HIGGS
Hydrogen in Gas Grids

A systematic validation approach at various admixture levels into high-pressure grids

D2.2

Assessment document of RCS barriers and enablers at EU level

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Executive Summary

The HIGGS project started with a review on regulation, standardisation and certification (RSC) barriers at EU level for hydrogen in the gas transmission network. The results are described in the present deliverable report D2.2 “Assessment document of RCS barriers and enablers at EU level”.

The first assessment of the current European regulation, standardisation and certification for hydrogen and hydrogen admixtures in natural gas in the European transmission gas grids and systems has shown that a lot of activities around hydrogen are currently in development. The European Union increased the climate emission reduction goals and subsequently announced their ambitions to publish a separate European hydrogen strategy. A roadmap outlining this strategy is already available. Presently, the European regulative framework does not cover the demands on gas quality of hydrogen and the admissible concentrations of hydrogen in natural gas. The same applies for the current standardisation, where first activities to support hydrogen and hydrogen admission to natural gas have been commenced. Still there is no uniform standard on hydrogen admixture concentrations. A list of CEN/TCs that have started to develop standardisation deliverables related to hydrogen or H2NG has been provided as well as a list of CEN/TCs that could be involved in these activities in the sight of the authors. Furthermore, the roadmap suggestion of CEN and CENELEC shows a possible way towards hydrogen standardisation. Guarantees of origin for hydrogen demanded by the REDII are in operation on a pilot basis and have to be implemented in the member states until July 2021. Resulting from that the timeframe for the standardisation update of EN 16325 is about 20 months. In order to bridge the missing regulation and standards the demand for conformity assessment procedures, e.g. technical well-designed certification programmes, is high and first pilot programmes for condensation boilers are in development. Due to the wide range of potential demand this temporary solution can only serve as a bridge and for selected use cases. Further current testing methods are presented and briefly explained.

The assessment showed, the barrier in regulations, standardisation and certification (RSC) is the fact, that presently the development of the hydrogen energy system in the EU is ahead of the committees work on RSC. The main bottleneck is the timeframe and the different velocities in the European Union and the member countries, in which RSC with respect to hydrogen is either updated, extended or newly developed. Thus, to draw the full map of RSC of all EU member countries a questionnaire was sent out to relevant stakeholders in all member countries. With the input and the results of this questionnaire the RSC map shall be completed and provided in D2.3.

1 Objective

The objective of the present deliverable report is to give a first overview on the current existing European regulations, standardisation and certification (RSC) and testing methods concerning the allowed hydrogen concentrations and gas quality requirements on regards of hydrogen in the transmission gas system.

The deliverable report D2.2 gives the first insight into RSC in Europe by summarising literature and by the consultation of RSC bodies like CEN, DIN and DVGW CERT. Further contact will be established to NEN, AFNOR, KIWA, HIPS-NET and feedback is expected to be gathered and included into D2.3 – Final document review on specific technical and RCS barriers and enablers. In addition, a questionnaire has been sent to the relevant stakeholders in Europe’s gas industry that will complement the deliverable report. It is expected to receive the results in the coming months and the results will be included in D2.3.

2 Introduction

In order to identify possible bottlenecks in the present European legislation, standardisation and certification in regards of hydrogen gas quality and allowed hydrogen concentrations in the natural gas system and its appliances, a comprehensive view on these frameworks is needed. The present report considers the RSC until June 2020.

To generate this assessment document a review on existing literature has been performed. The contact to RSC bodies has been established. Furthermore, knowledge has been gathered from the various experts in the partner's organisations and their insights in the gas sector. It is important to notice that numerous activities are ongoing and are 'work in progress' now. This introduces insecurities since knowledge is not absolute and still subject to developments. It also means that not all information provided can be used in a public deliverable, as it is subject to disclosure and have not yet been published by the respective organisations providing the information themselves. The focus of the HIGGS project is the hydrogen injection into the transmission gas grid at European level. Thus, the scope of this deliverable is the current RSC in Europe. The focus and the development of RSC regarding hydrogen on EU member country level are varying. Some countries are further advanced than others. A detailed analysis of the RSC in the EU member countries is foreseen in deliverable report D2.3 of the HIGGS project. This document (D2.3) will also provide a thorough and more detailed analysis of the subjects covered by this report.

3 Regulation, standardisation and certification map of the European Union

At the Paris climate conference (COP21) in December 2015, around 190 countries adopted the first-ever universal, legally binding global climate agreement. The nations agreed on a long-term goal of keeping the increase in global temperature well below 2 °C above pre-industrial levels and to aim to limit the increase to 1.5 °C. The EU ratified the Paris Agreement in October 2016 [1].

Following the ratification of the Paris Agreement the EU published the initiative “Clean energy for all Europeans” in 2016. The package “Clean energy for all Europeans” consists of eight legislative acts in the fields of energy performance in buildings, renewable energies, energy efficiency, governance regulation and electricity market design. The EU pledged to achieve a 40 % reduction of greenhouse gases until 2030 [2] [3]. The recast of the Renewable Energy Directive is part of this package as well as the national energy and climate plans.

To meet the energy and climate targets of the EU until 2030 the European Commission has issued the Regulation on governance of the energy union and climate action (EU) 2018/1999, which demanded every EU Member State to establish a 10-year integrated national energy and climate plan (NECP) by the end of 2019. The NECPs cover the topics of energy efficiency, renewables, greenhouse gas, emission reductions, interconnections as well as research and innovation [4]. The International Association of Oil & Gas Producers developed an assessment report (2019) to mirror the attitudes of the EU Member States towards the solutions provided by the oil and gas industry including hydrogen. The report concludes that 17 of the 28 EU Member States are positive towards hydrogen. Positive aspects associated with hydrogen in the NECPs are that it provides a system solution (mobility, energy production, energy transport, energy storage and feedstock), stabilises the energy system (integration of intermittent renewable), reduces emissions and allows to utilise the existing gas grid infrastructure [5].

In December 2019, the Commission presented the European Green Deal, which foresees a vast set of actions in all sectors to achieve the climate ambitions and pave the way for transition to a sustainable Union. The climate goals concerning greenhouse gas reductions have been further increased. The goal for 2030 was raised to 50-55 % (a comprehensive plan expected in summer 2020) and no net emissions in 2050. This shall be transformed from a political goal into a binding legal obligation through the European climate law that will be binding for EU institutions and national governments. Also, by July 2020 a new strategy on energy system integration will be presented as part of the Green Deal in order to encourage smart sector integration.

One important element of this strategy will be hydrogen, but due to its key role and its wider scope the European Commission will adopt a new European strategy on hydrogen. This strategy will be in line with the climate goals of the Green Deal and be published in the second quarter of 2020. First ideas have been presented in a hydrogen strategy roadmap in June 2020. The Green Deal will be further supported by the Commission's recovery plan for Europe that aims to soften the impact of the corona crisis on European society and economy [6] [7] [8] [9] [10] [11].

3.1 European Legislation and Regulation concerning hydrogen

European legislation and regulation consist mainly of directives and regulations. While regulations are a legislative binding act, directives are legislative acts with the purpose to set out goals, which must be achieved by the EU member countries. Every EU member country is thereby free in how to achieve these goals and develop individual ways in how to adapt the directive into national law. The current framework of the European legislation does not yet cover hydrogen and hydrogen admixtures in natural gas in the European high-pressure gas transmission grids and systems (e.g. admissible hydrogen concentrations in natural gas (H2NG), quality of hydrogen (pure and as admixture)).

In the following the current existing framework for natural gas will be shortly introduced, which builds a relevant basis for the future framework for hydrogen. The Directive of the European Commission 2009/73/EC sets common rules for the internal market in natural gas. This Directive has been followed by three subsequent Regulations (Regulation (EC) No 714/2009; 715/2009 and 713/2009). The main focus is set on the storage, transmission, distribution and customer-based supply of natural gas [12]. The Commission Regulations (EU) 2015/703 and 2017/460 establish network codes on interoperability and data exchange rules as well as on harmonised transmission tariff structures for gas. The renewable energy Directives (EU) 2009/28/EC and 2018/2001 (RED I & II) promote the use of energy from renewable sources. Regulation (EU) 2016/426 of the European Parliament and of the Council regulates appliances burning gaseous fuels. The Regulation (EU) 2017/1938 of the European Parliament and of the Council from October 2017 concerns measures to safeguard the security of gas supply. Furthermore, the Directive (EU) 2014/34 about equipment and protective systems intended for use in potentially explosive atmosphere and the Directive (EU) 2010/75 on industrial emissions have to be regarded. The Regulation (EU) 2019/942 of the European Parliament and of the Council (05.06.2019) establishes an Agency for the Cooperation of Energy Regulators [13].

In the finished FCH JU project HyLAW (see section 4.1) the legislative background in some of the EU member countries was investigated. This existing data will be updated and extended in D2.3 to all EU member countries in order to create the map on state-of-the-art RSC throughout the European member countries.

3.2 European technical framework by standardisation

Standards are technical documents designated to be used as rules, guidelines or definitions unifying the general, security or quality requirements on products, processes, services, management and organisation. During the creation of standards all interested parties are included in order to reach high consensus. The European Committee for Standardisation (CEN) consists of its 34 national members, working together in decentralised technical groups that are coordinated by the CEN-CENELEC Management Centre (CCMC). The development of standards can root from different initiatives, such as a ‘bottom-up' initiatives of the technical committees or in the form of a standardisation request (mandate) from the European Commission [14] [15] [16] [17].

Presently, there is no uniform standard on hydrogen admixture concentrations on CEN level. European standardisation committees prepare a comprehensive set of standards for all uses of hydrogen. According to the 2018 Update report of the CEN – CENELEC Sector Forum Energy Management – Working Group Hydrogen at least the technical committees shown in

Table 1 have started to develop standardisation deliverables on standards related to hydrogen or H2NG [18].

Table 1: List of CEN/TCs that started to develop standardisation deliverables on standards related to hydrogen or H2NG [18]

Technical committee	Topic description
CEN/CLC/JTC 6	Hydrogen in energy systems
ISO/TC 197	Hydrogen technologies
IEC/TC 105	Fuel cell technologies
CEN/TC 234	Gas infrastructure
CEN/TC 237	Gas meters
CEN/TC 238	Test gases, test pressures, appliance categories and gas appliance types
CEN/TC 268	Cryogenic vessels and specific hydrogen technologies application
CEN/JTC 14	Energy management and energy efficiency in the framework of energy transition

Despite of that the scope of HIGGS is on the transmission gas grid, for the development and deployment of hydrogen in energy systems, all different components and applications need to be hydrogen-ready/adjusted.

Table 2 shows a list of CEN technical committees that should be involved in further standardisation actions in regards of hydrogen in the view of the authors. Despite the length of the list, there is no claim made that it is complete.

Table 2: List of CEN/TCs with potential need for further standardisation activities related to hydrogen (TCs with relevance for gas transport and gas transport systems are bold)

Technical committee	Topic description
CEN/TC 12	Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries
CEN/TC 48	Domestic gas-fired water heaters
CEN/TC 49	Gas cooking appliances
CEN/TC 58	Safety and control devices for burners and appliances burning gaseous or liquid fuels
CEN/TC 62	Independent gas-fired space heaters
CEN/TC 69	Industrial valves
CEN/TC 106	Large kitchen appliances using gaseous fuels
CEN/TC 109	Central heating boilers using gaseous fuels
CEN/TC 131	Gas burners using fans
CEN/TC 155	Plastics piping systems and ducting systems
CEN/TC 180	Decentralized gas heating
CEN/TC 208	Elastomeric seals for joints in pipework and pipelines
CEN/TC 234	Gas infrastructure
CEN/TC 235	Gas pressure regulators and associated safety devices for use in gas transmission and distribution
CEN/TC 236	Non industrial manually operated shut-off valves for gas and particular combinations valves-other products
CEN/TC 237	Gas meters
CEN/TC 238	Test gases, test pressures, appliance categories and gas appliance types
CEN/TC 244	Measurement of fluid flow in closed conduits - dormant
CEN/TC 256	Railway applications

CEN/TC 262	Metallic and other inorganic coatings, including for corrosion protection and corrosion testing of metals and alloys
CEN/TC 264	Air quality
CEN/TC 268	Cryogenic vessels and specific hydrogen technologies applications
CEN/TC 270	Internal combustion engines
CEN/TC 299	Gas-fired sorption appliances, indirect fired sorption appliances, gas-fired endothermic engine heat pumps and domestic gas-fired washing and drying appliances
CEN/TC 305	Potentially explosive atmospheres - Explosion prevention and protection
CEN/TC 326	Natural gas vehicles - Fuelling and operation
CEN/TC 399	Gas Turbines applications - Safety
CEN/TC 408	Natural gas and biomethane for use in transport and biomethane for injection in the natural gas grid
CEN/TC 459	ECISS - European Committee for Iron and Steel Standardization
CEN-CLC/JTC 14	Energy management and energy efficiency in the framework of energy transition
CEN-CLC/JTC 6	Hydrogen in energy systems
CLC/TC 57	Power systems management and associated information exchange
CLC/TC 216	Gas detectors
IEC/TC 8	System aspects of electrical energy supply
IEC/TC 31	Equipment for explosive atmospheres
IEC/TC 105	Fuel cell technologies
ISO/TC 22	Road vehicles
ISO/TC 30	Measurement of fluid flow in closed conduits
ISO/TC 70	Internal combustion engines
ISO/TC 158	Analysis of gases
ISO/TC 192	Gas turbines
ISO/TC 193	Natural gas
ISO/TC 197	Hydrogen technologies
ISO/TC 255	Biogas

Corresponding to the list of CEN/TCs, in Table 3 a list of standards related to hydrogen is given.

Table 3: List of standards related to hydrogen [16]

EN ISO 15848-1 2015	Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 1: Classification system and qualification procedures for type testing of valves
EN ISO 15848-2: 2015 (EN 16325:2013 prA1:2015):	Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 2: Production acceptance test of valves
EN ISO 15330: 1999	Fasteners – Preloading test for the detection of hydrogen embrittlement – Parallel bearing surface method
EN 1594:2-2013	Gas infrastructure – Pipelines for maximum operating pressure over 16 bar – Functional requirements
EN 1775:2007	Gas supply – Gas pipework for buildings than or equal to 5 bar – Functional recommendations
EN 437:2003 + A1:2009	Test gases – test pressures – appliance categories
EN 16325: 2013 (under development A1:2015)	Guarantees of Origin related to energy – Guarantees of Origin for Electricity
EN ISO 6974:2012	Natural gas – Determination of composition and associated uncertainty by gas chromatography
ISO/TR 16922:2013	Natural gas – Odorization
EN ISO 13734:2013	Natural gas – Organic components used as odorants – Requirements and test methods
ISO/TR 15916:2004	Basic considerations for the safety of hydrogen systems
ISO 22734-1: 2008	Hydrogen generators using water electrolysis process – Part 1: Industrial and commercial applications
ISO 22734-2: 2011	Hydrogen generators using water electrolysis process – Part 2: Residential applications
ISO 26142:2010	Hydrogen detection apparatus – Stationary applications
EN IEC 60079-10-1:2015	Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres
EN IEC 60079-29-1:2007	Gas detectors – Performance requirements of detectors for flammable gases

The European Committees for Standardisation CEN and CENELEC presented their sight on the way “Towards a roadmap for hydrogen standardisation” at the Madrid Forum in October 2019. Enabling the use of hydrogen is seen in three different end applications, the first being as admixture with natural gas in natural gas systems, second being the conversion of natural gas systems for the use of pure hydrogen and third being hydrogen in dedicated systems. A roadmap for hydrogen standardisation includes the commitment on a set of needed standards and of the responsible technical committee to develop these.

All relevant partners along the value chain need to be included, as illustrated in Figure 1. This should be complemented by a timeline defining the timeframe in which the standardisation activities should be carried out and finished [19].

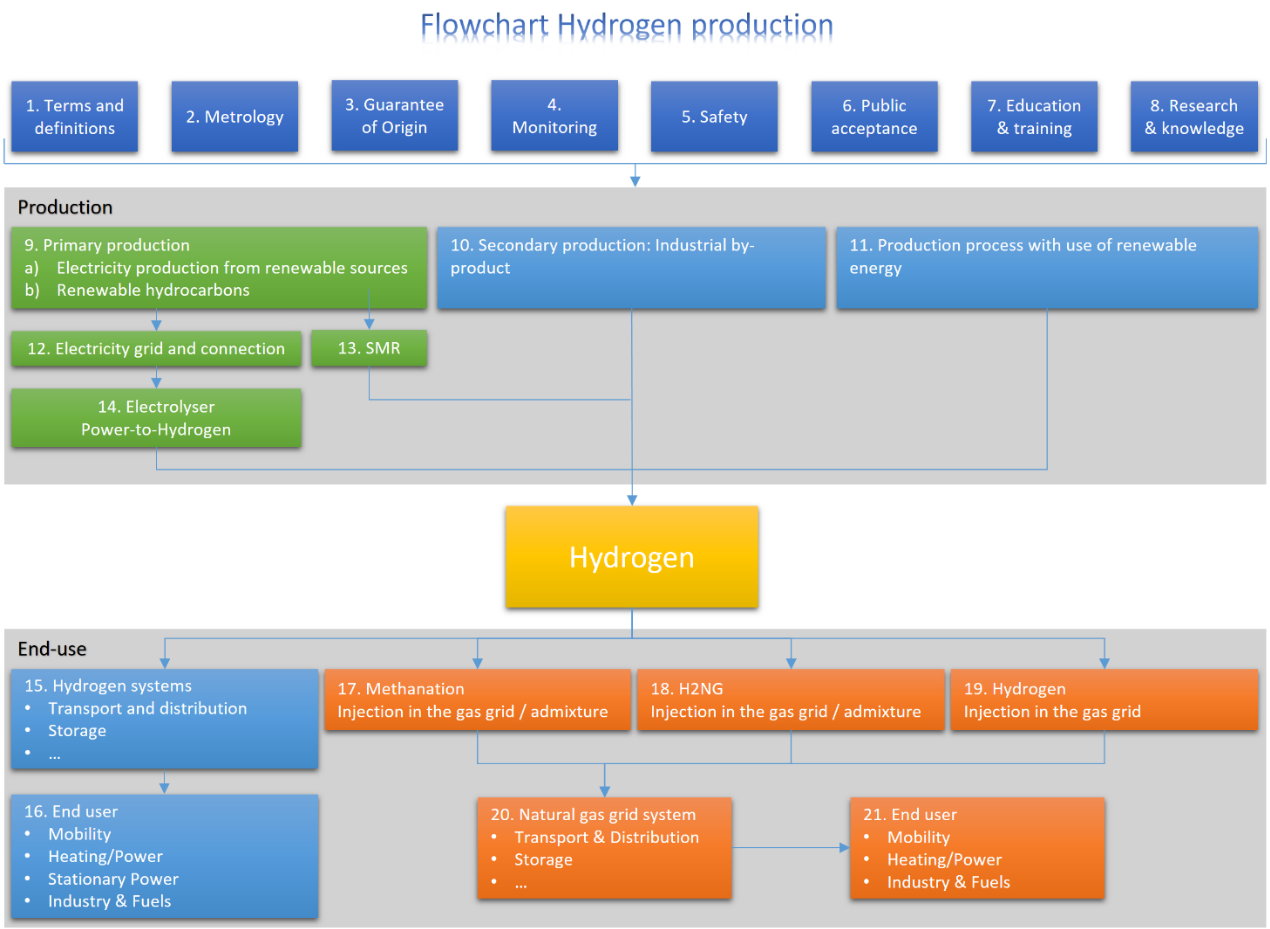

Figure 1: Flowchart of hydrogen production (own graphic) [19]

This roadmap approach is supported by the sector forums for energy management (SFEM WG Hydrogen), gas infrastructure (SFG-I) and gas utilisation (SFG-U), who now establish a joint taskforce for hydrogen in natural gas.

Complementary to the roadmap the technical committees are actively preparing the standardisation on hydrogen regarding gas quality, gas pipelines, gas infrastructure or measurement utilities. The technical committee 234 on gas infrastructure works on a technical report on “consequences of hydrogen on gas infrastructure and the identification of standardisation needs in the scope of CEN/TC 234”. This report will be published towards third quarter of 2020 and can be assessed in detail in deliverable report D2.3 of the HIGGS project. Concerned standards are listed in Table 4.

Table 4: Standards under the scope of CEN/TC 234 in regards of hydrogen

EN 1594:2013	2013-09-11	Gas infrastructure - Pipelines for maximum operating pressure over 16 bar - Functional requirements
EN 1776:2015	2015-12-16	Gas infrastructure - Gas measuring systems - Functional requirements
EN 1918-5:2016	2016-03-23	Gas infrastructure - Underground gas storage - Part 5: Functional recommendations for surface facilities
EN 1918-4:2016	2016-03-23	Gas infrastructure - Underground gas storage - Part 4: Functional recommendations for storage in rock caverns
EN 1918-3:2016	2016-03-23	Gas infrastructure - Underground gas storage - Part 3: Functional recommendations for storage in solution-mined salt caverns
EN 1918-2:2016	2016-03-23	Gas infrastructure - Underground gas storage - Part 2: Functional recommendations for storage in oil and gas fields
EN 1918-1:2016	2016-03-23	Gas infrastructure - Underground gas storage - Part 1: Functional recommendations for storage in aquifers
EN 12186:2014	2014-10-22	Gas infrastructure - Gas pressure regulating stations for transmission and distribution - Functional requirements
EN 12279:2000/A1:2005	2005-08-17	Gas supply systems - Gas pressure regulating installations on service lines - Functional requirements
EN 12583:2014	2014-03-12	Gas Infrastructure - Compressor stations - Functional requirements
EN 12732:2013+A1:2014	2014-04-23	Gas infrastructure - Welding steel pipework - Functional requirements
EN 16348:2013		Gas infrastructure - Safety Management System (SMS) for gas transmission infrastructure and Pipeline Integrity Management System (PIMS) for gas transmission pipelines - Functional requirements

3.3 National legislation, standardisation and technical codes of practice

In the European context the national energy and climate plans (NECP) including hydrogen are published or in development.

For national standards and codes of practice, there are different approaches throughout the European Union member states. Some member countries only have standards, while other countries use a combination of standards and technical rules or technical codes of practice. At the moment preparations for standardisation activities on national level take place in parallel to the European activities shown in section 3.2 due to the New Green Deal. During writing of this deliverable report, Spain for instance changed the way how hydrogen is considered in the national gas grid. The final results from Spain were not available at the time this document was finalised.

Some other countries stipulated already limited values for hydrogen in natural gas in legislation and/or in standards or codes of practice. As elaborated in 4a questionnaire on the RSC in the European member countries has been conducted. Thus, all these activities and their results will be included in the RSC map in deliverable report D2.3 of the HIGGS project.

3.4 Present certification and testing methods concerning hydrogen in the European gas network (06.2020)

3.4.1 Certification

Article 19 of the Renewable Energy Directive 2018/2001 (REDII) sets up a framework for guarantees of origin that builds on the provisions of the previous renewable energy directives (2009/28 and 2001/77). The term Guarantee of Origin (GO or GoO) is commonly used by electricity system operators and market participants.

The market for GO on electricity continues to grow, with electricity generation that received a GO reaching 791 TWh in 2018. Power generation eligible for certification but not currently receiving it is consistently decreasing and had reduced to 176 TWh in 2018.

Key to the credibility of a GO system is the reliability of the data inscribed on the GO certificate itself. Ensuring the reliability of this data requires a system that is well set up in the first instance, with accurate measurement infrastructure, secure data reporting systems, and transparent, accessible system information tools. Together, these requirements should assure delivery of the fundamental principle of a GO system – that one MWh of electricity production may receive one, and only one, reliable and accurate GO certificate that can be easily tracked by system operators as it is quickly and safely transferred between market participants.

GO schemes are in operation for electricity and gas, and more recently, for hydrogen on a pilot basis. Many of the initial challenges for setting up GO systems were described in the E-track, RE-DISS, CertifHy and Biosurf projects. Up to now, only GOs for electricity were covered by the regulatory framework through REDI, while REDII (article 19) requires GOs to be used to guarantee the origin of all energy from renewable sources. Article 19 has to be implemented until 1st July 2021.

Additionally, the REDII mentions in article 19.7, that the guarantee of origin shall specify whether it relates to:

1) Electricity;

2) Gas, including hydrogen; or

3) Heating or cooling.

Renewable energy can also be delivered through a liquid energy carrier, and gases are also traded in liquified form.

GO systems for different energy carriers have a lot in common: Indeed, in order to achieve their purpose, they all need to incorporate measures for:

- the avoidance of double counting,
- reliable data registration,
- designing procedures and allocating roles for measuring, auditing, registering, issuing, supervising transfer and cancellation, and
- supervising disclosure and expiry.

CEN/CENELEC SFEM, JTC 14, JTC 14 WG 5, and JTC 6, the EU Commission as well as with the members of the Association of Issuing Bodies (AIB), the competent bodies designated by 18 EU Member States, Iceland, Norway and Switzerland are responsible for supervising the issuance, transfer and cancellation of guarantees of origin. The need is identified to revise the EN 16325 standard, and to include in this revision besides electricity from renewables, the energy carriers gaseous hydrocarbons, incl. biomethane, hydrogen, and heating and cooling.

The first publication of the standard is related to the European Energy Certificate System (EECS), which was developed by the AIB to provide an integrated European framework for issuing, holding, transferring and otherwise processing guarantees of origin which guarantee the source of energy. The purpose of the EECS Rules is to secure, in a manner consistent with European Community law and relevant national laws, that systems operating within the EECS framework are reliable, secure and inter-operable.

The implementation, under the EECS Rules, of harmonised standards for issuing and processing EECS Certificates enables the owners of EECS Certificates to transfer them to other Account Holders at both the domestic and international level.

RED II and EN 16325, the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, otherwise known as RED II, has been published on 24 December 2018. Of special interest is Article 19.6 which provides that:

"Member States or the designated competent bodies shall put in place appropriate mechanisms to ensure that guarantees of origin are issued, transferred and cancelled electronically and are accurate, reliable and fraud-resistant. Member States and designated competent bodies shall ensure that the requirements they impose comply with the standard CEN – EN 16325".

As article 19 of REDII has to be implemented until 1st July 2021, the timeframe of standardisation of EN 16325 is about 20 months.

Certification programmes (CP)

Already today there are hydrogen projects in the planning, which have to be realised in a timely manner. At the same time the intended integration of hydrogen related rules into the technical framework of standards and codes of practice is not yet complete. Due to this reason certification programmes concerning hydrogen are developed by DVGW CERT GmbH as well as other certification bodies in EU member countries.

These certification programmes are used additionally or alternatively to the existing testing specification for natural gas and describe the necessary, fundamental requirements and partly also the testing methods to assure the secure use of products with 20 % admixture of hydrogen or pure hydrogen as combustion gas. Certification programmes for condensation boilers currently serve as a pilot.

Prospectively there will be the demand to fill further existing gaps in the standards and codes of practice concerning appliances and devices of gas distribution and gas application as well as, if necessary, for the hydrogen production by developing certification programmes. This is due at least for as long as it takes to fill the gaps in the respective standards itself. Since the capacities to develop these certification programmes are limited, there will be the need to focus on work areas with priority. The wide range of potential demand cannot be satisfied with this rather temporary element. With technical well-designed certification programmes the demand for conformity assessment procedures on regards of hydrogen readiness can be accounted for, at least in a selective manner. The authors expect to be able to provide more information on released certification programmes in the final document of this work package, deliverable report D2.3.

3.4.2 Testing methods

Blending hydrogen into natural gas pipelines may cause the diffusion of the hydrogen inside the pipeline walls, resulting in the embrittlement of the material. In general, hydrogen embrittlement (HE) in hydrogen gas is evaluated by mechanical testing with two categories of environmental conditions: a) testing in high-pressure hydrogen gas (applying stress concurrent with hydrogen gas exposure) or b) testing in air subsequent to pre-charging with hydrogen (applying stress following hydrogen gas exposure). The latter is not considered appropriate for carbon and low-alloy steels and the combination of several testing techniques is usually recommended. Eight common mechanical tests are highlighted in Table 5 with their corresponding standards that regulate them. The non-mechanical H_2 permeation test is also considered. The procedures to perform these tests are briefly explained in the annex.

Table 5: Mechanical test with corresponding standards

Type of test	Standards
Slow Strain Rate Test: SSRT method	• ASTM G142: Determination of susceptibility of metals to embrittlement in hydrogen containing environments at high pressure, high temperature or both. • EN ISO 7539-7: Corrosion of metals and alloys. Stress corrosion testing - Part 7: Method for slow strain rate testing. • ASTM G129: Standard practice for Slow Strain Rate Testing to evaluate the susceptibility of metallic materials to environmentally assisted cracking. • NACE TM0198: Slow Strain Rate Test method for screening corrosion resistant alloys (CRAs) for stress corrosion cracking in sour oilfield service.
Fracture toughness	• EN ISO 11114-4: Transportable gas cylinders. Compatibility of cylinder and valve materials with gas contents- Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement • ASTM E1820: Standard test method for measurement of fracture toughness • ISO 12135: Metallic materials. Unified method of test for the determination of quasistatic fracture toughness
Threshold stress-intensity factor	• ASTM E1681: Standard Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials.
Fatigue	• ASTM E647 is the standard test method for measurement of fatigue crack growth rates

Constant load test	• ASTM F519: Mechanical hydrogen embrittlement evaluation of plating processes and service environments • ASTM F1624: Measurement of hydrogen embrittlement threshold in steel by the incremental step loading technique • NACE TM0177: Laboratory testing of metals for resistance to sulfide stress cracking and stress corrosion cracking in H2S environments.
3-point and 4-point bend testing	• ASTM F519: Mechanical hydrogen embrittlement evaluation of plating processes and service environments • NACE TM0316: Four-point bend testing of materials for oil and gas applications • ISO 16540: Corrosion of metals and alloys. Methodology for determining the resistance of metals to stress corrosion cracking using the four-point bend method • ASTM C393 • ASTM C1161 • ASTM D790
Impact	• ASTM E23: Standard test methods for notched bar impact testing of metallic materials
Disk Pressure (rupture) test	• EN ISO 11114-4: Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement. • ASTM F1459: Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement
Hydrogen permeation test	• EN ISO 17081: Method of measurement of hydrogen permeation and determination of hydrogen uptake and transport in metals by an electrochemical technique

Further testing methods can be found in the report “Verhalten bei volatilen Wasserstoffanteilen” (Behaviour with volatile shares of hydrogen) of the DBI Gastechnologisches Institut Freiberg (GTI) . [20] Further relevant test methods in regards of the transmission, as well as the distribution gas grid will be assessed in detail in deliverable report D2.3.

4 Questionnaire on RSC of hydrogen concentrations and injection in the European gas network

4.1 Basis for the data generation

One of the goals inside the HIGGS project's work scope is the creation of a thorough state-of-the-art regulatory, standardisation and certification map of the EU and its member countries concerning the injection and the transport of hydrogen in the high-pressure transmission gas system. This map will be finished in deliverable report D2.3 and shall give a broad overview on the current existing state and planned activities with respect to regulation, standardisation and certification in all member countries of the EU.

The finished FCH-JU project HyLAW (Hydrogen Law and removal of legal barriers to the deployment of fuel cells and hydrogen applications) has provided a database [20] with information on the legal framework of the injection of hydrogen at the transmission gas grid level. For example, information on the responsible authority in each country, the national legislation, the national technical rule-setting bodies and the max. allowed concentrations of hydrogen admixture in the national gas grids have been collected. This already available information deals as a basis of the RSC map developed in HIGGS.

The HyLAW project by design has not dealt with all EU member countries and for some countries information have not been available and are missing. The HIGGS project team decided to use this information as a basis and to expand it to the HIGGS project's scope considering all EU member countries. Additionally, Norway, the United Kingdom and Switzerland have been included as well. It is necessary to ensure compatibility with the existing data in HyLAW. The generated information within HIGGS will be mirrored back to the HyLAW project by one of the partners, FHa, who participated in the HyLaw project.

The following sixteen questions form the questionnaire that was sent out to relevant stakeholders in all EU member countries, Norway, UK and Switzerland:

1. Which is the responsible authority/legal entity for the permission of the connection/injection of hydrogen in the gas grid?

2. What is the existing national legislation and/or regulation concerning the injection of hydrogen into the gas grid?

3. What is permitted or restricted according to national legislation under your responsibility as TSO regarding the transport of pure hydrogen and mixtures of hydrogen and natural gas?

4. Is there a maximum concentration of hydrogen (0-100 %) that you are allowed to transport as a TSO? (e.g. you are allowed to transport 100% hydrogen)

5. What is the maximum allowed concentration in your country for injection in the gas grid on transmission level?

6. In case the maximum hydrogen concentration in your transmission grid (system) is less than 100%, is it allowed to inject pure hydrogen (100%) into gas grid on transmission level (up to the allowed concentration)? Yes/No
   - If no,

   1) who is responsible for the blending with natural gas?

   2) Is there an obligation for the TSO to provide the necessary natural gas for blending the hydrogen? (With several EU Directives transposed into national legislations, the functions of gas grid operator and natural gas supplier are separated)

7. Are there specific requirements for increasing or decreasing the admissible threshold of hydrogen concentration (upstream and downstream networks, infrastructure elements and appliances with lower tolerance)? Please describe them.

8. Are there specific restrictions/permissions for the transport of hydrogen other than “concentration” and “quality”? Which ones?

9. If it can be guaranteed that the gas is on the required quality specification (on spec) at the next customer, is it allowed to feed in off-spec gas (read: a higher concentration of Hydrogen)?

10. Which part of the connection facility is owned by or under the responsibility of the TSO? (Please, consider that the injection installation is part of the connection facility)

11. As TSO, do you see legal and administrative restrictions with regard to the ownership of your part of the connection facility of hydrogen into the grid? (Please, consider that the injection installation is part of the connection facility)

12. Is there a difference in legal and administrative restrictions between connections for hydrogen injection into TSO and DSO-networks? If so, could you please specify the differences?

13. Are there specific national (add-on) restrictions for the connection/injection of hydrogen in TSO networks compared to the connection/injection of natural gas? Please name them.

14. Are there other requirements for the injection of H2NG-blends in TSO networks compared to pure Hydrogen?

15. Is it foreseen to review the current regulation to consider hydrogen injection into natural gas network? On which term?

16. Do you as TSO find any information missing in this questionnaire that may be relevant for the transport of hydrogen in the gas grid? Please, provide it.

4.2 Identification of stakeholders, generation of distribution list

After finalising the questionnaire the next step is to identify the stakeholders that can contribute the desired information. This was done by using the existing network of the partners. Mainly transmission system operators, but also national gas associations have been contacted, sometimes both. When there has been no direct contact available, it has been tried to establish contact via ENTSOG.

Table 6 shows the distribution list of stakeholders that were contacted and asked to fill out the questionnaire.

Table 6: List of stakeholders contacted by the partners

Country	Stakeholder	Association type
Austria	ÖVGW	Gas association
Belgium	FLUXYS	Transmission System Operator
Bulgaria	Via ENTSOG	Transmission System Operator
Croatia	PLINACRO	Transmission System Operator
Cyprus	DEFA, CYS	Transmission System Operator, Standardisation Body
Czech Republic	CGOA, Innogy	Gas association
Denmark	ENERGINET	Transmission System Operator
Estonia	EGL	Gas association
Finland	ENTSO-G	
France	GRTgaz, afgaz	Transmission System Operator, Gas association
Germany	DVGW	Gas association
Greece	DESFA	Transmission System Operator
Hungary	MOL	Transmission System Operator
Ireland	Gas networks Ireland	Transmission System Operator
Italy	snam, retegas	Transmission System Operator
Latvia	ENTSO-G	
Lithuania	Amber Grid	Transmission System Operator
Luxembourg	ENTSO-G	
Malta	Gov Malta	Ministry
The Netherlands	Gas Transport, Gasunie	Transmission System Operator
Poland	Gazsystem	Transmission System Operator
Portugal	ITG	Technical Gas Institute
Romania	ENTSO-G	
Slovakia	SK TSO	Transmission System Operator
Slovenia	via DVGW office Sarajewo	
Spain	Enagas	Transmission System Operator
Sweden	Swedegas	Transmission System Operator

Non-EU countries:

Norway	ENTSO-G	
United Kingdom	Nationalgrid, Greenflame	Transmission System Operator
Switzerland	SVGW	Gas association

4.3 Further needed steps

The results of the questionnaire will be processed and used to complement the map of RSC on EU level with the current state in the EU member countries. A visual map of the EU with its member countries will be designed in a way that a comprehensive overview will be given and will be part of the deliverable report D 2.3 of the HIGGS project.

5 Conclusions

This report assessed the current European regulation, standardisation and certification for hydrogen and hydrogen admixtures in natural gas in the European transmission grids and systems. A lot of activities concerning hydrogen are currently under development. The European Union has developed comprehensive framework programmes with the European Green Deal and the recent recovery plan. The climate emission reduction goals have been increased and subsequently the publication of a separate European hydrogen strategy has been announced. A corresponding roadmap is already available. Presently, the European regulative framework does not cover the gas quality of hydrogen and the admissible concentrations of hydrogen in natural gas. The same applies for the current standardisation, where first activities to support hydrogen and hydrogen admission to natural gas have been commenced. Still there is no uniform standard on hydrogen admixture concentrations. A list of CEN/TCs that have started to develop standardisation deliverables related to hydrogen or H2NG as well as a list of CEN/TCs that could be involved in these activities from the sight of the authors has been provided. Furthermore, the roadmap suggestion of CEN and CENELEC shows a possible way towards hydrogen standardisation. Guarantees of origin for hydrogen demanded by the REDII are in operation on a pilot basis and must be implemented in the member states until July 2021. Resulting from that the timeframe for the standardisation of EN 16325 is about 20 months. In order to bridge the missing regulation and standards the demand for conformity assessment procedures, e.g. technical well-designed certification programmes, is high and first pilot programmes for condensation boilers are in development. Due to the wide range of potential demand this temporary solution can only serve as a bridge and for selected use cases. Further current testing methods are presented and briefly explained.

The assessment showed, the barrier in regulations, standardisation and certification (RSC) is the fact, that presently the development of the hydrogen energy system in the EU is ahead of the committees work on RSC. The main bottleneck is the timeframe and the different velocities in the European Union and the member countries, in which RSC with respect to hydrogen is either updated, extended or newly developed. Thus, to draw the full map of RSC of all EU member countries a questionnaire was sent out to relevant stakeholders in all member countries. With the input and the results of this questionnaire the RSC map shall be completed and provided in D2.3.

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Annex

Concerning testing methods in section 3.4:

1) Slow Strain Rate Test: SSRT method

Specimens are tensile strained to failure, using strain rates in the range 10^{-6} - $10^{-4}s^{-1}$, under both corrosive or embrittling environment and inert environment (air/N_2/ argon/helium) for comparison. Time to failure and reduction in area ratios are mainly assessed. Common specimen designs are based on cylindrical tensile specimens, but they could be modified by including a circumferential notch.

2) Fracture toughness

Since hydrogen has a significant influence on the crack initiation and growth behaviour on materials exposed in high-pressure hydrogen environment, fracture mechanics is usually required to assess the maximum allowable stress and service life of a component in such environment. Two common types of fracture properties are the threshold stress intensity factor (KTH) and the associated crack growth rates.

3) Threshold stress-intensity factor

It is a measure of a material's resistance to hydrogen-assisted crack propagation under static loading. In these tests, an initial stress intensity factor less than K_{IEAC} is applied before placing the precracked specimen in a high-pressure hydrogen environment. If susceptible to environment assisted fracture, the precrack will extend under decreasing stress-intensity factor until the crack arrests at the threshold value.

4) Fatigue

Fatigue is a material failure mode particular to cyclic loading. This failure mechanism must be considered in the design of hydrogen gas components subjected to pressure cycling. The frequency of the load cycle and the ratio of minimum load to maximum load (R-ratio) are two important variables that have been shown to affect fatigue properties measured in hydrogen gas. a) Low-cycle (LCF) and high-cycle fatigue (HCF) and b) fatigue crack propagation are two categories of fatigue tests.

5) Constant load test

For instance, the ASTM F519 standard is a pass/fail test based on a sustained load of 75% of the fracture stress of the specimen maintained for 200 hours. It is possible however, to adapt these tests to evaluate other exposures, such as hydrogen gas. An important benefit of these self-loading fixtures is an exposed to hydrogen environments without interruption.

6) **<u>3-point and 4-point bend testing</u>**

The assemblies can be inserted into closed test vessels or autoclaves and exposed to hydrogen environments without interruption during the test.

7) **<u>Impact</u>**

Notched-bar impact tests, such as Charpy impact, are standard methods of estimating fracture toughness in steels.

8) **<u>Disk Pressure (rupture) test</u>**

This method involves pressurizing identical membranes of material with hydrogen gas and with inert gas (usually helium) until the membranes fail. If the burst pressures of disks exposed to hydrogen and helium are essentially the same, it is concluded the material is not susceptible to HE.

9) **<u>Non mechanical tests: Hydrogen permeation test</u>**

This permeation test can be used to measure the diffusible hydrogen in steel. This permeation test is basically a double cell set up in which one chamber is entry cell also called a charging cell and another is oxidation cell (exit cell). These two chambers are separated by a steel membrane. The electrochemical process has used to hydrogen charging. This hydrogen is firstly introduced in charging the cell and then goes to oxidation cell with the help of membrane.

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