Interreg North-West Europe H2SHIPS

EUROPEAN UNION

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

State of the art in training & education products related to hydrogen applications in shipping

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ECTS	European Credit Transfer and Accumulation System
FCH	Fuel Cell & Hydrogen
PEFC	Polymer Electrolyte Fuel Cell
SOFC	Solid Oxide Fuel Cell

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1 Current education and training activities

In this report, an overview is given of current educational and training activities within individual EU Member States and at the European level.

1.1 Introduction

Due to the fact that FCH technologies are predominantly in the R&D stage, mostly academic education and training elements were identified. While comparing education and training within different countries, the following terms will be used:

Level	Cycle	Bologna terminology
Undergraduate	First Cycle	Bachelor's degree (BSc, BEng)
Postgraduate	Second Cycle	Master's degree (MSc, MEng)
	Third Cycle	Doctoral and post-doctoral studies (PhD/PostDoc)

Four types of education and training were distinguished [1]:

A. Occasional training modules such as workshops, short courses and (summer) schools which are not part of a larger educational programme;
B. Higher education course modules dealing with FCH as part of an educational programme not solely focussed on FCH but on a wider related area, such as Energy;
C. Higher education programmes entirely dedicated to FCH technologies;
D. Relevant Marie Curie actions.

1.2 Map of existing educational and training activities

1.2.1 A: Occasional training modules (Table 1 and Table 2)

Various universities, institutes for professional education, and other organisations currently offer occasional training modules broadly directed at engineers, planners, department managers, manufacturers, system integrators, inspection and safety bodies, and researchers. These modules cover the basic principles of hydrogen technology, including topics such as physical properties, production, processing, conditioning, cleaning, compression, storage, and transport. In addition, various applications are addressed, such as fuel cells (PEFC and SOFC), heating technologies, hybrid systems, and smart grids. Each module is attended by roughly 10-30 persons.

Several of these training and education activities are part of specific (EU and national) projects and were accordingly discontinued once the projects are completed. The organisers of courses include academia, vocational training institutions (including those offering CPD accredited courses), and research institutions. Only few of these have been

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established on a sustainable basis, continuously delivering courses. This applies to those offered on a commercial basis (e.g. Haus der Technik, WBZU, TÜV), as well as a number of courses sponsored by universities and research institutions such as the Lower Saxony Summer School, or JESS. Without industry sponsoring (Lower Saxony), unpaid-for lecturing activities (both Lower Saxony and JESS), and cost sharing between the organising institutions (i.e. institutional sponsoring) (JESS) these initiatives would not be possible.

Table 1: Occasional training events

Training institution	Country	Duration	Course title
TÜV SÜD Akademie	DE	1 day	*Hydrogen technologies*
	DE	1 day	*Basics of hybrid and FC technology in vehicles*
	DE	3 days	*Hydrogen installations for vehicles according to TRBS1203*
	DE	1 day	*Uninterruptible Power Supplies with FC*
Ulster University	UK	5 days	*International short course series Advanced Research Workshop "Progress in hydrogen safety"*
Haus der Technik, Essen	DE	1 day	*Hydrogen and its meaning for the energy sector*
	DE	3 days	*Hydrogen and FC for mobile applications*
Weiterbildungszentrum Brennstoffzelle Ulm e.V.	DE	1 day	*Fuel Cell and Hydrogen technology*
	DE	3 days	*Safety aspects when handling hydrogen*
	DE	5 days	*Polymer electrolyte FC*
	DE	4 days	*"Polymer Electrolyte Fuel Cell Introduction Course (PEFC)"*
	DE		*"International Master Class on Fuel Cells & Hydrogen"*
	DE	1 days	*Uninterruptible Power Supplies with FC*
Inst. für berufliche Bildung	DE	10 days	*Fuel Cells*
HyFacts consortium	EU	2-5 days	*Training short courses for regulators*
Hychain	EU	1-5 days	*Hydrogen, PEMFC and mobile applications*
HyFCAcademy School, Aalborg University	EU	4 days	*topics change annually*
Christian-Doppler- Lab. for Fuel Cell Systems with Liquid Electrolytes	AT	4 days	*International Summer School on PEFC*

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Ostfalia University of Applied Sciences	DE	12 days	*International Summer University "Sustainable Energy Technologies"*
Solar-Institut Jülich	DE	15 days	*Summer School Renewable Energy*
Menéndez Pelayo Intern. Univ (UIMP), Spain	ES	3 days	*"Hydrogen and Fuel Cells: electric vehicle and energy storage"*
European Fuel Cell Forum	CH	1 day	*Fuel Cell Tutorial*
University of Birmingham / Forschungszentrum Jülich/ DTU	UK/DE/DK	5 days	*Joint European Summer School on Fuel Cell, Electrolyser, and Battery Technology (JESS)*
Ingeoexpert in collaboration with CNH2 (Centro Nacional de Hidrógeno)	ES	>7 days	*Curso de tecnologias de Hidrogeno*
Politecnico di Torino	IT	>7 days	*H2 technologies*
Energy Skills Partnership	UK	1 day	*Hydrogen Online Awareness Course*
INSTN	FR	2 days	*Hydrogen sector*
CEA-INSTN	FR	1 days	*Fuel Cell*
STAR ENGINEERING	FR	2 days	*Hydrogen: context, regulation and risk management*
Kiwa	EU	1 day	*Hydrogen Commercial Training Course*
Kiwa	EU	1 day	*Hydrogen Awareness Course*
Kiwa	EU	1-2 days	*H2 training for the Automotive*
Kiwa	EU	1-2 days	*Safety courses related to hydrogen in the automotive sectors*
Kiwa	EU	1-7 days	*Certification Processes for Hydrogen Vehicles Components*
Kiwa	EU	1-2 days	*Hydrogen Safety and Hydrogen Infrastructure Safety*
The Renewable Energy Institute - European Centre of Technology (ECT)	UK	>7 days	*Hydrogen Energy Expert Certificate*
ARIEMA Energía y Medioambiente S.L.	ES	>7 days	*Curso H2*
Energy Delta Institute in cooperation with Hydrogen Europe	NL	1 days	*Masterclass Hydrogen*
Energy Delta Institute	NL	7 days	*Intensive Course Hydrogen*

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Energy Delta Institute	NL	2 days	*Hydrogen Role in the Energy Transition*
Energy Delta Institute	NL	1 day	*Masterclass Waterstof*
Aragon Foundation; University of Catalonia UPC; University of Rovira and Virgili; UPV/EHU; Zaragoza University	ES	>7 days	*Hydrogen technologies*
University of Technology of Belfort-Montbeliard	FR	1-2 days	*Fuel Cell Technology for Transport applications*
Coorganised by FORTH/ICEHT and the University of Birmingham	GR	<7 days	International Workshop On Degradation Issues of Fuel Cells and Electrolysers
University of Birmingham	UK	<7 days	Bruges Workshop on Fuel Cell Systems
HyCentA Research GmbH	AT	<7 days	Workshops in the fields of hydrogen production, storage, distribution, application and hydrogen safety
University of Technology of Belfort-Montbeliard	FR	1 day	Real time simulation challenges for PEM fuel cells
Energy Academy	NL	>7 days	*Several programmes with regular courses on H2: Energy Academy Certificate, Micro MBA*
Orkney College Maritime Studies Dept. University of the Highlands and Islands	UK	≤6 months	*Crew certificate for Hydrogen Fuelled Shipping*
Orkney College Maritime Studies Dept. University of the Highlands and Islands	UK	≤6 months	Hydrogen Awareness for End Users
Orkney College Maritime Studies Dept. University of the Highlands and Islands	UK	≤6 months	Carriage of Hydrogen as Cargo on Vessels
Energy College	NL	≤6 months	*Regular hydrogen courses*
Drenthe College	NL	≤6 months	*Masterclass 'Hydrogen in practice'*

Table 2: Summer Schools and equivalent events

Training designation	**Project's name/provider**	**Project's duration**
Technical schools on FCH	H2FC	48 months

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Joint European Summer School on FCH Technology (2011 & 2012)	TrainHy	24 months
Joint European Summer School on Fuel Cell, Electrolyser, and Battery Technology (JESS) (since 2013)	privately organised by University of Birmingham / Forschungszentrum Jülich/ DTU	n/a
Real-SOFC Summer School (International SOFC Summer School #1 to #4) (2004-2007)	EU Integrated project Real-SOFC	48 months
LargeSOFC Summer School (International SOFC Summer School #5 to #6) (2008-2009)	EU Integrated Project LargeSOFC; Forschungs-zentrum Jülich	24months
The European Summer School on Hydrogen Safety (2006-2009)	Ulster University	48 months
Niedersächsischen Brennstoffzellen Summer School (Lower Saxony Summer School on Fuel Cells)	Institut für Turbomaschinen und Fluid-Dynamik, Leibniz Universität Hannover	48 months
ISCARW courses	Ulster University	4 years
Short course "Hydrogen safety facts for regulators and safety officials"	HYFACTS	3 years
Pilot sessions of European Hydrogen Safety Training Programme for first responders	HyResponse	3 years
grEnoble eNerGy conversIoN & storagE (ENGINE)	Université Grenoble Alpes	n/a
FC-Lab Summer School on Hydrogen	LEMTA, University of Lorraine, Nancy, France	n/a
International Summer School on PEFCs	Graz University of Technology and the Institute of Chemical Engineering and Environmental Technology (CEET)	n/a
International Summer School Hydrogen & Fuel Cells Technology	CEFT Transport Phenomena Research Center	n/a

This shows a worrying lack of commitment at all European levels to overcoming the fragmentation of such initiatives and securing a long-term sustainable financial background for these key activities in educating the European workforce. Without the

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stubborn private initiative of single institutions, Table 1 and 2 would simply collapse and be reduced to single events run by disconnected projects on a one-off basis without the necessary professional educational background.

Additionally, The University of Salerno, HyCentA Research and the German Aerospace Centre all host internship placements focusing on aspects such as electrochemistry, hydrogen production, storage, distrubution and transport applications.

1.2.2 B: Higher education course modules (Table 3 and Table 4)

Several educational programmes in Europe address FCH technologies in dedicated course modules, with an average course weight of 5 ECTS credits (corresponding to 125-150 hours of studying). The availability of undergraduate modules is very scarce: there exist only two dedicated undergraduate modules both focusing on fuel cells but not specifically on hydrogen. Both course modules are offered in Sweden:

Table 3: Undergraduate course modules

Undergraduate module	University	ECTS*	Country
The Fuel Cell (KH1405)	KTH Royal Institute of Technology	6	Sweden
Fuel Cell Technology (LU2730T)	Lund University	6	Sweden
Sustainable Energy Engineering	Technical University of Denmark	-	Denmark
Energy storage (for sustainable energy systems)	Norwegian University of Science and Technology	-	Norway
Hydrogen Technology, Fuel Cells, Batteries and Solar Cells		-	
Hydrogen in transportation for a safe and sustainable future		-	
Renewable hydrogen (RH2) for a cleaner and better society		-	

*60 ECTS correspond to one academic year (1500-1800 hrs)

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The content of these undergraduate courses implies acquiring general understanding of fuel cells at both theoretical and practical levels. At the end of the course the student can decide what fuel cell systems are preferable for a given application. This course aims to enhance deeper knowledge, wider vision and improved understanding of the mechanisms as well as a better insight into theories, analysis and design of fuel cell and integrated energy systems.

Among postgraduate course modules there are over 100 modules addressing FCH aspects (mostly parts of educational programmes on energy) offered in 13 European countries:

Table 4: Postgraduate course modules

Postgraduate module	University	ECTS	Country
Hydrogen energy and FC (26130)	Denmark University of Technology	5	DK
SOFC and Electrolysis		5	DK
Material for H_2 production, storage and FC applications (45200)		5	DK
Experimental SOFC & electrolysis (45103)		5	DK
45101- Functional Ceramics: Defect Chemistry and Transport Properties		5	DK
26120- Hydrogen and Fuel Cell Chemistry- Experimental course		5	DK
Energy storage and conversion		-	DK
Functional materials		-	DK
Fuel cell systems (WB4425-09TU)	Delft University of Technology	3	NL
Sustainable hydrogen and electrical energy storage (SET3031)		2	NL
Introduction to Fuel Cell Systems (WB3570TU)		2	NL
Material for the H_2 economy (MS4221)		2	NL
Automotive FC systems (3C5625)	KTH Royal Institute of Technology	7.5	SE
Fuel cell (KE2170)		6	SE

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Renewable fuel production processes (KE2130)		6	SE
The Fuel Cell (KH1405)		6	SE
Hydrogen technology, FC and solar cells (TMT4285)	Norwegian University of Science and Technology	7.5	NO
Energy use in Buildings		-	NO
Sustainable Heat Pumping Processes and Systems		-	NO
Sustainable Energy Systems and Markets		-	NO
Renewable energy: H_2& FC technology	University of Newcastle	5	UK
Fuel Cell and Hydrogen Technology	University of Birmingham	5	UK
Fossil fuel based hydrogen technology (6KM40)	Eindhoven University of Technology	3	NL
FCH Technology (Tfy-56.4332)	Helsinki University of Technology	5	FI
Material for the hydrogen economy	Heriot-Watt University Eindburg	5	UK
MES-R-13-K Fuel Cells for Stationary Application	FH Aachen – University. of Applied Sciences, Jülich Campus	2.5	DE
Conversion des ressources fossiles et des vecteurs énergétiques: Hydrogène GMCH213	Université Montpellier 2	5	FR
Convertisseurs électrochimiques : Piles à Combustible GMCH34C		2.5	FR
New power production technologies	Ecole Centrale de Nantes	3	FR
Hydrogen derived technologies	Université de Nantes	4	FR
Matériaux et Technologies de l'Energie FC&H2	University Paris Sud & Paris Est	2	FR
Energies renouvelables: présentation des différentes filières	Grenoble Institute of Technology	2	FR
Electrochimie pour l'énergie		4	FR
Electric mobility		-	FR
Generation and Storage		-	FR

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New Sustainable Technologies		-	FR
Energies for Ecodistricts		-	FR
Electrochemistry (M1)		-	FR
Process engineering Labwork (M1)		-	FR
Electrochemistry / Hydrogen carrier (M2)		-	FR
Multidisciplinary project on conversion and storage of energy (M2)		-	FR
Electrochimical Reactor (M2)		-	FR
Life Cycle of Technology Objects		-	FR
Composants électrochimiques	INP Toulouse	5	FR
Polygeneration and Advanced Energy Systems	Politecnico di Torino	10 (5 on FCH)	IT
Fuel Cells	Ecole Polytechnique Fédérale de Lausanne	2	CH
Engines and fuel cells		-	CH
Catalysis for energy storage		-	CH
Electrochemical engineering		-	CH
Nanomaterials for chemical engineering application		-	CH
System Design	INP-ENSEEIHT	-	FR
Hybrid systems, storage, and H2 energies		-	FR
Renwable Energies		-	FR
Actuators and generators		-	FR
System and Power Grids		-	FR
Design of static converters		-	FR
Materials for Energy	University of Turin	-	IT
Smart Energy and Hydrogen Management	South Brittany University	-	FR
Hydrogen and fuel cell technologies	Universidad Politécnica de Madrid	-	ES
Sostenibilidad de las EERR		-	ES

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Tecnologías Limpias de la Combustión		-	ES
Fuel Cells Technology And Hydrogen Energy		-	ES
Vehículos Híbridos y Eléctricos		-	ES
Transporte Sostenible		-	ES
Diseño del Tren Propulsor		-	ES
Eficiencia Energética en el Transporte		-	ES
Electrochemical Energy Conversion and Storage	Politecnico di Milano	-	IT
Advanced Energy Systems		-	IT
Fundamentals of Chemical Processes		-	IT
Advanced Thermodynamics and Thermoeconomics		-	IT
Hydrogen as Energy carrier	Karlsruhe Institute of Technology	-	DE
Internal combustion engines, hydrogen engines and CO2-neutral fuels		-	DE
Hydrogen in Materials: from Energy Storage to Hydrogen Embrittlement		-	DE
Hydrogen in Energy and Vehicle Technology	Graz Universtiy of Technology	-	AT
Advanced Thermodynamics		-	AT
Innovative Propulsion Systems		-	AT
E-Mobility		-	AT
Energy Storage Systems		-	AT
Advanced Fuel cell Systems	University of Burgundy Franche-Comté	-	FR
Fuel cells		-	FR
Energy Storage and Conversion		-	FR
Clean and Sustainable Energy Production		-	FR
Modelling and Control		-	FR
Control of Power Systems		-	FR
Advanced Energy and Propulsion Systems	University of Salerno	-	IT

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Engineering for Environmental Sustainability	Unimore	-	IT
Automotive engineering		-	IT
Energy Vector Hydrogen I. Storage and Transport	Universidad de Alicante	-	ES
Electrochemistry and Fuel Batteries		-	ES
Energy Vector Hydrogen Ii: Uses		-	ES
Technologic Applications of Electrochemistry I		-	ES
Computational Fluid Dynamics (CFD) and Multi-phase Flow	Aalborg University	-	DK
Fluid Mechanics and Compressible Flow		-	DK
Probability Theory, Stochastic Processes and Applied Statistics		-	DK
For international students: Control Theory and MATLAB		-	DK
Fuel Conversion and Production		-	DK
Chemical Reactors and Process Systems		-	DK
Non conventional energy resources	University of the Basque Country (UPV/EHU)	_	ES
Sustainable Technologies for Energy Resources	University of Bologna	-	IT
Sviluppo e gestione dei processi chimici industriali con laboratorio		-	IT
Chimica della catalisi		-	IT
Processi chimici a basso impatto ambientale		-	IT
Green Chemistry and sustainable chemical technologies		-	IT
Catalysis for renewables		-	IT
Circular economy and sustainable business models		-	IT

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Fuel cell technology - fundamentals, technology and systems	University of Stuttgart	-	DE
Fluid Dynamics and Thermotechnical Systems	Università degli studi di Perugia	-	IT
Fuel Cells and Hydrogen Technology	Aalto University	-	FI
Fuel Cells and Batteries: Materials and Technology	University of Tartu	-	EE

The average 'value' of these modules is 5 ECTS (125-150 hrs.). The course modules present a general overview of FCH from fundamental aspects to applications such as hydrogen as energy carrier, basics of fuel cell technology, electrochemical principles, thermodynamics, ion conductors, catalysts, hydrogen storage, fuel processing, hydrogen production, system integration, applications, etc. along with demonstration experiments.

It should be noted that among the disciplines that are of importance to FCH technologies, **Electro-chemistry** has been declining in the past decades. If this trend continues, the lack of electro-chemistry expertise will likely cause significant damages to the FCH sector. The recommendation of industry is that education efforts in this field should perpetuate in both initial and continuous training.

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1.2.3 C: Fully dedicated educational programmes (Table 5)

Nine fully dedicated educational programmes in three countries have been identified:

Table 5: Dedicated educational programmes

Name	University	ECTS	Country
Post-graduate Cert in Hydrogen Safety Engineering	Ulster University (discontinued)	28	UK
Post-graduate Dip in Hydrogen Safety Engineering		56	UK
Post-graduate in Hydrogen Safety Engineering		84	UK
MRes in Hydrogen, FC and their applications	University of Birmingham	60	UK
MSc in Fuel Cell and Hydrogen Technology (TeacHy)		120	UK
PhD with integrated Study Fuel Cells and their Fuels		240	UK
MSc in FC and Hydrogen Technology	Aalborg University	120	DK
Master of Science in Engineering (Sustainable Energy) • Study line in hydrogen and fuel cells • Elite master education "Fuel Cells and Hydrogen", an industrial oriented education under Sustainable Energy	Denmark University of Technology	120	DK
Electrochemistry and Processes for Energy and the Environment (EPEE)	Grenoble Institute of Technology	120	FR

As can be seen from the table, the majority of universities offering (or having offered) these courses are members of this consortium. Each post-graduate full programme consists of 10-20 students. The curricula of the dedicated FCH programmes are briefly presented below.

MSc in Hydrogen Safety Engineering (Ulster University): This programme was intended for students who wished to pursue a career in hydrogen safety and for professionals already working in industry (process, energy, civil works, aerospace, automotive industry), transport and distribution, fire and rescue brigades, insurance, teaching institutions and legislative bodies. It was composed of 6 modules: (i): Principles of Hydrogen Safety (14 ECTS) compulsory; (ii): Hydrogen Safety Technologies (14 ECTS), compulsory; (iii): Regulations, Codes and Standards (14 ECTS), compulsory; (iv-a): Hydrogen Powered Transport and Infrastructure Safety (14 ECTS) optional or (iv-b): Progress in FC and Hydrogen Technologies (14 ECTS) optional; (v).Dissertation module: research project (28 ECTS) compulsory.

MRes in Hydrogen, FC and their applications (UBHAM): This programme provides systematic knowledge and understanding of hydrogen, fuel cells and their applications,

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including developments and problems at the forefront of the discipline. The curriculum consists of modules in science, engineering and team building, as well as business management, and a dissertation. The core modules deal with the following topics: (i) Material for H&FC Technologies; (ii) The Energy System; (iii) Marketing and Total Quality Management; (iv) Effective Project Management; (v) Business Methods, Economics & Strategy. The research thesis will focus on selected topics directly related to FCH.

PhD with integrated Study in Hydrogen, FC and their applications (UBAHM): This integrated programme has the duration of 4 years. The taught modules are given in the first 18 months, focusing on Science, Engineering, Energy, Teambuilding, Business, Economics, Management, and Safety. The programme is placed within the Centre for Doctoral Training in Fuel Cells and their Fuels. Led by the University of Birmingham in collaboration with Loughborough University, University of Nottingham, University College of London, and Imperial College, this represents a unique joint action of this kind in Europe.

MSc in FC and Hydrogen Technology (Aalborg Uni): This FCH programme gives an in-depth understanding of the technologies of FC systems and Hydrogen production and storage. The programme is multidisciplinary, integrating general engineering disciplines, such as thermal systems, fluid dynamics, control engineering and electrical engineering. The course modules are taught within three semesters. The fourth semester is devoted to a Master's Thesis in FCH technology.

Electrochemistry and Processes for Energy and the Environment (EPEE) (EPFL): This course provides a mixed taught content of physics and chemistry, orientated towards the key areas of modern industry: electrochemistry and physicochemical processes. The programme is at the forefront of developments in energy (e.g. fuel cells), sustainable development and micro-electronics. This training in engineering aspects is complemented by exposure to the processes of quality and safety controls, and sustainable development through eco-industry, eco-design, and eco-processes. In addition, the education provided by the course requires students to analyse the complex phenomena which arise in physico-chemical operations and to appreciate multidisciplinary models and cross-disciplinary analysis.

1.2.4 D: Marie Curie actions (as part of FP7 'People')

Under the Seventh Framework Programme several "People" actions dealt specifically with FCH or Energy including FCH. Among these actions, four can be distinguished as those containing educational elements:

1.2.4.1 D.1: Initial Training Networks (ITN)

The objective of the ITN action is to improve career perspectives of early stage researchers in both academia and the private sector.

SUSGHEN: Sustainable Hydrogen Generation (12-2009 to 11-2013) was coordinated by the University of Newcastle Upon Tyne (UK). The aim of this ITN was to form a collaborative training programme that focuses on hydrogen production from water using

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advanced medium-temperature proton exchange membrane electrolysers. Other partners are: NTNU, Trondheim (Norway); CNRS (France); Fundacion CIDETEC; San Sebastian (Spain); Institute of Electrochemistry & Energy Systems, Bulg. Acad. Sci., Sofia (Bulgaria); Centre for Process Innovation Ltd, Redcar (UK); Advanced Energy Technol. AE Ereunas, Athens (Greece).

1.2.4.2 D.2: International Research Staff Exchange Scheme (IRSES)

The objective of IRSES is to reinforce the extra-European dimension of the European Research Area through mobility, training, knowledge transfer and cooperation.

BIOWET: The advanced Biological Waste-to-Energy Technologies (01-2012 to 12-2015) was coordinated by the Institute for Chemical Technology, ICT, Prague (Czech Republic). The aim of this research was to apply biological methods for energy production using waste, contaminated material or polluted environments, thus coupling energy production to waste minimization/reclamation. Other partners: Czech Republic, UNESCO-IHE for Water Education (Netherlands), University of South Florida (USA).

1.2.4.3 D.3: Industry-Academia Partnerships and Pathways (IAPP)

The objective of IAPP is to open and foster dynamic pathways between public research organisations and private research commercial enterprises.

ATLAS-H2: Advanced Metal Hydride Tanks for Integrated Hydrogen Applications (07-2010 to 06-2014) coordinated by DEMOKRITOS National Center for Scientific Research, Aghia Paraskevi (Greece).

The aim of this partnership was to develop, test (in the short term) and bring to the market (in the medium to longer term) integrated advanced metal hybrid tanks with added value applications designed for stationary systems and hydrogen compression. Even if the training & education aspects are less developed than in the two previous programs, the dynamic pathways between public and private research entities equip the staff with necessary skills. Other partners: CNRS (France), Hystore Technol. Ltd, Lefkosia (Cyprus), McPHY Energy Sa., La Motte Fanjas (France).

1.2.4.4 D.4: COST networks

The European Action MP1103 "Nanostructured Material for Solid State Hydrogen Storage" started October 25, 2011 with support of the intergovernmental framework for European Cooperation in Science and Technology (COST). It adopts the "COST Strategy towards increased support for early stage researchers (ESR)". The COST Action puts into practice the ESR related measures foreseen by the COST Action community, such as Short Term Scientific Missions (STSMs), Training Schools, Conference Grants and ESRs as national MC delegates. This year 7 STSMs have been executed by 7 ESR, 3 for 15 days and 4 for 30 days. Moreover, The First European Early Stage Researcher's Conference on Hydrogen Storage will be held in Belgrade on December 3-5, 2012. This Conference will strongly promote the involvement of European ESRs into the Action. Recent results on nanostructured material for SSHS achieved mainly by the partners of this Action will be

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discussed, highlighting the cooperation among partners and support gained by the STSMs instrument in favour of ESRs.

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2 Industry requirements for skills development

The SET-Plan Education elaborated in 2012 for the EU [2] mapped out the number of 'skilled personnel' required by European businesses in the field of Fuel Cell and Hydrogen (FCH) technologies in the time period up to 2030. Fig. 1 shows the results for the year 2030. The numbers were built on estimates of products supplied and the number of employees required to produce them. The result has been widely published [3] and indicates that a total of 200,000 trained workers will be needed, half of which would be factory and workshop floor workers, 25% trained technicians, and 25% university graduates. This covers all aspects of product development stages and acknowledges a high percentage of R&D still going on in this period. As has been pointed out elsewhere [3], the projected human resources will be difficult to establish and a concerted action of European educational bodies will be required to supply this skills base. It can be assumed that a high number of this 'skilled staff body' will already be working today and will thus receive a training 'on the job' or via professional development. Nevertheless, even assuming only a reduced fraction of the training will be for new graduates at any level of technical, college and university training, results in a tremendous effort necessary in conveying fuel cell and hydrogen technology knowledge to the professional realm.

2030									
	Est. annual production		Market value	CAGR	Number of companies involved		Employment		
Application area	Unit		(M€)	2020-2030	SMEs	Large companies	Workers	Technicians	Engineers
Fuel cell electric vehicles	#	500 000	12 500	7%	2	15	62 500	31 250	31 250
Hydrogen refuelling infrastructure	#	300	420	3%	3	7	2 250	1 125	1 125
Hydrogen Production	ton	425 635	3 405	5%	5	10	11 350	11 237	11 237
Stationary fuel cells	#	150 000	1 500	5%	5	8	11 250	5 625	5 625
Early markets - forklifts	#	30 000	240	5%	5	8	1 000	1 000	1 000
Early markets - power generation	#	30 000	42	2%	5	8	500	500	500
TOTAL			**18 107**	**7%**			**88 850**	**50 737**	**50 737**

Fig. 1: Estimated human resources required in 2030 to support a growing EU FCH industry base. 'Workers' refers to factory and workshop floor workers, 'technicians' to specially trained staff, and 'engineers' to university graduates (BEng, Meng, or PhD) (from [2]).

The following list compiles the different levels of education encountered in the EU and the standards applied in general (specific arrangements in the different countries will vary in definition and content) in the sequence of level of university or other qualifications (adapted from [4]):

1. PhD students – in their 1st, 2nd, 3rd PhD year,
2. Master graduates (MSc/MEng) – usually 5 years of higher university education in science or engineering,

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3. Bachelor students – in their 1st, 2nd, 3rd year of Group 1 or 2,
4. Graduated technical engineers (BEng) – usually 3 years of higher education in engineering,
5. Technicians (vocationally trained) – usually 3 years of vocational training,
6. Employees and professionals from industry and businesses,
7. Employees and officials of government (central and local), permitting and safety related organisations,
8. 'Stakeholders' (to be defined and selected),
9. General public.

There are 3 different delivery forms of adult education, addressing these different target groups:

1. a full course, carrying a number of 'credit points' (ECTS in the Bologna system) leading to an accredited degree (usually min. 6 months, and up to 2 years) (vocational degrees, list items 1 to 5);
2. short courses or individual topics (modules) leading to a certificate (a few days, up to 1 to 2 weeks); training can be 'initial' (1st contact) or 'continued' (specialisation) (list items 6 & 7);
3. as brochures, leaflets, videos, factsheets etc., for easy access to a wide audience including nonprofessionals and the general public (list item 8).

Item (1.) covers full professional training, in the sense of Fig. 1 and the previous discussion accounting for about 25 to 30% of the specialised FCH human resources in 2030. Items (2.) and (3.) address recipients with an existing degree or professional training requiring re- or up-skilling, and lowlevel information to be issued to more or less the general public. Industry, as the 'customer' sourcing the human resource it requires, has not (yet) voiced much concern about the numbers of university graduates being trained in current programmes. The main feedback received was through [5], where industry laid emphasis on the practical elements of training. As is also documented in the Roadmaps that form the base of the Clean Hydrogen for Europe partnership (CH4E, the successor to the Fuel Cell and Hydrogen Joint Undertaking, FCH JU), the educational sector is rather taken for granted and little initiative can be felt from industry side to shape and develop requirements for professional training in the field of FCH technologies [6].

Specialised educational initiatives in the field of FCH technologies have been listed in Section 1 of this document. An update of current activities can be drawn from the pages of the Hydrogen Observatory [7] at any time, although that information is not always up to date, complete, and accurate.

Industry-relevant educational programmes currently found publicly promoted are in their main character Continuous Professional Development (CPD) type courses, or short

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courses (as defined above). There also appears to be an interest in supporting employees in following part-time courses and programmes, including MSc and Meng programmes. A distinctive interest of companies has been recorded for employees following CPD courses at universities, or requesting universities to organize university-type modules as CPD courses for their employees. This is the case with several companies buying into the modules offered by the University of Birmingham in the scope of the MSc programme 'Fuel Cell and Hydrogen Technologies' [8] or attending the JESS Joint European Summer School in Fuel Cell, Electrolyser, and Battery Technologies. On the other hand, companies are also seen to be reluctant to up-skill employees too much, as they seem to fear that they could use the new qualifications to apply for jobs elsewhere and/or increase their salaries. One indicator for this is the disinterest of industry to have the participants of courses issued with qualification certificates (beyond the general participation certificates).

Training programmes favoured by industry should be [5]

- limited in time spent on the educational activity,
- limited in cost to anything between €500 and €2,000,
- compatible with part-time participation.

3 References

[1] Wancura H, Mayo B, Reijalt M., Mertens J.J., Classen P., *Draft implementation report WG5 cross cutting issues*. The European Hydrogen and FC Technology Platform, Implementation Panel.

[2] Assessment Report SET-Plan on Education and Training - Working Group: Fuel Cells and Hydrogen. Brussels, 14. Nov. 2012.

[3] R.Steinberger-Wilckens, A.Purushothaman Vellayani, M.Santarelli, Y.Brodnikovskyi, L.N. Cleemann, K.Bouzek, J.Van herle, J.-L.Delplancke, I.Iordache, F.Druart, V.Molkov, O.Jedicke: An MSc Course in FCH Technologies. Proceedings of the European Fuel Cell Forum, 29/06-02/07/2021, Lucerne, paper A1505.

[4] TeacHy project Deliverable D1.1: Definition of target groups, topics and modules. Ecole Polytechnique de Lausanne, 2019.

[5] TeacHy project Deliverable D9.2: Industry advisory board training needs document. University of Birmingham, 2018.

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