Interreg
North-West Europe
H2SHIPS

EUROPEAN UNION

System-Based Solutions for H2-Fuelled Water Transport in North-West Europe

Training programme covering innovation, technology transfer, installation and new product/process design

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List of Abbreviations

FCEV	Fuel Cell Electric Vehicle
FCHRC	Fuel Cell & Hydrogen Research Centre
HT-FC	High Temperature Fuel Cell
LT-FC	Low Temperature Fuel Cell
NWE	North-West Europe
PEMFC	Polymer electrolyte membrane fuel cell
SOFC	Solid oxide fuel cell
UoB	University of Birmingham
TU Delft	Delft University of Technology

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1 Introduction

In this report, a proposal of training and teaching programme is given. The programme aims to maintain skills of engineers and technicians working in shipping industry based on hydrogen propulsion systems. The outcomes of the training will contribute to the growth of a hydrogen value chain in water transport in order to be able to match the decrease of GHG objectives for 2030. The design of the programme is based on experience of the universities involved in H2SHIPs project, mainly the University of Birmingham (UoB). The Fuel Cell and Hydrogen Research Centre (FCHRC) at UoB has developed courses and education materials that can be adapted to address the challenges of hydrogen in shipping projects, and to adopt new lessons learned and innovations from H2SHIPS pilots and work packages. Also, the materials can be transferred in order to create specific training and educational offers that could support development of new activities.

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2 Education and Training Programmes

The University of Birmingham is running different courses and training programmes.

The currently available programmes are:

- *KnowHy* blended technician training
- *TeacHy* MSc programme implemented
- Joint European Summer School on Fuel Cell and Battery.

2.1 Technicians training (*KnowHy*):

The programme [1] aims to provide the fuel cell and hydrogen sector with a training offer for technicians and workers featuring quality in contents, accessibility in format and language, practicality for the targeted audience, ease of scalability and update, and at competitive costs. Thanks to this project both OEMs as well as professionals can rely on third parties to provide a sound and effective first training, covering the understanding of the technology, safety and regulatory aspects and the practical theoretical as well as hands on contents. The training is delivered at the University of Birmingham in English. The *KnowHy* consortium consists of partners from European countries covering 7 of the most usual languages, as English, German, French, Italian, Spanish, Portuguese and Dutch.

The trainees are technicians, workers and professionals in general with a practical knowledge in installation, maintenance and operation of hydrogen and fuel cell applications. The courses and modules will mainly target H2 Safety, FCEV applications, distributed generation, or back-up systems. Also, *KnowHy* can take into consideration the findings H2SHIPs project.

The training materials consists of 4 specialised modules:

1- **Introduction to Fuel Cells:** The module is meant to give the trainee first insights into fuel cells and fuel cell systems and components.
2- **Hydrogen production and Hydrogen Safety:** The module is about hydrogen, its basic properties, methods of production and storage, and safe handling.
3- **Introduction to tools, rules of thumb and applications:** The module is about the fuel cell stack and how to test it in terms of performance. The content also touches on the operating conditions of fuel cells and control.
4- **Installation, maintenance, and troubleshooting:** The module looks into fuel cell systems with a focus on components, maintenance and service. The module concludes with case studies that demonstrate fuel cell systems.

The training can be delivered as 4-week part time course including online materials through UoB Canvas, and practical and tutorial sessions. By the end of the training, students should be able to understand Fuel cell systems architectures, understand sub-system functions and their issues, system packaging for different applications. Also,

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introducing the background and history of fuel cell technology, explain the hurdles facing fuel cell technology, and highlighting the main advantages and drawbacks of fuel cell technology. The trainees with have knowledge about considerations must take when working with hydrogen, the types of ventilation employed when working with hydrogen in an enclosed space, the design consideration for a hydrogen pipe system, standards for hydrogen are already in place, and how standards are employed for certification of products or for obtaining building and operating permits.

The practical sessions include experimenting/demonstrating basic fuel cell operation using hydrogen fuel. Figure 1 shows example of fuel cell experiment rig.

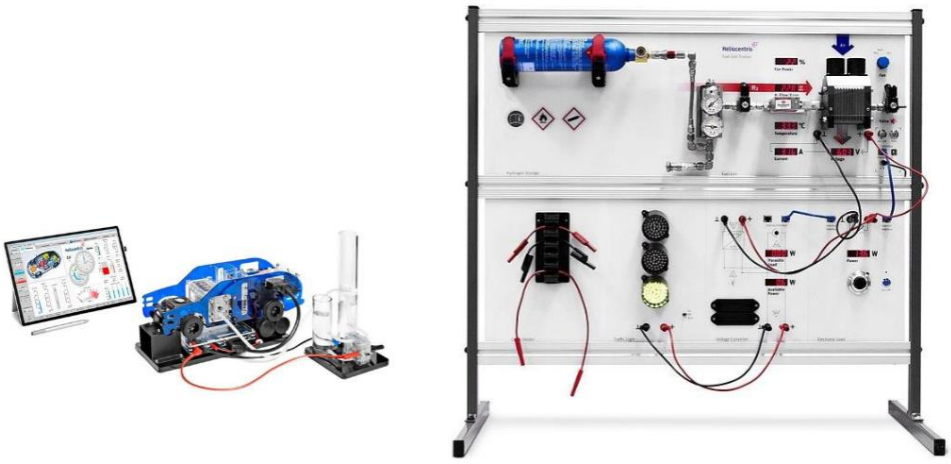

Figure 1: Laboratory rig for fuel cell experiments

2.2 MSc programme (*TeacHy*):

The programme includes two routes/approaches of enrolment and students' engagement with course modules.

2.2.1 Fuel Cell and Hydrogen Technologies Masters/MSc:

The course aims to address an immediate need of the industry in Fuel Cell and hydrogen technologies as part of a nationwide and global drive for sustainable energy. This MSc programme offers vital training that has been developed around real world industry need so that graduates will be able to join research teams at the forefront of this technology and make a difference to the global effort for sustainability. The course consists of 120 taught credits which typically involves 12 modules taught in one week blocks [2]. The modules have been carefully designed to give a solid grounding in those aspects of fuel cell and hydrogen technology that are most relevant to industry and ongoing research in this field. The students will also have opportunity to study business and project management modules that give advanced training in knowledge and skills that industry partners have helped identify as most valuable for the leaders of tomorrow.

Students will undertake a 60 credit research project that will allow to take an in-depth and focussed look at a particular area conducting cutting-edge research supported by leading

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academics in the field of fuel cell technology. During this project, students will gain a thorough grounding in experimental and theoretical research work. The core modules of the course are:

- Fuel Cell and hydrogen laboratories - 10 credits
- Fuel cell modelling tools and control- 10 credits
- Fuel cell technologies - 10 credits
- Hydrogen and hydrogen based fuels- 10 credits
- Introduction to electrochemistry - 10 credits
- Principles of Hydrogen Safety - 20 credits
- Techniques for Fuel Cell Characterisation- 10 credits
- Research project - 60 credits

Students will have the opportunity to select 40 credits from optional modules, which are:

- Advanced electrochemical applications - 10 credits
- Energy Storage - 10 credits
- Fuel cell electric vehicles - 10 credits
- High temperature fuel cells - 10 credits
- Low temperature fuel cells - 10 credits
- Renewable energy systems - 10 credits

By the end of the course, graduates will gain expertise not only in fuel cells but also in the energy sector in general and the processes by which energy is generated and utilised.

2.2.2 Master Level Continued Professional Development (CPD) programme:

The programme aims to provide CPD microcredential modules at master's level. The training provides industry and individuals an opportunity to train in specific fuel cell and hydrogen related topics relevant to their need at a universally recognised level of academic competence. The University of Birmingham microcredential training [2] allows those with work and other personal commitments to build a portfolio of credit over a period of time that can be applied as accredited prior learning to masters qualifications.

The course materials include:

- **Advanced Electrochemical Applications** (10 credits): The module will cover the theories and applications of electrochemistry.
- **Fuel Cell and Hydrogen Technology** (10 credits): The module will cover the Fuel Cell & Hydrogen technologies and their science.
- **Techniques for Fuel Cell Characterisation** (10 credits): The module aims to develop an understanding of how the different measurement techniques can be applied for characterisation of various components of the PEMFC and SOFC.

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- **Hydrogen and Hydrogen Based Fuels** (10 credits): The module will cover the production and storage of hydrogen as a fuel for fuel cells and for decarbonising industry and the overall energy system.
- **Fuel Cell Electric Vehicles** (10 credits): The module will cover Introduction to FCEVs, the design of FCEVs, battery and fuel cell-battery hybrid vehicles, energy flow and management in FCEVs, electric vehicles drive train components, and system and life cycle analysis for fuel cell vehicles
- **High Temperature Fuel Cells** (10 credits): This module will cover High Temperature Fuel Cell (HT-FC) technologies and their science.
- **Introduction To Electrochemistry** (10 credits): The module with cover the basics of modern electrochemistry including equilibrium electrochemistry & thermodynamics, dynamic electrochemistry & kinetics, Faradaic vs Galvanic electrochemistry, and common experimental techniques.
- **Low Temperature Fuel Cells** (10 credits): The module will cover the low temperature fuel cells (LT-FCs) their science, materials, construction issues and applications.

2.3 Joint European Summer School (JESS):

The JESS programme [3] aims to deliver intensive courses on fuel cells, electrolyser, and battery technologies. The programme offers 1-week intensive and high-quality graduate level courses on selected topics of vehicle technology, innovation & business development, safe handling of hydrogen, modelling, high & low temperature fuel cells and electrolysers, and batteries.

This JESS programme targets an audience of university students (MSc and PhD levels) and post-doctoral researchers. The programme also welcomes more experienced researchers and engineers wishing to expand their general knowledge, for instance, to suit a newly acquired position or collect credits for Continuous Professional Development (CPD). The course content is tailored to the needs of a diverse audience: newcomers to the field, experienced students, and young professionals working at the forefront of fuel cell and hydrogen applications.

The programme has two individual weeks of lectures each divided into a number of classes. Students can enrol for one or two weeks as following:

Week 1: Introductory Classes

Week 2: Advanced Classes

These courses are accredited at the University of Birmingham and each carry 3 ECTS points.

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3 Hydrogen and Fuel Cells Training for Shipping Industry

With respect to the situation in the shipping industry and harbour and port management, a slight shift in emphasis is observed as to the topics to be covered in any training programmes. The following lists topics to be covered in the sequence of importance (the first being the most important):

1. hydrogen safety and regulations,
2. hydrogen handling (storage, transport, bunkering),
3. hydrogen application in shipping (fuel cell and other drive trains),
4. hydrogen application in harbour vehicles (fuel cell and other drive trains).
5. Maintenance of H2 drive trains (High voltage systems, High pressure systems)
6. Alternative hydrogen-based fuel (Hydrogen carriers)

Due to the high importance given to safety in the marine environment, hydrogen safety training receives a completely different level of attention than in other, land-based technologies. Here, the training and education of permitting and certification body officers and employees is of a decisive nature in order to proliferate hydrogen technologies across harbours, ports, and marine vessel operations.

As the maritime environment is an area of technology application, and less so of R&D, the focus of skills programme development within H2SHIPS is on technician, and operations and supervising engineer training rather than the proliferation of academic knowledge. The specialisation of engineers in R&D, vessel design etc. is very high and university courses and programmes can be limited to the few universities in the EU where naval officers and engineers are trained, adding specialised modules to their curricula.

H2SHIPS project partners (UoB and TU Delf) with STC Group [4] (a vocational training provider for shipping, logistics, port & process industry based in Netherlands) have discussed training programmes currently available by STC Group. The programmes that offer hydrogen knowledge-based training are: (i) Renewable Energy Training and (ii) Hydrogen Technology Training. These two programmes are meant to gain more insight into the background and the current and new applications of hydrogen, and into the energy transition and the different types of renewable energy. Also, STC Group is developing a new curriculum for training in maritime hydrogen for fuel cell engineers and technicians.

The proposed curriculum is:

1) Energy use and CO2 emission from past to present
2) Environment, climate and climate agreement

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3) Energy carriers and properties
4) Use of hydrogen, history, present and future
5) Properties of hydrogen
6) Production of hydrogen
7) Electrolysis and fuel cells
8) Storage and transport of hydrogen
9) Hydrogen further applied
10) Other forms of energy
11) Efficiency
12) Projects and future hydrogen
13) Safety and regulations
14) Attachments and external resources

The proposed programme seems include generic topic related to hydrogen and fuel cell technology. The discussion concluded that further development is required for the training proposal to include hydrogen application in shipping and in ports, maintenance of hydrogen drive trains including handling high-voltage systems and high-pressure systems. The training courses can be categorised according to the training levels:

Level 3: Technician Training

The course is designed to provide technicians with hydrogen safety fundamentals and basic knowledge of hydrogen and fuel cell technology. The course can be delivered entirely through colleges. Course materials can be proposed by colleges under supervised from universities according to service level agreement between all parties. Trainees can get a Level 3 certification from the training institute (The college).

Level 5: Train the Trainer.

The course is designed to prepare qualified trainers on hydrogen and fuel cell technology. The trainees will be capable of delivering L3 training. The course can be manged through colleges with collaboration from universities. Course materials can be a property of the university. Trainees can get a Level 5 certificate from the training institute (The University).

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[1] "*KnowHy*." https://*KnowHy*.eu/ (accessed Aug. 15, 2022).

[2] "Birmingham Centre for Hydrogen and Fuel Cell Research - Education and Training." https://www.birmingham.ac.uk/research/activity/chemical-engineering/energy-chemical/fuel-cells/education-training/education-and-training.aspx (accessed Aug. 15, 2022).

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[4] "STC Group: education and knowledge institution for the shipping, transport and port industry." https://stc.nl/home (accessed Oct. 01, 2022).

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