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HySkills IMPLEMENTATION HANDBOOK

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Contents

1. Introduction

The HySkills project brings together the knowledge, expertise and innovation of five European partners to design a comprehensive training course aimed at the future workforce in the hydrogen sector. The modular course provides key skills and knowledge to learners in the EQF level 5 range, allowing them to pursue hydrogen-related career paths while equipped with the relevant technical and safety skills.

This Implementation Handbook is part of HySkills' "Train the Trainer" element, which supports and enables VET trainers to be able to successfully deliver the HySkills modules. This handbook is also supported by resources such as an explanatory video, which can be found at hyskills.org.

This document contains:

- A detailed description of the HySkills project and information about the project partners, as well as the main results of the HySkills survey which was carried out to assess skill requirements;
- A description of the structure of the programme, including the modules, their learning outcomes, as well as the suggested sequence and pre-requisites;
- A guide through the materials of each module of the HySkills programme;
- An overview of pedagogical techniques, including teaching approaches and meta skills, to support the delivery of the course.

It is important to highlight that this document – and the "Train the Trainer" package as a whole – are not meant to be prescriptive or limiting. In fact, these resources are supporting materials which aim to assist teachers and trainers in the delivery of the HySkills programme, suggesting best practices and serving as a guide for the modular course. The exact method of delivery of the modules invariably will (and should be) tailored to local and individual needs, language aspects and available resources.

We hope this guide is useful to you as a teacher, trainer or course facilitator, and that this handbook's contents help you deliver the HySkills programme to learners in an effective, dynamic and productive manner.

2. The HySkills Project

2.1. Overview and objectives

The transition to a net-zero carbon society within the next three decades will require comprehensive adjustments in business, behaviour and policy. Many employees will spend the bulk of their careers within this transition. It is essential that they are equipped with the skills and knowledge needed for the challenges they will face, and it is imperative to develop an all-encompassing long-term approach to deliver the skills that will enable industry and society to decarbonise.

Green hydrogen, which is currently receiving widespread attention from a variety of sectors, is a clean energy vector seen as central in the aim to decarbonise industries and economies. The emerging green hydrogen sector will require workers who are fully competent and accredited in key skills, being capable of working in this critical sector in a safe and efficient manner.

The **HySkills** project, co-funded by the Erasmus+ Programme of the European Union, is grounded on the premise that there will be a skills gap in the upcoming hydrogen sector and therefore a need for a suitably educated workforce. In order to meet this need, an international consortium came together to create HySkills – an industrially relevant, modular, vocational education and training (VET) course aimed at educating learners for the hydrogen sector. The HySkills modules focus on fundamentals of hydrogen, imparting technical and practical knowledge, as well as the important critical safety considerations of hydrogen.

The project commenced in December 2020 and closed in September 2023, and featured the collaboration of a consortium of 5 European partners with expertise in hydrogen, sustainability and education. The main outputs of the project are:

- A range of learning outcomes and units informed by a survey performed with industry representatives and academic institutions;
- An open-source modular course, based on the needs analysis, containing resources and materials divided into 8 modules;
- A “Train the Trainer” toolkit, which includes this implementation handbook.

2.2. Project partners

United Kingdom

South West College (SWC) is one of the largest vocational and technical Colleges in the United Kingdom employing over 900 staff and servicing 22,000 full-time and part-time learners. The College is rurally located in the western region of Northern Ireland.

The scope of curriculum at the College ranges from Level 1-7 provision including a portfolio of further education, higher education and apprenticeship programmes. South West College offers a broad range of modern and industry-relevant curriculum delivered across three faculties.

www.swc.ac.uk

Ireland

Dublin City University (DCU) in Ireland is education, research & sustainability focused. DCU has a mission of transforming lives and societies. DCU's Strategic Plan has renewed the curriculum experience for students and staff.

One of the university's key drivers is the need to prepare students for the workplace environment working in multi-disciplinary teams and gaining real world experiences to be successful.

www.dcu.ie

Norway

Uniquely located at 70 degrees north, UiT – The Arctic University of Norway is the northernmost university in the world, surrounded by some of Europe's last pristine wild nature. Established in 1968, the University is a modern, broad, high-tech university with outstanding degree programs at bachelor, master and PhD level in 8 faculties.

UiT supports the development of outstanding research, both basic and applied, in all disciplines, but with particular emphasis on cross- and interdisciplinary research efforts focusing on the needs, problems and opportunities of the North.

https://en.uit.no/startsida

Greece

The Hellenic Society for the Promotion of Research and Development Methodologies (PROMEA), based in Athens, Greece, is a Non-profit Association.

PROMEA's goal is to address societal challenges related to workforce re-training and upskilling, resource efficiency, circular economy, quality improvement in education, inclusiveness, and equal opportunities.
www.promea.gr

Germany

The European Institute for Innovation – Technology is a registered non-profit organisation. EIfI-Tech works on a variety of projects, merging technical innovation with economic deployment. Thus, the EIfI-Tech is known for its work with innovation & entrepreneurs; it shortens the connection with industry & academia partners.

Furthermore, the Institute is active in applied research, feasibility, testing, development, demonstration with the purpose of ultimately supporting economic deployment.
www.eifi.info

2.3. The HySkills survey

In early 2021, a questionnaire was carried out with company/industry representatives and educational institutions located across the five countries, aiming to align their needs with the content and materials that would then be produced by HySkills. Responses were recorded and valuable input was gathered regarding the needs of the employment market in the green hydrogen sector.

Within the sample surveyed, it can be highlighted that:

- **3 in 4** (75.0%) companies have (or had in the past) hydrogen related activities;
- **Nearly half** (46.4%) already collaborate with universities or training centres in the field of hydrogen;
- **The vast majority** (82.1%) already collaborate with other companies in the field of hydrogen;
- **Nearly all** (96.4%) believe that hydrogen and/or fuel cells will be a market opportunity in the near future.

In terms of findings, the main results indicate that:

- **2 in 3** (64.3%) companies surveyed claimed that it is hard to find qualified and skilled professionals;
- **4 in 5** (78.6%) affirm that they need to train workers for hydrogen related activities;
- Technical as well as regulatory/security aspects are the main training aspects of interest (see Figure 1);
- Internal training and short courses are the preferred type of training (see Figure 2).

Figure 1. Out of companies that need to train workers for hydrogen activities, these are the main training aspects of interest.

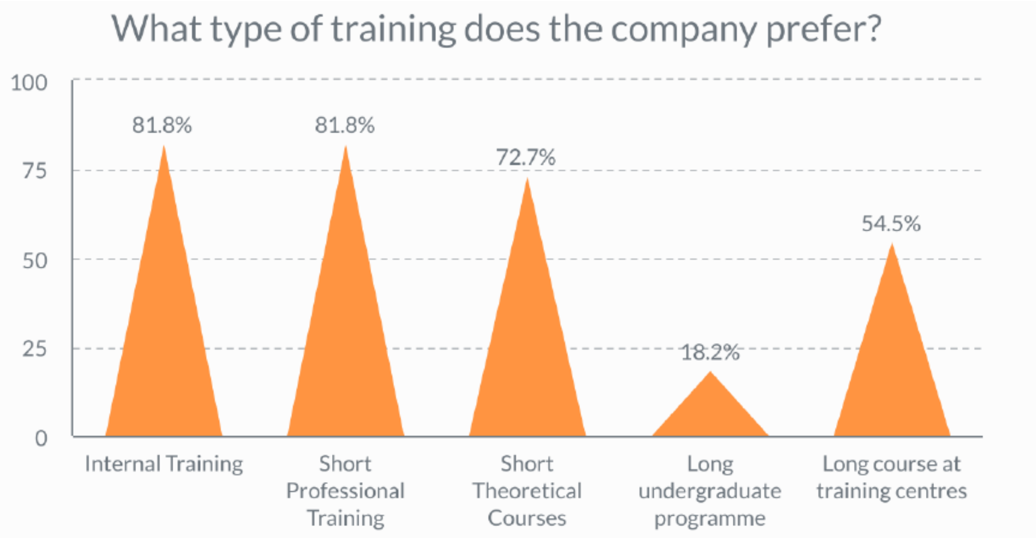


Figure 2. Preferred types of training for hydrogen related activities.

The questionnaire also allowed respondents to list or select the jobs for which organisations intend to offer education/training/skills development. The results are shown in Figure 3.

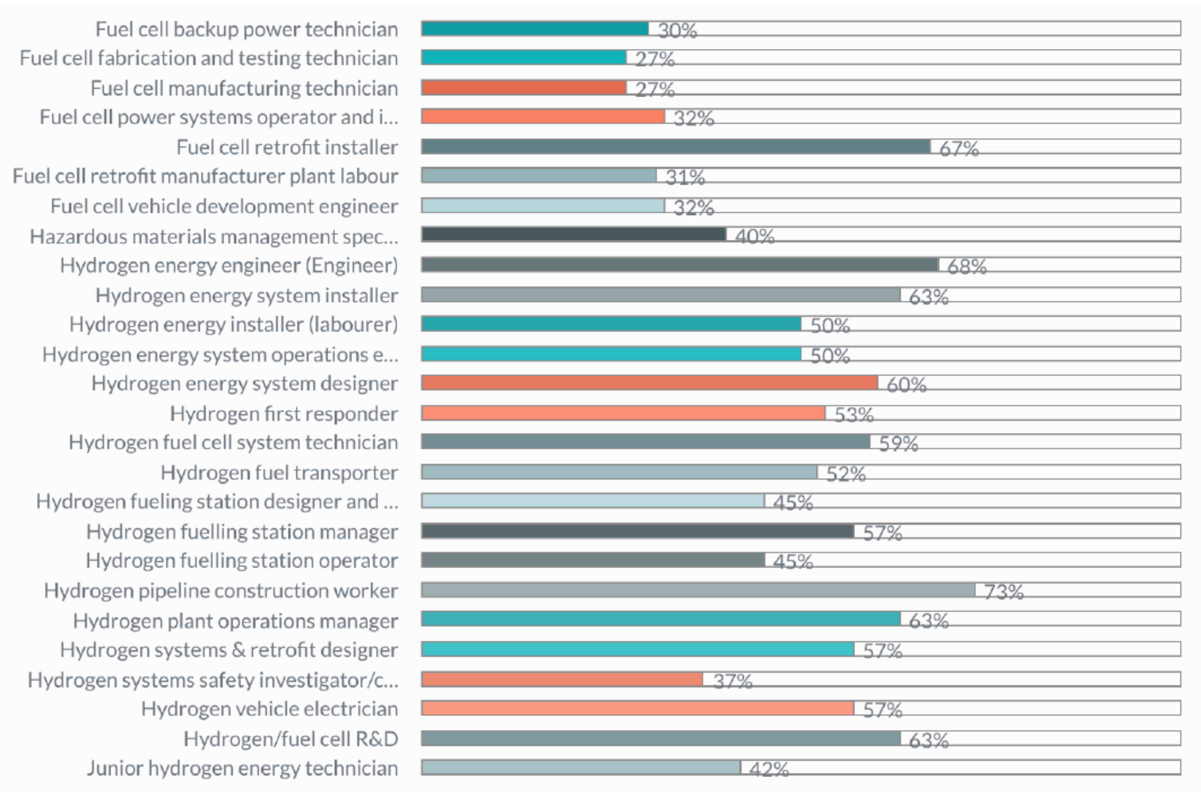


Figure 3. Jobs that organisations are prepared to offer.

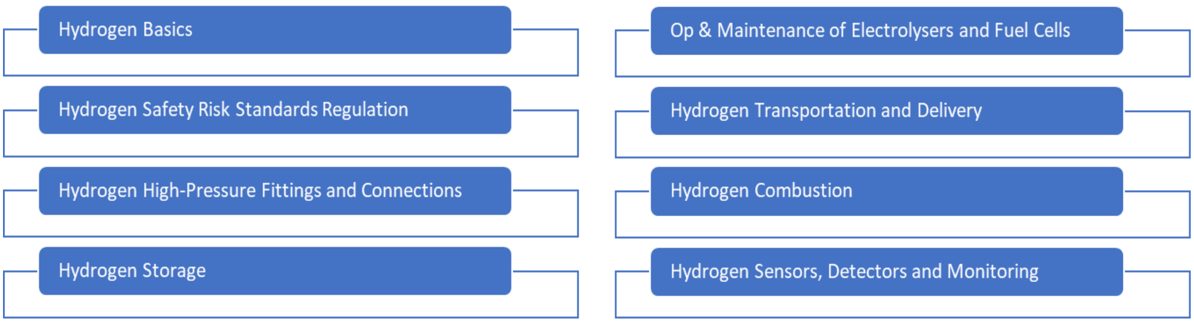
For further information, the full results of the needs analysis survey can be found below:

Access full report

3. HySkills Structure

3.1. Overview of modules

The HySkills modular course is composed of eight modules, or learning units, which were carefully chosen to provide the learner with a wide range of skills from essential hydrogen knowledge areas. The modules are briefly described in this section.



Learning Unit 1

Hydrogen Basics

This module provides the learner with a baseline knowledge and understanding of the proprieties and characteristics of hydrogen and hydrogen technologies, as well as the potential roles and uses for hydrogen in industry and in the energy sector, aiming to develop the learners' understanding of the opportunities and challenges inherent to the production and use of this versatile gas. The module will provide learners with a solid knowledge base on hydrogen and hydrogen technologies, allowing them to progress toward the various other modules of the programme and, thus, deepen and expand their knowledge into more specific areas.

Learning Unit 2

Hydrogen Safety, Risks, Standards and Regulation

The content of this module is designed to allow learners to work safely within a hydrogen environment/workplace. 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 safe handling of hydrogen, where possible. This is underpinned by the learner gaining knowledge of the relevant legislation, roles/responsibilities and requirements of Common Law in the interpretation of current legislation.

Learning Unit 3

Hydrogen High-Pressure Fittings and Connections

This module covers foundational knowledge and hands-on experience to enable learners to learn, develop and practice the critical safety skills required for hydrogen high-pressure fittings and connections, including: tube fitting installation and inspection; medium and high-pressure cone and thread installation; and hose, valve and regulator selection in order to minimise the risk of leakage and ensure system integrity.

Learning Unit 4

Hydrogen Storage

This module covers the different methods available for storing and transporting hydrogen, including high-pressure gas compression, liquefaction, metal hydride storage, and carbon nanotube adsorption. The module reviews up-to-date examples of the various solutions and their deployment, and explores energy efficiency issues and economic aspects, as well as environmental and safety issues of various hydrogen storage technologies.

Learning Unit 5

Operation and Maintenance of Electrolysers and Fuel Cells

This module provides a baseline knowledge and understanding of the operation and maintenance of electrolysers and fuel cells in industry and in the energy sector, aiming to develop the learner's understanding of the opportunities and challenges inherent to the production and use of this versatile gas.

Learning Unit 6

Hydrogen Transportation and Delivery

The module complements the other HySkills modules by allowing learners to learn, develop and practice the critical safety skills required for the loading, movement and unloading of hydrogen, enabling future workers to achieve the programme's intended learning outcomes and become fully competent in the different aspects of the hydrogen sector.

Learning Unit 7

Hydrogen Combustion

This module aims to provide the learner with a knowledge and understanding of hydrogen combustion and flammability, developing a competence in issues related to hydrogen combustion and safety technologies. The module complements the other HySkills modules by providing learners with key knowledge and practical training in hydrogen combustion systems, enabling future workers to achieve the programme's intended learning outcomes and become fully competent in the different aspects of the hydrogen sector.

Learning Unit 8

Hydrogen Sensors, Detectors and Monitoring

The module complements the other HySkills modules by allowing learners to learn, develop and practice the critical safety skills required for the sensing, detection and monitoring of hydrogen, enabling future workers to achieve the programme's intended learning outcomes and become fully competent in the different aspects of the hydrogen sector.

3.2. Learning outcomes

Each of the HySkills modules has two to five key Learning Outcomes (LO's), which describe the knowledge, understanding, skills and values learners should be able to demonstrate after completing each respective learning unit. The LO's of each module of the programme are described in this section.

LU1 – **Hydrogen Basics**

- *Outcome 1*: Recognise the importance of hydrogen in the energy sector as a potential clean fuel in the context of the current energy transition.
- *Outcome 2*: Describe the chemical properties of hydrogen gas and the different methods that are employed to produce it, differentiating between their environmental impacts.
- *Outcome 3*: Identify roles for hydrogen in electricity production, energy storage, heating and transport.
- *Outcome 4*: Discuss current and future technologies for hydrogen storage, distribution and combustion.
- *Outcome 5*: Identify applications for hydrogen in industry as a chemical and industrial feedstock.

LU2 – **Hydrogen Safety, Risks, Standards and Regulation**

- *Outcome 1*: State the current Health and Safety legislation covering employers and employees.
- *Outcome 2*: Prepare to handle hydrogen gas.
- *Outcome 3*: Perform a risk assessment exercise within a given hydrogen environment.

LU3 – **Hydrogen High-Pressure Fittings and Connections**

- *Outcome 1*: Understand piping system criteria and installation of components up to the system's readiness to start up.
- *Outcome 2*: Describe maintenance and repair procedures of high-pressure hydrogen installations in terms of inspection, grounding system, maintenance, and records.

LU4 – **Hydrogen Storage**

- *Outcome 1*: Understand the different methods and technologies available for storing hydrogen.

- *Outcome 2*: Understand the different methods of hydrogen compression technologies.
- *Outcome 3*: Understand the different methods available for storing hydrogen in liquid and gaseous forms, in high-pressure hydrogen storage vessels and cryogenic flasks, and solid-state hydrogen storage in metal hydride storage and carbon nanotube adsorption.

LU5 – **Operation and Maintenance of Electrolysers and Fuel Cells**

- *Outcome 1*: Describe the basic principles of electrolyser & fuel cell technology systems.
- *Outcome 2*: Describe the basic characteristics of fuel cells and the function of their component parts.
- *Outcome 3*: State the relevant Standards and Regulations used for the design, installation, commissioning and maintenance of electrolyser & fuel cell technology systems.

LU6 – **Hydrogen Transportation and Delivery**

- *Outcome 1*: Describe the situations where purging of hydrogen systems is required and the correct procedure for purging.
- *Outcome 2*: Describe the basic characteristics of a hydrogen gas network and its component parts.
- *Outcome 3*: State the relevant Standards and Regulations used for the commissioning, maintenance and operation of hydrogen transportation and delivery systems.
- *Outcome 4*: Demonstrate competence in the delivery of gaseous hydrogen to a hydrogen storage facility.
- *Outcome 5*: Demonstrate competence in the delivery of liquid hydrogen to a hydrogen storage facility.

LU7 – **Hydrogen Combustion**

- *Outcome 1*: Describe the conversion of hydrogen in end use applications focusing on hydrogen combustion.
- *Outcome 2*: Examine the principles of hydrogen combustion and safety technologies and systems.
- *Outcome 3*: Describe and compare the operation and maintenance of different hydrogen combustion technologies.
- *Outcome 4*: Demonstrate compliance with safety regulations and workplace policies, procedures and practices required for working with the combustion of hydrogen.

LU8 – **Hydrogen Sensors, Detectors and Monitoring**

- *Outcome 1*: Describe the technologies and strategies used in hydrogen detection.
- *Outcome 2*: Describe the situations where the detection of hydrogen is required.

3.3. Pre-requisites and sequence

HySkills aims to offer flexibility, and learners can opt to complete it as a short or long course. It is advised, however, that Learning Units 1 (Hydrogen Basics) and 2 (Hydrogen Safety, Risks, Standards and Regulation) should be a mandatory pre-requisite for any of the additional modules. The remaining six learning units, therefore, may be taken as add-ons according to the desired qualification.

Figure 4 shows suggested sequences according to different entry requirements, presenting sample paths of learning with core and optional modules.

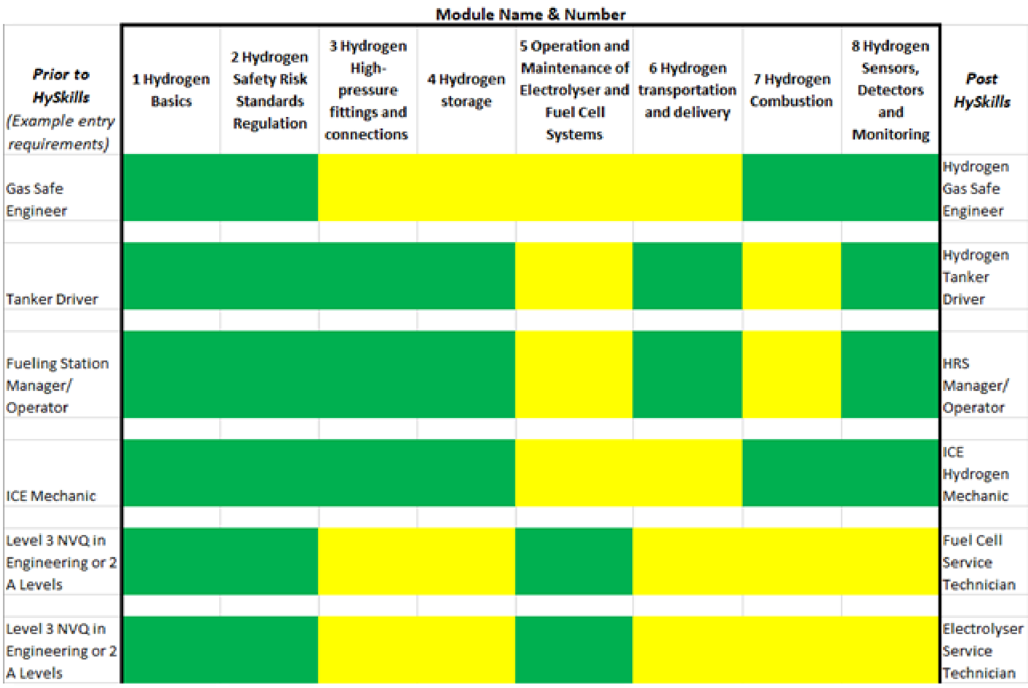


Figure 4. Suggested module sequencing, with core modules in green and optional ones in yellow.

For vocational education and training (VET) students and upskilling learners, entry pre-requisites also include:

- Relevant EQF Level 4 Award/Diploma or at the level of GCE/GCSE or equivalent;
- Learner must be 18 years or older at the beginning of the course;
- Mature learners (over 21) with industry experience (individually assessed).

4. The Materials

The suggested delivery of the HySkills learning units are divided into blocks. A block is effectively a package of content that groups materials of a similar nature, so that they can be delivered sequentially as learners build up knowledge and skills.

The following subsections explore the eight HySkills modules, guiding the course deliverer through the materials and the suggested topics and activities of each learning unit.

4.1. Hydrogen Basics

The suggested delivery of the *Hydrogen Basics* learning unit is divided into five blocks. It is important to highlight that any specific hydrogen technologies that are covered in other modules (such as electrolysers, fuel cells and hydrogen combustion) are covered in this module in an introductory manner. The aim is to provide learners with a basic knowledge of these technologies, which will then be reviewed and explored in much more depth in each applicable module of the programme.

Block	Summary of Topics	Suggested Assessment
1	A climate emergency and the need for change. The potential of hydrogen as a decarbonising agent.	Quiz
2	Characteristics and properties of hydrogen gas. Hydrogen production methods and colours.	
3	Power-to-Gas processes and electrolysers. Roles for hydrogen in heating and transport.	Production of an electrolyser and fuel cell diagram
4	Hydrogen compression, storage, distribution and piping. Hydrogen combustion and fuel cells.	
5	Current uses for hydrogen in the petrochemical industry. Other uses for hydrogen today.	Case Study

Block 1

The first block explores the current climate emergency and the world's existing fossil-based energy infrastructure, highlighting the need to transition to a more sustainable scenario. A review of the main types of fossil fuel (oil, coal, peat and natural gas) is presented, as well as the implications in terms of greenhouse gas emissions and climate change. An **in-class discussion** is recommended to highlight issues with fossil fuels and problems inherent to the current fossil-based energy infrastructure. In addition, this block explores the main types of renewable energy (e.g., solar and wind) as well as their environmental and social advantages, with a recommended **in-class discussion** to identify and describe other types of renewable energy production.

Block 1 then introduces hydrogen and its potential role in the energy transition, as an energy carrier, energy storage medium and decarbonising agent. A brief history of hydrogen is presented, as well as the principles of a "hydrogen economy". An **in-class discussion** is recommended to identify roles that hydrogen can play in the much-needed energy transition, and to discuss the strengths and weaknesses of hydrogen as a decarbonising agent. As a **suggested reading** for learners, the World Energy Council's report "Hydrogen on the Horizon: Ready, Almost Set, Go?" is available at: https://bit.ly/3KG4Gca.

Block 2

The second block explores the physical and chemical properties of hydrogen gas, as well as the main methods of hydrogen production (Steam Methane Reforming, Coal Gasification, Biomass Gasification and Water Electrolysis). Particular emphasis should be given to Water Electrolysis and its potential for producing hydrogen from renewable sources. Additionally, an overview of the colours of hydrogen is provided, identifying the greenhouse gas emissions and environmental impact associated with hydrogen according to its source, and the advantages of green hydrogen.

A CNBC **video** entitled "What Is Green Hydrogen And Will It Power The Future?" is available at: https://www.youtube.com/watch?v=aYBGSfzaa4c. Also, as a **suggested reading**, IRENA's report "Decarbonising end-use sectors: Practical insights on green hydrogen" is available at: https://bit.ly/3KwlGBE.

Block 3

The third block introduces learners to the issues of curtailment of renewable energy, with a recommended **in-class discussion** to highlight ways to store (and then use) excess renewable electricity that ends up being dispatched-down – methods such as traditional batteries and pumped hydro should be discussed and evaluated in terms of advantages and disadvantages. The block then explores the potential role of Power-to-Gas (PtG) systems in this context, with hydrogen as an energy storage solution. Another **in-class discussion** is recommended to identify (preliminarily) how and where the large-scale storage of hydrogen can occur, and there is an opportunity to present **case studies** of existing and proposed Power-to-Gas systems across the world.

Since electrolysers are the core elements of PtG systems, this block also provides an introduction to electrolysers and their main elements, complementing what was covered in

Block 2 regarding Water Electrolysis. A **lab experiment** is recommended so that learners can operate a small electrolyser and visualise its main components – a 64 W electrolyser commercialised by the Fuel Cell Store is suggested (https://www.fuelcellstore.com/manuals/e206-e207-electrolyzer-65-230.pdf), however, the course deliverer can choose to perform this experiment with any other available electrolyser. Alternatively, if no electrolysers can be procured, DIY systems such as the ones shown in this **video** (https://youtu.be/d85OX6yEwE0) can also be helpful learning tools.

Lastly, block 3 highlights roles for hydrogen in heating, both industrial and residential/commercial; and roles for hydrogen in transport. An **in-class discussion** is recommended to analyse the suitability of hydrogen as a fuel for light and, particularly, heavy transport. Additionally, the controversial article "Why Hydrogen Will Never Be The Future Of Electric Cars" by James Morris is a **suggested reading**: https://bit.ly/3SmpRC9.

Block 4

The fourth block explores the logistics of hydrogen, encompassing an overview of the different methods of hydrogen compression, aboveground storage, underground storage, and an introduction to hydrogen distribution and piping. The European Hydrogen Backbone (EHB) initiative is given as a **case study** of hydrogen distribution infrastructure.

Block 4 also provides an introduction to the two main methods of converting hydrogen into energy: fuel cells and combustion. For the former, the operation of fuel cells is explained and possible applications are explored. A **lab experiment** is recommended so that learners can operate a small fuel cell and visualise its main components – a 1W fuel cell stack commercialised by the Fuel Cell Store is suggested (https://www.fuelcellstore.com/manuals/f108-f109-f110-fuel-cell-stacks.pdf), however, the course deliverer can choose to perform this experiment with any other available fuel cell. For the latter method, the basic principles and applications of hydrogen combustion are explored, and an **in-class discussion** is recommended to highlight key differences between using hydrogen in fuel cells and in combustion, as well as to discuss the issue of NOx emissions in the combustion of hydrogen.

At this stage, when that the main types of hydrogen technologies have been introduced, learners can visualise some of them in this **3D model** that includes an electrolyser and a fuel cell: https://hydrogencyclerig.netlify.app.

Block 5

The fifth block focuses on current common uses for hydrogen, which are mostly not related to renewable energy or decarbonisation. It describes processes in the oil industry that employ hydrogen, as well as ammonia production, highlighting how these processes use mostly grey and blue hydrogen. An **in-class discussion** is recommended to identify how the current scenario of hydrogen in the petrochemical industry could be more sustainable.

Block 5 also identifies current uses for hydrogen in other industries, such as hydrogenation, semiconductor manufacturing, aerospace applications and the use of hydrogen as coolant in power plants. Puerto Rico's Aguirre Power Plant, who swapped hydrogen storage tanks for an on-site electrolysis facility, is a very good **case study** (https://www.azom.com/article.aspx?ArticleID=10539).

Guest Speakers are also suggested at this stage – industry representatives can bring value and add a fresh perspective to the course by sharing their real-world experiences. Speakers may be selected by the course facilitator in different areas according to availability.

4.2. Hydrogen Safety, Risks, Standards and Regulation

The suggested delivery of the *Hydrogen Safety, Risk, Standards and Regulation* learning unit is divided into three blocks. Each block should 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 safe handling of hydrogen, where possible. Supporting materials, particularly that of the interactive activities, should aim to be utilised during the delivery of each block.

Block	Summary of Topics	Suggested Assessment
1	Current Health and Safety legislation covering employers and employees.	Quiz
2	Prepare to handle hydrogen gas.	Case study
3	Perform a risk assessment exercise within a given hydrogen environment.	Written evidence (group activity)

Block 1

Block 1 gives an introduction to the current Health and Safety legislation covering employers and employees. Relevant standards are listed throughout this block. Learner knowledge will translate to an awareness of the standards which are relevant. A short **quiz** to test learner knowledge could be used for assessment.

The content of this module is designed to allow the learners to work safely within a hydrogen environment/workplace. This is supported by **reading and video material** underpinned by the learner gaining knowledge of the relevant legislation, roles/responsibilities and requirements of Common Law in the interpretation of current legislation (suggested video: https://rb.gy/9tvs4). The study of **legislation** should include an awareness of the purpose and application of EU health and safety acts (EU) such as the Management of Health and Safety at Work Regulations 1999 (EU): https://bit.ly/3r1nXgs.

Block 2

This block ideally requires a link up with trained professionals (e.g., fire brigade) during an **onsite training/visit** at a hydrogen production. An **in-class discussion** is also recommended to exchange the various techniques used for hydrogen handling. Appropriate tools, materials and equipment should be explained and discussed, including personal protective equipment (PPE) for work and the fact that they should be checked for safety and correct functionality in accordance with workplace procedures and relevant industry standards (suggested video: https://rb.gy/qs2x6).

Video and reading material should be provided to demonstrate health and safety requirements, legislative requirements, hydrogen handling (especially hazards) and workplace procedures for a given work area are identified, obtained and applied. Suggested video: https://rb.gy/s1qqi.

Furthermore, learners can apply safety practices, procedures and compliance standards for handling hydrogen gas in a centre-devised **hydrogen working environment** to cover the following (as examples):

- Relevant work area access, clearances and isolation permissions/permits;
- Relevant stakeholders, including authorised persons, authorities, and clients;
- Relevant safe work method statements and/or risk mitigation processes.

Block 3

The third block focuses on the performance of a risk assessment exercise within a given hydrogen environment. It is recommended that an experienced **guest speaker** be invited, since some assessments of the relationship between hazard and risk are very precise, based on numerical assignments of values which are calculated from detailed considerations of engineering and other disciplines. Furthermore, on-site training and guidance need to be followed in accordance with regulatory requirements and workplace procedures.

Thus, it is necessary that the learners get an insight of the techniques to check tools, materials and equipment for safety and correct functionality. Also, **video and reading material** as well as **an in-class discussion** are suggested to identify those and to make sure that a risk assessment and a pro-forma documentation is completed accordingly. In addition, **video material** (such as: https://rb.gy/bc3am) can be provided to support a **case study** about Health and Safety documentation, including incident and maintenance records, making sure these are completed in accordance with regulatory requirements and workplace procedures.

Learners should be able to describe how to apply the building regulations, in particular the regulations for gas safety, pressure equipment and engineering standards. An **in-class discussion** is recommended to demonstrate awareness of the measures required to minimise risks when designing and installing hydrogen systems.

4.3. Hydrogen High-Pressure Fittings and Connections

The suggested delivery of the *Hydrogen High-Pressure Fittings and Connections* learning unit is divided into four blocks.

Block	Summary of Topics	Suggested Assessment
1	Fittings, threads, tubing and piping systems.	Quiz
2	Valves and other components required for piping systems.	
3	Hydrogen installations techniques, choice of material and tubing codes.	Presentation or video (recording) of hydrogen installations techniques, choice of material seen on site visit
4	Maintenance and repair procedures of high-pressure hydrogen installations in terms of inspection, grounding system, maintenance, and records.	Case Study related to maintenance and inspection seen on site visit

Block 1

The first block starts by introducing the different types of fittings and the terminology and acronyms necessary for understanding piping. An overview of the main types of fittings is presented, focusing on the basics of fittings, joints and threads. An **in-class discussion** about the different types of fittings and their principle of work is highly recommended. This discussion can be followed by **videos** such as the one provided by *Piping Mantra* (https://www.youtube.com/watch?v=p7yQsHqfxnA), which can be helpful learning tools for describing the different types of fittings and their principle of work.

Ideally, classes should be conducted in a **lab** or **workshop** area where students can see physical models of different fittings, threads tubes, etc. If access to certain types of fittings is not available, models or 3D-printed version of these parts could be used to demonstrate how they work and operate. A **site visit** would also be beneficial, wherever possible.

Additionally, an **in-class discussion** about the pros and cons of different types of fittings is recommended, in which groups of learners can discuss and identify the different piping components.

Block 2

The second block introduces learners to the different types of valves, how they operate and where they should be installed. An **in-class discussion** is recommended to identify the advantages and disadvantages of each type. Also, emphasis should be given to address certain safety measures associated with these types of valves, including their classifications and limitations. This discussion can be followed by **videos** such as: https://www.youtube.com/watch?v=1fAPXh9ddhA, which can be helpful learning tools for describing the different types of valves and their principle of work.

Ideally, classes should be conducted in a **lab** or **workshop** area where students can see physical models of different types of valves. If access to certain types is not available, models or 3D-printed version of these parts could be used to demonstrate how they work and operate. A **site visit** would also be beneficial, wherever possible. Also, a **case study** about any specific type of valve can follow the site visit to further enhance the learners' reading and critical thinking skills.

Additionally, an **in-class discussion** about the pros and cons of different types of valves is recommended, in which groups of learners can discuss and identify the different piping components.

Block 3

The third block explores different hydrogen installation techniques, as well as issues pertaining to choice of material and tubing codes.

An **in-class discussion** is recommended to explain the various techniques used for hydrogen installations. Emphasis should be given to identifying advantages and disadvantages of each technique used and the types of hydrogen storage vessels in each type as well as their classifications and limitations.

Site visits to hydrogen generation and storing facilities are highly recommended in order to study and visualise different types of hydrogen installation techniques. Also, an **in-class discussion** is suggested to identify these techniques, creating the opportunity to present **case studies** of existing and proposed technologies of hydrogen installation techniques across the world.

Block 4

The fourth block focuses on hydrogen installations maintenance, repair and inspection. An **in-class discussion** is recommended to explore the various methods and procedures in maintaining hydrogen installations. Further **in-class discussion** is also suggested to explore the inspection and maintenance codes followed in hydrogen installations.

Site visits to hydrogen generation and storing facilities are highly recommended in order to study and visualise the maintenance and inspection techniques used in these facilities. Also, an **in-class discussion** is suggested to identify the maintenance and inspection techniques used in these sites, creating the opportunity for learners to present their understanding of the techniques used and how these can be enhanced.

4.4. Hydrogen Storage

The suggested delivery of the *Hydrogen Storage* learning unit is divided into four blocks. Hydrogen storage technologies that are introduced in the *Hydrogen Basics* module are now explored in more depth, helping learners understand hydrogen properties related to its storage in detail.

Block	Summary of Topics	Suggested Assessment
1	The fundamentals of hydrogen properties related to its storage.	Quiz
2	The different methods of hydrogen storage technologies.	Case Study related to site visit
3	Hydrogen storage utilisation and applications.	Presentation or video (recording) about applications seen on site visit
4	Hydrogen storage performance, regulations, codes and standards.	Quiz

Block 1

The first block starts by identifying the reasons for hydrogen storage. An **in-class discussion** is recommended to highlight the reasons for and difficulties inherent to hydrogen storage by relating these to basic hydrogen properties, such as thermophysical and physiochemical properties. Understanding hydrogen embrittlement and its effect on storage should be discussed in detail as it explains some storage difficulties and challenges. In addition, methods for hydrogen embrittlement avoidance and/or prevention are highly recommended to be **discussed in-class.**

Block 1 then introduces the principles of both hydrogen compression and liquefaction technologies as they are the main methods historically used for hydrogen storage. An **in-class discussion** is recommended to identify the advantages and disadvantages of each technology used for compression and liquefaction. In addition, the Joule–Thomson effect should be introduced and **discussed.**

Block 2

The second block introduces learners to the three main different methods of hydrogen storage technologies: compressed hydrogen gas under high pressures, liquid hydrogen under cryogenic temperatures, and hydrogen storage in other media including on the surface of or within solid and liquid materials. An **in-class discussion** is recommended to identify the advantages and disadvantages of each technology used for hydrogen storage. Emphasis should be given to the different types of storage vessels, as well as their classification and limitations. Additionally, an overview of ideal gas laws should be introduced as it can help in the understanding of the thermodynamics of hydrogen (which is almost an ideal gas). As **suggested readings**, the report "Hydrogen Storage: State-of-the-Art and Future Perspective" is available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC26493, and "Hydrogen Storage Technologies" is a book by Mehmet Sankir and Nurdan Demirci Sankir (ISBN 978-1-119-45988-0).

Site visits to hydrogen producing and storing facilities are highly recommended to study and visualise some of the methods for hydrogen storage. Also, an **in-class discussion** is suggested to identify these methods, creating the opportunity to present **case studies** of existing and proposed methods of hydrogen storage across the world.

Block 3

The third block explores the utilisation and applications of hydrogen storage, focusing on types, issues and priorities for vehicular and stationary hydrogen storage.

An **in-class discussion** is recommended to explain the various technologies used for vehicular and stationary hydrogen storage. Emphasis should be given to identifying advantages and disadvantages of each technology used and the types of hydrogen storage vessels in each type as well as their classifications and limitations. The same report mentioned in block 2 is a **suggested reading**.

Site visits to hydrogen storing facilities including vehicular hydrogen fuelling stations are highly recommended, in order to study and visualise some of the various technologies used for this regard. Also, an **in-class discussion** is suggested to identify these technologies, creating the opportunity to present **case studies** of existing and proposed technologies for hydrogen storage across the world.

In addition, a **computer lab modelling experiment** can be used so that learners can calculate the size and weight of different hydrogen vessels used for different vehicular and stationary storage technologies.

Block 4

The fourth block focuses on understanding hydrogen storage performance, regulations, codes and standards used in Europe and worldwide. An **in-class discussion** is recommended to identify hydrogen storage performance parameters and the expectations and their relationship to specific storage system properties. The Institute of Energy's report mentioned in block 2 is again a valuable **suggested reading**.

An **in-class discussion** is recommended to explore technical targets for hydrogen storage systems: capacity, cost, charging & discharging rates, hydrogen quality, durability & operability requirements, as well as environmental, health, and safety requirements. Also, hydrogen storage regulations, codes and standards should be thoroughly discussed. Another **in-class discussion** is suggested to investigate hazards in hydrogen storage facilities and discuss the best safety guidelines.

Guest Speakers are also suggested at this stage – industry representatives can bring value and add a fresh perspective to the course by sharing their real-world experiences. Speakers may be selected by the course facilitator in different areas according to availability.

4.5. Operation and Maintenance of Electrolyser and Fuel Cell Systems

The suggested delivery of the *Operation and Maintenance of Electrolysers and Fuel Cells* learning unit is divided into three blocks. Each block should be delivered using a variety of learning and teaching approaches such as structured lessons with comprehensive assessments. Additionally, practical demonstration of components and characteristics of electrolyser and fuel cell technology systems should be used, where possible.

Block	Summary of Topics	Suggested Assessment
1	The basic principles of electrolyser & fuel cell technology systems.	Presentation or video (recording) based on site visit
2	The basic characteristics of fuel cells and the function of their component parts.	Quiz
3	Relevant Standards and Regulations used for the design, installation, commissioning and maintenance of electrolyser & fuel cell technology systems.	Written evidence

Block 1

Site visits to electrolyser & fuel cell technology facilities are highly recommended, in order to study and visualise some of the various technologies used for this regard. Also, an **in-class discussion** is suggested to identify these technologies. Learners should be able to demonstrate knowledge of the atomic structure of hydrogen and its basic properties, specifically the ease of combination with other atoms and the properties of being colourless, odourless and light. Learners should be able to demonstrate an understanding of the basic electrochemical reaction in hydrogen fuel cells including anode, cathode, and net reaction formulae.

An **in-class discussion** is recommended to promote an understanding of the operating principles of electrolyser & fuel cells as well as knowledge of hydrogen as an energy carrier, the need for fuel replenishment and the sourcing of hydrogen fuel from electrolysis. Learners should also understand and demonstrate knowledge of the applications of electrolyser & fuel cell technology systems and their use in power generation, backup power and transportation. **Suggested video**: https://rb.gy/wj4xg.

Learners should be able to clearly state at least three advantages of electrolyser & 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, lack of moving parts, and the relative efficiency of fuel cells. Through an **in-class discussion**, learners should be able to demonstrate knowledge of the main disadvantages of electrolyser & fuel cells, in particular their cost, hydrogen containment issues, and the durability and reliability of some types of systems.

Block 2

Block 2 explores the location and function of the main component parts of a fuel cell. Components should be identified and located in a **diagram**, including the anode, cathode, electrolyte, catalyst, fuel inputs and outputs, and the electrical circuit and load. A short **quiz** to test learners' knowledge could be used for assessment. Learners should also be able to describe the function of each of these components and should be able to demonstrate knowledge of the function of the fuel cell processor, stack and inverter.

An **in-class discussion** is recommended to discuss 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. **Suggested videos** include https://rb.gy/1ys6y and https://rb.gy/ycglh.

Block 3

The third block focuses on the basic planning requirements and procedures for the design and installation of electrolyser & fuel cell technology systems. Design and installation factors will include the siting of electrolyser & 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. **Site visits** to hydrogen electrolyser and fuel cell (PEM is recommended) applications/demonstrator are highly recommended in order to study and visualise different types of electrolyser and fuel cell technology. Also, an **in-class discussion** and **video materials** (such as https://rb.gy/hegqm) are suggested to identify those. Additional **reading** can support the understanding of how the building regulations apply, in particular the regulations for Gas Safety, Pressure Equipment and Engineering Standards.

An **in-class discussion** is recommended to promote 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 (**suggested video**: https://rb.gy/1epuq). Learners should be able to demonstrate an understanding of the installation and maintenance of electrolyser & fuel cell technology systems, the importance of installation and commissioning checklists as well as of maintenance and servicing plans.

4.6. Hydrogen Transportation and Delivery

The suggested delivery of the *Hydrogen Transportation and Delivery* learning unit is divided into five blocks. In this module, the theory relating to hydrogen's transport and delivery options is discussed. Additionally, this module will focus on the types of compressors used to compress hydrogen in order for it to be transported, as well as material selection properties for hydrogen pipelines.

Block	Summary of Topics	Suggested Assessment
1	Introduction to hydrogen transport. Transportation and storage.	Interactive element
2	Hydrogen transportation network. Pipeline materials and hydrogen compression.	Case study & group project
3	Hydrogen transportation. Relevant standards.	Quiz
4	Delivery of gaseous hydrogen.	Onsite assessment
5	Delivery of liquid hydrogen.	Onsite assessment

Block 1

Block 1 topics include an introduction to hydrogen transportation and the means and forms by which hydrogen can be transported. This considers some different types of storage systems and the safety considerations for hydrogen when compared with other fuels such as methane. A **quiz** is suggested here to assess learner knowledge in terms of these safety considerations. Online learning tools such as the Articulate Rise platform could be used as an **interactive element** to visualise discrete parts of hydrogen storage systems such as this example.

Block 2

In this block, two of the main constituents of a gas network are considered: pipelines and compressors. Some **suggested reading** material on the gas networks is available at: https://bit.ly/3Cwfl4e.

An **in-class discussion** looking at a **case study** on the feasibility of converting gas networks to support hydrogen could be viewed in the form of videos such as:
https://www.youtube.com/watch?v=dUKAMQ-c0Uc and

https://www.youtube.com/watch?v=tP2L7k9Z9Ys.

Additional **suggested reading** supports the case study further: H21 Case study and a downloadable PDF from link here. Learners could work on a group **study project** to determine the feasibility of gas networks and materials weighing up pros and cons, issues, and public perception. Technical considerations of general pipe materials are available at: https://bit.ly/3Jddo06.

This block also details some of the compressor types that are essential in hydrogen gas transportation. An **interactive element** to include labelling of compressor components and/or a **quiz** could be used by learners to assess knowledge of the compressor types.

Block 3

Block 3 covers the standards for commission, maintenance, and operation of hydrogen transportation and delivery systems. Learners will understand the significance of these regulations and their role in ensuring safety and efficiency. A concise **quiz** can be created and used to assess their knowledge and application of the standards. This evaluation will assist trainers in identifying areas of weakness in the learners understanding. Block 3 equips learners with the necessary knowledge to contribute to the advancement of hydrogen infrastructure while ensuring its adherence to industry standards.

Block 4

Block 4 will require a close collaboration with local industry and skilled professionals to thoroughly evaluate competency in the handling and transport of gaseous hydrogen. To accomplish this, an **onsite visit/training session** will be organised, allowing for direct engagement and observation of the relevant practices and expertise. This hands-on approach will enable a comprehensive assessment of the processes, standards, and specific requirements carried out by the local company. By partnering with trained professionals in the field, we can utilise their knowledge and experience to inform and develop trainees of the future hydrogen industry. This ensures that the module aligns effectively with the needs and expectations of the local demographic.

Block 5

In a similar manner to block 4, block 5 will require linkages with local industry and trained professionals to thoroughly evaluate competency in the handling and transport of liquid hydrogen. To accomplish this, an **onsite visit/training session** will be organised, allowing for direct engagement and observation of the relevant practices and expertise. This hands-on approach will enable a comprehensive assessment of the processes, standards, and specific requirements carried out by the local company. By partnering with trained professionals in the field, we can utilise their knowledge and experience to inform and develop trainees of the future hydrogen industry. This ensures that the module aligns effectively with the needs and expectations of the local demographic.

4.7. Hydrogen Combustion

The suggested delivery of the *Hydrogen Combustion* learning unit is divided into three blocks. The base combustion knowledge from learning unit 1 (Hydrogen Basics) is recapped and expanded, with hydrogen combustion technologies now studied in depth.

Block	Summary of Topics	Suggested Assessment
1	Introduction to combustion. The combustion of hydrogen.	Quiz
2	Hydrogen flammability and safety aspects. Hydrogen combustion management.	Quiz
3	Hydrogen combustion engines. Hydrogen boilers.	Production of a hydrogen boiler diagram

Block 1

The first block introduces general combustion, its main elements and terminology. The differences between complete and incomplete combustion are explored, as well as the three main types of combustion (rapid, spontaneous and explosive). An **in-class discussion** is recommended to highlight examples of the abovementioned categories.

Block 1 then proceeds to focus on the combustion of hydrogen, highlighting that, even though no carbon emissions are produced, Nitrogen Oxides (NOx) are emitted and are an issue that needs to be addressed. An **in-class discussion** is recommended to highlight key differences and similarities between fuel cell systems (studied in Learning Unit 5) and hydrogen combustion systems.

Lastly, an overview of applications of hydrogen combustion is provided. For hydrogen combustion engines, a **suggested reading** entitled "How hydrogen combustion engines can contribute to zero emissions" is available at: https://mck.co/3ETPhBw. As an alternative to fossil natural gas, several **case studies** can be explored, including the H21 Leeds City Gate project (https://h21.green/projects/h21-leeds-city-gate/) and the HyDeploy initiative (https://hydeploy.co.uk). For gas turbines applications, a **suggested reading** entitled "Zero Emission Hydrogen Turbine Center: A closed loop of the energy future" is available at: https://bit.ly/41MstO6.

Block 2

The second block explores the flammability of hydrogen, especially compared to other common fuels, as well as the NFPA 704's fire diamond of hydrogen. Particularities and safety aspects of the hydrogen flame are discussed, while a **video** illustrating the differences between a hydrogen flame and a propane one is available at: https://youtu.be/r-8H5u4YzuY. At this point, a simple **lab experiment** is recommended so that learners can visualise a hydrogen flame and compare it with the flame from other common fuels, highlighting the relevant safety aspects.

Block 2 also details the three key areas of hydrogen combustion management: preventing, detecting and suppressing (undesired/uncontrolled) combustion, highlighting that hydrogen is no more or less dangerous than other flammable fuels, but has specific safety aspects. An **in-class discussion** is recommended on the management of hydrogen combustion, emphasising particularities and generalities as well as comparing it with the learners' potential existing knowledge of the combustion of other fuels.

Block 3

The third block focuses on specific hydrogen combustion systems, the first one being Hydrogen internal combustion engines (ICEs). The four-stroke combustion cycle is explained, and the advantages and disadvantages of hydrogen as fuel in this context are presented. A useful publication by *H_2 tools* about safety aspects of hydrogen-fuelled vehicles with combustion engines is a **suggested reading**, available at: https://bit.ly/3y7007Z.

Block 3 also explores the principles and operation of hydrogen boilers, going into issues such as cost and complexity, differences from traditional methane systems, sample projects, and the four basic steps of the operation of hydrogen boilers. A **video** (https://youtu.be/241Ltw7B8ZA) by Viessmann illustrates how such systems work, and an **in-class discussion** is recommended on the extra components of a hydrogen boiler, as well as on general safety considerations.

4.8. Hydrogen Sensors, Detectors and Monitoring

The suggested delivery of the *Hydrogen Sensors, Detectors and Monitoring* learning unit is divided into three blocks. It details sensors, their demands/specifications and the various types that exist in the market today. The module looks at the location, maintenance and calibration of these sensors. Additionally, the module will touch on the importance of hydrogen detection and briefly touches on hydrogen properties which are exploited in order to be detected. Finally, it also goes into detail on hydrogen flame detection and thermal detectors & imaging systems.

Block	Summary of Topics	Suggested Assessment
1	Introduction to hydrogen sensors. Hydrogen sensing technologies.	Quiz
2	Introduction to hydrogen sensors & detection. Maintenance, testing and calibration.	Class tutorial/quiz
3	Hydrogen detection. Hydrogen properties and importance of detection.	Design project

Block 1

The first block focuses on the types of hydrogen sensors currently available, providing a detailed comparison between the different sensor types (including electrochemical, thermal conductivity sensors and catalytic) their characteristics, as well as the measurement and performance specifications required in a hydrogen sensor.

Within this first block, **suggested readings** from the sensor handbook can be used to give a full overview of the material, and quizzes can be used to test knowledge. Demonstrative **lab experiments** or lessons using real sensors to analyse and gain understanding of sensor types can also be employed.

Block 2

Block 2 focuses on the maintenance and testing of hydrogen detectors, including the importance of calibration. This block could include an **in-class discussion** on the need for maintenance and calibration and comparison of other more common sensor types. Demonstrative **lab experiments** to disassemble and observe detectors and analyse clean and unclean sensors, as well as the implications of this, are recommended.

Demonstrative **lab experiment** could also take place using an inert gas, such as nitrogen, to analyse a calibration curve and ensure the correct sensor response, especially with the low detection limit required. A **lab tutorial** using excel (https://bit.ly/467cmfW) can be performed to generate calibration curves and allow for graphical representation of accuracy of the different sensor types discussed in block 1.

Block 3

The third block summarises hydrogen's properties with regards to detection, and two important detection considerations: gaseous hydrogen and hydrogen flames. Further detail of these properties is found in the second block of the *Hydrogen Basics* module. A **quiz** on properties could be used here to test learner knowledge of the main properties.

Block 3 also includes considerations of risks of gaseous hydrogen leaks, causing both an asphyxiation risk and potential explosive environment, as well as the importance of sensor location, and the need to assess risk. A **design project** is recommended here to assess the learners' knowledge of correct sensor placement using further **suggested reading** from the Gas Detection Handbook (https://bit.ly/4447ab7). An **interactive video/3D render**, or augmented or virtual reality, could also be used to test the learners' knowledge by providing scenarios, with learners being able to move sensors to best locations.

5. Pedagogical Techniques

Pedagogy refers to the methods and practices of a teacher. In the modern teaching world, teachers are required to be aware of the pedagogical techniques and approaches which can enhance the process of learning, in addition to enhancing learning through technology.

This section describes the five pedagogical approaches which can be incorporated in the delivery of the HySkills learning units to enable learners to reach their full potential; as well as meta skills and T-shaped skills which should be fostered in learners throughout the programme.

5.1. Pedagogical Approaches

- **Constructivism**

Constructivist teaching is based on constructivist learning theory. It is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information. Learners are the makers of meaning and knowledge. So according to constructivism theory, the role of the teacher is to provide learners with opportunities and experiences to learn.

Hence, it could be said that the teacher should become more of a facilitator. In doing so, learners become active participants, with the facilitator providing learners with a learning environment which will support and challenge their thinking, no better way in doing this than using technology. Facilitators should aim to give learners ownership of their own learning process so that they will be effective thinkers. Whilst digital technology can improve learning the contrary can be true also if a well-designed pedagogical approach is not created and evaluated, so care must be taken.

- **The Inquiry-Based Approach**

Inquiry-based learning is very much active learning that starts by a teacher / facilitator posing questions, problems or scenarios. Traditionally a teacher would simply present or demonstrate proven facts. This pedagogy lend itself to STEM subjects and higher-level education and training, as it includes problem-based learning and is generally used in small scale investigations and projects.

The inquiry-based pedagogy is principally strongly associated to the development and practice of thinking skills. As an illustration of STEM, the implementation of digital technologies into engineering/science education can help a great deal in the process of scientific inquiry. Well-structured inquiry-based learning should channel the minds of the learners in such a way that problems encourage them to reach for solutions, independently or collectively. Unlike traditional learning where the information is simply provided to learners, inquiry-based learning nurtures the critical and analytical minds of learners, digital technology allows learners to be independent in capturing necessary data and information.

- **The Reflective Approach**

Reflective teaching is a regular process where practitioners think over their teaching practices, analysing how something was taught and how the practice might be improved or improved for better learning outcomes, commonly why it is being done and how well learners are learning. Teachers use reflection as a way to simply learn more about their own practice, improve a particular practice, group or individual learning, for example, or to focus on a problem learners are having.

The use of digital technology supports the reflective approach. Teachers are able to use online forums to reflect upon each other's teaching immediately as technology and internet have become an inseparable part of their daily lives. Moreover, social media sites like make it possible for learners and teachers to build professional communities that can model and practice teaching as inquiry. Much research points to the fact that unless teachers begin instilling technology into the curriculum, the gap between the needs of learners and the ability of teachers to create meaningful learning opportunities will steadily increase.

- **The Collaborative Approach**

Collaborative learning is a situation in which two or more people learn or attempt to learn something together. Unlike independent learning, learners engaged in collaborative learning capitalise on one another's resources and skills which now extends to the use of digital technology and all of the resources of the internet. One could say that the traditional collaborative approach would have been learners asking one another for information, evaluating one another's thoughts, checking one another's work, etc. Now, even independent learning has an element of the collaborative approach through the use of video conference platforms and other digital resources at the disposal of the learner.

It is very apparent that the role of teacher and learner is changing. Teachers need to exploit the strength of technology by letting learners learn at their own pace, in a project based, collaborative approach, there are many benefits of this. Today's learners expect technology as part of their learning experience more than their parents' generation did. Everything from social media through to technology games, mobile phones and apps, form a large part of their lifestyle, so teachers accept this reliance to encourage collaborative learning, through digital formats or offer a blended approach, depending on the subject being delivered.

- **The Integrative Approach**

Integrative learning is a learning theory describing a movement toward integrated lessons helping learners make connections across curricula, an essential ingredient in a modern curriculum. This concept is distinct from lower level of education, as there is required prior understanding. Integrated investigation involve bringing together traditionally separate subjects so that learners can grasp a more authentic understanding, this approach is very much aligned to STEM and is enhanced through the use of digital technologies, bring to life many of the interdisciplinary aspects to STEM.

Interdisciplinary curricula have been shown by several studies to support learner's engagement. Specifically integrating engineering/science with comprehension such as report writing sessions has been shown to improve learners understanding in both science and English language. It is important to note that teachers who want to introduce digital technology tools must thoroughly learn how the tools work, make sure to carefully design learning situations, paying attention to detail when implementing those situations either physical or virtually, or both. It is crucial not to just give learners technology, but to work together with them to foster shared, differentiated and situated learning practices.

5.2. 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) technologies.

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. Besides 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. A comprehensive list is shown in Table x.

Table x. Overview of meta skills.

Capacity to focus and prioritising	Empathy (emotional intelligence)	Curiosity and Creativity
Integrity and self-awareness	Service orientation	Learning-to-learn
Adaptability, resilience and persistence	Communication and storytelling	Critical thinking and sense-making
Cognitive flexibility	Collaboration and Coordination	Problem solving
Self-initiative and entrepreneurship	Leadership and People management	Judgment, or ability to connect the dots
Time management	Negotiation	Decision making
Responsibility	Persuasion	Researching (including effective interviewing)
Having impact and having purpose	Prototyping and iteration	Pain-spotting
Co-creation	Lateral thinking	

Meta skills are most effective when learned and developed in the workplace. 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 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.

HySkills aims to ensure that learners acquire adaptable and transferable meta skills as part of the programme, with meta skills being achieved via delivery of content or through assessment. Course deliverers are highly encouraged to ensure that the relevant meta skills are interspersed throughout the delivery of the HySkills modules and measured.

5.3. 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 was amply considered within the HySkills curricula development, as meta skills enables the workforce to cope with future technological uncertainties especially with the multidisciplinary nature of decarbonisation.

6. Final Considerations

This Implementation Handbook presented the HySkills project, its deliverables, the learning units developed, and suggested pedagogical approached for training and teaching. Overall, it constitutes a guide for the project materials which are now available for teachers, trainers, course designers, students, and anyone who wishes to use them.

It is important to reiterate once more the non-prescriptive nature of this document. As mentioned in the introduction, while teaching approaches, materials and methods are suggested throughout this handbook, the delivery of the programme is ultimately envisaged to be centre-devised and adapted to local needs and circumstances. Factors such as the availability of resources, geography, and specific needs will dictate the actual format and contents of each learning unit in practice, while this document and other project materials should be seen as guides and resources that can be modified, tailored and built upon.

Additionally, any institution who wishes to obtain accreditation for the programme is welcome to do so. The course has not been accredited in any country by project partners as this is beyond the scope of the project and was never intended as a deliverable. Therefore, those who wish to seek accreditation by an awarding body are free to do so.

The HySkills team would like to thank you for your interest in the project and welcomes any questions or feedback. This can be done on the project's website (https://hyskills.org), where you will also find all project materials and content for download. We hope that the HySkills outputs will be useful for your training needs, and that they will be an important resource in the development of green skills for a knowledgeable and qualified hydrogen workforce.