DESCRIPTION OF COMPETENCIES IN SELECTED HYDROGEN ECONOMY PROFESSIONS

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SPECIALISATION FRAMEWORK: Hydrogen system safety engineer

With the global drive towards energy transition and achieving climate neutrality, hydrogen is emerging as a key energy carrier of the future. Its potential in the energy, transport and industrial sectors is enormous, but fully exploiting these opportunities requires rigorous compliance with safety standards and norms.

The safety of hydrogen plants is a fundamental issue. Hydrogen, as a gas with unique physico-chemical properties-flammability, a wide explosive range and high permeability-poses specific technological and organisational challenges to engineers. Therefore, the design, implementation and monitoring of safety systems in production, storage and distribution facilities becomes a priority.

Effective risk management of such installations requires interdisciplinary competence, combining knowledge of engineering, technology, materials science, safety procedures and regulation. In this context, hydrogen plant safety engineers play a strategic role in ensuring the stable development of the hydrogen economy.

Demand for competences in a 10-year perspective:

Looking ahead to the next decade, the demand for hydrogen system safety specialists will grow rapidly due to the following factors:

- **Intensive energy transition:** the implementation of hydrogen technologies requires adherence to strict safety standards that protect life, health and the environment.
- **Dynamic development of hydrogen infrastructure:** The increasing number of production, storage and distribution facilities and hydrogen refuelling stations necessitates professional protection of these facilities against the risk of failure.
- **Progressive regulation:** growing awareness of risks and the need to meet stringent safety standards is placing new legal requirements on hydrogen installations.
- **Development of new security technologies:** Advanced detection, monitoring and active security systems will continue to evolve, requiring constant updating of engineering knowledge.

Specialists in hydrogen plant security will be highly sought after by companies involved in the production, transmission, storage and use of hydrogen. Their competence will be crucial not only for meeting environmental objectives, but also for securing critical infrastructure, public health and the environment.

The job market for hydrogen system safety specialists will be characterised by rapid growth and high qualification requirements, making this specialisation extremely attractive to those looking for a stable and promising profession.

Job Qualification Description: Hydrogen Safety Engineer includes skills in hazard identification, design, implementation and management of hydrogen safety systems in accordance with applicable technical, legal and environmental standards.

The proposed topics are particularly recommended for:

- Engineers and safety professionals wishing to gain specialist competence in hydrogen installations.

- Technicians and engineers in the energy, chemical and industrial sectors who wish to extend their qualifications to include safety aspects of hydrogen technology.

- Health, safety and emergency workers, for whom hydrogen systems are a new and important area of responsibility.

- Graduates and students from technical and natural science universities interested in future technologies related to the hydrogen economy.

- Specialists and safety auditors seeking specialist expertise in the fast-growing hydrogen sector.

- The offer is also aimed at those interested in working in the renewable energy sector, the chemical industry, transport and any industry that uses hydrogen as an energy source or fuel.

The table below lists the learning outcomes and verification criteria for each competence:

Competence 1: Application of safety principles in the design, construction and operation of hydrogen systems

- It describes in detail the hazards of operating hydrogen systems, including explosions, fires, hydrogen leaks.
- Selects hydrogen-resistant construction materials and safety devices.
- Applies the applicable technical standards and safety guidelines for plant design (e.g. ISO/TR 15916, EN 60079, API RP).
- Analyses the specifics of hydrogen systems in terms of the risk of hydrogen embrittlement, corrosion and material damage.
- Applies the personal and group protection measures required when operating the installation.
- Identifies and applies preventive measures against potential failures due to the properties of hydrogen (e.g. detection, ventilation, emergency shutdown of gas flow).
- Creates project documentation incorporating safety procedures (e.g. operating instructions, safety plans for installations).

Competence 2: Risk analysis and crisis management for hydrogen facilities

- Carries out detailed risk analysis using methods such as HAZOP, FMEA and 'fault tree analysis' (FTA).
- Develops emergency event scenarios (fire, explosion, plant leak, hydrogen leak) and mitigation strategies.

- Develops emergency procedures and emergency and preventive action plans for hydrogen facilities.
- Explains the mechanisms of critical situations in hydrogen systems (e.g. ignition from a spark, explosion due to exceeding flammability limits).
- It conducts emergency simulations and emergency and incident response training.
- Proposes strategies to minimise the risk of hydrogen system failures, taking into account technical, environmental and organisational factors.
- Liaises with emergency services and control authorities during emergencies.

Competence 3: Application of knowledge of the physico-chemical properties of hydrogen for the safety of installations

- Describes and analyses the physical properties of hydrogen (flammability, explosivity, diffusivity, density in different states of matter).
- Distinguishes between hydrogen isotopes (protium, deuterium, tritium) and explains their specific properties relevant to safety.
- Analyses the impact of ortho and para-hydrogen on plant storage and operation processes.
- Identifies key hydrogen temperatures (e.g. boiling, critical, triple point) and their impact on plant design and safety.
- Explains the mechanisms of hydrogen embrittlement and the effects of hydrogen on structural materials (steel, aluminium, composites).
- Justifies the importance of the explosion limits of hydrogen in air (lower and upper limits) for the safety of the installation.
- Describes and assesses the risks arising from the high chemical reactivity of hydrogen in reactions with oxygen, halogens and metals.
- Analyses the behaviour of hydrogen under extreme pressure and temperature conditions, assessing potential risks to the system.

Competence 4: Application of legislation, industry standards and technical standards concerning the safety of hydrogen systems

- Identifies applicable national and European legislation governing the design, construction and operation of hydrogen systems.
- Interprets and applies the requirements of ISO, EN, IEC standards for the safety of hydrogen systems and explosion-proof equipment.
- Draws up technical documentation in accordance with current legislation and technical standards (operating instructions, UDT documentation, safety procedures).
- It applies the requirements of the ADR regulations for the transport and storage of hydrogen.

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- It follows legislative and normative changes in the field of hydrogen technology, updating technical and organisational solutions.
- Assesses the compliance of existing hydrogen systems with current safety standards, making recommendations for adaptation to current legal requirements.

Competence 5: Inspection and safety audit of hydrogen systems

- Designs and implements processes for monitoring plant operating parameters (e.g. pressure, temperature, hydrogen concentration, structural integrity).
- Applies the methodology for auditing hydrogen installations for compliance with regulations and safety standards.
- Analyses the technical data of hydrogen systems, identifying potential risks and anomalies.
- Prepares audit reports and recommendations for improving the technical safety of installations.
- Carries out inspections and technical checks of the installation, taking into account the specific risks associated with hydrogen (e.g. hydrogen corrosion, leaks).
- Implements procedures for the continuous improvement of the safety of hydrogen installations, taking into account the results of audits, incidents and recommendations from supervisory authorities.
- It carries out practical exercises on auditing and analysing the safety documentation of hydrogen systems.

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

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- Conducts effective discussions with customers and the team in simulated scenarios (e.g. discussing the hydrogen production safety plan, logistics).
- 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. reports in accordance with ATEX, ADR, etc.).
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 plant safety.
   - 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.

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 hydrogen system safety 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 safety challenges of designing and operating hydrogen systems.
   - Identifies improvements to existing 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, breakdowns).
   - 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 on new hydrogen technologies.
8. **Keeps abreast of technological innovations and regulatory changes.**
   Verification criteria:

- Presents new technologies and regulations during team meetings.
- Prepares notes or reports on regulatory developments in the subject of safety in the operation of hydrogen systems.
- Uses newly learned tools or technologies in practical tasks.

9. **Participates in training courses and conferences.**

Module 1: Safety and risk analysis for hydrogen systems (24 hours)

Module 2: Introduction to hydrogen and its properties (20 hours)

Module 3: Hydrogen production technologies (24 hours)

Module 4: Hydrogen storage technologies (16 hours)

Module 5: Hydrogen transport safety (16 hours)

Module 6: Design of safety systems for hydrogen systems (20 hours)

Module 7: Monitoring, control and safety auditing of hydrogen systems (20 hours)

Module 8: Safety law, standards and regulations. Emergency procedures in hydrogen management (20 hours)

Module 9: Social and economic aspects of the use of hydrogen in the economy (16 hours)

Module 10: Soft skills and communication in hydrogen safety management (16 hours)

Module 11: Megatrends, climate change, energy transition (18 hours)

MODULE 12: Integrated project on the safety of hydrogen systems (30 hours)

TOTAL 240 hours

PROPOSED THEMATIC SCOPE OF THE MODULES:

MODULE 1: SAFETY AND RISK ANALYSIS IN HYDROGEN HANDLING

Duration: 24 hours (10 hours lecture, 8 hours practical exercises, 6 hours workshop).
EQF level: 5-6

Aim: To gain knowledge of regulations, norms and standards for hydrogen logistics and the ability to analyse risks and deal with emergency situations.

Topics:

1. Current ISO and IEC standards for hydrogen (4 hours):

- Discussion of key standards such as ISO 14687 (specification of hydrogen as a fuel) and IEC 60079 (explosion safety).

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- An overview of standards for the transport, storage and use of hydrogen in various industrial sectors.
- Analysis of the latest guidelines related to the certification of hydrogen devices.

2. National and international safety and environmental regulations (4 hours):

- EU regulations (e.g. Seveso III Directive, ADR, IMDG, ATEX regulations).
- National regulations for the handling of hazardous substances and environmental protection.
- Case studies: hydrogen-related accidents and their legal implications.

3. Emergency procedures (spill, fire, explosion) (4 hours - 2 hours lecture, 2 hours exercise):

- Mechanics and physics of emergency events involving hydrogen.
- Detailed discussion of procedures for specific situations (e.g. area isolation, hydrogen firefighting).
- Interactive simulations of responses to hydrogen leaks, fires and explosions.

4. Principles of first aid in case of hydrogen poisoning/burns (2 hours):

- Physiological effects of exposure to hydrogen and its derivatives (e.g. cryogenic burns, gas poisoning).
- Standard procedures for assisting casualties.
- Practical workshop: simulation of first aid in various scenarios.

5. Risk analysis methods (4 hours):

- Introduction to HAZOP (Hazard and Operability Study) and FMEA (Failure Mode and Effects Analysis) methods.
- Identification of potential risks in the hydrogen logistics chain.
- Assessing the impact and likelihood of risk events.

6. Developing emergency plans and preventive procedures (6 hours - 2 hours lecture, 4 hours workshop):

- Creating comprehensive contingency plans for hydrogen facilities.
- Practical exercises: developing preventive and emergency procedures for hypothetical scenarios.
- Analysis of the effectiveness of plans based on simulated emergency situations.

MODULE 2: INTRODUCTION TO HYDROGEN AND ITS PROPERTIES

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Duration: 20 hours (8 hours lecture, 8 hours exercise, 4 hours workshop).
EQF level: 4-5
Aim: To understand the basic physical and chemical properties of hydrogen, which are key to safe storage and transport.

Topics:

1. 1. Hydrogen, Isotopes of hydrogen, characterisation (1 hr - lecture, 1 hr - lab).

- 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 (1 hr - lecture, 1 hr - exercise).

- 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 (1 hr - lectures, 1 hr - exercises).

- 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 (boiling, critical, triple point) (1 hr - lecture, 1 hr - exercise).

- 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 (1 hour - lecture, 1 hour - exercise).

- 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 (1 hour - lectures, 1 hour - exercises).

- 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 (1 hour - lecture, 1 hour - lab).

- 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.

10. overview of hydrogen production methods and the concept of "green hydrogen" (6 hrs - lecture, 1 hr - workshop)

- Hydrogen production methods: steam reforming of methane, water electrolysis, biomass pyrolysis.
- Explaining the concept of 'green hydrogen' and its role in the energy transition.
- Group discussion: assessment of the potential for green hydrogen production in Poland and worldwide.

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11. overview of hydrogen utilisation methods (6 hrs - lecture, 1 hr - workshop)

- Fuel cells: Alkaline fuel cells (AFC), Phosphate fuel cells (PAFC), Carbonate fuel cells (MCFC), Solid oxide fuel cells (SOFC), Polymer fuel cells (PEFC, SPCF, PEMFC), Methanol fuel cells (DMFC - a subgroup of PEMFC), Proton fuel cells (PCFC)
- Hydrogen combustion (internal combustion engines, hydrogen boilers and burners, others)
- Use of hydrogen in chemical processes (fertiliser production, steel production, oil refining process, others)

MODULE 3: HYDROGEN STORAGE TECHNOLOGIES AND THEIR SAFETY

Duration: 24 hours *(10 hours lecture, 10 hours practical exercises, 4 hours workshop)*
EQF level: 5-6

Module objective: The aim of the module is to familiarise participants with various hydrogen storage technologies - both physical and chemical - and the risks and safety requirements associated with these technologies. Participants will gain an understanding of the characteristics of storage systems, the selection of suitable solutions for industrial applications and methods to minimise the risk of failure.

1. introduction to hydrogen storage methods ***(2 lecture hours)***

- Method classification:
  - Physical storage: compressed hydrogen, liquid hydrogen
  - Chemical storage: metal hydrides, organic liquids, chemical compounds (e.g. ammonia)
- Comparison of basic parameters: energy density, safety, costs, applications

2. hydrogen storage in the form of compressed gas (CGH_2) ***(2 hours lecture + 2 hours exercise)***

- Pressure vessels: types (I-IV), construction materials, resistance to hydrogen embrittlement
- Operating parameters: operating pressure (350-700 bar, B+R), charge/discharge cycles
- Principles of safe tank operation: standards, inspections, safety systems
- Exercises: selection of tank for application, volume calculation, risk analysis

3 Liquid hydrogen storage (LH_2) ***(2 hours lecture + 2 hours exercise)***

- Hydrogen liquefaction and storage process at -253 C°
- Construction and types of cryogenic tanks - isolation, boil-off, loss management

- Cryogenic and explosion hazards, safety procedures
- Exercises: boil-off loss analysis, cryogenic tank design for a given plant

4 Hydrogen storage in metal hydrides (hydrides) ***(1 hour lecture + 1 hour exercise)***

- Mechanism of hydrogen bonding and release in metallic materials
- Typical materials: $LaNi_5$, MgH_2, TiFe, intermetals
- Advantages and disadvantages: safety, energy density, operating temperature
- Exercises: analysis of the properties of a selected hydride and simulation of the storage process

5. hydrogen storage in the form of liquid organic compounds (methanol, ethanol) ***(1 hour lecture + 1 hour exercise)***

- Mechanism of action: reforming of methanol and ethanol - production of hydrogen on demand
- Safe storage and transport of alcohol - fire and toxic hazards
- Comparison with compressed and liquid hydrogen in terms of efficiency and cost
- Exercises: analysis of an emergency scenario involving methanol as hydrogen carrier

6. hydrogen storage in ammonia (NH_3) ***(1 hour lecture + 1 hour exercise)***

- Ammonia as a hydrogen carrier: energy density, decomposition to H_2 and N_2
- Technical storage requirements (temperature, pressure)
- Toxic and environmental hazards - requirements for tanks, drainage systems, ventilation
- Exercise: risk analysis of an ammonia leak from a storage facility

7 Selection of storage technology according to application (1 hour lecture + 1 hour exercise)

- Factors determining the choice of technology:
    - Location and purpose of storage (stationary vs mobile)
    - Availability of energy, space, technology
    - Economic, environmental and safety aspects
- Exercises: case study - selection of a storage method for a H_2 mobile generator

8 Practical Workshop: Design of a hydrogen storage system for an industrial installation ***(4 hours workshop)***

- Development of a complete hydrogen storage system for an example installation (e.g. energy hub, chemical plant, refuelling station)
- Tasks:
    - Selection of storage method
    - Assessment of risks and emergency scenarios
    - Selection of safety devices (valves, sensors, ventilation, detection systems)
    - Technology diagram with safety system components
- Presentation of projects, joint analysis and discussion

MODULE 4: RISK ANALYSIS AND ASSESSMENT FOR HYDROGEN SYSTEMS

1. introduction to risk analysis in hydrogen management (2 hrs)

- Basic concepts and definitions related to risk analysis (threat, risk, consequences, probability)
- Specific risks of hydrogen systems (fire, explosion, toxicity, cryogenicity)
- Steps in the risk analysis process (hazard identification, emergency scenario analysis, risk assessment)

2 Methods for identifying hazards specific to hydrogen systems (4 hrs)

Detailed discussion of hazard identification methods:

- HAZOP (Hazard and Operability Study)
- FMEA (Failure Mode and Effects Analysis)
- FTA (Fault Tree Analysis)
- ETA (Event Tree Analysis)
- Practical exercises: carry out a simplified HAZOP analysis and FMEA for an example hydrogen production plant (e.g. electrolyser or steam reformer).

3. analysis of emergency scenarios in hydrogen systems (4 hrs)

- Creation of emergency scenarios: typical scenarios of leaks, fires, hydrogen explosions
- Characteristics of events initiating failures (e.g. valve failure, compressor failure, human error)
- Analysis of the influence of environmental conditions (temperature, humidity, wind) on the development of failures
- Practical exercises: development of emergency scenarios for a selected hydrogen storage or distribution installation (e.g. hydrogen refuelling station)

4 Quantitative Risk Assessment (QRA) in hydrogen installations (4 hrs)

- Introduction to QRA methods (probabilistic methods)
- Assessment of the probability of emergency events
- Modelling the consequences of accidents (e.g. explosions, fires, gas leaks)
- Practical exercise: performing a simplified QRA analysis for a hypothetical liquid or compressed hydrogen storage facility

5. analysis of the physical effects of failures in hydrogen systems (4 hrs)

- Modelling the physical effects of failure:
    - Dispersion and diffusion of hydrogen
    - Explosion characteristics (BLEVE, UVCE)
    - Radiation and effects of hydrogen fires
    - Deflagration
    - Review of computer programmes (PHAST, ALOHA, CFD)
    - ? Practical exercise: simulating the consequences of an accident (explosion, fire, gas diffusion) for a selected hydrogen system using a computer programme (e.g. ALOHA or PHAST).

6 Risk assessment in ATEX explosive atmospheres involving hydrogen (3 hrs).

- Basic requirements of the ATEX directive for explosive atmospheres with hydrogen
- Hydrogen explosion hazard zone classification (zone 0, 1, 2)
- Selection of explosion-proof equipment and its impact on risk reduction
- Workshop: classification of explosion hazard zones for a selected hydrogen production or distribution installation

7. risk assessment for critical infrastructure facilities using hydrogen (3 hrs)

- Definition and classification of critical infrastructure using hydrogen (e.g. large industrial installations, hydrogen power plants, transmission systems)
- Specificity of critical infrastructure risk: analysis of potential social, economic and environmental consequences of failure
- Practical workshop: Risk assessment of critical infrastructure failures using a hypothetical fuel cell power plant or hydrogen transmission facility as an example

MODULE 5: HYDROGEN TRANSPORT SAFETY

Duration: 20 hours (9 hours lecture, 7 hours practical exercises, 4 hours workshop)
EQF level: 5-6

Module Objective: To gain an understanding of the different methods of hydrogen transport, their specific characteristics, potential hazards and practical skills to ensure safety during hydrogen transport, with a focus on regulations, technical standards and emergency procedures.

1 Introduction to hydrogen transport safety (2 hrs)

- Characterisation of specific hazards in hydrogen transport (spills, fires, explosions, cryogenic hazards).
- Discussion of the main methods of hydrogen transport: pipelines, road tankers, rail tankers, sea transport.
- Hazard classification of the different forms of hydrogen (compressed gas, liquid gas, chemical compounds).

Safety in the transport of compressed hydrogen (3 hrs)

- Detailed description of the technology for hydrogen transport in the form of compressed gas (Type I-IV tankers, operating parameters up to 700 bar).
- Selection of structural materials for pressure vessels - analysis of resistance to hydrogen embrittlement.
- Safety procedures for loading, transporting and unloading compressed hydrogen tankers.
- Practical exercises: risk assessment of the transport of compressed hydrogen by land (simulations, case studies).

3 Safety of liquid hydrogen transport (3 hrs)

- Characterisation of liquid hydrogen (LH2) transport technology under cryogenic conditions (-253° C).
- Analysis of specific cryogenic risks: danger of fittings freezing, boil-off (evaporation), vacuum insulation of tanks.
- Safety procedures for loading, transporting and unloading liquid hydrogen.
- Practical exercises: simulation of safety analysis and transport procedures for liquid hydrogen.

4 Safety of hydrogen pipeline transport (3 hrs)

- Construction and operation of hydrogen pipelines - specific risks, including leaks, risk of embrittlement and hydrogen corrosion.
- Methods for condition monitoring of hydrogen pipelines (leak detection, pressure measurements, material analysis).

- Strategies for minimising risk during long-distance hydrogen transfers.
- Practical exercises: hazard analysis, risk assessment and development of safety procedures for a hypothetical pipeline infrastructure.

5 Safety of hydrogen transport in the form of chemical compounds: metal hydrides, methanol, ethanol, ammonia (4 hrs)

- Characterisation of hydrogen chemical carriers: physicochemical properties and hydrogen release mechanisms.
- Specificity of hazards during transport of chemically bound hydrogen (toxicity of ammonia, flammability of alcohols, stability of metal hydrides).
- Safety measures, selection of packaging and containers, temperature and pressure requirements.
- Overview of regulations and ADR designations for individual chemicals.
- Exercises: analysis of an emergency scenario involving the transport of hydrogen in the form of ammonia or methanol, emergency procedures.

6 Regulatory and safety standards for hydrogen transport (2 hrs)

- National and international regulations for the transport of hydrogen (ADR, IMDG, ATEX).
- ISO, EN technical standards governing the safety of hydrogen transport (e.g. ISO/TR 15916, ISO 19880).
- Legal obligations and documentation required for hydrogen transport (transport documents, emergency procedures).
- Examples of the application of regulations in practice.

7 Emergency procedures and risk management for hydrogen transport - workshop (3 hrs)

- Scenarios of typical hydrogen transport accidents (tanker leak, valve failure, roadside fire, tank explosion).
- Methodology for developing emergency procedures specific to hydrogen transport (site isolation, evacuation, rescue operations).
- Practical workshop: development of emergency plans for selected transport scenarios (e.g. simulation of an incident during road tanker transport).

MODULE 6: DESIGN OF SAFETY SYSTEMS FOR HYDROGEN SYSTEMS

Duration: 20 hours *(8 hours lecture, 8 hours practical exercises, 4 hours workshop)*
EQF level: 6

Module Objective: To acquire knowledge and skills in the design of safety systems for hydrogen systems, taking into account the physicochemical properties of hydrogen, normative requirements, selection of materials, safety components and integration of detection and control systems.

1. fundamentals of hydrogen system design including safety (2 hours lecture)

- Design principles for safe gas and cryogenic installations.
- Specifics of hydrogen systems (high diffusivity, wide flammability range, fragility of materials).
- Overview of typical risk areas in hydrogen installations: production, storage, transmission, use.

Selection of materials and components for hydrogen-resistant systems (2 lecture hours + 2 exercise hours)

- Properties of structural materials: resistance to hydrogen embrittlement, corrosion and pressure.
- Normative requirements for materials used in hydrogen systems (e.g. austenitic steel, composites).
- Selection of seals, valves, pipes and tanks.
- Exercises: analysis of technical sheets and selection of suitable materials for high-pressure or low-temperature installations.

3. design of hydrogen detection and monitoring systems (2 hrs lecture + 2 hrs exercise)

- Hydrogen detection technologies: electrochemical, semiconductor, optical sensors.
- Sensor deployment - principles due to the properties of hydrogen (lighter weight than air, rapid diffusion).
- Integration of sensors with alarm systems and control panels.
- Exercises: designing the layout of a hydrogen detection system in a plant (e.g. refuelling station or container electrolysis plant).

4 Technical security systems - passive and active (2 hours lecture + 2 hours exercise)

- Safety valves, shut-off valves, non-return valves, venting systems.
- Passive explosion protection systems (e.g. decompression panels, explosion baffles).
- Active safety systems (hydrogen extinguishing, emergency power cut-off, automatic shutdowns).
- Exercises: design of cryogenic and pressure plant protection system (valve selection, emergency diagrams).

5 Safe integration of technology - power supply, ventilation, control systems (2 hours lecture + 2 hours exercise)

- Principles of natural and mechanical ventilation in hydrogen explosive atmospheres.
- Design of emergency power and safety control under fault conditions.
- Requirements for power and communication systems in ATEX zones.
- Exercises: design of a ventilation and emergency power supply system for a selected installation (e.g. container station with electrolyser).

6 Design Workshop: Comprehensive development of a security system concept (4 hours workshop)

- Case study: design of a hydrogen refuelling plant or electrolyser in a container.
- Stages of project work:
  - Identification of risks
  - Selection of materials and equipment
  - Design of detection and ventilation system
  - Design of alarm system and safety valves
  - Development of a simplified functional diagram
- Presentation of the project in groups with discussion of risks and proposed hedging solutions.

MODULE 7: MONITORING, CONTROL, SAFETY AUDIT OF HYDROGEN SYSTEMS

Duration: 20 hours (8 hours lecture, 8 hours practical exercises, 4 hours workshop)
EQF level: 6

Module objective: The objective of the module is to prepare participants to conduct safety oversight of hydrogen facilities by implementing monitoring and control systems and performing technical and procedural audits. Participants will learn tools and standards for assessing the safety status and learn how to make decisions based on operational data.

1. safety monitoring systems for hydrogen systems (2 hours lecture + 2 hours exercise)

- Types of parameters to be monitored (pressure, temperature, flow, H_2 concentration, O_2 level, VOC).
- Use of SCADA systems, DCS, BMS and environmental sensors.
- Requirements for recording, archiving and analysing data from monitoring systems.
- Exercises: interpretation of data from an example SCADA system for a hydrogen production and storage facility.

2. real-time threat detection and diagnostics (2 hours lecture + 2 hours exercise)

- Integration of hydrogen detection sensors with safety automation (e.g. ESD - Emergency Shutdown systems).
- Recognition of anomalies in the operation of hydrogen systems: trend analysis, alarms, false signals.
- Early warning of potential failures - using machine learning and predictive algorithms.
- Exercises: analysis of operational trend charts, identification of possible sources of risk.

3. safety audit of hydrogen systems - theory and practice (2 hours lecture + 2 hours exercise)

- Types of audits: internal, external, technical inspections, regulatory compliance checks.
- Scope of the hydrogen safety audit: infrastructure elements, documentation, work organisation, safety culture.
- Tools and forms used in audits (checklists, assessment matrices, questionnaires).
- Exercises: simulation of a simplified audit for a containerised hydrogen station or hydrogen vehicle refuelling (HRS) station.

4 Assessing the effectiveness of safety and response systems (2 hrs lecture + 2 hrs exercise)

- Security performance indicators (KPIs): LOPA, number of incidents, response time, systems reliability.
- Security gap analysis and corrective action proposals (CAPA).
- Comparison of the current status with normative requirements (e.g. ISO 19880-1, IEC 61508/61511, EN ISO 45001).
- Exercises: evaluation of a hydrogen detection system based on a case study - audit recommendations.

5 Workshop: Security audit - design and simulation (4 hours)

- Group-led workshop - simulation of a full audit (technical + organisational) for a selected installation (e.g. hydrogen storage, electrolysis plant).
- Scope of the workshop:
    - Preparation of the audit plan
    - Development of a checklist
    - Analysis of data from monitoring systems
    - Assessment of compliance with standards and regulations

- Preparation of the final audit report and recommendations for corrective action

MODULE 8: LAW, STANDARDS AND REGULATIONS CONCERNING SAFETY. EMERGENCY PROCEDURES IN HYDROGEN MANAGEMENT

Duration: 20 hours *(8 hours lecture, 8 hours practical exercises, 4 hours workshop)*
EQF level: 6

Module objective: To familiarise participants with national and international regulations on the safety of hydrogen systems, including current technical standards, legislation and principles for developing and implementing emergency procedures. Participants will acquire the ability to interpret the regulations and their practical application in industry and transport.

1. national and international legislation on hydrogen and hydrogen facilities ***(2 hours lecture + 2 hours exercise)***

- Key EU and Polish legislation:
    - Seveso III Directive
    - CLP Regulation, REACH
    - Environmental Protection Act
    - National Hydrogen Strategy
- Provisions for facilities with increased and high risk (HZR and ZDR) - obligations of operators
- Legal liability in the event of an accident involving hydrogen
- Exercises: analysis of infringement cases and legal consequences

2 Technical and safety standards for hydrogen systems ***(2 hours lecture + 2 hours exercise)***

- Overview of key standards:
    - ISO/TR 15916: General principles for the safety of hydrogen systems
    - ISO 19880 (parts 1-8): Hydrogen refuelling, transfer systems
    - IEC 60079: Electrical apparatus for explosive atmospheres
    - PN-EN 60079, PN-EN ISO 45001 (BHP)
- Mandatory technical documentation (e.g. DoZW - Explosion protection document)
- Exercises: Assignment of relevant standards to selected components of the installation

Hydrogen transport and ADR, RID, IMDG regulations ***(2 hrs lecture + 2 hrs exercise)***

- Formal and documentary requirements for the transport of hydrogen in its various forms (gas, liquid, chemical compounds):
    - ADR - road transport
    - RID - rail transport
    - IMDG - Maritime transport
- Hazard classification, labelling, packaging, loading and unloading rules
- Obligations of the consignor, the carrier and the consignee
- Exercises: Completion of ADR documentation for the transport of liquid hydrogen or ammonia

4 Development and implementation of emergency procedures for hydrogen systems *(2 hrs lecture + 2 hrs exercise)*

- Types of emergency scenarios: leakage, ignition, explosion, cooling system failure
- Principles for building emergency response procedures in hydrogen systems
- Coordination of internal activities and cooperation with external services (PSP, UDT, environmental inspection)
- Exercises: development of an emergency procedure for a selected situation (e.g. leakage at a refuelling station, failure of an electrolyser)

5. practical workshop: analysis of regulations and procedures for a specific project *(4 hours workshop)*

- Case study: design of a hydrogen production and refuelling installation (e.g. hydrogen hub, electrolyser + refuelling station)
- Participants prepare:
    - analysis of existing legislation and standards
    - a set of required formal documents (including DoZW, PZA, emergency instructions)
    - outline of emergency procedures for specific risk scenarios
- Presentation of the developed plan and joint analysis of the correctness and compliance with regulations

MODULE 9: SOCIAL AND ECONOMIC ASPECTS OF THE USE OF HYDROGEN IN THE ECONOMY

Duration: 16 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 context for the development of the hydrogen economy - including the impact on society, the labour market, energy systems, the environment and business models. Participants will gain an understanding of the social, economic and regulatory factors influencing the deployment of hydrogen technologies, as well as the skills to evaluate hydrogen projects for their cost-effectiveness and social acceptability.

1. hydrogen as part of the energy transition and climate policy *(2 lecture hours)*

- Hydrogen in EU, Polish and global strategies (Fit for 55, Green Deal, National Hydrogen Strategy)
- The role of hydrogen in the decarbonisation of industry, transport, power and heating
- Integration of hydrogen with renewable energy sources (Power-to-Gas, seasonal storage)

2. economics of hydrogen projects - cost and financing models *(2 hrs lecture + 2 hrs exercise)*

- Levelised Cost of Hydrogen (LCOH)
- Analysis of CAPEX and OPEX costs in production, storage and distribution facilities
- Project funding: grants, loans, EU instruments (e.g. IPCEI, Horizon Europe)
- Exercises: simplified cost-effectiveness analysis of a hydrogen station or microgrid project

3. business models and value chains in the hydrogen economy *(1 hour lecture + 1 hour exercise)*

- Key players: manufacturers, infrastructure operators, end users
- Business models: on-site vs off-site, local energy clusters, public-private partnerships
- Hydrogen market analysis: demand, competition, risks
- Exercises: development of a simple value chain model for a local hydrogen investment

4 Social impact of hydrogen deployment - acceptance, education, communication *(2 hrs lecture + 2 hrs exercise)*

- Public perception of hydrogen: fears, misinformation, the role of education and the media

- Public acceptance of hydrogen investments (LESSONS LEARNED from projects in the EU and Japan)
- The role of local authorities and communities in the investment planning and implementation process
- Exercises: case study analysis - social conflicts around a hydrogen investment, development of a communication strategy

5. environmental footprint and sustainability in the hydrogen economy *(1 hour lecture + 1 hour exercise)*

- Life cycle analysis (LCA) of hydrogen - from production to use
- Comparison of the carbon footprint of grey, blue, green hydrogen
- Hydrogen and the Sustainable Development Goals (SDGs)
- Exercises: assessment of the environmental impact of the selected hydrogen technology (simplified LCA)

6 Workshop: Case study - socio-economic analysis of a hydrogen investment *(4 hours)*

- Work in groups to design an investment (e.g. local H_2 refuelling station, green hydrogen plant, industrial hub).
- Analysis:
  - Economic: costs, sources of funding, profitability
  - Social: impact on the labour market, local acceptance
  - Environmental: carbon footprint, compliance with climate policies
- Presentation of results and group discussion - conclusions and recommendations

MODULE 10: SOFT SKILLS AND COMMUNICATION IN HYDROGEN SAFETY MANAGEMENT

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

Module Objective: The aim of the module is to develop the interpersonal and organisational competencies necessary to effectively manage safety in hydrogen projects and installations. Participants will learn to conduct effective technical and social communication, manage a team, make decisions in emergency situations and build a safety culture in the work environment.

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

- Principles for creating safety documentation: reports, instructions, emergency plans

- Communicating in emergency situations and under stress
- Communication with different audiences (engineers, operators, public, decision-makers)
- Exercises: drafting a crisis message, simplified emergency instructions

2. safety culture and leadership in a technological environment *(2 hours lecture + 2 hours exercise)*

- What is safety culture - good and bad practices
- The role of the safety leader in a technical organisation
- Building team commitment - adherence to procedures and standards
- Exercises: simulating a conversation with an employee breaking procedures, techniques

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

- Working in multi-discipline teams (engineers, lifeguards, IT, management)
- Management styles in project and production environments
- Conflict and negotiation in the technical team - solutions
- 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
- Decision support with data - when and how to use models and simulations
- Ethical dilemmas and personal responsibility
- Exercises: decision-making scenarios involving a hydrogen facility

5 Workshop: Simulation of safety management in a hydrogen project *(4 hours)*

- Group work - simulating a full cycle of communication and coordination in the context of an emergency situation (e.g. hydrogen leakage at a plant)
- Roles: technical manager, safety officer, spokesperson, service representative
- Tasks:
    - Development of an action plan
    - Preparation of the message to the media
    - Simulation of an internal team briefing
- Reflection: assessing the effectiveness of cooperation and communication

MODULE 11: 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 the 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. strategic workshop: planning hydrogen projects in the context of megatrends and climate objectives *(4 hours)*

- Working in teams to simulate the project:
  - objective: sustainable development of the region/industry using hydrogen
  - taking into account: climate conditions, EU policies, geopolitical and social risks
- Elaboration:
  - operating model
  - risk analyses of megatrends
  - public communication plan and financing proposal
- Presentation and joint analysis of results

MODULE 12: INTEGRATED DESIGN FOR THE SAFETY OF HYDROGEN SYSTEMS

Duration: 30 hours (10 hours of lectures, 10 hours of practical exercises, 10 hours of workshops)

EQF level: 6

Aim: **To** apply and integrate the knowledge and skills gained in the previous modules by developing a comprehensive hydrogen plant safety project, including risk analysis, safety system design and development of emergency procedures.

1. Introduction to integrated design (2 lecture hours):

- Discuss the aims and scope of the project.

- An overview of the key technical, legal and organisational aspects related to the safety of hydrogen systems.

2. Risk analysis and hazard identification (4 hours - 2 hours lecture, 2 hours exercise):

- Application of risk analysis methods, such as HAZOP or FMEA, in the context of hydrogen installations.
- Identification of potential risks associated with the operation of hydrogen facilities.

3. Security systems design (6 hours - 2 hours lecture, 4 hours exercise):

- Selection of appropriate technologies and safety equipment.
- Integration of detection, alarm and explosion-proof systems.

4. Development of emergency procedures and evacuation plans (4 hours - 2 hours lecture, 2 hours exercise):

- Creating procedures to deal with emergency situations such as leaks or hydrogen fires.
- Planning for evacuation and cooperation with emergency services.

5. Design workshop: development of a comprehensive safety plan (10 hours):

- Team work to develop a safety plan for a selected hydrogen plant.
- Presentation of the developed plans and discussion of the solutions used.

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