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About TeacHy

As the FCHT industry gradually emerges into the markets, the need for trained staff becomes more pressing. TeacHy2020, or short TeacHy, specifically addresses the supply of undergraduate and graduate education (BEng/BSc, MEng/MSc, PhD etc.) in fuel cell and hydrogen technologies (FCHT) across Europe.

TeacHy2020 will take a lead in building a repository of university grade educational material, and design and run an MSc course in FCHT, accessible to students from all parts of Europe. To achieve this, the project has assembled a core group of highly experienced institutions working with a network of associate partners (universities, vocational training bodies, industry, and networks). TeacHy offers these partners access to its educational material and the use of the MSc course modules available on the TeacHy site. Any university being able to offer 20 to 30% of the course content locally, can draw on the other 80 to 70% to be supplied by the project (and its successor entity that will support the platform post-project).

This will allow any institution to participate in this European initiative with a minimised local investment. TeacHy will be developing solutions to accreditation and quality control of courses, and support student and industry staff mobility by giving access to placements. Schemes of Continuous Professional Development (CPD) will be integrated into the project activities. We expect a considerable leverage effect which will specifically enable countries with a notable lack of expertise, not only in Eastern Europe, to quickly be able to form a national body of experts.

TeacHy will offer some educational material for the general public (e.g. MOOC's), build a business model to continue operations post-project, and as such act as a single-stop shop and representative for all matters of European university and vocational training in FCHT. The project partnership covers the prevalent languages and educational systems in Europe. The associated network has over 70 partners, including two IPHE countries, and a strong link to IPHE activities in education.

1. Introduction

This deliverable presents the strategies to integrate, modify, or tailor modules and teaching content to different vocational training requirements in Europe as foreseen in Task 4.5. The topics have been chosen based on the probable fuel cell and hydrogen (FCH) technologies that will enter the market during the 2020 to 2050 period. Giving priority to such technologies that will have the most significant impact on the job market is what concerns the engineers' employment. Therefore the course content should be defined by specifying the type of trainees to be addressed. However, there are gaps in the training landscape and the possibility of using existing training material from TeacHy with modifications has to be explored.

The information has been modified according to the experience gained while carrying out the KnowHy project and brainstorming with the TeacHy project partners. Information provided by KnowHy regarding the local situations in the different European countries has been added. More in detail, information regarding FCH applications currently present or expected to enter the market and estimates of their impact on the employees' market, existing FCH training initiatives and the use of existing training material for the development of vocational training course content have been included. In this deliverable, the exact type of vocational training is targeted while the course contents is not reported. In the deliverable, thanks to the survey performed within Task 1.2 of the KnowHy project, the possible course content is briefly discussed. Then the strategies of vocational training interface are presented.

The following partners were involved in the task: Technical University of Denmark, University of Birmingham, University of Bucharest and Ulster University.

2. Market Analysis Outcomes

A new generation of FCH technologies is expected to enter the market in the next 5 to 10 years. Besides FCH technologies, also systems and infrastructure related to hydrogen production, distribution, and storage should be considered. In section 2.1, FCH applications are discussed in terms of time to market and size of the market while in section 2.2 their impact on the European labour force is presented. Section 2.3 presents the results of the investigation on existing FCH courses.

2.1 Fuel Cells and Hydrogen Applications

The use of fuel cells and hydrogen technologies can be categorised into three broad areas:
- Portable (auxiliary power units, military applications, portable products, personal electronics),
- Stationary (large and micro combined heat and power systems, uninterruptible power supplies), and
- Transport (material handling vehicles, fuel cell vehicles, trucks, buses, aircraft and ships).

Table 1 illustrates the differences between the three categories for what concerns the power range and typical fuel cell technology used, differentiated by electrolyte type: Polymer Electrolyte Fuel Cells (PEFC), Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC), Direct Methanol Fuel Cells (DMFC), Molten Carbonate Fuel Cells (MCFC), and Solid Oxide Fuel Cells (SOFC).

Table 1 – Categorisation of FCH applications (adapted from [1]).

Application Type	Portable	Stationary	Transport
Definition	Units that are built into, or charge up, products that are designed to be moved, including auxiliary power units (APU)	Units that provide electricity (and sometimes heat) but are not designed to be moved	Units that provide propulsive power or range extension to a vehicle
Typical power range	1 W to 20 kW	0.5 kW to 400 kW	1 kW to 100 kW
Typical technology	PEFC - DMFC – SOFC	PEFC – AFC - PAFC MCFC - SOFC	PEFC – DMFC – AFC - SOFC
Examples	non-motive APU (camper vans, boats, lighting), military applications (portable soldier-borne power, skid mounted generators), portable products (torches, battery chargers), small personal electronics (mp3 players, cameras)	large stationary prime power, large stationary combined heat and power (CHP), small stationary micro-CHP, uninterruptible power supplies (UPS)	material handling vehicles, Fuel Cell Electric Vehicles (FCEVs), lorries and buses

2.1.1 Transport applications

The attention of research and industry has been significantly focused on transport applications. The automotive fuel cell market is estimated to grow at a Compound Annual Growth Rate (CAGR) of 65.86% during the forecast period (2018 to 2025), to reach a market size of 268,786 units by 2025 [2]. Governments are taking initiatives, making investments, and promoting the use of fuel cells. To equal their Internal Combustion Engine (ICE) competitors, Fuel Cell Electric Vehicles (FCEVs) need to match and arguably improve upon 110 years of development and refinement, providing extremely cost-effective, ubiquitous and reliable transport. Achieving that takes time, large amounts of money, and several false starts. Since 2013 however, when Hyundai's first small-series production vehicles became available, the picture has improved. The Toyota Mirai followed with Honda's Clarity Fuel Cell becoming available to customers in 2016 [3].

Norway, the Netherlands and Germany have voted in some way to ban polluting vehicles by 2040, the former two by 2030 [4]. Volkswagen started a collaboration with Ballard and a partnership with SAIC, a partner of General Motors' fuel cell programme [5]. BMW announced a memorandum of understanding with Toyota for what concerns advanced drivetrains, thus suggesting the probable adoption of fuel cells on some of their vehicles [5].

Selling cars to individual consumers when refuelling infrastructure is hard to find, is near to impossible. Hence, along with the development of fuel cell technology, it is important to create a robust infrastructure that can cater to the needs of hydrogen-powered transportation. Therefore, governments are increasingly investing in the development of required hydrogen infrastructure, providing an opportunity for the automotive fuel cell market to grow in the future. The U.K. has planned 65 hydrogen refuelling stations by 2020 and 1,150 by 2030 [2]. In Munich, Linde opened multi-energy fuelling stations providing hydrogen for fuel cell cars. Target is that, by 2023, the number of hydrogen filling stations on the network in Germany will be increased to about 400. As a first step, it is planned that 100 hydrogen filling stations will be opened in Germany by the end of 2018 [6]. A hydrogen supply suitable for everyday use shall be created not only for densely populated areas and main traffic arteries, but also for rural areas. The objective is to offer a hydrogen station at least every 90 kilometers of motorway between densely populated areas in Germany [6]. The Danish government is following recommendations from a recent Danish industry coalition roadmap to implement hydrogen for transport and early in 2012 it announced an Energy Plan for 2020 that includes initiatives for hydrogen infrastructure and FCEV [7]. In France, a public hydrogen station opened in Paris-Orly airport area in 2017 with the support of the FCH JU. The station facilitates the deployment of the Paris hydrogen taxi fleet Hype. The project aims to deploy more than 1,300 hydrogen cars and 90 hydrogen stations in Europe [7].

Bigger vehicles are entering into the market. It appears 2019 will become the year when heavy duty vehicles will move on from diesel and into electric terrain. Not only Volvo Trucks wants to launch its first battery-electric semi that year, Tesla and Nikola Motors want to start production the same year [8]. Nikola Motors announced that it plans to construct a factory to build its fuel cell truck by 2019. Renault Trucks has been experimenting with electric mobility since 2009 through extensive field testing with customers [8]. Renault's 4.5t Maxity truck, converted to a fuel cell range extender in 2015. Daimler has just delivered the first Fuso eCanter to clients in Europe and the States. While it is a medium duty van, the company is also looking to expand their electric endeavors, however, potentially on hydrogen too. Toyota is working on fuel cell in the medium and heavy-duty sector already and is running trials [8].

In 2011, Plug Power announced the next generation of its GenDrive fuel cell products for electric forklift trucks and committed to purchase a minimum of 3,250 fuel cell stacks by the end of 2011 from Ballard Power Systems [9]. Plug Power also announced its intent to partner with Axnae, an Air Liquide subsidiary, to better penetrate the European forklift market, which the company estimates to include an installed base of 2,000,000 forklifts and 325,000 annual unit sales [10]. In December 2014, Hyster-Yale acquired Nuvera Fuel Cells and announced plans for a ground-up fuel cell MHE (Material Handling Equipment) product. This acquisition creates a unique capability to integrate fuel cells with MHE units in order to optimise performance and energy efficiency of the combined system [11]. Nuvera began shipping its fuel cell MHE to customers in mid-2016. As of March 2017, examples of companies that have purchased or ordered fuel cell powered forklift trucks are as follows [12]:

Ace Hardware	Golden State Foods	Stihl
Baldor Specialty Foods	IKEA	Sysco Food
BMW Manufacturing Co.	Kimberly-Clark/GENCO	Testa Produce
Bridgestone-Firestone	Kroger Co.	Unified Grocers
Central Grocers	Lowes	United Natural Foods, Inc. (UNFI)
Coca-Cola	Martin-Brower	U.S. Foodservice
CVS	Mercedes	Walmart
EARP Distribution	Nestle Waters	Wegmans
East Penn Manufacturing	Nissan North America	WinCo Foods, LLC

In February 2015, the Kansai International Airport in Japan announced it will start replacing its fleet of 400 forklift trucks with hydrogen fuel-cell models as part of efforts to reduce carbon dioxide emissions. These fuel cell forklift trucks will be manufactured by Toyota Industries [13]. Carrefour, Europe's largest retailer and the second largest retailer in the world behind WalMart, announced in 2016 to buy more than 150 fuel cell units from Plug Power for its distribution center outside of Paris [14].

Continuing and expanding the heavy-duty theme, fuel cells are now being demonstrated in light rail applications and locomotives. While overhead or ground electrification is an excellent way to eliminate local emissions from rail, it can be expensive or impractical, and again hydrogen may offer a solution. Hydrogenics announced in 2016 that it would supply fuel cell systems to Alstom for use in light trains in Germany, and the first tests were carried out on the train itself just after summer. Alstom expects firm orders for 40-70 trains in the near future as well as supplying Indian Railways with 800 double section freight electric locomotives between 2018 and 2028. In China, the first fuel cell tram was put into commercial operation in 2017.

Electronics maker, ABB, and Ballard Power Systems, a maker of fuel cell technology have signed a Memorandum of Understanding (MoU) to develop the next-generation zero emission/ fuel cell power system for ships. The two companies propose to develop an electrical generating capacity of 3MW (4,000 horsepower) module no bigger in size than a traditional marine engine running on fossil fuels.

In addition to land-based transport, fuel cells are moving to the air and sea too. The global aircraft fuel cells market is to grow at a CAGR of 6.37% during the period 2017-2021 [15]. European low-cost flight provider Easyjet was testing a fuel cell powered nosewheel for taxiing, and Hydrogenics has worked on similar tests with German Aerospace. DLR's Hy4 plane was demonstrated in a flight from Stuttgart Airport – the plane again relies on Hydrogenics FC technology [16]. The small regional carrier Wideroe Airlines, operating in Norway's far north, plans to renew its fleet of twin-engine Bombardier Dash 8 planes with electric-powered aircraft by 2030 [16]. Norway's short-haul airliners plan to be entirely electric by 2040 [16]. Airbus aims to develop a hybrid model, and has teamed up with British engine maker Rolls Royce and German industrial group Siemens. The first flight is planned for 2020 [16].

2.1.2 Stationary applications

Micro-CHP is expected to have a significant growth in the European markets. Within the project, supported by the FCH JU, 1,000 micro-CHP units (both PEFC and SOFC based) are expected to be installed with the collaboration of Hexis, Vaillant, Bosch, SOLIDpower, Elcore, Baxi, RBZ, Ceres Power and Dantherm Power, Sunfire, Logapower, and GdF Suez. Delta-ee consultants stated in 2013 that with 64% of global sales the fuel cell micro-combined heat and power passed the conventional systems in sales in 2012 [17]. Currently, micro-CHP applications are mainly located in Germany, thanks to the Callux programme. Three European based manufactures are taking part in the project, namely Hexis, Baxi and Vaillant. SOLIDpower acquired the activities of Ceramic Fuel Cells Limited, manufacturing their micro-CHP unit in Germany [1]. Regarding Italy, Electro Power Systems (EPS) shipped over 3,000 units worldwide of its back-up power system that incorporates the complete cycle from renewable-assisted water electrolysis to hydrogen oxidation [18].

When analysing the market, it is important to consider it globally since there is the possibility that the production (or any other stage of the chain) occurs outside Europe but the installation takes place in Europe, or vice versa. As an example, AFC Energy signed an agreement with Chang Shin Chemical for up to 5 MW of AFC units, while Hydrogenics signed an agreement with Kolon for a 1 MW PEFC [1]. Even though the final market in both cases is Korea, the manufacturing of the systems will be performed in Europe. Japanese manufacturers have launched joint ventures with European companies, namely Toshiba with Baxi, Panasonic with Viessmann, and Aisin with Bosch. Ceres Power is partnering with two Japanese Original Equipment Manufacturers and the Korean Navien [1]. Japanese industry has been working towards an ambitious target set by the Japanese Government for achieving 1.4 million installations by 2020, with 5.3 million by 2030. In 2012, over 20,000 units were sold in Japan as part of the EneFarm project. Among the other stationary applications, backup and primary off-grid systems are also entering the market. These devices are suitable for both developing and developed countries, with the telecommunications sector as one of the most promising targets. Electro Power Systems has 579 units in service, mainly for powering telecom towers. This company is also starting to produce a new system that combines an electrolyser generating hydrogen from renewable energies, stores it and successively uses it in a PEFC. SFC Energy is producing a DMFC unit to power anti-collision lights of wind turbines and, together with its Canadian Simark Controls, a unit to power oil and gas control and monitoring systems [1].

2.1.3 Portable application

In the 2012 Industry Review by Fuel Cell Today, a significant growth in shipments for portable fuel cells was expected, supported by the anticipated launch of three fuel cell chargers for consumer electronics (by myFC, Aquafairy and Horizon Fuel Cells). Only one of these devices reached the consumer market, and its adoption was lower than expected. However, the number of units shipped continued to increase, showing the potential in this sector [17]. Fuel cells for educational purposes belong to this category and continue to sell well, forming an important source of cash for many companies.

In the portable segment about 25 % more Auxiliary Power Unit (APU) were shipped in 2017 [19]. Horizon, SFC Energy and Fuel Cell Systems are also targeting the APUs sector with chargers for the camper van, the caravan and the yachting market. Military organisations around the world continue to show interest in fuel cell technology, evaluating it as a means to significantly reduce the weight carried by soldiers in the field. No other data on the size of this market has been found.

2.2 The European scene

Looking at the worldwide situation, fuel cells are becoming well established in a number of markets and as a matter of fact, fuel cell industry is growing. Favourable government policies and incentives towards the adoption of renewable energy technologies coupled with increasing demand for backup power source in off-grid areas will drive the fuel cell market size. Europe is one of the fastest growing regions in the FCH technology market due to creating a roadmap of reducing emissions of carbon dioxide by more than 80% by 2050 [19]. To achieve the target Europe is planning to improve the infrastructure and reducing the cost of the fuel cells. It is estimated that the European Fuel Cell market will grow with a CAGR of more than 70% during the forecasted period 2015 to 2027 due to increasing government initiatives and motivation under new renewable heat incentive policy [20]. The countries showing the most significant contribution to grow the FCH technology market are the United Kingdom, Scandinavia, Netherlands, and Germany, which is leading the group, especially for stationary applications [1]. Germany is the leading country in the FCH technology market in Europe. Universities, research institutes, R&D are taking initiatives in fuel cell market to study and to do business.

The German FCH technology market is expected to grow with a CAGR of more than 70% during the forecasted period 2015-2027 [21]. Germany accounts for more than 70% fuel cell installations in Europe due to huge government support. Some major market players include Siemens, Opel, and Daimler Chrysler, among others [21]. The United Kingdom (UK) is the emerging and active country in fuel cell technology market. The UK Fuel cell technology market is expected to grow with a CAGR of more than 25% during the forecasted period 2015 to 2027 [21]. At present, the UK exports more than 50% of the fuel cell products to other countries [21]. The Government of the UK has initiated the Renewable Heat Incentive programme which includes provisions for CHP units and aerobic digestion to produce biogas for heat production.

According to the report of the FCH JU technologies in Europe - Financial and technology outlook 2014 - 2020, the Industry Grouping of the Fuel Cell and Hydrogen Joint Undertaking plans to contribute to reach market penetration objectives set for 2020. Efforts are currently focused on four areas: transport (FCEVs and hydrogen filling stations), Energy production (hydrogen production), Early markets (forklift and power generation) and Heat and Power generation [22]. In the transport area, the goal is the introduction of 500,000 FCEVs and more than 1,000 HRS (hydrogen refueling stations). This contribution is needed to prepare for a full market roll out, expected to start in 2020. The FCH-JU aims to contribute also to the realisation of combined heat and power stationary fuel cell systems in more than 50,000 households in 100 districts and 100 industrial sites. The technology objective for hydrogen production is to reach a 50% production from renewable energies or from zero-CO2 emission sources. The use of hydrogen as large scale energy storage solution, to enable the integration of fluctuating renewable energies in the European grid, is expected to enter the market, but in the longer term (2030) [22]. The project HyProfessional indicates electrolyser companies, together with industrial gas companies and large energy companies, are significant players in the market of hydrogen production. Other applications expected to enter the market in the short period that will benefit from the FCH JU contribution are material handling vehicles (20,000 vehicles), back-up power (20,000 systems), and portable power applications (250,000 systems) [23]. More specifically, as previously illustrated, portable fuel cells have a market potential in education applications, auxiliary power systems, recreational applications and military applications.

Thanks to the experience gained from the KnowHy project and the information found in some reports, it has been possible to indicate which FCH technologies are currently present in the market, which are expected to enter and the estimated numbers. The technologies in the market and those that are expected to enter in the market are listed in Table 2. Unfortunately, it was not possible to find detailed information for all the countries.

Table 2: FC&H2 technologies in European markets.

Country	Technologies in the market	Technologies expected to enter in the market
France	Stationary application: UPS Backup power Portable application: micro fuel cells	
Belgium	- Filling station by DATS 24 - vehicle projects SWARM, High VLOCity and HyTransit	- Solvay will install a 1 MW PEM in its Antwerp plant
Germany	- Thousands of systems for on-board power supply, 500 fuel-cell heating systems, plants for off-grid power supply, a hundred cars and 20 buses were field-tested by 2014. - 24,000 portable units had been sold in 2012 [18].	- By 2025, NIP aims at having more than half a million CHP systems in operation, more than 1,000 MW operating fuel cell CHP plants and more than 25,000 reliable power supply systems in operation [24]. - 1 MW storage system will be built by Hydrogenucs and another one by ITM Power [25]. - Planning to reach 600,000 FCEVs and 1,000 filling stations by 2020, and stationary applications for combined heat and power production.
UK	- FCEV has been entered to the market from 2015 -Creating network of up to 15 stations with 50% of them obtaining their hydrogen locally using electrolysers [1].	- FCEVs have started to enter the market from 2015, reaching 1.6 million vehicles by 2030. - FCEVs will be initially supported by a minimum of 65 filling stations and by 1,150 stations by 2030. - Within 2030, half of the hydrogen required is expected to be produced via water electrolysis while the remaining by methane steam reforming and, in a small amount, by-product hydrogen from other processes [26]. - ITM Power will operate the Hydrogen Mini Grid System to convert wind power into hydrogen for vehicles [25].
Greece		FCEVs and micro CHP are expected to dominate the early market with hydrogen produced via wind Power to Gas
Poland		FCEVs and micro CHP are expected to dominate the early market with hydrogen produced via wind Power to Gas.
Italy	In 2013, 10 hydrogen refueling stations were already available but not all of them were active.	- The 2050 target will be of more than 5.000 hydrogen refu3lling stations. - In the period 2020-2022 a maximum of 109 vehicles and 11 buses are foreseen while between 2023 and 2025 these figures will reach 229 and 29, respectively. - Stationary applications will enter the market in both the residential and commercial sector. - Hydrogen will be produced via electrolysis using renewables and from MSR of biogas and methane.
The Netherlands		-Hydrogen will be produced via electrolysis using renewable power but also from steam reforming of biogas and methane for transport applications. - Material handling vehicles is expected to be the initial and dominant FC&H2 application.
Norway		-300,000 fuel cell cars expected enter to market by 2030. - Stationary applications will play a role at small scale in remote locations without access to the electricity grid. - Stationary use could be seen for offshore installation and in areas with limited electricity grid capacity.
Finland		-Transport (captive fleets, specialist vehicles), stationary markets (UPS and back-up power) and portable fuel cells.

Table 2 continued.

Austria	-A demonstration programme including 30 micro-CHP fuel cell systems took place in 2015. -Regarding transport applications, currently there are one public station and two non-public stations operational.	
Denmark	- 62 domestic stationary units installed and 250 stationary large scale; - 652 additional units have been installed abroad by Danish companies. - 3 refuelling stations in operation	Air Liquide will expand the network of refuelling stations.
Sweden	10 domestic stationary units	
Switzerland	- Around 15 domestic stationary units. - 10 stationary units for UPS and a large MCFC plant [18].	

2.3 Summary

It is clear that the fuel cell applications are becoming increasingly visible and are becoming attractive to industry and the wider society. It is also apparent that there is an increase in the popularity of different types of fuel cells and applications. The fact that hydrogen vehicles are significantly entering the market attracts attention to the need of more hydrogen filling stations. This all clearly paints a bright picture for fuel cell industry world over. With major European projects and national initiatives, Europe is clearly a happening place for fuel cells and fuel systems, though large differences exist between different countries in Europe.

3. Fuel Cells and Hydrogen Job Opportunities

As various fuel cell applications gain market share, the industry is expected to undergo significant growth. Employment opportunities will open up in businesses that develop, manufacture, operate, and maintain the fuel cell systems. The growth of fuel cell applications for material handling, portable, backup and stationary power are expected to generate a range of new jobs in the near term as well. Many of these jobs require engineering and science backgrounds related to product and technology development. Occupational data indicate that the hydrogen and fuel cell industries will create a variety of new high-paying jobs, many of which take advantage of technical and manufacturing skills currently going unused as industry continues to undergo restructuring in Europe. More specifically, the global fuel cell industry is expected to create 700,000 green manufacturing jobs over the next decade, for both the stationary and transport sectors [27]. For every job created in fuel cell manufacturing, another is expected in systems installation, maintenance and servicing, which could add up to a million jobs globally. And, as the market for fuel cells grows in Europe, there will also be growth in hydrogen related jobs (design and construction of production plant, on-going operation, distribution, analysis, etc.). In transport, many more job opportunities will be created over the next 10 to 20 years. This is particularly important for the European automotive industry, which is a vital part of the economy. UK is a leading developer of advanced internal combustion engines for conventional powertrains (petrol and diesel). There is a strong rationale, recognised by all automotive OEMs, to transfer existing industry know-how to ultra-low emission vehicles. Fuel cells and hydrogen may allow the UK to preserve approximately 145,000 jobs in automotive manufacturing [27]. Growing the European fuel cells and hydrogen sector provides clear opportunities to retain high quality expertise, especially in the following areas: mechanical engineering, chemistry and chemical engineering, electrical engineering, material science, industrial engineering, power plant operation and maintenance, fuelling infrastructure installation, and hydrogen production.

4. Vocational training interface strategy

As market demand for fuel cell and hydrogen technologies increases across sectors of the economy, there will be an increasing need for vocational training to provide job specific technical training for work in the trades across Europe. From the analysis of the applications entering the market, it is clear that industrial users may belong to a wide spectrum of sectors, from public transport companies, telecom, data servers, logistic warehouses, and in the medium to long term, plumbers, electricians, environmental (thermal) comfort installers, petrol stations, utilities, garage workshops and dealers, and many others [5].

Many FCH technologies will be introduced to the market as substitution for conventional products. As a consequence, one part of these new jobs will be completely new job positions while another part will be a transfer from already existing activity areas: there will be significant demand for complementary training for those employees switching to FCH technologies from other activity areas, which is aligned with the idea of life-long training. Nonetheless, the need for training is obviously necessary in both cases.

It can be noted that the application with the highest number of positions for engineers is fuel cell electric vehicles. Also in the European Hydrogen Roadmap, it is affirmed that in Europe, the largest employment potential is due to automotive industry, and to a lesser extent to the process and equipment industry [28]. From the expected number of FCEVs, as provided by the HyWays Roadmap, a total of 20,000 people that need to be trained by 2020, is calculated and this figure reaches 160,000 persons by 2030 [5]. Stationary fuel cells are expected to have a significant impact on job positions more specifically for combined heat and power generation and micro CHP, as well as backup power. Hydrogen production is expected to have a significant impact on job positions for energy system engineers. A conservative estimate indicates 50,000 employees, out of which 50% being engineers and the remaining equally distributed among researchers and technicians [22]. Hydrogen filling stations, forklift and fuel cells for power generation will account for 2,000 employees until 2030 [5].

It can be seen that a total of 88,850 workers, 50,737 technicians and 50,737 engineers are expected to be employed in the FCH sector by 2030 [22] with FCEVs accounting for the highest number of positions, followed by hydrogen production and stationary fuel cells. These numbers are largely in line with the bove mentioned estimates. The current situation sees FCEVs as the most important sector, followed by hydrogen production and filling stations. Based on a survey from KnowHy “safety”, related to the fuel cell and hydrogen technologies, is a main topic of interest for industries thus indicating the importance of the vocational training course development of such topic [29].

Safety aspects are important from several points of view such as:

- Risk management,
- Handling of chemicals (particles, nanoparticles…), and
- Electric power system safety.

Balance of plant components are important for all stakeholders, and they are also typically part of the maintenance operations (substitution, check, etc): this consideration must be taken into account in the development of the vocational training contents [29]. Based on the emerged stakeholders need, TeacHy will provide a vocational training that enables engineers to safely operate, install and maintain fuel cell systems (in both ordinary and extra-ordinary conditions), with a clear understanding of the real risk connected to their current/future work. The courses would be designed to introduce fuel cell and hydrogen technology to students across Europe, educating the engineers and potential end users. Vocational education at the post-secondary level, is often provided by colleges of further education, universities and Institutes of technology/ Polytechnic Institutes.

It is essential to give a strong attention to the topics connected to safety, automotive, stationary fuel cells, hydrogen filling stations, forklifts, and fuel cells for power generation as well as to the balance of plant components aspects. Hence vocational training at a higher level, i.e. Level 6 (trained technician) and Level 7 ("Meister" in the German speaking areas), which is equivalent to engineer and college training, will need to have fuel cell knowledge, so that the vocational training curriculum had to be updated and modified from contents developed in KnowHy. The modified and updated contents would be suitable for engineers to work on different work tasks that may additionally to conventional curricula also include aspects such as:

- Improving Fuel cell systems,
- Biofuels processes,
- Energy distribution to the general population,
- Energy optimisation of apparatus, systems and households,
- Development of new energy technologies and systems,
- Analysing new energy technologies,
- Researching energy resources,
- Assessing the sustainability of different forms of energy,
- Energy efficiency in the production and consumption of energy, and
- operation and maintenance of Hydrogen and Fuel Cells systems.

Courses designed for vocational training could use the same repository of teaching material; albeit with a slightly differently tuned focus and selection than chosen for an academic course. This supports the development of fuel cell education curricula that include general education courses, specialised science and engineering courses but less complex theoretical contents as well as less detailed contents of modelling and analysing. This would be suitable for multi-use (academic, CPD and vocational) but the modules will exist in several versions.

This is facilitated by re-using single lecture pgaes from the TeacHy MSc programme, re-shuffled and re-assembled in a slightly different context. A re-recording of lectures is avoided (as this constitutes a major effort), but the teaching content is re-contextualised and adapted to the needs of the audience. This goes to show the benefits of an e-learning approach to teaching new technology and DeepTech content.

The vocational training will build on the experience that (at least in the German speaking regions), a 'Meister' degree is fully equivalent to a MEng and thus puts a professional with a Meister degree on the same level as a university graduate.

The course would be linked with the manufacturers and carry out laboratory training actions, in order to focus on activities such as assembling and disassembling the main parts of an electric fuel cell vehicle, CHP and UPS system. Therefore it is essencial to develop and implement an e-learning platform freely accessible to provide training materials as modules (pdf files, video). The e-learning platform provides the opportunity for the implementation of the courses directly in the stakeholder's facilities, allowing to analyse the most crucial issues of fuel cell and hydrogen systems. Online training courses, webcasts and webinars are all tools that should be used to reach students and engineers in sectors who could benefit from learning about hydrogen and fuel cells. These sectors can include energy service companies, utilities, venture capital firms, insurance and underwriter industries, state government workforce development agencies, government code officials, first responders, and local public and community outreach.

5. Summary

A clear trend is visible that the demand of engineers for fuel cell and hydrogen industry is increasing (for multiple types of fuel cells and applications) and this points towards the need for training opportunities. Several tens of thousands of students and engineers might have to be trained in the coming years. The industry recognises this and a large fraction indicated that "vocational training" is the most suitable form of training that is required to be developed. At least according to one study, it also appears that the creation of jobs in manufacturing is expected to be mainly based in Asia, and jobs in the installation and maintenance are to be mainly located in North America and Europe. All these points towards the attractiveness of a potential vocational training based e-learning programme in Europe covering different types of fuel cells and applications and targeted mainly at hydrogen safety, automotive, stationary fuel cells, hydrogen filling stations, forklifts, and fuel cells for power generation, as well as the balance of plant components aspects. In the next step questions that need to be discussed include accreditation and integration of such modules into existing vocational training (e.g. 'Meisterschule', the training bodies and programmes directed at supplying the 'Meister' qualification in Germany and Austria).

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