Hydrogen Acceptance in The Portuguese Transport Sector

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The context of this work is inserted in the adoption of hydrogen as technology in transport, in the Portuguese and European markets, assessing the level of acceptance of this technology in the Portuguese transport sector, to identify the likelihood of investments, major blocking points to its implementation and to understand what are the chances of a successful adoption to occur. A series of interviews targeting transport company's decision makers and surveys to workers of the same companies were conducted, enabling to receiving feedback from the various corporate levels of the industry. Results found a strong acceptance level of H_2 from companies and workers. Companies have a reasonable level of knowledge about H_2, recognize its possible role in the future of transport, and are considering investing and implementing it. Hydrogen is likely to have a strong implementation in the country, provided that a strong political support and other favourable conditions are in place.

Keywords: Hydrogen, Transport, Portugal, TCO, Acceptance

1 INTRODUCTION

As the world is shifting towards the reduction of pollutant emissions, technology advances have been key in developing sustainable alternatives in the various sectors of our society: Industrial, Transport, Energy, among others.

While there are several emission agreements in place in the world, two stand out as the most important and global, which are the Kyoto Protocol and the Paris Agreements [1], [2]. The Kyoto Protocol was signed in 1997 by 37 countries, including the EU countries, encompassing an emissions reduction target of 5% compared to 1990 levels. The Paris Agreement, signed in 2015, was the first legally binding global climate agreement to exist, setting a framework of measures, with specific goals such as limiting global warming to 2 ºC, peaking global emissions as soon as possible, and reaffirming that developed countries should take the lead in providing financial assistance to less endowed and more vulnerable countries.

The effects of the Paris Agreement are already visible, with the surge of new low carbon solutions and technologies that are starting to significantly reduce emissions. One of such solutions in question is

hydrogen, a colourless gas, discovered in 1766 by Henry Cavendish [3], considered the most abundant element in the universe. It can be produced using only electricity and water, and as its use creates almost no emissions, it is seen as a serious candidate to power the world in the future, due to its low carbon footprint and versatility. As such, this work will focus on analysing the early adopters of H_2, measure the levels of acceptance and willingness to adopt of Portuguese companies in the transportation sector.

2 Literature Review

There are several studies that aim to understand who are the first early adopters of Fuel cell vehicles [4]–[6]. Hardman (2019), in its analysis concludes that Fuel Cell Electric Vehicles (FCEV) buyers will be typically male, middle aged, high income, highly educated and with more than one vehicle [5]. For Fuel cell Buses and Trucks, the situation is different, as most of these vehicles are owned by companies. Companies operating buses are often regarded as the best candidates for early adopters, due to the fact that they usually have small/medium sized fleets, have their own maintenance shops and crews, and can be served by a single HRS. This can be seen in multiple cities in Germany and Japan, where bus companies are increasingly growing small FCEB fleets[7], [8]. As for Heavy-duty truck companies, the adoption might take longer, as there aren't enough HRSs yet to allow for long distance, although smaller trucks or local fleets, like garbage disposal and maintenance, might be fit for an earlier hydrogen implementation.

A study conducted in Spain by Diego Iribarren in 2015 [9] showed that people are willing to accept hydrogen as a key player in the transport sector and also on the energetic market. Around 30% of participants answered that they weren't familiarized with the concept of hydrogen. The main barriers for H_2 implementation identified were the cost of vehicles and the availability of hydrogen. Christian Oltra et al. (2017), in his work based on a questionnaire in seven countries, found that the view of respondents on Fuel cells Vehicles (FCEV) was positive, with 63% considering it a good, or very good option. Moreover, 78% also supported the substitution of conventional buses with FCEBs, although at the same time participants reported a low likelihood of buying FCEVS. The authors also found that public acceptance for hydrogen technologies was high, even more so in younger generations and that less than half of the of participants weren't aware of the possibilities of hydrogen in energy production and storage.

3 DATA AND METHODS

With the goal of assessing the willingness to adopt H2 and the implementation possibilities of hydrogen in the Portuguese road transportation industry, this work will focus on two different elements: a set of interviews targeting decision makers in key companies of the Portuguese transport industry, and a questionnaire that surveyed workers of such companies who may or already work with hydrogen directly.

Case Study

In the process of data gathering, eight companies were part of the study, collaborating by performing enquiries and interviews. In Table 1 are presented the companies that were part of this study. The interviews were directed at company's decision makers, and the interviews at workers of the same companies.

Table 1: Companies interviewed categorized by city

Interview #	Organization	City	Interview	Questionnaire
	National Association of transportation of goods			
1	ANTRAM	Lisboa	Remotely	Remotely
	Passenger transport companies			
2	STCP	Porto	Remotely	Remotely
3	Carris	Lisboa	Remotely	Remotely
4	Cascais Próxima	Cascais	Presencially	Remotely
5	Rodoviária de Lisboa	Lisboa	Remotely	Remotely
	Trucking companies			
6	Patinter	Mangualde	Remotely	Presencially
7	Luís Simões	Loures	Presencially	Remotely
	Infrastruture			
8	PRF Gas solutions	Leiria	Remotely	Remotely

Questionnaire

The purpose of the questionnaire was to evaluate the acceptance levels of hydrogen among workers of transport and mobility industries, as they are or will be the early users of this technology. The survey was composed by a total of 28 questions, split into four different sections: participants socio-economic profile, knowledge on hydrogen technologies, opinion towards H_2 and main advantages/disadvantages of this technology. It took 6 minutes to fill. It was carried out online via google forms and 109 answers were collected between the 16th of September and 26th November 2021.

Interviews

In total 8 interviews were made during this study including three bus operating companies, two freight truck companies, a company that produces and instals hydrogen equipment and a national trucking association.

A script for the interviews was used, composed of 26 questions open answer questions divided in 4 categories: Company sustainability, hydrogen technology knowledge, hydrogen in the transport sector and adoption and implementation by the company.

competitive.

4 RESULTS

Survey analysis

Participant characterization

In Table 2, participant's age and corresponding gender are presented.

Table 2: Participant's gender and corresponding age

Gender	18-25	25-40	40-60	+60	Total (%)
Female	0,9	2,7	8,0	0,0	11,6
Male	1,8	33,0	48,2	4,5	87,5
I prefer not to say	0,0	0,0	0,9	0,0	0,9
Total (%)	2,7	35,7	57,1	4,5	100,0

Most of the respondents were male, which is common in this market. In terms of age, the majority were between 40 and 60 years old, which indicates a high level of career longevity.

Participants were then asked if they had already worked with hydrogen, technologies and what was the context of such involvement with 50% of the respondents

Table 3 : Question 18: Rate the level of safety you attribute to each powertrain option

Level of Safety	H2	Petrol	Diesel	LPG	LNG	Lithium Bateries	Etanol	
Very Unsafe	2,75	6,42	3,64	6,36	2,94	4,76	9,35	Percentage %
Unsafe	11,01	17,43	13,64	23,64	18,63	18,10	22,43	
Neutral	42,20	30,28	29,09	25,45	31,37	35,24	42,06	
Safe	38,53	40,37	41,82	40,91	42,16	37,14	22,43	
Very safe	5,50	5,50	11,82	3,64	4,90	4,76	3,74	
% Total	100	100	100	100	100	100	100	

stating they worked with H_2 in a public transport/bus driver context. Furthermore, respondents also worked in the infrastructure production and management area (25%) and in investigation in the transportation sector (25%).

Regarding training received, only 15% of the workers that responded to the survey stated they had a training regarding H_2. before. In another question, when asked if they felt the necessity of receiving training, 75% of the answers were positive, meaning that almost every worker that had no training about H_2, was interest in receiving training and acquiring information about the technology. Those who received training, learned mainly about the advantages and disadvantages of the use of hydrogen, risks and dangers associated with it and the concepts about how the technology works, as seen in Figure 1.

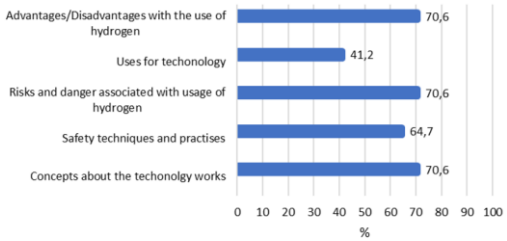

Figure *1: Question 15: What have you learned in your trainings about hydrogen and its uses?*

Table 3 presents the results for the safety level attributed to each power source for vehicles. As it can be verified, LPG and Ethanol were considered the least safe options, with around 30% in both cases saying these options were unsafe and very unsafe, while Lithium batteries, Diesel and H_2 were considered the safest. In categories where participants could be less informed as in the cases of hydrogen and ethanol, there was a tendency for people to choose the neutral option (42,20% and 42,06%), pointing towards a general lack of knowledge about these technologies.

Respondents identified, as seen in Figure 2 the lack of infrastructure as the main barrier for a successful implementation with the majority choosing this option (78,9%), while Price (44,7%), lack of government financing (36,8%) and lack promotion of the technology (39,5%) were seen as major obstacles to an effective implementation of the technology.

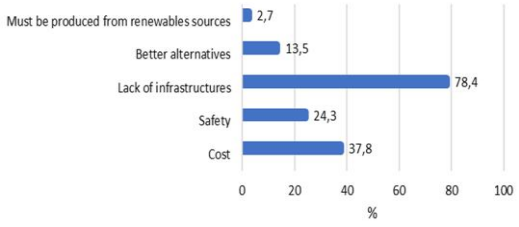

Figure *2: Question 24: What are the main disadvantages of hydrogen?*

Regarding the probability of the companies to buy hydrogen powered vehicles in the Future, it is possible to see in Figure 3, that

approximately 69% of the participants consider that the companies they work in will likely acquire FCEVs in the future (answers 4 - likely and 5 – very likely). This indicates respondents see transportation companies as the most likely adopters of this new technology. A reason for this could be the perception from participants that companies have the financial means to invest and efficiently use a small fleet of FCEV.

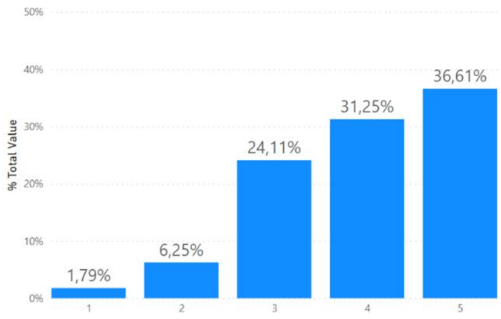

Figure *3: Question 28: How likely is your company to buy FCEVs in the future?*

Interview analysis

The analysis of the responses was organized around seven different topics: Environment and sustainability, Hydrogen's early adopter, Similarities with the electric situation, Views and opinions on hydrogen, Supporting the implementation of hydrogen in transport, Obstacles and Safety concerns. The main conclusions drawn from the interviews are presented in Table 4.

Environment and sustainability

In terms of environment and sustainability companies seem to be engaged in implementing more sustainable measures, being even open to support higher costs to achieve this goal. Constant fleet renewals and substituting diesel buses with lower emission options were the most referred aspects with one of the bus operating companies referring that 80% of their fleet was powered by natural gas, 5 % electric, and Eco driving was often referred as an implemented measure. Natural gas vehicles were identified as a short-to-midterm solution for the decarbonization of transport, as they allow for a substantial reduction compared to diesel, but rely on fossil fuels, as pointed by multiple interviewees.

Hydrogen's early adopters

Every decision maker interviewed agreed that companies could be early adopters of hydrogen, although severely restricted by several conditions. Having a situation where the operational costs wouldn't increase significantly, maintaining economical margins at a reasonable level, and ensuring sufficient financing, were seen as essential conditions for companies to invest in newer technologies, such as hydrogen. The difference between public and private companies was also highlighted in several interviews, as companies agree that funding for new technologies is often more accessible for public companies, due to the public service provided

Views and opinions on hydrogen

Every person interviewed considered themselves to be familiarized with hydrogen, demonstrating a minimum level of knowledge of the technology. This is a clear indicator that companies acknowledge that hydrogen has real potential of competing with other alternatives and that it could well be adopted in the Portuguese market.

When enquired about positive aspects of the use of hydrogen in transport, most companies recognized the fuel type as a clean and non-pollutant alternative with the good autonomy of Fuel cell vehicles being an often-referred point. The fact that FCEVs can be refuelled in minutes just like diesel or natural gas vehicles was also seen as a strong point, especially when compared with the electric alternative.

In terms of disadvantages, fuel and vehicle costs were pointed by all interviews as the main disadvantages compared to its alternatives. The lack of infrastructure was referred in most interviews, with the perception being that hydrogen is not yet available to use while the lack of legislation was highlighted by two companies, citing voids in the law and high levels of bureaucracy for H2 related projects. Safety of the refuelling process and storage of hydrogen was referred as a major point by two companies that expressed concern about storing and dealing with a high-pressure gas, such as hydrogen.

Supporting the implementation hydrogen in transport

Demonstrations and information campaigns were considered important factors to improve public perception on the technology and convey the idea that hydrogen is an available and safe fuel to use. A company suggested that pilot projects are an essential factor to promote hydrogen use, as they increase company's commitment towards H_2 and to demystify the dangers associated with refuelling stations, providing the example of Switzerland where a running pilot project led to a successful implementation in the country [10].

Subsidizing hydrogen refuelling stations and vehicles was also referred by several companies as essential to the implementation and growth of hydrogen use in transports as respondents consider fundamental to expand the HRS grid, to increase visibility and interest around the technology, in the country.

Table 4: Summary of the main conclusions of the interviews

Environment and sustainability	Hydrogen's early adopters	Similarities with the electric situation	Views and opinions on hydrogen	Implementation of hydrogen in transport	Obstacles	Safety concerns
• Companies recognize their role in promoting sustainable measures • Constant fleet renewals are a common measure • Substitution of diesel buses by natural gas and electric buses • Natural gas vehicles are a short-to-mid term solution for reducing emissions and electrics the future • Eco-driving and monitoring of driving beahavior is a common measure to imporve efficiêncy and reduce emissions	• The majority of the decision makers considers companies could be first adopters • Not increasing the costs and reducing economic margins would be key points • The difference between public and private companies in obtaining fuinding for newer technologies is considerable, and public companies having better acess	• Adoption of Electric buses required considerable infrastruture investments • ETs are not capable of providing the same level of service as DTs	• All interviewed decision-makers considered themselves to have a minimum level of knwoledge on hydrogen • One company operates two FCEBs, plans to expand to 10, and pointed the high autonomy of H2 buses • Most interviewees identified clean and non-plluant fuel type as positive aspect • Fuel and vehicle costs are the main disadvantages	• Demonstrations and information campaigns are important factors to improve public • Pilot projects would increase companies's commitment with the technology • Subsidizing HRSs is an essential step	• Maintenance and lack of technological knowledge is a considerable challenge • Possible accidents will have grave repercutions on people's trust in H2 • Political will and cost support are necessary factors for the expansion	• Companies lack information on safety and see it as a question for the future • Risk of accident must be recognized, analysed and accept as with other fuels • Trainings are very important •

Obstacles

One of the most important topics approached in the interviews was the obstacles companies see in the way to a successful national implementation of hydrogen, as this allowed to identify some of the points that are obstructing the implementation of hydrogen or could do so in the future, if not solved. One of the trucking companies highlighted that maintenance and technical knowledge would be a considerable challenge. Another company, that produces hydrogen infrastructure, highlighted that the rate of accidents would be "tragic" for the implementation of H_2, as it could undermine people's trust and reduce the interest of companies in investing in the technology.

Companies often stressed that costs of the technology are still considerably high compared to alternatives and that a strong political support is necessary to convince possible investors. That said, most companies consider hydrogen a viable option but only if there is political will and cost support for hydrogen implementation, as the investment costs are still significantly higher than other powertrain options.

Safety concerns

The safety of the refuelling was also mentioned, revealing diverse opinions. While some companies see this question as distant in the future, recognising, not to have enough information to answer, another company expressed concerns over this subject, stating there are multiple safety risks that must be thoroughly analysed and assessed, and lastly employees must then receive training to ensure acceptable levels of safety are achieved. One of the respondents had a different opinion, affirming current safety measures are sufficient and enough for refuelling to be conducted in a safe, controlled manner, and that the focus should be on ensuring workers have the appropriate training.

The results the interviews demonstrate that companies have moderate to very high level of awareness of hydrogen technologies, with 2 of the 8 companies interviewed already using hydrogen vehicles and or related infrastructure.

5 CONCLUSIONS AND FUTURE WORK

As a technology, hydrogen brings forward several incredibly promising attributes that are likely to significantly impact our economy and society. With an escalating demand for industries to decarbonize fleets and reduce emissions, the chances to capture interest and investment from companies on clean fuel sources such as hydrogen couldn't be higher.

Results from the enquiries demonstrated that workers from the transport sector have only a basic level of knowledge about hydrogen, and although they are generally weary of the safety risks it might pose to them, are willing and in many cases very interested to use the technology.

Interview results pointed out that decision makers have a reasonable level of knowledge about H_2 and its applications, and already see the technology as a possible solution to receive investment and be implemented. Respondents showed

significant interest in acquiring new information about the subject but considered that costs are still considerably high when compared to the other powertrain options, and that government funding is necessary to bridge the cost gap, and to convince companies that it is economically viable to invest in hydrogen.

A considerable percentage of participants still associate hydrogen with danger and risk of explosion causing some discomfort and reluctance to use the technology, with companies raising similar concerns. Informative campaigns, pilot projects, and ensuring an enforcement of the safety procedures are vital measures to mitigate as much as possible the risk of accidents and to make the public feel safe with the use of hydrogen vehicles.

The results of the scenario analysis demonstrate that hydrogen will be implemented in the future with various degrees of success, ranging from small, localized fleets to a dominant market position. LCOH will be a determining factor in the market outcome, and the CAPEX of electrolysers will strongly influence its variation.

Portugal is ready to receive hydrogen infrastructure. The first refuelling stations are already being built and will serve to fuel several pilot projects, increase proximity with companies and contribute to their commitment with the H_2

Lessons Learned

The industry is aware of the technology and its capabilities, and companies are observing investment and technological developments and evaluating the possibilities of future implementation.

An increase in refuelling infrastructure in Portugal is due to happen, with several ongoing projects for the installation of HRSs and electrolysers across the country, effectively expanding and enabling the deployment of H_2 fleets soon.

Future Work

An analysis focusing exclusively on a TCO for hydrogen would be a significant contribution to the current work developed on the subject. While this work does provide an analysis on this matter, a more in-depth study, including more variables and influencers would fill a gap on literature on the Portuguese hydrogen market.

Infrastructure investment costs were also an important point identified during this study. Previous works have failed to analyse what would the costs of installing and implementing a HRS grid be, especially when comparing with existing technologies in the market and their infrastructures

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