A legal overview on International & European safety standards for hydrogen applications

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Milestone 3.1.1 of HySUCCESS – Part I

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1. Executive Summary

This report covers the part on the International and European legal framework under the investigation in the research performed by HUAS under task 3.1. This report is part I of the two reports[1] on safety and environmental standards. Both reports are input for the ICT tool that will be developed by HUAS under task 3.1. The focus of this first report is only on the International and European standards, whereby the hierarchy between the standards and formal legislation is discussed. The second report focuses on the Dutch legal framework where the implementation of the International and European standards is discussed. This is done with a focus on identifying vague or open norms.

This study focuses on small scale storage of hydrogen, fuel cell technologies or fuelling stations for hydrogen. These applications for hydrogen tend to be the most common subject of the licensing procedures within the Netherlands at the moment. With regard to safety standards on international level, this report discusses several standards from the International Standardization Organization (ISO) that are relevant for these hydrogen applications. Often licensing institutions, such as municipalities and environmental services, refer to these standards in the procedures for licensing. The other international standards are published by the United Nations Economic Commission for Europe or the International Electrotechnical Commission. These organizations have no formal legislative power; however, their standards shaped the safety and environmental setting with regard to hydrogen for over decades.

At an European level, this study looks into the European legislation on safety and environmental standards as well. The most important directives, such as SEVESO III and ATEX, are discussed. They rank above the national regulations in the hierarchical order; however, these should be transposed into the national legal orders. Another important institute at European level is CEN/CENELEC. They are the primary officially recognized organizations for developing technical standards across the European Union. With regard to hydrogen several standards of CEN/CENELEC on gas cylinders, fuel cell technologies and on transportation and fuelling stations are taken into consideration. Although the standards of CEN/CENELEC are primarily voluntary, when EU legislation refers to it, producers and manufacturers should comply with these for placement of their products on the EU market. Finally, some important standards of EIGA have been part of this study as well. More specifically, the documents on safety and separation distances, hydrogen stations, and the distribution, storage and applications of hydrogen have been looked into. EIGA standards have a similar status as ISO standards, albeit for the European region. It can be concluded that even though most standards are voluntary in nature, they shape the framework for hydrogen applications in the licensing procedures.

[1] Part II: J.C.W. Gazendam, K. Hofman-Filadoro en M. den Uijl, Waterstof: normen bij vergunningverlening, Hanze Groningen, GroenvermogenNL, maart 2026.

2. Introduction

2.1. HySUCCESS

HySUCCESS is part of the broader research programme ‘GroenvermogenNL’. GroenvermogenNL is the programme for green capacity for the Dutch economy and society. With this, the Netherlands will be able to build a new industry and an appealing business climate. This transition will require well-trained people as well as a robust structure of knowledge sharing.[2]

HySUCCESS[3] stands for Social, User ACCeptable, Economically Sustainable Systems for Hydrogen. It is an initiative of a consortium consisting of ten universities, five universities of applied science, one research institute, three industrial partners and an industry association. The research is aimed at supporting a socio-techno-economic environment that promotes the adoption of hydrogen in the sectors where hydrogen is the best solution to reduce emissions. For example, through the deployment of business economics lessons, proposed policy recommendations and regulatory frameworks, inclusion of regional labour market effects, understanding the drivers of public acceptance, and ensuring a just hydrogen transition.

2.1.1. Scope and research question

Within the legal task of the project, Hanze University of Applied Sciences (hereinafter: HUAS) focusses on the safety regulations and standards of hydrogen. The contribution of the Hanze consists of two phases. In the first phase an overview is provided on the relevant safety regulations and their hierarchical order as well as the Dutch framework on safety and environmental standards for hydrogen. In the second phase an ICT- tool will be developed that includes most relevant safety standards for the relevant hydrogen small scale storage, hydrogen generators (and fuel cell technologies) and fuelling stations. The ICT-tool will assist users of these hydrogen applications and regulators to better interpret and apply open or vague norms in safety regulations. For the first phase of this task, the authors analysed relevant safety standards at all levels: international, European and Dutch (whereby the Dutch part is covered in Part II). The scope of the researched safety standard ranges therefore from international standards of the International Standardization Organization (ISO) to Dutch national standards such as the *Publicatiereeks Gevaarlijke Stoffen* (PGS). In order to limit the research, it was decided to only look at standards related to hydrogen fuelling stations, fuel cell technologies and (small scale) hydrogen storage. The production of hydrogen and transport of hydrogen via pipelines is covered by the other GroenvermogenNL work packages.

The outcomes of the first part of the report are presented in two separate reports. Part I elaborates on the international and European safety standards. Part I also describes the underlying relationship between these regulations and standards. Since often these regulations and standards are implemented in national legal orders, the more in-depth analysis is in report part II. Part II elaborates on the national standards in the Netherlands. The focus is on the *Environmental Act,* and the Dutch technical standards are taken into consideration. Here, the open norms are identified and discussed.

This research for part I (of the two reports) uses the following research question:

> *What safety and environmental standards apply to hydrogen fuelling stations, fuel cell technologies (regarding hydrogen) and (small scale) storage that are relevant for the licensing and permitting procedure and what is the hierarchical relation between these standards and formal European legislation?*

It is important to emphasize that most of the standards (such as those from the ISO, CEN and NEN) are often only accessible behind a paywall. It is therefore not possible to share extensive content within this

[2] https://groenvermogennl.org/en/over-groenvermogennl/.

[3] https://groenvermogennl.org/en/project/hysuccess/.

report (without infringing their rights). Hence, the approach is to describe the standard on a more abstract level.

2.1.2. Research methods

To answer the research question, literature research is conducted in combination with interviews with experts on the topic. Because of the interconnected nature of the topics discussed in this part I and part II, some of research efforts benefited both reports.

This study builds on earlier work on hydrogen as developed under projects such as the Green Hydrogen Booster (translated from Dutch “Groene Waterstofbooster”)[4], Emission free construction sites (translated from Dutch “Emissieloze bouwplaatsen”)[5] and H_2opper[6]. These research projects involved multidisciplinary research wherein technical and legal research was combined. In previous research the Dutch Environmental Act was studied to map the licencing regime for hydrogen activities. The application of safety standards was addressed in our previous research. This research builds upon that previous research as it now considers the way in which the technical safety standards should be interpreted and what can be done to make technical safety standards more accessible for licensing authorities and users of hydrogen applications.

All websites consulted during this study and referred to in this report have been accessed the latest in March 2026.

2.2. Hydrogen Licensing

The European Union is a *sui generis* organization that operates on a system of shared and exclusive competences. The environment and energy policies are a shared competence, whereby the European Union legislator has to take the principles of subsidiarity and proportionality into account when making legislation. Therefore, EU law can only regulate an activity when this cannot be done effectively on member state level, whereby the economies of scale offer a normative benchmark to assess the benefits of allocating policy responsibilities at the centralized level.[7] Because of the local impact of working with hydrogen applications, it is assumed that the member state is the best level to regulate the use of hydrogen activities with the aim of reducing external risks.

There is currently no full harmonization within the European Union with respect to the procedures for licensing and permitting of hydrogen applications as such, however, some significant steps towards streamlining permitting procedures related to energy has been made. For example, in the Net Zero Industry Act[8] member states should organize for manufacturing projects a ‘single point of contact’ (art. 6), provide online access to information (art. 7) and assistance (art. 8) and within a certain period of time (art. 9). Furthermore, some additional criteria have been provided on environmental assessment and authorization as well as spatial planning (art. 10-11). On the level of EU Directives similar streamlining of permitting procedures are found in RED II and RED III[9]. Where RED II introduced rules to simplify the

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[4] H.J. Smeltekop, D.G. Tempelman, T.H. Ubbens-Elings & M. den Uijl, *Juridische Handvatten voor Innovatieve Ondernemers in Waterstof,* Hanze, July 2022.

[5] J.C.W. Gazendam, Waterstof op de bouwplaats: vergunnings- en zorgplichten voor gebruik waterstof op de bouwplaats, Hanze, December 2024.

[6] J.C.W. Gazendam & D.G. Tempelman, *Legal Aspects of a Hydrogen Hub: related to the development of a hydrogen hub in Delfzijl (the Netherlands),* Hanze, 2026.

[7] Steinbach, Armin, 'Leveraging economies of scale', EU Law and Economics (Oxford, 2025; online edn, Oxford Academic, 6 Jan. 2025), https://doi.org/10.1093/9780198920915.003.0007, accessed 18 Mar. 2026.

[8] Regulation (EU) 2024/1735 of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe’s net-zero technology manufacturing ecosystem, OJ L1735/1.

[9] Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion and the use of energy from renewable sources, OJ L328 and Directive (EU) of the European Parliament and of the Council as regards the promotion of energy from

administrative procedures, RED III imposes a more proactive approach to drastically accelerate deployment. Art. 15 RED III set standards for the administrative procedures, including permitting procedures in a more general wording. Procedures should be proportionate and necessary, administrative charges should be transparent and cost-related, and rules concerning authorisation, certification and licensing should be objective, non-discriminatory and transparent. Art. 15 paragraph 2 clearly makes reference to European standards (which includes safety standards) and provides the hierarchical order:

*“**Member States shall clearly define any technical specifications** which are to be met by renewable energy equipment and systems in order to benefit from support schemes and to be eligible under public procurement. **Where harmonised standards or European standards exist, including technical reference systems established by the European standardisation organisations, such technical specifications shall be expressed in terms of those standards**. **Precedence shall be given to harmonised standards, the references of which have been published in the Official Journal of the European Union in support of Union law**, including Regulation (EU) 2017/1369 of the European Parliament and of the Council (*) and Directive 2009/125/EC of the European Parliament and of the Council (**). In their absence, other harmonised standards and European standards shall be used, **in that order**. Such technical specifications shall not prescribe where the equipment and systems are to be certified and shall not impede the proper functioning of the internal market*.”

Art. 15.b to art. 15e RED III were introduced with the revision of RED II and include now the obligation for member states to map and designate the areas (on land surface, subsurface and sea) that can become ‘renewable acceleration areas (RAAs), which are locations particularly suitable for specific technologies where environmental risks deemed to be low. Rather relevant for permitting procedures is art. 15d that members states shall ensure that the public should be directly and indirectly involved in these projects, and they shall ensure public participation regarding the plans designating RAAs. Art. 15e links the deployment of renewable production to the mapping of grid and storage infrastructure, ensuring that administrative acceleration is not decoupled from physical network capacity.

Art. 16 RED III includes rules on the first step within the process of permitting: within 30 days for renewable energy plants located in RAAs or within 45 days for renewable energy plants outside RAAs the applicant should receive a receipt of an application for a permit or the request for additional information if the applicant did not provide it in the first time. The day of acknowledgement of completeness of the application shall count as the first day of the permit-granting procedure (paragraph 3). Furthermore, member states shall create `contact points’ for the application which should provide the applicants of the permit with all necessary information and guidance; however, during the permit-granting process the applicant should not be required to contact more than one contact during the entire procedure. This contact point is responsible for guidance throughout the entire process, making sure deadlines in RED III are met, provide digital information and the option for digital applications (art. 3 and 4). Member states shall ensure that there is easy access to simple procedures for the settlement of disputes concerning the permit-granting procedure and the issuance of permits to build and operate renewable energy plants, including, where applicable, alternative dispute resolution mechanisms (paragraph 5).

Art. 16a RED III provides rules on the permit-granting procedure of renewable energy projects in RAAs including a timeframe. Relevant for safety of hydrogen projects is paragraph 2:

“Where duly justified on the ground of extraordinary circumstances, such as on grounds of overriding safety reasons where the repowering project has a substantial impact on the grid or on the original capacity, size or performance of the installation, Member States may extend the six-month period by up to three months and the 12-month period for offshore wind energy projects by up to six months. Member States shall inform the project developer clearly about the extraordinary circumstances that justify such an extension.”

renewable sources, OJ L 2413. Although the streamlining of the procedure was introduced by RED II, for this study, we focus mainly on the revised text in RED III.

Art. 16b RED III imposes lesser rules on the permit-granting procedure outside RAAs, since the member states are not obliged to include a screening procedure of the applications. Art. 16c RED III provides rules on the permit-granting process of repowering power plants, art. 16d RED III sets out rules on the installation of solar energy equipment and art. 16e RED III does so for the installation of heat pumps.

Rules on the permit-granting procedure are also provided in the legislative package on Gas and Decarbonisation[10], the fourth Gas Directive (EU) 2024/1788,[11] regarding the deployment of hydrogen production facilities and hydrogen system infrastructure. Recital 60 mentions "*Permitting procedures for the connections to the transmission or distribution network should not be hampered by a lack of administrative capacity. Furthermore, such permitting procedures should not establish hurdles in relation to the achievement of the national renewable energy target*." The rules are particularly relevant to industrial consumers of hydrogen, providing rights to have access to the hydrogen networks (see art. 43), and to storage and terminals (art. 51). It also includes rights more similar to the gas and electricity market for hydrogen customer (art. 2) and final customer (art. 2 paragraph 3), whereby the latter category includes industrial applications and fuelling stations. The streamlining of the permit-granting procedures is laid down in art. 8, which mandates member states to establish a transparent and non-discriminatory system for authorizing the construction and operation of hydrogen infrastructure. It also includes the 'single point contact' as discussed above and a timeframe. Worth mentioning is paragraph 9 of art. 8, where the authorisations granted under national law for natural gas should also apply to hydrogen infrastructure.

Finally, it is to be expected that in the near future the streamlining of the permitting procedures will go to a more harmonised situation within the European Union. In 2025 the European Parliament and the Council proposed a new directive dedicated to the acceleration of permit-granting procedures particularly for energy projects.[12] This includes the permitting of energy infrastructure projects, including transmission and distribution grids, storage and recharging stations and renewable energy projects. It states that the rules provided in RED III did not fully address all issues which delay permitting and integration of renewables, such as slow permitting for grids, storage or recharging stations, limited digitalisation of procedures or public acceptance. Even though the full implementation of the existing framework is still ongoing, stakeholders still encounter bottlenecks that hinder fast permitting and the deployment of the renewable energy projects.[13]

The stagnation in project deployment due to extended permitting timelines is twofold: it reflects both the incomplete transposition of existing EU legislation by Member States and significant unresolved deficiencies within the Union's regulatory framework. Key barriers that remain insufficiently addressed at the EU level include the excessive duration of environmental impact assessments, obstacles to public acceptance, and a lack of standardized digital procedures. Furthermore, administrative bottlenecks are exacerbated by under-resourced national authorities, a lack of integrated coordination between relevant agencies, and the absence of comprehensive rules governing storage technologies and recharging infrastructure.

The proposal will include some revisions to the rules on the permit-granting procedures in RED II, the fourth Gas Directive (EU) 2024/1788 and in the fourth Electricity Directive (EU) 2019/944. It will, however, not directly be relevant for hydrogen applications. For example, a new art. 16h RED II is introduced in the proposal to regulate the permit-granting procedure of energy storage, other than hydrogen storage.

With the new proposal for the acceleration of the permit-granting procedures, the future seems promising. However, it will take the necessary time for the proposal to enter into force and for member states to implement the relevant permit-granting procedures.

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[10] European Commission, Energy, *Hydrogen and Decarbonised Gas Package*, https://energy.ec.europa.eu/topics/markets-and-consumers/hydrogen-and-decarbonised-gas-market_en.

[11] Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, OJ L 2024/1788.

[12] European Commission, Proposal for a Directive on the acceleration of permit-granting procedures, Brussels, 10.12.2025, COM(2025) 1007 final 2025/0400(COD).

[13] Ibid, p. 3.

2.3. Safety standards and regulations

A standard is defined as "*a technical specification, adopted by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory*." It includes the international standards that are adopted by an international standardization body, European standards that are adopted by European standardization bodies, harmonized standards adopted on the basis of a request made by the Commission for the application of Union harmonisation legislation and national standards adopted by national standardisation bodies.[14]

Safety standards have a peculiar position within licensing regimes. In general, licensing regimes introduce a licensing obligation and criteria for the licensing authority which are to be used when deciding on a licence application. The technical safety standards are generally not included in the statutory licensing regime. The licensing regime refers to the technical safety and makes them applicable. Therefore, the technical safety standards are placed 'below' the statutory licensing provisions within the hierarchy of regulations.

Technical safety standards are generally not made by the government, but by experts. Because these standards are not made by a formal legislator, the standards are non-binding. There are some exceptions to this, which will be discussed below. Safety standards have been always welcomed by practitioners and governments, since it provides clarity, safety and often simplicity. It helps the market and international trade of products and services.

In is important to bear in mind the distinction between formal regulations and technical safety standards which can be called regulations sometimes. Formal regulations come from a body with legislative powers, such as the European Union or national governments. There are also regulations that come from other institutions such as the United Nations Economic Commission for Europe (UNECE). In some cases, reference in legislation is made to them. For example, in Regulation (EU) 2010/2144 a reference is made to UN Reg. 100 for electric vehicles. Needless to say, but important to emphasize is that regulations coming from the bodies of the EU, such as the European Commission and the European Parliament are higher in rank within the EU than a regulation from the UNECE.[15]

Standards differ from regulations, since the designer is not an official legal governmental body. It comes from experts with a renowned expertise in the matter, working closely together in different committees. It is good to mention that there is also a certain hierarchy between the standards. On a global level there is the International Organization for Standardization (ISO) and also relevant is the Compressed Gas Association (CGA). The standards, in particular from the ISO, are well known and used all over the world. In 1963, however, the CEN (European Centre for Normalization) was founded to connect to national standardization bodies of the European Union.

It took a few decades before the CEN (in combination with CENELEC) became the official standardization body for the European Union. Since 1991 the ISO and the CEN signed the Vienna Agreement.[16] This agreement was signed with the aim of preventing duplication of effort and reducing time when preparing standards. As a result, new standards projects are jointly planned between CEN and ISO. Wherever appropriate priority is given to cooperation with ISO provided that international standards meet European legislative and market requirements and that non-European global players also implement these standards.[17]

Hence, the scope of ISO standards is global and are often also the origin for standards from CEN. The scope of CEN standards are the EU member states and is confined also by the procedures from the European Union. Standards from ISO start with "*ISO…..*" and standards from CEN start with "EN*…"*. If the standards from CEN originate from ISO, the reference will start with "EN ISO….". When CEN adopts a standard, they apply in all member states and conflicting national standards should be withdrawn.

[14] Art. 2 paragraph 1 Regulation (EU) 1025/2012 of The European Parliament And Of The Council of 25 October 2012 on European standardisation, *PB* L316/12.

[15] It goes beyond the scope of this research to discuss the legislative procedures of the safety regulations of the EU or the UNECE regulations.

[16] Agreement on Technical Co-Operation between ISO and CEN, *VA Codified version 3.3,* 2009-09-20, available via: https://boss.cen.eu/media/CEN/ref/vienna_agreement.pdf>, last accessed 14 January 2026.

[17] https://www.cencenelec.eu/about-cen/cen-and-iso-cooperation/.

Member states have their own national standardization body as well, i.e. in the Netherlands they are called “NEN”. They have the authority to design national standards as well, whereby the reference will be “NEN….”. These standards can only be drafted if there are no European standards from CEN dealing with the matter. If the standards from CEN are transposed to Dutch standards, the reference will be “NEN-EN…” or “NEN-EN-ISO…”.

Important to emphasize is that there are also industrial standards coming from specific institutions established with the goal to harmonize a certain sector, mostly the industrial sector. Although ISO standards rank in that sense in the same way as these industrial standards, since they are often only binding when a contract or a piece of legislation refers to it. When visualizing the hierarchy of the regulations and standards, the pyramid is the best form.

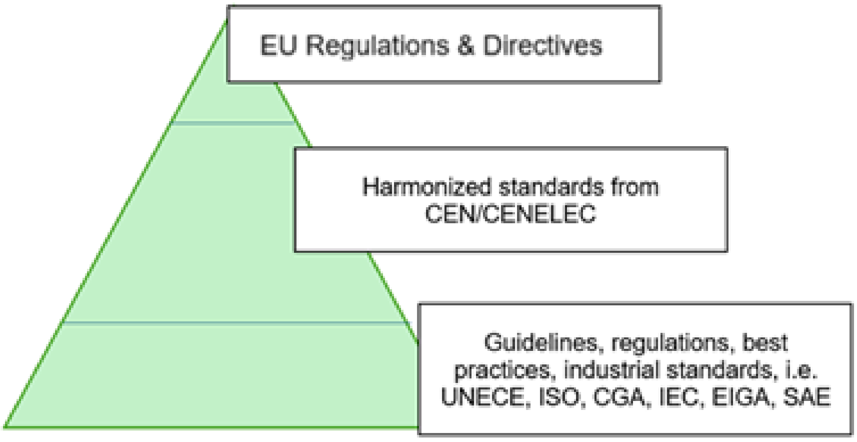

Figure 1 hierarchy of regulations and standards.

Once legislation refers to a specific ISO standard (i.e. adopted by the CEN) or CEN standard, it becomes part of the secondary legislative framework. According to art. 10 paragraph 6 of Regulation (EU) 1025/2012[18] a CEN standard becomes a harmonized standard (hEN) once it is published in the Official Journal of the EU (OJEU). On top are the EU regulations and directives as a primary source of law. Second are the CEN/CENELEC standards, part of secondary law. Third in place are the majority of industrial standards, guidelines, best practices, regulations documents of organizations such as UNECE, ISO, CGA, IEC, EIGA, SAE.

Finally, there are various types of safety standards, and some crucial distinctions have to be made. Firstly, a distinction can be made with regard to the target audience (addressees) of the standards. Roughly divided, there are standards for manufacturers and standards for users of hydrogen applications. Standards for manufacturers are related to product safety. They focus on design, material selection and construction of components. In example, the manufacturer has to use materials that are compatible with hydrogen to prevent hydrogen embrittlement.[19] Secondly, there are standards that are designed for users: operational and installation standards. These standards focus more the ‘site’ and the environment of where the hydrogen is being used, such as standards on safety and separation or standards on ventilation. These standards also govern the operator’s training and emergency response procedures.[20] Often these standards are considered to be ‘vertical’ standards, meaning that they apply

[18] Regulation (EU) No 1025/2012 Of The European Parliament And Of The Council of 25 October 2012 on European standardisation, *PB* L316/12.

[19] Within this report, a good example of a standard for manufacturers is ISO standard 12619 as discussed in section 3.2.3.

[20] For example, see section 3.2.1 for ISO standard 15916 or section 4.3.1 for EIGA doc 75/21.

to a specific product, system or technology domain. Thirdly, there are also standards that are called ‘cross-cutting’ standards. These standards link the manufacturer and the user of hydrogen applications or systems and are therefore, crucial for safety in the entire value chain of hydrogen applications. For example, standards on the quality of hydrogen on protocols on refuelling.[21] All these types are relevant in the licensing procedures since the applications need to be safe as well as the operation of it, however, the focus is mainly on standards for users and cross cutting standards. The cross-cutting standards are also referred to as ‘horizontal’ standards.

In addition, there are different approaches between formal regulations (such as EU legislation) and safety standards. Formal legislation is originally risk-based: “*What are potential risks and how can they be reduced?”.* EU Directives, (such as the PED directive, see section 4.1) focus on the goal, it tells you *what* to achieve. Usually via a risk assessment (obligatory by law) these risks are mitigated by effect-based standards for safety. Effect-based are ‘prescriptive’ in nature, *how* to achieve it: “*If X happens, then the effect Y occurs; hence, measure Z must be taken”.* Safety standards are originally effect-based, prescribing what measures need to be taken for safe operation. There is, however, a shift from the effect-based approach towards a more risk-based regulatory framework with regard to hydrogen.[22]

[21] See in this report section 3.2.2 for ISO standard 14687 or section 3.2.5 for ISO 19880.

[22] It goes beyond the scope of this study, see further: OECD (2023), Risk-based Regulatory Design for the Safe Use of Hydrogen, OECD Publishing, Paris, https://doi.org/10.1787/46d2da5e-en.

3. International framework

The main focus of this report is on the European safety standards for hydrogen applications, but in practice the European standards are supplemented and/or influenced by international standards. Firstly, there is the United Nations that established the UN Economic Commission for Europe (UNECE), which is a regional commission promoting pan-European economic integration. Secondly, the international Standardization Organization (ISO) must be referred to as well. Not only is it an authority on safety standards for the past decades, but also its influence in the national legal order is relevant in several sectors. Thirdly, there are regional standards as well. The standards of the Compressed Gas Association (CGA) are applicable in North America, the Japanese standardization organization (JIMGA) and the standard for Japan, the standards of the Asian organization for standardization (AIGA) are applicable in the rest of Asia, and finally the standards of the European Industrial Gas Association (EIGA) are applied in Europe. Within the International Harmonization Council, there is collaboration between these regional harmonisation bodies. This chapter focuses on the international standards from the UNECE (section 3.1), ISO (section 3.2) and IEC (section 3.3). In section 3.4, it is briefly discussed how the international harmonisation process operates of several regional standards.

Since the focus of the project is on the European and national standards, only international and regional standards are discussed insofar these standards are relevant in the European Union. Therefore, the focus is primarily on the ISO standards due to their close cooperation with the European Standardization Centre (CEN).

3.1. United Nations Economic Commission for Europe (UNECE)

At global level, technical harmonisation of vehicles is governed by two international agreements: the 1958 Agreement and the 1998 parallel Agreement.[23] These agreements establish harmonised requirements at global level to ensure high levels of safety, environmental protection, energy efficiency, and theft protection. Both agreements help eliminate existing technical barriers to trade and prevent the creation of new ones. The involvement of the EU (as a contracting party to the agreement) enables easy access to non-EU markets for manufacturers.[24] When vehicles, components, and equipment meet the UNECE regulatory requirements, they receive an E-marking, which allows them to be marketed in all participating countries without undergoing additional testing. This mutual recognition framework provides a significant advantage by simplifying market entry and reducing duplication of approval procedures. In this study three standards are discussed, whereby Regulations134 (section 3.1.1) and 100 (section 3.1.2) considered to be more vertical standards, while Regulation 10 is covering aspects relevant to all vehicles (section 3.1.2) and therefore a horizontal cross-cutting standard.

3.1.1. Hydrogen vehicles UNECE Reg. 134[25]

One – for the hydrogen sector – important regulation is UN Regulation 134 Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles (HFCV). In several European States this regulation is adopted, in example, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Moldova, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, but also Serbia and the

[23] Agreement Concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations, E/ECE/TRANS/505/Rev.3 (latest version based on ECE/TRANS/WP.29/2016/2), 20 October 2017.

[24] https://single-market-economy.ec.europa.eu/sectors/automotive-industry/technical-harmonisation/international-technical-harmonisation_en.

[25] 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], *PB* L129/43.

Russian Federation. Furthermore, Japan, New Zealand, Nigeria and some other states have adopted it.[26] Within the European Union a specific reference is made to these standards in Regulation (EU) 2021/535, which will be discussed in chapter 4.

Regulation 134 establishes safety requirements for hydrogen-powered vehicles, including criteria on the integrity of storage systems, leak prevention, collision protection, and specific testing procedures. It focuses on the high-pressure storage systems (typically operating at nominal working pressures of 35 MPa or 70 MPa) and the downstream fuelling lines. Furthermore, it mandates rigorous verification of the storage system integrity, leakage mitigation and post-crash safety.

It is adopted by the European Union and published in the official journal (L 129/43) as an 'Act adopted by bodies created by International agreements'.[27] This entails that it becomes part of the European legal order through incorporation and will be binding upon member states that apply it, even if the those Acts are not formally binding under international law, but are capable of decisively influencing European legislation.[28] The same applies for the two other regulations, discussed in section 3.1.2.

3.1.2. Electric vehicles UNECE Regulations 10[29] and 100[30]

There are two more UNECE regulations relevant for hydrogen fuelled vehicles, which need to be addressed. These are Reg. 10 concerning the approval of vehicles with regard to electromagnetic compatibility and UNECE reg. 100 concerning the approval of vehicles with regard to specific requirements for the electric power train. Although both regulations focus on the electric parts, they are relevant to hydrogen fuelled vehicles since those are defined as electric vehicles with regard to EU-type of approval law. In Regulation (EU) 2018/858[31] establishes the whole EU vehicle type-approval system, making reference to regulations of the UNECE in the annexes. In practice, the manufacturer of a hydrogen vehicle should ensure that the system or the component is approved under i.e. UNECE Regulation No 10, whereby that approval is recognized under Regulation (EU) 2018/858. In that case the vehicle meets all the requirements on EU safety, environmental and production standards, ready to be sold and registered across EU member states without further testing.[32]

3.2. International Standard Organization (ISO)

The International Organization for Standardization is an independent, non-governmental, international standard development organization composed of representatives from the national standards organizations of member countries. In 1946 a meeting took place in Londen hosting 65 delegates from 25 countries. In 1947, ISO came into existence with 67 technical committees and in Geneve in 1949 it established its first own office. Two years later it published its first ISO standard[33]. In 1955 it already included 35 members and published 68 standards (at the time 'recommendations'). Furthermore, it

[26] ECE/TRANS/WP.29/343/Rev.34. Via www.treaties.un.org.

[27] This is rooted in art. 218 paragraph 9 TFEU, concerning acts of bodies set up by international agreement. See for a more thorough analysis on art. 218 (9) TFEU: Polakiewicz, J. (2021). A Council of Europe perspective on the European Union: Crucial and complex cooperation. Europe and the World: A Law Review, 5(1), paragraph 4.4.2.

[28] As ruled by the Europe Court of Justice, ECJ, Case C-399/12 *Germany v Council*, EU:C:2014:2258.

[29] Regulation No 10 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility, OJ L 234/1.

[30] Regulation No 100 of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train [2015/505], OJ L 87/1.

[31] 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, OJ L151/1.

[32] See https://single-market-economy.ec.europa.eu/sectors/automotive-industry/technical-harmonisation/technical-harmonisation-eu_en.

[33] ISO/R 1:1951 *Standard reference temperature for industrial length measurements.*

developed the first international agreement on measurements: ISO 80000-1:2022 (the latest version), whereby one unit for each quantity is set out: in example, the meter for length and the second for time.[34]

ISO standards are relevant for renewable energy and hydrogen in particular. Since 1996 ISO published standards on environmental management systems, whereby the standards provide tools for companies and organizations to assist in identifying and controlling environmental impact which can also be used for hydrogen projects. These standards are known as the standards from the 14001 family. Since then, the ISO introduced new standards. In 2011 the ISO published 50001 standards, which provides public and private sector organizations with management strategies to increase energy efficiency, reduce costs and improve energy performance. Regarding to hydrogen some standards applied already decades ago since they apply i.e. to gaseous systems, however, more recently ISO also published standards specifically for hydrogen.

Authors and audience

The experts involved in designing the ISO standards come from organizations and institutions with renowned knowledge on the matters involved. Think of manufacturers, sellers, buyers, customers, trade organizations, users and regulators. All have a clear view on what is necessary in their field of expertise. The ISO standards are designed as to say, "by practitioners, for practitioners".

Legal Status

ISO standards are voluntary guidelines by nature. The standards can become part of a contractual obligation when contract parties refer to them, leading to a breach of contract when failing to adhere to them. Furthermore, national or regional authorities may incorporate these standards into legislation by reference, thereby codifying them into legal requirements. Under such frameworks, while the standards originate as voluntary instruments, compliance becomes a mandatory prerequisite for legal adherence. In a few rare cases the legislation can state that certain ISO standards must be considered. They will get a binding status in those situations when they apply.[35]

There are several ISO standards that apply to the application of hydrogen. As discussed earlier, the standards itself will be described but the actual texts can be accessed via the website in the footnotes of the standards.[36]

3.2.1. Basic considerations for the safety of hydrogen systems

When ISO includes "TR" in the name, it refers to a Technical Report. Hence, ISO/TS 15916:2026 'Hydrogen – Basic Considerations for the safety of hydrogen systems'[37] is not a full international standard, which content does not meet the criteria or maturity requirements for a publication as such. The considerations do not hold any normative clauses, meaning they are only informative with the intention to support other ISO standards and provide guidance. This standard includes 67 pages on guidelines for the use of hydrogen in its gaseous and liquid forms as well as its storage in either of these or other forms (hydrides). It identifies the basic safety concerns, hazards and risks, and describes the properties of hydrogen that are relevant to safety. More detailed safety requirements related to specific hydrogen applications are treated in separate International Standards, which will be discussed below. There is a revision of these standards on its way, whereby the status will change to a Technical Specification (ISO/TS). This entails that some normative clauses can be included. The CEN (see chapter 4.2) adopted this standard as well: CEN ISO/TS 15916:2026.

[34] www.iso.org/about.

[35] In section 4.1.3, the Pressure Equipment Directive will be discussed.

[36] Although there are also ISO standards with regard to for example cryonic vessels of hydrogen, the application of it is mostly in airspace (and rockets), heavy road transport and as a source for the chemical industry. The latter is governed by other work packages of the project GroenvermogenNL and is therefore not discussed here.

[37] https://www.iso.org/standard/56546.html.

In chapter 4 of the standard, three hydrogen applications were identified for basic hydrogen infrastructure: production, storage & transport and hydrogen end use applications. Regarding the latter, the standard mentions possible applications: fuel cells, combustion reciprocating and turbine engines, turbines, rocket thrusters, process feedstock and (mixed) within the gas infrastructure. Furthermore, the chapter elaborates on the different types of components that are typical for hydrogen systems, detection methods and environmental effects. Chapter 5 describes the basic properties of hydrogen, such as the atomic and molecular properties. It mentions also its appearance and general characteristics: gaseous hydrogen is flammable, non-toxic, non-corrosive, colourless, odourless, tasteless, and does not support life, whereas liquid hydrogen is non-corrosive and transparent with a light blue tint.

Chapter 6 provides safety considerations for the use of gaseous and liquid hydrogen. It describes related hazards involved as a consequence of the properties of hydrogen and factors involving in combustion hazards. Here it elaborates on different aspects of combustion, non-premixed combustion processes and explosions, whereby it explains how detonation and the transition from deflagration to detonation works, as well certain safety considerations. Chapter 6 further discusses factors involved in pressure hazards, low temperature hazards, hydrogen embrittlement hazards and health hazards. Chapter 7 focuses on mitigation and control of hazards and risks, covering prevention and mitigation of fire and explosion hazards and risks, detection, considerations for operations and facilities and recommended practices for organizations. Annexes A-D provide informative data on the hydrogen properties, hydrogen combustion data, material data and other storage options.

3.2.2. Hydrogen Fuel Quality – product specification

ISO 14687:2025[38] 'Hydrogen Fuel Quality – Product Specification' defines minimum quality specifications for hydrogen fuel intended for use across residential, commercial, industrial, vehicular, and stationary applications. The standard establishes parameters designed to ensure safe operation and adequate performance, particularly in light of hydrogen's increasing integration into energy systems aimed at reducing greenhouse gas emissions. This standard includes specific quality requirements for different types of applications, such as Proton Exchange Membrane (PEM), fuel cell road vehicle applications and PEM fuel cell stationary applications.

By setting consistent quality criteria, the standard supports technological development, facilitates market adoption, and promotes compatibility between hydrogen production, storage, and end-use systems, while contributing to broader objectives related to environmental sustainability and energy security. The significance of ISO 14687 therefore lies in its role in harmonizing hydrogen fuel quality to enable reliable and efficient use in emerging and established technologies, including PEM fuel cells and hydrogen-fuelled internal combustion engines.

For PEM fuel cell applications (for road vehicles) ISO set the purity level of hydrogen on 99,97%. Analytical methods to measure the impurities with the hydrogen are published in ISO standard: ISO 21087:2019 'Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles'[39]. This standard provides a list of suitable analytical techniques used to measure each impurity in hydrogen, according to the specification of hydrogen grade D defined by ISO 14687-1. There is also a close relationship with ISO 19880-8:2024 part 8 (see section 3.2.5).

3.2.3. Road vehicles: hydrogen blends fuel components

The ISO standard 12619 'Road vehicles – Compressed gaseous hydrogen and hydrogen/methane blends fuel components' covers over 16 specific (mostly vertical) standards. These series of standards[40] specify the general requirements and definitions for compressed gaseous hydrogen (CGH_2) and hydrogen/natural gas blend fuel system components intended for use in motor vehicles as defined in

[38] https://www.iso.org/standard/82660.html.

[39] https://www.iso.org/standard/69909.html.

[40] All of them are findable on the website: https://www.iso.org/search.html?PROD_isoorg_en%5Bquery%5D=12619.

ISO 3833. Every five years the ISO reviews the standards. If they are confirmed they still apply and are considered to be up to date. In these series of standards many related subjects are covered:

ISO 12619-1:2014 part 1 covers in 8 pages the general requirements and definitions. It also provides general design principles and specifies requirements for instructions and markings.

ISO 12619-2:2024 part 2 specifies in 11 pages the performance and general test methods. It was amended two years later by ISO 12619-2:2014/Amd 1:2016.

ISO 12619-3:2014 Part 3 specifies in 6 pages tests and requirements for the pressure regulator.

ISO 12619-4:2016 part 4 deals in 5 pages with the standards on the check valve.

ISO 12619-5:2016 part 5 covers in 5 pages the standards on the manual cylinder valve.

ISO 12619-6:2017 part 6 specifies in 5 pages the requirements for the automatic valve. It explicitly states that this document may not apply to fuel cell vehicles in compliance with international guidelines.

ISO 12619-7: 2017 part 7 sets out the standards for the gas injector of the vehicles in 6 pages.

ISO 12619-8:2017 part 8 provides the standards for the pressure indicator in 5 pages. It is noted that all references to pressure in ISO 12619-8:2017 are considered gauge pressures unless otherwise specified.

ISO 12619-9:2017 part 9 specifies the tests and requirements for the pressure relieve valve (PRV) in 5 pages. It refers to gauge pressures unless otherwise specified.

ISO 12619-10:2017 part 10 provides in 12 pages the tests and requirements with regard to the pressure relieve device (PRD).

ISO 12619-11:2017 part 11 sets out the standards for the Excess flow valve in 6 pages.

ISO 12619-12:2017 part 12 concerns the tests and requirements for gas tight housing and ventilation hoses. It covers 5 pages.

ISO 12619-13:2017 part 13 specifies in 4 pages the tests and requirements for the rigid fuel line in stainless steel.

ISO 12619-14:2017 part 14 deals with the tests and requirements for the flexible fuel line in 6 pages.

ISO 12619-15:2017 part 15 covers the specifications for the tests and requirements for the filter (4 pages).

ISO 12619-16:2017 part 16 specifies in 5 pages the tests and requirements for the fittings.

In all cases they do not apply to liquefied hydrogen (LH2) fuel system components, fuel containers, stationary gas engines, container mounting hardware, electronic fuel management and refuelling receptacles.

3.2.4. Hydrogen Generators

The first standard (ISO 16110-1:2007 'Hydrogen generators using fuel processing technologies' Part 1: Safety)[41] applies to packaged, self-contained, or factory-matched hydrogen generation systems with a production capacity of less than 400 m³/h, measured at 0 °C and 101.325 kPa. These systems, hereafter referred to as hydrogen generators, convert an input fuel into a hydrogen-rich output stream with a composition and operating conditions appropriate for downstream hydrogen-utilizing devices, such as fuel cell power systems or hydrogen compression, storage, and delivery systems.

The scope includes hydrogen generators that operate using one or a combination of the following input fuels:

- Natural gas and other methane-rich gases originating from renewable (biomass-based) or fossil fuel sources, including but not limited to landfill gas, digester gas, and coal mine gas.
- Fuels derived from oil refining processes, such as diesel, gasoline, kerosene, and liquefied petroleum gases (in example propane and butane).

[41] https://www.iso.org/standard/41045.html.

- Alcohols, esters, ethers, aldehydes, ketones, Fischer-Tropsch liquids[42], and other suitable hydrogen-rich organic compounds derived from renewable (biomass-based) or fossil fuel sources, including methanol, ethanol, dimethyl ether, and biodiesel.
- Gaseous mixtures containing hydrogen, such as synthesis gas and town gas.

This standard covers 75 pages and is applicable to stationary hydrogen generators intended for indoor and outdoor use in commercial, industrial, light industrial, and residential settings. It is a product safety standard, with the goal to identify and address all significant hazards, hazardous situations, and events associated with hydrogen generators when operated as intended and under conditions anticipated by the manufacturer, with the exception of hazards related to environmental compatibility and installation conditions.

ISO 16110-2:2010 'Hydrogen generators using fuel processing technologies Part 2: Test methods for performance'[43] deals with test methods for performance and covers 38 pages. A review (Approved Work Item) is currently being developed. This standard specifies test procedures for evaluating the performance of packaged, self-contained, or factory-matched hydrogen generation systems with a production capacity of less than 400 m³/h, measured at 0 °C and 101.325 kPa. These systems, hereafter referred to as hydrogen generators, convert an input fuel into a hydrogen-rich output stream with a composition and operating conditions appropriate for downstream hydrogen-utilizing devices, such as fuel cell power systems or hydrogen compression, storage, and delivery systems.

For safety around hydrogen applications, it is not uncommon that member states develop national standards as well. In example, in the Netherlands, there is the standard 'NPR 8090 on hydrogen and fuel cells'[44] and the national standard for hydrogen generators – mobile applications is currently being developed.[45] In France the national standardization body AFNOR developed: 'NF M58-003 Systèmes de production d'hydrogène par procédé électrolytique - Guide d'installation' for hydrogen systems.[46]

3.2.5. Gaseous Hydrogen Fuelling stations ISO 19880

Concerning refuelling stations, there is a standard widely used at global level (norm ISO 19880) that recommends the minimum design characteristics for safety and, where appropriate, for performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty land vehicles (e.g. Fuel Cell Electric Vehicles). It is a series of several standards:

ISO 19880-1:2020[47] part 1 defines the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles (e.g. fuel cell electric vehicles). It covers 173 pages.

ISO 19880-2:2025[48] part 2 specifies in 35 pages safety requirements and associated test methods for components and systems that facilitate the transfer of compressed hydrogen to hydrogen-fuelled vehicles, as defined in ISO 19880-1, using hydrogen dispensers with dispensing pressures up to the H70 pressure class designation.

ISO 19880-3: 2018[49] part 3 provides the requirements for the safety performance of high-pressure gas valves that are used in gaseous hydrogen stations of up to the H70 designation. It covers 30 pages and

[42] The Fischer–Tropsch process is a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen, known as syngas, into liquid hydrocarbons.

[43] https://www.iso.org/standard/41046.html.

[44] See NPR 8090:2013, *waterstof en brandcelaggregaten,* www.nen.nl.

[45] See NTA 8091 *"Waterstofaggregaten - Mobiele toepassingen"*, announced via https://www.nen.nl/media/PDF/Overzicht_nieuwe_en_lopende_NTA_projecten_28.pdf.

[46] https://www.boutique.afnor.org/fr-fr/norme/nf-m58003/installation-des-systemes-mettant-en-oeuvre-lhydrogene/fa167332/42499.

[47] https://www.iso.org/standard/71940.html

[48] https://www.iso.org/standard/85839.html.

[49] https://www.iso.org/standard/64754.html.

the following gas valves: check valve, excess flow valve, flow control valve, hose breakaway device, manual valve, pressure safety valve and the shut-off valve.

ISO 19880-5:2025[50] **part 5** specifies in 29 pages the safety requirements for material, design, manufacture and testing of gaseous hydrogen hose and hose assemblies for hydrogen fuelling stations.

ISO 19880-7:2025[51] **part 7** identifies in 23 pages the requirements for rubber O-rings and their housing dimensions which seal gaseous hydrogen in high-pressure hydrogen devices used in hydrogen fuelling stations.

ISO 19880-8:2024[52] **part 8** sets out the protocol for ensuring the quality of the gaseous hydrogen at hydrogen distribution facilities and hydrogen fuelling stations for proton exchange membrane (PEM) fuel cells for road vehicles. It covers 36 pages.

ISO 19880-9:2024[53] **part 9** outlines the requirements from hydrogen fuelling stations for samples taken at the dispenser. It provides the best practice for sampling at the nozzle of a hydrogen fuelling station in 39 pages.

3.2.6. Other ISO standards[54]

More standards are under development, such as the ISO/AWI 19980-11 part 11 for high pressure liquid hydrogen pumps or the ISO/CD TS 19880-10 part 10 covering the specifications for mobile fuelling stations.

With regard to the scope of this report, some needs to be highlighted.

- ISO/TC 58/SC 3 ISO 11119-1:2020 on ‘Design, construction and testing of refillable composite gas cylinders and tubes — Part 1: Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l’
- ISO/TC 58/SC 3 ISO 11119-2:2020 on ‘Design, construction and testing of refillable composite gas cylinders and tubes — Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners’.
- ISO/TC 58/SC 3 ISO 11119-3:2020 on ‘Design, construction and testing of refillable composite gas cylinders and tubes — Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with non-load-sharing metallic or non-metallic liners or without liners’.
- ISO/TC 58/SC 3 ISO 11119-4:2016 on ‘Refillable composite gas cylinders — Design, construction and testing — Part 4: Fully wrapped fibre reinforced composite gas cylinders up to 150 l with load sharing welded metallic liners’.
- ISO/TC 19885-1:2024 on Fuelling protocols ISO/TC 19885-1:2024 on Fuelling protocols for hydrogen-fuelled vehicles — Part 1: Design and development process for fuelling protocols’
- ISO 22734:2019 Part 1 on ‘Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications’.

The ISO standards mentioned here are the most frequently used standards related to hydrogen applications and fuelling technologies. Some ISO standards have been adopted by the CEN/CENELEC and integrated into the European standardization system. In chapter 4 more detailed description is provided.

3.3. International Electrotechnical Commission

The International Electrotechnical Commission (IEC) is a global organization, founded in 1906, preparing and publishing international standards for all electrical, electronic and related technologies.

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[50] https://www.iso.org/standard/87684.html.

[51] https://www.iso.org/standard/81701.html.

[52] https://www.iso.org/standard/83949.html.

[53] https://www.iso.org/standard/82251.html.

[54] All of them are findable on the website: https://www.iso.org/search.html?PROD_isoorg_en%5Bquery%5D=12619.

These are known collectively as “electrotechnology”.[55] They bring almost 170 countries together, working with over 30.000 experts on the safety of electrotechnology. Based on the Dresden Agreement and later reconfirmed by the Frankfurt Agreement, the IEC works closely with the CENELEC (see section 4.2) whereby almost 80% of the standards of CENELEC are identical to or based upon the IEC standards.[56]

Regarding the way in which these standards are made and their legal status, these are similar to ISO. The standards target the specific group of manufacturers and (end) users and are drafted by experts in the field. Also, the legal status is similar to ISO standards: they are voluntary and non-binding, unless otherwise specified by competent European and national authorities.

The IEC standards on fuel cell technologies are in particular relevant for hydrogen vehicles. Similar to ISO standards, these IEC charges fees for access as well. The core series for hydrogen is IEC 62282, a series of standards developed by the Technical Committee 105 (IEC/TC 105).

IEC 62282-2-100: Fuel cell technologies – Part 2-100: Fuel cell modules – Safety.[57] This one covers 90 pages and provides safety related requirements for construction, operation under normal and abnormal conditions and the testing of fuel cell modules.

IEC 62282-3-100:2019 Fuel cell technologies – Part 3-100: Stationary fuel cell power systems – Safety[58] applies to stationary packaged, self-contained fuel cell power systems or fuel cell power systems comprised of factory matched packages of integrated systems which generate electricity through electrochemical reactions. It covers 166 pages.

IEC 62282-3-200:2025 Fuel cell technologies – Part 3-200: Stationary fuel cell power systems – Performance test methods.[59] covers operational and environmental aspects of the stationary fuel cell power systems performance. The test methods apply as follows: (a) power output under specified operating and transient conditions; (b) electrical and heat recovery efficiency under specified operating conditions; (c) environmental characteristics, for example, exhaust gas emissions, noise, under specified operating and transient conditions.

It is worth noting that the European Standardization body (CEN/CENELEC, discussed below in section 4.2) in some cases adopted the IEC standards, as well as the Dutch standardization body NEN.

3.4. International Harmonization Council

The International Harmonization Council is a cooperation effort between four continental standardization organizations: Compressed Gas Association (CGA) that covers the area of the United States and Canada, European Industrial Gas Association (EIGA), Asia Industrial Gases Association (AIGA) and Japan Industrial and Medical Gases Association (JIMGA).

The goal of the International Harmonization Council is to harmonize standards, including those on hydrogen. There are currently 18 existing harmonized standards covering hydrogen. These standards cover carbon footprint and GHG Emission Technology (ISO/TS 19870), safety and storage of hydrogen (ISO/TR 15916), hydrogen refuelling infrastructure (ISO 19880) or hydrogen quality (ISO 14687). It is worth noting that in most cases the harmonized standard can be identified by the name, combining the letters of the organizations such as “UN/EN”; however, within the IHC the members publish the standards under their own reference. For example, the document on safe quantities of oxygen is known as “CGA G-4.11” and “EIGA doc. 139”.[60]

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[55] www.iec.ch/who-we-are.

[56] https://www.cencenelec.eu/about-cenelec/cenelec-and-iec-cooperation/.

[57] https://webstore.iec.ch/en/publication/59780.

[58] https://webstore.iec.ch/en/publication/59566.

[59] https://webstore.iec.ch/en/publication/76289.

[60] CGA G-4.11 can be accessed via https://webstore.ansi.org/standards/cga/cga112017 and EIGA doc. 139 via https://www.eiga.eu/uploads/documents/DOC139.pdf.

4. European framework

4.1. European Union legislation

In the European Union there are several EU directives that have introduced rules on the use of hydrogen. The most relevant are the ATEX directives and the SEVESO III directive. However, this does not cover the entire framework of European legislation on hydrogen. In general, European Directives state *what* shall be done, and regulations and standards outline *how* the Directive requirements can be achieved.

4.1.1. ATEX Directives

The ATEX Directives (derived from the French *Appareils destinés à être utilisés en ATmosphères EXplosibles*) represent the cornerstone of European industrial safety for environments where explosive mixtures of air and flammable substances are present. There are two ATEX directives: ATEX 114[61] on safe equipment design and ATEX 137[62] for safety within the workplace. In the ATEX classification system, hydrogen is placed in Gas Group IIC, the most volatile category. This requires equipment with the highest level of protection, such as tighter flameproof gaps or stricter intrinsic safety parameters. For the hydrogen sector, ATEX compliance is a fundamental technical requirement, given hydrogen's unique combustion characteristics.

ATEX 114

In 1994 the first ATEX directive on equipment was published (Directive 94/9/EC, also known as ATEX 95 as a reference to art. 95 of the EC Treaty, later art. 114 TFEU) which was replaced by Directive 2014/34/EU (ATEX 114, as a reference to art. 114 of the TFEU dealing with the establishment of the internal market). The legal foundation of the ATEX 114 is art. 114 TFEU. This provision empowers the Union to implement measures aimed at the approximation of national laws, thereby facilitating the establishment and seamless operation of the internal market. In accordance with the Treaty, such legislative frameworks must prioritize a high level of protection regarding public health, safety, and environmental integrity. Consequently, the Directive serves a dual mandate: ensuring the free movement of goods within the Union while simultaneously upholding rigorous safety standards for equipment used in potentially explosive atmospheres.[63] It applies to technical and non-technical equipment, protective systems, safety devices and components for use of explosive atmospheres. Manufacturers must ensure that their products meet the essential requirements for safety and health, perform conformity assessments and use the "Ex- marking".

ATEX 114 classifies equipment based on the level of protection it provides. Hydrogen has a very low ignition energy and high flame speed. Art. 1 – 3 define the scope of the Directive, art. 4 – 11 basically sees on the obligations of the manufacturers, importers and distributors, such as labelling their products or keep copies of the EU declaration of conformity. Art. 12 – 16 covers the rules on (the assessment of) the conformity of the products. Chapter 4, art. 17 – 33 regulates the procedure on the notification of conformity assessment bodies. Art. 34 – 38 discuss the surveillance and control of products placed on the market and art. 39 – 43 concern the final provisions such as penalties for violating and the implementation deadline for member states.

The manufacturer is responsible to verify if the product is within the domain of the ATEX 114 or not (art. 6). An ATEX analysis begins with a clear definition of the equipment or product. Components of the equipment should also be assessed (art. 6 paragraph 2 juncto art. 13 paragraph 3). Furthermore, art. 13 obliges the manufacturer to draw up technical documentation (referred to in annex III – IX) and to carry out the relevant conformity assessment procedure. In art. 12 paragraph 1, a reference is made to

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[61] Directive 2014/34/EU of the European Parliament and of the Council 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 (recast), OJ L 96/309.

[62] Directive 1999/92/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, OJ L 23/57.

[63] European Commission, Guidelines for implementing ATEX 2014/34/EU, 4th edition, November 2022, p. 14-15.

(harmonized) standards: "*Products which are in conformity with harmonised standards or parts thereof the references of which have been published in the Official Journal of the European Union shall be presumed to be in conformity with the essential health and safety requirements set out in Annex II covered by those standards or parts thereof*."

The deadline for transposing the directive into national legislation was 19 April 2016 and, in the Netherlands, the Directive was implemented into the 'Warenbesluit Explosief Materiaal 2016'.[64]

ATEX 153

Directive 1999/92/EC is referred to as ATEX 153 (as a reference to art. 153 of the TFEU) and is also known as ATEX 137 (as a reference to art. 137 of the EC Treaty). It complements Directive ATEX 114. Contrary to ATEX 114 is the legal foundation of ATEX 153 on the social, working environment. Therefore, the ATEX 153 is also referred to as the ATEX Worker protection Directive and is considered the 'social' or 'workplace' directive next to the 'product' directive. Stakeholders primarily engaged with ATEX 153 are those involved in the organization's core processes, including plant and machinery operators, installation technicians, maintenance engineers, and logistics personnel. It provides obligations for employers to protect their employees and defines minimum requirements, which every employer must apply to improve the safety and health protection of his employees potentially at risk from explosive atmospheres. Every employer shall assess specific risks arising from an ATEX, by taking into account the risks mentioned in article 4.

The ATEX 153 is a (horizontal cross-cutting) directive containing rules that apply to all sectors where an explosive atmosphere may occur and therefore applies to situations where hydrogen is produced, transported or used in applications, due to the explosive characteristics of hydrogen.

Art. 1-2 contain information on the object and scope and the definition of 'explosive atmosphere'. Art. 3-10 govern the obligations for the employer, including the risk assessment, duty of coordination, holding an up-to-date explosion protection document and rules on prevention and protection against explosive atmospheres. Art. 11-15 are the miscellaneous provisions, including the obligations for member states on the implementation. The annexes provide more information on the classification of places where explosive atmospheres may occur (Annex I), minimum requirements for improving the safety and health protection of workers (Annex II) and the symbol for explosive atmospheres (Ex) is in Annex III.

The deadline for transposing the clauses into national law was set for 30 June 2003 and is in the Netherlands, since July 2006, implemented in the 'Arbeidsomstandighedenbesluit'.

4.1.2. Chemical Agent Directive (98/24/EC)

Next to ATEX workers directive 153, another important directive came from the (what is also called the mother-) directive on occupational safety and health framework.[65] Council Directive 98/24/EC[66] (also known as the Chemical Agents Directive (CAD) establishes the minimum requirements for protecting workers from the risks associated with chemical agents at the workplace (art. 1). While the CAD is often associated with toxic chemicals (like solvents or heavy metals), its application to hydrogen is critical due to hydrogen's classification as a "hazardous chemical agent" under the Regulation for classification, labelling and packaging (CLP Regulation (EU) 1272/2008)[67]. The CAD is a (horizontal cross-cutting) directive applying to all situations and sectors where chemical substances are produced, handled, stored, generated and used and due to its characteristics, it also applies to situations where there is hydrogen used, stored, produced, transported, generated et cetera.

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[64] Official Documents, Staatsblad 2020/26, 23 January 2020. See Milestone 3.1.1 part II, second part of this report on safety standards within the licensing and permitting procedures.

[65] See Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, OJ L183/1.

[66] 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 (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), OJ L 131/11.

[67] Regulation 1272/2008/EC of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, OJ L 353/1.

In the Netherlands, the CAD is implemented in the 'Arbeidsomstandighedenwet' (with regard to the duty of care)[68] and its underlying legislation, such as the 'Arbeidsomstandighedenbesluit' (i.e. art. 4.1 for the risk assessment or 4.3 for the hierarchy of control) and the 'Arboregeling'. Although risk assessment was already mandatory under the "mother" Directive in 1989, it was the CAD in 1998 that set details for chemical risk assessment`. Substantial and significant information on risk assessment are available in many countries and sectors (i.e. via trainings, specialists' services and support tools).[69]

There is also a close link with the 'Publicatiereeks 35', which will be further discussed in Part II of this report, dealing with the standards within the Netherlands. Whereas art. 4 CAD prescribes a risk assessment for dangerous substances (such as hydrogen) and discusses the exposure limits for workers with a focus on prevention and control, the PGS 35 provides more precise technical measures for handling the installation. Furthermore, the CAD is closely related to the ATEX directives (see section 4.1.1) and the SEVESO Directive (see section 4.1.4).

4.1.3. Pressure Equipment Directive (2016/68/EU)

The first Pressure Equipment Directive (PED) 97/23/EC entered into force on 29 November 1999, and mandatory implemented into national law by 30 May 2002. This Directive was repealed by Directive (PED) 2014/68/EU entered into force on 20 July 2016 and should be implemented in national law by 2 March 2018. The PED is a set of European standards and applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0,5 bar. It is relevant to hydrogen applications with, for example, hydrogen storage vessels, refuelling station components, piping and safety accessories. It requires that manufacturers place the CE marking and that the product meets all relevant criteria in the PED. In order to minimize ignition risks, the PED works together with the ATEX 114. The PED is a horizontal cross-cutting directive, applying to all sectors where pressure equipment is used. It is not only addressing manufacturers providing design and manufacturing requirements but also presenting essential safety requirements for pressure hazards.

The scope of the PED encompasses four primary categories of hardware:

1. Pressure Vessels: Housings engineered to contain fluids under pressure, including complex integrated components.
2. Piping Systems: Conduits intended for the transport of fluids within a pressurized circuit.
3. Safety Accessories: Critical instruments designed to prevent the exceedance of operational limits (e.g., pressure relief valves, buckling pins).
4. Pressure Accessories: Functional components with pressure-bearing housings, such as regulators or filters.

Within the Netherlands, the requirements of Directive 2014/68/EU are implemented in the 'Warenwetbesluit Drukapparatuur 2016' and the 'Warenwetregeling Drukapparatuur 2016'. The implementation of this Directive in the Netherlands will be discussed in part II.[70]

4.1.4. SEVESO III Directive (2012/18/EU)[71]

When hydrogen is being stored in large quantities, the EU Directive 2012/18/EU SEVESO III is one of the most important directives, since it demands from operators of storage facilities to develop and implement procedures on planning and responses. This is the third SEVESO directive, after the second one in 1996 (Directive 96/82/EC SEVESO II) and the first one that was adopted in 1982 (Directive

[68] See also chapter 4.2 in J.C.W. Gazendam, K. Hofman-Filadoro en M. den Uijl, Waterstof: normen bij vergunningverlening, Hanze Groningen, GroenvermogenNL, Part II, maart 2026.

[69] L. Lissner and R. Zayzon, *Is the European Directive 98/24/EC on chemical agents effective? Evaluation of its practical implementation at workplaces,* Gefahrstoffe Reinhaltung der Luft, 71, p. 250.

[70] See J.C.W. Gazendam, K. Hofman-Filadoro en M. den Uijl, Waterstof: normen bij vergunningverlening, Hanze Groningen, GroenvermogenNL, Part II, maart 2026.

[71] 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, OJ L 197/1.

82/501/EEC). SEVESO III, as well as its predecessors, aims at preventing major accidents involving dangerous substances and limit their consequences for humans and the environment.

SEVESO III is a (horizontal cross-cutting) directive applying to any establishment where substances listed in Annex I, are present (or likely to be generated during an accident) in quantities exceeding specific thresholds. It applies a two-tier system: there is a low tier establishment falling within the second column of Annex I (5 – 50 tonnes of storage). There is also the upper tier establishment, which is for storage of 50 tonnes or more of the dangerous substance such as hydrogen. SEVESO III places a burden of proof on the operator. Art. 5 provides general obligations for the operators and art. 7 obliges the operator to notify the competent authority of the establishment's existence, as well as the substances present and the potential hazards. Art. 10 determines that a safety report is obligatory for the upper tier establishments. Art. 15 states that member states shall ensure that the public can provide their opinion regarding individual projects, and the public should also be informed by public notices and other appropriate means (paragraph 2). Furthermore, the directive includes obligations on how information should be supplied by operators and member states following a major accident.

This directive is particularly important for national permit-granting procedures. In the Netherlands the installations that meet the criteria of the SEVESO directive, i.e. exceeding 50.000k of hydrogen, are considered to be an activity that is harmful for the environment and are subject to a more stringent regime of safety requirements.[72] Hydrogen is categorized by its low ignition energy and wide flammability range (4% - 75% in air). In the Netherlands this directive is implemented into the "Omgevingswet" and the 'Besluit Activiteiten Leefomgeving'. For the safety control system, usually the National Technical Agreement NTA 8620[73] is being referred to.

4.2. CEN/CENELEC

CEN (European Committee for Standardization) and CENELEC (European Committee for Electrotechnical Standardization) are the backbone of technical safety and interoperability in Europe. CEN is the association bringing 24 national standardization bodies together of 34 European countries. It provides a platform for the development of technical standards in relation to various kinds of products, materials, services and processes in the broadest sense covering sectors such as health, consumer products, air and space, food or energy.[74] CENELEC is part of the same association and supports standardization activities in relation to a wide range of fields and sectors including electromagnetic compatibility, primary cells and batteries, electric motor or smart grids.[75]

Authors and audience

There are over 50 CEN and CENELEC Technical Committees that involves hydrogen since it is a cross-sector topic. The CEN-CENELEC Coordination Group on Hydrogen ensures coordinated and efficient standardization by aligning efforts with EU policies and the European Clean Hydrogen Alliance (ECH2A) Roadmap.[76] The CEN and CENELEC delegated the work of the actual standardization to technical committees and joint technical committees, and (often underlying) working groups, that consist predominantly out of representatives from national standardization bodies, as well as the representatives from commercial firms, trade organizations or consumer groups.[77]

Often these committees have their secretariat in one of the national standardization bodies. One of the committees that focuses on hydrogen for energy systems is Committee CEN/CLC/JTC/ 6, and its

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[72] See section 4.2.2.1.1. of Part II (Gazendam, Hofman-Filadoro, Den Uijl 2026).

[7373] https://www.sccm.nl/waarom-nta-8620.

[74] See www.cencenelec.eu/about-cen/.

[75] See www.cencenelec.eu/about-cenelec/.

[76] www.cencenelec.eu/areas-of-work/cen-sectors/energy-and-utilities-cen/hydrogen/. See for the roadmap: https://ec.europa.eu/docsroom/documents/53721.

[77] M. Egan, *Constructing an European market: Standards, Regulations and Governance,* Oxford University Press, 2001, p. 133 et seq.

secretariat is placed by the Dutch standardization organization NEN.[78] This committee is established in 2016 following the recommendations in the report of 2015 by the Working Group on hydrogen of the CEN. Since it is closely linked to the focus of CENELEC they established a joint technical committee (JTC) filling the European gap on normalization of hydrogen. Within the CEN/CLC/JTC 6, there are three different working groups: WG 1 focuses on terms and definitions, WG 2 deals with the specifics on guarantees of origin[79] and WG 3 is a hydrogen and safety Ad hoc group: interface electrolyzer to the e-grid.

There is an overlap with regard to the guarantees of origin for hydrogen with Committee CEN/CLC/JTC 14 working group 5 that has a specific focus on guarantees of origin related to energy. The Technical Committee of CEN, CEN/TC 268 covers the storage and transport of liquid hydrogen and CEN/TC 23 focuses on the storage and transport of compressed hydrogen. The injection of hydrogen and the mixture of hydrogen with natural gas into the natural gas infrastructure is covered within the scope of CEN/TC 234.

In general CEN/CENELEC standards apply in the entire European Market including all its manufacturers and consumers, since standards are an important means to achieve the European Internal Market.

Legal status

While they are private, non-profit associations, they hold a unique "quasi-legislative" status in the EU.[80] In earlier rulings of the European Court of Justice, it has been determined that “harmonized standards are part of European law”.[81] It has led to some discrepancies within the legal order related to the rule of law within the EU. There is ambiguity whether or not these standards should then become freely accessible without costs. It goes beyond the scope of this research to elaborate extensively on the matter. In 2025, the European Commission published its communication on a Single Market Strategy in an uncertain geopolitical world. Here it devoted a paragraph on the status of standards. "*Standards are the embodiment of innovation and are at the core of a resilient, green and digital Single Market. They provide legal certainty, facilitate access to new technologies and boost the global competitiveness of EU businesses. However, our standardisation framework struggles to meet market and policy needs, in particular on timeliness, inclusiveness and access to standards. Businesses are faced with the absence or late availability of harmonised standards, generating costs and uncertainty, hampering their competitiveness and slowing down the uptake of new technologies in the Single Market. The Commission will seek to make the EU framework for harmonised standards futureproof by reviewing the Standardisation Regulation.*”[82]

Hence, its legal status is under consideration within a broader process of the revision of the European Standardisation system, whereby Regulation 1025/2012 (EU) on standardization will be revised as well.

4.2.1. Gas cylinders

Several standards apply to gas cylinders that can also be used for hydrogen. In example, there are a substantial number of standards adopted by CEN originally from ISO on gas cylinders, such as:

- EN ISO 11120:2015 on ‘Refillable seamless steel tubes of water capacity between 150 l and 3000 l. Design, construction and testing’
- EN ISO 11623:2023 on ‘Composite construction - Periodic inspection and testing’
- EN ISO 7866+A2:2025 on ‘Refillable seamless aluminium alloy gas cylinders – Design, construction and testing’

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[78] www.nen.nl.

[79] Guarantees of origin are used in the energy sector to prove the origin of energy.

[80] Both organizations are private organizations, whereto the EU delegated the authority for standardization.

[81] See case C-613/14 (*James Elliott Construction v Irish Asphalt*), ECLI:EU:C:2016:821 para. 40-43 and case T-185/19 (*PRO and Right to Know v Commission*), ECLI:EU:T:2021:445 paras 53-54.

[82] See Communication European Commission, *The Single Market: our European home market in an uncertain world: A Strategy for making the Single Market simple, seamless and strong,* Brussels, 21.5.2025 COM(2025) 500 final, p. 9-10.

Furthermore, CEN developed over 18 standards on gas cylinders, from very specific till more broader standards. With regard to the scope of this report, some needs to be highlighted.

- EN 12862:2000 on 'Transportable gas cylinders – Specification for the design and construction of refillable transportable welded aluminium alloy gas cylinders'
- EN 13322-1:2024 on 'Refillable welded steel gas cylinders – Design and construction – Part 1: Carbon steel'
- EN 17339:2024 (under amendment): on 'Hoop wrapped and fully wrapped carbon composite cylinders and tubes for hydrogen'.
- EN 17533:2025 on 'gaseous hydrogen – cylinders and tubes for stationary storage'.

There are also very specific standards with regard to gas cylinders, such as EN 12257:2002, EN 13807:2017 or the EN 16325:2025. For a more detailed overview, the CEN provides an overview of the hydrogen landscape of standards and technical committees.[83]

4.2.2. Transportation and Fuelling stations

Using hydrogen in fuelling stations is a relevant new application of hydrogen. However, hydrogen fuelling stations and hydrogen used in transportation has become increasingly relevant. The Alternative Fuel Directive of 2014 instigated the development of a substantial number of hydrogen fuelling stations within the European Union. With regard to the safety standards the following standards of CEN are relevant:

- EN 17124:2022 on 'Product specification and quality assurance for hydrogen refuelling points dispensing gaseous hydrogen – Proton exchange membrane (PEM) fuel cell applications for vehicles'.
- EN 17127:2024 on 'Outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocols'.
- EN 45545-7:2013 on 'Railway applications – Fire protection on railway vehicles – Part 7: Fire safety requirements for flammable liquid and flammable gas installations'.
- EN 16509:2014 on 'Transportable gas cylinders. Non-refillable, small transportable, steel cylinders of capacities up to and including 120 ml containing compressed or liquefied gases (compact cylinders). Design, construction, filling and testing'.

When it comes to transportable gas cylinders, the standards mentioned above in chapter 4.2.1 also apply to transportation. For this study the standards with regard to the hydrogen network and infrastructure is not taken into account. There are, however, a substantial number of safety standards applicable to hydrogen infrastructure.

4.2.3. Fuel cell technologies

Fuel cell technologies are used for the production of hydrogen, either industrial or small scale. Within CEN several standards have been developed or are being developed. The following are highlighted:

- EN IEC 62282-8-101:2020 on 'Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of solid oxide single cells and stacks, including reversible operation'.
- EN IEC 62282-8-102:2020 on 'Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of single cells and stacks with proton exchange membranes, including reversible operation'.
- EN IEC 62282-8-201:2020 on 'Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of power-to-power systems'.
- EN IEC 62282-8-301:2023 on 'Energy storage systems using fuel cell modules in reverse mode – Power-to-methane energy systems based on solid oxide cells including reversible operation – Performance test methods'.
- EN 62282-3-400:2022 on 'Stationary fuel cell power systems – Small stationary fuel cell power system with combined heat and power output'.

[83] See https://www.cencenelec.eu/areas-of-work/cen-sectors/energy-and-utilities-cen/hydrogen/.

- EN IEC 62282-8-102 (under development) on ‘Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of single cells and stacks with proton exchange membrane, including reversible operation’.
- EN IEC 62282-8-101 (under development) on ‘Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of solid oxide single cells and stacks, including reversible operation.

More standards are being developed on fuel cell technologies, since the application of it – in particular related to hydrogen – is increasing. Fuel cell technologies will be also more implemented in the maritime and the transportation sectors, which will lead to more standards; however, these sectors are not included in this study.

4.3. European Industrial Gases Association (EIGA)

The European Industrial Gases Association (hereafter: “EIGA”) was established on 15 December 1923 in Paris, under the name “*Commission Permanente Internationale (CPI) de l’acétylène, de la soudure autogène et des industries qui s’y rattachent*”. In 1989, CPI merged with EDIA, the “European Dry Ice Association” (CO2) producers which itself was founded in 1953. The merged association, also known as CPI, moved to Brussels in 1990 and changed its name to the European Industrial Gases Association in April 1991. EIGA standards are renowned standards and focus on the European Region.

EIGA tracks safety incidents involving hydrogen since 1977 and installed a Safety Advisory Council (SAC) that provides every quarter a training package with relevant incidents, their identified sources and the lessons learned for its members.[84] EIGA has over 22 Working Groups, whereby WG11 focuses on hydrogen energy, WG12 on hydrogen production and WG 22 on regulatory energy and climate. However, more working groups publish standards that are relevant to hydrogen fuelling, transport and storage such as WG 6 on cryonic vessels or WG 19 on the REACH EU regulation on protection of the environment and public health.

Authors and audience

Since the standards are meant for industries, the experts taking place in the committees are industrial experts. There is a global network of experts working in the industry contributing to the development of EIGA standards. Working Groups are created by the Councils of EIGA, with the approval of EIGA’s Board of Directors, after establishing a scope and terms of reference for their activities. The Councils fall directly under the EIGA board and ensure that countries and EIGA members are well represented in the WGs. They must also ensure that the experts are qualified and available for the WG activities.[85] The standards are for consumers, producers and transporters of industrial gases or for one who is confronted with these standards in other ways. Although the primary target is users of industrial gases, the application of these standards can be also outside the industrial sector.

Legal status

The EIGA standards are best to be compared to the ISO standards at international level. The region where the EIGA standards are most commonly used is in Europe. When referred to in contractual agreements or, in rare cases, in legislation, the EIGA standards become binding upon these parties or the subjects of the legislation. Other, the EIGA standards are voluntary and non-binding. It is worth noting that unlike ISO, EIGA does not charge fees for the standards, they are in most cases directly accessible via their website.

Although several standards can (indirectly) apply to the storage, transportation or fuel cell technology of hydrogen, this study focuses on the ones most likely to be applied in licensing and permitting

[84] www.eiga.eu.

[85] www.eiga.eu/who-we-are/structure/structure.

procedures. Hence, one of the most relevant standards is EIGA standard 75, providing safety and separation distances.

4.3.1. Hydrogen distribution, storage and applications

Within EIGA Doc 247 'Hydrogen overview – distribution, storage and applications'[86] a guide is found that explains the different types of storage (Type I – IV cylinders) and how to manage small-to-medium storage setups. It covers hydrogen safety, distribution of hydrogen, storage systems and hydrogen applications. It excludes hydrogen production facilities, cylinder filling facilities, detailed facility or plant design and specifications, product quality and transportation by air. This publication provides general information on equipment and methods used in the hydrogen supply chain. It is written in a way to be understood by all, including newcomers to the industry (art. 2.2). Chapter 4 provides information on the physical characteristics of hydrogen and chapter 5 discusses general safety concerns related to hydrogen.

The document further gives a clear and detailed definition of different types of hydrogen, such as gaseous hydrogen (art. 6.2.1), cryogenic liquid hydrogen (art. 6.2.2), chemical hydrogen compounds (art. 6.2.3). It further elaborates in chapter 6 on how hydrogen can be transported, such as transportation of hydrogen by road, rail, inland waterways and sea and pipeline, distribution by packages or by cylinders and tubes. This becomes particularly relevant when using fuel cell technology that converts hydrogen into power, for example with hydrogen generators on rural construction sites or festivals. Chapter 7 covers the higher volume of hydrogen, stored in vessels and containers. Chapter 8 focuses on the application of hydrogen.

4.3.2 Safety and separation distances

The EIGA standard Doc 75/21 "Methodology for determination of safety and separation distances"[87] describes the basic principles to calculate appropriate safety and separation distances for the industrial gases industry. Historically safety distances referred to an effect-based distance; however, due to an increasing density of industrial installations, a shift towards the risk-based distances took place (art. 1).

What is also very clear within EIGA standards is the explanation of the use of wordings in art. 3. Here it is explained what is meant by words such as 'may', 'shall', 'should', 'will' and 'can'. According to art. 3.1.1 "Shall" indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation. Art. 3.1.2 states that "Should" indicates that a procedure is recommended. According to 3.1.3 "May" indicates that the procedure is optional and art. 3.1.4 states that "Will" is used only to indicate the future, not a degree of requirement. Finally, art. 3.1.5 clarifies that "Can" indicates a possibility or ability.

Art. 3.2.1.8 describes a safety distance as "*the minimum separation between a hazard source and an object that will mitigate the effect of a likely foreseeable incident*". Art. 3.2.1.9 distinguishes from this the separation distance "*Distance that will mitigate the effect of a foreseeable incident and prevent a minor incident escalating into a larger incident due to damage to equipment or environment*". Art. 4 explains the connection between both. The safety distance is to provide a minimum separation that will mitigate the effect of any foreseeable event. The separation distance will also provide protection for the equipment from foreseeable external impacts such as roadway, flare or activities outside the control of the operation, for example a plant or customer station boundary and prevent it from escalating into a larger incident. In order to do so, the following steps shall be followed:

1. Identify the hazard sources and events, for example release of gas, taking into account the likelihood.
2. Calculate the effects on neighbouring objects and population taking into account mitigating factors.
3. Determine the safe distance to each object or population to meet the minimum hazard criteria.

[86] https://www.eiga.eu/?s=247.

[87] https://www.eiga.eu/?s=075.

4. Consider additional prevention or mitigating factors and re-calculate safe distance.

The EIGA doc also includes a methodology to identify harm potential (art. 5.2 et seq), foreseeable events and includes calculation principles for thermal or explosion effects as well. This standard is particularly important for this study, due to its general applicability. It is a horizontal cross-cutting standard, applicable to the industrial gases industry, for all equipment, pipework and storage; hence, it applies to hydrogen within the scope of this study as well.

4.3.3 Gaseous hydrogen installations

When discussing applications of hydrogen, the EIGA Doc 15/21 on 'Gaseous hydrogen installations'[88] becomes relevant. This standard addresses the compression, purification, filling into containers, and above-ground storage of gaseous hydrogen at industrial consumer sites. It explicitly excludes hydrogen production, transportation, distribution, and underground storage. Additionally, it does not consider safety aspects associated with the utilization or application of hydrogen in technical or chemical processes. Hydrogen fuelling stations are also outside the scope of this document and are instead addressed in other standards, such as ISO 19880-1 (see chapter 3.1 or 2.5). This document of EIGA focuses on the technical requirements for gaseous storage and the layout of supply stations. It is a key reference for permitting under national frameworks, such as the *Publicatiereeks Gevaarlijke Stoffen* (PGS) 35 is used in the Netherlands. This will further be discussed in Part II of this report.[89]

4.3.4 Other EIGA standards

EIGA Doc. 211/24 'Hydrogen Vent Systems for Customer Applications'[90] is particularly relevant for manufacturers and operators of fuelling stations for hydrogen. This standard does not only covers the design, installation and maintenance of hydrogen vent systems used for equipment located at a customer site, but also applies to hydrogen fuelling stations with standard supplies of hydrogen (liquid, gas bulk, gas cylinders, on-site production of less than 5000 Nm3/hr of hydrogen), ex chapter 3. According to chapter 4, the size of the venting system matters, while chapter 5 covers the structural design. Chapter 9 also includes safety on location and the separation distances. In phase two of this study (the development of the ICT tool, see section 1.2), these distances will be compared with the safety distances mentioned in PGS 35.

EIGA Doc 100/20: 'Hydrogen Cylinders and Transport Vessels'[91] serves as a comprehensive guide for the safe design, selection, and operation of high-pressure hydrogen storage and transportation equipment. The primary technical driver of this standard is the management of Hydrogen Embrittlement (HE). Hydrogen molecules can diffuse into the crystalline structure of metals (especially high-strength steels), making them brittle and prone to sudden, catastrophic cracking.

EIGA 250/24 'Standard Procedures for Hydrogen Supply Systems'[92] is a harmonized international standard, as discussed in section 3.4, developed in collaboration within the International Harmonization Council. It covers mandatory and recommended procedures for electrical safety, purging and cleaning and emergency responses.

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[88] https://www.eiga.eu/?s=015.

[89] See section 4.3.1.2 of J.C.W. Gazendam, K. Hofman-Filadoro en M. den Uijl, Waterstof: normen bij vergunningverlening, Hanze Groningen, GroenvermogenNL, Part II, maart 2026.

[90] https://www.eiga.eu/uploads/documents/DOC211.pdf.

[91] https://www.eiga.eu/uploads/documents/DOC100.pdf.

[92] https://www.eiga.eu/uploads/documents/DOC250.pdf.

5. Concluding remarks

This research explored the most relevant international and EU safety standards for hydrogen applications. It was found that the European standards have to be read within the context of international standards. These international standards lack the quality of being law in the formal sense. However, the international standards have been developed before the EU legal safety standards were adopted. Therefore, the international standards have influenced regional standards like those in the European Union.

The international standards identified in this research that are relevant to the hydrogen sector are those of the United Nations Economic Commission for Europe, and International Standard Organization. The standards of the former organisation deal with safe application of hydrogen in vehicles. The standards of the latter organisation have a broader scope as they range from the safe usage of hydrogen in general, and the usage in specific activities like hydrogen fuelling stations. There is an European equivalent to the ISO standards as well and they are the standards (called documents) coming from EIGA.

The European standards discussed in this research can be subdivided into two categories. The first category is that of formal EU legislation. This includes the ATEX Directives, CAD Directive and the SEVESO III Directive that are binding on the member states and have to be implemented by national law. The second category is that of European technical safety standards such as enacted by CEN/CENELEC. The standards in this second category lacks the status of formal law but are considered to be quasi-legislative in nature. The current status within the European Union’s legal order is at discussion and subject to revision. These standards are highly relevant for the industry as they are used by the national legislator and are translated into national technical safety standards.

With this analysis of European and international standards the first part of this study into hydrogen safety standards is completed. The second part of the research discusses the national safety standards in the Netherlands and builds upon the outcomes of this research.

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