DESCRIPTION OF COMPETENCIES IN SELECTED HYDROGEN ECONOMY PROFESSIONS

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FERI

SPECIALISATION FRAMEWORK: Hydrogen production and maintenance engineer

In the context of the rapidly advancing energy transition, hydrogen is becoming one of the pillars of a modern, low-carbon economy. Its potential as an energy store, fuel and industrial substrate fits in with the key climate goals of the European Union. Hydrogen is used in power generation, transport, chemistry, metallurgy, heavy industry - and the development of this infrastructure requires the training of new cadres of operator designers and qualified engineers for hydrogen production and maintenance in plants.

In the actual operation of hydrogen plants, it is crucial to ensure process continuity, reliability, safety and cost optimisation. Hydrogen production, storage and transmission are high-risk processes, requiring close technical supervision, knowledge of the physico-chemical properties of hydrogen and the implementation of predictive and preventive maintenance procedures.

Hydrogen production and maintenance engineers are the strategic link between the design and safe operation of hydrogen infrastructure. Their technical and organisational competence is essential for the stable operation of hydrogen production plants, storage facilities (e.g. compressed tanks, cryogenic tanks, metal hydrides), and hydrogen transmission and distribution systems.

Competence needs in a 10-year perspective:

The increase in the number of hydrogen facilities - including refuelling stations, industrial hubs, local sources of green hydrogen - means they need to be maintained, inspected, upgraded and serviced.

The development of H_2 production technology - from classical reforming, through electrolysis, to novel methods (pyrolysis, fermentation) - requires specialists familiar with operational conditions, process parameters and operational risks.

The use of hydrogen in heavy industry - forces control of hydrogen consumption, quality and availability, as well as the operation of infrastructure in harsh environments (high pressure, temperature, hydrogen embrittlement).

Digitisation and automation - the growth of monitoring, predictive maintenance (PdM), IoT and SCADA systems in the H_2 sector increases the need for competencies that integrate engineering knowledge with data analysis.

Green competitiveness - the growing importance of energy efficiency, production optimisation and loss reduction requires engineers able to combine the operational aspect with cost and environmental impact analysis.

Professional qualification description: Hydrogen production and maintenance engineer

A specialist with knowledge and skills in:

- supervision of hydrogen production (electrolysis, reforming, etc.),
- operation of hydrogen equipment and systems (tanks, pipelines, cells),
- implementing predictive and preventive maintenance systems,

- monitoring performance and responding to deviations,
- application of safety procedures and compliance with standards,
- process optimisation in terms of cost, reliability and sustainability,
- maintain technical documentation, analyses, reports and communication with teams and technology partners.

Areas of professional activity:

- Hydrogen production plants (electrolysers, reforming, hybrid installations)
- Distribution and transport infrastructure (pipelines, refuelling stations)
- Hydrogen storage facilities (pressure vessels, cryogenic, hydrides, ammonia)
- Industrial plants using hydrogen in processes (e.g. metallurgy, chemical industry)
- Service and technology companies supplying H_2 equipment and systems.
- Diagnostic and monitoring centres for industrial installations

Competence 1: Organise and supervise the production of hydrogen under industrial conditions

Learning outcomes/verification criteria:

- Differentiates between hydrogen production technologies (electrolysis, steam methane reforming, pyrolysis, fermentation, photoelectrolysis) and selects them for specific applications.
- Explains the operational parameters of H_2 production processes (pressure, voltage, temperature, flow, pH, gas purity).
- Identifies key control points in hydrogen production processes and establishes operating ranges for equipment (e.g. electrolysers).
- It oversees the operation of production systems, monitors process data and responds to deviations.
- Recognises symptoms of malfunctions in production equipment and implements corrective action.
- Compiles operational documentation (shift reports, equipment operation logs, gas purity analyses).

Competence 2: Operation, inspection and maintenance of hydrogen systems

- Selects hydrogen storage methods (CGH_2, LH_2, hydrides, ammonia, methanol) according to technical conditions and needs.
- Characterises the construction, principle of operation and performance requirements of H_2 storage tanks and equipment.
- Follows procedures for technical inspection and servicing of system components: valves, pumps, tanks, cooling systems, hydrogen inlet and outlet systems.

- Implements condition monitoring systems (sensors, SCADA, IoT) and interprets basic diagnostic data.
- Analyses the causes of faults and failures in hydrogen systems (e.g. seals, overheating, hydrogen embrittlement).
- Organises planned and unplanned maintenance work, taking into account safety principles and minimising downtime.

Competency 3: Application of safety procedures for hydrogen production, storage and transport

- Recognises the hazards associated with working with hydrogen (flammability, explosivity, leakage, pressure, cryogenics).
- Interprets and applies standards and regulations for hydrogen safety (e.g. ISO 15916, ISO 19880, EN 60079, ADR, Seveso III).
- Selects appropriate individual and collective protective equipment (e.g. gas detectors, ventilation systems, explosion protection).
- Follows emergency procedures and knows the evacuation rules in the event of a leak, ignition or unsealed installation.
- Liaises with Health and Safety teams, UDT, PSP and other services when inspecting, receiving or responding to incidents.
- Maintains technical and operational documentation in accordance with legal requirements (job instructions, checklists, safety reports).

Competence 4: Planning and implementation of maintenance systems for hydrogen systems

- Selects a maintenance strategy to suit the specifics of equipment and processes (corrective, preventive, predictive, TPM).
- Sets schedules for inspection, maintenance and replacement of plant components (e.g. electrolyser membranes, seals, filters).
- It implements CMMS systems and uses IoT sensor data to monitor equipment status (e.g. temperature, vibration, hydrogen levels).
- Analyses historical operating data and proposes changes to the UR strategy (e.g. optimisation of maintenance intervals).
- He liaises with the production, automation and health and safety teams to plan process downtime.
- Documents operation and maintenance activities in an IT system or in the form of inspection cards.

Competence 5: Cost optimisation, energy efficiency and operational data analysis

- Calculates the costs of hydrogen production by different technologies (electrolysis, reforming, LH_2, CGH_2).
- Analyses the impact of operating parameters on energy consumption, component life and hydrogen losses (e.g. boil-off, leaks).
- Applies basic energy optimisation methods (e.g. heat recovery, efficient equipment operating profiles).
- Interprets data from SCADA/IoT systems and uses it to make operational decisions.
- Implements corrective and modernisation measures (e.g. component replacement, mode adjustment) to improve efficiency.
- Prepares efficiency analyses (e.g. OEE, MTTR, LCOH) and presents them in the form of technical reports.

Competence 6 - Personal competence

- Communicates clearly and accurately with other team members and customers.
- Prepares reports and documentation on hydrogen logistics.
- Works effectively in a team.
- Shares knowledge and experience with other team members.
- Resolves conflicts in a constructive manner.
- Implements measures to support local communities in developing the hydrogen economy.
- Builds and develops relationships with industry, local government and academia.
- Adapts work to the demands of the global market and cultural differences.

Personal competences with additional verification criteria

1. **Communicates clearly and accurately with other team members and customers.**
   Verification criteria:
   - Conducts effective conversations with customers and the team in simulated scenarios (e.g. discussing a logistics plan).
   - Creates clear and precise messages, adapting the style to the audience (e.g. technical details for the team, simplified information for the client).
   - It uses tools to support communication, such as presentations, visual reports and summary documents.
2. **Produces reports and documentation on hydrogen logistics.**
   Verification criteria:
   - Produces/reports on the implementation of the logistics project, including technical data, risk analysis and recommendations.

- Develops clear instructions and procedures for the operation of logistics equipment.
- Prepares documentation in accordance with legal requirements and industry standards (e.g. ADR-compliant reports).

3. **Cooperates effectively in a team.**
   Verification criteria:
   - Actively participates in simulated group tasks (e.g. joint development of a logistics plan).
   - Supports team members in solving technical or organisational problems.
   - Provides constructive feedback and suggestions to improve the work of the team.
4. **Shares knowledge and experience with other team members.**
   Verification criteria:
   - Provides a short training session or presentation to the team on a selected aspect of hydrogen logistics.
   - Shares developed materials (e.g. reports, checklists) with other team members.
   - Involves mentoring or coaching less experienced team members.
5. **Resolves conflicts in a constructive manner.**
   Verification criteria:
   - Carries out a simulation of conflict resolution in a team (e.g. differences of opinion on a transport plan).
   - Identifies causes of conflict and proposes realistic solutions.
   - Uses negotiation and mediation techniques in difficult team situations.
6. **Implements measures to support local communities in developing the hydrogen economy.**

Verification criteria:

- It initiates and participates in hydrogen education projects targeting local communities.
- It works with local organisations and institutions to promote awareness of hydrogen technologies.
- Prepares promotional material (e.g. brochures, presentations) on the benefits of the hydrogen economy for local communities.

7. **It builds and develops relationships with representatives from industry, local government and the scientific sector.**

Verification criteria:

- It organises meetings and workshops with representatives from different sectors to share knowledge and experience.
- Produces reports summarising the needs and expectations of various stakeholders in the context of the hydrogen economy.

- It implements joint initiatives such as pilot or demonstration projects in the field of hydrogen logistics.

8. Adapts work to the demands of the global market and cultural differences.

Verification criteria:

- Negotiates and cooperates with foreign partners, taking into account cultural and legal differences.
- Prepares project documentation and reports in English.
- Participates in international industry events (conferences, trade fairs, training courses) and applies the knowledge gained to local projects.

Competence 7 - Social competence

- He is responsible for his own safety and that of others.
- Conscientiously performs its tasks.
- Takes action in line with professional ethics.
- Independently plans and carries out assigned tasks.
- Shows initiative in finding new solutions.
- Able to make decisions in crisis situations.
- He is aware of the need to continuously improve his qualifications.
- Keeps abreast of technological innovations and regulatory changes.
- Participates in training courses and conferences.
- It is involved in initiatives to promote sustainable solutions in hydrogen logistics.
- It initiates activities for cooperation between the public, private and scientific sectors in the context of hydrogen logistics.
- He is involved in international logistics projects, taking an active role in the management and coordination of activities.

Social competence with verification criteria

1. **He is responsible for his own and others' safety.**
   Verification criteria:
   - Simulates a situation requiring a safety response.
   - Identifies potential risks in the logistics process and proposes preventive measures.
   - Monitors compliance with safety rules among team members.
2. **Performs his/her tasks conscientiously.**
   Verification criteria:
   - Provides regular reports and documentation according to the agreed schedule.

- Performs tasks with due diligence, meeting project guidelines.
- Commits to team goals, supporting other team members.

3. **Takes action in accordance with professional ethics.**
   Criteria for verification:
   - Carries out an analysis of the script for compliance with professional ethics.
   - Makes decisions that take into account the welfare of the team and clients.
   - Assesses the consequences of professional actions from a social responsibility perspective.
4. **Independently plans and carries out assigned tasks.**
   Verification criteria:
   - Creates a work schedule for a selected logistics task.
   - Completes the task within the agreed time, reporting on progress and difficulties encountered.
   - Makes amendments to the plan based on changing design conditions.
5. **Shows initiative in finding new solutions.**
   Verification criteria:
   - It proposes innovative approaches to the logistical challenges of hydrogen.
   - Identifies improvements to existing logistics processes.
   - Makes recommendations at team meetings, supported by data analysis.
6. **Able to make decisions in emergency situations.**
   Criteria for verification:
   - Simulates the response to an emergency situation (e.g. hydrogen leak, transport failure).
   - Assesses possible action scenarios and selects the optimal option.
   - It implements decisions quickly and effectively, minimising losses and risks.
7. **Is aware of the need for continuous improvement of skills.**
   Verification criteria:
   - Prepares a professional development plan, including training and certifications.
   - Assesses own skills in the context of labour market needs.
   - He regularly updates his knowledge of new technologies and logistics solutions.
8. **Keeps abreast of technological innovations and regulatory changes.**
   Verification criteria:
   - Presents new technologies and regulations during team meetings.
   - Develops notes or reports on regulatory developments in hydrogen logistics.
   - Uses newly learned tools or technologies in practical tasks.
9. **Participates in training courses and conferences.**
   Criteria for verification:

MODULE 1. INTRODUCTION TO HYDROCONIC AND ENERGY TRANSFORMATION TECHNOLOGIES (16 HOURS)

MODULE 2: INTRODUCTION TO HYDROGEN AND ITS PROPERTIES (20 HOURS)

MODULE 3: HYDROGEN PRODUCTION TECHNOLOGIES AND PROCESS MANAGEMENT (24 HOURS)

MODULE 4: HYDROGEN STORAGE AND MANAGEMENT (20 HOURS)

MODULE 5: SECURITY OF HYDROGEN TECHNOLOGY - STANDARDS, PROCEDURES AND SAFEGUARDS (20 HOURS)

MODULE 6: HYDROGEN TRANSPORT AND LOGISTICS IN AN INDUSTRIAL PLANT (16 HOURS)

MODULE 7 HYDROGEN SYSTEM MAINTENANCE - DIAGNOSIS AND PREVENTION (24 HOURS)

MODULE 8. INDUSTRY 4.0 IN HYDROGEN PLANTS - DIGITISATION AND AUTOMATION (20 HOURS)

MODULE 9: OPTIMISING OPERATIONAL AND ENERGY EFFICIENCY (16 HOURS)

MODULE 10: HYDROGEN ECONOMY AND SUSTAINABLE DEVELOPMENT AND ESG (16 HOURS)

MODULE 11. SOFT SKILLS AND COMMUNICATION IN HYDROGEN SAFETY MANAGEMENT (16 HOURS)

MODULE 12: MEGATRENDS, CLIMATE CHANGE, ENERGY TRANSITION (18 HOURS)

MODULE 13: INTEGRATED DESIGN - PRODUCTION, MAINTENANCE AND SAFETY OF HYDRO INSTALLATIONS (30 hours)

240 HOURS IN TOTAL

MODULE 1 INTRODUCTION TO HYDROGEN TECHNOLOGIES AND THE ENERGY TRANSITION

Duration: 16 hours (6 hours lectures, 6 hours exercises, 4 hours workshops)
EQF level: 5-6

Module Objective: The aim of the module is to understand the role of hydrogen in the context of global megatrends, energy transition, climate policy and industrial development. Participants will gain an understanding of the basic concepts related to the hydrogen economy, types of hydrogen, its applications and strategies for implementing hydrogen technologies in different sectors.

1. hydrogen economya, global and European context (2 hours lecture + 1 hour exercise)

- Hydrogen as an energy carrier - basic functions and applications

- Energy transition and EU climate policy (Green Deal, Fit for 55, REPowerEU) as part of building the European Union's competitive advantage
- Hydrogen in national and regional strategies (H2 Valleys, Poland strategy)
- Examples of implementation - e.g. Germany, the Netherlands, Japan, Korea, Australia

2. types and significance of hydrogen (1 hour lecture + 1 hour exercise)

- Green, blue, grey, turquoise hydrogen - sources, technologies, emissivity
- Comparison of the costs and carbon footprint of producing different types of H_2
- Importance of hydrogen purity in industry (quality classes)
- The issue of hydrogen colours - analysis and future standards

3. areas of application of hydrogen (1 hour lecture + 1 hour exercise)

- Industry: chemical, petrochemical, steel, food industry
- Energy: energy storage, microgrids, fuel cells
- Transport: rail, truck, sea, road
- Integration with RES - Coupling and Power-to-X sector

4. Hydrogen infrastructure (1 hour lecture + 1 hour exercise)

- System components: production, storage, transport, distribution, consumption
- Modern infrastructure solutions - hydrogen hubs, HRS stations
- Technical, regulatory and social barriers to infrastructure implementation

MODULE 2: INTRODUCTION TO HYDROGEN AND ITS PROPERTIES

Duration: 20 hours (8 hours lecture, 8 hours exercise, 4 hours workshop).
EQF level: 4-5

Module Objective: To understand the basic physical and chemical properties of hydrogen, which are key to safe storage and transportation.

Topics:

1 Hydrogen, Isotopes of hydrogen, characterisation (1 hour - lecture, 1 hour - exercise).

- Physical properties of hydrogen (physical state, colour, odour, density and solubility in different substances, melting and boiling points, thermal and electrical conductivity

- Chemical properties of hydrogen (reactivity with other elements and chemical compounds, flammability,
- The role of hydrogen in industry

2 Hydrogen: ortho and vapour - implications for storage (2 hrs).

- Explaining the differences between ortho- and para-hydrogen.
- The importance of hydrogen isomerism in the context of storage and stability at low temperatures.
- Calculations of energy changes in ortho- and para-hydrogen transformations.
- Analysis of liquid hydrogen storage processes in relation to isomer content.

3. density of hydrogen in different states of matter (2 hrs).

- Density of hydrogen in the gaseous, liquid and solid states - differences and their technological significance.
- Effect of pressure and temperature on hydrogen density.
- Hydrogen density calculations at different pressure and temperature parameters.
- Analysis of hydrogen phase diagrams.

4 Key temperatures for hydrogen (2 hrs)

- Explanation of key temperatures: boiling point, critical point, triple point.
- The importance of these parameters for liquid and gaseous hydrogen storage.
- Analysis of hydrogen phase diagrams.
- Exercise: identifying suitable storage conditions for hydrogen based on its thermodynamic parameters.

5. explosive range and flammability limits of hydrogen (2 hrs)

- Discussion of the flammability limits of hydrogen and its explosive range in air.
- Causes and mechanisms of hydrogen explosions.
- Analysis of hydrogen-related explosion cases in industry.
- Defining safety conditions for working with hydrogen.

6 Hydrogen diffusivity and its consequences (2 hrs).

- High hydrogen diffusivity and its impact on storage and transport safety.
- Discuss the potential risks of diffusion.
- Calculations for the diffusion of hydrogen through different materials.

- Selection of suitable materials for hydrogen storage.

7 Corrosive properties of hydrogen (2 hrs).

- The phenomenon of hydrogen embrittlement and its impact on structural materials.
- Corrosive properties of hydrogen in contact with metals.
- Analysis of hydrogen resistance data for materials.
- Exercise: design of hydrogen-resistant systems.

8. hydrogen hazards: causes of explosions and fires, hydrogen embrittlement (2 hrs - workshop)

- A case study of hydrogen-related failures.
- Designing safety procedures for working with hydrogen.

9. hydrogen detection methods and alarm systems (1 hr - lectures, 1 hr - workshop).

- Overview of hydrogen detection technology, including sensors and alarm systems.
- The role of detection systems in providing security.
- Configuration and testing of hydrogen sensors.

MODULE 3 HYDROGEN PRODUCTION TECHNOLOGIES AND PROCESS MANAGEMENT

Duration: 24 hours (10 hours lectures, 10 hours exercises, 4 hours workshops)
EQF level: 6

Module Objective: The aim of the module is to learn about the main hydrogen production technologies, their operational characteristics, energy efficiency and environmental and economic aspects. Participants will learn how to plan, supervise and analyse hydrogen production processes in industrial settings, with a particular focus on electrolysis and reforming-based plants.

Scope and structure of the module:

1. hydrogen production technologies - overview and classification (2 lecture hours + 1 exercise hour)

- Water electrolysis (PEM, alkaline, SOEC)
- Steam methane reforming (SMR), auto-thermal and partial oxidation
- Biomass pyrolysis, gasification, biological fermentation
- Comparison of efficiency, emissions and applications

2. electrolysis - installation, parameters and operation (2 hours lecture + 2 hours exercise)

- Principle of operation of electrolysers
- Operational requirements (voltage, temperature, pressure, water)
- Efficiency and quality of hydrogen produced
- Integration with RES, buffer and storage systems

3. reforming and other thermochemical methods (2 lecture hours + 2 exercise hours)

- Natural gas and biomethane conversion processes
- Use of catalysts and gas purification (CO, CO_2, sulphur)
- The importance of CO_2 capture in reforming (CCUS)
- Blue hydrogen and turquoise hydrogen technologies

4 Management of the hydrogen production process (2 hours lecture + 2 hours exercise)

- Monitoring and regulation of production parameters
- Control and automation systems
- Analysis of equipment operation: downtime, efficiency, losses
- Hydrogen quality management principles (purity grades, ISO 14687 standards)

5. economics and environmental balance of hydrogen production (2 hours lecture + 2 hours exercise)

- Levelised Cost of Hydrogen (LCOH)
- Carbon footprint of different production technologies
- Calculation of energy consumption, water consumption and CO_2 emissions
- Opportunities to improve efficiency and reduce costs

6 Workshop: Design of hydrogen production process (4 hours workshop)

- Case study: selection of technology for a specific application (e.g. chemical industry, refuelling station)
- Development of the installation concept: choice of technology, operational parameters, costs, place of integration with RES
- Analysis of operational risks and contingency scenarios
- Presentation of results in the form of a simplified techno-economic design

MODULE 4. HYDROGEN STORAGE AND MANAGEMENT

Duration: 20 hours (8 hours lectures, 8 hours exercises, 4 hours workshops)
EQF level: 6

Module objective: The aim of the module is to familiarise participants with hydrogen storage technologies in various forms and how to manage H_2 storage facilities. Participants will learn about the operational characteristics of storage systems and how to identify risks, optimise plant operation and ensure compliance with safety standards and procedures.

Scope and structure of the module:

1. forms of hydrogen storage - overview of technologies (2 hours lecture + 2 hours exercise)

- Gas storage (CGH_2) - high-pressure tanks
- Liquid hydrogen storage (LH_2) - cryogenic tanks
- Chemical storage: metal hydrides, ammonia, methanol, ethanol
- Comparison: energy density, safety, costs, application

2. hydrogen storage tanks - construction and operation (2 hours lecture + 2 hours exercise)

- Tank types: I, II, III, IV (composite and metal)
- Cryogenic tanks - insulation, exchangers, safety valves
- Control and measuring systems: pressure, temperature, gas sensors
- Hydrogen evaporation (boil-off), loss control and gas recovery

3. hydrogen storage in chemical form - specificity and safety (2 hours lecture + 2 hours exercise)

- Metal hydrides (MgH_2, $LaNi_5H_6$), their properties and applications
- Storage in ammonia, methanol, ethanol - transport and conversion
- Absorption and desorption processes - material and energy requirements
- Risks related to toxicity and chemical reactivity of carriers

4 Workshop: Design and evaluation of H_2 storage facilities (4 workshop hours)

- Case study: Selection of storage technology to suit the plant profile
- Development of a simplified installation scheme: choice of tank, safety devices, measuring systems
- Operational risk analysis and hydrogen volume/mass calculations
- Discussion: optimising efficiency and minimising losses

MODULE 5. SECURITY OF HYDROGEN TECHNOLOGY - STANDARDS, PROCEDURES AND SAFEGUARDS

Duration: 20 hours (8 hours lectures, 8 hours exercises, 4 hours workshops)
EQF level: 6-7

Module objective: The objective of the module is to equip participants with knowledge of applicable standards, regulations and procedures for safety in working with hydrogen. Participants will learn about the classification of explosion hazard zones, the selection of protective measures and how to respond to emergency situations, as required by national and international law.

Scope and structure of the module:

1. fundamentals of hydrogen safety (2 hours lecture + 2 hours exercise)

- Hazard characteristics: explosivity, flammability, pressure, cryogenics
- Failure mechanisms: leaks, ignitions, explosions, operational errors
- Threat models: BLEVE, deflagration, detonation
- Analysis of historical failure cases (case studies)

2. hydrogen safety standards, rules and regulations (3 hours lecture + 2 hours exercise)

- ISO, IEC, EN standards on the safety of hydrogen systems (e.g. ISO 15916, ISO 19880, IEC 60079)
- EU directives: ATEX, Seveso III, PED, RED II
- International agreements: ADR, IMDG, RID
- Requirements of Polish law (e.g. UDT, occupational health and safety, environmental)

3 Individual and collective protection measures (2 hours lecture + 2 hours exercise)

- Hydrogen detection and early warning systems
- Selection of protective equipment - hydrogen resistance, intrinsic safety
- Passive and active protection: ventilation, shut-off systems, pressure protection
- Explosive atmospheres (EX): classification, designations, selection rules for equipment

4 Workshop: simulating emergency situations and developing procedures (4 hours workshop)

- Analysis of an emergency scenario at a hydrogen industrial plant
- Development of an evacuation procedure and response plan
- Selection of technical and organisational measures to prevent escalation
- Exercise: preparing a safety plan for a selected installation

MODULE 6: HYDROGEN TRANSPORT AND LOGISTICS IN AN INDUSTRIAL PLANT

Duration: 16 hours (6 hours lectures, 6 hours exercises, 4 hours workshops)
EQF level: 5-6

Module aim: The aim of the module is to provide knowledge on the safe and efficient transport and internal logistics of hydrogen in an industrial environment. Participants will learn about the different forms of hydrogen transport, their technical limitations, legal standards and safety methods, taking into account the different hydrogen states and chemical forms.

Scope and structure of the module:

1. forms and means of hydrogen transport - technical characteristics (2 hours lecture + 2 hours exercise)

- Pipeline transport - design, operation, risks
- Road and rail tanker transport - tanks, loading/unloading procedures
- Transport of liquid, compressed hydrogen and chemical compounds (ammonia, methanol, hydrides)
- Comparison of efficiency and costs of different solutions

2. hydrogen transport standards and regulations (2 hours lecture + 2 hours exercise)

- ADR and RID regulations - documentation, classification, markings, technical requirements
- Health and safety regulations related to the movement of hydrogen within the plant
- Requirements for equipment and persons involved in transport
- Transport documentation and regulatory compliance (certificates, inspections)

3. internal hydrogen logistics - traffic and safety management at the plant (2 hrs lecture + 2 hrs exercise)

- Planning of hydrogen routes and storage sites
- Zone marking, buffer zones, flow control
- Logistics of mobile tanks and refuelling points
- Communication and procedures between production, warehouse, UR and H&S

4 Workshop: Logistics process design and transport risk assessment (4 hours workshop)

- Logistics pathway design for hydrogen transport within the plant
- Selection of means of transport and protection depending on the form of hydrogen
- Identification of critical points and development of emergency procedures

- Cost and efficiency analysis of the transport process

MODULE 7 HYDROGEN SYSTEM MAINTENANCE - DIAGNOSIS AND PREVENTION
Duration: 24 hours (10 hours lecture, 8 hours exercise, 6 hours workshop)
EQF level: 6-7

Module objective: The objective of the module is to prepare participants to plan and implement maintenance activities for hydrogen plants. The module emphasises failure prevention, condition diagnostics, maintenance organisation and the use of predictive strategies and supporting systems (CMMS, IoT, SCADA).

Scope and structure of the module:

1. maintenance strategies for hydrogen systems (2 hours lecture + 2 hours exercise)

- UR approaches: reactive, preventive, predictive, TPM
- Importance of UR planning in high-risk installations (hydrogen, pressure, EX zones)
- Integration of UR with health and safety, UDT and production management
- Selection of the strategy according to the type of installation and the life cycle of the facility

2 Technical diagnostics of equipment and infrastructure H_2 (3 hours lecture + 2 hours exercise)

- Diagnostic methods: vibration, thermal imaging, ultrasound, vision, leakage
- Diagnosis of tanks, valves, compressors, pumps, pipelines
- Critical parameters: pressure, temperature, flow, presence of hydrogen
- Wear and tear cases - analysis of causes and effects

3. maintenance support systems (CMMS, IoT, SCADA) (3 hours lecture + 2 hours exercise)

- Management of service work and technical documentation
- Fault logging, maintenance schedules, device card
- Sensors and systems for remote monitoring of technical parameters
- Digitisation and automation of UR activities - examples of solutions

4 Organisation of UR activities in hydrogen systems (2 hrs lecture + 2 hrs exercise)

- Rules for preparing and carrying out inspections in installations with H_2
- Working in explosive atmospheres - entitlements, protective measures
- Spare parts warehouse and resource availability management
- Communication and collaboration with production and safety teams

5 Workshop: UR planning and operational risk analysis (6 hours workshop)

- Preparation of a maintenance plan for an example installation (electrolyser, LH_2 tank)
- Selection of UR strategies for critical infrastructure elements
- Analysis of diagnostic data and design of preventive measures
- Development of inspection procedures, checklist, schedule and technical report

MODULE 8. INDUSTRY 4.0 IN HYDROGEN PLANTS - DIGITISATION AND AUTOMATION

Duration: 20 hours (8 hours lectures, 8 hours exercises, 4 hours workshops)
EQF level: 6-7

Module objective: The aim of the module is to prepare participants to work in an automated and digital hydrogen plant environment. Participants will learn about Industry 4.0 tools to support production, monitoring, maintenance and safety, and learn to use data from equipment and sensors to increase efficiency and predict failures.

Scope and structure of the module:

1 Industry 4.0 and the digitalisation of industrial installations (2 hours lecture + 2 hours exercise)

- What is Industry 4.0 - assumptions, technologies, directions of development
- Digital transformation in the energy and process industries
- Impact of digitalisation on production management and safety
- Smart factory and cyber-physical production systems in the hydrogen economy

2. hydrogen plant automation - control systems and integration (2 hours lecture + 2 hours exercise)

- PLC, SCADA, DCS control systems in installations with H_2.
- Industrial automation architecture in a hydrogen environment
- Integration of sensors and actuators - transmitters, actuators, valves
- Examples of automation schemes and process control scenarios

3. IoT and real-time data analytics (2 hours lecture + 2 hours exercise)

- Sensor and data networks (IoT, IIoT) - application in H_2 installations.
- Collection and processing of data from production and measurement equipment
- Fundamentals of data analysis - detecting trends, deviations and risks

- Application of cloud and edge computing in a production environment

4 Workshop: digital model of the installation and simulation of system operation (4 hours workshop)

- Development of a simplified digital model (digital twin) of a section of the installation
- Simulation of system operation - analysis of reactions to parameter changes and alarm signals
- Creation of visualisations (HMI) and basic operator screens
- Exercises using a simulation environment (e.g. Factory I/O, TIA Portal, Codesys)

MODULE 9 OPTIMISING OPERATIONAL AND ENERGY EFFICIENCY

Duration: 16 hours (6 hours lecture, 6 hours exercise, 4 hours workshop)
EQF level: 6-7

Module objective: The objective of the module is to equip participants with the skills to analyse, evaluate and improve the operational and energy efficiency of hydrogen-related installations. Participants will learn to identify sources of losses, implement technological and organisational improvements and analyse the technical and economic viability of modernisation measures.

Scope and structure of the module:

1. key operational performance indicators (2 hours lecture + 2 hours exercise)

- OEE (Overall Equipment Effectiveness) - methodology and application
- MTBF, MTTR, MTTF - indicators of equipment reliability
- KPIs in hydrogen systems - how to measure and interpret them
- Examples of efficiency benchmarks from the hydrogen industry

2. analysis of energy consumption and energy efficiency (2 hours lecture + 2 hours exercise)

- Calculation of energy balances for processes (e.g. electrolysis, compression, cooling)
- Identification of loss points: thermal, electrical, mechanical
- Energy efficiency indicators (e.g. kWh/Nm³ H_2, kWh/kg H_2).
- Optimisation of energy consumption - equipment selection, change of operating parameters, automation

3. technical and organisational optimisation of hydrogen systems (2 lecture hours + 2 exercise hours)

- Lean Manufacturing and Six Sigma - introduction and application
- Minimising downtime, micro-downtime and failures
- Work standardisation, maintenance scheduling, TPM systems
- Hydrogen plant start-up (boil-off, leaks, operator errors)

4. Workshop: Performance audit and optimisation action plan (4 hrs workshop)

- Carry out a simplified audit of the installation (simulation or case study)
- Calculations: energy consumption, efficiency, downtime, hydrogen conversion costs
- Development of a corrective and investment action plan
- Presentation of improvements with assessment of their impact on OEE and savings

MODULE 10. Hydrogen economy and sustainable development and ESG
Duration: 16 hours (6 hours lecture, 6 hours exercise, 4 hours workshop)
EQF level: 6-7

Module Aim**:** The aim of the module is to raise awareness of the role of the hydrogen economy in achieving the Sustainable Development Goals, Climate Transformation and ESG (Environmental, Social, Governance) requirements. Learning will include assessing the environmental impact of technological processes, developing strategies in line with climate policy guidelines and developing environmental and social reports.

Scope and structure of the module:
1. hydrogen and the sustainable development goals (SDGs) (2 hrs lecture + 2 hrs exercise)

- The 2030 Agenda and the links between hydrogen and the UN goals
- Hydrogen in EU climate policy and Fit for 55
- The importance of hydrogen for the decarbonisation of industry and transport
- Hydrogen as a pillar of the transition to a zero-carbon economy

2. ESG - reporting and accountability in industrial practice (2 hours lecture + 2 hours exercise)

- Introduction to ESG - pillars, requirements, relevance for companies
- Environmental, social and management indicators - examples from the hydrogen industry
- Reporting obligations according to CSRD, GRI, Taxonomy Regulation
- Examples of ESG reports in hydrogen projects

3. carbon, water and material footprint in hydrogen management (2 hrs lecture + 2 hrs exercise)

- Calculating the carbon footprint in hydrogen production and logistics (LCA, LCOH, CO_2eq)
- Hydrogen and the consumption of natural resources - an environmental cost analysis
- Impact on biodiversity and landscape - environmental assessments of investments
- Circular economy and material recovery in H_2 installations

4 Workshop: Sustainable development strategy in the H_2 project (4 hours workshop)

- Development of a "green hydrogen plant" concept (production, transport, operation)
- Creating a simplified ESG report for a sample project
- Simulation of investment appraisal for compliance with EU taxonomy
- Discussion: public acceptance of H_2 projects - preparation and construction?

MODULE 11. SOFT SKILLS AND COMMUNICATION IN HYDROGEN SAFETY MANAGEMENT
Duration: 16 hours (6 hours lectures, 6 hours exercises, 4 hours workshops)
EQF level: 6

Module Objective: To develop the interpersonal, organisational and communication skills necessary for effective safety management in hydrogen facilities. Participants will learn how to conduct effective technical and social communication, make decisions in emergency situations, collaborate in an interdisciplinary manner and develop a safety culture within technical teams.

1. technical communication in the context of hydrogen systems (2 hours lecture + 2 hours exercise)

- Creation of safety documentation: instructions, emergency plans, checklists
- Communication under stress and in emergency situations
- Tailoring the message to the audience: operators, management, external services, local community
- Exercises: drafting a crisis message and a simplified emergency instruction

2. safety culture and leadership in a technology environment (2 hrs lecture + 2 hrs exercise)

- What is safety culture - definitions, levels, practices

- Safety leader behaviour and impact on the team
- Motivating employees to comply with policies and procedures
- Exercise: interviewing an employee who violates security procedures

3. team management and interdisciplinary collaboration (1 hour lecture + 1 hour exercise)

- Coordinating the work of multi-discipline teams (technical, operational, health and safety, IT)
- Management styles in production and project environments
- Conflict resolution and negotiation
- Exercise: simulation of crisis staff meeting

4 Decision making in situations of risk and uncertainty (1 hour lecture + 1 hour exercise)

- Rapid risk analysis under time pressure
- Use of data and models in decision-making
- Ethical dilemmas and individual responsibility in emergency situations
- Exercises: decision-making scenarios in the context of H_2 installation risks

5 Workshop: simulation of safety management in a hydrogen project (4 hours workshop)

- Scenario: accident at a plant with a hydrogen system (e.g. gas leak, leakage)
- Team roles: technical manager, safety officer, spokesperson, operator, service representative
- Team tasks:
  - preparation of an emergency action plan
  - developing a message to stakeholders
  - conducting an internal crisis briefing
- Reflection: joint analysis of the effectiveness of cooperation, identification of strengths and communication gaps

MODULE 12: MEGATRENDS, CLIMATE CHANGE, ENERGY TRANSITION

Duration: 18 hours *(6 hours lecture, 6 hours exercise, 4 hours workshop)*
EQF level: 6

Module objective:

The aim of the module is to show the broader strategic context for the development of the hydrogen economy and security of hydrogen technologies as a response to the megatrends

of the 21st century: the climate crisis, decarbonisation, digitalisation, automation and geopolitical changes in access to energy resources. Participants will also learn about the concept of **green competitive advantage** as a basis for the European Union's transformational strategies and the development of modern economies.

1. MEGATRENDS - IMPACT ON THE ENERGY AND INDUSTRY SECTOR *(2 hours of lectures)*

- Key megatrends of the 21st century:
  - Climate change and environmental pressures
  - Geopolitical tensions and energy security
  - Developments in digital technology (AI, IoT, automation)
  - Ageing populations and changing work patterns
- Impact of megatrends on the energy transition, Industry 5.0 and the raw materials sector
- The place of hydrogen as an answer to global challenges

2 Climate change and its significance for the economy, industry and infrastructure *(2 hours lecture + 2 hours exercise)*

- Scientific basis for climate change: IPCC scenarios, forecasting systems
- The costs of climate change - an analysis of the costs of "inaction" vs. the costs of transformation
- Impact of climate change on energy and industrial infrastructure (physical hazards, adaptation)
- Exercises: climate risk assessment for critical infrastructure (e.g. hydrogen plant, refuelling station)

3 EU strategy: energy transition, low-carbon economy, European Green Deal *(2 hours lecture + 2 hours exercise)*

- The Green Deal and the EU's 2030 and 2050 climate targets.
- "Fit for 55", "REPowerEU" packages - The importance of hydrogen and renewable energy
- EU taxonomy and financial mechanisms to support sustainable investments
- Exercises: analysis of the compatibility of an investment project with the objectives of the European Green Deal (case study: electrolyser + hydrogen storage)

4 Green competitive advantage - a new paradigm for the development of the economy *(2 hours lecture + 2 hours exercise)*

- The concept of "green competitiveness" - how to build competitive advantage based on megatrends, climate and environmental protection as an impulse for innovation

- ESG, sustainable business models and carbon footprint as part of market and investment decisions
- Hydrogen as part of building the EU's technological competitiveness and economic sovereignty
- Exercises: developing the principles of a 'green business model' based on hydrogen

5. Workshop: Hydrogen economy development scenarios (4 hours workshop)

- Analysis of scenarios for the development of the H_2 economy in Poland and the EU up to 2030/2050
- Development of a concept for the competitive advantage of an industrial plant based on H_2 technologies.
- Team work: analysis of risks and opportunities of hydrogen deployment in different sectors (chemistry, heavy industry, transport)
- Presentation of regional hydrogen ecosystem development projects

MODULE 13: INTEGRATED PROJECT - PRODUCTION, MAINTENANCE AND SAFETY OF HYDROGEN SYSTEMS
Duration: 30 hours (10 hours lectures, 10 hours exercises, 10 hours workshops)
EQF level: 6

Module Objective:
To summarise the knowledge and skills acquired throughout the study programme. Participants complete a comprehensive integrated project on the planning, commissioning and operation of a hydrogen plant at an industrial site - including production, storage, logistics, maintenance and safety and sustainability aspects.

1. needs analysis and project conception (4 hours - 2 lectures, 2 exercises):

- Selection of the type of industrial plant and analysis of its hydrogen requirements.
- Identification of key components of the hydrogen plant.
- Development of a technological and organisational concept.

2. Production layout and infrastructure design (6 hours - 2 lectures, 4 exercises):

- Choice of hydrogen production method (e.g. electrolysis, reforming).
- Selection of hydrogen storage technologies and distribution methods within the plant.
- Planning of transport routes and control systems.

3. maintenance system design (4 hours - 2 lectures, 2 exercises):

- Development of a preventive diagnostics and maintenance strategy.
- Selection of tools for monitoring plant operation (sensors, SCADA, IoT).

4 Safety and risk management (4 hours - 2 lectures, 2 exercises):

- Development of safety procedures, evacuation and emergency response plans.
- Integration of hydrogen detection, condition monitoring and shut-off systems.

5 Assessing efficiency and operating costs (4 hours - 2 lectures, 2 exercises):

- Estimating energy costs, water consumption, maintenance.
- Process and energy efficiency analysis (KPI, OEE).

6 Environmental aspects, ESG and sustainability (4 hours - 2 lectures, 2 exercises):

- Environmental impact assessment of the project.
- Implementation of ESG elements for the management of the hydrogen plant.

7. design workshop - presentation and defence of the project (4 hours):

- Working in project teams - preparing full technical and management documentation.
- Presentation and discussion of projects.
- Evaluation of activities and self-reflection.

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