COMPETENCIES NEEDED FOR HYDROGEN IN THE INDUSTRY AND NETWORK

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BY

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Summary

The hydrogen industry in Groningen and Drenthe, as a major successor to the natural gas industry, is transforming the region into Europe's first Hydrogen Valley. With an investment plan of over €10 billion until 2030, it includes 75-100 projects. Education and research, such as the Hydrogen in Industry Practorate at Drenthe College, are crucial to the development of this sector.
The growing hydrogen industry affects jobs, sectors and skills needed. Skilled workers are needed to realize the energy transition and achieve climate goals. This paper provides an overview of educational areas in the hydrogen value chain, cross-cutting topics and studies around this topic, and employment opportunities in the hydrogen sector.
Research questions focus on the impact of the growing hydrogen industry on employment, available positions and requirements, the basic knowledge and skills required for workers in the industry. It also looks at specific competencies needed for working in the hydrogen industry.
Competency-based hydrogen education is essential for a successful career in the hydrogen industry. It promotes knowledge, skills, attitudes and behaviors needed for specific tasks and activities, with an emphasis on practical skills in hydrogen technologies and processes. Teamwork, communication, creativity and problem-solving skills are encouraged.
This literature review examines the competencies and training required for success in the hydrogen sector, the demand for qualified personnel and related positions. Topics range from safety and employment to trends in training and qualification needs in the context of hydrogen production.
The cessation of natural gas extraction may result in the loss of 10,000 to 20,000 jobs, but hydrogen offers opportunities for new industries and job growth. Four MBO elective courses have now been approved, including, Hydrogen in Industry. To train enough personnel, capable teachers are needed. Therefore, the Train the Trainer program started in 2023 and the regular course, Hydrogen in Industry, will start in September 2023 for students in Emmen at Drenthe College.
272 job titles within the hydrogen economy were identified, understanding the diversity and level of education required. Of the 17 hydrogen positions in high demand, 12 require an MBO background. Safety is an important aspect in almost all studies, as is knowledge of new equipment such as electrolysis.
Engineers need to master basic process engineering knowledge and operating skills with the rise of decentralized and automated hydrogen plants. Many companies train their staff internally, but would like to see regular education offered. The Netherlands is active in the hydrogen sector, but relatively small in electrolysis manufacturing.

In summary, the transition to a hydrogen economy offers opportunities for job growth, but this requires investment in education and training at various levels. Both horizontal and vertical integration is needed within hydrogen education and energy transition, and cooperation at national and international levels is essential for the further development of the sector and education around it.

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Keywords: Hydrogen Related Activities, Competency Standards, Health and Safety, Vocational Education, Hydrogen industry, Education and research, Energy transition
Employment opportunities, Safety, Electrolysis

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Terms

Learning	outcomesA concise description of the knowledge, understanding and skills that a worker working in the Hydrogen Network must have at the end of a course. Through learning objectives, with specific knowledge and skills, a class situation is used to flesh out the final term. These involve the steps the student must take to arrive at the end term.
He	Note: Throughout the document, "he" may be substituted for "she".

Abbreviations

BBLBeroepsbegeleidende leerweg -(More practice-oriented) BetrSichV Betriebssicherheitsverordnung
BIBBBundesinstitut form Berufdbildung - German VET education BOLBeroeps opleidende leerweg (More theory)
BOPBalance of Plant
CREBOEcognized training code
DCDrenthe College
DGUVDeutsche Gesetzliche Unfallversicherung DSODistribution System Operator
ECTSEuropean Credit Transfer and Accumulation system ESGEnvironmental , Social and Governance
EQFEEuropean Qualification Framework
GH_2 Gaseous hydrogen
H2-DRIHydrogen Direct Reduced Iron
IHIndustrie- und Handelskammer
HEMS Home Energy Management Systems
Higher Ed HigherEducation - Bachelor/Postgraduate
HyTecHydrogen Technology and Energy Curriculum KRITIScritical infrastructure
PPAPower Purchase Agreements
ParaprofParaprofessional - Advanced diploma or Associate Degree PEMProton Exchange Membrane
PtXPower to X
ROCRegional training center
TSOTransmission System Operator
VETVocational Education and Training
VIAG Safety instruction natural gas
WI WorkInstructions
HSDHigh School diploma
GEDGraduate Equivalency Degree/ General Educational Development similar to US high school
OJTOn-the-job training
PPEPersonal protective equipment
QINFORGEQualification and Occupation in the Interindustry Forecasting Germany QuBe Qualifikations- und Berufsprojektionen
SMEDSingle Minute Exchange of Dies
TSSAH2Technical Standards & Safety Authority Hydrogen TSTechnical School
VETVocational Education and Training
VIAG Natural Gas Safety Instructions
VWIVe Safety Critical Work Instructions

Chapter 1 Introduction

Soon, Groningen will no longer be one of Europe's main centers of natural gas. Recognizing that this threatens to leave a social hole in the already earthquake-stricken area, a strong movement has emerged in the region to reinvent itself based on its strengths and using the accumulated knowledge and infrastructure from the gas system. The idea, widely supported especially in Groningen and Drenthe, is to play a leading role in the value chain of the new, green gases that will play a central role in our future energy system and as green raw materials in the new circular production processes. Its basic variant, clean hydrogen, is central to this.
This starting point was described at the time by Prof. Ad van Wijk (Van Wijk 2017)[1] in his book for the Northern Innovation Board: 'The Green Hydrogen Economy in the Northern Netherlands'. To give this concept hands and feet, much has already happened in the region by now, so much so that Europe has declared the region Europe's first Hydrogen Valley[2] , not only because of the large scale of the new initiatives around green gases, but also because they cover the entire value chain, production, transport, storage and applications in industry, mobility and built environment. There is now an investment plan up to 2030 for 75-100 projects (Schutte, Rene 2023) with a combined financial volume of over €10 bln. In 2020, the investment was still about € 9 billion[3] .

Several initiatives have also emerged within the knowledge sector to respond to the theme in education and research. For example, the 2021 Hydrogen in Industry Practorate was established at Drenthe College. A Practorate is an expertise platform within an MBO institution where practical (focused) research is conducted. Drenthe College focuses on hydrogen because it is an important energy carrier in the energy transition. Hydrogen will play an increasingly important role within industry. Among other things, this will reduce $CO2_{emissions}$ from industry. A Practorate with this subject is unique in the Netherlands.[4] However, the developments initiated are still fragile, also because the entire hydrogen economy is still in its infancy. Real breakthroughs toward large-scale investments and further rollout through SMEs and startups are expected in the coming years, but that means the preliminary work needs to be done now. An important component of it is to ensure sufficient skilled personnel for the new technology and applications. This requires knowledge and takes time, but it must be done now.

As plans for hydrogen demand and production projects increase by the day, the need for expertise is growing. The urgency to implement the Energy Transition is greater than ever before. The role of hydrogen in this transition is important because of its great potential to reduce emissions in many sectors.
Strict emission reduction targets must be met within seven years in all sectors, but there is still a distinct lack of the experts needed to meet these targets. The shortage of skilled labor has always been a challenge in many circumstances. The skilled labor shortage, especially in areas vital to the energy transition, is critical to meeting climate goals in the remaining years.
In the context of hydrogen introduction, the exact extent of the required retraining is not yet known. The present paper provides an overview of the different areas of education in the hydrogen value chain, its cross-cutting topics and various studies around this topic. It also provides a practical view of the attractive

[1] NIB-BP-NL-DEF-webversion.pdf (profadvanwijk.com)
[2] Hydrogen Valley - New Energy Coalition
[3] Investeringsplan_Waterstof_Noord_-_Nederland_2020.pdf (provinciegroningen.nl)
[4] Practorate Hydrogen in Industry | Drenthe College | Drenthe College

employment opportunities in the hydrogen sector. This paper does not pretend to provide a holistic overview. But summarizes both national and international research. This paper is intended as a starting point for further discussions on the topic of knowledge development in the hydrogen sector to provide an overview that will guide those involved in ongoing change. Concrete examples are the projects in which I am playing a leading role on these topics, namely: the further deepening of the Hydrogen in Industry Practorate, GroenvermogenNL, WCM Fieldlab HYDRO-BOREAS program hydrogen and the EU Erasmus program (Greenskillsforhydrogen 2023)[5] -Greenskills4H2 - both of which latter projects will run between the end of 2022 and 2026.

Research questions:

1. How will the growing hydrogen industry affect employment, sectors (e.g., manufacturing, distribution, research and development)?
2. What positions are needed and currently available in the hydrogen industry and networks, what are the requirements for these positions in terms of educational attainment, how great is the need for different positions, and is there sufficient potential in the region based on demographics and inflow data to meet these needs?
3. What are the essential basic knowledge, skills and specific competencies, such as knowledge of electrolysis, transport, storage and applications, required for workers in the hydrogen industry and networks, and how can these be most effectively taught and trained?
4. To what depth should workers have knowledge of hydrogen technology and applications to contribute effectively to industry and networks?

Chapter 2 Content orientation (literature exploration)

The purpose of this literature review is to provide insight into the competencies and training required for success in the hydrogen sector and to determine the demand for skilled workers and related positions. Both national and international studies are systematically discussed, focusing on various target groups such as VWO students, firefighters and MBO to HBO/WO students. Topics such as safety, employment, training trends and qualification needs in the hydrogen production context are covered. The overview list (Appendix 2) includes a table with links to the original reports written between 2006 and 2023 by various authors and institutes from the Netherlands, Australia, Canada, the US, Germany and France. This study provides insights into the competencies needed and the demand for qualified personnel in the hydrogen sector, completed in April 2023.

Competency-based hydrogen education

Competency-based hydrogen education develops the skills needed for a successful career in the growing and important hydrogen industry. It includes promoting knowledge, skills, attitudes and behaviors needed for specific tasks and activities, and emphasizes the development of practical skills in hydrogen technologies and processes, including knowledge of chemical properties, system design and implementation, regulations and safety measures. It also focuses on promoting teamwork, communication, creativity and problem-solving skills needed for success in the industry. Fostering knowledge and skills is essential to improving the quality of professional education and preparing students for specific positions. Assessing student behavior can be done in a variety of ways, including observation,

[5] Green Skills for Hydrogen

reflection reports and peer feedback. Refer to Appendix 1 for more detailed information on competency-based hydrogen education, including knowledge, skills, behaviors and facilities.

International Curriculum on Hydrogen Safety Engineering (2016).

The International Curriculum on Hydrogen Safety Engineering from (Dahoe and Molkov 2006)[6] is a course that focuses on hydrogen safety and consists of fifteen modules divided into three categories: basic modules, fundamental modules and applied modules. More detailed information about this course can be found in Appendix 3 "International Curriculum on Hydrogen Safety Engineering.

Hydrogen Technology and Energy Curriculum (HyTec) (2013).

The Hydrogen Technology and Energy Curriculum (HyTec) (Nagle 2013) is an educational program designed to introduce students to hydrogen and fuel cells in the context of energy for transportation. The program consists of six classroom activities based on issue-oriented and inquiry-based approaches to teaching and learning science. The curriculum meets U.S. national education standards and state science standards. The six topics cover topics such as energy conversions, energy efficiency, chemical reactions, oxidation-reduction, stoichiometry and societal perspectives on energy problems. The program focuses on mobility-related topics, but the fuel cell section is also relevant to hydrogen in industry training.[7]

Energy College (2018)

The Energy College, a collaboration between seven MBO schools, more than 50 companies and the government in the Northern Netherlands, has examined what qualities and skills the energy professional of the future must possess (Hogt 2018). Appendix 4, entitled "Gas 2.0 Report Thematic Table Hydrogen Round 1B," describes the results of the hydrogen thematic table. In addition, the Hanzehogeschool in Groningen and partners united in the 'Green Hydrogen Booster' consortium and the 'Hydrogen Works' program have been working on a continuous learning line in the field of hydrogen in the northern Netherlands. This learning line includes education, training and courses at MBO, HBO, WO and post-initial level.

HyResponse (2016)

The (HyResponse 2016)[8] program works with 4 levels of knowledge for emergency responders, including first responder (EQF 2), shift commander (EQF 4), incident commander (EQF 5) and specialist (EQF 5). The program includes 9 modules that focus on various aspects of hydrogen safety, including the properties of hydrogen, compatibility with different materials, damage criteria for people and property, mitigation of hydrogen leaks, ignition prevention, firefighting, regulations and intervention strategies. The modules were developed for first responders and their contents are further detailed in Appendix 5.

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[6] Dahoe, A.E., and V.V Molkov. 2006. "On the Development of an International Curriculum on Hydrogen Safety Engineering and its Implementation into Educational Programmes." *WHEC.* Lyon France: WHEC. Accessed Feb 19, 2023. https://www.cder.dz/A2H2/Medias/Download/Proc%20PDF/PARALLEL%20SESSIONS/%5BS01%5D%20Safety/14-06-06/342.pdf

[7] Nagle, Barbara. 2013. Hydrogen Technology and Energy Curriculum (HyTEC). Berkeley: The Regents of the University of California (Berkeley), 25. Opened March 1, 2023. https://digital.library.unt.edu/ark:/67531/metadc844380/m2/1/high_res_d/1064422.pdf[8] HyResponse. 2016. "European Hydrogen Emergeny Response Training program for first responders." *http://www.hyresponse.eu/.* Accessed Mar. 15, 2023. http://www.hyresponse.eu/

Albert-Einstein-Gymnasium Ulm-Wiblingen, curriculumChemie_Kl.9_G9_Bp-(2016)

The (Albert-Einstein- Gymnasium 2016) Gymnasium chemistry lesson module "Water, Hydrogen and Molar Volume" lasts 10 hours and teaches students about the properties and uses of hydrogen as an energy carrier and simple calculations of gas volumes with molar volume.
Students will connect their everyday experiences with water with their newly acquired knowledge and learn about water treatment. They will also study the properties of hydrogen and learn ways to detect and produce hydrogen. The module includes process- and content-related competencies and practical activities such as the bang gas test and producing hydrogen from dilute hydrochloric acid and magnesium, pneumatic trapping. The flammability of hydrogen and its density compared to air are also highlighted, using the Hindenburg disaster as an example.

Bezdek study 'The hydrogen economy and jobs of the future' (2019)

The study by (Bezdek 2019)[9] titled "The Hydrogen economy and jobs of the future" highlights that the growth of the hydrogen and fuel cell industry will lead to huge new employment opportunities in various industries, skills, tasks and earnings.
While these jobs are not yet defined in official classifications and require many different skills and training than current jobs, it is important to evaluate training requirements to ensure adequately trained and qualified workers in this rapidly growing economy. (Bezdek 2019) Identifies emerging jobs in the growing hydrogen/fuel cell economy by occupational titles, estimates the average U.S. salary for each job, determines the minimum education level required to access that job, and specifies recommended education requirements. Of the 42 jobs listed in (Bezdek 2019), 36% of the jobs contain the word "Fuel Cell" in the job title. Appendix 6 contains a summary of these individual jobs, including the level of education and salary required in the U.S. for reference.

Skiba Competency Standards for Emerging Hydrogen Related Activities (2020)

The study by (Skiba 2020)[10] identifies key competencies needed for the emerging hydrogen industry, particularly focused on mobility and transportation. The study proposes five modules, four of which focus on vocational education and provide increasing levels of complexity. These modules include knowledge and skills on hydrogen, safety, environmental regulations, health and transportation. Currently, the current MBO curriculum does not cover module 5, which focuses specifically on hydrogen transportation and loading. Possibly this module should be offered as a separate module or included in the hazardous materials transportation course. Appendix 7 lists all competencies by module. In summary, (Skiba 2020) provides the most detailed analysis of the curriculum.

HYDELTA KIWA WP4 2021 educational track study (2021)

The study HYDELTA D4.1 (Van Greuningen, Suzanne; KIWA 2021)[11] shows that in 2021 there is no full MBO education in infrastructure engineering with a focus on hydrogen. However, in the coming years the demand for technical personnel with knowledge of both the natural gas and Hydrogen networks will increase to enable the transition from natural gas to hydrogen. Although

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[9] Bezdek, Roger H. 2019. "The hydrogen economy and jobs of the future." *Renewable Energy Environmental Sustainability* (Cavendish Energy LLC) 4 (1). Accessed Feb 25, 2023.
https://www.researchgate.net/publication/330217420_The_hydrogen_economy_and_jobs_of_the_future

[10] Skiba, Richard. 2020. "Competency Standards for Emerging Hydrogen Related Activities." Open Journal of Safety Science and Technology (SSRN) 10, 42-52.:11. Opened Feb 18, 2023. doi:DOI:10.4236/ojsst.2020

[11] WP4 track D4.1 The need for MBO technically trained personnel and advice for strengthening education on hydrogen.
https://hydelta.nl/wp4-development-of-dedicated-education-tracks,
D4_1_Overview_of_the_requirements_of_education_boardreview_NL.pdf
https://zenodo.org/record/6372782#.Y8kfMi8w0bx

courses on basic principles of hydrogen and the differences from natural gas are already available, such as Noorderpoort's 10-day 'Hydrogen' course and Kiwa Training's one-day practical course, there is a need for comprehensive MBO training. There is also a growing demand for personnel in infrastructure engineering and teachers to train these workers. The study explores the need for technically trained personnel for infrastructure and distribution related to hydrogen demand in the Netherlands for 2030 and 2050. Appendix 8 of the HyDelta WP 4.1 MBO education study discusses the final attainment levels, particularly focusing on mechanics working for grid operators. The study uses the Bloom model to classify the learning outcomes at three levels. However, the Bloom model has three additional levels: analysis, evaluation and creation, which are not included in this HyDelta study. For more information, see Appendix 9.

Maßnahmenkonkrete Strategie für den Aufbau einer Wasserstoffwirtschaft im Land Brandenburg (2021)

The policy report of the (Land Brandenburg Ministerium fur Wirtschaft, Arbeit und Energy 2021) describes various research areas around hydrogen, such as resistance of materials, energy storage and infrastructure development for mobility applications. The report highlights the important role of hydrogen in the energy transition and states that education and training are critical to the development of a hydrogen economy. Measure 53 recommends expanding existing student competitions and extracurricular learning sites to include hands-on projects with companies and research institutions to emphasize the importance of hydrogen. The report recommends incorporating concrete content on hydrogen technology into existing courses and working with regional industry and trade chambers to develop a training initiative. It lists specific subject areas requiring education and training, such as electrical power and process engineering, technical informatics, logistics, mechanical engineering, materials development and renewable energy technologies. The report states that development of modular simulation environments for energy systems and energy transition topics, policy tool development, optimization of operations and integration of hydrogen infrastructure into the energy supply system are needed.

K1319 Elective MBO hydrogen in industry (2022)

The elective course "Hydrogen in Industry" (K1319) by (Hazenberg and Hogt 2022)[12] was published in the Government Gazette on May 6, 2022 and adopted by Minister (Dijkgraaf, R.H; 2022, 2)[13] (Appendix 1D) and is now being developed at Drenthe College. This elective provides deeper knowledge and skills for entry-level professionals regarding the transition from natural gas to hydrogen gas as an energy carrier and feedstock in the industrial sector. It focuses specifically on applications in industry and gas networks and covers, among other things, the production processes, storage methods and chemical and physical conversion techniques for transport, storage and use of hydrogen in the industrial environment. The elective is divided into 10 subject knowledge and skills categories, including safety and regulation, application, engineering, construction, commissioning, operation - operating skills, fault analysis and troubleshooting, technical reading skills, ICT and digitization, communication and teamwork. Regulation related to ATEX, PED and safety are important topics covered. It provides novice professionals with in-depth knowledge and skills related to the transition from natural gas to hydrogen gas as an energy carrier and feedstock in the industrial sector For more

[12] Hazenberg Willem; Hogt; Roeland, K1319 Keuzedeel MBO hydrogen in industry
MijnSBB - Kwalificatieregister (s-bb.nl)

[13] Regulation of the Minister of Education, Culture and Science of April 26, 2022, no. MBO/32384870 amending the Regulation establishing optional subjects in connection with the establishment and expiration of optional subjects, Government Gazette 2022, 12020 | Overheid.nl > Official Announcements (officielebekendmakingen.nl)

detailed information, refer to Appendix 10 for the curriculum, Appendix 10B for the class schedule and in Appendix 11 the relevant entry-level qualifications functions for the hydrogen in industry solution.

Wasserstofferzeugung: einschlägige Ausbildungsberufe passen - zusätzlich notwendig sind sicherheitsrelevante Qualifikationen (2022)

A sector analysis called "Hydrogen Production" by the BIBB (H2Pro 2022)[14] found that hydrogen production does not require specific training, but employers must ensure that skilled workers have the necessary qualifications and follow instruction and further training as needed. Training occupations relevant to the specific tasks include metal and electrical engineering and process engineering occupations. Existing training occupations largely cover the required qualifications for skilled workers, including safety-related qualifications. There are six categories of training occupations: planning and development, construction and building, control and commissioning, operation, maintenance and safety monitoring. Existing regulations can also serve as a reference, as hydrogen technologies have been in use for many years. For detailed information on the suitability and assignment of training professions for the sub-process of hydrogen production one can refer to the BIBB sector analysis (Zinke, Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff 2022), with Annex 12A containing the functions from the report. In comparison to other studies, here the monitoring of safety has been named as a separate category, in which the functions of government permit holders or supervisors may also fall under this category.

Institute for innovation and technology (2022)

According to the (Institute for innovation and Technology 2022, 6)[15] , hydrogen training requires different types and levels of skills and knowledge. Key topics include basic skills in $_{H2}$ and related safety issues, knowledge of market analysis and business development, knowledge of feasibility studies (technical, economic and legal), know-how for pilot projects and system integration, specific technological knowledge for mechanical and plant engineering, $_{H2\ production}$ and applications in the steel, chemical and mobility industries. About 90% of the jobs requiring hydrogen expertise are of a technically oriented and highly complex nature (Grimm, Janser and Stops 2021)[16] . For more detailed information regarding jobs see Appendix 13A and concerns curriculum Appendix 13B.

University of Dresden MSc program Hydrogen Technology and Economics (2022)

The MSc program Hydrogen Technology and Economics at the University of Dresden provides comprehensive knowledge about hydrogen applications, including the prospects and potential of hydrogen-based energy systems. In addition to fundamental knowledge about hydrogen and its markets and value chain, the course also covers applications of hydrogen in mobility, industry and smart buildings, as well as safety aspects and material technical challenges. National and international hydrogen networks are also covered, the course
includes a master's thesis and final test. Particular attention is paid to hydrogen acceptance in comparison to other courses. Refer to Appendix 13C for a detailed overview of the course (Institute for innovation and Technology 2022)[17] .

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[14] H2Pro. 2022. factsheet II wasserstofferzeugung wasserstoff zukunft berufliche bildung energiewende H2PRO.pdf." BIBB.DE. Dec. Opened Mar. 11, 2023. https://www.bibb.de/dokumente/pdf/factsheet_II_wasserstofferzeugung_wasserstoff_zukunft_berufliche_bildung_energiewende_H2PRO.pdf.

[15] 19056 2022 Wasserstoff als Beruf Trends in der Aus- und Weiterbildung, PowerPoint-Präsentation (bremen-innovativ.de)

[16] Grimm, Veronika; Janser, Markus; Stops, Michael (2021): Neue Analyse von Online-Stellenanzeigen: Kompetenzen für die Wasserstofftechnologie sind jetzt schon gefragt. Institut für Arbeitsmarkt- und Berufsforschung (IAB). Nuremberg (IAB -KURZBERICHT, 11/2021). Online https://doku.iab.de/kurzber/2021/kb2021-11.pdf

[17] 19056 2022 Wasserstoff als Beruf Trends in der Aus- und Weiterbildung, PowerPoint-Präsentation (bremen-innovativ.de)

Hydrogen Industry workforce Development roadmap 2022-2032 - Australia (2022)



The Hydrogen Industry Workforce Development Roadmap 2022- 2032 of (Queensland. Department of Employment 2022)[18] aims to develop a strong and adaptable workforce for a safe and thriving hydrogen industry in Queensland. This roadmap identifies a series of short, medium and long-term actions to achieve this vision, including building a pipeline of skilled workers, sharing knowledge, maximizing the benefits of hydrogen for communities and planning for the long-term needs of the [illegible]rs. The report highlights the skills needed in certain fields of work, without going into the specific content knowledge required. The report also focuses on water treatment, emergency services, trainers and teachers and further breaks down export, mobility, energy and industry. Refer to Appendix 14 for more information on Australian hydrogen skills and the job map.

(Hydrogen France; 2022) Skills and professions of the hydrogen sector Planning ahead to successfully develop an industry of strategic importance

The study by (Hydrogene France; 2022)[19] provides an inventory of 84 occupations in the hydrogen sector. Of these occupations, 27 require in-depth knowledge of hydrogen, while 41 require basic knowledge and 16 require no specific knowledge. There are 27 positions considered difficult to fill, mainly focused on equipment and plant design. In the near future, technicians and operators for operation and maintenance activities will be in greater demand. Most occupations require at least an MSc level. The provision of appropriate hydrogen-specific training is essential to avoid skills and expertise shortages. Appendix 20A contains a detailed list of the job criteria, Appendix 20B shows the job versus criteria table, Appendix 20C describes the 84 jobs and job level, and Appendix 20D shows the technical and non-technical skills.

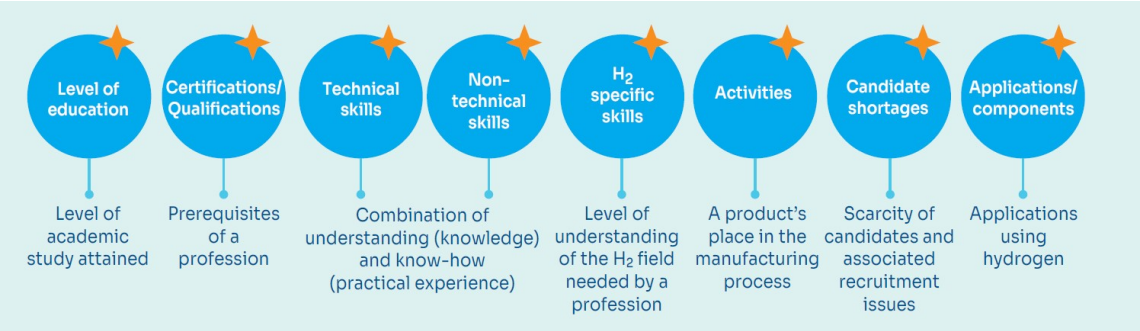


Figure 1 Criteria used to classify features

Of the 17 high-demand occupations in the hydrogen sector, 12 are MBO positions[20] and only one of them, regulatory compliance officer, is a hydrogen expert as described in Appendix 20E. Currently, there is a high demand for MBO positions in this sector and it is especially difficult to find positions such as supervisor, regulatory compliance officer, electromechanical engineer with ATEX certification, construction mechanic/cable installation technician, work engineer, architectural

[18] Queensland. Department of Employment, Small Business and Training. 2022. Hydrogen industry workforce development roadmap 2022-2032. Department of Employment, Brisbane, Queensland: Department of Employment, Small Business and Training, 2022, 24. Accessed Feb 18, 2023. https://www.publications.qld.gov.au/dataset/hydrogen-industry-workforce-development-roadmap-2022-2032

[19] Hydrogene France;. 2022. 19075 *Skills and professions of the hydrogen sector Planning ahead to successfully develop an industry of strategic importance.* France Hydrogene, Paris: France Hydrogene, 40. Opened March 1, 2023. https://s3.production.france-hydrogene.org/uploads/sites/4/2022/10/Livre-Blanc-France-Hydroge%CC%80ne-2022-En-Web.pdf

[20] B-H2 = Profession not requiring in-depth knowledge of H2 issues, E-H2 = Expert skills Expert on hydrogen, N/A - Not applicable Profession not requiring knowledge of H2

metalworker, welder with ATEX certification and accreditations for working under high pressure, test technician responsible for product evaluation, Industrial Maintenance Technician, Test Technician, Electrical Technician, Commissioning Technician and Pipe Welder/Pipeline Contractor to complete.

NVDO Maintenance Compass (2022)

The Maintenance Compass 2022 (NVDO 2022)[21] classifies workers at four different levels in the job house: strategic positions such as management require an HBO/WO education.
Tactical positions, such as reliability engineer and maintenance planner, require a college education.

For operational positions, such as administrative support, supervision, mechanical, process and operations engineer, electrical engineer and automation engineer, an HBO degree is required.
Executive positions, such as mechanic and technician, require an MBO degree.
education with an EQF level between 2 and 4. This information is based on public data from 2015 and has been updated to 2020.

New Energy Business School Hydrogen Specialist (2022)

The post-HBO program at the New Energy Business School specializes in hydrogen and covers various aspects related to it. The program includes the following tracks: energy production, transportation and storage, hydrogen geopolitics and economics, energy markets, hydrogen production, transportation and storage, regulatory landscape, hydrogen in industry, built environment and mobility, systems integration and sector linkage and hydrogen outlook. In addition, two tracks focus on engineering, legal aspects and soft skills are optimized. The program also includes visits to various locations, including DNV, North Sea Energy, Hystock, KIWA, Twinning Energy and the Port of Amsterdam.
The program concludes with final presentations of case studies, a closing ceremony and a visit to the World Hydrogen Summit 2023. Refer to Appendix 18 for a detailed overview of this course. (Van Gemert, Joris; Mollema, Anouk; 2022)

H2PRO factsheet (Zinke, Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung (2023)

As part of the BMBF-funded project "H2PRO - Hydrogen - a future-oriented subject of vocational training in the context of the energy transition", a fact sheet was published based on a preliminary sector analysis of qualification needs in the context of hydrogen production, recently published as a BIBB Discussion Paper (Zinke, Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung 2023)[22] . The Fact Sheet outlines the tasks and job profiles and required qualification needs in the context of hydrogen production. Only safety-related qualifications are additionally required for professionals. The BIBB Discussion Paper analyzes in depth the demand for qualification needs and compares the expected tasks and qualification requirements in hydrogen production with the skills, knowledge and abilities to be transferred according to the training requirements. The conclusion is that currently available training meets the expected requirements for all tasks, including planning, construction, commissioning, monitoring, operation or maintenance of hydrogen production facilities, associated storage or transportation systems. Safety-related requirements arise only from the hazardous potential of pressure, explosion and high voltage. For this purpose, receiver-appropriate qualification provisions and adaptations are needed, which are the responsibility of employers and must be acquired earlier as part of

[21] NVDO. 2022. *NVDO Maintenance Compass 2022.* NVDO. Opened Mar 16, 2023. https://www.nvdo.nl/onderhoudskompas-2022-735.
[22] Zinke, Gert. 2023. *Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung.* 16 1. Accessed Mar. 16, 2023. https://www.bibb.de/de/170100.php

continuing education. (Zinke, Neues Fact Sheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung 2023). For more detailed information, see Appendix 15.

BrazilH2 (2023)

BrazilH2 is a program that runs from 2021 to 2023 with the goal the project encourages universities and other educational institutions to include gaseous hydrogen ($_{GH2}$) in their curricula. It supports the establishment of $_{GH2}$ laboratories with learning infrastructure for vocational training in GH2 $_{technologies}$ - with a specific focus on gender integration. (Francke, Deutsche Gesellschaft fur internationale Zusammenarbeit (GIZ); 2022)[23] The final report is not yet available.

VDI_Wissensforum seminar 'CrashKurs Wasserstoff' (2023)

The seminar "CrashKurs Wasserstoff" (VDI_Wissensforum 2023) covers various aspects of hydrogen in an intensive 16-hour course. The program covers topics such as market stimulation, hydrogen as a future complementary energy form, technologies and infrastructure, applications and uses of hydrogen, technical challenges and problems, and an outlook on further developments. The seminar provides insights into hydrogen markets, different types of hydrogen, regulatory advantages, electrolysis technology and applications in various industries, as well as technical challenges and issues. You will also get an outlook on the future of hydrogen, with topics such as mass production of plants and components, miniaturization and evolution of the market and costs. Appendix 16 provides more information about the VDI teaching materials.

University of Oldenburg course Hydrogen for trade and executives (2023)

The continuing education course "Hydrogen for trade and executives" at the (University_Oldenburg 2023)[24] University of Oldenburg (2023) provides interdisciplinary knowledge about hydrogen projects, including technology, grid integration, legislation and financing. The program covers four main aspects, namely:
(1) Actors, strategies and political framework; (2) Hydrogen technology, business models and added value; (3) Legal framework and technical management; (4) Practical projects from theory to practice. Students will gain insight into the application possibilities of hydrogen in different sectors, such as mobility, industry and heating. Excursions to pilot plants are organized to introduce students to the dimensions of $_{H2\ projects}$ and to interact with responsible actors on site. The 24-week study period includes a project in which students work in small teams under the guidance of a mentor. The project is developed until the approval and funding phase. For a detailed overview of this course, see Appendix 17.

Hanze Minor Minor Hydrogen in the Energy Transition (2023)

The Minor Program Hydrogen in the Energy Transition (Hanzehogeschool 2023)[25] is specially designed for third-year Mechanical Engineering, Electrical Engineering and Technical Business Administration students. The program uses the principle that students only truly learn when they can apply the knowledge they have gained in practice. Therefore, students work on projects to put the knowledge they have learned into practice. The content of the minor varies depending on the project, and the minor earns 30 credits. In addition to the projects, all teams also receive a

[23] Francke, Markus; 2022 Deutsche Gesellschaft fur internationale Zusammenarbeit (GIZ); Promoting Green Hydrogen in Brazil (H2Brazil) , Promoting Green Hydrogen in Brazil (H2Brazil) (giz.de)
[24] https://uol.de/weiterbildung-wasserstoff
[25] Hanze University. 2023. *Hydrogen in the Energy Transition Hydrogen in the Energy Transition.* Accessed Mar. 25, 2023. https://www.hanze.nl/nl/opleidingen/minoren/waterstof-in-de-energietransitie?tab=tab1

overarching training in the safe design of hydrogen plants and a workshop on legislation in the energy transition. The program has a lead time of 6 months.

Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte part 1 &2 (2023)

In the articles by (Appel, Schanz, et al., Wissensvermittlung Wasserstoff: Der H_2-Markthochlauf braucht heute Fachkräfte (Teil 1) 2023, 88) and (Appel, Schanz, et al., Wissensvermittlung Wasserstoff
- Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2) 2023) discusses the need for specialized professionals in the emerging hydrogen market in Germany. Appendix 19A describes the hydrogen value chain, including different production methods, infrastructure and system integration, applications, safety and market introduction. The second part of the study (Appendix 19B) describes the functions needed in the German market to develop and grow the hydrogen market, including production, infrastructure and system integration, pipeline infrastructure and application/use. Examples of these functions include engineers, planners, project managers, plant builders and distribution network technology specialists. The value chain of Appel et al. is considerably broader than that of the aforementioned study.

Online learning environments

oZone Hydrogen training courses

The (oZone 2023)[26] program is a free online learning environment designed for and by engineering companies and provides basic learning about hydrogen engineering and energy storage. The program is designed to train new and existing company workforces. Seven modules are available, each with 30 to 45 minutes of online learning course material. Modules include hydrogen technology, safety, storage and transportation, manufacturing and chemistry, marine and automotive applications and energy storage technologies. More information about the modules can be found in Appendix 21. The program is free for member companies of A+O Metalektro and OOM.

EU Erasmus programs around Hydrogen

Under EU Erasmus, several projects have been developed to provide training and educational materials on hydrogen and fuel cells. These projects include KnowHy for hands-on training, TeacHy for educational online learning materials, HySkills for safety skills in green hydrogen, Hy2Green for training new professionals in energy modeling, NET Tools for digital learning tools, HyResponse for hydrogen safety training for emergency responders, FCH Observatory for data on the hydrogen sector, and FCHgo HySchool for promoting awareness and knowledge about hydrogen and fuel cells. For a complete table of these projects, see Appendix 22.

Practice facilities hydrogen laboratories

Hydrogen practice facilities are invaluable for developing students' skills in hydrogen technology and renewable energy. Working in a hydrogen practice allows students to gain hands-on experience and learn about advanced technologies and equipment. This enables them to develop into experts in hydrogen and renewable energy. In addition, a hydrogen practice provides an ideal environment for learning to work together as a team. It allows students not only to develop their individual skills, but also to learn how to work together effectively as a team to achieve a successful outcome. It is therefore essential that there be sufficient space

[26] Homepage - Ozone

available for a hydrogen practice. Appendix 23 contains some examples of commercial and educational hydrogen labs that can serve as inspiration for setting up your own hydrogen practice. By investing in a hydrogen practice, educational institutions and businesses are investing in the future of renewable energy and in the skills of today's and tomorrow's students.

Process control 2023

According to (Process control 2023)[27] , the labor market has been tight for years, mainly due to an aging population and low unemployment. However, there is still manpower to be gained among women in technical occupations. The biggest problem, however, is with the youth, as too few young people are choosing to study engineering. One possible solution is to implement research-based education, but this may pose problems within the rigid curriculum of MBO education. Companies also need to invest in lifelong learning programs for their current workforce. A strong link between business and education is needed to make this happen. Some companies still have business schools such as Tata-Steel, grid operators and in Germany this is still common. In addition, companies need to invest time in their existing staff through lifelong learning programs, for example.

Plug Power - electrolysis maintenance tasks

The Plug Power electrolysis plant requires several maintenance tasks, including inspections, cleaning and replacement of sensors, filters, pumps and seals in the overall system, water and cooling system and stack and hydrogen system. The maintenance plan includes calibration and replacement cycles of five to 10 years. Refer to Appendix 24 for more detailed information. (Hyver, Devon; 2021).

World Class Maintenance Fieldlab HYDRO-BOREAS - Working Group on Autonomous Operations (2023)

In 2023, the Autonomous Operation (Production & Maintenance) Working Group of the World Class Maintenance (WCM) Fieldlab HYDRO-BOREAS will conduct research on autonomous operation of hydrogen plants. They argue that autonomous operation will become the dominant operating form and that monitoring of the technical status/condition of an autonomously operating plant is necessary to recognize failure mechanisms early and ensure functionality and safety. Specifically for hydrogen plants, it is important to measure and monitor appropriate parameters. Research is also needed on the technical service organization of an autonomous plant and the technical and organizational conditions for providing remote support see Appendix 41 for autonomy definitions. This includes online access to operational and maintenance data, a 3D Digital Twin, VR tools and remotely adjustable plant settings. See Appendix 25 for HyCC strategic maintenance and operations strategies and goals (Te Boome, Cindy; Seurinck, Staff; 2023).

HyDelta WP11 Labor Market and Training Implementation (May 2023)

This unpublished study analyzed LinkedIn job postings within the HBO/WO field and then conducted interviews with interested parties. The primary result of the study is that the greatest demand for an engineering degree.[28]

[27] Process control, 2023 No. 1 Pages 15-18, FEDA brings industry challenges to the table.
[28] Interview with HyDelta researcher Tamez, Adrian Serna - 20-4-2023

Chapter 3 Results

Employment

The hydrogen economy is expected to create significant employment in a variety of functions and sectors. Exact numbers may vary depending on the source and region, but it is widely expected that the hydrogen economy could create hundreds of thousands to millions of jobs worldwide ((Bezdek 2019) over the next few decades.

Loss of existing employment due to reduction in natural gas extraction

Natural gas extraction in the northern Netherlands provides approximately 19,292 jobs, of which 3,350 are direct jobs, 9,000 are indirect jobs and nearly 7,000 additional jobs due to the induced effect (Van de Molen 2014)[29] . Different studies give different numbers on the number of jobs lost due to the cessation of natural gas extraction, with estimates ranging from 10,000 to 20,000 jobs (RTVNOORD, Loek and Minnema 2018). Professor of Regional Labor Market Analysis, Jouke van Dijk, emphasizes that the energy transition also offers opportunities for new jobs in alternative energy sources/carriers such as solar panels, wind energy and hydrogen (RTVNOORD, Loek and Minnema, 2018). There is a need for new industries where existing knowledge can be reused (AD; Voemans, Ton; 2019). "There is a lot at stake for Groningen, depending on which expert you ask, there are about 10,000 to 15,000 jobs here involved with natural gas. To that I add the jobs in the chemical industry that runs on natural gas,'' said former Groningen deputy Patrick Brouns at the time.

Whatever the exact number, jobs will be lost in the natural gas sector. Therefore, there is benefit to a new industry where existing knowledge can be reused.

Hydrogen-related jobs

Hydrogen plays an important role in the transition to renewable energy and could lead to significant job growth. Several studies have examined projected employment in this sector. According to (Van Wijk and Charzimarkakis 2020, 8)[30] , the construction and maintenance of 2x40 GW of electrolysis capacity could create between 140,000 and 170,000 jobs by 2030. (Van de Sander 2021) predicts that the transition to hydrogen could create up to 41,000 new jobs in the Netherlands. (Spisto, et al. 2020, 16)[31] predicts that the planned 100 MW hydrogen projects in Groningen and Drenthe will generate 6,000 FTE during construction and 500 FTE during operation in employment during the construction and operation phases. (Van Greuningen, Suzanne; KIWA 2021) estimates that the one-time labor demand linked to the realization of the hydrogen backbone in 2030 is 573 FTE, while the one-time labor demand linked to the conversion of the distribution grid is estimated at 161 FTE. (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 5)[32] reports that the demand for green hydrogen between 2030 and 2050 could generate on average between 1,800 and 20,000 one-time jobs and between 4,200 and 72,600 recurring jobs. The report "Hydrogen: Opportunities for Dutch Industry" by (EZK, Reijerkerk and Van Rhee, Hydrogen: Opportunities for Dutch Industry, 2019) shows that the Dutch manufacturing industry has significant opportunities to create jobs by switching to renewable energy,

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[29] Lisa van de Molen, RUG/VNO. 2014 May, When there's nothing left to win..., https://docplayer.nl/44997-Als-er-niets-meer-valt-te-win.html

[30] Van Wijk, AD; Charzimarkakis, Jorge, MENA conference 2x40-GW-Green-Hydrogen-Initiative-Mena-Hydrogen-Alliance-20-5-2020. https://dii-desertenergy.org/wp-content/uploads/2020/05/2x40-GW-Green-Hydrogen-Initiative-Mena-Hydrogen-Alliance-20-5-2020.pdf[31] European commission JRC technical report, Spisto A; Gerbelova H; Masera M; Barboni M;2020.,socio-economic impacts of the closure of the Groningen gas field, 2020, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120521/socio-economic_impacts_closure_groningen_gas_field.pdf

[32] Liguijt. Cor et al ; CE Delft, 2021 Work through green hydrogen investments; Update and expansion, Work through green hydrogen investments. Update and expansion - CE Delft

which could lead to 569,000 FTE (8% of jobs). Europe's ambition is to create 1 million highly skilled jobs in the hydrogen economy by 2030 and 5.4 million by 2050 (H2 Green skills for Hydrogen, 2013)[33] . Other countries, such as 7,600 FTE Australia, 13,000 FTE Germany (Zenk, et al. 2023, 16) 100,000 FTE France (Hydrogene France; 2022, 3) and 700,000 to 1 million FTE in the US (Bezdek 2019) , are also betting on the development of the hydrogen sector and associated job growth. A 2020 study by the Hydrogen Council (Hydrogen_Council; 2017, 9)[34] estimates that the hydrogen economy could create about 30 million jobs by 2050, mainly in the energy, transportation and manufacturing sectors. More information on hydrogen-related jobs can be found in Appendix 26.

Table 1 Overview of labor demand (rounded to the nearest hundred) (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 6)

Year CE Delft study 2021	Demand for green hydrogen PJ	Total one-time employment (average FTE/year)	Recurring employment (average FTE/year)
2030	10 - 40	1.800 - 4.700	4.200 - 12.500
2040	132 - 317	2.000 - 13.000	9.200 - 43.000
2050	254 - 593	2.200 - 20.000	14.200 - 72.600

From the analysis of the 7 international reports, namely, (Appel, Schanz, et al, Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2) 2023), (Bezdek 2019), (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022), (Queensland. Department of Employment 2022), (Hydrogen France; 2022), (HyResponse 2016) and (Zinke, Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung 2023). The reports contained 305 job titles. After removing duplicate job titles, 272 different job titles remained, which were then analyzed for the required EQF knowledge level (see Appendix 27 for explanation of EQF). Some of these functions partially overlap, as shown by examples of similar functions in Appendix 28. On the other hand, there are also functions in the hydrogen domain that are not specifically named, such as energy law and knowledge institutions, which are described in Appendix 29 (Professors-Lectors and Practitioners). Appendix 30 provides a detailed table with the EQF score and number of positions by educational level: VO, MBO, HBO and WO.
Currently, MBO outflow is too low to meet labor market demand. Moreover, the outflow is expected to decrease in the coming years (DUO 2022). Thus, in order to meet the labor market demand, it is necessary to look beyond regular education. (Scherpen 2023)[35] states "in the Northern Netherlands, the number of people who go on to study engineering after high school is even lower than in the rest of the country." More focus on primary and secondary schools would be needed. See Appendix 31 for detailed information.

Hydrogen-related functions

Appendix 32 lists the individual jobs with the matching EQF score jobs related to hydrogen technology, divided into different job groups and with their EQF scores. The groups include production workers, service workers at hydrogen fueling stations, technical occupations with practical skills, process operators and technical occupations such as fuel cell operators and mechanics. In addition to these groups, there are also jobs such as hydrogen vehicle drivers. The hydrogen economy offers many opportunities for employment and

[33] 2022 H2 Green skills for Hydrogen, Green Skills for Hydrogen
[34] Hydrogen_Council;. "Hydrogen Scaling up = a sustainable Pathway for the global energy Transition." *Hydrogen Counsel.* 13 Nov 2017. https://hydrogencouncil.com/en/study-hydrogen-scaling-up/ (accessed Apr 15, 2023).
[35] Scherpen, Jacquelien, interviewed by Gerdt Van Holslot. *With Mathematics you understand things better* Groningen: Dagblad van het Noorden, (April 1, 2023)

economic growth in various sectors and functions. Anticipated positions include researchers and developers of hydrogen technologies, engineers and technicians for the design, construction and maintenance of hydrogen plants and systems, hydrogen equipment installers and mechanics, energy trade and market analysis experts, policy makers and regulators, marketing and sales professionals, project managers and entrepreneurs, workers in the building and construction and transportation sectors.

The tables below summarize the main main classifications and associated education levels. Table 2 focuses on job types rather than the number of workers, while Table 3 indicates the competencies required by work area over the life cycle of a project, at both job and work area levels. Table 4 shows the number of workers with a particular knowledge background.

Table 2 Hydrogen functions and level of education

Education level	Education level EQF	Number	%
VMBO	EQF 1-2	14,5	5,4%
MBO	EQF 3-4	89,34	33,4%
Associate Degree	EQF 5	29,83	11,1%
BSc.	EQF 6	59	22,0%
Master	EQF 7	60,51	22,6%
PhD/PD	EQF 8	14,5	5,4%
Total	EQF 1-8	268	100,0%

Table 3 Area of work versus educational background analysis on data from (Hydrogene France; 2022)

Scope of work	Total	MSc and >	Associate and BSc Degree	High school	HBO non-technical
Design Features	46	44	16	2	5
Production Functions	21	7	18	6	0
implementation functions	10	7	8	3	0
Operations functions	24	10	16	9	2
Maintenance functions	23	10	18	7	0

There are variable academic entry requirements for the 23 professions listed. This explains the discrepancy between the total number of professionals listed (84) and the sum of the occupations here. Part of this study is workforce planning and need at Resato (gas station manufacturing industry).

Table 4 Resato 2030 workforce planning by functions for 2030 (Koning-Eggink, Hetty; Resato; 2023)[36]

Resato 2030 workforce planning	absolute ly	%
VMBO	66	6,7%
MBO	428,6	43,4%
HBO	413,9	41,9%
WW	79	8,0%
	987,5	100,0%
Direct personnel (Production)	660	66,8%
In direct staff	328	33,2%

[36] King-Eggink, Hetty; Resato;. 2023. " Resato workforce needs presentation 23-3-23 Techlab Assen." Assen, Mar. 23. hettykoning@resato.com

Hydrogen-related competencies

Combining the study nodes model (a 3 by 3 matrix) (Dexters and Greentech 2023, 29) with the 5 work areas of (Hydrogene France; 2022), the 6 work areas of (H2Pro 2022)[37] and the 5 performance levels of (Vollenbroek Training and Advice; 2020)[38] , creates a 6 by 5 matrix that can be used to build and teach knowledge. If we also add emergency response services, as indicated by (Queensland. Department of Employment 2022) and (HyResponse 2016), we get a 7 by 5 matrix. If we then add the prudential aspects of (Appel, Schanz, et al., Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2) 2023), (Queensland. Department of Employment 2022) and (Reijerkerk and Van Rhee 2019)[39] and funding added to the value chain and a 9 by 5 matrix emerges. The (Queensland. Department of Employment 2022) adds aspects of HR and ESG management and HyLaw the legal frameworks to the hydrogen technology curriculum. By integrating these elements, we can develop a comprehensive knowledge base summarized in a 12 by 5 matrix. The matrix provides an overview of the work areas and associated knowledge levels, providing a basis for further curriculum development. For most positions, the level will be between "Beginning" and "Competent" for each element within MBO education. Achieving higher levels requires long-term work experience and additional studies. See Appendix 33 for more details.

Process system boundaries process and asset layers

Accurately defining system boundaries is essential for accurate analysis of hydrogen systems, including production (downstream), transportation and storage (midstream), utilization (upstream) and life cycle. The asset layer model includes several key layers, such as environmental, emergency, security, control and production layers, which are critical to the planning and management of a hydrogen plant. See Appendix 34 for a detailed description of the process-system boundaries (horizontal) and asset layers (vertical).

Table 5 list of areas of work versus level of knowledge

Scope of work	Beginner	Advanced	Competent	Proficient	Expert
Engineering					
Production					
Installation					
Funding					
Operation					
Maintenance					
Safety					
Emergency Services					
Business and market introduction					
HRM - Training - Soft skills					
Environmental, Social and Governance (ESG) management and compliance					
Legal framework					

[37] H2Pro. 2022. factsheet II wasserstofferzeugung wasserstoff zukunft berufliche bildung energiewende H2PRO.pdf." BIBB.DE. Dec. Opened Mar. 11, 2023. https://www.bibb.de/dokumente/pdf/factsheet_II_wasserstofferzeugung_wasserstoff_zukunft_berufliche_bildung_energiewende_H2PRO.pdf.

[38] Vollenbroek Training and Consulting;. 2020. ", From beginner to export, https://minderfoutenmaken.nl/useruploads/files/expert.pdf." Sept. Opened Mar. 5, 2023. https://minderfoutenmaken.nl/useruploads/files/expert.pdf.

[39] Reijerkerk, Jaco, and Gigi Van Rhee. 2019. "Hydrogen Opportunities for Dutch Industry." *FME.* Oct. Opened Mar. 31, 2023. https://www.fme.nl/system/files/publicaties/import/Waterstof%20Kansen%20voor%20de%20Nederlandse%20industrie_HR_0.pdf

Several author have written about the required hydrogen competitions, where there were different points of interest such as place in value chain or field. Behind the author is an appendix where relevant part is elaborated. (Dahoe and Molkov 2006) (appendix 3), (Hogt 2018) (appendix 4), (HyResponder 2021) (appendix5), (Skiba 2020) (appendix 7), (Van Greuningen, Suzanne; KIWA 2021) (appendix 8), (Hazenberg, Drenthe College - Hydrogen in Industry Practorate 2022) (appendix 10), (Zinke, Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff 2022) (appendix 12B), (Institute for innovation and Technology 2022) (appendix 13A-C), (Queensland. Department of Employment 2022) (appendix 14) (Zinke, Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung 2023) (appendix 15), (VDI_Wissensforum 2023) (appendix 16), (University_Oldenburg 2023) (Appendix 17), (Van Gemert, Joris; Mollema, Anouk; 2022) (Appendix 18) (Appel, Schanz, et al, Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2) 2023) (Appendix 19A), (Hydrogene France; 2022) (Appendix 20D) (oZone 2023) (Appendix 21), (De Jong, Binnert; 2022) (Appendix 35) and (Hyver, Devon; 2021) (appendix 24), (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022), (appendix 36/37) and appendices 37-1 through 37-15 provide descriptions of positions related to entry-level qualifications, key activities and unique hydrogen requirements. Some functions fall within specific segments of the value chain, such as upstream, midstream or downstream, requiring different skills. For example, the maintenance of a PEM electrolysis differs from that of a hydrogen gas boiler or a hydrogen car because of the specific knowledge required. Thus, taking into account the place in the value chain, the above table can be considered in 3D.

Appendix 38 contains a compiled list of work areas and related competencies.

Chapter 4 Conclusions and discussion

1. The cessation of natural gas extraction could result in between 10,000 and 20,000 jobs will be lost. To absorb these job losses, it is important to develop new industries that can make use of existing knowledge. Hydrogen is seen as an important sector in which the northern Netherlands can play a crucial role. Besides the fact that hydrogen is crucial in the energy transition, this sector can generate significant job growth. According to recent research, the transition to hydrogen could generate as many as 41,000 new jobs in the Netherlands. Growth in the hydrogen sector is also observable internationally. Europe has a goal of one million highly skilled jobs in the hydrogen economy by 2030 and 5.4 million jobs by 2050. Other countries, such as Australia, Germany, France and the U.S., are also betting on the growth of the hydrogen sector and related jobs. According to a study by the Hydrogen (Hydrogen_Council; 2017), as many as 30 million jobs could be created globally in the hydrogen sector by 2050.

2. In the report of (Van Greuningen, Suzanne; KIWA 2021), point (1) is cited that there is a need for MBO elective courses. This point has since been resolved and MBO now has four formal elective courses approved by the sector chamber and minister (see model in Appendix 46). Annex 10 includes the elective element Hydrogen in Industry and Annex 10B the lesson format in 24 lesson blocks. Point (2) about insufficient personnel is also mentioned in the report. To get enough staff, it is essential to have capable teachers first. Therefore, a Train the Trainer program was started in February 2023 for nine ROC 's and four colleges to professionalize teachers while working on the development of teaching materials and assignments. The 5 goals are described in Appendix 39.

3. From the analysis of the (inter)national reports, 272 different job titles within the hydrogen economy were identified and these were examined based on the required EQF knowledge level, providing insight into the diversity and level of education required; the distribution of knowledge level is as follows: 5.4% PhD, 22.6% MSc, 22% WO BSc, 11.1% HBO BSc, 33.4% MBO and 5.4% secondary education or no specific prior knowledge required.

4. Of the 17 hydrogen positions in high demand, 12 require an MBO background. The hydrogen knowledge they need to acquire is mainly at a basic knowledge level. Only the position of supervisor requires expert knowledge in hydrogen. This means that attracting these workers may be even more challenging than teaching them hydrogen knowledge.

5. Several studies show that current training meets the required tasks for the hydrogen sector, including planning, building, commissioning, monitoring, operating and maintaining hydrogen production plants, storage and transportation systems. Although there is limited knowledge of new equipment, such as electrolysis, the studies emphasize the importance of safety knowledge and safety in the industry. Hydrogen professionals only need additional qualifications in safety. However, attention will need to be paid to developing knowledge about new equipment and further developing hands-on training.

6. With the emergence of decentralized and automated hydrogen plants, mechanics must master basic process engineering and operating skills in addition to mechanical or electrical engineering skills. This is crucial for safely shutting down and starting up plants after maintenance, especially in locations such as gas stations or power hubs where no operators are present. As operation and maintenance tasks continue to merge and the market demands more autonomous installations, job requirements of mechanics and operators must be integrated in certain areas.

7. Many companies working in the hydrogen economy are still training their people internally, but would like to see some of that with mainstream education.

8. We can distinguish two main streams: building hydrogen components and operating and maintaining hydrogen plants. The Netherlands is active in the field of compressors (Howden, Resato), filling stations (Resato), fuel cells (Nedstack) and hydrogen boilers (Remeha, Intergas, Bekaert Combustion Technology), hydrogen industrial burners and boilers (Stork Thermeq). However, in the field of electrolysis manufacturing, the Netherlands is relatively small compared to foreign players such as NEL, Siemens, ThyssenKrupp and ITM-Power. Locally, smaller players such as VDL, Hydron, HyGear and Douna Machinery and the larger Plug Power are present.

9. Through the "Train the Trainers" program, under the guidance of the Practors, the teachers are retrained and new teaching materials are developed together. At the same time, teacher professionalization is carried out at MBO and HBO level. This creates horizontal broadening and a national broadening to be able to offer the teaching materials in more places.

10. The skill and knowledge around high-pressure engineering are not mentioned much, even though he plays an important role in gas stations and mobility where pressures above 700 bar occur.

11. Experience with other large infrastructure projects such as power plants show that many components come from abroad, and they often bring some of their specialist personnel as well, or their partners. During the construction phase. This may mean that even in hydrogen projects not all the FTEs needed will be filled in from the (North) Netherlands.

12. The demand for certain positions are both time, when does an application become larger, and region dependent due to the types of projects and types of companies that are there.

13. The current outflow of MBO students does not meet the labor market demand and this is expected to decrease further in the coming years. To meet the labor market demand, it is necessary to look beyond regular education. Developing special modules that go deeper into specific sub-aspects or equipment is essential. These modules can then be offered as continuing education to the current workforce.

14. Initial plans are underway to exchange hydrogen knowledge nationally and internationally and to work on a continuous learning line VMBO, MBO, HBO, WO and postdoc.

15. Through the Professors, Lecturers and Practors Hydrogen Campus Europe network an optimal situation is created for the continuous learning line and mutual alignment. See Appendix 29 Professor - Lecturer - Practor for more detailed information. This is a vertical integration within hydrogen.

16. Through the new platform Practors in Energy Transition, a nationwide consultation platform at MBO level on energy transition is being created. See Appendix 40 what a horizontal integration on energy transition between national MBO-practices.

Discussion - Bottlenecks

Some bottlenecks emerged during the research and development of the elective, including the balance between generic and company-specific training in the hydrogen domain. Given the presence of 259 different organizations (Reijerkerk and Van Rhee 2019, 73)[40] in and about 272 functions with varying levels of knowledge in the hydrogen value chain, it is challenging to develop a generic H2 training course.

One bottleneck is funding for teachers. Per 240 hours of elective modules, only 40 hours are reimbursed by the government, meaning that half of the original 42 2-hour teaching modules are not funded. Solutions need to be found to still get the lesson material to the student, such as offering more online learning modules or expanding the course to 480 hours, although the latter is not preferred by the SBB. appendix 10B now shows the schedule set up of 4 blocks of 6 lessons with the main format, introduction and safety, upstream, midstream and downstream. Appendix 10C shows the breakdown of how the 240 SBU study load is structured.

One possible approach is to provide a hydrogen safety base with the mainline chain, after which various outflow specializations are available, such as:

1. Manufacturing industry (construction of hydrogen fueling stations, hydrogen burners, fuel cells, etc.)
2. Downstream (production, Auxiliary systems, small storage)
3. Midstream (TSO, DSO, compression, industrial hydrogen networks and large-scale storage, system integration, gas station maintenance)
4. Upstream (hydrogen turbines, hydrogen boilers, chemical processes)
5. System Integration.

[40] Reijerkerk, Jaco, and Gigi Van Rhee. 2019. "Hydrogen Opportunities for Dutch Industry." *FME.* Oct. Opened Mar. 31, 2023. https://www.fme.nl/system/files/publicaties/import/Waterstof%20Kansen%20voor%20de%20Nederlandse%20industrie_HR_0.pdf

6. The challenge lies in determining the boundary between generic training and specific training for a particular type of company, given the diversity of companies and functions in the hydrogen sector.

Chapter 5 Evaluation recommendations and suggestions for further research

This study serves as input to a number of international projects that have just started around the development of hydrogen competencies, or are currently under development and will run for the next 3-8 years. The results of this study will be made available to the following users - research groups that will use it in the following programs:

1. In 2023, CE Delft, in collaboration with SEO Economic Research, will conduct a labor market research hydrogen transition commissioned by Groenvermogen NL, as part of the Human Capital Agenda (HCA) (Renkers 2023)[41] . Some research questions that will be addressed in this research are: what knowledge is required for hydrogen, what specific knowledge is needed within a certain knowledge area, at what level should this knowledge be and can specific hydrogen skills be identified?

2. The European Hydrogen Skills Alliance, (Greenskills4H2 2023)[42] -(Greenskillsforhydrogen 2023) program in which Drenthe College is working with 33 partners to develop a European curriculum for MBO/HBO education in 15 EU countries. The goal of the program is to provide workers and industry with the new skills needed to achieve the challenging goals of the Green Transition. As responsible for the MBO curriculum from Drenthe College, I am collaborating on the development of the learning materials from my Practorate Hydrogen. The EU WP1 competencies program includes the GAP analysis and several work packages have been developed for the teaching materials. The Greenskills4H2 program runs from 2022 to 2026.

3. (Greentech 2023)[43] Objective is to provide solutions to train the next generation of engineers ready to work on the European energy mix. The program takes place in 5 countries with 7 partners and started in 2022. Completion is expected in 2024. Training module 4 is focused on hydrogen.

4. Input to the hydrogen competencies work package within the HYDRO-BOREAS program (2023-2026), which is part of the World Class Maintenance program. (De Jong, Binnert; 2022)[44] . Appendix 42 shows the schedule and Appendix 43 lists the parties involved for the upcoming interviews.

5. Input to curriculum development for hydrogen and wind courses in Canada, currently under investigation by Old Library Academy and CNA College of the North Atlantic; see Appendix 47 for their interview questions

[41] Renkers, Tessa; 2023, Draft assignment letter GroenvermogenNL,) t.b.v. Labor market research-hydrogen transition.
[42] Greenskills4H2 - EU program WP1 competencies GAP analysis
https://www.h2fc-net.eu/net-tools/objectives/e-learning-greenskill4h2/
[43] Greentech- Erasmus plus - https://greentech-erasmus.eu
[44] 2023 WCM Hydrogen Asset Management Project HYDRO-BOREAS, Fieldlab HYDRO-BOREAS - World Class Maintenance

6. The further optimization and roll-out of the subject of hydrogen in industry at Drenthe College and nationally within the Netherlands (Hazenberg, Drenthe College - Practorate Hydrogen in Industry 2022), combined with the strengthening of Practorate, Lectureship and development and the establishment of partnerships between Practors, Lecturers and Professors around green molecules. This will contribute to a better reflection of the hydrogen value chain in education, by closing gaps and providing education in missing areas with new Professors, Lecturers and Practorates that are better aligned with each other and with WO programs (see Annex 29 Professors, Lecturers and Practors consultation).

7. Investigating how the hydrogen laboratory at Greenwise campus can be optimally equipped and what skills related to hydrogen in industry can most optimally perform there.

8. Investigating the need for an Associate Degree hydrogen in industry as a continuous learning line on the elective course hydrogen in industry.

9. Work is currently underway within the national Green PowerNL program to develop a national hydrogen roadmap and identify educational opportunities and gaps. The inventory will continue until November 2023, after which scaling up will take place until 2026. The program includes several activities, including defining both regional and national roadmaps, identifying and closing knowledge and facility gaps through educational materials and facilities, developing a national hydrogen knowledge base and expanding hydrogen knowledge through train-the-trainer programs.

10. Research should be done to develop a hydrogen certification program inspired by the Canadian 'Hydrogen Technician (TSSAH2)' program (see Appendix 44) or the Dutch 'Veiligheidsinstructies Aardgas' (VIAG), with the adaptation of natural gas to hydrogen. This could lead to 'Safety Instructions for Hydrogen' (VIAW) and specific requirements for those in charge of hydrogen installations. An alternative to explore is to award Edubadges[45] to students who achieve certain levels of knowledge and skills. Drenthe College is not currently affiliated with Edubadges.

[45] edubadges: awarding digital certificates to students | SURF.nl

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Attachments

Appendix 1 Competency-based hydrogen education - knowledge, skills, behavior and facilities

Competency-based Hydrogen Education:

1. The core of competency-based hydrogen education is developing the competencies needed to be successful in the hydrogen industry. Competencies include knowledge, skills, attitudes and behaviors required to perform specific tasks and activities and achieve goals.

2. Competency-based hydrogen education focuses on developing practical skills students need to understand and apply hydrogen technologies and processes. This includes, for example, knowledge of the chemical properties of hydrogen, skills in the design and implementation of hydrogen systems, and knowledge of the regulations and safety measures needed to work with hydrogen.

3. Also important is developing the right attitudes and behaviors, such as teamwork, communication, creativity and problem-solving skills, that are needed to operate successfully in the hydrogen sector.

4. Competency-based hydrogen education focuses on developing the specific skills and competencies required for the hydrogen sector to prepare students for successful careers in this fast-growing and important industry.

Knowledge:

1. Knowledge is essential within hydrogen education because understanding the properties, production, applications and safety measures of hydrogen is critical to understanding and developing hydrogen technologies.

2. Hydrogen is a promising and sustainable energy carrier that is becoming increasingly important in the energy transition. To produce, store, transport and apply hydrogen in a safe, efficient and effective manner requires a thorough understanding of the physical, chemical and technical aspects of hydrogen.

3. Knowledge is also needed to understand the potential benefits and challenges of hydrogen technologies, such as their contribution to reducing CO_2 emissions and reducing our dependence on fossil fuels, as well as the potential risks and drawbacks, such as the production of greenhouse gases in the production of hydrogen from fossil fuels and the need for safety measures in the storage and application of hydrogen.

4. Knowledge is thus vital for educating professionals involved in the design, development and use of hydrogen technologies and for promoting innovation and sustainability in the energy sector.

Skills:

Skills are important in MBO education for several reasons:

1. Labor market preparation: MBO education aims to prepare students for specific professional practice. Practical skills are crucial for successful preparation. This is because employers are looking for employees who not only have the necessary knowledge, but are also able to apply this knowledge effectively in practice.

2. Lifelong learning: In a rapidly changing world, it is important for students not only to be prepared for their first job, but also to be able to develop throughout their careers. Skills such as problem-solving, collaboration and self-reflection are important for a successful career and can contribute to lifelong learning.

3. Quality improvement: Paying attention to skills can improve the quality of education. This is because skills have practical applications and therefore contribute directly to the quality of vocational education.

4. In short, skills are important in MBO education because they contribute to labor market preparation, competency-based education, lifelong learning and quality improvement of education.

Behavior:

Assessing the behavior of MBO students during their work in hydrogen training can be done in several ways. Here are some suggestions:

1. Observation: Observation is an important method of assessing student behavior during their work. Observation can be done by the teacher or field supervisor, as well as by fellow students. Observation should focus on behaviors important to the hydrogen sector, such as safety, accuracy, cooperation, communication and following instructions.

2. Reflection reports: Students may be asked to write reflection reports on their work and the behavior they exhibited. In doing so, they can describe what they did, how they worked together and how they communicated. This can help them evaluate and improve their own behavior and competencies.

3. Peer feedback: Students can give feedback to their peers about their behavior while working. In doing so, they can give feedback on specific behaviors and make suggestions for improvement. This can also help improve cooperation and communication between students.

4. Rubrics: A rubric is an evaluation tool that can be used to assess student behavior. This involves setting criteria for specific behaviors and giving a score based on how well the student meets the criteria.

Assessing the behavior of MBO students during their work in hydrogen training is important to ensure that students develop appropriate competencies and are prepared for a successful career in the hydrogen sector. It is important to emphasize that assessing behavior should not only focus on finding faults, but also on encouraging student growth and development.

Facilities to develop skills:

For MBO "hydrogen in industry" students to develop their skills, several facilities are needed. Here are some suggestions:

1. Practical space: A practical space is needed where students can work with hydrogen systems and processes. This space must be well ventilated and meet safety regulations for working with hydrogen.

2. Equipment: Specific equipment is needed to work with hydrogen, such as fuel cells, electrolysis equipment and storage systems. This equipment should be available for students to practice and experiment.

3. Materials: Materials, such as pipes, tanks and hoses, are also needed when working with hydrogen. These materials must be safe and meet the requirements for working with hydrogen.

4. Simulation software: Simulation software can also be used to allow students to practice designing hydrogen systems and processes. This software can help visualize and understand the concepts and processes. For example, the Interreg reseach project "electrolyser modeling" by Saxion Hogeschool Enschede and FH Münster, among others, which DC is working with to make this applicable for education.

5. Practice supervisors: Practice supervisors are needed to guide students in working with hydrogen. They should be experienced in working with hydrogen and aware of safety regulations.

6. Safety Precautions: Safety is very important when working with hydrogen. Thus, adequate safety measures must be taken, such as a proper ventilation system, fire extinguishers and emergency exits. In addition, students should be trained in safety regulations and safety drills should be held regularly.

7. Partnerships: In order for students to work on realistic projects and assignments, partnerships with companies in the hydrogen sector can be established. This allows students to gain practical experience and have direct contact with hydrogen industry professionals.

By making these facilities available, MBO "hydrogen in industry" students can develop their skills and be prepared for a successful career in the hydrogen sector.

Appendix 2 Reports for content orientation literature exploration

Table 6 Reports for content orientation literature exploration

Report title	Publi-cation year	Country	Target	Author link
On the development of an International Curriculum on Hydrogen Safety Engineering and its Implementation into Educational Programs	2006	Netherlands	HBO	Dahoe, A.E. and V.V Molkov. 2006[46]
HyTEC - Hydrogen Technology and Energy Curriculum	2013	America	Public	(Nagle 2013)[47]
Chemistry - Class 9 (Gymnasium), Wasser, Wasserstoff und Molares Volumes	2016	Germany	VWO	Albert-Einstein-Gymnasium [48]
HyResponse, International Curriculum on hydrogen safety training for First Responders	2016	EU	Fire Department	(HyResponse 2016)[49] (Tretsiakova-McNally, Svetlana; Molkov, Vladimir; Dey, Randy; Verbecke, Franck; Zanoto, Adrien 2015)[50]
Gas 2.0 Report theme table hydrogen Round 1B	2018	EN	MBO	(Hogt 2018, 7)[51]
The hydrogen economy and jobs of the future	2019	America	MBO-HBO/WO	(Bezdek 2019)[52]
Competency Standards For Emerging Hydrogen Related Activities	2020	Australia	MBO	(Skiba 2020)[53]
K1319 Elective MBO hydrogen in the industry	2021	Netherlands	MBO Industry	Hazenberg W. and Hogt R.[54]

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Report title	Publi-cation year	Country	Target	Author link
HyDelta WP4 Track D4.1. The need for MBO technically skilled personnel and advice for strengthening education on the field of hydrogen.	2021	Netherlands	MBO	(Van Greuningen, Suzanne; KIWA 2021) [55]
Plug power; Power the Future 1 MW PEM - Presentation	2021	Global	MBO	(Hyver, Devon; 2021)
CE Delft, 2021 Work through green hydrogen investments; Update and expansion.	2021	Netherlands	Work opportunity	(Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021)[56]
Wasserstoff als Beruf: Trends in der Aus- und Weiterbildung	2022	Germany	MBO-HBO-WO	[1] Institute for innovation and Technology[57]
Assessing workforce required to advance Canada's hydrogen economy	2022	Canada	MBO-HBO	Transition Accelerator reports[58]
Hydrogen industry workforce development roadmap 2022-2032	2022	Australia		Queensland [59]
Hydrogen France Skills and professions of the hydrogen sector Planning ahead to successfully develop an industry of strategic importance	2022	France	Basic/MBO-HBO/WO	(Hydrogene France; 2022) [60]
NVDO maintenance compass 2022	2022	EN	Maintenance	(NVDO 2022)[61]
Wasserstofferzeugung: "einschlägige" Ausbildungsberufe passen - zusätzlich notwendig sind sicherheitsrelevante Qualifikationen	2022	Germany	Government	(H2Pro 2022)[62]

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Report title	Publi-cation year	Country	Target	Author link
Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff	2022	Germany		Zinke 2022[63]
H2Brasil	2022	Brazil	government	(Francke 2022)[64]
Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte part 1 &2	2023	Germany	MBO-HBO	Apple et al.[65]
Wasserstoff für Fach- und Führungskräfte	2023	Germany	MBO-HBO	University Oldenburg[66]
Maßnahmenkonkrete Strategie für den Aufbau einer Wasserstoffwirtschaft im Land Brandenburg	2023	Germany		Land Brandenburg Ministerium[67]
Erste Abschätzung möglicher Arbeitsmarkteffekte durch die Umsetzung der Nationalen Wasserstoffstrategie bis 2030	2023	Germany	AFTER	(Zenk, et al. 2023)[68]
Greentech project mini conference presentation	2023	NL+	MBO	(Dexters and Greentech 2023)[69]
Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung	2023	Germany		(Zinke, Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung 2023)[70]
Not yet available 'Study on Demand for Professionals by the Labor Market" (to be released in early 2023 by SENAI).	2023	Brazil	MBO-HBO	SENAI-(H2verdebrasil 2023)[71]

[63] Zinke, Gert. 2022. Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff . Bundesinstitut für Berufsbildung, Bundesinstitut für Berufsbildung, Bonn: Bundesinstitut für Berufsbildung, 62. Accessed Mar. 20, 2023. https://www.bibb.de/dokumente/pdf/a24_zinke_sektoranalyse_wasserstoff_bdp.pdf

[64] Francke, Markus. 2022. "H2Brasil." Deutsche Gesellschaft für . Feb. Accessed Mar. 25, 2023. https://www.giz.de/de/downloads/H2%20Brasil_BMZ_DE.pdf

[65] Appel, Andrea, Michael Schanz, Marc Bovenschulte, Stefan Garche, Anja Heilmann, Ursula Hoffmann, Peter Preuss, et al. 2023, "Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2)." Bildungs Weiten, Feb: 5. Opened Feb 19, 2023. https://www.dvgw-veranstaltungen.de/medien/user_upload/ewp_0223_Bildungswelten.pdf.

[66] University_Oldenburg. 2023. *Wasserstoff für Fach- und Führungskräfte.* Opened Feb 20, 2023. https://uol.de/weiterbildung-wasserstoff

[67] Land Brandenburg Ministerium fur Wirtschaft, Arbeit und Energy. 2021. Maßnahmenkonkrete Strategie für den Aufbau einer Wasserstoffwirtschaft im Land Brandenburg. Land Brandenburg Ministerium fur Wirtschaft, Arbeit und Energy, 75. Accessed Feb 19, 2023. https://www.energy-saxony.net/fileadmin/user_upload/Wasserstoffstrategie_Brandenburg_2021.pdf.

[68] Zenk, Johanna, Anke Mönnig, Linus Ronsiek, Christian Schneemann, Alexander Schur, and Stefanie Steeg. 2023. *Abschätzung möglicher Arbeitsmarkteffekte durch die Umsetzung der Nationalen Wasserstoffstrategie bis 2030.* BIBB Bundesinstitut fur berufsbildung, Bonn: Bundesinstitut für Berufsbildung, 55. Accessed March 1, 2023. https://lit.bibb.de/vufind/Record/DS-780958

[69] Greentech. 2023. "Greentech project mini-Conference, ." Greentech. Jan. 19. Opened Mar. 5, 2023. https://greentech-erasmus.eu/wp-content/uploads/2023/01/2023-01-19_Dissemination_meeting-GREEN-TECH-all-presentations.pdf

[70] Zinke, Gert. 2023. *Neues Factsheet beleuchtet Qualifikationsbedarfe im Kontext der Wasserstofferzeugung.* 16 1. Accessed Mar. 16, 2023. https://www.bibb.de/de/170100.php

[71] H2verdebrasil. 2023. "Training and Human Resources ." *www.h2verdebrasil.com.br.* accessed Mar. 25, 2023. https://www.h2verdebrasil.com.br/en/training/

Appendix 3 International Curriculum on Hydrogen Safety Engineering.

The International Curriculum on Hydrogen Safety Engineering by (Dahoe and Molkov 2006)[72] is one of the courses that pays the most attention to the hydrogen safety component and consists of fifteen modules, grouped into three categories and namely:

1) Five basic modules:
    a) Thermodynamics;
    b) Chemical kinetics;
    c) Flow dynamics;
    d) Heat and mass transport;
    e) Fixed mechanics),
2) Six fundamental modules:
    a) Introduction to hydrogen as an energy carrier;
    b) Fundamentals of hydrogen safety;
    c) Release, mixing and distribution;
    d) Hydrogen ignition;
    e) Hydrogen fires;
    f) Explosions:
        i) Deflagrations and detonations.
3) Four applied modules:
    a) Effects of fire and explosions on people, structures and the environment;
    b) Accident prevention and mitigation;
    c) Computational hydrogen safety engineering;
    d) Risk Assessment.

E-Academy of Hydrogen Safety - Work Package 15 (hysafe.org)

Actions have been taken by HySafe partners to implement the development concept of the International Curriculum on Hydrogen Safety Engineering in education and training activities. The University of Ulster has begun offering a new higher education program, namely the PgCert/PgDip/MSc in Hydrogen Safety Engineering

[72] Dahoe, A.E., and V.V Molkov. 2006. "On the Development of an International Curriculum on Hydrogen Safety Engineering and its Implementation into Educational Programmes." *WHEC.* Lyon France: WHEC. Accessed Feb 19, 2023. https://www.cder.dz/A2H2/Medias/Download/Proc%20PDF/PARALLEL%20SESSIONS/%5BS01%5D%20Safety/14-06-06/342.pdf

Appendix 4 Gas 2.0 Hydrogen Theme Table Report Round 1B

Gas 2.0 Report Theme Table Hydrogen Round 1B (Hogt 2018) came that energy professional of the future must possess (especially)

1. Knowledge:
    a. Fuel cells;
    b. Safety (ATEX);
    c. Physical properties and energy conversions;
    d. High-pressure systems (pressure equipment, seals);
    e. Hydrogen central heating boilers;
    f. Materials Science;
    g. Systems knowledge & understanding;
    h. Design, conversion/new construction;
    i. Gas measurement technology;
    j. Choosing based on economic value/return.

2. Technical Skills:
    a. CAD, simulation;
    b. Programming;
    c. diagnose;
    d. system understanding;
    e. Welding.

3. Soft skills:
    a. Professional communication skills;
    b. Convey and share passion;
    c. Innovative mindset;
    d. Thinking in possibilities;
    e. Solution-oriented/improvement-oriented;
    f. Innovating by connecting in multidisciplinary collaboration;
    g. Project-based work;
    h. Report.

Appendix 5 European Hydrogen Emergency Response training program for First Responders, section Basics of hydrogen safety for first responders. (Tretsiakova-McNally, Svetlana; Molkov, Vladimir; Dey, Randy; Verbecke, Franck; Zanoto, Adrien 2015, 7)

1. Module 'Introduction to hydrogen safety for first responders'
    a. Overview of hydrogen production, storage, industry and energy use.
    b. Storage of gaseous hydrogen.
    c. Storage of liquid hydrogen.
    d. Fire resistance classification of hydrogen tanks.
    e. Consequences of catastrophic failure of on-board storage (pressure waves, fireballs, etc.).
    f. Bound hydrogen storage to a carrier.
    g. FCH vehicles.
    h. Hydrogen fueling stations.
    i. Hydrogen transportation.
    j. Stationary FC applications.
    k. Hydrogen-based energy storage systems.
    l. Overview of hydrogen incidents and accidents.
    m. Introduction to the hydrogen safety engineering framework.
2. Module 'Properties of hydrogen relevant to safety'
    a. Physical properties of hydrogen.
    b. Combustion properties, including flammability and detonation limits.
    c. Comparison of hydrogen properties with those of other fuels.
3. Module 'Compatibility of hydrogen with different materials'
    a. Interaction of hydrogen with metals.
    b. Interaction of hydrogen with nonmetals, polymer materials and gases.
    c. Mitigation measures for hydrogen embrittlement and good practices.
4. Module 'Damage criteria for people and property'
    a. Health risks of hydrogen.
    b. Thermal effects of fires on people, structures and environments.
    c. Pressure effects of explosions.
    d. Comparison of damage criteria for unprotected and protected people (firefighters).
5. Module 'Unignited outdoor hydrogen leaks and their mitigation'
    a. Compressed hydrogen leaks.
    b. Cryogenic leaks.
    c. How to reduce the distance to a hydrogen leak?
    d. Mitigation measures for non-ignited spills.
6. 'Ignition sources and prevention of ignition' module.
    a. Ignition sources.
    b. Hydrogen ignition mechanisms.
    c. Spontaneous ignition of sudden leaks.
    d. Prevention of inflammation.
7. Module 'Separation of hydrogen flames and fire fighting'
    a. Microflames.
    b. Jet fires and three separation distances.
    c. Effect of buoyancy on separation distances.
    d. Radiant heat fluxes from jet fires and fireballs.
    e. Burning liquid hydrogen.
8. Module "Regulations, Codes and Standards (RCS) for First Responders.
9. Module "Intervention Strategies and Tactics for First Responders.

Appendix 6 $_{H2\ positions}$, salary (2016) and minimum teaching requirements

From (Bezdek 2019, 4) sorted by salary (2016) where by you also immediately get a difference in educational requirements. It is not always the case that you have more salary with higher education but those are exceptions rather than the rule. Report base is America.

Table 7 $_{H2\ positions}$, salary (2016) and minimum teaching requirements

Job title	**Average salary (2016$)**	**Minimum training requirements**
Fuel cell engineering intern	$6,800	HSD/GED/OJT/Training
Fuel cell manufacturing technician	$23,150	HSD/GED/OJT/TS/apprenticeships
Hydrogen energy system assistant installer	$23,200	HSD/GED
Junior hydrogen energy technician	$23,400	HSD/GED/OJT/TS/apprenticeships
Hydrogen fueling station operator	$29,700	OJT
Hydrogen energy system installer	$31,500	HSD/GED/OJT/TS Apprenticeships
Fuel cell retrofit mechanic	$36,500	HSD/GED
Hydrogen fuel transporter - driver	$36,950	OJT
Hydrogen fuel cell system technician	$39,500	HSD/GED/OJT/TS/apprenticeships
Technician backup power system with fuel cell	$40,200	HSD/GED/OJT/TS Apprenticeships
Hydrogen laboratory technician	$40,600	Associate's
Fuel cell retrofit installer	$41,600	HSD/GED/OJT/TS Apprenticeships
Electrician hydrogen vehicle	$44,800	HSD/GED/OJT/TS Apprenticeships
Fuel cell manufacturing technician	$45,650	Associate's
Fuel cell manufacturing technician and testing	$45,800	Associate's
Hydrogen pipeline construction worker	$46,300	HSD/GED/OJT/TS/apprenticeships
Manager emission reduction credit portfolio	$47,400	Bachelor's (Business)
Hydrogen energy systems designer	$47,900	Apprenticeship/TS
Fuel cell power systems operator and instructor	$50,900	HSD/GED/OJT/TS Apprenticeships
Hydrogen systems sales consultant	$53,800	Bachelor's (Business)
Hazardous materials management specialist	$55,300	Bachelor's (Science)
Analyst policy and sales hydrogen fuels	$56,200	Bachelor's (Business)
Hydrogen fuel station manager	$56,300	Bachelor's (CE)
Manager emission reduction developer	$63,450	Bachelor's (various)
Consultant emissions accounting and report	$64,200	Bachelor's (various)
Hydrogen energy system operational engineer	$68,100	HSD/GED
Installation, operation, engineering and management manager hydrogen power plant	$69,700	Bachelor's (EE, ME, CE)

Senior engineer for power electronics of fuel cell cars	$69,700	Bachelor's (EE)
Development Engineer fuel cell vehicle	$69,800	Bachelor's (Engineer)
Hydrogen energy engineer	$72,300	Bachelor's (Engineer)
Hydrogen systems program manager	$73,220	Bachelor's (Engineer)
Designer and project engineer hydrogen fuel station	$74,200	Bachelor's (Engineer)
Fuel cell quality control manager	$74,600	Master's (Science/Engineering)
Fuel cell power systems engineer	$76,400	Master's (EE)
Fuel cell designer	$78,200	Master's (Science)
Manager emission reduction project	$78,600	Bachelor's (various)
Security researcher and analyst hydrogen systems - causes	$88,350	Bachelor's (various)
Fuel cell plant manager	$90,500	Bachelor's (EE, ME)
Hydrogen systems designer and retrofits	$90,600	Bachelor's
Manager of hydrogen plant operations	$95,200	Bachelor's (EE, ME)
Hydrogen/fuel cell R&D director	$129,000	Doctoral
Director of hydrogen energy development	$138,000	Bachelor's (Business)

Table 8 Breakdown functions EQF score list US Bezdek 2019

VS BEZDEK 2019 job level EQF	**Number**	**Percent**
EQF level 2	3	8,1%
EQF level 3	6	16,2%
EQF level 3-4	1	2,7%
EQF level 4	6	16,2%
EQF level 5	1	2,7%
EQF level 6	8	21,6%
EQF level 7	11	29,7%
EQF level 8	1	2,7%
total	37	100,0%

Table 9 Distribution of positions on VO. MBO, HBO and WO list VS Bezdek 2019

VS BEZDEK 2019 job level training	**Number**	**Percent**
VMBO	3	8,11%
MBO	13	35,14%
HBO	9	24,32%
WW	12	32,43%
Total	37	

Appendix 7 Hydrogen competencies according to Skiba General competency standards for people working with hydrogen

(Skiba 2020, 47-50)[73] has done a comprehensive listing assuming five modules with increasing complexity in them at modules 1 to 4, the fifth deals with the transportation case. Wherein the required knowledge and skills are detailed here.

Module 1 - Preparing to work in the hydrogen industry.

This competency standard includes an overview of the hydrogen industry, properties of hydrogen, relevant mandatory safety regulations and workplace policies, procedures and work practices required for working in the hydrogen industry.

Knowledge:

1. System International (SI) units and their use within gas applications.
2. Energy sources and heat transfer.
3. Combined gas laws (Charles' and Boyle's).
4. The interrelationship between pressure, volume and temperature.
5. Operation of pressure regulators.
6. Procedures/protocols for dealing with unplanned events.
7. Relevant licensing/regulatory requirements in the hydrogen industry.
8. Relevant processes for risk reduction in industry, including risk management and safe work practices.
9. Relevant industry standards, guidelines, codes of conduct and regulations.
10. Relevant workplace documentation.
11. Relevant workplace policies, procedures and instructions.
12. Requirements to enter the workspace.
13. Legal and regulatory bodies active in the hydrogen industry.
14. Sustainable energy principles and practices.

Skills:

1. Apply relevant industry standards, guidelines, codes of conduct and regulations.
2. Apply relevant health and safety requirements, including risk management and safe work practices.
3. Application of sustainable energy principles and practices.
4. Effectively communicate with relevant individuals.
5. Complete relevant workplace documentation.
6. Confirm and follow a schedule of work and job requirements.
7. Consult relevant individuals to coordinate work.
8. Handle unplanned events/situations in accordance with workplace procedures, in a manner that minimizes risk to personnel and equipment.
9. Follow workplace procedures and instructions related to hydrogen gas-related activities.
10. Maintain a clean work environment.

[73] Skiba, Richard. 2020. "Competency Standards for Emerging Hydrogen Related Activities." *Open Journal of Safety Science and Technology* (SSRN) 10, 42-52.:11. Opened Feb 18, 2023. doi:DOI:10.4236/ojsst.2020 https://www.scirp.org/pdf/ojsst_2020051514434707.pdf

11. Obtain relevant resources and materials to perform the work.
12. Perform quality control checks.
13. Work within agreed upon time frames or conditions.

Module 2 - Performing basic work activities in a work environment in the hydrogen industry
This competency standard includes following workplace procedures to properly and safely perform work activities in the hydrogen industry using appropriate materials, tools and measuring equipment.

Knowledge:

1. Proper selection, safe operation, cleaning and storage of relevant materials, equipment, tools and measuring instruments in the hydrogen industry.
2. Environmental principles and sustainable energy practices, including techniques to minimize waste.
3. Workplace hazards.
4. Hazardous substances and examples of each classification category, including: toxic, harmful, corrosive, irritant, oxidizing, highly flammable, hydrogen production techniques.
5. Hydrogen production from renewable sources - electrolysis, biofuels, photolysis.
6. Hazards when working in confined spaces.
7. Task specifications and task requirements.
8. Quality and safety checks.
9. Relevant materials, plans, diagrams, drawings and sources from the hydrogen industry, including graphs and tables.
10. Hydrogen storage technologies.
11. Relevant regulations, codes and legislation in the hydrogen industry.
12. Relevant machinery/plant/equipment.
13. Relevant manufacturer's instructions.
14. Relevant persons to consult to coordinate and complete work
15. Relevant workplace policies and procedures.
16. Relevant risk reduction processes, including relevant Personal Protective Equipment (PPE),
17. safety procedures and work schedules.

Skills:

1. Hazard identification and reporting.
2. Implement risk management measures.
3. Report hazards, risks and incidents to relevant persons.
4. Select and use relevant personal protective equipment (PPE).
5. Carrying out activities in the hydrogen gas industry.
6. Cleaning, checking and storing tools, equipment and measuring instruments
7. Effectively communicate with relevant individuals.
8. Completing documentation in the workplace.
9. Perform quality and safety checks.
10. Identify, select and use appropriate equipment, tools and measuring instruments for relevant work activities.
11. Obtain task requirements and work instructions.
12. Obtain relevant tools and materials to perform the work.

Module 3 - Complying with environmental policies and procedures in the hydrogen industry.
This competency standard includes compliance with relevant legislation, standards, regulations and codes of conduct and their application to relevant workplace tasks in the hydrogen industry and completion of relevant documentation for completion of work.

Knowledge:

1. Causes of environmental damage, including chemicals, oil, water pollution, carcinogens, gases, dust, waste pollution and noise
2. Environmental compliance in a utility work environment
3. Transport methods such as compressed gas, as a liquid or via ammonia or naphthenes
4. Transportation of hydrogen via pipelines
5. Environmentally friendly equipment and materials
6. Environmentally friendly waste disposal
7. Relevant environmental legislation, regulations, standards, laws and codes of conduct
8. Relevant manufacturer specifications
9. Relevant procedures to manage and minimize the impact of an environmental event
10. Relevant workplace documentation, including records and incident reporting
11. Relevant workplace policies and procedures, including environmental protection workplace procedures
12. Responding to environmental events in the workplace
13. Role of regulatory agencies in monitoring environmental related activities, risks and incident compliance.

Skills:

1. Apply environmental control measures and workplace procedures.
2. Apply relevant industry standards, guidelines, codes of conduct and regulations.
3. Apply relevant occupational health and safety requirements.
4. Apply sustainable energy and environmental principles and practices.
5. Completing work and relevant environmental documentation, reports, records and forms.
6. Compliance with environmental policies and procedures.
7. Control and minimize the impact of an environmental event.
8. Handle non-routine events, accidents and emergencies in accordance with workplace procedures.
9. Following procedures for assessing environmental events.
10. Following workplace procedures.
11. Identifying potential and actual environmental hazards and impacts.
12. Identify, interpret and apply relevant environmental procedures.
13. Make recommendations to prevent the occurrence.
14. Minimizing waste and damage to the environment.
15. Preparing to comply with environmental policies and procedures.
16. Assessing management measures.
17. Selecting and using environmentally friendly equipment and materials.

Module 4 - Apply workplace health and safety regulations, codes and practices in the hydrogen industry.
This competency standard covers executive-level responsibilities and applications for health and safety, risk management and compliance with safety practices in the hydrogen supply industry.

Knowledge:

1. Suitable fire extinguisher for a particular type of fire and its use
2. Common workplace safety signs.
3. Hierarchy of hazard management measures.
4. Hazards associated with hydrogen supply work environments, procedures used to manage risks.
5. Principles of risk assessment.
6. Handle safe work procedures.
7. Workplace emergencies that pose a threat to health and safety and the appropriate procedures for an emergency evacuation of the workplace
8. Chemicals in the workplace, including: hazardous substances and dangerous goods, safe storage procedures and purpose and interpretation of the safety data sheet (SDS), types and classes: fuel, flammable and other relevant gases, effects of gases on the human body, common causes of gas accidents and ignition, products of (complete and incomplete) combustion, precautions that can minimize the risk of gas accidents and ignition.
9. Requirements for working with gases, fire protection and control/extinguishing.
10. Reaction of hydrogen with metals.
11. Requirements for working in a designated hazardous area.
12. Relevant industry rules, legislation, guidelines, codes of conduct and regulations
13. Relevant manufacturer specifications.
14. Relevant safe work practices (SWMS)/function safety assessments or risk mitigation processes
15. Relevant legal requirements.
16. Relevant access to work area, space and isolation permits/permits.
17. Relevant workplace documentation.
18. Relevant workplace policies and procedures.
19. Techniques for checking tools and equipment for safety and proper functionality.
20. Techniques to monitor implemented management measures.
21. Working safely with electricity.
22. Working safely with gases.

Skills:

1. Applying relevant occupational health and safety requirements.
2. Implementing safe work practices.
3. Applying regulations and practices in the workplace.
4. Checking tools and equipment for safety and proper operation
5. Insulating plant/machinery/equipment.
6. Completing relevant documentation in the workplace.
7. Dealing with workplace accidents, emergencies and fires within the area of responsibility.

8. Following and applying working procedures and instructions related to risk control measures.
9. Identifying hazards and implementing and monitoring control measures.
10. Obtain applicable work permits, waivers and isolation consents prior to entering the work area.
11. Regularly participate in consultation processes.
12. Preparing to enter a hydrogen supply work area in accordance with operating procedures.
13. Reporting hazards to relevant persons according to work procedures.

Module 5 - Performing hydrogen transport and charging.

This competency standard includes following operating procedures to properly and safely transport and transfer hydrogen. This includes recognizing the characteristics of hydrogen and hydrogen tube trailers/tankers to ensure the safe transfer and transportation of fuel, performing pre-departure inspections, performing tests before loading the trailer/tanker and transporting the load to the customer location. It also includes preparing a site to accept delivery, managing delivery, completing post delivery activities and following emergency procedures.

Knowledge:

1. Compression hydrogen storage on board in tanks based on type IV carbon composite technology.
2. Processes for transporting compressed hydrogen via Tubetrailers.
3. Processes for transporting liquid hydrogen via road tankers
4. Hydrogen storage printing.
5. The use of cryogenic conditions in insulated tanks.
6. Possibility of evaporation during transport.
7. Hydrogen embrittlement caused by the interaction of hydrogen atoms with the crystalline lattices in steel.
8. Factors leading to accidents and incidents involving tube trailers/tankers.
9. Effects of weight distribution on loading behavior and vehicle stability.
10. Efficient driving techniques and environmentally friendly driving strategies .
11. Factors involved in trip preparation.
12. Factors that can cause traffic delays and detour and related actions that can be taken.
13. Fatigue management strategies.
14. How to select and use required personal protective equipment in accordance with industry and occupational health and safety standards
15. Procedures to be followed during a driving or emergency situation and response to an emergency using a company transportation emergency plan.
16. Properties of hydrogen.
17. Relevant dangerous goods (DG) information for the use of tube trailers/tankers.
18. Relevant legislation and industrial operating procedures for transporting hydrogen.
19. Relevant organizational requirements, including policies and procedures.
20. Relevant traffic rules, regulations, permit and license requirements of the State/Province transportation and traffic authorities.

21. Relevant health and safety and environmental procedures and regulations related to fuel tanker operations.
22. Techniques and procedures for the safe loading and unloading of a tube trailer/tank truck
23. Techniques for the safe delivery of hydrogen to a customer site.
24. Techniques to continuously identify and reduce environmental risks.
25. Workshop documentation.
26. Workplace driving and operational instructions.
27. Procedures for working at heights for Tubetrailer/Tanker Driver.

Skills:

1. Applying precautions and required actions to minimize, control or eliminate identified hazards associated with hydrogen transportation.
2. Communicating effectively with others in the workplace.
3. Completing documentation related to operating a hydrogen tube trailer.
4. Completing post-delivery activities.
5. Positioning a trailer/tanker correctly when loading and unloading it
6. Discharging hydrogen to the storage system.
7. Identifying compatibility between trailer/tanker and product.
8. Correctly identifying the product and sticking the proper labels on the trailer/tanker.
9. Implementing emergency plans.
10. Interpreting and following operational instructions and prioritizing work.
11. Charging hydrogen.
12. Meeting customer requirements in delivering hydrogen to the customer site
13. Adjusting activities depending on operational controls, risk situations and environments.
14. Monitoring and anticipating traffic hazards and taking appropriate action
15. Monitor the performance of the trailer/tanker, trailers and equipment and take appropriate action when necessary.
16. Operating and adjusting to differences in equipment in accordance with standard operating procedures.
17. Preparing a route to maximize safety and efficiency and to meet organizational route requirements.
18. Reading and interpreting relevant instructions, procedures, information and signs
19. Unloading hydrogen safely at a customer site
20. Selecting and using required personal protective equipment in accordance with industry and occupational health and safety standards.
21. Performing a pre-departure inspection of a trailer/tanker.
22. Using economical driving techniques when operating a trailer/tanker
23. Work systematically with required attention to detail, without injury to self or others, or damage to property or equipment.

Appendix 8 Learning outcomes from HyDelta WP 4.1 MBO educational research

(Van Greuningen, Suzanne; KIWA 2021, 24) overview final attainment levels. These final attainment levels mainly refer to mechanics working for the network companies or on their gas networks.

1. Remembering - Knowledge
    a. Name the reason for the use and application of hydrogen.
    b. Name the physical and chemical properties of hydrogen.
    c. Name the differences in physical and chemical properties between natural gas and hydrogen.
    d. Name the reason for using an inert gas when working with hydrogen.
    e. Name the risks associated with working with hydrogen.
    f. Name the risks are when mixing various (inert) gases with hydrogen.
    g. Name the measures to be taken according to the risks posed by the different gases.
    h. Name the measures to be taken to prevent the mixing of hydrogen and air.

2. Understanding
    a. Translate the consequences of difference in physical and chemical properties of natural gas and hydrogen to the work situation as described in the Safety Critical Work Instructions (VWIs).
    b. Explain the (safety) risks to be considered when working in the Hydrogen Network.
    c. Explain the (safety) risks associated with working with inert gases.
    d. Explain what (safety) risks occur when working with different gas mixtures.
    e. Explain what measures and actions are different when working in the Hydrogen Grid than in the natural gas grid to maintain safe operation.

3. Apply - skills
    a. Take appropriate personal safety measures in a given work situation when working with hydrogen to reduce and control risks.
    b. Take appropriate environmental safety measures in a given work situation when working with hydrogen to reduce and control risks.
    c. Use appropriate PPE, tools and measuring equipment in a given work situation when working on the Hydrogen Network.
    d. Be able to explain to the emergency services and environment the risks involved in fighting emergencies in the Hydrogen Network.

The learning outcomes are designed to make participants aware of the risks and measures involved in working in the Hydrogen Network. Participants must improve their behavior and attitudes to the risks they face while working. An awareness must be created as to why certain safety measures are chosen and why certain things are done differently than when working in the natural gas grid. They must show that they are capable of handling the safety measures while working, taking into account the risks on which these measures are based. It is therefore important to have

sufficient attention is paid during training to risk awareness, behavior, attitude and consequent action. (Van Greuningen, Suzanne; KIWA 2021, 23)
Examples of work situations include; converting the natural gas grid to a Hydrogen Grid, commissioning the grid and locating leaks and securing the environment.
In addition, the work in high pressure and low pressure also involve differences. These differences are shaped by the work situations at the learning objective level, not at the level of learning outcomes. (Van Greuningen, Suzanne; KIWA 2021, 23)

Relative to K1319, the following are additional and can be added:

1) Remembering - Knowledge:
   a) Name the reason for using an inert gas when working with hydrogen.
   b) Name the risks involved in mixing various (inert) gases with hydrogen.
   c) Name risks posed by the various gases.
   d) Name the measures to be taken to prevent the mixing of hydrogen and air.

2) Understanding:
   a) Explain the (safety) risks to be considered when working in the Hydrogen Network.
   b) Explain the (safety) risks associated with working with inert gases.
   c) Explain what (safety) risks occur when working with different gas mixtures.
   d) Explain what measures and actions are different when working in the Hydrogen Grid than in the natural gas grid to maintain safe operation.

Appendix 8 Model of Bloom



Figure 2 Model of [74]

[74] Download - Design & Enrich - Education Made Together

Appendix 10 K1319 Elective Hydrogen in Industry qualification specification



Figure 3 SBB image Hydrogen in industry

General information

Course load	:	240
hours Professional requirements:		No
Certifications:		No, Training Requirement/Country Recognition. After the elective is developed and established, an application for certification will be made.
Writers		(Hazenberg and Hogt 2022)

Developed for qualification(s) See www.s-bb.nl/kwalificatiedossiers

Notes

Under industrial environment, all hydrogen applications are considered from production to end application with two exceptions, viz:

1. The built environment, after the gas meter (Border TSO grid operator) so everything in the home.
2. Mobility in the broadest sense of the word, bicycles, cars, ships, planes.

The industrial plant stops after the hydrogen fuel nozzle at the hydrogen fueling station.
The elective deals with the application of hydrogen technology in the industrial environment as a chemical feedstock for combustion and the realization of high temperature heat. It is a specialization that deals specifically with the change of the industrial environment through the transition from the application of natural gas to hydrogen gas as an energy carrier and feedstock. The Hydrogen Technology in Industry elective distinguishes itself from the K1049 Hydrogen Technology (basic) elective and the Hydrogen Technology in the Built Environment elective. It is more in-depth than the K1049 elective and focuses specifically on applications in industry. Application areas include production, storage, distribution and use of hydrogen gas with pressures well above 8 bar. Work in industry differs from Hydrogen in the built environment because within the built environment, work is done at pressures up to 8 bar.
The safety aspects of working with hydrogen are highly dependent on the application and working environment. For example, hydrogen in mobility is a borderland of hydrogen in industry and hydrogen in the energy chain with distinctive safety aspects.

Relevance of the elective
The hydrogen economy as a successor to the natural gas economy is developing strongly in the Netherlands. Both from vision and also in product development and application. This involves the entire chain from generation of hydrogen, through storage to the application of hydrogen using fuel cell systems and in combustion applications.
In the context of energy transition and sustainability, there is an increasing need among companies to use hydrogen technology as an energy carrier. With this elective, the beginning professional can distinguish himself within companies in the industrial environment. It also increases his employability on the labor market by deepening his knowledge and skills with regard to hydrogen technology aimed at the industrial environment.

Description of the elective
This elective offers the beginning professional an insight into the various aspects of hydrogen economy and hydrogen technology within the industrial environment. It is a deepening of his knowledge and skills regarding industrial plants and systems with modern development within plant engineering. The emphasis is on the chain production processes, storage and chemical and physical conversion methods for transport, storage and application of hydrogen in the industrial environment such as high temperature heat and role as a process feedstock. In this regard, the transition from natural gas to hydrogen gas as an energy carrier and fuel plays an important role. In addition, regulations around ATEX, PED and safety are important components.

Nature of elective Deepening

Elaboration

D1-K1: Installs a system of hydrogen technology in the industrial environment

Complexity

The novice professional performs installation and operation work in the industrial environment, with or without the aid of (complex) equipment. The work is partly routine. It becomes more complex when the standard procedure does not produce the desired result. Then creative thinking is required or the novice professional has to seek help from third parties. Rapid developments in hydrogen technology and the associated documentation and manuals (mostly in English) also make the work complex. The novice professional possesses knowledge and skills regarding the performance of installation and/or operating activities in an industrial environment and knows the consequences of his actions in relation to hydrogen technology.

Responsibility and independence

The beginning professional works independently and in certain cases together with one or more colleagues in the (green) industrial environment. He is responsible for the results of his own work and is accountable to his supervisor. In case of unforeseen circumstances or when standard procedures do not produce the desired result, he decides when to seek help from third parties. He is also responsible for keeping up with new developments in hydrogen technology to keep in step with the energy transition.

Subject knowledge and skills

The Beginning Professional:

1. Safety and regulation:
    a. Has knowledge of the general safety aspects and regulations of liquid and gaseous hydrogen.
    b. Has knowledge of the safety aspects regarding plant design specifically for hydrogen in industry.
    c. Can take the safety measures necessary when working with hydrogen technology in an industrial environment.
    d. Can work safely with hydrogen technology in an industrial environment.
    e. Has knowledge of response methods in a hydrogen incident (e.g., spill or fire).
    f. Has knowledge of the specific safety aspects of working with hydrogen at pressures higher than 8 bar in industry.

2. Application:
    a. Has knowledge of relevant developments in hydrogen technology for industrial applications.
    b. Has knowledge of application areas of hydrogen technology in industry.
    c. Has knowledge of the advantages and disadvantages of hydrogen technology for industry.

3. Engineering:
    a. Has knowledge of design requirements regarding hydrogen plants specific to industry.
    b. Has knowledge of the operation and characteristics of relevant (sub)systems in hydrogen technology in industry.
    c. Has knowledge of various materials and components used in hydrogen technology in the industrial environment.
    d. Can assemble and test a hydrogen technology plant.

4. Construction:
    a. May install technical demonstration systems in the industrial environment.

5. Commissioning:
    a. Can analyze and test the operation of a hydrogen technology plant.

6. Operations - operating skills:
    a. May operate technical demonstration systems with hydrogen technology in the industrial environment.
    b. May perform hydrogen gas measurements.
    c. Has skills to work with associated modern technical equipment.

7. Analyze and resolve malfunctions:
    a. Can recognize and identify the causes of system failure.
    b. Can maintain and repair technical demonstration systems with hydrogen technology in the industrial environment.
    c. May identify malfunctions and complications on various hydrogen technology installations.
    d. May troubleshoot failures and complications on various hydrogen technology installations.

8. Technical Reading Skills:
    a. Can read and apply technical documentation in English.
    b. Can read technical drawings in hydrogen technology and associated process flows.

9. ICT and digitization:
    a. Can work with modern technical equipment (ICT skills).

10. Communication and teamwork:
    a. Can collaborate and communicate with technicians from multiple professional disciplines.
    b. Can communicate digitally with planning/work preparation colleagues.

D1-K1-W1: Prepares installation work.

Description
The novice professional receives the work assignment from the supervisor. If something is not clear to him, he asks for an explanation. He collects and checks the necessary information (work instructions, drawings, sketches, installation, operating instructions, etc.), materials, tools and resources. He explores the workplace. He assesses whether he can perform the work safely. He consults with the supervisor (on location), work planner and/or others involved if it appears that the workplace or the work order is incomplete or based on incorrect assumptions and resolves the problem.

Result
Materials, tools, test and safety materials and equipment for installing the hydrogen plant are available. All relevant data on the installation work to be performed are known.

Behavior
–

D1-K1-W1: Prepares installation work.

The Beginning Professional:

1. Carefully discusses work assignment with own supervisor and asks for explanation or additional information if unclear;
2. Accurately coordinates approach to work with on-site supervisor and/or other stakeholders;
3. Ensures timely that the work environment is safe and all relevant information and proper and sufficient materials, tools, equipment and personal protective equipment are present;
4. Ensures that installation work according to company procedures can be performed efficiently without problems.

The underlying competencies are: Collaborate and consult, Apply professional expertise, Plan and organize, Follow instructions and procedures.

D1-K1-W2: Places and assembles components and parts.

Description

The novice professional checks (visually) appliances, fittings for damage. During the inspection he takes into account the safety regulations regarding working with hydrogen. He places and assembles components and parts to the installed piping systems. For this purpose he consults regulations and/or manuals. He continuously checks whether the devices, fittings, equipment and piping are connected to each other correctly.

Result

Components and parts are connected and checked.

Behavior

The Beginning Professional:

1. Correctly interprets drawings and assembly instructions and assembles components and parts correctly;
2. Places and assembles components and parts systematically, smoothly and carefully according to applicable quality standards;
3. Uses the materials, tools, equipment and personal protective equipment required to install the hydrogen plant system efficiently and effectively.

The underlying competencies are: Apply professional expertise, Use materials and resources and Deliver quality.

D1-K2: Performs maintenance and troubleshoots problems

Complexity
The entry-level professional uses his knowledge of hydrogen technology, insight and a multitude of cognitive and practical skills in the operation of a wide variety of technical equipment and installations. When troubleshooting, he must be able to quickly master the specifications and regulations of the equipment or installation involved, and his analytical abilities and technical acumen are greatly called upon. If necessary, he must be able to break down the problem encountered and make connections between possible causes. He must be able to think ahead about steps to be taken, anticipate obstacles and separate facts from assumptions. He works according to standard methods and protocols and decides in what combinations he applies them. (Hazenberg and Hogt 2022)

Responsibility and independence
The entry-level professional has an executive role and works independently. He does his work within the standards and safety requirements of the manufacturer of the installation and those of the client/customer. Generally he works alone and has direct contact with clients. He reports to his technical supervisor. He is responsible for his own safety and the correct execution of maintenance work within the time allowed.

Subject knowledge and skills
The beginning practitioner: (SEE D1-K1) there it is completely summarized. May drop this section below, or use subset of earlier section.

D1-K2-W1: Locates and analyzes problems

Description
If possible, the novice professional makes inquiries with the person who operated the system and reported the complaint about circumstances under which the complaint first occurred and when it did or did not occur. Depending on the data and his suspicion of the location of the malfunction, he tries to rule out various options and looks specifically for the part of the system where the problem may be. If necessary, he disassembles parts of the equipment or installation. Where necessary, he listens, looks and feels again to get as complete a picture as possible of the problem. If necessary, he performs additional measurements and tests. He reviews all available data about the failure. He draws conclusions about possible causes. He devises possible solutions, whether or not in consultation with his supervisor, which he can implement.

Result
The location and cause of the failure are known, an analysis has been performed and possible solutions devised.

Behavior
–

D1-K2-W1: Locates and analyzes problems

The Beginning Professional:

1. Forms a clear picture of the fault environment using his abstraction ability, technical understanding, professional knowledge and available information;
2. Searches systematically and by following protocols for the location and causes of failure;
3. Demonstrates technical understanding and abstraction skills by making appropriate associations and taking appropriate follow-up steps in searching for the causes of failure;
4. Draws connections between partial data and arrives at logical inferences about the causes of the failure and its location in the hydrogen plant;
5. Handles his tools and monitoring and measuring equipment carefully and in a safe manner;
6. Works orderly and systematically and makes every effort to adequately resolve the breakdown in the least amount of time possible.

The underlying competencies are: Apply professional expertise, Use materials and resources, Analyze, Follow instructions and procedures, Deliver quality.

D1-K2-W2: Adjusts/repairs equipment, installation and troubleshoots problems

Description

Based on the analysis performed, the novice professional makes a selection of components and parts that he will remove/install in the hydrogen plant system. He disassembles components/parts to be replaced that are not functioning properly. He assembles new components, adjusts and adjusts them in the hydrogen plant system and tests the functioning of the plant with measuring and monitoring equipment. He programs the equipment and ensures that the equipment and the hydrogen plant system operate safely and problems are resolved.

Result

The equipment and/or hydrogen plant system is functioning properly (again).

Behavior

The Beginning Professional:

1. Works quickly and accurately following proper protocols applicable to hydrogen plants;
2. Selects appropriate components and sets/tunes them correctly for the hydrogen plant system;
3. Applies prescribed testing and inspection methods based on his technical understanding and professional knowledge;
4. Programs the equipment and/or hydrogen plant system to meet the manufacturer's required setpoints, operate correctly and meet the client's requirements.

The underlying competencies are: Apply professional expertise, Deliver quality, Follow instructions and procedures, Use materials and resources.

Appendix 10B Hydrogen industry draft curriculum K1319 (version 11-4-2023

Table 10 Hydrogen in industry training structure

KD (professional knowledge and skills)	class week	lesson hour Block of 2 hours	Main group	Description
basic	1	1	introduction	Introduction to hydrogen technology course
basic/D1-K1-2c	2	2	introduction	Background energy transition Climate agreement/EU Fit for 55, CES and Before and cons $_{H2}$, Resource use, rare earths, Water, space occupation,
basic	3	3	introduction	Hydrogen Basic Concepts Physical & Chemical properties, Gas quality Conversion methods
D1-K1-1a	4	4	Safety	Permits and regulations environmental permit, QRA study, BZRO, Hydrogen calamity abatement
D1-K1-1b/c /1e - D1-K1-5a/D1-K1-2c	5	5	Safety	Hydrogen ATEX and Ventilation - PED, Maintenance plan and causes of failure, Hydrogen materials and Embrittlement (Friability)
D1-K1-1b/1C/1f	6	6	Safety	Hydrogen safety Site and Installation safety, /ESD/SIS and Hydrogen PPE guidelines for site , Risk inventory HAZOP,
D1-K1-2b	7	1	Downstream	Hydrogen Technology, Production 1, incl. Colors hydrogen green, blue, gray.+ CCS technology - Project Porthos plus simulation show models
D1-K1-2b	8	2	Downstream	Hydrogen Technology, electrolysis
	9	3	Downstream	Utilities (Nitrogen and air), Water treatment
D1-K1-2b	10	4	Downstream	Hydrogen Technology, Power Supply, Hydrogen Technology, Measuring Equipment and sensors
D1-K1-6b/6c	11	5	Downstream	Hydrogen Technology, PLC/ESD/SIS/ Process control
	12	6	Downstream	Excursion to hydrogen downstream facility or Lab assignment

KD (professional knowledge and skills)	class week	lesson hour Block of 2 hours	Main group	Description
D1-K1-2b	13	1	Midstream	Hydrogen Technology, storage
	14	2	Midstream	Imports, TSO (HYway27) DSO, energy islands incl. economy
D1-K1-2b	15	3	Midstream	Hydrogen infrastructure TSO - DSO
	16	4	Midstream	Hydrogen blending , Hydrogen and heat grids
	17	5	Midstream	Hydrogen fueling stations
D1-K1-2b	18	6	Midstream	Hydrogen Technology, Compression
	19	1	Upstream	Hydrogen Boilers, Gas Turbines
	20	2	Upstream	Hydrogen in built environment, Hydrogen Energy Hubs
	21	3	Upstream	Hydrogen fuel cells
	22	4	Upstream	Hydrogen as a chemical feedstock NH3 LOHC DME Methanol
D1-K1-3a	23	5	Material - couplings	Hydrogen couplings - Weld - flange - Clamp couplings - Swagelok
D1-K1-2a	24	6	Business and case notes	Business Economics. Merit order - Budgeting - Basic engineering process and study cases for review

Appendix 10C Classification of 240 SBU study load accumulated for Hydrogen in Industry



Figure 4 Classification of study load of 240 SBU constructed

Appendix 10D Regulation of the Minister of Education, Culture and Science of April 26, 2022, no. MBO/32384870 amending the Regulation establishing elective courses in Hydrogen



Figure 5 Government Gazette publication hydrogen training programs

Regulation of the Minister of Education, Culture and Science of April 26, 2022, no. MBO/32384870 amending the Regulation on the Establishment of Choices in Connection with the Establishment and Cancellation of Choices The Minister of Education, Culture and Science, Having regard to article 7.2.4, second paragraph, subsection d, of the Education and Vocational Education Act and article 17d, first paragraph, of the Examination and Qualification Decree on Vocational Education and Training WEB; Decree: ARTICLE I The Regulation on the Establishment of Choices is amended as follows. (Dijkgraaf, Robert H: 2022)[75]

Naam keuzedeel	Code	Aantal sbu	Nieuw of bestaand
Waterstoftechnologie in de gebouwde omgeving	K1318	240	Nieuw
Waterstof in de industrie	K1319	240	Nieuw

Figure 6 Government Gazette publication hydrogen training industry and built environment

[75] Government Gazette 2022, 12020 | Government.nl > Official Announcements (officielebekendmakingen.nl)

Appendix 11 Hydrogen in industry can be chosen for these qualifications

Students with background training according to these recognized program code CREBOs can participate in the elective course Hydrogen in Industry.

Table 11 SBB qualifications for MBO Hydrogen in industry (Foundation for Vocational Education Business (SBB) 2023)[76]

CREBO	Qualification	File	Level
25345	All-round operations technician	Operational Engineering	4
25267	First mechanic gas, water and heat distribution	Infratechnology	3
25268	First mechanic gas stations	Infratechnology	3
25340	First mechanic mechatronics	Mechatronics	3
25304	First mechanic service and maintenance electrical engineering and instrumentation	Service and maintenance technology	3
25305	First mechanic service and maintenance gas turbines	Service and maintenance technology	3
25306	First mechanic service and maintenance mechanical engineering	Service and maintenance technology	3
25307	First mechanic service and maintenance mechanical installations	Service and maintenance technology	3
25348	First mechanic utility	Mechanical installations (assembly)	3
25341	Electrical Systems Mechanic	Mechatronics	2
25346	Operations technician	Operational Engineering	3
25297	Engineering technician	Middle Management Engineering	4
25344	Technician mechatronics systems	Mechatronic systems	4
25309	Technician service and maintenance electrical engineering and instrumentation	Service and maintenance technology	4
25310	Technician service and maintenance mechanical engineering	Service and maintenance technology	4
25311	Technician service and maintenance mechanical installations	Service and maintenance technology	4

[76] MySBB - Qualification Registry (s -bb.co.uk)

Annex 12A (Zinke, Sector Analysis: Erzeugung, Speicherung und Transport von Wasserstoff 2022) Functions

1) Sub-process planning and development of installations:
   a) Task Cluster Planning and Projecting:
      i) Typical eligible occupations:
      ii) Technical systems planner - electrical systems (IH) specialization;
      iii) Technical systems planner - steel and metal structural engineering (IH) specialization;
      iv) Technical systems planner - supply and equipment engineering (IH) specialization;
      v) Technical product designer - specialization in machine and plant construction (IH).
   b) Task Cluster Programming:
      i) IT specialist - digital networking (IH) specialization.
2) Building subprocess installations:
   a) Job cluster Production typical occupations to be considered:
      i) Installation technician (industrial and commercial);
      ii) Plumbing, heating and air conditioning (HW, IH) installation technician;
      iii) Tank and equipment manufacturer (HW);
      iv) Industrial mechanic (industrial and commercial);
      v) Machinist (industrial and commercial);
      vi) Mechatronics (industrial and commercial);
      vii) Electrical installer (industrial and commercial);
      viii) Electronics specialist - automation technology specialization (industrial and commercial);
      ix) Electronics specialist - business technology specialization (industrial and commercial);
      x) Electronics specialist - specialization in building and infrastructure systems (industrial and commercial);
      xi) IT specialist - specialization in digital networks (industry and commerce);
      xii) IT specialist - system integration specialization (industry and commerce);
      xiii) IT specialist - application development specialization (industry and commerce).
   b) Task cluster Assembly
      i) Installation Technician (IH);
      ii) Plumbing, heating and air conditioning (HW, IH) installation technician;
      iii) Industrial mechanic (industrial and commercial);
      iv) Electrical installer (industrial and commercial);
      v) Electronics specialist - automation technology specialization (industrial and commercial);
      vi) Electronics specialist - business technology specialization (industrial and commercial);
      vii) Electronics specialist - energy and building technology (HW) specialization;
      viii) IT specialist - specialization in digital networks (industry and commerce);
      ix) IT specialist - system integration specialization (industry and commerce);
      x) Mechatronics (IH).

3) Part process installations control and commissioning:
   a) Task Cluster: Checking:
      i) Installation technician plumbing, heating and air conditioning (IH);
      ii) Installation Technician (IH);
      iii) Industrial Mechanic (IH);
      iv) Mechatronics (IH);
      v) Production Technologist (IH);
      vi) Electrician (IH);
      vii) Automation Technology (IH) Electronics Technician;
      viii) Electronics Business Engineering (IH);
      ix) Building and Infrastructure Systems (IH) Electrician;
      x) IT specialist - application development (IH);
      xi) IT specialist - digital networks (IH);
      xii) IT specialist - systems integration (IH);
   b) Task cluster: programming, configuration and commissioning;
      i) Automation Technology (IH) Electronics Technician;
      ii) Electronics Business Engineering (IH);
      iii) Building and Infrastructure Systems (IH) Electrician;
      iv) IT specialist - application development (IH);
      v) IT specialist - digital networks (IH);
      vi) IT specialist - systems integration (IH);
      vii) Mechatronics (IH).
4) Operate sub-process installations:
   a) Technical process monitoring, process control and control;
      i) Chemical Technician (IH);
      ii) Chemistry Production Specialist (IH).
5) Monitor sub-process installations:
   a) Cluster of tasks: Monitor the safety of installations in the context of normal operation, prevent malfunctions and emergencies, act on incidents, IT security and cyber defense, Repel and prevent hazards (preventive fire protection), Monitor installations:
      i) Monitor plant safety in the context of normal operation, prevent malfunctions and emergencies, act in case of incidents, IT security and cyber defense, ward off and prevent dangers (preventive fire protection):
         (1) IT specialist - digital networks (IH);
         (2) Safety and Security Officer (IH);
         (3) Company Firefighter/Woman (IH).
6) Maintain subprocess installations:
   a) Job Cluster: Perform regular overhauls, check parameters, troubleshoot failures and emergencies, modify and expand installations:
      i) Professional maintenance training:
      ii) Chemical Technician (IH);
      iii) Industrial Mechanic (IH);
      iv) Installation Technician (IH);
      v) Mechatronics (IH);
      vi) Electrician (IH);
      vii) Automation Technology (IH) Electronics Technician;
      viii) Electronics Business Engineering (IH).

7) Subprocess Installations Maintenance:
   a) Task Cluster: Perform regular overhauls, check parameters, troubleshoot failures and emergencies, modify and expand installations:
      i) Maintenance appeals;
      ii) Chemical Technician (Industrial and Commercial);
      iii) Industrial Mechanic (Manufacturing and Trade);
      iv) Installation Engineer (Industry and Trade);
      v) Mechatronics (Industry and Commerce);
      vi) Electrician (Industry and Commerce);
      vii) Automation Electrician (Industry and Commerce);
      viii) Electrician for business technology (Industry and Commerce);
      ix) IT Specialist - FR Digital Networks (Industry and Commerce).

In German education and vocational training, "IH" refers to "Industrie- und Handelskammer," which can be translated into Dutch as Chamber of Commerce and Industry. This is an organization responsible for supporting businesses and entrepreneurs and promoting economic growth in a particular region of Germany. The IH offers various services, including providing education and training for employees in various professions and sectors, providing advice and information to entrepreneurs and issuing certificates and diplomas upon completion of education and courses.

Table 12 Breakdown of functions EQF score list (Zinke, Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff 2022)

Germany Zinke job level EQF	**Number**	**Percent**
EQF level 3	3	12,5%
EQF level 3-4	2	8,3%
EQF level 4	7	29,2%
EQF level 5	1	4,2%
EQF level 5-6	9	37,5%
EQF level 6-7	2	8,3%
Total	24	100,0%

Table 13 Breakdown of functions on VO. MBO, HBO and WO list (Zinke, Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff 2022)

Germany Zinke job level training	**Number**	**Percent**
VMBO	0	0,00%
MBO	12	50,00%
HBO	10	41,67%
WW	2	8,33%
Total	24	100,00%

Annex 12B (Zinke, Sektoranalyse: Erzeugung, Speicherung und Transport von Wasserstoff 2022, 32) competences

1) Table 7: Excerpt from the Training Framework for Professional Training in Production Technologist/Technologist (see BMWi 16.06.2008; BMWi June 2018) No. 3.1.
   a) Part of the professional profile:
      i) Determine, test and set process parameters (§ 3 paragraph 2 section A no. 3.1).
   b) Skills, knowledge and abilities to be transferred including independent planning, execution and control:
      i) Analyze products related to production processes.
      ii) Select production processes, process steps, production equipment, tools, fixtures, resources and production parameters.
      iii) Perform test runs, adjust process parameters, document results and use them to create and optimize process requirements.
      iv) Select test methods and means, plan measurements and tests, sample instructions and prepare test plans.

2) Table 8: Extract from the training framework for the profession of Mechatronics (see (BMWi June 2018)
   a) Part of professional image:
      i) Commissioning and operation of mechatronic systems (§ 3 para. 2 no. 20)
   b) Skills, knowledge and abilities to be imparted under including independent planning, execution and control:
      i) Testing protection against direct contact.
      ii) Testing the effectiveness of protective measures, especially fault current protection, measuring insulation, grounding and loop resistances.
      iii) Testing of mechanical and electrical safety devices, especially emergency stop switches and notification systems for their effectiveness.
      iv) Testing of auxiliary and control circuits including associated signal and command devices for measurement, control and monitoring systems and commissioning
      v) Testing main circuits and stepwise commissioning, determining measured values, setting target values.
      vi) Commissioning of fluidic systems.
      vii) Test and adjust mobility, sealing, running rest, rotation frequency, pressure, temperature and displacement trajectories.
      viii) Check and ensure attachment, power supply, lubrication, cooling and drainage
      ix) Load and secure programs and data, control and adjust program flow.
      x) Testing and commissioning of signal transmission systems, in particular fieldbuses
      xi) Commissioning of mechatronic systems, performing function tests.
      xii) Testing measures for electromagnetic compatibility.
      xiii) Determine system parameters during commissioning, compare with prescribed values and set.
      xiv) Operating machines and systems, performing test runs at nominal and limit values) Testing and commissioning of signal transmission systems, especially fieldbuses.
      xv) (k) Commissioning of mechatronic systems, performing function tests.

3) Table 9: Extract from the training framework for vocational training in Industrial Mechanics (see (BMWi 28.06.2018b) Seq. No. 14
   a. Part of vocational training
      i. Ensuring operational suitability of technical systems (§ 11 para. 1 no. 14)
   b. Skills, knowledge and abilities to be transferred including independent planning, execution and control:
      (i) Identify malfunctions of machines and systems while respecting interfaces and isolate faults
      (ii) Identify fault and error causes, assess resolution options and perform or arrange for repair or improvement
      (iii) Inspect installations and systems, ensure operational readiness
      (iv) Ensure or improve the functionality of machines and systems by regulating, controlling and monitoring movements and their auxiliary systems
      (v) Apply protective and safety devices and check their function

4) Table 11: Extract from the training plan for the chemical technician profession (see BMWi 10.06.2009).
   a) Current issue I 3.27 - Part of professional profile:
      i) Installation security (§ 4 paragraph 2 section I number 3.2).
   b) Skills, knowledge and abilities to be imparted including independent planning, execution and control:
      i) Note explosion zones, ignition protection classes and temperature classes;
      ii) Identify and monitor equipment for plant safety and take company-specific measures in case of failures.
   c) Current issue I.10 Part of professional profile:
      i) Operation of production facilities (§ 4 paragraph 2 section I number 10);
      ii) Skills, knowledge and abilities to be imparted including independent planning, execution and control;
      iii) Describe production processes including transport and disposal and taking into account environmental protection measures;
      iv) Start and stop and operate the plant or parts of the plant within the operating instructions;
      v) Part of the vocational training profile (See BMWi 10.06.2009) II.1)
      vi) Production processes (§ 4 paragraph 2 section II number 1);
      vii) Skills, knowledge and competencies to be conveyed through involvement in independent planning, execution and control;
      viii) Participate in the planning of production processes;
      ix) Produce inorganic, organic, polymer or bio and genetic engineering products in compliance with reaction behavior and legal and operating regulations;
      x) Perform process controls;
      xi) Inspecting products.
   d) Current issue II.2 Part of the vocational training profile:
      i) Processing technique (§ 4 paragraph 2 section II number 2).
   e) Skills, knowledge and competencies to be conveyed through involvement in independent planning, execution and control:
      i) Participate in the planning of treatment processes;
      ii) Commissioning of plants and sub plants for processing substances according to operating instructions;
      iii) Perform preventive maintenance; take action on malfunctions;
      iv) Document processing processes and perform quality checks.

5) Table 12: Extract from the training framework for the position of production specialist in chemistry (cf. (BMWA 23.03.2005) Lfd. No. 10
   a) Part of the vocational training profile:
      i) Operating equipment (§ 5 No. 10).
   b) Skills, knowledge and abilities to be taught including independent planning, execution and control:
      i) Take over and provide input and auxiliary materials, perform goods receipt checks;
      ii) Ensuring business readiness of equipment;
      iii) Turning equipment or parts of equipment on and off;
      iv) Operate and monitor equipment or parts of equipment according to company instructions.

1) Table 14: Extract from the training framework for the profession of IT specialist in digital network specialization (compare BMWi 28.02.2020) Item 3:
   a) Part of professional image:
      i) Work with connected systems and ensure system availability (§ 4(6)(3)).
   b) Skills, knowledge and abilities to be imparted, including independent planning, execution and control:
      i) Monitor system load and documentation of system status;
      ii) Collect system data and perform evaluations based on specified parameters, as well as detect and resolve system malfunctions;
      iii) Analyze data to optimize maintenance intervals and process workflows;
      iv) Analyze system, diagnostic and process data, identify weaknesses and take action;
      v) Distinguish and anticipate attack scenarios in cyber-physical systems;
      vi) Detect anomalies in connected systems and initiate protective measures;
      vii) Implement solutions for security in specific areas;
      viii) Perform system updates and suggest optimizations.

1) Table 16: Excerpt from the framework plan for the professional training of the mechanic (compare BMWi 28.06.2018c) Serial number 16
   a) Part of the professional profile:
      i) Maintenance; Identification, mitigation and correction of faults and malfunctions (§ 7 para. 1 no. 16).
   b) Skills, knowledge and competencies to be transferred including independent planning, execution and control:
      i) Inspect installations or components, identify faults, damages and failures;
      ii) Perform preparatory measures for maintenance of plant components in compliance with process and safety technical regulations;
      iii) Check parts for wear and damage;
      iv) Put plant components or supply equipment out of operation in compliance with safety and process regulations;
      v) Maintain installations or components;
      vi) Repair installations or components;
      vii) Document inspection results and maintenance measures.

1) Table 17: Excerpt from the framework plan for professional training of the process operator, related to maintenance (compare BMWi 10.06.2009). Serial number I.12:
   a) Part of the professional profile:
      i) Maintenance of production facilities (§ 4(2) Section I No. 12).
   b) Skills, knowledge and competencies to be transferred including independent planning, execution and control:
      i) Shut down production facilities for repair and maintenance in compliance with safety regulations and process conditions;
      ii) Replace assemblies and parts in compliance with specific assembly conditions;
      iii) Secure and transport assemblies and parts;
      iv) Perform and document preventive maintenance of production facilities.

1) Table 18: Extract from the training framework for the profession of Mechatronics (see (BMWi 28.06.2018a) item 21):
   a) Part of the professional image of the program:
      i) Maintenance of mechatronic systems (§ 3 paragraph 2 number 21).
   b) Skills, knowledge and abilities to be conveyed through independent planning, execution and control:
      i) Inspecting mechatronic systems, checking the functions of safety devices and documenting inspection results;
      ii) Maintain mechatronic systems according to maintenance plans and preventively replace parts that are worn out;
      iii) Extend devices and modules taking into account their functions and mark parts as to their position and function assignment;
      iv) Troubleshooting by rework and replacement of parts and modules;
      v) Software bug fixes;
      vi) Compare and set system parameters with prescribed values;
      vii) Repair mechatronic systems while respecting business processes;
      viii) Adapting mechatronic systems to changing operating conditions;
      ix) Using diagnostic and maintenance systems.

Appendix 13A Institute for innovation and Technology functions.

1) Academic professions, the hydrogen system is multidisciplinary:
   a) Energy/Renewable Energy;
   b) Civil engineering/High and low-rise buildings;
   c) Climate Engineering;
   d) Electrical engineering and industrial informatics;
   e) Software development;
   f) Materials Science;
   g) Mechanical Engineering;
   h) Industrial engineering/ Process engineering;
   i) Metal machining;
   j) Fluid Dynamics;
   k) Metrology;
   l) Assembly;
   m) Design tools;
   n) Quality, Safety and Environment.

Hydrogen specific knowledge and skills to design and manufacture electrolysers, fuel cells and other technical equipment, for example, to produce steel (H2-DRI
Hydrogen Direct Reduced Iron) or chemical plants (PtX) to establish and operate.

2) Digital skills for $_{H2}$ technology/economics:
   a) Software Engineer;
   b) Data science researcher;
   c) Software Developer.

3) Connection between digital and physical work:
   a) Modeling and design of parts, components and systems (CAD);
   b) Simulation of parts, components and systems;
   c) Manufacture of parts and components (CNC);
   d) Testing of parts, components and systems;
   e) Planning and construction of equipment and infrastructure;
   f) Integration and real-time operation of equipment and systems;
   g) Optimization, modernization and upgrading of equipment and systems.

4) Physical work:
   a) Mechanical engineer;
   b) Electrician;
   c) Industrial plant mechanic;
   d) Electrical engineer.

Appendix 13B Institute for innovation and Technology - Currucilium

Safety First - Basic Module:

1. Module introduction of hydrogen as an energy carrier;
2. Module basic principles of hydrogen safety;
3. Module release, mixing and distribution;
4. Hydrogen ignition module;
5. Hydrogen Fires Module;
6. Module explosions: Deflagrations and detonations.

1) Starting level: No or limited theoretical knowledge in engineering and work; not specific to gas and $_{H2}$
   a) Type of training:
      i) Absolute beginners (e.g., students in the elementary year):
         (1) Typical content:
            (a) Chemical and physical characterization of $_{H2}$, its behavior and related practical experiments (production and application);

2) Starting level: education and experience in technical occupations; not specific to $_{H2}$
   a) Type of training:
      i) H2-specific elements to be integrated into vocational training
         (1) Typical content:
            (a) All content of the training for "absolute beginners" plus expansion of specific skills and knowledge in preparation for the first real contacts with $_{H2}$ in traditional environments such as the automotive industry.

3) Starting Level: Demonstrated (certified) industry-specific technical skills, knowledge and experience:
   a) Type of training:

i) continuing education:
         (1) Typical content;
            (a) Similar to the elements to be integrated in vocational training, but more summarized and detailed due to extensive professional experience and know-how.

Appendix 13C University of Dresden MSc program in hydrogen technology and economics

(Institute for innovation and Technology 2022)[77] University Dresden provides the content of an MSc. program with the following content.

Table 14 Dresden International University 2022 MSc. Hydrogen Technology and Economics Program (Institute for innovation and Technology 2022, 14).

Semester	Module	Description	ECTS credits
Semester 1	Module 1	Future role of hydrogen applications - prospects and potential of hydrogen based energy systems	5 ECTS
Semester 1	Module 2	Hydrogen Basics - Fundamentals of the secondary energy carrier hydrogen	5 ECTS
Semester 1	Module 3	Hydrogen energy markets	5 ECTS
Semester 2	Module 4	Hydrogen-based energy systems - value chain of hydrogen	5 ECTS
Semester 2	Module 5	Hydrogen in mobility - application of hydrogen in mobility	5 ECTS
Semester 2	Module 6	Hydrogen in industry - application of hydrogen in industry	5 ECTS
Semester 2	Module 7	Hydrogen in smart buildings - application of hydrogen in building technology	5 ECTS
Semester 2	Module 8	Safety and public acceptance - safety aspects, acceptance and materials technical challenges of hydrogen	5 ECTS
Semester 3	Module 9	Hydrogen networks - national and international	5 ECTS
Semester 3	Dissertation	Master's thesis and colloquium	15 ECTS

[77] 19056 2022 Wasserstoff als Beruf Trends in der Aus - und Weiterbildung, PowerPoint-Präsentation (bremen-innovativ.de)

Appendix 14 Australia hydrogen skills - function folder

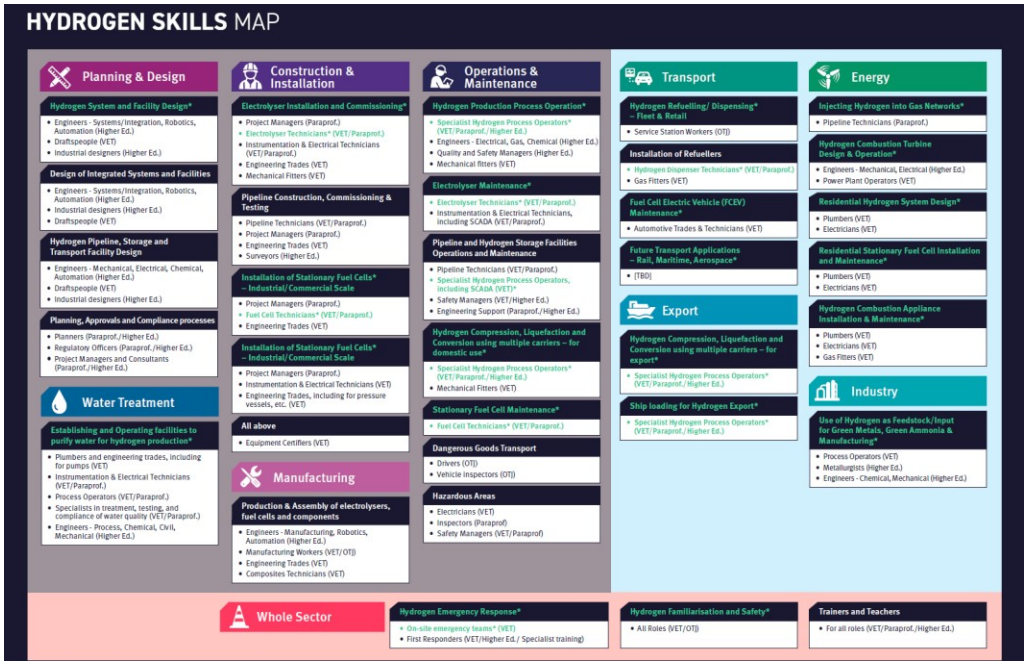


Figure 7 Hydrogen Skills Map Queensland government (Queensland. Department of Employment 2022, 10) *Table 15 Job breakdown EQF score list* *(Queensland. Department of Employment 2022)*

Australia job level EQF	Numb er	Percent
EQF level 1-2	3	5,6%
EQF level 2	1	1,9%
EQF level 3	5	9,3%
EQF level 3-4	4	7,4%
EQF level 3-5	5	9,3%
EQF level 4	7	13,0%
EQF level 4+	2	3,7%
EQF level 4-5	9	16,7%
EQF levels 5-7	1	1,9%
EQF level 6	1	1,9%
EQF level 6+	3	5,6%
EQF level 6-7	12	22,2%
EQF level 7	1	1,9%
Total	54	100,0%

Table 16 Breakdown of jobs on VMBO. MBO, HBO and WO list *(Queensland. Department of Employment 2022)*

Australia job level training	Numb er	Percent
VMBO	4	7,41%
MBO	23	42,59%
HBO	14	25,93%
WW	13	24,07%
Total	54	100,00%

WHICH SKILLS ARE NEEDED? (Queensland. Department of Employment 2022, 9)

The opportunities within the hydrogen industry for Queensland are diverse and will require a wide range of different functions.
Core skills will consistently appear at different stages and types of hydrogen projects, including plumbing, electrical work, process operations and engineering. Different skills and occupations will appear in relation to different hydrogen production processes and end uses, from maintenance of hydrogen-powered vehicles to loading ships for hydrogen export.
The engineers, technicians and specialists who have supported the growth of the LNG industry in Queensland have key skills that will be applicable to many hydrogen production and transportation facilities, including skills in instrumentation and pipeline construction.

Key skills for the hydrogen industry will also include project management, design and workplace safety. The industry will also require many other business and operational functions, including:

1. financial analysis,
2. human resources,
3. Environmental, Social and Governance (ESG) management and compliance.

A strong basic understanding of safety requirements will be essential. Workers with existing skills will need to be retrained to become familiar with the properties of hydrogen, its handling and the pressures at which it must be stored. Experts in hazardous area management, on-site emergency response and quality assurance will also need to develop specialized skills to work with hydrogen. Trainers, assessors, teachers and academic staff will need to be familiar with hydrogen technologies and keep their knowledge up-to-date as the sector evolves.
Renewable hydrogen will require further scale-up of renewable energy generation capacity in Queensland, with increasing demand for new and traditional energy skills and significant demand for construction personnel.

The Hydrogen Skills Map of the (Queensland. Department of Employment 2022, 9) provides insight into skills needs and training pathways for all aspects of the hydrogen value chain. The map shows that there are several training pathways, including vocational education and training (VET), higher education and non-accredited pathways, applicable to about 54 different positions at various knowledge and skill levels.

1) Planning & Design:
    a) Design of hydrogen system and facilities:
        a. Engineers - Systems/Integration, Robotics, Automation (Higher Education);
        b. Signers (VET);
        c. Industrial Designers (Higher Education).
    b) Design of Integrated Systems and Facilities:
        a. Engineers - Systems/Integration, Robotics, Automation (Higher Education);
        b. Industrial Designers (Higher Education);
        c. Signers (VET).
    c) Design of Hydrogen Pipelines, Storage and Transportation Facilities:
        a. Engineers - Mechanical, Electrical, Chemical, Automation (Higher Education);
        b. Signers (VET);

    c. Industrial Designers (Higher Education).
  d) Design planning, approval and compliance processes:
    a. Planners (Para professional/Higher Education);
    b. Regulatory QC officers (Para professional/Higher Education);
    c. Project Managers (Para professional/Higher Education;
    d. Consultants (Higher Education).

2) Water treatment and construction:
  a) Establish and operate facilities to purify water for hydrogen production
    a. Plumbers (VET);
    b. Technical occupations, including pumps (VET);
    c. Instrumentation and Electrical Technicians (VET/Paraprof.);
    d. Process Operators (VET/Paraprof.);
    e. Specialists in water quality treatment, testing and compliance (VET/Paraprof.);
    f. Engineers - process, chemical, civil, mechanical (Higher Education).

3) Construction and installation:
  a) Installation and commissioning of electrolysis plants:
    a. Project Managers (Paraprof.);
    b. Electrolysis Technicians* (VET/Paraprof.);
    c. Instrumentation and Electrical Technicians (VET/Paraprof.);
    d. Technical occupations, practical skills (VET);
    e. Mechanical Engineers (VET);
  b) Construction, commissioning and testing of pipelines:
    a. Pipeline Technicians (VET/Paraprof.);
    b. Project Managers (Paraprof.);
    c. Technical occupations, practical skills (VET);
    d. Surveyors (Higher Education).
  c) Installation of stationary fuel cells* - industrial/commercial scale:
    a. Project Managers (Paraprof.);
    b. Fuel cell technicians* (VET/Paraprof.);
    c. Technical occupations, practical skills (VET).
  d) Installation of stationary fuel cells* - industrial/commercial scale:
    a. Project Managers (Paraprof.);
    b. Instrumentation and Electrical Engineering Technicians (VET);
    c. Technical occupations, including pressure vessels, etc. (VET).
  e) All of the above:
    a. Certifiers of equipment (VET).
  f) Production:
    a. Production and assembly of electrolyzers, fuel cells and components;
    b. Engineers - manufacturing, robotics, automation (Higher Education);
    c. Production labor force (VET/OTJ);
    d. Technical occupations, practical skills (VET);
    e. Composites technicians (VET).

4) Operations and Maintenance:
  a) Hydrogen production process operation:
    a. Hydrogen Process Operator Specialist* (VET/Paraprof./Higher Education);
    b. Engineers - Electrical, Gas, Chemical (Higher Education);
    c. Quality Managers (Higher Education);
    d. Security Managers (Higher Education);

    e. Mechanical Engineering Fitters (VET).
b) Electrolyzer Maintenance:
    a. Electrical Engineer * (VET/Paraprof.);
    b. Instrumentation & Electrical Technicians, including SCADA (VET/Paraprof.).
c) Pipeline and hydrogen storage facilities operations and maintenance:
    a. Pipeline Technicians (VET/Paraprof.);
    b. Hydrogen Process Operator Specialist, including SCADA (VET);
    c. Safety Managers (VET/Higher Education);
    d. Technical Support (Paraprof./Higher Education).
d) Hydrogen compression, fluid making and conversion using multiple carriers - for domestic use:
    a. Hydrogen Process Operator Specialist* (VET/Paraprof./Higher Education).
    b. Mechanical fitters (VET).
e) Stationary fuel cell maintenance:
    a. Fuel Cell Technicians (VET/Paraprof.).
f) Transportation of dangerous goods:
    a. Drivers (OTJ);
    b. Vehicle Inspectors (OTJ).
g) Hazardous areas:
a. Electricians (VET);
b. Inspectors (Paraprof.);
c. Safety Managers (VET/Paraprof.).

5) Transportation:
a) Hydrogen fueling/dispensing - Fleet & Retail;
    a. Service labor force at hydrogen fueling stations (OTJ).
b) Installation of gas stations:
    a. Hydrogen Dispenser Technicians (VET/Paraprof.);
    b. Gas Fitters (VET).
c) Maintenance of fuel cell electric vehicles (FCEV):
    a. TBD.

6) Export:
a) Hydrogen compression, liquid making and conversion using multiple carriers - for export;
    a. Hydrogen Process Operator Specialist (VET/Paraprof./Higher Education).
b) Ship loading for hydrogen export:
    a. Hydrogen Process Operator Specialist (VET/Paraprof./Higher Education).

7) Energy:
a) Injecting hydrogen into gas networks:
    a. Pipeline Technicians (Paraprof.).

8) Design and operation of hydrogen combustion turbines:
    a. Engineers - Mechanical, Electrical (Higher Education):
    b. Power plant operators (VET).
b) Design of domestic hydrogen systems:
    a. Plumbers (VET);
    b. Electricians (VET).
c) Installation and maintenance of stationary fuel cells for residential use:
    a. Plumbers (VET);

   b. Electricians (VET).
d) Installation and maintenance of hydrogen combustion equipment:
   a. Plumbers (VET);
   b. Electricians (VET);
   c. Gas Fitters (VET).

9) Industry:
   a) Use of hydrogen as feedstock/input for green metals, green ammonia and manufacturing:
      a. Process Operators (VET);
      b. Metallurgists (Higher Education);
      c. Engineers - Chemical, Mechanical (Higher Education).
10) Emergency response to hydrogen incidents:
      a. On-site emergency teams (VET);
      b. First responders (VET/Higher Education/Specialist Training).
11) Hydrogen familiarization and safety:
      a. All functions (VET/OTJ).
12) Educators and teachers:
      a. For all positions (VET/Paraprof./Higher Education).

SKILLS AND TRAINING PATHS:

1. Vocational Education and Training (VET);
2. On the job training (OTJ);
3. Higher Education - Bachelor/Postgraduate (Higher Ed.);
4. Para professional - Advanced Diploma or Associate Degree (Paraprof.)

This Hydrogen Skills Map has been developed and tested with industry stakeholders across Queensland.

However, we know that there are many other skills and occupations not shown here. Hydrogen offers huge employment opportunities for Queensland.

Appendix 14B Recommendations from Australia (Queensland. Department of Employment 2022, 15)

The recommendations have been slightly adapted to the Dutch situation.

Focus area 1 Building a pool of skilled and adaptable workers for the hydrogen industry

ACTIONS " Government and industry will work together to:

1. Identify industry-led solutions for hydrogen skills and training to meet immediate industry needs through the VET Emerging Industries Initiative.
2. Conduct pilots of innovative training methods, such as the use of Virtual Reality, to support the delivery of hydrogen-related training.
3. Expand the Gateway to Industry Schools Program (GISP) to create pathways from school-to-hydro jobs and increase student engagement with industry.
4. Develop and test a specific online curriculum for hydrogen for high school students that builds awareness of the industry and required basic skills.
5. Provide a global training infrastructure for top-tier hydrogen.
6. Work with the higher education sector to ensure that university course offerings match the specialized skill needs of the hydrogen industry.
7. Connect the hydrogen industry with universities to offer internships that contribute to skills development and work experience.
8. Foster collaboration among hydrogen proponents, OEMs and other key training providers to share knowledge and skills in hydrogen technology and safety.
9. Better understand emerging skill needs in the hydrogen industry through close collaboration with industry skill advisors.
10. Engage emergency services in national programs to support hydrogen skills development.
11. To implement the draft version of the hydrogen fuel gas safety code.
12. Build safety requirements into training and skills programs.
13. Consider the possibility for a future hydrogen skills partnership or skills academy.
14. Develop a hydrogen industry skills and training toolkit for SMEs.
15. Support local students and workers for involvement in the hydrogen industry and link individuals to relevant government skills and training programs.
16. Connect participants in programs such as "Hydrogen Works" and "Hydrogen Campus Europe" with opportunities in hydrogen-related industries as they develop.
17. Work with regional stakeholders, including local administrators and councils, to deliver local skills and training initiatives linked to job opportunities in the local hydrogen industry.
18. Focus on developing local skills and employing local workers in the hydrogen industry and aiming for a diverse workforce.
    These actions will help promote hydrogen skills development, training and safety to support the industry in achieving its safety and sustainability goals.

Appendix 15 German regulations on various hydrogen functions

Currently, there are no separate requirements for specialized professionals for work related to plant planning, development and construction (H2Pro 2022). Commissioning is performed by qualified persons, depending on the type (initial or re-commissioning after maintenance, modification or cyclic inspection), size and environment of the plant. These persons are employed by the company or work for approved inspection agencies. Persons authorized to perform inspections must demonstrate certain qualifications, which differ for pressure equipment and explosion hazards. They are notified and appointed by the employer. The responsibility for employing professionals lies with the employer.

To operate plants, employers must employ competent persons. According to the Betriebssicherheitsverordnung (BetrSichV), a person is competent if he or she has the required professional knowledge to perform a certain task: The requirements for professional competence depend on the type of task. Requirements include appropriate vocational training, work experience or recent appropriate professional activities. Professional knowledge must be maintained through participation in training courses.

Maintenance work, according to the company safety regulation, may only be performed by qualified, appointed and informed employees or other contractors with similar qualifications to perform maintenance work.

For work on hydrogen pipelines or facilities and for the operation of the facilities, employers must establish suitable protective measures for workers as part of a risk assessment, taking into account the special properties of hydrogen. Appropriate guidelines are being developed by the Deutsche Gesetzliche Unfallversicherung (DGUV). To fulfill their mandate according to §14 of the Social Insurance Act VII (SGB VII), professional associations and accident insurers (accident insurers, UVT) issue regulations for accident prevention in their areas (DGUV regulations).

Appendix 16 VDI Hydrogen crash course hydrogen

(VDI_Wissensforum 2023)[78] Has developed a seminar CrashKurs Wasserstoff for 16 hours of class time, with the following breakdown:

1) Markets and incentives:
   a) What are the hydrogen markets and strategies of the German government, the European Union and globally?
   b) What is stimulated and how?
   c) What developments can be expected due to changing conditions such as CO2 prices?
   d) What has already been accomplished and what steps are next?

2) Hydrogen as a future complementary energy form:
   a) What types of hydrogen are there and what are their advantages and disadvantages?
   b) How does hydrogen compare to other energy carriers?
   c) German government and EU plans: Regulatory benefits of $_{H2}$.
   d) How does the new hydrogen industry work?

3) Technologies and infrastructure:
   a) Electrolysis technology, plant and equipment construction;
   b) Sector integration and electricity required for hydrogen production;
   c) Transportation and infrastructure;
   d) Storage and sequestration of hydrogen;
   e) By-products of hydrogen: Power-to-X and E-fuels from hydrogen, fuel cell technology;
   f) Technology;
   g) Potential cost savings;
   h) Mass production;
   i) Fuel cell systems.

4) Applications and uses of hydrogen:
   a) Markets for plants, machinery and vehicles that use hydrogen;
   b) Hydrogen use in mobility;
   c) Hydrogen use in industry (energy and equipment);
   d) Hydrogen use in building energy supply;
   e) Machinery and plant construction;
   f) Use of synergies in the use of hydrogen.

5) Technical challenges and problems:
   a) Hydrogen softening in metal and plastic;
   b) Pressure resistance of components;
   c) Density of components;
   d) Sensor technology;
   e) Direct hydrogen combustion in engines.

[78] 19056 2022 Wasserstoff als Beruf Trends in der Aus- und Weiterbildung, PowerPoint-Präsentation (bremen-innovativ.de)

6) Looking ahead to further developments:
   a) Mass production of plants and components;
   b) Miniaturization;
   c) Market and cost evolution of hydrogen and electrolysers;
   d) Hydrogen requires gas as a bridge technology.

Appendix 17 University of Oldenburg hydrogen for profession and leadership

After completing this (University_Oldenburg 2023)[79] 'Wasserstoff für Fach- und Führungskräfte-' continuing education, students will have application-oriented professional knowledge on planning, implementing and evaluating hydrogen projects. They provide you with interdisciplinary know-how on technology, grid integration, approval, legislation and financing. You can view projects from different perspectives and communicate with all stakeholders involved. The program covers four main aspects:

1. Actors, strategies and political framework:
    a. Hydrogen as key to decarbonization:
        i. Basic strategies for avoiding $_{CO2}$;
        ii. $_{CO2}$ avoidance in individual sectors;
        iii. Sector integration and storage.
    b. Hydrogen in energy and industrial policy:
        i. International level;
        ii. National level and states;
        iii. Regional level.
    c. Industry Perspective:
        i. Production, transportation, provision and application;
        ii. Overview of actors.

2. Hydrogen technology:
    a. Generation:
        i. Electrolysis;
        ii. Other modes of provision;
        iii. Components and process steps;
        iv. Storage.
    b. Transportation including all components and processes
    c. Applications and examples from industries:
        i. Basic processes and equipment for hydrogen application;
        ii. Mobility and transportation;
        iii. Industry;
        iv. Conversion to other energy carriers (Power-to-Fuel);
        v. Heating, hot water and industrial heat.
3. Added value, business models, legal framework and technical operations:
    a. Demand-side perspective;
        i. Price sensitivities and expectations;
        ii. Demand quantities and climate benefits.
    b. Energy-economic and legal frameworks:
        i. Renewable energy procurement;
        ii. Transport, trading and storage of renewable gas;
        iii. Legal aspects of licensing.
    c. Evaluation of delivery concepts:
        i. Economic perspective: determination of H2 $_{production\ costs}$;
        ii. Ecological perspective: life cycle analysis;
        iii. Opportunities and risks;
        iv. Case studies.

[79] https://uol.de/weiterbildung-wasserstoff

   d. Concepts and rough sketches for supply chains:
      i. Simple concepts;
      ii. Concepts with renewable energy producers;
      iii. Multi-level concepts.
4. Project work: From Theory to Practice:
   a. During the 24-week study period, trainees will work continuously on a project and develop it to the approval and financing stage. In the project, the different aspects of hydrogen technologies (technical characteristics, process engineering, business models, licensing, financing and operations) are practically addressed and implemented from different perspectives. The work is done in small teams with regular attendance and online meetings and is supervised at all stages by a mentor team.
   b. Excursions:
      i. As part of the training, there will be field trips to pilot plants in the region to learn about the dimensions of H2 projects and their components on site and to interact with responsible actors on site;
      ii. Together with project work and guest teacher experts, they form the connection between theory and practice.



Figure 8 training model of University of Oldenburg Hydrogen for professional and managerial staff (University_Oldenburg 2023)

Appendix 18 New Energy Business School Hydrogen Specialist

1) Main track:
   a) Energy production: from fossil to renewable, intermittency, CC(U)S and the role of hydrogen;
   b) Energy transport and storage: electrons versus molecules, natural gas infrastructure for hydrogen;
   c) Hydrogen geopolitics and economics;
   d) Energy markets: characteristics, economics, propositions, PPAs and forecasts, fit with hydrogen;
   e) Hydrogen production, transportation and storage: the colors and economics of the hydrogen value chain;
   f) Hydrogen Transport and Carriers: Liquid Hydrogen, Ammonia, Liquid Organic Hydrogen Carriers (LOHC) and the different pathways to enable a hydrogen economy;
   g) The hydrogen regulatory landscape: actors, hydrogen economics and regulation
   h) Hydrogen in industry: high temperature/raw materials, chemicals, steel, cement and infrastructure;
   i) Hydrogen and the built environment: hydrogen boilers, fuel cells, hybrid heat pumps and HEMS;
   j) Hydrogen in mobility: fuel cells versus batteries, fueling, shipping, aviation and synthetic fuels;
   k) System integration/sector linkage: Power-to-X concept, storage crucial and role of hydrogen - with case study;
   l) Hydrogen outlook: what's at stake for the future? Sunlight to hydrogen, methane pyrolysis and economics;
   m) Gasunie: NortH2 project.
2) Engineering track (#E):
   a) Hydrogenics, Power-to-Hydrogen technology outlook
   b) Stedin: Hydrogen as household energy, built environment sector
   c) Hy-Delta: Project dissemination of the latest research on technical application, safety and regulation.
3) Legal Track (#L):
   a) Policy and legal opportunities for hydrogen technologies Part 1;
   b) Policy and legal opportunities for hydrogen technologies Part 2;
   c) Hydrogen projects in practice: business case.
4) Soft skill track (S.#):
   a) Personal leadership: Who am I. What is the why/how/what in this new role and how can I be empowered within this new environment;
   b) Business development: mapping the playing field and stakeholder management (methods);
   c) Business Development: Understanding the needs of your stakeholders (skill development);
   d) Business Development: Influence and Negotiation Skills;
   e) Business development: presentation skills and end of soft skill training.
5) Site visit:
   a) DNV, hydrogen production system & Serious gaming: North Sea Energy;
   b) Visiting site: Hystock;
   c) Site visit: KIWA;
   d) Site visit: Twinning Energy;
   e) Visiting location: Port of Amsterdam.

6) Finale: Final case study presentations, closing ceremony and visit to the World Hydrogen Summit 2023.

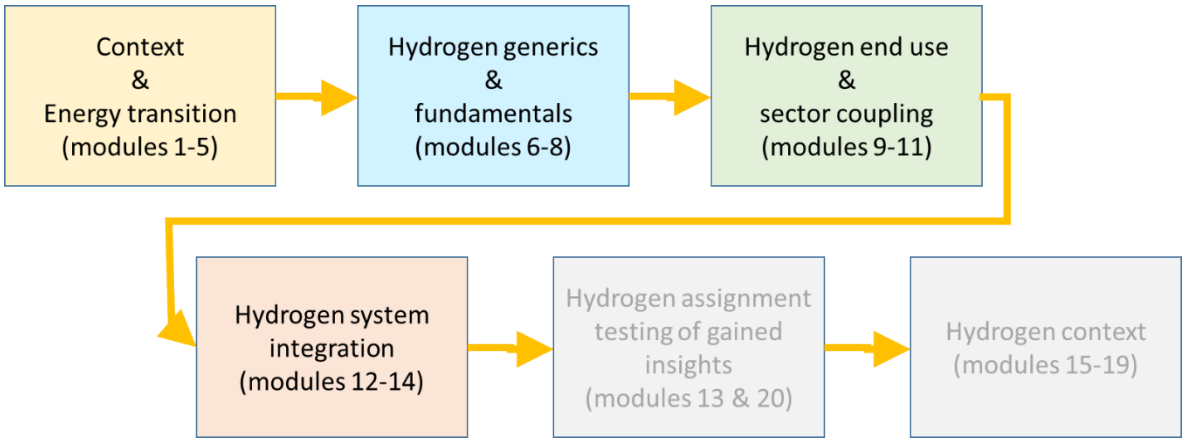


Figure 9 NEBS model hydrogen curriculum (Van Gemert, Joris; Mollema, Anouk; 2022)

Appendix 19A Appel, Schanz, et al - hydrogen value chain overview

Table 17 Overview of the hydrogen value chain (Appel, Schanz, et al., Wissensvermittlung Wasserstoff: Der H_2-Markthochlauf braucht heute Fachkräfte (Teil 1) 2023, 88) The value chain of Appel et al. Is quite broad with respect to the aforementioned study

Production method	**Infrastructure and systems integration**	**Application/use**	**Safety and market launch**
Electrolysis	Integral systems integration	Steel Industry	Safety technical questions
Photoelectronic	Non-lead bound infrastructure	Chemical industry	business models
Photo-biological	Pipeline bound infrastructure	Process heat	Sustainability of H2
Biomass	Medium and large storage systems	Stationary applications, turbines, engines and fuel cells	
Hydrogen via CCS/CCU		Road traffic	
Pyrolysis		Rail traffic	
Geological presence		Shipping	
Synthetic fuels		Aviation	
		Further industrial applications such as e.g. paper	

Annex 19B Hydrogen knowledge transfer: H_2 market acceleration needs specialized workers today (part 2)

The study by (Appel, Schanz, et al., Wissensvermittlung Wasserstoff - Der H_2-Markthochlauf braucht heute Fachkrafte (Teil 2) 2023) lists required functions and segments from the German market perspective.

1. Production:
    a. Electrical Engineer;
    b. Mechanical Engineer;
    c. Storage and renewable energy planner/project manager;
    d. Plant builder (electrolysis);
    e. Networking engineer;
    f. Infrastructure and general systems integration.
2. Infrastructure and systems integration:
    a. Infrastructure planner/project manager;
    b. Installation builder/network builder (electricity and gas);
    c. Labor force in management bodies;
    d. Electrical Engineer;
    e. Mechanical Engineering Engineer;
    f. (Network) master;
    g. Professional specialist in the field of distribution network technology.
3. Pipeline-bound infrastructure:
    a. Networking engineer;
    b. Welding engineer;
    c. Pipeline systems installation technician/installation engineer;
    d. Network senior;
    e. Professional specialist in the field of distribution network technology;
    f. Pipeline builder;
    g. Welder.
4. Application/use:
    a. stationary applications (fuel cell);
    b. Installation builder;
    c. Planner;
    d. Construction Engineer;
    e. Installer;
    f. Installation Manager.

Table 18 Breakdown functions EQF score list (Appel, Schanz, et al.

Germany job level EQF	**Number**	**Percent**
EQF level 2-4	2	9,5%
EQF level 3-4	2	9,5%
EQF level 4-5	3	14,3%
EQF level 5-6	1	4,8%
EQF level 5	1	4,8%
EQF level 4-7	2	9,5%
EQF levels 5-7	1	4,8%
EQF level 6-7	7	33,3%
EQF level 7	2	9,5%
Sum	21	1

Table 19 Distribution of positions on VO. MBO, HBO and WO list (Appel, Schanz, et al.

Germany job level training	**Number**	**Percent**
VMBO	2	8,1%
MBO	6	35,1%
HBO	4	24,3%
WW	9	32,4%
Total	21	

Annex 20A HYDROGEN France breakdown criteria for the 84 functions

The 84 functions are divided in the following ways:

1. Job title;
2. Technical education (yes/no);
3. Level of education for that position:
   a) PhD;
   b) Engineer;
   c) Technician;
   d) Tertiary-level non-technical qualification;
   e) High-School Diploma.
4. Professional qualification (experience, certificates, etc.):
   a) Electrical powers;
   b) HAZID and HAZOP certification;
   c) Knowledge of HAZOP and HAZID methods;
   d) ADR certificate;
   e) ATEX certification;
   f) MASE (safety);
   g) ADR certificate.
5. Degree of knowledge and understanding around hydrogen:
   a) NA;
   b) Basics;
   c) expanded.
6. work activity:
   a) design;
   b) manufacturing/production/construction;
   c) Installation/commissioning;
   d) Operation;
   e) maintenance.
7. High market demand (Yes/No):
8. Component /Application.
   a) Downstream:
      i) Electrolysis
      ii) Purification system ($_{H2}$, $_{H2O}$);
      iii) Biomass-based production system;
      iv) Hydrocarbon-based production system;
      v) $_{H2}$ co-production.
   b) Mid-stream:
      i) Storage system;
      ii) Compression system;
      iii) Transportation system (trailers, trucks, gas network).
   c) Upstream:
      i) Filling stations;
      ii) Heat Pumps (stack & Balance of Plant(BoP));
      iii) Hydrogen mobility from light to small vans;
      iv) heavy transport vehicles (truck and buses);
      v) Hydrogen Injection into the Gas Distribution Network;
      vi) $_{H2}$ trains;
      vii) Sea and river transportation (boats, shuttle boats, barge, coastal shipping;
      viii) $_{H2}$ aircraft;
      ix) Stationary fuel cell (boilers, emergency steam generators);
      x) Industrial processes that utilize hydrogen.

Appendix 20B 2 tables from (Hydrogene France; 2022) regarding these 84 functions

Table 20 Tables from (Hydrogene France; 2022) regarding these 84 functions Part 1

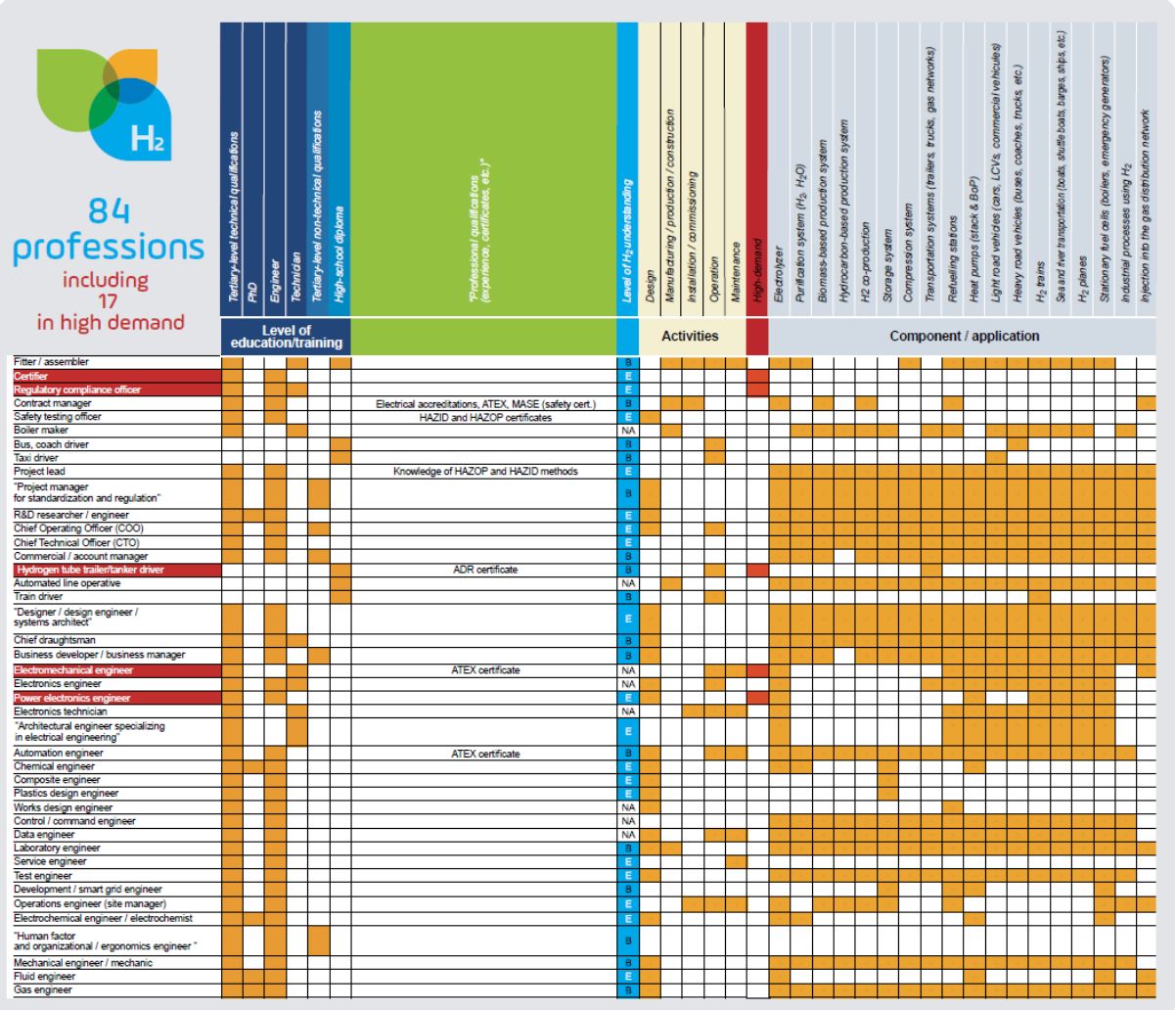
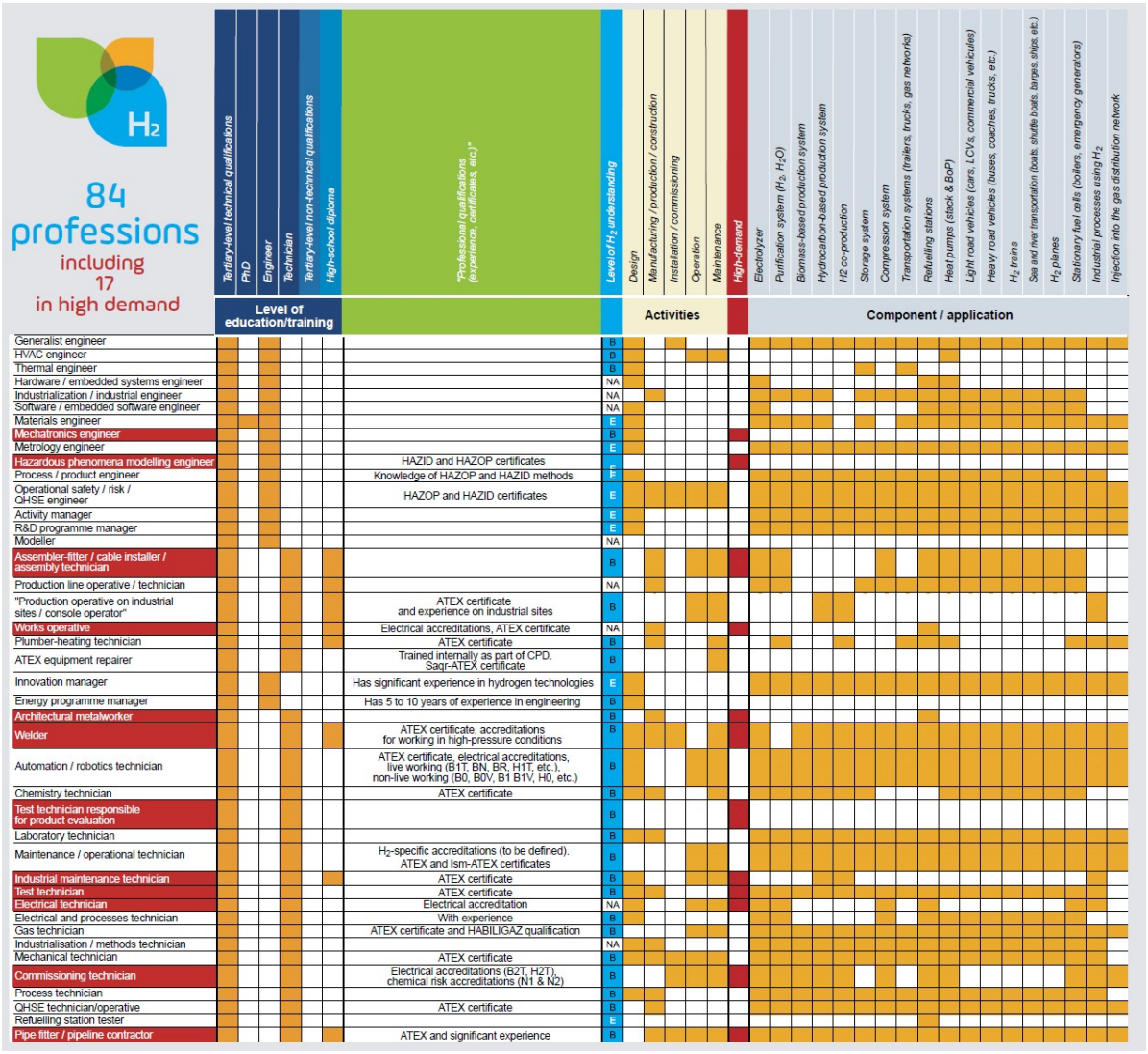


Table 21 Tables from (Hydrogene France; 2022) regarding these 84 functions Part 2



Appendix 20C List of the 84 positions from (Hydrogene France; 2022) report and EQF level

Table 22 List of the 84 positions from (Hydrogene France; 2022) report and EQF level

Job list France	**EAF Level**
Bus and coach driver	EQF level 2
Cab driver	EQF level 2
Mechanic/Assembler	EQF level 2/3
Driver of a hydrogen tube trailer/tanker truck	EQF level 2/3
Operator automated production line	EQF level 2/3
Production worker at industrial sites/console operator	EQF level 2/3
Mechanic/cable installer/assembly technician	EQF level 2/3
Gas station test technician	EQF level 3
Pipe fitter/pipeline contractor	EQF level 3
Safety Testing Officer	EQF level 3/4
Boiler builder	EQF level 3/4
Train driver	EQF level 3/4
Electronics technician	EQF level 3/4
Production line operator/technician	EQF level 3/4
Mechanical operator	EQF level 3/4
Plumber-heater technician	EQF level 3/4
ATEX equipment repairman	EQF level 3/4
Architectural metalworker	EQF level 3/4
Welder	EQF level 3/4
Electrical technician	EQF level 4
Electrical and process technician	EQF level 4
Gas Technician	EQF level 4
Industrialization/methods technician	EQF level 4
Mechanical technician	EQF level 4
Commissioning Technician	EQF level 4
Process Technician	EQF level 4
QHSE technician/operator	EQF level 4
Test technician responsible for product evaluation	EQF level 4
Certification Officer	EQF level 4/5
Cheftekenaar	EQF level 4/5
Automation/robotics technician	EQF level 4/5
Chemistry technician	EQF level 4/5
Laboratory technician	EQF level 4/5
Maintenance/operational technician	EQF level 4/5
Industrial maintenance technician	EQF level 4/5
Test technician	EQF level 4/5
Employee regulatory compliance	EQF level 5/6
Operational safety/risk/QHSE engineer	EQF level 6
Hardware /embedded systems engineer	EQF level 6
Industrialization/industrial engineer	EQF level 6
Software /embedded software engineer	EQF level 6
Contract Manager	EQF level 6/7
Project Manager	EQF level 6/7

Job list France	**EAF Level**
Commercial/account manager	EQF level 6/7
Business developer/business manager	EQF level 6/7
Electromechanical engineer	EQF level 6/7
Electronics engineer	EQF level 6/7
Power electronics engineer	EQF level 6/7
Architect engineer specializing in electrical engineering	EQF level 6/7
Automation Engineer	EQF level 6/7
Chemical engineer	EQF level 6/7
Composite engineer	EQF level 6/7
Plastic design engineer	EQF level 6/7
Mechanical design engineer	EQF level 6/7
Service engineer	EQF level 6/7
Test engineer	EQF level 6/7
Operations engineer (site manager)	EQF level 6/7
Mechanical engineer/mechanic	EQF level 6/7
General engineer	EQF level 6/7
HVAC engineer	EQF level 6/7
Process/product engineer	EQF level 6/7
Activities Manager	EQF level 6/7
Modeler	EQF level 6/7
R&D researcher/engineers	EQF level 6/7/8
Designer/design engineer/system architect	EQF level 6/7/8
Project manager for standardization and regulation	EQF level 7/8
Chief Operating Officer (COO).	EQF level 7/8
Chief Technical Officer (CTO).	EQF level 7/8
Process control engineer	EQF level 7/8
Data engineer	EQF level 7/8
Laboratory engineer	EQF level 7/8
Smart Grid Development Engineer	EQF level 7/8
Electrochemical engineer/electrochemist	EQF level 7/8
Engineer human factors and organization/ergonomics	EQF level 7/8
Fluid engineer	EQF level 7/8
Gas engineer	EQF level 7/8
Thermal engineer	EQF level 7/8
Material engineer	EQF level 7/8
Mechatronics engineer	EQF level 7/8
Engineer modeling hazardous phenomena	EQF level 7/8
Metrology engineer	EQF level 7/8
R&D program manager	EQF level 7/8
Innovation Manager	EQF level 7/8
Energy Program Manager	EQF level 7/8

Annex 20D Technical and non-technical skills. (Hydrogene France; 2022)

1. Energy/renewable energy:
    a. Green design;
    b. Energy (trade) markets;
    c. Smart networks.
2. Civil engineering HVAC engineering.
3. Electrical engineering and industrial informatics:
    a. Automation;
    b. Steering/Control;
    c. Electricity;
    d. Electronics;
    e. Power electronics;
    f. Electrical Engineering.
4. Software engineering:
    a. Cybersecurity;
    b. Programming.
5. Materials science (development and processing):
    a. Composites (including impregnation);
    b. Metallurgy (rolling, processing);
    c. Plastics (including blowing).
6. Mechanical engineering engineering
7. Mechanical Engineering Engineering and Electromechanics:
    a. Electromechanics;
    b. Mechanics.
8. Process Engineering:
    a. Chemistry;
    b. Electrochemistry;
    c. Thermochemistry.
9. Metalworking:
    a. Body Building;
    b. Boiler Construction;
    c. Plumbing;
    d. Welding;
    e. Pipelines.
10. Fluid mechanics:
    a. Fluids;
    b. Gas;
    c. Hydraulics.
11. Metrology:
    a. Physical measurements (features, leaks);
    b. Instrumentation/metering.
12. Construction/assembly
13. CAD software/blueprinting reading tools
14. QHSE (quality, health, safety and environment):
    a. Security (risk management and analysis);
    b. Quality (final product control, regulations, certification, standardization).
15. Good command of English
16. Project Management
17. Commercial negotiation/prospecting
18. Management of/familiarity with industrial sites
19. Team Management

Appendix 20E Identification of the most requested skills related to the components/applications

Table 3 - Identification of the most sought-after skills associated with the components/applications listed[8]

Components/applications



Skills	Electrolyzer	Purification system (H_2, H_2O)	Biomass-based production system	Hydrocarbon-based production system	H_2 co-production	Storage system	Compression system	Transportation systems (trailers, trucks, gas networks)	Refuelling stations	Fuel cell (stack and BoP)	Light road vehicles	Heavy road vehicles	H_2 trains	Sea and river transportation	H_2 planes	Stationary fuel cells	Industrial processes	Injection into the gas distribution network
Energy/Renewable energy	11	9,5	11	8	11	11	9,5	9,5	13	11	10	10	10	10	10	11	9,5	8
Civil engineering	1	0	1	0	1	0	0	0	3	0	0	0	0	0	0	0	0	1
HVAC engineering	5,5	5,5	5,5	6	7,5	6,5	4,5	6,5	7,5	6,5	4,5	4,5	4,5	4,5	4,5	6,5	7,5	6,5
Electrical engineering and industrial data processing	33	25	22	23	24	22	23	20	32	31	26	26	27	27	27	32	23	17
Software engineering	4,5	3,5	3,5	3,5	3,5	4	3,5	3,5	5	5	4,5	4,5	4,5	4,5	4,5	5	3,5	1,5
Materials engineering	12	10	9	9	8,5	12	7	11	13	13	11	11	11	11	11	12	9	7
Mechanical engineering	25	22	21	22	21	22	22	20	27	24	23	23	24	23	23	25	22	15
Process engineering	14	13	10	11	11	13	9,5	9,5	11	16	11	11	11	11	11	14	9,5	8,5
Metalworking	12	11	10	10	10	11	9	11	14	12	11	11	11	11	11	13	11	8
Fluid mechanics	21	19	18	17	18	21	16	17	22	22	16	16	16	16	16	21	18	17
Metrology	18	17	16	18	18	18	14	14	18	18	15	15	15	15	15	18	17	9,5
Build/assembly	15	12	8,5	11	11	9,5	12	8,5	15	14	14	14	14	14	14	15	11	5
CAD software/blueprint reading tools	19	14	11	11	9,5	13	13	12	21	19	17	17	18	18	18	19	11	5
QHSE (Quality, Health, Safety and Environment)	29	24	23	24	24	24	22	22	29	28	26	26	28	26	26	28	22	15

8- The figures correspond to the number of professions requiring the skills listed. A skill may be a key skill, in which case it has a value of 1 in the table. A secondary skill has a value of 0.5.

F igure 10 Identification of the most requested skills related to the components/applications (Hydrogene France; 2022, 24)

Appendix 20E - MBO positions in the hydrogen sector are in high demand and difficult to fill

Table 23 MBO positions in the hydrogen sector in particular are currently in high demand and difficult to fill.

Function	**Knowledge level** [80]
Supervisor, Regulatory Compliance Officer	E)
Electromechanical engineer - ATEX certification	NA)
Construction mechanic/cable installation technician	B-H2)
Work Executive	NA)
Architectural metalworker	B)
Welder - ATEX certification, accreditations for working under high pressure)	B)
Test technician responsible for product evaluation	B)
Industrial maintenance technician	B)
Test Technician	B)
Electrical Technician	NA)
Commissioning Technician	B)
Pipe welder/pipeline contractor	B)

[80] B-H2 = Occupation not requiring in-depth knowledge of H2 issues, E-H2 = Expert skills Expert on hydrogen, N/A - Not applicable Occupation not requiring knowledge of H2

Appendix 21 Ozone Hydrogen training courses

(oZone 2023)[81] is a user-friendly learning environment developed for and by technical companies. On the platform you will find basic learning materials that you can immediately use to train (new) workers. oZone is free of charge for affiliated companies of A+O Metalektro and OOM.

The following modules currently exist. Most modules are between 30 and 45 minutes of online learning course material.

1. Hydrogen engineering: the basics:
    a. What hydrogen is;
    b. Why it is used;
    c. What role hydrogen can play in the energy transition;
    d. What the current and desired situation is.
2. Hydrogen engineering: safety:
    a. The properties of hydrogen;
    b. The risks are of hydrogen;
    c. Safety measures;
    d. Safety procedures.
3. Hydrogen engineering: storage and transportation:
    a. In this module, you will learn about different storage methods and transportation.
4. Hydrogen engineering: production and chemistry:
    a. What is the chemical basis of hydrogen as a storage medium;
    b. How electrolysis works;
    c. How Steam Methane Reforming Works;
    d. What are the advantages and disadvantages of these production methods.
5. Energy storage:
    a. The various options available for energy storage, such as the battery, flow battery, flywheels, CAES, SMES, hydrogen, pumped storage and supercapacitors;
    b. Global how these techniques work;
    c. What the advantages and disadvantages of these techniques are.
6. Hydrogen engineering: marine:
    a. Safety in hydrogen boating;
    b. Onboard storage capacity;
    c. Necessary investments to run on hydrogen;
    d. Availability of hydrogen, safety and regulations during bunkering.
7. Hydrogen engineering: automotive engineering:
    a. How hydrogen fuel cell vehicles work;
    b. How it differs from "regular" electric cars;
    c. Different hydrogen vehicles out there now;
    d. What the developments are in automotive technology.

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Annex 22 EU Erasmus programs around Hydrogen

Table 24 Erasmus programs around hydrogen

Project Name	Description
KnowHy	Focuses on providing training to a broad audience of technicians on basis of modules and practical training
TeacHy	The project focuses on building an extraordinary and complete archive of university-level educational online learning materials
HySkills	Hands-on training focused on the topic of green hydrogen (H2) safety skills
Hy2Green	Specific training program for new professionals adapted to the new energy models based on ICTs. 7 models
NET Tools	Develops e-infrastructure and provides digital e-tools.
HyResponse	Hydrogen Safety, to provide training in hydrogen safety for aid workers throughout Europe.
FCH Observatory	Provides data (statistics, facts and analysis) and current information on the entire hydrogen sector.
FCHgo HySchool	Dedicated to promoting ecological awareness and technological knowledge of hydrogen and fuel cells

Appendix 23 Practice facilities

In order for the students to apply or experience their knowledge in practice, practical facilities are needed where the students can work on their skills around hydrogen equipment.
(Van Greuningen, Suzanne; KIWA 2021) Names the locations below with practical facilities for students. Now the term student is a broad one, and regular MBO students will not be able to go to many of these for practical work. That will be limited to a company visit.

Commercial organizations and grid operators

- Kiwa and grid operator Alliander have jointly built the Netherlands' first hydrogen demo house in Apeldoorn. The Hydrogen Experience Centre is a test and demo location set up as a home that is also used as a training location for mechanics and installers. Here they can learn how the current natural gas supply in residential areas can be made suitable for hydrogen.

- Stedin is running trials in Rozenburg and at The Green Village, where they are converting existing homes from natural gas to hydrogen, and in Uithoorn they have converted some demolition homes to hydrogen heating.

- The Green Village is the testing ground for sustainable innovations on TU Delft's campus. Here, Stedin, Alliander and Enexis Group are testing the paper conclusions about hydrogen on a 'normal' gas grid. In this way they are gaining knowledge and experience with the management and maintenance of a Hydrogen Network in an area where people live and work.

The above practice sites are mainly the training sites and research facilities of the network operators themselves.

Education - Knowledge institutions

RDM Center of expertise

In Rotterdam, there is H2Energylab of Hogeschool Rotterdam, at the innovation dock. Here cooperated with companies such as RDM Rotterdam, Port of Rotterdam Authority, Ennology, and students from various courses can receive hands-on education. This includes training at the HBO level.

If you watch the Video of the RDM Center of expertise you will see mostly small Horizon hydrogen training material is applied. The application is for students of Chemical Technology, Mechanical Engineering, Automotive, Maritime Engineering, Maritime Officer, Technical Informatics (approx. 20 students per semester). (RDM Center of expertise; 2023)[82]

[82] H2EnergyLab - RDM Centre of Expertise (rdmcoe.nl)

Arnhem University of Applied Sciences

(Suurs and Derksen 2023, 7)[83] The Hogeschool Arnhem has the HAN $_{H2}$ Lab[84] , this lab has safety facilities to work with hydrogen, capacity to test up to 11KW a fuel cell, multiple smaller stacks and systems, peripheral equipment BOP Equipment, gas analysis and potentiostat. Provides training courses for ROC, Bachelor and Master level.

Hogeschool Zeeland/Scalda - Flushing

Hogeschool Zeeland/Scalda - Vlissingen is currently working on the construction of the L019 hydrogen laboratory. The purpose of this laboratory is to provide sustainable hydrogen education and practical research for MBO, AD and HBO students, to provide retraining and further education for those working in the field of sustainable hydrogen. (Maas and Tolle 2023)

The L019 laboratory will be commissioned in 2024 and will have the following equipment and activities:

1) A gas cylinder storage for hydrogen (200 bar)
2) Two types of operational electrolysis devices (Alkaline and PEM) with a power of 5-10 kW for educational purposes
3) Two operational fuel cells (2.5 kW and 4-5 kW)
4) A hydrogen boiler as an alternative to a gas-fired central heating boiler
5) A hydrogen compressor (200 bar) with buffer tank and safety devices
6) Installation preparations to achieve a pressure range of 700 bar.

The cost of structural modification and E- and W-installations is between 500 and 600 k, to which is added the inventory about 200 k. The area of the room is 8 x 16 m = 128 m^2 . MBO

(Van Greuningen, Suzanne; KIWA 2021) states there are many projects on education and hydrogen going on right now. Yet the focus is on the Northern Netherlands and there is little to be found specifically for MBO education. Often the projects are more focused on higher education, or combine WO, HBO and MBO. In this, the Hydrogen Experience Centre of Kiwa and Alliander is an exception. Here, facilities have been built to prepare MBO students for the practicalities of working with hydrogen.

[83] Suurs, Roald, and Tjardo Derksen. 2023. ";Kiemt; EMP NL shared research and Test Facilities Overview." *electrolysermakersplatform.nl.* March 2. Opened March 2, 2023. https://www.elektrolysermakersplatform.nl/wp -content/uploads/2023/01/Overview-Shared-Facilities.pdf

[84] HAN H2Lab

EnTranCe

EnTranCe at the Hanze University of Applied Sciences in Groningen is a center of expertise, where education, research and entrepreneurship are given a testing ground to promote energy transition. Hydrogen also plays an important role in this. EnTranCe is an educational institution with the largest scale hydrogen hardware in Dutch educational country. (Suurs and Derksen 2023, 6) Indicates the Hydrohub Megawatt test center where a 250 kW PEM-Stack and a 250 Alkaline electrolysis is located along with the necessary BOP equipment.

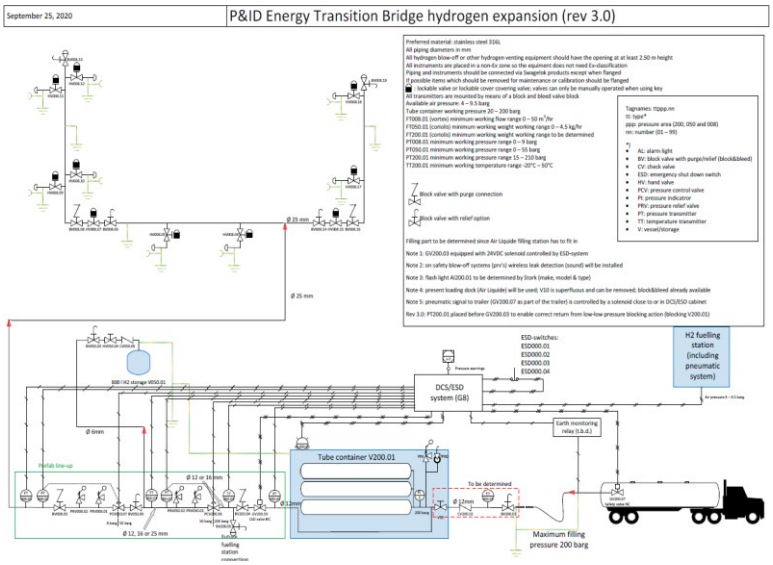


Figure 11 EntranCe Energy Bridge



Figure 13 Hydrogen reducing plant from 200 to 4 bar. EnTrance



Figure 12 EnTranCe location

Facilities for practicals

Drenthe College Hydrogen practice facilities

Using this hydrogen-fueled cell set, students at Drenthe College in Emmen can spend 30 class hours on hydrogen-related knowledge. This Lucas Nülle setup provides an excellent learning environment for students. Currently, Drenthe College is working to develop a much larger innovative hydrogen center, with equipment worth 1.5 million euros. This will give students the opportunity to get even closer to the real industrial environment and gain valuable practical experience.



Figure 14 Hydrogen fuel cell hydrogen training facility Drenthe College

The following practice assignments are possible with the above set (Lucas-Nülle 2023):

1. Design and operation of a fuel cell;
2. Design and operation of an electrolyser;
3. Design and operation of a metal hydride storage tank;
4. Thermodynamics of the fuel cell;
5. Characteristics and power curves of the fuel cell;
6. Efficiency;
7. Required components for autonomous power supply;
8. Power electronics and voltage conversion.

(Hogt, Roeland 2018)[85] has the following practicums and facilities are defined :

1. Hydrogen demo set 1: practical board: energy chain, electrolysis - fuel cell
2. Hydrogen demo set 2: pipes, valves, regulators, sensors,
3. Hydrogen demo set 3: specific auto industry components (hydrogen and EV), composition based on scale model, testing schemes, interplay with batteries
4. Hydrogen demo set 4: Construction of systems, hydrogen CV/combustion components
5. Hydrogen demo set 5: Focus on CHP, systems with coolant circuit



Figure 15 Example of Horizon



Figure 16 Example of Dr. fuel cell[86]

Setting up a hydrogen laboratory for education requires several components. A teaching-oriented hydrogen laboratory is a learning environment in which students can experiment and learn about hydrogen technology. This includes the basics of hydrogen as well as the design and construction of hydrogen systems and applications. Setting up such a hydrogen laboratory for education requires several components. Below are some examples:

- Hydrogen production system: a device that produces hydrogen from water and electricity. Different types of hydrogen production systems are available, such as electrolysis devices and fuel cells.
- Storage system: a container in which hydrogen can be stored. It is important to note that hydrogen is a very light and flammable gas, so safety precautions must be taken to ensure that the storage system is safe.
- Fuel cell: a device that converts hydrogen into electricity and heat. This can be used, for example, to power a vehicle or a building.
- Measuring instruments: various measuring instruments are needed to measure the performance of the hydrogen laboratory, such as a gas chromatograph to measure the purity of hydrogen, a wattmeter to measure the current and voltage, and a pH meter to measure the acidity of the electrolysis solution.
- Teaching materials: to guide students in using the hydrogen laboratory, a variety of teaching materials are needed, including manuals, worksheets, case studies and video materials.

There are several organizations that offer hydrogen laboratory kits for education. These kits contain all the necessary components and teaching materials to set up a hydrogen laboratory. An example of such an organization is Horizon Fuel Cell Technologies.

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[85] Hogt, Roeland, 2018, energy College, Realization of hydrogen technology education plan

[86] h ttp://www.fuelcellstore.com/fuel-cell-education-products/teacher-demonstration/dr-fuel-cell-professional-demo-391

Appendix 24 Plug Power PEM electrolysis maintenance tasks.

(Hyver, Devon; 2021) presentation for maintenance tasks for and PEM electrolysis of Plug Power 1 MW unit.

		Frequency inspection
1)	Overall system:	
	a) Inspect and clean electrical cabinets;	- A
	b) Inspect enclosure, replace air filters;	- A
	c) Inspect and clean air conditioning;	- A
	d) Inspect and clean dry cooler;	- A
	e) Inspect emergency plugs;	- A
	f) Inspect rectifier and check connections;	- A
	g) Calibrate environment hydrogen sensor;	- A
	h) Change condensation package on ambient hydrogen sensor;	- A
	i) Perform corrective actions identified during inspections;	- A
	j) Replace ambient hydrogen sensor.	- 5 years
2)	Water and cooling system:	
	a) Change filters on reverse osmosis unit;	- AN
	b) Check tank levels and glycol concentration;	- AN
	c) Exchange resin in ion exchange filter;	- A
	d) Change carbon filter on water purification system;	- A
	e) Replace filter cartridge;	- A
	f) Clean and lubricate circulation pump(s), check coupling(s);	- A
	g) Change Uv light;	- A
	h) Change DL and conditioning cartridge;	- A
	i) Inspect cooling system;	- A
	j) Change diaphragm and replace gear oil of pump;	- A
	k) Change ultra-microfiltration;	- 5 years
	l) Change glycol/water mixture;	- 5 years
	m) Inspect and replace cooling circuit seal;	- 10 years
	n) Replace pumps	- 10 years
3)	Stack and hydrogen system:	
	a) Check the torque on stack;	- A
	b) Calibrate hydrogen and oxygen sensors;	- A
	c) Change dew point sensor;	- A
	d) Change Drierite Desiccant on gas dryer;	- 5 years
	e) Replace hydrogen sensor;	- 5 years
	f) Replace the measurement sensor of the oxygen sensor;	- 5 years
	g) Replace pressure safety valves;	- 5 years
	h) External inspection of pressure vessel;	- 5 years
	i) Internal inspection of pressure vessel;	- 10 years
	j) Hydrogen stack(s).	- (VARIOUS)

Appendix 25 strategic maintenance and operation strategies goals of HyCC

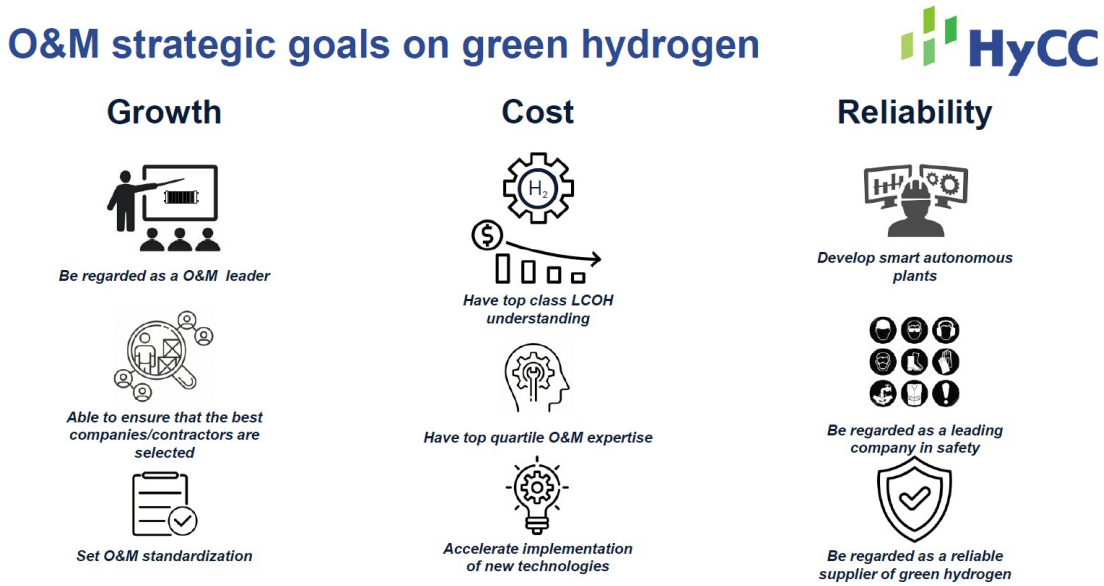


Figure 17 HyCC Operation and Maintenance Strategy (Salet, Victor 2023)

Appendix 26 Labor market supply and demand for labor in FTEs

Hydrogen-related jobs

(Van Wijk and Charzimarkakis 2020, 8)[87] indicate that construction and maintenance of the 2 times 40 GW electrolysis capacity will create between 140,000 and 170,000 jobs through 2030.
Saying goodbye to fossil fuels is not only good for the environment, but also for the labor market, argues Richard van de Sanden, professor and scientific director of sustainable energy institute EIRES. Switching to hydrogen as an energy source could save the Netherlands as much as
Create 41,000 new jobs (From the Sander 2021)[88]

(Spisto, et al. 2020, 13)[89] state that the planned 100 MW hydrogen projects until 2030 in Groningen in Drenthe, give 6,000 FTE of employment during the construction phase and 500 FTE during operation. (Spisto, et al. 2020, 14) mapped the opportunities for economic growth and renewable energy sources technical potential for the Netherlands (NL) and Northern Netherlands (NNL).

Table 25 Overview of labor demand (rounded to the nearest hundred) (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 6)

Year CE Delft study 2021	Demand for green hydrogen PJ	Total one-time employment (average FTE/year)	Recurring employment (average FTE/year)
2030	10 - 40	1.800 - 4.700	4.200 - 12.500
2040	132 - 317	2.000 - 13.000	9.200 - 43.000
2050	254 - 593	2.200 - 20.000	14.200 - 72.600

(EZK, Reijerkerk and Van Rhee, Hydrogen: Opportunities for Dutch Industry, 2019) looked at the opportunities for the Dutch manufacturing industry around hydrogen in the report "Hydrogen: Opportunities for Dutch Industry,"[90] . The study shows that 259 organizations are already involved in hydrogen.

- Maintain the Dutch position of import, storage, processing and transit of (fossil) energy by timely conversion to renewable energy. This concerns €67 billion of added value and 8% of jobs (569,000 FTE).
- Here we looked at the life stage of hydrogen systems and what type of companies operate there such as: design, construction, financing, operation, maintenance and recycle and disposal.
- The integral hydrogen production chain incl. R&D, Standardization, training and then the routes to transportation and distribution, storage and handling, hydrogen production and import as hydrogen as feedstock.
- The systems in the hydrogen chains such as: gas district power plant, buses, $_{H2}$ boilers, distribution grids, pressure tanks, compressors, storage, electrolysis, etc., are the most important.

Studies of the future labor demand for MBO technically trained personnel in the infrastructure and distribution sector related to green hydrogen are only in very limited

[87] Van Wijk, AD; Charzimarkakis, Jorge, MENA Conference 2x40-GW-Green-Hydrogen-Initiative-Mena-Hydrogen-Alliance-20-5-2020. https://dii-desertenergy.org/wp-content/uploads/2020/05/2x40-GW-Green-Hydrogen-Initiative-Mena-Hydrogen-Alliance-20-5-2020.pdf
[88] AD, Meijroos, From the Sander, Richard; 2021, Hydrogen Should Bring Thousands of New Jobs to Netherlands. 7-4-2021, https://www.ad.nl/werk/waterstof-moet-nederland-duizenden-nieuwe-banen-deliver~a3611d20/?referrer=https%3A%2F%2Fwww.linkedin.com%2F
[89] European commission JRC technical report, Spisto A; Gerbelova H; Masera M; Barboni M;2020.,socio-economic impacts of the closure of the Groningen gas field, 2020, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120521/socio-economic_impacts_closure_groningen_gas_field.pdf
[90] EZK, 2019, Hydrogen: Opportunities for Dutch Industry, https://www.fme.nl/nl/system/files/publicaties/Waterstof%20Kansen%20voor%20de%20Nederlandse%20industrie_HR_0.pdf

extent to be found. The above is mainly based on a recent report by CE Delft. The conclusions below are thus linked to the scenarios and related assumptions included in that report.(Van Greuningen, Suzanne; KIWA 2021)

- The one-time labor demand linked to the realization of the hydrogen backbone is estimated at 573 FTE. These additional jobs are expected to be filled by 2030.[91]
- The one-time labor demand linked to the conversion of the distribution network is estimated at 161 FTE. This labor demand occurs only in the 'high scenario', the scenario with both maximum application and maximum own production. It concerns additional jobs over a period of 20 years (2030-2050).
- The recurring labor demand for operation and maintenance will be mainly present in the high scenario and only come on stream in 2040. Labor demand is estimated to be about 3,500 FTE per year in 2040 and 7,000 FTE in 2050. The recurring labor demand is seen as replacement labor.
- In the shorter term (2022-2030), there is already a demand for hydrogen-trained technicians for the grid operators' and Gasunie's pilot projects. Taking into account the lead time for training, an inventory of the required crews and the necessary knowledge is necessary in the very short term.

Actual training of the mechanics required for the work on the hydrogen backbone coming out of the scenario study (2030) will also have to be started these years. Large-scale hydrogen rollout in the built environment is not expected before 2030. Training of mechanics by regional grid operators will therefore be limited to shifts for pilot projects before 2030

So it is especially important to retain jobs that may be lost and to reuse that knowledge **possibly with additional training.**

The ambition in Europe is 1 million highly skilled jobs in the hydrogen economy 2030 and 5.4 million by 2050. (H2 Green skills for Hydrogen, 2023)[92]

According to (Skiba 2020, 46) and the COAG Energy Council Working Group (2019) in Australia's National Hydrogen Strategy, in an optimistic scenario, the hydrogen industry could create 7,600 jobs and generate an additional GDP of 11 billion Australian dollars by 2050.

According to (Hydrogene France; 2022, 3), a budget of 7.2 billion euros is available until 2030 to develop the hydrogen sector in France. The goal is to create 100,000 jobs within the hydrogen sector by 2030.
The study by (Zenk, et al. 2023, 16) describes a hydrogen scenario where in 2030 there is 10 GW of electrolysis capacity in Germany and 28 TWh of domestically produced hydrogen. There is a total hydrogen demand of 50 TWh in 2030 of which 22 TWh must be imported from North Africa. Transportation will be 50% by ship and 50% by pipeline. A hydrogen transmission system will be built by converting gas pipelines and building new, with the share of conversion being 80% and the share of new construction 20%. There will also be an export of electrolysers, with 157 GW of electrolysis capacity available worldwide by 2030, with the German market having 20% of the capacity (Zenk, et al. 2023, 45)[93] state that between 2022 and 2030, the deployment of hydrogen will have a positive impact on the employment of

[91] This HyDelta conclusion is strange, since they want the total national backbone ready by 2027 and international to Belgium and Germany by 2030. Then that one-time staff should be available well before 2030, Possibly as early as 2024-2026.
[92] 2022 H2 Green skills for Hydrogen, Green Skills for Hydrogen
[93] Zenk, Johanna, Anke Mönnig, Linus Ronsiek, Christian Schneemann, Alexander Schur, and Stefanie Steeg. 2023. Abschätzung möglicher Arbeitsmarkteffekte durch die Umsetzung der Nationalen Wasserstoffstrategie bis 2030. BIBB Bundesinstitut fur berufsbildung, Bonn: Bundesinstitut für Berufsbildung, 55. Opened March 1, 2023.

13,000 people in Germany, compared to a scenario in which no hydrogen is applied. Remarkably, German researchers are strongly committed to being a producer of electrolysis equipment, with the goal of achieving a 20% market share.
In a study of nuclear power plant employment and its relation to large power plants, (Schepers, Benno; De Jong Femke; 2009)[94] reported that the construction of a nuclear power plant in Zeeland requires between 2,500 and 3,000 jobs, but that job leakage to foreign countries, other regions and displacement ensures that only
1,500 to 2,800 jobs remain. This means that only 120-150 jobs remain for Zeeland workers.

There will be several reasons for this, but a few are:
1 Components do not come from the Netherlands and that the engineers and commissioning technicians often come with the equipment for installation. In doing so, however, we can be supported by local partners and personnel.
2 There is great tightness in local supply of available workers among installers, bench workers, welders and electricians.
3 Lower rates of foreign workers when you see labor coming from countries like Albania, Poland and the Czech Republic.
4 To a large extent, the decline in the number of MBO students has an unavoidable, demographic background: there are simply fewer young people. But in addition, MBO also suffers from competition from havo. The pressure on young people to go for "higher is better" is still strong (MBO-Today 2023).

Table 26 Potential demand for labor taken from the "Hydrogen North Investment Plan" and "Employment through investment in green hydrogen. This is both one-time and recurring labor demand. HyDelta D4.1 2021, Page 9(Van Greuningen, Suzanne; KIWA 2021, 9) & (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 44)

Year	Region	Demand for Green hydrogen (PJ)	One-time labor demand (in FTW/year)	Recurring labor demand (in FTW/year)
<2030	Netherlands		2,500 FTEs	22,500 FTW
2020-2050	Netherlands		104,000 FTEs	66,000 FTE existing capture, 41,000 FTE new jobs
2020-2025	Northern NL		approx. 5.000	
2025-2030	Northern NL		approx. 25.000	
2030	Netherlands	10-40	1,800-4,700 (low-high)	4,200-12,500 (low-high)
2040	Netherlands	132-317	2,000-13,000 (low high)	9,200-43,000 (low-high)
2050	Netherlands	254-593	2,200-20,000 (low high)	14,200-72,600 (low-high)

The CE Delft study compiled the following breakdown for the grid operator projects.

[94] Schepers, Benno; De Jong Femke;. 2009. Employment through nuclear energy.pdf. Delft: CE Delft, 25. Accessed Mar 5, 2023. https://ce.nl/wp-content/uploads/2021/03/3006_defNotitie_BS.pdf.

Table 27 Total labor demand for gas transmission and distribution network conversion and modification and recurring demand for maintenance and operation of both networks = HyDelta D4.1 2021, (Van Greuningen, Suzanne; KIWA 2021, 10)

Nature of work	Year	One-time demand for labor in FT/Year	Recurring demand for labor (in FTW/year)
Hydrogen backbone construction	2030	573 - 573 (low-high)	
	2040	0 - 0 (low-high)	
	2050	0 - 0 (low-high)	
Adjust distribution network	2030	0 - 0 (low-high)	
	2040	0 - 161 (low-high)	
	2050	0 - 161 (low-high)	
Maintenance and Operation	2030		0 - 0 (low-high)
	2040		0 - 3,500 (low-high)
	2050		0 - 7,000 (low-high)

CE Delft has underestimated the lower limit regarding adaptation of the distribution network. Consider the hydrogen projects in the built environment, such as Lochem, Hoogeveen, Wagenborgen and Stad aan het Haringvliet. These will be operational as early as 2023 and the rest before 2026.

Table 28 Characteristics of labor demand in 2030 (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 40 Table 25)

Chain	2030 Sectors	Recurring/single	FTE	Features
Upstream	R&D	Recurring	2.815-3.321	Additional
	Wind at Sea	One-time	38-178	Additional
		Recurring	15-76	Additional
	Electrolysis	One-time	229-900	Additional
		Recurring	172-688	Additional
Midstream	Infrastructure	One-time	573	Additional
	Import	One-time	660	Additional
		Recurring	50	Additional
Downsteam	Mobility	Recurring	1.134-913	Replacement
	Total Additional		4.552- 6.446	
	Total Replacement		1.134-8.413	

The main conclusions from the CE Delft study (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, 5)[95] are:

1. Green hydrogen will contribute to employment in the Netherlands. Labor demand is between 6,000 and 17,300 FTE in 2030 and between 16,400 and 92,400 FTE.
2. Labor demand does not increase proportionally with hydrogen demand, but superlatively. This is firstly because in a scenario with higher hydrogen demand, a larger part of the hydrogen supply chain will be located in the Netherlands. Second, it is because relatively labor-intensive sectors will be involved (mobility and built environment).
3. Labor demand consists partly of job replacement, but also additional jobs from new economic activities.

[95] Liguijt. Cor et al ; CE Delft, 2021 Work through green hydrogen investments; Update and expansion, Work through green hydrogen investments. Update and expansion - CE Delft

4. It is not evident that labor demand is in line with a sufficient and properly qualified labor supply. Already now, many companies in the sectors studied are failing to find the right, qualified personnel to realize the energy transition at the intended pace.

(Process control 2023)[96] Stands that there has been tightness in the labor market for years, on the one hand there has been an aging population for a long time, little unemployment. However, where there is still personnel to be gained is in the female part of the labor force. The number of women in technical occupations is still very low. The biggest problem, however, is at the bottom of the demographic Pyramid: youth. It is not that youth are not interested in engineering. The problem is that too few young people choose a technical education.
One insertion was that another form of education must be sought, than young people are now not sufficiently stimulated to go into engineering. Research education is a term that comes up regularly. Within MBO education, this certainly creates problems within the fairly tight curriculum to make room for it. A strong link with business is also needed. Some companies still have business schools such as Tata-Steel, network operators and in Germany this is still very common.
Companies must additionally invest time in their existing workforce through, for example, lifelong learning programs.

His research states (Bezdek 2019) that the U.S. could create an estimated 700,000 to 1 million new jobs in the hydrogen energy and fuel cell industry over the next decade.

Table 29 FTE per GW installed capacity electrolyzer one-time and recurring (Leguijt, Cor; Van den Toorn, Emiel; Bachaus, Amanda; Jongsma, Chris 2021, Table 2)

Description	**2030**	**2040**	**2050**
Installed capacity low (GW)	1	2,4	3,7
Installed capacity high (GW)	4,1	18,8	33,4
One-time FTE gem- low	1.200	1.000	1.200
One-time FTE gem- high	4.000	12.100	18.900
Recurring FTE gem- low	4.100	6.400	8.600
Recurring FTE gem- high	12.500	40.100	67.000
FTE/GW low	5.100	3.100	2.700
FTE/GW high	4.000	2.800	2.600

Currently, the plans and targets for 2030 are almost double the 4.1 GW mentioned here. So that also means that the number of FTEs needed is going up sharply.

According to the report by (Ecorys; Van Til, Harry; Van Benthem, Menno; Thijsen, Maurice; Dijkhof, Yoeri; Wester, Menno 2021, 3)[97] an estimated (gross) 23,000 additional workers are needed to meet the goals of the Climate Agreement (-49% in 2030). If the target is scaled up by the European Green Deal (-55% by 2030), the shortfall will rise to 28,000. But while the shortage is rising, the supply of people with technical qualifications is actually falling sharply.
As the study by (Ecorys; Van Til, Harry; Van Benthem, Menno; Thijsen, Maurice; Dijkhof, Yoeri; Wester, Menno 2021) has made clear, even before 2030 there will likely be shortages of technically skilled workers who can realize the challenges of the climate transition. Especially now that Europe wants to raise the target even further and the Netherlands is also facing a

[96] Process Control, 2023 No. 1 Pages 15-18, FEDA brings industry challenges to the table.
[97] Ecorys, 2021. Climate policy and the labor market: An exploratory study of the employment effects of CO2 reduction measures Rotterdam. Microsoft Word - Climate policy and the labor market - final report 20210226 (nvde.nl)

goal of 60% reduction goes. If the Netherlands is to achieve its climate ambitions, investments in lower-level technical vocational education must be made. In addition, further training and retraining can help match labor supply and demand.

Table Opportunities for economic growth and renewables technical potential

Legend:

- Prod Production
- T&STransport and storage
- TRAD Trade
- SERV Services
- END End User
- RES PJ Regional energy strategy Potential (PJ) NL & NNL

Table 30 Opportunities for economic growth and renewables technical potential (Spisto, et al. 2020, 14)

Plans	**opportunity**	**Prod**	**T&S**	**TRAD**	**SERV**	**END**	**RES PJ EN**	**RES PJ NNL**
Central government	Import $_{H2}$		x	x		x		
Central government	Geothermal		x			x	50-170	
Central government	Green gas		x			x		
Region	Hybrid and heat pumps				x	x		
Region	Heat grids		x		x	x		
Region	Electrification					x		
Region	PV and CHP	x						
Region	Wind land and offshore	x					480-2,135	156
Region	Biomass	x					185	25
Region	Hydrogen	x	x		x	x		70
Otherwise	Conversion boilers and others applications				x	x		

Hydrogen offers one of the few areas where jobs can be found in all parts of the value chain.

Annex 27 European Qualification Framework (EQF).

The required knowledge levels in various programs, such as WCM, Greenskill4H2, GroenvermogenNL and Greenwise, are aligned with the European Qualification Framework (EQF) and mainly focus on EQF levels 3-4 and 5-6 (MBO-HBO).

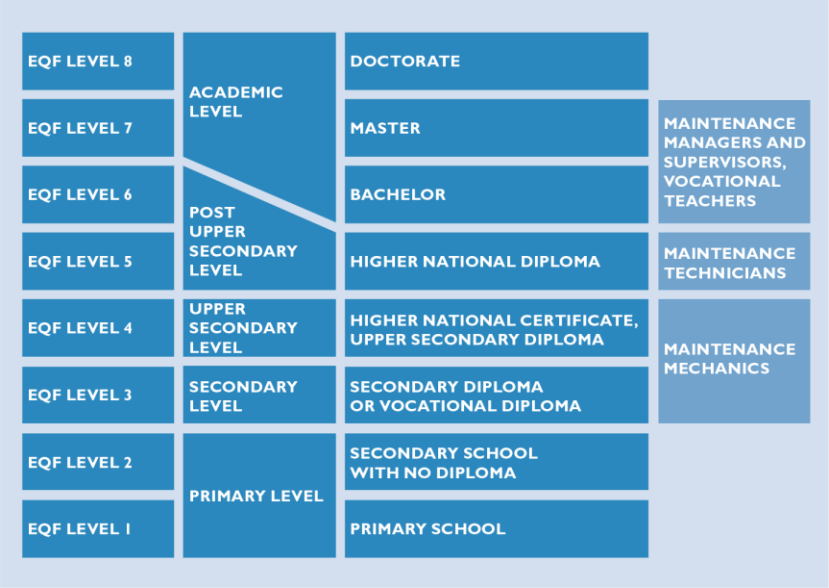


Figure 18 EQF level compared with achieved education and positions of maintenance personnel. (HLADÍK, et al. 2012) [98]

Table 31 The respective competency requirements for maintenance professionals of EQF levels 4, 5 and 6.(HLADÍK, et al. 2012)

	EQF 4	EQF 5	EQF 6
Knowledge	Factual and theoretical knowledge in broad contexts within a field of work study	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge.	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.
Skills	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems.	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study
Competence	Exercise self-management within the guidelines of work or study contexts that are usually precictable, but are subject to change. Supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities.	Exercise management and supervision in contexts of work or study activities where there is unpredictable change. Review and develop performance of self and others.	Manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or stucy contexts. Take responsibility for managing professional development of individuals and group. Review and develop performance of self and others. Organize a maintenance management system
Maintenance Qualifications	Maintenance mechanic, Foreman, Electrician, Welder etc.	Maintenance technician, Maintenance specialist, Maintenance engineer	Maintenance supervisor, Maintenance manager, Advanced maintenance engineer, Vocational teacher in the field of maintenance

[98] HLADÍK, TOMÁŠ, Ingemar Andréason, Sil Bruijsten, and Palle Grøndahl. 2012. *Application of European Qualification Framework (EQF) in Maintenance.* European Training Committee. May 7. Accessed Mar 17, 2023. https://www.maintworld.com/R-D/Application-of-European- Qualification-Framework-EQF-in-Maintenance.

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The European Qualifications Framework (EQF) is designed to compare the levels of different qualifications across Europe. It provides a common reference for education and training qualifications in different countries and sectors.

The European Qualifications Framework (EQF) is a standardized qualification framework for education and training in Europe. Below are the EQF levels corresponding to secondary education (VMBO), intermediate vocational education (MBO), higher vocational education (hbo) and scientific education (WO):

- EQF level 2: this level corresponds to the final level of VMBO and basic vocational courses in MBO.
- EQF level 3: this level corresponds to the final level of framework vocational courses in senior secondary vocational education (MBO).
- EQF level 4: this level corresponds to the final level of the theoretical course of the VMBO (intermediate vocational education) and the middle management vocational courses in the MBO.
- EQF level 5: this level corresponds to the final level of the college bachelor's degree.
- EQF level 6: this level corresponds to the final level of the wo bachelor degree.
- EQF level 7: this level corresponds to the final level of the wo-master's degree.
- EQF level 8: this level corresponds to the final level of a doctorate (PhD) or other postgraduate degree.

It is important to emphasize that the EQF (European Qualification Framework) is a general framework designed to compare and link qualification levels. The exact level determination of a specific diploma or certificate depends on its content, the level of knowledge and skills acquired in the program, and the educational institution's assessment criteria.

Without more specific information on the required skills, knowledge and responsibilities of each job, the EQF level of each job in this report cannot be accurately determined. It depends on the specific requirements of each job, the context in which it is performed and the country in which the job takes place.

In general, positions that fall within the Vocational Education and Training (VET) category are more focused on practical skills and often require less formal training than positions within the Higher Education or Paraprofessional categories. Jobs at higher EQF levels typically require higher levels of complexity, autonomy, responsibility and problem-solving skills.

Appendix 28 Function list comparison of total set

There are several functions that are similar or similar in this list. Here are a few examples:

1. Policy analyst and hydrogen fuels sales and Business developer/business manager - both functions focus on the development and sale of hydrogen fuels.
2. Asset performance manager and Energy program manager - both positions deal with the management and performance of energy infrastructure.
3. Commercial Engineering Electrician and Electrical Engineer - both positions focus on electrical installations and maintenance in an industrial environment.
4. Chief Operating Officer (COO) and Chief Technical Officer (CTO) - both positions are senior management positions in a company.
5. Data analyst, Data engineer and Data scientist - all three positions focus on working with data, although there are differences in the technical skills needed for each position.
6. Industrial Designers and Architects - both positions focus on the design of buildings and structures, although architects generally focus more on the aesthetic and functional aspects, while industrial designers focus more on the practical aspects of design.
7. Hydrogen Power Plant Installation Manager and Hydrogen Power Plant Installation, Operation, Engineering and Management Manager - both positions focus on the management and operation of hydrogen power plants, although there are differences in the level of responsibility and technical skills required for each position.
8. These are just a few examples of similar positions in this list. There are probably many more positions that are similar or comparable based on their responsibilities and required skills.

Appendix 29 Professor - Lecturer - Practor

A Practor, Lecturer and Professor each have different roles and responsibilities in higher and secondary education and research.

A Practorate is an expertise platform, led by a Practor. The core of a Practorate can be defined as follows: the development, exploration of new professional practices embedded in education through practice-based research, whereby a (qualitative) added value is created for the field of work (the professional practice), the students (better professional competence and better professional perspective) and the teachers (professionalization within the discipline) as a result of which the ultimate quality of education improves. (Practorates.co.uk 2023) This means that he or she works closely with companies and institutions to better align education with practice. A Practor can specialize in a specific field, such as hydrogen technology. The requirements for a Practor in the field of hydrogen are knowledge of and experience with hydrogen technology, experience in professional practice and understanding of the developments and needs of the field.

A Lecturer's role is to conduct practice-oriented research and innovate education. A Lecturer is usually attached to a college of higher education and works closely with the field to research current issues and find solutions. For example, a Lecturer in the field of hydrogen might conduct research on the applications and implementation of hydrogen technology in different sectors. The requirements for a Lecturer in the field of hydrogen are a doctorate or PhD in a relevant field, publications in reputable journals, research experience and knowledge of the developments and needs of the field.

A Professor is tasked with conducting research, teaching and leading research groups and projects and is affiliated with a university. For example, a Professor in the field of hydrogen might conduct research on the fundamental science behind hydrogen production and storage. The requirements for a Professor in the field of hydrogen are a doctorate or PhD in a relevant field, extensive publications in reputable journals, university-level research and teaching experience, and leadership qualities to lead research groups and projects.

Similarities between Practors, Lecturers and Professors in the field of hydrogen are their specialization in this field, their knowledge of the developments and needs of the professional field and their involvement in practice-oriented research and education. The Professors, Lecturers and Practitioners of the Northern Netherlands will work together to develop a continuous learning line. The participants and departments they lead are listed in Appendix 29B.

Continuous learning line

A continuous learning line in hydrogen is a coherent set of educational activities aimed at developing hydrogen technology knowledge, skills and attitudes. This learning line extends, as it were, from primary and secondary school to university education and professional practice. The purpose of a continuous learning line in hydrogen is to interest and excite pupils and students in this field and to prepare them for a future career in the hydrogen sector. The continuous learning line often starts as early as elementary school, where children can be introduced to hydrogen and its applications in a playful way. In high school, students can then take more in-depth courses in chemistry, physics and technology that tie in with hydrogen technology. In higher and university education, students can take

further specialize in areas such as energy technology, sustainability and innovation. By offering a continuous learning line in hydrogen, a wide audience can be reached and pupils and students can be encouraged to choose a career in the hydrogen sector. In addition, the continuous learning line contributes to the development of knowledge and skills in the field of renewable energy and contributes to the transition to a carbon-free energy supply.

Appendix 28B Professors - Lecturers and Practitioners consultation North Netherlands

The list below lists the relevant Professors, Lecturers and Practitioners around hydrogen in Northern Netherlands who will be working on the continuous learning line.

Table 32 Overview of Professors, Lecturers and Practitioners Northern Netherlands

Professor - Lecturer - Practor consultation					
Institute	**Institute detail**	**Role**	**Subject area**	**Hydrogen related part**	**name**
RUG	Director of the Wubbo Ockels School for Energy and Climate/Faculty of Law	Professor	energy law	Energy Law	Prof. Dr. Lorenzo Squintani
	Faculty of Law - Groningen Centre for Energy Law and sustainability	Assistant Professor of Energy law	energy law	technical standards for gas and hydrogen	Dr. Ruven Fleming
RUG	Faculty of Science and Engineering	Professor	Chair of Energy Conversion,		Prof. Dr. A. Purushotham an Vellayani
RUG	Faculty of Science and Engineering	Professor	adjunct professor of Environmental Science	energy transition process. I investigate this process from a systems perspective (Modeling)	Prof. M. A. (Machteld) van den Pants
RUG	Faculty of Behavioural and Social Sciences	Adjunct Professor	Professor acceptability energy transition	Acceptability of hydrogen	Prof. Dr. Goda Perlaviciute
RUG	Faculty of Behavioural and Social Sciences	Professor	Professor of environmental Psychology	Factors for sustainable behavior	Prof. Linda Steg
RUG				Tenure Track University Lecturer program profile 'Hydrogen and Fuel 'Cells' (222515)	Vacant
RUG		Professor			Prof. Dr. Mr. Catrinus Jepma
RUG	Faculty of Science and Engineering	Professor	Full Professor in Catalysis & Sustainability	electrocatalysis	Prof. Dr. Paolo Pescarmona
RUG	Faculty of Science and Engineering	Assistant Professor	materials	embrittelment	Dr. Francesco Maresca

RUG	Faculty of Science and Engineering	assistant professor	Assistant Professor in Energy Conversion & Processes	Electrochemistry; Technology, Chemical; Energy & Fuels	Dr. Vassilis Kyriakou
RUG	Faculty of Science and Engineering	assistant professor	Geology; Earth Sciences, Multidisciplinary	underground storage	Dr. Johannes Miocic
RUG	Faculty of Science and Engineering	Professor	Chair of Materials Chemistry		Prof. Dr. Moniek Tromp
RUG	Faculty of Science and Engineering	Professor	Professor of Mechatronics and Nonlinear Control Engineering.	Professor of Mechatronics and Nonlinear Control Technology	Prof. Dr. Bayu Jayawardhana
RUG	Faculty of Science and Engineering	Professor	Professor of environmental sciences	hydrogen likage	Prof. Dr. Harro Meijer
RUG	Faculty of Science and Engineering	Professor	Professor of environmental sciences	Multi-factors modeling (economic dimension)	Prof. Dr. Klaus Hubacek
RUG	Faculty of Spacial Sciences	Professor	Adjunct Professor of Spatial Planning	Spatial planning optimization	Prof. Dr. Chris Zuidema
RUG	Faculty of Economy and Business	Professor	Professor of Energy Logistics	Business Modeling and Operation Optimization	Prof. Dr. Evrim Ursavam
RUG	Faculty of Economy and Business	Professor	Professor of Energy Economics	macro/micro economic analysis or Hydrogen	Prof. Dr. Machiel Mulder
Hanze University of Applied Sciences	Entrance	Lecturer	Communication, Behaviour & the Sustainable Society	Among other things, support research (Hoogeveen)	Dr. Wim Elving
Hanze University of Applied Sciences	Entrance	Lecturer	Communication, Behaviour & the Sustainable Society		Dr. Carina Wiekens
Hanze University of Applied Sciences	Entrance	Lecturer	Energy Transition	Director of EnTranCe and runs the Hydrogen Application Lectorate. gene	Dr. Jan-jaap Aué
Hanze University of Applied Sciences	Entrance	Lecturer	Energy Transition	networking in the energy transition	dr. ir. Martien Visser
Hanze University of Applied	Entrance	Lecturer	Energy Transition	Lecturer in Systems Integration in the energy transition	Dr. Marten van der Laan

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Sciences					
Hanze University of Applied Sciences	Entrance	Lecturer	Legal and economic issues within energy transition	legal aspects of energy transition	Bert de Jonge

Hanze University of Applied Sciences	Entrance	Lecturer	Legal and economic issues within energy transition	Lecturer in Legal Issues in the Energy Transition	Dr. Daisy G. Tempelman
Hanze University of Applied Sciences	Entrance	Lecturer	Legal and economic issues within the energy transition	Lecturer in Economic Issues in the Energy Transition	vacant
Hanze University of Applied Sciences	Entrance	Lecturer	Wind Energy	Wind Energy	Dr. Gerard Schepers
Hanze University of Applied Sciences	Entrance	Lecturer	Life Science & Renewable Energy	Lecturer "Life Sciences & Renewable Energy'	Dr. Jan- Peter Nap
Hanze University of Applied Sciences	Entrance	Lecturer	Sustainable Gases and Fuels	Lecturer in Sustainable Gases and LNG Technology.	vacant
Hanze University of Applied Sciences	Entrance	Lecturer	New	Lecorate safety of energy and hydrogen systems (design and operation)	Vacant (new)
Hanze University of Applied Sciences	Entrance	Lecturer	New	Lectureship electro- chemical-technical conversion	Vacant (new)
Hanze University of Applied Sciences	BioBased Economy Knowledge Center	Lecturer	Lecturer	Lectureship Biorefinery	Dr. Janneke Krooneman
Hanze University of Applied Sciences	BioBased Economy Knowledge Center	Lecturer	Lecturer	Lectureship Biorefinery	Dr. Andre Heeres
Hanze University of Applied Sciences	North Space Knowledge Center	Lecturer	Lectorate of Spatial Transformations - Sustainability	Professorship of Spatial Transformations - Sustainability	Dr. Amar Bennadji
NHL Stenden	BioBased Economy Knowledge Center	Lecturer			

Competencies needed for hydrogen in the industry and network -.

NHL Stenden	CEW/Water Campus	Lecturer	Electrochemistry/Water tech nology	Lectureship Watersmart Hydrogen /Lector Water Smart Hydrogen	Dr. Michel Saakes
NHL Stenden	CoE Smart Sustainable Manufacturing/Green wise Campus	Associate Lecturer	Additive Manufacturing	Smart Sustainable Manufacturing	Dr.ing. Wilbert van den Eijnde

Alfa College	Alfa College	Practor	Decentralized energy storage in the built environment	Hydrogen in the Built environme nt	Vacant
Noorderpo ort	Noorderpoort	Practor	Practor Automotive and moderator new/future Automotive mobility and hydrogen technology	Hydrogen in mobility	Roeland Hogt Bsc (and partial course and master)
Drenthe College	Greenwise Campus	Practor	Hydrogen in industry	Hydrogen in industry and networks	Willem Hazenberg EUR ING MBA RI

Appendix 30 Detailed table of the EQF score.

Table 33 Detailed table of the EQF score.

Label	Number at EAF Level		VO	MBO	HBO	WW	WO Bc	WW Msc	WW PHD/PD
EQF 1-2	3		3						
EQF 2	6		6						
EQF 2-3	9		4,5	4,5					
EQF 2-4	4		2	2					
EQF 3	13			13					
EQF 3-4	27			27					
EQF 3-5	5			2,5	2,5				
EQF 4	27			27					
EQF 4+	1			1					
EQF 4-5	26			13	13				
EQF 4-7	1			0,34	0,33	0,33			
EQF 5	4				4				
EQF 5-6	22				11	11	11		
EQF 5-7	2				1	1	0,33	0,34	0,33
EQF 6	13					13	13		
EQF 6+	4					4	2	2	
EQF 6-7	64					64	32	32	
EQF 6-8	2					2	0,67	0,67	0,67
EQF 7	13					13		13	
EQF 7-8	25					25		12,5	12,5
EQF 8	1					1			1
Grand Total	**272**		15,5	90,34	31,83	134,33	59	60,51	14,5

Appendix 31 Labor market and education

MBO

Based on the outflow from education, we can estimate the number of new entrants to the labor market. The total number of MBO students in the Netherlands is expected to decrease from about 494 thousand in 2020 to 434 thousand in 2030. This forecast concerns the total number of students, with the exact decrease varying by MBO sector. For example, the number of MBO engineering students will decline by 18 percent until 2030. Each year, about one-third of the students will obtain a diploma, amounting to about 164 thousand MBO graduates in 2020 and almost 145 thousand MBO graduates in 2030. Almost half of these MBO graduates will continue studying (Markus and Van Smoorenburg 2019)[99] , while the other half will enter the labor market. This means that about 82 thousand MBO graduates will enter the labor market in 2020, which will decrease to 72 thousand in 2030. (MBO-Today 2023)[100] indicates that the number of BBL students in healthcare and engineering will increase in 2023, representing an 8% increase or 2,000 students growth. A total of 11,000 people are now training in built environment and engineering (Bakens, et al. 2021). There is a dichotomy within the engineering occupations in terms of bottlenecks: no bottlenecks are expected in 6 years for the construction occupations, but bottlenecks are expected for the other engineering occupations. This is especially true in the field of energy transition.

HBO

Similar trends can be seen in the development of the number of college and university graduates. College graduates in particular are expected to become scarcer in the future, increasing competition for them. For higher education, the estimated total number of undergraduate students nationwide has dropped from 384,900 in 2020 to 337,000 in 2030. During this period, the number of HBO graduates falls from 64,100 to 58,600 graduates.

In 2030, the share of graduates decreases by 9 percent in HBO economics, **8 percent** in **HBO engineering** and 6 percent in HBO health. The influx of hbo graduates into the Dutch labor market will thus become scarcer.

WW

The number of WO graduates does increase over the same period, from about 43,500 in 2020 to 47,800 in 2030 (Kasem S.H. 2019)[101] . However, this increase is insufficient to offset the decline in the number of college graduates. In WO, the number of graduates in economics (+9%) and engineering (+13%) is expected to increase over the next decade.

Maastricht University's Research Center for Education and the Labor Market (ROA) in their 2019 report predicts growth in employment at the college and wo level through 2024, which means more competition for companies to recruit higher skilled workers (Bakens, Bijlsma, et al., ROA Reports, No. 007, Vol. ROA-R-2019/. 2019)[102] but in their (Bakens, et al.

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[99] Markus, Nathan, and Michel Van Smoorenburg. 2019. *The labor market position of MBO school leavers* . UWV, 15. Accessed Mar 5, 2023. https://www.uwv.nl/overuwv/Images/de-arbeidsmarktpositie-van-MBO-schoolverlaters-vergeleken.pdf.

[100] MBO-Today. 2023. *Number of bbl students healthcare and engineering rising. Feb* 14. Accessed Mar 5, 2023. https://MBO-today.nl/aantal-bbl- students-care-and-tech-rises/

[101] Kasem S.H., Adriaens H., Bogaard C. van den, Gerritse S., Groeneveld R., Heres Hoogerkamp M., Noordzij T., Rentinck L., Rutten A., Schramp-Van Til. 2019. "Reference estimate OCW 2019." minocw, The Hague, 153. Accessed Mar. 22, 2023. https://www.opennieuwsbank.nl/rijksoverheid/2019/09/17/referentieraming-ocw-2019

[102] Bakens, J., Bijlsma, I., Dijksman, S., Fouarge, D., & de Lombaerde, G. 2019. *(2019). The labor market by education and occupation to 2024.* . Maastricht: Research Centre for Education and the Labour Market.

2021)[103] report they indicate. Greater uncertainties apply to labor market projections through 2026. This is because it is still unclear what the effects of the crisis will be on short- and medium-term growth. The latter was due in part to the Covid pandemic we were in at the time.
Covid is now behind us but the war in Ukraine and high energy prices are creating new uncertainties around energy prices, among other things.

The outflow at MBO is currently too low to meet the need in the labor market and the prognosis is that the outflow will decrease in the coming years (DUO 2022). Thus, to meet the need in the labor market, it is necessary to look beyond education.

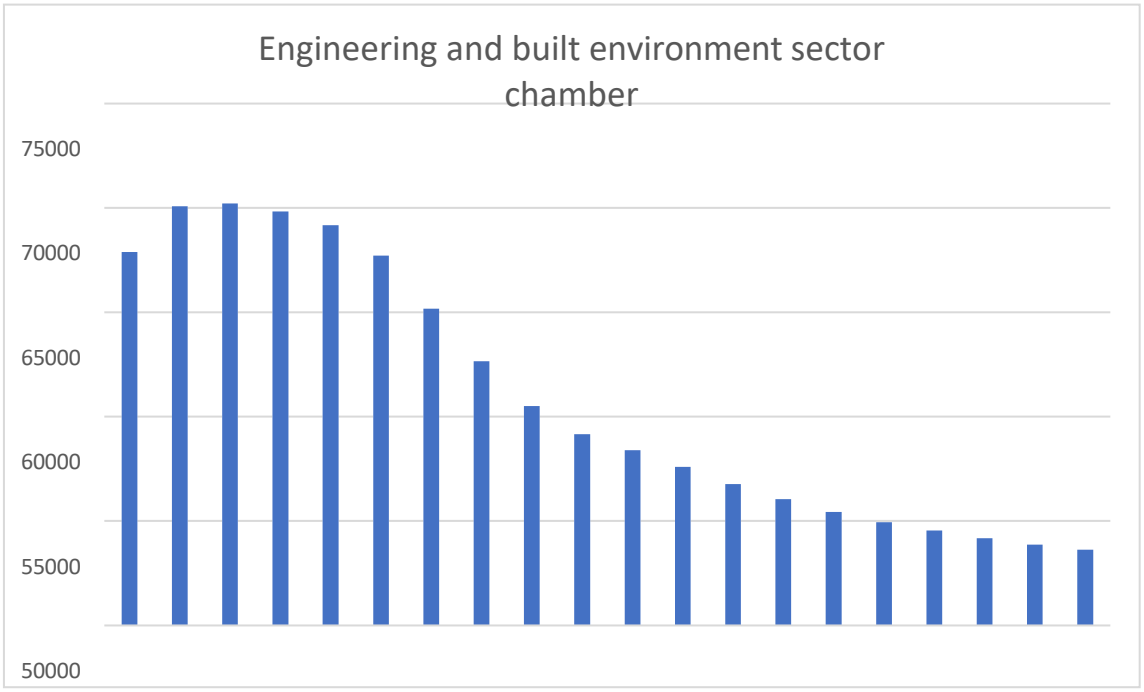


Figure 19 Expected MBO students toward engineering and built environment (DUO 2022)[104]

[103] Bakens, J., I. Bijlsma, S. Dijksman, D. Fouarge, and Goedhart R. 2021. *The labor market by education and occupation to 2026.* Maastricht: Research Centre for Education and the Labor Market, 81. Opened Mar 5, 2023. doi:0.26481/umarep.2021005. ROA_R_2021_5_ANOB2026.pdf (maastrichtuniversity.nl)

[104] DUO. 2022. studentenprognoses-MBO-totaalbestand-2017-2036-update13juni2022.xlsx. DUO. Groningen: DUO. Accessed Mar 5, 2023. https://duo.nl/open_onderwijsdata/images/studentenprognoses-MBO-totaalbestand-2017-2036-update13juni2022.xlsx

Appendix 32 Individual functions in relation hydrogen to the matching EQF score

All functions are listed here in the masculine form, but can also be read in the feminine form. The German study named state masculine and feminine forms. The other reports did not.

Table 34 Individual functions in relation hydrogen to the matching EQF score

Country/report	Function	EAF Level
VS Bezdek	Production labor force (VET/OTJ):EQF 1 or 2 (basic education or similar)	EQF 1-2
France	Service labor force at hydrogen fueling stations (OTJ):EQF 1 or 2 (elementary education or equivalent)	EQF 1-2
VS Bezdek	Technical occupations, practical skills (VET):EQF 1 or 2 (primary education or equivalent)	EQF 1-2
VS Bezdek	Fuel cell retrofit mechanic	EQF 2
France	Assistant hydrogen energy system installer	EQF 2
VS Bezdek	Bus and coach driver	EQF 2
France	Cab driver	EQF 2
France	Hydrogen fueling station operator	EQF 2
HyResponse	First responder (firefighter)	EQF 2
France	Operator completion of the well	EQF 2-3
Canada	Process Operator	EQF 2-3
Australia	Service rig crew	EQF 2-3
Australia	Station operators: compression	EQF 2-3
Australia	Assembler - assembler/cable installer/assembly technician	EQF 2-3
Germany Apple	Driver of a hydrogen tube trailer/tanker truck	EQF 2-3
Canada	Mechanic/Assembler	EQF 2-3
Germany Apple	Operator automated production line	EQF 2-3
Australia	Production worker at industrial sites/console operator	EQF 2-3
France	Drilling crew	EQF 2-4
Canada	Pipe fitter/steam fitter	EQF 2-4
Canada	Welder	EQF 2-4
Canada	Pipeline builder	EQF 2-4
Canada	Mechanical engineering fitters	EQF 3
Canada	Mechanical engineers (VET	EQF 3
Australia	Fuel cell manufacturing technician	EQF 3
Canada	Fuel cell retrofit installer	EQF 3
Australia	Electrician hydrogen vehicle	EQF 3
Canada	Electrician (IH)	EQF 3
France	Gas fitters (VET)	EQF 3
France	Industrial mechanic (Industry and Trade)	EQF 3
Australia	Pipe fitter/pipeline contractor	EQF 3
Canada	Plumbers (VET)	EQF 3
Germany Zinke	Hydrogen fuel transporter - driver	EQF 3

Canada	Hydrogen energy system installer	EQF 3
Canada	Hydrogen pipeline construction worker	EQF 3
VS Bezdek	Control room operator	EQF 3-4
France	Gas Technician	EQF 3-4
France	Maintenance Technician: Compression	EQF 3-4
Australia	Maintenance Technician: Electrical	EQF 3-4
France	Maintenance Professionals: Instrumentation & Control	EQF 3-4
France	Maintenance professionals: electrical, electromechanical, instrumentation & control, mechanical engineering	EQF 3-4
France	Process Control Technician	EQF 3-4
Canada	Service Technician	EQF 3-4
Australia	Supervisor completion of well	EQF 3-4
Canada	Maintenance professionals: mechanical engineering	EQF 3-4
VS Bezdek	Process Operators	EQF 3-4
France	Production and assembly of electrolyzers, fuel cells and components	EQF 3-4
Canada	Hydrogen Process Operator Specialist, including SCADA (VET)	EQF 3-4
Australia	Installation technician/installation engineer for piping systems	EQF 3-4
Canada	Architectural metalworker	EQF 3-4
France	ATEX equipment repairman	EQF 3-4
Canada	Electronics technician	EQF 3-4
VS Bezdek	Boiler builder	EQF 3-4
Canada	Plumber-heater technician	EQF 3-4
Canada	Production line operator/technician	EQF 3-4
Canada	Train driver	EQF 3-4
Canada	Safety Testing Officer	EQF 3-4
Australia	Mechanical operator	EQF 3-4
Australia	Company fireman/woman (IH).	EQF 3-4
Australia	Electricians (VET)	EQF 3-4
Canada	Fuel cell engineering intern	EQF 3-4
Canada	Installation technician (industrial and commercial)	EQF 3-4
Germany Apple	Hydrogen Process Operator Specialist	EQF 3-5
Canada	Specialists in water quality treatment, testing and compliance (VET/Paraprof	EQF 3-5
Canada	Technical occupations, including pressure vessels, etc.	EQF 3-5
Germany Zinke	Technical occupations, including pumps	EQF 3-5
France	Signers	EQF 3-5
VS Bezdek	Vehicle Inspectors (OTJ).	EQF 4
VS Bezdek	Fuel cell power systems operator and instructor	EQF 4

VS Bezdek	Certifiers of equipment (VET).	EQF 4
Australia	Composites technicians (VET).	EQF 4
Australia	Electrician for business technology (Industry and Trade)	EQF 4
Australia	Electrical and process technician	EQF 4
Australia	Electrical technician	EQF 4
France	Electronics specialist - business technology specialization (industry and trade)	EQF 4
France	Electronics specialist - specialization building and infrastructure systems (industry and commerce)	EQF 4
France	Electronics Technician Business Engineering (IH).	EQF 4
Canada	Building and infrastructure systems (IH) electrician.	EQF 4
France	Gas technician	EQF 4
Australia	Commissioning Technician	EQF 4
Australia	Industrialization/methods technician	EQF 4
France	Inspectors (Paraprof.).	EQF 4
VS Bezdek	Installation technician for plumbing, heating and climate control (HW, IH)	EQF 4
France	Junior hydrogen energy technician	EQF 4
France	On site emergency teams* (VET).	EQF 4
Australia	Planners (Para professional/Higher Education)	EQF 4
Australia	Process technician	EQF 4
VS Bezdek	QHSE technician/operator	EQF 4
VS Bezdek	Tank and equipment manufacturer (HW).	EQF 4
VS Bezdek	Technician backup energy system with fuel cell	EQF 4
VS Bezdek	Fuel cell manufacturing technician	EQF 4
VS Bezdek	Fuel cell testing technician	EQF 4
VS Bezdek	Mechanical technician	EQF 4
HyResponse	Shift fire chief	EQF 4
Australia	Safety Managers	EQF 4+
Germany Apple	CNC fabrication technician	EQF 4-5
France	Coating inspector	EQF 4-5
France	HVAC technician	EQF 4-5
Australia	Cathodic protection technician	EQF 4-5
Germany Apple	Laboratory Technician	EQF 4-5
France	Welding Inspector	EQF 4-5
Canada	Assembly Technician	EQF 4-5
VS Bezdek	Non-destructive (NDE) inspector and technician	EQF 4-5
VS Bezdek	Hydrogen Dispenser Technicians* (VET/Paraprof	EQF 4-5
France	Plant builder (electrolysis)	EQF 4-5
France	Installation builder/network builder (electricity and gas)	EQF 4-5
France	Stationary applications (fuel cell) plant builder	EQF 4-5

Canada	Automation/robotics technician	EQF 4-5
VS Bezdek	Certification Officer	EQF 4-5
France	Cheftekenaar	EQF 4-5
France	Chemistry technician	EQF 4-5
France	Industrial maintenance technician	EQF 4-5
Germany Zinke	Maintenance/operational technician	EQF 4-5
Germany Apple	Test Technician	EQF 4-5
Canada	Fuel cell technicians* (VET/Paraprof.).	EQF 4-5
Canada	First responders (VET/Higher Education/Specialist training)	EQF 4-5
Canada	Electrolyzer Technicians* (VET/Paraprof.).	EQF 4-5
Germany Apple	Fuel Cell Technicians* (VET/Paraprofessional).	EQF 4-5
VS Bezdek	Instrumentation & Electrical Technicians, including SCADA (VET/Paraprof.)	EQF 4-5
VS Bezdek	Power plant operators (VET).	EQF 4-5
VS Bezdek	Pipeline Technicians (VET/Paraprof.).	EQF 4-5
VS Bezdek	Labor force in management bodies	EQF 4-7
Australia	Electronics specialist - specialization energy and building technology (HW)	EQF 5
HyResponse	Incident commander fire department	EQF 5
HyResponse	Fire department specialist	EQF 5
France	Hydrogen laboratory technician	EQF 5
France	Employee regulatory compliance	EQF 5-6
Australia	Building Inspector	EQF 5-6
France	Energy Planner	EQF 5-6
France	Facility maintenance planner	EQF 5-6
France	Purchasing specialist	EQF 5-6
France	Inspectors for in service pressure equipment	EQF 5-6
France	Quality control specialist	EQF 5-6
Germany Zinke	Pipeline planner	EQF 5-6
France	Logistics coordinator	EQF 5-6
France	Maintenance planner	EQF 5-6
Canada	Process Control Specialist	EQF 5-6
Canada	Production Planner	EQF 5-6
France	Production Supervisor	EQF 5-6
Canada	Installation Manager	EQF 5-6
France	Chemical technician (Industry and Commerce)	EQF 5-6
Australia	Electronics specialist - automation technology specialization (industry and commerce)	EQF 5-6
Canada	Automation technology electronics technician (IH).	EQF 5-6
VS Bezdek	IT specialist - application development specialization (industry and trade)	EQF 5-6
Australia	IT specialist - digital networking specialization (industry and trade)	EQF 5-6

France	IT specialist - systems integration specialization (industry and trade)	EQF 5-6
Canada	Mechatronics (industry and commerce)	EQF 5-6
Canada	Chemistry production specialist (IH)	EQF 5-6
Canada	Occupational specialist in the field of distribution network technology	EQF 5-7
Canada	Educators and teachers for all positions (VET/Paraprofessional/Higher education)	EQF 5-7
France	Hardware /embedded systems engineer	EQF 6
Canada	Industrialization/industrial engineer	EQF 6
Canada	Surveyors (Higher Education)	EQF 6
Australia	Manager emission reduction credit portfolio	EQF 6
Germany Zinke	Manager of emission reduction project developer	EQF 6
VS Bezdek	Manager emission reduction project	EQF 6
Australia	Fuel cell quality control manager	EQF 6
France	Hydrogen fuel station manager	EQF 6
France	Operational safety/risk/QHSE engineer	EQF 6
Canada	Software /embedded software engineer	EQF 6
France	Hazardous materials management specialist	EQF 6
Australia	Hydrogen systems sales consultant	EQF 6
France	Hydrogen energy system operations engineer	EQF 6
Germany Zinke	Project Managers (Paraprof.):EQF 6 or higher (higher vocational education or university)	EQF 6+
France	Regulatory QC officers	EQF 6+
France	Security Managers	EQF 6+
Germany Zinke	Fuel cell manager	EQF 6+
Germany Zinke	Analyst, environmental, social governance leader	EQF 6-7
Germany Zinke	Asset performance manager	EQF 6-7
Germany Zinke	Compliance specialist	EQF 6-7
Germany Zinke	Compression Specialist	EQF 6-7
Germany Zinke	Corrosion Specialist	EQF 6-7
Germany Zinke	Cybersecurity specialist	EQF 6-7
Canada	Data analyst	EQF 6-7
France	Sustainability Specialist	EQF 6-7
Canada	Quality Engineer	EQF 6-7
Canada	Materials Specialist	EQF 6-7
VS Bezdek	Environmental Specialist	EQF 6-7
Australia	Minorities and indigenous relations specialist	EQF 6-7
France	Pipeline Engineer	EQF 6-7
Australia	Plant Manager	EQF 6-7
Canada	Process control engineer	EQF 6-7

Canada	Process Engineer	EQF 6-7
Canada	Process Safety Engineer	EQF 6-7
Canada	Production Engineer	EQF 6-7
France	Product Engineer	EQF 6-7
France	Regulatory analyst and compliance specialist	EQF 6-7
Canada	Reservoir Technologist	EQF 6-7
France	Software Developer	EQF 6-7
France	Renewable interconnections specialist	EQF 6-7
France	Leadership integrity specialist	EQF 6-7
Germany Zinke	Specialist measurements	EQF 6-7
France	Government relations specialist	EQF 6-7
Australia	Stakeholder engagement and communications specialist	EQF 6-7
Germany Apple	Systems integration specialist	EQF 6-7
Germany Apple	(Network) Senior	EQF 6-7
VS Bezdek	Construction engineer	EQF 6-7
France	Infrastructure and general systems integration	EQF 6-7
France	Infrastructure planner/project manager	EQF 6-7
Canada	Welding Engineer	EQF 6-7
Australia	Networking engineer	EQF 6-7
Australia	Storage and renewable energy planner/project manager	EQF 6-7
Australia	Activities Manager	EQF 6-7
Australia	Architect engineer specializing in electrical engineering	EQF 6-7
Australia	Automation Engineer	EQF 6-7
Australia	Business developer/business manager	EQF 6-7
Australia	Chemical engineer	EQF 6-7
Canada	Commercial/account manager	EQF 6-7
France	Composite engineer	EQF 6-7
Australia	Contract Manager	EQF 6-7
Canada	Electromechanical engineer	EQF 6-7
VS Bezdek	Electronics engineer	EQF 6-7
Germany Apple	HVAC engineer	EQF 6-7
Germany Apple	Plastic design engineer	EQF 6-7
Germany Apple	Modeler	EQF 6-7
Germany Zinke	Operations engineer (site manager)	EQF 6-7
Germany Zinke	Project Manager	EQF 6-7
Germany Apple	Service engineer	EQF 6-7
Australia	Test engineer	EQF 6-7
Germany Zinke	Power electronics engineer	EQF 6-7

Germany Zinke	Industrial designers (Higher Education)	EQF 6-7
Germany Zinke	Engineers _ civil, (Higher education)	EQF 6-7
Germany Zinke	Engineers _ Electrical (Higher Education)	EQF 6-7
VS Bezdek	Engineers _ manufacturing (Higher Education)	EQF 6-7
Canada	Engineers _ Systems/Integration (Higher Education)	EQF 6-7
France	Automation Engineers (Higher Education)	EQF 6-7
France	Engineers Gas, (Higher Education)	EQF 6-7
Australia	Robotics engineers, (Higher Education)	EQF 6-7
Canada	IT specialist - digital networking (IH) specialization	EQF 6-7
Canada	Quality Managers (Higher Education)	EQF 6-7
VS Bezdek	Metallurgists (Higher Education)	EQF 6-7
France	Designer/design engineer/system architect	EQF 6-8
Canada	R&D researcher/engineers	EQF 6-8
Australia	Policy analyst and hydrogen fuel sales	EQF 7
Germany Apple	Fuel cell designer	EQF 7
Canada	Consultant emissions accounting and reporting	EQF 7
Germany Apple	Consultants Higher Education)	EQF 7
France	Fuel cell power systems engineer	EQF 7
Canada	Installation, operations, engineering and management manager hydrogen power plant	EQF 7
Canada	Hydrogen systems safety researcher and analyst - causes	EQF 7
Canada	Designer and project engineer hydrogen fuel station	EQF 7
Australia	Hydrogen energy systems designer	EQF 7
France	Fuel cell vehicle development engineer	EQF 7
VS Bezdek	Hydrogen systems program manager	EQF 7
VS Bezdek	Hydrogen energy engineer	EQF 7
VS Bezdek	Mechanical engineer	EQF 7
VS Bezdek	Drilling & completion engineer	EQF 7-8
VS Bezdek	Data scientist	EQF 7-8
VS Bezdek	Electrical and instrumentation engineer	EQF 7-8
France	Facilities Engineer	EQF 7-8
Canada	Geophysicist	EQF 7-8
France	Geologist	EQF 7-8
Germany Zinke	Geotechnical specialist	EQF 7-8
France	Engineer for caverns/cavities in rock formations	EQF 7-8
Germany Apple	Chief Operating Officer (COO).	EQF 7-8
Australia	Chief Technical Officer (CTO).	EQF 7-8
France	Data engineer	EQF 7-8
Canada	Electrochemical engineer/electrochemist	EQF 7-8
Canada	Energy Program Manager	EQF 7-8

France	Engineer human factors and organization/ergonomics	EQF 7-8
Canada	Engineer modeling hazardous phenomena	EQF 7-8
France	Innovation Manager	EQF 7-8
Germany Apple	Laboratory engineer	EQF 7-8
Canada	Material engineer	EQF 7-8
Australia	Mechatronics engineer	EQF 7-8
France	Metrology engineer	EQF 7-8
Canada	Smart Grid Development Engineer	EQF 7-8
Canada	Project manager for standardization and regulation	EQF 7-8
Canada	R&D program manager	EQF 7-8
Canada	Thermal engineer	EQF 7-8
Canada	Fluid engineer	EQF 7-8
Canada	Senior engineer for automotive power electronics with fuel cells	EQF 8

Appendix 33 Study Notes - Knowledge area and knowledge levels.

(Dexters and Greentech 2023, 29) works with (Notes) notes that describe a problem and contain raw but validated data within a maximum of 30 pages. These notes can fit within one of the blocks below. Depending on one's function, a combination of notes (building blocks) can be used to construct a course or run a program

Table 35 Dexters study nodes model (Dexters and Greentech 2023).

Knowledge Area	Basic	Advanced	Expert
Engineering			
Implementation			
Maintenance and operation			

(Vollenbroek Training and Advice; 2020)[105] Knows five levels of performance and thus differentiates more than (Dexters and Greentech 2023) and provides a description for each level of performance : viz.

1. Beginner:
    a. Beginners need clear and set rules. Above all, they want to perform something as quickly as possible, to show what they can do and do not want to make mistakes in the process.
2. Advanced:
    a. As experience increases, the beginner discovers that the rules are not always so simple and that they often depend on the situation. By gaining experience, they discover that there are also ways to do something that the instructor did not teach you.
3. Competent:
    a. As experience increases, the number of situations with their own rules each time becomes too great to remember. To cope with this, we need a strategy for organizing information. Expertise and a hierarchy of decisions help in this regard. Taking initiative is also a characteristic of competent people.
4. Operated:
    a. Learning is always under the control of the learner, but at this stage you very clearly begin to take control of your own development process. Skilled people know very well what their weaknesses are and spend focused time to eliminate them one by one
5. Expert:
    a. Experts are a source of knowledge and information for others. Their knowledge does not consist of an endless list of facts and formulas, but they have managed to organize all that knowledge around a few key concepts. They are not walking encyclopedias, but pragmatists who are always looking for improvements or breakthroughs in their field.

(Hydrogene France; 2022) Knows 5 subdivisions in the process and 2 subdivisions on knowledge Basic or Expert.

[105] Vollenbroek Training and Consulting;. 2020. ", From beginner to export, https://minderfoutenmaken.nl/useruploads/files/expert.pdf." Sept. Opened Mar. 5, 2023. https://minderfoutenmaken.nl/useruploads/files/expert.pdf .



Figure 20 The distribution of functional requirements across the value chain in activities (Hydrogene France; 2022, 28)

However, other professions will need specific training in areas such as hydrogen:

1. Operational functions (maintenance technician, plumber-heating technician, gas technician, etc.) must know and apply the relevant safety procedures.
2. Designers must understand the specifics of working with gas (corrosivity, flammability, etc.) and associated materials and equipment/facilities.

Table 36 Identifying the most common areas of expertise associated with different activities (Hydrogene France; 2022, Table 2)

Activity	Electrical engineering and industrial data operation	Flow l honor	CAD-software/ blue-print reading tools	Mechanical engineering	Construction assembly	Metrology	QHSE
Design	29	24	20	20	-	18	29
Production	10	9,5	-	9,5	10	7,5	14
Installation	5,5	6	-	8,5	4	5,5	8,5
Operation	13	-	-	12	11	9,5	19
maintenance	13	8	-	13	13	11	17

The numbers correspond to the number of occupations requiring the listed skills. A skill may be a major skill, in which case it has a value of 1 in the table. A secondary skill has a value of 0.5.

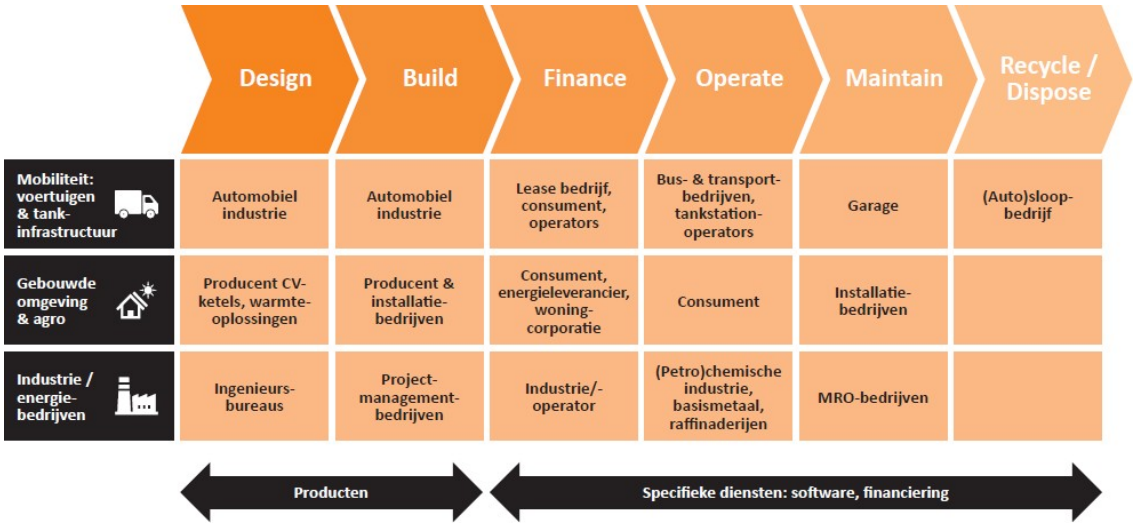


Figure 21 Different phases in the life stage of a hydrogen systee m (Reijerkerk and Van Rhee 2019, Figure 6)

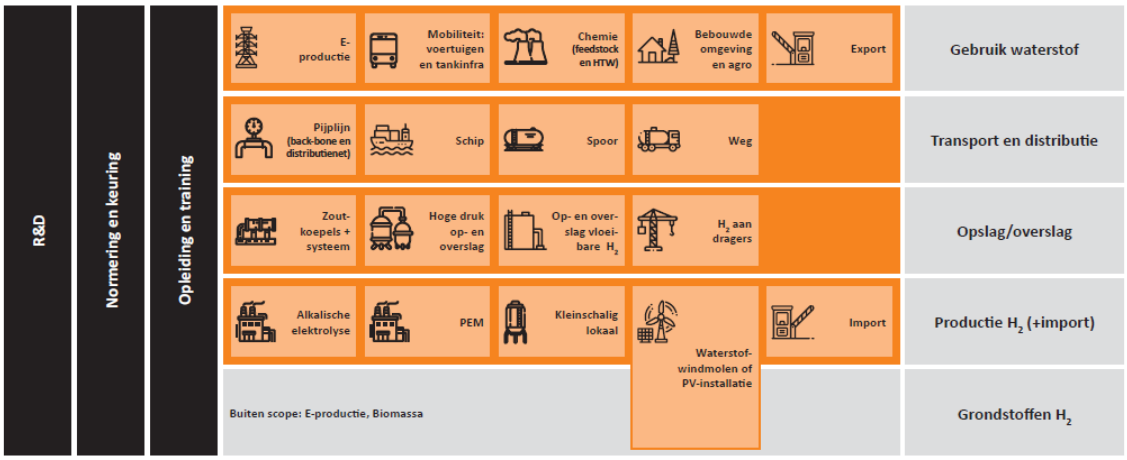


Figure 22 Integral hydrogen chain (Reijerkerk and Van Rhee 2019, Figure 7)

Appendix 34 System boundaries process and asset layers

System boundaries in a hydrogen system and hydrogen economy define the area being analyzed, such as a geographic area or scope. Choosing system boundaries is important because it determines the scope and complexity of the analysis. Several system boundaries can be used in the hydrogen value chain, including production, transportation and distribution, utilization and life-cycle system boundaries. Determining the appropriate system boundaries is crucial to obtaining an accurate and relevant analysis that can affect the conclusions and recommendations drawn from the analysis.

1. Production system boundary: this boundary includes all processes involved in the production of hydrogen, including extraction of the feedstock, production of the hydrogen and its distribution. This is also sometimes referred to as "Upstream.

2. Transportation and distribution system boundary: this boundary includes the processes involved in transporting and distributing hydrogen, such as loading the hydrogen into the transportation vehicles, transportation infrastructure and distribution system to end users. This is also sometimes referred to as "Midstream.

3. Use system boundary: this boundary includes all processes involved in the use of hydrogen, for example for transportation, power generation or industrial applications.

4. Life cycle system boundary: this boundary includes all processes involved in the production, transportation, use and end of life of hydrogen, including extraction of the feedstock, production of the hydrogen, transportation, use and disposal or recycling. This is also sometimes referred to as "Downstream.

Asset layers model

Table 37 Asset layer model

Low	description	Department
Environment model	Climate, land characteristics, Seismology	Engineers/ licensing
Calamity model	Fire department ed. Emergency Services	Government
Minimizing effects	Sprinklers - Tank Walls	WTB/Civil
PSV		WTB
Security layer	ESD	IA
Control layer	PLC/DCS/ Sensors	IA
Communication layer	Networking - Cyber security	IT - A
Buffer layer		WTB
Production layer	Input transport low - output t/day	WTB/Process
Utilities	Current - Air - Nitrogen - press pressure	WTB/Process
Emissions	Air water, Sound	Process
Heat balance		Process
Economic model		Business development/ finance/ procurement - sale
Maintenance and inspection model		EIA-WTB
HRM - Training - Soft skills		HRM

Appendix 35 World Class Maintenance

A group was formed from World Class Maintenance (WCM_Fieldlab_Hydro-Boreas 2022)[106] around hydrogen maintenance:
There are 5 central themes and the topic of security appears in each individual theme. The 5 main themes are:

1. Failure mechanisms, Lifetime expectations;
2. Maintenance Concepts, Design for Maintenance;
3. Competencies;
4. Autonomous Operations;
5. Chain integration.

This paper is input to work package 3, but obviously has interactions with the other modules.
Scope: Slogan is: 'Dancing with the wind' or slightly more complete: 'Dancing with the Sun, Wind & Demand' In terms of hardware, the scope is limited to:

1. **Production;**
2. **Compression;**
3. **Transportation;**
4. **Storage.**

This delineation fits the slogan and the technology/suppliers and WCM members.

Problem Statement

1) In this case, the focus is mainly on the flexible deployment of personnel and the competencies needed.
2) The availability of technicians in the Dutch market is currently limited. When there is no wind or solar, other industrial companies will also want to schedule more maintenance in the future. The question is whether this can be filled with the current population of technicians. Possibly the schedulability of maintenance should be increased by, for example, more redundancy or module swaps, or more technicians should be trained.
3) Technicians are expected to be deployed as follows:
   a) Hydrogen production sites require technicians who are broadly and flexibly deployable and trained. These technicians will primarily assemble parts, reserves and modules in relatively short periods of time (for example, using SMED, Single Minute Exchange of Dies), such as a complete pump. These technicians will need digital competencies, such as working with a Digital Twin or consulting digitally with remote specialist technicians.
   b) Awareness of electrical safety is important here.
4) In addition, technicians will be needed who will perform more in-depth and specialized work off-site, such as in a workshop. This work will be more schedulable.

Follow-up steps:

1) Gain insight into operational scenarios;
2) Understand what competencies technicians need;
3) Understanding the flexibility required;
4) Determine if the current group of technicians in the market can meet the requirements;
5) Determine how to address the desired flexibility:
   a) on an organizational level;
   b) on a technical level.
6) Involve asset owners, technical service providers and educational institutions in this analysis.

[106] https://www.worldclassmaintenance.com/project/fieldlab-hydro-boreas/
Flyer WCM project: https://www.worldclassmaintenance.com/wp-content/uploads/2022/08/2022Flyer-Hydro-Boreas-def.pdf

Appendix 36 Canada Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022) states that Canada is one of the largest and cheapest hydrogen producers in the world, with the following motivation:

1) Strong capabilities in hydrogen production, fuel cell technology and carbon capture, use and storage (CCUS) can advance the national commitment to net-zero by decarbonizing much of the heavy-emitting sectors important to the Canadian economy.
2) Combined with a skilled and available workforce, Canada is uniquely positioned to become both a world leader in the use and export of low-carbon hydrogen.
3) The purpose of this Hydrogen Workforce Assessment Tool (Tool) is to describe the workforce needed to advance Canada's hydrogen economy.
4) The Tool supplements the report on assessing the workforce needed to advance Canada's hydrogen economy. This identifies opportunities to utilize qualified and available labor, the extent to which an additional labor force needs to be developed, and potential risks to meeting the talent needs of the hydrogen industry.

Table 38 Breakdown functions EQF score list (Hufnagel-Smith, Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version 2022)

Canada job level EQF	**Number**	**Percent**
EQF level 2	2	2,4%
EQF level 2/3	5	6,0%
EQF level 3	2	2,4%
EQF level 3/4	10	11,9%
EQF level 4	9	10,7%
EQF level 4/5	9	10,7%
EQF level 5/6	1	1,2%
EQF level 6	4	4,8%
EQF level 6/7	22	26,2%
EQF level 6/7/8	2	2,4%
EQF level 7/8	18	21,4%
	84	100,0%

Table 39 Distribution of positions on VMBO, MBO, HBO and WO list (Hufnagel-Smith, Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version 2022)

Canada job level training	**Number**	**Percent**
VMBO	-	-
MBO	28	33,3%
HBO	36	42,9%
WW	20	23,8%
Total	84	100,0%

Breakdown by function: (Hufnagel-Smith 2022, 22)[107]

1. Core profession;
2. Typical qualification (minimum);
3. Main activities;
4. Unique Requirements for Hydrogen;
5. Potential talents/risks/opportunities.

PEM Electrolysis Production Workforce Requirements

Workforce Requirements for PEM Electrolysis Production (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022):

INGENIORS:
a. Process control specialist;
b. Process Engineer;
c. Electrical Engineer;
d. Electrical and instrumentation engineer;
e. Facilities Engineer;
f. Specialist measurements;
g. Mechanical Engineers: Compression, Equipment & Piping Systems, Reliability;
h. Process control engineer;
i. Process Safety Engineer;
j. Production Engineer;
k. Renewable Interconnections Specialist.

FACTORY OPERATION & MAINTENANCE:
a. Control Room Operator;
b. Laboratory Technician;
c. Maintenance planner;
d. Maintenance Professionals: Electrical, Instrumentation & Control, Mechanical;
e. Plant Manager;
f. Process Operator.

107 Hufnagel-Smith, Pat. 2022. *Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version.* TRANSITION ACCELERATOR REPORTS, TRANSITION ACCELERATOR REPORTS, 47. Accessed Mar. 16, 2023. https://transitionaccelerator.ca/wp- content/uploads/2022/07/Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version_1.pdf

Competencies needed for hydrogen in the industry and network -.

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 90)

1. Personnel requirements for underground hydrogen storage
2. INGENIORS:
    a. Drilling & completion engineer;
    b. Engineer for caverns/cavities in rock formations.

3. FIELDOPERATORS:
    a. Drilling crew;
    b. Heavy machinery and vehicles -mechanical engineering;
    c. Reservoir Technologist;
    d. Service rig crew;
    e. Operator completion of the well;
    f. Supervisor completion of well;

4. GEOGRAPHICAL PROFESSIONALS: Geologist, Geophysicist,
5. Geotechnical Specialist.

6. OPERATIONS & MAINTENANCE OF SURFACE FACILITIES:
    a. Control Room Operator;
    b. Compression Specialist;
7. Maintenance Professionals: Electrical & Instrumentation, Mechanical;
8. Specialist measurements.

Hydrogen pipeline personnel requirements

Hydrogen pipeline workforce requirements (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 105)

1. INGENIORS:
    a. Process Control Technician;
    b. Compression Specialist;
    c. Corrosion Specialist;
    d. Electrical and instrumentation engineer;
    e. Measurement Technology Specialist;
    f. Pipeline Engineer;
    g. Leadership integrity specialist;
    h. Process Safety Engineer.

2. OPERATIONS & MAINTENANCE:
    a. Control Room Operator;
    b. Pipeline Planner;
    c. Pipe Technicians: Electrical and Instrumentation, Mechanical Engineering;
    d. Station operators: Compression.

Hydrogen distribution by Truck - P 118 - not included.

Ammonia personnel requirements

1. INGENIORS:
    a. Process control engineer;
    b. Electrical and instrumentation engineer;
    c. Facilities Engineer;
    d. Measurement and sensor technology specialist;
    e. Mechanical Engineers: Equipment & Piping, Reliability;
    f. Process control engineer;
    g. Process Engineer;
    h. Process Safety Engineer;
    i. Production Engineer.

2. PLANT OPERATIONS & MAINTENANCE:
    a. Control Room Operator;
    b. Laboratory Technician;
    c. Maintenance planner;
    d. Maintenance Professionals: Electrical, Instrumentation & Control, Mechanical;
    e. Plant Manager.

1. Control room operator:
    f. Process Operator.

Competencies needed for hydrogen in the industry and network -.

Hydrogen fueling station personnel requirements

Hydrogen fueling station workforce requirements (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 157)

1. INGENIORS:
    a. Process control engineer;
    b. Electrical and instrumentation engineer;
    c. Mechanical engineers: Compression;
    d. Mechanical engineers: equipment & piping systems;
    e. Mechanical engineers: Reliability;
    f. Process control engineer;
    g. Process Engineer;
    h. Process Safety Engineer;
    i. Product Engineer;
    j. Quality Engineer.

2. OPERATIONS & MAINTENANCE:
    a. Hydrogen fueling station technician;
    b. Logistics Coordinator;
    c. Maintenance Technician: Compression;
    d. Maintenance Technician: Electrical;
    e. Maintenance technician: mechanical engineering;
    f. Truck driver (class 1 & 3) - hydrogen fuel delivery.

Hydrogen heating personnel requirements

workforce requirements (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 173) for hydrogen heating:

1. Asset performance manager;
2. Hydrogen Integration Specialist;
3. Welder;
4. Gas Technician;
5. HVAC Technician;
6. Utility Inspector;
7. Utility operator;
8. Utility Service Planner;
9. Utility Service Technician;
10. Welding engineer.

Hydrogen energy generation - personnel requirements

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 187)

Energy generation using hydrogen - Work force required

1. INGENIORS:
    a. Process control engineer;
    b. Compression Specialist;
    c. Electrical Engineer;
    d. Electrical and instrumentation engineer;
    e. Facilities Engineer;
    f. Hydrogen Integration Specialist;
    g. Mechanical engineers: Equipment & piping, reliability;
    h. Process control engineer;
    i. Process Engineer;
    j. Process Safety Engineer.

2. PLANT OPERATIONS & MAINTENANCE:
    a. Control Room Operator;
    b. Maintenance planner;
    c. Maintenance Professionals: Electrical, Instrumentation & Control, Mechanical;
    d. Plant Manager;
    e. Process Operator;
    f. Energy Planner.

Video about this research: What does Canada's future hydrogen workforce look like? Pat Hufnagel- Smith https://youtu.be/kJkZeYYUufE

Competencies needed for hydrogen in the industry and network -.

Manufacturing for the Hydrogen Economy: Core Occupations P209 personnel requirements

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 209)

The following is a generic list of occupations that may require specialized skills and knowledge for some hydrogen-related production processes.

WORKERS IN PRODUCTION PROCESSES

1. PRODUCT DESIGN, ASSEMBLY, QUALITY MANAGEMENT:
    a. Application Engineer;
    b. Assembly Technician;
    c. Compliance Specialist;
    d. CNC fabrication technician;
    e. Design Engineers: Electrical and Instrumentation;
    f. Design Engineers: Mechanical Engineering;
    g. Design Engineers: Mechatronics;
    h. Production Engineer;
    i. Material Specialist;
    j. Pipefitter/Steamfitter;
    k. Production Planner;
    l. Production Supervisor;
    m. Quality control specialist;
    n. Service Technician;
    o. Purchasing Specialist;
    p. Test Technician;
    q. Validation engineer;
    r. Welder.

2. FACILITY OPERATIONS AND MAINTENANCE:
    a. Facility Maintenance Planner;
    b. Maintenance Professionals: Electrical, Electromechanical, Instrumentation & Control, Mechanical;
    c. Mechatronics Engineer: Facility.

Core professions supporting hydrogen value chain development.

(Hufnagel-Smith 2022, 23) (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 228)

Core professions supporting hydrogen value chain development.

1. Business and commercial development specialist
    a. Digital professions:
        i. Cybersecurity Specialist;
        ii. Data analyst;
        iii. Data Engineer;
        iv. Data scientist;
        v. Software Developer;
        vi. Systems Integration Specialist.

2. Environmental, social and governance (ESG) functions such as:
    a. Environmental Specialist;
    b. Analyst, environmental leader, social governance;
    c. Government Relations Specialist;
    d. Health and Safety Advisor;
    e. Minorities and Indigenous Relations Specialist;
    f. Regulatory analyst and compliance specialist;
    g. Stakeholder engagement and communications specialist;
    h. Sustainability Specialist.

3. Inspectors:
    a. Cathodic Protection Technician;
    b. Coating inspector;
    c. Building Inspector;
    d. Corrosion Specialist;
    e. Inspectors for in-service pressure equipment;
    f. Non-destructive (NDE) inspector and technician;
    g. Safety codes inspector;
    a. Welding Inspector.

Appendix 37 The Hydrogen labor force assessment tool Hufnagel

The Hydrogen Workforce Assessment Tool (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022)[108] provides detailed information on the core tasks required for each hydrogen value chain (Hufnagel-Smith 2022)[109] :

1. Typical minimum qualifications;
2. Main activities performed by the professions;
3. Unique requirements required by those professions in the hydrogen industry;
4. Potential talent opportunities and/or risks.

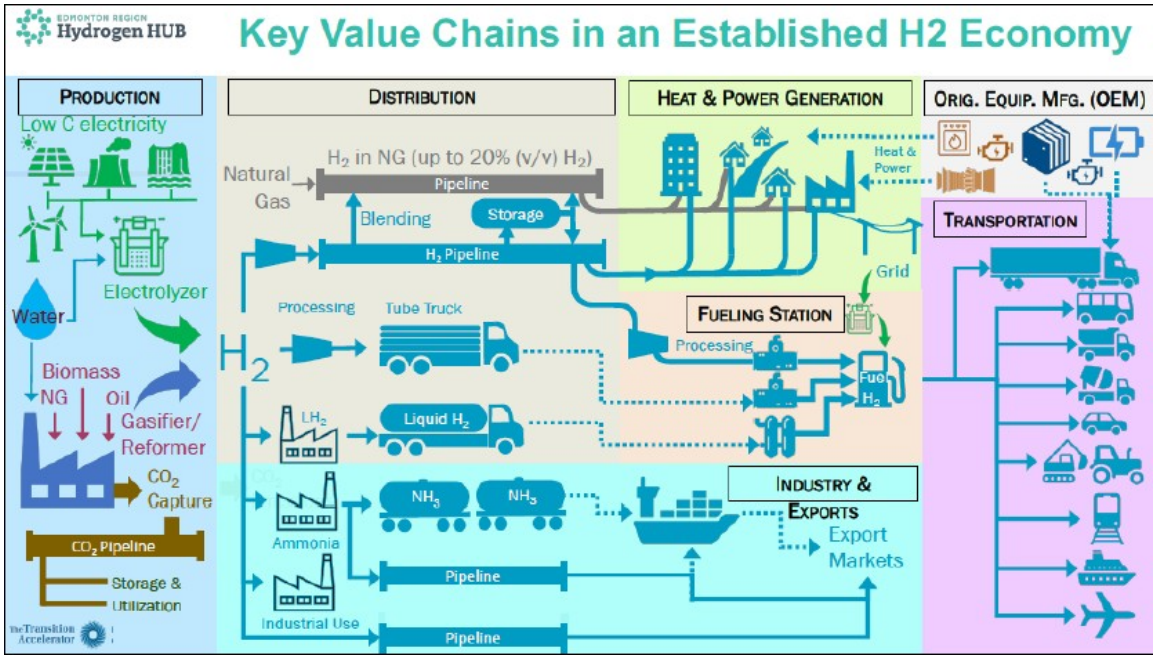


Figure 23 Hydrogen value chain (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022)

[108] Hufnagel-Smith, Pat ;The Transition Accelerator 2022 July Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment *Tool*

[109] Hufnagel-Smith, Pat. 2022. *Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version.* TRANSITION ACCELERATOR REPORTS, TRANSITION ACCELERATOR REPORTS, 47. Accessed Mar. 16, 2023. https://transitionaccelerator.ca/wp- content/uploads/2022/07/Assessing-Workforce-Required-to-Advance-Canadas-Hydrogen-Economy_Version_1.pdf

The Hydrogen Workforce Assessment Tool looks in detail at several different technologies, including gray, blue and green hydrogen. It distinguishes between the different technologies.

1. Low Carbon Production:
    a. Proton Exchange Membrane (PEM) Electrolysis;
    b. Steam Methane Reforming (SMR) & Autothermal Reforming (ATR);
    c. Carbon capture and storage (CCS).
2. Storage, upgrading and transportation:
    a. Underground hydrogen storage;
    b. Hydrogen lines;
    c. Hydrogen distribution by truck;
    d. Ammonia as a chemical carrier of hydrogen.
3. Create existing and new markets for low-carbonized hydrogen:
    a. Transportation using hydrogen;
    b. Hydrogen fueling stations;
    c. Hydrogen heating;
    d. Energy generation using hydrogen.
4. Manufacturing for the Hydrogen Economy:
5. Roles that are common across the value chain.

Appendix37-0-15 details the various functions for each category.
In this detail elaboration, the gray and Blue hydrogen routes incl. CCS/CCU, Hydrogen distribution by truck are not included within this overview.

Appendix 37-0 Canada Job Requirements

Work areas and positions included in the analysis from the study by (Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022)

1) PEM Electrolysis Production Work force requirements:
    a) Mechanical engineers: equipment and piping;
    b) Mechanical Engineers Reliability;
    c) Specialist Renewable Interconnection;
    d) Maintenance Crafts Electric;
    e) Maintenance Crafts Instrumentation & Controls;
    f) Maintenance Crafts Mechanical;
    g) Control Room Operator;
    h) Plant Operator.

2) Requirements for underground storage:
    a) Maintenance Crafts Mechanical;
    b) Hydrogen pipeline transmission;
    c) Maintenance Mechanic Mechanical/Pipeline Technician - Mechanical Engineering;
    d) Electrical & Instrumentation.

3) Filling station labor force requirements:
    a) Quality Engineer;
    b) Maintenance Technician: Compression;
    c) Maintenance Technician: Electrical;
    d) Maintenance Technician: Mechanical.

Appendix 37-1: Function: Mechanical engineers: Equipment & piping, Reliability/Mechanical engineers: Equipment and piping, Reliability

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 16)

Typical requirements (min)

Bachelor's Degree: Mechanical Engineering

Core competencies:
1. Design pressure and stationary equipment associated with hydrogen production, including electrolyzers, vessels, piping and related auxiliary systems.
2. Design rotating equipment associated with hydrogen production, including turbines, compressors, pumps and related auxiliary systems.
3. Provide technical expertise in the maintenance and repair of pressure equipment and systems and rotating equipment to ensure compliance with all applicable codes and standards.
4. Develop expertise in existing and emerging technologies related to PEM electrolysis production and related processes and equipment.
5. Participate in Root Cause and Failure Analysis (RCFA).

Unique requirements for hydrogen:
1. Properties, behavior and potential hazards of hydrogen;
2. Safety when working with or around hydrogen;
3. Appropriate selection, design and maintenance of electrolyzers, vessels, piping systems and fittings, valves and seals to withstand hydrogen pressures (high/low) and temperatures (hot/cold);
4. Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressures (high/low) and temperatures (hot/cold).

Potential talents/risks/opportunities:
Skills/knowledge and transferability to other industrial production processes, including oil & gas, chemicals, petrochemicals, pulp & paper:
1. Natural gas processing as closest match;
2. High pressure gas system;
3. Cryogenics/cooling systems;
4. Piping and pressure vessels;
5. Flammable gas;
6. Compressors.

Regulatory inspection requirements and inspection/testing procedures for the high-pressure manufacturing process, including ASME/API Pressure vessel, NBIC.

Appendix 37-2: Function: Mechanical engineers Reliability/ Mechanical engineers Reliability

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 17) Mechanical engineers Reliability/ Mechanical engineers Reliability

Typical Qualifications (min)

Bachelor's Degree: Mechanical Engineering

Core competencies:

1. Lead the development and implementation of PEM electrolysis plant reliability program in accordance with all applicable codes and standards;
2. Supervise inspection, maintenance and repair of pressurized and stationary equipment associated with hydrogen production, including electrolyzers, vessels, piping and associated fittings;
3. Supervise inspection, maintenance and repair of rotating equipment associated with hydrogen production, including turbines, compressors, pumps and associated attachments;
4. Develop expertise in existing and emerging technologies related to inspection and maintenance;
5. Participate in Root Cause and Failure Analysis (RCFA).

Unique requirements for hydrogen:

1. Properties, behavior and potential hazards of hydrogen;
2. Safety when working with or around hydrogen;
3. Appropriate selection, design and maintenance of electrolyzers, vessels, compressors, piping systems and fittings, valves and seals to withstand hydrogen pressure (high/low) and temperatures (hot/cold);
4. Appropriate selection, design and maintenance of combustion, compression, pumping and turbine systems and equipment to withstand hydrogen pressures (high/low) and temperatures (hot/cold).

Potential talents/risks/opportunities:
Skills/knowledge and transferability from industry to other industrial process production, including oil & gas, chemicals, petrochemicals, pulp & paper.

1. The closest match is natural gas processing;
2. High-pressure gas system;
3. Cryogenics/cooling system;
4. Piping and pressure vessels;
5. Flammable gas;
6. Compressors;
7. Regulatory inspection requirements and inspection/testing procedures for high pressure manufacturing, including ASME/API pressure vessel, NBIC.

Appendix 37-3: Position: Renewable Interconnection Specialist/ Renewable Interconnection Specialist

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 20)

Typical Qualifications (min):

Bachelor's Degree: Electrical Engineering
Renewable energy experience is desirable, including knowledge of associated codes and standards.

Core activities:

1. Design and management of interconnection from renewable energy generation sites to an electrolysis production plant;
2. Perform computer modeling to ensure stable power supply.

Unique Requirements for Hydrogen:

1. Hydrogen properties, behavior and potential hazards it can create
2. Safety when working with or around hydrogen;
3. Knowledge of major high power electrical equipment and interconnection applications;
4. associated with renewable electricity-powered electrolysis-produced hydrogen.

Potential Talent/Risk/Opportunity:

1) Skills/knowledge and transferability of industry opportunity with other industrial infrastructure, including energy and cogeneration systems for industrial plants;
2) Experience with renewable electricity and processes and compiling required input data for interconnection applications may be more difficult to find.

Appendix 37-4: Job: Maintenance Occupation: Electrical - Electro maintenance technician

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 23)

Typical qualifications (min)

1) Certificate of qualification in industrial electrician
2) Registered student

Core activities:

1. Inspect, repair, install, troubleshoot and modify electrical and electronic equipment and components, AC/DC motors and drives, low and high voltage motors/switches, programmable logic controllers (PLCs), control circuits, switchgear, transformers, motors, starters, relays and hydraulic and pneumatic electrical controls;
2. Install or replace electrical wiring, outlets, switch boxes, conduit, power cables, fiber optic and coaxial cable assemblies, lighting fixtures and other electrical components;
3. Install, replace or repair generators, alternators and industrial storage batteries
4. Interpret drawings, blueprints, schematics and specifications of electrical codes.

Unique requirements for hydrogen:

1. Properties of hydrogen, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Appropriate selection and maintenance of major electrical and electronic equipment and systems associated with an electrolyzer hydrogen production facility.

Potential talents/risks/opportunities

1. Skills/knowledge and transferability of industry opportunities: oil and gas, chemical, petrochemical, pulp and paper, etc.

Appendix 37-5: Function: Maintenance occupation: Instrumentation & control/Instrumentation & control

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 24)

Typical qualifications (min)

1) Certificate of qualification as an instrumentation technician
2) Registered student

Core activities:

1. Inspect, repair, install, troubleshoot and modify process controls, control valves, safety devices, analyzers, programmable logic controllers (PLC), instrumentation (pressure, level and flow), process monitoring equipment and control circuits and distributed control systems (DCS);
2. Perform preventive and corrective maintenance on instrumentation and electrical equipment;
3. Troubleshooting, repair and calibration of plant instrumentation and controls;
4. Improve equipment performance and/or system reliability/capacity.

Unique requirements for hydrogen:

1. Properties, behavior and potential hazards of hydrogen;
2. Safety when working with or around hydrogen;
3. Appropriate selection and maintenance of key instrumentation equipment and systems associated with a hydrogen production facility with an electrolyzer.

Potential talent/risk/opportunity factors:

1. Ability to transfer skills/knowledge and transferability to other industries such as oil and gas, chemical, petrochemical, pulp and paper, etc.
2. Supports digitization in various sectors and is therefore in high demand.
    a. Existing shortage of personnel with these skills.

Exhibit 37-6: Job: Maintenance occupation: mechanical engineer

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 17)

Typical qualifications (minimum):

Certificate of Qualification in Industrial Mechanics or Mechanical Engineering.

1. Registered Apprentice. In Ontario: Hydrogen Technician (TSSAH2) certification, see Appendix 44.
2. Obtained by working under our TSSA-H2 technicians.

Core activities:

1. Inspection, repair, troubleshooting, modification, installation and commissioning of mechanical equipment such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gear drives, steam turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders and piping systems;
2. Improve the condition and reliability of machines.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Maintenance of vessels, compressors, piping systems and fittings, valves, etc. to withstand hydrogen pressure and temperatures;
4. Knowledge of appropriate materials, seals, coatings.

Potential talent/risk/opportunity:

1. Skills/knowledge and industry transferability with other industrial process manufacturing, including oil and gas, chemical, petrochemical, pulp and paper.
2. Nearest deal: natural gas processing.

Exhibit 37-7: Function: control room operator

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 21)

Typical qualifications (min):

Mostly an experienced factory operator.
Multiple paths to this career:

1. Diploma in petrochemicals, chemical processes, Control Room Operator or power generation technology;
2. Class A, class B cooling technology for liquid process.

Core activities:

1. Oversee daily activities from the centralized control room
2. Assist plant operator in diagnosing operational deficiencies from instrument indications;
3. Resolve equipment problems and possible causes using instrument indications;
4. Assist in the preparation of equipment and systems for maintenance and commissioning;
5. Perform safety responsibilities such as hazard identification, equipment lockout, emergency response, etc;
6. Issue work permits to maintenance personnel and ensure they are aware of the risks associated with the work to be performed.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Understanding of the hydrogen production process using PEM electrolyzers.

Potential talents/risks/opportunities:

1. Skills/knowledge and transferability from industry to other industrial process production, including oil and gas, chemicals, petrochemicals, pulp and paper:
    a. Natural gas processing is the closest match;
    b. Factory monitoring and control via distributed control system (DCS) and programmable logic controller (PLC).

Exhibit 37-8: Function: plant operator/plant operator

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 26)

Typical qualifications (min):

Multiple paths to this career:

1. Technology degree in petrochemicals, chemical processes or power generation;
2. Class A, class B cooling technology for liquid process.

Core activities:

1. Guarantee safe operation and production of hydrogen gas and/or liquid hydrogen;
2. Monitor and analyze plant processes to recognize potential operational problems, determine causes and provide appropriate solutions;
3. Preparing equipment and systems for maintenance and start-up;
4. Capture daily production and performance data for optimization and to provide insight into equipment maintenance, safety and environmental performance;
5. Loading hydrogen trucks.

Unique requirements for hydrogen:
Hydrogen properties, behavior and potential hazards created;

1. Safety when working with or around hydrogen;
2. Understanding of electrochemical reactions, processes and hydrogen production using PEM electrolyzers.

Potential talents/risks/opportunities:

1. Skills/knowledge and transferability from industry to other industrial process manufacturing, including oil and gas, chemicals, petrochemicals, pulp and paper:
    a. Natural gas processing is the closest match;
    b. Factory monitoring and control via distributed control system (DCS) and programmable logic controller (PLC).

Appendix 37-9: Function: Maintenance job mechanic mechanic for underground storage

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 100)

Typical Qualifications (min)

1. Certificate of Proficiency:
    a. Industrial Mechanical Engineer (Mechanic);
    b. Registered student.
2. Technologist degree: Mechanical Engineering;
3. A valid driver's license + with no police registrations.

Core activities:

1. Ensure that all mechanical equipment and systems are maintained in accordance with regulatory and procedural requirements;
2. Inspect, repair, troubleshoot, modify, install and commission mechanical equipment such as reciprocating, centrifugal and screw compressors, cryogenic pumps, gearboxes, turbines, fans and blowers, vessels, heat exchangers, reciprocating and centrifugal expanders and piping systems;
3. Lead equipment isolation, shutdown and lockout/tagout activities.

Unique Requirements for Hydrogen:

1. Properties, behavior and potential hazards of hydrogen;
2. Safety when working with or around hydrogen;
3. Maintenance of mechanical equipment to withstand hydrogen pressure and temperatures;
4. Knowledge of appropriate materials, seals and coatings.

Potential Talents/Risk/Opportunities:

1. Skills/knowledge and industry transferability to other industrial production processes, including oil & gas, chemical, petrochemical, pulp & papie:.
    a. Underground natural gas storage is the most relevant comparable function.

Appendix 37-10: Function: Hydrogen Pipeline Transmission Maintenance Mechanic/Pipeline Technician - Mechanical Engineering

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 114)

Typical qualifications (min) Multiple

paths to this career:

1. Certificate of Qualification: Industrial mechanic (Millwright)
    a. Registered student
2. Technology degree: Mechanical Engineering
3. A valid driver's license + clean resume

Core activities:

1. Ensure that all stationary and rotating mechanical equipment and systems are maintained in accordance with regulatory and procedural requirements
2. Perform inspections, troubleshoot and repair mechanical equipment: pumps, valves, actuators, tank mixers, mechanical seals, motors, fans, compressors, turbines, etc.
3. Lead pipeline shut-off and isolation, depressurization, blow-off, purging and pressurization of pipelines and installation and operation of air movers/pressurizers.
4. Communicate with contractors, the public, landowners and government agencies as needed

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Appropriate selection and maintenance of stationary and rotating equipment and systems required for pipeline transmission of compressed hydrogen.

Potential talent/risk/opportunity:
Skills/knowledge and transfer capabilities between industries, including gaseous hydrocarbon pipelines.

Appendix 37-11: Job title: Hydrogen transmission pipeline technician - electrical & instrumentation

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 113)

Typical qualifications (min) Multiple

paths to this career:

1. Certificate of qualification as an instrumentation technician or industrial electrician;
    a. Registered student.
2. Technologist degree in Instrumentation Engineering or Electrical Engineering;
3. A valid driver's license + clean excerpt.

Core activities:

1. Ensure that electrical and instrumentation equipment and systems are maintained in accordance with regulatory and procedural requirements;
2. Troubleshoot, test, calibrate electrical systems associated with pumps, motors, valves, switchgear, flow meters, logic controls, motor control centers, compressors, power supplies, etc;
3. Programming and troubleshooting of instrumentation systems, including PLCs, RTAP, Flow Computer and SCADA systems;
4. Communicate with contractors, public, landowners and government agencies as required.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Proper selection and maintenance of electrical equipment and instrumentation systems required for pipeline transmission of gaseous hydrogen.

Potential talents/risks/opportunities:
Skills/knowledge and industry transferability with gaseous hydrocarbon pipelines.

Exhibit 37-12: Position: Gas station personnel requirements, Quality engineer/Quality engineer

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 164)

Typical qualifications (min) Multiple

paths to this career:

1. Bachelor's Degree in mechanical or industrial engineering;
2. Engineering technology degree in mechanical engineering, industrial engineering or chemistry + experience;
3. QA/QC certifications.

Core activities:

1. Develop and implement quality management systems for hydrogen fueling station;
2. Develop and implement quality standards, procedures and control systems for material and equipment selection and validation, installation and assembly, process requirements and operational procedures;
3. Inspect and test equipment, processes and facilities to meet quality specifications;
4. Validate procedures for engineering hydrogen assemblies and infrastructure installations;
5. Develop corrective actions, solutions and improvements to quality problems.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created
2. Safety when working with or around hydrogen;
3. Experience and knowledge of hydrogen fuel equipment, technology and systems, including on-site generation, compression, refrigeration systems, storage and distribution;
4. Knowledge of codes and industry standard processes related to hydrogen fueling station equipment.

Potential talent/risk/opportunity:

1. Skills/knowledge and industry transferability with other industrial process manufacturing, including chemical, petrochemical and oil and gas industries;
2. Knowledge of applicable ISO, CSA, ASME and other technical standards and codes.

Exhibit 37-13: Position: Fueling Station Workforce Requirements, Maintenance technician: Compression

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 167)

Typical qualifications (min) Multiple

paths to this career:

1. Certified Professional: Electrical, Industrial Mechanics (Millwright) or Instrumentation Technician;
    a. Registered student.
2. Technologist Degree: Aerospace, Instrumentation or Mechanical Engineering Technology Engineer;
3. Valid driver's license + clean excerpt.

Core activities:

1. Install, inspect and maintain hydrogen fuel station compression system and related instrumentation and control equipment and systems;
2. Commissioning and startup of new equipment;
3. Troubleshoot and diagnose problems.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards created;
2. Safety when working with or around hydrogen;
3. Proper selection and maintenance of pressure vessels, compression systems and related instrumentation and control equipment and systems associated with the hydrogen fuel system.

Potential talent/risk/opportunity:

1. Skills/knowledge and industry transferability with other industry sectors, including oil and gas, chemical, etc., servicing the following:
    a. High-pressure gas system;
    b. Cryogenics/cooling systems;
    c. Piping and pressure vessels;
    d. Flammable gas;
    e. Compressors;
    f. PLC logic as applied to compressor systems.

Appendix 37-14: Job: hydrogen fueling station occupational requirements Maintenance Technician: Electrical and Mechanical Engineering

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 168)

Typical qualifications (minimum)

There are multiple paths to this career:

1. Route certification: Aircraft Mechanic, Electrical, Gas Fitter (Class A or B), Industrial Mechanic (Millwright) or Instrumentation Technician;
    a. Registered student.
2. Technologist degree: Aerospace, Instrumentation or Mechanical Engineering Technical Engineer;
3. Experience with welding and soldering is a plus;
4. Valid driver's license + clean abstraction.

Core activities:

1. Install, inspect and maintain mechanical, electrical and instrumentation and control equipment and systems of the hydrogen fuel station;
2. Reading technical drawings, flow charts, equipment layouts, conduit drawings and electrical control diagrams;
3. Commissioning and startup of new equipment;
4. Troubleshooting and Diagnostics.

Unique requirements for hydrogen:

1. Hydrogen properties, behavior and potential hazards that may arise
2. Safety when working with or around hydrogen;
3. Knowledge of proper maintenance of hydrogen fuel systems, including pressure vessels, evaporators, flow, level and pressure control, instrumentation, dispensers, pumps, PLC and compressors, Human Machine Interface (HMI) and control software.

Possible talent/risk/opportunity factors:

1. Skills/knowledge and opportunities for transferability to other industrial sectors, including oil and gas, chemical, etc. that perform maintenance on:
    a. High-pressure gas system;
    b. Cryogenics/cooling systems;
    c. Piping and pressure vessels;
    d. Flammable gas;
    e. Compressors and pressure control instrumentation;
    f. Human Machine Interface (HMI) and control software.

Exhibit 37-15: Position: Fueling Station Workforce Requirements, Fueling station technician

(Hufnagel-Smith, Workforce Requirements for Advancing a Hydrogen Economy Hydrogen workforce Assessment Tool 2022, 165)

Typical qualifications (min)

1. Post-secondary training as a mechanical or compression engineer

Core competencies:

1. Oversees the operation of fuel stations and the sale of fuel to the public.
2. Inspects, maintains, repairs and calibrates fuel station equipment, compression and dispensing equipment.
3. Monitors component inventories and initiates repeat orders to ensure availability and delivery of components needed to complete routine maintenance requirements and activities.
4. Collects, analyzes and interprets relevant data on systems and operational activities; prepares status reports to ensure system compliance with systems design and standards.
5. Applies knowledge of federal, state and municipal codes and regulations.

Unique requirements for hydrogen:

1. Properties, behavior and potential hazards of hydrogen;
2. Safety when working with or around hydrogen;
3. Troubleshooting and routine maintenance of hydrogen fuel compression and distribution equipment.

Potential Talent/Risk/Opportunity:

1. Transferable experience in maintenance and operation of a computerized fuel control system, including natural gas (CNG) and petroleum fuels.

Appendix 38 summary hydrogen-related competencies

Engineering

1) Chemical and process engineering:
   a) Thermodynamics;
   b) Chemical kinetics;
   c) Flow dynamics;
   d) Heat and mass transport;
   e) Hydrogen production from renewable sources (electrolysis, biofuels, photolysis, plasma);
   f) Hydrogen storage techniques;
   g) Technologies and infrastructure;
   h) Reaction of hydrogen with metals and nonmetals;
   i) Units and applications International System of Units (SI) in gas applications.
2) Mechanical Engineering:
   a) Mechanical Engineering;
   b) Fixed mechanics;
   c) Materials Science;
   d) High-pressure systems (pressure equipment, seals);
   e) Welding;
   f) Design and operation of hydrogen combustion turbines;
   g) Transportation of hydrogen via pipelines.
3) Electrical engineering and electronics:
   a) Electromechanics;
   b) Fuel cells;
   c) Physical properties and energy conversions;
   d) CAD, simulation;
   e) Programming;
   f) Diagnose;
   g) Electrolysis technology, plant and equipment construction.
4) Hydrogen properties and applications:
   a) Properties of hydrogen;
   b) Name physical and chemical properties;
   c) Use of inert gas with hydrogen;
   d) Risks when mixing (inert) gases with hydrogen;
   e) Measures of risks from different gases;
   f) Measures to prevent mixing of hydrogen and air;
   g) Hydrogen as feedstock/input for green metals, green ammonia and manufacturing;
   h) Co-products of hydrogen.

5) Safety and Environmental Engineering:
   a) Introduction to hydrogen as an energy carrier;
   b) Release, mixing and distribution;
   c) Hydrogen ignition;
   d) Hydrogen fires;
   e) Explosions;
   f) Deflagrations and detonations;
   g) Computational hydrogen safety engineering;
   h) Mitigation measures for hydrogen embrittlement and good practices.
6) Energy and Sustainability Engineering:
   a) Comparison of hydrogen properties with those of other fuels;
   b) Hydrogen ignition mechanisms;
   c) Energy sources and heat transfer;
   d) Combined gas laws (Charles' and Boyle's), the interrelationship between pressure, volume and temperature;
   e) Environmentally friendly equipment and materials.
7) Systems and control engineering:
   a) Systems knowledge & understanding;
   b) Design, conversion/new construction;
   c) Gas measurement technology;
   d) Systems Insight.
8) Civil and Construction Engineering:
   a) Hydrogen plants and infrastructure;
   b) Design of integrated systems and facilities;
   c) Design planning, approval and compliance processes;
   d) Design of domestic hydrogen systems.

Competencies needed for hydrogen in the industry and network -.

Production

1) Hydrogen production and storage:
    a) Overview of hydrogen production, storage, industry and energy use;
    b) Operation of pressure regulators;
    c) Hydrogen production techniques;
    d) Potential cost savings.
2) Transportation and infrastructure:
    a) Transport methods such as compressed gas, as a liquid or via ammonia or naphthenes;
    b) Processes for transporting compressed hydrogen via Tubetrailers;
    c) Processes for transporting liquid hydrogen via road tankers;
    d) Infrastructure and systems integration:
        i) Integrated systems integration;
        ii) Non-pipeline infrastructure;
        iii) Pipeline-bound infrastructure;
        iv) Medium and large storage systems.
3) Installation and production:
    a) Environmentally friendly equipment and materials;
    b) Installation of technical demonstration systems in the industrial environment;
    c) Production and assembly of electrolyzers, fuel cells and components;
    d) Mass production of plants and components.
4) Industrial applications:
    a) Hydrogen in industry and mobility;
    b) Industry perspective: production, transportation, provision and application.
5) Materials Science and Metalworking:
    a) Design and manufacture of parts and components (CNC);
    b) Design pressure and stationary equipment associated with hydrogen production;
    c) Design rotating equipment associated with hydrogen production.

Installation

1) Installation of a hydrogen plant:
2) Preparation and planning:
   a) Prepare installation work;
   b) Plan and build equipment and infrastructure.
3) Construction and assembly:
   a) Place and assemble components and parts;
   b) Construction and assembly;
   c) Water treatment and construction.
4) Hydrogen engineering - Performing activities in the hydrogen gas industry:
   a) FCH vehicles;
   b) Hydrogen fueling stations;
   c) Hydrogen transportation;
   d) Stationary FC applications;
   e) Hydrogen-based energy storage systems;
   f) Hydrogen central heating boilers;
   g) Storage methods and transportation.
5) Built environment and smart buildings:
   a) Hydrogen and the built environment: hydrogen boilers, fuel cells, hybrid heat pumps and Home Energy Management Systems (HEMS);
   b) Hydrogen in smart buildings - application of hydrogen in building technology.
6) Infrastructure:
   a) Sector integration and electricity required for hydrogen production;
   b) Transportation and infrastructure;
   c) Storage of hydrogen.
7) Industrial applications:
   a) Installation applications in the steel industry;
   b) Installation applications in the chemical industry;
   c) Installation applications for process heat;
   d) Installation of stationary applications, turbines, engines and fuel cells.
8) Specific installations:
   a) Installation of gas stations;
   b) Electrolysis plant;
   c) H_2 compressor plant;
   d) Buffer vessel;
   e) H_2 filling station;
   f) Instrument air supply;
   g) Nitrogen supply;
   h) Piping;
   i) Installation of stationary fuel cells (industrial/commercial scale and residential use).
9) Maintenance and commissioning:
   a) Prepare equipment and systems for maintenance and commissioning;
   b) Install, inspect and maintain hydrogen fuel station compression system and related instrumentation and control equipment and systems.

10) Environment:
    a) Environmentally friendly waste disposal.
11) Communications and security:
    a) Communications layer (Networking, Cybersecurity).

Funding

Funding study topics for a hydrogen plant.

1) Economics:
    a) Choice based on economic value/return;
    b) Economic model.

2) Market Developments:
    a) Hydrogen energy markets;
    b) Energy markets: characteristics, economics, propositions, Power Purchase Agreements (PPAs) and forecasts, connection to hydrogen;
    c) Energy (trade) markets.

3) Incentives and policies:
    a) What is stimulated and how;
    b) What developments can be expected due to changing conditions, such as CO2 prices?

4) Future technologies and prospects:
    a) Hydrogen outlook: what's at stake for the future? Sunlight to hydrogen, methane pyrolysis and economics.

5) Project work:
    a) From theory to practice: During the study period, trainees can work continuously on a project and develop it to the approval and funding stage.
    b) Hydrogen projects in practice: business case.

6) Commercial skills:
    a) Commercial negotiation/prospecting.

Operation

1) Operation:
    a) Company of a hydrogen plant;
    b) Operation of the hydrogen production process;
    c) Pipeline and hydrogen storage facilities: operations and maintenance;
    d) Hydrogen compression, liquefaction and conversion using multiple carriers (for domestic use and export);
    e) Ship loading for hydrogen export;
    f) Injecting hydrogen into gas networks;
    g) Use of hydrogen as feedstock/input for green metals, green ammonia and manufacturing;
    h) Hydrogen fueling/distribution (fleet & retail);
    i) Markets for plants, machinery and vehicles that use hydrogen;
    j) Machine and plant construction;
    k) Use of synergies in the use of hydrogen;
    l) Simple concepts;
    m) Concepts and rough sketches for supply chains;
    n) Concepts with renewable energy producers;
    o) Multi-level concepts;
    p) Visiting hydrogen-related sites.

2) Transportation and mobility:
    a) Hydrogen transportation;
    b) Processes for transporting compressed hydrogen via tube trailers;
    c) Processes for transporting liquid hydrogen via road tankers
    d) Hydrogen storage pressure;
    e) Possibility of evaporation during transport;
    f) Effects of weight distribution on loading behavior and vehicle stability;
    g) Efficient driving techniques and environmentally friendly driving strategies;
    h) Factors involved in trip preparation;
    i) Factors that can cause traffic delays and detour and related actions that can be taken;
    j) Fatigue management strategies.

3) Technical Skills:
    a) May operate technical demonstration systems with hydrogen technology in the industrial environment;
    b) May perform hydrogen gas measurements;
    c) Possesses skills to work with associated modern technical equipment;
    d) Integration and real-time operation.

Competencies needed for hydrogen in the industry and network -.

Maintenance

1) Maintenance:
   a) General system (inspection, cleaning, calibration and replacement of various parts);
   b) Water and cooling system (maintenance and replacement of filters, sensors, pumps and seals);
   c) Stack and hydrogen system (checking, calibrating and replacing sensors and safety valves);
   d) Electrolyser installation;
   e) H2 compressor plant;
   f) Buffer vessel;
   g) H2 filling station;
   h) Instrument air supply;
   i) Nitrogen supply;
   j) Piping;
   k) Hydrogen networks - national and international;
   l) Stationary fuel cell maintenance;
   m) Maintenance of fuel cell electric vehicles (FCEV).
2) Maintenance and repair:
   a) Maintenance of mechanical, electrical and instrumentation and control equipment and systems;
   b) Inspect, repair, troubleshoot, modify, install and commission mechanical equipment;
   c) Oversee inspection, maintenance and repair of pressure, stationary and rotating equipment;
   d) Assist plant operator in diagnosing operational deficiencies from instrument indications;
   e) Resolve equipment problems and possible causes using instrument indications.
3) Equipment and tools:
   a) Cleaning, checking and storing tools, equipment and measuring instruments;
   b) Checking tools and equipment for safety and proper operation;
   c) Operating and adjusting to differences in equipment in accordance with standard operating procedures.
4) Skills and training:
   a) Can recognize and identify the causes of system failure;
   b) Can maintain and repair technical demonstration systems with hydrogen technology in the industrial environment;
   c) May identify and resolve malfunctions and complications at various hydrogen technology installations.
5) Environmental impact and optimization:
   a) Relevant manufacturer specifications;
   b) Relevant procedures to manage and minimize the impact of an environmental event;
   c) Optimization, modernization and upgrading of equipment and systems.

6) Monitoring and post-delivery activities:
   a) Completing post-delivery activities;
   b) Monitor the performance of the trailer/tanker, trailers and equipment and take appropriate action when necessary;
   c) Site visit to maintenance company;
   d) Maintenance and inspection model (EIA-WTB).
7) Specialist work:
   a) Technicians needed for off-site in-depth/specialist work in a workshop (more planable work).

Competencies needed for hydrogen in the industry and network -.

Safety

1) Fundamentals of hydrogen safety:
   a) Properties of hydrogen relevant to safety;
   b) Introduction to the hydrogen safety engineering framework;
   c) Comparison of damage criteria for unprotected and protected persons (firefighters);
   d) Relevant risk mitigation processes, including personal protective equipment (PPE), safety procedures and work schedules.
2) Effects of hydrogen incidents on people, structures and the environment:
   a) Effects of fire and explosions;
   b) Thermal effects of fires;
   c) Pressure effects of explosions;
   d) Radiant heat fluxes from jet fires and fireballs.
3) Hazards and risks of hydrogen:
   a) Health risks;
   b) Workplace hazards;
   c) Hazards when working in confined spaces;
   d) Cryogenic leaks;
   e) Compressed hydrogen leaks.
4) Prevention and control of hydrogen incidents:
   a) Accident prevention and mitigation;
   b) Risk Assessment;
   c) Hazard identification and reporting;
   d) Implementation of risk management measures;
   e) Reporting of hazards, risks and incidents to relevant persons.
5) Hydrogen leaks and ignition:
   a) Reducing the distance to a hydrogen leak;
   b) Mitigation measures for non-ignited spills;
   c) Ignition sources;
   d) Inflammation prevention;
   e) Spontaneous inflammation during sudden leaks.
   6) Hydrogen fires:
      a) Microflames;
   b) Jet fires and three separation distances;
   c) Effect of buoyancy on separation distances;
   d) Burning liquid hydrogen.

7) Safety regulations and practices in the hydrogen industry:
   a) Safety (ATEX);
   b) Application of workplace health and safety regulations, codes and practices in the hydrogen industry;
   c) Factors leading to accidents and incidents involving tube trailers/tankers
   d) Emergency response to hydrogen incidents;
   e) Attention to electrical safety;
   f) Procedures for working at height for Tubetrailer/Tanker drivers.
8) Personal protective equipment and workplace safety:
   a) Selection and use of relevant PPE;
   b) Safety when working with or around hydrogen;
   c) Awareness of electrical safety;
   d) Security systems (ESD).
9) Safety and Environment:
   a) Inflammation prevention;
   b) Effect of buoyancy on separation distances;
   c) Radiant heat fluxes from jet fires and fireballs;
   d) Take appropriate personal safety measures in a given work situation when working with hydrogen to reduce and control risks;
   e) Take appropriate environmental safety measures in a given work situation when working with hydrogen to reduce and control risks.
10) Issue work permits to maintenance personnel and ensure they are aware of the risks associated with the work to be performed.

Competencies needed for hydrogen in the industry and network -.

Emergency Services

1) Hydrogen storage and safety:
   a) Storage of gaseous hydrogen;
   b) Storage of liquid hydrogen;
   c) Fire resistance classification of hydrogen tanks;
   d) Effects of catastrophic failures from onboard storage (pressure waves, fireballs, etc.);
   e) Bound hydrogen storage to a carrier.
2) Regulations, codes and standards (RCS) for first responders.
3) Intervention and emergency procedures:
   a) Intervention strategies and tactics for first responders;
   b) Procedures/protocols for dealing with unplanned events;
   c) Responding to environmental events in the workplace;
   d) Role of regulatory agencies in monitoring environmental-related activities, risks and incident compliance;
   e) Driving or emergency procedures and emergency response using a company transportation emergency plan;
   f) Implementation of emergency plans;
   g) Explanation of risks when fighting emergencies in the HydrogenNet to emergency services and surrounding areas.
4) Emergency services and emergency teams:
   a) On-site emergency teams;
   b) First responders;
   c) Emergency response model (fire department, emergency services);
   d) Introduction to hydrogen safety for first responders.

Business and market entry

1) Renewable energy and environmental principles:
   a) Sustainable energy principles and practices;
   b) Environmental principles and sustainable energy practices, including techniques to minimize waste.
2) Hydrogen technology and application areas:
   a) Rationale and applications of hydrogen;
   b) Relevant developments in hydrogen technology for industrial applications;
   c) Applications of hydrogen technology in industry;
   d) Advantages and disadvantages of hydrogen technology for industry;
   e) Future role of hydrogen applications - prospects and potential of hydrogen-based energy systems;
   f) Types of hydrogen and their advantages and disadvantages;
   g) Relationship between hydrogen and other energy carriers,
3) Policy, market and strategies:
   a) Hydrogen markets and strategies of the German government, European Union and worldwide;
   b) Accomplished steps and future plans;
   c) National and EU plans: regulatory benefits of $_{H2}$;
   d) New hydrogen industry operation;
   e) Market and cost evolution of hydrogen and electrolysers.
4) Applications of hydrogen:
   5) Hydrogen use in building energy supply;
   a) Hydrogen in industry: high temperature/raw materials, chemicals, steel, cement and infrastructure;
   b) Hydrogen in mobility: fuel cells versus batteries, fueling, shipping, aviation and synthetic fuels;
   6) Miniaturization.
   7) Strategies and political framework:
   8) Hydrogen as key to decarbonization;
   9) Basic strategies for avoiding $_{CO2}$;
   10) $_{CO2}$ avoidance in individual sectors;
   11) Sector integration and storage;
12) Hydrogen in energy and industrial policy:
   a) International, national and regional levels;
   b) Hydrogen geopolitics and economics;
   c) Hydrogen regulatory landscape;
   d) Actors, hydrogen economics and regulation.
13) System integration/sector linkage:
   a) Power-to-X concept, storage crucial and role of hydrogen;
   b) Case study.
14) Business models and economics:
   a) Energy/renewable energy;
   b) Energy (trade) markets;

c) Analyze and interpret relevant data on systems and operational activities;
d) Economic model.

HRM - training and soft skills

1) Hydrogen plant and hydrogen operation HRM knowledge aspects:
   a) Communication and collaboration:
      i) Professional communication skills;
      ii) Effectively communicate with relevant individuals;
      iii) Communication and teamwork;
      iv) Collaborate with technicians from multiple professional disciplines;
      v) Communicate digitally with planning/work preparation colleagues.
2) Innovation and problem solving:
   a) Convey and share passion;
   b) Innovative mindset;
   c) Thinking in possibilities;
   d) Solution-oriented/improvement-oriented;
   e) Innovating by connecting in multidisciplinary collaboration.
3) Project and team management:
   a) Project-based work;
   b) Report;
   c) Consult relevant individuals to coordinate work;
   d) Regularly participate in consultation processes;
   e) Team management;
   f) Project Management.
4) Personal development and leadership:
   a) Personal leadership;
   b) Personnel - Training;
   c) Continuing education and transitional training.
5) Education and training:
   a) H2-specific elements to be integrated into vocational training;
   b) Expansion of specific skills and knowledge in preparation for the first real contacts with $_{H2}$ in traditional environments such as, for example, the automotive industry
   c) Educators and teachers.
6) Other competencies:
   a) Good command of the English language;
   b) Working with "Absolute Beginners" (e.g., students in the elementary year).

Environmental, Social and Governance (ESG) management and compliance

1) Environment:
   a) Compliance with environmental policies and procedures;
   b) Identify and reduce environmental risks;
   c) Emissions (air, water, noise);
   d) Heat balance;
   e) Sustainability of $_{H2}$;
   f) Establish and operate water treatment facilities.
2) Management:
   a) Licensing and regulatory requirements;
   b) Legal and regulatory authorities;
   c) Regulations, codes and legislation;
   d) Energy-economic and legal frameworks;
   e) Tender;
   f) Added value, business models, legal framework and technical management
   g) Demand-side perspective;
   h) Price sensitivities and expectations;
   i) Demand quantities and climate benefits.
3) Compliance:
   a) Health, safety and environmental procedures and regulations for fuel tanker operations;
   b) QHSE (quality, health, safety and environment);
   c) Quality (end-product control, regulations, certification, standardization);
   d) Maintain daily production and performance data.

Competencies needed for hydrogen in the industry and network -.

Legal

Legal framework for hydrogen installations and operations:

1) Hydrogen properties:
    a) Comparison with other fuels;
2) Industry standards and guidelines:
    a) Relevant industry standards, guidelines, codes of conduct and regulations.

3) Workplace documentation and procedures:
    a) Workplace documentation;
    b) Workplace policies, procedures and instructions;
    c) Workspace access requirements;
    d) Manufacturer Instructions;
    e) Relevant legislation and industrial operating procedures for transporting hydrogen;
    f) Relevant traffic rules, regulations, permit and license requirements of the State/Province transportation and traffic authorities.

4) Environmental laws and standards:
    a) Environmental legislation, regulations, standards, laws and codes of conduct.
5) Industry regulations and legislation:
    a) Industry rules, legislation, guidelines, codes of conduct and regulations.
6) Transportation of hydrogen:
    a) Hydrogen transportation legislation and industrial operating procedures;
    b) Traffic rules, regulations, permit and license requirements of State/Province transportation and traffic authorities;
7) Communication:
    a) Communication with contractors, public, landowners and government agencies.
8) Regulation at different levels:
    a) National, provincial and municipal codes and regulations.
9) Environment model:
    a) Climate, land features, seismic.
10) First Responders:
    a) Regulations, Codes and Standards (RCS) for First Responders.

Appendix 39 Train the trainer

The $_{H2}$ teacher $_{professionalization\ program}$ (Hogt, Oosting, et al. 2022)has five goals, in which the participant:

1. Part of a teacher learning community, in connection with other educational communities, such as a MBO community with connections to HBO, including HBO instructors.
2. Work with others to develop a regional $_{H2}$ education $_{program}$ (including testing) focused on innovative learning.
3. Make external connections with companies in your own $_{H2\ region}$ for participation in education, with an understanding of $_{H2}$'s importance to the energy transition, its issues, activities and facilities, and an understanding of the professional images of the contributions your target groups can make to it.
4. Possesses relevant professional knowledge.
5. Be practically competent in working safely with simple $_{H2}$ systems and supervising (practical) teaching in a lab or at locations where safe working with simple $_{H2\ systems}$ is warranted.

Requirements for a hydrogen lecturer

A hydrogen educator must have a thorough knowledge of hydrogen technology and its applications and be able to convey this knowledge in an understandable and engaging way. He or she must also be up to date with the latest developments in the industry and be able to integrate them into teaching materials. It is important that the teacher can organize practical training and exercises so that students can put their knowledge into practice. Furthermore, the lecturer should have good communication skills and be able to motivate and inspire students. It is important that the teacher has structured teaching and can guide and support students in their learning process.

Appendix 40 Practitioner platform energy transition and mission

Mission

Several MBO Practorates are jointly strengthening the knowledge base around energy transition. This platform strives to bring together the expertise and insights of these Practorates to gather compelling evidence from their lines of research. The goal is to use this platform to contribute at the local, regional and national level to strengthen the knowledge base around energy transition.

Table 40 Practitioner platform energy transition

Practorate name	Setting	Practor
Energy Transition Practicum	ROC Mondriaan	Nico Person
Practorship Energy Transition & Human Capital	ROC of Amsterdam	Martin de Haan
Practorship in Circular Entrepreneurship & Smart Maintenance	Nova College	Daisy Beelen
Practorship in Hydrogen in Industry	Drenthe College	William Hazenberg
Practorship Sustainability & Energy Transition	Summa College	Guido van Eijk
Automotive Practicum	Noorderpoort	Roeland Hogt
Practicum Smart Industries	Da Vinci College	Timon Jongkind
Practorship of Circular Regional Economy	ROC of Flevoland	Maurine Ode
Practorship Sustainable Thinking, Sustainable Doing	Friesland College	Menno Wierdsma

Organizations involved

MBO Council - BTG TGO - Bob Klaasen and Sabine Mul
Top Sector Engineering -Marsha Wagner and David vanPetersen
Regieorgaan SIA - Annejet Spierenburg

Appendix 41 Autonomy definitions

There is a demand for autonomous hydrogen plants. However, what that means in concrete terms will need further investigation. There are different definitions of autonomy, here are some examples.

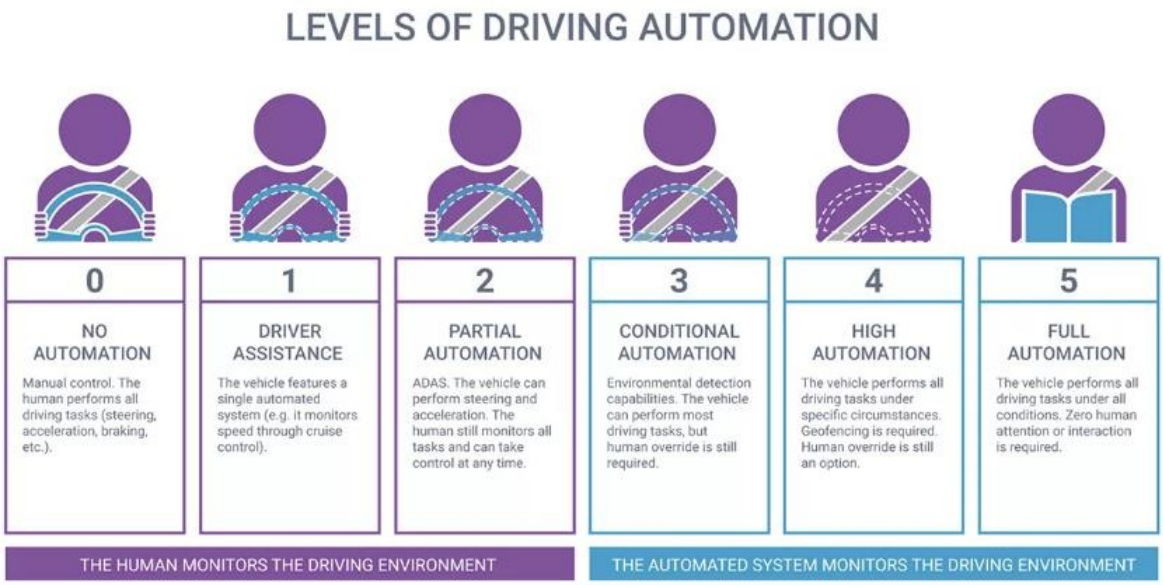


Figure 24 levels of autonomous driving [110]

For autonomous operation, strong interaction between the system and environmental signals is essential. For example, when a person approaches an electrolyzer, a signal (such as a sound or flashing light) should indicate whether it is safe or still in operation.

An example of automation levels in a process plant:

1. Level 0 - No Automation. The operator performs all process control tasks locally.
2. Level 1 - A PLC/DCS controls a package unit to maintain the setpoint.
3. Level 2 - A PLC/DCS controls a package unit and executes process transitions with a sequential program.
4. Level 3 - The system can automatically bring the plant to a safe process state using an ESD/SIS system.
5. Level 4 - Manual tasks such as leak checks, nitrogen bottle changes, laboratory analyses and truck couplings are fully automated.
6. Level 5 - No more people are needed on site for operation.

[110] h ttps://www.synopsys.com/automotive/autonomous-driving-levels.html

(TNO 2023)[111] TNO Hybrid AI algorithms and concerns has the following format:

1. **Environmental awareness** - recognize objects and situations not previously encountered.
2. **Self-awareness** - reliably assess one's own competencies.
3. **Decision-making** - plan actions that are safe and effective.
4. **System integration** - implementing real-time hybrid AI algorithms for environmental awareness, self-awareness and decision-making on commercially available robots.

Table 41 Level of automation (PetroWiki 2016)[112]

Autonomous level	Description
Level 1	The human operator performs the task and transfers it to the computer to implement.
Level 2	The computer helps by determining the options.
Level 3	The computer helps determine and suggest options. The human operator may choose to follow the recommendation.
Level 4	The computer selects the action and the human operator decides whether or not to should not be implemented.
Level 5	The computer selects and performs the action when the human operator performs the action approves.
Level 6	The computer selects the action and informs the human operator in case the operator wants to cancel the action.
Level 7	The computer performs the action and tells the human operator what happened.
Level 8	The computer performs the action and tells the human operator only if this one calls for it
Level 9	The computer performs the action when told to do so and tells the human operator only when the computer decides the operator needs to be notified brought.
Level 10	The computer performs the action when it decides it should. The computer Tells the human operator only if he decides the operator needs to be notified

111 TNO. 2023. *Autonomous systems in the real world.* Accessed Mar 24, 2023. https://www.tno.nl/nl/digitaal/artificiele-intelligence/safe-autonomous-systems/autonomous-systems-real-world/.

112 Levels of automation - PetroWiki (spe.org)

Annex 42 WCM - follow-up steps and planning.

The table below shows the original WCM schedule for the 2023.

Table 42 WCM - Elaboration Follow-up Steps and Planning - WP competencies

Period	Description	Time
February/March 2023	Determine scenarios and job roles that we want to include in this study	16 hours
April/May 2023	Analyze and create summary existing studies	40 hours
April/May 2023	Drafting questionnaire	40 hours
June/July 2023	Interviews of 1-2 hours each, plus elaboration	40 hours
September 2023	Summarize the needs of the various stakeholders	24 hours
October 2023	Cross-compare with the other work packages for further deepening and adjustments	16 hours
December 2023/2024	Determine what technical and/or hydrogen training programs already exist in the Netherlands and see if all requirements are already in those programs are or should be added	16 hours

Further questions within the WCM:

1. Assuming certain operational scenarios (which ones?), the hypothesis is that a highly flexible deployment of technical workers will be required. How does this affect the competency profiles of these technicians?
2. How does this demand compare with the current supply of technicians?
3. What are the expected drivers seen from the asset owners' point of view regarding maintenance scheduling? How flexible should this be?
4. What technical solutions are being considered to increase planability?

Appendix 43 WCM What parties are involved - with whom to speak

1) Suppliers providing or integrating systems:
   a) ResatoCompression and storage
   b) Howden Thomassen Compression
   c) SiemensCompression and electrolysis
   d) NetstackFuel cells
   e) SmitTransformers , ABB, Honeywell
   f) McPhy - ITM-Power, Plugpower, Green Hydrogen Systems - electrolysis, ITM, TK, ... (electrolysis)

2) Technical service providers:
   a) Technip;
   b) Worley;
   c) Stork;
   d) Wedge;
   e) Equans;

3) Hydrogen Products and End Users:
   a) Sinnewetter dust;
   b) HYCC;
   c) Gasuni;e
   d) Holthausen - gas stations;
   e) BIOMCN;
   f) Air liquid;
   g) Shell;
   h) EnTranCe Groningen;
   i) Everfuel.

4) Education & Research:
   a) Drenthe College - Hydrogen in Industry and Networking;
   b) Gas 2.0;
   c) Hanze University of Applied Sciences - EnTranCe.

There are ongoing research programs t.b.v. labor force development for energy transition involve data. WCM will not conduct its own market research. At most questions in the own organizations of WCM partners, or with the parties to be involved, such as asset owners, technical service providers and education in this analysis.

We need to prepare a list of standard questions that we want to ask the various parties to validate whether our hypotheses match the market.

Appendix 44 Hydrogen Technician (TSSAH2) certification program.

We will need to further explore the rollout of a certification program in the Netherlands. The

Hydrogen Technician (TSSAH2) certification program was developed by the National Alternative Fuels Training Consortium (NAFTC) and the National Science Foundation (NSF) to train and certify technicians to work with hydrogen as a fuel. This program provides training in the basics of hydrogen technology, including safety regulations and the installation, maintenance and repair of hydrogen systems and equipment. Upon completion of the program and certification, technicians are equipped with the knowledge and skills needed to safely and efficiently operate hydrogen systems and equipment in a wide range of applications, including fuel cell vehicles, hydrogen production plants and other industrial applications.

Appendix 45 Hydrogen value chain

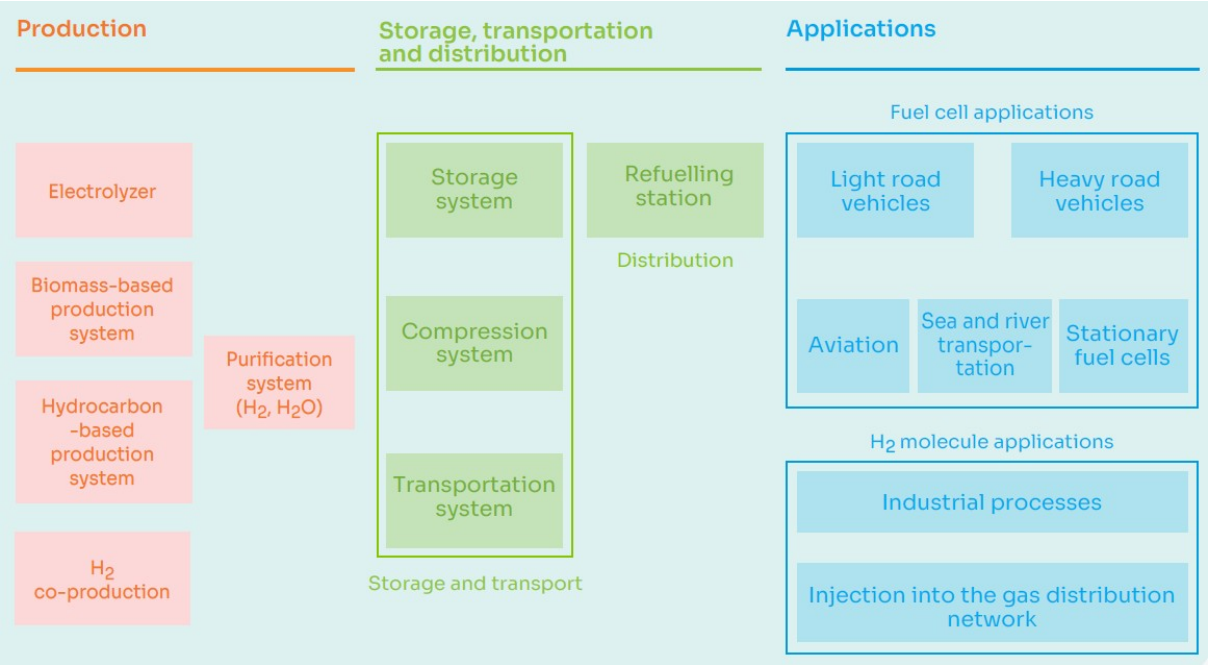


Figure 25 The Hydrogen value chain

Appendix 46 MBO hydrogen training model

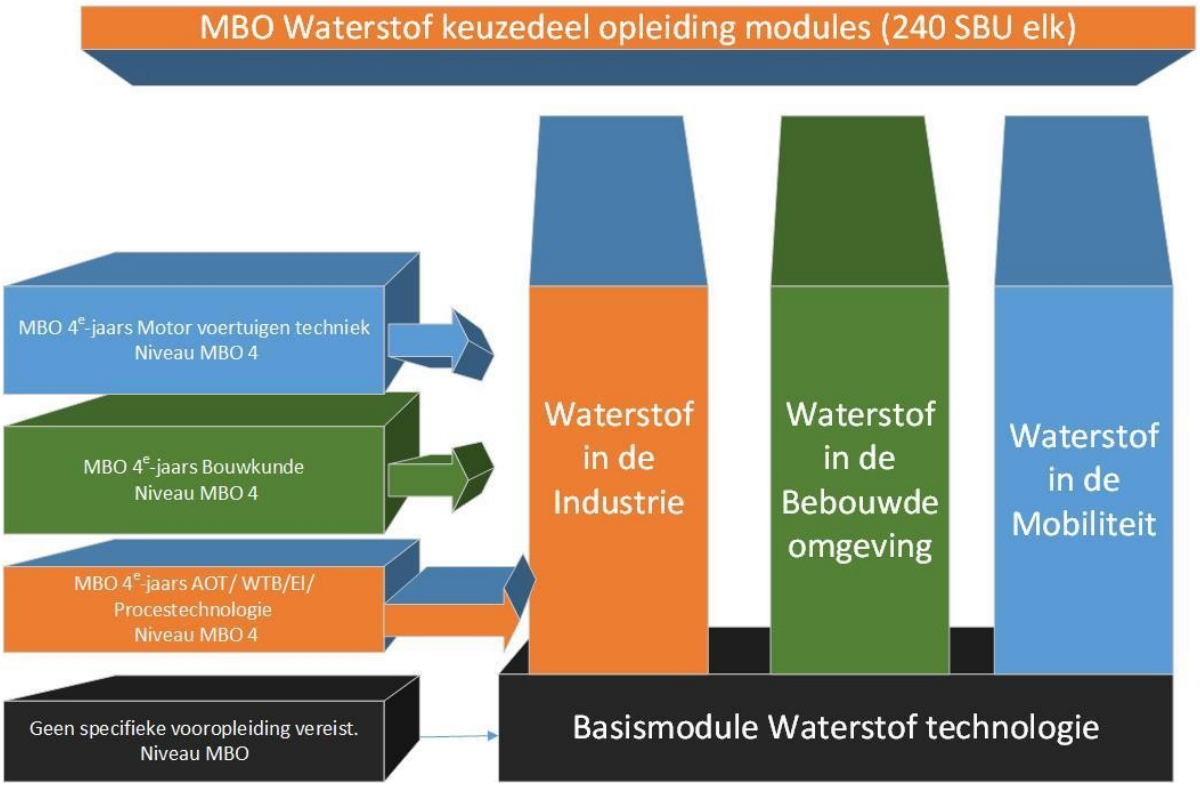


Figure 26 Hydrogen MBO training scheme in the Netherlands (Hazenberg, Willem 2022) [113]

[113] Hazenberg, Willem; 2022 "Practorate speech Hydrogen in Industry Willem Hazenberg EUR ING MBA RI 8-4-2022 Emmen." *Practorate address Hydrogen in Industry Willem Hazenberg EUR ING MBA RI 8-4-2022 Emmen.* Emmen: Drenthe College, 2022. (PDF) Practorate address Hydrogen in Industry Willem Hazenberg EUR ING MBA RI 8-4-2022 Emmen (researchgate.net)

Appendix 47 Questions Canada The Old Library Academy and CNA College of the North Altantic -16-2-2023 interview

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Below are the questions that the CAN college asked me and will also ask others for their research. this report will also go their way for further curriculum collaboration,
Organizations : The Old Library Academy and CNA College of the North Altantic

Questions for interviewees

1. introduce the project both CNA and world energy as background for the interviewees add a visual of layout of the project

opener

   a. When you're hearing the role wind turbine tech or hydrogen operator what do you think about?
   b. What are the competences required for these workers?
   c. What could be a part of the curriculum for CNA that could be overlooked and needs to be included?
   d. What are you looking for when hiring people?
   e. What is the minimum knowledge level for hiring from which you will train them in house?

2. **Hydrogen**
   a. What are the different jobs related to working in a hydrogen plant?
   b. For which jobs is this education program relevant? How much is in house training?
   c. should there be a separate hydrogen operator program or is it possible with micro credentials?
   d. What is the job titles of someone who works with an electrolyzer? (hydrogen operator, power engineer, etc.)
   e. Which of the workforce within a Hydrogen plant needs to have knowledge of electrolysers?
   f. if you were to develop your own program what would you include?
   g. What does an ideal hydrogen operator look like?
   h. Do you have any suggestions for people in the green hydrogen industry that we can reach out to?
   i. Are there any tools or simulation available/possible for part of the programs?
   j. anything you would like to add that we did not talk about?