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High Performance PEM Electrolyser for Cost-effective Grid Balancing Applications

HPEM2GAS

HPEM2GAS - Deliverable report

D2.3 Background document on policies and regulations for grid-balancing service

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Summary

The deliverable 2.3 "Background document on policies and regulations for grid-balancing service" collects relevant information and data regarding directives, policies and regulations for the hydrogen production through the water electrolysis in power to gas processes aiming to compensate for the discontinuity of renewable energy generation and for grid-service applications.

This document discusses regulations and interactions with policy makers and local authorities of different European regions and addresses issues, gaps, barriers, education and market potentials to drive future policy on this energy technology.

The activity of this task is addressed to:

- Regulations for using electrolysers in grid service applications;
- Energy policies aiming to increasing the use of hydrogen technologies as well as the share of renewable energy sources by the electrical grid;
- An analysis of the normative dealing with hydrogen production in grid-balancing service.

The specific contents are concerning with:

- Definition of new policies regarding the energy efficiency and storage related to the use of electrolysis over the short- and long-term.
- Definition of specific requirements for achieving highly distributed electrolysis systems.
- Comparison of different utility business models to demonstrate the feasible integration of electrolysers, along with the renewable energy sources, in the transmission line.
- Quantification of the impacts arising from the storage through water electrolysis on the utility system.
- Monitoring the implementation of the Directive on the Deployment of Alternative Fuels Infrastructure (DAFI 2014/94/EU) and any other directive on alternative fuels in the countries of the HPEM2GAS partners.
- The implementation of the hydrogen technologies in National Policy Frameworks or Regional Energy Plans.

The general aim of this activity is to provide policy makers and local authorities with relevant information and data so they can design appropriate measures to accelerate the energy storage and the efficient implementation of energy technologies with particular regard to hydrogen and water electrolysis penetration into the market.

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Nomenclature

Abbreviation	Meaning
ACER	Agency for the Cooperation of Energy Regulators
ADR	Accord europeen relatif au transport international des merchandises Dangereuses par Route
ATR	Auto-Thermal Reforming
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
DAFI	Deployment of Alternative Fuels Infrastructure
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FCs	Fuel Cells
GHGs	GreenHouse Gases
HyLaw	Hydrogen Law
NPFs	National Policy Frameworks
NRA	National Regulatory Authority
PtG	Power to Gas
PtH	Power to Hydrogen
RES	Renewable Energy Sources
SMR	Steam Methane Reforming
TPED	Transportable Pressure Equipment Directive

1 Introduction

The object of the present deliverable is related to an analysis of energy policies and regulations for the electrolysers application in grid-balancing service. The focus lies in drafting a reference document for policy makers and local authorities of different EU regions. As a reference, the Directive on the Deployment of Alternative Fuels Infrastructure (DAFI 2014/94/EU) and any other directive on alternative fuels in the countries of HPEM2GAS partners are considered.

During the Conference of the Parties, 28 Member States of the Europe have signed the Paris agreement to keep global warming "well below 2 degrees Celsius above preindustrial levels, and to pursue efforts to limit the temperature increase even below 1.5 degrees Celsius." The aim is to reduce emissions up to 95% in the long term by promoting the decarbonisation of transport, buildings, and industry through a large share of intermittent renewable energy sources (RES) including the so-called Power to Hydrogen (PtH), the conversion of (renewable) electricity to hydrogen, by 2050. In fact, green Hydrogen as clean fuel seems to represent a valid alternative to fossil fuels, despite the present cost, since it can be produced using RES and its combustion produces only water as by-product. Hydrogen can be employed as an energy vector since it represents a carbon-neutral energy supply and enables the long-term storage and the transport where energy is required. In this regard, the discontinuity of renewable sources can be overcome and balanced by hydrogen: the excess of renewable electricity in the grid can be used to produce hydrogen and minimize seasonal variations in the energy supply, thus providing support for the electricity grid balancing. Thanks to these advantages, the green Hydrogen technology can provide a sustainable energy supply and it shows many perspective applications both in the mobile and stationary field: hydrogen can be fed to different fuel cell types for the power production in stationing, aerospace, automotive, portable electronics and maritime applications [1].

The current hydrogen production methods can be classified into three main groups:

- reforming of natural gas or biogas;
- as by-product from the chemical industry processes;
- water electrolysis.

Nowadays, the 70% of hydrogen is produced by reforming of hydrocarbons, such as natural gas or biogas. The Steam Methane Reforming (SMR) involves the reaction between methane (syngas) and gaseous water to produce Carbon monoxide CO and hydrogen H_2. Conversely, Auto-Thermal Reforming (ATR) oxidize methane to syngas, a mixture of hydrogen, carbon monoxide and carbon dioxide CO_2. SMR and ATR represent, until now, the most diffuse and cheapest way to produce hydrogen. The hydrogen steam can be purified coupling reforming with a system for the carbon capture and storage (CCS), which is essential for the achievement of the decarbonisation targets. However, these technologies require the use of fossil fuels that are characterised by limited availability, are still involving emission of pollutants and greenhouse gases (GHGs) and CCS cannot satisfy the large-scale production and the wide applications required by the hydrogen economy.

Hydrogen is also obtained as a by-product from other industrial processes, such as the production of caustic soda and chlorine. In these processes, the by-product represents an interesting and cheap source of hydrogen that can be employed for other applications on site. For example, hydrogen as by-product could feed stationary combined heat and power systems as well as fuel cell-based electric forklifts and vehicles. However, at the present its application is limited to the area where it is produced mainly for industrial uses.

Despite the different and numerous production processes of hydrogen, the most interesting but also promising way consists of the water splitting into hydrogen and oxygen by using electricity through the electrolysis process. Water electrolysis still does not significantly contribute to the main hydrogen production (only for 4% of the worldwide hydrogen production) but, if compared to the other available methods, it keeps the advantage of producing extremely pure hydrogen (>99.99%). The process occurs with energy input and it is by far more sustainable if the involved electricity derives from renewable sources (e.g., wind, solar, hydro, etc.). Figure 1 shows a simple scheme for the integration between RES and water electrolysis in the electricity grid. The electricity produces by RES may be merged into the grid or be converted into hydrogen. When renewable energy is abundant, the excess of energy may be converted into hydrogen by using electrolysis: in this way water electrolysis can overcome the discontinuity of RES for providing energy. The stored hydrogen can be used in three different ways: directly in Fuel Cells (FCs) to generate electricity, as fuel for heating applications, as feedstock chemical for industrial uses (ammonia synthesis, metallurgy, semiconductor industry, etc.).

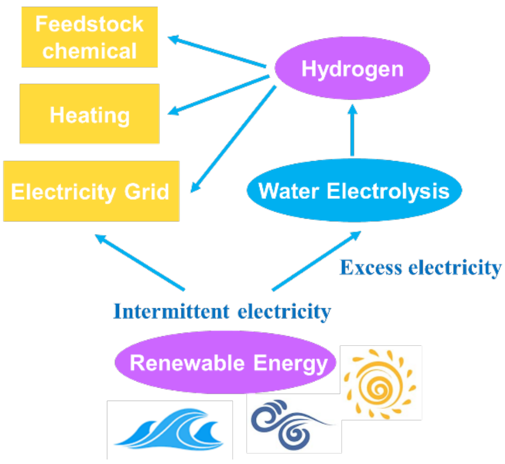

Figure 1. The Hydrogen role in the energy system: the integration between the renewable energy sources and water electrolysis in the electricity grid *[2]* .

Electrolysis represents a promising solution for supplying energy to the remote areas that show abundant availability of sun, waves and wind, the hydrogen thus produced overcome the distance of these areas from the electricity grid and may meet their energy demand. Thanks to its high mobility, hydrogen can also be transported over long distances and allows the distribution of energy between countries.

The cost of electrolysers depends on the application scale: on a small scale the cost of the electrolysis system is still significant, on the large-scale, conversely, the electricity costs has a relevant impact. A large deployment requires greater improvements in the energy efficiency, operating life, current density, safety and, especially, reduction in costs of devices. Moreover, the possibility of working with pressurized systems reduces the energy needed to compress hydrogen after the production [2].

Great efforts should be pursued by policymakers, industry players, and investors to make this technology competitive with current hydrogen production methods from fossil fuels. The growing interest towards the development of hydrogen technologies as well as the share of RES by the electrical grid should be encouraged by a series of measures that include new regulations and advantages regarding the use of electrolysers in the grid-balancing. Hydrogen-based technologies have to especially meet the social acceptability since there are still many unsupported doubts about the safety of this energy carrier, mainly because the safety measures are still scarcely known. A more careful analysis of the benefits such as best quality of air and life could reduce the common opinion over hydrogen dangerousness and argue for the safety and reliability of hydrogen production through water electrolysis. The success of this transformation could not just reduce the use of fossil resources and, as a consequence, the global warming; it could provide energy independence, cut energy costs and promote industrial competitiveness.

This document deals with the current policies and regulations regarding the electrolysis systems application in grid-balancing service. The needed requirements for highly distributed electrolysers and their integration along with RES in the transmission line are investigated and the quantification of the resulting impacts is evaluated. The application of DAFI 2014/94/EU and other directives about this topic in the countries of HPEM2GAS partners is analysed and the implementation of hydrogen technologies in National Policy Framework or Regional Energy Plan is discussed.

The information derived by this analysis can provide guidelines for regulators to further develop the electrolysers market within the Europe Union countries and, as consequence, to promote a fast-acceleration of hydrogen and fuel cells deployments on a large scale.

2 New policies regarding the energy efficiency and storage over the short- and long-term

The introduction of hydrogen in the European energy system represents a great challenge and requires considerable efforts to replace the fossil fuels and integrate renewables energy sources. In this context, a series of strategic initiatives and targets have been addressed by the Member States with regard to energy efficiency and the renewable energy share in the electricity production, control of polluting emissions, reduced energy taxation levels and considerable growth of the actual technologies through the support of regional funds and research projects. The penetration of hydrogen in the energy system depends on the actual energy policies; a positive regulatory framework for hydrogen requires two actions. The first consists in a positive legislation that acknowledges and supports the multiple roles of hydrogen, described in Figure 2, e.g. Hydrogen Europe's advocacy work.

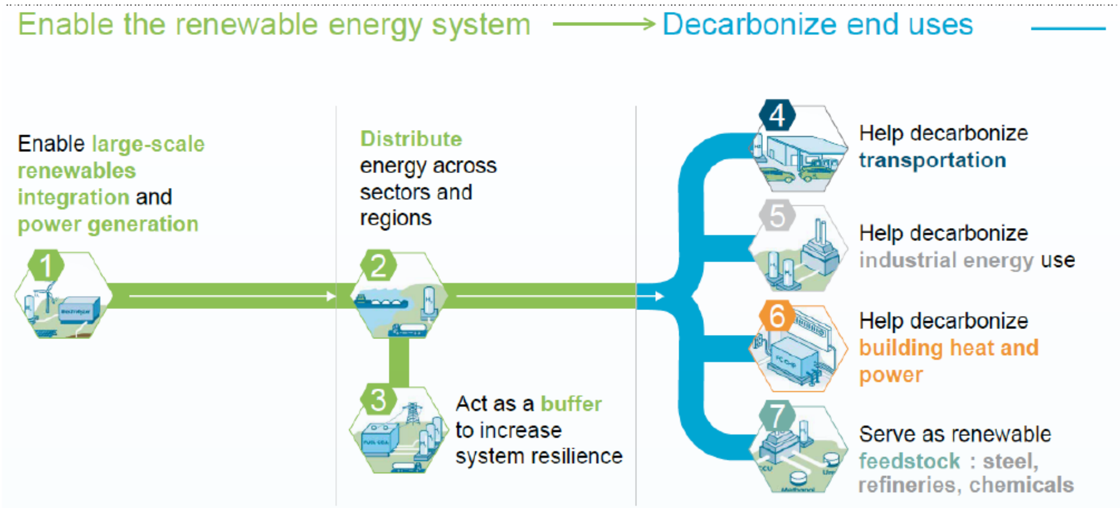

Figure 2. Hydrogen in the energy system, role and applications *[3]* .

Several EU organisations are actively working on these aspects. Beside the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) that operates in close cooperation with the European Commission on this topic there are some other association that are involved on complementary aspects. Among these, Hydrogen Europe is a supporting organisation of the Hydrogen Council, which represents the European hydrogen and fuel cell sector with more than 115 companies, 65 research organisations and 10 national associations as members. The organisation supports the European Commission in the innovation programme FCH JU promoting hydrogen as the enabler of a zero-emission society. Moreover, Hydrogen Europe in collaboration with the FCH JU support assist and monitor almost all fuel cells and hydrogen programs in Europe including those covered by Structure Funds. These aspects are addressed both at the EU and national level, in particular, by the above mentioned EU organisation and national hydrogen association e.g., H2IT in Italy. The second action aims at removing barriers that hinder the hydrogen deployment. Specific efforts in this regard are also played by specific projects. As an example, the HyLAW project (HyLaw stands for Hydrogen Law and removal of legal barriers to the deployment of fuel cells and hydrogen applications) that is supported by the FCH JU. HyLAW is a flagship project aimed at boosting the market uptake of hydrogen and fuel cell technologies providing market developers with a clear view of the applicable regulations whilst calling the attention of policy makers on legal barriers to be removed. The project brings together 23 partners from European countries and is coordinated by Hydrogen Europe. The HyLaw partners will first identify the legislation and regulations relevant to fuel cell and hydrogen applications and legal barriers to their commercialisation. They will then provide public authorities with country specific benchmarks and recommendations on how to remove these barriers [3] .

2.1 European regulatory framework for hydrogen

The European regulatory framework for hydrogen is reported in Table 1; each sector shows the corresponding requirements, legislative and financial tools and the hydrogen's role. Transport is the only major economic sector in the European Union where GHGs emissions have increased since 1990: it is responsible for 23 % of CO_2 emissions, which are still growing, and its decarbonisation requires a valid alternative to oil for the supply of energy to improve the environmental performance in such sector.

EU framework

Hydrogen Europe

Sector	Requirement	Legislative Tools	Financial Tools	Hydrogen's role
Transport	-CO_2 -PM/NO_X/SO_X reduction -integration of RES	1. Fuel Quality Directive 2. Renewable Energy Directive (RED2) 3. CO_2 emission standards 4. Clean vehicle Directive 5. Alternative Fuel Infrastructure Directive		-H2 as a fuel -H2 made fuels -green hydrogen for refineries
Energy-intensive industries	Decarbonisation	EU ETS	Modernisation Fund / Innovation Fund	Green/Decarbonised hydrogen as feedstock switch
Gas/Heating	Decarbonisation (to remain a player)	(1. RED (2)) 2. Upcoming Gas Regulation (2019/2020)	Possibly CEF Energy	1. Green/Decarbonised hydrogen as feedstock 2. Fuel cell as energy converter
Power	Storage / ancillary services	Electricity Market Design Directive / Regulation		Rapid response electrolysers + Sectoral Integration

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Table 1. Simplified scheme of European regulatory framework for hydrogen *[3]* .

Since 1998, the European Parliament emended the Fuel Quality Directive with the aim to reduce the greenhouse gas intensity of energy supplied for road transport. In 2016, the EU set in the Renewable Energy directive (RED2) the overall target to increase the Renewable Energy Sources consumption to at least 32% by 2030. The Commission's original proposal did not include a transport sub-target, which has been introduced by co-legislators in the final agreement: Member States have to require fuel suppliers to provide a minimum of the energy consumed in road and rail transport as renewable energy (14%). The integration of RES in transport provides a link with hydrogen technology: the direct use of renewable electricity or the indirect use of renewable electricity through green hydrogen facilitates the fast decarbonisation of the transport sector. The renewable energy involved has to be demonstrated by a guarantees of origin and power purchase agreements. In 2017, the European Commission presented a legislative proposal setting new CO_2 emission standards for passenger cars and light commercial vehicles (vans) for the period after 2020. In order to monitoring the CO_2 emissions of road transport the benchmark objectives were fixed: 15% reduction in 2025 and 30% reduction in 2030. Along with the new CO_2 emission standards in 2017, the commission emended the Directive on the promotion of Clean and Energy Efficient Road Transport Vehicles, which aims at a broad market introduction of environmentally-friendly vehicles. The directive requires that energy and environmental impacts, linked to the operation of vehicles over their whole lifetime, are taken into account in all purchases of road transport vehicles. The directive defines the rules for calculating the lifetime costs linked to the operation and impacts of vehicles [3].

2.2 The directive on the deployment of the alternative fuels infrastructure

The last European directive on the deployment of the alternative fuels infrastructure (DAFI 2014/94/EU) was published in 2014 as part of the 'Clean Power for Transport' package. DAFI represents a key directive to unlock the potential for hydrogen-based fuels. Electricity, hydrogen, biofuels, natural gas and liquefied petroleum gas have been identified, currently, as the main alternative fuels with long-term potential in terms of an alternative to oil, also in light of their possible simultaneous and combined use through, for example, systems that make use of dual power technology. Without prejudice to the list of alternative fuels in this Directive, there are others types of clean fuels that can represent potential alternatives to fossil fuels and whose results of research and development activities are promising. In this regard, the rules and legislation should be drawn up without favouring any particular type of technology with the only aim to reduce GHGs and polluting emissions, so as not to hinder the further deployment of alternative fuels and energy carriers.

The final Directive, as adopted by the European Parliament and the Council on 29 September 2014 following the inter-institutional negotiations included the following requirements from Member States:

- To develop national policy frameworks (NPFs) for the market development of alternative fuels and their infrastructure;
- To foresee the use of common technical specifications for recharging and refuelling stations;
- To pave the way for setting up appropriate consumer information on alternative fuels, including a clear and sound price comparison methodology.

Each Member State adopted a NPFs for market development with regard to the alternative fuels in the transport sector and the construction of the related infrastructure. Each member state was requested to include in the NPF at least the following elements:

- an assessment of the current status and future market developments regarding alternative fuels in the transport sector, also in light of their possible simultaneous and combined use, and of the infrastructure development considering the cross-border continuity;
- the national objectives for the infrastructure construction, which are established and can be reviewed ensuring compliance with the minimum infrastructure requirements illustrated in the article 4 of the Directive;
- the necessary measures to ensure the national objectives contained in the respective strategic framework;
- the measures that can promote the infrastructure construction in the services related to public transport;
- the designation of urban/suburban agglomerations, other densely populated areas and networks, which, depending on market needs, can be equipped with recharging points accessible to the public.

The national strategic frameworks were thus requested to take into account the needs of the different existing transport modes on the territory, including those for which limited alternatives to fossil fuels are available. Member States were asked to guarantee the cooperation, through joint consultations or strategic frameworks, to achieve the coordinated objectives of the Directive and to adapt NPFs to the current EU legislation on environmental and climate protection.
The introduction of alternative fuels in the transport sector imposes necessarily the development and the realisation of a new infrastructure. In fact, the actual infrastructure is not adequate and the lack of a harmonised alternative fuel infrastructure at European level may hamper the market introduction of vehicles fed with alternative fuels and delay the benefits for the environment. In this regard, the Directive constitutes one of the main actions concerning the development of the infrastructure for alternative fuels announced by the European Commission. Accordingly, Member States drew up their national strategic frameworks in which they set out their national objectives and related support actions, concerning the development of the alternative fuels market and of the necessary infrastructure to be implemented. These support actions were realised in close collaboration with regional and local authorities and with private sector actors, also taking advantage of a wide range of incentives and regulatory and non-regulatory measures. The coordination of the strategic frameworks of all Member States should ensure, therefore, the long-term security necessary to favour public and private investments in the technologies of fuels, infrastructure and vehicles, in order to pursue the dual objective of minimising dependence on oil and mitigating the environmental impact of transport. As an example, in order to obtain an accessible infrastructure for the supply of electricity, the appropriate number of accessible recharging points was established in the respective national strategic plans. The construction of sufficient refuelling points in the infrastructure is therefore essential to make possible the large-scale deployment of vehicles powered by alternative fuels. The Annex II of such Directive 2014/94/EU refers to technical specifications ensuring the interoperability of the alternative fuels infrastructure: the aim is to allow driving across Europe without any compatibility problem in the refuelling stations. In fact, the European Commission has requested the European standardization organizations to develop standards that address these technical specifications.

Among all the alternative fuels considered in the directive, electricity and hydrogen are suitable energy sources in particular to promote the diffusion of electric and FCs vehicles in the populated areas, with advantages in terms of improving air quality and reducing acoustic pollution. The electric-mobility contributes significantly to achieving the ambitious goals set by the member states in the Conference of the Parties. Hydrogen is included in 14 NPFs (Austria, Belgium, Bulgaria, Czech Republic, Germany, Estonia, Spain, Finland, France, Hungary, Italy, Netherlands, Sweden, and UK). Member States that decided to include hydrogen refuelling points in their national strategic frameworks ensured an open circulation of hydrogen-powered vehicles and the continuity of the infrastructure coverage throughout all the European countries. The fuel cells vehicles powered by hydrogen show currently very low market penetration rates. The construction of a sufficient hydrogen refuelling infrastructure is therefore essential to make possible a large-scale deployment of such vehicles.

The Commission is committed to communicate to European Parliament and to the Council every three years starting from 18 November 2020:

- an evaluation of the implemented measures by the Member States, carrying out an assessment of the NPFs and their coherence at Union level, including an attainment level evaluation of the national targets and objectives referred to the Article 3 of the Directive;
- an assessment of the effects of this directive on market development with regard to infrastructure for alternative fuels and its contribution to the alternative fuels market for transport, as well as its impact on the economy and the environment;
- information on technical progress and market development of alternative fuels in the sector transport.

3 Definition of requirements for highly distributed electrolysis systems

The definition of appropriate codes and standards, which identify the specific requirements of highly distributed water electrolysis systems, represents a question still under debated. For the market introduction of electrolysers, it is necessary to individuate along with the analysis of performance requirements, the standardization of tests for electrolyser qualification and the development of business models taking into account different electrolyser uses.

The actual costs of such devices inhibit their unique use for providing hydrogen to a profitable application, for this reason, it is very difficult to individuate and analyse the relative business cases.

In order to maximize profits, electrolysers may be further applied to perform electricity grid service and be coped with the transmission line and renewables. Nowadays, some cases involve the use of pre-qualified water electrolysis systems for the operation under grid-balancing service. In these cases, the local transmission and distribution system operator have to validate an individual pre-qualification procedure of the specific electrolyser system. The identification of this standardised testing protocol, and consequently, the definition of the relative performance requirements can immediately demonstrate the capability of the system to support the operating conditions of a grid sharing a large amount of renewable power sources. An assessment of electrolysis system properties in relation to the operating conditions allows manufacturers and potential customers to demonstrate its feasible application for the required service [4].

A detailed discussion of the requirements for highly distributed electrolysis systems, subject of the present paragraph, is reported in the deliverables D2.1 and D2.2, which respectively collect all the technical specifications concerning the protocols for characterisation of system components and PEM water electrolysers assessment (D2.1) and the complete set of technical and operational requirements for field-testing (D2.2). Whereas D6.3 provides practical information about the actions that were addressed to get approval for field testing activity in Emden with injection of the Hydrogen produced by an electrolyser connected to a local electrical grid sharing a large fraction of renewable energy was injected into the natural gas grid.

3.1 HPEM2GAS route taken for the approval of the Power to Gas field testing activity

The regulatory framework for the electrolysis plant installed in Emden (DE) is shortly discussed in the following.

In Germany, the approval of a plant is essentially regulated by the Federal Immission Control Act. This determines the procedure and the necessary steps for approval. The authority responsible for the approval is the trade supervisory office. This decides on the approval for building and operation. A TÜV (Technischer Überwachungsverein), certification was strictly needed for the electrolysis plant before that a continuous injection of the hydrogen produced by the electrolyser into the gas grid was carried out. The official request was made to this agency after the positive SAT (site acceptance test). This step was preceded by the authorisation DVGW - German Association of Gas and Water Industries about the stability, leaks and connections of pipelines.

The construction and operation of the new plant for the electrolytic production of hydrogen requires a permit pursuant to § 4 para. 1, § 6 para. 1, § 10 of the Federal Immission Control Act (Bundesimmissionsschutzgesetz - BImSchG) in conjunction with §§ 1 and 2 of the 4th Ordinance on the Federal Immission Control Act (4th BImSchV), No. 4.1.12 of the Annex to the 4th BImSchV.

For an operating time less than 12 months, no approval is required

A licensing procedure in accordance with § 10 BImSchG (with public participation) must be carried out.

The project is a plant pursuant to Art. 10 of Directive 2010/75/EU.

When the plant produces less than 250 Nm^3/h, no public participation is necessary.

The necessary arrangements for P2G field testing are discussed below:

1. Explosion protection document

As part of a risk assessment, an explosion protection document must be drawn up in accordance with § 6 of the Hazardous Substances Ordinance.

2. Lightning protection

The lightning protection needs to be implemented according to the lightning protection document of Vektor Plan dated 30.07.2017.

3. Expansion lines

Gases released into the atmosphere from expansion and relief lines, in particular from safety valves, shall be safely discharged.

4. Pipelines

The pipelines must at least be technically tight in accordance with TRBS 2141 Part 3 2.4.

5. Declaration of Conformity/CE marking

The companies involved must have a CE marking and an EC declaration of conformity for all system components covered by one or more harmonization directives.

6. Instructions

Employees must be instructed in accordance with the operating instructions.

Inspections are carried out first by the DVGW - German Association of Gas and Water Industries and deal with stability and leak tests. A second inspection is made in accordance with the TÜV- Technical Inspection Association and it deals with acceptance of the plant in accordance with the "Ordinance on Pressure Vessels, Pressurized Gas Vessels and Filling Plants (Druckbehälterverordnung - DruckbehV)". This includes a classification into test groups

The pressure vessels are divided into the following groups according to the permissible operating overpressure P in bar, the volume of the pressure chamber I in litres and the pressure content product pûI - in the case of several pressure chambers separated from each other, the product is determined separately for each pressure chamber:

Pressure vessels in which the pressure is exerted by gases or vapours, by liquids or solids with gas or vapour cushions or by liquids whose temperature exceeds the boiling temperature at atmospheric pressure:

Group I:

Pressure vessels intended for the carriage of cryogenic liquefied gases with a maximum allowable working pressure p of more than 0,01 bar and not more than 0,1 bar;

Pressure vessels with a working gauge pressure p of not more than 25 bar and a pressure content product p*I of not more than 200 ; pressure vessels as pipe assemblies consisting solely of pipes with a clear cross-section of not more than 100 cm^2 , if the product of the working gauge pressure in bar and the clear diameter d in millimetres does not exceed 2000.

Group II:

Pressure vessels with a working gauge pressure p of more than 25 bar and a pressure content product p û I of not more than 200;

Pressure vessels with an allowable working pressure p of not more than 1 bar and an allowable pressure content product pûI of more than 200; The HPEM2GAS electrolyser falls under this directive (group 2; 29 bar).

Regarding hydrogen injection into the gas grid in Emden, the following considerations are made: currently, less than 5 % hydrogen may be fed into the natural gas grid in Germany, there is no clear legal framework. In Emden an der Pfälzer Straße, a maximum of 2 % H2 may be fed into the natural gas network, the reason being a natural gas filling station in the immediate vicinity. To do this, the quality of the natural gas must be guaranteed in order to rule out possible damage to the refuelled cars. Integration of the plant and related requirements need also to address lightning protection system and explosion protection document

For commissioning, the ex-zone (area of ignitable concentration of flammable gases) for the control station needs to be determined and the ex-zone document of the electrolyzer needs to be provided.

Inspection of the system by the German Gas and Water Association (DVGW) expert includes acceptance of the control station and the lines to the electrolyzer. Tests to be performed stability and leak testing. The TÜV acceptance of the electrolyzer regards an acceptance of the plant in accordance with the "Ordinance on Pressure Vessels, Pressurized Gas Vessels and Filling Plants (Druckbehälterverordnung - DruckbehV)".

§8 - Classification into test groups

The pressure vessels are determined separately for each pressure chamber according to the permissible operating overpressure p in bar, the volume of the pressure chamber L in litres and the pressure content product p*L - in the case of several separate pressure chambers the product is determined separately for each pressure chamber - here it is divided into groups I - VII:

For the electrolyser used in the project, a TÜV approval according to Group II is required, as the pressure vessels have a volume of 20 to 29 L and a pressure of 35 bar.

Group II:

Pressure vessels with a permissible operating overpressure p of more than 25 bar and a pressure content product p*L of not more than 200;

Pressure vessels with a maximum allowable working pressure p of not more than 1 bar and a maximum allowable pressure content product p*L of more than 200;

4 Impact analysis

Nowadays the power generation, transport and industry heating and feedstock production represent the sectors that in Europe mostly contribute to the CO_2 emissions in the atmosphere, respectively for the 33%, 32% and 15%. The aim of the Paris agreement is to reducing approximately from 3,500 Mt to 770 Mt of CO_2 per year emissions promoting the decarbonisation of transport, buildings, and industry through the largest share of renewable energy sources and the renewable production of hydrogen, by 2050. Hydrogen has a positive ecological and societal impact, since it can be produced using RES and its combustion produces only water as by-product. Thanks to these features, it is able to significantly contribute to zero-emission transport, increase electric grid flexibility, make cleaner industrial processes and to further promote the penetration of renewable energy sources.

Hydrogen may reduce emissions of 20% in the only transport segment, but the decrease of heavy-duty and long-distance transport that are responsible for high CO_2 emissions would lead to a significant reduction. In other sectors as heating and power for building, the role of hydrogen is fundamental for the decarbonisation. The impact on the emissions is negligible in the case of the power generation segment.

Hydrogen compensates the energy fluctuations in the electricity generation of renewable energy sources: solar and wind provide electricity with discontinuity during the year, the excess energy that cannot be stored into the electricity grid can be used to produce hydrogen. Electricity is transformed into hydrogen and this stored energy can be transported and used where it is necessary.

As carbon neutral fuel promotes decarbonisation reducing CO_2 emissions and the need to use fossil fuels. If employed for end use applications, hydrogen decreases also local emissions such as sulphur oxides, nitrogen oxides and particulates. At this regard, the reduction of NO_X emissions, which are estimated about 7.9 Mt in Europe today, is noteworthy. In road transportation, responsible for the actual 40% of NO_X emissions, hydrogen powered vehicles could reduce more than 0.5 Mt of NO_X emissions in 2050.

The current emissions are responsible of high air pollution levels, which above the established thresholds cause illness and even death. For this reason, European cities like Madrid, Paris, or Oslo have launched different initiatives to mitigate the risk reducing, for example, the circulation of diesel vehicles and promoting hydrogen-powered ones, which represents a clean and sustainable alternative [1].

5 Application of DAFI 2014/94/EU and other directives in the countries of HPEM2GAS

The purpose of this chapter is to evaluate the national policy and the application of DAFI 2014/94/EU and other directives in each country of HPEM2GAS partners. The project brings together seven partners from Denmark, Germany, Italy, the Netherlands and United Kingdom (Figure 3). The situation of each country is analysed in detail through a critical assessment of the current state, of the legal and administrative processes, of the barriers and incentives and finally through an overview of the initiatives adopted to promote the deployment of hydrogen technology.
This document aims to attract the attention of policy makers to eliminate the barriers, as well as to adopt the best practices obtained from the comparison with the other countries of the European Union.

Figure 3. Locations of HPEM2GAS partners.

5.1 Denmark

Denmark has supported hydrogen technologies already from three decades. At the beginning, initial research funding for Universities was the main support through research grants, demonstration programmes and a series of policy initiatives to promote the development and the deployment of hydrogen technologies. In the second decade, Denmark dedicated research to the development and production of fuel cells with increasing attention to the energy production from renewable sources, in spite of the use of fossil fuels. Large investments have been profuse in the conversion of wind energy into green electricity and into the hydrogen technology, which can help to overcome the discontinuity of renewable energy sources. In order to promote the use of green energy in the transport sector, hydrogen production through electrolysis is individuated as the best solution to connect the different energy sectors. Since June 2018, the Danish parliament turned its efforts towards a gas-based strategy: the aim is to base the integration of different systems and a strong market on gas. Electrolysis seems to represent the most promising solution from different points of view. The production of renewable energy from wind turbines and the decarbonisation of transport sector through the use of CO_2-neutral and zero-emissions fuel are connected by hydrogen. The Danish policy framework depends strictly on hydrogen production: excess power of grid is converted into hydrogen, which is employed as fuel in transport.

Denmark shows a national hydrogen-refuelling grid, well distributed throughout the country: 10 stations are currently in operation or under development. At the moment, Denmark holds about 83 Fuel Cell electric vehicles on the road, thanks to the competitive prices and the registration fees exemption, and it does not have any hydrogen-powered busses, trucks or ships, but several bus projects are underway.

Danish legal framework regarding hydrogen-refuelling stations is acceptable but it can be improved according to the opinion of the stakeholders. The system does not show specific legal problems but some issues related to the operation of the stations and payment of fuel supply by credit card have to be solved.

Electrolysis when integrated into the electricity grid does not meet legal barriers. The process is considered as an industrial activity and as such the renewable electricity used for the hydrogen production may be exempted from the electricity tax. Nevertheless, electrolysis plants pay the Public Service Obligation tariff, which the Danish government decided to eliminate in order to decrease the operating costs of electrolysers after 2022. On the contrary, a significant barrier is represented by the grid tariffs, which are not related to the consumption and flatten the flexibility ensured by electrolysers. The grid tariffs represent a serious problem for the integration of renewable sources in the grid. The diagram reported in Figure 4 depicts the production of wind in the western electricity grid (DK1), while DK1 Down is the amount of energy lost when the wind turbines are limited.

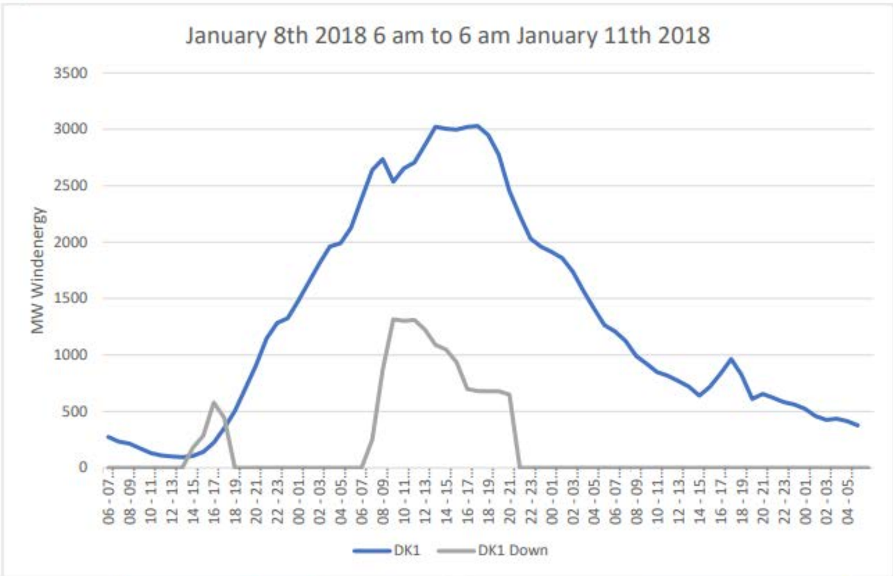

Figure 4. The diagram depicts the production of wind in the western electricity grid (DK1), DK1 Down represents the amount of energy lost when the wind turbines are limited.

Denmark is losing renewable energy since the consumption of electricity is not suitable potential for the electricity supply.
Denmark does not show significant obstacles to hydrogen deployment but should provide incentives as the grid-tariff reform and facilitate inclusion of electrolysers in the grid connection agreements in order to decrease costs and promote hydrogen technology [5].

5.2 Germany

With respect to many other European countries, Germany shows relevant and different hydrogen and fuel cell applications in the current legal and regulatory framework. Different legal acts, ordinances, standards and worksheets attest the efforts related to the construction and operation of hydrogen production plants, hydrogen refuelling stations, hydrogen storage, injection of hydrogen in the gas grid, procedures for approval of hydrogen vehicles, tax treatment, incentives etc.
The German government has adopted the European Directive 2014/94/EU where hydrogen is defined as an alternative fuel with a potential for long-term oil substitution, irrespective of the primary energy source. The renewable produced hydrogen is recognised as a renewable transport fuel of non-biological origin by Directive (EU) 2015/15137 amending the current legislation for biofuels (Renewable Energy Directive and Fuel Quality Directive). In Germany, the binding target of the Fuel Quality Directive for 6% reduction of the GHGs intensity of transport fuels is transposed into §37a of Federal Immission Control Act. The Council Directive (EU) 2015/652 is implemented with the Ordinance on counting electricity-based fuels and processed biogenic oils against the greenhouse gas quota – 37th Federal Immission Control Ordinance. According to §3 (2) of 37. Federal Immission Control Ordinance, the renewable produced hydrogen could be counted against the greenhouse gas quota in three cases:
1. The electricity used in the production plant is directly supplied from a renewable energy plant that is not connected to the electricity supply grid;
2. The electricity used is taken from the public supply grid when the production plant is:
a) built in a network extension area according to § 36c (1) of Renewable Energy Act where the transmission grids have to be expanded due to the wide production of electricity from RES (Netzausbaugebiete) and
b) operated exclusively on the basis of a contract for switchable loads with the respective transmission operator in accordance with § 13 (6) of the German Energy Industry Act (Zuschaltbare Lasten);
3. By derogation from P. 2, the electricity used may be taken from the public supply network if the renewable hydrogen is placed on the market before 1 January 2021 and produced in plants that produced such fuels for the first time before 25 April 2015, the origin of electricity from renewable sources of non-biogenic origin has to be certified.
Germany holds currently more than 50 publicly accessible hydrogen refuelling stations in operation: this makes the country, ahead of the USA, with the second largest hydrogen refuelling infrastructure,

after Japan. Germany in the "National Electro-mobility Development Plan" set the ambitious goal to promote the electro-mobility through the deployment of one million electric vehicles by 2020.
Hydrogen production plants are considered as chemical production plants, which work on large scale releasing inorganic emissions in the atmosphere. Among these production methods, there is no differentiation based on the presence or absence of hazardous substances involved in the process or on other standards. Electrolysis systems, featured by small capacities, undergo the same permitting procedure of large-scale plant that requires controls of Federal Immission Control Act and of Environmental Impact Assessment Act. The long and restrictive measures may hinder investments and thus economies of scale for small units, hence may hamper hydrogen deployment.
At present, Power to gas does not have a legal definition both at European and at national level. Power to gas represents, at the same time, an energy conversion and storage technology and for this reason is connected to electricity and gas network and to the correlated EU legislation, the 2009 Third Energy Package and the proposed Clean Energy for all Europeans Package of 2016. The Electricity Market Directive 2009/72/EC50 and Natural Gas Market Directive 2009/73/EC51 are taken as a reference and transposed into German law by the German Energy Industry. Power to Hydrogen is considered as end user in electricity system and the produced hydrogen is not used for power recovery. Since the electricity price for end users includes various energy charges and allocations (e.g. network charges, cogeneration, electricity tax etc.), very high price of hydrogen forbids its competitive use. A limited number of Power to gas plants is used for energy storage of renewable energy and power recovery. In these cases, the stored gas used to produce electricity are exempted from apportionment for the purchased electricity from renewable energy sources under the Renewable Energy Act (§61k (1) (2), from electricity and gas network charges according to Energy Industry Act (§118) and from electricity tax for electricity, used for electricity production according to Electricity Tax Act (§9) 53. The Cogeneration- apportionment is reduced according to Cogeneration Act (§27b). The electricity cost influences the product costs of a Power to gas plant: the electricity has to come from RES in order to minimise costs.
The actual legal restrictions and the missing incentives limit the sector coupling through hydrogen, necessary for the achievement of climate goals by 2050. Hydrogen is defined as biogas in Energy Industry Act, but the Renewable Energy Act and Renewable Energy Heating Act call biogases only gases obtained by biomass anaerobic digestion. A unified definition of hydrogen and renewable gases, based on the guarantees of origin, is required as well as the connection of electrolysis plant to a renewable energy production plant and the hydrogen injection into the gas grid are needed.
Transport and distribution of hydrogen, due to its very low volumetric energy density at standard temperatures and pressures, require its compression. The quantity of compressed hydrogen, which can be transported by today usual trailers, is suitable only for relatively small demands and is limited by the International Carriage of Dangerous Goods by Road (ADR) and Transportable Pressure Equipment Directive 2010/35/EU (TPED). The ADR and TPED are transposed into German legislation through the ADR Act, the Ordinance on the international and cross-border carriage of dangerous goods by road, railways and inland waterways, the Ordinances amending Annexes A and B to the ADR

Agreement (26th ADR Amending Ordinance - 26th ADR) and the Ordinance for Transportable Pressure Equipment. Lightweight composite gas cylinders at 700 bar and higher volume tubes (up to 10,000l) have been already developed, making possible to increase the overall payload. A revision of the most important ISO standards e.g., to increase the cylinder and tube volumes and the permitted working pressures, as well as to optimise the safety factors specified in the ADR is required.

In principle, the German legislation does not provide specific limitations about the hydrogen concentration in the natural gas network. The fed gas has to be ensured as compatible with the grid by all grid users. The technical requirements refer to the latest version of the German Association of Gas and Water Supply (DVGW) Worksheets (DVGW G 260 and G 262). The actual DVGW Worksheets G 260 (Gas quality) and G 262 (Use of gas from renewable resources in public gas supply) allow the hydrogen injection in the public grid with a concentration below 10 Vol%, in several cases a limitation of 5% is applied [6]. For the HPEM2GAS' field testing activity in Emden, since the plant is allocated very close to a gas refilling station a limitation of 2% hydrogen injection into the gas station is applied.

5.3 Italy

Italy is one of the leading countries in Europe in the hydrogen and fuel cell sector, with about 128 projects financed by the European Commission in the period 2008-2017 that involved 80 Italian partners and the mobilization of 90 M€ funding. As the fourth most industrialised country in the EU, Italy may become a competitive player in the transition to hydrogen and to a more integrated, flexible, sustainable and energy-efficient system. This purpose can be achieved through the promotion of proactive policies, on the example of Germany, France and UK. Relevant efforts have been made in Italy for the implementation of hydrogen technologies by the Autonomous Region of Trentino Alto Adige with the realisation of one of the most efficient EU Hydrogen Valley. With Legislative Decree n. 257 of 16 December 2016, the Italian government has adopted the European Directive 2014/94/EU for the creation of an infrastructure for alternative fuels. In order to officially include hydrogen among the alternative fuels a project named "Mobilità idrogeno Italia" (MH2.It) was launched in 2015 by the Italian Hydrogen and Fuel Cells Association (H2IT). The aim of project was to set out the objectives in the National Policy Framework that each Member State had to transmit to Brussels until 18 November 2016.

Italy actually holds four continuously running hydrogen refuelling stations developed with private or state funds and several other operating on this purpose in the framework of specific projects. This constitutes a minimum infrastructure but it is inadequate for the wide commercialisation of hydrogen zero-emission vehicles. Italy holds about 10 Hydrogen-powered buses and others are planned to be demonstrated in recent demonstration projects. The Ministerial Decree of 31 August 2006 until 2018 regulated the hydrogen production and handling and considered hydrogen as an industrial product, which requires fossil sources for its production at large scale. Such decree did not take into account the possibility of producing localised hydrogen from water and electricity, without GHGs emission. This imposed extremely stringent prevention measures on the hydrogen storage plant, inhibiting the latest technological developments in this field.

The Ministerial Decree entitled "Technical rule of fire prevention for design, construction and operation of hydrogen distribution facilities for automotive applications" and published in November 2018 has overcome the barriers of the previous legislation through the synergic work among the Fire Department, Ministries, the Italian Association for Hydrogen and Fuel Cells and several interested stakeholders. With respect to the previous one, the new decree takes into account the risk analysis allowing for operation of systems that transport and supply hydrogen at 700 bar and better alignment to ISO 19880. The installation of a hydrogen production unit requires the approval of several legal and administrative processes (land use plan, permitting process, legal requirements). Renewable hydrogen favours small-scale and localized production, but is subject to the same and heavy limitations of industrial activities and large-scale plant, which hinder the deployment of renewables and electrolysis. From an environmental point of view, the production of hydrogen for industrial uses is very different from the production of hydrogen as an energy carrier; environmental impact studies are necessary to differentiate both cases and to increase and favour the electrolysis competitiveness.

Hydrogen storage technology represents a critical point of hydrogen infrastructure and application and depends on different variables: energy density, storage capacity, safety requirements and low investment cost. Italy does not provide specific national regulations for hydrogen storage and consequently the situation is handled among the different local Fire Departments and Municipalities: hydrogen is actually considered, from a legal and administrative point of view, as flammable and dangerous gas and some severe restrictions affect the cost. Excessive precautions can lead to structural barriers that forbid the development of commercially viable applications, hence risk and safety analysis and environmental assessment could minimise these barriers.

Hydrogen production for a refuelling station or for industrial purposes requires an open access to the electricity grid, hence the regulatory framework covering the European electricity grid and transmission/distribution networks has to remove the market and legal barriers to favour the network access and ensure the electrolysers inclusion. Electrolysers-based Power to Gas plant allows grid balancing service 'switching-on' electrolysers when the network has excess power (using electricity to generate hydrogen) and generating power (using stored hydrogen) in order to maintain the grid load/frequency. The main EU Legislation framework affecting grid access in general and thereby electrolyser access has been introduced via three 'energy packages':

- The first, Directive 96/92/EC (concerning common rules for the internal market in electricity, promoted the independence of the transmission system operator, and laid down the rules relating to the organisation and functioning of, and access to, the wholesale electricity market);
- The second, Directive 2003/54/EC (concerning common rules for the internal market in electricity (Electricity Directive)), focused on the concepts of unbundling and third-party network access);
- The third comprised two Directives (Directive 2009/72/EC and Directive 2009/73/EC) and three Regulations (Regulation (EC) No 714/2009; 715/2009 and 713/2009) to further open up the gas and electricity markets in the European Union with the separation of companies' generation and sale

operations from their transmission networks (and thereby independent distribution networks). It also provided for the establishment of a National Regulatory Authority (NRA) for each Member State and for the Agency for the Cooperation of Energy Regulators (ACER), which provides a forum for NRA to work together.

These energy legislation packages have recently been complemented by the Commission Regulation 2016/1388 for establishing a network code on demand connection – giving the legal basis for regulatory authorities to ensure that objective and non-discriminatory technical rules would establish minimum technical design and operational requirements for the connection to the grid system. Since 2016, this regulation acts as binding and is directly applicable in all Member States. For the Power to Gas application of a grid connected electrolyser to generate hydrogen (to be transported / stored in the existing gas infrastructure), as discussed above the Directive 2009/73/EC sets common rules for the transmission, distribution, supply and storage of gas, access to the market, the criteria and procedures applicable to the granting of authorisation for transmission, distribution, supply and storage of gas and the operation of gas network systems. In the context of grid balancing services, Commission Regulation 2017/2195 of 23 November 2017 represents a guideline on electricity balancing and has to be taken into consideration about grid operation and supply security. Italy does not expressly recognise electrolysers as devices for grid balancing.

The introduction of hydrogen, not pure but in the form of mixture, in the Italian gas transport network is still under study / demonstration phase. The experimentation, the first of its kind in Europe, takes place near Salerno and involves the supply of a mixture of hydrogen and natural gas by Snam Rete Gas to two industrial companies in the area. In this case, the maximum allowed concentration of hydrogen is 0.5% by volume. The Ministerial Decree of 23 October 2018 ("Technical rule of fire prevention for design, construction and operation of hydrogen distribution facilities for automotive applications") refers primarily to hydrogen refuelling stations, gas grid connection and hydrogen injection do not meet yet formal basis in Italy. Any hydrogen injection facility is expected to be connected to a local distribution network, in this case the ATEX Directive 2014/34/EU, transposed by Legislative Decree n.85, 16 May 2016 can be applied [7].

5.3.1 Implementation of the Italian National Policy Framework

In order to accomplish the objectives of the 2014/94/UE directive, and especially to benefit of the European support measures for the infrastructure for hydrogen refuelling for transport, on 5th June 2015 a project was launched by the Italian Hydrogen and Fuel Cells Association (H2IT) among Italian stakeholders named "Mobilità idrogeno Italia" (MH2.It).

This project was made necessary to reach the objectives of including explicitly hydrogen among the alternative fuels set out in the National Policy Framework (Quadro Strategico Nazionale (QSN)) that each Member State shall transmit to Brussels until 18 November 2016.

The QSN was planned to indicate the objectives and the support measures to ensure the development of a market of alternative fuels and the realization of their fuelling infrastructure. In particular, according to the 2014/94/UE directive, the document was including the strategy for the deployment of the necessary infrastructure to be put into place, in close cooperation with regional and local authorities and with the industry concerned, while taking into account the needs of small and medium-sized enterprises

The "MH2.It" project was providing an Italian platform for Hydrogen Mobility and it was asked by the Italian Ministry of Economic Development to prepare the QSN for hydrogen infrastructure development. As said, the formation of this Consortium was promoted by the Italian Association of Hydrogen and Fuel Cells (Associazione Italiana dell'Idrogeno e delle Celle a combustibile (H2IT)) especially by initiative of his past President Prof. Angelo Moreno. MH2.It was managed by a strategic committee (Comitato strategico) composed by representatives of members, that had the role of individuating the most appropriate strategies and to promote an hydrogen infrastructure in Italy.

MH2.It includes the main Italian stakeholders in the field. Its main objectives are to support the competent authorities and policy makers in the definition of a National Plan for the Development of Sustainable Mobility with zero impact based on hydrogen.

The aim of the specific activities carried out by the stakeholders was to provide Italy with an appropriate hydrogen refuelling infrastructure for transport by 2025, in line with the other EU countries to fulfil the deadlines indicated by the Directive 2014/94 / EU.

This initiative was also addressing fill the gap with respect to other EU countries since only modest efforts have been carried out, until now, in Italy by the policy makers to promote zero emission hydrogen-based mobility.

In this regard, a renewed interest in this field by the national automakers could provide a favourable basis for supporting hydrogen technology.

According to a recent Eurostat analysis, the Italian energy dependency from abroad has reached the level of 75%. On the other hand, the objective of achieving 17% of the total energy consumption by renewables assigned by the EU to Italy by the 2020 has been achieved already. The share of renewable energy in Italy is mainly on the consumption of electrical energy (>30%), but it is approaching 20% for heating whereas it is only 5% for transportation in comparison to a target of >10% by 2020.

A significant fraction of the renewable energy produced in Italy is from wind and photovoltaic power sources which are strongly affected by the weather conditions and thus characterised by large degree of intermittency. If the share of energy from renewables will increase, according to the recent trend, together with the need to accomplish the EU directives, there will be the risk that a significant fraction of the excess of renewable energy could in the next future be curtailed by grid operators. Whereas, there is the need to increase the fraction of renewable fuels in transportation at least to reach the EU target that has been already agreed. A wide deployment of electrolysers for hydrogen generation from renewables, also providing grid-balancing service, and fuel cell vehicles is thus strongly needed and should be supported by proper government incentives. Thus, it is widely recognised that an hydrogen infrastructure must be put in place in Italy.

MH2.It uses a bottom-up approach to deal with all technical and financial aspects including regulations in order to allow the development of an adequate network of hydrogen refuelling infrastructure by 2025 in accordance with the Directive 2014 / 94 / EU.
MH2.It thus issued a first draft of the National Development Plan (Piano Nazionale di Sviluppo delle Infrastrutture per il Rifornimento di Idrogeno nei Trasporti (PNS)) that was transmitted to the Ministry of Economic Development for their evaluation. The final document, officially approved by the Ministry was transmitted to both the Italian Parliament and the Government in order to have this plan included in the National Strategic Framework (Quadro Strategico Nazionale) that was submitted to the European Commission.
The PNS was addressing the following points:

• Develop appropriate legislation in this field and update the normative; in particular, provide compliance with EC 79/2009 and EC 406/2010 regulations; contribute in providing a set of rules and authorization procedures, valid for all Member States. Accomplish the directive 2014/94 / EU: requirements and technical standards for manufacturing of hydrogen filling stations.
• Define the objectives to be pursued with regard to the environmental issues and security of supply;
• Identify the most suitable financial models for the Italian national context.
• Determine the most appropriate market-based approach for the development of hydrogen mobility.
• Analysis of the costs and benefits for the Country;
• Be consistent with the development strategies of the TEN-T Core Network Corridors and the priorities identified by the FCH JU.

The legislative decree regarding the transposition of the EU DAFI "Deployment of Alternative Fuels Infrastructure" directive was issued in Italy on 21.11.2017. Its National Policy Framework was including hydrogen for sustainable mobility and specific measures to implement the hydrogen infrastructure in the Country.
A presentation about the National Implementation of the Directive DAFI 2014-94-EU in Italy (National policy Framework) was given by the project coordinator at a FCH JU SRG meeting in Brussels.

5.4 Netherlands

The Netherlands shows the second largest hydrogen production in Europe, after Germany. The country shows a mature hydrogen technology since 50 years: hydrogen used as a feedstock is mainly produced by the chemical and the petrochemical industry and the production plants are connected with hydrogen pipelines. In recent years, hydrogen is employed as energy carrier and one of the biggest challenges is to produce green hydrogen from renewable energy sources.
No specific legislation takes into account the need of producing hydrogen from water and electricity, without emissions and production of hazardous substances. Hydrogen production through electrolysis is considered as an industrial activity and imposes the same stringent prevention measures of emitting processes. This inhibits the latest technological developments in this field. The "extended WABO procedure" is the regulation procedure that is applied. The lack of a simplified process for electrolysis

increases costs for developers and leads to disproportional requirements for localized production facilities like the following:

• Land use plan (zone prohibition);

• Permitting requirements.

Electrolysis addressing hydrogen production is subjected to:

− Risk Assessments (SEVESO);

− Health and Safety requirements (ATEX);

− Integrated Environmental obligations (IED);

− Environmental Impact Assessment procedures (SEA and EIA).

All these requirements put some constrains, to the deployments of electrolysis plants and the Hydrogen Refuelling Stations with on-site production.

The general provisions of the environmental legislation act (Wabo) came into effect in 2010 and will eventually be included in the Environmental Act. The Wabo includes several acts as the Wro and the wet milieubeheer (environmental Conservation Act). The Wabo will be replaced by the Omgevingswet (Environmental Act) in due time (expected 2021). The WABO is already one stop shopping to get permission but the regulations will be even more increased by the Omgevingswet. The “Omgevingswet” (Environmental Act) is umbrella legislation that incorporates several acts, among which laws for construction, destruction, environment, flora/fauna, and mining. The WABO and Omgevingswet are national regulations.

Transport and distribution of hydrogen are well developed and are regulated by the ISO standards for technical and safety requirements of cylinders and tubes. Restrictions about road transport, through tunnels or bridges is subjected to the provisions of ADR, which standardises transport of dangerous goods by road. ADR is implemented in Member states through harmonised transposition of the Directive 2008/68. The hydrogen is treated in the same way as other flammable gases: ADR classifies hydrogen as category types and its transport in tanks is forbidden through most of tunnels for security reasons and is only permitted through five tunnels. Tie WVGS is the Dutch implementation of the ADR.

The Netherlands holds until 2018 three operational public Hydrogen Refuelling Stations. The stations will become respectively 14 in 2019 and 20 in 2020. A well-distributed hydrogen infrastructure for mobility purposes is fundamental in order to meet the environmental goals of the Netherlands. The Alternative Fuels Infrastructure Directive (DAFI Directive 2014/94/EU) established a common framework of measures for the deployment of alternative fuels infrastructure in the Union in order to minimize dependence on oil and to mitigate the environmental impact of transport and sets out minimum requirements for the building-up of alternative fuels infrastructure, including refuelling points for hydrogen. Hydrogen is recognized as an alternative fuel in all countries which have correctly transposed the directive. Besluit infrastructuur alternatieve brandstoffen is the National transposition of the Netherlands concerning DAFI. The absence of Guarantee of Origin for renewable hydrogen hampers the market development, as well as the lack of fuel quality requirements.

In 2018 the Netherlands holds 40 Hydrogen Fuel Cell Electric Vehicles, other 100 vehicles have been sold until 2019. Hydrogen-powered 5 buses, a few garbage trucks and some special vehicles (e.g. street sweepers) are operational. In 2019 50 new buses are expected to be on roads in the Netherlands.

Proton-exchange membrane electrolysers integrated into the e-grid in the Netherlands provide a consolidated technology since 25 years. The integration in the Dutch grid is possible as long as the grid connected equipment (e.g. electrolyser) is able to meet the grid services requirements.

Gas Injection at transmission and distribution level is both regulated under the Dutch Gas Act. Injection of hydrogen is only allowed to the maximum specified concentration in the Ministerial Decree on gas quality. The concentration limit is fixed to 0.02 mol-% and 0.5 mol-% for the transmission and distribution grid, respectively. The hydrogen concentration limits are very low. The injection of hydrogen up to <50%, provided the gas grid contains >50% methane, could be facilitated by the Ministery of Economic Affairs and Climate (EZK) by amending the Ministerial Decree for the removal of this barrier [8] .

5.5 United Kingdom

United Kingdom UK since 1842 is one of the leading countries in Europe in the hydrogen and fuel cell sector, across multiple portable, transport and stationery power applications. UK shows consolidated and growing industry based on hydrogen technologies utilised in a wide spectrum of applications on national and global basis.

The national regulatory framework classifies hydrogen technologies as high-risk activities: for this reason, legal and administrative controls and strong limitations have been imposed. UK assumes land use planning permission and related production site regulatory arrangements for the large-scale production, but it does not provide a ‘simplified process’ for low volume production and storage. Hydrogen is recognised in the UK as a transport fuel in 2016, with the adoption of the European Directive 2014/94/EU for the creation of an infrastructure for alternative fuels. Currently, there is no common definition of renewable hydrogen as an alternative fuel, whose origin is certified by the guarantee of origin. DAFI was transposed in the UK in October 2017. However, the transposition for UK hydrogen refuelling points includes only the reference to ISO 17268 for refuelling nozzles – to ensure standardisation of relevant equipment.

According to the Town & Country Planning Act for England & Wales (and Town and Country Planning (Scotland) Act, 2006), a centralised hydrogen production at a high volume site is considered as an industrial activity and requires the land use planning approval and site permitting (through an Environmental Impact Assessment). The main legislation framework affecting production of Hydrogen has been introduced at EU level by three legislative acts:

- SEVESO Directive;
- ATEX Directive;
- Directive 2010/75/EU on industrial emissions.

Each of these acts has been transposed into UK law and imposes several limitations on plant design and on operators involved in the production of hydrogen, as well as on the equipment used. The control activity of hydrogen production plant depends further on the quantity of hydrogen storage on the production site:

- at >2 tonnes the Planning Hazardous Substances regime comes into effect;
- at >5 tonnes the Control of Major Accident Hazards (COMAH) 2015 regulations come into effect.

Renewable hydrogen favours small-scale and localized production, but is subject to the same and heavy limitations of industrial activities and large-scale plant, which hinder the deployment of renewables and electrolysis. From an environmental point of view, the production of hydrogen for industrial uses is very different from the production of hydrogen as an energy carrier; environmental impact studies are necessary to differentiate both cases and to increase and favour the electrolysis competitiveness. Zone prohibitions and administrative practice should recognise that hydrogen production can take place in different ways and that methods (such as electrolysis) having little environmental impact and generate little to or no emissions could be treated differently from a land use planning perspective. Limited hydrogen production site and local hydrogen distribution are localised in UK, although there have been exceptions based on technology validation and demonstration projects (e.g. Scotland and the BIG HIT Orkney's project).

Hydrogen is actually considered, from a legal and administrative point of view, as chemical storage of flammable and dangerous (industrial) gas and the most severe restrictions may affect the cost. The hydrogen storage is correlated to the storage type and volume, its transport is the same of dangerous goods by road and is standardised in ADR and implemented across the EU through harmonised transposition of Directive 2008/68.

Hydrogen production for a refuelling station or for industrial purposes requires an open access to the electricity grid, hence the regulatory framework covering the European electricity grid and transmission/distribution networks has to remove the market and legal barriers to favour the network access and ensure the electrolysers inclusion. EU Legislation framework impacting grid access has been introduced via three 'energy packages':

• Directive 96/92/EC (subsequently revoked by the third Directive as below) was based on Directive 96/92/EC (concerned common rules for the internal market in electricity, promoted the independence of the transmission system operator, and laid down the rules relating to the organisation and functioning of, and access to, the wholesale electricity market);

• Directive 2003/54/EC, (also subsequently revoked by the third Directive as below) was based on Directive 2003/54/EC (concerning common rules for the internal market in electricity (Electricity Directive)), focused on the concepts of unbundling and third-party network access);

• The third energy package comprised two Directives (Directive 2009/72/EC and Directive 2009/73/EC) and three Regulations (Regulation (EC) No 714/2009; 715/2009 and 713/2009) to further open up the gas and electricity markets in the European Union with the separation of companies generation and sale operations from their transmission networks (and thereby independent distribution networks). It also provided for the establishment of a National Regulatory Authority (NRA) for each Member State and for the Agency for the Cooperation of Energy Regulators (ACER), which provides a forum for NRAs to work together;

• Complemented by Commission Regulation 2016/1388 for establishing a network code on demand connection – giving the legal basis for regulatory authorities to ensure that objective and non-discriminatory technical rules would establish minimum technical design and operational requirements for the connection to the grid system. It came into force on 7th September 2016 as binding and directly applicable in all Member States.

UK does not provide specific national recommendations for connecting an electrolyser to the e-grid as for any other industrial or similar load. A Power to gas plant involves an electrolyser that is connected to the grid or directly to a renewable energy system (solar, wind), which provide electricity to the electrolyser for producing hydrogen. It can be temporarily stored and then supplied to fuel cells, turbines or other power-electric generation system, or injected directly into the gas grid.

The current legal framework does not provide regulations for Power to gas: no rule is foreseen for the grid and market access. The other Member states, as Germany, France and Austria that hold detailed regulatory frameworks, do not set specific recommendations for the integration of Power to gas. Due to this gap, the technology deployment meets significant barriers. Electrolysers-based Power to Gas plant allows grid balancing service 'switching-on' electrolysers when the network has excess power (using electricity to generate hydrogen) and generating power (using stored hydrogen) in order to maintain the grid load/frequency. The lack of legal recognition and of coherent policy framework for PtG forbid its deployment through financial or other measures and the possibility to decrease taxes and fees. The main EU Legislation framework affecting grid access in general refers to the Directive 2009/73/EC and three Regulations (Regulation (EC) No 714/2009; 715/2009 and 713/2009) that provide for access to gas markets with clear procedures applicable to granting authorisation for transmission, distribution, supply and storage of natural gas. The previous regulations do not include the hydrogen injection in the grid, the overview is quite complex.

The UK regulatory framework is set via:

• Gas Act 1996 (Privatisation and unbundling of the gas industry; limiting the market power of British Gas; extending competition to industrial and domestic markets to obtain benefits of competition in terms of market entry and in benefits to customers);

• Gas Safety Management Regulations 1996 (It sets the UK gas quality specification and the Wobbe index range appropriate for the UK, including a 0.1%vol H_2 concentration limit);

• Pipeline Safety Regulations 1996 (Enacted ahead of EC Directives covering gas grids and safety requirements such as ATEX and subsequently updated in line with ATEX Directive 2014/34/EU);

• Utilities Act 2000 (Provided for the establishment and functions of the Gas and Electricity Markets Authority and the Gas and Electricity Consumer Council; to amend the legislation regulating the gas and electricity industries; and for connected purposes – subsequently to become the Office for Gas & Electricity Markets as the sector Regulator).

6 Limits regarding Hydrogen injection in the gas grid across the European Union

The limits for hydrogen concentration in the gas grid, set either by primary legislation or in accordance with long standing safety standards or/and gas quality standards, are very different: from a 'minimal' concentrations of hydrogen at 0.1% vol and up to 'high' concentrations of 6% or up to a maximum of 10% vol.

As reported in Table 2 there is not coherence between the hydrogen thresholds of each Member state: a common and safe regulatory framework is required for the network implementation, at a national level and across the EU.

Legal framework 'Acceptable' H2 level (typically mandated by legislation)	MS (HyLaw) Countries
'Minimal' H2 concentration at **0.1% to 0.5% vol** ' (reflecting typical background concentrations in natural gas):	**IT, LV, SE, UK**
'Low' H2 concentration at **1.0% to 4.0%** vol	**FI, AT**
'Mid' H2 concentration at **6.0%vol**	**FR**
'High' H2 concentration at **up to 10.0% vol*** The applicable H2 threshold may fall below this, depending on down-stream consumers H2 tolerance and other factors (e.g. underground storages, large scale gas turbines, vehicle CNG cylinders type 1 / CNG refueling stations)	**DE**
No formal H2 concentration rules but based on safety limits with reference to natural gas operations	**BE, BG, DK, ES**

Table 2. Permissible level of Hydrogen concentration in the gas grid of the Member states *[9]*.

Higher hydrogen compositions may require modification to, or replacement of, end-user gas equipment which had initially been designed for operation with conventional natural gas and the calorific value and flame and heat characteristics of the natural gas spectrum [9].

There is no body of experience on safety issues and additional requirements for injecting hydrogen rich gasses into the gas grid. Power to gas is still a relatively new approach and of the 27 PtG projects currently underway (http://europeanpowertogas.com/projects-in-europe), most are mainly at the proof of concept and technical / operational / safety assessment stage. Figure 5 depicts the map in which the power-to-gas demonstration projects that are operational or planned at this moment are highlighted. About the specific projects, the operation status and output product of the PtG plant are reported [10] .

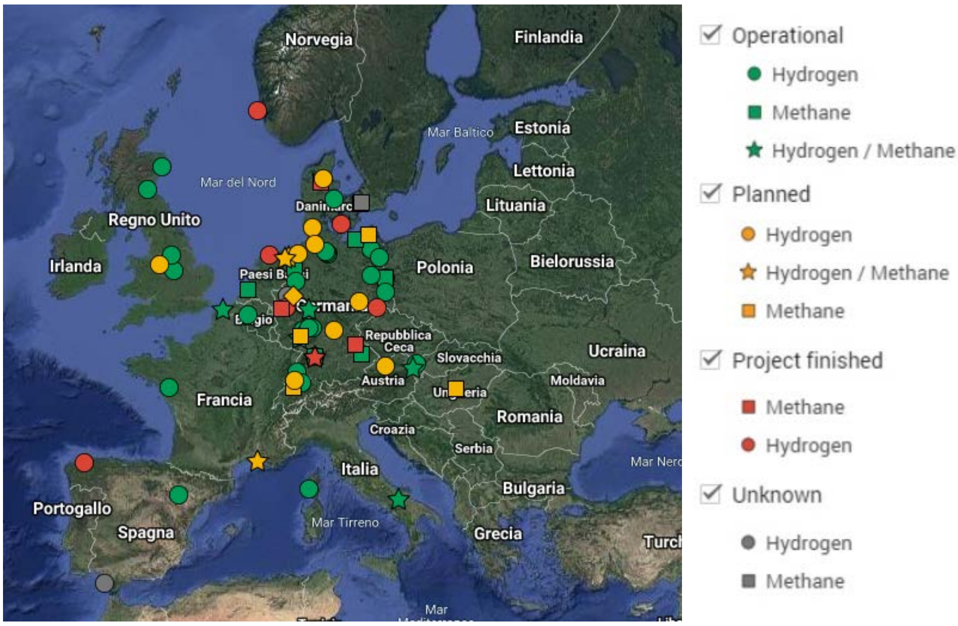

Figure 5. Map of Power to gas demonstration projects operational or planned at this moment *[10]*.

7 Specific activities promoted by HPEM2GAS members

All HPEM2GAS members have been actively involved in contributing to the preparation of the National Policy Frameworks as part of the national legislative transposition decrees for the 'Directive on the Deployment of Alternative Fuels Infrastructure' (2014/94/EU).
Specifically all Consortium members have contributed to include hydrogen in the set of alternative fuels proposed by each country for the transmission of the EU DAFI directive in each member state.

The impact of a project like HPEM2GAS can be achieved more effectively when the Consortium is able to involve policy makers and local authorities of different EU regions, demonstrating on the one hand technical feasibility of Power-to-Gas. This was made at different levels including the involvement of local policy makers in Emden during a dedicated workshop. The scope is to focus on the many direct and indirect links between energy technology and policy, in particular between energy efficiency and energy storage using electrolysis, over short and long periods of time, as well as viable business cases. This is part of our dissemination and exploitation plans aiming at approaching policy makers and local authorities to promote hydrogen technologies as made for the implementation of the EU DAFI directive in the member states. In this regard, working in close collaboration with the local government to implement hydrogen technologies in the Regional Energy Plan was also addressed by some project partners.

A report prepared in May 2017 about the implementation of FCH technologies in Italy for the SRG FCH JU and for the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) by Antonino Aricò (project coordinator) and Angelo Moreno (ENEA, Italy) was delivered.
Important aspects identified in this task as requisites to promote Power-to-Gas and Grid-Balancing Service are listed below:

- ✓ Define appropriate codes and standards to identify specific requirements that will be codified for having highly distributed water electrolysis systems;
- ✓ Address different electricity regulators in EU and address different utility business models to prove the ability of PEM electrolysis to cope with the transmission line and renewables;
- ✓ Provide data standardization to promote the development of national and or local data sets to allow an accurate quantification of the impacts that storage through water electrolysis will have on the utility system;
- ✓ Address consumer education: individuate strategies to educate residential and commercial consumers to the benefits of on-site energy storage and hydrogen as energy carrier.
- ✓ Address policies and regulations for grid balancing service. Improve the links between energy technology and policy to address issues, gaps, barriers. Promote education and address market potentials to drive future policy.

An important aspect is related to safety issues. Ensuring the electrolytic generation of hydrogen is performed safely is critical to the successful implementation of electrochemical hydrogen production.

Hydrogen electrolysis has the potential to make a large positive impact on the environment. Unsafe practices can set this back, often years. Education of hydrogen safety is critical to making hydrogen a consumer used fuel that is used safely and responsibly. These aspects have been dealt in D2.1 deliverable of HPEM2GAS that was made available to the general public.

8 Conclusions

The aim of the present deliverable is to provide policy makers and local authorities with relevant information and data so they can design appropriate measures to accelerate for the hydrogen production through water electrolysis, which is able to compensate for the discontinuity of renewable energy sources in grid-service applications.

The document addresses issues, gaps, barriers, education and market potentials to drive future policy on this energy technology for grid balancing.

In this deliverable it is reported the state of the art regarding regulations about the use over the short- and long-term of electrolysers for grid service applications along with an assessment of the European directive on the deployment of the alternative fuels infrastructure and of national regulatory frameworks adopted by different HPEM2GAS' countries. Localized hydrogen production is yet legally considered as large-scale (centralized) hydrogen production and no simplified procedure is provided for distributed hydrogen generation. Simplification of procedures, addressing technical aspects and changes in regulations, codes and standards for the gas value chain are needed to allow a wide scale injection of hydrogen into the gas grid, in order to meet the target of the EU set plan with regard to the decarbonisation of the energy system.

9 References

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