DEMANDS OF ENERGY PARADIGM SHIFT TOWARD EDUCATION: STUDY ON HYDROGEN TECHNOLOGY EDUCATION IN HUNGARY

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Abstract

The term "energy paradigm shift" denotes a significant transformation in the comprehension, utilization, and administration of energy in recent years. This shift involves overhauling energy systems, technologies, regulations, and methodologies, moving away from a reliance on fossil fuels. Discussions surrounding the concept of an energy paradigm shift have been widespread, especially in energy security policies. Furthermore, the transition towards eco-friendly solutions in accordance with the Paris Agreement necessitates the formulation of novel operational, regulatory, organizational, and societal energy policies, as well as revolutionary shifts in socio-economic consciousness. Crafting strategies that integrate energy efficiency, security, commercial facets, and ecological consciousness demands an interdisciplinary, globally conscious, and lifecycle-oriented methodology. Energy transition necessitates substantial changes in our educational and training system. A thorough transformation of educational curricula and methodologies, as well as increasing the contribution of higher education, is important in order to guarantee that professionals are adequately prepared to deal with the challenges and opportunities of the energy sector. In alignment with these ideas, this study presents the findings of an investigation concerning domestic hydrogen technology conducted by HUMDA Plc, a member of the Széchenyi University Group.

Keywords: energy paradigm shift, hydrogen, system approach, hydrogen related education

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Some thoughts of energy paradigm shift

In recent decades, the search for sustainable energy sources, environmental protection, and addressing the challenges of climate change have increasingly become the focus of global attention. The term "energy paradigm shift" denotes a significant transformation in the comprehension, utilization, and administration of energy in recent years (Ujhazi 2022). This transformation encompasses the overhaul of energy systems, technologies, regulations, and methodologies, steering away from a resource-centric stance focused on the availability of fossil fuels (Zilinszky 2021).

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Discussions surrounding the concept of an energy paradigm shift have been widespread (Dincer 2023), particularly in the realm of energy security policies. These policies have experienced a shift in fundamental principles due to evolving dynamics in energy markets, exemplified by events such as the Russia-Ukraine conflict (Osicka 2022), and global economic advancements. Furthermore, the transition towards eco-friendly solutions in accordance with the Paris Agreement necessitates the formulation of novel operational, regulatory, organizational, and societal energy policies, as well as revolutionary shifts in socio-economic consciousness. Crafting strategies that integrate energy efficiency, security, commercial aspects, and ecological awareness requires an interdisciplinary, globally conscious, and lifecycle-oriented approach (Pastukhova 2020).

Hungary's National Energy and Climate Plan succinctly outlines and illustrates the underlying trends that are pivotal in shaping the future of energy systems and energy market dynamics (NECP 2018). These significant industry trends encompass decarbonization, democratization, electrification, decentralization, digitalization, and the convergence of energy systems. It is crucial to emphasize that the increasing prominence of electricity should not be narrowly interpreted as a strict electrification strategy, as context-specific, tailored solutions do not adhere to predetermined notions. The adoption of a systemic approach and a diverse array of skills are indispensable not only at the global, national, regional, or regulatory levels, but also for stakeholders such as households assuming roles as prosumers in the realm of carbon-neutral energy systems. Enhancing customer and social awareness presents an opportunity for educational renewal (Zilinszky et. al. 2018). A value-added technical education system emphasizes the need for variety in the tailored curriculum, methods, structures, and educational connections. The inquiry arises: Who teaches, what is taught, and what is the methodology? Moreover, what kind of institutional backing exists for the relationships between "masters and disciples" and their networks (Mészáros 2022)? Education should be viewed as a means of empowering individuals for future problem-solving and decision-making, rather than focusing solely on abstract subjects such as advanced mathematics and physics[4]. Student engagement could be heightened by fostering a problem-solving mindset. Considering the aforementioned diversity and systemic approach, a shift in the educational and energy approach may reveal common pathways.

One of the most significant challenges facing us in this period of evolution is that we cannot focus on just one specific energy carrier or primer energy source. Therefore, a “one-man-show” solution should not be expected. The forthcoming landscape of the energy sector is projected to embrace diversity and varied energy systems. The incorporation of nuclear energy into the low-carbon energy mix is essential, as renewable sources vulnerable to weather conditions necessitate storage capabilities; thus, discussions on green power should always include considerations for green energy storage. Accordingly, at this point we should take a step toward hydrogen.

[4] Nevertheless, it is important to note that effective solutions demand the utilization of sound methodologies. While challenging subjects are essential, it is imperative to convey to students the importance of these subjects. (!)

Potential of hydrogen in new energy age

The ongoing energy transition is characterized by the current deep involvement in integrating renewable energy sources to replace fossil fuels, with hydrogen technology emerging as a promising solution (Kovac 2021). Hydrogen plays a crucial role in the green transition towards sustainable energy systems. It is considered a key component for achieving net-zero goals by enabling renewable energy integration and storage (Estevez et al 2023). Green hydrogen, produced using renewable sources, is gaining attention globally as a clean energy carrier with the potential to drive decarbonization efforts (Tries et al 2023). Furthermore, integrating surplus renewable energy production for hydrogen generation can address energy needs in the mobility sector, emphasizing the comprehensive approach needed for a holistic green transition (Dimou et al 2023). Furthermore, hydrogen production from anaerobic digestion processes presents opportunities for generating low-carbon hydrogen, contributing to the transition to a carbon-neutral future and the development of a hydrogen economy (Al-Ali et al 2023). Overall, hydrogen's potential lies in its ability to facilitate the transition to sustainable energy systems, offering solutions for energy storage, transportation, and decarbonization.

Hydrogen can be a clean energy carrier, a promising mean of energy storage, it can serve as carbon-free fuel in several powertrains. Hydrogen can decarbonize hard to electrify sectors and can make certain industrial processes greener. Hydrogen can help enhance grid stability, offers possibilities for economic growth, can create employment and academic opportunities. We need to acknowledge that hydrogen can only find its place in new energy system as a glocal solution along complex projects, integrating sectors and industrial and mobility decarbonisation – representing an innovative power in terms of system integration.

In the automotive sector, while battery electric vehicles dominate the zero emissions area, concerns over charging times and infrastructure highlight hydrogen as a future solution, as demonstrated by the Neumann H2 prototype. This integrates advanced energy storage systems and AI-driven energy management and environmental sensing capabilities (Kun 2024).

The target of this study

The widespread application of hydrogen technologies poses significant challenges for professionals, educational institutions, and the industry (Sazali 2020). Establishing the necessary expertise and appropriate training structures is essential for innovation and sustainable development. In this paper, we examine the critical points that are crucial in the planning and implementation of training related to hydrogen technology. Our primary objective is to identify the requirements of the key relevant industrial stakeholders in terms of competencies within the realm of hydrogen technology. We are presenting their requests regarding the type and form of educational programs.

In this study, we pay special attention to the following areas:

- Training and ongoing education of professionals:
  Acquiring proper handling of new technological solutions is essential for efficient operation and innovation. Developing and continuously updating training programs for professionals is very important to ensure safe and effective application of hydrogen technology.

- Capacity building in educational institutions:
  Educational institutions need to adapt to new technological challenges. Providing adequate laboratories, lecturers, and educational materials is also critical for the training of professionals.
- Flexibility and relevance of training programs:
  Due to the rapid development in industry and technology, it is principal for training programs to be flexible and continuously updated to adapt to new developments.

The hydrogen working group of HUMDA[5] collected the opinions of industry stakeholders involved in the hydrogen value chain through a questionnaire survey to identify their needs, as well as higher education, vocational training, and adult education perspectives. The survey aimed to gather insights on competencies related to the technology and the training providers' ideas about integrating hydrogen education programs and launching new initiatives.

In Europe, hydrogen technology education launches numerous training programs to meet the demand for industrial professionals, covering all levels of education. European universities and educational institutions increasingly offer interdisciplinary courses for students with comprehensive knowledge in the field of hydrogen energy (Warmuth et al 2022). During these courses, students are provided with opportunities for hands-on laboratory work and practical experience. This may include testing hydrogen-powered vehicles, installing fuel cells, designing and operating hydrogen production systems, and more.

The European Hydrogen Academy plays a crucial role in advancing the adoption of hydrogen technology in Europe. With its focus on research, education, and collaboration, the academy serves as a hub for industry experts, policymakers, and enthusiasts to come together and work towards a common goal – a sustainable energy future. This is basically a knowledge-sharing platform that aims to educate and empower individuals and organizations in the field of hydrogen energy. By bridging the gap between academia, industry, and policymakers, the European Hydrogen Academy plays a pivotal role in shaping the future of hydrogen energy. It offers comprehensive training programs designed to equip participants with the knowledge and skills needed to develop themself in the field of hydrogen technology. The training programs cover a wide range of topics, including hydrogen production, storage, transportation, and applications in sectors such as power generation, transportation, and heating (European Hydrogen Academy homepage 2024).

In May 2021, the Hungarian government approved the National Hydrogen Strategy, placing green hydrogen at the forefront for the long term. In addition to hydrogen produced using electricity generated from renewable sources, the strategy also considers the possibility of hydrogen production based on electricity obtained from the nuclear power network (Hungary's National Hydrogen Strategy 2021).

Regarding the expansion of knowledge related to hydrogen and hydrogen technology, two key directions can be identified:

1. Education and professional training
2. Providing adequate information to the wider society

[5] Hungarian Mobility Development Agency

The central focus of the education activities is the development of the set of competencies necessary to achieve the objectives. We proceed in three main steps to identify proposals for training interventions:

- Exploration of competencies deemed necessary by the industry in the field of hydrogen and hydrogen technologies
- Identification of the current and planned training programs related to hydrogen technology at influential domestic educational institutions
- International overview, primarily focusing on European hydrogen technology training portfolios

Methodology of the survey

As mentioned in the introduction, we have collected the opinions of industry stakeholders, higher education and vocational training institutions about hydrogen technology through a questionnaire survey. The compilation of the questionnaire was based on international practices, following the methodology presented in the 'Education & Training' module of the EU 'FCH Observatory' project. This can be considered as the most focused and comprehensive survey on hydrogen technology education currently available in Europe.

The data collection took place in the first quarter of 2023 in an online format using the Unipoll system of SDA Informatikai Zrt.[6] From a methodological perspective, it is important to note that the dissemination of relevant information for various levels of education follows the applicable international standard ISCED (ISCED 2024).

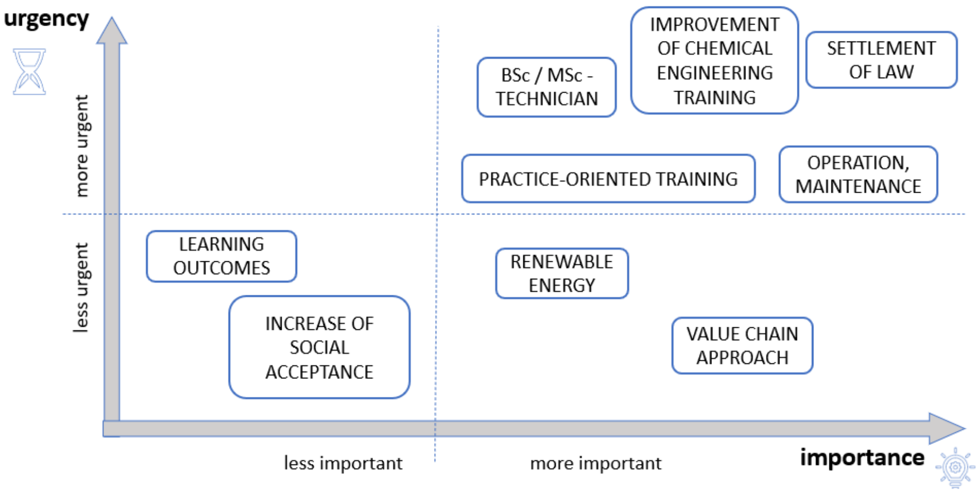
After defining the population, the sampling was carried out using the snowball method. The snowball sampling method is a non-probability sampling technique where initial participants are selected based on specific criteria. These participants then refer others who meet the study's criteria, creating a chain reaction. This approach is particularly useful for studying rare or hidden populations where traditional sampling methods may be impractical. However, it can introduce bias because participants are not randomly selected, potentially affecting the generalizability of findings (Naderifar et al 2017).

Results

A workshop has been organized for members of the target audience to align on their perceptions of hydrogen technology education and assessed industry needs. The key focal points relevant to education in terms of importance and urgency have been determined, which will play a significant role in the integration of hydrogen technology education in the upcoming period. The result of this workshop can be seen in Figure 1, which shows the urgency importance matrix composed by industrial stakeholders.

[6] For further information see the webpage of SDA Informatika Zrt. and Unipoll system: https://www.unipoll.hu

Figure 1: Urgency – Importance diagram composed by industrial key players



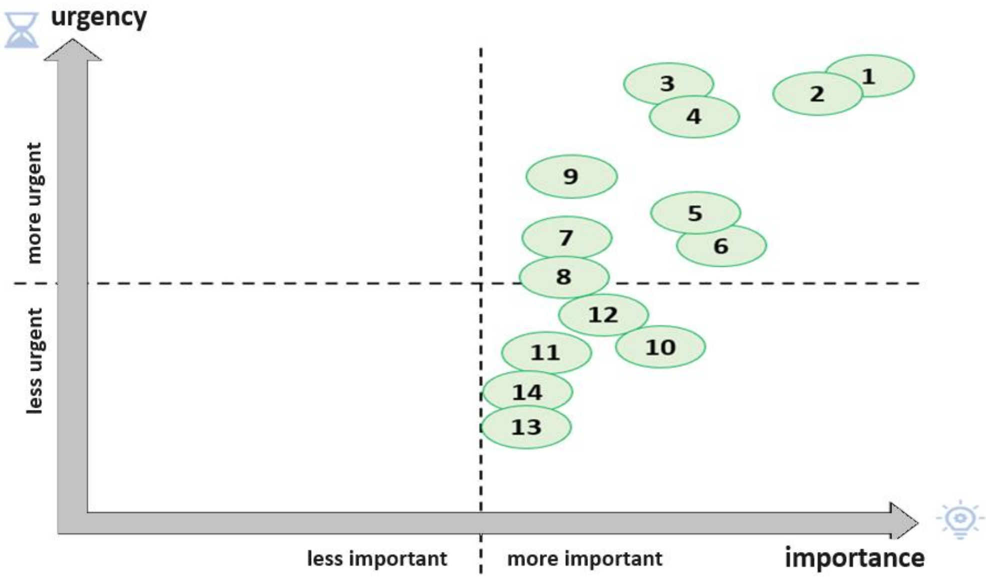
Source: own editing

It is visible, that addressing the relevant legal framework is of paramount importance. The reason for this is that the legal framework for hydrogen, despite its crucial role in the development and dissemination of hydrogen technology, remains unsettled. Ensuring appropriate legal frameworks and regulations brings numerous advantages to the field of hydrogen technology and contributes to increasing societal acceptance.

Within specific professional training programs, workshop participants have identified the upgrade of chemical engineering education as an urgent and important task. Currently, hydrogen-specific education does not receive much attention in Hungarian secondary and tertiary education. Although hydrogen technology is expected to impact various industries, its primary applications lie in efficient and environmentally friendly production, storage, transportation, and industrial utilization. Educational priorities must accordingly be defined, hence, there is a highlighted emphasis on updating chemical engineering education and harmonizing BSc and MSc degree programs.

The educational stakeholders, however, determined another matrix based on their experience in hydrogen industry, which is shown in Figure 2.

Figure 2: Urgency – Importance diagram composed by educational key players



1 – Cooperation, integrator role; 2 - Defining industrial demands (competencies and depth, headcount requirements for the next 10 years); 3 - Surveying and synthesizing industrial demands; 4 - Developing adult education programs tailored to industrial demands; 5 - Introducing mindset-shaping education; 6 - Mindset-shaping programs; 7 - Basics: manufacturing, utilization, safety; 8 - Short-term training + elective subjects, projects; 9 - Alternative energy sources » mindset-shaping (students, educators); 10 - Curriculum development; 11 – Vocational training, teacher training, possibly through participation in courses; 12 - Determining curriculum content; 13 – Vocational training, curriculum development (elimination of unnecessary content, integration of new ones), possibly in the case of alternative vehicle propulsion technician training; 14 - Curriculum content development, integration into the curriculum of certain professions in secondary and higher education

Source: own editing

From Figure 2 it can be seen that education plays an important role in the development and dissemination of hydrogen technology, with the cooperative and integrator roles playing the most significant part. We received responses to our questionnaire from 61 out of approximately 99 surveyed companies, representing a 61% completion rate. It is noteworthy that about 39% of the responding businesses are already engaged in activities related to hydrogen technology, while 44% plan to undertake activities in this field in the future.

Form of competence development related to hydrogen technology

In the questionnaire, we looked for the answer in which form the companies want to develop competences related to hydrogen technology in their company.

Figure 3: Developing the competencies required for your current or planned hydrogen technology-related project/activity

Source: own editing

From the results it is visible, (Figure 3) that in the field of hydrogen technology training, companies often prefer the training of their own employees. This approach can have several advantages:

Among other things, the training of the companies' own employees enables flexible and quick adaptation to changes and developments in hydrogen technology. Companies thus do not have to turn to external training sources and are able to handle the changes and challenges that arise in the hydrogen industry.

It is important to note that keeping the competences related to hydrogen technology up-to-date requires continuous development. For this reason, it may still be important for companies to work with experts, research institutes and educational institutions to access the latest information and best practices. The above is also supported by the results of Figure 4. The question was formulated as to what schedule the companies would like to start technology-specific training, and in what form they would do it. Based on the results it is visible that H-technology-related training is already running, but this demand will increase in the future. The reason for this trend is obvious: in the field of technology, hydrogen-based solutions are getting more and more attention, as they offer the opportunity to switch to clean energy sources.

Figure 4: Forms of training related to hydrogen technology and their timeliness

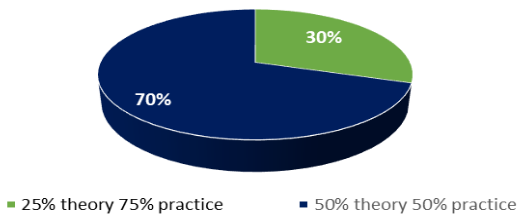
Source: own editing

As a result, interest in hydrogen technology may increase, so companies may attach importance to hydrogen-related training and internal training programs. However, with the passage of time and technological development, training needs and trends may change. The knowledge accumulated during the rapid pace of innovation and new developments can be made public by companies, research institutes and educational institutions, because of which the role of external training increases over time.

The acceptable theory-practice training ratio and the form of training

The use of a theoretical and practical training ratio of 25-75% means that more emphasis is placed on practical aspects during the training. This approach allows participants to acquire the necessary theoretical knowledge while applying and practicing hydrogen technology knowledge in a real-world environment (see Figure 5).

Figure 5: Preferred theoretical and practical training rates based on company's needs



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The training priorities of enterprises in the field of hydrogen technology may depend on the profile, size and specific needs of the enterprise. However, in general, it can be said that hydrogen technology is a relatively new and rapidly developing field, in which there is a great need for highly qualified professionals.

Many businesses may focus on higher education, such as MSc and BSc courses, as well as further specialist training. The MSc (master's) training, as well as specialized further training in the field of hydrogen technology, generally provides more specialized and detailed knowledge, which is needed by professionals working in the fields of research and development, planning, engineering and management.

Table 1: Distribution of demand for training forms

What form of training would you focus on?	Number companies	Ratio
Vocational training	2	20%
Adult training	3	30%
Higher education - bachelor's degree (BSc)	1	10%
Higher education - Master's degree (MSc)	1	10%
Professional further education - Hydrogen technology engineer	3	30%

Source: own editing

The BSc education usually provides more comprehensive basic knowledge in the field of hydrogen technology. This form of training rather prepares students to pursue second-level training in the field of hydrogen technology or to take on entry-level positions in companies.

As Table 1 illustrates, adult education and vocational training are also important players in the field of hydrogen technology, as businesses need professionals who can participate in practical work, for example in the maintenance or installation of hydrogen-powered systems. Technician training focuses on skills that focus on practical applications and technical operations.

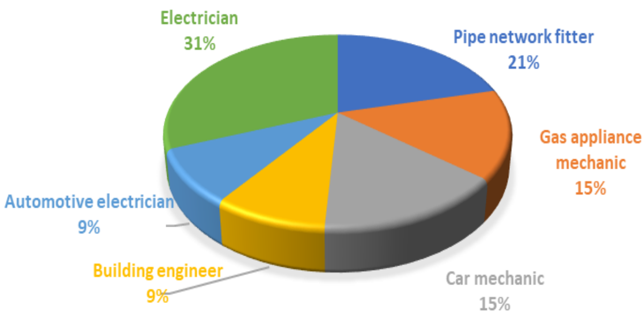
It is important to emphasize that the needs and priorities of businesses may differ. The focus on specific forms of training depends on the business policy, goals and labour market needs experienced in the given period.

Plan for enrolment of secondary and higher education graduates

The field of hydrogen technology contains many possibilities, so the successful implementation and development of the technology requires a wide range of specialists with different qualifications.

In the questionnaire, the respondents were asked which secondary and higher education graduates they plan to enrol in school in the future. In the case of those with a secondary education, Figure 14 shows the intention to enrol in school according to their qualifications.

Figure 6: Plan for enrolment of secondary school graduates



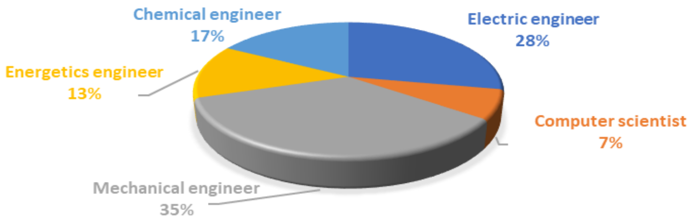
Source: own editing

The secondary education of pipe network fitters, electricians and car mechanics can be an important step in the field of hydrogen technology, as professionals working in such areas can be key in both the construction and operation of hydrogen gas-based systems.

The importance of the mentioned professions is that they play an essential role in the establishment and maintenance of Hydrogen-powered systems.

In the questionnaire, it was also asked what kind of advanced training the industrial companies plan for those with a higher degree in the field of hydrogen technology. Enrolment intentions according to qualifications are described in the diagram below.

Figure 7: Plan for enrolment of higher education graduates



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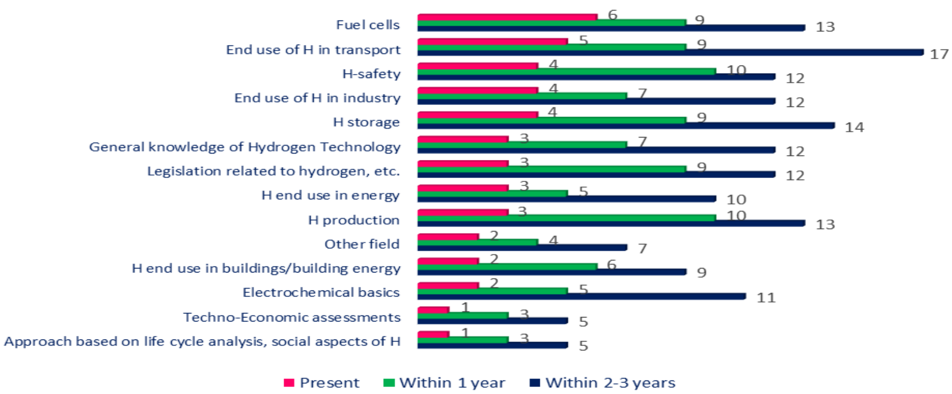
The respondents placed a lot of emphasis on the professional training of mechanical engineers, electrical engineers and chemical engineers (Figure 7), so these professionals already have the knowledge and skills related to technology even in terms of their basic education.

When enrolling in higher-level education in the field of hydrogen technology, it is worth looking for courses that pay special attention to hydrogen energy storage, hydrogen-powered vehicles, hydrogen fuel cells and engineering and scientific knowledge of hydrogen production. In addition, it is important that the given training provides the opportunity to gain practical experience and participate in research projects.

Identification of hydrogen-related trainings and teaching materials used and planned in industry

Trainings on hydrogen are of increasing interest in the field of energy efficiency and sustainability. During the survey, the industry actors answered how the respondents see the future of the industry, whether they see the need to train specialists dealing with hydrogen technology, and whether they need such knowledge to perform their duties. We also examined what current training courses they consider important, as well as what future plans they have for training courses (Figure 8).

Figure 8: Courses on the topic of hydrogen used or planned in industry



Source: own editing

The evaluation of the answers to the question shown in the figure above provides insight into the training courses planned in industry. Most of the respondents are currently holding courses in the field of hydrogen technology, and we can also see that a significant number of new hydrogen technology courses will be required in the industrial sector within 3 years.

Among the training activities related to hydrogen technology, fuel cells, transport applications, hydrogen safety and storage, as well as industrial use account for most of the current training.

Regarding the future, the most important topics include the use of hydrogen for transport purposes, hydrogen storage, safety technology, production and industrial use, these are complemented by training aimed at acquiring basic electrochemical and general knowledge and the related legal knowledge.

At present, the greatest demand is for training in the field of fuel cells, in the future the focus will be on the end-use of hydrogen for the purpose of convergence.

The integration of hydrogen technology related topics into the education system

The incorporation of hydrogen technologies into educational frameworks is crucial for the transition towards sustainable energy systems. Beyond conventional courses and subjects, survey results reveal promising future opportunities and developmental trajectories, such as the issuance of specialized micro-credentials in hydrogen technology by some institutions. These micro-credentials, such as a "Hydrogen Supply" micro-credential, attest to the learning outcomes acquired through short-term educational experiences (e.g., a defined set of subjects within a university curriculum). They provide a flexible and targeted means for individuals to enhance the knowledge, skills, and competencies essential for their personal and professional growth.

The integration process within educational systems can encompass several key steps, including:

- Curriculum development
- Professional training
- Continuing education and lifelong learning
- Organizing expert discussions (workshops) and conferences
- Research, development, and innovation (R&D&I)
- Provision of incentives and support
- International collaboration

Embedding hydrogen technology into the educational system can significantly contribute to the development of future professionals, innovators, and researchers in this vital and rapidly evolving sector. Consequently, students will be better equipped to enter the workforce and actively participate in advancing sustainable energy utilization and environmental protection.

Summary

Today, the significance of hydrogen technology is paramount with regards to the shift towards environmental sustainability, ensuring a stable energy supply and storage solutions aimed at curbing greenhouse gas emissions and fostering sustainable environments. To effectively address these challenges, it is imperative to establish suitable training frameworks and educational resources for industry professionals. Interventions in training pertaining to hydrogen technology play a crucial role in knowledge dissemination and the enhancement of professional competencies. Based on the findings of the HUMDA study, emphasis should be placed on various facets such as the utilization of hydrogen for transportation, fuel cell technology, storage methods, industrial applications, and production processes. Individuals aspiring to engage in this field must acquire comprehensive knowledge encompassing the entire spectrum of hydrogen technology. Specifically in the realm of utilizing hydrogen for transportation, the emphasis lies on the critical aspects of vehicle design, manufacturing, and operational functionalities.

The educational materials should comprehensively cover the functioning, benefits, and obstacles of hydrogen-fuelled vehicles, along with associated infrastructural advancements. In the realm of fuel cells, emphasis should be placed on operational principles, practical applications, and the configuration of fuel cell systems. Curricula ought to align with industry demands and progressions to facilitate the widespread integration of fuel cells. Concerning storage, it is imperative for students to grasp diverse hydrogen storage methods, encompassing safety measures and practical applications. The practical expertise should concentrate on technologies capable of effectively tackling the challenges linked to hydrogen storage. In the domain of industrial applications, there exists a necessity to explore a broad range of hydrogen uses, encompassing the energy and chemical sectors. The instructional materials should equip professionals with the skills to adeptly implement hydrogen technologies in industrial settings. Noteworthy training strategies include cooperative and dual programs, fostering opportunities for students to garner hands-on experience in authentic industrial settings. Such training initiatives significantly enhance practical know-how and cultivate industry connections, bolstering the proficient and adaptable capabilities of professionals.

Coupling post-graduate specialized engineering training with hydrogen technology education is vital. This equips engineers with the requisite expertise to engage in advanced engineering tasks within the hydrogen sector. Lastly, a focus on practice-oriented training is essential. This type of training enables students to apply theoretical knowledge in real-world scenarios. Developing professional competencies in hydrogen technology is fundamental for aspiring professionals aiming to actively contribute to this dynamic and innovative sector. By considering these intervention points, a diverse array of knowledge and skills related to hydrogen technology can be cultivated, thereby supporting the sector's growth and sustainable future.

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AZ ENERGETIKAI PARADIGMAVÁLTÁS OKTATÁSI IGÉNYEI: A HIDROGÉN TECHNOLÓGIÁVAL KAPCSOLATOS OKTATÁS MAGYARORSZÁGON

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Az "energetikai paradigmaváltás" kifejezés az elmúlt években az energia megértésében, felhasználásában és kezelésében bekövetkezett jelentős átalakulást jelöli. Ez a váltás magába foglalja az energiarendszerek, technológiák, szabályozások és módszerek átalakítását, elmozdulva a fosszilis tüzelőanyagoktól való függéstől. Az energetikai paradigmaváltás koncepcióját övező viták széles körben elterjedtek, különösen az energiabiztonsági politikákban. Ezenkívül a Párizsi Megállapodással összhangban a környezetbarát megoldásokra való áttérés szükségessé teszi új operatív, szabályozási, szervezeti és társadalmi energiapolitikák megfogalmazását, valamint a társadalmi-gazdasági tudatosság forradalmi változásait. Az energiahatékonyságot, a biztonságot, a kereskedelmi szempontokat és az ökológiai tudatosságot integráló stratégiák kidolgozása interdiszciplináris, globálisan tudatos és életciklus-orientált módszertant igényel. Az energetikai átállás jelentős változtatásokat tesz szükségessé oktatási és képzési rendszerünkben. Az oktatási tantervek és módszertanok mélyreható átalakítása, valamint a felsőoktatás hozzájárulásának növelése fontos annak biztosítása érdekében, hogy a szakemberek megfelelően felkészültek legyenek az energetika kihívásainak és lehetőségeinek fogadására. A tanulmány ezekkel a gondolatokkal összhangban mutatja be a Széchenyi Egyetemi Csoporthoz tartozó HUMDA Zrt. hazai hidrogén technológiával kapcsolatos vizsgálatának eredményeit.

Kulcsszavak: energetikai paradigmaváltás, hidrogén, rendszerszemlélet, hidrogénnel kapcsolatos oktatás