STATUS, GAPS AND RECOMMENDATIONS REGARDING STANDARDISATION AND THE USE OF HYDROGEN IN SUSTAINABLE BUILDINGS

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ABSTRACT

The use of and interpretation of Regulations, Codes and Standards is important input when developing hydrogen systems and applications. This paper presents the work related to standardisation undertaken by DNV as part of the EU supported project H2SusBuild. During the H2SusBuild project a renewable (solar and wind) based, full scale energy system with components for hydrogen storage, hydrogen production by electrolysis, and hydrogen consumption by fuel cell and burner was built and integrated into an existing office building in Lavrion, Greece. The relevant standards identified and applied, the standardisation gaps identified and the recommendations made for further standardisation activities are presented.

1.0 INTRODUCTION

The overall vision of the H2SusBuild project (Project Acronym: H2SusBuild; Grant Agreement No,: FP7-NMP2-LA-2008-214395) was to develop a clean, zero emission, and energy self-sustained building in the vision of integrating the hydrogen economy with renewable energy sources. The Renewable Energy Sources (RES) in the project are thin-film Photovoltaic (PV) solar panels and wind turbines (WT) located within the demo site area at Lavrion. Sufficient renewable energy supply to make the building self-sustained, and cover foreseeable electric power, heating and cooling (tri-generation) demands, was a key project requirement. To meet this requirement, excess energy was converted to hydrogen and stored to be used when the energy demand exceeds the generation of renewable energy. The concept applied would work equally whether the building is residential, commercial or an office building, or even for districts of buildings.

This paper summarises the work undertaken in the task on Standardisation [1] in the H2SusBuild project. The overall goal was to contribute to the development of a strategy towards better regulations and standards for the use of hydrogen within civil and domestic environments. The objective of the Standardisation work was to use inputs from other project tasks [2] as input to identify gaps and practical issues with current regulations and standards.

The degree of detail obtained directly based on the experiences from the H2Susbuild project was influenced by the fact that most of the system components used in the project were prototypes, and therefore still under development. At this stage, where most of the system components still had a way to go to be developed into a potentially commercial product, validation of compliance with standards was not prioritised by the developers.

1.1 Approach

The work was conducted through a number of interactions both within the H2SusBuild project and with external parties and by studying various reference sources. Fig. 1 illustrates the overall approach.

As part of the work process, key partners were invited to a workshop at DNV [3] to share and discuss the work processes selected to reach compliance for the individual system components. Focus areas included overall safety, control systems and the building as a whole. The workshop was used to exchange experiences on regulations and how product requirements and standards were used to find practical compliance requirements. The partners responsible for the system components were invited to explain their perception of the gaps between existing standards and the standards applied in the H2SusBuild project. Thereafter, the findings and results were circulated to the consortium. Finally, a second review workshop [4], conducted at the demo site in Lavrion, was arranged with both the consortium and external parties.

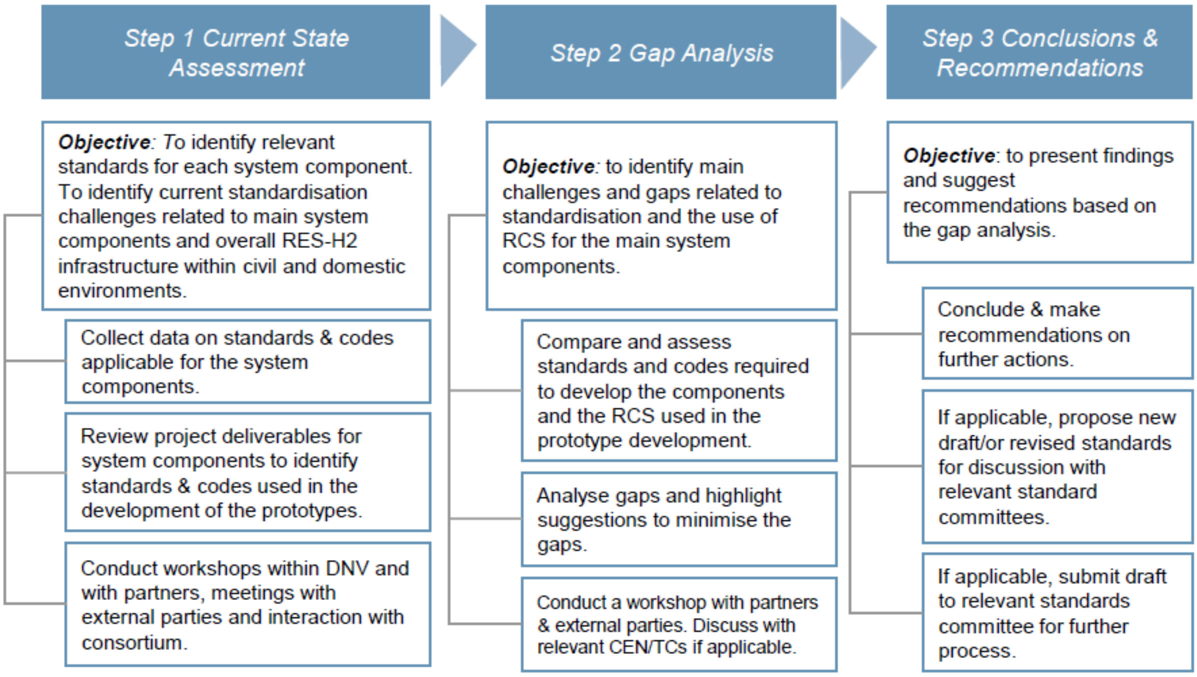

Figure 1. Project approach

2.0 THE DEMO BUILDING

The work on standardisation considered the following system components:

- Electrolyser
- Fuel Cell-based micro cogeneration system
- Hydrogen storage and hydrogen piping network
- Hydrogen burner and boiler
- Energy management and control system
- Safety system
- Building as a whole

Fig. 2 shows the main layout for the hydrogen areas in the demo-building [5]. The hydrogen systems were installed in areas that were separated from the rest of the demo building with a fire resistant wall. The electrolyser, the fuel cell and the burner were installed in separate rooms, and the hydrogen storage cylinders were placed outside the building. This was possible since there was plenty of space available within the demo building and its surroundings.

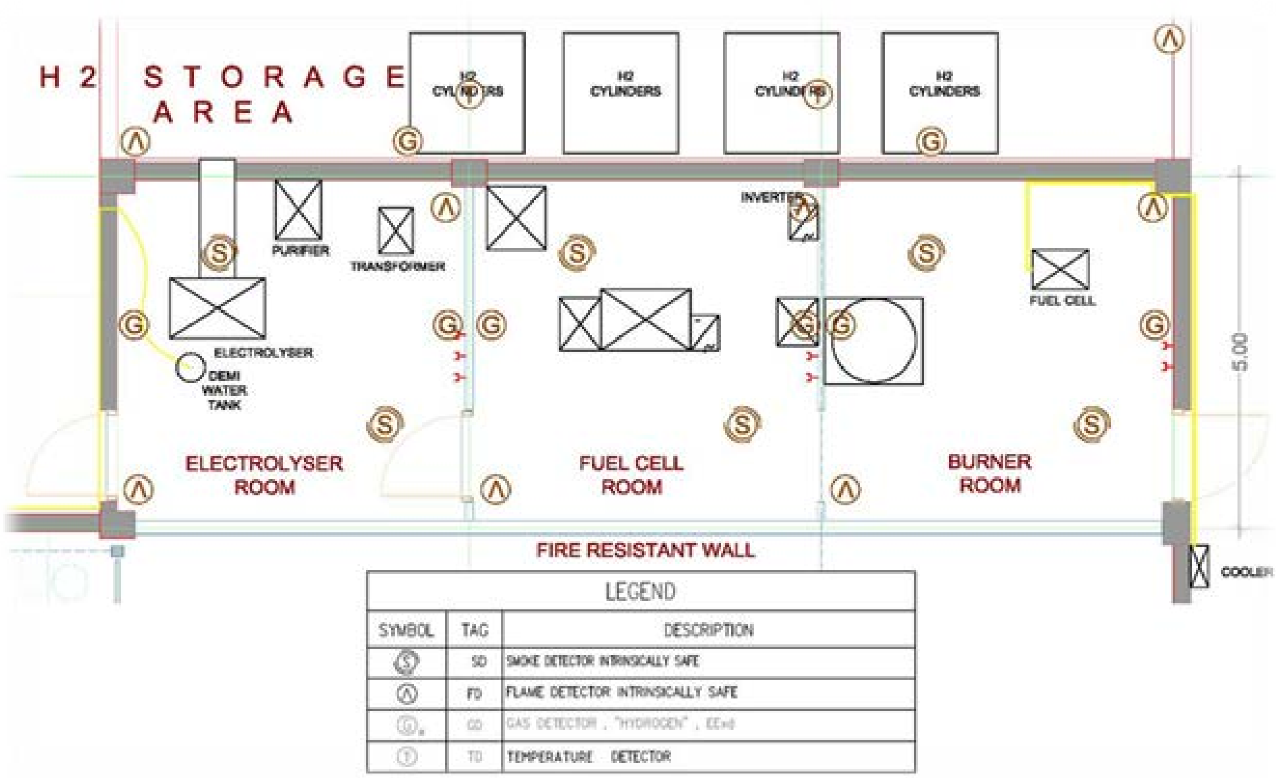

Figure 2. Overview of the hydrogen areas in the demo building; electrolyser room (hydrogen production), fuel cell and burner rooms (hydrogen consumption) and the (outside) hydrogen storage

The H2SusBuild project integrated the renewable energy sources (RES) with the hydrogen system components. Specific gap assessment related to the RES was not part of the standardisation activities.

3.0 REVIEW OF STANDARDS

This section presents a summary of the review of standards undertaken within the H2SusBuild project.

The principal European regulations for products/goods are covered by the 'New Legislative Framework for marketing of products' [6]. For most products this means application of various directives under the 'CE marking framework', using available (harmonized) standards as detailed compliance reference.

Most relevant for hydrogen facilities are the ATEX Directives and the Pressure Equipment Directive (PED). Their requirements are not specific to hydrogen but would equally apply to any fuel that is capable of generating a flammable atmosphere, for example natural gas or LPG, or more generally equipment that contains fuel under pressure.

Other generic directives are also relevant, depending on the nature of the sub-component e.g.:

- Gas Appliance Directive (2009/142/EC)
- Machinery Directive (2006/42/EC)

- Electromagnetic compatibility Directive (2004/108/EC)
- Low Voltage Directive (2006/95/EC)

Several directives are hence normally applicable for a given system component.

Products/sub-components requirements (directives) generally put responsibility on the manufacturer to produce instructions/guidelines for safe installation, use (intended and foreseeable misuse), maintenance and dismantle, which will greatly help the system engineers in meeting the building regulations.

Building regulations related to fire safety, ventilation, explosion protection (Ex)-zones, electrical safety, etc. are covered by national legislations. This does, to a certain extent, interfere with installation requirements of products/sub-components. Hence, there is a complex interface between product legislations and building legislations to take into consideration.

The acceptance of hydrogen as an energy storage medium is not homogenous within the different member states of Europe. At the current state of development, final specifications always depend on the opinions of the relevant national bodies, and sometimes also on local authorities. As such, it is expected that each future project will have to interact with these bodies to get approval for their installation. This means that it is likely that the H2SusBuild demo project's approval requirements would be different if the demo site was in another European country.

When it comes to standards, The ISO has published or is developing standards specifically dealing with hydrogen production systems. General guidance on the safety of hydrogen systems can be found in Technical Report ISO/TR 15916:2004.

3.1 Relevant regulations

A summary of regulations that are relevant for the system components in the H2SusBuild project are given in Table 1.

Table 1. Summary of relevant applicable regulations.

	System					
Relevant Regulations	Electro-lyser	Fuel Cell micro CHP	H_2 storage, piping	H_2 burner, boiler	Energy management, control system	Safety system
ATEX Directive (94/9/EC)	X	X	X			
Pressure Equipment Directive (97/23/EC)	X	X	X			
Gas Appliance Directive (2009/142/EC)		X		X		
Electromagnetic compatibility Directive (2004/108/EC	X	X		X	X	X
Low Voltage Directive (2006/95/EC)	X	X		X	X	X
Hot Water Boiler Directive (92/42/EEC)				X		

3.2 Relevant standards

This sub-chapter lists some of the most relevant standards applicable for the system components in the H2SusBuild project.

Electrolyser

ISO 22734-1: 2008 Hydrogen generators using water electrolysis process – Part 1: Industrial and commercial applications. This standard is applicable to hydrogen generators intended for indoor and outdoor commercial and industrial use (non-residential use).

ISO 22734-2: 2011 Hydrogen generators using water electrolysis process – Part 2: Residential applications. This standard is applicable to hydrogen generators intended for indoor and outdoor residential use.

Fuel Cell-based micro cogeneration system

IEC 62282-X-YYY Fuel Cell Technologies. This is a series of standards divided into 7 parts, covering stationary, portable, and micro fuel cell power systems.

EN 50465 Gas appliances - Fuel cell gas heating appliances - Fuel cell gas heating appliance of nominal heat input inferior or equal to 70 kW.

ISO/DIS 14687-3 Hydrogen Fuel – Product Specification — Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances. This standard specifies the quality characteristics of hydrogen fuel in order to assure uniformity of the hydrogen product for utilisation in stationary proton exchange membrane (PEM) fuel cell power systems.

Hydrogen storage and hydrogen piping network

European standards covering pressure vessels used for pressures exceeding 0.5 bar are harmonised with PED. EN 1252-1:1998 on storage tank materials, EN 1797:2001 on gas/material compatibility, and EN 13648 part 1, 2, and 3 on safety devices for protection against excessive pressure are some of the standards related to hydrogen storage.

The standard ISO 15649:2001 on piping for petroleum and natural gas industries is used as a guideline also for hydrogen technologies. This standard is applicable to piping within facilities and for packaged equipment, with exclusion of transportation pipelines and associated plant.

The standard EN 13480:2002 is divided in 7 parts specifying the requirements for industrial piping systems and supports made of metallic materials.

ISO 26142:2010 Hydrogen detection apparatus - Stationary applications. This standard defines the performance requirements and test methods of hydrogen detection apparatus that measure and monitor hydrogen concentrations in stationary applications. The standard cover hydrogen detection apparatus used to achieve the single and/or multilevel safety operations, such as nitrogen purging or ventilation and/or system shut-off corresponding to the hydrogen concentration. The requirements applicable to the overall safety system and the installation requirements are excluded. This standard sets out only the requirements applicable to a product standard for hydrogen detection apparatus, such as precision, response time, stability, measuring range, and selectivity and poisoning. This standard is intended to be used for certification purposes.

ISO 15399 Gaseous Hydrogen - Cylinders and tubes for stationary storage. This standard covers cylinders and tubes intended for the stationary storage of gaseous hydrogen of up to a volume of 10 000 l and a pressure of 110 MPa, of seamless metallic or composite construction.

The EIGA code of practice IGC 15/06 covers storage of gaseous hydrogen. IGC 15/06 on gaseous hydrogen, compression, purification, and filling into containers and storage installations at consumer site shall serve as a guide for designers and operators of gaseous hydrogen stations and reflect the best practices currently available. It includes issues such as safety of personnel, operations instructions, protection, and emergency situations.

There are also some relevant American standards/guidelines, e.g. through ASME and NFPA. US standards are not harmonised with EC directives, but they can still be used for practical purposes as long as there is no conflict with the European regulations.

Hydrogen burner and boiler

The following natural gas guidelines are relevant as reference during the design of the burner and boiler system:

EN 303-X Heating Boilers. This is a series of standards divided into 7 parts, covering burners of various sorts, including those with forced draft burners.

ISO 23550/1/2 Safety and control devices for gas and/or oil burners and gas and/or oil appliances.

IEC 60730-2-5 Ed 4.0: Automatic electrical controls for household and similar use - Part 2-5: Particular requirements for automatic electrical burner control systems.

Gas safety valve, class A, in accordance with EN 161.

Energy management and control system

There are standards for virtually every component forming a control system, e.g.:

IEC 60364 series: Low-voltage electrical installations

IEC 61439 series: Low-voltage switchgear and control gear assemblies

IEC 60947 series: Low-voltage switchgear and control gear

For Electromagnetic Compatibility (EMC) aspects the following standards apply, in cases where component specific standards do not address EMC:

IEC 61000-6-X Electromagnetic Compatibility (EMC) – Generic standards

Safety system

IEC 61508-X Functional safety of electrical/electronic/programmable electronic safety-related systems. This is a series of standards divided into 7 parts, covering all phases of the safety lifecycle.

IEC 61511-X Functional safety - Safety instrumented systems for the process industry sector. This is a series of standards divided into 3 parts, applying the principles of IEC 61508 to the process industry sector.

The standards mentioned for the energy management and control system above can also be considered as relevant.

Building as a whole

The technical report ISO/TR 15916 “Basic considerations for the safety of hydrogen systems Special considerations” is currently being revised by ISO/TC 197 WG16. This technical report provides guidelines for the use of hydrogen in gaseous and liquid form. The report identifies the basic safety concerns and risks, and describes the properties of hydrogen that are relevant to safety, e.g. related to risk assessment, layout issues and safety distances.

4.0 GAP ANALYSIS

A gap analysis was carried out to identify and review the main challenges related to standardisation and the use of regulations, codes and standards for the main system components installed at the H2SusBuild demo site. Available information concerning current regulations, codes and standards together with the experiences gained by the H2SusBuild partners responsible for the different system components were the main basis for the gap analysis. The H2SusBuild project experiences were reviewed based on information available in internal project deliverables and the outcome from the first of two dedicated standardisation workshops conducted during the project [3].

Some general challenges/gaps that were found to be common to all the considered system components are outlined in the following:

It was found that requirements are presented on different ‘application level’. Some requirements apply to components, while other requirements apply to the system. This is a challenge, as at the same time safety can only be assessed on a system level, commonly referred to as ’functional whole’.

During the project, the H2SusBuild partners found that there can be hundreds of standards per directive. This makes it very challenging to navigate in the “jungle of requirements”. There is a hierarchy of standards, and many contain references, also circular references, which tend to make it difficult to decide what the relevant requirements are.

Many product standards, although available, are not harmonised to the specific directive. As an example the standard IEC 62282-3-1 covers many aspects, also related to pressure safety and Explosion protection (Ex). However the standard is currently only harmonised to the Low Voltage Directive (LVD).

There are regulations beyond safety, e.g. environmental issues, in the coming (RoHS, EuP, etc.).

4.1 Defining responsibility

The issue of responsibility was addressed and discussed during both standardisation workshops held during the project. At the second workshop [4], the lack of understanding of who is responsible for certification of the equipment, was raised as an issue of concern by external participants. There is also an issue related to the responsibility for ‘re-certification’ of the equipment, both regarding who is responsible and how this should be done. Re-certification is necessary to cover the full lifetime of the equipment.

The gap analysis clearly revealed that defining responsibility is a key element. In particular it is essential to address who is responsible for the different interfaces. Both the Pressure Equipment Directive (PED) and the Machinery Directive (MD) contains relevant clauses.

Relevant clause in Pressure Equipment Directive (PED):

> *“Whereas this Directive relates also to assemblies composed of several pieces of pressure equipment assembled to constitute an integrated and functional whole; whereas these assemblies may range from simple assemblies such as pressure cookers to complex assemblies such as watertube boilers; whereas, if the manufacturer of an assembly intends it to be placed on the market and put into service as an assembly — and not in the form of its constituent non-assembled elements — that assembly must conform to this Directive; whereas, on the other hand, this Directive does not cover the assembly of pressure equipment on the site and under the responsibility of the user, as in the case of industrial installations”; (Guideline 3/1).*

Relevant clause in Machinery Directive (MD):

> *"Although the requirements of this Directive do not apply to partly completed machinery in their entirety, it is nevertheless important that the free movement of such machinery be guaranteed by means of a specific procedure." (Art. 13 / Guideline)*

To deal with the responsibility for the interfaces, it is necessary to identify and address who is responsible for connecting/installing the goods. This includes who is responsible for defining the Ex Zones. This is a 'chicken and egg' dilemma, because knowledge about the sub-components is needed to identify 'weak spots', outlets etc. A related issue is how internal Ex hazards are addressed? In PED, this is inherit in the hazards term, while the MD address this in Art. 1.5.7.

When considering the responsibilities and the interfaces is it necessary to understand and clarify who is responsible for operating and maintaining the goods/installation. This includes who is responsible for overall safety, and that safety issues are satisfactory addressed:

- When installed – is it safe to operate?
- Are safety functions thoroughly tested?
- Are selected safety functions appropriate
- Have overall safety been looked at from different angles (functional, risk oriented and prescriptive)
- Have best practices for analysing electrical/electronic/programmable electronic safety functions been applied, ref. IEC 61508?

5.0 RECOMMENDATIONS

A number of specific recommendations were identified based on the standardisation activities undertaken in the H2SusBuild project.

5.1 Structural

It is recommended to continue to support hydrogen industry with practical knowledge about the regulatory framework in the EU (CE marking regime). Further work towards better linkage between the directives and relevant standards is needed.

It is recommended to initiate work on establishing a simplified guidance document for hydrogen installations (or broader: installations containing gaseous fuels) to support overall site approval. The existing Permitting Guidance for Hydrogen and Fuel Cell Stationary Applications from the HYPER project [7] is considered a very relevant reference source for this work. As the HYPER project partly ran in parallel with the H2SusBuild project, the final results from HYPER became available very late in the H2SusBuild project. The InsHyde project in HySafe [8] investigated small-medium size indoor hydrogen leaks and provided recommendations towards safe use and storage associated with the use of indoor hydrogen systems and does as such also contain valuable reference data.

It is recommended to establish this simplified guidance document as a European guideline for hydrogen installations, endorsed by the authorities in the various EU countries and hence becoming the best practice reference.

It is recommended to establish a European or international forum for exchange of experiences to set the right level of safety, as these installations become commoditized. Existing organisations, as the International Association for Hydrogen Safety (IA HySafe) or the European Hydrogen Association

(EHA), are examples of organisations that might be suited to contribute to the establishment of such a forum, provided they obtain sufficient support.

5.2 Project execution

In a future project of this size and complexity it is recommended to appoint a coordinator to follow up sub suppliers all the way from identification of requirements, through compliance documentation to formalism around certification and/or self declaration.

It is recommended to set deadlines for completion of sub-system instructions covering installation, operation, maintenance and safety. This would be part of the compliance documentation, and would allow system integration and related safety considerations to draw upon the knowledge base of the sub suppliers.

Future projects should, in addition to demonstrating feasibility, also look into likely ‘parallel scenarios’ for similar installations in commercial/residential buildings and analyse related safety challenges, in particular location of hydrogen storage tanks, related ventilation issues and hydrogen leakage mitigation. Suggested simplifications must be looked at and analysed from a safety point of view.

6.0 CONCLUSIONS

Based on the input and the experiences from the standardisation activities undertaken in the H2SusBuild project, the following main conclusions can be drawn.

6.1 Technical

There are generally enough technical standards available for the system components.

The requirements in the standards are generally relevant and adequate.

There are no major technical shortcomings or gaps in the standards.

6.2 Structural

Due to the structure of the regulatory framework in the EU, the requirements are scattered (found in different directives).

There is not a very clear linkage between standards and regulations (due to lack of reference to these standards as being harmonized).

The overall safety of an installation is subject to national regulations, and is not harmonised across Europe. This can be a challenge when trying to replicate a sustainable building solution in different countries. Most national regulations, however, refer to international standards and best practices.

As most regulations have functional requirements, rather than prescriptive, it is not possible to find an absolute answer w.r.t. the extent of safety (barriers) to include in an integrated hydrogen system.

As a result of the above, it can be a real challenge to determine the most relevant compliance requirements for a given component/product/system and for the total installation as a whole. Due to this, manufacturers tend to not document compliance activities and evidence properly.

6.3 Project execution

Throughout the project, there were challenges in documenting compliance with the identified regulations and standards, partly due to the share number of standards identified, partly due to problems in finding compliant sub-components and partly due to the fact that sub-systems were prototypes and that, hence, time and cost was an issue.

Having a physical demo installation available, will ease/help future discussions related to other configurations and related safety solutions, with a view of using similar installations in commercial and residential applications.

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The opinions expressed in this paper are those of the authors and should not be constructed to represent the views of Det Norske Veritas.

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