Alliance, which will lead the conversation on skills strategy and develop new solutions to support the low-carbon workforce. According to the latest Low Carbon and Renewable Energy Economy (LCREE) data, approximately 600 people are working in alternative fuels, of which hydrogen is a core component. This is far off the 12,000 jobs estimated by 2030 and the upper limit of the 100,000 jobs the hydrogen sector could support up to 2050.[41] **Figure 18** is an excerpt from the UK Hydrogen Strategy that states the high-level milestones and objectives needed to achieve this ramp-up in job action for skills.

This rough outline was followed by the Hydrogen Sector Development Action Plan, which further established actions to boost skill development. This outlined the Government's intention to continue working with industry to understand the specific technical skills needed, implement a skills action plan, and develop the hydrogen gas installation standards, competence frameworks and training specifications. Prior to this, BEIS commissioned Energy & Utility Skills to develop and deliver the Hydrogen Competency Framework as part of the Hy4Heat program.[42] The scope of that research primarily relates to the domestic end-use of hydrogen, with a focus on the skills gaps, practical skills and knowledge required, and the training needs for jobs related to the installation and maintenance of new hydrogen appliances. For this reason, the chart below is an integrated list of hydrogen jobs, their corresponding value chain steps, and the required levels, based on Canada's Transition Accelerator's Workforce Assessment Tool, which provides a more complete representation of the full hydrogen value chain.[43] To cross-check this work, other sources, such as Bezdek et al. which looks at the US job market, and a study carried out by PwC in Australia.[44] [45]

The Australian report estimates that by 2030, their hydrogen workforce will be comprised of approximately 21% Engineers; 60% Technicians and Tradespersons; 5% Logistics; 7% Management; 6% Safety and Quality Control; and 1% Specialists. Applying these ratios to the UK's workforce projections suggests that by 2030, the UK's hydrogen industry could require the following:

- 2,550 Engineers
- 7,200 Technicians and Tradespersons
- 600 Logistics personnel
- 800 Management professionals
- 700 Safety and Quality Control personnel
- 150 Specialists

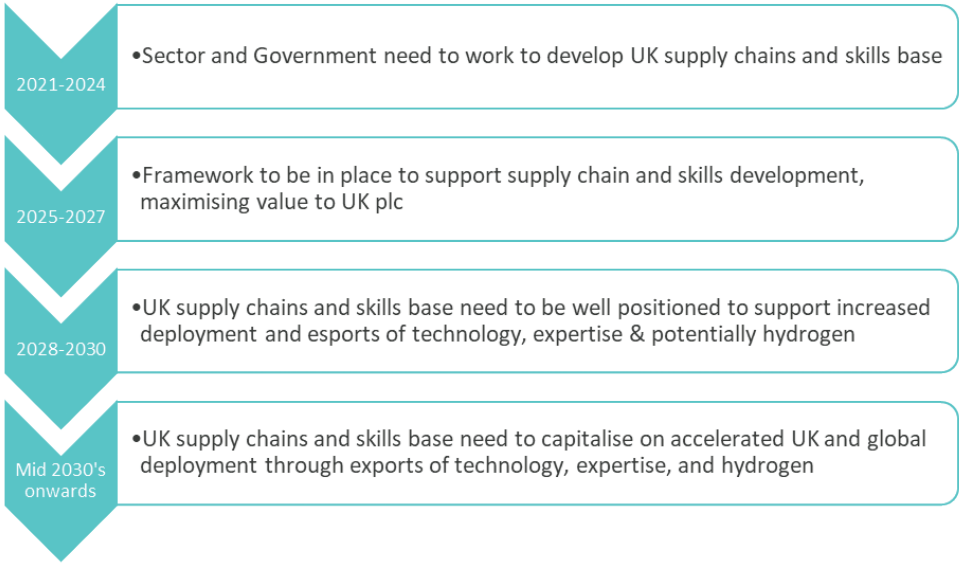


Figure 18: The UK Hydrogen Strategy's plan of action for skills development

41. Department for Business, Energy and Industrial Strategy: Hydrogen Sector Development Action Plan, 2022.
42. Energy & Utility Skills: Hydrogen Competency Framework Report, 2021.
43. The Transition Accelerator: Assessing the Workforce Required to Advance Canada's Hydrogen Economy. Report Plus Hydrogen Workforce Assessment Tool, 2022.
44. Renewable Energy and Environmental Sustainability: The Hydrogen Economy and Jobs of the Future, Bezdek et al, 2019.
45. PwC: Developing Australia's Hydrogen Workforce, 2022.

Figure 19 summarises the key activities in the hydrogen value chain with a more detailed breakdown of specific qualification areas and job roles. The job types and competencies defined in all studies mentioned are expected to be like those required in the UK.

Value Chain Steps		Subject Areas	Job Types	
Low Carbon Hydrogen Production	PEM (Proton Exchange Membrane) Electrolysis, SMR (Steam Methane Reforming) and ATR (Autothermal Reforming)[46]	Instrumentation & Controls Electrical Engineering Electrochemistry Chemical, Process, Mechanical Engineering	Engineers	
			Automation specialist Control specialist Chemical/Process Engineer Electrical Engineer Electrical & Instrumentation Engineer Facility Engineer	Measurement Specialist Mechanical engineers Process control engineer Process safety engineer Production Engineer Renewable Interconnection Specialist
		Petrochemistry Petroleum technology Industrial electrician/mechanic Instrumental technician	Plant Operations & Maintenance	
			Control room operator Lab technician Maintenance planner	Maintenance trades Plant manager Plant operator

Figure 19: Roles and qualifications mapping for the hydrogen sector

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

46. There are more electrolysis methods than listed in the table and other technologies such as pyrolysis.

Figure 19: Roles and qualifications mapping for the hydrogen sector Cont'd

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

Value Chain Steps		Subject Areas	Job Types	
Storage, Upgrading and Transporting	Underground Storage of Hydrogen	Chemical, Mechanical, Petroleum Engineering Geological Engineering Geology Geophysics Industry mechanic Aerospace Engineering	Engineers	
			Drilling & Completion Engineer	Cavern engineer
			Field Operators	
			Drilling Crew Heavy duty mechanic Reservoir technologist	Service rig crew Well completions operator Well completions supervisor
			Geoscience Professionals	
			Geologist Geophysicist	Geotechnical Specialist
			Surface Facility Operations & Maintenance	
			Control centre operator Compression specialist	Maintenance trades Measurement specialist
	Hydrogen Pipelines	Automation, Instrumentation & Controls Electrical Engineering Instrumental Engineering Aerospace, Chemical or Mechanical Engineering Petroleum Engineering Civil Engineering Materials, Metallurgical Engineering Power Engineering Business, Commerce	Engineers	
			Automation and control technician Compression specialist Corrosion Specialist Electrical & Instrumentation Engineer	Measurement Specialist Pipeline Engineer Pipeline Integrity Specialist Process Safety Engineer
			Operations & Maintenance	
			Control Centre Operator Pipeline Scheduler	Pipeline Technicians Station Operators
	Hydrogen Distribution by Truck	Refrigeration and Air Conditioning, Heavy Duty or Instrumentation Supply Chain or Logistics Designation Drivers Licence	Truck Transport	
			Cylinder technician Heavy duty mechanic	Logistics Coordinator Tank Inspector Truck Drivers (Class 1 & 3)
	Ammonia as a Chemical Carrier of Hydrogen	Automation, Instrumentation, Controls, Electrical Engineering Process or Mechanical Engineering Power Engineer	Engineers	
			Automation and Control Specialist Electrical & Instrumentation Engineer Facility Engineer Measurement Specialist Mechanical Engineers	Process Control Engineer Process Engineer Process Safety Engineer Production Engineer
			Plant Operations & Maintenance	
			Control room operator Lab Technician Maintenance Planner	Maintenance Trades Plant Manager Plant Operator

Value Chain Steps		Subject Areas	Job Types	
Expanding existing and creating new markets for low-carbon hydrogen	Transporting Using Hydrogen	Heavy duty mechanic Truck and Transport Certification Management Supply Chain/Logistics Battery/Storage Thermal System Cooling Locomotive Engineering Chemical, Mechanical Engineering	Transportation (end-user)	
			Dual fuel heavy duty mechanic Fleet Manager Fuel cell electric vehicle technician	Locomotive engineer Locomotive mechanic Transportation solutions advisor Transit Operator Truck Driver
	Hydrogen Fuelling Stations	Automation, Instrumentation & Controls Electrical Engineering Chemical, Mechanical Engineering Supply Chain/Logistics Business Aerospace Engineering	Engineers	
			Automation & Control Specialist Electrical & Instrumentation Engineer Mechanical Engineer	Process Controls Engineer Process Engineer Process Safety Engineer Quality Engineer
			Operations & Maintenance	
			Fuelling Station Technician Maintenance Technician	Logistics Coordinator Truck Driver (Class 1 & 3)
	Heating Using Hydrogen	Mechanical Engineering Low Carbon Transition Construction Safety Welding Refrigeration and Air Conditioning Civil Mechanical Engineering Gas Utility	Asset Performance Manager Hydrogen Integration Specialist Gas Fuser Gasfitter HVAC Technician	Utility Inspector Utility Operator Utility Service Planner Utility Service Technician Welding Engineer
	Power Generation Using Hydrogen	Automation, Controls, Instrumentation Electrical Engineering Chemical, Mechanical Engineering Commerce Economics	Engineers	
			Automation and Control Specialist Compression Specialist Electrical Engineer Electrical & Instrumentation Engineer Facility Engineer	Hydrogen Integration Specialist Mechanical Engineer Process Control Engineer Process Engineer Process Safety Engineer
			Plant Operations & Maintenance	
			Control room operator Maintenance Planner Maintenance Trades	Plant Manager Plant Operator Power Scheduler
	Manufacturing for the Hydrogen Economy	Automation, Instrumentation & Controls Electrical Engineering Mechanical, Chemical Engineering Robotics Manufacturing Mechanical, Mechatronics Supply Chain Inventory Management Electro-Mechanical Engineering	Product Design, Assembly, Quality Control	
			Applications Engineer Assembly Technician Compliance Specialist CNC Fabrication Technician Design Engineers Manufacturing Engineer Materials Specialist Pipefitters/Steamfitters	Production Scheduler Production Supervisor Quality Control Specialist Service Technician Sourcing Specialist Test Technician Test Validation Engineer Welder
			Facility Operations & Maintenance	
			Facility Maintenance Planner Maintenance Trades	Mechatronics Engineer

Figure 19: Roles and qualifications mapping for the hydrogen sector Cont'd

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

Although it is reported in the Green Jobs Taskforce that over 90% of the UK's oil and gas workforce have medium to high skills transferability into other energy sectors, there is only medium transferability to the hydrogen sector, and this is only specific to blue hydrogen.[47] It was estimated that approximately 50% of the 200,000 total jobs in the UK offshore energy sector in 2030, which includes hydrogen, will be filled by workers transferring from the oil and gas sector, new graduates and recruits from outside the offshore energy sector. However, more research and analysis is needed to understand the specific details at a job type and location level. Although much knowledge and skills are transferable, a report by The Transition Accelerator identifies knowledge-base and skills gaps between hydrogen and the oil and gas sector.[48] Based on this report and others, the specific areas that require upskilling and reskilling include:

- Deep experience in the processing, compression, pipeline transmission, truck transportation and safe handling of gas and liquid fuels
- Hydrogen hazard risk analysis and reviews
- Mechanical integrity and instrumented system analysis and operation readiness inspection
- Selection and application of materials, coatings and sealants, equipment, and measurement and detection technologies appropriate for hydrogen
- Understanding of electrochemical processes and ability to install, troubleshoot, service and maintain equipment and technology associated with the deployment of hydrogen fuel cells, electrolysers, etc.
- Knowledge and understanding of regulations, codes and standards
- Expanded training for fire, law enforcement and emergency medical personnel required to respond to incidents involving hydrogen and hydrogen fuel cell vehicles
- Training for working in underground storage of hydrogen gas, which includes specialised knowledge for assessing salt caverns
- Construction using drilling and completions
- Maintenance using mechanical integrity testing (MIT) and well workovers and surface infrastructure for ongoing operation and controls

Although these findings relate to Canada's workforce, it aligns well with separate studies conducted by Bezdek et al. in the US and by PwC in Australia.[49] [50] The desk research and jobs mapping also uncover that a significant proportion of jobs in the hydrogen will require Level 6+ qualifications, long term professional development and relevant trade certificates. And while hydrogen is highly adaptable to the existing energy systems, the different chemical properties and processes mean that workers require specific training and a different set of skills.

47. Green Jobs Taskforce: Report to Government, Industry and the Skills Sector, 2021.
48. The Transition Accelerator: Assessing the Workforce Required to Advance Canada's Hydrogen Economy. Report Plus Hydrogen Workforce Assessment Tool, 2022.
49. Renewable Energy and Environmental Sustainability: The Hydrogen Economy and Jobs of the Future, Bezdek et al, 2019.
50. PwC: Developing Australia's Hydrogen Workforce, 2022.

CURRENT SKILLS SUPPLY

As we map out the skills needed for the transition to a hydrogen economy, the size and composition of the future workforce become clearer. The first wave of projects seeking funding via the UK Government's revenue support scheme are set to make final investment decisions within the next 12 months. As these projects progress and begin to define their specific labour and skills requirements, they can serve as a reference point for predicting acute skills shortages in the sector as it grows. Nevertheless, several challenges and barriers have already been identified during the stakeholder engagement workshops and literature review.

A recent report by the Energy & Utilities Skills Partnership (EUSP) assessed the current UK energy sector workforce.[51] It raised concerns of a shrinking talent pool, citing projections that 27% of the current workforce will retire in the next decade. When this is combined with the growth of new and replacement jobs, they estimate the need to replace or retrain 48% of the current workforce, equivalent to 277,000 vacancies in the next ten years. This was reflected in the stakeholder workshops with broad agreement (particularly among traditional oil and gas employers) that it has become increasingly difficult to retain workers in the sector, primarily due to retirement, but also as the workforce feels less confident investing their career in the sector. While it is noted that companies looking to produce and use hydrogen are not exclusively oil and gas companies, they do account for a significant portion of the jobs required in the emerging hydrogen sector.

Policies such as the gradual phasing out of the internal combustion engine fuel the perception that the industry's future is uncertain and that there will be limited opportunities for career growth. At the same time, competition for workers is intensifying with the growth of renewable energy sectors, such as solar and wind, that do not suffer from the same attraction and perception issues. This has led to recruitment gaps where there are no skills in-house, and companies need to outsource for certain professions. This recruitment gap aligns with EUSP's insight into the general shift away from lower-level STEM and engineering vocational qualifications, a trend of decreasing number of Level 2 certificates awarded in the UK, and the attractiveness of Level 3 and above qualifications. If traditional oil and gas companies cannot attract and retain the workforce they require, it could impede the UK's ability to rapidly scale-up its hydrogen production capabilities and slow progress towards achieving net zero. Therefore, industry needs to take proactive measures to address concerns and emphasise the opportunities for innovation and growth in the sector.

The Australian PwC study concluded that, although not many new job roles were required (46 existing job roles could be 'augmented' to undertake hydrogen activities), training gaps existed for 85% of the hydrogen-specific capabilities identified for the job roles. In the UK, EUSP noted that an estimated 17% of energy sector workers would need more than six months of reskilling and 23% between one and six months. While this may help to maintain the size of the talent pool long term, workers who intend to remain will also need to take time away to retrain, creating challenging fluctuations in the workforce.

Participants also noted that there is uncertainty surrounding the level of qualifications required for certain jobs as well as overarching uncertainty of when this workforce will be required. This is due to perceived risks arising from indirect factors, such as delays in the provision of financial support for hydrogen production projects or a shortage of construction workers to carry out various infrastructure projects. This uncertainty makes it difficult to accept the risk of early pipeline development and discourages engagement with the apprenticeship market, as some companies are currently unable to guarantee employment upon completion of training. At the same time, providers need evidence that there is sufficient demand for viable cohorts of learners on relevant apprenticeship standards to encourage the supply and delivery of training. This misalignment between training and workforce demand creates challenges for companies seeking to invest in the development of skills required for future hydrogen deployment.

Nevertheless, despite some misalignment between training providers and industry, some universities have taken it upon themselves to develop bespoke courses. Brunel in the Netherlands have developed the world's first accredited post-graduate hydrogen education program, training qualified professionals with technical and legal backgrounds to become Hydrogen Specialists. In the UK, the University of Birmingham Fuel Cell and Hydrogen Technologies MSc, and the PhD 'Hydrogen, Fuel Cells and their Application' offered by the University of Nottingham are two early examples of degree level qualifications specifically addressing the hydrogen sector.

51. Energy & Utilities Skills Partnership: Workforce Renewal and Skills Strategy, 2020.

Case Study: First National Occupational Standard for Hydrogen Production, Storage and Transportation

Cogent Skills have been working with employers and stakeholders to develop the UK's first National Occupational Standards (NOS) for hydrogen production, storage, and transportation. Developing these new standards is a critical step towards establishing a highly skilled and competent workforce. They set out the standards of performance individuals must achieve, together with the knowledge and skills required to work safely and effectively in the hydrogen production, storage, and transportation industry. Recognised across all four nations, NOS are an important part of the skills landscape, recognised by employers, regulators and awarding bodies, and can be directly transferred into qualifications or training programmes, influence job descriptions or be used to measure workplace competence.

Carbon Capture

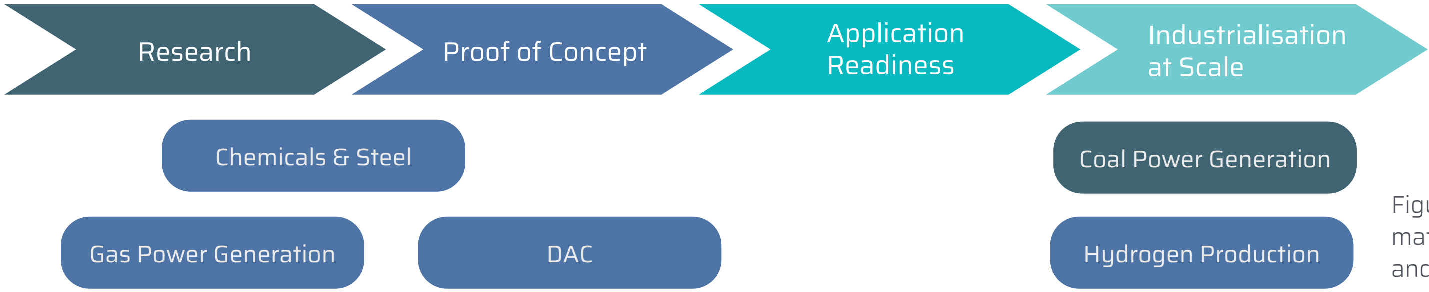


Figure 20: The technology maturity of carbon capture and storage

SUMMARY OF TECHNOLOGY AREA

Carbon Capture and Storage (CCS) is a suite of technologies that capture CO_2 emissions from industrial processes such as steel and ammonia production or from the burning of fossil fuels in power generation. The CO_2 is then compressed and transported via pipelines, road transport or ships to a site where it is injected into rock formations deep underground for permanent storage. Carbon Capture, Utilisation and Storage (CCUS) is a related concept, but instead of storing carbon, it is used in an industrial process by converting it into, for example, plastics, concrete or biofuel. Once carbon is captured, it can be stored permanently or used in a variety of different ways. Valuable materials such as carbon nanofibres and bioplastics can be produced from captured carbon, while several start-ups are developing methods of turning captured CO_2 into animal feed.

While the transition to a low-carbon economy is underway, in some sectors it is difficult to decarbonise fully. Industrial processes that use high temperature heat and long distance, heavy-duty transport still rely on energy dense fuels with high carbon emissions. CCS and CCUS are, therefore, often considered as a necessary solution to provide the energy required for these activities with little or no emissions. This technology also has a significant role to play for some of the most scalable greenhouse gas removal (GGR) technologies, such as bioenergy with CCS (BECCS) and direct air carbon capture with storage (DACCS). These technologies actively remove CO_2 from the atmosphere and are reliant on CCUS infrastructure to transport and store the CO_2 they capture. The Climate Change Committee (CCC) have been clear that to achieve net zero, these technologies will be required to balance residual emissions from some of the most difficult to decarbonise sectors.

The 6th UK Carbon Budget shows a prominent role for CCS and BECCS in its decarbonisation scenarios.[52]The CCC estimate that both these technologies could reduce 12 million tonnes of CO_2 equivalent by 2045, representing just under 20% of total UK industrial manufacturing emissions. CCUS is also important globally, with the IEA reporting that CCUS could contribute between one-quarter to two-thirds of emissions reductions in carbon intensive industries.[53] As these heavy industries are estimated to account for 20% of global CO_2 emissions, CCUS plays a significant role in realising decarbonisation. It is important to note that while CCUS is often treated as a supplement to existing infrastructure or carbon intensive processes, it is also a stand-alone solution to remove CO_2 from the atmosphere itself in the process of offsetting. As blue hydrogen is a key solution for the hard-to-electrify, high energy sectors, CCUS is considered in this report alongside the development of a hydrogen workforce.

52. Climate Change Committee: The Sixth Carbon Budget: The UK's Path to Net Zero, 2020.
53. International Energy Agency: About CCUS, 2021.

The successful deployment of CCS and CCUS relies on the availability of technologies at each stage of the process, including capture, transport, and utilisation or storage. However, technologies throughout the value chain vary in their levels of maturity, with many processes in the advanced pilot stage yet to be widely adopted and therefore cannot be considered as mature.(54) More than 40 CCUS facilities are currently planned or in pilot operation in the UK, with over half supplementing power generators and approximately one-quarter capturing emissions from hydrogen production.(55) However, many of these facilities are still in the small-scale pilot stage, and some are not yet operational. Despite the need to develop a workforce to support upcoming facilities and the extensive value chain, the CCUS sector in the UK is under pressure to meet the national ambition of capturing and storing between 20-30Mt of CO_2 per year by 2030.(56)

Generally, scaling up of CCUS is already complex due to the geological complexities and its early stage of development. However, the UK has one of the greatest CO_2 storage potentials of any country in the world, making it a particularly suitable and competitive geography to scale CCUS. It is estimated that the UK Continental Shelf could safely store 78 billion tonnes of CO_2, equivalent to 200 years of the UK's annual CO_2 emissions.(57) This accounts for approximately 85% of Europe's total CO_2 storage potential.

Unlocking this potential through the development of CO_2 transport and storage networks could generate strategic national assets that could, as well as storing our own emissions, store internationally imported CO_2; a market which, according to Government-commissioned analysis, could be worth up to £14 billion by 2050. A key challenge to scale CCUS in the UK remains the need for Government and the sector to develop the frameworks to deploy CCUS.(58)

With one of the largest potential CO_2 storage capacities in Europe, the UK is in the top 5 countries globally for CCUS readiness and ideally positioned to grow CCUS technology and deployment. In recognition of the sector's potential, the UK Government announced in the 2023 Spring Budget an allocation of £20 billion in funding for the early deployment of CCUS. Funding so far has supported the development of CCUS in four industrial clusters, also known as 'SuperPlaces' (59). While the Government estimates £8.3bn in potential total UK captured turnover from CCUS by 2050, the strategies and industry reports have highlighted that the skills sector remains a 'bottleneck'.(60) This is especially true since CCUS needs to compete for low to medium level roles that are also in demand from other energy sectors, such as hydrogen, and transitioning industries such as chemicals.

OCCUPATION AND SKILLS MAPPING

Carbon capture is currently an emerging industry, supporting approximately 700 jobs in the UK according to ONS LCREE Survey. It is widely recognised across CCUS stakeholders that there is little information about the current workforce in the UK, its capabilities, and the recruitment needed to meet the demands of the necessary workforce. While many stakeholders are conducting research in this area, there are some estimates to work from. The Government estimates that the UK CCUS sector could support up to 50,000 jobs by 2050.(61) It has also been reported that the existing UK engineering workforce has transferable skills that could be used to manage a CCUS project.(62)

Figure 21 provides an integrated list of CCUS jobs, the corresponding value chain steps, and the required levels, taken from Canada's Transition Accelerator's Workforce Assessment Tool.(63) This tool is a good representation of the CCUS value chain, and the job types and competencies defined in the Canadian study are expected to be similar to those required in the UK. And while the CCUS value chain is shorter than that of the hydrogen sector, it still requires a large proportion of Level 4-7 skills.

54. International Energy Agency: Energy Technology Perspectives 2020: Special Report on Carbon Capture Utilisation and Storage, 2020.
55. Global CCS Institute: Facilities Database, 2023.
56. HM Government: CCUS Net Zero Investment Roadmap, 2023.
57. Department for Business, Energy and Industrial Strategy: Policy paper: The Carbon Capture and Storage Infrastructure Fund, 2022.
58. Department for Business, Energy and Industrial Strategy: The UK Carbon Capture, Usage and Storage (CCUS) Deployment Pathway: An Action Plan, 2018.
59. Department for Business, Energy and Industrial Strategy: CCUS Supply Chains: A Roadmap to Maximise the UK's Potential, 2021.
60. Department for Business, Energy and Industrial Strategy: North Sea Transition Deal: CCUS Supply Chain Report, 2022.
61. HM Treasury: Build Back Better, 2021.
62. Department for Business, Energy and Industrial Strategy: North Sea Transition Deal: CCUS Supply Chain Report, 2022.
63. The Transition Accelerator: Assessing the Workforce Required to Advance Canada's Hydrogen Economy: Hydrogen Workforce Assessment Tool, 2022.

Figure 21: Jobs and qualification mapping for carbon capture, utilisation and storage

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

Value Chain Steps	Subject Areas	Job Types	
Carbon Capture	Automation, Instrumentation & Controls, or Electrical Engineering Mechanical Engineering Chemical or Process Engineering Petroleum Technology Laboratory Technician	Engineers	
		Automation & Control Specialist Electrical & Instrumental Engineer Facility Engineer Measurement Specialist	Mechanical Engineer Process Control Engineer Process Engineer Process Safety Engineer Production Engineer
	Power Engineer Stationary Engineer	Operations & Maintenance	
		Control Room Operator Lab Technician Maintenance Planner	Maintenance Trades Plant Manager Plant Operator
CO_2 Pipeline Transmission	Automation, Instrumentation & Controls Electrical Engineering Aerospace Engineering Chemical, Mechanical Engineering Corrosion Engineering Materials, Metallurgical Engineering Process Engineering Power Engineering Petrochemical engineering Business and Commerce	Engineers	
		Automation & Control Specialist Compression Specialist Corrosion Specialist Electrical & Instrumental Engineer	Hydraulics Engineer Measurement Specialist Pipeline Engineer Pipeline Integrity Specialist Process Safety Engineer
		Operations & Maintenance	
		Control Centre Operator Pipeline Scheduler Pipeline Technicians	Station Operators: Compression, Pump
Underground Storage	Chemical, Mechanical, Petroleum Engineering Geology Geophysics Oilfield Safety Certifications Drivers Licence	Engineers	
		Drilling & Completion Engineer	Reservoir Engineer
		Geoscience Professionals	
		Geologist	Geophysicist
		Field Operators	
		Drilling Crew Heavy Duty Mechanic Reservoir Technologist Service Rig Crew	Well Completions Operator Well Completions Supervisor
Measurement, Monitoring & Verification	Chemical, Mechanical, Petroleum Engineering Geology Geophysics Instrumentation Technician Biology, Environmental Engineering	Engineers	
		Measurement Specialist	Reservoir Engineer
		Geoscience Professionals	
		Geologist	Geophysicist
		Technologist & Technicians	
		Instrumentation Technician Reservoir Technologist	Sampling and Analysis Technician Seismic Crew

Carbon Capture: The jobs related to carbon capture are moderately specialised, typically requiring skill levels of 7 and above. Various types of engineers are needed with backgrounds in automation, mechanical engineering, and petroleum technology. There are also a small number of jobs within operations & maintenance which require level 3 skills and above, such as control room operators, lab technicians, maintenance trades, and plant operators.

CO_2 Pipeline Transmission: The jobs required in CO_2 pipeline transmission are relatively specialised, requiring skills ranging from engineering (hydraulics engineer, pipeline engineer, process safety engineer and electrical engineer) to chemistry (compression specialist and corrosion specialist). These engineering-based roles require level 6 skills and above, and the operations & maintenance (control centre operators, pipeline scheduler, and station operators) require level 5 skills and above.

Underground Storage: While many jobs in underground storage do not require high levels of skill, specialised training is still necessary. Field operators, who are essential for this stage, need training in drilling, heavy-duty mechanics, and servicing rigs. These professionals will require technical training but not necessarily degrees. On the other hand, engineering jobs such as drilling and completion engineer, reservoir engineer, and geoscience professionals such as geologists and geophysicists require skills at level 6 and above.

Measuring/Monitoring/Verification: Compared to the previous stages, this stage requires the fewest number of jobs. Reservoir engineers and measurement specialists are vital engineering roles that require skills above level 5. Geoscience professionals such as geologists and geophysicists must have at least a bachelor's degree. Monitoring also requires technologists and technicians in instrumentation and sampling/analysis roles, requiring skills above level 5. A seismic crew is also needed to measure and monitor underground storage; these roles do not require skills above level 5 however, specialised training is needed.

CURRENT SKILLS SUPPLY

While there are some insights around the type of jobs required in CCUS, there is currently a significant gap in the research around the current workforce profile and the future workforce needed in the UK. The main jobs in this area are in engineering and construction, followed by non-construction professionals, IT, and other office-based staff. Unfortunately, a recent report explained that while demand is especially surging in specialised skill areas such as nuclear engineering and construction, the UK construction skills gap is currently over 200,000 in July 2021.[64]

While there are some apprenticeship standards that are suitable for the transitioning industries, there are currently very few specialised routes into carbon capture. One possible exception is the recently developed Level 3 'Skills Bootcamp' In the Principles of Carbon Capture and Storage[65]. Some universities offer modules on Carbon Capture, such as Herriot Watt, Imperial College, and the University of Edinburgh.[66] The UK Carbon Capture and Storage Research Centre (UKCCSRC) occasionally delivers CPD style courses such as a CCUS for Net Zero Seminar, a twice-weekly webinar through Summer 2021.[67]

Analysis by Vivid Economics provides some proxy estimates on the size of the existing workforce based on hydrogen and CCUS developments in one industrial cluster.[68] The analysis suggests that the development of carbon capture and hydrogen alone could create 48,000 jobs in The Humber Estuary at the peak of the construction phase in 2027. This includes up to 25,000 high-quality jobs in construction and operations, such as welders, pipefitters, machine installers and technicians. The report highlights that the ongoing operations can create 3,300 long-term, skilled jobs in the cluster by the early 2030s.

The Humber Industrial Cluster reveals two major challenges in addressing the skills gap. Firstly, a relatively small proportion of school leavers in the Humber area possess the necessary qualifications for specialist technical and practical roles. As such, school leavers and those in industries with transferable skills must be given the support to get specialised training. Secondly, the plan reveals the dependency of CCUS on the construction industry. While construction is out of scope for this report, a shortage of construction workers could mean the demand for science and engineering-based operations, maintenance and R&D staff will be significantly delayed.

64. The Construction Industry Training Board: Construction Skills Network, 2021.
65. Selby College: Skills Bootcamp in the Principles of Carbon Capture and Storage, 2023.
66. United States Energy Association: CCS / CCUS Academic Curriculum, 2016.
67. UK Carbon Capture & Storage Research Community: CCUS for Net Zero seminars: resources, 2021
68. Vivid Economics: Capturing Carbon at Drax: Delivering Jobs, Clean Growth, and Levelling Up the Humber, 2020.

Batteries

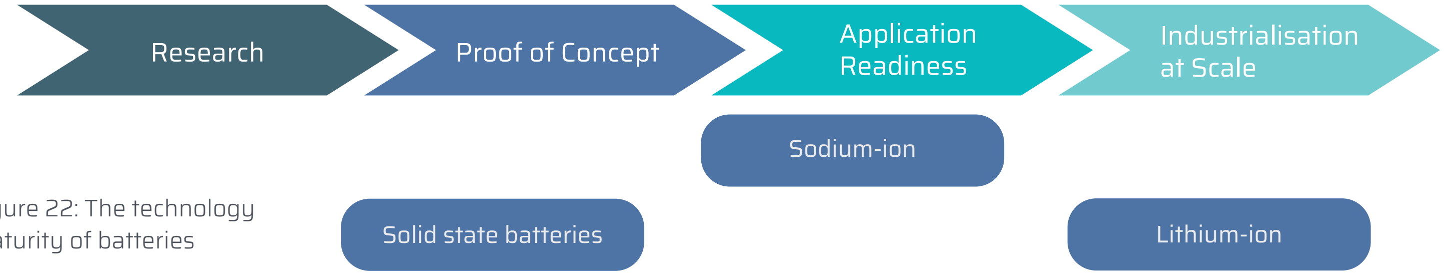


Figure 22: The technology maturity of batteries

SUMMARY OF TECHNOLOGY AREA

Batteries are a cornerstone technology for many industries, reaching economies of scale across the world. In this report, batteries will refer to lithium-ion batteries which are crucial for the transformation of industries such as automotive and energy storage. Other forms of batteries may also play a role during the transition and are mentioned if they are strategically important for the UK. Lithium-ion batteries are chemical energy storage devices, typically referred to as secondary battery systems as they can be recharged. They have emerged as the dominant technology for EVs due to their high energy density, low cost and relatively long cycle life. Manufacturing lithium-ion batteries requires a clean environment, specialised equipment, and trained operators. **Figure 23** details the manufacturing steps involved in making a lithium-ion battery cell. While most of the manufacturing processes are automated, skilled workers are needed to maximise productivity and reduce scrappage rates.

Before cells can be produced, companies conduct years of R&D to prove whether cells can meet customer standards and be manufactured at scale. This activity generates highly skilled R&D jobs requiring specialised Masters or PhD graduates. Through the sustained work of the Faraday Institution, the UK has built upon its academic strengths in battery science and is creating a strong pipeline of highly skilled battery scientists.

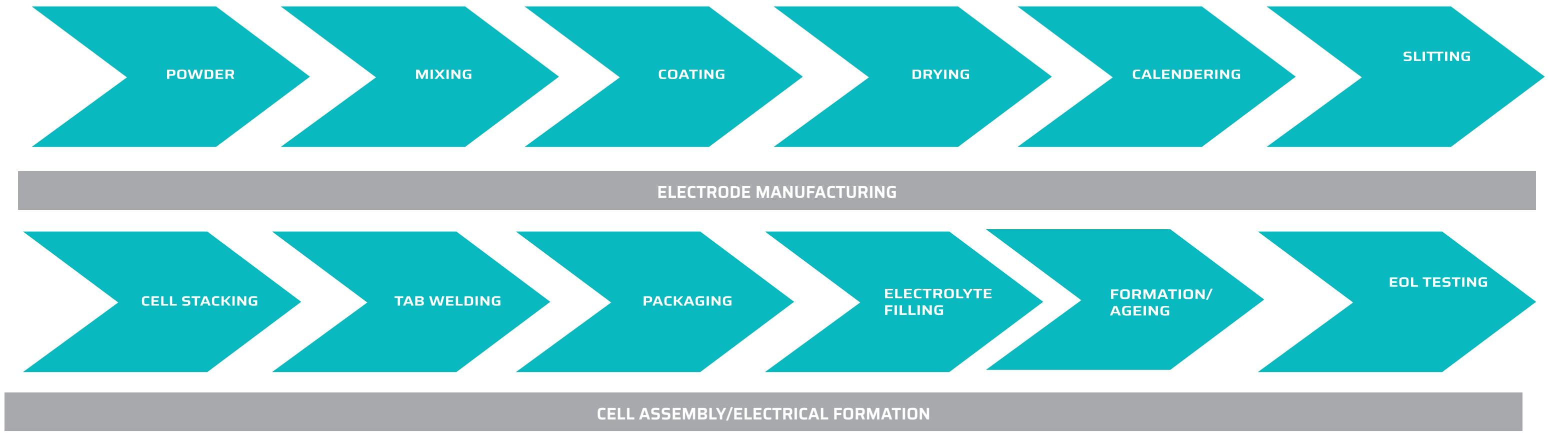


Figure 23: Typical battery cell assembly process[69]

69. WMG, University of Warwick: Automotive batteries 101, 2018.

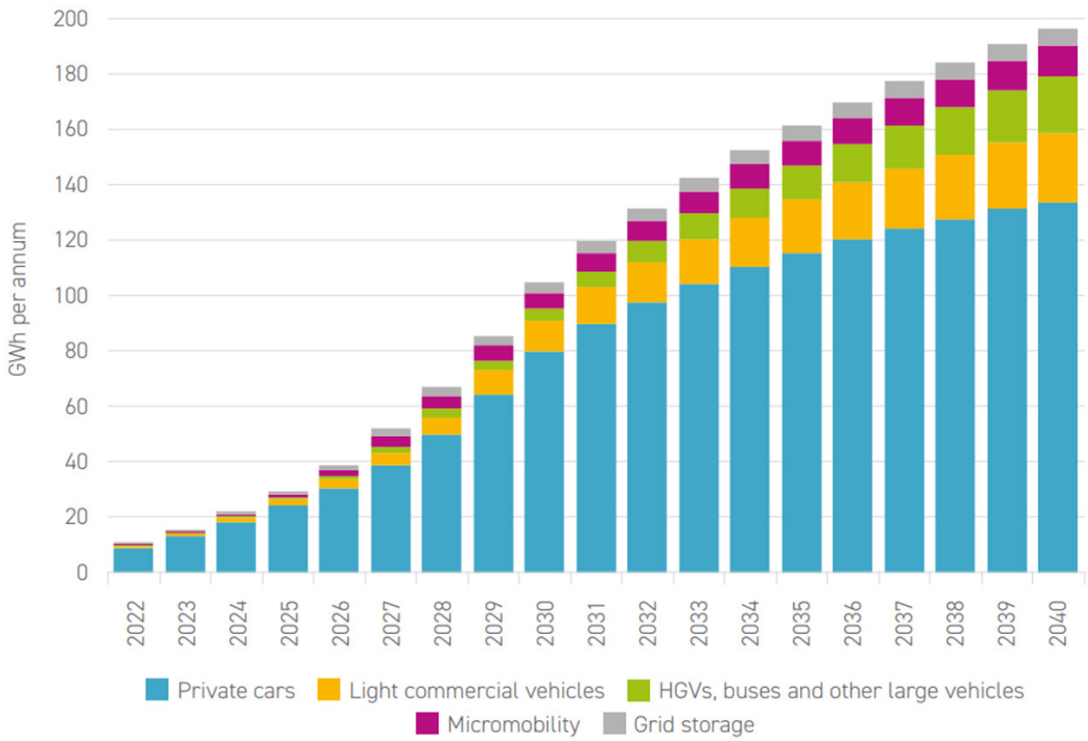
Pioneering innovations such as low-cost sodium-ion batteries, energy dense silicon anodes and next generation solid state electrolytes are being trialled across many UK university research labs.[70] These technologies are crucial for batteries to reach into more industrial sectors, including stationary energy storage, drones and eVTOLs.

Anchoring gigafactories in the UK is a key priority for industry and Government. This is reflected in the continued support for the Faraday Battery Challenge and the co-investment by Envision AESC and the Automotive Transformation Fund into their UK gigafactory.[71]

Projections vary on future battery demand, but the two most authoritative sources in the UK are the Advanced Propulsion Centre and Faraday Institution. The Advanced Propulsion Centre estimate that UK demand for automotive batteries could reach 96GWh by 2030 based on an anticipated production of around 1.6 million vehicles.[72] A report from the Faraday Institution, looking more broadly at battery demand, predicts the UK could need just over 100GWh per annum by 2030 and just under 200GWh per annum by 2040 based on current assumptions around domestic manufacturing.[73]

While gigafactories are undoubtedly a strategic investment for the UK, other investments across the battery value chain are also important, especially for battery sub-components and chemical refining. In fact, most of the value inside battery cells comes from complex chemical formulations of the cathode, anodes, and electrolytes. Irrespective of whether the UK builds an extensive gigafactory capability, the UK's strong chemical sector is an asset. The industry is in a good position to identify the current and future battery chemical needs and produce competitive products for both UK and European markets.

Figure 24: Projected battery demand across sectors



70. Advanced Propulsion Centre UK: 2025 and Beyond: Promising Battery Cell Innovations for the UK Automotive Sector, 2022.
71. Department for Business, Energy and Industrial Strategy: Record Funding Uplift for UK Battery Research and Development, 2022.
72. Advanced Propulsion Centre: Q3 2022 – Automotive industry demand forecast, 2022.
73. The Faraday Institution: UK Electric Vehicle and Battery Production Potential to 2040, 2022.

Anchoring this activity in the UK would also generate a knock-on demand for highly skilled jobs in the chemicals sector if sub-component manufacturers co-locate to the UK. Analysis conducted by the Fraunhofer Institute in Germany suggests that for every 1 job created in cell manufacturing, 4-6 are created in the downstream supply chain.[74] This activity would mainly be generated in the chemical supply chain. Therefore, failure to attract this activity to the UK would reduce the GVA potential of building a lithium-ion battery industry and risk missing out on a productive chemical workforce. Other risks of not building a battery chemical supply chain include leaving the UK more open to material price volatility and not fulfilling the localisation requirements for battery rules of origin.[75]

OCCUPATION AND SKILLS MAPPING

As lithium-ion batteries have matured, a rich literature has emerged on the skills needed to grow the battery ecosystem. The following section merges insight from the Faraday Institution, Fraunhofer, ALBATTS and FBICRC to summarise the relevant subjects and expected roles needed across the battery value chain.[76] [77] [78] [79] **Figure 25** summarises the specific qualification areas and job roles typically required across the value chain.

Battery Chemicals: The skills and roles relating to battery chemicals are highly specialised compared to cell or pack assembly. Much of the value is in the chemical formulations and manufacturing processes. Given the high levels of process automation and the use of continuous processes, fewer jobs are needed, but the skill level is high. The importance of manufacturing equipment means trained process technicians and operators are a highly integral part of facility operation. Evidence from FBICRC suggests that some skills in battery chemicals can be transferrable from other chemical, refining and mining operations.[80] However, the viability of transitioning specific roles within adjacent sectors into battery chemical companies needs detailed mapping by sector experts. Encouragingly, some battery chemical expertise already resides in the UK. Several battery chemical refining companies have operations in key UK industrial clusters such as Vale, Green Lithium and Phillips 66. Battery component production skills are also well supported in the UK via pilot line cathode facilities and high-volume electrolyte production facilities.

Figure 25: Jobs and qualifications mapping for batteries.

Value Chain Steps		Battery Subject Areas		Illustrative Job Roles	
Battery Chemicals		Chemical Engineering Organic Chemistry	Inorganic Chemistry Electrochemistry Metallurgy	Material Engineer Electrochemist Battery R&D Scientist	Chemical Safety Engineer Waste Management Process Operators Process Technicians
Battery Cells & Packs	Cell Manufacturing	Electrical Engineering Physics Robotics & Automation	Chemistry Energy Materials Mechanical Engineering	Battery Design Engineer Process Engineer Quality Control Lead Senior R&D Engineer	Machine Operator Material Handling Maintenance Technician Battery Test Technician
	Pack Manufacturing & Components	Software Engineering Electrical Engineering Thermal & Fluid Engineering	Mechanical Engineering Control & Systems Engineering Tribology	System Engineer Software Engineer Production Manager Electrical Assembler	Machine Operator Material Handling Mechanical Assembler Battery Test Technician

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

74. EIT Raw Materials: Future Expert Needs in the Battery Sector, 2021.
75. Green Finance Institute: Powering the Drive to Net Zero, 2022.
76. The Faraday Institution: UK Electric Vehicle and Battery Production Potential to 2040, 2022.
77. EIT Raw Materials: Future Expert Needs in the Battery Sector, 2021.
78. Project Albatts: Results, 2023.
79. Future Battery Industries: Vocational Skills Gap Assessment and Workforce Development Plan, 2021.
80. Future Battery Industries: Vocational Skills Gap Assessment and Workforce Development Plan, 2021.

Battery Cells & Packs: Battery cell and pack production is more labour intensive than battery chemicals and can draw upon expertise across more sectors and disciplines. Cell manufacturing, while highly automated, still requires several staff members to maintain and operate the machinery across the process steps. As The Faraday Institution outlines, 80% of gigafactory roles are in production, maintenance and engineering, with the majority being Level 2-3 operators and maintenance staff.[81] Some current apprenticeships offered may be suitable for battery manufacturing, such as Lean Manufacturing Operatives (Level 2), Maintenance and Operations Engineering Technician (Level 3) and Science Manufacturing Technician (Level 3).[82]

Despite this, workshop participants expressed the view that these roles could be better filled via battery dedicated apprenticeships or retraining existing workers in adjacent sectors (i.e., engine manufacturing). To address the lack of training opportunities, Cogent Skills has facilitated the development of a new "Battery Manufacturing Technician" Level 3 apprenticeship standard, which will be available for delivery later this year.

Routes for experienced battery R&D can emerge from existing graduate and post-graduate courses in chemical and electrical engineering. Given the quick ramp-up of interest in lithium-ion in the UK, a key challenge is finding candidates with industry or pilot line lab experience. The Faraday Institution, established in 2017, has been instrumental in improving this situation. Via its multi-year, multi-university R&D programmes, it has been instrumental in sharing facilities, exchanging knowledge, and providing graduates and post-graduates with valuable industry and lab experience in battery science.

81. The Faraday Institution: UK Electric Vehicle and Battery Production Potential to 2040, 2022.
82. High Value Manufacturing Catapult: The Opportunity for a National Electrification Skills Framework and Forum, 2021.

CURRENT SKILLS SUPPLY

According to the latest Low Carbon and Renewable Energy Economy (LCREE) data, approximately 6,000 people work in energy storage and fuel cells.[83] While not all these jobs are in lithium-ion batteries, there are a few sites across the UK manufacturing lithium-ion battery cells. The two most notable private companies are Envision AESC UK, employing more than 400 people at their site in Sunderland, and AMTE Power, with over 60 people at their sites in Scotland.[84] [85] UKBIC, a pilot line facility in Coventry, also employs and trains battery operators, technicians, and R&D scientists to support UK innovation programmes and private businesses. Other companies assembling battery packs in the UK include Hyperbat, Williams Advanced Engineering, McLaren Applied Technologies, Turntide, Cummins and Ricardo.

But despite the positive activity, a report published by the SMMT asserts that the UK currently doesn't possess enough qualified workers to manufacture battery cells.[86] Citing the latest report by the Faraday Institution, it claims that by 2025 the UK will require 5,000 such engineers, increasing rapidly to 20,000 in 2030. The workshop participants also expressed concern over impending skills shortages, particularly around attracting enough gigafactory operating staff (Levels 2-3) to support the UK's scale-up ambitions. Participants commented on the attractiveness of manufacturing environments compared to other career pathways for a new generation of workers. This was linked to shifting expectations of more hybrid working (which is more difficult in manufacturing environments) and poor understanding of what technicians, operatives, and engineers do (i.e., problem solvers rather than just repairing things).

There was also concern that a shortage of skilled operators could create a wage spiral as local gigafactories bid for a limited pool of talent. This has been exasperated by there being no real access to lower-level skills from current migration routes, creating a real scarcity of operators. And so, while the potential workforce demand is relatively well-understood for batteries, a major obstacle is how to spark enthusiasm, especially among younger generations, into pursuing a career in the sector.

A good understanding of the skills required has meant that there is now a variety of relevant courses that have the potential to fulfil the needs of the industry. However, there are also challenges affecting the provision of training, with the further education and skills sector itself struggling to attract and retain suitably qualified staff.

While there has been much discussion around regulatory, funding, and qualification reforms within skills policy, less emphasis has been given to the issue of recruiting and retaining experienced industry experts who are also skilled in teaching.[87] A major challenge here is the inability of colleges to offer competitive salaries compared to private sector jobs in advanced engineering and manufacturing. As a result, there is a persistent risk that teachers employed on precarious contracts with uncertain pay prospects will be lured away by better-paying industry jobs unless some form of mitigating action is taken. If training providers are unable to attract teachers with up-to-date industry experience and expertise, it will be difficult to deliver training at the scale and quality that is needed to meet the potential workforce demand.

The literature also pointed out the possibility of retraining employees from adjacent industries that need batteries, such as automotive. The Faraday Institution breaks down battery cell assembly roles into 50% production staff, 30% maintenance and engineering, 10% quality, and the remaining 10% split between management (1%) and other roles (9%). This occupation split maps closely with the current automotive industry workforce split. Of the 182,000 workers employed directly by the automotive sector, it is estimated that 120,000 (65%) are in engineering or production roles. This breaks down further into operatives (65%), technicians (15%), engineers (15%) and senior engineers/managers (5%).[88] Therefore, as internal combustion engine manufacturing ramps down, there is an opportunity to transition engine assembly workers into battery cell assembly workers.

Despite the challenges of the UK immigration system, some cell manufacturers in the workshop reported a greater proportion of overseas staff applying to work as battery cell assemblers. The group expressed a desire to develop localised workforces to stimulate local economies. However, a concern shared by some participants was that scaling up gigafactories requires workers immediately, which would need a degree of immigration to enable growth. The group felt that greater access to overseas labour could lead to faster scaling up and economic growth on a macro level, but it also carries the risk of missing out on human capital development at a local level. However, attracting skilled migrant workers to the UK could also be an issue. Participants mentioned the increasing difficulty of EU nationals' ability to work in the UK as a barrier. Given these factors, upskilling and retraining a local UK workforce should be a cornerstone of the UK's battery manufacturing strategy but needs a long-term commitment from national and local government. Without this long-term strategy and the adequate training mechanisms in place, gigafactory scale-up would likely be delayed because of skills shortages.

83. Defined in the ONS as "the design, manufacture and installation of energy storage systems, flywheel energy storage, fuel cells, batteries and any other form of energy storage systems".
84. Envision AESC UK, LinkedIn profile, 2023.
85 AMTE Power plc: Annual Report and Accounts, 2021.
86. Society of Motor Manufacturers and Traders: Full Throttle to Full Charge: Driving Forward UK Automotive, 2022.
87. Lifelong Education Commission: Developing industry-expert teaching for higher skills, 2023.
88. Society of Motor Manufacturers and Traders: Full Throttle to Full Charge: Driving Forward UK Automotive, 2022.

Case Study: UKBIC Battery Skills Engagement

A key function of the UK Battery Industrialisation Centre (UKBIC) is to train the future cohort of battery operatives, technicians, and engineers to work in UK gigafactories. As part of its skills outreach agenda, UKBIC engages all educational levels, from primary schools to post-graduate. UKBIC has been involved in the design of the upcoming L3 Battery Manufacturing Technician standard and currently offers learners experience working across a battery manufacturing line.

Fuel Cells

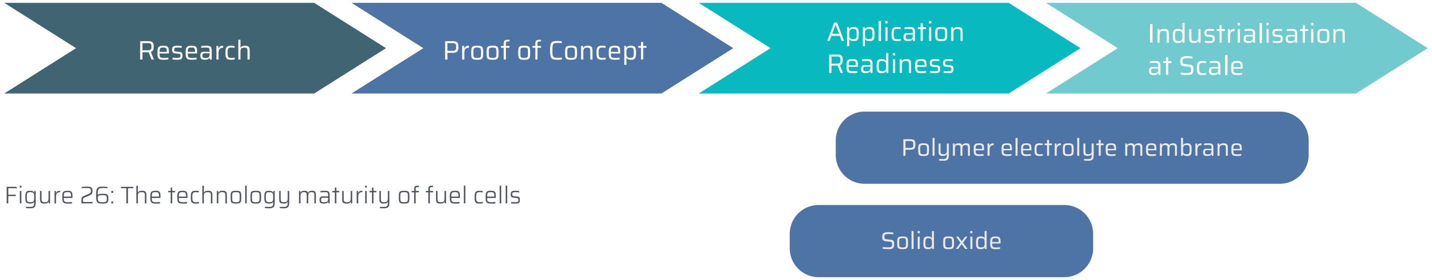


Figure 26: The technology maturity of fuel cells

SUMMARY OF TECHNOLOGY AREA

Fuel cells are a mature technology with many potential applications but have not yet reached industrialisation at scale. They are electrochemical devices that produce electricity by oxidising a fuel (most commonly hydrogen) in a reaction that generates an electrical current and creates water vapour as a by-product. Their main applications are expected to be in the transport and stationary power sectors. This report will focus primarily on polymer electrolyte membrane fuel cells (PEMFC), given their dominant position in the market.

The skills required for fuel cell assembly are heavily dependent on the production volume. Low volume facilities typically need highly skilled operatives as the stacks are manually assembled. As production volumes increase, however, the skill level reduces as higher levels of automation are introduced into the manufacturing processes. One exception is integrating a fuel cell stack into the fuel cell system. Elements such as air handling equipment, and thermal and water management systems need integrating, requiring mechanical and electrical engineers who understand system architectures. Like batteries, fuel cell companies also employ highly skilled R&D staff to develop, test and integrate fuel cell stacks into end applications.

Authoritative UK demand projections for fuel cells across multiple sectors are difficult to source. Data from the Advanced Propulsion Centre presented in **Figure 27** suggests a later ramp-up of fuel cells, with up to 14GW per annum required by 2035 for cars and vans produced in the UK.[89] These numbers don't include stationary power or other transport applications, including heavy goods vehicles, construction equipment, maritime or short haul aviation, where fuel cells could be a promising solution. The issue of uncertain demand was raised in the battery and fuel cell workshop. Participants highlighted the lack of clear demand signals, citing it as one potential reason why more bespoke training provision and skills mapping hadn't been undertaken as the technology was further away.

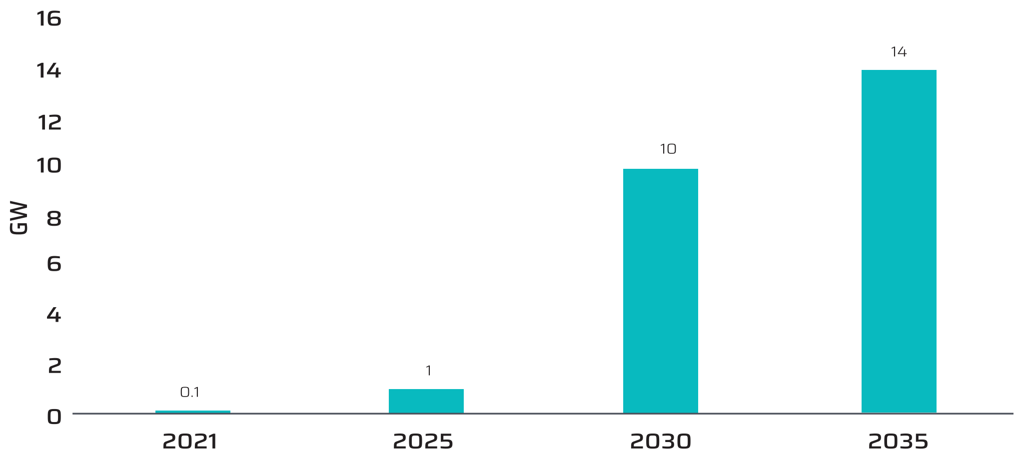


Figure 27: Projected UK fuel cell demand (cars and vans)

89. Advanced Propulsion Centre UK: An Ambition for the UK Hydrogen Vehicle Supply Chain, 2022.

OCCUPATION AND SKILLS MAPPING

As fuel cells are in their infancy, the industry is still developing its knowledge of the required job roles and qualifications. The table below draws on research conducted by the US Office of Energy Efficiency and Renewable Energy, the Advanced Propulsion Centre's Fuel Cell Roadmap and a PwC to provide insight into the skills needed to grow the fuel cell market.[90] [91] [92]

Fuel Cell Stack Components: Figure 29 breaks down the membrane electrode assembly (MEA), which is the most valuable part of a fuel cell stack. This consists of the catalyst coated membrane (MEA3), the gas diffusion layers (MEA5) and the sealing material (MEA7), which integrates into a fully functioning MEA. Like battery chemicals, the MEA is incredibly IP rich, with the value being in the chemical formulation and how the catalyst is coated onto the membrane. This activity generally requires high skill level roles to conduct continuous R&D in improving both the material formulation and manufacturing processes. This would typically require PhD level understanding of chemical engineering or a specialised Masters, such as the University of Birmingham's Fuel Cell and Hydrogen Technologies course.[93] In terms of MEA manufacturing, some low to intermediate skilled staff are employed as chemical process engineers or maintenance staff to maintain the production line and troubleshoot. Relevant courses identified for this activity include the Process Leader Level 4 Apprenticeship. This could be transferable for managing an MEA production line, coordinating operatives and implementing process improvements. The Science Manufacturing Process Operative Level 2 could also be relevant for entry level operators responsible for operating and maintaining production lines.

Figure 28: Jobs and qualification mapping for fuel cells

Value Chain Steps		Fuel Cell Subject Areas		Illustrative Fuel Cell Roles	
Fuel Cell Stack Components		Mechanical Engineering Civil Engineering Materials Engineering	Inorganic Chemistry Electrochemistry Metallurgy	Material Engineer Electrochemist R&D Scientist Metal Fabricator Process Leader	Chemical Safety Engineer Waste Management Chemical Process Operator Lean Manufacturing Operative
Fuel Cell Systems	Fuel Cell Stacks	Electrical Engineering Physics Mechanical Engineering	Chemistry Energy Materials	Fuel Cell Stack Engineer Electrical Testing Process Engineer Production Manager	Machine Operator Material Handling Maintenance Technician
Fuel Cell Systems	Balance of Plant	Software Engineering Electrical Engineering Thermal & Fluid Engineering	Mechanical Engineering Control & Systems Engineering Tribology	System Engineer Software & Control Engineer Production Manager	Machine Operator Material Handling Mechanical Assembler Electrical Assembler
Fuel Cell Systems	Hydrogen Storage	Materials Engineering Mechanical Engineering Composite Engineering	Chemistry Physics Polymer Science	Machine Operator Quality Control Materials Scientist	Production Manager Maintenance Technician Polymer Scientist

Black text = Entry or low skill level
Green text = Intermediate skill level
Purple text = High skill level

90. US Office of Energy Efficiency & Renewable Energy: Hydrogen and Fuel Cells Career Map, 2023.
91. Advanced Propulsion Centre UK: Fuel Cell Roadmap 2020
92. PwC: Developing Australia's Hydrogen Workforce, 2022.
93. University of Birmingham, Fuel Cell and Hydrogen Technologies Masters / MSc.

Other important elements for fuel cells include bipolar plates, which are stamped pieces of metal attached at either end of a single fuel cell laminate. Techniques and skills for producing these are commonly used in existing metal stamping companies, with some metal fabricators potentially moving into this space naturally to pivot away from reduced demand for engines. Therefore, existing apprenticeships like Lean Manufacturing Operatives Level 2 are highly suitable given the similarities bipolar plate manufacturing has with multiple metal forming techniques used across the engineering sector.

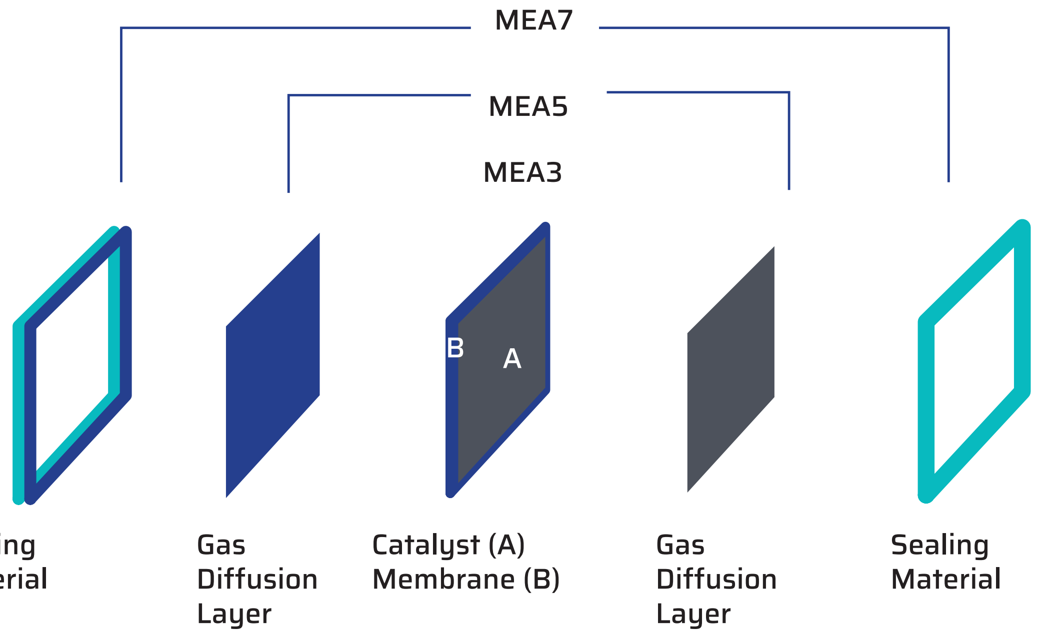


Figure 29: How a membrane electrode assembly is made[94]

Fuel Cell Systems: There is significant overlap between fuel cell systems and battery packs as both are packaged electrochemical devices that require thermally managing with complex control software. In fact, a common argument in favour of fuel cells in mobility is that it shares many elements with engines, such as similar thermal management, air handling and fuel injection systems and tanks for hydrogen storage and delivery. Therefore, a lot of skills and roles geared towards engine manufacturing could be quickly redeployed to some aspects of the fuel cell system value chain.

Designing a fuel cell system and managing its integration into an end application typically requires a higher-level qualification in Systems Engineering. This is necessary as it requires an understanding of the interplay of mechanical, electrical, and thermal engineering and the skill to integrate a fuel cell effectively into a vehicle or grid setting. One participant reinforced the need for skilled systems engineers, arguing that a higher level of dexterity is needed due to wiring competency, mechanical assembly skills as well as some hydrogen training. Fuel cell systems also require more mechanically orientated skills, such as mechanical engineering, for stack design and air handling or an understanding of metallurgy to understand the behaviour of bipolar plates.

One unique difference a fuel cell system possesses compared to engines and batteries is the hydrogen storage tanks. Type IV tanks, the current choice for mobility applications use carbon fibre with a polymer liner. Both the highly skilled elements and the intermediate skilled roles have considerable cross over with existing degrees and apprenticeships prevalent in the polymer industry. At the R&D end, highly skilled material scientists must understand the properties and interaction of the polymer and carbon fibre. This would typically require Polymer Science Masters offered at institutions like The University of Manchester, Warwick University or Loughborough University. Regarding the manufacturing of carbon fibre and storage tanks, existing apprenticeships such as the Science Manufacturing Technician Level 3 may be appropriate.

94. Fuel Cell Store: Membrane Electrode Assemblies (MEA), 2020.

CURRENT SKILLS SUPPLY

According to the latest Low Carbon and Renewable Energy Economy (LCREE) data, approximately 6,000 people work in energy storage and fuel cells.[95] Only a segment of those are working in fuel cell development, with three major companies operating in the UK. Intelligent Energy, who assemble PEM fuel cell stacks for mobility applications, employs approximately 185 people at their site in Loughborough.[96] Ceres Power assemble solid oxide fuel cells and employs just under 500 people globally, with the majority based in the UK.[97] Some employees are based outside the UK next to their strategic partners, such as Bosch, Doosan, and Shell. The final large UK employer is Arcola Energy, recently acquired by global manufacturer Ballard Power, a global manufacturer of fuel cell systems. Arcola specialise in integrating fuel cell stacks into buses, trucks, and other heavy-duty transport applications and employed just under 100 people before the Ballard Power acquisition.[98] Smaller organisations conducting UK research, low volume manufacturing and engineering support in fuel cell stacks in the UK include Bramble Energy, AFC Energy, Adelan and Loop Energy.

A strong message from participants in the battery and fuel cell workshop was that future demand for fuel cells was more uncertain. This makes it difficult for training providers, colleges, and universities to provide the relevant courses as the signals from industry are mixed. Of the courses and training that are available, the vast majority are from higher education institutions like the University of Birmingham and the University of Loughborough (see case study).

These are typically partly funded by publicly funded research either from the UK Government or EU innovation funding and perhaps reflects the maturity of fuel cells. One fuel cell company noted that many roles in their company are still graduate or post-graduate level, even on the assembly line. This is because economies of scale haven't been achieved, so a lot more manual assembly takes place, resulting in a higher skill level being needed. Encouragingly, however, the participant explained that existing apprentices in engineering and other fields would be well suited for fuel cell stack assembly as volumes grow. This is due to the similar manufacturing processes used across other engineering disciplines, such as automotive.

While participants stated that fuel cell skills have similarities with electrical, mechanical, and automotive engineering, some recruitment difficulties were noted. For example, system engineers were considered difficult to recruit as few people have experience integrating fuel cells into vehicles or stationary power applications. This point was also identified in the recent PwC study investigating the need to transition Australia's workforce to hydrogen.[99] The study, mapping out the extent to which future jobs are needed for Australia's hydrogen industry, identified "Fuel Cell Vehicle Development Engineer" and "Hydrogen Systems and Retrofit Engineer" as two new roles in fuel cells.

Another specific challenge was safety, especially given the interaction with hydrogen. Industries have different or developing certifications and standards regarding hydrogen safety, and it was expressed that finding experienced people who are familiar with multiple standards is difficult.

A broader point includes the rate at which the UK trains electrical engineers, particularly in the face of extensive competition from other low-carbon sectors such as batteries and renewable energy generation. Even non-science and engineering fields, such as finance and consulting, are luring away talent. Control and software engineers are in short supply, with some participants suggesting that their companies typically hire from India as the UK pipeline for this talent is weak. The Recruitment and Employment Confederation has also noted a significant shortage of software engineers in the UK.[100] Between June and July 2022, just over 45,000 job postings mentioned software development skills, and one member claimed that "they [software engineers] are just not around anymore. Supply just isn't keeping up with demand".

95. Office for National Statistics: Low carbon and renewable energy economy estimates, 2023.
96. Companies House: Intelligent Energy Limited, 2023.
97. Ceres Power: Ceres Annual Report, 2023.
98. Ballard Power: Ballard Power announces acquisition of Arcola Energy to help customers integrate fuel cell engines into heavy-duty mobility, 2021.
99. PwC: Developing Australia's Hydrogen Workforce, 2022.
100. Recruitment and Employment Confederation: Written evidence, 2022.

Case Study: The Birmingham Centre for Hydrogen and Fuel Cell Research

Established in 2009, the Centre has led two collaborative Engineering and Physical Sciences Research Council (EPSRC) funded Centres for Doctoral Training (CDT) with over £10 million of investment, training over 100 PhD students. The programme developed in the CDT is now offered for self-funded PhD candidates. Students completing these courses have gone on to work in a diverse range of employment from patent attorney to banking and business development. But the vast majority have continued working in research both in private sector organisations and research institutions, many contributing to the development of fuel cells for transport and buildings.

Nuclear

Figure 30: The technology maturity of nuclear

SUMMARY OF TECHNOLOGY AREA

Nuclear technology is already well-established and is at the 'Industrialisation at Scale' stage of development, having been deployed globally for the past 70 years. According to NSSG research, the nuclear sector in the UK currently employs approximately 58,000 people. Employment is highly centralised and essential to the local economies in which they are located. Interest in nuclear has grown in recent years due to its potential for low-carbon electricity generation as part of the transition to net zero. In 2022, a planning application was approved for the construction of a new nuclear power station, Sizewell C, which is expected to create thousands of new jobs in the sector. This makes the nuclear sector of growing importance in the context of the UK's low-carbon skills requirement.

Electrification refers to the shift towards using electricity as the primary energy source instead of fossil fuels. It is seen as a critical pillar of the UK's transition to net zero, and, as a result, the demand for electricity is projected to increase dramatically in the coming years. The CCC forecasts a doubling of electricity demand by 2050, from approximately 300 TWh at present to 610 TWh by 2050. This excludes the production of hydrogen using surplus generation, which could lead to an additional 30 TWh of electricity generation in 2035 and 120 TWh in 2050.[101] Key drivers for the increase in demand include electric vehicles, energy requirements for domestic and industrial buildings and processes, and increased production of hydrogen as an energy carrier. To achieve net zero by 2050 the CCC contends that the electricity grid needs to be decarbonised by 2035, and all electricity demand growth should be net zero-driven.

As one of the proven, scalable, baseload low-carbon industries, the UK Government, in its Net Zero Strategy and British Energy Security Strategy, set out ambitious plans to accelerate nuclear generation, aiming to increase the proportion of nuclear in the energy mix from 18% to 25%.[102][103] Given projected increases in overall electricity demand; this represents a tripling of nuclear generating capacity to 24 GWe. With the rapid development of capacity comes an associated requirement for skilled workers to meet both expansion and replacement demand. This commitment to nuclear was reaffirmed in the Independent Review of Net Zero, where recommendations were made to expedite the set-up of Great British Nuclear in early 2023, ensuring the right funding and skills are in place.[104]

The nuclear industry is well-established, so the skills needed in this field are relatively well-known compared to the other areas. However, there are possible future developments that still need to be considered and could affect the skills required for the nuclear industry. For example, the Government's ambition to build Small Modular Reactors (SMRs) alongside traditional large-scale plants will require additional skill sets related to off-site manufacturing and construction.

101. Climate Change Committee: The Sixth Carbon Budget: The UK's Path to Net Zero, 2020.
102. Department for Business, Energy and Industrial Strategy: Net Zero Strategy: Build Back Greener, 2021.
103. Department for Business, Energy and Industrial Strategy: British Energy Security Strategy, 2022.
104. Mission Zero: Independent Review of Net Zero, Chris Skidmore MP, 2023.

OCCUPATION AND SKILLS MAPPING

The skills required for the nuclear industry have a significant overlap with those needed for other infrastructure development projects, making them relatively transferable. However, the scale of infrastructure development needed to support the net zero transition may create intense competition for skills in an already tight labour market. The table below was drafted by the Nuclear Skills Strategy Group, bringing together a wealth of knowledge and experience in the nuclear sector.

Function	Operating Areas	Roles & Responsibilities
Engineering	Civils	Architectural Engineers, Building Envelope Specialists, Civil and Structural Engineers, Other Construction (not otherwise counted)
	Commissioning and other Engineers	Commissioning Engineers, Mechanical and Electrical (combined) Engineers, Other Engineers (including non-specific), Systems Engineers, Construction Engineers
	Control & Instrumentation	Control and Instrumentation Engineers
	Design	Design Engineers (C and I), Design Engineers (Electrical), Design Engineers (Mechanical)
	Electrical	Electrical Engineers, Fault Analysis Engineers
	Manufacture	Manufacture (C E & I offsite), Manufacture (Mechanical offsite)
	Mechanical	Maintenance Engineers, Mechanical Engineers, Mechanical Fitters, Non-destructive Testing
	Nuclear	Nuclear Engineers
	Safety Case Management	Nuclear Criticality and Shielding, Nuclear Radiological Protection Criticality and EP (regulation), Nuclear Safety Case Preparation, Regulation Site Inspection
Operations	Facilities Management Infrastructure	Facilities Management and Services – Field Services, Ventilation Engineers
	Fuel and Plant	Fuel Processing, Generation, Nuclear Materials Accountancy and Control, Post Irradiation Examination
	Processing	Decommissioning, Process Engineers
	Transport	Nuclear Materials Transport, Nuclear Materials Transport Assessment, Operations Transport
	Waste Management	Waste Management

Figure 31: Jobs and qualification mapping for nuclear sector

Figure 31: Jobs and qualification mapping for nuclear sector cont'd

Function	Operating Areas	Roles & Responsibilities
Project and Programme Management	Project & Programme Management, Construction	Construction Management
	Project Controls	Cost Control Engineers, Estimating, Expediting, Project Planning and Control
	Project Management	Programme Management, Project Engineers, Project Inspection (Regulation), Project Management
Science Technical Health Safety & Environment	Environment/Geology	Environmental Science Geology Hydrology and Modelling
	Industrial Safety	Health and Safety Regulation, Industrial Health & Safety
	Quality Management	Quality Assurance, Quality Audit
	Radiological Safety/Health Physics	Health and Safety - Radiological Protection
	Remote Engineering and Robotics	Remote Engineering and Robotics
	Research	Operational Research, Research Facility Operators
	Science	Analytical Sciences, Chemical Engineers, Chemists, Fuel Scientists, Material Science, Mathematicians, Physicists
Trades	Building Trades	Construction Plant Operators, General Mates, Labourers, Non-Construction Operatives, Other Construction Roles, Scaffolders, Specialist Building Operatives (not otherwise counted), Steel Erectors, Wood Trades and Interior Fit-Out
	ME & I	Cable Pullers, Cable Tray Fixers, Control and Instrumentation Pipe Fitters, Craft Workers (not otherwise counted), Engineering Construction Erectors, Offsite Shop Based Workshop, Pipefitters, Platers, Riggers, Supervisors, Supervisors (not otherwise counted), Support (not otherwise counted), Technicians (not otherwise counted), Trades Support (not otherwise counted), Welders

The construction, manufacturing, and assembly phases of development are where the nuclear sector has the highest demand for skills. Once these phases are completed, the operational workforce required per GW is relatively low. This is not new to the industry and means that for nuclear, low-carbon skills are essentially more of the same, albeit with a recognition of new technology developments, increased digitalisation and enhanced automation. The most significant change will be in the factory manufacturing and assembly of components for modular reactors. Although there is still some uncertainty about the exact nature and locations of these factory units and how many will be in the UK, planning and intervention will be necessary to ensure the required skills are available.

Apprenticeships have been an important aspect of generating and upskilling new entrants to the nuclear labour market in the UK. There are six nuclear-specific Apprenticeship Standards in England, with one more in development. However, a wide range of more generic Apprenticeship Standards and Frameworks are also used in the sector. The top two named Standards are Maintenance & Operations Engineering Technician (Level 3), and Engineering Technician (Level 3), which account for more than half of the total number of apprentices reported. These Standards are found in other STEM sectors, as are other common apprenticeship areas, such as Project Management, Controls and Business Administration. This demonstrates the importance of more generic “skills for nuclear” as distinct from nuclear-specific skills. Finally, like most industries, there would also be a need for general business support functions, such as health and safety and finance. Note that these do not yet reflect the use of apprenticeships to meet future manufacturing demands as outlined above.

CURRENT SKILLS SUPPLY

Current skills supply includes the current workforce of around 80,000 Full-Time Equivalents (FTEs) across civil and defence and an inflow of graduates and apprentices (24% of recruitment), and experienced hires from other sectors (58% of recruitment). The remainder is the redeployment of existing staff as less labour efficient plants are decommissioned. An expansion of civil generating capacity to 24 Gwe would triple the annual inflow requirement for new workers in the industry, although this will reduce as construction moves into operations. While the volume requirement is significant, there are already some areas where a tight labour market exists for critical skills. Among the most important are the following:

- Nuclear Engineers
- Systems Engineers
- Health and Safety – Radiological Protection
- Project Planning and Control
- Generation
- Welders
- Trades Support
- IT and Telecoms
- Civil and Structural Engineers
- Nuclear Safety Case Preparation
- Control and Instrumentation Engineers
- Mechanical Engineers
- (To be defined) Manufacturing Capability

To address the skills implications of the renewed focus on the sector, there were two skills reviews in the summer of 2022. The first was the Civil Defence Nuclear Skills Review (Kingman Review) – led by the Cabinet Office to "identify the interventions required to turn around the decline in the UK nuclear skills base". The second was the Great British Nuclear Review, laying the groundwork for the formation of Great British Nuclear, a body to support the UK's nuclear industry in developing a pipeline of new build projects. The Nuclear Skills Strategy Group had significant input into both reviews. A recent analysis for the forthcoming Kingman review established that the sector has a current and growing skills deficit. Given predicted increases in the UK nuclear workforce and retirement patterns, significant investment is needed. This is set against a general deficit across multiple sectors regarding relevant STEM skills in the workforce. The overall effect of these public policies is to significantly increase the opportunities for organisations operating in the sector and for potential new entrants. Career opportunities for individuals (often highly skilled) will follow.

In terms of new entrants to the nuclear workforce, the Nuclear Standards Advisory Group's Apprenticeship Survey 2021 demonstrated that the apprenticeship route remains vital to the nuclear sector.[105] The analysis covered 2,669 current apprentices; 62% were new entrants to the sector, while the remaining 38% were existing staff re-skilling or upskilling to fulfil new roles. About half were in the traditional 16–24-year-old category. Apprenticeship completion and retention rates in the sector are very high. Employers reported a completion rate of 96%; much higher than the average rate seen across all apprenticeships in England, which stands at 67%. The retention figure is even higher, at 99%. Despite the relative success of apprenticeships in the sector, several risks remain posed for the future workforce and skills in the industry. The Nuclear Skills Strategy Group has identified these as:

- Insufficient and/or uncertainty over work to train the workforce
- Insufficient training infrastructure – training providers may not have the capacity or capability to deliver the training required.
- Robustness and use of labour market intelligence
- Insufficiently diverse talent pipeline
- Lack of workforce transferability
- Industry response to changing reactor technologies, innovation or advanced production and manufacturing
- Retention of SME knowledge/ expertise
- Recruitment of foreign nationals post-Brexit

Although the nuclear industry has a well-established skills base, there is still a need to proactively manage and mitigate potential risks.

105. Nuclear Skills Strategy Group: Nuclear Apprenticeship Survey 2020-21, 2021.

Recommendations

Despite the varying pressures, technology maturity levels and industry nuances between the sectors, four key themes emerged from the stakeholder engagement workshops and the literature review.

The following section summarises each recommendation and is assigned a priority level across the six sectors. Evidence from the stakeholder workshops and literature review is used to validate the priorities. When assigning a priority ranking, examples of influencing factors include the timescales of a technology ramp-up, the level of sectoral specific expertise needed and the existing levels of analysis and strategy being implemented.

SKILLS STRATEGY

A comprehensive, strategic plan that instils confidence and stability in both industry and government, supporting long-term investment in skills development planning.

SKILLS SYSTEM

The methods and precise mechanisms utilised by industry to address the current skills demand.

FUTURE WORKFORCE

Activities that aim to create a sustainable talent pipeline to meet future skills demand.

ENABLING THE TRANSITION

Short-term measures to facilitate the UK's transition towards a net zero economy.

Skills Strategy

ESTABLISH CLEARLY DEFINED ROLE PROFILES FOR KEY POSITIONS

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Medium ●●	Low ●	High ●●●	High ●●●	Medium ●●	Medium ●●

The rapid growth and development of low-carbon industries have given rise to new job roles and workforce requirements that existing skills frameworks do not fully address. And while this report sheds light on the various roles that will be important in the transition and the challenges facing employers, there is a pressing need to define the precise skills requirements for key positions.

A clear understanding of job roles benefits employers, employees, educational institutions, government, and investors. Employers can identify the skills they need and recruit the right talent. Employees and job seekers can make informed career decisions and pursue targeted training. Educational institutions and training providers can design relevant, industry-aligned courses. Governments and policymakers can create targeted policies for workforce development, industry growth, and low-carbon transition. Investors can gain confidence in the sector's growth potential. The absence of clear role profiles can therefore lead to skills gaps, inefficient training and education, difficulty attracting talent, hindered industry growth, and reduced investment.

A role profile exercise involves identifying key job roles within the sector, defining their responsibilities, and outlining the required skills, qualifications, and competencies for each role. The Cogent Skills Gold Standard is an ideal foundation for developing such a framework, as it offers a proven benchmark for training and development in the science industry. Role profiles are designed collaboratively with industry stakeholders, including employers, trade associations, and educational institutions, to ensure relevance and alignment with industry needs.

Typical role profile elements include:

- Job title and description: A clear, concise description of the job role, its purpose, and associated tasks and responsibilities.
- Key competencies: A list of essential technical and transferable skills for the job role, covering areas such as problem-solving, communication, teamwork, and technical expertise.
- Qualifications and experience: Required educational qualifications, certifications, and relevant work experience, ensuring candidates possess the necessary background and expertise.
- Training and development: Information on recommended training courses, apprenticeships, or work placements to help individuals develop skills and competencies for the role, including initial training for new entrants and ongoing professional development for experienced workers.
- Career progression: An outline of potential career pathways and advancement opportunities within the sector, assisting individuals in planning career development and understanding the steps needed for progression in their chosen field.

Without clearly defining the precise skills requirements of key roles, it is difficult to accurately quantify how many jobs will be created or how much of the exiting workforce have genuinely transferable skills. This lack of clarity also means that there is uncertainty around which roles will need dedicated courses and training.

Skills Strategy

DELIVER AN INDUSTRY-LED LOW CARBON SKILLS STRATEGY FOR EACH TECHNOLOGY AREA

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Medium ●●	Medium ●●	High ●●●	Medium ●●	High ●●●	Medium ●●

The Independent Review of Net Zero, led by Chris Skidmore MP, underlined the importance of a green skills strategy in achieving net zero. The review urged "Government to publish an action plan for Net Zero skills that includes a comprehensive roadmap of when, where, and in which sectors there will be skills needs specific to net zero". [106] There is a role for Government within what should be a collaborative process, but skills strategies work best when they are industry-led. Employers have a better understanding of the skills, knowledge and competencies needed for their workforce to be productive, efficient, and competitive. This includes defining and quantifying relevant job roles and training requirements. They can also provide valuable insights into the emerging trends, technologies, and practices within industry.

Any strategy must build a clear evidence base of the current position of skills, identify gaps in training provision, and provide a plan for skills development with actionable recommendations. It's also imperative that each strategy encompasses both the skills and qualifications required for ramp-up and the skills needed to keep ahead of the innovation curve. This ensures that the workforce is adequately prepared and equipped to meet the evolving demands of industry. To deliver the detail necessary for this process to work, a key recommendation from this report is that each area needs its own skills strategy that provides a forward-looking review and strategy for skills development.

Sectors such as nuclear, hydrogen and batteries are expected to ramp-up quickly because of the public and private investment accelerating their development. As a result, these sectors have been deemed a higher priority. The Nuclear Skills Strategy Group and the Hydrogen Skills Alliance are best placed to lead the development of skills strategies for their industries.

Transitioning industries were also deemed a high priority as participants felt there wasn't a cohesive, joined up strategy to enable those in industries to reskill into new areas. Fuel cells and CCUS were deemed medium priorities due to the slightly longer lead times required for skills development. However, a national hydrogen and fuel cell-specific skills mapping document, especially for the UK market, is currently lacking, highlighting the need for a strategy in this area. In terms of staying ahead of the innovation curve, batteries, nuclear, and hydrogen were also highlighted as areas with emerging disruptive technologies that may require skills realignment as certain technologies come to dominate.

106. Mission Zero: Independent Review of Net Zero, Chris Skidmore MP, 2023.

Case Study: Hydrogen Skills Alliance

A collaboration between Cogent Skills and the High Value Manufacturing Catapult (HVMC), the Hydrogen Skills Alliance (HSA) aims to establish a clear line of sight between the development of the hydrogen economy and its current and future skills requirements. The group convenes industry, academia, research organisations, industrial clusters, government, skills bodies, and all others with a genuine interest in collaborating to ensure the industry has access to the skills needed to support the growth and development of the UK hydrogen sector.

It serves as a forum where skills capacity and capability requirements are scoped, foresighted and articulated, where good practice is shared and where requirements for policy interventions are clearly articulated. The aim is to promote a more effective and coordinated approach, ensuring the education and skills system aligns with the needs of employers to deliver the necessary training, resources, and skills infrastructure.

Our members work in collaboration to:

- Map the existing hydrogen skills landscape to create a live database of skills provision available to all
- Identify a prioritised list of Hydrogen skills challenge areas that will enable "foresighting"
- Undertake a series of foresighting cycles to define and map the required skills capabilities
- Quantify the skills demand based on known requirements and build in future requirements as they emerge
- Create a skills framework(s) to support pathway & curriculum development

Skills Strategy

DEVELOP WORKFORCE PROJECTIONS TO ANTICIPATE FUTURE SKILLS DEMAND IN DIFFERENT GROWTH SCENARIOS

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	Medium ●●	High ●●●	High ●●●	Medium ●●	High ●●●

A key message conveyed throughout the workshops was the importance of having robust and reliable demand signals. Having a clear understanding of the potential demand for skills helps training providers and educational institutions to develop courses and curricula that align with the emerging needs of industry. At the same time, enabling an existing government or industry body to provide demand projections can give the market greater confidence with standardised forecasts that consider a range of industries with impartial and objective analysis.

Batteries is an example of a sector where demand signals are relatively strong, and as a result, it has a medium priority rating in the recommendations table. Joint industry and government organisations like the Faraday Institution (see case study) and the Advanced Propulsion Centre already give regular updates on expected UK battery demand. This provides a common set of trusted numbers for the industry to work from, with the confidence cascading down to the supply chain, universities, and other training providers. This understanding of the future skills demand has meant that there is now a variety of relevant courses that have the potential to fulfil the needs of the batteries industry.

Through the stakeholder workshops and desk research, CCUS, fuel cells and hydrogen stakeholders all stated that a lack of clear demand signals was a factor in the limited training provision. For large infrastructure projects with only a few sites across the UK, like nuclear and CCUS, indicating timelines of future projects was deemed a priority. The Nuclear Skills Strategy Group suggested that the UK Government should provide certainty by laying out the timeline of nuclear projects in both the civil and defence areas, a role that Great British Nuclear could fulfil.

The hydrogen sector is further ahead in this regard with some demand projections provided in the UK Government's Hydrogen Strategy and subsequent Hydrogen Sector Development Action Plan documents. While the Sector Development Action Plan does list the type of hydrogen projects across the country, more granular data is required to understand the scale locally and when projects are likely to be in the design, construction and operation phases.[107] Fuel cells demand profile is perhaps the most uncertain and long term. This is due to conflicting perspectives on their uptake potential in transport and stationary power, which makes it difficult for training providers to authoritatively plan for training courses. And while future demand for transitioning industries was considered less of a priority, a specific recommendation (see Enabling the Transition) focuses on the upskilling and reskilling of workers in these industries.

107. Department for Business, Energy and Industrial Strategy: Sample of potential hydrogen projects across the UK, 2022.

Case Study: Faraday Institution

Since its creation by UK Government and industry in 2017, the Faraday Institution has been a respected UK organisation in the fundamental research and development of batteries. One of its functions is to provide forecasts for battery demand across key UK sectors. These forecasts have been used routinely in Government and industry to provide the basis for investments as well as skills development. Replicating this model across other emerging sectors could strengthen UK demand signals to training providers, giving them the confidence to invest in courses.

Skills System

ENABLE A STABLE AND CONSISTENT POLICY ENVIRONMENT THAT FOSTERS EMPLOYER ENGAGEMENT ON SKILLS AND ENCOURAGES LONG-TERM STRATEGIC PLANNING

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●

Policy uncertainty from the Government discourages employer investment because it creates an environment of unpredictability and risk. Employers may be hesitant to invest in long-term projects or commit significant financial resources if they are uncertain about the future policy environment. This uncertainty can make it difficult for businesses to make informed decisions about where to allocate their resources and may lead to delayed or reduced investment. The same is true for skills development, where uncertainty in skills policy makes it difficult for employers to plan for future workforce needs and can lead to a reluctance to invest and engage in training programs. Inconsistent or changing policy can create confusion and complexity, adding to the costs of doing business and making it more difficult for employers to understand the requirements and regulations around different training and development initiatives.

A relevant example comes from the English apprenticeship system, which has undergone significant change in recent years, most prominently with the introduction of the Apprenticeship Levy. However, the Levy is just one of a long list of policy changes that also includes changing the minimum thresholds for course duration and off-the-job training, the introduction of end-point assessments, removal of qualifications from some apprenticeships and the withdrawal of frameworks and introduction of new standards. Despite these reforms, the number of apprenticeship starts in the science sector fell by 51% between 2015/16 and 2020/21.[108] Our engagement with industry suggests that seemingly constant change and uncertainty is damaging employer engagement with apprenticeships and limiting training and development opportunities for individuals. Employers need stability in the skills system to maximise its effectiveness and have the confidence to invest in long-term growth and development plans for their workforce. This is especially true for time-poor SMEs that often lack the dedicated internal staff resource needed to understand the different aspects of the technical education system.

This theme of an unstable skills system was also expressed across all the stakeholder workshops. Many felt the education system's constant reforms had confused employers, parents, and learners. One example given was the roll out of T Levels, which received mixed receptions from participants. One observation was that certain education institutions outside of major cities lacked relationships with businesses to provide the necessary on-site learning. Another participant commented that the length of T-Levels was insufficient to train learners on various aspects of a production line or process. It was also expressed that many in industry weren't aware of T-Levels, or what employers needed to do to prepare for them, which contributed to the sense of confusion and uncertainty within the UK education system. This is backed up by a recent survey of engineering and manufacturing employers which indicates that more needs to be done to ensure enough employers are willing to offer industry placements for T Levels. Currently, only 9% of surveyed employers provide T Level placements, and only 12% plan to do so in the coming year.[109]

Promoting a stable and consistent policy environment is a high priority across all the identified sectors. It is essential to building trust and confidence among employers, encouraging them to invest in science capabilities and training for their workforce.

108. Science Industry Partnership: Building tomorrow's workforce, Insights into the adoption of apprenticeships in the science sector, 2023.
109. MAKE UK: Unlocking talent: Ensuring T Levels deliver the workforce of the future, 2022.

Skills System

DEVELOP AND MAINTAIN A DIVERSE RANGE OF APPRENTICESHIP STANDARDS THAT REFLECT MODERN TECHNOLOGICAL DEVELOPMENTS AND INDUSTRY NEEDS

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	Medium ●●	High ●●●	Medium ●●	High ●●●	Medium ●●

Apprenticeships are vital for the science sector to grow its capabilities and provide alternative talent pools outside the traditional university routes. In the nuclear sector, for example, apprenticeships were responsible for bringing in a considerable pipeline of 16–24-year-olds. Nevertheless, three broad sub-themes emerged from the stakeholder workshops and desk research regarding improving the current apprenticeship system:

- Ensure that subject specific apprenticeships are available where bespoke training on sector specific skills is needed.
- More flexibility in the Apprenticeship Levy to promote low-carbon skills, shorter courses and a focus on workplace training and reskilling.
- Develop mechanisms to de-risk the recruitment of apprentices for large capital infrastructure projects such as nuclear power plants, CCUS installations and gigafactories.

Despite some concerns regarding the current apprenticeship system, apprenticeships remain vital in promoting a pipeline of talent for low-carbon skills. While they continue to be highly valued by employers, some participants felt they can be rigid and increasingly generic in their content. Although broad apprenticeships allow learners to move across industries more easily, emerging sectors such as hydrogen, batteries, fuel cells, and CCUS have unique skill requirements that are specific to their industries. For instance, gigafactory equipment is highly specialised, working with hydrogen requires specific safety training, and CCUS demands technical knowledge of how CO_2 reacts with various storage mediums. Consequently, participants emphasised the importance of developing specialist apprenticeship programmes tailored to these unique requirements, ensuring apprentices receive relevant, up-to-date training.

In addition to creating new programmes, reviewing existing apprenticeship standards to ensure they are fit for purpose is essential. Regular reviews help identify gaps, redundancies, or misalignments with industry needs. As industries evolve and new technologies and methodologies emerge, apprenticeship standards should be updated accordingly to maintain their relevance.

A related point was the need to give employers more flexibility regarding how they can utilise the Apprenticeship Levy. Currently, the Levy cannot be recovered for use on smaller modules or short courses. In cases where the skills gap is relatively small, such as transitioning from engine manufacturing to battery assembly or from gas storage to hydrogen or carbon storage, shorter courses may be a more appropriate way to retrain the existing workforce. A consistent suggestion from the literature is for the Apprenticeship Levy to be expanded so that a proportion can be used for short courses and Continuing Professional Development Courses. The Science Industry Partnership's "Building tomorrows workforce" report underscores this finding, with 69% of survey respondents wanting greater flexibility to spend their Apprenticeship Levy on other forms of training.

The final point, which emerged from the Nuclear Skills Strategy Group but also applies to other large capital investment projects like CCUS installations and battery gigafactories, relates to the risk of early pipeline development. Given the long lead time for approval and some historical examples of projects not progressing to build, some contractors are unable to accept the risk of early pipeline development ahead of a contract award. By the time contracts are awarded, there is often insufficient time to use apprenticeships to meet workforce demand, especially considering the fixed-term requirement for these skills on a project-by-project basis. To ensure the availability of skills and prevent the risk of poaching from other industries, it would be beneficial to develop mechanisms that de-risk the recruitment of apprenticeships by individual employers and incentivise collective recruitment in advance of actual demand.

Skills System

ENSURE THE UK VISA SYSTEM FACILITATES THE FLOW OF WORKERS INTO THE SECTOR TO MEET URGENT AND CRUCIAL SKILLS REQUIREMENTS

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	Medium ●●	Medium ●●	Medium ●●	High ●●●	Medium ●●

Immigration is a key part of the UK jobs and skills system, with the topic being brought up numerous times in the workshops. It was widely discussed regarding battery manufacturing, with concerns voiced that a real shortage of Level 2-3 operators domestically could impact any upcoming scale-up of UK gigafactories. This sentiment was reinforced by a House of Lords report into the state of the UK battery industry. As part of its skills section, the report recommended "greater flexibility for recruiting international staff for research and manufacturing, including by reducing the costs associated with visas, particularly for short-term contracts".[110] There are some immigration routes available, but these are predominately based on higher-level skills. In some instances, lower-level skills can be harder to recruit, and access to them is just as important. At the same time, the sheer plethora of post-Brexit immigration routes has confused industry, meaning the full benefits of utilising them have not yet been realised. Employers need to be better informed of the options, and support should be offered (particularly to SMEs) to assist with the new processes.

In some specific cases then, enabling a level of targeted immigration could support the UK's net zero ambitions by facilitating rapid scale-up. This could also be the case for nuclear as workforce demand is based on the awarding of large contracts. Once projects are approved, job opportunities are created quickly, making immigration a potentially crucial factor. For the other sectors, such as hydrogen and fuel cells, immigration was deemed a lower priority given the longer lead times for scale-up, so more emphasis could be placed on developing a local workforce. However, across all groups, some specialist skill sets were best found abroad (such as control engineers for fuel cells in India). In transitioning industries, immigration was also deemed a lower priority as concerns in this industry centre around retaining talent and pivoting jobs to net zero compatible areas.

The Migration Advisory Committee (MAC) recently launched a Call for Evidence to update the Shortage Occupation List (SOL). The SOL lists occupations where there is a shortage of suitable skilled labour in the UK and where it is reasonable to fill those shortages with migrant workers through a skilled work visa. The review asked for evidence on which occupations on the current SOL should continue to be included, which should be removed, and which, if any, should be added. Cogent Skills have responded to the consultation on behalf of the low-carbon sector to ensure that the key occupations listed in this report are considered.

110. Science and Technology Select Committee: Battery strategy goes flat: Net-zero target at risk, 2021.

Future Workforce

PROMOTE CAREERS OUTREACH PROGRAMMES TO EDUCATE AND INSPIRE YOUNG PEOPLE TO ENTER THE SECTOR

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●

A consistent point raised during the stakeholder workshops was that the sector's influence over learners is infrequent and often occurs too late in their educational journey. Research suggests that career aspirations are set from a young age, as the top four sectoral preferences aged 7-8 are also three of the top four aged 17-18.[(111)] Participants in the workshops also highlighted how personal experiences from a young age shaped their future career choices, often citing family members exposing them to certain careers. It was felt that young people and their influencers (parents, guardians, teachers, career advisers, and siblings) often lack awareness of the breadth of opportunities available in the science sector, meaning it is not always seen as a career destination of choice.

Another theme to emerge was that the range of further and higher education options on offer can be confusing to parents and school children. Industry outreach should seek to clarify this when working with schools, highlighting the benefits of apprenticeships and other qualification avenues. Workshop participants also felt that apprenticeships were not always promoted as a natural option by some schools when advising students, citing the dominance of A-Levels in the education discourse. This is backed up by research by Education and Employers, which suggests that over 60% of 17-18 year-olds are encouraged by their schools to apply for university, while only 16% are supported to apply for an apprenticeship.[(112)]

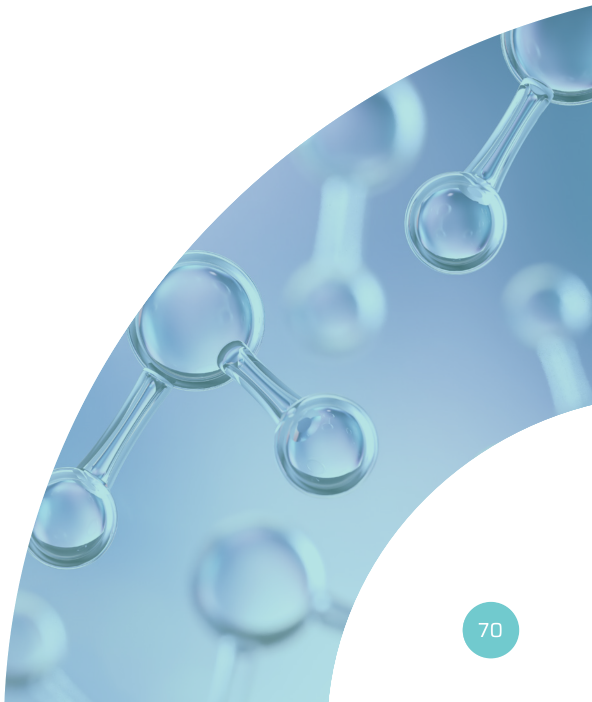
Research by Engineering UK further reinforces this, with recent surveys suggesting that only 43% of young people aged 11 to 19 were aware of the apprenticeship options available to them, and only 37% knew what T levels are.[(113)] This underscores the need for industry and representative organisations like Cogent Skills to educate schools, colleges, and learners on the broad educational options available post-16. This could be achieved by fostering deeper relationships with colleges and schools near hubs of activity associated with a sector (i.e., Suffolk for nuclear) and targeting SIP / STEM ambassadors in those areas to inspire the next generation of scientific talent. Through the SIP ambassadors programme, SIP is developing green modules as part of the wider outreach to schools (see case study).

Many participants in the stakeholder workshop also felt the secondary curriculum needed updating to reflect technologies necessary for a net zero transition. Employers were therefore keen to ensure that the curriculum reflects modern technological demands to demonstrate the range of occupations available in the sector. A final point raised in the workshop was to highlight the importance of basic science skills for those not choosing to go to university. As the promoted pathway for future education beyond schools leans towards A-Levels and undergraduate degrees, learners who don't want to go to university tend to switch off from developing their core skills like English, Maths and Science

111. Education and Employers: Disconnected: Career aspirations and jobs in the UK, 2020.
112 Education and Employers: Disconnected: Career aspirations and jobs in the UK, 2020.
113 Engineering UK: Engineering UK response: The Net Zero Review, 2022.

Case Study: SIP Ambassadors Programme

The SIP Careers Programme is set to develop modules that SIP Ambassadors can deliver in schools, with a focus on green skills and sustainability. The modules will cover topics such as low-carbon and hydrogen and will demonstrate how science can be applied to address everyday issues, using examples such as fuel cells in electric cars. The programme will emphasise the significance of green skills and highlight the range of careers available, with the goal of inspiring young people to enter the low-carbon sector.



Future Workforce

RAISE AWARENESS OF THE SECTOR'S IMPORTANCE IN SECURING THE NET ZERO TRANSITION

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	High ●●●	Medium ●●	High ●●●	Medium ●●	Low ●

Positive case studies are crucial for transitioning industries to showcase how they can successfully pivot their operations to support the move towards net zero (see case study). The absence of such success stories negatively impacts the influx of new workers and prompts existing employees to exit, according to the sentiments expressed in the workshops. This view is supported by research conducted by National Grid, which suggests that more than three-quarters of UK adults (78%) believe it's important to play their part in the UK's net zero journey.[114] More than half (57%) of those surveyed said they want to work for an organisation that specifically contributes to reaching net zero. If the transitioning industries are not viewed as being part of the solution, they will struggle to attract the workforce needed to deliver the considerable disruptive technological improvements that are so important to the national effort for net zero.

This is also a high priority for the nuclear and CCUS industries that are facing similar challenges related to perceptions about their compatibility with net zero. Batteries, fuel cells and hydrogen were viewed as having positive perceptions of their contribution to net zero, so this problem wasn't as profound. However, battery employers did express difficulty in attracting Level 2 and 3 level workers, though the feeling was that this was more to do with the overall appeal of manufacturing environments rather than concerns about the sector's net zero credentials. There are several reasons why someone might want to work in battery manufacturing. There is significant opportunity for career growth and advancement for those looking for a challenging and rewarding long-term career in a growing sector. The sector is also at the forefront of technological innovation, which can be attractive to individuals who are interested in working on cutting-edge technology. More work is needed to engage with the wider workforce and promote awareness of the variety of roles available in these new and emerging industries.

114. National Grid: Building the net zero energy workforce, 2020.

Case Study: Petrochemicals as a Feedstock for Batteries

The world is rightly transitioning away from burning fossil fuels for energy generation, mobility, and other uses. However, petrochemicals are still an important feedstock for many cornerstone industries, including batteries. Phillips 66, based in the Humber, is one of Europe's largest producers of needle coke, a key precursor material for anode materials in batteries. Process engineers, R&D scientists and quality control roles are still needed to pivot their current operations towards more sustainable markets. Therefore, stressing the importance of established industries to the successful deployment of net zero technologies is a crucial message for graduates and those considering leaving transitioning industries like downstream.

Future Workforce

UNDERTAKE RESEARCH TO UNDERSTAND THE EQUALITY, DIVERSITY & INCLUSION (ED&I) ISSUES OF THE WORKFORCE AND IDENTIFY BEST PRACTICES TO INFORM THE ACTION PLAN

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	High ●●●	High ●●●	High ●●●	High ●●●	High ●●●

Young people today are often motivated by a desire to work for companies that align with their moral and ethical values. They are increasingly aware of social and environmental issues and want to work for companies that are doing their part to address these challenges. Companies that take ED&I seriously have a better chance of attracting and retaining workers because they can create an inclusive workplace culture where employees feel valued and respected regardless of their background, gender, ethnicity, religion, or sexual orientation. Employees who feel included and supported are more likely to be engaged, productive, and committed to the company's mission and goals. This can lead to higher job satisfaction, better employee retention rates, and increased innovation and creativity. Consequently, it is now widely accepted that companies that attract and develop individuals from diverse backgrounds and experiences consistently perform better.

A lack of diversity within the STEM workforce is a longstanding issue. For example, research by the All-Party Parliamentary Group on Diversity and Inclusion in STEM found that approximately just 9% of the UK's engineering STEM workforce are women.[115] The same research also found that the engineering STEM workforce was less ethnically diverse than the wider economy and had a smaller proportion of workers classed as having a disability. This has undoubtedly contributed to a lack of diversity within the transitioning industries workforce. The data on ED&I is relatively well-established for these sectors, along with the reasons and causes for the lack of diversity, and there are already some policies and initiatives in place to address them. And while recent progress has been broadly positive, change is a slow process, given the size of the industries in question and long-standing practices.

The same applies to the nuclear sector, which also has a good understanding of the issues and is already working to address them. The Nuclear Sector Deal, published in 2018, set a target of achieving a 40% female workforce in the sector by 2030, and the Nuclear Skills Strategy Group work with a range of other organisations to address this issue. Whilst it has a good handle on the sector wide position on gender, more work is underway to mature the approach to other targeted areas.

Benchmarking for the new and emerging sectors is challenging due to current data limitations, such as the ONS LCREE survey not being broken down by diversity characteristics. Nonetheless, it is important to understand the early challenges that companies are facing in order to develop and implement an ED&I strategy that promotes best practices and opens up access to a diverse future pipeline of talent. This suggests that there should be two distinct areas of analysis in the future: one focused on evaluating the current state and interventions needed to advance ED&I within the transitioning industries and another aimed at embedding the principles of ED&I into the new and emerging sectors from the outset.

115. APPG on Diversity and Inclusion in STEM: Inquiry into the STEM Workforce - Data Analysis Brief, 2020.

Enabling the Transition

PROMOTE A CULTURE OF LIFELONG LEARNING AND CONTINUING PROFESSIONAL DEVELOPMENT (CPD) TO ENSURE A SKILLED AND COMMITTED WORKFORCE CAPABLE OF DELIVERING THE TRANSITION.

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
Medium ●●	High ●●●	Medium ●●	Medium ●●	Medium ●●	Low ●

As companies adapt to the green agenda and adopt low-carbon technologies, their workforce will need to be either upskilled or reskilled in order to operate and maintain the new technologies effectively. This will require ongoing training and professional development to keep up with the rapidly evolving nature of the industry and the technology. Even if the workforce is not using new technologies, there will still be a need for upskilling and reskilling. Process improvement often involves changes to existing systems, procedures and practices and may require workers to learn new methods and techniques.

As companies seek to reduce their carbon footprint and transition to more sustainable business practices, workers may need to understand and adopt new approaches to energy efficiency, waste reduction, and other environmentally friendly practices. This could involve training on new equipment, tools or software or gaining new knowledge of regulatory requirements and sustainability standards. Existing workers are often best placed to move into new roles as they can build upon their valuable experience and knowledge of the company and its processes.

At the same time, a lack of opportunities for continuing professional development (CPD) can be a significant factor in an employee's decision to leave a company. Professional growth and development are essential for most workers as they seek opportunities to acquire new skills and knowledge to remain competitive in the job market. When workers feel that their professional development needs are not being met or that there are no opportunities for career advancement within the company, they may become dissatisfied and seek employment elsewhere. This is particularly challenging for industries such as downstream that are already reporting difficulties in attracting and retaining workers due to concerns about their ability to offer long-term career opportunities.

According to a recent LinkedIn survey, 94% of workers say they would stay at a company longer if it simply invested in helping them learn.[116] Interestingly, research by PWC also shows a strong influence in attracting workers by suggesting that "opportunities for career progression" is the most important factor overall that makes an organisation an attractive place to work.[117]

And so investing in upskilling and reskilling opportunities is crucial if companies want to remain competitive and take advantage of new opportunities in the low-carbon economy.

116. LinkedIn: Workforce Learning Report, 2019.
117. PWC: Winning the fight for female talent, 2017.

Enabling the Transition

DEVELOP CLEARLY DEFINED PATHWAYS TO FACILITATE THE TRANSITION OF WORKERS FROM ADJACENT INDUSTRIES TO BRING CROSS-SECTOR LEARNING

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture	Batteries	Fuel Cells
High ●●●	Medium ●●	High ●●●	High ●●●	High ●●●	Medium ●●

Creating pathways for workers to transition into new industries is crucial for facilitating cross-sector learning, which is vital for the growth and development of emerging industries. Companies can benefit from the knowledge and experience that workers bring from their previous roles and industries, driving innovation, increasing efficiency, and improving overall performance. It can also help alleviate potential skills shortages by opening up access to a pool of workers with relevant skills and experience, saving time and resources on training and upskilling.

To create effective pathways, it is essential to clearly define the roles and skills required within the industry, including any necessary qualifications, technical expertise, or potentially transferable skills. This can then be used to compare with the skills profile of the wider workforce, identifying any gaps or areas where additional training or support may be needed. A training plan can then be developed to outline the specific skills and competencies the workforce needs to acquire to transition into new roles. Where possible industry should ensure mutual recognition of training certification and supply chain standards to ease the transfer of workers between businesses and sectors and maximise the use of existing skills. Apprenticeships and work-based learning programs can then be tailored to build upon existing skills and knowledge, allowing workers to learn and adapt quickly to new roles.

It is also important to provide workers with easily accessible information about the skills required in the low-carbon economy and how to transition into new roles so they can make informed decisions about their career paths. To ensure that all workers can access training and acquire the necessary skills, the accessibility and provision of relevant courses must be improved while also addressing practical and financial barriers to training.

Skills Bootcamps are a relatively new offering overseen by the Department of Education and are an option to explore for transitioning industries. They are free to learners and can be used either to gain skills for a new career path or to improve skills related to an existing job. Regional courses linked to 'green skills' have already been approved and have been running for over a year. While it is still too early to call this model a success, it could prove effective in providing upskilling and reskilling opportunities for the transitioning workforce. At the same time, some trade associations and professional bodies are already providing their own courses on transitioning, such as IChemE's Sustainability Hub, which offers members information on key low-carbon principles such as life cycle analysis and an introduction to sustainability. More specific courses such as 'Energy from Waste' and 'Cleaner Process Design' are also being developed.

Enabling the Transition

UNDERSTAND AND DEFINE REGIONAL SKILLS REQUIREMENTS, CONNECTING ECONOMIC HUBS AND INDUSTRIAL CLUSTERS TO DELIVER NATIONALLY FOR INDUSTRY

Nuclear	Transitioning Industries	Hydrogen	Carbon Capture, Use & Storage	Batteries	Fuel Cells
High ●●●	Medium ●●	Medium ●●	High ●●●	Medium ●●	Low ●

While local factors certainly play a role in skills development, the skills needs of a particular industry are best defined at the national level and then adapted to regional priorities. This approach provides a consistent and reliable data source for policymakers, employers, and other stakeholders to make informed decisions about skills development. This can help to promote greater coordination and collaboration and ensure that resources are used effectively and efficiently by avoiding duplication of effort between different regions.

That said, some sectors discussed in this report tend to cluster around specific locations. Understanding the economic geography of these sectors is essential because it can help to identify where the specific skills are needed and where there may be shortages in the labour force. For example, nuclear power plants are concentrated in a select few locations across the UK and serve as anchor employers for their local areas. Similarly, CCUS installations will typically be located near high-emitting industries, such as refineries, and so are concentrated in specific industrial clusters.

By understanding the specific skills needed in these regions, training providers and policymakers can tailor education and training programs to meet the needs of local employers and ensure that the local workforce is equipped with the necessary skills. Hydrogen, on the other hand, is more national in its scope given the wide range of activities the hydrogen value chain encompasses, from refuelling infrastructure to networks and power generation. However, some supply chain elements will be centralised in a few locations, such as hydrogen storage and production from electrolysis and CCUS.[118] The same applies to batteries as gigafactories tend to occur in localised areas (next to vehicle assembly plants), but the extended supply chain is dispersed based on other factors.

The need to understand and solve regional skills needs was also a key recommendation from the Independent Review of Net Zero. The report urged the regions to produce “robust regional green jobs statistics (ideally at local authority level), breakdowns of green jobs considering protected characteristics, and publish information about salary levels”. This shift to regional skills planning is already underway, with many local authorities developing, or having developed, Local Skills Improvement Plans (LSIPs). The plans typically identify the priority sectors for skills development in the area, the skills gaps that need to be addressed, and an action plan/key recommendations that could be taken to improve the supply of skilled labour.

LSIPs also provide a framework for collaboration between local authorities, employers, training providers, and other stakeholders. This collaboration is particularly important for new and emerging industries because there may not yet be an established pipeline of talent or a clear understanding of the skills needed. Similarly, these industries will likely experience rapid growth and change, which can quickly create new skills needs and gaps that require attention. Regular updates to the skills planning process can help to ensure the plans remain relevant and effective.

118. Department for Business, Energy and Industrial Strategy: Sample of potential hydrogen projects across the UK, 2022.

Next Steps

Cogent Skills, the UK's leading strategic body for skills in the science and technology sector, recognises its responsibility in supporting employers as they navigate the low carbon transition. This report serves as a starting point for examining how the transition will impact the skills development trajectory for the sector.

Our primary objective is to foster collaboration within the sector, bringing together employers, training providers, trade associations, and policymakers. This collective approach enables stakeholders to identify knowledge and skills gaps, develop customised training programmes, and formulate targeted policies that support workforce development and industry growth. We look forward to working closely with the Green Jobs Delivery Group to ensure that holistic skills strategies are developed, instilling confidence, and providing a clear pathway forward.

The need for proactive action cannot be overstated. If we fail to act decisively and strategically, we risk failing to develop a workforce capable of delivering the low carbon transition. By prioritising collaboration and adopting an agile approach to the challenges ahead, Cogent Skills is well-positioned to drive the development of the skilled workforce necessary for achieving the UK's net zero targets.

Outlined below is a list of actions encompassing the various ways Cogent Skills and its partners can contribute to a successful transition. These actions demonstrate a shared commitment to developing solutions to the challenges facing the industry during this critical period of change.

Working together to...

1. Develop role profiles for key occupations within the hydrogen sector based on the Cogent Gold Standard competency framework.
2. Quantify the relevant job roles, skills, and qualification requirements to understand the preparedness of the current workforce and provide a forward-looking 15+ year perspective.
3. Scope and facilitate a new trailblazer group of interested parties to identify and develop new science manufacturing apprenticeship standards.
4. Coordinate and lead lobbying efforts on behalf of the sector for consistency in the skills system and better, more responsive training and education policies.
5. Develop low carbon modules that SIP Ambassadors can deliver in schools, focusing on green skills and sustainability.
6. Develop a science manufacturing careers outreach campaign to secure the future talent pipeline of both established and emerging low carbon industries.
7. Implement a skills value chain approach for new low-carbon technologies, delivering an agile skills framework.
8. Undertake research into the sector's current position on ED&I, benchmarking against other industries to identify best practices.
9. Conduct a gap analysis to map the courses currently available for upskilling and reskilling the existing workforce to facilitate the low carbon transition.
10. The Nuclear Skills Strategy Group and the Hydrogen Skills Alliance to lead the development of skills strategies for their industries, working closely with the Green Jobs Delivery Group.

Appendix 1: Skill Level Definition

The different jobs are coloured based on the level of skill. For this research, a qualification level is described as entry level or low skilled, intermediate skill levels are green, and blue represents the highest skilled labour. This is based on widely accepted terminology in the skills literature and a taxonomy Gemserv have used previously in other green skills work.

Qualification Level	Description
Entry Level	No Qualifications
Low	NVQ Level 1 Equivalent – 3/4 GCSE Grades D-G NVQ Level 2 Equivalent – 4-5 GCSE Grades A*-C
Intermediate	NVQ Level 3 Equivalent – 2 A Levels NVQ Level 4 Equivalent – Higher Education Certificate/BTEC
High	NVQ Level 5 Equivalent – Higher Education Diploma/ Foundation Degree Degree or above

Appendix 2: Additional Skills Mapping

Hydrogen Associated Professions

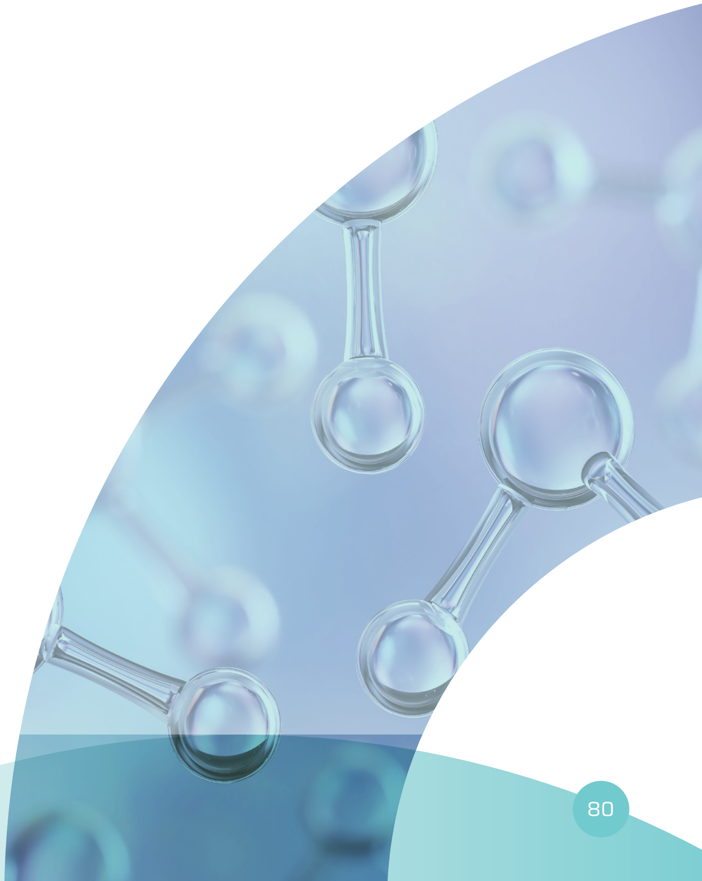
As well as deep technical roles, the hydrogen sector is closely connected to a wider array of value chains beyond energy production and distribution. The need to ensure that energy is produced with reduced negative socio-environmental impacts means that the hydrogen sector also requires jobs within Environmental, Social, and Governance (ESG). Other job types specific to the hydrogen economy beyond production and distribution are listed below.

<table>
<tr><th>Value Chain</th><th colspan="2">Subject Areas</th><th colspan="2">Job Types</th></tr>
<tr><td>Professional Services</td><td colspan="2">Chemical, Mechanical Engineering
Business Administration
MBA</td><td colspan="2">Business & Commercial Development Specialist</td></tr>
<tr><td rowspan="2">AI. Data & Digital</td><td colspan="2" rowspan="2">Computer Engineering
Computer Science
Software Engineering</td><td colspan="2">Digital Occupations</td></tr>
<tr><td>Cybersecurity Specialist
Data Analyst
Data Engineer</td><td>Data Scientist
Software Developer
Systems Integration Specialist</td></tr>
<tr><td rowspan="2">Social Sciences</td><td rowspan="2">Environmental Sciences
Geography
Resource Management
Public Policy
Natural Resources
Management Governance</td><td rowspan="2">Law
Business
Engineering
Health and Safety
Indigenous Studies
Political Science
Social Sciences</td><td colspan="2">Environmental, Social, Governance</td></tr>
<tr><td>Environmental Specialist Environment, Social, Governance Analyst/ LeaderGovernment Relations SpecialistHealth & Safety Advisor</td><td>Local Communities Engagement
Regulatory Analyst and Compliance Specialist
Stakeholder Engagement and Communications Specialist
Sustainability Specialist</td></tr>
<tr><td rowspan="2">Testing and Inspection</td><td colspan="2" rowspan="2">Electrical Materials Engineering
Chemical, Mechanical Engineering
Materials, Metallurgical
Welding</td><td colspan="2">Inspectors</td></tr>
<tr><td>Cathodic Protection Technician
Coating Inspector Construction Inspector
Corrosion Specialist</td><td>In-service Pressure Equipment Inspectors
Non-destructive Inspector and Technician
Safety Codes Inspector
Welding Inspector</td></tr>
</table>

US Department of Energy Hydrogen Professions

The following table also draws upon information from the US Department of Energy's mapping of the hydrogen and fuel cell skills and roles landscaping exercise.

Research and Development, Engineering and Manufacturing	Operations and Management	Communications, Training and Outreach
Advanced Manufacturing Technician	Asset Management	Communication Manager
Assembler and Fabricator	Solicitor	Editor
Chemical Engineer	Budget Analyst	Educational Aide
Civil Engineer	Buyer	Professor
Computer Numerical Control Operator	Computational Scientist	Public Affairs Specialist
Electrical Engineer	Construction Worker	Writer
Environmental Scientist	Economist	
Industrial Equipment Mechanic	Finance Manager	
Instrumentation and Electronics Technician	Industrial Engineer	
Materials Scientist	Legal Assistant	
Plant Operator	Logistician	
Research Engineer	Power Marketer	
Software Engineer	Power Systems / Transmission Engineer	
	Project Developer	
	Project Manager	
	Regulatory Expert	
	Safety and Occupational Health	
	Sales Engineer	
	Salesperson	
	Site/Plant Manager	
	Trade Worker	
	Transportation Worker	



Cross-Cutting Battery and Fuel Cells Skills Mapping

During the literature review, several cross-cutting skills were identified that are crucial in successfully scaling up fuel cells and batteries. These can be grouped into two broad categories. The first is systems integration which focuses on the skills needed to integrate batteries and fuel cells into an end application. The second category is enabling skills which are "wrap around" services or skill sets that will allow the smooth ramp-up of batteries and fuel cells. The table below describes the broad areas surrounding batteries and fuel cells. This draws upon the previously mentioned literature to map out these different requirements.

Value Chain Steps		Cross-Technology Subject Areas		Cross-Technology Roles	
System Integration	Mobility	Mechanical Engineering Aerospace Engineering Rail Engineering	Electrical Engineering Automotive Engineering Systems Engineering	Machine Operator Materials Handling Product Engineer	Production Line Operator
	Energy Storage	Renewable Energy Systems Engineering	Sustainable Engineering	Energy Storage Engineer	Renewable Energy Engineer Maintenance Technician
Enabling Skills	Mining & Construction	Environmental Geography Civil Engineering	Metallurgy Environmental Management	Mining Engineer Equipment Operator Geotechnical Engineer Architects	Surveyor Electrician Quality Control Construction Workers
	AI, Data & Digital	Software Engineering Data Science Physics	Artificial Intelligence Statistics Mathematics	Data Scientist Data Analyst Research Scientist	Machine Learning Engineer Software Engineer
	Professional Services	Communications Finance	Law Business Management	Solicitor Patent Lawyer Finance Manager	Marketing Manager Strategy Buyer / Purchaser
	Recycling & 2nd Life	Environmental Management Sustainable Development	Chemical Engineering Metallurgy Mechanical Engineering	Recycling Engineer Dismantling Technician Process Engineer Research Scientist	Compliance Engineer Machine Operator Materials Handling Test Engineer

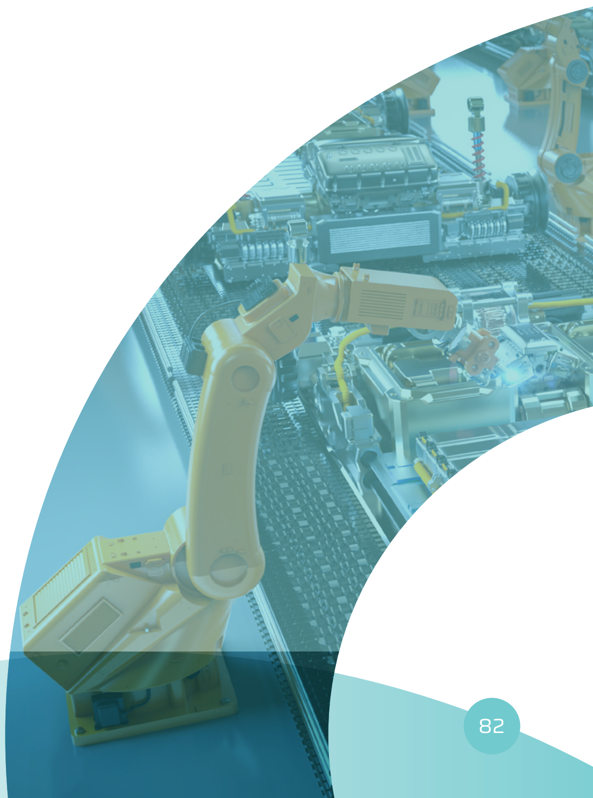
System Integration: These skills reside in existing engineering and sectors such as automotive, aerospace and the growing energy storage industry. Some reskilling will be required via professional development courses and mobility and renewable energy sectors retraining their existing workforces.

Enabling Skills: Enabling skills are broken down into four sub-sections. Mining and Construction focus on civil engineering skills for building facilities and the extraction know-how for battery and fuel cell components. Construction skills are required to plan, manage, and build complex manufacturing facilities that are compliant with local regulations (i.e. UK REACH or local emission regulations) and can integrate seamlessly into local energy systems. This requires highly skilled surveyors, architects, and geotechnical engineers to survey the local area and draw up viable plans. Particularly for batteries, gigafactories are very large facilities that take years to fully permit, build and mobilise. Other sub-components, such as cathode and anode sites, also have very few specialists with long lead times in specifying factory layout and build times, given the dearth of skills that marries battery knowledge with construction knowledge. On the mining side, extraction and refining skills are needed in battery chemicals and catalysts for fuel cells, so they require specialist skills. A report by the Australian FBICRC suggests that mining engineers, on-site electricians and quality technicians don't require much reskilling to pivot into batteries.[119] As fuel cells use existing platinum group metal supply chains, the skills would also be very similar and not change.

Artificial Intelligence, Data and Digital: is a catch-all term for digital engineering that impacts the entire value chain. Specific examples include connected telematics to improve mining extraction techniques, AI-based models that could predict promising future battery chemistries or fuel cell catalyst formulations or using in-situ production line data to optimise fuel cell or battery production techniques. The roles needed to conduct these activities are growing across all manufacturing industries and will be equally crucial for batteries and fuel cells. The data in the Appendix shows that roles in this field require degree-level education, with some needing PhD-level qualifications. Many product-based sectors are leaning into more software and services orientated businesses.

Professional services: is a catch-all term for operational roles, including legal, strategy, finance and marketing roles that are non-engineering based. These are common across multiple industries and are highly transferable, with the roles often needing Level 3+ qualifications.

Recycling and 2nd life: developing skills in this area is becoming increasingly important to the long-term viability of battery and fuel cell technologies. Adjacent skills and roles in sorting and separating or metal recycling processes can be leveraged to a certain extent, especially in the initial testing and dismantling of fuel cell systems and battery packs. As the technologies are broken down into sub-components, more specialised skills and roles are required to understand the technology and individual chemical separation processes.



119. Future Battery Industries: Vocational Skills Gap Assessment and Workforce Development Plan, 2021.

Appendix 3: LCREE Sector definitions

Sector	Description
Carbon capture and storage	The capture of waste CO_2 and/or other greenhouse gases at the point of emission, or from the atmosphere more generally and using it for additional economic activity and depositing it where it will not enter the atmosphere. The design, manufacture, specialised consultancy services and installation of infrastructure for this purpose. Other greenhouse gases include: Methane; Nitrous oxide; Perfluorocarbons (PFCs); Hydrofluorocarbons (HFCs); Sulphur hexafluoride (SF6).
Nuclear power	The production of electricity from nuclear power. The design, development, construction and/or production, specialised consultancy services and installation of infrastructure for producing electricity from nuclear power. The operation and maintenance of infrastructure for producing electricity from nuclear power. Examples of nuclear power activity include: Light water reactors; Fast breeder reactors; Thermal breeder reactors. EXCLUDE: Nuclear energy attained from nuclear decay (geothermal energy; see code 9) and decommissioning.
Fuel cells and energy storage systems	The design, development, manufacture, specialised consultancy services and installation of energy storage systems, referring to the conversion of energy into a form which can be stored, the storing of that energy and subsequent use of that energy. Examples of fuel cells and energy storage activity include: Flywheel energy storage; Batteries; Fuel cells; Thermal energy storage; Any other form of energy storage system.
Alternative Fuels	The production of alternative fuels for low-carbon and renewable energy use. Include design, development, construction and/or production, specialised consultancy services and installation of infrastructure for producing energy from alternative fuels, which is not classed as bioenergy. The operation and maintenance, design, production, and installation of technologies using these fuels. Examples of alternative fuels include: Alcohol fuels (ethanol, methanol, butanol); Ammonia; Carbon-neutral synthetic fuels; Hydrogen produced by electrolysis and/or low-carbon thermochemical processes; Low carbon fuels from fossil waste, e.g. waste industrial gases or unrecyclable; Renewable fuels of non-biological origin, e.g. power to liquid. EXCLUDE: Hydrogen produced by thermochemical processes without carbon capture usage and storage, compressed natural gas and LPG. For nuclear power, see code 16.