Skills Framework

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Introduction

Given the net zero 2050 targets across its member states, the European Union must transition towards a new sustainable energy system. In doing so, green hydrogen can play many important roles. Green hydrogen is a clean and safe energy carrier that can be used as a fuel in transportation and electricity production, as well as a feedstock for industry. Alternative green energy sources such as solar, wind, wave, geothermal, etc., are being considered as plausible providers for meeting the growing demand. However, none of these energy sources except hydrogen (as a vector) has all the desirable qualities to replace petroleum and natural gas, especially with the ambitious decarbonisation strategies.

As a rapidly emerging opportunity, it understandable that to date, the hydrogen industry has centred its measures of success on technological and economic factors. These will remain important as they arrange interest, investment, and growth as efforts continue to create a viable and cost-effective energy alternative. Just as critical, though, is the human element. These are the competency skills that drive success and help analyse gaps in knowledge and know-how and identify opportunities for expansion. It is important to note that a competent workforce will also provide positive public acceptance. Whilst some references have been made about skills and workforce requirements within the multitude of strategic documents and conferences around across the EU, ensuring the right skills are available in the right place at the right time has been largely neglected. International research has offered little in terms of hydrogen-related career paths or the workforce intelligence that this emerging industry will need to accelerate its development.

The EU Context

The European Union's commitment to hydrogen comes with an economic rationale, driven by approximately 35% cost reduction in GH2 over the past five years, and additional 55% cost reductions of GH2 expected towards 2030. The EU sees scaling up green hydrogen production as a cost-effective decarbonisation solution as it becomes cost-competitive with grey hydrogen and fossil fuels towards 2030. It is expected that the cost reduction of green hydrogen production will result in select applications achieving commercial viability before 2030 at forecast carbon prices (e.g., €60 to €100 per tonne of CO_2 equivalent for steel).

Notably, many North-western and Central EU countries have similar commitments to reduce emissions from transport, heat, and power generation. Each one presents diverse strategic and policy drivers to ensure that change occurs, depending on the country's specific circumstances. Many Northern EU countries have green hydrogen policies and deployments[1] already in place. In Sweden in particular, Luleå University of Technology is investing 60 million SEK over 6 years for hydrogen research and education[2], which is carried out in collaboration with some of the most significant names in Swedish industry who see the need for qualified competence in the field of hydrogen.

Hydrogen can enable decarbonisation across the energy and industrial sectors, aiding the EU to meet its environmental commitments. To fully benefit from these opportunities, the green hydrogen workforce requires upskilling and retraining especially in production applications, storage, and safe handling of hydrogen. With appropriate technical skills and the right training and accreditation (industry endorsed) programmes, industry is poised to maximise growth opportunities in the green hydrogen value chain that enables an economically sustainable green hydrogen industry. In turn, this will help to address concerns around energy security and supply, providing economic and environmental cohesion.

[1] https://www.iea.org/regions/europe

[2] https://www.ltu.se/centres/CH2ESS/Nyheter/Lulea-tekniska-universitet-ger-full-gas-mot-vatgassamhallet-1.208823?l=en

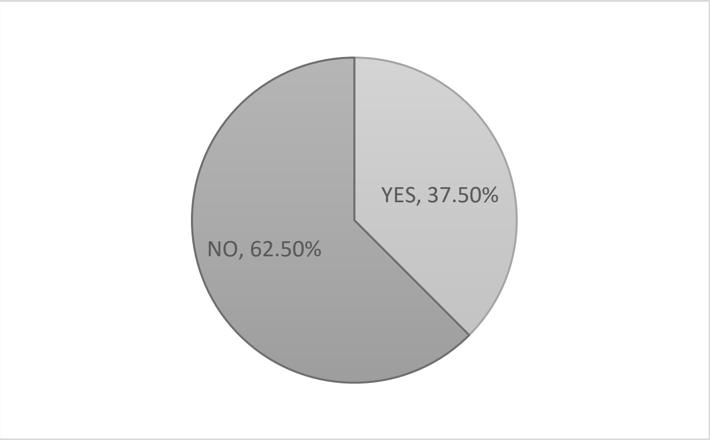
Labour Market

Employment in the green energy sectors varies according to the type of renewable energy in which the employer is engaged. Recent developments in the green hydrogen sector present a more promising future outlook for the green hydrogen industry than was predicted in the recent past. Current scenarios reflect shifts away from activities such as planning and development, and towards more implementation and maintenance-oriented functions.

This is a feature of the future maturation of the industry and, crucially, also marks a transition to more permanent jobs, which are sustained by the requirement to supply renewable electricity, rather than jobs that depend on continued construction. In this context, more of the industry's future jobs will be long-term, rather than short-term, in nature. While the sector has a steady growth, policy support is critical to ensure that this continues apace in the coming decade.

A questionnaire along with face-to-face meetings were conducted in the context of this report to address several questions related to employment market needs in the energy and decarbonisation transition. Interestingly enough, the sample consisted of 35% enterprises that had already been involved in the green hydrogen and related sectors.

Figure 1. Does your company already offer a service in the hydrogen or fuel cell field?



The interests of these companies cover the full spectrum of hydrogen and fuel cell fields is clearly indicated in Table 1 below.

Table 1. Green hydrogen and fuel cell sector of interest

H2 and Fuel Cell sector of interest	
GH2 Production and Distribution, GH2 Storage	56.25%
GH2 Production and Distribution, GH2 Storage, Fuel Cell Applications, Other	31.25%
GH2 Production and Distribution, GH2 Storage, Other	6.25%
GH2 Storage, Fuel Cell Applications	6.25%
GH2 Storage, Fuel Cell Applications, Other	6.25%

Skills Needs and Challenges

Although the days of labour- and skills-intensive traditional heavy engineering manufacturing are mainly over, as more automated methods are now deployed, the engineering sector can have an optimistic future and provide significant opportunities for people to have rewarding and interesting careers in an industry that is an essential part of the EU's economy and its recovery from Covid-19.

The green hydrogen sector is a skills-intensive business, reliant on a diverse range of occupations and a maintainable supply of professional, technical and operator skills to service all the green hydrogen sector's needs.

This report will outline the challenges and key actions required in developing a coherent skills structure to ensure the sector workforce is competent to capitalise on the opportunities in a post-Covid-19, net zero environment.

Currently within parts of the manufacturing and engineering sectors demand for skills is greater than supply. Consideration must be given with respect to recruitment and training programmes as they can be difficult to manage and hard to slow down, so a careful approach is required with intervention as shortage could quickly turn to a surplus. Skills shortages are evident today in manufacturing and engineering sectors across each of the member states with employers choosing to manage the situation by competing for staff within the sector, recruiting only from industry supply chains which do not add capacity and are not sustainable.

Realising real present and potential future growth opportunities, such as those foreseen in the development of the green hydrogen economy will require the manufacturing, engineering, and construction sectors to overcome some significant challenges now and in the future. All sectors across the EU-27 face major skills challenges as the nature of work alters, global competition intensifies, and the present workforce ages. The emerging green hydrogen sector depend on a range of skills relating to Science, Technology, Engineering & Mathematics (STEM). Significant investment to ensure that the right people with the right skills are in place is critical to productivity, competency, and innovation.

Given the optimistic view of hydrogen technologies in political circles (at the time of writing), the pace of skills and training change is likely to be particularly rapid. Future skill needs for emerging technologies, advanced manufacturing, and the low-carbon renewable energy value chains is radically changing both the scope and scale of the skills requirement.

Skills Development

The technological advances in green hydrogen and demographic change have a great work and society reshaping potential, generating a growing demand for higher levels and new sets of skills. It is apparent that assessing the green hydrogen challenges and opportunities for building a more effective skills system depends on the development of policy responses that are tailored to specific skills needs. The foundation of this approach is the OECD Skills Strategy Framework, which allows for an exploration of what countries can do better to:

1) Develop relevant skills over the life course;

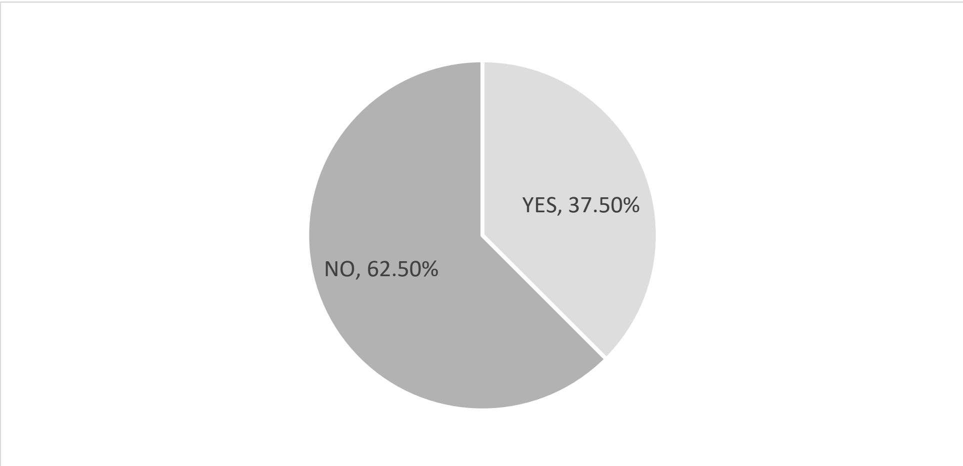
2) Use skills effectively in work and in society;

3) Strengthen the governance of the skills system.

This report found that partnerships between education and training providers and private sector could be better served if vocational education and training programmes are co-created. In doing so, it would be beneficial in reducing the cost of training for companies in transferable and expensive to develop skills, particularly when considering advanced skills and apprenticeships. Indeed, despite this high cost of training for companies, subsidies and incentives targeting the private sector were not evenly present. This presents an opportunity for collaborative working with educational training providers and private sector companies to share technological resources, as well as knowledge, to improve the skills output and to reduce cost of delivery.

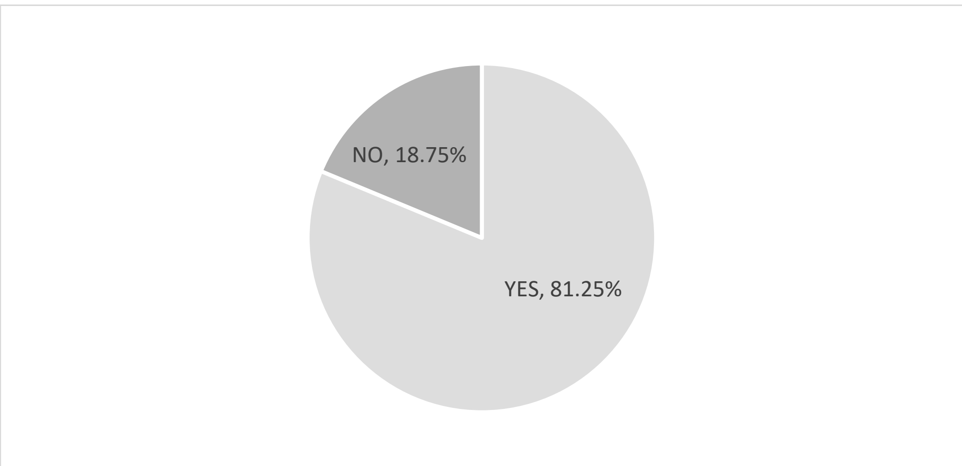
Currently, there are few approaches in place by VET and higher education institutions in place to adapt to the skills gaps in the field of hydrogen and hydrogen safety. For example, one German further education institute involved in the field of innovative energy technologies, and interviewed within HYTREC2, currently offers basic seminars on hydrogen and fuel cells; this is in addition to certificate courses for competent persons according to TRBS-1203 and specialists for gas systems in vehicles according to DGUV-FBHM-099. However, as can be seen from Figure 2 on the following page, approximately two-thirds of companies surveyed and/or interviewed within the scope of the HYTREC2 project currently do not cooperate with educational and training providers.

Figure 2. Does the company have any cooperation with educational /training centres?



It is not surprising that the majority of companies (81.75%) have to train their workers in order to meet their operation needs. This training often comes at a great cost to the employer, who must frequently send employees for training beyond their national borders.

Figure 3. Does the company need to train workers for hydrogen or fuel cell activities?



As Table 1 illustrates, companies rely on different kinds of training, both internal and external.

Table 1. Kinds of training provided by companies.

Internal training	**81.80%**
Short professional training	81.8%
Short theoretical courses	72.70%
Long undergraduate programs at Universities	18.20%
Long courses at training centres	54.50%

In terms of aspects of training, regulatory / security / safety aspects appear to be the most important for the development of a knowledgeable workforce.

Table 2. Aspects of training

Technical aspects	**78.60%**
Regulatory/ security aspects	92.90%
Asset management	7.1%

The most surprising result seems to be the answer to the question: who should be trained? All companies believe that engineers need training.

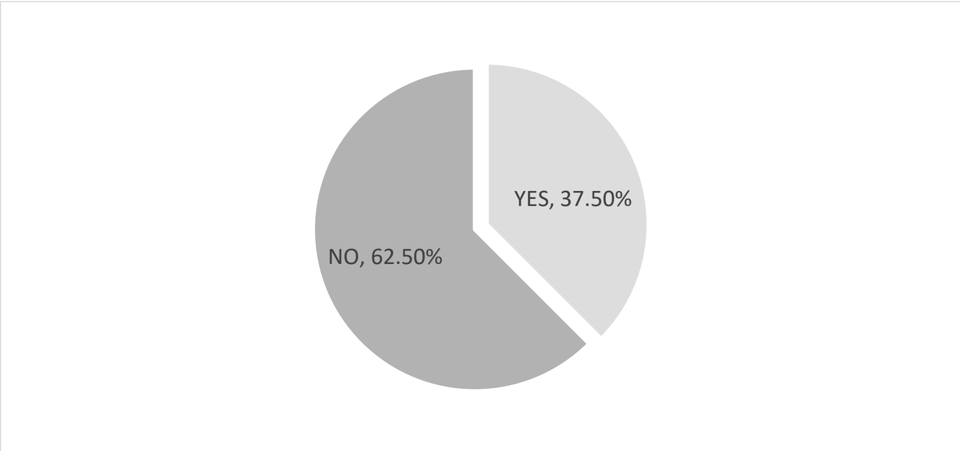
Table 3. Who should be trained for hydrogen or fuel cell related activities?

Technicians	**69.20%**
Engineers	100.00%
Academics	15.40%

Skills Gaps

Today, skills gaps are increasing for a number of reasons. This report reveals that the training of recent recruits has narrowed, especially in STEM related areas. Skills gaps are not easy to overcome by recruitment alone, they should be addressed by industry itself in collaboration with educational and training providers, industry led programmes with more transition training from other sectors is essential, especially in the skillsets required in the green hydrogen economy. In the questionnaires used in this report the following was obtained: 62.50% of the participants reported a difficulty in finding specialised personnel.

Figure 4. Is it easy to find qualified/ skilled professionals operatives?



The Skills of the Future: Meta Skills

In the future we can expect an increase of digital technologies across all places and working fields as well as a continuous increase in new ways of connection between people and equipment—this is especially true in the energy sector through energy management system control from Industrial Internet of Things (IIOT) technology. This will allow people to cooperate across industries and open new market opportunities. Consequently, the volume of data generated will be immense, requiring people to develop skills to manage this complexity. The green hydrogen workforce will have to learn how to work alongside these technologies. Beside the technical skills required to thrive in this emerging new energy environment, people will need to develop a new intersectional set of skills to be applied to the green hydrogen industry, broadly called ‘’meta skills.’’

Meta skills include the following aptitudes: capacity to focus and prioritise, integrity and self-awareness, adaptation and resilience, cognitive flexibility, self-initiative and entrepreneurship, time management, responsibility, empathy (emotional intelligence), communication, collaboration and coordination, leadership and people management, negotiation and persuasion, service orientation, curiosity, and creativity. Meta skills are most effective when learned and developed in the workplace[3]. For instance, meta skills could be learnt through case studies or through real assignments to be carried out at companies. This creates the opportunity for vocational, education and training providers to

[3] Skills Development Scotland (2018), Skills 4.0: a skill model to drive Scotland’s future.

work more closely with companies, also stimulating them to be innovative in the workplace, making this an optimal space for skills development; for example, fostering practices such as openness to new ideas or autonomous working.

T-shaped Skills

T-shaped skills are a method used to describe specific skills and attributes of desirable workers; this is particularly true in technology industries such as those skills required in the green hydrogen sector. The description is thus, the vertical bar of the "T" refers to expert knowledge and experience in a particular vocational field; this can be seen as competency in a technical discipline. The top of the "T" refers to an ability to communicate, collaborate, or co-operate with experts in other disciplines and a willingness to utilise the knowledge gained from this collaboration; this can be seen as the necessary meta skills. It is accepted that a T-shaped person has deep knowledge/skills in one technical vocation/profession and a broad base of general supporting knowledge/skills. This will be highly desired within the HYTREC2 skills development, as meta skills enable the workforce to cope with future technological uncertainties especially with the multidisciplinary nature of decarbonisation.

Figure 5. T-Shaped Skills

Competency Requirements

This report found that there is a current need for training and competency standards across the industry responses received in the HYTREC2 questionnaires and face-to-face meetings. Many of the responses mentioned such competencies in the context of safe handling and storage of hydrogen, gas properties, relevant legislative framework, system design, and operational impacts. All responses in relation to specific activities require measures to ensure risks are properly controlled. Responses incorporated those associated to production, storage, transportation, and distribution of green hydrogen. They also extended to installation of green hydrogen-based systems, such as hydrogen refuelling stations (HRS), fuel cells into vehicles, etc.

Through a comprehensive questionnaire conducted within the HYTREC2 project on the identification of skills gaps and needs in the hydrogen and fuel cell field from the education and training sector, VET providers were prompted to provide data on which kind of training activity should be implemented (by VET) in order to reach their institutional/organisational requirements. Responses ranged across the five partner countries, with one representative from Skills Development Scotland stating skills gaps should be addressed by the following: “Short, flexible, training interventions and transition training will aid the redeployment of these workers particularly in areas such as infrastructure installation and servicing. Vital to renewable energy are core competencies and experience in large scale infrastructure schemes and in safety critical environments, plus specific skills in gas engineering and operations and power grid management.” Further, the “reframing of skills and work practices to contribute to the decarbonisation efforts of oil and gas sector, as well as to the renewables sector. This reframing will also be required for technical and higher-level occupations including instrumentation and control, design, chemical, commissioning, civil and electrical engineering, as well as initiatives to support recruitment and retention of apprentices and graduates.’’

A representative from the Netherlands added another crucial perspective to take into account, supporting the HYTREC2 objective of ensuring future hydrogen skills development is industry-focused: “It will be all about the growing demand and interest in Hydrogen technologies, as well as sourcing qualified educators and trainers.” In Aberdeen, VET providers aim to address the current need for training and competency standards across the industry through introducing a formally recognised and accredited training course for mechanics and technicians; meanwhile on-site training or training on the job was a method of addressing the lack of competencies in hydrogen-related skills/jobs across all partner countries surveyed. In Germany, “on the job training” (WS Reformer GmbH), or specifically “on-site training at hydrogen filling stations; safety training related to hydrogen and filling station operation" (H2 MOBILITY Deutschland GmbH & Co. KG) were suggested to help close existing skills gaps. In Scotland, specifically "service and maintenance" training (Aberdeen City Council) was suggested.

Furthermore, the questionnaire analysis exposes further gaps in education and training for hydrogen-related skills and jobs. At the Norwegian University of Science and Technology (NTNU), the NTNU Team Hydrogen is comprised of world experts on hydrogen energy and is the largest hydrogen R&D cluster in Scandinavia. The team consists of professors and researchers from different disciplines, departments, and faculties across NTNU that works within the hydrogen R&D value chain. As one of the main tasks of the team is to develop new research programmes and projects both nationally and internationally with academia, research organisations and industry – as well as to coordinate hydrogen activities within NTNU – there are already structured educational programmes (Masters and PhD with Integrated Studies) in place relating specifically to hydrogen skills. However, these programmes are identified as knowledge and understanding skills programmes primarily. NTNU is currently educating and training research leaders, innovating, providing solutions and stimulating the industry. CENEX (UK) suggested "detailed information on the real-world performance and technical set up of hydrogen refuelling stations" is critical to VET achieving institutional/organisational requirements whilst considering skills gaps pertaining to hydrogen.

When prompted to elaborate on which kinds of training should be provided at the VET (and/or university level) to meet the needs of their companies, German stakeholders – ranging from manufacturers of H2 filling systems and heat exchangers to those involved in project planning and implementation of the construction of public H2 filling stations – offered the following: basic and certificate courses; safety training courses; on-site training at hydrogen filling stations; safety training related to hydrogen filling station operations; product training, material training; technology training, regulatory training; and, on-the-job training, especially relating to occupational safety (e.g., handling high pressures, handling hazardous gases, connection and bolting systems, pressure tests, etc.).

Figure 5 on the following page details the responses from VET providers in regard to identifying specific relevant jobs in the field of hydrogen and fuel cells that are and shall be required to address the increasing need for trained and experienced personnel and accompanying services: for example, qualified maintenance technicians, installers, manufacturing professionals, trainers, insurers, and educators. Participants were asked to select the job aggregates that their institutions are prepared to offer from a comprehensive list taken from a survey conducted in the USA.

Figure 5. Identifying relevant jobs in the field of Hydrogen and Fuel Cells

Identifying relevant jobs in the field of Hydrogen and Fuel Cells

There will be an increasing need for trained and experienced personnel and accompanying services such as qualified maintenance technicians, installers, manufacturing professionals, trainers, insurers, and educators. Please select the job aggregates that your institution is prepared to offer from the ones given below taken from a survey conducted in the USA.

*Analysis conducted from **102** questionnaire responses across 5 countries.*

With respect to job functions in the hydrogen sector the following roles were revealed: Hydrogen pipeline operative; Fuel cell retrofit installer; Hydrogen vehicle electrician; Hydrogen lab technician, Hydrogen energy system installer; Fuel cell manufacturing technician; Fuel cell fabrication and testing technician; Hydrogen energy systems designer; Hydrogen fuel; Hydrogen refuelling station operator. In addition to the above, it should be noted that there would be upskilling requirements with respect to traditional engineering and construction operatives and technicians, such as gas installation, electrical installation, electrical and mechanical engineering, vehicle/HGV mechanics, etc. All of these skills sets will have to be maintained and indeed expanded to meet the growing demand, as decarbonisation progresses.

This report found that all personnel who will be working with or around hydrogen should be adequately trained on hydrogen safety procedures; however, the findings from questionnaires and one to one interview(s) found a range of definitions on the term trained. Suffice to say, all personnel at the very least have knowledge of and understand hydrogen properties and behaviour, safety requirements for working with or around hydrogen gas and cryogenic liquid hydrogen and hydrogen equipment, operation, and maintenance, irrespective of pressure scale. Health and Safety aspects related to working with hydrogen are critically core skills with such knowledge being an integral part of the HYTREC2 training modules.

A framework for general standards for those working directly with hydrogen is provided. The work of Dahoe and Molkov[4] provides a basis from which learning outcomes or performance criteria can be developed given the variation in vocational education and training (VET) systems across the EU. The key module topics as presented by Dahoe and Molkov have been integrated into a manufactured standard framework. The findings of the HYTREC2 report goes beyond the work of Dahoe and Molkov extending the number of standards required to cover those involved with installation, commissioning and maintaining hydrogen and fuel cell applications as this technology evolves and uptake of its use increases. Indeed, the term competency is required to be defined within HYTREC2, especially how this is assessed and measured. Dahoe and Molkov used competency in their work, although no formal assessment methodology of competency measurement was provided.

[4] Dahoe, A.E. and Molkov, V.V. (2006) On the Development of an International Curriculum on Hydrogen Safety Engineering and Its Implementation into Educational Programmes. WEHC, 4

Dahoe and Molkov Standards Framework

1—Prepare to work in the hydrogen industry.

This standard includes an overview of the hydrogen industry, characteristics of hydrogen, relevant mandatory safety regulations and workplace policies, procedures and work practices required for working in the hydrogen industry.

2—Carry out basic work activities in a hydrogen industry work environment.

This standard includes following workplace procedures to carry out hydrogen industry work activities correctly and safely using appropriate materials, tools and measuring devices.

3—Comply with environmental policies and procedures in the hydrogen industry.

This standard includes complying with relevant legislations, standards, regulations and codes of practice and their application to relevant workplace tasks in the hydrogen industry and completing relevant work completion documentation.

4—Apply workplace health and safety regulations, codes and practices in the hydrogen industry.

This standard includes responsibilities and application at operative levels for health and safety, risk management and adherence to safety practices in the hydrogen supply industry.

5—Carry out hydrogen transport and loading.

This standard includes following workplace procedures to correctly and safely transport and transfer hydrogen. This includes recognising the characteristics of hydrogen and hydrogen tube trailers/tankers to ensure the safe transfer and transport of fuel, conducting pre-trip inspections, performing tube trailer/tanker loading tests and transporting load to customer site. It also includes preparing a site to accept delivery, managing delivery, completing post-delivery activities and following emergency procedures.

Learner Outcomes

The HYTREC2 learner outcomes shall be completely learner centred and shall describe what both the teacher/trainer/facilitator shall teach/train/provide, and what the learner will ultimately learn, consequently developing skills and competencies that are in demand from the industries related to green hydrogen production and application. The HYTREC2 learning outcomes shall follow S.M.A.R.T. (Specific, Measurable, Achievable, Realistic, and Timely) criteria and utilise behavioural verbs that are measurable and based on Bloom's Taxonomy. Below is a framework that sets out the learning outcomes for the HYTREC2 training modules that shall be built upon on these guiding principles.

1. HYTREC2 training modules should be presented for validation in terms of intended learning outcomes.
2. Credit is awarded for the successful achievement of learning outcomes at a specified level, in the case of the HYTREC2 this has been agreed and is set at EQF4/5 due to the range of occupations and professions.
3. Learning outcomes should express what it is intended the learner will have learn and therefore be able to do in order to successfully pass each module.
4. All learning outcomes should be assessable and must be assessed as part of each module.
5. Learning and teaching methods and activities should be designed to support learners towards demonstrating their achievement of the learning outcomes through completion of the module and hence assessment.
6. The learning outcomes of the HYTREC2 training modules should include reference to knowledge and understanding, intellectual or cognitive skills and meta or transferable skills as well as critical safety competency skills expected of a learner successfully completing the module.
7. Learners should be provided with explicit information in the form of assessment criteria and/or grade descriptors about what is necessary to obtain grades above the pass threshold.
8. Module and assignment specific assessment criteria/grade descriptors should be benchmarked commonly across all HYTREC2 training module descriptors.

Conclusion

Hydrogen gas could successfully replace natural gas in many applications including industry, power generation, and domestic heating; simultaneously, hydrogen is also a clean alternative to conventional fossil fuel transport. Hydrogen safety training should be provided to all employees who handle hydrogen or materials from which hydrogen can be evolved. Employers should ensure that workers have access to proper training to do their jobs safely. The HYTREC2 training modules will be based on a competency standard designed specifically around hydrogen related activities and the hazards related to these activities. Aside from job role-specific competency standards, uniform general hydrogen competency standards shall include preparing to work in the hydrogen industry, work practices in the hydrogen industry, complying with environmental policies and procedures, application of health and safety and transporting hydrogen. It is recommended that the HYTREC2 training modules will be industry endorsed, and in time accreditation shall be provided through an appropriate awarding body(s).

It is recommended that intellectual output 1 (IO1/T5 & 6) should establish specific hydrogen training pathways. These pathways will provide the foundation for vocational education and training strategies to ensure specialist skills and knowledge can be acquired in a timely manner, as several of these may have a long lead-in times towards competence. Intellectual outputs 5 & 6 should use the following questions to form the basis of the pathways.

- Which job roles within existing trades and disciplines can be adapted and/or contextualised to transition into the green hydrogen industry and how can HYTREC2 training modules support each?
- Would the required skills and knowledge be acquired through competency training and what other short course provision type training will be required?
- Would the job profiles as set out in this report be the most suitable to transition into the green hydrogen sector or would there be a need to recruit from other sectors? If so, which sectors would be most impacted?
- It is important to understand what the timelines are required to ensure that:
- Relevant standards are in place to ‘train the trainers’ who will be responsible for the accreditation of new technicians for the green hydrogen Industry?
- Necessary numbers of future technicians required for the green hydrogen industry to successfully get off the ground are available when needed?

Sufficient notice is provided to adequately promote and engage the required number of new or transitioning technicians to successfully support the creation of a viable green hydrogen industry.

To support the development of the HYTREC2 training modules an exemplar module “Fuel Cell Technology Systems” and a module checklist have been developed—these can be seen in annex 1 & 2 respectively. A series of HYTREC2 work package 5 meetings shall now be held to establish additional modules to complete the HYTREC2 training modules.

Annex 1 Module Exemplar

Module Fuel Cell Technology Systems

Acceptable performance in this module will be the satisfactory achievement of the standards set out in this part of the Module Specification. All sections of the statement of standards are mandatory and cannot be altered.

OUTCOME 1

Describe the basic principles of fuel cell technology systems

Performance Criteria

(a) Describe the basic electrochemical reaction in hydrogen fuel cells.
(b) Describe the operating principles of fuel cells
(c) Describe applications of fuel cell technology systems.
(d) State the main advantages of fuel cell technology systems.
(e) State the main disadvantages of fuel cell technology systems.

OUTCOME 2

Describe the basic characteristics of fuel cells and the function of their component parts

Performance Criteria

(a) Show by means of a diagram the location of the main component parts of a single fuel cell
(b) Describe the function of the main component parts of a fuel cell technology system
(c) Describe the basic characteristics of Proton Exchange Membrane (PEM) fuel cells

OUTCOME 3

State the relevant Standards and Regulations used for the design, installation, commissioning and maintenance of fuel cell technology systems

Performance Criteria

(a) State the basic planning requirements and procedures in relation to the design and installation of fuel cell technology systems.
(b) State clearly how Standards and Regulations apply to fuel cell technology systems
(c) State clearly how to minimise the risk to personnel and building occupiers when installing fuel cell technology systems.
(d) State the basic commissioning and maintenance requirements of a fuel cell technology system.

EVIDENCE REQUIREMENTS FOR THIS MODULE

Evidence is required to demonstrate that learners have achieved outcomes and performance criteria. Written and / or recorded oral evidence should be produced to demonstrate that the learner has achieved all the outcomes and performance criteria. The evidence should be produced under the form of "open-book" supervised and controlled conditions.

OUTCOME 1

(a) The learner must correctly describe the basic electrochemical reaction in hydrogen fuel cells. This description must include:
    - Atomic structure of hydrogen
    - The basic properties of hydrogen
    - Anode reaction $2H_2 \rightarrow 4H_+ + 4e_-$
    - Cathode reaction $O_2 + 4H_+ + 4e_- \rightarrow 2H_2O$
    - Net Reaction $2H_2 + O_2 \rightarrow 2H_2O$ + Energy
    - The production of direct current

(b) The learner must correctly describe the operating principles of fuel cells. This description must include:

- Hydrogen as an energy carrier
- The need for fuel replenishment
- Sourcing of hydrogen from electrolysis

(c) The learner must correctly describe three applications of fuel cell technology systems. This description must include:

- Power generation
- Backup power
- Transportation

(d) The learner must clearly state at least three advantages of fuel cell technology systems. This description must include three of the following:

- Reduction in pollutant emissions
- Fuel Cells can be used in a wide range of sectors
- Fuel Cells can be used as a store for renewable energy
- No moving parts
- Relative efficiency of fuel cells

(e) The learner must clearly state three disadvantages of fuel cell technology systems. This description must include three of the following:

- Cost of fuel cells
- Hydrogen containment issues
- Durability and reliability issues

OUTCOME 2

(a) The learner must show by production of a diagram the location of the main component parts of a single fuel cell. The diagram must indicate:

- Anode
- Cathode
- Electrolyte
- Catalyst
- Fuel inputs and outputs

- Electrical circuit and load

(b) The learner must correctly describe the function of the main component parts of a fuel cell technology system. This description must include:
  - Anode
  - Cathode
  - Electrolyte
  - Catalyst
  - Fuel inputs and outputs
  - Electrical circuit and load
  - Fuel cell processor
  - Stack
  - Inverter

(c) The learner must correctly describe the basic characteristics of Proton Exchange Membrane fuel cells. This description must include:
  - Water and air management
  - Temperature management
  - Electrical output range
  - Quick start up

OUTCOME 3

(a) The learner must correctly state the basic planning requirements and procedures in relation to the design and installation of fuel cell technology systems. Design and installation factors must include:
  - Siting of fuel cell installations
  - Hydrogen containment and piping
  - Air intake, exhaust outlets and ventilation requirements
  - Safety and separation distances
  - Positioning of hydrogen sensors

(b) The learner must state clearly how Standards and Regulations apply to fuel cell technology systems. This must include the following:

- Gas Safety Regulations
- Pressure Equipment Regulations
- Engineering Standards

(c) The learner must clearly state the measures required to minimise risk to personnel and building occupiers when installing fuel cell technology systems. This must include the following:
  - Avoidance of fire and explosion
  - Avoidance of pressure related hazards
  - Avoidance of thermal hazards
  - Avoidance of electric shock

(d) The learner must clearly state the basic commissioning and maintenance requirements of a fuel cell technology system and the importance of the following:
  - Installation and commissioning checklists
  - Maintenance and servicing plans

GUIDANCE ON THE CONTENT AND CONTEXT FOR THIS MODULE

Outcome 1

Learners must be able to demonstrate knowledge of the atomic structure of hydrogen of one proton and one electron and the basic properties of hydrogen specifically the ease of combination with other atoms and the properties of being colourless, odourless and light. Learners must be able to demonstrate an understanding of the basic electrochemical reaction in hydrogen fuel cells including anode, cathode and net reaction formulae.

Learners must be able to demonstrate an understanding of the operating principles of fuel cells and demonstrate knowledge of hydrogen as an energy carrier, the need for fuel replenishment and the sourcing of hydrogen fuel from electrolysis.

Learners must also understand and demonstrate knowledge of three applications of fuel cell technology systems their use in power generation, backup power and transportation

Learners must be able to clearly state at least three advantages of fuel cell technology systems from the following; reduction in pollutant emissions, fuel cells can be used in a wide range of sectors, fuel cells can be used as a store for renewable energy, no moving parts and the relative efficiency of fuel cells. Learners must be able to demonstrate knowledge of the main disadvantages of fuel cells in particular the cost of fuel cells, hydrogen containment issues and the durability and reliability of some types of fuel cell.

Outcome 2

Learners must be able to demonstrate knowledge of the location and function of the main component parts of a single fuel cell. Components to be identified and located in a diagram are the anode, cathode, electrolyte, catalyst, fuel inputs and outputs and the electrical circuit and load.

The Learners must also be able to describe the function of each of these components. Learners must be able to demonstrate knowledge of the function of the fuel cell processor, stack and inverter

Learners must be able to describe the basic characteristics of Proton Exchange Membrane fuel cells in particular water and air management, temperature management, electrical output range and the quick start up of these types of fuel cell.

Learners must be able to demonstrate a knowledge and understanding of the basic characteristics of Direct Methanol fuel cells specifically water and carbon dioxide management, electrical output range and the use of cartridges for fuel replenishment

Outcome 3

Learners must be able to state the basic planning requirements and procedures for the design and installation of fuel cell technology systems. Design and installation factors will include the siting of fuel cell installations, hydrogen containment and piping, air intake and exhaust outlets and their ventilation requirements, safety and separation distances and the positioning of hydrogen sensors

Learners must be able to describe how the building regulations apply in particular the Regulations for Gas Safety, Pressure Equipment and Engineering Standards.

Learners must also demonstrate awareness of the measures required to minimise risks when designing and installing fuel cell technology systems. In particular, the following risks should be detailed and avoidance measures described: Avoidance of fire and explosion, avoidance of pressure related hazards, avoidance of thermal hazards and the avoidance of electric shock.

Learners will be able to demonstrate an understanding of the installation and maintenance of fuel cell technology systems and the importance of installation and commissioning checklists and maintenance and servicing plans.

GUIDANCE ON LEARNING AND TEACHING APPROACHES FOR THIS MODULE

This module is to be delivered using a variety of learning and teaching approaches such as structured lessons with formative and summative assessments; in addition to practical demonstration of components and characteristics of fuel cell technology systems, where possible. Support material particularly that of the interactive activities should be fully utilised during the delivery of all HYTREC2 training modules.

This module is not intended to endorse successful Learners as competent operatives of fuel cell technology systems. However, HYTREC2 do seek to get industry endorsement ultimately leading to competency accreditation.

OPPORTUNITIES FOR META SKILLS DEVELOPMENT

There are opportunities for the learner to develop aspects of meta skill inside of this module and hence there they should be integrated at EQF level 4/5.

Annex 2 Module Checklist

Module title and level	
Date of check	
Evaluator's name	

Essential Information			
	Key Questions	Y/N or N/A	COMMENT REQUIRED AGAINST 'NO'RESPONSES
Module title	Does the title of the module give a clear indication of what the module is about?		
	Does the title reflect the skills and / or knowledge covered?		
Module Summary	Does the module summary give the reader a clear idea of the content and objectives of the module?		
	Is it consistent with the module title and module outcomes?		
	Has the target audience(s) been identified?		
	Has the context for delivery been identified?		
Module Outcomes	Has due consideration been given to the command verbs used in the learning outcomes of a module?		

Module Recommend entry	Has guidance on the level of skills, knowledge, experience, or the qualifications a learner should have achieved prior to starting the module been given?		
Meta Skills	Has meta skills been fully integrated into the module and is measurable?		

Guidelines			
	Key Questions	Y/N or N/A	COMMENT REQUIRED AGAINST 'NO'RESPONSES
Outcomes	Does each Outcome state clearly the skills or knowledge that must be demonstrated by the learner?		
	Are the Outcomes written in the order a learner will work through them?		
	Does each Outcome link to the module summary?		
	Do the Outcomes match the characteristics of the corresponding EQF level?		
	Do the outcome contain at least 50% digital content?		
	Are you satisfied that the Outcomes do not present a barrier to the learner in terms of the safeguarded rights? Safeguarded rights are the following, it must be noted that this is not an exhaustive list - disability, race, age, religion or		

	belief, sex, gender re-assignment, pregnancy and maternity or sexual orientation.		
	Do the performances criteria (PC): clearly describe the way the learner carries out the activity described in the Outcome, (process) or whatever is produced as a result of that activity (product)?		
Performance Criteria	clearly indicate the standard or quality of performance expected?		
	run in the order a learner will work through them?		
	facilitate holistic assessment of the Outcome?		
	Is each PC an essential part of the definition of what it is to be competent in the Outcome?		
	Are you satisfied that the PCs do not present a barrier to learners in terms of the safeguarding rights?		
	Do the Evidence Requirements clearly specify: what the learner has to do?		
	to what standard?		
Evidence Requirements for this module	the type of evidence required?		
	how much evidence is required?		

	the number of assessment occasions i.e. different points throughout or in one assessment occasion		
	the conditions in which the evidence must be produced ? i.e. online, open/closed book, controlled conditions, final integrated assessment etc.		
	Do the Evidence Requirements cover the content of the module and relate back to the Outcomes and PCs?		
	Do the Evidence Requirements only relate to what is asked for in the Outcomes and PCs? i.e. they do not ask for more		
	Has the choice of instrument of assessment been left open? Note: the instrument of assessment should not be specified in the Evidence Requirements		
	Do the Evidence Requirements encourage holistic assessment (within and across Outcomes) where possible, like an assignment or project?		
	Is the mode of assessment as open and flexible as possible e.g., if it is acceptable to submit evidence in electronic or online?		
	Are you satisfied that the Evidence Requirements do not present a barrier to learners in terms of the protected characteristics?		

Heading	Key Questions	Y/N or N/A	COMMENT REQUIRED AGAINST ‘NO’RESPONSES
Guidance on the content/ context	Does the information provided help the reader gain a better understanding of the module principles?		
Guidance on learning and teaching approaches	Does the information provided help the reader gain an understanding of how learning teaching/delivery might be organised? Note that at least 50% of the learning and teaching process should be based on TEL.		
	Have possible TEL delivery methods been identified?		
Guidance on approaches to assessment	Does the information provide the reader with a greater understanding of how the Outcomes will be assessed?		
	Is it consistent with the Evidence Requirements?		
TEL - assessment	Have opportunities been identified? Is there the opportunity to use AI in the assessment process?		
Development of Meta Skills	Have opportunities to develop aspects of Meta Skills been signposted?		
Overall	Is the module content technically accurate?		

	Is the content appropriate to the level and time allocated to deliver it?		