

Legal Framework



WP 1.1 Legal framework

Inception report on European Union Legal Framework



Content

Glossary	3
1. Summary	5
1.1. Report Objectives	5
1.2. Brief Overview of Identified Gaps, Challenges and Roadblocks.....	6
1.3. Summary of Key Findings and Recommendations	7
2. Project.....	9
2.1. BSR HyAirport Project Summary.....	9
2.2. BSR HyAirport Project group activity 1.1. – legal framework summary	9
2.3. Scope of Analysis	10
2.4. Implementation Method.....	10
3. Overview of the Regulatory Landscape.....	11
3.1. Key Regulatory Bodies	11
3.2. International Influences	14
3.3. EU Strategies and Policy Framework for Hydrogen Implementation	18
4. EU Regulatory Framework	20
4.1. Construction and Aerodrome Infrastructure Standards.....	20
4.2. Vehicle and Equipment Safety Standards	21
4.3. Hydrogen Market Development and Energy Transition.....	26
4.4. Aviation Safety and Incident Management	29
4.5. Chemical and Environmental Safety Regulations	31
4.6. Transport Network and Infrastructure Integration.....	33
4.7. Environmental Impact and Emissions Control	35
4.8. Ground Operations and Critical Entity Resilience.....	39
4.9. Brief Overview	41
5. Roadblocks and Regulatory Gap Analysis.....	41
5.1. Hydrogen Production within the Airport.....	41
5.2. Hydrogen Storage at the Airports.....	43
5.3. Hydrogen Fuelling Infrastructure	44
5.4. Hydrogen Transportation.....	46
6. Recommendations for Regulatory Improvements.....	47
6.1. Policy Considerations.....	48
6.2. Institutional Recommendations.....	49
6.3. Strategic Recommendations	50

Glossary

ACER	- Agency for the Cooperation of Energy Regulators to foster cooperation among the EU's energy National Regulatory Authorities (NRAs) and help ensure that a single European market for electricity, and similarly natural gas, functions well.
ADR	- European Agreement concerning the International Carriage of Dangerous Goods by Road.
AFIR	- Alternative Fuels Infrastructure Regulation or Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure.
ATEX Equipment Directive	- ATEX Equipment Directive or Directive (EU) 2014/34 covers equipment and protective systems intended for use in potentially explosive atmospheres replacing the previous Directive 94/9/EC.
ATEX Workplace Directive	- ATEX Workplace Directive or Directive 99/92/EC refers to minimum requirements for improving the health and safety protection of workers at risk from an explosive atmosphere. Also known as ATEX 137.
BSR	- Baltic Sea Region.
BSR HyAirport Project	- BSR Hydrogen Air Transport - Preparation of Baltic Sea Region Airports for Green Hydrogen. A project within the BSR framework, with Work Package 1.1 focusing on assessing the legal framework for integrating hydrogen into airport operations, covering production, storage, fuelling infrastructure, and transportation.
CAEP	- Committee on Aviation Environmental Protection.
CE marking	- Conformité Européene marking, which appears on products traded on the extended Single Market in the EEA signifying that products sold have been assessed to meet high safety, health, and environmental protection requirements.
CEF	- Connecting Europe Facility is a key EU funding instrument in delivering the European Green Deal and an important enabler towards the Union's decarbonisation objectives for 2030 and 2050. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services.
CER Directive	- Critical Entities Resilience Directive or Directive (EU) 2022/2557 lays down obligations on EU Member States to take specific measures, to ensure that essential services for the maintenance of vital societal functions or economic activities are provided in an unobstructed manner in the internal market.
Chicago Convention	- The Convention on International Civil Aviation, signed on December 7, 1944, establishing the International Civil Aviation Organization (ICAO) and governing international aviation under 193 state parties.
CO ₂	- Carbon dioxide.
CORSIA	- Carbon Offsetting and Reduction Scheme for International Aviation.
EASA	- European Union Aviation Safety Agency established in 2002 under Regulation (EC) No 1592/2002 (replaced by Regulation (EU) 2018/1139), oversees aviation safety and environmental protection across the EU.
EC	- European Commission.
EHB	- European Hydrogen Backbone.
EIA	- Environmental impact assessment.
EIA Directive	- Environmental Impact Assessment Directive or Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (codification).
ENNOH	- European Network of Network Operators for Hydrogen non-profit organisation to be established for the cooperation of the EU Hydrogen Transmission Network Operators.
EP	- European Parliament.

EU	- The European Union.
European Green Deal	- A policy framework introduced by the European Commission in 2019, targeting climate neutrality by 2050, driving hydrogen adoption in aviation through derivative regulations like Regulation (EU) 2023/2405 and the EU Hydrogen Strategy.
Fly Net Zero	- An initiative by IATA, emphasizing SAFs and hydrogen to achieve net-zero CO ₂ emissions by 2050, providing technical expertise and operational frameworks for airport hydrogen infrastructure.
GH2	- Gaseous Green Hydrogen.
Green Hydrogen	- Hydrogen produced from renewable energy sources, such as through electrolysis, identified as critical for decarbonizing aviation under the European Commission's EU Hydrogen Strategy (2020) and supported by Directive (EU) 2018/2001.
GSE	- Ground support equipment, equipment used at airports to service aircraft between flights. Services include refuelling, towing airplanes or luggage/freight carts, loading luggage/freight, transporting passengers, loading potable water, removing sewage, loading food, de-icing airplanes, and firefighting.
Hydrogen IPCEI	- Hydrogen Important Project of Common European Interest, a funding initiative by the European Commission allocating €5.4 billion to support hydrogen infrastructure projects, including production and refuelling systems at airports.
IATA	- International Air Transport Association an organization founded in 1945 representing approximately 330 airlines (over 80% of international air traffic).
ICAO	- International Civil Aviation Organization, a United Nations specialized agency established in 1944 under the Chicago Convention, with 193 member states, responsible for setting global aviation standards, including guidelines for hydrogen use through CAEP and CORSIA.
IEA	- International Energy Agency, an agency established in 1974 within the Organisation for Economic Co-operation and Development framework.
IED	- Industrial Emissions Directive or Directive (EU) 2010/75 – Industrial Emissions aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU.
ISO	- International Organization for Standardization, an entity developing voluntary international standards.
Member State	- A member state of the EU.
NZIA	- Net Zero Industry Act or Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724, supporting hydrogen production equipment manufacturing for airports.
R&D	- Research and Development.
Red II	- Renewable Energy Directive or Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
Red III	- Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652.
ReFuelEU Aviation	- Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport.
RePowerEU Plan	- An initiative introduced by the European Commission on May 18, 2022, targeting 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes imported by 2030, accelerating hydrogen availability for airport infrastructure.

RFNBO	- Renewable fuels of non-biological origin, which are liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomass. This includes GH2.
SAE	- Society of Automotive Engineers, a global professional association and standards organization.
SAF	- Sustainable Aviation Fuel is fuel, including hydrogen-derived synthetic aviation fuel, mandated under Regulation (EU) 2023/2405. This includes GH2, if it qualifies as a synthetic aviation fuel.
SEA Directive	- Strategic Environment Directive or Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.
Seveso III	- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC.
synthetic aviation fuel	- Aviation fuels that are RFNBOs, which comply with the lifecycle emissions savings threshold of at least 70 % and are certified in compliance with Article 30 of Directive 2018/2001. This includes GH2, which meets the aforementioned requirements.
TEN-T	- Trans-European Transport Network based on a framework under Regulation (EU) 2024/1679 of the European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of such network.
ToR	- Terms of Reference.
TRAN Committee	- European parliament transport and tourism committee.
UN	- United Nations.
UN ECE Regulation No. 134	- Regulation No 134 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles (HFCV) [2019/795].
WFD	- Water Framework Directive or Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

1. Summary

1.1. Report Objectives

The primary objective of this Inception Report, developed under Work Package 1.1 of the BSR HyAirport Project, is to provide a comprehensive assessment of the existing legal and regulatory framework governing the integration of hydrogen technologies into airport operations within the EU, with a focus on the BSR.

The report aims to map the international and EU-level regulatory landscape, identify key institutions, policies, and standards relevant to hydrogen adoption in aviation, and evaluate their applicability to critical operational areas: 1) hydrogen production, 2) storage, 3) fuelling infrastructure, and 4) transportation at airports. By analysing these elements, the report seeks to pinpoint regulatory gaps, operational challenges, and roadblocks that impede the safe, efficient, and scalable deployment of hydrogen as an energy carrier used in airport operations.

This assessment is driven by the urgent need to align airport infrastructure with the EU's decarbonization goals, notably the European Green Deal's target of climate neutrality by 2050.

The report further aims to support the broader ambitions of international frameworks, such as ICAO commitment to net-zero CO₂ emissions by 2050 and the CORSIA. Through this analysis, the report intends to

deliver recommendations to bridge regulatory deficiencies, enhance safety and environmental compliance, and facilitate the transition to hydrogen-based aviation systems.

Specifically, the report objectives include:

Mapping the Regulatory Ecosystem

To outline the roles of key regulatory bodies (e.g., ICAO, EASA, European Commission) and standards (e.g., ISO 19880-1, SAE AIR8466) in shaping hydrogen use at airports.

Identifying Gaps and Challenges

To highlight deficiencies in current regulations, such as the lack of hydrogen-specific safety standards, inadequate environmental assessment frameworks, and insufficient infrastructure integration provisions, across production, storage, fuelling, and transportation domains.

Proposing Solutions

To recommend policy adjustments, institutional enhancements, and strategic initiatives that address identified barriers, ensuring alignment with EU strategies like the Hydrogen Strategy (2020), REPowerEU Plan (2022), and the Hydrogen and Decarbonised Gas Market Package (2024).

Supporting Project Goals

To provide a foundational legal analysis for the BSR HyAirport Project partners, enabling stakeholders to prioritize infrastructure investments, refine operational protocols, and contribute to regional and global decarbonization efforts in aviation.

By achieving these objectives, the report serves as a critical tool for policymakers, airport operators, and industry stakeholders, offering a roadmap to overcome regulatory hurdles and accelerate the adoption of hydrogen technologies in support of a sustainable aviation future.

1.2. Brief Overview of Identified Gaps, Challenges and Roadblocks

The integration of hydrogen into airport operations faces significant regulatory and practical obstacles that hinder its safe, efficient, and scalable adoption as an energy carrier at airports. This report identifies a range of gaps, challenges, and roadblocks across four key domains – 1) hydrogen production, 2) storage, 3) fuelling infrastructure, and 4) transportation.

No Definitive Barriers or Roadblocks at EU Level

The current EU legal framework does not impose direct prohibitions against incorporating GH2-related solutions at airports. Effective implementation requires a strong risk management system and compliance with existing legislation.

The report identifies regulatory gaps and challenges that hinder the safe, efficient, and scalable integration of hydrogen technologies in airport operations, including production, storage, fuelling infrastructure, and transportation. Key issues include a lack of hydrogen-specific safety standards, inadequate environmental impact assessment frameworks, and infrastructure integration difficulties.

Despite these gaps, the report emphasizes that, with adherence to safety and environmental standards, hydrogen technologies can be integrated at airports. Recommendations focus on refining the regulatory framework to support hydrogen adoption and advance the EU's climate neutrality goals by 2050.

Hydrogen Production

A primary gap is the lack of hydrogen-specific safety standards for on-site production facilities, such as electrolyzers, under Regulation (EU) No 139/2014 and Annex 14 of the Chicago Convention, leaving airports without clear protocols to manage high-pressure and flammable gas risks.

Environmental impact assessment frameworks, notably EIA Directive, fail to address water and energy demands adequately, while renewable energy integration remains constrained by insufficient infrastructure mandates in RED III. Permitting delays, high costs, and inconsistent harmonization across member states further complicate deployment.

Hydrogen Storage

The absence of aviation-specific storage safety standards in Directive 2014/34/EU and Regulation (EU) No 139/2014 poses risks for managing high-pressure (up to 700 bar) hydrogen systems. Inadequate risk assessment and emergency response provisions under Directive 2012/18/EU and Regulation (EU) No 996/2010 heighten vulnerabilities.

Spatial constraints limited environmental guidelines in SEA Directive, and a lack of binding technical standards (e.g., beyond voluntary ISO 19880-1:2020) hinder infrastructure integration and certification, while funding shortages exacerbate economic barriers.

Hydrogen Fuelling Infrastructure

The aviation-specific fuelling standard SAE AIR8466, now established, addresses hydrogen fueling protocols, yet Regulation (EU) No 965/2012 still omits hydrogen-specific risks, contributing to inconsistent safety protocols across implementations. Integration into existing airport layouts remains challenged by spatial and operational limitations under Regulation (EU) No 139/2014 and Council Directive 96/67/EC, despite the standard's guidance.

Certification gaps in Directive 2014/68/EU, supply chain reliability issues under Regulation (EU) 2023/2405, and insufficient funding tailored to fuelling stations slow progress, compounded by environmental and permitting hurdles.

Hydrogen Transportation

Transportation to airports lacks hydrogen-specific standards beyond Directive 2008/68/EC, with no aviation-focused provisions for delivery logistics. Pipeline connectivity via the EHB is limited for airports outside key corridors, as noted in Regulation (EU) 2024/1679, forcing reliance on costlier road transport.

Safety frameworks, environmental assessments, and equipment certification (e.g., under Directive 2014/68/EU) are inadequate for aviation needs, while economic barriers and supply chain uncertainties under Regulation (EU) 2023/1804 impede reliable delivery.

Collectively, these gaps reflect a fragmented regulatory landscape, characterized by the absence of tailored standards, insufficient safety and environmental provisions, and limited financial and infrastructural support. Addressing these challenges is critical to aligning hydrogen adoption with the EU's decarbonization targets, including the European Green Deal.

1.3. Summary of Key Findings and Recommendations

The "Inception Report on European Union Framework BSR Hydrogen Air Transport WP 1.1 Legal Framework" reveals a complex yet incomplete regulatory landscape for integrating hydrogen into airport operations, underscoring both the potential and the challenges of aligning with the EU's decarbonization ambitions.

Overall, there are no barriers for implementing GH2 related solutions in airports, such implementation must have an ironclad risk management system and must follow all relevant obligatory legislation.

1.3.1. Key Findings

Regulatory Fragmentation

International and EU regulations, including ICAO's Annex 14, Regulation (EU) No 139/2014, and Directive 2014/34/EU, lack hydrogen-specific provisions for production, storage, fuelling, and transportation, resulting in inconsistent safety and operational standards. Voluntary standards like ISO 19880-1:2020 and the SAE AIR8466 (primarily focuses on hydrogen powered aircraft), while valuable, are not binding.

Safety and Risk Management Gaps

The absence of tailored protocols for managing hydrogen's flammability and high-pressure properties, across production (e.g., electrolyzers), storage (e.g., tanks), fuelling (e.g., dispensing systems), and transportation (e.g., pipelines, trucks), poses significant risks, unaddressed by frameworks like Directive 2012/18/EU and Regulation (EU) No 996/2010.

Environmental and Permitting Challenges

Directives such as EIA Directive and SEA Directive lack specific guidelines for assessing hydrogen-related impacts (e.g., water use, land-use conflicts), while permitting processes under Regulation (EU) No 139/2014 and national frameworks are not streamlined, delaying infrastructure deployment.

Infrastructure and Supply Chain Limitations

The EHB and Regulation (EU) 2024/1679 (TEN-T) prioritize regional hubs over airport connectivity, leaving many reliant on less efficient road transport. Renewable energy integration for production and operational continuity for fuelling and storage remain constrained by inadequate mandates and funding.

Economic Barriers

High capital costs for hydrogen infrastructure, highlighted by IEA projections, and limited airport-specific financial incentives under Hydrogen IPCEI (€5.4 billion) and ReFuelEU Aviation hinder investment, particularly for smaller airports.

1.3.2. Recommendations

Policy Adjustments

Amend key regulations to incorporate hydrogen-specific standards, such as updating Regulation (EU) No 139/2014 for production and storage safety, finalizing SAE AIR8466 as a binding fuelling standard under Regulation (EU) No 965/2012, and enhancing Directive 2008/68/EC for transportation logistics. Strengthen environmental assessments via EIA Directive and mandate renewable energy integration through RED III.

Institutional Enhancements

Expand EASA's mandate under Regulation (EU) 2018/1139 to certify hydrogen production, storage, and fuelling systems, ensuring aviation-specific oversight. Nominate an existing centralized EU body under the European Commission to harmonize standards and engage ACER and ENNOH to optimize energy supply and infrastructure planning for airports.

Strategic Initiatives

Launch pilot projects via Hydrogen IPCEI and CEF to test on-site production and fuelling prototypes, prioritizing airports in the BSR. Invest in R&D under Horizon Europe for cost-effective technologies (e.g., modular storage,

efficient electrolysis) and extend the EHB to ensure airport connectivity by 2040, aligning with Regulation (EU) 2024/1789.

Funding and Incentives

Tailor ReFuelEU Aviation and CEF funding to support airport-specific hydrogen infrastructure, including storage and transportation logistics, and introduce economic incentives under AFIR to offset high costs, ensuring equitable adoption across EU airports.

These findings and recommendations collectively aim to transform the regulatory framework into a cohesive, supportive structure for hydrogen adoption, aligning with the BSR HyAirport Project's goals and the EU's broader climate neutrality objectives by 2050.

2. Project

2.1. BSR HyAirport Project Summary

The BSR HyAirport project is a strategic initiative aimed at positioning the BSR as a pioneer in sustainable aviation through the adoption of GH2 as a future energy source.

Recognizing the geo-economic importance of efficient air transport for mobility and connectivity in the BSR, an environmentally sensitive region with numerous short-haul flights, the project seeks to prepare airports for the storage, handling, and delivery of GH2. This aligns with the anticipated market entry of hydrogen-powered aircraft in the coming years, offering a transformative opportunity to decarbonize aviation in a region where peripheral access and cross-border connectivity are vital for economic and social cohesion.

The project unites a diverse partnership of airports, technology providers, airlines, and research institutions across the BSR, including Latvia, Lithuania, Estonia, Poland, Denmark, Sweden, Finland, and Germany.

This collaboration fosters a unique platform for addressing common challenges, such as developing regional GH2 supply chains tailored to local demand, ensuring compliance with legal and safety requirements, and testing innovative refuelling and handling solutions. By leveraging the collective expertise of its partners, the BSR HyAirport project aims to deliver practical, scalable solutions that not only meet the specific needs of BSR airports but also set a precedent for hydrogen-powered aviation globally.

2.2. BSR HyAirport Project group activity 1.1. – legal framework summary

Group Activity 1.1 of the BSR HyAirport project focuses on establishing a robust legal foundation for the integration of hydrogen-powered aviation across BSR airports. This activity is tasked with conducting a comprehensive analysis of existing legal frameworks at the international, EU, and national levels within the BSR countries (Latvia, Lithuania, Estonia, Poland, Denmark, Sweden, Finland, and Germany).

The primary objective is to identify regulatory gaps, challenges, and opportunities related to the deployment, implementation, and application of GH2 in aviation and airport operations, culminating in actionable recommendations for legislative amendments.

The scope of this activity encompasses a broad spectrum of legal domains, including safety, environmental protection, building and authorization regulations, and standards for GH2 production, transportation, storage, and refuelling. It addresses both aircraft-specific requirements and ancillary airport operations, such as ground handling equipment and energy supply systems.

The legal framework analysis under Activity 1.1 is designed to deliver multi-national benefits by fostering harmonization across BSR jurisdictions, addressing the region's unique geographical and operational context.

2.3. Scope of Analysis

The scope of analysis for Group Activity 1.1 is structured to provide a comprehensive evaluation of the legal frameworks governing the use of GH2 in aviation across multiple jurisdictional levels, with a specific focus on the BSR. Geographically, the analysis targets the eight BSR countries (Latvia, Lithuania, Estonia, Poland, Denmark, Sweden, Finland, and Germany) while situating their national regulations within the broader context of EU and international legal frameworks. This transnational approach ensures that the findings are relevant to the diverse regulatory environments of the BSR while promoting interoperability and consistency across borders.

At the international level, the analysis examines key frameworks such as the Chicago Convention (1944) and its Annex 14 (Aerodromes), ICAO's CORSIA, and standards from the ISO, such as ISO 19880-1:2020 (gaseous hydrogen fuelling stations) and ISO 14687:2019 (hydrogen fuel quality).

These global benchmarks provide a foundation for assessing compatibility with BSR-specific needs and identifying gaps in aviation-specific hydrogen regulations. Within the EU, the scope includes critical legislation such as the European Green Deal, ReFuelEU Aviation Regulation (EU) 2023/2405, the AFIR Regulation (EU) 2023/1804, and directives addressing safety (e.g., ATEX Equipment Directive) and environmental protection (e.g., EIA Directive). These EU frameworks are analysed to determine their applicability to GH2 implementation and their influence on national transposition in BSR countries.

Nationally, the analysis will delve into regulations across the eight BSR countries concerning GH2 deployment in airport infrastructure, aircraft operations, and ancillary equipment. This will include laws governing production, transportation, storage, refuelling procedures, and handling of hydrogen-powered aircraft, as well as environmental, safety, and building authorization requirements.

A comparative analysis will highlight disparities and commonalities among these jurisdictions, focusing on challenges to uniform application and opportunities for harmonized best practices. The scope also encompasses strategic planning documents and standards, ensuring a holistic view of the regulatory landscape. Ultimately, the analysis aims to inform a set of recommendations that address identified gaps, enhance safety and sustainability, and facilitate the seamless integration of GH2 into the BSR's aviation ecosystem.

2.4. Implementation Method

The implementation method for Group Activity 1.1 is designed to ensure a rigorous, evidence-based, and collaborative approach to analysing and refining the legal framework for hydrogen-powered aviation in the BSR.

The methodology integrates qualitative and legal research techniques, drawing on primary and secondary sources to deliver actionable outcomes. It comprises three key components: data collection, legal analysis, and stakeholder engagement, executed in a structured sequence to align with the project's objectives and timeline.

2.4.1. Data Collection

The process will begin with a comprehensive review of existing legal texts, including EU regulations (e.g., Regulation (EU) 2023/2405, Directive 2014/68/EU), international standards (e.g., ISO 19880-1:2020), and national legislation from the eight BSR countries. Additional data will be sourced from strategic planning documents, technical standards, and prior studies referenced in the ToR, ensuring a robust evidentiary base.

Additionally, interviews will be conducted with partner airports across the BSR (Latvia, Lithuania, Estonia, Poland, Denmark, Sweden, Finland, and Germany) to gather insights into their operational realities, legal challenges, and perspectives on GH2 adoption.

2.4.2. Legal Analysis

The collected data will undergo a detailed legal analysis to assess the current regulatory landscape at international, EU, and national levels. This involves identifying provisions relevant to GH2 production, storage, transportation, refuelling, and handling, as well as pinpointing gaps and inconsistencies, such as the lack of hydrogen-specific safety standards in Regulation (EU) No 139/2014 or Annex 14 of the Chicago Convention.

A comparative analysis across the BSR countries will evaluate variations in national regulations, focusing on safety, environmental protection, and authorization processes, to propose harmonized standards and best practices.

2.4.3. Stakeholder Engagement

To validate findings and refine recommendations, the method includes ongoing consultation with project partners, including airports, technology providers, airlines, and research institutions. Bilateral workshops with representatives from politics, industry, and non-governmental organisations will facilitate dialogue and ensure the usability of the final deliverables.

3. Overview of the Regulatory Landscape

3.1. Key Regulatory Bodies

The deployment of hydrogen as a sustainable fuel carrier in aviation represents a transformative step toward achieving global decarbonization objectives, particularly within the complex operational environment of airports. Given hydrogen's flammable nature and the critical need for safety, environmental compliance, and interoperability, its integration into airport infrastructure is subject to rigorous oversight by an array of international and regional regulatory bodies. These entities establish standards, policies, and frameworks to govern the storage, handling, and distribution of hydrogen, ensuring its safe and efficient use in aircraft and ground operations.

This section examines the roles and responsibilities of key regulatory authorities at both the international and EU levels, highlighting their contributions to the legal, technical, and operational frameworks that facilitate hydrogen's adoption in aviation hubs worldwide.

International Level

3.1.1. International Civil Aviation Organization¹

ICAO, a UN specialized agency established in 1944 under the Chicago Convention, plays a pivotal role in shaping global aviation standards and policies. With 193 member states, ICAO's importance in the context of hydrogen at airports lies in its leadership on the CORSIA and its commitment to net-zero CO₂ emissions by 2050, adopted at the 41st Assembly in October 2022.²

ICAO facilitates the integration of hydrogen as a SAF by setting international guidelines for its safe use in aircraft and airport operations. Through its CAEP, ICAO evaluates hydrogen's environmental benefits, such as zero-emission potential, and coordinates with states to harmonize safety and emissions standards. For airports, ICAO's influence ensures that hydrogen infrastructure development aligns with global aviation decarbonization goals, fostering interoperability and regulatory consistency worldwide.

¹ International Civil Aviation Organization. Available on: <https://www.icao.int/Pages/default.aspx> [accessed 05.03.2025.]

² Destination 2050 Road map 2025-2050. Available on: <https://www.acieurope.org/downloads/resources/DESTINATION-2050-Roadmap-2025.pdf> [accessed 05.03.2025.]

3.1.2. International Air Transport Association³

IATA, founded in 1945, represents approximately 330 airlines globally, accounting for over 80% of international air traffic. IATA's significance in hydrogen adoption at airports stems from its advocacy for industry-wide decarbonization, targeting net-zero CO₂ emissions by 2050, as outlined in its 2021 resolution. IATA actively promotes hydrogen as a viable fuel for aircraft and ground operations, collaborating with airports and manufacturers to develop supply chains and refuelling protocols.

Its Fly Net Zero initiative emphasizes SAFs and hydrogen, providing technical expertise and operational frameworks to integrate hydrogen infrastructure at airports. By issuing guidelines, such as those for fuel handling, and partnering with ICAO, IATA ensures that hydrogen deployment enhances safety, efficiency, and scalability, bridging the gap between airlines and airport stakeholders.

3.1.3. International Energy Agency⁴

IEA, established in 1974 within the Organisation for Economic Co-operation and Development framework, serves as a leading authority on global energy policy and analysis. In the context of hydrogen at airports, the IEA's importance lies in its comprehensive research and strategic roadmaps, such as the 2021 Net Zero by 2050 report, which identifies hydrogen as critical for decarbonizing aviation.

The IEA provides data-driven insights into hydrogen production costs, supply chains, and energy demand, projecting that aviation could account for 10% of global hydrogen use by 2050. For airports, the IEA's work informs investment decisions and policy design, ensuring hydrogen infrastructure aligns with renewable energy integration. Its collaboration with governments and industry bodies supports the scaling of hydrogen technologies, making it a key knowledge partner for sustainable airport transitions.

3.1.4. International Organization for Standardization⁵

ISO develops voluntary international standards across industries, ensuring safety, compatibility, and efficiency. In the context of hydrogen at airports, ISO's role is essential for establishing technical standards for hydrogen storage, transport, and refuelling systems. Standards such as ISO 19880 (gaseous hydrogen fuelling) and ISO 14687 (hydrogen fuel quality) provide a framework for safe and reliable airport infrastructure, critical for handling liquid or gaseous hydrogen for aircraft and ground equipment.

ISO's collaboration with ICAO and industry stakeholders ensures that hydrogen deployment meets global safety and performance benchmarks, reducing risks and enabling cross-border consistency. For airports, adherence to ISO standards facilitates regulatory approval, boosts investor confidence, and supports the scalable adoption of hydrogen technologies.

EU Level

3.1.5. European Commission⁶

EC, the EU's executive body, drives the bloc's climate and energy policies, making it a central player in hydrogen adoption at airports. Through the European Green Deal (2019) and the EU Hydrogen Strategy (2020), the EC targets 40 GW of renewable hydrogen electrolyser capacity by 2030, with aviation identified as a key sector.⁷

³ International Air Transport Association. Available on: <https://www.iata.org> [accessed 05.03.2025.]

⁴ International Energy Agency. Available on: <https://www.iea.org> [accessed 05.03.2025.]

⁵ International Organization for Standardization. Available on: <https://www.iso.org/home.html> [accessed 05.03.2025.]

⁶ European Commission. Available on: https://commission.europa.eu/index_en [accessed 05.03.2025.]

⁷ European Hydrogen Observatory, "EU Hydrogen Strategy under the EU Green Deal". Available on: <https://observatory.clean-hydrogen.europa.eu/eu-policy/eu-hydrogen-strategy-under-eu-green-deal> [accessed 05.03.2025.]

The ReFuelEU Aviation, proposed by the EC, mandates SAF blends at airports, escalating to 70% by 2050. The EC's funding initiatives, such as the €5.4 billion Hydrogen IPCEI, support airport hydrogen infrastructure, from production to refuelling systems.⁸

By setting legally binding targets and coordinating with EASA and ICAO, the EC ensures that hydrogen deployment at EU airports aligns with safety, environmental, and economic objectives, positioning the region as a global leader.

3.1.6. European Union Aviation Safety Agency⁹

EASA, established in 2002 under Regulation (EC) No 1592/2002 (replaced by Regulation (EU) 2018/1139), oversees aviation safety and environmental protection across the EU. EASA's role in hydrogen at airports is critical for certifying hydrogen-powered aircraft, ground equipment, and refuelling systems.

It develops safety standards, e.g., for hydrogen storage, and collaborates with ICAO to ensure global harmonization. The European Aviation Environmental Report 2025, co-published by EASA, highlights hydrogen's potential to cut airport emissions, advocating for its integration into operations.¹⁰ EASA's regulatory oversight ensures that hydrogen infrastructure meets stringent safety criteria, enabling airports to adopt this fuel without compromising operational integrity. Its technical expertise supports the EC's decarbonization agenda, bridging policy and practical implementation.

Currently, EASA is working on the development of certification standards and regulatory frameworks for hydrogen-powered aircraft. This includes establishing safety and performance requirements for hydrogen propulsion systems, as well as guidelines for hydrogen storage and distribution within the aviation sector. It is planned that EASA will develop consolidated certification strategies and draft rules by end of 2025.

3.1.7. European Parliament (EP)¹¹

EP, as the EU's co-legislative body, shapes the legal framework for hydrogen in aviation through its adoption of key regulations. It endorsed the European Climate Law (Regulation (EU) 2021/1119), setting the 2050 climate neutrality goal, and the ReFuelEU Aviation rules, mandating SAF at airports.¹²

The EP's TRAN Committee actively supports hydrogen infrastructure funding, as seen in its backing of the CEF, which allocates resources for airport energy projects. By influencing budget allocations and policy priorities, the EP ensures that hydrogen deployment at airports aligns with EU climate targets, providing political momentum and legislative clarity. Its oversight role reinforces accountability in the transition to sustainable aviation.

3.1.8. European Hydrogen Backbone¹³

EHB, an initiative launched in 2020 by European gas infrastructure companies, plans a 39,700 km hydrogen pipeline network by 2040, connecting production hubs to demand centres, including airports.¹⁴

In the context of hydrogen at airports, the EHB's importance lies in its role as a physical enabler, ensuring a reliable supply of Green Hydrogen for aviation fuel and ground operations. Its 2023 vision update estimates that 60% of the network will repurpose existing gas pipelines, reducing costs to €0.21-0.64/kg of hydrogen

⁸ European Commission, "State Aid: Commission approves up to €5.4 billion of public support by fifteen Member States for an Important Project of Common European Interest in the hydrogen technology value chain". Available on: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_4544 [accessed 05.03.2025.]

⁹ European Union Aviation Safety Agency. Available on: <https://www.easa.europa.eu/en/home> [accessed 05.03.2025.]

¹⁰ European Union Aviation Safety Agency, "European Aviation Environmental Report 2025". Available on: https://www.easa.europa.eu/sites/default/files/eaerdownloads/EASA_EAER_2025_BROCHURE_WEB_EN_v2.pdf [accessed 05.03.2025.]

¹¹ European Parliament. Available on: <https://www.europarl.europa.eu/portal/en> [accessed 05.03.2025.]

¹² Regulation (EU) No 2021/1119 of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') Available on: <https://eur-lex.europa.eu/eli/reg/2021/1119/oj/eng> [accessed 22.01.2025.]

¹³ European Hydrogen Backbone. Available on: <https://ehb.eu> [accessed 05.03.2025.]

¹⁴ "Extending the European Hydrogen Backbone". Available on: <https://ehb.eu/files/downloads/European-Hydrogen-Backbone-April-2021-V3.pdf> [accessed 05.03.2025.]

transported. For airports near EHB corridors, access to this infrastructure reduces reliance on on-site production and enhances scalability. Supported by the EC, the EHB aligns with EU decarbonization goals, making hydrogen a viable, cost-effective option for aviation hubs.

3.1.9. Agency for the Cooperation of Energy Regulators¹⁵

ACER, established under Regulation (EC) No 713/2009 (recast as Regulation (EU) 2019/942), oversees the EU's energy markets and infrastructure. In the context of hydrogen at airports, ACER's role is to ensure that hydrogen supply chains, particularly via pipelines like the EHB, operate efficiently and comply with market regulations.

Its 2023 opinions on hydrogen network codes emphasize fair access and pricing for hydrogen transport, critical for airports integrating this fuel into their energy mix. ACER's coordination with national regulators supports the cross-border flow of hydrogen, aligning energy markets with the EC's renewable energy targets. For airports, ACER's oversight facilitates cost-effective and reliable hydrogen delivery, underpinning operational decarbonization.

3.1.10. Brief Overview

The successful integration of hydrogen as a sustainable fuel in aviation, particularly within the operational and infrastructural framework of airports, is contingent upon the comprehensive and interdependent regulatory frameworks established by a network of international and EU bodies. Entities such as ICAO, IATA, and ISO play indispensable roles in shaping global standards for safety, environmental performance, and technical compatibility. ICAO's leadership in initiatives like CORSIA and its net-zero CO₂ emissions target by 2050, adopted in 2022, exemplifies the international commitment to decarbonization, while ISO's technical standards, such as those governing hydrogen storage and fuel quality, provide the practical backbone for safe implementation. Similarly, IATA's advocacy for industry alignment and operational protocols ensures that hydrogen's adoption is both efficient and scalable across the aviation ecosystem.

At the EU level, the EC drives strategic ambition through policies like the European Green Deal and the ReFuelEU Aviation regulation, mandating SAF blends at airports and channelling significant funding into infrastructure development via programs like the Hydrogen IPCEI. This is complemented by EASA, which provides rigorous certification and safety oversight, ensuring that operational risks are meticulously managed.

The EP further bolsters this framework by enacting binding legislation, such as the European Climate Law, and securing financial resources through mechanisms like the Connecting Europe Facility, thereby embedding hydrogen within the EU's broader climate neutrality objectives. Additionally, initiatives like the EHB and the ACER address the logistical and economic dimensions of hydrogen supply, guaranteeing reliable and cost-effective access for airports transitioning to this fuel.

Together, these regulatory bodies mitigate the inherent challenges of hydrogen, its flammability, storage complexities, and infrastructural demands, while fostering a harmonized and forward-looking approach to its deployment. Their collaborative efforts ensure that safety is not compromised, environmental benefits are maximized, and cross-border consistency is achieved, all of which are critical for airports serving as hubs in the global aviation network.

3.2. International Influences

The global aviation sector stands at a critical juncture in its pursuit of decarbonization, with hydrogen emerging as a transformative energy carrier for achieving net-zero emissions. International airports, as pivotal nodes in

¹⁵ Agency for the Cooperation of Energy Regulators, "EU Agency for the Cooperation of Energy Regulators (ACER)". Available on: https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/search-all-eu-institutions-and-bodies/agency-cooperation-energy-regulators-acer_en [accessed 05.03.2025.]

this ecosystem, are increasingly tasked with integrating hydrogen technologies to support aircraft propulsion, GSE, and ancillary energy systems.

This section examines the existing framework of international regulations and standards governing the deployment of hydrogen in airport operations, including treaties, conventions, and technical standards that shape its adoption.

However, the absence of harmonized, binding regulations specific to hydrogen infrastructure at airports presents significant challenges. This analysis evaluates the scope, applicability, and limitations of these frameworks, underscoring their implications for safety, interoperability, and scalability in the transition to hydrogen-based aviation infrastructure.

International Standards and Regulations for Hydrogen in Airports

3.2.1. Paris Agreement¹⁶

The Paris Agreement (2015), ratified by 196 parties under the United Nations Framework Convention on Climate Change, is a legally binding treaty aiming to limit global warming below 2°C, with a 1.5°C target, through nationally determined contributions updated every five years. Article 4 mandates domestic mitigation, while Article 6 enables cooperative mechanisms like carbon markets.

While lacking explicit hydrogen mandates, the Agreement indirectly drives aviation decarbonization by encouraging ambitious nationally determined contributions. The aviation sector, responsible for ~2.5% of global CO₂ emissions (in 2023), faces pressure to transition from fossil fuels to hydrogen. Hydrogen supports aircraft propulsion, ground operations, and energy storage, reducing emissions. Policies like the EU Green Deal and ReFuelEU Aviation further push hydrogen adoption, requiring airport investments in production, storage, and refuelling infrastructure to comply with national climate targets.

3.2.2. ICAO Carbon Offsetting and Reduction Scheme¹⁷

CORSIA, adopted by ICAO in 2016 and operational since 2019, is a global market-based measure under Resolution A39-3.¹⁸ It aims to stabilize net CO₂ emissions from international flights at 2019 levels through offsetting and, since the 41st ICAO Assembly (2022), supports a long-term goal of net-zero by 2050.

CORSIA includes a baseline phase (2021-2023) and mandatory phases (2027-2035), requiring airlines to offset emissions via credits or use CORSIA-eligible fuels, including hydrogen-derived synthetic fuels.

3.2.3. Chicago Convention (1944)¹⁹

Chicago Convention, signed on December 7, 1944, established ICAO and governs international aviation under 193 state parties. Annex 14 (Aerodromes), first published in 1951²⁰ and regularly updated (19th edition, 2022), sets standards and recommended practices for aerodrome design, operations, and safety.

It covers runways, taxiways, and facilities but has not yet explicitly addressed hydrogen infrastructure as of 2025, though future amendments are anticipated.

¹⁶ Paris Agreement, adopted on 12 December 2015. Available on: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [accessed 06.03.2025.]

¹⁷ Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Available on: <https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx> [accessed 06.03.2025.]

¹⁸ Resolution A39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme. Available on: https://www.icao.int/environmental-protection/documents/resolution_a39_3.pdf [accessed 06.03.2025.]

¹⁹ Convention on International Civil Aviation, signed on 7 December 1944 (Chicago Convention) Available on: https://www.icao.int/publications/Documents/7300_cons.pdf [accessed 06.03.2025.]

²⁰ Annex 14 to the Convention on International Civil Aviation, 1st ed. (ICAO, 1951). Available on: https://www.icao.int/APAC/Meetings/2015%20WAWG1/an14_1ed_1951.pdf [accessed 06.03.2025.]

3.2.4. UN ECE Regulation No. 134 – Hydrogen-Fuelled Vehicles

UN ECE Regulation No. 134 specifies safety requirements for hydrogen-powered vehicles. It covers fuel system integrity, storage (up to 700 bar for gaseous hydrogen), and leak prevention, applying to road vehicles but not explicitly extending to non-road mobile machinery like airport GSE.

Regulation No. 134 is vital as a source of inspiration for hydrogen in airports by ensuring the safe deployment of hydrogen-powered GSE, baggage tugs, pushback tractors, and service trucks, which are key to decarbonizing ground operations. Regulation No. 134 mandates rigorous testing and safety features like pressure relief devices, directly applicable to GSE fuelling stations at airports. As airports transition from diesel to hydrogen GSE, this standard ensures compliance with international safety norms, reducing explosion or leak risks in dense operational zones.

3.2.5. ISO 14687:2019 – Hydrogen Fuel Quality

ISO 14687:2019, published by ISO, specifies hydrogen fuel quality for proton exchange membrane fuel cells in road vehicles and stationary applications, with grades (e.g., Type I, Grade D) defining purity levels (99.97% minimum) and contaminant limits (e.g., 0.2 $\mu\text{mol/mol}$ CO). ISO 14687:2019 implementation is critical for hydrogen in airports by ensuring fuel quality for fuel cell applications, spanning GSE and, potentially, aircraft propulsion.

High-purity hydrogen prevents fuel cell degradation, ensuring reliability in airport operations where downtime is costly. For aircraft, emerging hydrogen fuel cell systems demand similar standards, making this a foundational benchmark as aviation adapts vehicle-derived tech.

Its importance lies in scalability: consistent quality enables airports to serve diverse hydrogen users (GSE, planes, backup power), fostering interoperability and investor trust. Non-compliance risks equipment failure or safety issues, underscoring its role in operational efficiency and decarbonization at airports.

3.2.6. ISO 19880-1:2020 – Gaseous Hydrogen – Fuelling Stations – Part 1: General Requirements

ISO 19880-1:2020, published by ISO, provides comprehensive requirements for gaseous hydrogen fuelling stations, covering design, safety, performance, and operation for pressures up to 700 bar. It addresses station layout, equipment, and risk management. ISO 19880-1:2020 applies to hydrogen refuelling infrastructure at airports, critical for both aircraft and GSE.

It specifies safe station design, e.g., separation distances, ventilation, tailored to high-pressure gaseous hydrogen, ensuring compatibility with airport layouts under relevant regulations. For aircraft, it supports refuelling points for hydrogen combustion or fuel cell planes; for GSE, it enables efficient, safe dispensing.

Its importance is multifaceted: it mitigates safety risks, standardizes refuelling globally, and accelerates infrastructure deployment by providing a ready framework. For airports, compliance ensures regulatory approval, operational uptime, and scalability, making it indispensable for hydrogen's broad integration.

3.2.7. ISO 19885-1:2024 – Gaseous hydrogen -- Fuelling protocols for hydrogen-fuelled vehicles -- Part 1: Design and development process for fuelling protocols

ISO 19885-1:2024 is an international standard by ISO, it provides guidelines for designing and developing fuelling protocols specifically for dispensing compressed hydrogen gas to vehicles equipped with compressed hydrogen storage systems.

This standard focuses on ensuring safe, efficient, and consistent hydrogen fuelling processes for a wide range of applications, including light, medium, and heavy-duty road vehicles, as well as other vehicles like motorbikes, off-road vehicles, industrial trucks, rail locomotives, and even drones. It does not cover the dispensing of hydrogen to vehicles with hydride-based storage systems.

The standard is intended for use by both individual companies developing fuelling protocols for specific products and standards development organizations creating broadly applicable protocols for commercial or industrial markets. It includes general guidance and, in Annex A, offers specific requirements for fuelling protocols tailored to road vehicles at public fuelling stations, referencing ISO 19880-1.

ISO 19885-1:2024 is not directly tailored to airports in a general sense, as its primary focus is on fuelling protocols for hydrogen-fuelled vehicles, particularly road vehicles, as well as other specific applications such as off-road vehicles, industrial trucks, rail locomotives, and drones. However, its relevance to airports depends on the context of hydrogen use within airport operations.

Airports could find this standard applicable if they are integrating hydrogen-fuelled vehicles or equipment into their ground operations, such as baggage tugs, service trucks, or other industrial vehicles that fall under the scope of the standard. For instance, if an airport deploys hydrogen-powered GSEs with compressed hydrogen storage systems, ISO 19885-1:2024 would provide relevant guidance for designing and developing safe and efficient fuelling protocols for those vehicles.

3.2.8. SAE AIR8466 – Hydrogen Fuelling Stations for Airports (Gaseous and Liquid)

SAE AIR8466, developed by SAE Aerospace division, is a forthcoming standard tailoring hydrogen fuelling protocols for airports. It addresses gaseous (up to 700 bar) and liquid (stored at -253°C) hydrogen, specifying flow rates, safety measures, and aviation-specific needs, building on SAE J2601 (vehicle fuelling).

SAE AIR8466's importance lies in its aviation-specific focus, customizing hydrogen refuelling for airports beyond general standards like ISO 19880-1 or ISO 19885-1:2024. It optimizes flow rates, safety protocols, and integration with aerodrome operations. This supports all use cases: rapid aircraft refuelling for turnarounds, GSE refuelling for ground operations, and energy supply for airport facilities. For airports, it serves as a pivotal framework, facilitating hydrogen scalability, ensuring adherence to aviation regulations, and reinforcing their role as leaders in net-zero infrastructure. Its development reflects hydrogen's rising role, making it a linchpin for future-ready airports.

3.2.9. Brief Overview

The integration of hydrogen into airport operations represents a cornerstone of aviation's commitment to achieving net-zero emissions by 2050, yet the current international regulatory landscape reveals a fragmented and incomplete framework.

While the Paris Agreement and ICAO CORSIA establish overarching decarbonization imperatives, and technical standards such as ISO 19880-1:2020 and the SAE AIR8466 provide critical safety and operational benchmarks, the lack of mandatory, aviation-specific hydrogen regulations impedes progress.

The Chicago Convention's Annex 14, though foundational for aerodrome standards, has yet to incorporate hydrogen infrastructure requirements, while UN ECE Regulation No. 134 addresses GSE but falls short of encompassing aircraft-related applications. This regulatory disparity fosters uncertainty, delays investment, and risks inconsistent safety practices across jurisdictions.

To fully realize hydrogen's potential in airports, spanning fuel cell aircraft, ground operations, and energy resilience, states and international bodies must prioritize the development of a unified, legally binding framework.

Such a regime should harmonize existing standards, address gaps in storage and refuelling infrastructure, and ensure compliance with global climate and aviation safety objectives. Until then, airports navigating this transition face a complex interplay of voluntary standards and national policies, underscoring the urgent need for coordinated action to support hydrogen's role in sustainable aviation.

3.3. EU Strategies and Policy Framework for Hydrogen Implementation

The EU's commitment to achieving climate neutrality by 2050, as outlined in the European Green Deal, establishes a framework for net-zero greenhouse gas emissions across all sectors, including aviation.²¹ Legally, the European Green Deal drives action through derivative policies such as 'Fit for 55' and ReFuelEU Aviation, which mandate the uptake of SAF in airports (e.g., 6% by 2030, 70% by 2050) and incentivize the development of renewable hydrogen. In line with this objective, the 'Fit for 55' legislative package, which targets a 55% reduction in emissions by 2030, underscores the urgency of this transition, introducing specific measures for aviation through the ReFuelEU Aviation initiative.²²

Building on this regulatory foundation, the ReFuelEU Aviation regulation mandates the use of synthetic aviation fuels, increasing from 1.2% in 2030 to 35% by 2050. Gaseous hydrogen is categorized as synthetic fuel and SAF. By integrating hydrogen into aviation fuel standards, the regulation ensures investment in hydrogen infrastructure, supporting the transition to zero-emission aviation and aligning with the EU's climate goals.²³

The RED II²⁴, adopted in 2018, sets binding renewable energy targets, including a requirement for 42% of industrial hydrogen to come from renewable sources by 2030. The updated RED III (2023) further strengthens ambitions, particularly for RFNBOs like Green Hydrogen. By defining sustainability criteria and supporting certification schemes, RED II prevents reliance on fossil-based hydrogen and promotes investment in electrolyzers, facilitating hydrogen adoption in aviation and airport operations.

The AFIR²⁵, adopted in 2023, sets binding targets for the development of alternative fuel infrastructure across the EU. A key provision of AFIR is the requirement for the installation of hydrogen refuelling stations, ensuring access to hydrogen infrastructure along major transport routes, with a target of having stations every 200 kilometres by 2030. This regulation serves as a direct enabler of hydrogen adoption at airports, guaranteeing that those located on key routes will have the necessary refuelling infrastructure for hydrogen-powered aircraft. By integrating hydrogen refuelling capabilities, AFIR supports the aviation sector's decarbonization efforts and strengthens airport readiness for sustainable hydrogen solutions.

Achieving climate neutrality by 2050, as set by the European Green Deal, requires the successful integration of hydrogen into aviation. While the EU has established a strong regulatory framework, its impact will depend on effective implementation, large-scale infrastructure development, and sustained investment. Ensuring technological progress and policy alignment is crucial to scaling hydrogen adoption. By maintaining regulatory momentum and financial commitment, the EU can position hydrogen as a key driver of aviation decarbonization, accelerating the transition to a sustainable, zero-emission future.

²¹ Communication (COM(2019) 640 final) The European Green Deal. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52019DC0640> [accessed 06.03.2025.]

²² European Union Aviation Safety Agency, "Fit for 55 and ReFuelEU Aviation". Available on: <https://www.easa.europa.eu/en/light/topics/fit-55-and-refueeu-aviation> [accessed 06.03.2025.]

²³ Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation) Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405> [accessed 06.03.2025]

²⁴ Directive (EU) 2018/2001 on the promotion of the use of energy from renewable source. Available on: <https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng> [accessed 06.03.2025.]

²⁵ Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU. Available on: <https://eur-lex.europa.eu/eli/reg/2023/1804/oj/eng> [accessed 06.03.2025.]

3.1.11. REPowerEU Plan^{26,27}

The REPowerEU Plan, introduced by the European Commission on May 18, 2022, aims to swiftly reduce the EU's dependence on fossil fuels and expedite the green transition. A significant aspect of this plan is the focus on hydrogen, which plays a crucial role in achieving energy independence and sustainability.

The plan sets an ambitious target to boost hydrogen availability by producing 10 million tonnes of domestic renewable hydrogen and importing an additional 10 million tonnes by 2030. This increase in hydrogen supply is essential for replacing natural gas, coal, and oil in hard-to-decarbonize industries and transport sectors, including aviation.

To support this hydrogen expansion, the plan includes measures to accelerate the readiness of airport infrastructure for hydrogen use. This involves developing major hydrogen corridors in the Mediterranean and North Sea, facilitating the joint purchasing of renewable hydrogen, and enhancing the EU's hydrogen market through increased funding and legislative support.

In summary, the REPowerEU Plan integrates hydrogen as a key element in reducing fossil fuel consumption, promoting renewable energy, and ensuring energy security. By focusing on hydrogen, the plan not only addresses the immediate energy crisis but also lays the foundation for a sustainable and resilient energy future for Europe.

3.1.12. Hydrogen and Decarbonised Gas Market Package²⁸

The EU hydrogen and gas decarbonisation package, consisting of Directive (EU) 2024/1788 and Regulation (EU) 2024/1789, was adopted in May 2024.

It updates the rules on the EU natural gas market set out in the Gas Directive 2009/73/EC and the Gas Regulation 715/2009. It also introduces a new regulatory framework for dedicated hydrogen infrastructure.

The package establishes a regulatory framework for dedicated hydrogen infrastructure, facilitating the development of a cost-effective, cross-border hydrogen network. It aims to repurpose some existing natural gas infrastructure for hydrogen, resulting in cost savings and supporting decarbonisation.

The revised rules create a level-playing field for the hydrogen market, removing barriers that hinder its development. ENNOH will focus on developing hydrogen infrastructure and ensuring efficient transport across EU borders.

Additionally, the package introduces a system of terminology and certification for low-carbon hydrogen and low-carbon fuels, complementing the revised RED III. This ensures consistency and reliability in the hydrogen market.

EU countries have until mid-2026 to transpose the new rules into national law. When transposed, they will facilitate the uptake of renewable and low-carbon gases, including hydrogen, while ensuring security of supply and affordability of energy.

To summarise, the Hydrogen and Decarbonised Gas Market Package is a crucial step in promoting hydrogen market growth and infrastructure development, ensuring that hydrogen becomes a key element in Europe's energy transition.

²⁶ European Commission. REPowerEU Plan, 2022. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0230> [accessed 12.03.2025.]

²⁷ European Commission. "REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition." Published on 18.05.2022. Available on: https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_22_3131/IP_22_3131_EN.pdf [accessed 12.03.2025.]

²⁸ European Commission. "Hydrogen and decarbonised gas market." *Energy.ec.europa.eu*, (n.d.). Available on: https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en [accessed 12.03.2025.]

4. EU Regulatory Framework

The EU has positioned itself as a global leader in the transition to a sustainable and decarbonized economy, with ambitious targets set under the European Green Deal to achieve climate neutrality by 2050. Central to this vision is the promotion of renewable energy sources, including hydrogen, as a transformative fuel for sectors traditionally reliant on fossil fuels, such as aviation. Airports, as critical nodes in the transport network, are increasingly exploring hydrogen technologies to power aircraft, ground operations, and infrastructure, aligning with the EU's objectives of reducing greenhouse gas emissions and enhancing energy security.

The integration of hydrogen into airport operations, encompassing production, storage, transportation, and usage, presents unique regulatory, safety, and environmental challenges. The EU has developed a comprehensive legislative framework to govern these activities, ensuring compliance with safety standards, environmental protection requirements, and market harmonization principles. While these regulations often overlap in certain areas due to the interconnected nature of hydrogen applications, they are typically categorized into distinct groups to address specific technical, operational, and sectoral needs. This document provides a structured analysis of the key EU regulations and directives relevant to the deployment of hydrogen technologies in airports, assessing their scope, application, and implementation challenges. The analysis aims to offer actionable insights for stakeholders, including airport operators, policymakers, and industry participants, as they navigate the legal landscape governing hydrogen adoption in the aviation sector.

4.1. Construction and Aerodrome Infrastructure Standards

This group encompasses regulations critical to the physical infrastructure supporting hydrogen use at airports.

These regulations ensure that airport infrastructure can safely accommodate hydrogen technologies, though their implementation demands significant coordination and investment to adapt existing facilities. The key conclusion is that while the framework provides a solid basis for safe construction, the rapid deployment of hydrogen infrastructure may strain certification timelines and resource availability.

4.1.1. Regulation (EU) No 305/2011 – Construction Products Regulation

Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC.

This Regulation lays down the conditions for the placing on the market or making available on the market of construction products by establishing harmonised rules for the expression of the performance of construction products in terms of their essential characteristics and for the use of the CE marking on these products.²⁹ It lays down essential requirements for the performance of buildings and construction products, including safety, health and environmental protection. The Regulation requires construction products to meet certain requirements to ensure their safe and efficient use in construction, which is particularly important if a hydrogen plant is planned for an airport site, which requires higher safety and compliance standards.

It requires compliance with the general essential requirements, which include fire safety and environmental protection.³⁰ For example, construction products must be designed so that they do not present a risk of fire spreading, which is essential when flammable gas such as hydrogen is used.

All construction products used shall be certified and meet certain safety and quality requirements. This is particularly important when a new fuel/energy transfer mode is introduced at airports, as it will help to eliminate

²⁹ Regulation (EU) 305/2011 laying down harmonised conditions for the marketing of construction products, Article 1. Available on: <https://eur-lex.europa.eu/eli/reg/2011/305/oj/eng> [accessed 05.03.2025].

³⁰ Regulation (EU) 305/2011 laying down harmonised conditions for the marketing of construction products, Annex 1. Available on: <https://eur-lex.europa.eu/eli/reg/2011/305/oj/eng> [accessed 05.03.2025].

potential risks from materials used in engineering structures and infrastructure to ensure the safe and efficient use of hydrogen.

4.1.2. Regulation (EU) No 139/2014 – Aerodrome Requirements

Regulation (EU) No 139/2014 laying down requirements and administrative procedures related to aerodromes.

Aerodromes must have and maintain valid certification in compliance with applicable safety and operational standards.³¹ To receive new certification, aerodromes must: 1) establish a certification basis per Annex II³², using EASA specifications; 2) demonstrate compliance with updated EU requirements differing from prior national standards.

Competent Authorities may waive compliance demonstrations if deemed excessively burdensome. Records of certificate conversions are maintained for five years.

The airport operator is responsible for conducting a comprehensive risk assessment prior to the construction of new infrastructure. In the specific case of the hydrogen plant, this implies a detailed safety analysis, considering the requirements for risk management. The implementation of a hydrogen plant at an airport site will require several approvals from the competent authorities.

This will include a full security assessment, which evaluates the potential threats to the airport's core business, considering the specific risks of hydrogen production and storage. It would also require the airport operator to ensure compliance and assume the liability that would be associated with the construction and use of such facilities.³³ Member States must regularly consult on human activities and land use in the aerodrome area, ensuring that any development or changes in land use do not pose a risk to aerodrome safety.³⁴

4.2. Vehicle and Equipment Safety Standards

This group focuses on the safety of vehicles and equipment involved in hydrogen operations. These instruments collectively safeguard the operational integrity of hydrogen-related equipment, yet their effectiveness hinges on adapting to evolving technologies and ensuring consistent enforcement across Member States. The conclusion here is that while robust safety standards exist, specialized certification for hydrogen applications remains a gap needing attention.

4.2.1. Regulation (EU) 2018/858 – Motor Vehicle Approval

Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC

Regulation (EU) 2018/858 establishes the administrative provisions and technical requirements for the type-approval and market placement of new motor vehicles (categories M and N) and their trailers (category O), as well as their systems, components, and separate technical units. It also includes provisions for the market surveillance of these vehicles and their parts to ensure they meet high safety, environmental, and performance standards. This regulation applies to vehicles intended for use on public roads, including those designed and

³¹ Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council, Article 6-7. Available on: <https://eur-lex.europa.eu/eli/reg/2014/139/oj/eng> [accessed 21.01.2025.]

³² Please refer to the Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council, Annex II. Available on: <https://eur-lex.europa.eu/eli/reg/2014/139/oj/eng> [accessed 21.01.2025.]

³³ Regulation (EU) 139/2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008. Available on: <https://eur-lex.europa.eu/eli/reg/2014/139/oj/eng> [accessed 04.03.2025.]

³⁴ Regulation (EU) No 139/2014 laying down requirements and administrative procedures related to aerodromes, Article 9. Available on: <https://eur-lex.europa.eu/eli/reg/2014/139/oj/eng> [accessed 21.01.2025.]

constructed in one or more stages.³⁵ The manufacturer of vehicles designed and constructed for use principally on airport facilities may apply for type-approval or individual vehicle approval under Regulation 2018/858, but it is not mandatory.³⁶

In case a manufacturer wishes to obtain this type-approval or individual vehicle approval, the vehicle must comply with Regulation 2018/858. Hydrogen powered vehicles (either using a fuel cell or internal combustion engine) of categories M, N and O³⁷ must comply with technical requirements set out in Regulation 2019/2144, as well as specific requirements with regard to vehicle hydrogen systems and components.³⁸ Such specific requirements are laid out in Commission Implementing Regulation (EU) 2021/535 of 31 March 2021.³⁹

Regulation (EU) 2018/858 faces several gaps and challenges. Firstly, the complexity of compliance due to detailed technical specifications and procedures can be burdensome, especially for smaller manufacturers. Secondly, the rapid pace of technological advancements may outstrip the regulatory framework, necessitating frequent updates to stay relevant. Thirdly, there are harmonization issues, as differences in interpretation and implementation by member states can lead to inconsistencies and affect the internal market's seamless operation.

In summary, Regulation (EU) 2018/858 establishes the framework for the type-approval and market surveillance of categories M, N and O, including their systems, components, and separate technical units. It ensures vehicles meet high safety, environmental, and performance standards. Challenges include the complexity of compliance, rapid technological advancements outpacing the regulatory framework, harmonization issues across member states, and the need for clearer market surveillance and recall procedures. Additionally, integrating hydrogen systems introduces specific safety concerns and technical requirements that may not be fully addressed by the current regulation. However, it is very important to note that type-approval or individual vehicle approval is not an obligation for vehicles used principally on airport facilities, though the associated technical specifications may serve as a reference or source of guidance in their design and construction.

4.2.2. Directive (EU) 2014/34 – ATEX Equipment Directive

Directive (EU) 2014/34 of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.

The ATEX Equipment Directive establishes uniform EU rules for the sale and commissioning of equipment and protective systems designed for use in potentially explosive atmospheres. The primary objective is to ensure a high level of protection for human health and safety, particularly for workers, as well as the safety of domestic animals and property.⁴⁰

The directive applies to various categories of products. It covers equipment and protective systems intended for use in potentially explosive atmospheres, ensuring their safety and effectiveness in hazardous conditions. It also applies to safety, controlling, and regulating devices that function outside such environments but contribute to explosion risk mitigation. Additionally, components designed to be incorporated into equipment and protective systems used in explosive atmospheres fall under the directive's scope. The directive applies to means of transport, i.e. vehicles and their trailers intended solely for transporting passengers by air or by road, rail or water networks, as well as means of transport in so far as such means are designed for transporting goods

³⁵ Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018, Articles 1 and 2. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018R0858> accessed [05.03.2025].

³⁶ Regulation (EU) 2018/858, Article 2, paragraph 3. Available on: <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32018R1139> [accessed 20.01.2025]

³⁷ Category M vehicles are power-driven vehicles having at least four wheels and used for the carriage of passengers. Category N vehicles are power-driven vehicles having at least four wheels and used for the carriage of goods. Category O vehicles are trailers.

³⁸ Regulation (EU) 2019/2144, Article 10. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02019R2144-20240707> [accessed 20.01.2025]

³⁹ Commission Implementing Regulation (EU) 2021/535. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R0535&qid=1739364263518> [accessed 12.02.2025]

⁴⁰ Directive (EU) 2014/34 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres, Consideration 50. Available on: <https://eur-lex.europa.eu/eli/dir/2014/34/oj/eng> [accessed 07.03.2025]

by air, by public road or rail networks or by water. However, certain products are excluded from the directive. These include medical devices intended for use in medical environments, as well as equipment where explosion hazards arise solely from the presence of explosive or unstable chemical substances, et al.⁴¹

The directive outlines specific responsibilities for manufacturers, importers, and distributors regarding equipment and protective systems for use in potentially explosive atmospheres. All products must bear the CE marking, which signifies compliance with essential EU safety standards. Before affixing this marking, manufacturers are required to conduct a safety and conformity assessment and maintain technical documentation to support their compliance. Importers play a crucial role in ensuring product safety by verifying that manufacturers have properly conducted conformity assessments. If any discrepancies are found, importers must notify the relevant safety monitoring authorities. Additionally, safety monitoring authorities must have the ability to access product conformity information electronically, allowing for better oversight and enforcement.

If gaseous hydrogen were to be implemented as an energy or fuel source at an airport, the ATEX Equipment Directive would likely apply to several aspects, including production, transportation, usage, and storage. Hydrogen is a highly flammable gas, and its presence in confined or open environments could create potentially explosive atmospheres. The directive would require that equipment used in hydrogen facilities meets stringent safety standards to mitigate explosion risks. During transportation, both the containment systems and any safety or regulatory devices involved in handling hydrogen would need to comply with the ATEX Equipment Directive requirements to prevent leaks or ignition sources. The storage and production infrastructure at the airport, including tanks, piping, and safety systems, would also most likely need to adhere to the directive to ensure that no uncontrolled explosive atmospheres develop. Finally, any hydrogen-fuelled vehicles or ground support equipment operating in potentially explosive zones would need to be designed and certified under the ATEX Equipment Directive to minimize ignition risks. The directive ensures that all these aspects are managed with a high level of safety, reducing hazards associated with hydrogen use in sensitive environments like airports.

In conclusion the ATEX Equipment Directive modernizes and streamlines EU rules governing the sale and use of equipment in potentially explosive environments. It enhances protection across a variety of industrial sectors. The directive also strengthens national authorities' ability to oversee product safety, helping to prevent the import of hazardous products from non-EU countries. By standardizing regulations and promoting compliance, the directive ultimately improves both market transparency and worker protection in hazardous environments.

4.2.3. Directive (EU) 2014/68 – Pressure Equipment Directive

Directive (EU) 2014/68 of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

Directive 2014/68/EU establishes essential safety requirements for pressure equipment and assemblies. It aims to ensure that pressure equipment placed on the EU market meets strict safety standards to protect human health and property. This directive replaces the previous Directive 97/23/EC and is part of a broader framework. The objective of this directive is to harmonize safety standards across member states, ensuring free movement of pressure equipment within the EU.⁴²

The directive applies to the design, manufacture, and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure greater than 0.5 bar, this applies to GH2. It encompasses both newly manufactured and imported used items entering the EU market.⁴³

⁴¹ Directive (EU) 2014/34 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres, Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2014/34/oj/eng> [accessed 07.03.2025]

⁴² Directive (EU) 2014/68 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, Consideration 62. Available on: <https://eur-lex.europa.eu/eli/dir/2014/68/oj/eng> [accessed 07.03.2025]

⁴³ Directive (EU) 2014/68 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2014/68/oj/eng> [accessed 07.03.2025]

Subjects to this act must ensure that their products comply with safety regulations before being placed on the market. This includes providing identifiable information (such as name, trademark, and address) on the equipment, its packaging, or accompanying documentation in a language easily understood by consumers and market surveillance authorities. The directive outlines a comprehensive conformity assessment process to verify that equipment meets the required safety standards. Process involves testing the equipment against specific technical criteria. Compliant products must bear the CE marking and be accompanied by the EU Declaration of Conformity. Annexes within the directive detail essential safety requirements, conformity assessment procedures, and a correlation table linking the directive to its predecessor. Certain categories of equipment are excluded from the directive. This ensures that the directive focuses on the most relevant and potentially hazardous pressure equipment.

Directive could be applicable to various aspects of gaseous hydrogen implementation at airports. Hydrogen production facilities at airports must comply with the directive if their pressure equipment exceeds 0.5 bar, ensuring safety during the hydrogen production and pressurizing process. The directive governs the design and manufacture of pressure vessels used to store hydrogen, requiring compliance with safety standards and the CE marking. Equipment used in the handling and distribution of hydrogen within the airport must also undergo conformity assessment procedures to ensure they meet safety criteria.⁴⁴

For the transportation of hydrogen, the directive applies to pressure equipment involved in the transport process with pressurized containers. Overall, the directive ensures that pressure-related risks associated with hydrogen are minimized, enhancing safety for airport personnel and infrastructure while maintaining regulatory compliance.

Directive plays a crucial role in ensuring the safety and free circulation of pressure equipment within the EU. By standardizing essential safety requirements and enforcing conformity assessments, the directive protects public health, domestic animals, and property while promoting fair competition. The directive reflects the principles of subsidiarity and proportionality, ensuring that regulations are effective without imposing unnecessary burdens. Overall, this enhances product safety, ensures compliance, and facilitates the seamless operation of the internal market for pressure equipment in the EU.

4.2.4. Regulation (EU) No 748/2012 – Airworthiness and Environmental Certification

Commission Regulation (EU) No 748/2012 of 3 August 2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations

This regulation that lays down the implementing rules for airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and manufacturing organisations. This regulation is designed to ensure a high level of civil aviation safety and environmental protection and to establish common technical requirements and administrative procedures for the certification of aircraft.⁴⁵

The regulation outlines common technical requirements and administrative procedures necessary for ensuring the airworthiness and environmental compatibility of aeronautical products. It specifies the conditions for issuing various types of certificates, including type certificates, certificates of airworthiness, and noise certificates. The regulation also mandates compliance with environmental protection requirements, as detailed

⁴⁴ Directive (EU) 2014/68 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, Article 14 and 18. Available on: <https://eur-lex.europa.eu/eli/dir/2014/68/oj/eng> [accessed 07.03.2025]

⁴⁵ Regulation (EU) 748/2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations, Article 1. Available on: <https://eur-lex.europa.eu/eli/reg/2012/748/oj/eng> [accessed 05.03.2025.]

in,⁴⁶ which designates applicable environmental protection requirements and certification specifications, including noise and emission standards as per the Chicago Convention.

It highlights the role of EASA in developing certification specifications and guidance material to facilitate regulatory uniformity. The regulation also addresses the need for organizations involved in the design and production of aircraft to comply with specific technical requirements to demonstrate their capability and ensure compliance with airworthiness standards.

It sets requirements for certificates, which are particularly important when considering the use of hydrogen as a fuel at airports. The introduction of hydrogen at airports may also require adjustments to existing certification procedures, regarding environmental requirements. In addition, when a new fuel such as hydrogen is introduced, it must be ensured that it meets all aircraft airworthiness requirements. The use of hydrogen as a fuel at airports can create new opportunities, but it must meet all regulatory requirements to ensure that it is a safe and environmentally friendly alternative.

Currently, no specific airworthiness code exists for hydrogen-powered aircraft. Therefore, if an airworthiness assessment were required, EASA would likely need to issue special conditions due to the novelty of GH2-fueled aircraft. Special conditions are detailed technical specifications established by EASA to address safety requirements when existing airworthiness codes are insufficient. They are issued in cases involving novel or unusual design features, unconventional intended use, or when experience with similar products indicates potential safety concerns. However, the decision to issue special conditions remains at EASA's discretion, as this is also a time and resource consuming process.

In case existing aircraft are retrofitted with GH2 fuel cells or propulsion systems, a new type certificate or a supplemental type certificate may be required. A new type certificate is required if the EASA finds that the proposed changes in design, power, thrust, or mass is so extensive that a substantially complete investigation of compliance with the applicable type certification basis is required. A supplemental type certificate is an approval issued by the EASA for a major modification or repair to an existing type-certified aircraft, engine, or propeller. It is considered "supplemental" as it extends the original type certificate by authorizing additional design changes.

However, for the purposes of development, among other reasons, a type certificate is not necessary. But for flight of an aircraft, which does not hold a valid certificate of airworthiness or restricted certificate of airworthiness, a permit to fly must be issued. A permit to fly is issued on the basis of approved flight conditions, and these will identify the applicable limitations. Under Regulation (EU) 748/2012, permits to fly may be issued by the national competent authority of a state, EASA, or authorized Design or Production Organisations, provided they meet the necessary compliance requirements.

The certification and regulation of hydrogen-powered aircraft remain in the early stages of development. While EASA is presently working on developing consolidated certification standards and regulatory frameworks for hydrogen-powered aircraft, such legislative measures will not be available until at least the end of 2025.⁴⁷ no specific airworthiness code currently exists for GH2-fueled aircraft.

In conclusion, Regulation (EU) 748/2012 represents a significant step towards enhancing the quality and consistency of airworthiness and environmental certification processes within the EU. It aligns with broader EU goals for aviation safety and environmental sustainability. However, the regulation also faces challenges in

⁴⁶ Regulation (EU) 748/2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations, Annex 1. Available on: <https://eur-lex.europa.eu/eli/reg/2012/748/oj/eng> [accessed 05.03.2025.]

⁴⁷ EASA presentation "H2 Certification Roadmap" from "EASA Certification Roadmap on H2 - International Workshop 2024". Available on: <https://www.easa.europa.eu/en/newsroom-and-events/events/easa-certification-roadmap-h2-international-workshop-2024#group-event-materials> [accessed 11.02.2025]

implementation, particularly regarding the need for technical expertise and robust public participation mechanisms.

4.3. Hydrogen Market Development and Energy Transition

This section covers regulations and directives driving the hydrogen market and its integration into aviation. These measures collectively propel hydrogen's role in aviation, though substantial investment and harmonization challenges persist. The key takeaway is that the EU's proactive market framework supports hydrogen adoption, but economic and infrastructural hurdles must be addressed for widespread implementation.

4.3.1. Regulation (EU) 2024/1789 – Internal Markets for Renewable Gas and Hydrogen

Regulation (EU) 2024/1789 of the European Parliament and of the Council of 13 June 2024 on the internal markets for renewable gas, natural gas and hydrogen

Regulation (EU) 2024/1789 establishes non-discriminatory rules for access to natural gas and hydrogen systems, considering national and regional market characteristics to ensure the proper functioning of internal markets and contribute to energy system flexibility.⁴⁸ It facilitates the emergence of transparent markets for natural gas and hydrogen with high security of supply and harmonizes network access rules for cross-border exchanges.

The regulation sets harmonized principles for tariffs, third-party access services, capacity allocation, congestion management, transparency requirements, balancing rules, imbalance charges, and capacity trading. It applies to specific natural gas and hydrogen storage facilities and allows member states to establish entities for transmission system operations, subject to certification and designation requirements.⁴⁹

The regulation faces significant challenges in developing the necessary infrastructure for renewable gas and hydrogen, as existing systems are primarily designed for natural gas. This requires substantial investments to adapt or build new infrastructure. Rapid technological advancements in hydrogen technology may outpace the regulatory framework, necessitating frequent updates to address specific safety and technical requirements.

Achieving a fully integrated market for renewable gas and hydrogen is complex due to varying levels of market maturity and regulatory frameworks across member states, making harmonization essential but challenging. Additionally, the high costs associated with producing, storing, and transporting hydrogen and renewable gases can hinder widespread adoption, necessitating economic incentives and support from the EU and member states. Ensuring consumer rights and protections, particularly regarding pricing, supply security, and transparency, is also critical in the evolving market for renewable gases and hydrogen.

To summarise, Regulation (EU) 2024/1789 is a significant step towards creating integrated internal markets for renewable gas, natural gas, and hydrogen, aligning with the EU's climate neutrality goals. However, it faces challenges related to infrastructure development, technological advancements, market integration, economic viability, and consumer protection. Addressing these gaps will be essential for the regulation's long-term effectiveness and relevance in promoting a sustainable and decarbonized energy system.

⁴⁸ Regulation (EU) 2024/1789 of the European Parliament and of the Council of 13 June 2024, Article 1. Available on: <https://eur-lex.europa.eu/eli/reg/2024/1789/oj/eng> [accessed 05.03.2025.]

⁴⁹ Regulation (EU) 2024/1789 of the European Parliament and of the Council of 13 June 2024, Article 1 and Paragraph 113. Available on: <https://eur-lex.europa.eu/eli/reg/2024/1789/oj/eng> [accessed 05.03.2025.]

4.3.2. Regulation (EU) 2023/2405 – ReFuelEU Aviation

Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport.

It is important to note that pursuant to the ReFuelEU Aviation regulation a Union airport⁵⁰ is an 'airport'⁵¹ where passenger traffic was higher than 800 000 passengers or where the freight traffic was higher than 100 000 tonnes in the previous reporting period, and which is not situated in an outermost region.⁵²

Any airport that is located in the EU Member State but does not fall within the scope of the 'airport' within the context of ReFuelEU Aviation may make a request to be treated as one.⁵³ Additionally, provisions laid out in ReFuelEU Aviation apply only to commercial air transport flights.⁵⁴

Union airport managing bodies⁵⁵ shall take all necessary measures to facilitate the access of aircraft operators to aviation fuels containing minimum shares of SAF.

Where aircraft operators report to the competent authority or authorities difficulties in accessing at a given Union airport aviation fuels containing minimum shares of SAF, the competent authority or authorities shall request the Union airport managing body to provide the information necessary to prove compliance and they shall provide the information without undue delay.

Union airport managing bodies, aviation fuel suppliers and fuel handlers shall, where appropriate, cooperate with their respective Member State for the preparation of the national policy frameworks for the deployment of alternative fuels infrastructure in airports falling within the scope of Regulation (EU) 2023/1804 of the European Parliament and of the Council.⁵⁶

Union airport managing bodies, aviation fuel suppliers and fuel handlers shall, where appropriate, in accordance with the national policy frameworks referred above in "Promoting hydrogen and electricity supply at the Union airports" section (when such a framework has been adopted), cooperate and undertake efforts to facilitate the access of aircraft operators to hydrogen or electricity used primarily for the propulsion of an aircraft and to provide the infrastructure and services necessary for the delivery, storage and uplifting of such hydrogen or electricity to refuel or recharge aircraft in line with national policy frameworks for deployment of alternative fuel infrastructure where relevant.

By 31 March 2025, and every two years thereafter, Union airport managing bodies shall report to the competent authorities and the Agency on the state of advancement of existing projects, for their respective Union airport, that pursue any of the initiatives referred to above in "Projects" sub-section.⁵⁷

⁵⁰ ReFuelEU Aviation, Article 3, paragraph 1. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405> [accessed 20.01.2025]

⁵¹ As defined in Article 2, point (1), of Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges. Available on: <https://eur-lex.europa.eu/eli/dir/2009/12/oj/eng> [accessed 20.01.2025.]

⁵² As listed in Article 349 TFEU. Available on: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:12012E/TXT:en:PDF> [accessed 20.01.2025.]

⁵³ ReFuelEU Aviation, Article 2, paragraph 2. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405> [accessed 20.01.2025]

⁵⁴ ReFuelEU Aviation, Article 2, paragraph 1. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405> [accessed 20.01.2025]

⁵⁵ Means, in respect of a Union airport, the 'airport managing body' as defined in Article 2, point (2), of Directive 2009/12/EC or, where the Member State concerned has reserved the management of the centralised infrastructures for fuel distribution systems for another body pursuant to Article 8(1) of Council Directive 96/67/EC (13), that other body.

⁵⁶ ReFuelEU Aviation, Article 7. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R2405> [accessed 20.01.2025]

⁵⁷ That report shall include information, which is publicly available or which can be made public, including, where appropriate, projections on the volumes and type of hydrogen and electricity production and supply to aircraft operators at the Union airport as well as deployment plans for recharging and refuelling infrastructure and services where such plans are adopted.

4.3.3. Regulation (EU) 2024/1735 – Net Zero Industry Act

NZIA - Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724.

The aim is to improve the functioning of the internal market by increasing domestic production of clean technologies and reducing dependence on imports. The Regulation includes measures to attract investment, develop innovation and reduce bureaucratic red tape.

The Regulation is designed in the light of the objectives of the European Green Deal and the need to accelerate decarbonisation while preserving the Union's industrial competitiveness. It provides for measures to promote security of supply of critical raw materials, support sustainable energy production and develop strategic technologies such as wind turbines, solar panels, batteries and electrolyzers.⁵⁸ In addition, the Regulation provides for a facilitated permitting process and supports the creation of industrial clusters to foster industrial cooperation and efficiency.⁵⁹ Scales up hydrogen production equipment manufacturing, securing supply chains for airports.

4.3.4. Directive (EU) 2023/2413 – RED III

Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending RED II, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652.

It establishes a common framework for promoting energy from renewable sources, setting a binding Union target for renewable energy's share in the EU's gross final consumption by 2030.⁶⁰ It includes rules on financial support for renewable electricity, self-consumption, and the use of renewable energy in heating, cooling, and transport sectors. The directive also covers regional cooperation, guarantees of origin, administrative procedures, and information and training. It sets sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids, and biomass fuels. Supplementing Regulation 2019/807 defines criteria for high and low indirect land-use change-risk biofuels.⁶¹

The directive faces challenges in achieving the ambitious renewable energy targets set for 2030, including the need for significant infrastructure development and investment. Existing infrastructure may not be fully equipped to handle the increased share of renewable energy, requiring substantial upgrades and new installations. Rapid technological advancements in renewable energy may outpace the regulatory framework, necessitating frequent updates to ensure relevance and effectiveness.

Additionally, harmonizing the varying levels of market maturity and regulatory frameworks across member states is complex but essential for a fully integrated renewable energy market. The high costs associated with renewable energy production, storage, and distribution can hinder widespread adoption, necessitating economic incentives and support from the EU and member states. Ensuring consumer rights and protections, particularly regarding pricing, supply security, and transparency, is also critical in the evolving renewable energy market.

⁵⁸ Regulation (EU) 2024/1735 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem, Article 4. Available on: <https://eur-lex.europa.eu/eli/reg/2024/1735/oj/eng> [accessed 04.03.2025]

⁵⁹ Regulation (EU) 2024/1735 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem, Article 17. Available on: <https://eur-lex.europa.eu/eli/reg/2024/1735/oj/eng> [accessed 04.03.2025]

⁶⁰ Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023, Article 3 (1). Available on: <https://eur-lex.europa.eu/eli/dir/2023/2413/oj/eng> [accessed 05.03.2025.]

⁶¹ Climate Change Laws of the World. "Directive 2023/2413 (Renewable Energy Directive) amending Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Supplementing Regulation 2019/807 and Commission Implementing Regulation 2022/996." *Climate-laws.org.*, (n.d.). Available on: <https://climate-laws.org/document/directive-2023-2413-renewable-energy-directive-amending-directive-eu-2018-2001-on-the-promotion-of-the-use-of-energy-from-renewable-sources-supplementing-regulation-2019-807-and-commission-implementing-regulation-2022-996-7559> [accessed 05.03.2025.]

In summary, RED III is a significant step towards promoting the use of renewable energy sources and creating integrated internal markets for renewable gas, natural gas, and hydrogen. However, it faces challenges related to infrastructure development, technological advancements, market integration, economic viability, and consumer protection. Addressing these gaps will be essential for the directive's long-term effectiveness and relevance in promoting a sustainable and decarbonized energy system.

4.3.5. Directive (EU) 2024/1788 – Renewable Gases and Hydrogen Framework

Directive establishes a unified regulatory framework for renewable gases, natural gas, and hydrogen in the EU. Its goal is to accelerate the shift from fossil fuels to sustainable energy sources, supporting the EU's 2030 climate objectives and the 2050 target of climate neutrality.⁶²

The directive promotes the transition to renewable energy by ensuring that renewable gases, low-carbon gases, and hydrogen play a central role in the EU's decarbonization strategy. A major focus is integrating sustainable biomethane into the gas system to diversify energy sources and strengthen energy security.

To achieve these goals, the directive introduces several regulatory measures:

Market Compliance: All energy market participants, including those from non-EU countries, must adhere to EU and national environmental and safety regulations. **Hydrogen Infrastructure:** The directive encourages the development of an interconnected EU-wide hydrogen network, ensuring long-term energy flexibility and emissions reductions, especially in hard-to-decarbonize sectors. **Consumer Protection:** Consumers have the right to choose their energy providers and must receive transparent information about their energy sources, fostering competition and affordability.

The directive could play a crucial role in facilitating hydrogen adoption in airports, particularly by regulating hydrogen transport, storage, and supply. It mandates the development of safe and efficient hydrogen transport networks to meet demand, ensuring seamless integration into airport energy systems. Additionally, it requires cross-border hydrogen transport capacity, supporting supply chain logistics from production sites to airports. By complying with these regulations, airports can enhance their sustainability efforts and contribute to the EU's broader hydrogen strategy.

Concluding, directive marks a significant step toward decarbonizing the EU's energy sector. By setting clear regulations for renewable gases, natural gas, and hydrogen, it fosters a sustainable, competitive, and secure energy market. The directive balances climate objectives, consumer rights, and market stability, ensuring a resilient and sustainable energy future for Europe.

4.4. Aviation Safety and Incident Management

These regulations provide a safety net for hydrogen integration in aviation operations, yet they require updates to fully account for hydrogen's properties and consistent application across Member States. The conclusion is that while the framework enhances aviation safety, adapting it to hydrogen-specific scenarios is essential for effective risk management.

4.4.1. Regulation (EU) No 996/2010 – Civil Aviation Accident Investigation

Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC.

⁶² Directive (EU) 2024/1788 on common rules for the internal markets for renewable gas, natural gas and hydrogen, Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2024/1788/oj/eng> [accessed 07.03.2025]

Regulation (EU) No 996/2010 aims to improve aviation safety by ensuring a high level of efficiency, expediency, and quality in EU civil aviation safety investigations. It establishes rules for the timely availability of information relating to all persons and dangerous goods on board an aircraft involved in an accident.

Additionally, the scope of the regulation includes safety investigations into accidents and serious incidents that occur within the territories of EU Member States, involve aircraft registered in a Member State or operated by a company established in a Member State, or where a Member State has a special interest due to fatalities or serious injuries to its citizens. The regulation does not apply to safety investigations involving aircraft engaged in military, customs, police, or similar services.^{63,64}

A primary difficulty of the Regulation (EU) No 996/2010 is ensuring the consistent and effective implementation of safety investigations across different Member States. The regulation mandates the participation of accredited representatives and experts, but variations in national procedures and resources can lead to discrepancies in investigation quality and outcomes.⁶⁵

Additionally, the regulation does not fully address the integration of new technologies, such as hydrogen-powered aircraft, into the existing safety investigation framework. The unique risks associated with hydrogen systems, including flammability and explosion potential, require specialized investigation protocols and expertise. Ensuring timely and accurate information availability, especially in complex international incidents, also poses a significant challenge.

Overall, Regulation (EU) No 996/2010 aims to enhance aviation safety by establishing efficient and high-quality safety investigations for civil aviation accidents and incidents. While it provides a comprehensive framework, challenges such as consistent implementation, integration of new technologies like hydrogen systems, and timely information availability remain. Addressing these gaps through updated protocols, specialized training, and coordinated efforts is essential for improving aviation safety and supporting victims and their families.

4.4.2. Regulation (EU) No 965/2012 – Air Operations

Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations.

The following measures are to be implemented to ensure effective operational management: Appropriate ground handling facilities shall be utilized to guarantee the safe handling of flights. Operational support facilities at the main operating base shall be arranged in alignment with the specific requirements of the operational area and type of operations conducted. Sufficient working space shall be provided at each operating base to accommodate personnel whose duties impact flight safety. This includes consideration of the needs of ground crew, operational control staff, and provisions for the storage and display of critical records, as well as facilities for crew flight planning.⁶⁶

An adequate aerodrome is one that, at the expected time of use, is available and equipped with essential ancillary services, including air traffic services, adequate lighting, communication systems, weather reporting facilities, navigation aids, and emergency services.⁶⁷

⁶³ Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010, Paragraphs 1,2 and 36, Article 1. Available on: <https://eur-lex.europa.eu/eli/reg/2010/996/oj/eng> [accessed 06.03.2025.]

⁶⁴ EUR-lex. "Civil aviation accidents and incidents." *European Union*. Last modified 18.10.2021. Available on: <https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32010R0996> [accessed 06.03.2025.]

⁶⁵ *Ibid.*

⁶⁶ Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations, Annex III, ORO.AOC.140 Facility requirements. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012R0965> [accessed 22.01.2025.]

⁶⁷ Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations, Annex IV, CAT.OP.MPA.107 Adequate aerodrome. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012R0965> [accessed 22.01.2025.]

The aeroplane shall be operated in accordance with the applicable performance class requirements. When full compliance with the applicable requirements is not possible due to specific design characteristics, approved performance standards shall be applied to ensure an equivalent level of safety.⁶⁸

4.5. Chemical and Environmental Safety Regulations

Addressing chemical and worker safety, this group comprises of regulations which form a comprehensive safety framework, but their complexity and the need for hydrogen-specific guidelines pose implementation challenges. The key finding is that robust protections exist yet tailoring them to hydrogen's unique properties is vital for airport safety.

4.5.1. Regulation (EC) No 1272/2008 – Classification, Labelling, and Packaging

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006

Regulation (EC) No 1272/2008 lays down uniform requirements for the classification, labelling, and packaging of chemical substances and mixtures according to the UN globally harmonised system. It requires companies to classify, label, and package hazardous chemicals appropriately before placing them on the market.

The regulation aims to ensure a high level of protection for human health and the environment, as well as the free movement of substances, mixtures, and articles within the EU. The main areas not covered by this regulation include radioactive substances and mixtures, cosmetics, medicines and certain medical devices, food, and the transport of dangerous goods. The regulation supplements the REACH system for the registration, evaluation, authorisation and restriction of chemicals. It replaces and repeals Directive 67/548/EEC on chemical substances and Directive 1999/45/EC on dangerous preparations.^{69,70}

One of the main challenges of Regulation (EC) No 1272/2008 is keeping up with the rapid advancements in chemical substances and mixtures. The regulation has been amended approximately on a yearly basis to update the harmonised classification and labelling of hazardous substances through adaptations to technical progress.

These amendments are based on the scientific opinions of the European Chemicals Agency's Committee for Risk Assessment.⁷¹ However, the continuous need for updates can create challenges for companies in staying compliant with the latest requirements. Additionally, the regulation does not fully address the specific risks associated with emerging technologies, such as hydrogen systems, which may require specialized classification and labelling protocols.

In summary, the Regulation (EC) No 1272/2008 establishes uniform requirements for the classification, labelling, and packaging of chemical substances and mixtures to ensure safety and environmental protection. While it provides a comprehensive framework, the need for frequent updates and the integration of new technologies like hydrogen systems present ongoing challenges. Addressing these gaps through continuous adaptation and specialized protocols is essential for maintaining the regulation's effectiveness and ensuring the safe handling of hazardous chemicals.

⁶⁸ Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations, Annex IV, CAT.POLA.100 Performance classes. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012R0965> [accessed 22.01.2025.]

⁶⁹ Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008, Article 1. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008R1272> [accessed 06.03.2025.]

⁷⁰ EUR-lex. "Classification, packaging and labelling of chemical substances and mixtures." *European Union*. Last modified 31.07.2023. Available on: <https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32008R1272> [accessed 06.03.2025.]

⁷¹ *Ibid.*

4.5.2. Directive 2012/18/EU – Seveso III

Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC

Seveso III aims to prevent major accidents involving dangerous substances and to limit their consequences for human health and the environment. It applies to establishments where dangerous substances are present in quantities equal to or exceeding specified thresholds. The directive sets out requirements for the identification and control of major-accident hazards, including the preparation of safety reports, emergency plans, and land-use planning. It also mandates public information and participation, as well as cooperation between member states in the event of cross-border impact.⁷²

A significant obstacle of the directive is in ensuring consistent transposition across member states due to varying national legal frameworks and administrative capacities. The complexity of assessing and managing risks associated with a wide range of dangerous substances requires advanced technical expertise and comprehensive data collection. Additionally, the directive's provisions for public information and participation necessitate robust mechanisms to ensure transparency and effective engagement. For hydrogen systems in airports, the directive may not fully address specific environmental and safety challenges, necessitating further updates and specific guidelines to ensure comprehensive assessments.

Overall, Directive 2012/18/EU is a crucial tool for preventing major accidents involving dangerous substances and mitigating their impacts on human health and the environment. However, it faces challenges related to consistent implementation, technical complexity, and the need for robust public information and participation mechanisms. Addressing these gaps are essential for the directive's long-term effectiveness in promoting safety and environmental protection.

4.5.3. Directive 99/92/EC – ATEX Workplace Directive

Directive 99/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

ATEX Workplace Directive, establishes minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. It applies to workplaces where explosive atmospheres may occur due to the presence of flammable gases, vapours, mists, or dusts. The directive mandates employers to take technical and organizational measures to prevent the formation of explosive atmospheres, avoid ignition sources, and mitigate the effects of explosions. It also requires the preparation and maintenance of an explosion protection document, detailing the explosion protection measures and ensuring compliance with Directive 89/391/EEC.⁷³

The directive faces challenges in ensuring consistent implementation across member states due to varying national legal frameworks and administrative capacities. The complexity of assessing and managing risks associated with explosive atmospheres requires advanced technical expertise and comprehensive data collection. Additionally, the directive's provisions for public information and participation necessitate robust mechanisms to ensure transparency and effective engagement. For hydrogen systems in airports, the directive

⁷² Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012, Articles 1 and 2. Available on: <https://eur-lex.europa.eu/eli/dir/2012/18/oj/eng> [accessed 05.03.2025.]

⁷³ Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999, Articles 1 and 2. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01999L0092-20070627> [accessed 05.03.2025.]; EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL. "POTENTIALLY EXPLOSIVE ATMOSPHERES EU DIRECTIVE 1999/92/EC." EIGA, (n.d.). Available on: <https://www.eiga.eu/uploads/documents/DOC134.pdf> [accessed 05.03.2025.]

may not fully address specific environmental and safety challenges, necessitating further updates and specific guidelines to ensure comprehensive assessments.⁷⁴

In summary, Directive 1999/92/EC is a crucial tool for improving the safety and health protection of workers potentially at risk from explosive atmospheres. However, it faces challenges related to consistent implementation, technical complexity, and the need for robust public information and participation mechanisms. Addressing these gaps will be essential for the directive's long-term effectiveness in promoting safety and environmental protection.

4.5.4. Council Directive 98/24/EC – Chemical Agents at Work

Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work.

Council Directive 98/24/EC sets out minimum requirements throughout the EU for protecting workers from risks to their safety and health arising from the effects of chemical agents present at the workplace or as a result of any work activity involving those agents. It is a 'daughter' directive of framework Directive 89/391/EEC, which introduces measures to encourage improvements in the safety and health of workers at work. The directive applies to workers exposed to hazardous chemicals when its rules are more favourable than those of Directive 2004/37/EC on protecting workers from risks from carcinogens and mutagens. Employers are obligated to assess risks, prevent exposure, establish occupational exposure limit values, deal with accidents and emergencies, and inform and train workers.^{75,76}

A significant obstacle of Directive 98/24/EC is ensuring comprehensive risk assessments and preventive measures for all hazardous chemicals, including emerging substances like hydrogen. The directive mandates employers to replace dangerous chemicals with less hazardous ones where possible but integrating hydrogen systems in workplaces presents unique challenges. Hydrogen's flammability and potential for explosion require stringent safety protocols, specialized equipment, and continuous monitoring. Additionally, the directive's scope may not fully address the specific risks associated with hydrogen production, storage, and use, necessitating updates to include detailed guidelines for hydrogen safety. Ensuring consistent implementation across Member States and keeping up with technological advancements in hydrogen applications are also significant challenges.⁷⁷

To summarise, Council Directive 98/24/EC aims to protect workers from chemical risks by setting minimum safety and health requirements. While it provides a robust framework for managing hazardous chemicals, integrating hydrogen systems poses unique challenges due to its specific risks. Addressing these gaps through updated guidelines, specialized safety protocols, and consistent implementation is crucial for effectively managing hydrogen-related risks in the workplace.

4.6. Transport Network and Infrastructure Integration

This section includes regulations that include measures, which facilitate hydrogen's logistical integration, though high costs and cross-border coordination remain significant barriers. The conclusion is that the framework supports hydrogen transport infrastructure, but its success depends on overcoming economic and harmonization challenges.

⁷⁴ *Ibid.*

⁷⁵ Council Directive 98/24/EC of 7 April 1998, Consideration 4 and Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/1998/24/oj/eng> [accessed 06.03.2025.].

⁷⁶ EUR-lex. "Exposure to chemical agents." *European Union*. Last modified 16.12.2021. Available on: <https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:31998L0024> [accessed 06.03.2025.]

⁷⁷ *Ibid.*

4.6.1. Regulation (EU) 2024/1679 – Trans-European Transport Network

Regulation (EU) 2024/1679 of the European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013.

This Regulation establishes guidelines for the development of a TEN-T consisting of comprehensive network and of a core network and extended core network, with the core network and extended core network to be established on the basis of the comprehensive network. The Act also identifies European Transport Corridors of highest strategic importance on the basis of priority sections of the TEN-T and projects of common interest, and specifies the requirements to be complied with for the development and implementation of the infrastructure of the TEN-T. Finally, it sets out development priorities and provides for implementation measures.⁷⁸

The Regulation aims to align the development of the transport network with the objectives of the European Green Deal and climate neutrality by reducing the environmental impact of the transport sector and promoting the introduction of sustainable alternative fuels, including hydrogen. It also sets investment priorities and planning mechanisms to improve infrastructure connectivity and efficiency. The implementation of the Regulation faces several challenges. Infrastructure development and modernisation will require significant investment to meet the requirements of new technologies and environmental sustainability. The different transport and investment plans of the different Member States may complicate the development of an integrated transport network, as regards cross-border connections and the introduction of new technologies such as hydrogen refuelling infrastructure. Moreover, meeting the requirements of the Regulation by 2030, 2040 and 2050 implies a rapid adaptation to new transport standards which may require frequent regulatory updates.

The Regulation sets out key priorities for the development of the TEN-T network, including high performance rail networks, efficient aviation and inland waterway transport, and the development of alternative fuels infrastructure, as well as requirements for refuelling points for alternative fuels, including hydrogen and electricity infrastructure, in transport corridors and urban nodes.⁷⁹ It also sets out a plan for the development and monitoring of the network, which may have implications and relevance for hydrogen infrastructure projects. There is also a requirement for airports to integrate into this network with various solutions that may have an impact on the development of hydrogen infrastructure at airports and altogether.

To meet the targets, strong economic incentives and EU support are needed to overcome the high costs associated with the deployment of new transport solutions. Consumer protection will also be essential, ensuring transparent pricing, security of supply and efficient services. Overall, Regulation (EU) 2024/1679 is an important step towards a connected and decarbonised transport system, but its success could depend on infrastructure development, technological adaptation and coordinated cooperation between the EU and Member States.

4.6.2. Regulation (EU) 2023/1804 – Alternative Fuels Infrastructure

By 31 December 2024, Member States were obliged to prepare and submit a draft national policy framework to the Commission for the development of the alternative fuels market and infrastructure in the transport sector. A final version of the framework shall be submitted by 31 December 2025.⁸⁰

The framework includes an assessment of the current and future state of the market and infrastructure, considering intermodal access, cross-border continuity, and infrastructure in islands and outermost regions.

⁷⁸ ESO information on Regulation 2024/1679. Available at: <https://www.europeansources.info/record/proposal-for-a-regulation-on-union-guidelines-for-the-development-of-the-trans-european-transport-network/> [accessed 04.03.2025]

⁷⁹ Regulation (EU) 2024/1679 on Union guidelines for the development of the trans-European transport network, Article 13, 41. Available on: https://publications.europa.eu/resource/cellar/cc3395a5-3516-11ef-b441-01aa75ed71a1.0006.03/DOC_1 [accessed 04.03.2025.]

⁸⁰ Regulation (EU) 2023/1804 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU, Article 14. Available on: <https://eur-lex.europa.eu/eli/reg/2023/1804/oj/eng> [accessed 21.01.2024.]

It outlines national targets and objectives, policies, and measures to achieve these targets, along with actions to address obstacles in planning, permitting, procurement, and operation. The framework also provides an overview of the current state, future plans, and measures for deploying alternative fuels infrastructure in airports, such as hydrogen refuelling, excluding stationary aircraft electricity.

Member States shall cooperate through consultations or joint frameworks to ensure coherence and coordination. Support measures must comply with Union State aid rules, and draft frameworks must be publicly available with opportunities for early and effective public participation.

4.6.3. Directive (EU) 2008/68 – Inland Transport of Dangerous Goods

Directive (EU) 2008/68 of 24 September 2008 on the inland transport of dangerous goods.

This directive establishes a regulatory framework for the inland transport of dangerous goods within the EU. It ensures safety in the transportation of hazardous materials by road, rail, and inland waterways. It aims to harmonize the legal provisions governing the transport of dangerous goods, thereby minimizing the risks associated with accidents and ensuring a high level of safety in transport operations.

The directive addresses the considerable risks posed by the transport of dangerous goods, which can lead to severe accidents if not managed properly. The directive emphasizes the need for uniform rules to facilitate safe transport practices and to ensure the proper functioning of the common transport market within the EU.⁸¹

The regulation outlines specific provisions regarding the classification, packaging, labelling, and documentation of dangerous goods. It mandates that Member States implement safety measures that align with international agreements, such as the ADR. Member States are granted the authority to impose stricter national regulations if deemed necessary for safety reasons, while also allowing for certain derogations based on specific national circumstances.

The directive mandates that dangerous goods, including hydrogen, must be transported in accordance with the conditions laid out in the annexes, which include specific requirements for packaging, labelling, and documentation. This includes compliance with the ADR for road transport ensuring that all transport operations are conducted safely and in accordance with the established guidelines. The directive's provisions would ensure that any transport of hydrogen adheres to the necessary safety protocols to mitigate risks associated with its flammability and potential hazards.

In conclusion, Directive 2008/68/EC plays a vital role in regulating the inland transport of dangerous goods within the EU. By establishing a unified legal framework, it aims to enhance safety and reduce the risks associated with the transport of hazardous materials. The directive not only facilitates the harmonization of transport practices across Member States but also empowers them to maintain or adopt additional safety measures as necessary. Ultimately, this directive contributes to the protection of public safety, environmental integrity, and the efficient functioning of the transport market in the EU.

4.7. Environmental Impact and Emissions Control

Encompassing environmental and emissions regulations, this group includes instruments which ensure environmental compliance, though their complexity and need for updates to address hydrogen-specific risks present challenges. The key conclusion is that the framework promotes sustainability, but consistent application and adaptation are critical for effectiveness.

⁸¹ Directive (EU) 2008/68 on the inland transport of dangerous goods, Article 1. Available on: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32008L0068> [accessed 07.03.2025]

4.7.1. Directive 2001/42/EC – Strategic Environmental Assessment

Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

SEA Directive aims to ensure that environmental considerations are integrated into the preparation and adoption of certain plans and programmes which are likely to have significant effects on the environment. It applies to plans and programmes prepared by public authorities at national, regional, and local levels, including those related to land use, transport, energy, waste management, water management, and telecommunications. The directive requires that an environmental assessment be carried out for these plans and programmes before their adoption, including the preparation of an environmental report, public consultation, and consideration of the environmental report in decision-making.^{82,83}

The directive is challenged in its implementation, particularly in ensuring that all relevant plans and programmes are subject to environmental assessment. There can be inconsistencies in how member states interpret and apply the directive, leading to variations in the level of environmental protection.⁸⁴

Additionally, the directive may not fully address the specific requirements and risks associated with emerging technologies, such as hydrogen systems in airports. Hydrogen production, storage, and transportation at airports pose unique environmental and safety challenges that may not be adequately covered by the current framework, necessitating updates and specific guidelines to ensure comprehensive environmental assessments.⁸⁵

In conclusion, the SEA Directive is a crucial tool for integrating environmental considerations into the preparation and adoption of plans and programmes with significant environmental impacts. However, it faces challenges related to consistent implementation across member states and the need to address emerging technologies like hydrogen systems in airports. Addressing these gaps will be essential for the directive's long-term effectiveness in promoting sustainable development and environmental protection.

4.7.2. Directive 2014/52/EU – Environmental Impact Assessment

Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment

The EIA Directive aims to improve the quality of EIA reports, and the information gathered, reinforcing environmental protection. The directive extends the coverage of environmental issues to include climate change, biodiversity, and the risk of major accidents and disasters. It also provides detailed requirements for assessing cumulative effects, broadens the assessment of reasonable alternatives, mandates monitoring procedures, and enhances public participation and access to information.⁸⁶

The directive faces several challenges in its implementation. Ensuring consistent application across member states is difficult due to varying national legal frameworks and administrative capacities. The requirement to assess cumulative effects and consider climate change and biodiversity introduces complexity, necessitating advanced technical expertise and comprehensive data collection. Additionally, the directive's provisions for public participation and access to information require robust mechanisms to ensure transparency and effective

⁸² Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001, Articles 1 and 3. Available on: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32001L0042> [accessed 05.03.2025.]

⁸³ Government of Ireland. "Implementation of SEA Directive (2001/42/EC)." *Stationary Office*, 2004. Available on: <https://www.opr.ie/wp-content/uploads/2019/08/2004-Implementation-of-the-SEA-Directive-2.pdf> [accessed 05.03.2025.]

⁸⁴ *Ibid.*

⁸⁵ *Ibid.*

⁸⁶ Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014, Paragraphs 37 and 41. Available on: <https://eur-lex.europa.eu/eli/dir/2014/52/oj/eng> [accessed 05.03.2025.]; European Parliament. "Transposition and implementation of the 2014 Directive on the assessment of the effects of certain public and private projects on the environment." *European Union*, 2018. Available on: https://www.europarl.europa.eu/cmsdata/226410/Briefing_Transposition_and_implementation_of_the_2014_Directive_on_the_assessment_of_the_effects_of_certain_public_and_private_projects_on_the_environment_.pdf [accessed 05.03.2025.]

engagement. For hydrogen systems in airports, the directive may not fully address specific environmental and safety challenges, necessitating further updates and specific guidelines to ensure comprehensive assessments.⁸⁷

To summarise, the EIA Directive is a significant step towards enhancing the quality and scope of environmental impact assessments, aligning with the EU's broader environmental and climate goals. However, it faces challenges related to consistent implementation, technical complexity, and the need for robust public participation mechanisms. Addressing these gaps will be essential for the directive's long-term effectiveness in promoting sustainable development and environmental protection.

4.7.3. Directive (EU) 2010/75 – Industrial Emissions

Directive (EU) 2010/75 of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

IED aims to regulate industrial emissions across the EU. This directive is part of the EU's broader strategy to achieve a high level of environmental protection and to ensure that industrial activities do not adversely affect air, water, and soil quality. The directive emphasizes the importance of integrated pollution prevention and control to minimize emissions from industrial operations.⁸⁸

The directive establishes a comprehensive framework for controlling emissions from various industrial sectors, particularly those that significantly contribute to pollution. It applies to a wide range of activities listed in its annexes, including energy production, waste management, and manufacturing processes. The directive sets out specific emission limit values for pollutants which must be adhered to by operators of industrial installations.

One of the key aspects of the directive is the requirement for member states to implement best available techniques to minimize emissions. This involves assessing the environmental performance of industrial processes and adopting technologies that are proven to be effective in reducing pollution. The directive also mandates regular monitoring and reporting of emissions, ensuring transparency and accountability in industrial operations. Furthermore, the directive encourages the use of economic instruments and incentives to promote cleaner technologies and practices. It recognizes the need for flexibility in implementation, allowing member states to tailor their approaches based on specific national circumstances while still meeting the overarching goals of the directive.

The implementation of GH2 as an energy source at the airport could invoke several provisions of Directive. Hydrogen production at airports would fall within the scope of the Directive. In particular, the operator should comply with the rules laid down in Chapter 2.⁸⁹ Storage and transportation of hydrogen at the airport would also fall under the directive's scope, particularly in terms of safety and environmental impact assessments, as the directive emphasizes the need for monitoring and controlling emissions during the handling of hazardous substances. Overall, the integration of hydrogen as an energy source at the airport would require a comprehensive approach to comply with the directive's provisions, ensuring that all aspects of hydrogen production, usage, storage, and transportation are managed to minimize environmental impact.

In conclusion, it represents a significant step towards achieving sustainable industrial development within the EU. By establishing stringent emission limits and promoting the use of best available techniques, the directive aims to protect the environment and public health from the adverse effects of industrial pollution. The integrated approach to pollution prevention and control not only enhances environmental quality but also fosters innovation and competitiveness in the industrial sector.

⁸⁷ *Ibid.*

⁸⁸ Directive (EU) 2010/75 on industrial emissions (integrated pollution prevention and control), Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2010/75/oj/eng> [accessed 07.03.2025]

⁸⁹ Directive (EU) 2010/75 on industrial emissions (integrated pollution prevention and control), Annex I. Available on: <https://eur-lex.europa.eu/eli/dir/2010/75/oj/eng> [accessed 07.03.2025]

4.7.4. Directive (EU) 2000/60 – Water Framework Directive

Directive (EU) 2000/60 of 23 October 2000 establishing a framework for Community action in the field of water policy.

WFD establishes a comprehensive framework for the protection and sustainable management of water resources across the EU. It aims to ensure the long-term sustainability of water resources, addressing both the quality and quantity of water in various ecosystems. The directive regulates water resources by recognizing water as a heritage that must be protected, defended, and treated as a common good.⁹⁰ It emphasizes that water is not merely a commodity but a vital resource that supports ecosystems and human life. The WFD sets out specific objectives, including the preservation and improvement of water quality, the sustainable use of water resources, and the protection of aquatic ecosystems.

To achieve these goals, the directive requires member states to implement a series of measures. These include the establishment of river basin management plans, which must be developed through a participatory process involving stakeholders and the public. The directive also introduces a combined approach to pollution control, which involves setting emission limits and environmental quality standards for pollutants. It mandates the gradual reduction of pollution from priority hazardous substances and the establishment of monitoring programs to track the status of water bodies. Member states are required to report on their progress and adapt their strategies based on the findings of these monitoring efforts.

The implementation of GH2 as an energy source at the airport could be significantly influenced by Directive, particularly in terms of water resource management and environmental protection. The production of hydrogen involves the electrolysis of water, necessitates careful consideration of water quality and quantity. This includes ensuring that the water used for hydrogen production does not compromise the ecological status of local water bodies, as mandated by the directive's objectives to maintain and improve water quality.⁹¹ Additionally, the storage and transportation of hydrogen must adhere to the directive's standards for preventing contamination of water resources, as any leaks or spills could potentially pose a risk to both surface and groundwater.⁹²

In conclusion, the directive marks a significant advancement in integrated water resource management within the EU. By creating a legal framework focused on protecting water resources and ecosystems, it aims to secure clean and adequate water supplies for future generations. Its collaborative approach encourages stakeholder participation and supports sustainable practices, contributing to environmental health and public welfare.

4.7.5. Commission Delegated Regulation (EU) 2023/1184 – RFNBOs Methodology

Commission Delegated Regulation (EU) 2023/1184 on establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin supplements RED II. This Regulation is essential to increase the share of renewable energy in sectors still dependent on fossil gaseous and liquid fuels.

For hydrogen production, the Regulation defines strict sustainability criteria. The production of Green Hydrogen requires the use of renewable energy sources, but electricity can also be produced by other means and can be considered as renewable electricity if the conditions are met.⁹³

⁹⁰ Directive (EU) 2000/60 on establishing a framework for Community action in the field of water policy, Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng> [accessed 07.03.2025]

⁹¹ Directive (EU) 2000/60 on establishing a framework for Community action in the field of water policy, Article 4. Available on: <https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng> [accessed 07.03.2025]

⁹² Directive (EU) 2000/60 on establishing a framework for Community action in the field of water policy, Article 10. Available on: <https://eur-lex.europa.eu/eli/dir/2000/60/oj/eng> [accessed 07.03.2025]

⁹³ Regulation (EU) 2023/1184 supplements Directive (EU) 2018/2001 Article 3, 4. Available on https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj/eng [05.03.2025]

The Regulation also recognises the importance of non-biological renewable liquid and gaseous transport fuels in sectors such as aviation. The document underlines the importance of these fuels for increasing the share of renewable energy in sectors where the use of liquid and gaseous fuels is expected in the long term.⁹⁴

Overall, the Regulation is an important step towards Green Hydrogen by setting strict criteria for electricity generation to minimise the carbon footprint, define what electricity can be considered renewable and green and promote the transition to clean energy in the transport sector. However, while it provides a clear EU-wide standard for Green Hydrogen, fostering a borderless market with uniform requirements, it also presents significant challenges. After 2028, compliance with the temporal conditions—requiring hydrogen production facilities to be linked to renewable electricity installations within 36 months—could pose investment hurdles and slow deployment. The reliance on low-emission grids, which are not yet widely available, adds further complexity, highlighting the need for substantial financial support and accelerated permitting processes to maintain progress.

4.7.6. Commission Delegated Regulation 2023/1185 – Greenhouse Gas Emissions Savings

Commission Delegated Regulation 2023/1185 on establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels supplementing RED II.

This Regulation sets a minimum required level of greenhouse gas emission reductions for recycled carbon fuels and defines the method for calculating emission savings from renewable liquid and gaseous transport fuels that are not derived from biomass, as well as from recycled carbon fuels.⁹⁵

It helps to establish clear rules for calculating emissions savings from renewable and recycled fuels. It ensures full life-cycle emissions accounting, prevents double counting of captured CO₂, and defines how electricity use in fuel production should be assessed. A fossil fuel comparator etalon is set, and time limits for considering emissions from non-sustainable fuels as avoided are introduced.

4.8. Ground Operations and Critical Entity Resilience

This category covers directives which support operational efficiency and safety, but their implementation requires coordination and updates to address hydrogen's unique demands. The conclusion is that while the framework facilitates ground operations, refining it for hydrogen-specific resilience and safety is necessary for seamless integration.

4.8.1. Council Directive 96/67/EC – Ground Handling Market Access

Council Directive 96/67/EC of 15 October 1996 on access to the groundhandling market at Community airports

Directive 96/67/EC aims to liberalize the ground handling market at Community airports by ensuring fair and open access to ground handling services. In accordance with this directive, the introduction of hydrogen fuel must align with the market liberalization principles set out in Directive 96/67/EC. Member States are required to permit at least two independent suppliers of ground handling services, including fuel handling, unless exemptions apply due to space constraints.⁹⁶ According to the directive, fuel and oil handling comprises the

⁹⁴ Regulation (EU) 2023/1184 supplements Directive (EU) 2018/2001 Consideration 1. Available on https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj/eng [05.03.2025]

⁹⁵ Regulation (EU) 2023/1185 supplements Directive (EU) 2018/2001 Consideration 1. Available on https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj/eng [05.03.2025]

⁹⁶ Directive 96/67/EC, Article 6(2). Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01996L0067-20240520> [accessed 12.02.2025]

organization and execution of fuelling and defuelling operations, including the storage of fuel and the control of the quality and quantity of fuel deliveries as well as the replenishing of oil and other fluids.⁹⁷

Certain ground handling infrastructures can remain centralized where division or duplication would be impractical.⁹⁸ Hydrogen fuelling stations, pipelines, and storage systems may qualify as centralized infrastructures if their complexity or environmental impact necessitates exclusive control by the airport's managing body or a designated authority. In such cases, the directive mandates that centralized infrastructure management must be transparent and non-discriminatory, ensuring equal access to all authorized service providers and self-handling airlines.

All in all, Directive 96/67/EC is designed to liberalize the groundhandling market at Community airports, promoting competition and improving service quality. However, challenges such as maintaining safety standards, integrating new technologies like hydrogen fuel systems, and addressing space constraints remain. Addressing these issues through clear guidelines and coordinated policies is crucial for the successful implementation of the directive and the integration of hydrogen related ground handling and GSEs in airport operations.

4.8.2. Directive (EU) 2022/2557 – Critical Entities Resilience

CER Directive focuses on ensuring that essential services, which are crucial for the functioning of society and the economy, are provided in an unobstructed manner, even in the face of disruptions caused by various risks such as natural disasters, terrorism, or cyberattacks. The directive establishes clear obligations for both Member States and critical entities to identify risks, improve resilience, and ensure the continuous availability of these vital services.⁹⁹

CER Directive establishes a framework to enhance the resilience of essential sectors, such as energy and transport, within the EU. It requires Member States to identify critical entities through risk assessments and ensure these entities address potential threats. Member States are required to develop a national strategy, conduct regular risk assessments, and provide support to critical entities through guidance, training, and other resources. Additionally, they must ensure that national authorities have the power to supervise and enforce compliance with the directive.

Critical entities must regularly assess risks and implement appropriate measures to enhance their resilience. The directive also encourages cooperation between Member States and the European Commission by facilitating information sharing and promoting cross-border coordination while ensuring the careful handling of confidential information.

If GH2 is used as an energy source at an airport, the CER Directive applies in several areas. Hydrogen production must meet resilience requirements to prevent disruptions. Airports using hydrogen for fuelling or operations must implement security and organizational measures to maintain uninterrupted operations. Furthermore, hydrogen storage facilities must be resilient against risks such as accidents, leaks, or sabotage to ensure a secure supply.

In conclusion, the CER Directive is a vital measure to safeguard essential services across the EU, ensuring their continuity during crises. By mandating risk assessments, resilience measures, and fostering international cooperation, the directive strengthens the EU's critical infrastructure and promotes a secure internal market.

⁹⁷ Directive 96/67/EC, Annex, Paragraph 7. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01996L0067-20240520> [accessed 12.02.2025]

⁹⁸ Directive 96/67/EC, Article 8. Available on: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01996L0067-20240520> [accessed 12.02.2025]

⁹⁹ Directive (EU) 2022/2557 on the resilience of critical entities and repealing, Article 1. Available on: <https://eur-lex.europa.eu/eli/dir/2022/2557/oj/eng> [accessed 07.03.2025]

4.9. Brief Overview

The EU's regulatory framework provides a robust foundation for integrating hydrogen technologies into airport operations, addressing safety, environmental, and market considerations. Regulations such as (EU) No 305/2011 and (EU) 2023/2405 ensure infrastructure and fuel supply compliance, while directives like 2012/18/EU and 2014/34 safeguard against hydrogen's inherent risks. However, challenges persist, including the need for hydrogen-specific updates to existing regulations, harmonization across Member States, and significant infrastructure investments. However, there are no barriers or prohibitions preventing project partners from effectively integrating hydrogen solutions into their operations.

For airport operators and policymakers, navigating this framework requires a proactive approach, conducting thorough risk assessments, leveraging EU funding opportunities, and collaborating with national authorities to align with evolving standards. As hydrogen emerges as a cornerstone of sustainable aviation, the EU must continue refining its legislative tools to address technological advancements and ensure seamless adoption. This analysis underscores the critical interplay between regulation and innovation, offering a roadmap for stakeholders to advance hydrogen's role in achieving a decarbonized aviation sector by 2050.

5. Roadblocks and Regulatory Gap Analysis

The report identifies several regulatory gaps and roadblocks hindering the safe, efficient, and scalable integration of hydrogen technologies into airport operations, encompassing hydrogen production, storage, fuelling infrastructure, and transportation. These shortcomings primarily relate to a lack of hydrogen-specific safety standards, inadequate environmental impact assessment frameworks, and challenges in infrastructure integration.

However, it is crucial to highlight that the current EU legal framework does not contain any direct prohibitions or barriers that would prevent project partners from effectively integrating GH2-related solutions at airports. As the report states, the implementation of such solutions necessitates a robust risk management system and adherence to all relevant obligatory legislation.

Therefore, despite the identified gaps and the fact that the existing EU legal framework is not yet fully tailored to the specifics of hydrogen and the unique needs of the airport environment, it does not explicitly deter the introduction of hydrogen technologies, provided that general safety and environmental protection requirements are met. The recommendations outlined in the report aim to refine this regulatory framework to ensure a coherent, supportive, and safe structure for hydrogen adoption in aviation and to facilitate the achievement of the EU's climate neutrality goals by 2050. This report underscores the need for further development to create a more tailored and enabling regulatory environment while acknowledging that current legislation does not inherently forbid the integration of hydrogen at airports.

5.1. Hydrogen Production within the Airport

The integration of hydrogen production within airport premises represents a critical step toward decarbonizing aviation and achieving EU's climate neutrality goals by 2050. However, the current regulatory landscape reveals significant roadblocks and gaps that hinder the safe, efficient, and scalable deployment of on-site hydrogen production facilities.

This section identifies these challenges, drawing from the regulatory frameworks outlined in this Report, and highlights areas requiring further development to support hydrogen adoption at airports.

5.1.1. Lack of Hydrogen-Specific Safety Standards for Airport On-Site Production

While hydrogen's use as a fuel is governed by general safety frameworks, such as ATEX Equipment Directive and Seveso III for major-accident hazards, these regulations do not specifically address the unique risks associated with on-site hydrogen production at airports. Electrolysis involves high-pressure systems, flammable gas handling, and potential explosion risks in densely populated operational zones.

The absence of tailored safety protocols under Regulation (EU) No 139/2014 (aerodrome requirements) or Regulation (EU) No 748/2012 (airworthiness certification), as well as no specific EASA guidance as of today (even if work is underway), creates uncertainty for airport operators seeking to establish production facilities.

5.1.2. Inadequate Environmental Impact Assessment Frameworks

Hydrogen production, particularly via electrolysis, relies heavily on water and energy inputs, raising environmental concerns that are not fully addressed by existing regulations. WFD (Water Framework Directive) mandates sustainable water management but does not specify criteria for large-scale water use in hydrogen production at airports.

Similarly, EIA (Environmental Impact Assessment) Directive requires EIAs for projects with significant effects, yet it lacks detailed guidelines for assessing the cumulative impacts of hydrogen production on an EU level, such as energy demand, emissions from non-renewable electricity sources, and potential land-use conflicts within airport boundaries.

5.1.3. Insufficient Certification and Conformity Assessment Procedures

The production of hydrogen at airports requires pressure equipment and systems that comply with Directive 2014/68/EU (pressure equipment) and must bear CE markings. However, the directive's general requirements do not account for the specific technical demands of hydrogen production units, such as electrolyzers operating at pressures exceeding 700 bar.

Furthermore, Regulation (EU) No 748/2012 focuses on aircraft airworthiness and environmental certification but currently does not extend to certifying hydrogen production facilities as part of airport infrastructure. This gap leaves operators without a clear pathway to certify production systems, risking non-compliance with EU safety and performance standards.

5.1.4. Permitting and Infrastructure Development Delays

Establishing hydrogen production facilities requires navigating a complex permitting process under Regulation (EU) No 139/2014, compounded by the absence of streamlined procedures outlined in the NZIA (Regulation (EU) 2024/1735). The construction of electrolyzers or storage units must comply with Regulation (EU) No 305/2011 (construction products), which emphasizes fire safety and environmental protection.

AFIR mandates hydrogen refuelling infrastructure along transport corridors by 2030 but does not explicitly address on-site production facilities at airports or any other airport operator obligations, leading to delays in planning and investment. This regulatory fragmentation increases costs and timelines for airport operators.

5.1.5. Inconsistent Harmonization Across Member States

The Hydrogen and Decarbonised Gas Market Package (Directive (EU) 2024/1788 and Regulation (EU) 2024/1789) aims to create a unified hydrogen market, yet its implementation by mid-2026 depends on national transposition, risking inconsistent standards across EU member states.

Variations in safety, environmental, and operational requirements could complicate cross-border hydrogen supply chains and affect airports relying on imported hydrogen as a backup to on-site production. The EHB

initiative supports pipeline networks, but its focus on regional hubs may not prioritize airport-specific production needs, exacerbating supply chain uncertainties.

5.1.6. Conclusion

The deployment of hydrogen production within airports faces multifaceted regulatory and practical challenges, including the absence of hydrogen-specific safety and certification standards, inadequate environmental assessment frameworks, and barriers to renewable energy integration. Permitting delays, inconsistent harmonization, and economic uncertainties further compound these issues.

Addressing these gaps requires targeted regulatory updates, such as amending Regulation (EU) No 139/2014 to include hydrogen production safety protocols, enhancing EIA Directive with hydrogen-specific EIA guidelines, and establishing airport-focused funding streams under EU initiatives. It is also important to follow EASAs progress on developing hydrogen related guidance and regulations, as this is one of the key regulatory bodies within the EU. Without these improvements, the scalability and safety of on-site hydrogen production will remain constrained.

However, it is important to note that despite the identified gaps, there are no barriers or prohibitions preventing project partners from effectively integrating hydrogen production solutions into their operations by implementing stringent risk management controls and working in compliance with available regulation.

5.2. Hydrogen Storage at the Airports

Hydrogen storage at airports is a cornerstone of enabling the widespread adoption of hydrogen as an energy carrier for ground operations. GH2's unique properties, high flammability and low density pose significant challenges to its integration within the constrained and safety-critical environment of airports.

5.2.1. Absence of Hydrogen-Specific Airport Storage Safety Standards

The storage of hydrogen at airports involves managing high-pressure systems (up to 700 bar for GH2), which presents explosion and leak risks in operational zones. While ATEX Equipment Directive governs equipment in explosive atmospheres and Seveso III addresses major-accident hazards, neither provides specific safety standards for hydrogen storage infrastructure at airports.

Similarly, Regulation (EU) No 139/2014 (aerodrome requirements) and Annex 14 of the Chicago Convention lack provisions for hydrogen storage facilities, leaving a critical gap in aerodrome design and operational safety. Standards such as ISO 19880-1:2020 (GH2 fuelling stations) offer voluntary guidelines, but their non-binding nature could result in inconsistent safety protocols across airports.

5.2.2. Inadequate Risk Assessment and Emergency Response Frameworks

Hydrogen's flammability and potential for rapid dispersion necessitate robust risk assessment and emergency planning, yet existing regulations fall short. Seveso III mandates safety reports and emergency plans for establishments handling dangerous substances, but it does not explicitly address hydrogen storage at airports, where spatial constraints and proximity to aircraft operations heighten risks.

Regulation (EU) No 996/2010 (aviation accident investigation) lacks specialized protocols for investigating hydrogen-related incidents, such as leaks or explosions, complicating post-incident analysis and prevention.

It is necessary to align internal risk management assessments and emergency response frameworks with particular risks in connection with hydrogen storage.

5.2.3. Limited Environmental and Land-Use Regulation

Hydrogen storage facilities, particularly large-scale tanks, require significant space and may impact local ecosystems, yet environmental regulations are not fully equipped to address these needs. SEA Directive and

EIA Directive require assessments for plans and projects with significant environmental effects, but they lack specific criteria for evaluating the ecological footprint of hydrogen storage, such as potential groundwater contamination from leaks or energy-intensive cooling systems.

Additionally, Regulation (EU) No 305/2011 (construction products) emphasizes fire safety for buildings but does not cover land-use planning for hydrogen storage within airport boundaries, risking conflicts with existing infrastructure.

5.2.4. Infrastructure Integration and Spatial Constraints

Airports face significant challenges in integrating hydrogen storage into existing layouts, governed by Regulation (EU) No 139/2014 and Regulation (EU) 2024/1679 (TEN-T). AFIR mandates hydrogen refuelling points along transport corridors by 2030 but does not address storage infrastructure within airports.

Spatial limitations, combined with the need for separation distances (per ISO 19880-1:2020) to mitigate explosion risks, complicate compliance with aerodrome safeguarding rules under Council Directive 96/67/EC. Retrofitting or expanding storage facilities also requires approvals that current permitting processes, lacking hydrogen-specific streamlining, prolong.

5.2.5. Supply Chain and Energy Reliability Concerns

Hydrogen storage at airports depends on a reliable supply, either from on-site production or external transport via the EHB. However, Regulation (EU) 2024/1789 (hydrogen markets) and Directive (EU) 2024/1788 (renewable gases) focus on market development rather than ensuring storage resilience, as required by CER Directive.

Airports near EHB corridors benefit from pipeline access, but those outside these networks face supply chain vulnerabilities, exacerbated by the lack of mandatory storage capacity targets under ReFuelEU Aviation regulation. This uncertainty undermines operational continuity for hydrogen-dependent systems.

5.2.6. Conclusion

Hydrogen storage at airports is hindered by a lack of specific safety and technical standards, inadequate risk and environmental frameworks, and challenges in infrastructure integration, supply reliability, and funding. Regulatory gaps in Regulation (EU) No 139/2014, Directive 2014/68/EU, must be addressed through hydrogen-tailored amendments, while EIA Directive requires enhanced EIA guidelines for storage impacts.

Harmonizing standards via Regulation (EU) 2024/1789 will be critical to ensure safe, scalable, and economically viable storage solutions. Without these advancements, hydrogen's role in airport decarbonization will remain limited, stalling progress toward net-zero aviation.

However, it is important to note that despite the identified gaps, there are no barriers or prohibitions preventing project partners from effectively integrating hydrogen storage solutions into their operations by implementing stringent risk management controls and working in compliance with available regulation.

5.3. Hydrogen Fuelling Infrastructure

Hydrogen fuelling infrastructure at airports is essential for enabling the use of hydrogen as powering GSE, aligning with the EU's decarbonization goals under the European Green Deal and ReFuelEU Aviation.

This infrastructure encompasses refuelling stations, dispensing systems, and associated safety measures for gaseous hydrogen. However, significant roadblocks and regulatory gaps exist, spanning safety, technical standards, operational integration, and economic feasibility.

5.3.1. Lack of Aviation-Specific Hydrogen Fuelling Standards

The safe and efficient operation of hydrogen fuelling infrastructure at airports requires tailored standards, and while progress has been made, challenges persist. ISO 19880-1:2020 provides voluntary guidelines for gaseous hydrogen (GH₂) fuelling stations, addressing design and safety up to 700 bar, but it is not aviation-specific and lacks mandatory enforcement. SAE AIR8466 (hydrogen fuelling stations for airports) offers a tailored, aviation-specific framework and is voluntarily enforceable, though its non-mandatory status limits its binding regulatory impact.

Meanwhile, Regulation (EU) No 139/2014 (aerodrome requirements) and Annex 14 of the Chicago Convention do not address hydrogen refuelling infrastructure, leaving a gap in aerodrome safety and operational protocols. This absence of mandatory, aviation-focused standards leads to inconsistent implementation and heightened safety risks.

5.3.2. Insufficient Safety and Risk Management Provisions

Hydrogen's high flammability and potential for leaks or explosions necessitate robust safety measures at fuelling points, particularly in busy airport environments. ATEX Equipment Directive regulates equipment in explosive atmospheres, and ATEX Workplace Directive protects workers from such risks, but neither specifically addresses hydrogen refuelling operations near aircraft or GSE.

Regulation (EU) No 965/2012 (air operations) mandates safe ground handling but lacks provisions for hydrogen-specific risks, such as rapid dispensing under tight turnaround schedules. The lack of harmonized emergency response protocols under Regulation (EU) No 996/2010 (accident investigation) further complicates incident management, delaying adoption.

5.3.3. Inadequate Integration with Existing Airport Infrastructure

Integrating hydrogen fuelling stations into airport layouts poses significant challenges due to spatial constraints and operational demands. Regulation (EU) No 139/2014 governs aerodrome certification and safeguarding, but it does not account for the spatial requirements of fuelling infrastructure, such as separation distances mandated by ISO 19880-1:2020 to mitigate explosion risks.

Council Directive 96/67/EC (ground handling market access) requires fuel handling services but lacks guidance on transitioning from fossil fuels to hydrogen, risking coordination issues among multiple suppliers. The AFIR mandates hydrogen refuelling along transport corridors by 2030 but does not prioritize airport-specific infrastructure, hindering seamless integration with aviation operations.

5.3.4. Supply Chain and Operational Reliability Challenges

Reliable hydrogen supply to fuelling stations is critical, yet regulatory frameworks do not fully ensure continuity. ReFuelEU Aviation mandates hydrogen-compatible SAF blends (e.g., 1.2% by 2030, 35% by 2050) and requires airports to facilitate access, but it lacks specific targets for fuelling infrastructure capacity or uptime.

The EHB supports pipeline transport, but airports outside its corridors depend on less reliable trucking or on-site production, as noted in Regulation (EU) 2024/1789 (hydrogen markets). CER Directive emphasizes operational continuity but does not prioritize fuelling infrastructure resilience, risking disruptions in hydrogen availability.

5.3.5. Environmental and Permitting Hurdles

The construction and operation of hydrogen fuelling stations trigger environmental assessments under EIA Directive and SEA Directive, yet these lack specific guidelines for assessing fuelling-related impacts, such as emissions from auxiliary power systems or land-use changes.

IED regulates emissions but does not cover small-scale fuelling operations typical at airports. Permitting processes under Regulation (EU) No 139/2014 and national frameworks are not streamlined for hydrogen infrastructure, as highlighted by the NZIA, leading to delays and increased costs that discourage deployment.

5.3.6. Conclusion

Hydrogen fuelling infrastructure at airports faces a complex array of roadblocks, including the lack of aviation-specific standards, insufficient safety and integration provisions, and gaps in certification, supply reliability, environmental regulation, and funding.

Addressing these requires targeted updates, such as incorporating hydrogen fuelling protocols into Regulation (EU) No 139/2014, finalizing SAE AIR8466 as a binding standard, and enhancing AFIR to prioritize airport infrastructure. Dedicated funding streams under ReFuelEU Aviation and streamlined permitting via Regulation (EU) 2024/1735 are also essential.

Without these advancements, the scalability and operational readiness of hydrogen fuelling at airports will remain constrained, undermining aviation's path to net-zero emissions.

However, it is important to note that despite the identified gaps, there are no barriers or prohibitions preventing project partners from effectively integrating hydrogen fuelling solutions into their operations by implementing stringent risk management controls and working in compliance with available regulation.

5.4. Hydrogen Transportation

The transportation of hydrogen to airports, whether via pipelines, trucks, or other means, is a critical component of ensuring a reliable supply for aviation fuel and ground operations, supporting the EU's decarbonization objectives under the European Green Deal.

Hydrogen's unique properties, such as its flammability, low energy density by volume, present distinct logistical and safety challenges. This section identifies the regulatory and operational roadblocks and gaps hindering efficient and safe hydrogen transportation to airports, highlighting areas for improvement to enable scalable adoption.

5.4.1. Lack of Hydrogen-Specific Transportation Standards for Aviation Supply Chains

Transporting hydrogen to airports requires standards tailored to aviation's operational needs, yet current regulations are insufficiently specific. Directive 2008/68/EC (inland transport of dangerous goods) aligns with the ADR and regulates hydrogen transport by road, rail, and inland waterways, but it does not address airport-specific requirements, such as rapid delivery schedules or integration with aerodrome operations.

Similarly, UN ECE Regulation No. 134 ensures safety for hydrogen-powered vehicles but excludes broader transportation infrastructure like pipelines or aircraft refuelling logistics. The absence of binding, aviation-focused standards under Regulation (EU) No 139/2014 (aerodrome requirements) or the Chicago Convention creates uncertainty for operators managing hydrogen supply chains.

5.4.2. Inadequate Safety and Risk Management Frameworks

Hydrogen transportation involves high-pressure gaseous systems, both of which pose explosion and leak risks during transit and unloading at airports. Directive 2014/68/EU (pressure equipment) governs the design of transport vessels, but its general safety requirements do not account for the dynamic conditions of airport delivery, such as frequent loading/unloading near operational zones.

Seveso III addresses major-accident hazards but focuses on fixed establishments, not mobile transport systems. Furthermore, Regulation (EU) No 996/2010 (aviation accident investigation) lacks protocols for investigating

transportation-related hydrogen incidents, leaving gaps in emergency preparedness and response planning for airport-adjacent routes.

5.4.3. Limited Pipeline Infrastructure and Connectivity

The EHB, outlined in Regulation (EU) 2024/1789 and Directive (EU) 2024/1788, plans a 39,700 km hydrogen pipeline network by 2040, repurposing 60% of existing gas pipelines. While this initiative promises cost-effective transport (€0.21-0.64/kg), its current focus on regional hubs and industrial clusters does not prioritize connectivity to airports, as noted in the EHB's 2023 vision update.

Airports outside these corridors rely on less efficient road transport, increasing costs and emissions. Regulation (EU) 2024/1679 (TEN-T) supports alternative fuels infrastructure but lacks specific mandates for linking hydrogen pipelines to aviation hubs, limiting scalability and reliability.

5.4.4. Environmental and Permitting Challenges

Transporting hydrogen to airports triggers environmental oversight under EIA Directive and SEA Directive, yet these frameworks lack detailed guidance for assessing transportation impacts, such as potential leaks affecting water bodies (Directive 2000/60/EC) or emissions from diesel-powered transport trucks.

Permitting for pipeline construction or road transport routes near airports is governed by national frameworks and Regulation (EU) No 305/2011 (construction products), but the absence of hydrogen-specific streamlining, as highlighted by the NZIA, delays infrastructure development. This regulatory fragmentation increases compliance burdens and project timelines.

5.4.5. Supply Chain Reliability and Market Integration Issues

Ensuring a consistent hydrogen supply to airports depends on a mature market, yet Regulation (EU) 2024/1789 (hydrogen markets) focuses on market access and tariffs without mandating transportation capacity targets for aviation. The AFIR requires hydrogen refuelling stations every 200 km along TEN-T corridors by 2030 but does not guarantee supply chain resilience for airports, as emphasized by CER Directive.

Variability in member state implementation, noted in the Hydrogen and Decarbonised Gas Market Package, risks supply disruptions, particularly for airports reliant on imported hydrogen rather than on-site production.

5.4.6. Conclusion

Hydrogen transportation to airports faces significant hurdles, including the lack of aviation-specific standards, inadequate safety and pipeline connectivity, and gaps in environmental regulation, certification, supply chain reliability, and funding. Addressing these requires targeted actions, such as integrating hydrogen transport protocols into Directive 2008/68/EC and Regulation (EU) No 139/2014, expanding the EHB to prioritize airport links under Regulation (EU) 2024/1679, and enhancing AFIR with aviation-focused transport mandates.

Dedicated funding via ReFuelEU Aviation and streamlined permitting through Regulation (EU) 2024/1735 are also critical. Without these advancements, hydrogen transportation will remain a bottleneck, constraining airports' ability to adopt hydrogen at scale and meet net-zero targets.

However, it is important to note that despite the identified gaps, there are no barriers or prohibitions preventing project partners from effectively integrating hydrogen transportation solutions into their operations by implementing stringent risk management controls and working in compliance with available regulation.

6. Recommendations for Regulatory Improvements

The successful integration of hydrogen into airport operations hinges on overcoming the regulatory gaps and roadblocks identified in production, storage, fuelling infrastructure, and transportation.

This section proposes targeted policy considerations, institutional enhancements, and strategic initiatives to strengthen the EU's regulatory framework, ensuring safety, scalability, and alignment with decarbonization goals under the European Green Deal and ReFuelEU Aviation regulation. Recommendations are tailored to each aspect of hydrogen implementation, drawing from international standards and EU directives.

6.1. Policy Considerations

Policy-level adjustments are essential to address the lack of hydrogen-specific standards, streamline permitting, and incentivize adoption across production, storage, fuelling, and transportation at airports.

6.1.1. Hydrogen Production

Develop Hydrogen-Specific Safety Regulations. Amend Regulation (EU) No 139/2014 (aerodrome requirements) to include safety standards for on-site hydrogen production facilities, such as electrolysers, specifying risk management for high-pressure and flammable gas systems. Integrate these with ATEX Equipment Directive to ensure uniform application.

Update EIA Directive with specific criteria for assessing water and energy impacts of hydrogen production, ensuring sustainable resource use aligns with WFD.

Responsible authorities:	Time of completion:
European Union Aviation Safety Agency, Directorate-General for Energy, Directorate-General for the Environment	2027 - 2029

6.1.2. Hydrogen Storage

Incorporate hydrogen storage protocols into Regulation (EU) No 139/2014, detailing requirements for high-pressure tanks, including separation distances and fire suppression systems, building on ISO 19880-1:2020.

Revise SEA Directive to include land-use planning guidelines for hydrogen storage within airport boundaries, addressing spatial constraints and environmental impacts identified in Regulation (EU) No 305/2011.

Responsible authorities:	Time of completion:
European Union Aviation Safety Agency, Directorate-General for Mobility and Transport	2026 - 2029

6.1.3. Hydrogen Fuelling Infrastructure

Enforce SAE AIR8466 as a binding standard under Regulation (EU) No 965/2012 (air operations), specifying rapid refuelling protocols for aircraft and GSE, and integrate with ISO 19880-1:2020 for consistency.

Update Council Directive 96/67/EC to include hydrogen fuelling guidelines, ensuring safe coordination among suppliers and alignment with Regulation (EU) 2023/2405 mandates for SAF access.

Amend Regulation (EU) 2024/1735 (NZIA) to fast-track permitting for hydrogen fuelling stations, reducing delays noted in Regulation (EU) No 139/2014.

Responsible authorities:	Time of completion:
--------------------------	---------------------

European Union Aviation Safety Agency, Directorate-General for Mobility and Transport	2026 - 2027
---	-------------

6.1.4. Hydrogen Transportation

Expand Directive 2008/68/EC (inland transport of dangerous goods) to include aviation-specific hydrogen transport requirements, such as delivery schedules and unloading protocols, complementing UN ECE Regulation No. 134.

Revise Regulation (EU) 2024/1679 (TEN-T) to mandate hydrogen pipeline connections to major airports under the EHB, aligning with Regulation (EU) 2024/1789 goals.

Responsible authorities:	Time of completion:
Directorate-General for Mobility and Transport, Directorate-General for Energy	2028 - 2029

6.2. Institutional Recommendations

Institutional enhancements are crucial to improve coordination, expertise, and enforcement across EU bodies and member states for hydrogen implementation at airports.

6.2.1. Hydrogen Production

Follow EASA's guidance under Regulation (EU) 2018/1139 leveraging its technical expertise to address regulatory gaps. As EASA is currently working on addressing hydrogen related questions, further developments have to be awaited regarding airport related hydrogen production topics.

Nominate an existing centralized EU body under the European Commission (EC) to harmonize production standards across member states, mitigating inconsistencies noted in Directive (EU) 2024/1788.

Support National Energy Regulators. Task ACER with developing guidelines for renewable energy integration into airport production, per Regulation (EU) 2019/942.

Responsible authorities:	Time of completion:
European Union Aviation Safety Agency, European Commission, Agency for the Cooperation of Energy Regulators	2026 - 2027

6.2.2. Hydrogen Storage

Follow EASA's guidance under Regulation (EU) 2018/1139 leveraging its technical expertise to address regulatory gaps. As EASA is currently working on addressing hydrogen related questions, further developments have to be awaited regarding airport related hydrogen storage topics.

Coordinate and engage with ENNOH to prioritize airport storage infrastructure planning, as per Regulation (EU) 2024/1789.

Responsible authorities:	Time of completion:
--------------------------	---------------------

European Union Aviation Safety Agency, European Network of Network Operators for Hydrogen, Directorate-General for Energy	2026 - 2028
---	-------------

6.2.3. Hydrogen Fuelling Infrastructure

Follow EASA's guidance under Regulation (EU) 2018/1139 leveraging its technical expertise to address regulatory gaps. As EASA is currently working on addressing hydrogen related questions, further developments have to be awaited regarding airport and aircraft related hydrogen fuelling topics.

Partner with the IATA to develop operational frameworks for fuelling infrastructure under its Fly Net Zero initiative, enhancing safety and scalability.

Task the EC with monitoring compliance with Regulation (EU) 2023/2405 fuelling mandates, ensuring airport managing bodies report progress as required.

Responsible authorities:	Time of completion:
European Union Aviation Safety Agency, International Air Transport Association, European Commission, Directorate-General for Mobility and Transport	2026 - 2028

6.2.4. Hydrogen Transportation

Follow EASA's guidance under Regulation (EU) 2018/1139 leveraging its technical expertise to address regulatory gaps. As EASA is currently working on addressing hydrogen related questions, further developments have to be awaited regarding airport related hydrogen transportation topics

Collaborate with the ISO to extend ISO 19880-1:2020 to transport-specific guidelines, supporting Directive 2008/68/EC updates.

Utilize the TRAN to advocate for airport-focused transport policies within Regulation (EU) 2024/1679, enhancing cross-border logistics.

Responsible authorities:	Time of completion:
European Union Aviation Safety Agency, International Organization for Standardization, European Parliament	2026 - 2028

6.3. Strategic Recommendations

Strategic initiatives are needed to align long-term planning, investment, and innovation with the practical needs of hydrogen adoption at airports.

6.3.1. Hydrogen Production

Fund pilot projects via Hydrogen IPCEI and CEF to test on-site Green Hydrogen production, informing future Regulation (EU) 2024/1735 updates and scaling best practices.

Cultivate research into cost-effective electrolysis under Horizon Europe, addressing economic barriers noted by the IEA and aligning with REPowerEU Plan targets.

Integrate with Regional Energy Hubs. Link airport production to renewable energy clusters via Regulation (EU) 2023/2413, enhancing supply chain resilience.

Responsible authorities:	Time of completion:
European Commission – Directorate-General for Competition, European Climate, Infrastructure and Environment Executive Agency, European Commission – Directorate-General for Research and Innovation, European Commission – Directorate-General for Energy	2025 - 2028

6.3.2. Hydrogen Storage

Develop Modular Storage Solutions. Invest in R&D for compact, scalable storage systems (e.g., modular tanks) under Regulation (EU) 2024/1735, overcoming spatial constraints identified in Regulation (EU) No 139/2014.

Create a strategic plan under Regulation (EU) 2023/2405 to connect airport storage to the EHB, ensuring supply reliability across regions.

Responsible authorities:	Time of completion:
European Commission – Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, European Commission – Directorate-General for Energy, European Commission – Directorate-General for Mobility and Transport, European Network of Network Operators for Hydrogen	2026 - 2028

6.3.3. Hydrogen Fuelling Infrastructure

Fund fuelling station prototypes at major airports through ReFuelEU Aviation and CEF, testing SAE AIR8466 and refining operational standards.

Promote industry collaboration via IATA and ISO to develop universal hydrogen fuelling connectors, enhancing interoperability.

Integrate fuelling infrastructure into Regulation (EU) 2024/1679 (TEN-T) as strategic nodes, supporting long-term aviation decarbonization.

Responsible authorities:	Time of completion:
European Climate, Infrastructure and Environment Executive Agency, European Commission – Directorate-General for Mobility and Transport, SO Technical Committee 197, European Commission –	2026 - 2028

Directorate-General for Internal Market, Industry,
Entrepreneurship and SMEs

6.3.4. Hydrogen Transportation

Prioritize airport connections in the EHB's 2040 roadmap under Regulation (EU) 2024/1789.

Support R&D for hydrogen transport alternatives (e.g., hydrogen carriers) via Horizon Europe, addressing Directive 2008/68/EC limitations.

Responsible authorities:	Time of completion:
European Commission – Directorate-General for Energy, European Network of Network Operators for Hydrogen, European Commission – Directorate-General for Research and Innovation	2025 - 2029