

Evolutions in Hydrogen and Fuel Cell Standardization: The HarmonHy Experience

Van den Bossche Peter*, Van Mierlo Joeri**, Timmermans Jean-Marc**, Matheys Julien**,
Maggetto Gaston (†)**, Vergels Frédéric***

HarmonHy is a European Union-funded *Specific Support Action* aiming to make an assessment of the activities on hydrogen and fuel cell regulations, codes and standards (RCS) on a worldwide level. On this basis, gaps have been identified and potential conflicts between regulations, codes and standards have been investigated. Types of document to be referred to include international, regional and national standards, EU directives, UNECE regulations, ... Particular attention will be paid to the identification of the needs for standards as perceived by the industry as well as to actions aiming to ensure concordance between standards, codes and regulations.

Standards and regulations require harmonization.

HarmonHy pursues the elaboration of an action plan and a roadmap for future work on harmonizing regulations, codes and standards on hydrogen and fuel cells on an international level.

Keywords: standardization, regulation, RCS, fuel cell, hydrogen

1. HARMONHY

HarmonHy is a *Specific Support Action* performed 2005-2006 by an international consortium of industrial, research and academic stakeholders in the field of hydrogen and fuel cells. The project was funded under the Sixth Framework Programme of the Commission of European Communities. HarmonHy was structured in five work packages (WP):

- WP1 aimed at identifying and mapping the state-of-the-art of ongoing activities in hydrogen and fuel cell specific RCS in international organizations, namely the UNECE, ISO and IEC.
- WP2 aimed to review pre-normative data relevant for RCS. This included mapping existing R&D projects on fuel cells and hydrogen for transport and stationary applications; identifying gaps, lacks or limited comparability of data, supporting the development of common data collection methodology, and defining specific international collaborations for pre-normative research activities.
- WP3 consisted of identifying the organizations that should establish liaisons with a view of facilitating the harmonization of RCS.

- WP4 consisted of the analysis of industrial and societal needs, identifying gaps and conflicts and making propositions to solve fragmentation.
- WP5 consisted of preparing an action plan for further work on harmonization of RCS on an international basis at UNECE, ISO and IEC.

2. OVERVIEW OF ONGOING STANDARDIZATION WORK

A first part of HarmonHy concerned the assessment of ongoing standardization work concerning hydrogen and fuel cells on a global basis. Such work is being performed by the various international standardization bodies such as ISO and IEC, as well as by regional organizations. The standardization landscape for fuel cells and hydrogen is very complex, because of the number of actors involved and also because of the differences in *standardization culture* encountered in different sectors or different regions.

2.1 ISO TC22 SC21: Electric road vehicles

ISO technical committee 22 is responsible for standardization concerning all aspects of road vehicles; its subcommittee 21 specifically deals with electrically propelled vehicles. The activities of this committee are progressing in a continuous way. Documents published or in an advanced state of preparation cover both safety and performance issues, and include:

- ISO 23273 - Fuel cell road vehicles - Safety specifications - Part 1: Vehicle functional safety

* Erasmushogeschool Brussel, IWT, Nijverheidskaai 170, 1070 Anderlecht, Brussels, Belgium;

peter.van.den.bossche@docent.ehb.be
** Vrije Universiteit Brussel, IR-EETEC, Pleinlaan 2, 1050 Elsene, Brussels, Belgium; jvmierlo@vub.ac.be, jptimmer@vub.ac.be, jmatheys@vub.ac.be

*** AVERE, Pleinlaan 2, 1050 Elsene, Brussels, Belgium; avere@vub.ac.be.

- ISO 23273 - Fuel cell road vehicles - Safety specifications - Part 2: Protection against hydrogen hazards - vehicles fuelled with compressed hydrogen
- ISO 23273 - Fuel cell road vehicles - Safety specifications - Part 3: Protection of persons against electric shock
- ISO/CD 23829-1: Pure Fuel Road Vehicles - Energy consumption measurement - Part 1: Using compressed hydrogen.

ISO TC22 SC21 also has a Task Force dealing with terminology, which is now working on a Technical Report summarizing all terms and definitions (*tad*) used and listed in the clauses 3 of the standards developed by the SC21. These terms are specific to the electric propulsion systems of such vehicles, i. e. battery electric vehicles, hybrid electric vehicles and (pure and hybrid) fuel cell vehicles.

2.2 ISO TC197: Hydrogen technologies

ISO technical committee 197 is responsible for standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. Its activities are of course of high relevance for fuel cell applications, both vehicles and stationary. TC197 has established liaison with several other ISO TCs, such as TC58 which deals with gas cylinders but also TC22 which deals with road vehicles.

TC197 has shown a considerable level of activities over the past few years and has published a number of international standards with other documents in the preparation stage.

- ISO 13984:1999 - Liquid hydrogen - Land vehicle fuelling system interface
- ISO 14687:1999 - Hydrogen fuel - Product specification
- ISO/PAS15594:2004 - Airport hydrogen fuelling facility operations
- ISO TR 15916:2004 - Basic considerations for the safety of hydrogen systems
- ISO/DIS 13985-3 - Liquid hydrogen - Land vehicle fuel tanks
- ISO/AWI 14687-2: Hydrogen fuel- Product specification - Part 2: Hydrogen for fuel cells
- ISO/CD 15869 - Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks
- ISO/FDIS 16110-1 - Hydrogen generators using fuel processing technologies - Part 1: Safety
- ISO/DIS 17268 - Compressed hydrogen surface vehicle refuelling connection devices
- ISO-CD 22734-1 - Hydrogen generators using water electrolysis process - Part 1: Industrial and commercial applications
- ISO/CD 16110-2 - Hydrogen generators using fuel processing technologies - Part 2: Procedures to determine efficiency
- ISO/WD 16111 - Transportable gas storage devices - Hydrogen absorbed in reversible metal hydride
- ISO/DTS 20012 - Gaseous hydrogen - Service stations

- ISO-CD 22734-2 - Hydrogen generators using water electrolysis process - Part 2: Residential applications
- ISO/AWI 26142 - Hydrogen detector

2.3 IEC TC105: Fuel cells

The fuel cell being a device generating electricity, its main standardization can rightly be considered the province of IEC. The technical committee 105 *Fuel cell technologies* was founded in 1998 and has since developed a high level of activity taking into account various aspects of fuel cell technology. All IEC fuel cell standards belong to the IEC 62282 family of international standards, and are focused on the following subjects:

- Terminology
- Fuel cell modules
- Stationary fuel cell power systems - Safety
- Performance of Fuel Cell Power Systems
- Stationary Fuel Cell Power Systems - Installation
- Fuel cell system for propulsion and auxiliary power units (APU) – *these activities have been transferred to ISO TC22 SC21*
- Portable fuel cell power systems - Safety
- Micro fuel cell power systems - Safety, Performance and Interchangeability

2.4 Regional European fuel cell standards

Fuel cell standardization activity within European standards bodies (CEN and CENELEC) is limited, since it has been quite righteously decided to perform the standardization work at once on international (ISO and IEC) level, as to allow a global approach of the issues involved.

There is however a specific European activity on the issue of fuel cell gas heating appliances which are used as distributed generation equipment. A joint CEN/CENELEC working group is active on this issue, with subgroups on the following subjects:

- definitions and basics
- PEM fuel cell issues
- SOFC fuel cell issues

Appliances considered have a maximum heat output of 70 kW and electrical output of 11 kW. The document will cover aspects such as definitions, construction and operational requirements, test methods, EMC issues, marking and operating instructions.

2.5 Fuel cell standardization at SAE

In the United States, large-scale actions on automotive fuel cell standardization have been launched by SAE in the framework of the *SAE Fuel Cell Initiative* which was formed in 1999 to facilitate and accelerate the development of standards, codes and recommended practices for fuel cell powered vehicles. To this effect, a Fuel Cell Standards Committee has been set up, with members from vehicle manufacturers, fuel cell manufacturers, component suppliers, energy providers, government agencies and other organization involved. This Committee liaised with ISO TC22 SC21

in order to build an effective standardization landscape for the fuel cell vehicle industry.

Published standards by SAE include:

- SAE J1766:2005 - Post Vehicle Collision Electric Energy Storage Safety
- SAE J2574:2002 - Fuel Cell Vehicle Terminology.
- SAE J2578:2002 - Recommended practice for general fuel cell vehicle safety.
- SAE J2594 - Recommended practice to design for recycling proton exchange membrane fuel cell systems.
- SAE J2600 - Compressed hydrogen surface vehicle refuelling connection devices.
- SAE J2615:2005 - Testing performance of fuel cell systems for automotive applications,
- SAE J2616:2005 - Recommended practice for testing performance of the fuel processor subsystem of an automotive fuel cell system
- SAE J2719:2005 - Hydrogen quality specifications guideline for fuel cell vehicles

Other standards are still under development:

- SAE J2572 - Fuel consumption and range for fuel cell vehicles using compressed hydrogen from an off-board source and stored as a compressed gas, including hybrid versions.
- SAE J2579 - Recommended practice for hazardous fluid systems in fuel cell vehicles
- SAE J2601 - Compressed hydrogen fuelling communication devices
- SAE J2617 - Recommended practice for testing performance of PEM fuel cell system for automotive applications
- SAE J2722 - Recommended practice for the durability testing of PEM fuel cell systems.

2.6 Other regional American Standards pertaining to Fuel Cells and Hydrogen

As the standardization landscape in the United States is quite scattered, other standards relevant to the subject have been prepared for publication by various other organizations, such as the ASME (American Society of Mechanical Engineers), the ASTM (American Society for Testing and Materials), the CGA (Compressed Gas Association), the ANSI (American National Standards Institute), CSA America, the NFPA (National Fire Protection Association) and UL (Underwriters' Laboratories).

2.7 Japanese national standards

The following documents are published by the Japanese Standards Association:

- JIS C8800: Glossary of terms for fuel cell systems
- JIS C8801: General rules for phosphoric acid fuel cell power generating systems
- JIS C8802: Test methods for durability of phosphoric acid fuel cell power facilities
- JIS C8803: Indication of phosphoric fuel cell power facility
- JIS C8811: Indication of polymer electrolyte fuel cell power facility

- TR C0003: Technical report - Test methods for performance of phosphoric acid fuel cell power facility
- TR C 0004: Technical report - Test methods for environment and maintenance of phosphoric acid fuel cell facility

Furthermore, Japanese national vehicle regulations have been published which pertain to fuel cell vehicles, including amendments to existing regulations.

3. REGULATIONS

Regulations are not the same as standards. While standards come forward from the technical community and are in principle voluntary documents, regulations are government-endorsed documents enforceable as law. For vehicles, regulations are a prerequisite for type approval of vehicles. In Europe, regulations can be established either on UNECE level as an ECE regulation or on European Union level as EU directive. The advantage of the UNECE level however is that it is not only recognized in the EU, but by various other countries supporting the UN agreement. The UN 1998 agreement has a nearly global coverage encompassing various global markets like Europe, the USA, Canada, China and Japan. The advantage of this agreement is that it allows global technical regulations (GTR), while letting the different world regions pursue their own style of approval procedures in use for the certification of road vehicles, i.e. the whole vehicle type approval approach in Europe and Japan and the self-certification approach in North America.

The globalisation of the approval of hydrogen fuelled road vehicles shall be achieved by developing *Global Technical Regulations*. The GTRs will be submitted to WP.29 of UNECE for discussion and approval. Issues to be covered include:

- on-board system storage safety
- whole vehicle safety
- other aspects including energy and environmental considerations

Currently, work is being performed on UNECE regulations concerning hydrogen storage on road vehicles.

- TRANS/WP29/GRPE/2003/14 and add. 1 - Liquid hydrogen tanks. The contents of this document will be harmonized with ISO 13985
- TRANS/WP29/GRPE/2004/3 and add. 1- Gaseous hydrogen tanks. The contents of this document will be harmonized with ISO 15869

These regulations are also being considered for adoption as EU directive. This directive will make use of the so-called split level approach, preparing legislation through two parallel routes:

- first, the fundamental provisions will be laid down by the European Parliament and the Council in a Regulation through the co-decision procedure;
- secondly, the technical specifications implementing

the fundamental provisions will be laid down in a Regulation adopted by the Commission with the assistance of a regulatory committee

The proposal will include the general description of the applicable test procedures for the type-approval of the elements of the hydrogen system when liquid or compressed hydrogen is used. It will also specify which of these tests are necessary to carry out in order to obtain type-approval for the components of the fuel system. The basic provisions for the installation of specific components will be included as well. The applicable test procedures and technical specifications for the type-approval of hydrogen components will be specified in detail in the proposal.

This process has been initiated in 2006 and will take at least two years.

Concerning other regions, it has to be assumed that also the USA may implement a national regulation based on the FMVSS (Federal Motor Vehicle Safety Standards and Regulations).

Japan as a first country established a national regulation for the WVTA in Japan in 2005.

A GTR then would have to be developed on UN level, taking into account these three national/ regional regulatory frameworks. The process to develop a UN GTR though has been initiated at UNECE WP.29 (GRPE-H2FCV).

The introduction of hydrogen as an automotive fuel will also necessitate the amendment of a number of existing UNECE regulations concerning various safety and performance issues, with work to be performed to include and encompass hydrogen use.

4. INDUSTRIAL AND SOCIETAL NEEDS

One key action of HarmonHy concerned the identification of industrial and societal needs for RCS. A number of domains can in fact be identified where new RCS work is deemed necessary. These cover both vehicle propulsion and stationary fuel cell applications. These gaps should be filled with new standardization work, preferably performed on a global level, i.e. by ISO or IEC where appropriate.

It can be further stated that pre-normative research is necessary as being an integral part of standardization work, as the development of high quality standards requires the availability of scientifically sound knowledge and information to provide the basis for objective standardization work. The availability of scientific knowledge is essential in achieving rapid consensus and has a positive effect on the standards development process. Standardization issues should thus be integrated in the European research programmes, which can be a two-fold process:

- technical committees making use of research findings in the standards drafting process
- research consortia exploiting their standardization knowledge in a strategic way

The establishment of liaisons between research and

standardization bodies thus comes out as a key conclusion of the HarmonHy programme.

Regulations, Codes & Standards can be seen as a means towards a well established hydrogen market, since they give indications of requirements for approval (regulations) and technical guidelines (codes and standards). Even if hydrogen has been used for many years in industry, there is lack of RCS because of hitherto limited application areas. The experience in hydrogen already present in industry will be needed however to speed-up its introduction in mass market.

A classification of industrial needs has been done not only on the application, but also on the adopted technology. Fuel cells have different requirements than other hydrogen-based systems. Hydrogen quality, problems of EMC and/or electrical hazards are related to fuel cells, while they are not affecting systems where hydrogen is burned as a fuel.

Societal needs also encompass safety hazard abatement and consumer protection issues. It has to be ensured that normal members of the public can use hydrogen applications at least as safely as conventional applications. This is an area where regulations and standards can facilitate proper handling and management of hydrogen. The confidence of the user in the product or service has to be sufficiently developed in order to motivate the consumer to finally buy and use the product without any preoccupation.

Looking at the final target of mass production industry, issues that are related to “legal” approval of systems play a major role. Type approval procedures can still be a time consuming process because of different permits and documents to be released by authorities in different countries. The situation becomes particularly complex in the case of vehicle type approval, where the need for a GTR becomes obvious.

5. FINDINGS

The overview of standardization and regulation activities described in the paragraphs above makes it clear that the hydrogen and fuel cell RCS landscape is in a state of rapid development and transition.

Experts from all over the world can be found working together in the various committees in order to realize a set of documents with the aim to provide the international community with a consistent family of standards that are contextualized into a systemic approach of the Regulations, Codes & Standards problem as a whole.

In a sense, a number of approaches to this problem can be discerned; an effective solution however will have to take into account both the mere technological evolutions and the innate opposition between standards on one hand and regulations on the other. In this framework, a key factor is the behaviour of relevant stakeholders such as government services, research centers, R&D programs and trade associations, which are in a position to provide relevant input to the

standardization bodies on one hand and the regulation bodies on the other hand.

Furthermore, with several standardization organizations active on the same subject, there is a real danger that much effort will be lost through parallel work, leading to different and potentially conflicting standards on the same topic. Such “standards” are a source of confusion and are of no useful purpose.

The collaboration between different organizations, if implemented efficiently, will however allow standardization work to advance and to obtain positive results.

To avoid the proliferation of RCS conflicts, it is recommended to put in place a mechanism to facilitate global harmonization in the field of hydrogen and fuel cell RCS. It should be stressed that the different standardization bodies involved, both on organizational level (IEC and ISO), as on committee level within these organizations, should not consider themselves as competitors, but as complementary bodies, each bringing their expertise to the field. The division of standardization work on a specific subject like the electrically propelled vehicle, often grown for historical reasons, has involved a lot of discussions, which can run out of hand when each party keeps defending its turf, reasoning out of tradition and emotion.

It is essential that such differences be overcome and that the future standardization work is performed in a spirit of collaboration and joint effort toward a common goal which is the drafting of clear and useful standards which benefit both the manufacturer and the user. For the electrically propelled vehicle, the idea to have vehicle aspects treated by ISO and electrical aspects treated by IEC is a reasonable solution, which is specifically highlighted by the transfer of standardization work specific for the fuel cell vehicle from IEC TC105 to ISO TC22 SC21.

This whole issue needs to be followed closely at all levels, in order to optimize mutual information exchange and collaboration not only between ISO and IEC, but also between individual technical committees (like ISO TC197 and ISO TC22 SC21) and with regional standardization bodies such as the SAE.

The development of new technologies such as fuel cells thus has created new challenges for standardization. The definition of an appropriate standardization landscape for this new application will allow the structuring of effective collaboration and interaction between different standardization committees involved, avoiding double work which might lead to conflicting standards.

The interaction with regulations, codes and legislations however will necessitate the definition of further collaborative structures. The *New Approach* philosophy or the introduction of *global technical regulations* may constitute a worthwhile example to be followed in this framework. In the *New Approach* philosophy, which is now being implemented in the European Union, regulations enforced by the government (e.g. EU directives such as the machine

directive, low voltage directive or pressure vessel directive) define "essential safety requirements", but do not state technical details. For these, reference is made to European or international standards. These standards remain standards, that is, they are voluntary, but complying to the standard implies complying to the directive.

For road vehicles however, this system has not yet been implemented, the type approval regulations being issued by the UNECE which is beyond the level of the EU only. The advantages of the *New Approach* are clear since the discrepancy between standards and regulations is eliminated, and the restriction of technological development through obsolete specifications enshrined in legislation or overspecification by overzealous legislators can be avoided. The issuance of technical specifications by political legislative bodies without a solid technical base may in fact give rise to unusual, inadequate or foolish specifications which do not establish a tangible benefit nor for the manufacturers nor for the end users of the technology involved.

However, one has to recognize that the main vehicle manufacturers are not in favor of an adoption of this system on EU level, since it deviates from existing, proven practices and could introduce additional discrepancies with the rest of the world which is covered by ECE and might be covered by global technical regulations (GTR). The initial work on GTR specification at UNECE level is thus clearly a step forward.

The situation for road vehicles, the type approval of which is defined by international regulations, stands in contrast with the situation for stationary applications, where no international regulating body responsible for harmonizing regulations exists.

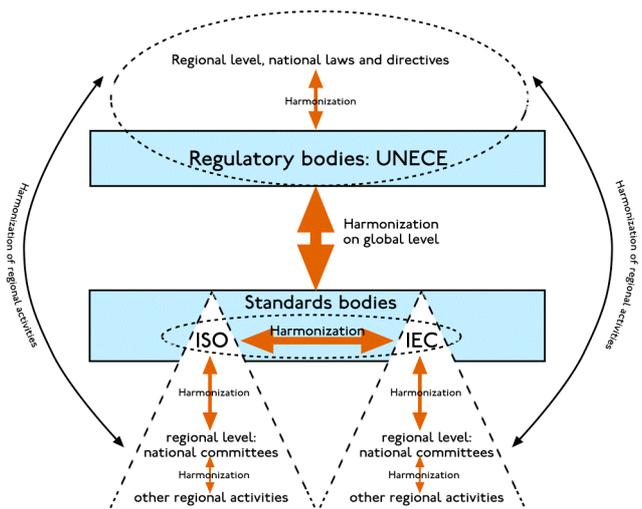


Fig. 1: Standardization collaboration and harmonization

It is clear that one of the main findings from the project is the need of close collaboration and harmonization between the different organizations in charge of RCS. The figure 1 shows the various

interactions which are necessary for this harmonization. In order to ensure that standards are properly used in regulations, both the standards bodies and regulatory bodies have to intensify joint cooperation on all levels.

6. RECOMMENDATIONS

The HarmonHy project has brought together various stakeholders allowing an overall view of the RCS landscape of hydrogen and fuel cell vehicles. It is clear that the exciting technical developments in this field will only result in a wide societal spread of advanced technological applications if safety, efficiency and compatibility of equipment is ensured through the application of appropriate standards and regulations.

An *ideal* RCS landscape would follow a *New Approach* philosophy, with international standards on all appropriate technical matters, and globally accepted technical regulations referring to these standards. All RCS work would be closely co-ordinated in order to avoid parallel or conflicting work. Also, RCS work should be targeted to relevant subject in order to avoid bad practices such as overstandardization, or what is even worse, overregulation.

To achieve such aim, as shown by HarmonHy, can only be done by a thorough collaboration between all parties involved. To this effect, the HarmonHy consortium has recommended the creation of an EU platform specifically for this matter.

This *EU RCS Platform for Hydrogen and Fuel Cells* would support the existing EU Hydrogen and Fuel Cell Technology Platform, facilitating and prioritizing RCS issues and interacting in liaison with regulation and standardization bodies. The platform would however in no way directly participate in the drafting of standards and regulations, as this work shall be done by the relevant technical committees on a global level.

7. CONCLUSION

The HarmonHy project has contributed to this ideal situation by raising awareness of the problems and promoting collaboration towards the creation of an European RCS platform. The collaboration structure defined by the project (including the website) will remain active to act as a clearinghouse for relevant information exchange with a view to future projects in the field.

HarmonHy thus has been preparing the way to achieve a real harmony between conflicting actors in the regulation and standardization field, in order to pave the way to a clean energy for the future.

ACKNOWLEDGMENT

The research performed in the framework of the HarmonHy project has been co-funded by the Sixth Framework Programme of the Commission of European Communities.

REFERENCES

The full reports of the HarmonHy project are available at <http://www.harmonhy.com>

BIOGRAPHIES



Prof. dr. ir. **Peter Van den Bossche** graduated as civil mechanical-electrotechnical engineer from the Vrije Universiteit Brussel, and got involved in the research activities on electric vehicles at that institution. Since its inception in 1990, he has been co-ordinating the international association CITELEC, more particularly in the field of electric and hybrid vehicle research and demonstration programmes. Furthermore, he has a particular research interest in electric vehicle standardization issues on which he finished his PhD work "The electric vehicle: raising the standards". He is currently lecturer at the Vrije Universiteit Brussel and its associated institution Erasmushogeschool Brussel, where he acts as co-ordinator of common research programmes with the Vrije Universiteit Brussel in the field of electromechanical engineering. He also participates in several international standardization committees, among which ISO TC22 SC21 and IEC TC69 of which latter he acts as Secretary.



Prof. dr. ir. **Joeri Van Mierlo** graduated in 1992 as civil mechanical-electrotechnical engineer at the Vrije Universiteit Brussel, and obtained his PhD, entitled "Simulation Software for Comparison and Design of Electric, Hybrid Electric and Internal Combustion Vehicles with Respect to Energy, Emissions and Performances" in 2000. Currently his research is devoted to the development of DC-DC converters for hybrid propulsion systems as well as traffic and emissions models and environmental comparison of vehicles with different kind of drive trains and fuels.



Ir. **Jean-Marc Timmermans** graduated as civil mechanical-electrotechnical engineer at the Vrije Universiteit Brussel, and is now preparing a Ph.D. on advanced drive trains for fuel cell vehicles.



Ir. **Julien Matheys** graduated as bio-engineer and is now performing research at the Vrije Universiteit Brussel on the impact of vehicle technologies on the environment, including life-cycle analyses of advanced vehicles such as electric and fuel cell vehicles.



Prof. Em. dr. ir. **Gaston Maggetto** (†) is the founder of the department Electrical Engineering and Energy Technology at the Vrije Universiteit Brussel, which he led from 1970 to 2004. He has been involved in managing international associations such as AVERE, CITELEC, EPE (of which he was the founder), and KBVE/SRBE. He was vice-president of AVERE and of the Advisory Commission “Mobility” of the Brussels Capital Region until his passing away in 2007.



Frédéric Vergels graduated as commercial engineer and is General Secretary of AVERE, in which position he was responsible for the general planning and management of European projects among which the HarmonHy project.