Hydrogen Mobility: Chances and Challenges

Bachelorarbeit

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1. INTRODUCTION

"Yes, my friends, I believe that one day water will be used as a fuel
and that the hydrogen and the oxygen which constitute it,
will provide an inexhaustible source of heat and light
of an intensity unknown to petroleum."
Jules Vernes, The Mysterious Island, 1874

1.1. Relevance of the topic

At the COP 21 (Conference of the Parties) meeting in Paris in 2015, 195 countries concluded an agreement committing themselves and the European Union to reduce their greenhouse gas emissions to stabilize global warming due to various human activities [1]. In the long term, the objective is to achieve climate neutrality (i.e. to ensure that no more CO_2 is produced than the earth is able to absorb, via the oceans or forests) [1]. Besides, achieving such deep decarbonization will require a radical transformation of the global energy system [2].

Used for years in the oil and chemical industries, hydrogen is beginning to find its place as an important building block to solving future energy transition challenges in a world characterized by the growing development of renewable energies [3]. This gas is increasingly emerging as a clean alternative fuel and an effective way to decarbonize different sectors of the economy and facilitate the integration of renewable energy.

Around 70 million tons of hydrogen are used today, mostly in oil refining and for the production of fertilizers [4]. The demand for hydrogen, which has grown more than threefold since 1975 [4], continues to rise and could increase tenfold by 2050 [1]. However, the global hydrogen consumption is still low, representing less than 2% of global energy [5]. But according to the Hydrogen Council, this consumption could reach 25% by 2050 [5].

For it to make a significant contribution to clean energy transitions, hydrogen also needs to be adopted in sectors where it is almost absent at the moment, such as transport, buildings and power generation [4]. Therefore, the number of countries with policies that directly support investment in hydrogen technologies is increasing, along with the number of sectors they target (Figure 1) [4]. These public policy actions underscore the importance many believe hydrogen has in the future of the industry and transportation systems.

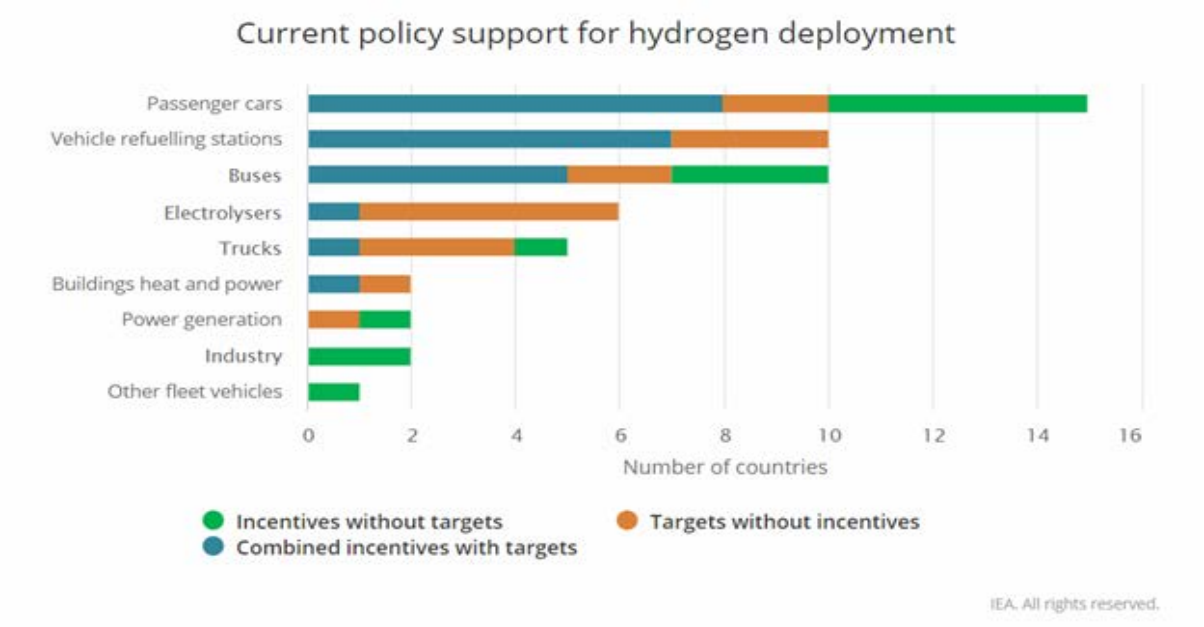

Figure 1: Current policy supply for hydrogen deployment [4]

Hydrogen represents in the transport sector one of three main options for low-carbon mobility alongside biofuels and battery electric vehicles [5]. However, its suitability differs between the various means of transportation and reflects the varied nature of the transport sector that covers land, sea, and air, plus freight and passengers, as shown in Figure 2 [6]: Nearly half of global transport energy demand is from light-duty vehicles and by 2050 the amount of passenger cars around the world is predicted to increase from 1 billion to 2.5 billion [6].

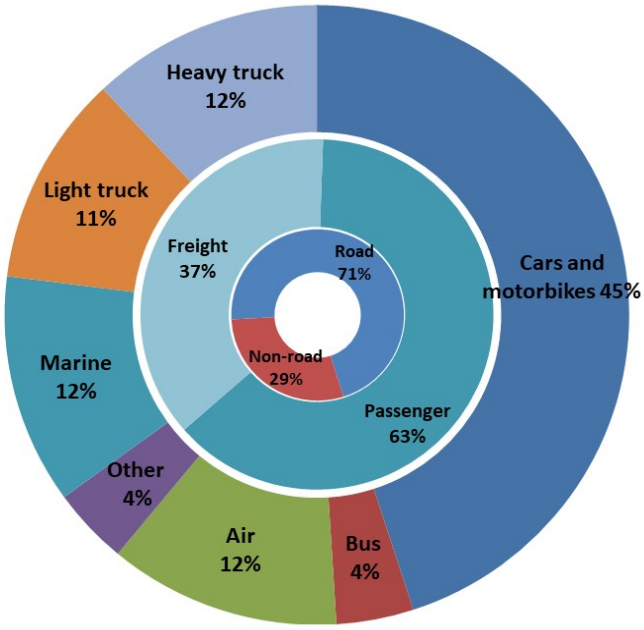

Figure 2: Breakdown of energy usage in the transport sector globally in 2015 [6]

In fact, to meet the growing demand in transport and meet the reduction targets of the world's greenhouse gas emissions by 2050, major technological innovations are necessary with regard to the passenger car (engine, structure, accessories, etc.) and its use.
Thus, the passenger vehicles are potential candidates for hydrogen mobility, because they commonly operate on fixed routes or within fixed regions and are fueled from a centralized station [7].
In addition, with their long autonomy and fast charging time, hydrogen fuel cell vehicles are attracting a growing number of local authorities, passenger cars manufacturers or fleet managers, station or logistics platform operators. They offer a tempting alliance between the comfort of use, continuity of service and participation in the fight against air pollution.
However, although the use of hydrogen in fuel cell vehicles (which allow for better energy conversion efficiency and zero emission of gaseous pollutants) is the ultimate goal of sustainable mobility, much attention needs to be devoted to a transition technology with the use of hydrogen as fuel for fueling internal combustion engines. In this context it is important to note that replacing other fuels like gasoline with hydrogen means that the car does not pollute the air [8].
Another promising way of using hydrogen is in hybrid electric vehicles. This technology leaves a " considerable opportunity for improving the fuel economy of the light-duty vehicle fleet without a switch to a radical new technology " [8]. Nevertheless, it is clear that these solutions must overcome many obstacles standing in the way of commercialization of hydrogen as vehicles' fuel.

1.2. Thesis outline

This research combines empirical and theoretical approaches and has been organised in the following way: Chapter 2 provides the reader with a complete overview of the methods of production, storage and transport of hydrogen as an energy source, and addresses its safety related issue.
In the third, fourth and fifth chapters, the paper focuses on the differences between the diverse uses of hydrogen in the automotive industry, reflects the current technological progress in this sector through the different vehicle models on the market, and underlines the importance and the role of FCEVs and PHEVs. Hydrogen ICEVs will only be described as a technology that existed for a short period of time but is now being withdrawn by car manufactures.
Chapter 6 examines the main question addressed in this paper: How do alternative drive systems, primarily battery electric and hydrogen fuel cell vehicles, compare in costs and performance? A comparison of energy costs is therefore the main part of this chapter, followed

by a review of a conducted study which not only analyses the current TCO of FCEVs but also compares the different powertrains like BEVs, ICEVs or PHEVs in terms of TCO and provides a prognosis of the market share of each vehicle type in the future.
Chapter 7 addresses the question of public acceptance of hydrogen vehicles based on a study conducted on this subject.
The last parts of this paper deal with the current barriers that limit hydrogen mobility and try to identify the technological accomplishments that encourage the commercial development of hydrogen FCEVs and PHEVs by reducing the technology's costs for example.

10. CONCLUSIONS AND OUTLOOK

Dominated by fossil fuels (oil, gas, and coal), our current energy system poses a double threat to our environment: it exposes the planet to the depletion of its natural reserves and contributes to the greenhouse effect. If we want sustainable development for future generations, it becomes necessary to diversify our energy production methods.

The most obvious finding to emerge from this study is that hydrogen, as an energy carrier, is attracting an increasing interest in the debate on energy transition, particularly for mobility. Indeed, it can be produced from renewable energies and then restore this energy in the form of electricity via a fuel cell, without polluting emissions and for a cost that has fallen sharply in a few years. This form of electricity storage is thus similar to battery storage, whose costs have also dropped sharply and which is already shaking up the market for conventional internal combustion engine vehicles. In addition, if produced in a sustainable way, hydrogen has the potential to increase the use of renewable energy in Europe, as it could be used as an energy storage means and thus facilitate the large-scale introduction of resources such as wind or solar energy. In countries with highly carbon-intensive electricity (e.g. Germany), BEVs alone will not solve the problem of decarbonizing transport, while FCEVs could both reduce transport-related emissions and balance intermittent electricity production from renewable sources.

Furthermore, even if hydrogen technology is still relatively expensive compared to the battery's technology, it offers similar performances to those of internal combustion engines in terms of recharge time and autonomy. These advantages make it attractive for certain uses, particularly for heavy vehicles (trains, trucks, buses, construction machinery, certain ships or aircraft) and for part of the automotive market. It can also easily hybridize with battery storage (rechargeable hydrogen vehicle) to provide high efficiency for short trips.

In other words, the hydrogen sector is taking off. The consumer will sooner or later - depending on the accomplishments made in this field - have a choice of a wide range of charging options depending on the type of vehicle: Internal combustion engine or hydrogen, which can be quickly recharged but only at petrol stations; battery, which can be recharged slowly but during the night at home or during parking at a charging station for example; or hybrid, which offers both options.

Thus, the border between the different market segments will depend on not only potential new technological breakthroughs and investments for each segment, but also on the ability to create synergies between sectors. The challenges here are multiple: technical, political, socio-economic, climatic and health.

Germany and Europe have assets in this new industrial sector, whose foreseeable market is worth billions of euros, and which can contribute to our energy independence and environmental transition. It is therefore important, in addition to the ongoing deployment of

the battery sector, to maintain the R&D effort, support experiments in this field, and strengthen coordination between stakeholders to seize the opportunities offered by this new hydrogen mobility sector.