The role of hydrogen in the energy transition

Hydrogen is a key energy vector for achieving climate neutrality through the decarbonization of the global economy proposed by the European Union for 2050. Its properties make it a renewable element capable of providing safe, economically competitive and CO^2 emission-free energy, as long as reference is made to renewable hydrogen. It is the most abundant element in the universe and, therefore, an inexhaustible source of energy.

The amount of energy of one kilogram of hydrogen is at least two point five times greater than one kilogram of any fossil fuel. Specifically, 1 kg of H^2 is equivalent to the energy of 2.5 kg of CH^4 (methane, NG), 2.8 kg of gasoline or diesel, 6.5 kg of NH^3 (ammonia), 6.0 kg of Met-OH (methanol) and 4.5 kg of Et-OH (ethanol). [Figure 1]

However, although hydrogen represents a promising green solution for the energy transition, different technical barriers such as its storage and supply still need to be overcome if it is to be widely used in both stationary and automotive applications. [Figure 2]

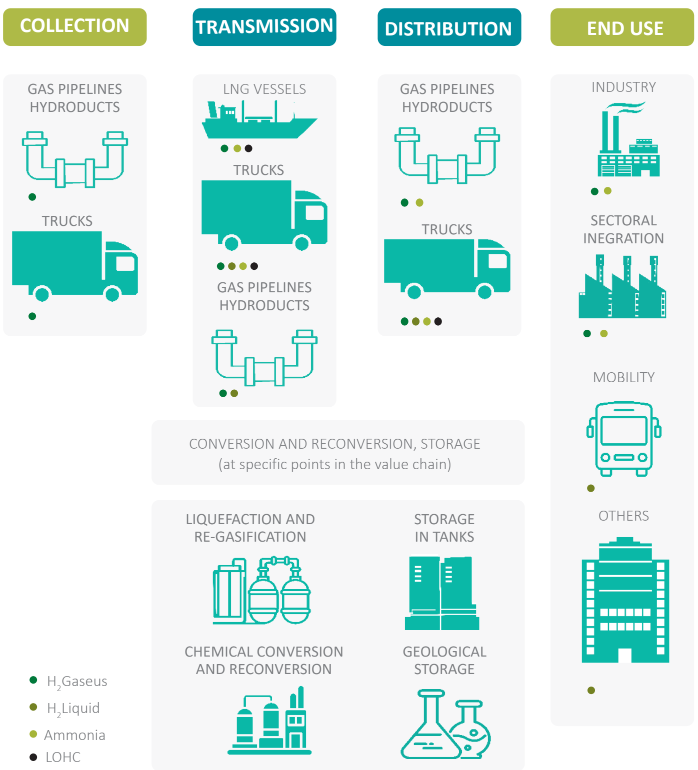

Figure 2.Hydrogen Logistic diagram

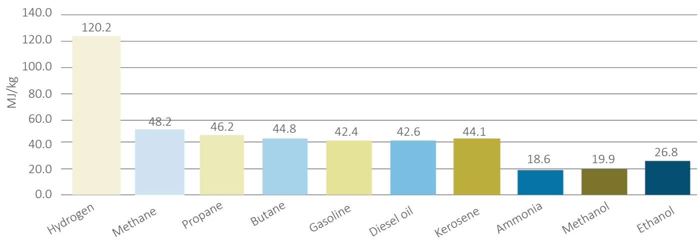

Figure 1. Lower calorific power of different fuels.
Source: Pubchem. [3] Compiled in-house.

Due to the low density of hydrogen gas (0.071 g/L at 0 °C and 1 atm), its storage requires large volumes and is associated with high pressures and low temperatures, which is a challenge both for storage and distribution infrastructures, as well as for the materials that constitute them. [Table 1]

Pressure (MPa)	0.101325	200	350	700
Volume (L)	11934	68.4	42.7	58.7

Tabla 1: Necessary volume for storing 1kg of hydrogen at 20ºC depending on pressure.

One of the main obstacles to the growth of the hydrogen economy is the safety incidents that can occur in the supply chain. Hydrogen can damage storage tank construction material, piping, valves and other equipment through the embrittlement mechanism induced by hydrogen gas, even leading to leaks. In order to avoid oversizing and loss of cost-effectiveness, advanced materials with increased resistance to hydrogen embrittlement and enough mechanical strength to withstand current and future working pressures are required.

One promising material for the hydrogen economy is stainless steel: recyclable, low maintenance and with an extensive range of grades that allow a wide window of properties. Compared to other types of metallic alloys, stainless steels with an austenitic structure have a high resistance to hydrogen embrittlement. However, such steels can become vulnerable if they are not sufficiently stable against martensitic transformation during processing. Therefore, in hydrogen gas environments, a commonly used material is 316L austenitic stainless steel, as it is sufficiently stable against such transformation [Figure 3].

However, its mechanical strength is too low to withstand high working pressures. Therefore, strategies are needed to increase the mechanical performance of these steels without detriment to their resistance to hydrogen embrittlement.

In response to this need, ACERINOX EUROPA is carrying out different R&D projects with the aim of developing new stainless steels for the manufacture of pressurized hydrogen containers with significant improvements in their mechanical properties (thus increasing the pressure conditions and/or reducing the weight of the tanks), corrosion behaviour and resistance to embrittlement phenomena, providing advanced levels of safety and durability.

H_2EPA: Stainless steel pressure containers.

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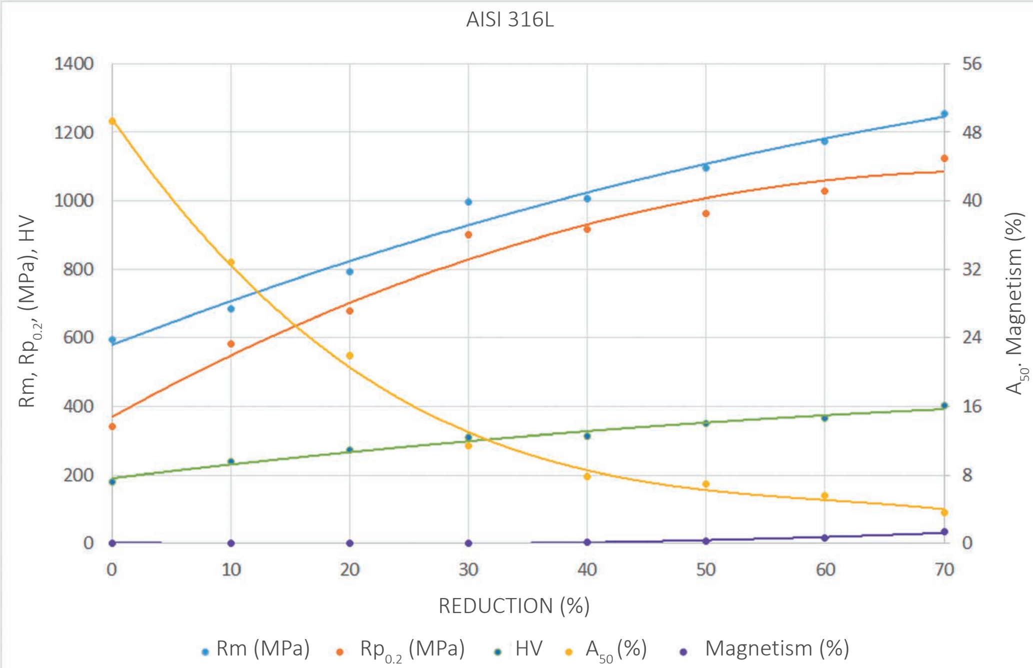

Figure 3: Properties of AISI 316L

ACERINOX EUROPA, in cooperation with TECNALIA Research and Innovation, the University of Cadiz and the University of Oviedo, is developing the H2EPA Project, with the aim of experimentally developing new formulations of stainless steels with application in pressurized hydrogen containers.

This project evaluates different conventional stainless steels such as AISI 316L, 904L, 430 and 2205, for their use in applications in contact with H^2 with the aim of obtaining exclusive knowledge for high demand applications.

For this purpose, an exhaustive analysis of the behaviour of these materials in presence of hydrogen and the effects on the microstructure and composition in terms of diffusion and hydrogen embrittlement is being carried out. Besides, mathematical models for the design of chemical compositions that allow optimizing the hydrogen embrittlement resistance of these steels, together with an improvement of mechanical properties, are being applied.

HYADES: I Industrial research for the formulation of new stainless steels with advanced properties for application in pressurized hydrogen environments.

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ACERINO EUROPA, with subcontracts from TECNALIA Research and Innovation, IDONIAL Foundation and the University of Cadiz, is working on the HYADES project, whose main objective is to evaluate modifications based on AISI 316L with micro-additions of elements that allow to obtain hydrogen traps in the microstructure and improvements in the mechanical properties for applications in pressurized hydrogen environments.

To this end, a comprehensive study is being carried out on the influence of the different alloying elements on the key microstructural parameters and characteristics for applications in H^2 storage tanks, as well as the influence of the steelmaking processes on both the microstructure of the new steels developed and the characteristics of the precipitates obtained.