Standards, codes and regulations of Hydrogen Refueling Stations and Hydrogen Fuel Cell Vehicles

FINAL DEGREE PROJECT

IMSI Department – Fuel cell

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Abstract

The origin of the project appears because of the necessity of the "*Laboratoire de pile à combustible"* of UTBM University to work on the safety and normative aspects of their project. They work on the field of hydrogen refueling station (HRS) and hydrogen fuel cell vehicles (HFCV). For that reason the objective of this project has been to create an efficient database where all the standards, codes and regulations (International, European, USA, Canadian, French and Spanish) that concerns to their project were collected.

In order to reach the final objective, the project begins with a study of hydrogen properties and hazards. This part is very important to understand why hydrogen is considered as a dangerous gas and what is the potential severity of the accidents that it could cause.

Then a description of the project parts (hydrogen delivery, hydrogen refueling stations and hydrogen fuel cell vehicles) has been made. In this part, the general characteristics and the principal elements of each one are explained.

Before starting with efficient classification of the normative, it has been necessary to do a deep research of all the standards, codes and regulations that concern the project. With them, the first database has been created, where the main information like the title, the abstract, the restrictions and the cost of each one has been collected.

Finally, with all this information it has been possible to start with the efficient classification. For that, the two main parts HRS and HFCV have been divided in its different components and all the normative has been organized according to them. A website has been created with the objective of containing all this classification in a useful media where the user can find easily and quickly, and, the most important, from everywhere, all the information that he needs.

Moreover, a survey to people from different countries has been made in order to do a social and cultural study about the feelings that people have about HFCV and also to do a normative comparison between standards of different countries and regions, to understand the different perceptions of the hazards.

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Abbreviations and symbols list

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road

AFNOR: Association française de Normalisation

AFV: Alternative Fuel Vehicle

ANSI: American National Standards Institute

AP: Aparatos a Presión (Pressure Devices)

ASME: American Society of Mechanical Engineers

BEV: Battery Electric Vehicles

BPVC: Boiler and Pressure Vessel Code

CE: Commission Européen

CEN: European Committee for Standardization

CENELEC: European Committee for Electrotechnical Standardization

CFR: Code of Federal Regulations

CGA: Compressed Gas Association

CHSV: Compressed Hydrogen Surface Vehicle

CH_2: Compressed Hydrogen

CIS: Commonwealth of Independent States

CLC: CENELEC

CMVSS: Canadian Motor Vehicle Safety Standard

COP: Code Of Practice

CSA: Canadian Standards Association

DOE: Department Of Energy

DOT: Department Of Transport

EC: European Commission

ECA: Economic Commission for Africa

ECLAC: Economic Commission for Latin America and the Caribbean

ECOSOC: Economic and Social Council

EEA: European Economic Areal

EEC: European Economic Community

EFTA: European Free Trade Association

EIGA: European Industrial Gases Association

EN: European Standard (Comes from the French word Norme Européen)

EPA: Environmental Protection Agency

ESCAP: Economic and Social Commission for Asia and the Pacific

ESCWA: Economic and Social Commission for Western Asia

ETSI: European Telecommunications Standards Institute

EU: European Union

EV: Electric Vehicle

EWR: Early Warning Reporting

FC: Fuel Cell

FCEV: Fuel Cell Electric Vehicle

FCGA: Fuel Cell Gas Application

FCHEA: Fuel Cell & Hydrogen Energy Association

FCS: Fuel Cell System

FCV: Fuel Cell Vehicle

FD: Final Draft

FMEA: Failure Modes and Effects Analysis

FMVSS: Federal Motor Vehicle Safety Standards

FPS: Fuel processor subsystems

FR: Federal Register

GHLV: Gaseous Hydrogen Land Vehicle

GTR: Global Technical Regulations

GVM: Gross Vehicle Mass

HEV: Hybrid Electric Vehicles

HFCV: Hydrogen Fuel Cell Vehicles

HGV: Hydrogen Gas Vehicle

HRS: Hydrogen Refueling Station

HSV: Hydrogen Surface Vehicles

HQTF: Hydrogen Quality Task Force

ICC: International Code Council

ICE: Internal Combustion Engine

IEC: International Electrotechnical Commission

IEEE: Institute of Electrical and Electronics Engineers

IFC: International Fire Code

IGC: Industrial Gases Council

ISO: International Standards Organization

ITU: International Telecommunication Union

IWG: Interface Working Group

JWG: Joint Working Group

LANL: Los Alamos National Laboratory

LFL: Lower flammability limit

LHV: Lower Heating Value

LH_2: Liquid Hydrogen

LPG: Liquefied Petroleum Gas

MAE: Model Acoustic Emissions

MAPFP: Maximum Allowable Pump Feed Pressure

MAWP: Maximum Allowable Working Pressures

mCHP: micro Combined Heat and Power

MDP: Maximum Developed Pressure

MEGC: Multiple elements gas containers

MH: Metal Hydride

MIE: Ministerio de Industria y Energía (Industrial and Energy Ministry)

NASA: National Aeronautics and Space Administration

NC: National electrotechnical Committee

NDE: NonDestructive Evaluation

NEC: National Electrical Code

NF: Normative Française

NFPA: National Fire Protection Association

NHTSA: National Highway Traffic Safety Administration

NREL: National Renewable Energy Laboratory

OSHA: Occupational Safety and Health Administration

PED: Pressure Equipment Directive

PEFC: Polymer Electrolyte Fuel Cell

PEM: Proton Exchange Membrane

PNNL: Pacific Northwest National Laboratory

PRD: Pressure Relief Devices

PS: Position Statements

PTC: Performance Test Code

RESS: Rechargeable Energy Storage Systems

SAE: Society of Automotive Engineer

SC: Sub Committees

SCC: Standards Council of Canada

SNL: Sandia National Laboratory

SME: Small and Medium-sized Enterprises

TC: Technical Committee

TLV: Threshold Limit Value

TPED: Transport Pressure Equipment Directive

TR: Technical Report

TS: Technical Specification

TSD: Technical Standards Document

UHP: Ultra High Purity

UNECE: United Nations Economic Commission for Europe

UL: Underwriters Laboratories

UN: United Nations

UPL: Upper Pressure Limit

US: United States

USA: United States of America

UTBM: Université de Technologie Belfort-Montbéliard

WG: Working Group

WP: Working Party

1. Introduction

Everybody should be aware of nowadays energy problems. Humanity is running out of the energy resources used today. These resources are the result of what nature has given us after thousands of years, and these are being devastated in a short period of industrial development.

Almost everything you do in your daily life has required or requires the use of energy resources which, additionally, have awful consequences on environment and human health.

1.1 Why does this project exist?

Fossil fuels are the current resources of today's world. They are derivatives of plants and animal fossils that are millions years old. The three main fuel sources are coal, natural gas and oil/petroleum and these help to meet the energy and electricity demands.

When overconsumption of these fossil fuels takes place, they lead to disastrous effects such as air pollution. They are non-renewable sources of energy and are no longer available if once used. Their source is limited and they are depleting at a fast rate.

Fig. 1.1-1: Paris air pollution

Consumption of fossil fuels has severe consequences on the habitats and human health and its disadvantages have been studied thoroughly, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions.

Pollution is the most important disadvantage for the release of carbon dioxide when burnt (one of the main aspects of global warming since it increases the earth temperature). It also produces acid rain (sulphur dioxide gas is produced when fuel is burnt) and the greenhouse gases (which have direct consequences in the ozone layer). Moreover, so many other problems should be taken into account, as impact on aquatic life by oil spill, coal mining, world division due to fossil fuels owner countries…

Thus, one important aim of today's world is to investigate alternative and renewable resources. Technologies to get more resources out of the earth are progressing, but they don't seem to be doing it as quickly as our demand is growing.

Hydrogen is one of the recent alternatives to try to make the world "healthier". The abundance of hydrogen on earth, minimal environmental consequences of its use and the need to replace fossil fuels, makes it one ideal fuel for the future.

Hydrogen is not an energy source. It is an energy carrier like electricity. On earth, hydrogen is found combined with other elements. The technological challenge that researchers face is to separate hydrogen from other naturally occurring compounds in an efficient and economic process.

In conclusion, it's for all these reasons, among others, that justify the viability and the existence of this project.

1.2 Project objectives

As mentioned before, there is need currently and in the future of alternative ways of energy to cope with today's world demands. The main renewable resources are tidal power, wave power, solar power, wind power, hydroelectricity, radiant energy, geothermal power, biomass and compressed natural gas. Unfortunately, it doesn't mean these renewable resources do not have environmental impacts. The exact type and intensity of environmental impacts varies depending on the specific technology used, the geographic location and a number of other factors.

Other energies have been studied not as a direct source, but as energy carrier, so that other resources are needed to get them. Secondary energy sources are electricity, the entire range of petroleum, coal and manufactured gas.

Increasingly, hydrogen (as a manufactured gas) is becoming an important synthetic fuel of the future because of its characteristics of being renewable, abundant and non-polluting.

This project concentrates on the study of hydrogen fuel cells in the field of land transport in general and transport in particular in closed circuit. More specially, it will be confined to the development of tools for the exploitation of the standards and regulations for the use of hydrogen in this field.

In order to carry out the project aims, an introduction to the chemical hydrogen aspects and the hazards related to hydrogen will be done, followed by the research and summaries of applicable standards and laws.

1.3 Market research

Hydrogen is a chemical element which is used in lots of different fields. The aim of this section is to do a market research and investigate which are the applications of hydrogen nowadays, especially in the transports field. Some of the most important applications of hydrogen are the following:

1. Hydrogen vehicles:

   As previously mentioned, one of the biggest XXI Century problems are fossil fuels because of their polluting production and their non inexhaustible character, among others. According to the *Center for Climate and Energy Solutions (C2ES)*, globally, **transportation accounts for 62.3 percent of petroleum consumption**. The remaining uses are non-energy related, including lubricants and asphalt production (16.8 percent); agriculture, commercial and public services, residential, and non-specified other (12 percent); and industry (8.9 percent). In the United States, transportation accounts for over two-thirds of U.S. petroleum consumption, with the remainder used by the industrial (25.1 percent), residential and commercial (4.5 percent), and electric power sector (0.6 percent). The following graphic represents the petroleum consumption by section in 2013 in the U.S.:

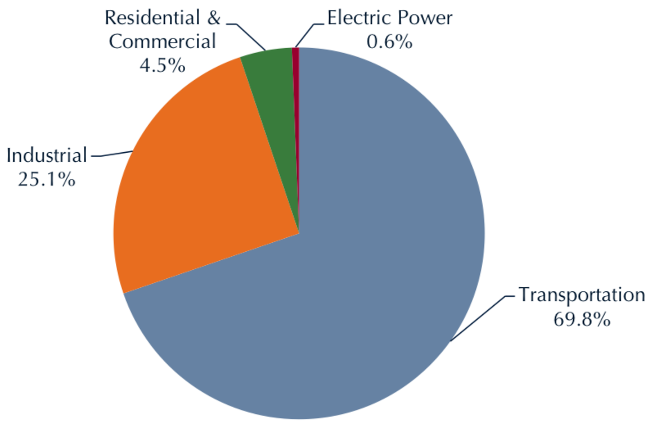


Fig. 1.3-1: Petroleum Consumption by section (2013); Source: U.S. Department of Energy

As shown in Fig. 1.3-2, light-duty vehicles – cars and pickup trucks – account for 58.6 percent of transportation petroleum consumption with the rest used by medium- and heavy-duty trucks (22 percent), airplanes (8 percent), and water transport, such as ships (4.5 percent).

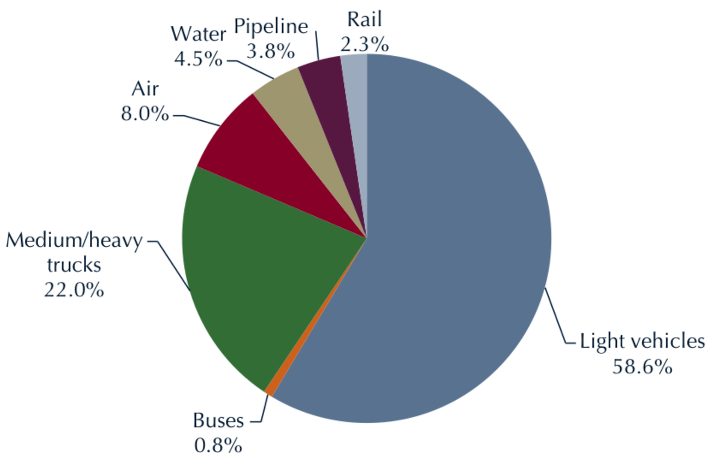


Fig: 1.3-2: U.S. Consumption of Transportation Energy, Petroleum (2012); Source: U.S. Department of Energy

These charts explain why one of the most important fields of hydrogen studies and researches is focused on hydrogen vehicles.

In general there are two different ways of using hydrogen to produce enough energy for running a vehicle; burning the hydrogen in an internal combustion engine or reacting it with oxygen in a fuel cell.

One of the advantages of the first procedure is that no many changes have to be done to existing engines (which work with fossil fuels) to utilize hydrogen as a combustible. In the internal combustion engines, hydrogen is burned within an explosion engine, same as it's done with fossil fuels. Four-stroke engines allow taking advantage of the special features that hydrogen presents as a fuel, like high flame speed, high flammability limits, high temperature detonation and a low energy ignition required.

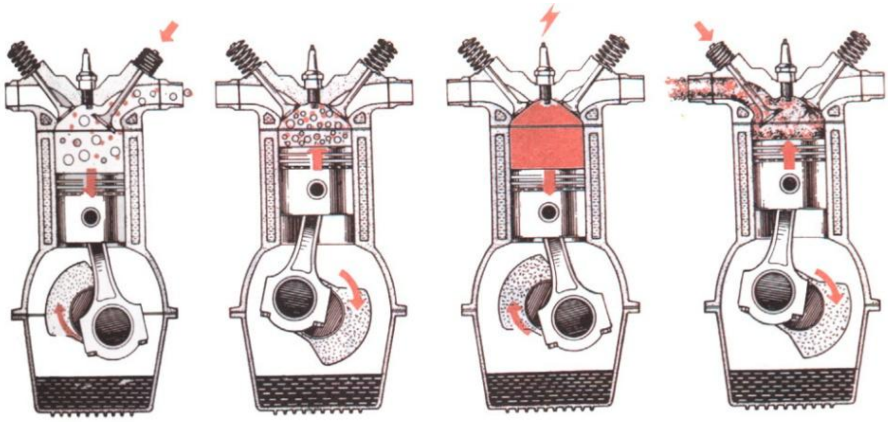


Fig. 1.3-3: Four-stroke engine

However, hydrogen can be also used as a petrol or diesel complement in an internal combustion engine.

The second procedure consists in obtaining electrical energy through fuel cells. A fuel cell is a device that generates electricity by an electrochemical reaction (redox reaction) and its technical definition is "electrochemical energy conversion device". Every fuel cell contains two electrodes, one positive and one negative, called, respectively, the anode and cathode. In hydrogen fuel cell the reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes. One great appeal of fuel cells is that they generate electricity and heat being water its unique waste.

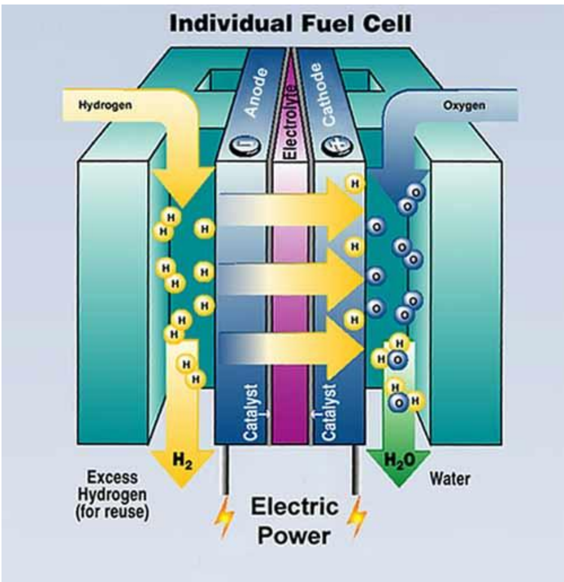


Fig. 1.3-4: Fuel cell schematic

The purpose of a fuel cell is to produce electrical current that can be directly used for activities like powering an electric engine or illuminating a light bulb.

The fuel cell is supplied by the anode with hydrogen atoms where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized" and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. Oxygen from air, enters to fuel cell by the cathode and, in some cell types, it combines with electrons returning from the electrical circuit and hydrogen ions and in other cell types the oxygen picks up electrons and then travels through the electrolyte to the anode, where it combines with hydrogen ions. The electrolyte plays a key role. It must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction. The combination of oxygen and hydrogen forms water which drains out of the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

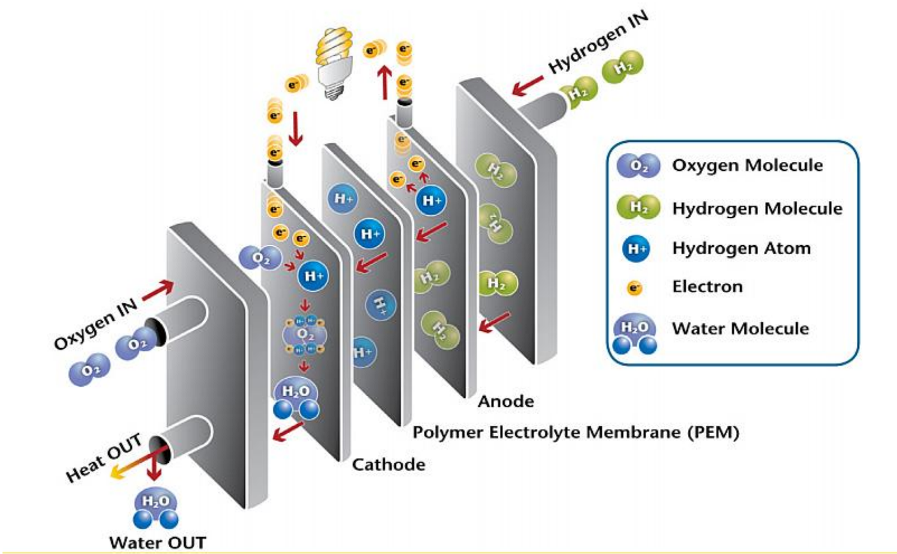


Fig. 1.3-5: Fuel cells operation

So, fuel cells are more efficient in extracting energy from hydrogen and some waste heat generated by cells can be also harnessed, boosting system efficiency still further.

Many people around the world are working on developing hydrogen vehicles and both procedures, among others, have been and are being implemented in different vehicles like buses, motorcycles, scooters, quads, fork trucks, automobiles…Most of them are enrolled in experimental programs because there are lots of things, specially related with the safety and hydrogen hazards, that have not already been completely studied.

Hydrogen is still used in space rockets which were one of the first fields where hydrogen started to be used as a combustible. During lots of years space programs have been the biggest consumers of liquid hydrogen, having acquired great experience in its handling.

2. <u>Autonomous electric generator</u>:

Fuel cells are also used as autonomous electric generators. Their objective is to address deficiencies in the supply of energy for users of high drain devices, as well as to provide inexpensive energy storage options for emergency uses.

Fig. 1.3-6: Hydrogen autonomous electric generator

3. Chemical industry:

   Hydrogen is a compound of huge interest in the chemical industry, taking place in hydrogenation processes as reducing agent in reduction reactions. There are lots of processes where the hydrogen is involved as ammonia synthesis, refinery processes, inorganic and organic synthesis among others.

4. Metallurgical industry:

   In this field, hydrogen is mainly used for reducing the iron ore and in some non-ferrous metals production processes.

1.4 Project scope

Hydrogen has recently become more popular among new types of energy and there are lots of research studies ongoing. How hydrogen works and how it should be used are the main questions in order to benefit from all of its features.

This project must be conceived as a support of information about hydrogen, its fundamental properties and the safety standards.

The scope of this project is restricted to the research and the analysis of the standards and guidelines for the use of hydrogen fuel cells in the field of land transport in general and transport in particular in closed circuit.

This project is not related to researching new technologies or to hydrogen investigation; it is a deep study of European and some other countries standards. The idea is to create a database where a summary of all the standards, codes and regulations will be collected so that anyone who needs to consult them could do it quickly and easily. The study will be supported by informatics and engineering tools like Excel or Minitab. A website will be created in order to have this entire database in an efficient and useful media.

More specifically, the project will be focused on the hydrogen refueling stations cycle. This involves hydrogen transport to the refueling stations, station storage and distribution, and the hydrogen fuel cell vehicles that will refuel there.

The objective of this project is to work on the normative that concerns to *"Laboratoire de pile à combustible"* of UTBM University project. They work on hydrogen refueling station and hydrogen fuel cell vehicles construction. For that reason all the normative that will be studied inside this project will be the one that principally refers to safety and operation issues. Normative relative to design, construction, material etc of specific components is not included in the project scope.

Moreover, a social and cultural comparison between the standards of different countries and regions will be done to understand political reasons of these diferencies.

2. Fundamental knowledge of hydrogen properties and hazards

Hydrogen is the focus of this project, so to be able to study and work with the different standards and regulations subjected to fuel cells and other hydrogen engines, it's necessary to have fundamental knowledge of hydrogen properties and hazards. In this section the basic physical and chemical hydrogen properties are shown as well as a detailed study of types of hazards associated with it and its safety in different fields.

2.1 Physical and chemical properties

The word hydrogen comes from the Greek words *hydro* and *genes* which together mean "water forming". It was recognized as a distinct element in 1766 by Henry Cavendish. Composed of a single proton and a single electron (atom electrically neutral), hydrogen is the simplest and most abundant element in the universe (the atomic hydrogen represents the 75% of the elemental mass of the universe).

Moreover there are three types of hydrogen isotopes depending on his nuclear composition. If the nucleus consists of just one proton it's called protium ^{1}H, if it consists of one proton and one neutron it's called deuterium ^{2}H and finally if in the nucleus there are one protons and two neutrons it's called tritium ^{2}H (it can be artificially produced and appears in small quantities in the nature, it's unstable and radioactive). The two heavier isotopes (deuterium and tritium) are used for nuclear fusion. Naturally occurring hydrogen is a mixture of the two isotopes ^{1}H and ^{2}H with natural abundances of 99.99% and 0.01% respectively.

The hydrogen molecule exists in two forms, ortho-hydrogen and para-hydrogen, depending on the relative rotation of the nuclear spin. These molecules have differences in physical properties but are chemically equivalent. Hydrogen consists of a mixture of these two molecules and its concentration depends of the temperature. At normal temperature (20ºC) the hydrogen is formed by 75% of ortho-hydrogen and 25% of para-hydrogen ant it is called normal hydrogen.

In normal conditions (standard temperature and pressure) hydrogen is a gas formed by diatomic molecules H_2 (covalent bond between two hydrogen atoms). On Earth, the major location of hydrogen is in water, H_2O, but it is also present in organic matter such as living plants, petroleum, coal, etc. Although pure hydrogen is a gas, we find very little of it in our atmosphere because it is so light that, uncombined, hydrogen will gain enough velocity from collisions with other gases that they will quickly be ejected from the atmosphere.

Hydrogen is colorless, odorless and insipid what makes it difficult to detect if a leak occurs. It's the lightest gas with a density of 0,0899 kg/m3, fourteen times lighter than air, what makes that it diffuses faster than any other gas.

It is a non-toxic and non-corrosive element; even so, it can cause a significant deterioration in the mechanical properties of metals.

Hydrogen is highly flammable and has an almost invisible flame, which can lead to accidental burns. It also has very low ignition energy.

In the following table the equivalences between hydrogen gas, liquid and solid are shown:

Gas (m^3)	Liquid (liter)	Solid (kg)
1	1,163	0,0989
0,856	1	0,0709
12,126	14,104	1
Pressure = 981 mbar and Temperature = 20 ºC		

There are three different ways of storage of hydrogen depending on its state, gas, liquid or solid:

- Physical storage of compressed hydrogen gas in high pressure tanks (up to 700 bar).

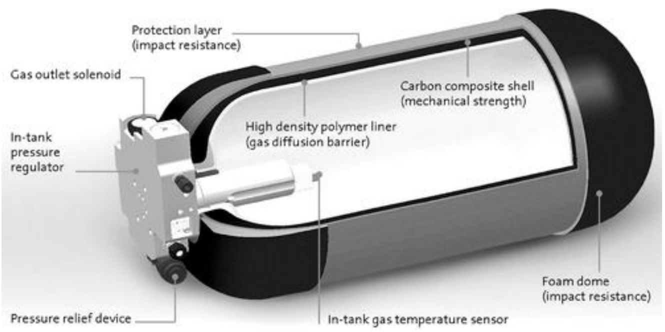


Fig. 2.1-1: Liquid hydrogen tanks

- Physical storage of cryogenic hydrogen (cooled to -253°C, at pressures of 6-350 bar), stored in insulated tanks.

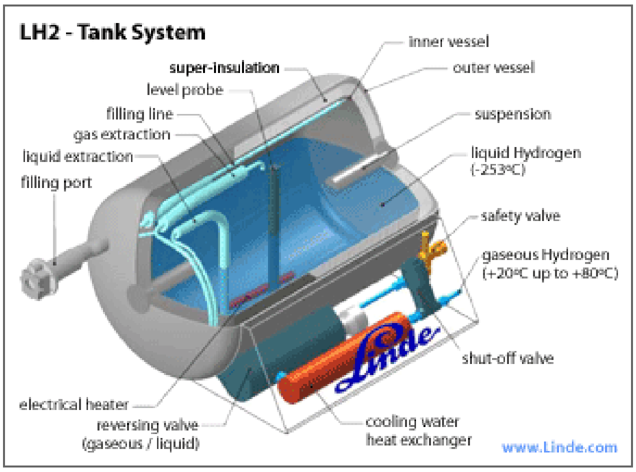


Fig. 2.1-1: Compressed hydrogen gas tanks

- Storage in advanced materials within the structure or on the surface of certain materials, as well as in the form of chemical compounds that undergo a chemical reaction to release hydrogen. Today we mainly use a technique of "trap" hydrogen in magnesium metal pellet (MgH_2). This technology minimizes the risk associated with large amounts of hydrogen storage. A tablet of 43g contains 0.5 m^3 of hydrogen.

Fig. 2.1-1: Magnesium metal tablet

Liquid hydrogen is the easiest one for being stored and transported, but as its shown in the previous table, going from liquid to gas the hydrogen volume increases in 856 times. This can produce lots of hazards like asphyxia, and an enormous increase of the pressure that can produce the breaking or destruction of the storage.

In the next table the principal hydrogen properties are shown:

Data	Value	Units
Density	0,08988	kg/m^3
Lower heating value	119,93	MJ/kg
Upper heating value	141,86	MJ/kg
Ignition energy	0,02	MJ
Ignition temperature	520	ºC
Lower flammability limit (vol. % in air)	4,1	Vol.%
Upper flammability limit (vol. % in air)	72,5	Vol.%
Flame velocity	2,7	m/s

Compared with other conventional fuels, hydrogen has the highest mass energy density with a LHV of 120 MJ/kg. Therefore, on a weight basis, the amount of fuel required to deliver a given amount of energy is significantly reduced when hydrogen is utilized.

The key criteria for an ideal fuel are inexhaustibility, cleanliness, convenience, and independence from foreign control. Hydrogen possesses all these properties; it is versatile, energy-efficient, low-polluting, and a renewable fuel. Hydrogen is a high-quality energy carrier, which can be used with a high efficiency and zero or near-zero emissions at the point of use.

2.2 Obtaining hydrogen process

It's very difficult to find pure hydrogen in our atmosphere because of its low density, so it can be considered that pure hydrogen does not occur naturally, it has to be manufactured. One of the huge benefits of hydrogen is its versatility; it can be produced from a variety of conventional and alternative feedstock. In the following table appears a summary of the sources and hydrogen production:

Energy source	Energy types	Energy technology	Producing methods
Renewable	Electricity	Wind	Electrolysis
		Water	
		Waves	
		Sun	
			Photovoltaic
	Fuel	Biomass	Reforming
			Biological
Fossil	Electricity	Nuclear	Electrolysis
			Thermonuclear
	Fuel	Natural gas	Reforming
		Methanol	
		Petroleum	
		Coal	Gasification

Nevertheless, one of the disadvantages of using hydrogen as fuel is that it is not an energy source, it is an energy carrier like electricity, it means that an energy expenditure is needed to obtain it. For example, today, hydrogen is mainly produced by steam reforming fossil fuels such as natural gas. Even though hydrogen generated from fossil fuels has the advantage of zero-tailpipe emissions, the production chain still leaves a carbon footprint. Well-to-wheel emissions of a hydrogen fuel-cell car are nonetheless 30% lower than those of a conventional diesel-powered car.

However, carbon emissions can be lowered to almost zero if renewable energies are used to source the hydrogen.

At present, electrolysis of water using wind, water or solar power and gasification/reforming of biomass are viable alternatives that offer a zero-emission hydrogen energy cycle.

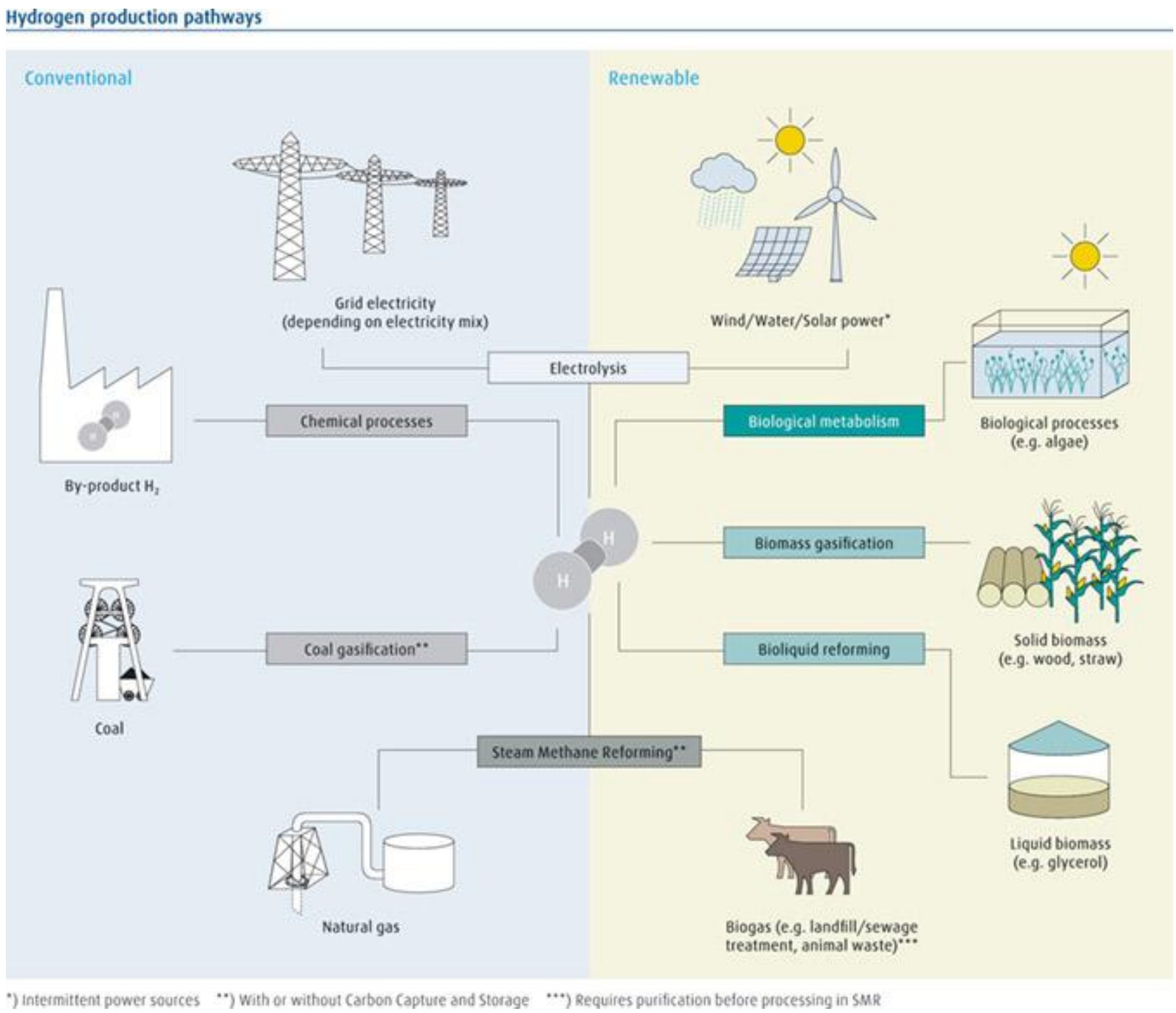


Fig. 2.2-1: Hydrogen production pathways

2.3 Hydrogen hazards

A hazard is defined as a "chemical or physical condition that has the potential for causing damage to people, property, or the environment". For fuels, the hazard is due to the physical properties of the fuel (in this case, due to the flammable and explosive nature of hydrogen).

After a complete description of the system is available, the hazards are first identified.

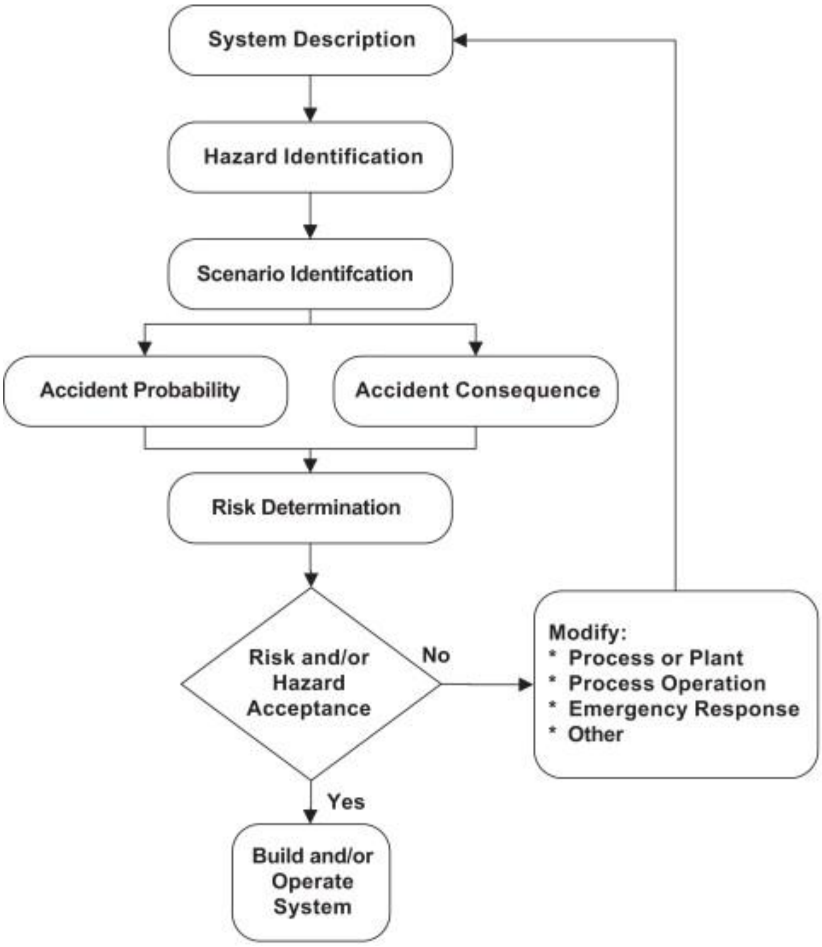


Fig. 2.2.-1: The hazard identification and risk assessment procedure

Next, the scenarios are identified. The scenarios are “a description of the events that result in an accident”. The accident begins with an incident (the loss of containment or control of material or energy). Most incidents are followed by events that propagate the accident. Finally, the *incident outcome* is “the physical manifestation of an incident” and this includes human injury, environmental damage and loss of production and equipment.

Next, both the probability and consequence of the scenario are estimated for all of the scenarios identified. Then, these two are combined to determine the risk.

Finally, a risk acceptance procedure is applied. This can be done using fixed risk acceptance criteria, or a number of other approaches.

- <u>Physiological hazards</u>

Hydrogen is classified as a simple asphyxia gas, it has no threshold limit value (TLV) and it is not a carcinogen (NASA, 1997).

Inhaling vapor or cold hydrogen produces respiratory discomfort and can result in asphyxiation. Asphyxiation occurs when H2 or another nontoxic gas displaces O_2 reducing concentration below 19.5% by volume.

Thermal burns occur due to radiant heat emitted by H_2 fire.

Contact with liquid hydrogen or its splashes on the skin or in the eyes can cause burns by frostbite or hypothermia (cryogenic burns).

- <u>Physical hazards</u>

Hydrogen is the guilty of the embrittlement: the process by which some metals become brittle and fracture following exposure to hydrogen. It depends on environmental temperature and pressure, purity of metal, and exposure time to H2, and surface conditions.

It has also to be considered the thermal contraction coefficients al cryogenic temperature to avoid leaks due to dimensions change.

- <u>Chemical hazards</u>

Hydrogen combustion reaction in the air corresponds to the following balance equation:

$$H_2 + \frac{1}{2}\, O_2 + 2N_2 \rightarrow H_2O + 2N_2$$

Hydrogen is a highly flammable gas at standard conditions of temperature and pressure. Flammability limits depend on ignition energy, temperature and pressure diluents, size and configuration of equipment. Ignition energy is very small, so open flames, electrical and heating equipment should be safely isolated in buildings containing hydrogen systems.

- Explosion phenomena

Explosion is manifested by rapid energy release. An explosion cannot occur in a tank or any contained location that contains only hydrogen.

An oxidizer, such as oxygen, must be present in a concentration of at least 10% pure oxygen or 41% air. Furthermore, there is a little likelihood that hydrogen will explode in open air, due to its tendency to rise quickly.

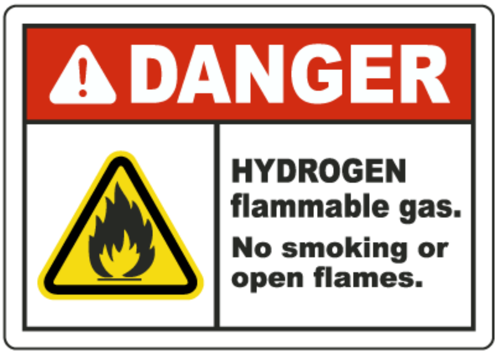
Hydrogen flames are difficult to quench, and hydrogen has the lowest quenching distance, i.e. the lowest critical size that the inflamed volume must attain to propagate unaided, compared to other flammable gases.

Deflagration is represented by the flame front which moves through the flammable mixture in the form of a subsonic wave, so that hot burning material heats the next layer of cold material and ignites it.

Detonation has the flame front coupled to a shock wave propagates through a detonable mixture in the form of supersonic wave. Detonation propagates much faster than the initial reactions. Hence, detonation may cause more injury and damage than deflagration.

2.4 Hydrogen safety

As mentioned before, hydrogen is odorless, colorless and tasteless, so human senses can't detect a leak. Moreover, hydrogen tends to rise quickly and remain on the ceiling in closed spaces. For that and other reasons, industry often uses different ways of detecting hydrogen leaks. One example is hydrogen sensors and, since these have been used for decades, a high safety record has been reached.



- Safety in production

Pure hydrogen has to be artificially produced, and it could be in a number of different ways: from hydrocarbons, thermo-chemical biomass processing, solar energy or hydrogen separation and purification. Pure hydrogen can be burned in a gas turbine for electricity generation, converted to electricity in a fuel cell and then be used as fuel for an internal combustion engine.

Any building that contains a potential source of hydrogen, like hydrogen factory, should have good ventilation, strong ignition suppression systems for all electronic devices, and preferably be designed to have a roof that can be safely blown away from the rest of the structure in an explosion.

- Safety in storage

Hydrogen can be physically stored as either a gas or a liquid. Large quantities of hydrogen are stored as liquid hydrogen (LH_2) in insulated vessels.

Storage is expensive and more importantly product loss due to evaporation makes this process inefficient. One kilogram of compressed hydrogen (CH_2) occupies 11 m^3 of volume at ambient conditions, such that storage requires enormous compression. The current challenge is to develop conformable pressure vessels that can optimize space in FCVs. The net energy utilized for CH_2 storage is the lowest compared to LH_2 and all the other storage options. As hydrogen molecules can penetrate some metals, it could lead to hydrogen leaks or contribute to cracks spread.

Finally, hydrogen can be stored through the reaction of hydrogen-containing materials with water. In this case, the hydrogen is effectively stored in both the material and in the water. This form of hydrogen storage is called "chemical hydrogen storage".

In conclusion, hydrogen storage is one of the biggest challenges with hydrogen and hazards in storage are mainly related to leaking and ventilation which may result in mixing hydrogen with air hence burning.

- Safety in transmission

Once the hydrogen is produced it has to be transported from the factory to the point of use. It has to be transported in the safest condition, not neglecting the cost-effective and energy-efficiency of the method. There are three primary options for transporting hydrogen:

1. Pipelines and tube trailers for gaseous hydrogen, or a mixture of hydrogen and natural gas transportation.
2. Trucks, rails, barges, and ships with cryogenic tanks for liquefied hydrogen delivery.
3. High energy-density carriers such as ethanol, methanol, and other liquids derived from renewable biomass that can be transported and reformed to hydrogen at the endpoint of use.

The transmission is still developing because of hydrogen relatively low volumetric energy density, its transportation, storage, and final delivery to the point of use comprise a significant cost and result in some of the energy inefficiencies associated with using it as an energy carrier. Lots of different technologies have been investigated to transport hydrogen in a safety, cost-effective and energy-effective way.

One of the principal problems remains in the pipelines materials because of the damage that hydrogen causes to the metals mechanical properties. So it’s in this field where many investigations remain.

- Safety in applications

Hydrogen can be used in severe industry fields. The main future use of hydrogen is as a fuel for transport.

Taking a look at current other fuels, it is known that gasoline is the easiest and perhaps the safest fuel to store. Nevertheless, hydrogen and methane can also be safely stored using adequate technology. Conclusively, hydrogen has been used and stored safely in the industry and consideration of future hydrogen applications reveals no safety problems in the industrial and commercial markets.

However, hydrogen hazards associated with transport should be thoroughly investigated. Potential hazards are commonly related with fire, explosion, or toxicity as in any other case. Toxicity won't be taken into account, as combustion products are not malignant.

Fire and explosion may come from the fuel storage on vehicle, the fuel supply lines, or from the fuel cell if such a system is used.

In conclusion, counter measures to avoid failures could be leak prevention by a suitable safety design; using leak detection by a proper detector using an odorant; and ignition prevention by automatic disconnection of the battery.

3. Description of hydrogen delivery, HRS and HFCV

This project has been divided in three different sections: hydrogen transport, hydrogen refueling stations and hydrogen fuel cell vehicles. In the following section, each of these parts is going to be described. However, the project will only be focused on the two last ones, as hydrogen transportation is not so related to it.

3.1 Hydrogen delivery

This section explains the different ways to transport hydrogen to refueling stations. The hydrogen delivery must deal with several challenges like reducing delivery cost, increasing energy efficiency, maintaining hydrogen purity, and minimizing hydrogen leakage.

As mentioned beforehand, in point "*2.1 Physical and chemical properties*" of this project, hydrogen can be in the three physical states; liquid, gas and solid. Pure hydrogen appears in its natural state as a gas. The problem is that it is the smallest and lightest element on the earth (as a point of comparison, gasoline density is approximately 719.7 kg/m^3 whereas hydrogen density is only 0.08988 kg/m^3). Because of its relatively low volumetric energy density, its transportation, storage, and final delivery to the point of use comprise a significant cost and result in some of the energy inefficiencies associated with using it as an energy carrier. That meaks that in order to transport large amounts of hydrogen it must be pressurized and delivered as a compressed gas, liquefied gas or within metal hydrides.

Moreover, the location where the hydrogen is produced can have a big impact on the cost and best method of delivery. For example, a large, centrally located hydrogen production facility can produce hydrogen at a lower cost because of the large production, but it can have a higher transportation cost if the point of use is farther away. In comparison, distributed production facilities produce hydrogen on site so delivery costs are relatively low, but the cost to produce the hydrogen is likely to be higher because production volumes are less. It is for that reason that it is important to know all the possible options production/transportation to be able to perform a lowest landed cost analysis.

Today most common types of hydrogen transportation are the following:

- Pipelines

  Gaseous hydrogen can be transported through pipelines much the way natural gas is today. Transporting gaseous hydrogen via existing pipelines is a low-cost option for delivering large volumes of hydrogen. The high initial capital costs of new pipeline construction constitute a major barrier to expanding hydrogen pipeline delivery infrastructure. Research today therefore focuses on overcoming technical concerns related to pipeline transmission, including:

  - The potential for hydrogen to embrittle the steel and welds used to fabricate the pipelines.
  - The need to control hydrogen permeation and leaks.
  - The need for lower cost, more reliable and more durable hydrogen compression technology.

Fig. 3.1-1: Hydrogen pipelines

Transport of hydrogen in the existent natural gas pipelines is possible with just a few modifications and only if the pipelines transport natural gas with a maximum of 15% of hydrogen. To use the existent natural gas pipelines to transport pure hydrogen more modifications have to be made and that implies higher costs.

- Cryogenic liquid tanks

Hydrogen is most commonly transported and delivered as a liquid when high-volume is needed and in the absence of pipelines.

In order to liquefy hydrogen it must be cooled down to cryogenic temperatures through a liquefaction process. Gaseous hydrogen is liquefied by cooling it to below −253°C. Once it is liquefied it can be stored at the liquefaction plant in large insulated tanks. The main problem of cryogenic hydrogen is that it takes lots of energy to produce it. Using today's technology, hydrogen liquefaction consumes more than 30% of the energy content of the hydrogen and is therefore very expensive. In addition, some amount of stored hydrogen will be lost through evaporation, or "boil off".

Fig. 5.3-2: Hydrogen liquid tankers.

For long distances, hydrogen is usually transported as a liquid in super-insulated, cryogenic tanker trucks. After liquefaction, the liquid hydrogen is dispensed to delivery trucks and transported to distribution sites where it is vaporized to a high-pressure gaseous product for dispensing. Trucks transporting liquid hydrogen are referred to as liquid tankers.

- Gas compressed tanks

Hydrogen is typically produced at relatively low pressures (20–30 bar) and must be compressed prior to transport. Most compressors used today for gaseous hydrogen compression are either positive displacement compressors or centrifugal compressors. Positive displacement compressors can be reciprocating or rotary. Alternatives to mechanical compression that are currently in the research and development stage include the use of electrochemical reactions, metal hydrides, and ionic liquids.

Trucks that haul gaseous hydrogen are called tube trailers. Gaseous hydrogen is compressed to pressures of 180 bar or higher into long cylinders that are stacked on a trailer that the truck hauls. This gives the appearance of long tubes, hence the name tube trailer.

Fig. 3.1-3: Hydrogen tube trailer

Railcars, ships, and barges can also be used to deliver hydrogen as a compressed gas or cryogenic liquid, or within novel liquid or solid carrier materials. These methods are currently uncommon and typically are not economical unless the hydrogen is in liquid form.

Fig.3.1-4: Hydrogen transportation ship

Hydrogen used in portable or stationary applications can be stored directly in cylinders instead of tanks. This is the case of some hydrogen refueling stations. There are some of them that store hydrogen similar to petrol stations, in big underground tanks. Hydrogen is carried to them in tube trailers. Others hydrogen refueling stations use directly hydrogen cylinders.

3.2 Hydrogen Refueling Station (HRS)

Hydrogen is a gas that is stored above ground in cylinders at high pressure. Hydrogen can be delivered to the station as a compressed gas or as a liquid. As it has been mentioned, this project will be focused on compressed gas hydrogen.

Fig.3.2-1: Hydrogen refueling dispenser

The technology used for storing hydrogen onboard vehicles directly affects the design and selection of the delivery system and infrastructure. In the near term, 700 bar gaseous onboard storage has been chosen by the original equipment manufacturers for the first vehicles to be released commercially, and 350 bar is the chosen pressure for buses and lift trucks.

Hydrogen fueling equipment includes a dispenser, storage tubes and a compressor. A hydrogen dispenser looks similar to a gasoline dispenser. Most dispensers have two hoses, one for H35 and one for H70. These are not interchangeable. If the vehicle uses H70, the hydrogen first passes through a boost compressor.

Fig.3.2-2: HFCV 70 MPa connector

Drivers pull into a filling station, connect the dispenser to the vehicle, fill, disconnect, pay, and then drive away with a full tank. Refueling a FCEV takes approximately the same amount of time as refueling a gasoline powered car, 3 - 5 minutes. This is one of the advantages of hydrogen vehicles on electric vehicles, with 6 - 8 hours charging time.

Each of the companies involved in hydrogen station development use different technology and equipment and, therefore, will have different specifics. So standards, codes and regulations are required to establish some guides for everyone.

Fig. 3.2-3: Woman filling her car in a HRS

Whit regards to hydrogen station economics, although they have higher capital costs and greater operating and maintenance expenses than stations for existing fuels, the long-term opportunity is greater than with other alternative fuels. Regulations to sell fuel by unit weight (sold by the kilogram, “kg”) are still in development. When the regulations are finished, hydrogen is expected to be priced competitively with other fuels.

There are still many challenges to take into account in this section. One of the greatest challenges to commercial dispensing of hydrogen is the accurate metering of the hydrogen delivered. Also the availability of stations providing reasonably priced hydrogen in places where vehicles will be deployed remains a key challenge to the adoption of this technology.

3.3 Hydrogen Fuel Cell Vehicle (HFCV)

In this section, HFCV will be introduced and described. The idea is to identify its different parts to later be able to do an efficiency classification of the standards, codes and regulations concerning to it.

FCVs resemble normal gasoline or diesel-powered vehicles from the outside. Similar to electric vehicles (EVs), they use electricity to power a motor that propels the vehicle. Yet unlike EVs, which are powered by a battery, FCVs use electricity produced from on-board fuel cells to power the vehicle.

As shown in the picture below the main parts in which a HFCV is divided are: the fuel cell stack, the hydrogen tank, the electric motor, the power control unit and finally the battery.

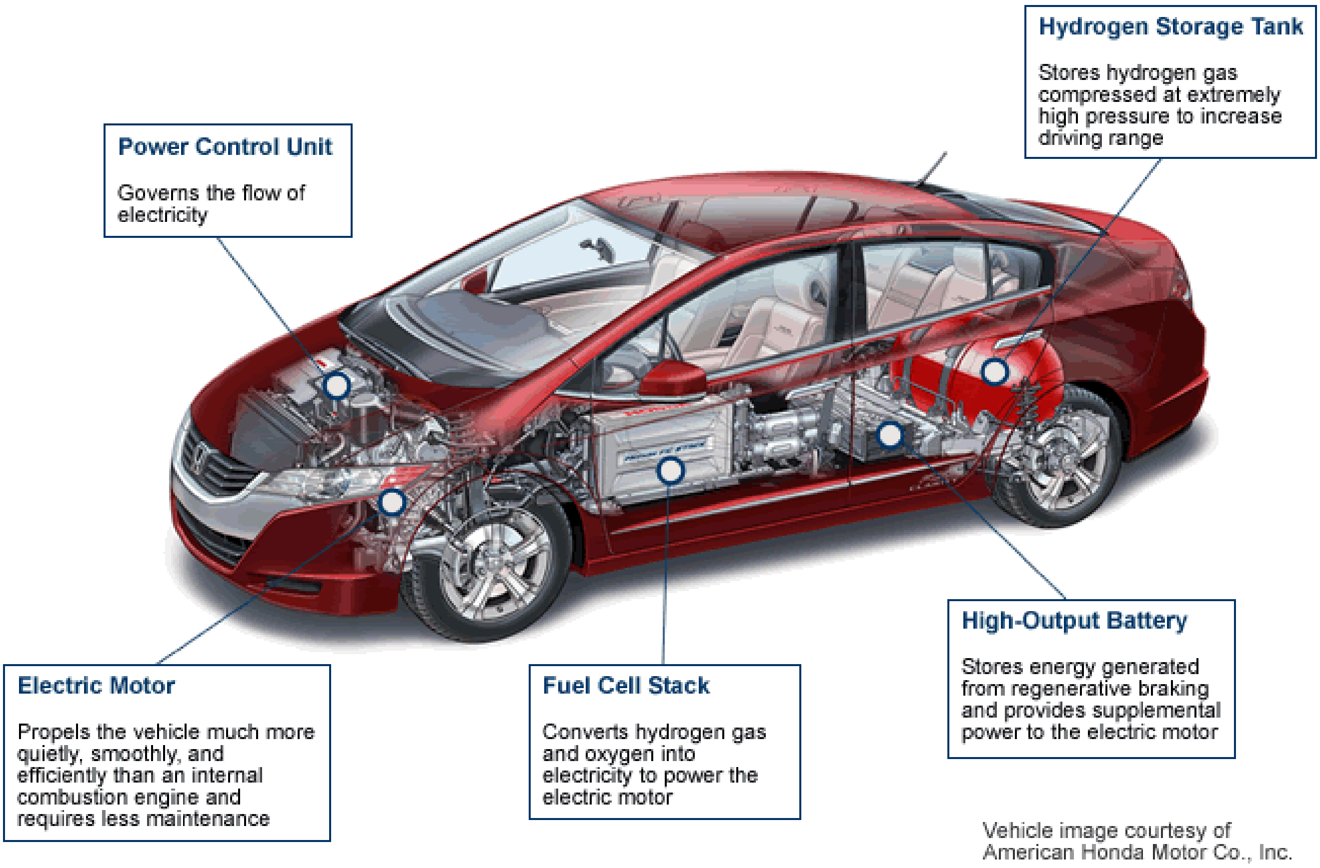


Fig. 3.3-1: Hydrogen Fuel Cell Vehicle parts

Now, each of these parts is going to be explained and described.

- Fuel cell stack

  The fuel cell is an electrochemical device that produces electricity using hydrogen and oxygen. In very simple terms, a fuel cell uses a catalyst to split hydrogen into protons and electrons, the electrons then travel through an external circuit (thus creating an electric current), and the hydrogen ions and electrons react with oxygen to create water. In section "*1.3 Market research*" from "*hydrogen vehicles*" part, a deep explication about the functioning of fuel cells is made.

- Hydrogen storage tank

  Instead of a gasoline or diesel tank, an HFCV has a hydrogen storage tank. Storing enough hydrogen on-board a vehicle to achieve a driving range greater than 500 km is a significant challenge. On a weight basis, hydrogen has nearly three times the energy content of gasoline (120 MJ/kg for hydrogen versus 44 MJ/kg for gasoline). However, on a volume basis the situation is reversed (8 MJ/liter for liquid hydrogen versus 32 MJ/liter for gasoline). For this reason, hydrogen storage tanks need to be pressurized, perhaps cooled and sometimes manufactured with special materials.

  Hydrogen storage tanks, as explained before, come in three popular kinds: compressed hydrogen, liquid hydrogen and metal hydride tanks.

  Compressed hydrogen storage tanks are the most popular nowadays since they don't require the super-cooling and super-insulation that liquid hydrogen does. Unlike pressurized natural gas, hydrogen is less dense and must be compressed at extremely high pressure (350 to 700 bar) to store enough fuel to obtain adequate driving range (compressed natural gas vehicles use high-pressure tanks at only 200 to 250 bar). The higher storage pressure also requires better seals. In addition, hydrogen storage tanks need to be made from lighter materials such as aluminum or carbon / graphite compounds because of the hydrogen embrittlement.

Storing liquid hydrogen in automobile tanks takes special handling and materials to contain and keep the fuel cool. Hydrogen does not liquefy until -253°C and much energy must be employed to achieve such temperatures.

Because of all these factors approximately 30 to 40-percent of the energy content of hydrogen can be lost due to the storage methods.

Metal hydride tanks are perhaps the future for hydrogen storage for H2 cars. Metal hydrides are specific metallic compounds and alloys that act like a sponge to both absorb and release hydrogen at consistent pressures. But this method is still in development.

- Electric motor and power control unit

  The electricity generated by fuel cells flows through a power control unit, which governs the flow of electricity in the vehicle, to the electric motor, which then uses the electricity to propel the vehicle.

- Battery

  Like electric vehicles, HFCVs also have a battery that stores electricity generated from regenerative braking, increasing the overall efficiency of the vehicle. The size and type of these batteries, will depend on the "degree of hybridization" of the vehicle, i.e., how much of the power to propel the vehicle comes from the battery and how much comes from the fuel cell stack.

Following this classification of the HFCV components the different standards, codes and regulations will be organized.

4. Hydrogen fears

This section has been divided in two parts. Into the first one, the most important hydrogen historic accidents will be briefly explained and in the second one a statistical study of a survey will be made.

4.1 Hydrogen historic accidents

Once hydrogen properties and some of its applications have been explained, it will be exposed which is the origin of this project. Hydrogen is seen as one of the future fuels, but also as a fear.

Hydrogen has been often synonymous of danger, especially since the **Hindenburg disaster** on 6 May 1937. The disaster killed 35 of the 97 passengers on the airship (miraculously, 62 survived). This fact brought end to rigid airship age. The zeppelin carried 200.000 m^3 of H_2, which ignited in less than a minute. The cause of the ignition was the combined combustion of hydrogen and the coating of the shell, although the origin of the ignition is unknown. Some people think it was caused by an electrostatic discharge (i.e., a spark) that ignited leaking hydrogen.

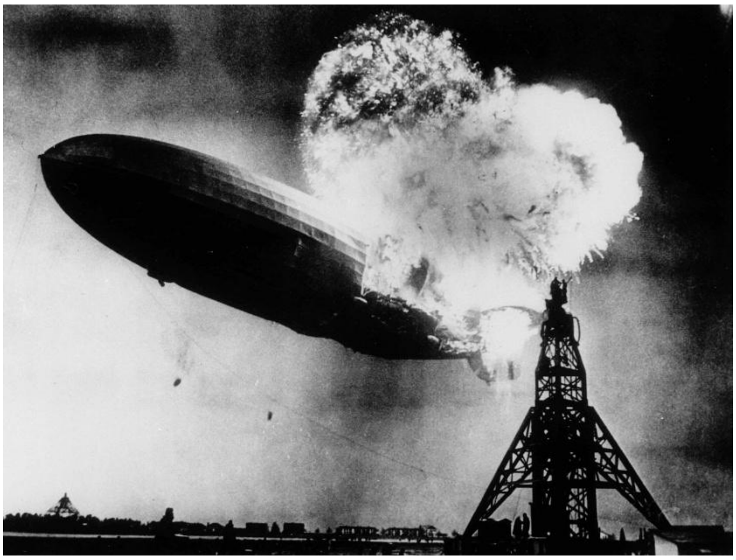


Fig. 4.1-1: Hindenburg, while fired

Analysis of the origin of some hydrogen accidents show that "organizational and human factors" contribute to the causes of most of these accidents (in over 70%), which have been the causes of people minds against hydrogen.

After the Hindenburg disaster, hydrogen usage as a fuel was stopped. This accident was not the first hydrogen accident. A long list of other hydrogen-inflated airships that were destroyed by fire from accidental causes could be made. Following, a selection of some historical hydrogen accidents has been collected:

- **LZ-10 Schwaben** (June 28, 1912): The passenger airship Schwaben was destroyed by fire at the airship field of Düsseldorf when its hydrogen was ignited by static electricity from the ship's rubberized fabric gas cells.

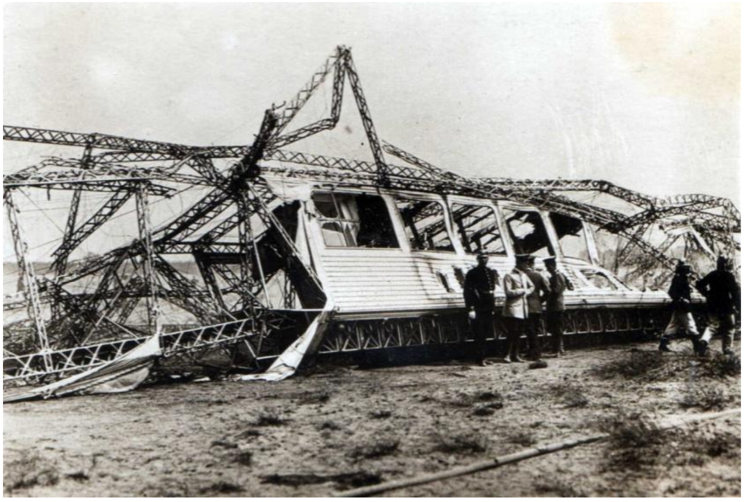


Fig. 4.1-2: Wreck of LZ-10 Schwaben at Düsseldorf

- **LZ-40/L-10** (September 3, 1915): L-10 airship was destroyed by a hydrogen fire during a thunderstorm near Cuxhaven as it was returning to its base at Nordholz. It is likely the ship rose in an updraft and released hydrogen which was ignited by the atmospheric conditions. All 19 members of the crew were killed.

- **Wingfoot Air Express** (July 21, 1919): Goodyear's Wingfoot Air Express ignited in mid-air and crashed through the skylight of the Illinois Trust & Savings Building in Chicago, Illinois, killing three persons on the ship and ten bank employees and injuring another 27 people. All subsequent Goodyear airships were inflated with helium.
- **Roma** (February 21, 1922): The United States Army airship Roma (built by Umberto Nobile) ignited when it hit high-tension electrical

wires near Langley Field at Hampton Roads, Virginia, killing 34 of the ship's 45 crew members. After the Roma disaster the United States government decided never again to inflate an airship with hydrogen.

Fig. 4.1-3: Airship Roma after ignition

- **Dixmude** (December 21, 1923): The French-operated Dixmude was destroyed over the Mediterranean Sea near the coast of Sicily by a hydrogen explosion visible from miles away. Dixmude gas cells had apparently been contaminated with air, creating an explosive mixture, and the ship may have been lifted by updrafts in a thunderstorm, causing hydrogen to be vented and then ignited by the electrically charged atmosphere.

Moreover, people use to be afraid of what is unknown or uncommon. Nowadays, hydrogen is known as an important chemical element, but its applications are not very popular, e.g. hydrogen vehicles as current vehicles. People need to be aware of the advantages that hydrogen can give today's world.

In order to face the so called "Hindenburg syndrome" and hydrogen fears in general, the best way is to carry out an analysis of risks to implement preventive and protective measures to avoid accidents or at least keep the consequences to a strict minimum.

So, in conclusion, existence of standards, codes and regulations are necessary to apply all of the measures in a legal and common way among countries or enterprises.

4.2 Survey & Statistics

After seeing some hydrogen accidents, what people think nowadays about hydrogen fuel cell vehicles can be an interesting field of study. Hydrogen science could benefit of people thoughts.

For that reason, a survey about hydrogen fuel cell vehicles has been developed in order to make a social study.

The survey has been created in three languages: Spanish, French and English. Then, depending on the language, it will be easier to make statistics according to each nationality (above all, for the project scope, it is interesting Spanish and French nationality).

Through the survey, people have been asked about hydrogen fuel cell vehicles, and some explanations of how a fuel cell vehicle works have been cleared up, in case the survey respondent didn't know anything about it. Every respondent has been asked about their hydrogen fears, as it is a new fuel technology that it's still not very popular. Respondents have also been questioned what type of vehicle they would buy in some hypothetical situations.

The survey can be found in ANNEX A. Once a reasonable number of people (131) have responded the survey, the statistics of some interesting questions have been concluded. It has to be mentioned that the majority of respondents are Spanish, according to the following graph.

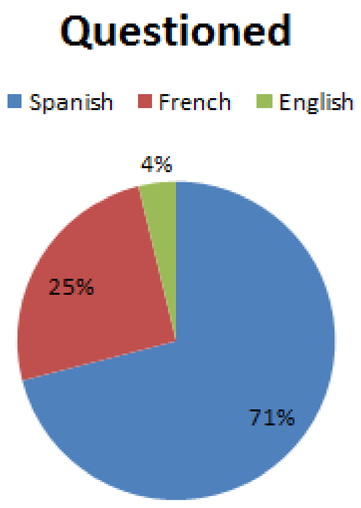


Fig. 4.2-1: Graph of percentage of respondents according their nationality

Focusing on the **Spanish nationality** study, a little majority had not heard of hydrogen fuel cell technologies. Even so, when told that a conventional vehicle and a hydrogen fuel cell vehicle could have the same characteristics, autonomy and price, and that a HFCV is non-polluting, 77% would buy a hydrogen fuel cell vehicle. In the case they chose “conventional vehicle” in the previous question, they have been asked the reasons, and there were a variety of responses (see in the following graph).

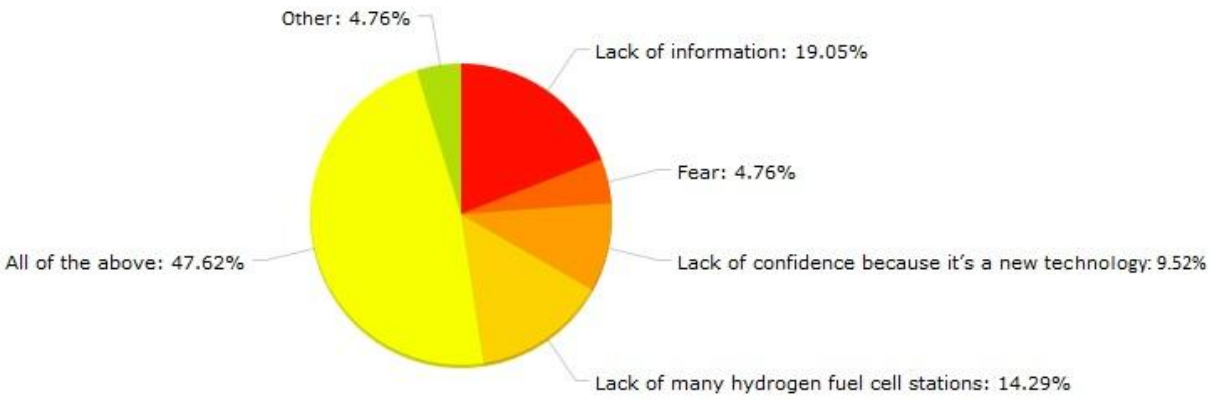


Fig. 4.2-2: Graph of answers to one of the survey’s questions

As we can see in the graph, the lack of information dominates as single answer, as well as the majority chose “all of the above”: lack of information, fear, lack of confidence because it’s a new technology and lack of many hydrogen fuel cell stations.

They have also been asked if it is enough for them to know that hydrogen regulations, standards and safety were currently being investigated in order to encourage them to use this kind of vehicle. 62% answered “no”.

The reasons are varied again, but the single winning answer is “that these vehicles investigation and testing were seen on the news”. It is clear here the importance of media in this kind of fields. Moreover, some of them have written some interesting answers: “that after a period of research, there was no fault, achieving high reliability”, “to demonstrate scientifically that there is no risk”, “to be sure that they are as safe as conventional vehicles”, etc.

After being explained some characteristics about HFCV, the majority of Spanish respondents have chosen this type of vehicle again, instead of a conventional or an electric one.

In case of **French nationality**, unlike the Spanish people, 90% affirm having knowledge of hydrogen fuel cell vehicles. Even so, less percentage of respondents, 57% of French ones, would buy a HFCV if this had the same characteristics, autonomy and price than a conventional vehicle, and taking into account that a HFCV is non-polluting.

In addition, around 50% affirmed that, in order to encourage them to use this kind of vehicle, it would be enough to know that hydrogen regulations, standards and safety are currently being investigated. In case of having answered “no”, they have been asked the reasons, and this is what they answered:

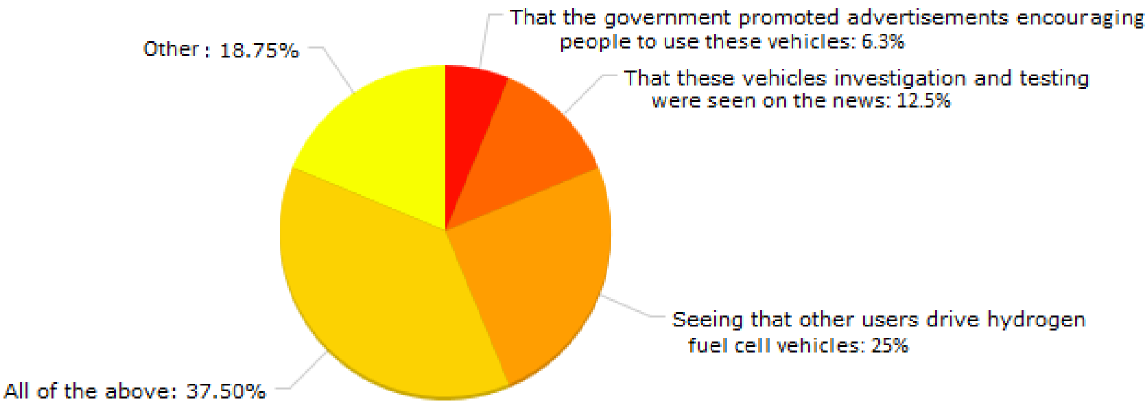


Fig. 4.2-3: Graph of answers to one of the survey’s questions

As single answer, “seeing that other users drive hydrogen fuel cell vehicles” dominates. This could be due to people trusting more what the others drive than what they could be told about this kind of vehicles. Also, there are “other answers”, of which it is noted: “That research is effective in terms of results and not only political. In addition, hydrogen production is a serious concern for the environment. Use electricity to produce is hardly "environmental friendly”.

Finally, after being explained some characteristics about HFCV, as Spanish people, the great majority of French respondents have chosen this type of vehicle again, instead of a conventional or an electric one.

In conclusion, the majority of both nationalities would be willing to have/buy a HFCV and this could be a good way of alternative fuel for vehicles. However, it is important not to forget people won't tolerate any type of mistake or any involuntary accident, so the most indispensable thing is to work hard on safety. That is the main reason of this project: to ensure safety by standards, codes and regulations of hydrogen fuel cell vehicles and its surroundings.

5. Standards, codes and regulations research and classification

The purpose of this section is to identify the different standards organizations, national and international, that concerns to hydrogen fuel cells in the field of land transport in general and to all the actions related to a hydrogen refueling station (HRS) in particular.

These actions involve hydrogen transport to the refueling station, storage and distribution in the station and the hydrogen fuel cells vehicles that will refuel there. The European and French regulations among others, will be also studied.

A classification of the standards and codes of each organization will be made, as well as a brief introduction of each standard organization.

However, first of all, it is necessary to know well what standards, codes and regulations are, and to understand the differences between them.

- Standards:

  A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.

  Standards are very important in our daily lives. Not only industrial products and equipment use standards. Standardization covers new fields, such as services, risks, management and more. Standardization permits the progress to the globalization of markets, guaranteeing the global openness and consultation of the same standards. The objective of standardization is to find a consensus between the national, European and international levels to establish the best compromise between the state of a technology or procedure and economic constraints.

  Standards also represent a major challenge for companies. They facilitate the free movement of their products on a market by encouraging the interoperability and comparability of products and services. They thus contribute to the competitiveness of organizations and enable a certain rationalization of production or the business. The standardization of organization methods enables bodies to have the best of practices to optimize their resources and be more efficient. Quality, safety and environment management standards therefore provide the methodological tools for improving the effectiveness of organizations.

Standards are voluntary in nature and there is no obligation to conform to them. They represent companies' commitments to satisfying a recognized and approved level of quality and safety. By being cited as reference documents, standards can support mandatory regulations issued by public authorities.

- Codes:

First of all it is necessary to understand that the notion of "Code" is different in USA and in Europe. In the USA, a code refers to a standard or collection of rules made binding by a local or national government whereas in Europe it is not mandatory.

In Europe, codes, also referred to as codes of practice, are generally understanding as the top-tier documents, providing a set of rules that specify the minimum acceptable level of safety for manufactured, fabricated or constructed objects. **It is not a law, but can be adopted into law.** They give detailed practical guidance on how to comply with requirements and obligations under work health and safety laws.

Comparing with codes, standards tend to be more elaborate and they involve the nuts and bolts of meeting a code. So a code could be understood as the document that tell you "what do you need to do" and standard that one which tells you "how to do it". For example, a code may say that a hydrogen tank must have a sensor to detect leaks and a standard may say what kind of sensor and how it must work.

However both of them serve as guidelines and characteristics developed by interested parties to support the free exchange of goods and services, and to promote safety and common understanding. These interested parties are typically companies and associations.

While standards are developed by standardization organizations, where lots of workgroups of different parties are involved, codes may be developed by a few or only a single company or association. Due to their more extensive development process, standards generally have a wider acceptance and importance than codes.

But in both cases, what makes commissions around the world becoming involved in this large-scale work is their desire to define a level of quality and safety for products and services.

- Regulations:

A regulation is defined as a rule or order issued by an executive authority or regulatory agency of a government and having the force of law generally when public safety is an issue.

Local, national or international authorities, provide compelling regulations to protect public, workers and environment from dangers and hazards. An example of regulations in Europe is European Community Directives. This is a collective legislative act requiring member states to achieve a particular result without dictating the means of achieving that result. In addition each country typically has their own national or local regulations and they may also apply.

Standards and codes, unlike regulations, are not legal documents. Moreover standards may be included or referred to in regulations and, through the regulation, may be made legally binding. In this case the standard is said to be harmonized with the regulation and becomes a harmonized standard.

In conclusion, the purpose of regulations, standards and codes are to ensure the safe and reliable design and operation of a product or facility.

In the following table, the different standards, codes, regulations and documents organizations are collected and classified according to their origin and type.

Type	Organization	Origin
Standards & Codes	AFNOR *(Association française de Normalisation)*	France
	ANSI *(American National Standards Institute)*	USA
	ASME *(American Society of Mechanical Engineers)*	USA
	CEN *(European Committee for Standardization)*	Europe
	CENELEC *(European Committee for Electrotechnical Standardization)*	Europe
	CGA *(Compressed Gas Association)*	USA
	CSA *(Canadian Standards Association)*	Canada
	ICC *(International Code Council, Inc.)*	International
	IEC *(International Electrotechnical Commission)*	International
	ISO *(International Standards Organization)*	International
	NFPA *(National Fire Protection Association)*	USA
	SAE *(Society of Automotive Engineers)*	USA
	UL *(Underwriters Laboratories)*	International
Regulations	UNECE *(United Nations Economic Commission for Europe)*	International
	European Directives	Europe
	Canadian regulation	Canada
	French regulations	France
	Spanish regulations	Spain
	USA regulations	USA
Documents	EIGA *(European Industrial Gases Association)*	Europe
	FCHEA *(Fuel Cell & Hydrogen Energy Association)*	USA
	LANL *(Los Alamos National Laboratory)*	USA
	NREL *(National Renewable Energy Laboratory)*	USA
	PNNL *(Pacific Northwest National Laboratory)*	USA
	SNL *(Sandia National Laboratory)*	USA

Fig. 5-1: Standards, codes, regulations and documents organizations classification

In this point a first classification will be made. The idea is to divide this classification in three parts: standards and codes organizations, regulations and documents. The objective is to construct a database where all standards; codes, regulations and documents related to this project are collected. In this point the main information of each document can be found: codification, abstract, cost and link (among others).

5.1 Standards and codes organizations

In this section there is a collection of the standards and codes organizations more relevant to the project of study. They are organized in alphabetical order. In tables appear codification and title of the standard or code and abstract and further information appears into Annex B.

There are some standards and codes marked with (*). It means that their information is not directly related with the project of study. However, they have been considered interesting.

Association française de Normalisation (AFNOR)

AFNOR, the French standardization organization, is an international services delivery network that revolves around 4 core competency areas: standardization, certification, industry press, and training.

The AFNOR has the unique stance of carrying out its standardization mission as a public-benefit organization while conducting some of its business in the competitive arena.

AFNOR directs and coordinates the establishment of national standards (NF) and participation in the definition of European standards (EN) and International standards (ISO and IEC). It is the French member of European and international non-governmental standards organizations such as CEN and CENELEC in Europe, and ISO and IEC internationally. Thanks to the investment of all the players in the French economy, AFNOR is one of the most influential members of these organizations, strategically and technically.

AFNOR also provides expertise for international technical cooperation in the field of quality infrastructure in order to develop synergies and reinforce French influence internationally.

Ninety percent of standards established within AFNOR are of European or international origin. Indeed, AFNOR takes an active part in standardization activities carried out in international and European bodies with the aim of promoting and defending French interests. A French delegation of experts attends the meetings of these bodies and takes part in the work in hand. This delegation then reports back on the exchanges and actions to the national standards commission responsible for monitoring the proceedings from the French standpoint.

Codification	Title
NF M58-003 (2013)	Installation of hydrogen-related systems

As AFNOR has taken standards of international organizations (ISO and IEC) which have been explained previously, here, a recompilation of these standards have been done.

Code	Title	Link	Origin
NF EN 62282-2:2012	Fuel cell technologies - Part 2: fuel cell modules	http://www.boutique.afnor.org/standard/nf-en-62282-2/fuel-cell-technologies-part-2-fuel-cell-modules/article/678287/fa173026	IEC
NF EN 62282-5-1:2007	Fuel cell technologies - Part 5-1 : portable fuel cell power systems - Safety	http://www.boutique.afnor.org/standard/nf-en-62282-5-1/fuel-cell-technologies-part-5-1-portable-fuel-cell-power-systems-safety/article/683290/fa141440	IEC
NF EN 60079-29-1:2008	Explosive atmospheres - Part 29-1: gas detectors - Performance requirements of detectors for flammable gases	http://www.boutique.afnor.org/standard/nf-en-60079-29-1/explosive-atmospheres-part-29-1-gas-detectors-performance-requirements-of-detectors-for-flammable-gases/article/677395/fa149421	IEC
NF EN 60079-29-2:2008	Explosive atmospheres - Part 29-2: gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen	http://www.boutique.afnor.org/standard/nf-en-60079-29-2/explosive-atmospheres-part-29-2-gas-detectors-selection-installation-use-and-maintenance-of-detectors-for-flammable-gase/article/717424/fa149422	IEC
NF EN 60079-29-3:2014	Explosive atmospheres - Part 29-3: gas detectors - Guidance on functional safety of fixed gas detection systems	http://www.boutique.afnor.org/standard/nf-en-60079-29-3/explosive-atmospheres-part-29-3-gas-detectors-guidance-on-functional-safety-of-fixed-gas-detection-systems/article/807426/fa180715	IEC
NF EN 60079-29-4:2010	Explosive atmospheres - Part 29-4: gas detectors - Performance requirements of open path detectors for flammable gases	http://www.boutique.afnor.org/standard/nf-en-60079-29-4/explosive-atmospheres-part-29-4-gas-detectors-performance-requirements-of-open-path-detectors-for-flammable-gases/article/680544/fa161798	IEC
NF EN 50465:2009	Gas appliances - Fuel cell gas heating appliance - Fuel cell gas heating appliance of nominal heat input inferior or equal to 70 kW	http://www.boutique.afnor.org/standard/nf-en-50465/gas-appliances-fuel-cell-gas-heating-appliance-fuel-cell-gas-heating-appliance-of-nominal-heat-input-inferior-or-equal-to-70/article/667617/fa148353	IEC
FD ISO/TR 15916:2006	Basic considerations for the safety of hydrogen systems	http://www.boutique.afnor.org/standard/fd-iso-tr-15916/basic-considerations-for-the-safety-of-hydrogen-systems/article/674379/fa130240	ISO

American National Standards Institute (ANSI)

The American National Standards Institute (ANSI) has served in its capacity as administrator and coordinator of the United States private sector voluntary standardization system for more than 90 years. It is a private, nonprofit membership organization supported by a diverse constituency of private and public sector organizations.

Comprised of Government agencies, Organizations, Companies, Academic and International bodies, and individuals, the American National Standards Institute (ANSI) represents the interests of more than 125,000 companies and 3.5 million professionals.

The ANSI process serves all standardization efforts in the United States by providing and promoting a process that withstands scrutiny, while protecting the rights and interests of every participant. In essence, ANSI standards quicken the market acceptance of products while making clear how to improve the safety of those products for the protection of consumers.

The standards that concerns to the project of study are the following:

Codification	Title
ANSI/CSA HGV 3.1-2015	Fuel system components for compressed hydrogen gas powered vehicles
ANSI/CSA HGV 4.1-2013	Hydrogen dispensing systems
ANSI/CSA HGV 4.2-2013	Hoses for compressed hydrogen fuel stations, dispensers and vehicle fuel systems
ANSI/CSA HGV 4.4-2013	Breakaway devices for compressed hydrogen dispensing hoses and systems
ANSI/CSA HGV 4.5-2013 (*)	Priority and sequencing equipment for hydrogen vehicle fueling
ANSI/CSA HGV 4.10-2012	Standard for fittings for compressed hydrogen gas and hydrogen rich gas mixtures
ANSI/CSA FC 3-2004	Portable Fuel Cell Power Systems

American Society of Mechanical Engineers (ASME)

ASME is a not-for-profit membership organization that enables collaboration, knowledge sharing, career enrichment, and skills development across all engineering disciplines, toward a goal of helping the global engineering community develop solutions to benefit lives and livelihoods. Founded in 1880 by a small group of leading industrialists, ASME has grown through the decades to include more than 140,000 members in 151 countries. Thirty-thousand of these members are students.

ASME is the leading international developer of codes and standards associated with the art, science, and practice of mechanical engineering. It develops voluntary standards that enhance public safety, health, and quality of life as well as facilitate innovation, trade, and competitiveness.

Codification	Title
ASME BPVC-VIII-1 (2013)	Rules for Construction of Pressure Vessels Division 1.
ASME BPVC-VIII-2 (2013)	Rules for Construction of Pressure Vessels Division 2-Alternative Rules.
ASME BPVC-VIII-3 (2010)	Rules for Construction of Pressure Vessels Division 3-Alternative Rules for Construction of High Pressure Vessels.
ASME PTC 50 (2002)	Fuel Cell Power Systems Performance.
ASME STP-PT-005 (2006)	Design Factor Guidelines for High-Pressure Composite Hydrogen Tanks.
ASME STP-PT-021 (2008)	Non-destructive Testing and Evaluation Methods for Composite Hydrogen Tanks
ASME STP-PT-014 (2008)	Data Supporting Composite Tank Standards Development for Hydrogen Infrastructure Applications.

European Committee for Standardization (CEN)

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 33 European countries.

CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level.

This association provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes.

CEN supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defence and security, energy, the environment, food and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging.

a) CEN/TC 23 Transportable gas cylinders: Standardization of transportable gas cylinders, their fittings, and requirements relating to their design, testing and operation. The scope does not include LPG cylinder or non-refillable cartridges. The scope does not include containers for cryogenic gases.

Codification	Title
EN 1920 (2000)	Transportable gas cylinders - Cylinders for compressed gases (excluding acetylene) - Inspection at time of filling

b) <u>CEN/TC 305 Potentially explosive atmospheres - Explosion prevention and protection</u>: To develop standards where necessary in the fields of:

- Test methods for determining the flammability characteristics (ignition, propagation, explosion effects, etc.) of substances;
- Equipment and protective systems for use in potentially explosive atmospheres and equipment and systems for explosion prevention and protection.

Codification	Title
EN 1127-1 (2011)	Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
EN 1127-2 (2014)	Explosive atmospheres - Explosion prevention and protection - Part 2: Basic concepts and methodology for mining
EN 13463-1 (2009)	Non-electrical equipment for use in potentially explosive atmospheres - Part 1: Basic method and requirements
EN 13463-2 (2004)	Non-electrical equipment for use in potentially explosive atmospheres - Part 2: Protection by flow restricting enclosure 'fr'
EN 13463-3 (2005)	Non-electrical equipment for use in potentially explosive atmospheres - Part 3: Protection by flameproof enclosure 'd'
EN 13463-5 (2011)	Non-electrical equipment intended for use in potentially explosive atmospheres - Part 5: Protection by constructional safety 'c'
EN 13463-6 (2005)	Non-electrical equipment for use in potentially explosive atmospheres - Part 6: Protection by control of ignition source 'b'
EN 13463-8 (2003)	Non-electrical equipment for potentially explosive atmospheres - Part 8: Protection by liquid immersion 'k'

c) <u>CEN/TC 393 Equipment for storage tanks and for filling stations:</u> Standardization of equipment for all kinds of storage tanks and for filling stations. The general interest of CEN/TC 393 is for equipment relating to the storage of fuels, that are liquids under atmospheric conditions, but the equipment may be used for other purposes. The standardization may include performance requirements and product descriptions together with the necessary test methods and the requirements concerning the evaluation of conformity.

Codification	Title
EN 13160-1 (2003)	Leak detection systems - Part 1: General principles

d) <u>CEN/CLC/JWG FCGA - Fuel cell gas appliances</u>: Product standards are to be elaborated for gas fired appliances with combined heating and power to be harmonized with the essential requirements of the Gas Appliance Directive (90/396/EC).

Codification	Title
EN 50465 (2015) (*)	Gas appliances - Combined heat and power appliance of nominal heat input inferior or equal to 70 kW

<u>European Committee for Electrotechnical Standardization (CENELEC)</u>

CENELEC is a non-profit international association, designated as a European Standards Organization by the European Commission and it takes part into the officially recognized European Standards Organizations (ESOs) together with CEN, the European Committee for Standardization and ETSI, the European Telecommunications Standards Institute.

It is responsible for standardization in the electrotechnical engineering field. CENELEC prepares voluntary standards, which, among other activities, help facilitate trade between countries and support the development of a Single European Market. In general European Standards are created in order to encourage technological development, to ensure interoperability and to guarantee the safety and health of consumers and provide environmental protection.

European Standards (ENs) are based on a consensus, which reflects the economic and social interests of 33 CENELEC Member countries channelled through their National Electrotechnical Committees (NCs). Most standards are initiated by industry. Other standardization projects can come from consumers, Small and Medium-sized Enterprises (SMEs) or associations, or even European legislators.

It is important to emphasize that CENELEC creates market access at European level but also at international level, adopting international standards wherever possible, through its close collaboration with the International Electrotechnical Commission (IEC), under the Dresden Agreement.

The standards classification of CENELEC is done in the following table, because they are the same standards that in the IEC (see the abstract in IEC section or by clicking in the link).

Code	Title	Link
EN 62282-2:2012	Fuel cell technologies - Part 2: Fuel cell modules	http://www.cenelec.eu/dyn/www/f?p=104:110:127751350377001::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258419,54304,25
EN 62282-5-1:2012	Fuel cell technologies - Part 5-1: Portable fuel cell power systems - Safety	http://www.cenelec.eu/dyn/www/f?p=104:110:127751350377001::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258419,45385,25
FprEN 60079-29-1:2015	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases	http://www.cenelec.eu/dyn/www/f?p=104:110:127751350377001::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258803,60293,25
EN 60079-29-2:2015	Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen	http://www.cenelec.eu/dyn/www/f?p=104:110:127751350377001::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258803,47404,25

Compressed Gas Association (CGA)

The Compressed Gas Association is an American non-governmental organization that represents all facets of the industry; manufacturers, distributors, suppliers, and transporters of gases, cryogenic liquids, and related products. It influence encompasses industrial, medical, and specialty gases in compressed or liquefied form, and a range of gas handling equipment.

The objective of CGA is to develop and promote safety standards and safety practices in the industrial gas industry. Its activities include the manufacture, transportation, storage, transfiling, and disposal of gases (liquefied, non-liquefied, dissolved, and cryogenic); and the containers and valves which hold the compressed gases. The scope shall also include related apparatus if such apparatus is necessary for the safe dispensing or delivery of the gases in a commercial, industrial, research, or medical application. Additionally, the scope will cover providing safety information or warnings about the chemical or physical properties of gases and their containers, but will not cover the specifics of the application or use of such gases.

The work of CGA is carried out by committees of volunteers from member companies having expertise in the particular areas targeted. Each of these committees focuses on work item projects through its subcommittees and task forces.

The standards that concerns to the project of study are the following:

a) Standards and Specifications: Position Statements (PS):

Codification	Title
CGA PS-31	Position Statement on Cleanliness for Proton Exchange Membranes Hydrogen Piping/Components
CGA PS-33	Position Statement on Use of LPG or Propane Tank as Compressed Hydrogen Storage Buffers

b) Standards and Specifications: Hydrogen (H):

Codification	Title
CGA H-4 (*)	Terminology Associated with Hydrogen Fuel Technologies

c) Standards and Specifications: Gases (G):

Codification	Title
CGA G-5 (*)	Hydrogen
CGA G-5.3 (*)	Commodity Specification for Hydrogen

d) Standards and Specifications: Pressure Relief Devices (S):

Codification	Title
CGA S-1.1	Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases

Canadian Standard Association (CSA)

CSA Group is an independent, not-for-profit member-based association dedicated to advancing safety, sustainability and social good. It is an internationally-accredited standards development, testing and certification organization. Its broad range of knowledge and expertise includes: industrial equipment, plumbing and construction, electro-medical and healthcare, appliances and gas, alternative energy, lighting and sustainability. The CSA mark appears on billions of products around the world.

It marks are widely accepted by code officials and authorities having jurisdiction (AHJ) throughout North America. It is accredited and recognized by regulatory bodies including the Standards Council of Canada (SCC) and the U.S. Occupational Safety and Health Administration (OSHA) to test & certify a wide variety of products including electrical, electronics, gas-fired, building, plumbing, and more.

CSA Group is accredited by the American National Standards Institute (ANSI), an organization that co-ordinates the standards strategy for the U.S. It maintains ANSI accreditation by developing consensus standards that comply with ANSI Essential Requirements. It’s for that reason that most of CSA standards that concerns to this project are published by ANSI (so will be recollected in the ANSI part). That ones that are published by CSA are:

Codification	Title
CSA HGV 4.3-2012	Test methods for hydrogen fuelling parameter evaluation

International Code Council (ICC)

The International Code Council (ICC) was established in 1994 as a non-profit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes.

Nowadays; the International Code Council is a member-focused association dedicated to developing model codes and standards used in the design, build and compliance process to construct safe, sustainable, affordable and resilient structures. Its International Codes are choosing for most U.S. communities and many global markets.

The International Codes®, or I-Codes®, published by ICC, provide minimum safeguards for people at home, at school and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes. Building codes benefit public safety and support the industry's need for one set of codes without regional limitations.

Many of its Codes are adopted for different governments whose give them a jurisdictional level. For example, federal agencies including the Architect of the Capitol, General Services Administration, National Park Service, Department of State, U.S. Forest Service and the Veterans Administration also enforce the I-Codes. The Department of Defense also references the *International Building Code®* for constructing military facilities. Amtrak uses the *International Green Construction Code®* for new and extensively renovated sites and structures. Puerto Rico and the U.S. Virgin Islands enforce one or more of the I-Codes.

The ICC Codes that concerns to the project of study are:

Code name
2015 International Fire Code
2015 International Fuel Gas Code

The International Electrotechnical Commission (IEC)

The International Electrotechnical Commission (IEC) is the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies. The IEC is one of three global sister organizations (IEC, ISO, ITU) that develop International Standards for the world.

The IEC is a not-for-profit, non-governmental organization, founded in 1906. The IEC's members are National Committees, and they appoint experts and delegates coming from industry, government bodies, associations and academia.

When appropriate, IEC cooperates with ISO (International Organization for Standardization) or ITU (International Telecommunication Union) to ensure that International Standards fit together seamlessly and complement each other.

The IEC internal structure is divided in several technical committees (TC). Each TC deals with a different subject. Those that concerns to the project of study are:

a) IEC/TC 8 Systems aspects for electrical energy supply: To prepare and coordinate, in co-operation with other TC/SCs, the development of international standards and other deliverables with emphasis on overall system aspects of electricity supply systems and acceptable balance between cost and quality for the users of electrical energy. Electricity supply system encompasses transmission and distribution networks and connected user installations (generators and loads) with their network interfaces.

   The standards that specifically concerns to the project of study are:

Codification	Title
IEC/IEEE/PAS 63547 (2011-09)	Interconnecting distributed resources with electric power systems

b) IEC/TC 31 Equipment for explosive atmospheres: this work in order_to prepare and maintain international standards relating to equipment for use where there is a hazard due to the possible presence of explosive atmospheres of gases, vapours, mists or combustible dusts.

The standards that specifically concerns to the project of study are:

Codification	Title
IEC 60079-29-1 (2007-08)	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases
IEC 60079-29-2 (2015-03)	Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
IEC 60079-29-3 (2014-03)	Explosive atmospheres - Part 29-3: Gas detectors - Guidance on functional safety of fixed gas detection systems
IEC 60079-29-4 (2009-11)	Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases

c) IEC/TC 95 Measuring relays and protection equipment: Standardization of measuring relays and protection equipment used in the various fields of electrical engineering covered by the IEC, taking into account combinations of devices to form schemes for power system protection including the control, monitoring and process interface equipment used with those systems.

Codification	Title
IEC 60255-27 (2013-10)	Measuring relays and protection equipment - Part 27: Product safety requirements

d) IEC/TC 105 Fuel cell technologies: This Technical Committee prepares international standards regarding fuel cell (FC) technologies for all FC applications such as stationary FC power systems, FC for transportation such as propulsion systems and auxiliary power units, portable FC power systems, and micro FC power systems.

The standards that specifically concerns to the project of study are:

Codification	Title
IEC 62282-2 (2012-03)	Fuel Cell Modules
IEC 62282-5-1 (2012-09)	Portable Fuel Cell Appliances - Safety
IEC 62282-7-1 (2010-06)	Single Cell Test Method for Polymer Electrolyte Fuel Cells

International organization for Standardization (ISO)

ISO is an independent, non-governmental membership organization and the world's largest developer of voluntary International Standards.

ISO provides a standards database for different beneficiaries. For business provide strategic tools and guidelines to tackle some of the most demanding challenges of modern business. They ensure that business operations are as efficient as possible, increase productivity and help companies access new markets. For society, when products and services conform to international standards, consumers can have confidence that they are safe, reliable and have a good quality. And for government, they can use ISO standards to support public policy.

The ISO internal structure is divided in several technical committees (TC). TCs are made up of representatives of industry, NGOs (Non-Governmental Organisations), governments and other stakeholders, who are put forward by ISO's members. Each TC deals with a different subject. Those that concerns to the project of study are:

a) ISO/TC 22 Road Vehicles: This TC works on all questions of standardization concerning compatibility, interchangeability and safety, with particular reference to terminology and test procedures (including the characteristics of instrumentation) for evaluating the performance and their equipment of mopeds, motor cycles, motor vehicles, trailers; semi-trailers, light trailers, combination vehicles and articulated vehicles.

The standards of that committee that concerns the project of study are collected in the following sub committees:

Subcommittee (SC)	Codification	Title
SC 21 Electrically propelled road vehicles	ISO 6469-1:2009	Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)
	ISO 6469-2:2009	Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures
	ISO 6469-3:2011	Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock
	ISO 23273:2013	Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
SC 25 Vehicles using gaseous fuels	ISO 16380:2014	Road vehicles -- Blended fuels refuelling connector

b) ISO/TC 197 Hydrogen technologies: This TC works on standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen.

The standards that specifically concerns to the project of study are:

Codification	Title
ISO 15869:2009	Gaseous hydrogen and hydrogen blends -- Land vehicle fuel tanks
ISO/TR 15916:2004	Basic considerations for the safety of hydrogen systems
ISO 17268:2012	Gaseous hydrogen land vehicle refuelling connection devices
ISO/TS 20100:2008	Gaseous hydrogen -- Fuelling stations
ISO 26142:2010	Hydrogen detection apparatus -- Stationary applications

National Fire Protection Association (NFPA)

The National Fire Protection Association (NFPA) is an international nonprofit organization established in 1896. The company's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. With a membership that includes more than 70.000 individuals from nearly 100 nations. NFPA is the world's leading advocate of fire prevention and an authoritative source on public safety. Our International Operations department works to develop and increase global awareness of NFPA, its mission and expertise by promoting worldwide use of NFPA's technical and educational information.

NFPA publishes 300 codes and standards that are designed to minimize the risk and effects of fire by establishing criteria for building, processing, design, service, and installation in the United States, as well as many other countries. Its more than 200 technical code- and standard- development committees are comprised of over 6.000 volunteer seats. Volunteers vote on proposals and revisions in a process that is accredited by the American National Standards Institute (ANSI).

The codes and standards NFPA related to this project are collected below:

Codification	Title
NFPA 2 (2011)	Hydrogen Technologies Code
NFPA 55 (2013)	Compressed Gases and Cryogenic Fluids Code
NFPA 70 (2014)	National Electrical Code® (NEC®)
NFPA 221 (2015)	Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls
NFPA 853 (2015)	Standard for the Installation of Stationary Fuel Cell Power Systems

Society of Automotive Engineers (SAE)

SAE is an international association of more than 138.000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries. SAE International's core competencies are life-long learning and voluntary consensus standards development.

SAE standards are internationally recognized for their role in helping ensure the safety, quality, and effectiveness of products and services across the mobility engineering industry. The more than 10.000 standards in the SAE database now include historical standards, and can be accessed through enterprises, small business, academia and individuals.

The standards that concerns to the project of study are the following:

a) Fuel Cell Standards Committee: this technical committee is responsible for establishing standards for vehicle fuel cell systems and its interfaces to the vehicle. Standards will cover the safety aspects of fuel cell systems in the vehicle, test procedures to establish the performance of the system/components, and interface requirements. The standards that specifically concerns to the project of study are:

Codification	Title
SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
SAE J2572	Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen
SAE J2578	Recommended Practice for General Fuel Cell Vehicle Safety
SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles
SAE J2600	Compressed Hydrogen Surface Vehicle Fuelling Connection Devices
SAE J2601	Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
SAE J2616	Testing Performance of the Fuel Processor Subsystem of an Automotive Fuel Cell System

SAE J2617	Recommended Practice for Testing Performance of PEM Fuel Cell Stack Sub-system for Automotive Applications
SAE J2719 (*)	Hydrogen Fuel Quality for Fuel Cell Vehicles.
SAE J2799 (*)	Hydrogen Surface Vehicle to Station Communications Hardware and Software
SAE J2990/1 (*)	Gaseous Hydrogen and Fuel Cell Vehicle First and Second Responder Recommended Practice

Underwriters Laboratories (UL)

UL is a global independent safety science company with more than a century of expertise innovating safety solutions from the public adoption of electricity to new breakthroughs in sustainability, renewable energy and nanotechnology. Dedicated to promoting safe living and working environments, UL helps safeguard people, products and places in important ways, facilitating trade and providing peace of mind.

UL certifies, validates, tests, inspects, audits, and advises and trains. It provides the knowledge and expertise to help customers navigate growing complexities across the supply chain from compliance and regulatory issues to trade challenges and market access.

UL Underwriters Laboratories

UL works with a diverse array of stakeholders every day to make the world safer and provide assurance. It optimizes the supply chain for manufacturers and provides them a broad range of services that support every stage of the product life cycle. UL works with retailers on inspections and audits. It consults with governments on initiatives that facilitate global trade and collaborate with industry on standards that create level playing fields.

The UL standard that concerns to the project of study is:

Codification	Title
2262	Fuel Cell Modules for Use in Portable and Stationary Equipment

5.2 Regulations

As it was explained in previous sections, regulations are obligatory. That means that they have got a legal and mandatory character. In this section the different regulations that concern to the project of study are collected. They are classified in International, European and National. Inside the National classification the French, American, Canadian and Spanish regulations will be studied.

There are some regulations mark with (*), it means that their information is not directly related with the project of study but they have considered interesting.

5.2.1. International regulations

The international regulations that concerns to the project of study are the following:

United Nations Economic Commission for Europe (UNECE)

The United Nations Economic Commission for Europe (UNECE) was set up in 1947 by ECOSOC (Economic and Social Council). It is one of five regional commissions of the United Nations. The others are the : Economic Commission for Africa (ECA), Economic and Social Commission for Asia and the Pacific (ESCAP), Economic Commission for Latin America and the Caribbean (ECLAC) and Economic and Social Commission for Western Asia (ESCWA).

UNECE's major aim is to promote pan-European economic integration. To do so, it brings together 56 countries located in the European Union, non-EU Western and Eastern Europe, South-East Europe and Commonwealth of Independent States (CIS) and North America. All these countries dialogue and cooperate under the aegis of UNECE on economic and sectoral issues. However, all interested United Nations member States may participate in the work of UNECE. Over 70 international professional organizations and other non-governmental organizations take part in UNECE activities.

Fig.5.2.1-1 Map of the UNECE members

The United Nations Economic Commission for Europe (UNECE) as a multilateral platform facilitates greater economic integration and cooperation among its fifty-six member States and promotes sustainable development and economic prosperity through:

- policy dialogue,
- negotiation of international legal instruments,
- development of regulations and norms,
- exchange and application of best practices as well as economic and technical expertise,
- technical cooperation for countries with economies in transition.

The UNECE develop different legal instruments with the objective that countries adopt common international standards and harmonize their technical regulations.

It works in different field but that one that concerns to the project of study is the transport field. The UNECE has established 57 transport agreements and conventions which are negotiated by government representatives and become legally binding for countries which ratify or accede to them. These agreements and conventions create international safety and environmental standards and regulations for transport and for motor vehicles and their trailers, harmonize national regulations, make border crossings less complicated, and provide for the development of coherent infrastructure networks for road, rail and inland waterway transport.

Within the transport field, UNECE works in different areas. That one which refers to the project of study is:

Motor vehicles and their Trailers

The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) is a unique worldwide regulatory forum within the institutional framework of the UNECE Inland Transport Committee.

Three UN Agreements, adopted in 1958, 1997 and 1998, provide the legal framework allowing Contracting Parties (member countries) attending the WP.29 sessions to establish regulatory instruments concerning motor vehicles and motor vehicle equipment.

Moreover only the 1958 and 1998 agreement concerns nowadays to France, because at this date in the 1997 agreement France is pending of ratification.

1. 1958 Agreement: this agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions. It concluded on 20 March 1958. The 1958 Agreement, establishes the uniform requirements to which nearly every component of road-using vehicles should conform. It is composed of a list of regulations which provide for equal safety requirements and set environmental protection and energy saving criteria for Governments and vehicle manufactures in the territories of 51 Contracting Parties to the 1958 Agreement, including 41 UNECE countries (**France including**), as well as the European Union, Japan, Australia, South Africa, New Zealand, Republic of Korea, Malaysia, Thailand, Tunisia and Egypt. (This agreement is found in the following link http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/505ep29.pdf)

   In this agreement the UN regulations are collected. They contain provisions (for vehicles, their systems, parts and equipment) related to safety and environmental aspects. They include performance-oriented test requirements, as well as administrative procedures. The latter address the type approval (of vehicle systems, parts and equipment), the conformity of production (i.e. the means to prove the ability, for manufacturers, to produce a series of products that exactly match the type approval specifications) and the mutual recognition of the type approvals granted by Contracting Parties.

HFCV are a type of vehicles, that means that they have to follow all the regulations that concerns vehicles in general. Moreover in this agreement there are no specific regulations for hydrogen fuel cell vehicles, all of them concerns vehicles in general.

All these regulations could be found in the following links:

- http://www.unece.org/trans/main/wp29/wp29regs1-20.html
- http://www.unece.org/trans/main/wp29/wp29regs21-40.html
- http://www.unece.org/trans/main/wp29/wp29regs41-60.html
- http://www.unece.org/trans/main/wp29/wp29regs61-80.html
- http://www.unece.org/trans/main/wp29/wp29regs81-100.html
- http://www.unece.org/trans/main/wp29/wp29regs101-120.html
- http://www.unece.org/trans/main/wp29/wp29regs121-140.html

2. 1997 Agreement: this concerning the adoption of uniform conditions for periodical technical inspections of wheeled vehicles and the reciprocal recognition of such Inspections. It concluded on 13 November 1997, and it provides the legal framework and procedures for the adoption of uniform rules for carrying out technical inspections of vehicles in use and for the reciprocal recognition of the certificates of such inspections. Twelve countries are Parties to the 1997 Agreement, which entered into force on 27 January 2001. Seventeen countries are signatories pending ratification (France is one of those countries). (This agreement is found in the following link http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/1997agr/conf4efr.pdf)

3. 1998 Agreement: this Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles. It concluded on 13 November 1998 and it provides Governments with a legal framework and procedures for the adoption of global technical

regulations (gtrs) applicable to road vehicles, their equipments and parts, with a view to the improvement of their safety, environmental protection, energy efficiency and anti-theft performance. The Agreement is intended to have parallel technical provisions to those of the 1958 Agreement. (This agreement is found in the following link:
http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29glob/tran132.pdf)

To date, Australia, Azerbaijan, Canada, China, Cyprus, Finland, **France**, Germany, Hungary, India, Italy, Japan, Kazakhstan, Lithuania, Luxembourg, Malaysia, Netherlands, Norway, New Zealand, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Slovakia, Slovenia, South Africa, Spain, Sweden, Tajikistan, Tunisia, Turkey, United Kingdom, United States of America, European Union are Contracting Parties to the 1998 Agreement, which entered into force on 25 August 2000.

In this agreement the UN GTRs are collected. They contain globally harmonized performance-related requirements and test procedures. They provide a predictable regulatory framework for the global automotive industry, consumers and their associations. They do not contain administrative provisions for type approvals and their mutual recognition.

Sixteen global technical regulations have been included in the global registry. Moreover the unique one that concerns directly to hydrogen fuel cell vehicles is the following:

Codification	Title
UN GTR No. 13	Hydrogen and fuel cell vehicles

It is also interesting the following document which is a proposal made in August 2014 for Electric Vehicle Regulatory Reference Guide. It can be found in the link above:

http://www.unece.org/fileadmin/DAM/trans/doc/2014/wp29/ECE-TRANS-WP29-2014-81e.pdf

5.2.2 European legislation

The EU is a unique economic and political partnership between 28 European countries that together cover much of the continent. The EU was created in the aftermath of the Second World War. The first steps were to foster economic cooperation: the idea being that countries who trade with one another become economically interdependent and so more likely to avoid conflict. The result was the European Economic Community (EEC), created in 1958, and initially increasing economic cooperation between six countries: Belgium, Germany, France, Italy, Luxembourg and the Netherlands. Since then, a huge single market has been created and continues to develop towards its full potential.

What began as a purely economic union has evolved into an organization spanning policy areas, from development aid to environment. A name change from the EEC to the European Union (EU) in 1993 reflected this.

Fig. 5.2.2-1 European Union countries

Union law is divided into two types of law:

- Primary law: it refers in particular to the Treaties that are the basis for all EU action.

  The European Union is based on the rule of law. This means that every action taken by the EU is founded on treaties that have been approved voluntarily and democratically by all EU member countries. For example, if a policy area is not cited in a treaty, the Commission cannot propose a law in that area.

  A treaty is a binding agreement between EU member countries. It sets out EU objectives, rules for EU institutions, how decisions are made and the relationship between the EU and its member countries.

  Treaties are amended to make the EU more efficient and transparent, to prepare for new member countries and to introduce new areas of cooperation – such as the single currency.

- Secondary law: it is derived from the principles and objectives set out in the Treaties and includes regulations, directives and decisions.

  - **Regulation**: it is a binding legislative act. It must be applied in its entirety across the EU.

  - **Directive**: it is a legislative act that sets out a goal that all EU countries must achieve. However, it is up to the individual countries to decide how.

    Directives are used to bring different national laws into line with each other, and are particularly common in matters that affect the operation of the single market (e.g. product safety standards).

    Each directive contains a deadline by which Member States must adopt national transposition measures – which incorporate the obligations of the directive into national law.

  - **Decision**: it is binding on those to whom it is addressed (e.g. an EU country or an individual company) and is directly applicable.

Member States have primary responsibility for the correct and timely application of EU Treaties and legislation, and the Commission monitors the application of Union law.

The Commission may take action if a Member State:

- fails to incorporate EU directives into its national law and to report/communicate to the Commission what measures it has taken;
- or is suspected of breaching Union law.

If no solution can be found at an early stage, the Commission can open formal infringement proceedings and eventually refer the Member State to the European Court of Justice.

The regulations that concerns to the project of study are the following:

Codification	Title
32012R0630 EU No 630/2012	Type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions
32010R0406 EU No 406/2010	Type-approval of hydrogen-powered motor vehicles
32009R0079 EC No 79/2009	Type-approval of hydrogen-powered motor vehicles
32014R0559 EU No 559/2014 (*)	Establishing the Fuel Cells and Hydrogen 2 Joint Undertaking

The directives that concerns to the project of study are the following:

Codification	Title
31994L0009 Directive 94/9/EC (*)	Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres
32014L0034 Directive 2014/34/EU (*)	Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast) Text with EEA relevance
31997L0023 Directive 97/23/EC	Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

32006L0042 Directive 2006/42/EC	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance)
32014L0068 Directive 2014/68/EU	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment Text with EEA relevance
32008L0058 Commission Directive 2008/58/EC	Classification, packaging and labelling of dangerous substances
32004L0073R(01) Corrigendum to Commission Directive 2004/73/EC	Corrigendum to Commission Directive 2004/73/EC; Classification, packaging and labelling of dangerous substances
32014L0045 Directive 2014/45/EU	–

The European Commission is working on a new directive for the deployment of recharging and refueling points for alternative fuels, including hydrogen. Its code is “52013SC0005” and all its information can be found in the following link:

http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:52013SC0005&qid=1428913945793

5.2.3 National regulations

In this part some countries regulations will be explained. This countries are Canada, France, Spain and USA.

5.2.3.1 Canada regulations

The Canadian government department that contain the acts and regulations that concerns to the project of study is the Canadian Transport department. It has the responsibility and authority to propose and enforce laws and regulations to ensure safe, secure, efficient and clean transportation.

The Canadian law is divided in acts and regulations. When the federal government makes changes to Canadian law, often it will create "amending" Acts or regulations. These amending documents make changes to existing laws. For example, if the government wishes to add a new offence to the

Transport Code, it will not rewrite the entire document or create a new, separate Code, but will create an amending Act. The amending Act will add new sections or make changes to existing sections of the Transport Code. A consolidated Act or regulation is one that has been updated and incorporates the amendments into the original text.

Then it can also be found technical standards documents; which are voluntaries in nature, that have been become obligatory attached them into a regulation or act.

In the Canadian law there aren't lots of acts and regulations that concern the project of study. It can just be found the following ones:

Codification	Title
Technical Standards Document No. 301, Revision 2R	Motor Vehicle Safety Regulations 301.1 - Fuel System Integrity
Technical Standards Document No. 305, Revision 3R	Motor Vehicle Safety Regulations 305 - Electrolyte Spillage and Electrical Shock Protection

These are the unique specific regulations that concern some items of the project of study. Then there are lots of different acts and regulations that concerns vehicles in general.

5.2.3.2 French regulations

The law in France is essentially made up of written rules called sources of law. These can be rules adopted by States or between States at national level, but they also include case-law from national and international courts. In addition, they cover rules made at local level, such as municipal by-laws, or by professional and trade organizations, or rules established by citizens between themselves, such as collective agreements or contracts, and finally mere custom.

As national sources of law in France, there are the following:

- Constitutional rules: the constitution in force is the Constitution of 4 October 1958.

- Legislative rules: legislation, passed by Parliament, is subordinate to the Constitution. When addressed, the Constitutional Council reviews the constitutionality of legislation before it is enacted, that is, it checks to see if it conforms to the Constitution.

- Statutory instruments:

1. Orders: they have the rank of regulations until such time as they have been ratified by the legislature

2. Regulations: they differ according to the authority which introduced them:
   - Decrees from the President of the Republic or the Prime Minister (when they are adopted in the Council of Ministers or the Council of State they may only be amended under the same circumstances);
   - Interministerial or ministerial orders;
   - Regulatory decisions taken by authorities delegated by the State (prefect, mayor etc.) or decentralized authorities.

3. Collective agreements: define employment conditions and guaranteed employment benefits for the employees of the organizations concerned

The regulations found that concerns the project are the following:

Type	Codification
Laws	Law 2009-967 of the 3rd of August 2009 of Programming on the implementation of the Grenelle Environment (*)
	Law 2005-781 of the 13th of June 2005 of program setting the guidelines for energy policy (*)
Decrees/ Orders	Decree of the 12th of February 1998 on general requirements for installations classified for environmental protection subjected to reporting under No. 1416 (*)
	Decree of the 9th of February 2009 on the registration procedures for vehicles (*)
	Decree of the 23th of July 1943 on the regulation of production equipment, storage or implementation of compressed, liquefied or dissolved gas

5.2.3.3 Spanish regulations

According to Royal Decree 181/2008, of February 8 the "Boletín Oficial del Estado" (Official Gazette), the official newspaper of the Spanish State, is the means of publication of laws, regulations and acts of obligatory insertion.

In the Official Gazette, there are published:

a) General orders of state bodies and international treaties or conventions.

b) General orders of the autonomous communities, in accordance with the orders of the Statute of Autonomy and the rules with the force of law issued for the development thereof.

c) Resolutions and acts of the constitutional organs of the State, in accordance with the provisions of their respective organic laws.

d) Orders that are not general, resolutions and acts of the ministries and other state bodies and public authorities, when a law or a royal decree so provide.

e) Calls, subpoenas, requisitions and announcements when a law or a royal decree so provide.

The regulations related to this project are the following:

Codification	Title
Royal Decree 1999/1979	New text of the National Regulations on Dangerous Goods by Road and complementary to the same standards
Order of September 1, 1982 by the Technical Instruction MIE-AP7	Pressure Equipment Regulation on bottles of liquefied and compressed gases dissolved under pressure passes

5.2.3.4 USA regulations

The law in North America is divided in federal laws and federal regulations.

- Federal laws: they generally apply to people living in the United States and its territories. Congress creates and passes bills. The President then signs those bills into law. Federal courts may review these laws and strike them down if they think they do not agree with the U.S. Constitution.

  The United States Code contains the general and permanent laws of the United States. It does not include regulations issued by executive branch agencies, decisions of federal courts, treaties, or laws enacted by state or local governments.

  New laws are assigned a public law number and included in the next edition of the United States Statutes at Large.

- Federal regulations: they are issued by federal agencies, boards, or commissions. They explain how the agency intends to carry out a law.

  Federal regulations are created through a process known as rulemaking. By law, federal agencies must consult the public when creating, modifying, or deleting rules in the Code of Federal Regulations. This is an annual publication that lists the official and complete text of federal agency regulations.

  Once an agency decides that a regulation needs to be added, changed, or deleted, it typically publishes a proposed rule in the Federal Register to ask the public for comments.

  After the agency considers public feedback and makes changes where appropriate, it then publishes a final rule in the Federal Register with a specific date for when the rule will become effective and enforceable. The terms "rules" and "regulations" have the same meaning within the Federal Register publication system.

There are two types of regulations and laws, federal and state ones. The first type is mandatory to all states (federal means national) meanwhile the second ones are specific to each state. In this project, only the federal laws and regulations will be studied.

Nowadays there are not specific federal laws that concerns to the project of study, all of them talk about vehicles general requires. However, it exists specific federal regulations.

Federal regulations that concern the project of study are:

Codification	Title
75 FR 33515	Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection
76 FR 45436	Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection
76 FR 39477	Revisions and Additions to Motor Vehicle Fuel Economy Label
78 FR 51381	Early Warning Reporting, Foreign Defect Reporting, and Motor Vehicle and Equipment Recall Regulations
80 FR 2320	Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection

The lack of regulation and legislation on new technologies related to hydrogen is a barrier to entry into the market. The lack of, for example, international standards is one of the main impediments for suppliers to market their technology. In addition, there are no differences between national and regional standards.

5.3 Documents

During the research of the different standards, codes and regulations another kind of text has been found also providing interesting information to the project of study. These documents are free, and they are not obligatory. For these reasons it can not be considered as standards and codes or regulations. Most of them are published for companies associations created to put their knowledge and experiences in common.

The most important associations that refer to this project are:

European Industrial Gases Association (EIGA)

EIGA is a safety and technically oriented organization representing the vast majority of European and also non-European companies producing and distributing industrial, medical and food gases.

The member companies closely co-operate in technical and safety matters achieve the highest level of safety and environmental care in the handling of gases.

EIGA is in frequent touch with Standardization and Regulatory Organizations and Authorities as well as trade and industrial organizations.

EIGA actively promotes safety, health and environmental care through working groups at management and technical expert levels, through the publication of a wide range of technical literature, and through the organization of conferences and symposia.

EIGAs documents contain a summary of the current industrial practices and it is not intended to be a mandatory standard or code. They are based upon the experience, and practices of members companies from different gas associations.

The documents that EIGA provides related with this project are the following:

Codification	Title
IGC Doc 15/06	Gaseous hydrogen stations
IGC Doc 75/07/E	Determination of Safety Distances
IGC Doc 78/14/E	Leak Detection Fluids Cylinder Packages
IGC Doc 80/14/E	Handling Gas Container Emergencies
IGC Doc 81/06/E	Road vehicle emergency and recovery
IGC Doc 86/09/E	Gas cylinders and valves with restricted use in the EU
IGC Doc 90/13/E	Incident/Accident Investigation and Analysis
IGC Doc 91/10/E	Use of pressure relief devices for gas cylinders
IGC Doc 100/11/E	Hydrogen Cylinders and Transport Vessels
IGC Doc 106/03/E	Environmental issues guide
IGC Doc 107/10	Guidelines on environmental management systems
IGC Doc 108/14	Environmental Legislation applicable to Industrial Gases Operations within the EU
IGC Doc 113/11/E	Environmental Impacts of Transportation of Gases
IGC Doc 134/12/E	Potentially Explosive Atmospheres EU Directive 1999/92/EC
IGC Doc 171/12/E	Storage of Hydrogen in Systems Located Underground

National Renewable Energy Laboratory (NREL)

NREL is the only federal laboratory, in the USA, dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

NREL analysis informs policy and investment decisions as energy-efficient and renewable energy technologies advance from concept to commercial application to market penetration. With objective, technology-neutral analysis, NREL aims to increase the understanding of energy policies, markets, resources, technologies, and infrastructure and connections between these and economic, environmental, and security priorities.

NREL works on different projects focus on ensuring safe operation, handling, and use of hydrogen and hydrogen systems through safety sensors and hydrogen buildings and equipment.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

To facilitate hydrogen safety, NREL is testing hydrogen sensors that detect leaks and monitor gas purity at the Safety Sensor Testing Laboratory. Because hydrogen is colorless and odorless, sensors are important for safe hydrogen fueling stations, equipment, and facilities.

The documents that NREL provides related with this project are the following:

Title
Pressure Relief Devices for High-Pressure Gaseous Storage Systems: Applicability to Hydrogen Technology
Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen; Workshop Proceedings
Fuel Cell Technologies National Codes and Standards Development and Outreach
An overview of hydrogen safety sensors and requirements
A National Agenda for Hydrogen Codes and Standards

For further information in the following link lot of hydrogen safety information could be found http://www.nrel.gov/hydrogen/pdfs/48306.pdf

Pacific Northwest National Laboratory (PNNL)

For more than 50 years, Pacific Northwest National Laboratory has put discovery in action, reshaping the way they work and live. PNNL's scientific discoveries and innovations have led to more fuel efficient cars and an electric power grid that is more reliable and efficient. They have made airports, borders and workplaces safer. And they have created better ways to address environmental challenges and protect natural resources. Today, they continue to address big challenges like their nation's energy capacity, helping to curb their dependence on imported fuel, and protecting the nation from acts of violence.

The documents that PNNL provides related with this project are the following:

Codification	Title
PNNL-18523 (2009)	Secondary Protection for 70 MPa Fueling - A White Paper from the Hydrogen Safety Panel
PNNL-23704 (2014)	Electronic Safety Resource Tools – Supporting Hydrogen and Fuel Cell Commercialization

Apart of these associations there are also another interesting laboratories and organizations where lot of useful information can be found. These associations are:

- **Los Alamos National Laboratory (LANL)**
  Link: http://www.lanl.gov/

- **Sandia National Laboratory (SNL)**
  Link: http://www.sandia.gov/

- **Fuel Cell & Hydrogen Energy Association (FCHEA)**
  Link: http://www.fchea.org/

6. Normative classification according to HRS and HFCV components

In the previous point a research on standards, codes and regulations has been done in order to build a database where all the important information is collected. Once the database is finished it is possible to start with an efficient classification which is the purpose of the project.

The objective of this efficient classification is to help the user to find the information that he is looking for in a quick and easy way. For this reason it has been decided to organize the normative depending on the project parts.

As it is explained in point three; this project can be divided in three physical parts: hydrogen delivery, hydrogen refueling stations (HRS) and hydrogen fuel cell vehicles (HFCV). Moreover, the project is only specialized on the last ones (HRS and HFCV).

6.1 HRS and HFCV components description

To do an efficient classification, both HRS and HFCV have been divided in different components with the objective of facilitating to the user the research of the standards, codes and regulations. In this section all these components are briefly explained in order to clarify which parts involve each component.

HRS components

1. Breakaway devices: it concerns all the safety devices for compressed hydrogen dispensing hoses and systems. The objective of these devices is to minimize the escape of gaseous hydrogen by automatically shutting off the flow of gas from the dispenser and controlling the depressurization of the hose. A second objective is to minimize damage to the vehicle and dispenser.

Fig. 6.1-1: Safety breakaway device

2. Connectors: the nozzles that connect the hose which carries the hydrogen from the dispenser to the vehicle, with the vehicle.

Fig. 6.1-2: Hydrogen refueling connector

3. Dispensers: a fuel dispenser is a machine at a filling station that is used to pump_fuel_into vehicles. In the case of hydrogen dispensers mostly of them have two kind of hoses, one for H35 (hydrogen vehicles with a working pressure of 35 MPa) and one for H70 hydrogen vehicles with a working pressure of 70 MPa.

Fig. 6.1 - 3: Hydrogen dispenser

4. <u>Filing inspection requirements</u>: all the inspection requirements that all the HRS elements involved in the process of fuelling have to pass to ensure their correct utilization.

5. <u>Fueling process for HFCV:</u> all the normative that refers to the fueling process like safety performances, fuel temperature, maximum fuel flow rate, rate of pressure increase and end pressure among others.

Fig. 6.1 - 4: Hydrogen fueling process

6. <u>Gas detectors:</u> all the apparatus that are designed to measure and monitor hydrogen leaks. Gas detectors are in lots of different parts inside the HRS like hydrogen storage tubes, hoses, dispensers among others.

7. <u>General characteristics</u>: all the standards, codes and regulation that refers to the HRS in general. They specify the characteristics of outdoor public and non-public hydrogen refueling stations without talking in detail of their parts.

8. <u>Hoses</u>: in this case the HRS hoses are understood as the hoses which connect the dispenser to the fueling nozzle.

Fig. 6.1 - 5: HRS hoses

9. Reused LPG storage tubes: These tubes were originally designed for LPG or propane service and now they have to be used as vessels that can store hydrogen gas.

10. Safety: the meaning of safety in this context is everything related to ensure people safety in a general way: specifications, basic considerations, practice, etc. to provide safety. This part has been divided in two according to the field that the standard, code or regulation refers to. These two parts are: explosive atmospheres safety and fire safety.

11. Storage tubes: cylinders where the hydrogen is stored in the HRS. There are several types of storage tubes; underground and on the ground. There is also different size, materials etc.

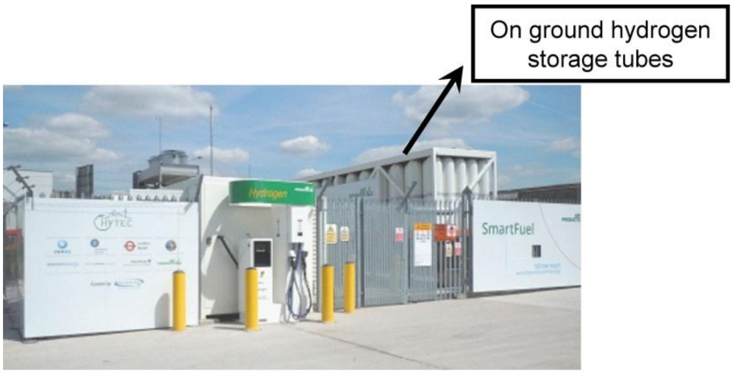


Fig 6.1 - 6: HRS hydrogen storage tubes

12. Testing: all the standards, codes and regulations that establishes test methods, criteria, and apparatus to evaluate a hydrogen fueling station. The testing evaluation applies to fueling stations designed to fill vehicle storage systems that target rapid fills, while respecting temperature, pressure, and fuel density safety limits.

HFCV components

1. Battery: part of the HFCV that stores electricity generated from regenerative braking. The size and type of these batteries will depend on the "degree of hybridization" of the vehicle.

Fig 6.1 - 7: HFCV battery

2. Electric connections: everything related to vehicle electrical connections. It establishes criteria and requirements for interconnection of distributed resources with electric power systems.

3. Electric motor: as explained before, the electric motor is the part of the vehicle that uses the electricity generated by fuel cells to propel the vehicle.

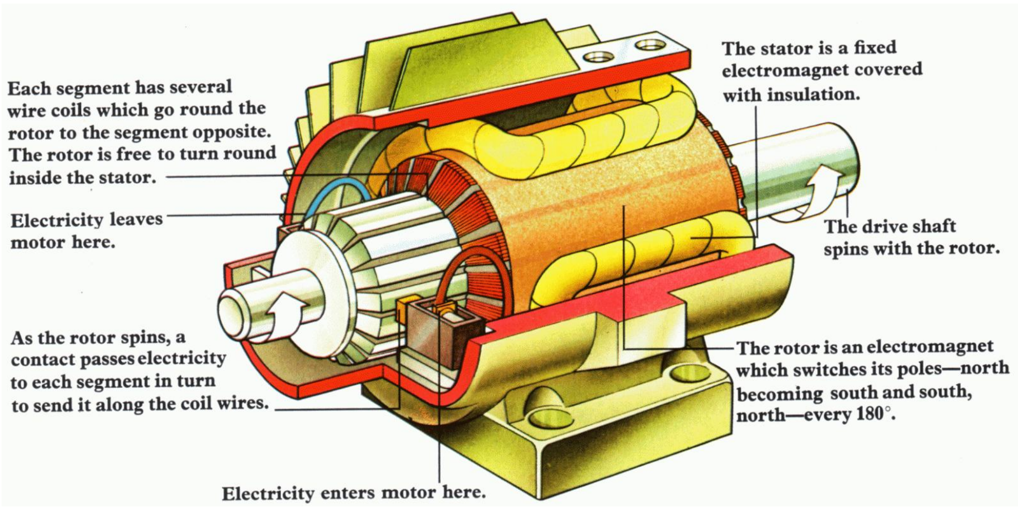


Fig 6.1 - 8: Electric motor

4. Electric systems: all electrical components found in the vehicle: wiring and equipment installation issues, including minimum

provisions for the use of connections, voltage markings, conductors, and cables.

5. Explosive atmospheres requirements: due to the flammability of hydrogen, atmospheres that enclose hydrogen is considered explosive, and must have specials requirements, both in open and closed spaces.

6. Fuel cell stack: it is an electrochemical device that produces electricity using hydrogen and oxygen. It must have its own requirements, cell assemblies, test apparatus, measuring instruments and measuring methods, performance test methods, and test reports.

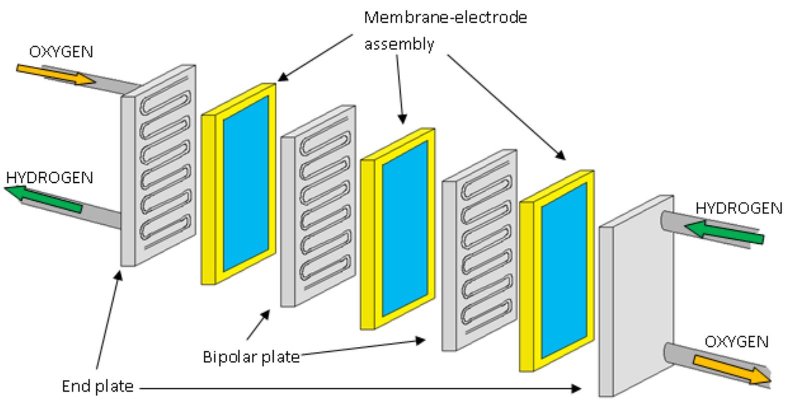


Fig 6.1 - 9: Fuel Cell Stack

7. Fuel processor subsystem: Fuel processor subsystems (FPS) include all components required in the conversion of input fuel and oxidizer into a hydrogen-rich product gas stream suitable for use in fuel cells.

8. Gas detectors: all the_apparatus that are designed to measure and monitor hydrogen leaks. Gas detectors are in lots of different parts inside the HFCV like hydrogen storage tanks, fuel cell stacks...

Fig 6.1 - 10: Hydrogen gas detector

9. Hydrogen components and system installation: this part refers to hydrogen fuel cell vehicle components and those ones that take part of the system installation: valves, injectors, regulators...among others.

10. Hydrogen storage: in the case of the vehicle, the storage is referred to the tanks or tubes that contain and stock up the hydrogen in the vehicle; they are used to refuel the vehicle and provide hydrogen to the fuel cell stack, and they may be of different sizes.

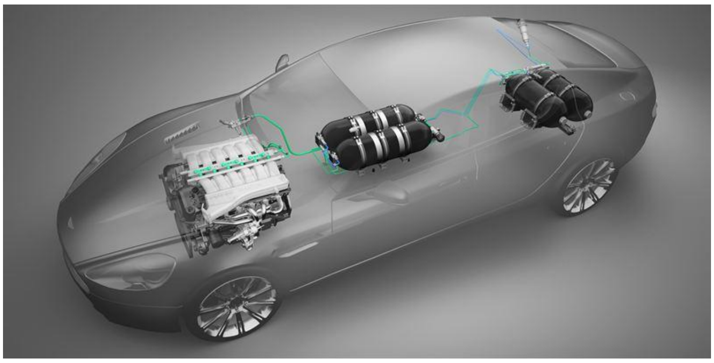


Fig 6.1 - 11: Hydrogen storage

11. Homologation: is the process of certifying or approving a product to indicate that it meets regulatory standards and specifications. The standards talk about its requirements, rules, etc. to pass the type-approval.

12. Hoses: in this case the HFCV hoses are understood as the hoses inside the vehicle used for the fuel systems

13. Pressure relief devices: this device is designed to ensure the hydrogen pressure of the fuel that comes into the vehicle.

Fig 6.1 - 12: Pressure relief device

14. Refueling connection devices: it means a receptacle and a protective cap (mounted on vehicle), and a nozzle that ensure the correct refueling.

15. Reused LPG hydrogen storage: These tubes were originally designed for LPG or propane service and now they have to be used as vessels that can store hydrogen gas.

16. Safety: the meaning of safety in this context is everything related to ensure people safety in a general way: specifications, basic considerations, practice, etc. to provide safety.

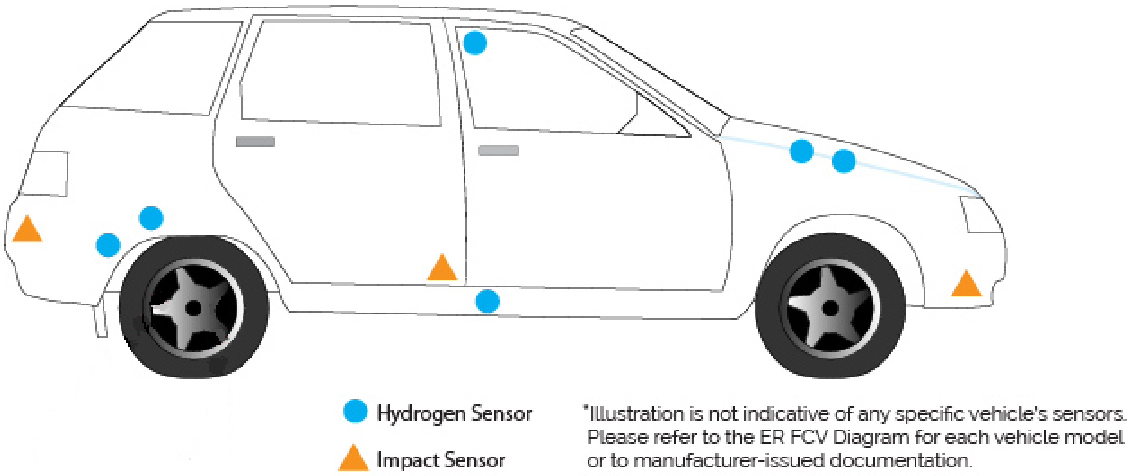


Fig 6.1 - 13: Example of vehicle sensors

17. Testing: it concerns all the standards, codes and regulations that establish test methods, criteria and apparatus to evaluate a hydrogen fuel cell vehicle. It aims to improve road safety by setting minimum requirements for periodic roadworthiness tests of vehicles.

6.2 Efficient classification

Once all the parts are clearly defined is the time to explain how this classification would be. Inside each component of each of the both parts (HRS and HFCV) the normative will be classified in Regulations and Standards & Codes. Then inside Regulations, they will be organized in International, European and National. And finally inside national there will be another classification where the regulations will be classified in USA regulations, Canadian regulations; French regulations and Spanish regulations. In the following image this classification is represented:

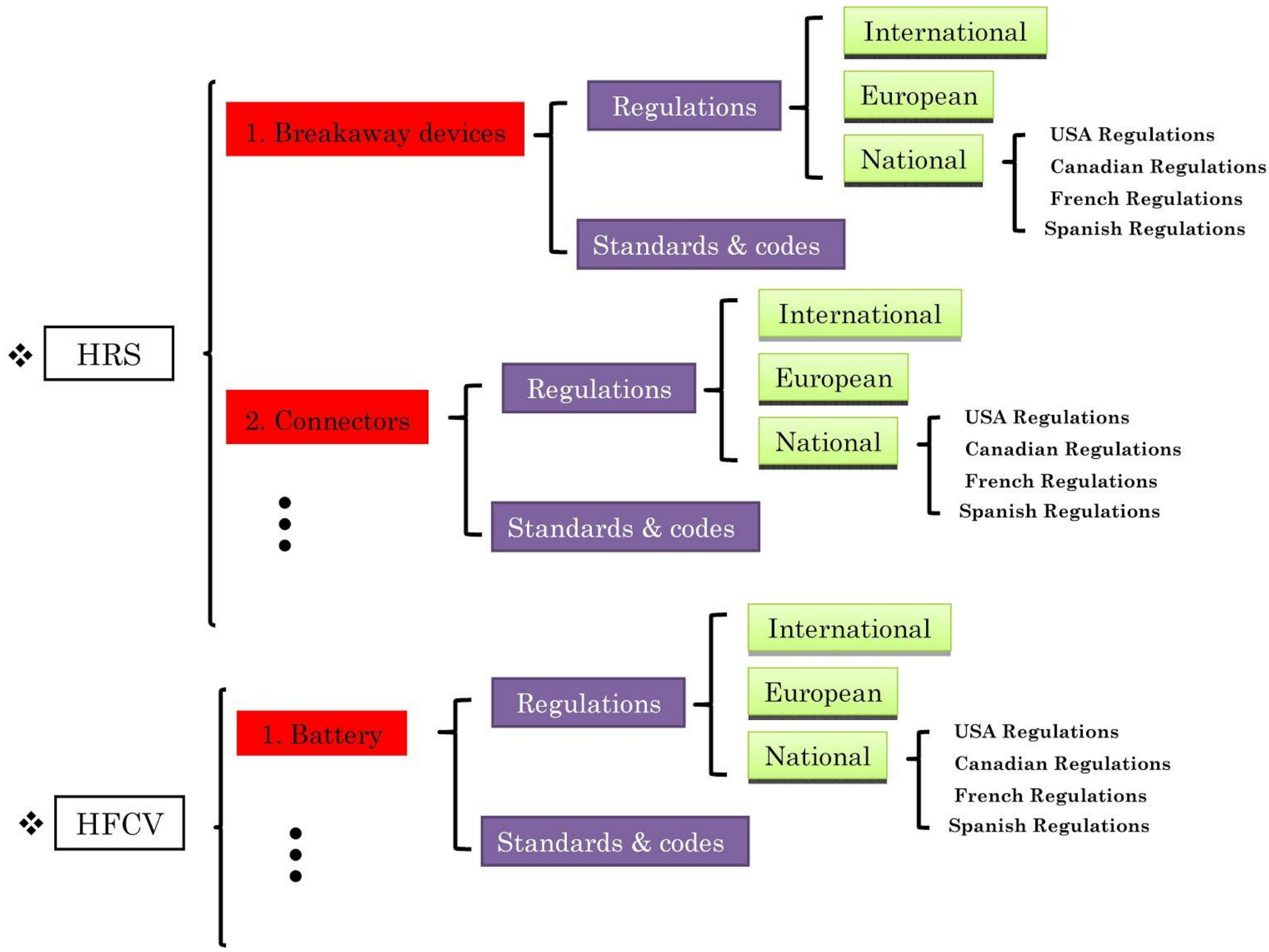


Fig 6.2-1: Efficient classification diagram

Inside the Standards & Codes part, if there is more than one standard or code that applies to the component, a comparative table between them will be done. Here it is explained how these tables are made.

All the tables will have the following aspect and components:

Title	Relevance	Standard 1	Standard 2	Standard 3
Cost	0,15			
Amount of useful information	0,15			
Specific characteristics	0,70			
Restrictions				
Total	1		The best	

Fig 6.2-2: Example of an empty table

- In purple, the standards and codes codification that concern to the component of study will be marked.
- In green, the cost which is a characteristic that will appear in all the tables and will be the row where the cost comparison will be made, will be marked.
- In yellow, the "Amount of useful information" will be marked. It will also appear in all the tables.
- In blue, the specific characteristics of each component will be marked. Those characteristics will refer to general topics.
- In orange, the restrictions will be marked. This will be specific of each component.
- In red, the standard or code with the best punctuation will be marked.

You can now see how tables are filled. For that, it is used the comparison table of the component "Refueling connection devices" which is a part of HFCV.

Refuelling connection devices	Relevance	ISO 16380	ISO 17268	SAE J2600
Cost	0,15	2,19	2,50	5
Amount of useful information	0,15	5	4	2,50
Design	0,06	5	5	5
Testing	0,02	0	0	5
Safety	0,15	0	5	0
Construction	0,05	5	0	0
Operation	0,12	0	5	0
Performance	0,1	5	0	0
Working pressure 70 MPa	0,15	0	5	5
Working pressure 35 MPa	0,05	5	5	5
Total	**1**	**2,38**	**3,63**	**2,53**

Fig 6.2-3: Refueling connection devices table

In this case, there are three different standards that talk about this component: ISO 16380, ISO 17268 and SAE J2600.

Each standard and code will be punctuated with a mark between 0 and 5, being 0 the worst mark and 5 the better one. Then, if inside the abstract doesn't appear clearly if the standard or code contains the specific characteristic or not but with the abstract context and the title information can be deduced that probably it is, this standard or code will be punctuated with a 2,5. Each characteristic is punctuated in a different way:

- Cost: The standard with the lowest cost will be punctuated with a 5 and the others will be proportionately punctuated in comparison to it. For example in this case the respective costs of ISO 16380, ISO 17268 and SAE J2600 are 151,25 €, 132,10 € and 64,23 €. That means that SAE J2600 is punctuated with a 5, ISO 17268 with a $5 * 64{,}23/132{,}10 = 2{,}43$ and ISO 16380 with a $5 * 64{,}23/151{,}25 = 2{,}12$ (the operation is inverse proportion).

Refuelling connection devices	Relevance	ISO 16380	ISO 17268	SAE J2600
Cost	0,15	2,12	2,43	5

Fig 6.2-4: Example of "Cost" row

- Amount of useful information: this characteristic refers to the standard information available before buying it; if there's enough information, if the information is useful etc. In this case, the standard with the best information will be punctuated with a 5 and if there is no information (if only the standard's title can be consulted before buying it) it will be punctuated with a 0. The other standard will be punctuated in comparison to the better one. There could be a case where none of the standards or codes has a good abstract, in this case none of them will be punctuated with a 5. In this example the standard with the best useful information is ISO 16380 and for that reason it is punctuated with a 5. The abstract of ISO 17268 is also good but contains a little less information compared with the first one and for that reason is punctuated with a 4. And finally SAE J2600 doesn't have a lot of information for this reason it has a mark of 2,5.

Refuelling connection devices	Relevance	ISO 16380	ISO 17268	SAE J2600
Amount of useful information	0,15	5	4	2,50

Fig 6.2-5: Example of "Amount of useful information" row

- Specific characteristics and restrictions: if a standard contains/talks about the characteristic it will be punctuated with a 5 and if not it will be punctuated with a 0. For example, in the case of the general characteristics, these standards talk about design, testing, safety… In the case of the "Testing" characteristic, only the ISO 17268 contains information about it and for this reason it is punctuated with a 5 whereas the other two don't have any information about testing, and for that reason are punctuated with a 0.

Refuelling connection devices	Relevance	ISO 16380	ISO 17268	SAE J2600
Testing	0,02	0	0	5

Fig 6.2-6: Example of specific characteristic row

The relevance column is constructed once all the standards have been punctuated. In this column, the relevance that have each characteristic in this project will be specified.

Refuelling connection devices	Relevance
Cost	0,15
Amount of useful information	0,15
Design	0,06
Testing	0,02
Safety	0,15
Construction	0,05
Operation	0,12
Performance	0,1
Working pressure 70 MPa	0,15
Working pressure 35 MPa	0,05
Total	**1**

Fig 6.2-7: Example of relevance column

The relevance of the "cost" and "amount of useful information" will be the same in all the tables. It has been considered that both of them will have a relevance of 15%. This number, in the case of "cost" has been chosen because there are lots of standards with a very high cost and that could be an impediment to buy them. For that reason, we think that 15% reflects a good relevance as it represents a significant importance but not excessive. In the case of "amount of useful information" 15 % has been chosen because there are lots of standards with just a line of abstract or even without it. We think it's risky to buy a standard without having enough information because you can't be sure if the standard will include the desired information.

Then, the remaining 70% will be divided among the specific characteristics and restrictions. For example, in this project the safety and operation of refueling connection devices is more important than the construction and design. For that reason the "safety" characteristic has a relevance of 15% and "Construction" 5%.

In the case of restrictions the same logic is used. For example, in this case all the standards specify the work pressure. For this project the interesting working pressures are 70 MPa and 35 MPa because they are the ones used in hydrogen vehicles. Between them it is more important 70 MPa than 35 MPa because most of vehicles use 70 MPa. For this reason 70 MPa working pressure has a relevance of 15% and 35 MPa a relevance of 5%.

Finally, each standard column will be multiplied by the relevance column and added in total value. In this case, the standard with the highest punctuation is ISO 17268 with a total punctuation of 3,63.

Refuelling connection devices	Relevance	ISO 16380	ISO 17268	SAE J2600
Total	1	2,38	3,63	2,53

Fig 6.2-8: Example of "Total" row

With this kind of tables it will be easier to the client to decide which standard to buy. It should be stated that these tables are just an aid, they can't be 100% precise.

All the comparison tables can be found in ANNEX C.

6.3 Normative classification

In this section it is found the normative classification according HRS and HFCV components. Inside each component it is possible to found its standards, codes and regulations as well as if it has a standard or code's comparative table.

<u>HRS components</u>

1. <u>Breakaway devices</u>:

Type	Codification	Title
Standard	ANSI/CSA HGV 4.4-2013	Breakaway devices for compressed hydrogen dispensing hoses and systems

2. <u>Connectors</u>:

Type	Codification	Title
Standard	ANSI/CSA HGV 4.10-2012	Standard for fittings for compressed hydrogen gas and hydrogen rich gas mixtures

3. <u>Dispensers</u>:

Type	Codification	Title
Canadian regulation	TD No. 301, Revision 2R	Motor Vehicle Safety Regulations 301.1 - Fuel System Integrity
Standard	ANSI/CSA HGV 4.1-013	Hydrogen dispensing systems
Standard	2015 international Fire Code	-

(*) A standards comparative table is available in ANNEX C

4. Filing inspection requirements:

Type	Codification	Title
Standard	EN 1920 (2000)	Transportable gas cylinders - Cylinders for compressed gases (excluding acetylene) - Inspection at time of filing

5. Fueling process:

Type	Codification	Title
Standard	SAE J2601	Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles

6. Gas detectors:

Type	Codification	Title
Standard	EN 13160-1 (2003)	Leak detection systems - Part 1: General principles
Standard	IEC 60079-29-1 (2007-08)	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases
Standard	IEC 60079-29-2 (2015-03)	Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
Standard	IEC 60079-29-3 (2014-03)	Explosive atmospheres - Part 29-3: Gas detectors - Guidance on functional safety of fixed gas detection systems
Standard	IEC 60079-29-4 (2009-11)	Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases
Standard	ISO 26142:2010	Hydrogen detection apparatus -- Stationary applications

(*) A standards comparative table is available in ANNEX C

7. General characteristics:

Type	Codification	Title
Standard	ISO/TS 20100:2008	Gaseous hydrogen -- Fuelling stations

8. Hoses:

Type	Codification	Title
Standard	ANSI/CSA HGV 4.2-2013	Hoses for compressed hydrogen fuel stations, dispensers and vehicle fuel systems

9. Reused LPG storage tubes:

Type	Codification	Title
Standard	CGA PS-33	Position Statement on Use of LPG or Propane Tank as Compressed Hydrogen Storage Buffers

10. Safety:

Type	Codification	Title
European regulation	32006L0042 Directive 2006/42/EC	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance).
Standard	EN 1127-1 (2011)	Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
Standard	EN 1127-2 (2014)	Explosive atmospheres - Explosion prevention and protection - Part 2: Basic concepts and methodology for mining
Standard	NFPA 2 (2011)	Hydrogen Technologies Code
Standard	NFPA 221 (2015)	Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls

(*) A standards comparative table is available in ANNEX C

11. Storage tubes:

Type	Codification	Title
European regulation	32014L0068 Directive 2014/68/EU	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonization of the laws of the Member States relating to the making available on the market of pressure equipment Text with EEA relevance
European regulation	32008L0058 Commission Directive 2008/58/EC	Classification, packaging and labeling of dangerous substances
European regulation	32004L0073R (01) Directive 2004/73/EC	Corrigendum to Commission Directive 2004/73/EC; Classification, packaging and labeling of dangerous substances
European regulation	31997L0023 Directive 97/23/EC	Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment
Spanish regulation	Order of September 1, 1982	Pressure Equipment Regulation on bottles of liquefied and compressed gases dissolved under pressure passes
Standard	ASME BPVC-VIII-1 (2013)	Rules for Construction of Pressure Vessels Division 1
Standard	ASME BPVC-VIII-2 (2013)	Rules for Construction of Pressure Vessels Division 2-Alternative Rules
Standard	ASME BPVC-VIII-3 (2010)	Rules for Construction of Pressure Vessels Division 3-Alternative Rules for Construction of High Pressure Vessels
Standard	ASME STP-PT-005 (2006)	Design Factor Guidelines for High-Pressure Composite Hydrogen Tanks
Standard	ASME STP-PT-014 (2008)	Data Supporting Composite Tank Standards Development for Hydrogen Infrastructure Applications
Standard	ASME STP-PT-021 (2008)	Nondestructive Testing and Evaluation Methods for Composite Hydrogen Tanks
Standard	NFPA 55 (2013)	Compressed Gases and Cryogenic Fluids Code
Standard	SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

(*) A standards comparative table is available in ANNEX C

12. Testing:

Type	Codification	Title
Standard	CSA HGV 4.3-2012	Test methods for hydrogen fueling parameter evaluation

HRS components

1. Batteries:

Type	Codification	Title
Canadian regulation	TS No. 305, Revision 3R	Motor Vehicle Safety Regulations 305 - Electrolyte Spillage and Electrical Shock Protection
Standard	IEC 60255-27 (2013-10)	Measuring relays and protection equipment - Part 27: Product safety requirements
Standard	ISO 6469-1:2009	Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)

(*) A standards comparative table is available in ANNEX C

2. Electric connections:

Type	Codification	Title
Standard	IEC/IEEE/PAS 63547 (2011-09)	Interconnecting distributed resources with electric power systems

3. Electric motor:

Type	Codification	Title
International regulation	UN GTR No. 13	Hydrogen and fuel cell vehicles
Standard	IEC 60255-27 (2013-10)	Measuring relays and protection equipment - Part 27: Product safety requirements
Standard	ISO 6469-3:2011	Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock

(*) A standards comparative table is available in ANNEX C

4. Electric systems:

Type	Codification	Title
Standard	NFPA 70 (2014)	National Electrical Code® (NEC®)

5. Explosive atmospheres requirements:

Type	Codification	Title
Standard	EN 13463-1 (2009)	Non-electrical equipment for use in potentially explosive atmospheres - Part 1: Basic method and requirements
Standard	EN 13463-2 (2004)	Non-electrical equipment for use in potentially explosive atmospheres - Part 2: Protection by flow restricting enclosure 'fr'
Standard	EN 13463-3 (2005)	Non-electrical equipment for use in potentially explosive atmospheres - Part 3: Protection by flameproof enclosure 'd'
Standard	EN 13463-5 (2011)	Non-electrical equipment intended for use in potentially explosive atmospheres - Part 5: Protection by constructional safety 'c'
Standard	EN 13463-6 (2005)	Non-electrical equipment for use in potentially explosive atmospheres - Part 6: Protection by control of ignition source 'b'
Standard	EN 13463-8 (2003)	Non-electrical equipment for potentially explosive atmospheres - Part 8: Protection by liquid immersion 'k'

(*) A standards comparative table is available in ANNEX C

6. Fuel cell stack:

Type	Codification	Title
Canadian regulation	TS No. 305, Revision 3R	Motor Vehicle Safety Regulations 305 - Electrolyte Spillage and Electrical Shock Protection
Standard	ANSI/CSA FC 3-2004	Fuel Cell Power Systems Performance
Standard	ASME PTC 50 (2002)	Non-electrical equipment for use in potentially explosive atmospheres - Part 3: Protection by flameproof enclosure 'd'

Standard	CGA PS-31	Position Statement on Cleanliness for Proton Exchange Membranes Hydrogen Piping/Components
Standard	IEC 62282-2 (2012-03)	Fuel Cell Modules
Standard	IEC 62282-5-1 (2012-09)	Portable Fuel Cell Appliances – Safety
Standard	IEC 62282-7-1 (2010-06)	Single Cell Test Method for Polymer Electrolyte Fuel Cells
Standard	NFPA 853 (2015)	Standard for the Installation of Stationary Fuel Cell Power Systems
Standard	SAE J1766	Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
Standard	SAE J2572	Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen
Standard	UL – 2262	Fuel Cell Modules for Use in Portable and Stationary Equipment

(*) A standards comparative table is available in ANNEX C

7. Fuel processor subsystems:

Type	Codification	Title
Standard	SAE J2616	Testing Performance of the Fuel Processor Subsystem of an Automotive Fuel Cell System
Standard	SAE J2617	Recommended Practice for Testing Performance of PEM Fuel Cell Stack Sub-system for Automotive Applications

(*) A standards comparative table is available in ANNEX C

8. Gas detectors:

Type	Codification	Title
Standard	EN 13160-1 (2003)	Leak detection systems - Part 1: General principles
Standard	IEC 60079-29-1 (2007-08)	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases

Standard	IEC 60079-29-2 (2015-03)	Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
Standard	IEC 60079-29-3 (2014-03)	Explosive atmospheres - Part 29-3: Gas detectors - Guidance on functional safety of fixed gas detection systems
Standard	IEC 60079-29-4 (2009-11)	Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases

(*) A standards comparative table is available in ANNEX C

9. Homologation:

Type	Codification	Title
European regulation	32012R0630 EU No 630/2012	Type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions
European regulation	32010R0406 EU No 406/2010	Type-approval of hydrogen-powered motor vehicles
Standard	SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

10. Hoses:

Type	Codification	Title
Standard	ANSI/CSA HGV 4.2-2013	Hoses for compressed hydrogen fuel stations, dispensers and vehicle fuel systems

11. Hydrogen components installation:

Type	Codification	Title
European regulation	32009R0079 EC No 79/2009	Type-approval of hydrogen-powered motor vehicles
Standard	NF M58-003 (2013)	Installation of hydrogen-related systems
Standard	ANSI/CSA HGV 3.1-2015	Fuel system components for compressed hydrogen gas powered vehicles

Standard	2015 International Fuel Gas Code	-
Standard	SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

(*) A standards comparative table is available in ANNEX C

12. Hydrogen storage:

Type	Codification	Title
International regulation	UN GTR No. 13	Hydrogen and fuel cell vehicles
European regulation	32014L0068 Directive 2014/68/EU	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonization of the laws of the Member States relating to the making available on the market of pressure equipment Text with EEA relevance
European regulation	32008L0058 Directive 2008/58/EC	Classification, packaging and labeling of dangerous substances
European regulation	32004L0073R (01) Directive 2004/73/EC	Corrigendum to Commission Directive 2004/73/EC; Classification, packaging and labeling of dangerous substances
European regulation	31997L0023 Directive 97/23/EC	Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.
Canadian regulation	TS No. 301, Revision 2R	Motor Vehicle Safety Regulations 301.1 - Fuel System Integrity
Spanish regulation	Real Decreto 1999/1979	New text of the National Regulations on Dangerous Goods by Road and complementary to the same standards
Spanish regulation	Order of September 1, 1982	Pressure Equipment Regulation on bottles of liquefied and compressed gases dissolved under pressure passes
Standard	ASME BPVC-VIII-1 (2013)	Rules for Construction of Pressure Vessels Division 1
Standard	ASME BPVC-VIII-2 (2013)	Rules for Construction of Pressure Vessels Division 2-Alternative Rules
Standard	ASME BPVC-VIII-3 (2010)	Rules for Construction of Pressure Vessels Division 3-Alternative Rules for Construction of High Pressure Vessels

Standard	ASME STP-PT-014 (2008)	Data Supporting Composite Tank Standards Development for Hydrogen Infrastructure Applications
Standard	ASME STP-PT-021 (2008)	Nondestructive Testing and Evaluation Methods for Composite Hydrogen Tanks
Standard	ISO 15869:2009	Gaseous hydrogen and hydrogen blends -- Land vehicle fuel tanks
Standard	NFPA 55 (2013)	Compressed Gases and Cryogenic Fluids Code
Standard	SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

(*) A standards comparative table is available in ANNEX C

13. Pressure relief devices:

Type	Codification	Title
Standard	ANSI/CSA HGV 3.1-2015	Fuel system components for compressed hydrogen gas powered vehicles
Standard	CGA S-1.1	Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases

(*) A standards comparative table is available in ANNEX C

14. Refueling connection devices:

Type	Codification	Title
Canadian regulation	TS No. 301, Revision 2R	Motor Vehicle Safety Regulations 301.1 - Fuel System Integrity
French regulation	Decree of the 23th of July 1943	Regulation of production equipment, storage or implementation of compressed, liquefied or dissolved gas
Standard	ISO 16380:2014	Road vehicles -- Blended fuels refueling connector
Standard	ISO 17268:2012	Gaseous hydrogen land vehicle refueling connection devices
Standard	SAE J2600	Compressed Hydrogen Surface Vehicle Fueling Connection Devices

(*) A standards comparative table is available in ANNEX C

15. Reused LPG hydrogen storage:

Type	Codification	Title
Standard	CGA PS-33	Position Statement on Use of LPG or Propane Tank as Compressed Hydrogen Storage Buffers

16. Safety:

Type	Codification	Title
European regulation	32006L0042 Directive 2006/42/EC	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance)
Standard	EN 1127-1 (2011)	Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
Standard	EN 1127-2 (2014)	Explosive atmospheres - Explosion prevention and protection - Part 2: Basic concepts and methodology for mining
Standard	ISO 6469-2:2009	Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures
Standard	ISO 6469-3:2011	Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock
Standard	ISO 23273:2013	Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
Standard	ISO/TR 15916:2004	Basic considerations for the safety of hydrogen systems
Standard	NFPA 2 (2011)	Hydrogen Technologies Code
Standard	SAE J2578	Recommended Practice for General Fuel Cell Vehicle Safety

(*) A standards comparative table is available in ANNEX C

17. Testing:

Type	Codification	Title
European regulation	32014L0045 Directive 2014/45/EU	-

6.4 Website creation

All this classification will be now implemented in a Website. This will allow having the classification in an informatics media that can be modified, update and that easily allows to add information, to have an easy and quick access, etc.

The website name is “Life & Hydrogen Normative” and its link is http://paulahuertasgaja.wix.com/hydrogen-normative

This title pretends to reflect the importance of hydrogen normative to improve and implement HFCV in daily life.

It consists of four different principal pages. The first one is the “Home” page. In this one, a brief introduction of the project is made and from it the user can be directly to the “HRS” page and “HFCV” page.

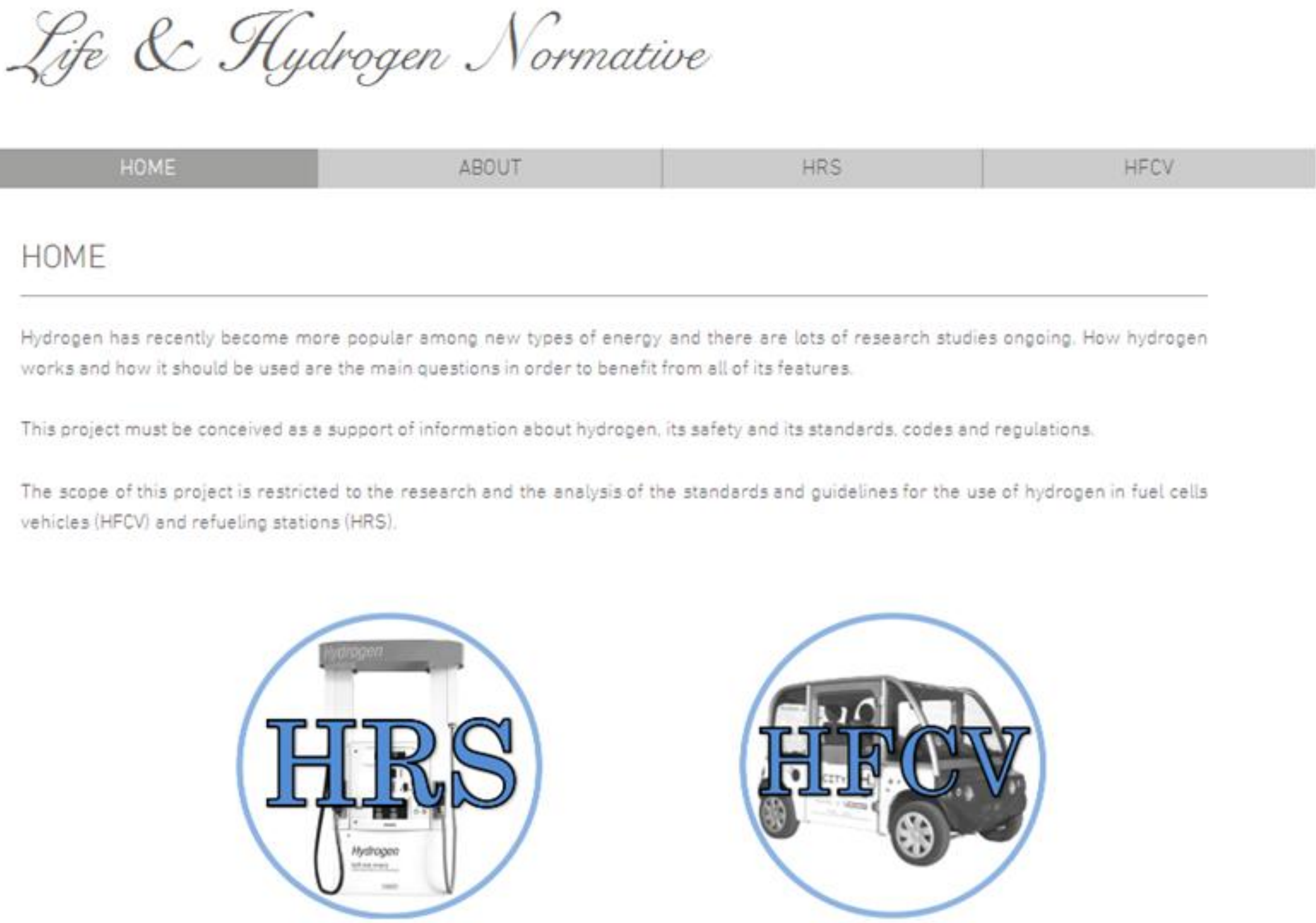


Fig. 6.4-1: Website “Home” page

The second one, is the “About” page, that explains what the user will found in the website and how it is organized.

Fig. 6.4-2: Website “About” page

The other two principal pages are “HRS” and “HFCV”. Inside these pages a brief description of HRS and HFCV is respectively made. They also contain a components list with an image, description and normative link for each one.

Fig. 6.4-3: Website “HFCV” page

Every component of the list has a normative link. This link takes the user to a new page, the components page. For each one, there is a page with a component's image and description and all the normative. This normative is organized according to the efficient classification explained in point "*6.2 Efficient classification explanation*". In these pages there is also a comparative table button which contains the standards and codes comparative tables explained in the point 6.2.

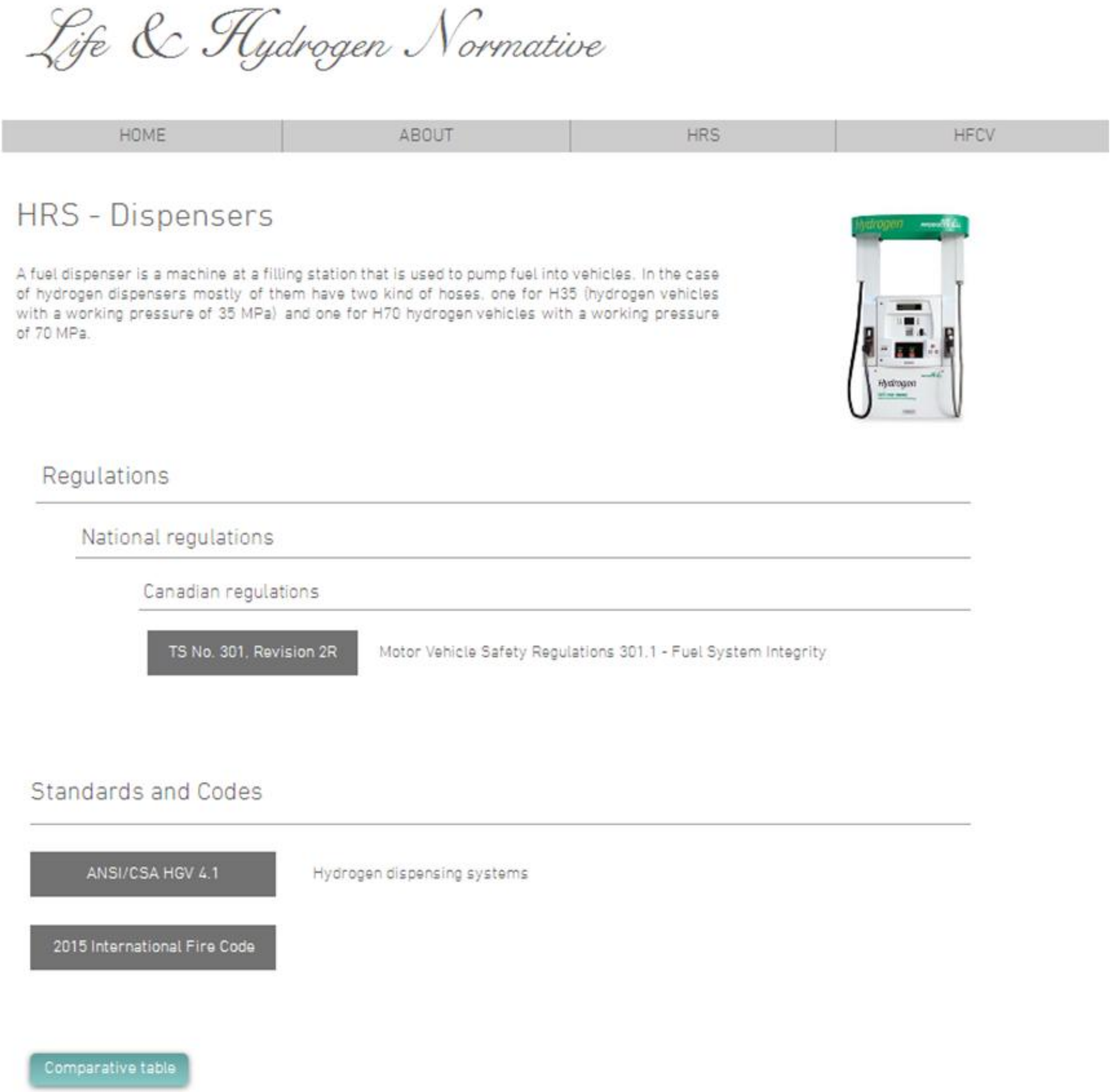


Fig. 6.4-4: Website "Component" page

This website is the perfect tool for people who work in the field of HRS and HFCV safety. It allows to have an easy and efficient access to the normative information, standards, codes and international regulations (European, USA, Canadian, French and Spanish).

7. Environmental impact

Every project has to contain the study of the environmental impact that it produces. This type of studies has to include, on one hand the environmental impact produced during the project development and realization; and on the other hand the environmental impact produced during its implementation.

The environmental impact produced during the project development and realization is almost zero. The only relevant aspect has been the energy expenditure consumed during the project realization. This energy expenditure is not significant and comes from the usage of electronic devices like computers, tablets, mobile phones, projectors etc. The possible office supplies used, like paper, pencils etc are also insignificant as nearly everything has been made digitally.

Fig. 7-1: Environmental impact

The small amount of CO_2 produced during the project development will be now calculated. One computer has an average power of 200 W. In this project two computers have been used, with a total power of 0,4 kW. This is a 27 credits project and each credit equate to 20 hours. So this project has been done in approximately 540 hours. As 1 kWh = 0,264 Kg of CO_2, after the 540 hours of work, the total Kg of CO_2 produced are approximately 540 * 0,4 * 0,264 = 57,024 Kg of CO_2.

Machine	Time (h)	Power (kW)	Consumption (kWh)	kg CO2
Computer	540	0,4	216	57,024

In the case of the environmental impact produced during its implementation, it is zero. This project has consisted of creating a website which contains the normative database of the principal HRS and HFCV components. Once this has been done there is no more things to build or implement.

So in conclusion, it can be said that the environmental impact of this project is approximately zero.

8. Temporal planning and project costs

This section explains the temporal planning during the project realization and the project budget.

8.1 Temporal planning

In all the projects it is necessary to specify the planning, including the project development planning and the implementation one.

In this project only the development and realization planning can be done as there is nothing to implement or build afterwards. This project consists of creating a website where all the normative of the different HRS and HFCV components is collected. After its creation there is nothing more to do in terms of design, building or installation.

In ANNEX D a Gantt graph can be found, that represents the different stages that have been necessary to arrive to the final objective.

The Gantt graph shows that the project has been done in 14 weeks. It does not take into account the holydays nor the weekends, only the working days.

8.2 Project budget

To estimate the project costs, the salary of nowadays untitled engineers has been used. This is a 27 credits project and each credit equate to 20 hours. So this project has been done in approximately 540 hours. In the following conversion, it is showed the calculation of the two untitled engineers cost, supposing that a untitled engineer earns 8 €/hour:

2 untitled engineers 8€/hour*540 hours = 8640 €

Moreover, there are the material costs. These could be because of electricity consumption and material things expenses (these last ones valued at 50€): paper sheets, photocopies, computers and office supplies, etc. The electricity consumption calculation has been made following the next method:

Consumption/computer = 0,2kW/h

Electricity cost = 0,14 €/kWh

2 computers * 0,2kW/ h *0,14 €/kWh*540 h = 30,24 €

The total amount of material costs are 50+30,24 = 80,24€ .

In summary, the project budget is:

Expenses	Cost (€)
Professionals	8640
Material	80,24
Total	8720,24

Fig. 8.2 - 1: Project budget

9. Conclusions

First of all, this project has helped us to discover a field so extended as it is hydrogen. Before doing this project, we only knew hydrogen as a very important chemical element, but we didn't know so much about hydrogen applications, above all in vehicles.

Hydrogen fuel cell vehicles are a big field that is still being investigated and needs a deep research. We think this research and its implementation is unbalanced around the world. There are countries, as the United States and Canada, that have progressed a lot in this field. For example, there, one can find lots of hydrogen refueling stations or more facilities to get a hydrogen fuel cell vehicle. Moreover, in other countries, there is not coordination between local and international regulations. Maybe it is necessary to work harder in the standards, codes and regulations in some countries.

Thanks to this project we have got involved into the normative world, and we have realized how complex and extensive it is. There are plenty of standards and codes organizations around the world who work every day in order to make this world safer. We have also realized how important the standards and codes are to make possible the global harmonization. Without them each country or region would build and design their products in different ways making the exportation and importation impossible.

In addition, with the realization of a survey, we have been able to collect people thoughts about hydrogen vehicles, as well as to compare French and Spanish believes.

Moreover, the fact of creating a website has been for us a good way to organize the basic information with an informatics tool, that can be used and modified in the future.

Finally, we hope this project will be helpful in the future, because it is for a good cause, as it has been said many times before: to be an alternative fuel source for land transport, so that it contributes to reduce global nowadays pollution.

10. Acknowledgements

We are very glad of having collaborated in this project of standards, codes and regulations of hydrogen fuel cell vehicles. We want to express our gratitude to our three tutors R. Kouta, J-M Le Canut and X. Francois for having let us contribute in this research.

We want also to thank to Teresa Crespí and Jorge Huertas to revise the grammatical and orthographic issues all the times that we have required it.

Finally, we want to thank to the UTBM University for giving us two places in the Erasmus studies plan.

ANNEX A

HYDROGEN FUEL CELL VEHICLES SURVEY

1. Have you ever heard of hydrogen fuel cell vehicles?
    - Yes
    - No

2. If you were to buy a vehicle and you could choose between a conventional one and a hydrogen fuel cell one — both with the same characteristics, autonomy and price —, which one would you choose knowing that hydrogen fuel cell vehicles are non-polluted?
    - Conventional vehicle
    - Hydrogen fuel cell vehicle

3. In case the previous answer was "conventional vehicle", which would the main reason be? (If you chose "hydrogen fuel cell vehicle" please choose "none of the above")
    - Lack of information
    - Fear
    - Lack of confidence because it's a new technology
    - Lack of many hydrogen fuel cell stations
    - All of the above
    - None of the above

A hydrogen fuel cell vehicle is a car which externally looks like a conventional one, but uses a different propulsion system. This is a fuel cell system, which is a device that generates electricity from an electrochemical reaction between hydrogen and oxygen. This electricity is used to feed an electric motor that makes the car work.

The main problem with hydrogen is that it is a high flammable gas which can produce fire in case of incident (as a leak or a crash).

4. In order to encourage you to use this kind of vehicle, is it enough for you to know that hydrogen regulations, standards and safety are currently being investigated?
    - Yes
    - No

5. If the answer to the previous question is negative, which actions would you consider enough to convince you? (If the answer is affirmative, please choose "none of the above")
    - That the government invested in hydrogen fuel cell public vehicles
    - That the government promoted advertisements encouraging people to use these vehicles
    - That these vehicles investigation and testing were seen on the news
    - Seeing that other users drive hydrogen fuel cell vehicles
    - All of the above
    - None of the above

6. In case you wanted to buy a new car and hydrogen refueling was cheaper than conventional refueling (petrol/diesel) and there was hydrogen in most refueling stations, which one would you choose?
    - Conventional vehicle
    - Hydrogen fuel cell vehicle

With hydrogen fuel cell vehicles, it is possible to break the dependency to fossil fuels and produce non-pollution vehicles, and moreover, to maintain the same comfort (same autonomy, same refueling time and place, etc.). However, the hydrogen fuel cell vehicles are not the only non-pollution cars — there also are the electric ones. These have the disadvantage that they require more time to be charged.

7. Taking this information into account, which car would you choose?
    - Conventional vehicle
    - Hydrogen fuel cell vehicle
    - Electric vehicle

Survey results

Survey results	Spanish	French	English	Global
Question 1:				
➢ Yes	43,5	90,9	80,0	56,9
➢ No	56,5	9,1	20,0	43,1
Question 2:				
➢ Conventional vehicle	22,6	42,4	20,0	27,5
➢ Hydrogen fuel cell vehicle	77,4	57,6	80,0	72,5
Question 3:				
➢ Lack of information	19,0	21,4	0,0	19,4
➢ Fear	4,8	7,1	0,0	5,6
➢ Lack of confidence because it's a new technology	9,5	0,0	0,0	5,6
➢ Lack of many hydrogen fuel cell stations	14,3	21,4	0,0	16,7
➢ All of the above	47,6	35,7	100,0	44,4
➢ None of the above	4,8	14,3	0,0	8,3
Question 4:				
➢ Yes	37,6	51,5	60,0	42,0
➢ No	62,4	48,5	40,0	58,0
Question 5:				
➢ That the government invested in hydrogen fuel cell public vehicles	4,9	0,0	0,0	3,8
➢ That the government promoted advertisements encouraging people to use these vehicles	6,6	6,3	0,0	6,3
➢ That these vehicles investigation and testing were seen on the news	21,3	12,5	50,0	20,3
➢ Seeing that other users drive hydrogen fuel cell vehicles	6,6	25,0	0,0	10,1
➢ All of the above	47,5	37,5	50,0	45,6
➢ None of the above	13,1	18,8	0,0	13,9
Question 6:				
➢ Conventional vehicle	15,2	18,2	0,0	15,4
➢ Hydrogen fuel cell vehicle	84,8	81,8	100,0	84,6
Question 7:				
➢ Conventional vehicle	11,8	21,2	0,0	13,7
➢ Hydrogen fuel cell vehicle	64,5	66,7	40,0	64,1
➢ Electric vehicle	23,7	12,1	60,0	22,1

ANNEX B

Standards and codes organizations

- **Association française de Normalisation (AFNOR)**

The standard AFNOR related to this project is collected below:

- **NF M58-003 (2013)**
    - Title: Installation of hydrogen-related systems
    - Abstract: This document is intended to set the requirements for the installation of hydrogen production facilities, equipment running on hydrogen, hydrogen distribution equipment, hydrogen storage containers, piping hydrogen, and their accessories. It covers all applications using hydrogen gas, including non-industrial environment and public buildings, **except** for the following applications (among others):
        - the use of hydrogen in oil refineries and chemical plants as feedstock and the production process;
        - Industrial facilities that produce or use, continuous mass flow rates exceeding 400 Nm3 / h;
        - Industrial facilities which hydrogen is a by-product;
        - Equipment hydrogen in vehicles, boats, aircraft and spacecraft.
    - Cost: 84,54 €
    - Link:http://www.boutique.afnor.org/standard/nf-m58-003/installation-of-hydrogen-related-systems/article/807603/fa167332

- **American National Standards Institute (ANSI)**

The standards ANSI related to this project are collected below:

- **ANSI/CSA HGV 3.1-2015**
    - Title: Fuel system components for compressed hydrogen gas powered vehicles
    - Abstract: This Standard establishes requirements for newly produced compressed hydrogen gas fuel system components,

intended for use on hydrogen gas powered vehicles. It addresses the pressure containment, performance, and safety characteristics.

- Restrictions: This Standard applies to devices that have a service pressure of either 25MPa, 35MPa, 50MPa, or 70MPa hereinafter referred to in this Standard as the following:
    a) H25 - 25 MPa;
    b) H35 - 35 MPa;
    c) H50 - 50 MPa;
    d) H70 - 70 MPa.

  This Standard does not apply to the following:
    a) hydrogen gas fuel system components incorporated during the manufacture of motor vehicles originally manufactured in compliance with the Federal Motor Vehicle Safety Standards (FMVSS) for Compressed Hydrogen Gas Fueled Vehicles and the Canadian Motor Vehicle Safety Standard (CMVSS);
    b) fuel containers;
    c) stationary gas engines;
    d) container mounting hardware;
    e) electronic fuel management;
    f) refueling receptacles; or
    g) three-way valves.
- Cost: 327,86 €
- Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+3.1-2015

- **ANSI/CSA HGV 4.1-2013**
    - Title: Hydrogen dispensing systems
    - Abstract: This standard applies to:

        a) The mechanical and electrical features of newly manufactured systems that dispense compressed hydrogen gas for vehicles (HGV) where such systems are intended primarily to dispense the fuel directly into the fuel storage container of the vehicle.
        b) HGV dispensers that integrate in a single unit multiple dispensing functions (e.g., fuel metering, registering, control and management devices, vehicle

fuel cylinder overfill and over pressure protection with listed hoses with nozzles).

c) The following service pressures are applicable, 25MPa, 35MPa, 50MPa, 70MPa. Each dispenser may have the capability of independently fueling more than one vehicle simultaneously.

- Cost: 299,20 €
- Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+4.1-2013

- **ANSI/CSA HGV 4.2-2013**
  - Title: Hoses for compressed hydrogen fuel stations, dispensers and vehicle fuel systems
  - Abstract: This publication represents a standard for safe operation, substantial and durable construction and performance testing of gaseous hydrogen hose and hose assemblies which are used as a part of the dispensing station to connect the dispenser to the refueling nozzle; used as part of a vehicle on-board fuel system; or used as vent lines which carry gas to a safe location for either vehicles or dispensing systems. This standard contains safety requirements for material, design, manufacture and testing of gaseous hydrogen hose and hose assemblies. This standard applies to newly manufactured hose and hose assemblies for:
    - connecting the dispenser to the fueling nozzle, high pressure (class A)
    - used as part of a vehicle on-board fuel storage system, high pressure (class B)
    - used as part of a vehicle low pressure fuel delivery system, (class C)
    - flexible hoses used on hydrogen fuel station equipment (class D)
  - Cost: 286,66 €
  - Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+4.2-2013

- **ANSI/CSA HGV 4.4-2013**
  - Title: Breakaway devices for compressed hydrogen dispensing hoses and systems.

- Abstract: This standard contains safety requirements for the design, manufacture and testing of fueling hose breakaway devices for use in hydrogen gas fueling applications, hereinafter referred to as devices. This standard applies to newly manufactured devices. Devices covered by this standard are intended to perform the following functions when a vehicle is driven off with the nozzle attached to the vehicles fueling receptacle.
    a) Minimize the escape of gaseous hydrogen by automatically shutting off the flow of gas from the dispenser and controlling the depressurization of the hose; and
    b) Minimize damage to the vehicle and dispenser.
- Cost: 305,47 €
- Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+4.4-2013

- **ANSI/CSA HGV 4.5-2013 (*)**
    - Title: Priority and sequencing equipment for hydrogen vehicle fueling.
    - Abstract: This publication represents a standard for requirements for priority and sequencing equipment, which is part of a hydrogen gas vehicle fueling system.
    - Cost: 327,96 €
    - Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+4.5-2013

- **ANSI/CSA HGV 4.10-2012**
    - Title: Standard for fittings for compressed hydrogen gas and hydrogen rich gas mixtures.
    - Abstract: This standard specifies uniform methods for testing and evaluating the performance of fittings, including connectors and stud ends for ports, used with compressed hydrogen gas and hydrogen rich gas mixtures.
    - Restrictions: This standard does not include quick action couplings, flanges, or welded joints.
    - Cost: 296,26 €
    - Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+HGV+4.10-2012

- **ANSI/CSA FC 3-2004**
  - Title: Portable Fuel Cell Power Systems.
  - Abstract: This Standard applies to ac and dc type portable fuel cell power systems, with a rated output voltage not exceeding 600 V, for commercial, industrial, and residential indoor and outdoor use in non-hazardous locations, in accordance with the Rules of the National Electric Code, ANSI/NFPA 70.
  - Cost: 690,61 €
  - Link:http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fCSA+America+FC+3-2004

- **American Society of Mechanical Engineers (ASME)**

The standards NFPA related to this project are collected below:

- **ASME BPVC-VIII-1 (2013)**
  - Title: Rules for Construction of Pressure Vessels Division 1
  - Abstract: It provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Such pressure vessels may be fired or unfired. Specific requirements apply to several classes of material used in pressure vessel construction, and also to fabrication methods such as welding, forging and brazing. It contains mandatory and non-mandatory appendices detailing supplementary design criteria, non-destructive examination and inspection acceptance standards.
  - Cost: 521,59 €
  - Link:https://www.asme.org/products/codes-standards/bpvcviii1-2013-bpvc-section-viiirules

- **ASME BPVC-VIII-2 (2013)**
  - Title: Rules for Construction of Pressure Vessels Division 2-Alternative Rules
  - Abstract: this Division of Section VIII provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig. Such vessels may be fired or unfired. This pressure may be obtained from an external source or by the application of heat from a direct or

indirect source, or any combination thereof. These rules provide an alternative to the minimum requirements for pressure vessels under Division 1 rules. In comparison the Division 1, Division 2 requirements on materials, design, and non-destructive examination are more rigorous; however, higher design stress intensify values are permitted. Division 2 rules cover only vessels to be installed in a fixed location for a specific service where operation and maintenance control is retained during the useful life of the vessel by the user who prepares or causes to be prepared the design specifications.

- Cost: 521,59 €
- Link:https://www.asme.org/products/codes-standards/bpvcviii2-2013-bpvc-section-viiirules

- **ASME BPVC-VIII-3 (2010)**
  - Title: Rules for Construction of Pressure Vessels Division 3-Alternative Rules for Construction of High Pressure Vessels
  - Abstract: It provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures generally above 10,000 psi. Such vessels may be fired or unfired. This pressure may be obtained from an external source, a process reaction, by the application of heat from a direct or indirect source, or any combination thereof. Division 3 rules cover vessels intended for a specific service and installed in a fixed location or relocated from work site to work site between pressurizations. The operation and maintenance control is retained during the useful life of the vessel by the user who prepares or causes to be prepared the design specifications. Division 3 does not establish maximum pressure limits for either Section VIII, Divisions 1 or 2, nor minimum pressure limits for this Division.
  - Cost: 569,87 €
  - Link:https://www.asme.org/products/codes-standards/bpvcviii3-2010-bpvc-section-viiirules

  *There is a newer edition of this document available in July 2015.

- **ASME PTC 50 (2002)**
  - Title: Fuel Cell Power Systems Performance
  - Abstract: This Code provides test procedures, methods and definitions for the performance characterization of fuel cell power systems. Fuel cell power systems include all components required in the conversion of input fuel and oxidizer into output electrical and thermal energy. Performance characterization of fuel systems includes evaluating system energy inputs and electrical and thermal outputs to determine fuel-to-electrical energy conversion efficiency and where applicable the overall thermal effectiveness.
  - Cost: 75,58 €
  - Link:https://www.asme.org/products/codes-standards/ptc-50-2002-fuel-cell-power-systems-performance

- **ASME STP-PT-005 (2006)**
  - Title: Design Factor Guidelines for High-Pressure Composite Hydrogen Tanks
  - Abstract: The scope of this study included stationary and transport tanks; it does not include vehicle fuel tanks. The report provides recommended design factors relative to short-term burst pressure and interim margins for long-term stress rupture based on a fixed 15-year design life for fully wrapped and hoop wrapped composite tanks with metal liners.
  - Cost: 44,38 €
  - Link:https://www.asme.org/products/books/stppt005-2006-stppt005-design-factor-guidelines

- **ASME STP-PT-014 (2008)**
  - Title: Data Supporting Composite Tank Standards Development for Hydrogen Infrastructure Applications
  - Abstract: The industry has adapted to changes and has developed new and revised standards to address these changes and to reflect a better understanding of service conditions. It includes review of applications, materials of construction; standards used and field service issues. Recommendations are made for validation testing of materials and pressure vessels, with consideration for failure modes and effects analysis (FMEA) involving the field use of the vessels.

- Cost: 44,31 €
- Link:https://www.asme.org/products/books/stppt014-2008-data-supporting-composite-tank

- **ASME STP-PT-021 (2008)**
  - Title: Non-destructive Testing and Evaluation Methods for Composite Hydrogen Tanks
  - Abstract: It includes a study of various non-destructive evaluation (NDE) techniques for composite overwrapped pressure vessels intended for gaseous hydrogen infrastructure applications. The majority of the study focuses on Model Acoustic Emissions (MAE) techniques. Testing was performed on various composite tank designs including small high pressure plastic-lined fully-wrapped composite pressure vessels designed for portable, stationary or vehicular storage and large steel-lined hoop-wrapped pressure vessels designed for bulk transport and stationary storage.
  - Cost: 53,19 €
  - Link:https://www.asme.org/products/books/stppt021-2008-nondestructive-testing-evaluation

- **European Committee for Standardization (CEN)**

The standards that specifically concerns to the project of study are:

a) CEN/TC 23 Transportable gas cylinders:

- **EN 1920 (2000)**
  - Title: Transportable gas cylinders - Cylinders for compressed gases (excluding acetylene) - Inspection at time of filling
  - Abstract: It specifies the inspection requirements at the time of filling and applies to seamless or welded transportable gas cylinders made of steel or aluminium alloy for compressed gases (excluding acetylene) of water capacity from 0,5 litre up to 150 litres. It also applies, as far as practicable, to cylinders of less than 0,5 litre water capacity; - does not apply to manifolded bundles or manifolded trailer cylinders.

- Cost: 79 €
- Link:"http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:537,6007&cs=1F8837422C806EEA56D23485AA4698647"

b) CEN/TC 305 Potentially explosive atmospheres - Explosion prevention and protection:

- **EN 1127-1 (2011)**
  - Title: Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology
  - Abstract: It specifies methods for the identification and assessment of hazardous situations leading to explosion and the design and construction measures appropriate for the required safety. This is achieved by: risk assessment and risk reduction. The safety of equipment, protective systems and components can be achieved by eliminating hazards and/or limiting the risk.
  - Cost: 172 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:32055,6286&cs=13889EDBA2EA67261AB47EC6082D9012D

- **EN 1127-2 (2014)**
  - Title: Explosive atmospheres - Explosion prevention and protection - Part 2: Basic concepts and methodology for mining
  - Abstract: This European Standard specifies methods for explosion prevention and protection in mining by outlining the basic concepts and methodology for the design and construction of equipment, protective systems and components. This standard is applicable to any equipment, protective systems and components intended to be used in potentially explosive atmospheres. These atmospheres can arise from flammable materials processed, used or released by the equipment, protective systems and components or from materials in the vicinity of the equipment, protective systems and components and/or from the materials of construction of the equipment, protective systems and components.
  - Cost: 73,76 €

- Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:39087,6286&cs=13147CD01A8C786E38FB39839C7E097BB

- **EN 13463-1 (2009)**
  - Title: Non-electrical equipment for use in potentially explosive atmospheres - Part 1: Basic method and requirements
  - Abstract: This European Standard specifies the basic method and requirements for design, construction, testing and marking of non-electrical equipment intended for use in potentially explosive atmospheres in air of gas, vapour, mist and dusts. Such atmospheres can also exist inside the equipment. In addition, the external atmosphere can be drawn inside the equipment by natural breathing produced as a result of fluctuations in the equipment's internal operating pressure, and/or temperature.
  - Cost: 123,20 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:25138,6286&cs=166AD886E500BA92EDC3152B6482FF281

- **EN 13463-2 (2004)**
  - Title: Non-electrical equipment for use in potentially explosive atmospheres - Part 2: Protection by flow restricting enclosure 'fr'
  - Abstract: specifies the requirements for the construction and testing of flow restricting enclosures for non-electrical equipment intended for use in potentially explosive atmospheres if the atmosphere outside the enclosure becomes explosive rarely and for short durations only. This standard supplements the requirements in EN 13463-1 the contents of which apply in full to equipment constructed in accordance with this standard.
  - Cost: 89 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:14887,6286&cs=140AD26A0D053D320C539775078802502

- **EN 13463-3 (2005)**
  - Title: Non-electrical equipment for use in potentially explosive atmospheres - Part 3: Protection by flameproof enclosure 'd'
  - Abstract: This EN contains requirements for the construction and testing of equipment with type of protection flameproof enclosure, intended for use in potentially explosive atmospheres.
  - Cost: 64,46 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:14888,6286&cs=13F7E3AAE78B783BAA74DF930B6A5AAE6

- **EN 13463-5 (2011)**
  - Title: Non-electrical equipment intended for use in potentially explosive atmospheres - Part 5: Protection by constructional safety 'c'
  - Abstract: It specifies the requirements for the design and construction of non-electrical equipment, intended for use in potentially explosive atmospheres, protected by the type of protection Constructional Safety "c". This European Standard supplements the requirements in EN 13463-1, the contents of which also apply in full to equipment constructed in accordance with this European Standard. The type of ignition protection described in the standard can be used either on its own or in combination with other types of ignition protection.
  - Cost: 131 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:31071,6286&cs=1DBCF65B3208A16F67EC81B633A342438

- **EN 13463-6 (2005)**
  - Title: Non-electrical equipment for use in potentially explosive atmospheres - Part 6: Protection by control of ignition source 'b'
  - Abstract: This EN specifies a type of protection for non-electrical equipment which can be applied to equipment of categories 2 and 1. By means of mechanical or electrical operating control or monitoring devices, effective ignition sources are avoided. The standard covers the basic

requirements for the design and the concept of application of this type of protection.
- Cost: 64,46 €
- Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:14891,6286&cs=1DE31D26EC50D8AA17C40F714121CD8A1

- **EN 13463-8 (2003)**
  - Title: Non-electrical equipment for potentially explosive atmospheres - Part 8: Protection by liquid immersion 'k'
  - Abstract: This European Standard specifies the requirements for the design, construction, testing and marking of ignition protected equipment using liquid immersion 'k' as a means of preventing potential ignition sources from becoming effective according to the category, or categories, of the equipment to which it is constructed. It may be used to provide ignition protection, either as an independent means, in addition to, or in combination with, other types of ignition protection.
  - Cost: 86 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:20483,6286&cs=11E9E17ECAC034C1A3272AB7156DD1483

c) CEN/TC 393 Equipment for storage tanks and for filling stations:

- **EN 13160-1 (2003)**
  - Title: Leak detection systems - Part 1: General principles
  - Abstract: This standard specifies the general principles for leak detection systems for use with double-skin tanks, single-skin tanks and pipework designed for water polluting fluids.
  - Cost: 111,21 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:10262,679233&cs=12ABFC6A664078C2DE56C8936B60251BA

d) CEN/CLC/JWG FCGA - Fuel cell gas appliances:

- **EN 50465 (2015) (*)**
  - Title: Gas appliances - Combined heat and power appliance of nominal heat input inferior or equal to 70 kW
  - Abstract: This European Standard specifies the requirements and test methods for the construction, safety, fitness for purpose, rational use of energy and the marking of a micro combined heat and power appliance ("mCHP appliance").
  - Cost: 213,95 €
  - Link:http://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:37230&cs=148DAE8E5CEC76AC788B5ECF1820E62A5

- **Compressed Gas Association (CGA)**

The standards that concerns to the project of study are the following:

a) Standards and Specifications: Position Statements (PS):

- **CGA PS-31**
  - Title: Position Statement on Cleanliness for Proton Exchange Membranes Hydrogen Piping/Components
  - Abstract: This position statement addresses the potential negative impact of impurities on Proton Exchange Membrane (PEM) equipment and the steps that may be taken to manage the solid, liquid, and transitional impurities that can be introduced into a hydrogen supply system during the fabrication and installation of a hydrogen supply system.
  - Cost: 7,14 €
  - Link:http://www.cganet.com/customer/publication_detail.aspx?id=PS-31

- **CGA PS-33**
  - Title: Position Statement on Use of LPG or Propane Tank as Compressed Hydrogen Storage Buffers
  - Abstract: This position statement provides guidance on the safety consideration for those considering conversion of a vessel

originally designed for LPG or propane service to a vessel that can store hydrogen gas.

- Cost: 4,46 €
- Link:http://www.cganet.com/customer/publication_detail.aspx?id=PS-33

b) Standards and Specifications: Hydrogen (H):

- **CGA H-4 (*)**
  - Title: Terminology Associated with Hydrogen Fuel Technologies
  - Abstract: This publication provides a description of the technologies and terminology as they apply to hydrogen fuel production, storage, transport, and use. This publication is a single source of uniform terminology for hydrogen fuel technologies. This publication will be useful to persons involved with hydrogen production, storage, transport and use technologies, regulators, and codes and standards developers.
  - Cost: 84,74 €
  - Link:http://www.cganet.com/customer/publication_detail.aspx?id=H-4

c) Standards and Specifications: Gases (G):

- **CGA G-5 (*)**
  - Title: Hydrogen
  - Abstract: A complete monograph with physical properties is included, as well as how hydrogen is made, used, contained and transported. This publication complements G-5.4 and G-5.5 to ensure safe and effective hydrogen installations.
  - Cost: 57,99 €
  - Link:http://www.cganet.com/customer/publication_detail.aspx?id=G-5

- **CGA G-5.3**
  - Title: Commodity Specification for Hydrogen
  - Abstract: This publication describes the current commodity specification for gaseous and liquid hydrogen including hydrogen for fuel cell applications. The document also provides pertinent information on methods of analysis and sampling technique, quality verifications, typical use tables, as well as supplemental graphs and data tables.
  - Cost: 41,93 €
  - Link:http://www.cganet.com/customer/publication_detail.aspx?id=G-5.3

d) Standards and Specifications: Pressure Relief Devices (S):

- **CGA S-1.1**
  - Title: Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases
  - Abstract: CGA S-1.1 is the definitive standard for the selection of the correct pressure relief device that is required to meet the requirements of the US DOT in 49 CFR 173.301(f) for over 150 gases. It provides guidance on when a pressure relief device can be optionally omitted, and when the use of a pressure relief device is prohibited. It provides direction and guidance on the manufacture and testing of pressure relief devices as well as the operation parameters and maintenance.
  - Cost: 164,73 €
  - Link:http://www.cganet.com/customer/publication_detail.aspx?id=S-1.1

- **Canadian Standard Association (CSA)**

Most of CSA standards that concerns to this project are published by ANSI (so will be recollected in the ANSI part). That ones that are published by CSA are:

- **CSA HGV 4.3-2012**
  - Title: Test methods for hydrogen fuelling parameter evaluation
  - Abstract: This standard establishes the test method, criteria, and apparatus to evaluate a hydrogen fuelling station as it

relates to achieving the protocol specified in SAE TIR J2601 - 2010, Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles, for fuelling, and the SAE TIR J2799, 70 MPa Compressed Hydrogen Surface Vehicle Fuelling Connection Device and Optional Vehicle to Station Communications for communications with light duty vehicle hydrogen storage systems less than 10 kg (37.2 lbs). The testing evaluation applies to fuelling stations designed to fill vehicle storage systems following the prescribed protocol defined in SAE TIR J2601 - 2010 that targets rapid fills, while respecting temperature, pressure, and fuel density safety limits. Newly manufactured hydrogen fuelling stations shall be tested according to this standard prior to initial operation of the station for fuelling vehicles. This standard is also intended to provide test methods for validation of existing hydrogen fuelling stations.

- Cost: 393,42 €
- Link:http://shop.csa.ca/en/canada/hydrogen-gas-vehicle-and-fueling-installations/csa-hgv-43-2012/invt/27033762012

- **International Code Council (ICC)**

The ICC Codes that concerns to the project of study are:

- **2015 International Fire Code® (IFC)**
  - Abstract: The IFC contains guidelines to safeguard life and property from fires and explosion hazards. Topics include general precautions, emergency planning and preparedness, fire department access and water supplies, automatic sprinkler systems, fire alarm systems, special hazards, and the storage and use of hazardous materials. Among others; the IFC includes hydrogen motor fuel-dispensing and generation facilities, high-piled combustible storage, flammable gases and flammable cryogenic fluids etc.
  - PDF: In this link it can be found a Document with the IFC contents:http://shop.iccsafe.org/media/wysiwyg/material/3400S15-TOC.pdf

- Cost: 109,96 €
- Link:http://shop.iccsafe.org/codes/2015-international-codes-and-references/2015-international-fire-code-and-references/2015-international-fire-coder.html

- **2015 International Fuel Gas Code®**
  - Abstract: It addresses the design and installation of fuel gas systems and gas-fired appliances through requirements that emphasize performance. It provides practical learning assignments covering gas appliance and equipment installation, fuel gas piping systems, combustion and ventilation air, chimneys and vents, gaseous hydrogen systems and other general requirements related to fuel gas systems.
  - PDF: In this link it can be found a Document with the IFC contents:http://shop.iccsafe.org/media/wysiwyg/material/3600S15-TOC.pdf
  - Cost: 85,94 €
  - Link:http://shop.iccsafe.org/codes/2015-international-codes-and-references/2015-international-fuel-gas-code/2015-international-fuel-gas-coder.html

- **The International Electrotechnical Commission (IEC)**

The standards that specifically concerns to the project of study are:

a) IEC/TC 8 Systems aspects for electrical energy supply:

- **IEC/IEEE/PAS 63547 (2011-09)**
  - Title: Interconnecting distributed resources with electric power systems
  - Abstract: provides interconnection technical specifications and requirements, and test specifications and requirements. It establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).
  - Cost: 182,78 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/045527!opendocument

b) IEC/TC 31 Equipment for explosive atmospheres:

- **IEC 60079-29-1 (2007-08)**
  - Title: Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases
  - Abstract: It specifies general requirements for construction, testing and performance, and describes the test methods that apply to portable, transportable and fixed apparatus for the detection and measurement of flammable gas or vapour concentrations with air. The apparatus, or parts thereof, are intended for use in potentially explosive atmospheres and in mines susceptible to firedamp. This first edition of IEC 60079-29-1 cancels and replaces the first edition of IEC 61779-1 to IEC 61779-5:1998 series and constitutes a technical revision with numerous changes with respect to the previous edition.
  - Cost: 221,25 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/038205!opendocument

- **IEC 60079-29-2 (2015-03)**
  - Title: Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
  - Abstract: It gives guidance on, and recommended practice for, the selection, installation, safe use and maintenance of electrically operated Group II equipment intended for use in industrial and commercial safety applications and Group I equipment in underground coal mines for the detection and measurement of flammable gases complying with the requirements of IEC 60079-29-1 or IEC 60079-29-4. This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision. Please refer to the Foreword of the document for a listing of the changes from the previous edition. Keywords: gas detectors, flammable gases, vapours.
  - Cost: 298,20 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/050934!opendocument

- **IEC 60079-29-3 (2014-03)**
  - Title: Explosive atmospheres - Part 29-3: Gas detectors - Guidance on functional safety of fixed gas detection systems
  - Abstract: It gives guidance for the design and implementation of a fixed gas detection system, including associated and/or peripheral gas detection equipment, for the detection of flammable gases/vapours and oxygen when used in a safety-related application in accordance with IEC 61508 and IEC 61511. This International standard also applies to the detection of toxic gases. Other parts of this international standard and pertinent local, national and international standards separately specify the performance requirements of a gas detector and a gas detection control unit (logic solver). These standards are commonly known as Metrological Performance Standards and are concerned with the accuracy of the measured value, the overall system performance, but not the device or system integrity with respect to the safety function. This international standard applies to the integrity of the safety function.
  - Cost: 221,22 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/049520!opendocument

- **IEC 60079-29-4 (2009-11)**
  - Title: Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases
  - Abstract: It specifies performance requirements of equipment for the detection and measuring of flammable gases or vapours in ambient air by measuring the spectral absorption by the gases or vapours over extended optical paths, ranging typically from one meter to a few kilometres. Such equipment measures the integral concentration of the absorbing gas over the optical path in units such as LFL meter for flammable gases. This standard supplements and modifies the general requirements of IEC 60079-0. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard shall take precedence. The contents of the corrigendum of August 2010 have been included in this copy.

- Cost: 182,75 €
- Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/043512!opendocument

c) IEC/TC 95 Measuring relays and protection equipment:

- **IEC 60255-27 (2013-10)**
  - Title: Measuring relays and protection equipment - Part 27: Product safety requirements
  - Abstract: It describes the product safety requirements for measuring relays and protection equipment having a rated a.c. voltage up to 1 000 V with a rated frequency up to 65 Hz, or a rated d.c. voltage up to 1 500 V. Above these limits, IEC 60664-1 is applicable for the determination of clearance, creepage distance and withstand test voltage. This standard details essential safety requirements to minimize the risk of fire and hazards caused by electric shock or injury to the user.
  - Cost: 288,58 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/48714?OpenDocument

d) IEC/TC 105 Fuel cell technologies:

- **IEC 62282-2 (2012-03)**
  - Title: Fuel Cell Modules
  - Abstract: It provides the minimum requirements for safety and performance of fuel cell modules; it applies to fuel cell modules with or without an enclosure which can be operated at significant pressurization levels or close to ambient pressure. Deals with conditions that can yield hazards to persons and cause damage outside the fuel cell modules.
  - Working group: 2
  - Cost: 221,29 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/046257!opendocument

- **IEC 62282-5-1 (2012-09)**
  - Title: Portable Fuel Cell Appliances – Safety
  - Abstract: This covers construction, marking and test requirements for portable fuel cell power systems intended to produce electrical power. Applies to a.c. and d.c. type portable

fuel cell power systems, with a rated output voltage not exceeding 600 V a.c., or 850 V d.c. for indoor and outdoor use. The major technical changes with respect to the first edition are as follows:

  - referencing an alternative test method; reduction of the limit on flammable atmospheres;
  - consideration of additional effluents and criteria to establish if a system is suitable for indoor or outdoor operation;
  - revision of specific criteria for oxygen detector sensor performance;
  - new test method and new drop heights; addition of a table giving limits on emission of effluents.

- Working group: 7
- Cost: 269,18 €
- Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/046912!opendocument

- **IEC 62282-7-1 (2010-06)**
  - Title: Single Cell Test Method for Polymer Electrolyte Fuel Cells
  - Abstract: It covers cell assemblies, test apparatus, measuring instruments and measuring methods, performance test methods, and test reports for PEFC single cells. This Technical Specification is used for evaluating:
    - the performance of membrane electrode assemblies (MEAs) for PEFCs;
    - materials or structures of other components of PEFCs;
    - or the influence of impurities in fuel and/or in air on the fuel cell performance.
  - Working group: 11
  - Cost: 221,21 €
  - Link:http://webstore.iec.ch/webstore/webstore.nsf/artnum/044187!opendocument

- **International organization for Standardization (ISO):**

a) ISO/TC 22 Road Vehicles:

The standards of that committee that concerns the project of study are collected in the following sub committees:

SC 21 Electrically propelled road vehicles:

- **ISO 6469-1:2009**
  - Title: Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)
  - Abstract: specifies requirements for the on-board rechargeable energy storage systems (RESS) of electrically propelled road vehicles, including battery-electric vehicles (BEVs), fuel-cell vehicles (FCVs) and hybrid electric vehicles (HEVs), for the protection of persons inside and outside the vehicle and the vehicle environment. It does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.
  - Restrictions: Flywheels are not included in the scope of this standard. It does not apply to RESS in motorcycles and vehicles not primarily intended as road vehicles, such as material handling trucks or fork-lift trucks, it applies only to RESS in on-board voltage class B electric circuits for vehicle propulsion.
  - Cost: 55,52 €
  - Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=45477

- **ISO 6469-2:2009**
  - Title: Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures
  - Abstract: specifies requirements for operational safety means and protection against failures related to hazards specific to electrically propelled road vehicles, including battery-electric vehicles (BEVs), fuel-cell vehicles (FCVs) and hybrid electric vehicles (HEVs), for the protection of persons inside and

outside the vehicle and the vehicle environment. However, the requirements related to internal combustion engine (ICE) systems of HEVs are not covered and comprehensive safety information for manufacturing, maintenance and repair personnel are not provided.

- Restrictions: it does not apply to motorcycles and vehicles not primarily intended as road vehicles, such as material handling trucks or fork-lift trucks, it applies only if the maximum working voltage of the on-board electrical propulsion system is lower than the upper voltage class B limit.
- Cost: 36,37 €
- Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=45478

- **ISO 6469-3:2011**
  - Title: Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock
  - Abstract: specifies requirements for the electric propulsion systems and conductively connected auxiliary electric systems, if any, of electrically propelled road vehicles for the protection of persons inside and outside the vehicle against electric shock. It does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.
  - Restrictions: it does not apply to motorcycles and vehicles not primarily intended as road vehicles, such as material handling trucks or forklifts, it applies only to on-board electric circuits with maximum working voltages according to voltage class B.
  - Cost: 84,24 €
  - Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=45479

- **ISO 23273:2013**
  - Title: Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
  - Abstract: This International Standard specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside

the vehicle against hydrogen-related hazards. The requirements of this International Standard address both normal operating (fault-free) and single-fault conditions of the vehicles.

- Restrictions: It applies only to such FCV where compressed hydrogen is used as fuel for the fuel cell system. It does not apply to manufacturing, maintenance, and repair.
- Cost: 36,37 €
- Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=64047

SC 25 Vehicles using gaseous fuels:

- **ISO 16380:2014**
  - Title: Road vehicles -- Blended fuels refuelling connector
  - Abstract: This International Standard applies to compressed blended fuels vehicle nozzles and receptacles hereinafter referred to as devices, constructed entirely of new, unused parts and materials.
  - Restrictions: it applies to devices which have a service pressure of 20 MPa, 25 MPa, and 35 MPa:
    - size 1: M200, M250, and M350;
    - size 2: N200 and N250.

    This International Standard refers to service pressures of 20 MPa, 25 MPa, and 35 MPa for size 1 and 20 MPa and 25 MPa for size 2. It also applies to devices with standardised mating components. This International Standard applies to connectors which

    a) Prevent blended fuels vehicles from being fuelled by dispenser stations with working pressures higher than the vehicle fuel system working pressure.

    b) Allow blended fuels vehicles to be fuelled by dispenser stations with working pressures equal to or lower than the vehicle fuel system working pressure.

    c) Allow blended fuels vehicles to be fuelled by dispenser stations for compressed natural gas.

    d) Allow blended fuels vehicles to be fuelled by compressed natural gas dispenser stations with working pressures equal to or lower than the vehicle fuel system working pressure.

e) Prevent blended fuels vehicles size 1 being refuelled on blended fuels dispenser stations equipped with a size 2 nozzle and vice versa.

f) Prevent natural gas vehicles from being fuelled by blended fuels station, and dispensers.

g) Prevent pure hydrogen vehicles from being fuelled by blended fuels station dispensers.

This International Standard is applicable to mixtures of hydrogen from 2 % to 30 % in volume and compressed natural gas containing:

a) Natural gas in accordance with ISO 15403-1 and ISO 15403-2;

b) Pure hydrogen in accordance with ISO 14687-1 or ISO/TS 14687-2.

- Cost: 151,25 €
- Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=56593

b) ISO/TC 197 Hydrogen technologies:

The standards that specifically concerns to the project of study are:

- **ISO 15869:2009**
  - Title: Gaseous hydrogen and hydrogen blends -- Land vehicle fuel tanks
  - Abstract: specifies the requirements for lightweight refillable fuel tanks intended for the on-board storage of high-pressure compressed gaseous hydrogen or hydrogen blends on land vehicles. It is not intended as a specification for fuel tanks used for solid, liquid hydrogen or hybrid cryogenic high-pressure hydrogen storage applications.
  - Restrictions: it is applicable for fuel tanks of steel, stainless steel, aluminium or non-metallic construction material, using any design or method of manufacture suitable for its specified service conditions. It applies to the following types of fuel tank designs:
    - Type 1: metal fuel tanks;
    - Type 2: hoop-wrapped composite fuel tanks with a metal liner;

  - Type 3: fully wrapped composite fuel tanks with a metal liner;
  - Type 4: fully wrapped composite fuel tanks with no metal liner.
- Cost: 151,25 €
- Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52871

- **ISO/TR 15916:2004**
  - Title: Basic considerations for the safety of hydrogen systems
  - Abstract: provides guidelines for the use of hydrogen in its gaseous and liquid forms. It identifies the basic safety concerns and risks, and describes the properties of hydrogen that are relevant to safety. Detailed safety requirements associated with specific hydrogen applications are treated in separate International Standards.
  - Cost: 170,39 €
  - Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=29145

- **ISO 17268:2012**
  - Title: Gaseous hydrogen land vehicle refuelling connection devices
  - Abstract: defines the design, safety and operation characteristics of gaseous hydrogen land vehicle (GHLV) refuelling connectors consisting of, as applicable, a receptacle and a protective cap (mounted on vehicle), and a nozzle.
  - Restrictions: It applies to refuelling connectors which have working pressures of 11 MPa, 25 MPa, 35 MPa and 70 MPa, referred to as:
    - H11 - 11 MPa at 15 °C,
    - H25 - 25 MPa at 15 °C,
    - H35 - 35 MPa at 15 °C,
    - H35HF - 35 MPa at 15 °C (high flow for commercial vehicle applications), and
    - H70 - 70 MPa at 15 °C.

  Nozzles and receptacles that meet the requirements of this standard will only allow GHLVs to be filled by fuelling stations dispensing hydrogen with nominal working pressures equal to or lower than the vehicle fuel system working pressure. They will not allow GHLV to be filled by fuelling stations dispensing blends of hydrogen with natural gas.

- Cost: 132,10 €
- Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=51194

- **ISO/TS 20100:2008**
  - Title: Gaseous hydrogen -- Fuelling stations
  - Abstract: specifies the characteristics of outdoor public and non-public fuelling stations that dispense gaseous hydrogen used as fuel onboard land vehicles of all types.
  - Restrictions: residential and home applications to fuel land vehicles are not covered.
  - Cost: 152,37 €
  - Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=39206

- **ISO 26142:2010**
  - Title: Hydrogen detection apparatus -- Stationary applications
  - Abstract: defines the performance requirements and test methods of hydrogen detection apparatus that is designed to measure and monitor hydrogen concentrations in stationary applications. The provisions in this International Standard cover the 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.
  - Restrictions: This International Standard sets out only the requirements applicable to a product standard for hydrogen detection apparatus, such as precision, response time, stability, measuring range, selectivity and poisoning. The requirements applicable to the overall safety system, as well as the installation requirements of such apparatus, are excluded.
  - Cost: 132,10 €
  - Link:http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52319

Currently ISO is also developing a technical specification ISO/TS 20012 on gaseous hydrogen service stations.

- **National Fire Protection Association (NFPA)**

The codes and standards NFPA related to this project are collected below:

- **NFPA 2 (2011)**
  - Title: Hydrogen Technologies Code
  - Abstract: it consolidates all the fire and life safety requirements applicable to generation, installation, storage, piping, use, and handling of hydrogen in compressed gas form or cryogenic liquid form into a single comprehensive resource. It includes fundamental requirements for hydrogen in both gaseous and liquid phases and contains additional use-specific categories, such as: vehicle fueling facilities, systems for fuel cell power and generation, applications involving combustion processes and special atmospheres, operations in the lab, etc.
  - Technical Committee: Hydrogen Technology
  - Cost: 51,95 €
  - Link:http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=2&tab=about

- **NFPA 55 (2013)**
  - Title: Compressed Gases and Cryogenic Fluids Code
  - Abstract: It provides the latest fundamental requirements essential for safe installation, storage, use, and handling of gases in portable and stationary containers, cylinders, equipment, and tanks in all occupancy types.
  - Technical Committee: Industrial and Medical Gases
  - Cost: 51,95 €
  - Link:http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=55&tab=about

- **NFPA 70 (2014)**
  - Title: National Electrical Code® (NEC®)
  - Abstract: Adopted in all 50 states, the NEC is the benchmark for safe electrical design, installation, and inspection to protect

people and property from electrical hazards. It covers the latest requirements on electrical wiring and equipment installation issues, including minimum provisions for the use of connections, voltage markings, conductors, and cables. Chapters address specific circumstances surrounding special occupancies and industrial equipment and machines. It also contains specific details on the safe installation and use of communications and signaling conductors.

- Technical Committee: National Electrical Code®
- Cost: 85,08 €
- Link:http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70&tab=about

- **NFPA 221 (2015)**
  - Title: Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls
  - Abstract: It identifies and provides a focus to differentiate between types of fire walls. It presents comprehensive requirements for the design and construction of all types of rated wall assemblies including: high challenge fire walls, fire walls, fire barrier walls, protection of openings and penetrations.
  - Technical Committee: Building Construction
  - Cost: 39,86 €
  - Link:http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=221&tab=about

- **NFPA 853 (2015)**
  - Title: Standard for the Installation of Stationary Fuel Cell Power Systems
  - Abstract: This standard provides fire prevention and fire protection requirements (design, construction, and installation) for safeguarding life and physical property associated with buildings or facilities that employ stationary fuel cell systems of all sizes.
  - Technical Committee: Electric Generating Plants
  - Cost: 34,49 €
  - Link:http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=853&tab=about

- **Society of Automotive Engineers (SAE):**

a) Fuel Cell Standards Committee:

The standards that specifically concerns to the project of study are:

- **SAE J1766**
  - Title: Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing
  - Abstract: Electric, Fuel Cell and Hybrid vehicles may contain many types of high voltage systems. Adequate barriers between occupants and the high voltage systems are necessary to provide protection from potentially harmful electric current and materials within the high voltage system that can cause injury to occupants of the vehicle during and after a crash.This Recommended Practice addresses post-crash electrical safety, retention of electrical propulsion components and electrolyte spillage.
  - Restrictions: this SAE Recommended Practice is applicable to Electric, Fuel Cell and Hybrid vehicle designs that are comprised of at least one vehicle propulsion voltage bus with a nominal operating voltage greater than 60 and less than 1,500 VDC, or greater than 30 and less than 1,000 VAC.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j1766_201401/

- **SAE J2572**
  - Title: Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen
  - Abstract: This SAE Recommended Practice establishes uniform procedures for testing fuel cell and hybrid fuel cell electric vehicles, excluding low speed vehicles, designed primarily for operation on the public streets, roads and highways. The procedure addresses those vehicles under test using compressed hydrogen gas supplied by an off-board source or stored and supplied as a compressed gas onboard.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2572_201410/

- **SAE J2578**
  - Title: Recommended Practice for General Fuel Cell Vehicle Safety
  - Abstract: This SAE Recommended Practice identifies and defines requirements relating to the safe integration of the fuel cell system, the hydrogen fuel storage and handling systems (as defined and specified in SAE J2579) and high voltage electrical systems into the overall Fuel Cell Vehicle. The document may also be applied to hydrogen vehicles with internal combustion engines. This document relates to the overall design, construction, operation and maintenance of fuel cell vehicles.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2578_201408/

- **SAE J2579**
  - Title: Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles
  - Abstract: The purpose of this document is to define design, construction, operational, and maintenance requirements for hydrogen fuel storage and handling systems in on-road vehicles. Performance-based requirements for verification of design prototype and production hydrogen storage and handling systems are also defined in this document. Complementary test protocols (for use in type approval or self-certification) to qualify designs (and/or production) as meeting the specified performance requirements are described. Crashworthiness of hydrogen storage and handling systems is beyond the scope of this document. SAE J2578 includes requirements relating to crashworthiness and vehicle integration for fuel cell vehicles. It defines recommended practices related to the integration of hydrogen storage and handling systems, fuel cell system, and electrical systems into the overall Fuel Cell Vehicle.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2579_201303/

- **SAE J2600**
  - Title: Compressed Hydrogen Surface Vehicle Fuelling Connection Devices
  - Abstract: SAE J2600 applies to the design and testing of Compressed Hydrogen Surface Vehicle (CHSV) fuelling connectors, nozzles, and receptacles. Connectors, nozzles, and receptacles must meet all SAE J2600 requirements and pass all SAE J2600 testing to be considered as SAE J2600 compliant. This document applies to devices which have Pressure Classes of H11, H25, H35, H50 or H70.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2600_201211/

- **SAE J2601**
  - Title: Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
  - Abstract: SAE J2601 establishes the protocol and process limits for hydrogen fuelling of light duty vehicles. These process limits (including fuel temperature, the maximum fuel flow rate, and rate of pressure increase and end pressure) are affected by factors such as ambient temperature, fuel delivery temperature and initial pressure in the vehicle's compressed hydrogen storage system.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2601_201407/

- **SAE J2617**
  - Title: Recommended Practice for Testing Performance of PEM Fuel Cell Stack Sub-system for Automotive Applications
  - Abstract: This recommended practice is intended to serve as a procedure to verify the design specifications or vender claims of any PEM (Proton Exchange Membrane) type fuel cell stack sub-system for automotive applications. In this document, definitions, specifications, and methods for the performance characterization of the fuel cell stack sub-system are provided. The performance characterization includes evaluating electrical outputs and controlling fluid inputs and outputs based on the test boundary defined in this document.
  - Cost: 64,23 €

- Link: http://standards.sae.org/j2617_201108/

- **SAE J2719 (*)**
  - Title: Hydrogen Fuel Quality for Fuel Cell Vehicles
  - Abstract: This Standard provides background information and a hydrogen fuel quality standard for commercial proton exchange membrane (PEM) fuel cell vehicles. This Report also provides background information on how this standard was developed by the Hydrogen Quality Task Force (HQTF) of the Interface Working Group (IWG) of the SAE Fuel Cell Standards Committee.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2719_201109/

- **SAE J2799 (*)**
  - Title: Hydrogen Surface Vehicle to Station Communications Hardware and Software
  - Abstract: This standard specifies the communications hardware and software requirements for fuelling Hydrogen Surface Vehicles (HSV), such as fuel cell vehicles, but may also be used where appropriate, with heavy duty vehicles (e.g., busses) and industrial trucks (e.g., forklifts) with compressed hydrogen storage. It contains a description of the communications hardware and communications protocol that may be used to refuel the HSV. The intent of this standard is to enable harmonized development and implementation of the hydrogen fuelling interfaces.
  - Cost: 64,23 €
  - Link: http://standards.sae.org/j2799_201404/

- **SAE J2990/1 (*)**
  - Title: Gaseous Hydrogen and Fuel Cell Vehicle First and Second Responder Recommended Practice
  - Abstract: Electric and alternative fuelled vehicles present different hazards for first and second responders than conventional gasoline internal combustion engines. Hydrogen vehicles including Fuel Cell Vehicles (FCVs) involved in incidents may present unique hazards associated with the fuel storage and high voltage systems. The electrical hazards

associated with the high voltage systems of hybrid-electric vehicles and FCVs are already addressed in the parent document, SAE J2990. This Recommended Practice therefore addresses electric issues by reference to J2990 and supplements J2990, to address the potential consequences associated with hydrogen vehicle incidents and suggest common procedures to help protect emergency responders, tow and/or recovery, storage, repair, and salvage personnel after an incident has occurred. Industry design standards and tools were studied and where appropriate, suggested for responsible organizations to implement.

- Considerations: this standard is still in progress.
- Cost: Not available
- Link: http://standards.sae.org/wip/j2990/1/

- **Underwriters Laboratories (UL)**

The UL standard that concerns to the project of study is:

- **2262**
  - Title: Fuel Cell Modules for Use in Portable and Stationary Equipment
  - Abstract: It covers component fuel cell modules for building into equipment, including portable and stationary fuel cell applications. It also covers proton exchange membrane (PEM), alkaline, phosphoric acid, molten carbonate, solid oxide type fuel cell modules that are intended to be factory installed in complete products.
  - Restrictions: It does not cover removable fuel cartridges for refueling the fuel cell module.
  - Price: 161,71 €
  - Link:http://www.comm-2000.com/ProductDetail.aspx?UniqueKey=24720

Regulations

1. International regulations

- **United Nations Economic Commission for Europe (UNECE)**

The regulation that concerns directly to hydrogen fuel cell vehicles is the following:

- **UN GTR No. 13**
    - Title: Hydrogen and fuel cell vehicles
    - Abstract: this regulation specifies safety related performance requirements for hydrogen fuelled vehicles. The purpose of this regulation is to minimize human harm that may occur as a result of fire, burst or explosion related to the vehicle fuel system and/or from electric shock caused by the vehicle's high voltage system.
    - Restrictions: This regulation applies to all hydrogen fuelled vehicles of Category 1-1 and 1-2,with a gross vehicle mass (GVM) of 4,536 kilograms or less. *("Category 1 vehicle" means a power driven vehicle with four or more wheels designed and constructed primarily for the carriage of (a) person(s). "Category 1-1 vehicle" means a category 1 vehicle comprising not more than eight seating positions in addition to the driver's seating position. A category 1-1 vehicle cannot have standing passengers. "Category 1-2 vehicle" means a category 1 vehicle designed for the carriage of more than eight passengers, whether seated or standing, in addition to the driver.)*
    - Appendix:http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29registry/ECE-TRANS-180a13e.pdf
    - Link:http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29registry/ECE-TRANS-180a13e.pdf

2. European legislation

- **Regulations**

The regulations that concerns to the project of study are the following:

- **32012R0630 EU No 630/2012**
    - Title: Type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions
    - Abstract: it amends Regulation (EC) No 692/2008, as regards type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions, and the inclusion of specific information regarding vehicles fitted with an electric power train in the information document for the purpose of EC type-approval Text with EEA relevance.
    - Date of document: 12/07/2012
    - Date of effect: 02/08/2012; Entry into force Date pub. + 20 See Art 2
    - Date of end of validity: 31/12/9999
    - Author: European Commission
    - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32012R0630

- **32010R0406 EU No 406/2010**
    - Title: Type-approval of hydrogen-powered motor vehicles
    - Abstract: it implements Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles. This Regulation supplements Regulation (EC) No 79/2009 by specifying the precise definitions of terms such as “hydrogen sensor”, “filling cycle”, “fitting” or “hydrogen filter”. It also lays down administrative provisions for EC type-approval of a vehicle with regard to hydrogen propulsion, and administrative provisions for EC component type-approval of hydrogen components and systems.
    - Date of document: 26/04/2010
    - Date of effect: 07/06/2010; Entry into force Date pub. + 20 See Art 6
    - Date of end of validity: 31/12/9999

- Author: European Commission
- Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32010R0406

- **32009R0079 EC No 79/2009**
  - Title: Type-approval of hydrogen-powered motor vehicles
  - Abstract: This Regulation establishes rules relating to the approval of hydrogen-powered motor vehicles. This Regulation applies to:
    - Hydrogen-powered vehicles of categories M (motor vehicles with at least four wheels designed and constructed for the carriage of passengers) and N (motor vehicles with at least four wheels designed and constructed for the carriage of goods). It is understood as a hydrogen-powered vehicle a motor vehicle that uses hydrogen as fuel to propel the vehicle.
    - Hydrogen components listed in Annex I to this Regulation (understanding as hydrogen component hydrogen container and all other parts of the hydrogen-powered vehicle that are in direct contact with hydrogen or which form part of a hydrogen system)
    - Hydrogen systems (assembly of hydrogen components and connecting parts fitted on hydrogen-powered vehicles, excluding the propulsion systems or auxiliary power systems).

    It also defines a framework relating to the installation of hydrogen components and systems.

    Manufacturers are obliged to equip hydrogen-powered vehicles with hydrogen components and systems that comply with the requirements of this Regulation. They shall also provide the approval authorities with appropriate information concerning the vehicle specifications and test conditions.
  - Date of document: 14/01/2009
  - Date of effect: 24/02/2009; Entry into force Date pub. + 20 See Art 16
  - Date of end of validity: 31/12/9999
  - Author: European Parliament, Council of the European Union
  - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32009R0079

- **32014R0559 EU No 559/2014 (*)**
  - Title: Establishing the Fuel Cells and Hydrogen 2 Joint Undertaking
  - Abstract: it establishes the Fuel Cells and Hydrogen 2 Joint Undertaking. It replaces the EC No 521/2008 and EU No 1183/2011.
  - Date of document: 06/05/2014
  - Date of effect: 27/06/2014; Entry into force Date pub. +20 See Art 20
  - Date of end of validity: 31/12/9999
  - Author: Council of the European Union
  - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32014R0559&qid=1428570278956

- **Directives**

The directives that concerns to the project of study are the following:

- **31994L0009 Directive 94/9/EC (*)**
  - Title: Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres
  - Abstract: The Directive applies to electrical and non-electrical protective devices and systems (surface and mining equipment) used in potentially explosive atmospheres and to items of equipment for use outside potentially explosive atmospheres but which impinge upon devices that are present in any such atmospheres.
  - Date of document: 23/03/1994
  - Date of effect: 09/05/1994; Entry into force Date pub. + 20 See 192E191-P2
  - Date of end of validity: 20/04/2016; Repealed by 32014L0034
  - Author: European Parliament, Council of the European Union
  - Link:/eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:31994L0009&qid=1429101432299

- **32014L0034 Directive 2014/34/EU (*)**
  - Title: Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast) Text with EEA relevance
  - Abstract: This Directive shall apply to the following, hereinafter referred to as 'products':
    - equipment and protective systems intended for use in potentially explosive atmospheres;
    - safety devices, controlling devices and regulating devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment and protective systems with respect to the risks of explosion;
    - components intended to be incorporated into equipment and protective systems referred to in point (a).
  - Date of document: 26/02/2014
  - Date of effect: 18/04/2014; Entry into force Date pub. +20 See Art 44
  - Date of effect: 20/04/2016; Implementation Partial implementation See Art 44
  - Date of end of validity: 31/12/9999
  - Author: European Parliament, Council of the European Union
  - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32014L0034&qid=1429102155953

- **31997L0023 Directive 97/23/EC**
  - Title: Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment
  - Abstract: This Directive aims to harmonize the national legislation of Member States concerning the design, manufacture, testing and conformity assessment of:
    - pressure equipment;
    - assemblies of pressure equipment constituting an integrated whole.

    It seeks to ensure that the relevant equipment in the European Union (EU) and certain other associated countries, such as those in the European Economic Area (EEA), can be placed on the market freely. The Directive's provisions apply to equipment subject to a maximum allowable pressure greater than 0.5 bar (i.e. 0.5 bar above atmospheric pressure) that poses a hazard due to pressure.

- Date of document: 29/05/1997
- Date of effect: 29/07/1997; Entry into force Date pub. + 20 See 11992E191-P1
- Date of end of validity: 18/07/2016; Repealed by 32014L0068
- Author: European Parliament, Council of the European Union
- Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:31997L0023&qid=1429092383769

- **32006L0042 Directive 2006/42/EC**
  - Title: Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance)
  - Abstract: The aim of this Directive is to lay down the essential health and safety requirements relating to design and construction in order to improve the safety of machinery placed on the European market. Before placing machinery on the market the manufacturer shall ensure that:
    - it complies with the relevant essential health and safety requirements;
    - the technical file is available. The technical file must demonstrate that the machinery complies with the requirements of this Directive. It must cover the design, manufacture and operation of the machinery to the extent necessary for assessing such compliance;
    - the necessary information is available;
    - the conformity assessment procedures are applied;
    - the EC declaration of conformity is drawn up;
    - the CE marking is affixed.

    Before placing partly completed machinery on the market, the manufacturer shall:
    - ensure that the relevant technical documentation is prepared;
    - prepare assembly instructions;
    - draw up a declaration of incorporation.

    Member States shall not prohibit, restrict or impede the placing on the market and/or putting into service in their territory of machinery which complies with the provisions of this Directive. They shall take all appropriate measures to ensure that machinery may be placed on the market only if it satisfies the provisions of this Directive and does not compromise the health and safety of persons, domestic animals or property.

- Date of document: 17/05/2006
- Date of effect: 29/06/2006; Entry into force Date pub. + 20 See Art 28
- Date of end of validity: 31/12/9999
- Author: European Parliament, Council of the European Union
- Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32006L0042

- **32014L0068 Directive 2014/68/EU**
  - Title: Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment Text with EEA relevance
  - Abstract: This European Union law lays down essential safety requirements for pressure equipment and assemblies (such as boilers, pressure cookers, fire extinguishers, heat exchangers and steam generators). All stationary pressure equipment must conform to strict specifications if it is to be sold in the EU. The directive applies to the design, manufacture and conformity of pressure equipment with a maximum allowable pressure greater than 0.5 bar. It covers all pressure equipment and assemblies that are new to the EU market, whether manufactured in the EU or elsewhere. This also includes imported used items.
  - Date of document: 15/05/2014
  - Date of effect: 17/07/2014; Entry into force Date pub. +20 See Art 51
  - Date of effect: 19/07/2016; Implementation Partial implementation See Art 51
  - Date of end of validity: 31/12/9999
  - Author: European Parliament, Council of the European Union
  - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32014L0068&qid=1429093385942

- **32008L0058 Commission Directive 2008/58/EC**
    - Title: Classification, packaging and labelling of dangerous substances
    - Abstract: It amends, for the purpose of its adaptation to technical progress, for the 30th time, Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.
    - Date of document: 21/08/2008
    - Date of effect: 05/10/2008; Entry into force Date pub. + 20 See Art
    - Date of end of validity: 31/12/9999
    - Author: European Commission
    - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32008L0058

- **32004L0073R(01) Corrigendum to Commission Directive 2004/73/EC**
    - Title: Corrigendum to Commission Directive 2004/73/EC; Classification, packaging and labelling of dangerous substances
    - Abstract: It adapts to technical progress for the 29th time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.
    - Date of document: 16/06/2004
    - Author: European Commission
    - Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32004L0073R%2801%29

- **32014L0045 Directive 2014/45/EU**
    - Abstract: It aims to improve road safety by setting minimum requirements for periodic roadworthiness tests of vehicles and trailers in the European Union (EU). The law applies to vehicles capable of more than 25 km/hour in the following categories:
        - passenger cars and light commercial vehicles (categories M1 and N1): to be tested 4 years after the date when first registered, and thereafter every 2 years;

- o vehicles in category M1 used as taxis or ambulances, buses or minibuses (M2, M3), heavy goods vehicles (N2, N3) and heavy trailers (O3, O4): to be tested 1 year after first registration, and thereafter yearly;
- o fast tractors with a design speed above 40km/h (T5) and used commercially: to be tested 4 years after registration, and thereafter every 2 years.

Powerful motorcycles (category L vehicles with an engine larger than 125 cm3) will be tested from 2022 unless road safety statistics for the previous 5 years show that the same level of road safety could be achieved by alternative measures.

- Restrictions: vehicles of historic interest, diplomatic vehicles, vehicles used by the armed forces, police, customs, fire services or for agricultural and forestry purposes only, as well as vehicles used exclusively on small islands.
- Date of document: 03/04/2014
- Date of effect: 19/05/2014; Entry into force Date pub. +20 See Art 25
- Date of end of validity: 31/12/9999
- Author: European Parliament, Council of the European Union
- Link:http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32014L0045&qid=1428570278956

3. National regulations

- **Canadian regulations**

In the Canadian law there aren't lots of acts and regulations that concern the project of study. It can just be found the following ones:

- **Technical Standards Document No. 301, Revision 2R**
  - Title: Motor Vehicle Safety Regulations 301.1 - Fuel System Integrity
  - Abstract: This Technical Standards Document (TSD) specifies requirements for the integrity of motor vehicle fuel systems. Its purpose is to reduce deaths and injuries occurring from fires that result from fuel spillage during and after motor vehicle crashes and resulting from ingestion of fuels during siphoning.
  - Date of effect: 24/07/2010

- Link:https://www.tc.gc.ca/media/documents/roadsafety/301_TSD_rev_2R.pdf

- **Technical Standards Document No. 305, Revision 3R**
    - Title: Motor Vehicle Safety Regulations 305 - Electrolyte Spillage and Electrical Shock Protection
    - Abstract: This Technical Standards Document (TSD) specifies requirements for limitation of electrolyte spillage, retention of electric energy storage/conversion devices, and protection from harmful electric shock during and after a crash. Its purpose is to reduce deaths and injuries during and after a crash that occurs because of electrolyte spillage from electric energy storage devices, intrusion of electric energy storage/conversion devices into the occupant compartment, and electrical shock.
    - Date of effect: 08/10/2011
    - Link:https://www.tc.gc.ca/media/documents/roadsafety/305_TSD_rev_3R.pdf

- **French regulations**

The regulations found that concern to the project are the following:

➢ Laws

- **Law 2009-967 of the 3rd of August 2009 of Programming on the implementation of the Grenelle Environment (*)**
    - Title I: Combating climate change
    - Chapter V: Research in the field of sustainable development
        - *Article 22:* Research plays a central role in the analysis of environmental processes and is the source of technological innovation essential to the preservation of the environment and adaptation to global changes in the world. The national research effort will emphasize renewable energy, including solar photovoltaic energy from thin layers, ocean energy and resources of geothermal energy at different depths, the energy storage, batteries fuel cells, hydrogen technology, mastery of the capture and storage of carbon dioxide,

including plants, the energy efficiency of buildings, vehicles and land transport systems, water and air, etc.

- Link:http://www.legifrance.gouv.fr/affichTexteArticle.do?idArticle=LEGIARTI000020950524&cidTexte=JORFTEXT000020949548&dateTexte=20150414&fastPos=1&fastReqId=661704002&oldAction=rechExpTexteCode

- **Law 2005-781 of the 13th of June 2005 of program setting the guidelines for energy policy (*)**
  - Title I: National Energy Strategy
    - *Article 4:* The transport sector must have a profound reorientation, as it constitutes the main source of emissions of greenhouse gases and pollution air. The state supports the use of hybrid and electric vehicles and research on the use of fuel cells and hydrogen.
    - Link:http://www.legifrance.gouv.fr/affichTexteArticle.do?idArticle=LEGIARTI000006628577&cidTexte=JORFTEXT000000813253&dateTexte=20150414&fastPos=2&fastReqId=1871855780&oldAction=rechExpTexteCode

    - *Article 5:* The research policy should allow France to 2015 to acquire one in new areas by pursuing the following objective, among others:

      Exploiting the potential of new rupture vectors such as hydrogen, for which should be developed or improved, firstly, production methods such as electrolysis, reforming hydrocarbons, gasification of biomass the photo-electrochemical decomposition of water or physicochemical cycles using heat delivered by new nuclear reactors at high temperatures and, on the other hand, storage technologies, transport and use, in particular with the fuel cell engines and turbines.
    - Link:http://www.legifrance.gouv.fr/affichTexteArticle.do?idArticle=LEGIARTI000022494539&cidTexte=JORFTEXT000000813253&dateTexte=20150414&fastPos=3&fastReqId=1638061876&oldAction=rechExpTexteCode

➢ Decrees/Orders

- **Decree of the 12th of February 1998 on general requirements for installations classified for environmental protection subjected to reporting under No. 1416 (Storage or use of hydrogen) (*)**
  - Link:http://www.legifrance.gouv.fr/affichTexte.do?dateTexte=20150414&cidTexte=JORFTEXT000000571176&fastPos=1&fastReqId=236749989&oldAction=rechExpTexteCode

- **Decree of the 9th of February 2009 on the registration procedures for vehicles (*)**
  - Abstract: Abbreviation of hydrogen: H2
  - Link:http://www.legifrance.gouv.fr/affichTexteArticle.do?idArticle=LEGIARTI000025741696&cidTexte=JORFTEXT000020237165&dateTexte=20150414&fastPos=57&fastReqId=854942223&oldAction=rechExpTexteCode

- **Decree of the 23th of July 1943 on the regulation of production equipment, storage or implementation of compressed, liquefied or dissolved gas**
  - Abstract: The test must be periodically renewed at the request of the owner, for fixed or semi-fixed devices, at the request of the filler for mobile devices. The maximum time of the event is set at ten years for the following fixed devices containing gas: air, oxygen, nitrogen, rare gases of the air, hydrogen, hydrocarbons, free of corrosive impurities, ammonia, carbon dioxide, mono bromomethane, monochloromethane, déthylène oxide, methyl ether, monomethylamine, dimethylamine and monochloroethylene.
  - Link:http://www.legifrance.gouv.fr/affichTexteArticle.do?idArticle=LEGIARTI000006276809&cidTexte=JORFTEXT000000830995&dateTexte=20150414&fastPos=241&fastReqId=526894257&oldAction=rechExpTexteCode

- **Spanish regulations**

The regulations related to this project are the following:

- **Real Decreto 1999/1979 (Royal Decree 1999/1979)**
  - Title: New text of the National Regulations on Dangerous Goods by Road and complementary to the same standards
  - Abstract: Technological advances collected in international agreements, ratified by Spain, related to international transport of dangerous goods, have been very important, affecting almost all of the national regulation.
    Hydrogen is considered as a flammable material, classified according to their chemical properties, the materials and objects of class 2.
  - Link:http://www.boe.es/buscar/doc.php?id=BOE-A-1979-20518

- **Order of September 1, 1982 by the Technical Instruction MIE-AP7**
  - Title: Pressure Equipment Regulation on bottles of liquefied and compressed gases dissolved under pressure passes.
  - Abstract: All requirements, technical inspections and tests prescribed by this Code shall apply in the same manner as described, the bottles for compressed gases, liquefied or dissolved under pressure.
    Hydrogen is classified as a inflammable material.
  - Link:http://www.boe.es/buscar/doc.php?id=BOE-A-1982-29442

- **USA regulations**

Those Federal regulations that concerns to the project of study are:

- **75 FR 33515**
  - Title: Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection
  - Abstract: In response to a petition for rulemaking from the Alliance of Automobile Manufacturers, NHTSA is issuing this final rule to facilitate the development and introduction of fuel cell vehicles, a type of electric-powered vehicle, and the next generation of hybrid and battery electric powered vehicles. It does so by revising the agency's standard regulating electrolyte

spillage and electrical shock protection for electric-powered vehicles to align it more closely with the April 2005 version of the Society of Automotive Engineers (SAE) Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing (SAE J1766). The standard currently requires manufacturers to design their vehicles so that, in the event of a crash, a vehicle's propulsion battery system will be electrically isolated from the vehicle's electricity-conducting structure. As amended, this rule provides greater flexibility, requiring manufacturers to design their electrically powered vehicles so that, in the event of a crash, the electrical energy storage, conversion, and traction systems are either electrically isolated from the vehicle's chassis or their voltage is below specified levels considered safe from electric shock hazards.

- Date of effect: 14/06/2010
- Link:http://www.gpo.gov/fdsys/search/pagedetails.action?sr=2&originalSearch=collection%3AFR+and+content%3Ahydrogen&st=collection%3AFR+and+content%3Ahydrogen&ps=10&na=_companiesnav_granuleclassnav__agenciesnav&se=_DEPARTMENT+OF+TRANSPORTATIONfalse_RULEtrue__National+Highway+Traffic+Safety+Administrationtrue&sb=re&timeFrame=&dateBrowse=&govAuthBrowse=&collection=&historical=true&granuleId=2010-14131&packageId=FR-2010-06-14

- **76 FR 45436**
  - Title: Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection
  - Abstract: This document responds to petitions for reconsideration of a final rule issued by this agency on June 14, 2010. This final rule amended the electrical shock protection requirements to facilitate the development and introduction of fuel cell vehicles (a type of electric- powered vehicle) and the next generation of hybrid and battery electric powered vehicles. This document addresses issues raised in the petitions for reconsideration relating to the scope and applicability of the standard, the definitions in the standard, the retention requirements for electric energy storage/conversion systems, the electrical isolation requirements, the test specifications and

requirements for electrical isolation monitoring, the state-of-charge of electric energy storage devices prior to the crash tests, a proposed protective barrier compliance option for electrical safety, the use of alternative gas to crash test hydrogen fuel cell vehicles, and a proposed low-energy compliance option for electrical safety.

- Date of effect: 01/09/2011
- Link:http://www.gpo.gov/fdsys/search/pagedetails.action?na=_companiesnav_granuleclassnav_agenciesnav&se=_DEPARTMENT+OF+TRANSPORTATIONfalse_RULEtrue_Transportation+Departmenttrue&sm=&flr=&ercode=&dateBrowse=&govAuthBrowse=&collection=&historical=true&st=collection%3AFR+and+content%3Ahydrogen&psh=&sbh=&tfh=&originalSearch=collection%3AFR+and+content%3Ahydrogen&sb=re&sb=re&ps=10&ps=10&bread=true&granuleId=2011-19216&packageId=FR-2011-07-29

- **76 FR 39477**
  - Title: Revisions and Additions to Motor Vehicle Fuel Economy Label
  - Abstract: The Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) are issuing a joint final rule establishing new requirements for the fuel economy and environment label that will be posted on the window sticker of all new automobiles sold in the U.S. The labeling requirements apply for model year 2013 and later vehicles with a voluntary manufacturer option for model year 2012. The labeling requirements apply to passenger cars, light-duty trucks, and medium duty passenger vehicles such as larger sport-utility vehicles and vans. The redesigned label provides expanded information to American consumers about new vehicle fuel economy and fuel consumption, greenhouse gas and smog-forming emissions, and projected fuel costs and savings, and also includes a smartphone interactive code that permits direct access to additional Web resources. Specific label designs are provided for gasoline, diesel, ethanol flexible fuel, compressed natural gas, electric, plug-in hybrid electric, and hydrogen fuel cell vehicles.
  - Date of effect: 06/09/2011
  - Link:http://www.gpo.gov/fdsys/search/pagedetails.action?na=_companiesnav_granuleclassnav_agenciesnav&se=_DEPARTMENT+OF+TRAN

SPORTATIONfalse_RULEtrue_Transportation+Departmenttrue&sm=&flr=&ercode=&dateBrowse=&govAuthBrowse=&collection=&historical=true&st=collection%3AFR+and+content%3Ahydrogen&psh=&sbh=&tfh=&originalSearch=collection%3AFR+and+content%3Ahydrogen&sb=re&sb=re&ps=10&ps=10&bread=true&granuleId=2011-14291&packageId=FR-2011-07-06

- **78 FR 51381**
  - Title: Early Warning Reporting, Foreign Defect Reporting, and Motor Vehicle and Equipment Recall Regulations
  - Abstract: NHTSA is adopting amendments to certain provisions of the early warning reporting (EWR) rule and the regulations governing motor vehicle and equipment safety recalls. The amendments to the EWR rule require light vehicle manufacturers to specify the vehicle type and the fuel and/or propulsion system type in their reports and add new component categories of stability control systems for light vehicles, buses, emergency vehicles, and medium-heavy vehicle manufacturers, and forward collision avoidance, lane departure prevention, and backover prevention for light vehicle manufacturers. These amendments will also require light vehicle manufacturers to segregate their Service Brake EWR data into two new discrete component categories. In addition, NHTSA will require motor vehicle manufacturers to report their annual list of substantially similar vehicles via the Internet. As to safety recalls, we will now require certain manufacturers to provide a VIN-based recalls lookup tool on their Web site or the Web site of a third party; require the submission of recalls reports and information via the Internet; and require adjustments to the required content of the owner notification letters and envelopes required to be issued to owners and purchasers of recalled vehicles and equipment.
  - Date of effect: 21/10/2014
  - Link:http://www.gpo.gov/fdsys/search/pagedetails.action?sr=4&originalSearch=collection%3AFR+and+content%3Ahydrogen&st=collection%3AFR+and+content%3Ahydrogen&ps=10&na=_companiesnav_granuleclassnav_agenciesnav&se=_DEPARTMENT+OF+TRANSPORTATIONfalse_RULEtrue_Transportation+Departmenttrue&sb=re&timeFrame=&dateBrowse=&govAuthBrowse=&collection=&historical=true&granuleId=2013-19785&packageId=FR-2013-08-20

- **80 FR 2320**
  - Title: Federal Motor Vehicle Safety Standards; Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection.
  - Abstract: This document denies a petition for reconsideration of Federal Motor Vehicle Safety Standard (FMVSS) No. 305, “Electric-powered vehicles; electrolyte spillage, and electrical shock protection” from Nissan Motor Company (Nissan) requesting the use of a megohmmeter as an alternative measurement method for the electrical isolation test procedure. Further, this document adopts various technical corrections and clarifications to the regulatory text of FMVSS No. 305 that do not change the substance of the rule.
  - Date of effect: 16/01/2015
  - Link:http://www.gpo.gov/fdsys/search/pagedetails.action?sr=6&originalSearch=collection%3AFR+and+content%3Ahydrogen&st=collection%3AFR+and+content%3Ahydrogen&ps=10&na=_companiesnav_granuleclassnav_agenciesnav&se=_DEPARTMENT+OF+TRANSPORTATIONfalse_RULEtrue_Transportation+Departmenttrue&sb=re&timeFrame=&dateBrowse=&govAuthBrowse=&collection=&historical=true&granuleId=2015-00423&packageId=FR-2015-01-16

Documents

- **European Industrial Gases Association (EIGA)**

The EIGA documents related with this project are the following:

- **IGC Doc 15/06**
  - Title: Gaseous hydrogen stations
  - Abstract: This Code of Practice has been prepared for the guidance / best practices of designers and operators of gaseous hydrogen stations. Its application will achieve the primary objective of improving the safety of gaseous hydrogen station operation. It covers gaseous hydrogen, compression, purification, filling into containers and storage installations at consumer sites.
  - Restrictions: It does not include production, transport or distribution of hydrogen, nor does it cover any safety aspects in the use and application of the gas in technical or chemical processes.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc%2015%2006%20E.pdf

- **IGC Doc 75/07/E**
  - Title: Determination of Safety Distances
  - Abstract: The primary objective of this document is to define a philosophy to determine suitable separation distances for all equipment, pipe work and storage to allow member companies to develop consistent standards across the industry. The work process can be used for equipment required for the storage and processing of all industrial, medical and speciality gases. These may be in cryogenic liquid, pressurised liquid or gaseous phase.
  - Restrictions: Offsite transport and pipelines are not specifically addressed.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_75_07_E.pdf

- **IGC Doc 78/14/E**
  - Title: Leak Detection Fluids Cylinder Packages
  - Abstract: This publication applies to gas cylinder packages. It covers the selection and use of specialized leak detection fluids that are suitable for industrial gases including medical and food gases that have particular compatibility requirements. This publication may be used as a guideline when fluids are used for leak detection in other gas applications.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_78_14_Leak_Detection_Fluids_Cylinder_Packages.pdf

- **IGC Doc 80/14/E**
  - Title: Handling Gas Container Emergencies
  - Abstract: This practical guide is limited to handling emergencies involving pressurised gas containers including cylinders, small cryogenic vessels (up to 450 litres), drums, bundles, battery vehicles, MEGCs and tube trailers. This practical guide is intended for the use of technically competent and trained practitioners only. Before attempting to tackle an emergency situation, the methods and techniques to be employed should be discussed and agreed with the customer and/or emergency services representatives.
  - Restrictions: The management issues associated with setting up and operating an Emergency Service are outside the scope of this practical guide.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_80_14_Handling_Gas_Container_Emergencies.pdf

- **IGC Doc 81/06/E**
  - Title: Road vehicle emergency and recovery
  - Abstract: This document provides information about transported products, identification of the products and major design features of gases industry road transport equipment. The document also provides advice on product handling, vehicle recovery, preparing transport emergency plans, safety aspects and training. This document is intended for all persons within and outside the Gases Industry who may become involved in a Gases Industry Road Vehicle Emergency or Recovery operation. This may include Hauliers under contract,

Emergency Service personnel, vehicle recovery operators and members of other organisations (e.g. Environmental Agency). This document provides guidance on Road Vehicle Recovery, and on the following:

- product safety information;
- incidents where there is product release or potential product release;
- damage to pressure vessels/receptacles (e.g . Cylinders, Tubes and Bundles) and manifolds;
- prevention of fire; and,
- actual fires which may have occurred.

Road transport equipment included are Road Tankers (vacuum insulated), Road Tankers (insulated),Tank Containers, Multiple-element gas containers (MEGCs) and Battery Vehicles manufactured for the products covered in Section 4.0 when full, part full and nominally empty.

- Restrictions: Other equipment, cylinder vehicles and vehicles owned by customers and used to carry transportable receptacles are not included, but some of the principles and guidelines may be applicable. Gases Industry railway wagons are not included in the scope of this document, but the principles involved are generally similar.
- Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc%2081%2006%20E.pdf

- **IGC Doc 86/09/E**
  - Title: Gas cylinders and valves with restricted use in the EU
  - Abstract: The document covers lists of cylinders and valves with known restrictions on use in European Union Member States. In addition those cylinders and valves which are subjects of EIGA Safety Alerts, are included.
  - Restrictions: This document does not cover restrictions of a non-technical nature.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_86_09_E.pdf

- **IGC Doc 90/13/E**
  - Title: Incident/Accident Investigation and Analysis
  - Abstract: The purpose of this document is to provide guidance in respect of the key elements of the incident/accident investigation process, i.e.:
    - Collection of incident data;
    - Classification, identification of loss and loss potential;
    - Immediate and root cause analysis;
    - Identification of appropriate control/improvement measures;
    - Facilitate shared learning between departments and different company sites.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_90_13_Incident_Accident_Investigation_and_Analysis.pdf

- **IGC Doc 91/10/E**
  - Title: Use of pressure relief devices for gas cylinders
  - Abstract: This document specifies the use, when needed, of pressure relief devices according to the nature of the gas contained in the gas cylinder to protect the cylinder against over pressurisation. Material, design and testing of pressure relief devices are not part of this document.
  - Restrictions: Pressure relief devices for cryogenic vessels are excluded from the scope of this document.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_91_10_E_Use_of_pressure_relief_devices_for_gas_cylinders.pdf

- **IGC Doc 100/11/E**
  - Title: Hydrogen Cylinders and Transport Vessels
  - Abstract: This document describes industry experiences with hydrogen cylinders and transport vessels and provides a number of recommendations for the specification, manufacture, testing, maintenance and mounting of the cylinders and vessels.
  - Restrictions: new applications of hydrogen with working pressure more than 300 bar and using composite cylinders are not covered by this document.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_100_11_Hydrogen_Cylinders_and_Transport_Vessels.pdf

- **IGC Doc 106/03/E**
  - Title: Environmental issues guide
  - Abstract: This document provides guidance for operating and technical managers on the European legislation concerning the main environmental issues relevant to the Industrial Gases Industry. It also provides recommendations on the good practices used to control the impacts and to comply with the legislation. In all cases the relevant national legislation should consulted for the specific implementation in each country or region.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc%20106%2003%20E.pdf

- **IGC Doc 107/10**
  - Title: Guidelines on environmental management systems
  - Abstract: This document provides guidance on environmental management system implementation relevant to the Industrial Gases Industry.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_107_10_E.pdf

- **IGC Doc 108/14**
  - Title: Environmental Legislation applicable to Industrial Gases Operations within the EU
  - Abstract: This document provides guidance on the European legislation concerning the main environmental aspects relevant to the Industrial Gases Industry. In all cases the relevant national legislation should consulted for the specific implementation in each country or region.
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_108_14_Environmental_Legislation_applicable_to_Industrial_Gases_Operations_within_the-EU.pdf

- **IGC Doc 113/11/E**
  - Title: Environmental Impacts of Transportation of Gases
  - Abstract: The document concentrates on the environmental impact s of the main distribution method for gases –road transportation. This document does not give specific advice on health and safety issues, which shall be taken into account

before undertaking any activity. On these issues the relevant EIGA documents, and / or national legislation should be consulted for advice. This document is intended to serve as a guide for Industrial Gases transportation operations to assist in putting in place a formal environmental management system that can be certified by an accredited 3rd party verifier. It also aims to provide a guide for operating managers for identifying and reducing the environmental impacts of these operations.

- Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_113_11_Environmental_Impacts_of_Transportation_of_Gases.pdf

- **IGC Doc 134/12/E**
  - Title: Potentially Explosive Atmospheres EU Directive 1999/92/EC
  - Abstract: The EC Directive 1999/92/EC, which defines the minimum requirements to protect workers from potentially explosive atmospheres (ATEX 137A) came into force some years ago. This document was issued to facilitate and harmonize the interpretation and implementation among EIGA members of the required risk assessments and specifically the classification of areas where an explosive atmosphere can occur according to the directive and related standards. The scope includes handling and storage of flammable gases and liquids where an explosive atmosphere with air under atmospheric conditions might arise at industrial gases companies' plants.
  - Restrictions: It does not apply to the use of flammable medical gases or the risk arising in piping systems, cylinders and vessels with increased pressure. However it will also provide guidance on the storage of flammable gas cylinders in open air
  - Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_134_12_Potentially_Explosive_Atmospheres_EU_Directive_1999_92_EC.pdf.

- **IGC Doc 171/12/E**
  - Title: Storage of Hydrogen in Systems Located Underground
  - Abstract: This document addresses the safety issues that are specific to the storage of hydrogen in systems located underground. Although it is preferable that hydrogen storage

and related equipment is located above ground in a well ventilated area, this form of installation may be needed when it is beneficial to keep above ground areas free of equipment, such as may be the case for hydrogen vehicle refuelling stations. It covers the requirements specific to the installation of a hydrogen storage system in an underground space with top or side access, hereafter called a vault. It covers:

- liquid hydrogen storage and ancillary systems,
- compressed hydrogen storage composed of a single container, or multiple cylinders or tubes.

The document also provides requirements that are specific to the storage of liquid hydrogen in buried vessels. There are particular challenges with regards to the periodic inspection of buried gaseous storage systems and such installations are not addressed in this document.

- Restrictions: This document does not address the generic design, materials and construction aspects of hydrogen pressure vessels.
- Link:https://www.eiga.eu/fileadmin/docs_pubs/Doc_171_12_Storage_of_Hydrogen_in_Systems_Located_Underground.pdf

- **National Renewable Energy Laboratory (NREL)**

The documents related to this project that NREL provides are the following:

- **Pressure Relief Devices for High-Pressure Gaseous Storage Systems: Applicability to Hydrogen Technology**
  - Abstract: This report describes the function of the common types of pressure relief devices (PRDs) currently used in industry; examines several recent PRD failure incidents specifically involving hydrogen; reviews the applicable among others.
  - Link:http://www.nrel.gov/docs/fy14osti/60175.pdf

- **Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen; Workshop Proceedings**
  - Abstract: The U.S. Department of Energy (DOE) sponsored the Refueling Infrastructure for Alternative Fuel Vehicles: Lessons Learned for Hydrogen workshop to gather input on the role of refueling infrastructure in introducing alternative fuel vehicles (AFVs) and how lessons from past experiences can inform ongoing and future efforts to commercialize hydrogen vehicles. Infrastructure-related challenges include consumer convenience and refueling availability, fueling station siting and installation, permitting, liability, capital and operating costs, technological compatibility, and consumer acceptance. This document captures the highlights of the workshop's presentations and the major themes that emerged during discussion sessions.
  - Link: http://www.nrel.gov/docs/fy08osti/43669.pdf

- **Fuel Cell Technologies National Codes and Standards Development and Outreach**
  - Abstract: The fundamental purpose of this work is to support the safe deployment of hydrogen technologies. To achieve this objective codes and standards must be in place to protect public safety and any significant safety issues must be resolved. The work under this project has helped develop a national set of codes and standards to safely deploy hydrogen technologies.
  - Link:http://www.hydrogen.energy.gov/pdfs/progress13/viii_1_rivkin_2013.pdf

- **An overview of hydrogen safety sensors and requirements**
  - Abstract: Internationally, there is a commitment to increase the utilization of hydrogen as a clean and renewable alternative to carbon-based fuels. Hydrogen safety sensors are critical to assure the safe deployment of hydrogen systems; but, because there exists a broad range of sensor options, selecting an appropriate sensor technology can be complicated. Some sensor technologies might not be a good fit for a specific application. Facility engineers and other end-users, however, are expected to select the optimal sensor for their systems. Making informed decisions requires an understanding of the

general analytical performance specifications that can be expected for a given sensor technology. Although there are many commercial sensors, most can be classified into relatively few specific sensor types. Each specific platform has characteristic analytical trends, advantages, and limitations. Knowledge of these trends can guide the selection of the optimal technology for a specific application.

- Link:http://www.sciencedirect.com/science/article/pii/S0360319910009274

- **A National Agenda for Hydrogen Codes and Standards**
  - Abstract: This document contains a summary of the different codes and standards organizations as well as the different websites that concerns to hydrogen codes and standards.
  - Link: http://www.nrel.gov/hydrogen/pdfs/48306.pdf

For further information in the following link lot of hydrogen safety information could be found http://www.nrel.gov/hydrogen/pdfs/48306.pdf

- **Pacific Northwest National Laboratory (PNNL)**

The documents related to this project that PNNL provides are the following:

- **PNNL-18523 (2009)**
  - Title: Secondary Protection for 70 MPa Fueling - A White Paper from the Hydrogen Safety Panel
  - Abstract: In developing a 70 MPa fueling infrastructure, it is critical to ensure that a vehicle equipped with a lower service pressure fuel tank is never filled from a 70 MPa fueling source. Filling of a lower service pressure vehicle at a 70 MPa fueling source is likely to result in a catastrophic event with severe injuries or fatalities. The Hydrogen Safety Panel recommends that DOE undertake a two-step process to address this issue: 1. Perform an independent risk analysis of a 70 MPa dispenser filling a lower pressure vehicle tank and develop different approaches for prevention and mitigation to meet an acceptable level of safety. 2. Until such time as this analysis is complete and any recommended actions implemented, communicate the

potential risk to responsible parties and strongly encourage those parties to add a secondary layer of protection to the existing system of mechanically non-interchangeable nozzles/receptacles. This will reduce the probability of a pressure mismatch during this developmental phase for hydrogen fuel cell vehicles and infrastructure.

- Authors: SC Wiener and RA Kallman
- Link:http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18523.pdf

- **PNNL-23704 (2014)**
  - Title: Electronic Safety Resource Tools – Supporting Hydrogen and Fuel Cell Commercialization
  - Abstract: The PNNL Hydrogen Safety Program conducted a planning session in Los Angeles, CA on April 1, 2014 to consider what electronic safety tools would benefit the next phase of hydrogen and fuel cell commercialization. A diverse, 20-person team led by an experienced facilitator considered the question as it applied to the eight most relevant user groups. The results and subsequent evaluation activities revealed several possible resource tools that could greatly benefit users. The tool identified as having the greatest potential for impact is a hydrogen safety portal, which can be the central location for integrating and disseminating safety information. Such a tool can provide credible and reliable information from a trustworthy source.
  - Author: NF Barilo
  - Link:http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23704.pdf

ANNEX C

HRS comparative tables

1. Dispenser

Dispenser	Relevance	ANSI/CSA HGV 4.1	2015 International Fire Code
Cost	0,15	1,84	5
Amount of useful information	0,15	5	1,5
Safety	0,25	0	5
Operation	0,1	5	0
Construction	0,05	5	0
Testing	0,05	5	0
Working pressure 70 MPa	0,15	5	2,5
Working pressure 35 MPa	0,05	5	2,5
Multiple function dispenser	0,05	5	2,5
Total	**1**	**3**	**2,85**

Fig. ANNEX C-1: HRS dispensers' comparative table

2. Gas detectors

Gas detectors	Relevance	EN 13160-1	IEC 60079-29-1	IEC 60079-29-2	IEC 60079-29-3	IEC 60079-29-4	ISO 26142
Cost	0,15	5	2	1,86	2	3,04	4,21
Amount of useful information	0,15	0,5	5	5	5	5	3
Safety	0,2	2,5	0	0	0	0	0
Selection	0,15	2,5	0	5	0	0	0
Maintenance	0,1	2,5	0	5	0	0	0
Performance	0,1	2,5	5	0	0	5	5
Installation	0,06	2,5	0	5	5	0	0
Design	0,03	2,5	0	0	5	0	0
Construction	0,03	2,5	5	0	0	0	0
Testing	0,03	2,5	5	0	0	0	5
Total	**1**	**2**	**1**	**2**	**1,58**	**1,71**	**1**

Fig. ANNEX C-2: HRS gas connectors' comparative table

3. Safety

3.1 Explosive atmospheres safety

Explosive atmospheres safety	Relevance	EN 1127-1	EN 1127-2
Cost	0,15	2,14	5
Amount of useful information	0,15	3,5	5
Prevention methods	0,1	0	5
Protection methods	0,1	0	5
Hazardous situation identification	0,09	5	0
Hazardous situation assessment	0,09	5	0
Design measures	0,06	5	0
Construction measures	0,06	5	0
Design of equipment	0,05	0	5
Design of protective systems	0,05	0	5
Construction of equipment	0,05	0	5
Construction of protective systems	0,05	0	5
Total	**1**	**2**	**3,5**

Fig. ANNEX C-3: HRS explosive atmospheres safety comparative table

3.2 Fire safety

Fire safety	Relevance	NFPA 2	NFPA 221
Cost	0,15	3,81	5
Amount of useful information	0,15	3	3
Use/Handling	0,25	5	0
Storage	0,2	5	0
Installation	0,15	5	0
Design of fire walls	0,05	0	5
Constructions of fire walls	0,05	0	5
Total	**1**	**4**	**1,7**

Fig. ANNEX C-4: HRS Fire safety comparative table

4. Storage tubes

Storage tubes	Relevance	ASME BPVC-VIII-1	ASME BPVC-VIII-2	ASME BPVC-VIII-3	ASME STP-PT-005	ASME STP-PT-014	ASME STP-PT-021	NFPA 55	SAE J2579
Cost	0,15	0,42	0,42	0,39	4,99	5	4,17	4,26	3,45
Amount of useful information	0,15	3	3,5	3	3	4	5	1	4,5
Safety	0,15	0	0	0	0	0	0	5	0
Handling	0,1	0	0	0	0	0	0	0	5
Maintenance	0,1	0	0	0	0	0	0	0	5
Inspection	0,08	5	5	5	0	0	0	0	0
Design	0,05	5	5	5	5	0	0	0	5
Fabrication	0,05	5	5	5	0	0	0	0	5
Testing	0,05	5	5	5	0	5	5	0	5
Working pressure above 350 bar	0,1	5	5	0	2,5	2,5	2,5	2,5	2,5
Working pressure above 690 bar	0,02	5	5	5	2,5	2,5	2,5	2,5	2,5
Total	**1**	**2**	**2**	**1**	**1**	**1**	**1,93**	**1,84**	**3**

Fig. ANNEX C-5: HRS storage tubes comparative table

HRS comparative tables

1. Battery

Battery	Relevance	IEC 60255-27	ISO 6469-1
Cost	0,15	0,96	5
Amount of useful information	0,15	5	4
Safety	0,4	5	5
Working voltage starting from 0V	0,3	0	5
Total	**1**	**2,89**	**4,85**

Fig. ANNEX C-6: HFCV battery comparative table

2. Electric motor

Electric motor	Relevance	IEC 60255-27	ISO 6469-3
Cost	0,15	1,46	5
Amount of useful information	0,15	5	4
Safety	0,4	5	5
Working voltage starting from 0V	0,3	0	5
Total	**1**	**2,97**	**4,85**

Fig. ANNEX C-7: HFCV electric motor comparative table

3. Explosive atmospheres requirements

Explosive atmospheres requirements *(For non-electrical equipments)*	**Relevance**	**EN 13463-1**	**EN 13463-2**	**EN 13463-3**	**EN 13463-5**	**EN 13463-6**	**EN 13463-8**
Cost	0,15	2,61	3,62	5	2,46	5	3,75
Amount of useful information	0,15	5	3,5	2	3,5	2	3,5
Design	0,07	5	0	0	5	0	5
Construction	0,07	5	0	0	5	0	5
Testing	0,07	5	0	0	0	0	5
Marking	0,07	5	0	0	0	0	5
Construction of flow restricting enclosures	0,07	0	5	0	0	0	0
Testing of flow restricting enclosures	0,07	0	5	0	0	0	0
Construction of protection flameproof enclosure	0,07	0	0	5	0	0	0
Testing of protection flameproof enclosure	0,07	0	0	5	0	0	0
Design of monitoring devices	0,07	0	0	0	0	5	0
Application of monitoring devices	0,07	0	0	0	0	5	0
Total	1	2,54	1,77	1,75	1,59	1,75	2,49

Fig. ANNEX C-8: HFCV explosive atmospheres requirements comparative table

4. Fuel cell stack

Fuel cell stack	Relevance	ANSI/CSA FC 3	ASME PTC 50	CGA PS-31	IEC 62282-2	IEC 62282-5-1	IEC 62282-7-1	NFPA 853	SAE J1766	SAE J2572	UL - 2262
Cost	0,15	0,05	0,47	5	0,16	0,13	0,16	1,04	0,56	0,56	0,22
Amount of useful information	0,15	1,5	4	1,5	5	5	5	2	4	3,5	2
Safety	0,15	2,5	0	0	5	0	0	5	5	0	2,5
Fire prevention	0,13	0	0	0	0	0	0	5	0	0	0
Fire protection	0,13	0	0	0	0	0	0	5	0	0	0
Performance	0,1	2,5	5	0	5	0	5	0	0	0	2,5
Cleanliness	0,1	0	0	5	0	0	0	0	0	0	0
Construction	0,03	2,5	0	0	0	5	0	0	0	0	2,5
Assembly	0,03	2,5	0	0	0	0	5	0	0	0	2,5
Testing	0,03	2,5	5	0	0	5	5	0	0	5	2,5
Total	**1**	**1,08**	**1,32**	**1,48**	**2,02**	**1,07**	**1,57**	**2,51**	**1,43**	**0,76**	**1,18**

Fig. ANNEX C-9: HFCV fuel cell stack comparative table

5. Fuel processor subsystem

Fuel processor subsystem	Relevance	SAE J2616	SAE J2617
Cost	0,15	5	5
Amount of useful information	0,15	5	5
Performance	0,3	5	5
Design	0,1	5	5
Evaluation of energy system	0,15	5	0
Evaluation of electric system	0,15	0	5
Total	**1**	**4,25**	**4,25**

Fig. ANNEX C-10: HFCV fuel processor subsystem comparative table

6. Gas detectors

Gas detectors	Relevance	EN 13160-1	IEC 60079-29-1	IEC 60079-29-2	IEC 60079-29-3	IEC 60079-29-4
Cost	0,15	5	2,51	1,86	2,51	3,04
Amount of useful information	0,15	0,5	5	5	5	5
Selection	0,2	0	0	5	0	0
Handling	0,15	2,5	0	5	0	0
Maintenance	0,13	0	0	5	0	0
Performance	0,1	2,5	5	0	0	5
Design	0,03	2,5	0	0	5	0
Construction	0,03	0	5	0	0	0
Installation	0,03	2,5	0	5	5	0
Testing	0,03	0	5	0	0	0
Total	**1**	**1,6**	**1,93**	**3,58**	**1,43**	**1,71**

Fig. ANNEX C-11: HFCV gas detectors comparative table

7. Hydrogen components installation

Hydrogen components installation	**Relevance**	**ANSI/CSA HGV 3.1**	**International Fuel Gas Code**	**NF M58-003**	**SAE J2579**
Cost	0,15	0,98	3,74	3,8	5
Amount of useful information	0,15	4	2	3	5
Safety	0,2	5	0	0	0
Handling	0,1	0	0	0	5
Performance	0,1	5	5	0	5
Maintenance	0,1	0	0	0	5
Design	0,05	0	5	0	5
Construction	0,05	0	0	0	5
Installation	0,05	0	5	5	0
Testing	0,05	0	0	0	5
Total	**1**	**2,25**	**1,86**	**1,27**	**3,75**

Fig. ANNEX C-12: HFCV hydrogen components installation comparative table

8. Hydrogen storage

Hydrogen storage	Relevance	ASME BPVC-VIII-1	ASME BPVC-VIII-2	ASME BPVC-VIII-3	ASME STP-PT-014	ASME STP-PT-021	ISO 15869	NFPA 55	SAE J2579
Cost	0,15	0,42	0,42	0,39	5	4,17	1,46	4,26	3,45
Amount of useful information	0,15	3	3,5	3	4	5	3,5	1	4,5
Safety	0,25	0	0	0	0	0	0	5	0
Handling	0,15	0	0	0	0	0	0	0	5
Maintenance	0,1	0	0	0	0	0	0	0	5
Inspection	0,05	5	5	5	0	0	0	0	0
Design	0,05	5	5	5	0	0	2,5	0	5
Construction	0,05	5	5	5	0	0	2,5	0	5
Testing	0,05	5	5	5	5	5	2,5	0	5
Total	**1**	**1,51**	**1,59**	**1,51**	**1,60**	**1,63**	**1,12**	**2,04**	**3,19**

Fig. ANNEX C-13: HFCV hydrogen storage comparative table

9. Pressure relief devices

Pressure Relief Devices	**Relevance**	**ANSI/CSA HGV 3.1**	**CGA S-1.1**
Cost	0,15	2,51	5
Amount of useful information	0,15	5	4
Safety	0,2	5	0
Selection	0,15	0	5
Handling	0,1	0	5
Maintenance	0,08	0	5
Performance	0,07	5	0
Construction	0,05	0	5
Testing	0,05	0	5
Total	**1**	**2,48**	**3,50**

Fig. ANNEX C-14: HFCV pressure relief devices comparative table

10. Refueling connection devices

Refueling Connection Devices	**Relevance**	**ISO 16380**	**ISO 17268**	**SAE J2600**
Cost	0,15	2,19	2,5	5
Amount of useful information	0,15	5	4	2,5
Design	0,06	5	5	5
Testing	0,02	0	0	5
Safety	0,15	0	5	0
Construction	0,05	5	0	0
Operation	0,12	0	5	0
Performance	0,1	5	0	0
Working pressure 70 MPa	0,15	0	5	5
Working pressure 35 MPa	0,05	5	5	5
Total	**1**	**2,38**	**3,63**	**2,53**

Fig. ANNEX C-15: HFCV refueling connection devices comparative table

11. Refueling connection devices

Safety	Relevance	EN 1127-1	EN 1127-2	ISO 6469-2	ISO 6469-3	ISO 23273	ISO/TR 15916	NFPA 2	SAE J2578
Cost	0,15	1,06	2,47	5	2,16	5	1,07	3,50	2,83
Amount of useful information	0,15	4	5	2,5	2,5	2	2	1,5	3,5
Explosion prevention	0,1	0	5	2,5	2,5	2,5	2,5	2,5	0
Explosion protection	0,1	0	5	2,5	2,5	2,5	2,5	2,5	0
Identification of hazards	0,08	5	0	0	0	0	0	0	0
Assessment of hazards	0,08	5	0	0	0	0	0	0	0
Design of measures	0,06	5	0	2,5	2,5	2,5	2,5	0	0
Construction of measures	0,06	5	0	2,5	2,5	2,5	2,5	0	0
Design of equipment	0,04	0	5	0	0	0	0	0	5
Construction of equipment	0,04	0	5	0	0	0	0	0	5
People safety	0,06	0	0	5	5	5	2,5	5	0
Environment safety	0,02	0	0	5	0	5	2,5	2,5	0
Fire safety	0,02	0	0	0	0	0	0	5	0
Fuel cell	0,02	2,5	5	0	0	5	5	0	5
Storage	0,02	2,5	5	0	0	0	5	5	5
Electric system	0,02	2,5	5	5	5	0	0	0	5
Total	**1**	**2,31**	**2,82**	**2,43**	**1,9**	**2,35**	**1,66**	**1,8**	**1,65**

Fig. ANNEX C-16: HFCV safety comparative table

ANNEX D

	23/02 - 27/03	9/03 - 13/03	16/03 - 20/03	23/03 - 27/03	30/03 - 3/04	7/04 - 10/04	13/04 - 17/04	20/04 - 24/04	4/05 - 7/05	11/05 - 13/05	18/05 - 22/05	26/05 - 29/05	1/05-5/05	8/05 - 12/05
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Introduction to hydrogen world	■	■												
Why does this project exist?		■	■											
Project objectives		■	■											
Market research		■	■											
Project scope		■	■											
F. knowledge of hydrogen properties and hazards			■	■										
Hydrogen fears				■	■	■	■	■	■	■				
Standards, codes research				■	■	■	■							
Documents research					■	■	■							
International regulations research							■	■						
European regulations research							■	■						
USA regulations research							■	■						
French regulation research							■	■						
Survey								■	■	■	■	■		
Canadian regulation research									■					
Spanish regulation research									■					
Hydrogen delivery, HRS and HFCV description									■	■				
HRS and HFCV components description										■				
Efficient classification										■	■			
Website creation												■		
Environmental impact													■	
Temporal planning and project costs													■	
Conclusions													■	
Memory edition													■	■
Presentation preparation														■

Fig. ANNEX D-1: Gantt graph

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Chapter 1: Introduction

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