Haute Ecole
Groupe ICHEC – ECAM – ISFSC

Enseignement supérieur de type long de niveau universitaire

Which strategic decisions should Belgian fuel stations take to distribute hydrogen fuel in the light of European Union's promotion of green hydrogen policy?

Mémoire présenté par :
Andrea Rodondi

Pour l'obtention du diplôme de :
Master en gestion de l'entreprise
Année académique **2020-2021**

Promoteur :
Christophe Lejeune

Boulevard Brand Whitlock 6 - 1150 Bruxelles

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- Retired Deputy Head of department at European Commission at General Directorate of Energy;
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Engagement Anti-Plagiat du Mémoire

« Je soussigné, RODONDI Andrea, en Master 2, déclare par la présente que le Mémoire ci-joint est exempt de tout plagiat et respecte en tous points le règlement des études en matière d'emprunts, de citations et d'exploitation de sources diverses signé lors de mon inscription à l'ICHEC, ainsi que les instructions et consignes concernant le référencement dans le texte respectant la norme APA, la bibliographie respectant la norme APA, etc. mises à ma disposition sur Moodle.

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Dans le cadre de ce dépôt en ligne, la signature consiste en l'introduction du mémoire via la plateforme ICHEC-Student.

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Introduction

In 2010, one could read in the journal Independent: "[In 2020,] zippy electric cars have also become a ubiquitous presence on the roads, as have charge points, which have been built into parking meters, street lamps and every Tesco and McDonald's parking space in the country." (Savage, 2009) Despite the article's enthusiasm, it seems that, in reality, the world has landed in a far different situation. Little more than 2% of all vehicles registered in Europe are battery powered (European Environement Agency, 2020). Far from a "ubiquitous presence on the roads." (Savage, 2009).

This begs the questions: why haven't the battery electric vehicles lived up to their 2010 hype? and what other source of energy could replace fossil fuels? One of which could be hydrogen.

Hydrogen as a technology and as a mean of energy storage has already been studied extensively by the scientific community during the past decades. Industrial use and practical examples have proven that hydrogen is a gas that has a future.

In 2020 the European Commission has recognised the role that hydrogen could occupy in the European energetic transition towards a climate-neutral continent by 2050. This role has been acknowledged for the transport sector amid its importance on a worldwide scale. Its importance is shown by the level of energy that the transport industry consumes, the level of greenhouse gasses that it emits and the variety of modes of transports available to the society.

Unfortunately, it appears from this exploratory research that there is a gap in the scientific and academical literature about the benefits and perspectives of hydrogen fuel technologies in the transport sector. An impulse from the EU institutions as well as governments will be pivotal for the future development of the hydrogen technology. As hydrogen electric vehicles increase in number, demand in hydrogen will follow. Despite the current marginal number of hydrogen vehicles on our Belgian roads, refuelling stations should anticipate the changing behaviour of customers. A small number of studies (if none) have been led on the distribution of hydrogen to private consumers. This specific, yet crucial, activity in the hydrogen supply chain is the last step before consumption. This research aims at proposing recommendations to fuel stations' managers to distribute hydrogen.

Objectives such as the creation of a potential financial plan that includes hydrogen distribution at fuel stations and the setup of a business framework for their managers to take future strategic decisions in regard to the developing hydrogen distribution networks will help to solve the problem which is the lack of preparation of today's fuel stations to distribute hydrogen. The operational objectives will lead to recommendations for fuel stations' managers to prepare for hydrogen distribution in the coming decades. By collecting fuel station's managers' views, through interviews, on possible financial plans, a deep understanding of their sensitivity to risk will be acquired which will enable the formulation of accurate recommendations.

The structure of this paper is split, as follows: an exploratory research (parts 1,2 and 3) about hydrogen as a mean of energy storage, the EU's strategy for hydrogen and the business model of current fuel stations is led. The identification of an issue found in the literature takes place in part

4. Research method and its results are laid out in part 5. Finally main results and suggestions for further discussions are dealt with in the final part.

1 Hydrogen as a mean of energy storage

1.1 The electric car

Electric cars are vehicles that rely on one or multiple electric motors. They can be categorised in two distinct groups: electric cars requiring large batteries to function which are charged at electric refuelling facilities and those relying on hydrogen as a method of energy storage.

1.1.1 History

First and foremost, electric vehicles (EV) are not a novelty. In the early days of the automobile industry, two main competing forms of engine-driven vehicles coexisted: the well-known internal combustion engine (ICE) vehicles and the one with an electric propulsion engine. The first internal combustion engine vehicle (ICEV) was produced by Benz and Daimler in 1886. However, in 1900, EV held a significant share of all engine-driven vehicles. The turning point for the industry came with the decision of H. Ford in 1908 to mass produce ICEV. This killed the battery electric vehicles (BEV), postponing their technical progress by a century.

More recently, the come-back of electric vehicles owes its success to environmentally driven politics aiming at offsetting greenhouse gas emissions caused by the use of internal combustion engines in the transport industry. In fact, Helmers and Marx argue that opting for an ICEV over EV for over a century of automotive industry "from an environmental perspective, may have been one of the biggest mistakes in the history of technology." (Helmers & Marx, 2012).

1.1.2 Electric vehicle (EV) categories

As a result of governments' regulations around the world, a multitude of EV spawned. These differentiate among themselves in terms of the source of energy storages available. According to a definition by the National Renewable Energy Laboratory, "a plug-in hybrid-electric vehicle (PHEV) is a hybrid-electric vehicle (HEV) with the ability to recharge its electrochemical energy storage (battery) with electricity from an off-board source (such as the electric utility grid)." (Simpson, 2006). This definition includes the subcategory of HEV, called the plug-in hybrid-electric vehicles which have the capacity to be electrically charged, in addition to connecting to the grid, also through braking recuperating energy and by their internal combustion engine. The second sub-category, the battery electric vehicles (BEV), has on-board, a very large capacity battery and the possibility to recharge only from an off-board source. They lack an ICE and rely on a sole energy converter: the electric motor.

Furthermore, battery electric vehicles (BEV) can be segmented in two distinct variants depending on the type of energy storage: the ones using "traditional" battery for their energy storage and the ones using hydrogen as an energy storage mean. These are called fuel cell electric vehicles (FCEV). This latter technology requires a smaller battery, used as a buffer, compared to the one present in vehicles using batteries as the sole mean of energy storage.

1.1.3 Technical components of a BEV

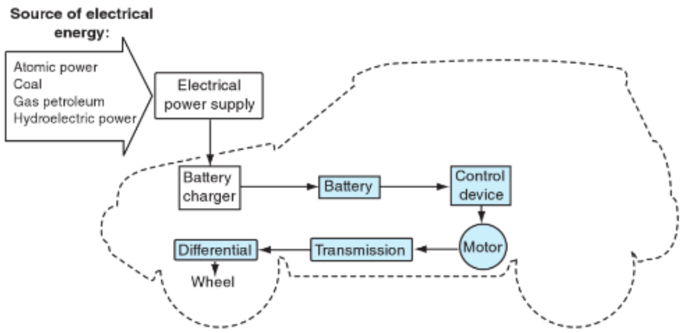

Figure 1 Important components of an electric car. (Erjavec, 2012)

As showed in Figure 1, a BEV includes four main components: the charger, the high voltage battery, the electric controller and the electric motor.

The high voltage battery is charged via the charger which collects its energy from an off-board source or via regenerative braking. The controller supplies the electric motor with variable power depending on power needs and availability. Finally, the electric motor location can vary from being centrally mounted to being placed inside the hub wheels. In some cases, a transmission is added for consumption purposes to gain driving efficiency.

As a result, the battery is crucial component of a BEV as it is its source of power.

1.1.4 Technical components of an FCEV

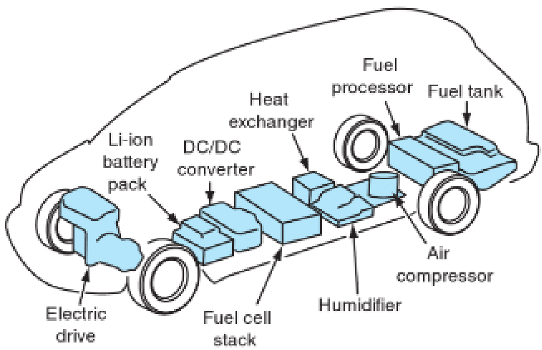

Figure 2 Components of a FCEV. (Erjavec, 2012)

As shown by Figure 2, the Hydrogen tank stores compressed hydrogen gas onboard the vehicle. The gas is then transferred to the fuel cell stack which, through a chemical reaction, combines it with oxygen to produce electricity and water as a by-product. The electricity is then transferred to the electric motor which drives the vehicle's wheels. Batteries are found on FCEV. These are used to recuperate energy from the regenerative braking system from the vehicle as well as power electronics onboard.

1.1.5 The FCEV market

The FCEV market have not gone through any noticeable development during the past years. The demand of such vehicles has been mainly fulfilled by Japanese and South Korean manufacturers. However, "most large OEMs (car manufacturers) have teamed up to work on the technology—

for example, Daimler and Volvo, Toyota and Traton, Honda and Isuzu. New players, such as Nikola and Hyzon, are entering the market while, Chinese companies are moving fast." (Gersdorf, Hertzke, Schaufuss, & Schenk, 2020). Currently, the research in "hydrogen technology is nearing its maturity with a great number of prototypes being presented by large manufactures destined to be used in vehicle fleets by companies or public authorities." (Air Liquide, 2018)

According to the European Automobile Manufacturers Association, less than 0.1 % of car sold in the European Union were FCEV. "Fuel-cell cars account for a negligible share of total EU passenger car sales for the time being" (European Automobile Manufacturers' Association (ACEA), 2019). Figure 3 shows the evolution between 2012 and 2019, in Belgium, of the number of registrations of new hydrogen cars. These represent less than 0.001% of all registrations in Belgium.

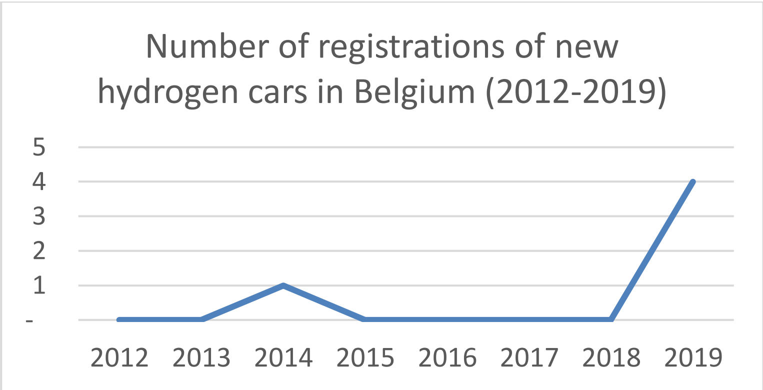

Figure 3: Number of registrations of new hydrogen cars in Belgium between 2012 and 2019. (Direction générale statistique - Statistics Belgium, 2021)

As for market projections, only 4 manufacturers have announced strategies to produce FCEV. At a current rate of 5000 vehicles per manufacturer these will continue to represent 0.01% of the global vehicle sales.

1.2 From well to wheel

The literature states that the supply chain of hydrogen from its production phase to its consumption by the end user includes multiple steps as showed in Figure.

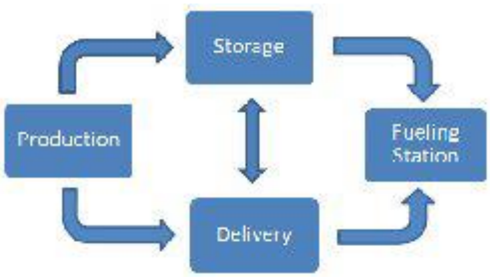

Figure 4: Steps involved in hydrogen supply chain. (Upreti, Dhingra, Sawhney, & Wilck, 2011)

Such supply chain configuration is heavily dependent on the geographical location of the fuelling station as this determines the storage capacity, the delivery methods and the configuration of fuelling station required to distribute hydrogen fuel and satisfy the demand. Finally, it is necessary to bear in mind that the latter is highly unpredictable as sales of FCEV remain uncertain. (Upreti, Dhingra, Sawhney, & Wilck, 2011)

1.2.1 Production of hydrogen

Hydrogen does not exist in a pure form on our planet. For this reason, hydrogen must be produced following various methods.

Currently, 95% of the global production of hydrogen originates from the steam methane reforming method. It consists in extracting hydrogen from methane (CH4) molecules while minimising the production of its largest by product: carbon dioxide (CO2). Such method can be located "on site or at a central location depending upon the size." (Upreti, Dhingra, Sawhney, & Wilck, 2011)

Fuel cell reformers are systems that rely on the combination of two fuel cells that, combined in a fuel cell stack, react and produce hydrogen. In addition to the hydrogen, such systems are capable to produce heat to be used in buildings for warming. This combined heat and power generation is "more appropriate for universities, hospitals and manufacturing facilities." (Upreti, Dhingra, Sawhney, & Wilck, 2011).

Another production method of hydrogen calls for electrolysers which use water and electricity (electrolysis process). This production method is the most backed by the European Union and is highly attractive from an environmental point of view as its production does not produce any by product and, if done by using renewable energy, it is nearly emission-less.

This led to a fundamental point that will be developed later: "the price of hydrogen is largely reliant on the cost of electricity, efficiencies of the systems, and its initial costs." (Upreti, Dhingra, Sawhney, & Wilck, 2011)

1.2.2 Storage

Once the hydrogen produced, the second step of the supply chain consists in storing it awaiting to be delivered to the refuelling station. Storage can be carried out either in a liquid or gaseous state. The pivotal point is about increasing energy density. To do so, hydrogen gas can be pressurised up to 700 bars. Storing hydrogen in high-pressure pipes of various capacities is a widely accepted method. Moreover, in addition to the option of very large-scale underground tanks, distribution pipeline webs (pressure: 35 – 75 bar) can be used as a storage system to take up peaks in supply too. This storage technology is widely used in the natural gas industry and can be easy converted to hydrogen.

The liquid state of hydrogen has better energetic density properties than diesel or gas. It consists of lowering the temperature of the hydrogen to its evaporation point (-253°C) and to store it in highly insulated tanks. Unfortunately, this comes at a higher cost. Also, it is necessary to note that high levels of leakages are observed as the difference of temperature between the liquefied hydrogen and the ambient temperature is very important. (Rivard, Trudeau, & Zaghib, 2019)

1.2.3 Delivery

This step covers the transportation of hydrogen between its storage location and the refuelling station. It is necessary to mention that this step can be skipped in the case of on-site production facilities of hydrogen. Hydrogen could be produced through hydrolysis directly at the fuel station simply requiring electricity and water (from an aqueduct or even rain) as inputs.

Two delivery methods exist and they depend on the demand level of the refuelling station.

Hydrogen can be delivered to refuelling station by truck. The compressed hydrogen gas is transported by batches of 300 kg which makes such supply method quite unpractical when the level of demand is high (on average, a FCEV embarks up to 6kg of hydrogen).

Another delivery method consists in a pipeline network. This would be the most efficient in terms of cost and leakage. Indeed, it is very cheap to transport compressed hydrogen in pipelines, especially in large quantities. However, initial capital investment is high, making it initially very unattractive until demand is high enough to amortise the initial cost. Actually, because of the physical properties of hydrogen, conventional natural gas pipelines require upgrades in order to transport hydrogen. (Upreti, Dhingra, Sawhney, & Wilck, 2011) However, the lowering hydrogen pressure could potentially solve the problems linked to leakages.

1.2.4 Distribution

The distribution phase refers to the selling operations of hydrogen at the refuelling station. Hydrogen refuelling stations may come in various shapes and sizes: hydrogen-only refuelling station or fuel stations that include a hydrogen offering. The objective of the thesis is to study the possibility to include a hydrogen refuelling pump to an already existing fuel station making it more attractive for all vehicle types simultaneously (i.e., ICE vehicles and FCEV). Dedicated hydrogen refuelling stations include five major components necessary to distribute hydrogen to fuel cell electric vehicles. Such components should be included in fuel stations servicing ICE vehicles that seek to integrate a hydrogen pump.

The literature indicates that, at a refuelling station, hydrogen follows a five steps process to reach the customer's FCEV. From its arrival in cylinder tanks, the hydrogen is compressed to a pressure equal to the one distributed to the FCEV. It is then stored in buffer tanks that can absorb demand fluctuations of highly pressurised hydrogen. It is then cooled to -40°C using an exchanger and a refrigeration unit. Finally, the highly pressurised hydrogen is distributed through the dispenser. (Air Liquide - Hydrogen Refueling Station, 2020)

1.3 Benefits and limits to the use of hydrogen in the transport industry

This section lays out the pros and cons of the hydrogen technology, its infrastructure and its use in FCEV as stated in the literature.

1.3.1 Benefits

Studies have shown that direct GHG emission of electric cars in operation is nil. According to Erjavec, "FCEV emit few, if any, GHG or any other pollutants." (Erjavec, 2012) This is the major reason for the development of FCEV. Actually, the fight against global warming seems to be the main driver behind the development and adoption of FCEV.

However, for a comprehensive GHG evaluation, indirect GHG emissions must be considered. It is then necessary to include emissions originating from the production processes and supply of the hydrogen consumed by the FCEV. These vary vastly from country to country as some have favoured more GHG emissive systems which include, for instance, reforming methane (explained hereabove) instead of water electrolysis.

Also, studies have shown that FCEV have a noticeably simpler architecture than the one found on ICEV as they do not need any "starting system, exhaust, or lubrication system, usually no gearbox and sometimes and not even a cooling system." (Helmers & Marx, 2012). Hence, this would reduce further the GHG emissions running cost of FCEV compared to ICE vehicles and also HEV.

Reports show that hydrogen has a higher calorific power in comparison to gas, diesel oil or natural gas. "Calorific value is a measure of the thermal energy released when a substance is burned. It is expressed in megajoules per kilo of fuel (MJ/kg) or in kilowatt hours per kilo of fuel (kWh/kg)." (Air Liquide, 2018).

Finally, benefitting from the electric engine, FCEV are more than twice as efficient as diesel- or petrol-powered drivetrains. "Engine efficiency is the ratio between the amount of energy used to make it work and the quantity of mechanical energy it produces." (Air Liquide, 2018).

1.3.2 Limits

According to the literature, multiple hurdles seem to stack up against a wide-spread adoption of FCEV. As Air Liquide puts it, "today, the factors limiting the growth of hydrogen cars are the lifespan of the fuel cell (around 150.000km), the price of the vehicle, and the hydrogen distribution network." (Air Liquide, 2018).

FCEV prices range from 60.000 € to 100.000 € for relatively large vehicles. For an equivalent level of performance, an ICEV retails for 30 % to 50 % less. The price of refuelling a medium sized hydrogen tank is equivalent to an ICE's fuel tank, thanks to local promotion mechanisms such as subsidies or grants. This over dependency on such mechanisms shows a limit to a widespread adoption of FCEV.

The hydrogen distribution network is cruelly underdeveloped according to the literature. A few hundred hydrogen refuelling stations are open worldwide and only 140 are in Europe (as of end of January 2021) (H2 MOBILITY Deutschland GmbH & Co. KG, 2021).

Concerns over the energy balance and carbon footprint of its production have been uprooted. The goal of the transition towards hydrogen as a fuel to power vehicles' drivetrain is the planet preservation. If its production is done through the oxidation of gas petroleum (methane), its core purpose to fight climate change would be jeopardised. (Erjavec, 2012) The whole purpose to use hydrogen is cancelled. Unfortunately, more than 90% of the world's hydrogen is currently produced from fossil fuels. Therefore, it is necessary to ensure a green production of hydrogen from water electrolysis from the power generated by renewable energies (wind turbines, solar farms, etc).

Another hurdle highlighted by studies is the problem of highly pressurised hydrogen storage needed for a FCEV to offer an attractive driving range. Indeed, 6 Kg hydrogen tanks must hold a pressure of 700 bars to guarantee a driving range of 500 to 800 Km depending on the vehicle's consumption.

Finally, hydrogen-powered vehicles have proven to have one limit which is inherent to its technology. FCEV show an energy efficiency of 19% to 30 % (= 70% to 81% loss of energy). This owes to the fact that during production and consumption the efficiency is respectively 50% and 60%. (Helmers & Marx, 2012). In the end, this is very similar to and ICEV's efficiency but considerably lower than BEV's efficiency.

1.4 Intermediary conclusion to part 1.

Understandably, alternative energies are gaining traction and popularity. As for hydrogen, technical benefits seem to outweigh drawbacks. Experts argue that hydrogen has a potential to develop itself as a sustainable alternative fuel, especially if it is produced thanks to renewable energy. Despite very positive points in favour of hydrogen technology, hydrogen remains heavily bogged down by important limits. The process of adoption of such technology seems to be slowed by economic factors such as price of vehicles and hydrogen, and refuelling stations' availability. These limits depend heavily on political will to develop such fuel. Therefore, one may ask himself about the importance of politics in the process of adoption of new technologies.

Furthermore, the public's view on hydrogen safety and its lack of public knowledge is surely an obstacle to its development. Studies have shown that societies do not perceive hydrogen as a safe energy yet. This is due to the considerably low public awareness of hydrogen as a method of energy storage.

In order to combat such public's lack of awareness, the European Commission presented its strategy aiming at a climate-neutral Europe by 2050. Hydrogen plays a major part in this strategy in sectors such as industry and transport. In the following part, we will explore about European commission's actions towards such an aim. EU's Green Deal, an integrated energy system and the strategy for hydrogen will be developed.

2 European Union's strategy for hydrogen and the Energy System Integration

In addition to a literary documentation research, an exploratory interview has been conducted in in order to understand the EU's strategy for hydrogen and the energy system integration. The full transcript of the interview can be found in annex 1: exploratory interview 1. Mr. K desired to remain anonymous for the interview. He is a retired deputy head of department at European Commission at the General Directorate of Energy.

2.1 EU's objective: Europe as the first climate neutral continent by 2050 (The European Green Deal)

With its aim to become climate-neutral by 2050, the European commission has the objective to cut emissions while promoting growth. "It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use." (European Commission, 2019).

According to Mr. K. (2021), this strategy plays the role of an investment package for the European economy while promoting environmental advancements. Actually, "it is a reaction to the decrease of the economic cycle caused by the pandemic" (K, 2021) which needs to be coupled to the EU's Next Gen EU strategy.

Supplying clean, affordable, and secure energy is at the top of EU's priorities regarding the Green Deal. In order to reduce GHG emissions, member states will have to align their policies according to the EU's climate plans. In fact, energy consumption contributes to 75% of all EU's GHG emissions.

Smart infrastructure will be required to make sure that clean energy transition benefits the consumer and that the risk of energy poverty is addressed. "This framework should foster the deployment of innovative technologies and infrastructure, such as smart grids, hydrogen networks or carbon capture, storage and utilisation, energy storage, also enabling sector integration." (European Commission, 2019)

All in all, the shift to smart and more sustainable mobility will happen thanks to an increase in "the production and deployment of sustainable alternative transport fuels." (European Commission, 2019). 2050 is a date that serves as an objective to guide nation-wide transitions. According to Mr. K (K, 2021), it is also distant enough to carry any unforeseen adjustment that my put into peril the Green Deal's strategy.

2.2 EU's strategy on Energy System Integration.

The Eu's Strategy on Energy System Integration spawns from the realisation that "too few synergies between industries" (K, 2021) existed. As a result, "the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors." (European Commission, 2020) is the driving principle of this strategy.

At the present, Mr. K depicts the energy system as being linear. The objective of the integration strategy is to create an EU energy system boasting a more efficient and circular use of energy, a cleaner power system through electrification and the use of cleaner fuels in hard-to-electrify sectors.

The main operations of the EU's Energy Integration Strategy include the creation of a more circular energy system while encouraging waste reuse. Electrifying the system thanks to renewable energies which is necessary to power buildings, industry, and transport. Efficiency in the transport industry will take the form of sustainable and smart mobility. This should be sustained by the fact that total ownership cost of electric vehicles is projected to become competitive with ICE vehicles around 2025. Promotion of renewable and low-carbon fuels such as hydrogen by creating a market encouraging innovative projects.

In 2020, hydrogen accounted for less than 2% of EU's energy mix and it was almost solely produced from fossil fuels. In "hard-to-decarbonise" (European Commission, 2020) sectors, hydrogen has an important role to hold. In sectors such as long-haul transports or in steel manufacturing, hydrogen can be a solution do GHG emissions. The European commission sets out a hydrogen strategy to lay out further actions to ensure that green hydrogen production is underway.

2.3 EU's Hydrogen strategy

As explained by Mr. K, "there are two approaches: the production of hydrogen from renewable resources (clean hydrogen) or continue to use traditional energy sources such as coal, gas while making them greener with Carbon Capture and Storage." (K, 2021).

The Commission aim of a carbon neutrality for Europe by 2050 will only be possible through the decarbonisation of a multitude of industries including transport but also steel or chemicals. The promotion of clean renewable hydrogen produced from wind and solar power represents an important step towards climate neutrality.

"By 2050, there will be [according to the European Commission] maybe 24 to 25% of all renewable energy that could go towards hydrogen." (K, 2021)

According to Mr. K the cost hurdle to produce green hydrogen (low-carbon hydrogen and green hydrogen) in comparison to fossil-fuel-derived hydrogen is not to be taken as secondary. As a result, the European Union plans to follow a path made up of three steps to reach a European hydrogen eco-system. The first phase of the EU's roadmap sets a first deadline in 2024. By then, it will be necessary to have accomplished the installation of a capacity of at least 6 GW of electrolysis producing renewable hydrogen in the EU with a production of up to one million tonnes of renewable hydrogen to decarbonise existing hydrogen production. Thus, it will be necessary to build large-scale electrolysers that should be located near locations where a heavy demand could be observed (for instance: refineries, steel plants, chemical factories).

The second phase of the EU's roadmap extends from 2025 to 2030. This phase will enable hydrogen to become part of an EU integrated energy system with the strategic objective of achieving an installed electrolysis capacity of at least 40 GW producing up to 10 million tonnes of hydrogen from renewable sources. Thanks to higher level of demand, it is expected that, at this stage, green hydrogen will become cost competitive with other forms of hydrogen production. This integrated system will yield more scattered production sites to supply local distributors in order to reduce as much as possible hydrogen's transportation costs.

Finally, the third and last phase of the EU's roadmap towards carbon neutrality envisage that by 2050, renewable hydrogen technologies mature and are deployed on a large scale to reach all the sectors that are difficult to decarbonize. During this phase, production of renewable electricity will have to greatly increase as approximately a quarter of it will have be dedicated to green hydrogen production.

Unfortunately, Mr. K estimates that "although it has been declared a good way out of the pandemic crisis, investment remains colossal." (K, 2021). It is foreseen that the newly created European Alliance for clean hydrogen will oversee the co-ordination of public and private funding in Europe towards the enhancement of the hydrogen value chain. It is clear that investments in electrolysers, wind, and solar technologies as well as transformation of energy consumption will be paramount to ensure a smooth adoption of hydrogen.

Setting this roadmap with variable deadlines may be a testimony to the European Commission's position regarding hydrogen. "We notice that we are a little out of breath because the deadlines are divided into three uneven phases: 4 years, then 6 years, then 20 years. It may be seen as realism or a certain lack of ambition." (K, 2021).

Demand by the end consumer needs to be stimulated. The European Commission identifies first adopters as being the industry, as a whole, though its potential use in steel manufacturing and the transport industry, where electrification has proven to be more complex than anticipated, is delayed. Commercial fleets, rail networks and public transports seem to be the main first drivers to increase demand of hydrogen in the transport sector. Fuel cell stacks seem at the core of the transport industry as its technology helps to promote the wide spread of hydrogen through transportation means (e.g., rail, road, water, and air).

In addition, each phase of the EU's roadmap includes different development phases for the hydrogen infrastructure. These seek to closely follow the evolution of demand throughout the roadmap. As a result, during the first phase, local or onsite production infrastructure should spur more investment. As from 2025, when demand should further increase, other steps of the hydrogen supply chain infrastructure will need to be upgraded (i.e., optimising production, use and transport) to get an overall greater efficiency of the system. Mr K's view on the future of hydrogen includes that "by 2050, there will be [according to the Commission] maybe 24 to 25% of all renewable energy that could go towards hydrogen." (K, 2021). This efficiency gain could be the answer to a better energy system integration. Moreover, taking notice of the gradual divestment in low-calorific-value natural gas, reassignment of already existing infrastructure may provide an opportunity for a cost-effective energy transition in combination with the (relatively limited) construction of new hydrogen-specific infrastructure.

On the question of the possibility for the European Commission to leverage on its power to trigger the energetic transition, Mr. K stated that "it is also possible to create a legislative framework such as directives. But for the Commission it is clear that if there is a number of Member States that do not line up" (K, 2021) it would be useless to go forward. Published in 2014 and entered into effect as of 2017, the directive on the deployment of alternative fuel infrastructure (Directive 2014/94/UE) is a testimony to the power of the European Commission to enforce policies' adoption by member states. In fact, a refuelling stations network for alternative fuels will have to grow in compliance with technical specifications examined by the European commission. (Parlement Européen, 2014)

Technical progress is necessary for a widespread hydrogen adoption. As a starting point, larger, efficient, and profitable electrolysers should enable large hydrogen consumers to have access to this fuel. Secondly, innovation in distribution storage and delivery of hydrogen in large quantity should take place. As mentioned hereabove, this should consider already existing natural gas infrastructure. Thirdly, new large-scale applications such as in the steel industry or in the transport sector will have to gradually increase. (European Commission, 2020).

2.4 Intermediary conclusion to part 2.

EU's Green deal acts as an objective that countries should converge to. Unfortunately, it seems to lack practical solutions and it is probably too ambitious. Although green hydrogen production being technically possible, changing the trend from an almost-fully grey hydrogen to a green hydrogen in few years seems highly improbable as numerous experts consider that steam methane reforming is still too predominant to be overcome. A solution that has been brought to the table, is low-carbon hydrogen which consists of coupling methane reforming with carbon capture and storage technology. Unfortunately, this possible solution has not yet been tested and therefore is highly improbable to be used in the short future.

Electric vehicles have been at the centre of attention in the automotive industry during the past years. In the meantime, hydrogen technology has been progressing. However, one question needs to be answered: why has the EU favoured hydrogen over electricity? The Belgian Federation of Fuel Retailers (BRAFCO) advocates that the European Commission has valued green hydrogen as being environmentally friendlier than BEV – especially when considering battery production. Additionally, in urban environments, BEV charging stations would have to be placed very densely at "each street corner" to accommodate the demand in electricity of the cars circulating in large towns. As a result, dual fuelling stations (petrol + hydrogen) seem more adapted to large cities. Moreover, thanks to shorter refuelling times, hydrogen technology could have been favoured by the European Commission.

Another possibility for this choice by the EU institutions are the potential economic benefits. In Belgium, these opportunities have been valued at 90 million EUR annually until 2030 in the form of higher wages for employees, margins for companies and taxes. As a high scenario, the European Commission claims that up to 1.140 million EUR could be captured by the Belgian economy, annually. Unfortunately, these benefits are equal to the estimated annual cost in hydrogen technology during a period up to 2030. (Fuel Cells and Hydrogen Joint Undertaking, 2020)

Following the analysis of the EU's strategy, we will focus on understanding the business model of fuel stations using the Business Model Canvas tool. As the EU's strategy for hydrogen applies as well to fuel stations, it is necessary to gain a clear understanding of their innerworkings. In order to do so, exploratory interviews will be conducted to collect qualitative data.

3 From macro to micro: presentation of current fuel stations' business model through the Business Model Canvas

In addition to a literary documentation research, an exploratory interview has been conducted in in order to understand the business model of fuel stations. The full transcript of the interview can be found in annex 2: exploratory interview 2. Mr. H desired to remain anonymous for the interview. He is a retail manager for Benelux at G&V (a Belgian fuel retailer).

Understanding the business model of today's fuel stations is necessary to assess the transition towards an environment including hydrogen. Indeed, to fully understand what are the various forces that apply to stations, a business model canvas should be set. Osterwalder and Pigneur define a business model as being "the rationale of how an organization creates, delivers, and captures value" (Osterwalder & Pigneur, 2010). This definition shows the importance of such concept to any business. It defines how a business is run, operated and how it creates value for both the customer and the business owner. Osterwalder and Pigneur lay out nine buildings blocks that form any business model. In other words, the "nine basic building blocks that show the logic of how a company intends to make money" (Osterwalder & Pigneur, 2010) simplify and allows the description of business models which enable the creation and evaluation of strategic decisions.

The Business Model Canvas' 9 building blocks of a current refuelling station are laid out hereunder. It is necessary to consider that the following business model canvas is the one of a generic fuel station which is not linked to any specific brand. Different scenarios will be presented for each building block.

Fuelling stations operate in Business to Consumer (B2C) as well as in Business to Business (B2B) markets.

A B2C market, or mass consumer market, is a market where "companies selling goods and services to individuals seek to build an attractive brand image and a qualitative offer that is easily accessible to the target audience." (Kotler, Keller, & Manceau, 2015). This is the case of refuelling stations as they focus on selling fuel to car owners which are private individuals and use their cars for number of purposes.

The same fuel stations are also "companies that sell goods and services to other companies and are faced with professional buyers who are trained, informed and accustomed to comparing competing offers." (Kotler, Keller, & Manceau, 2015). In this case their customers are companies that have to refuel their vehicles necessary to their business to function.

The oil and gas industry distinguishes two main areas of a refuelling station. The forecourt and the backcourt. According to Mr. E, the backcourt is the shop area where goods other than fuel are sold. The forecourt is the zone on a fuel station where vehicles can be refuelled. The latter includes the canopy (?) and fuel pumps as the main visible elements. Underground fuel tanks are also included in the forecourt and are used to store fuels.

3.1 Business model canvas of a fuel station.

Table 1 summarises major elements of each building blocks. A detailed explanation is available in Annex 3: Refuelling station Business model Canvas 9 building blocks.

<table>
<tr><td>Key Partners</td><td>Key Activities</td><td>Value Proposition</td><td>Customer Relationships</td><td>Customer Segments</td></tr>
<tr><td rowspan="3">Oil and gas companies.
Construction contractors.
HR agencies.
Banks.
Convenience store chain.
Grocery suppliers.
Fuel wholesalers.</td><td>Fuel supply and logistics
Grocery supply and logistics
Facilities
Customer service</td><td rowspan="3">Provide fuel at competitive price.
Provide quality fuel for a qualitative experience.
Provide grocery-items for time-valuing customers.</td><td>Self-service
Personal assistance.
24/7 offering.</td><td rowspan="3">Vehicle owner/driver.
Shop buyer.
Ancillary services buyers.</td></tr>
<tr><td>Key Resources</td><td>Promotion Channels</td></tr>
<tr><td>Human.
Financial.
Market knowledge.
Physical infrastructure.</td><td>Fuel station.
Billboards.
Website.
Radio,
Television,
newspaper.
Social media.
Email.
Fuel card.</td></tr>
<tr><td colspan="2">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="2">Fuel purchase
Salaries
Upfront infrastructure investment
Bank fees
Repair and maintenance</td><td colspan="3">Fuel sales
Convenience-store sales
Ancillary services sales
Unique transactions paid by debit card</td></tr>
</table>

Table 1: Summary of a fuel station's Business Model Canvas.

3.1.1 Customer segments

According to Mr. E, "anyone who has a car is our customer. The clientele is very large." (E, 2021). This is a testimony that refuelling stations use a business model mainly based on mass market demand. The positioning of a fuel station largely depends on the type of customer it desires to reach. Two main classes are identified by Mr. E: "… the price buyer: the person who is not too attached to the quality of the fuel or not too attracted by a savings system" (E, 2021) and "those who go into a pump with a shop and are probably a little more sensitive to the relational aspect." (E, 2021). It is the second group of customers that a Boston Consulting Group's (BCG) paper reports about.

3.1.2 Value proposition

According to Mr. E, price, and therefore value proposition, varies depending on the position that a fuel station takes. “One is price-oriented and the other is focused on product quality, reliability, the fact that people do not want to take the risk of putting white product in their car because a car is a big investment, and you want to have a quality product.” (E, 2021). Depending on whether the fuel station boasts an express layout without the presence of a backcourt, it will attract different type of customer that are typically either price-sensitive or not.

3.1.3 Channels

As a general principle, “effort comes more from the brand (oil company) thanks to its the large scale, they develop communication where the Branded Wholesaler will communicate more on his shop.” (E, 2021). During the whole customer lifetime, customers touchpoints are multiple. Communication can occur before, during and after the purchase.

3.1.4 Customer relationships

In terms of personal assistance, “the [station] operator will try to play on the personal link. He greets the customer at the checkout and tries to create a link with the customer. […] Relationship is very important. Especially since people who give little importance to the relationship will go to a cheap pump, possibly without staff: an express pump. Those who go into a pump with a shop are probably a little more sensitive to the relational aspect.” (E, 2021).

Refuelling stations are also able to create some relationship at self-service facilities. This can be found in express stations even without any backcourt offering. With the help of automated services, a relationship with the customer can be built. Oil companies leverage their fuel card or savings programs by engaging in a relationship that is aimed at customer retention.

3.1.5 Revenue Streams

Revenues are generated by both the forecourt and the backcourt and, according to Mr. E, both are generally profitable on their own. However, “there is a synergy between the two that is observed. […] Historically, we had more income in the forecourt. The shops have really grown in importance to arrive at a set-up of gains of about 50/50 or even a little more on the shop.” (E, 2021).

The trend towards digitalisation of payment methods is underway. As Mr. E explains, "cash remains quite marginal" (E, 2021) as "debit card [payments] makes up, according to him, for 70% of transactions." (E, 2021) Another method of payment is the fuel card, which is available for companies operating a fleet of cars. In this case, consumers have no choice of method of payment other than to pay with a fuel card.

3.1.6 Key resources

In the case of a refuelling station, “they need a piece of land. They must invest in infrastructure: pumps, tanks, etc.” (E, 2021). Physical assets are important as fuel stations are businesses based on the delivery of physical goods. Another recognisable piece of physical infrastructure of a fuel station is the branded canopy.

Patents and other intellectual properties matters are delt by the oil company that supplies the forecourt of fuel stations. No specific research and development programs are led by refuelling stations. The knowledge of the market reflected in the choice of the level of discount on fuel prices is the main intellectual resource at the disposal of the station operators. It is capital for bringing value to the business as it directly impacts revenue streams potentially captured in the forecourt.

In all business models, human resources keep a certain role. This is also true for fuel stations; especially those offering backcourt services. "As for the backcourt, it is possible to make an alliance with a chain such as a "shop and go" or express crossroads etc. Staff will be needed to manage it." (E, 2021)

Without financial resources, none of the physical, intellectual or human resources can be obtained, therefore falling short of delivering the value proposition to the customers. Mr. E says that "the staff always costs a lot of money. The most variable position is the presence of staff in the station. The job market is not always hyper-flexible in Belgium. There are a lot of professional expenses in Belgium so it's still a very important burden." (E, 2021).

3.1.7 Key activities

Fuel station customers' main concern remains getting the fuel for their vehicles. Different types of fuels exist and are not all suitable to all vehicles' engines. The activities surrounding forecourt include the logistics of transportation of different fuels, buying and selling them and storing them on site. As for the backcourt, customers' needs are generally focussed on groceries and convenience shopping.

3.1.8 Key partnerships

Simply put, Mr. E identifies the key partners necessary for a fuel station's business model to work: "there is the fuel supplier, the employees present when there is the presence of the backcourt. Possible franchises for the shop, relations with banking financial systems, maintenance contracts for both forecourt and backcourt need important partners as well as companies handling cash payments." (E, 2021). According to Mr. E, a fuel station is heavily dependent on its partners to deliver its valuable offer to the customer segment.

3.1.9 Cost structure

When discussing the cost structure of a fuelling station, it is necessary to distinguish those originating from the forecourt from those finding their source in the backcourt.

Concerning the forecourt, variable operating costs depend largely in the purchase of fuel. This is usually either purchased from a wholesaler or directly at an oil company's terminal. Its price varies depending on factors linked to production and refining. The most important operating cost besides the fuel, according to Mr. E, are the employees. "The staff always costs a lot of money. The most variable position is the presence of staff in the station. The job market is not always hyper-flexible in Belgium. There are a lot of professional expenses in Belgium so it's still a very important burden." (E, 2021).

When present, the backcourt largely contributes to the costs of a station and employees represent an even larger portion of the backcourt's costs than in the forecourt. Other costs include products bought to be sold in the shop as well as bank fees that are like those incurred in the forecourt.

3.2 The driving forces of change and the future for fuel stations.

The Boston Consulting Group identifies the future trends in the evolution of the gas stations' business models. As previously explained, gas stations operate under a business model based on the sale of fuels as well as the management of convenience stores or supermarkets.

Their 2019 report cites three major forces that are disrupting the retail fuel market:

1) The boom in alternative fuels (electricity, hydrogen, LNG and LPG)

2) The emergence of advanced mobility models

3) Changing consumer expectations

The alternative fuels boom is supported by two factors. The first one is the roll-out of regulations to limit greenhouse gas emissions. These regulations can take the form of incentives for the use of alternative fuel solutions via lower taxation levels, or, on the contrary, of disincentives to the consumption of fossil fuels by using higher taxes. The second one are the consequences of the strength of the technological developments. While the cost of batteries continues to fall, automotive manufacturers are investing heavily in electric vehicles. By 2030, more than a third of all new vehicles sold will be fully or partially electric. This development poses a major threat to fuel retailers, particularly those that manage many gas stations for which fuel sales account for a large share of revenue. Being an alternative fuel and a source of energy usable in electric vehicles, hydrogen (production and distribution) represents a foreseeable competitor not only to batteries producers but also to traditional fuel retailers. On the technical side, the literature is adamant about this statement. However, its economic viability is still a question that remains to be answered.

The evolving landscape in which forecourt retailers run their activities puts an increasing load on the resilience of their business. The declining fuel revenues and margins as well as rising operational expenditures put pressure on profitability. As explained above, it is possible to observe a transition of source of revenue from the forecourt to the backcourt. Hence, extensive investments are being carried out in outlets, technology and infrastructure to, respectively, "increase customer experience" (KPMG, 2020), to ""better serve customers" (KPMG, 2020) or to serve the "new fuel landscape." (KPMG, 2020). Additionally, as customers become more sophisticated, modern demands include increased "convenience in products, services and location" (KPMG, 2020) and a qualitative and easy shopping experience. Finally, a general rise in uncertainty looms over the fuel retailing market. This is applicable to both forecourt and backcourt as uncertainty on the future fuel landscape mix and the role of the different types of forecourts rise.

KPMG imagines the future forecourt that is set to exist in 10 to 15 years from now. The revenue portion originating from fuel sales should experience a drop of 30% to a level of 20%. Backcourt revenues will grow steadily yet without gain ground on revenue proportion of fuel station, stabilising at 35 to 40% of total revenues. Adjacent services such as carwash and repair, co-working spaces and laundry services will experience the greatest rise. Supported by a growing demand in convenience; adjacent services will represent up to 30% of a fuel station's revenue in the next 10 to 15 years whereas they are virtually non-existent nowadays. Finally, charging points for electric vehicles should represent 10% of the revenues. This is the area where hydrogen pumps could play a major role in the changing fuel station's infrastructure.

The current COVID-19 pandemic has influenced forecourt retailers. Challenges faced by retailers range from demand fluctuations to uncertainties. According to KPMG, a previously unseen demand for food retail resulted, first, in a supply shortage and loss of potential sales. As for the forecourt, a "significant drop in demand for fuel and also for traditional products of some convenience categories like cigarettes and food to-go" (KPMG, 2020) resulted in large amount of inventory, driving prices down. Consequently, revenues and margins on the fuel side were heavily impacted by the weak oil sector's demand. Another direct consequence from the pandemic is the added operating expenses linked to increased cleaning and sanitation of fuel stations, making it "difficult to sustain the underlying operating margin level" (KPMG, 2020).

Luckily, convenience stores were in a favourable position in terms of liquidity at the beginning of the global pandemic, making it possible to sustain the business model longer through the crisis caused by the Covid-19 pandemic. However, this situation marked a deep scar in the business model of fuel stations as these must "proactively manage balance sheets and liquidity — as lenders and investors are being more selective than they were prior to the pandemic" (KPMG, 2020).

3.3 Fuel stations' necessary changes

According to KPMG, changes must be focussed towards developing the backcourt experience "in a bid to attract customers and increase the probability of impulsive purchases" (KPMG, 2020). Convenience stores' designs are developing to better suit the modern consumer mind by increasing retail space, differentiating from competitors, and adding "food-to-go [offerings] for customers who would prefer to eat in-store." (KPMG, 2020). Product choice and assortment is enhanced by "introducing new menus and concepts, such as live preparation to stay up-to-date and sustain consumer interest and offering healthy and locally produced products (e.g., fresh fruits and vegetables, dairy, deli and low-calorie drinks and snacks) to cater to different age groups and customers" (KPMG, 2020).

Additionally, with the previously explained changing environment of the fuel retailing market, KPMG considers that, in most cases, performance improvement and cost reduction should be realised thanks to "back-office standardisation and digitalisation" (KPMG, 2020) as well as front-end digitalisation. Customer experience should be increased by starting adjacent services to better respond to ever evolving consumers' demand and adapt to declining fuel sales.

On the other hand, KPMG states that "hydrogen has the potential to become a vital part of the transport mix in a low-carbon future — requiring players to re-invent their business models to account for new infrastructure requirements (around fuel production, storage, and distribution)." (KPMG, 2020). Concerning distribution of the consumer, "hydrogen is fuelled into the consumer's vehicle in few minutes. A 4 kg hydrogen tank holds the energy equivalent of 4 gallons of gasoline. Such a tank is filled in 3-5 minutes" (KPMG, 2020). As a result, forecourt retailers might see a potential business opportunity. As a hydrogen vehicle can be refuelled considerably more quickly than those equipped with batteries, forecourt retailers could see a real potential in this technology. Despite this, several issues must be considered about the hydrogen supply chain. In fact, "transporting, storing, and delivering [hydrogen] to the fuelling station is considered to be expensive on a per gasoline gallon equivalent basis." (KPMG, 2020). As a higher cost will be incurred by hydrogen station owners, strategic decisions will have to be taken. As an example: "expected cost to build a hydrogen economy could be [approximately] US$280 billion during 2018 to 2030, including US$80 billion for infrastructure to store, transport and distribute hydrogen." (KPMG, 2020).

Other considerations are those directly linked to the refuelling infrastructure. Three distinct configurations of distribution are foreseen: integrating a hydrogen facility into an existing refuelling station, establishing a dedicated hydrogen infrastructure, creating a network of mobile hydrogen refuelling stations. As for the integration of a hydrogen facility into an existing fuel station, space is the primary requirement "there should be sufficient space on the existing site for the required hydrogen facilities and that the delivery, storage and dispensing of hydrogen alongside other liquid or gaseous fuels is possible from both a technical and a regulatory perspective" (KPMG, 2020). A positive impact of the establishment of a dedicated standalone hydrogen site is the lack of constraints of an existing infrastructure, according to KPMG. Finally, mobile hydrogen refuelling stations are used where there is an absence of any permanent hydrogen infrastructure. However, such business if often used for a product launch and for demonstration purposes.

3.4 Intermediary conclusion to part 3.

The changing forecourt market environment reflects a rapid shift in demand. Where the 9 building blocks of the business model canvas where quite stagnant in the past, it seems that in the span of the last decade, the business model of a fuel station has dramatically changed. Fundamentally, the concept did not evolve dramatically, however the proportions of revenues have shifted towards the backcourt. Whereas customers solely used to fill up their vehicle, now, the backcourt is becoming the primary source of income for fuel retailers. This shift in the source of income shows a real shift in customers' behaviours that needs to be captured. As a result, hydrogen might play a significant role in attracting new consumers and recapture income from the sales of fuels.

Unfortunately, heavy investments are needed to develop the hydrogen infrastructure. This points out the question of who must take the lead to overcome a chicken-and-egg phenomenon where few hydrogen vehicles are sold because of the poor availability of hydrogen stations which in turn are not developed due to low hydrogen demand by car drivers. Investments in renewable electricity could serve as a base to launching an environmentally friendly hydrogen which private actors could find interest in, hence further pursuing hydrogen storage, transportation, and distribution.

On the other hand, it is unknown whether hydrogen vehicle owners' consumption behaviour is the same as ICE vehicles' owner. Is the business model of a fuel station offering hydrogen going to be different from the one we know? Is the backcourt going to further gain prominence with hydrogen sale? Station managers must ask themselves these questions when looking at distributing hydrogen.

4 Problem: Issue definition

The objective of the research is to understand the role of hydrogen in the alternative fuels market environment. On the whole, the aim is to understand how the stakeholders involved in the supply chain of the alternative fuels' markets must adapt.

At the start of my research, various initial questions led my exploratory journey. Topics on the importance of hydrogen as well as the politics governing its growth fascinated me. Questions such as why is hydrogen picking up traction in the press? Or why has hydrogen, as a source of energy, regained interest in the eyes of the European Commission? Are leading questions that guided my research. Others included how the "Oil and Gas" industry will be impacted by a future growth in the use of hydrogen? How to accommodate the distribution of multiple fuel types simultaneously? And finally, how does a fuel station operate?

The concepts that guided my exploratory research can be separated into three topics: hydrogen as a mean of energy storage, EU's policy and fuel stations' business model.

Concerning hydrogen, concepts such as its industry, its market and the fuel cell electric vehicle environment as well as the "well to wheel" journey of hydrogen are pivotal for my research. Regarding European matters, the EU Commission's goal to facilitate a better integration of its energy system is one of the concepts that drove my exploratory research. The role of hydrogen within the global green strategy and the future European economy are two aspects that steered my research. The study of the business model of a refuelling station was conducted because this could be the site of the last step of the hydrogen supply chain. If the fuel mix of the future were to change, refuelling stations' business models will have to adapt accordingly. Hence the study of the business model of current fuelling stations.

From the exploratory research it appears that hydrogen technology should further develop thanks to an impulse from the EU institutions. As hydrogen electric vehicles increase in number, demand in hydrogen should consequently increase as well. Despite the current marginal number of hydrogen vehicles on our Belgian roads, refuelling stations will have to take into account the expected changing demand of customers when planning investments. The issue that spurs from the exploratory research is the lack of preparation of today's fuel stations to distribute hydrogen fuel. This problem statement leads to the research question formulation.

4.1 Research question formulation

On the basis of the exploratory research, concepts such as distribution, hydrogen, green hydrogen and European Commission arise from the analysis. They can be grouped into a single research question: *"Which strategic decisions should Belgian fuel stations take to distribute hydrogen fuel in the light of European Union's promotion of green hydrogen policy?"*.

As Van Campenhoudt, Marquet and Quivy explains it, "a "good" research question meets three criteria" (Schrooten, Paquet, & Simons, 2018): clarity, relevance and feasibility.

That research question is not excessively long, it is precise and unequivocal. Its 23 words-long phrase and its concepts are defined by scientific sources which make it clear. The question is neutral, based on facts and not on implicit judgements. Finally, on the feasibility side, it is worthwhile investigating on the possible material and technical constraints that could be reached during the research. Extensive documents on hydrogen fuel stations are available publicly and access to information is possible through interviews with fuel station groups. Answering this question should be possible within the available time.

5 Answering the research question: *"Which strategic decisions should Belgian fuel stations take to distribute hydrogen fuel in the light of European Union's promotion of green hydrogen policy?"*

5.1 Methodology

5.1.1 The analysis model.

The analysis model aims at answering the research question. In order to do so, operational objectives for will be set. According to Tremblay and Perrier (2006), analysis operational objectives relate to activities that the researcher intends to conduct in order to solve the research question asked. As these objectives drive the research and data collection, it is necessary for the researcher to characterise them as:

- Specific: Objectives must be clear, precise and understandable.
- Measurable: Objectives must be quantified or qualified. This represents a numerical value that seeks to be attained.
- Attainable: Objectives must be ambitious, realistic and aim towards virgin areas of knowledge.
- Realistic: Goals must be able to be achieved with means within reach.
- Temporal: Goals must be achieved within a specified period of time.

Following these guidelines, operational objectives for the research are the following:

- Creation of a potential financial plan based on three different investment plans aiming at a hydrogen distribution in a fuel station.
- Submit the financial plan to fuel station owners or managers to identify incentives and disincentives to launch a hydrogen distribution service.
- Set up a framework for business stations' managers to take future strategic decisions regarding the developing hydrogen distribution network.

Such objectives will help to identify problem solutions for the lack of preparation of today's fuel stations to distribute hydrogen fuel. The operational objective will lead to recommendations for fuel stations' managers to prepare for hydrogen distribution in the coming decades. By collecting fuel station's managers' view on possible financial plans of hydrogen sale, a deep understanding of their sensitivity to risk will be acquired which will enable the formulation of accurate recommendations.

5.1.2 Construction of data collection tools

Secondary data will be found in published documents such as reports or researches. Analyses are also an important source of information. "These resources can be very useful for the researcher, especially when it comes to data that only organizations with significant resources can gather. (...) they were not produced by the researcher himself and therefore do not necessarily present themselves in a form that corresponds to his research needs." (Schrooten, Paquet, & Simons, 2018).

The envisioned data collection includes mainly literary documents emanating from private organizations.

Researchers, experts in fuel stations' business models and in the field of hydrogen, well know consultancy companies and industry reports are the targeted publishers of documents. Additionally, online availability is paramount as document recencies and publicity can be important elements.

The analysis grid is a tool that aims at helping the researcher to gauge whether documents have a real added value towards the research and contribute to attaining the objective of the research. It should assemble concepts and their characteristics to help guide the researcher in the choice of the data source. The analysis grid's intended use is the following: the researcher must assess whether characteristics of concepts are covered or not by the document and whether it contributes effectively to answering the research question.

Concepts	**Characteristics**	**Effective contribution to the research?**	
		Yes	No
Financial plan	Sales volume		
	Sales price		
	Investment amount		
	Payback period		
	Break-even point		

Secondly, data collection should take place through qualitative semi-directed interviews.

The aim of the qualitative interview is to understand how fuel retailer value the impact of the external environment on a Belgian hydrogen station. The objective is to identify elements that must be taken into consideration by a Belgian fuel station's manager when taking strategic decisions in order to distribute hydrogen.

The so-called non-direct interview is favoured thanks to its capacity of establishing a genuine exchange where the interviewee expresses his perceptions or opinions in a free manner. "The the interviewee is free to address any aspect the interview that the investigator starts with a general question such as: "Tell me about yourself!" The questions are few and open and aim to gather new information, to develop the point of view of the interviewee." (Schrooten, Paquet, & Simons, 2018).

The target of the interviews are forecourt retailers that are in a position of decision-maker. Forecourt retailers are at the forefront of fuel distribution and therefore are the first to be impacted by the evolution of hydrogen. In addition, their knowledge of a fuel station's business model is another reason to target them. Fuel wholesalers, that are owners of a large number of fuel stations, are targeted for their knowledge of the environment and of the future possibilities around hydrogen distribution in Belgium.

Interview guide:

Who		Name and position of the interviewee	
Where and when		Place, date, and time	
What	**Concepts**	**Characteristics**	**Questions**
	Hydrogen's prospects.	The literature generally is in favour of hydrogen growth. Pivotal elements that could act as determinants to hydrogen growth are not yet identified in Belgium.	How do you see hydrogen developing over the next 20 years?
	EU's strategy for hydrogen	The European Commission is aiming at promoting clean renewable hydrogen produced from wind and solar power.	The EU started to actively promote hydrogen last year. Do you think that petrol station owners should adapt? Why or why not?
	Hydrogen distribution.	Only two hydrogen stations are fully operational in Belgium. More than 3.000 fuel stations operate in Belgium.	What do you think about the possibility of adding a hydrogen pump to one of your service stations to attract a new customer segment?
		Before financial performances of potential hydrogen sales, fuel retailers react and think about actions to be taken.	What are your thoughts on the proposed potential financial plan of hydrogen distribution? (Not disclosed prior to interview to avoid bias) What are the elements you pick up in your decision-making process?
		Elements that drive a business owner to open a business is the return on investment.	What are the incentives for installing a hydrogen pump at a petrol station?
		A negative return on investment will prevent any long-term investment.	What are the barriers to installing a hydrogen pump at a petrol station?
		BRAFCO represents and defends independent fuel retailers in Belgium.	What would you advise petrol station managers/owners to do about hydrogen?

To fulfil the first and second operational objectives of this research, a proposal of three financial plans has been created and will be submitted to the interviewee as explained above, in the interview guide. The following table lays out the financial plans proposal which differ in the proportion of the total investment, required for the installation for hydrogen, paid by the fuel retailer. It is proposed that fuel retailers and oil companies enter in an agreement of co-investment to finance initial costs of installation. The following table lays out the financial plan proposition. All figures and computations are explained below and in sections 5.2.1, 5.2.3 and 5.2.4.

Scenario 1 considers a full investment for a hydrogen station installation of $1.51 million (as estimated by Hecht and Pratt) by fuel retailers without any involvement from oil companies. Scenario 2 represents a situation where fuel retailers would invest 2/3rd of the initial required investment – the rest would be contributed by oil companies. Scenario 3 lays out an investment level of 1/3rd by fuel retailers and 2/3rd by oil companies.

Financial Plan Proposition: 3 scenarios analysis		
Scenario 1: 100% investment from fuel retailer.	**Scenario 2:** 2/3rd investment from retailer, 1/3rd from oil company.	**Scenario 3:** 1/3rd investment from retailer, 2/3rd from oil company.
Hypotheses Investment: 1.51M €. Quantity sold: 50 kg/day (8.3 cars). Selling price: 39.22 €/kg. Cost: 1,370 €/day. **Financial performance** Revenue: 1,961 €/day. Profit: 591 €/day. Payback period: 7 years.	**Hypotheses** Investment: 996.600 €. Quantity sold: 50 kg/day (8.3 cars). Selling price: 39.22 €/kg. Cost: 1,581.04 €/day. **Financial performance** Revenue: 1,961 €/day. Profit: 379 €/day. Payback period: 7.2 years.	**Hypotheses** Investment: 513.400 €. Quantity sold: 50 kg/day (8.3 cars). Selling price: 39.22 €/kg. Cost: 1,787 €/day. **Financial performance** Revenue: 1,961 €/day. Profit: 173.7 €/day. Payback period: 8.1 years.

Costs are incremental in function to the level of investment. Oil companies request a fee to amortise their investment in scenario 1 and 2. Oil companies' investment amortisation plan are two folds:

1. Scenario 2: linear amortisation + 5% interest rate = 211.05 €/day
2. Scenario 3: linear amortisation + 7% interest rate = 417.3 €/day

Finally, in all scenarios, investment is made for a distribution capacity of 100 kg/day and the current number of new hydrogen cars in Belgium is less than 10. In order to calculate the financial performance of the addition of a potential hydrogen pump in a fuel station, several hypotheses must be set. As of 2019, the traffic of hydrogen vehicles in Belgium represents less than 0.0007%. Therefore, considering the current low and future potential demand, and almost inexistant supply, a capacity of distribution of 100 kg per day has been chosen. A review of the literature shows us that total installed cost of a hydrogen station, with a distribution capacity of 100 kg per day, amounts to $1.51M.

5.1.3 Pre-testing data collection tools

"Before collecting the first data that will be analysed to validate/invalidate the hypothesis or operational objectives, it is essential to pre-test the data collection tool(s)" (Schrooten, Paquet, & Simons, 2018). As such, this section is dedicated to pre-testing the literary data collection tool as well as the interview data collection tool.

The literary data collection tool has been pre-tested by subjecting the analysis grid to a limited number of documents. In this case, two sources have been selected for the pre-test: one is a scientific paper written by Hecht and Pratt (2017) while the second one is an article newspaper published by the Wall Street Journal. Annex 6 shows the results of the pre-testing of the literary data collection tool.

The analysis grid will enable the researcher to evaluate the quality of a data source in terms of adequacy and quality of information that it might bring. The researcher sets a threshold of 80% of effective contribution brought by a data source in order to be accepted.

Concepts	**Characteristics**	**Effective contribution to the research?**	
		Yes	No
Financial plan	Sales volume		
	Sales price		
	Investment amount		
	Payback period		
	Break-even point		

Unfortunately, due to the lack of potential available respondents, pretesting of the interview guide has not been carried out. As a result, data collection will be carried out through two tools: the literary collection tool and the qualitative semi-directed interviews.

5.2 Data Presentation and analysis.

5.2.1 Research assumptions.

The research considers hydrogen distribution. No other element of a fuelling station is considered because backcourt activities are expected to increase in the future regardless of the fuel distributed. Additionally, the objective of the research is to identify the decisions that must be taken by a fuel station's manager to include hydrogen distribution. Therefore, hydrogen distribution is the sole subject to be studied without the backcourt business of a fuel station.

As explained above, hydrogen refuelling stations differ in type, location, size and throughput. This influences greatly the business model of hydrogen distribution. For this research, conventional stations with hydrogen that is delivered as compressed gas from a centralised, already operational production facility is considered. Such assumption was made because, in general, existing fuel stations already have built infrastructures which could be used for hydrogen distribution such as the canopy, parking spaces and a building plot. Throughput of hydrogen fuel is set at 100 kg per day in order to accommodate for realistic demand and capacity of supply by hydrogen delivery trailers.

5.2.2 Hydrogen refuelling station types.

The literature presents two types of hydrogen refuelling stations categorised by design. Stations are either conventional or modular. Conventional stations are characterised by their fixed design and are not made to be dismantled. On the other hand, modular hydrogen stations are conceived to be relocated according to specific needs.

Conventional stations are further split into three subcategories and modular stations are split into two. For conventional stations, hydrogen can be delivered as compressed gas from a centralised location. In this scenario, delivery is guaranteed by trailers. Alternatively, hydrogen can be produced on-site via steam methane reforming. This method uses methane to produce hydrogen. Finally, the last possibility is to produce hydrogen through water electrolysis on-site. These three methods of hydrogen delivery characterise the three subcategories of convention hydrogen refuelling stations.

As for modular hydrogen stations, hydrogen in a compressed state can be delivered form a centralised location or can be produced on-site via electrolysis. These are two types of the modular hydrogen refuelling stations.

Each type of hydrogen station incurs different costs at various levels. Hecht and Pratt show us the most common costs inherent to hydrogen stations: "the cost components of hydrogen fuelling stations consist of capital cost of equipment, installation, site acquisition and development, and operating expenses." (S. Hecht & Pratt, 2017) On the revenue side, for the purpose of this research, we assume the sale of hydrogen is the sole revenue source. This is to isolate any effect brought from backcourt offerings and to focus on hydrogen distribution.

Furthermore, as this research aims at proposing recommendations to fuel stations' managers to distribute hydrogen, we take the option to focus on the first type of conventional stations where hydrogen is delivered in a compressed state from a centralised location. This is quite similar to the current business model of existing fuel stations and would guarantee the best understanding by fuel stations' managers of hydrogen fuel business. As they possess already-built infrastructures, these can be re-used for their future hydrogen offering, hence lowering their upfront investment cost. However, due to a lack of available data, the following financial analysis, cannot consider this element.

5.2.3 Valuing cost contributors

Hecht and Pratt's study breakdown the total cost of hydrogen delivered to a conventional hydrogen station. Under assumption of a hydrogen station capacity of 100 kg per day, this increases progressively to $200.000 (see figure 5 below) on the seventh year. Figure 5 depicts the evolution of the total cost of hydrogen until the 25th year of activity. Costs are adjusted to 1.9% inflation and grows steadily at a rate of 10k$/year. This is to account for higher volumes as production increases depending to hydrogen demand.

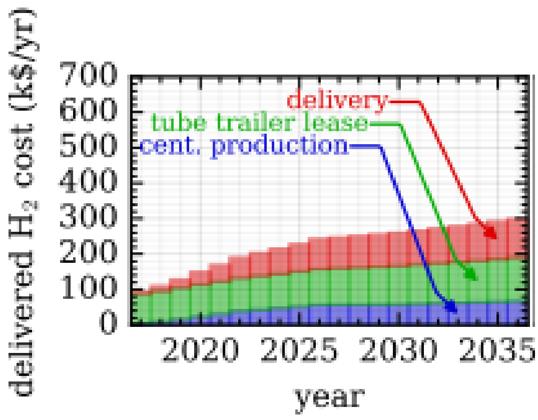

Figure 3: Breakdown of delivered hydrogen cost (k$/year) (S. Hecht & Pratt, 2017)

Delivered hydrogen cost is split up into three categories: delivery of hydrogen in tube trailers with a 300kg capacity, lease of tube trailers and centralised production of hydrogen. Lease of tube trailers is constant and its price is set as a of $3,500/month per tube trailer. It is assumed that a lease of two tube trailers will be necessary to guarantee an uninterrupted supply and avoid risks of shortage or supply disruption. As a result, this amounts to $84.000/year. Centralized production of hydrogen grows until reaching peek distribution level of 100kg/day.

Delivery cost is further broken down by Hecht and Pratt. Delivery cost is composed of permits, maintenance, insurance, labour and fuel. In figure 6, as trailers milage increase, so does delivery of hydrogen. However, we notice that as peek distributing capacity is reached by year 7, milage stabilises, hence limiting delivery cost growth. Confirmed by table 2, delivery costs of hydrogen are highly dependent on the distance travelled by the delivery trailers.

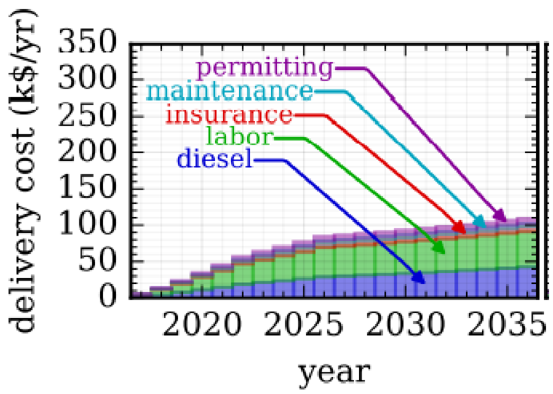

Figure 4: Break down of cot of delivery of hydrogen year on year (k$/year). (S. Hecht & Pratt, 2017)

Description	Value
Average delivery mileage	6 mpg
Average delivery speed	37.8 mph
Tube-trailer capacity	300 kg
Tube-trailer maximum pressure	250 bar
Delivery labour cost	21.21 $/hr
Overhead on labour	20%

Insurance cost	$0.106/mile
Licencing and permits	$0.116/mile
Maintenance cost	$0.078/mile
Lease price	$3,500/mile

Table 2: Summary of delivery-related assumptions. (S. Hecht & Pratt, 2017)

Consequently, we identify one of the largest drawbacks of this type of refuelling station. The distance from a production facility of a conventional station supplied with hydrogen coming from a centrally produced location is key to determine its operational costs.

Furthermore, initial upfront costs must be covered. According to Hecht and Pratt, these amount to $1.51M for a conventional refuelling station with delivery of hydrogen that has a capacity of 100kg/day. 60% of $1.51M represents station capital. These are physical infrastructure elements that are necessary for hydrogen distribution. As an example, hydrogen is delivered by truck at a pressure of 250 bar and sold at 700 bar to consumers. As a result, a compressor, dispenser, coolants, and various pipes and systems are required to guarantee a smooth distribution. Table 3 breaks down in detail elements that are included in the station capital. Such costs are incurred before any hydrogen sale. A total of $894,256 of station capital will be necessary. Highest contributors to this costs are dispensers, compressors, tanks and hydrogen chiller and cooling blocks.

Description	Quantity	Cost	Total
Tanks	3	$45,633	$136,899
Pressure transducer and indicator	6	$1,141	$6,845
Block and Bleed valve	6	$570	$3,422
Air operated valve	6	$2,282	$13,690
Pilot solenoid valve	7	$57	$399
Isolation hand valve	12	$570	$6,845
Check valve	3	$456	$1,369
Coolant pump	1	$1,369	$1,369
Water chiller	2	$4,563	$9,127
Coolant filter	1	$57	$57
Instrument air compressor	1	$1,141	$1,141
Instrument air dryer and filter	1	$2,909	$2,909
Hydrogen compressor	1	$189,827	$189,827
Hydrogen dispenser	1	$250,000	$250,000
Hydrogen chiller and cooling block	1	$150,000	$150,000
IR flame detector	2	$1,711	$3,422
Hydrogen filter	1	$2,852	$2,852
PLC	1	$5,704	$5,704
Tubing	-	$22,817	$22,817
Fittings	-	$17,112	$17,112
Electrical upgrades	-	$57,041	$57,041
Fencing	-	$5,704	$5,704
Bollards	-	$5,704	$5,704
Total (100 kg/day station)			$894,256

Table 3: Break down of costs included in station capital. (S. Hecht & Pratt, 2017)

Finally, Hecht and Pratt present total cost proportions in Figure 7. During a 25-year life, operational expenses represent most of the expense (52.8%) in the form of delivered hydrogen (32.6%), maintenance (11.8%), labour (6.5%) and electricity (1.9%). Initial investment composes the rest of costs in the form of capital expenditure on station (28%), station installation (9.8%) and site preparation (9.4%). (S. Hecht & Pratt, 2017)

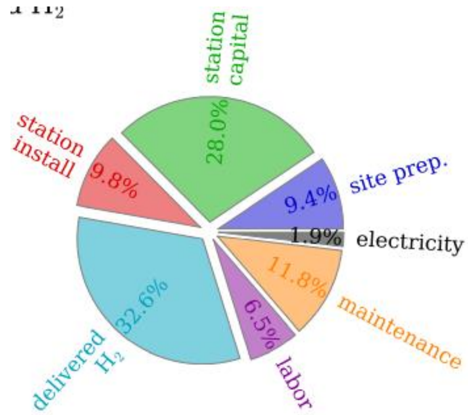

Figure 5: Break down of total installation cost of a hydrogen station with a distributive capacity of 100 kg/day. (S. Hecht & Pratt, 2017)

Questions about funding possibilities arise when talking about the initial investment of $1.51M. This research studies the possibility of an alliance between the fuel retailer and an oil company to finance the initial required investment. In practical terms, this would resemble to a co-investment where both parties would settle on contractual terms to divide rights and obligations reflecting their level of investment. As mentioned above, 3 scenarios of financing the initial investment have been submitted to interviewees. The data collected indicate that oil companies "will first make an investment in their own installations and if they realise that there is a great deal of interest in hydrogen, then yes, they will form partnerships." (Neirynck, 2021). Oil companies feel the need to acquire knowledge of the business model before proceeding to form an alliance with any fuel retailer. As a result, it is very probable that the first fuel stations that will include hydrogen pumps will be owned or supervised by oil companies.

5.2.4 Discussing income projections

Figure 8 suggests that as sales level off after 7 years of activity, costs are mainly linked to operations and take the form of delivery of hydrogen, maintenance of infrastructure, labour cost and electricity. Other costs, that appear only years after first sales, are the disappearing tax cuts linked to the sale of hydrogen. This measure of support by the Belgian government should decrease year on year. Hecht and Pratt consider the first year as a year of investment where no sale is made. This is to account for the time necessary for station installation and site preparation. Revenues should appear as from second year of activity.

As sales increase steadily, revenues increase as sales price is set to remain stable. Figure 8 shows that variable costs increase in absolute terms. However, in comparison to operational costs, they increase less quickly while incomes increase each year. As sales level off, revenues and variable costs stabilise. In order to further increase income, it will be necessary to pursue further investments into higher capacity which would decrease unit sales cost as secondary investment levels would be lower that the initial ones.

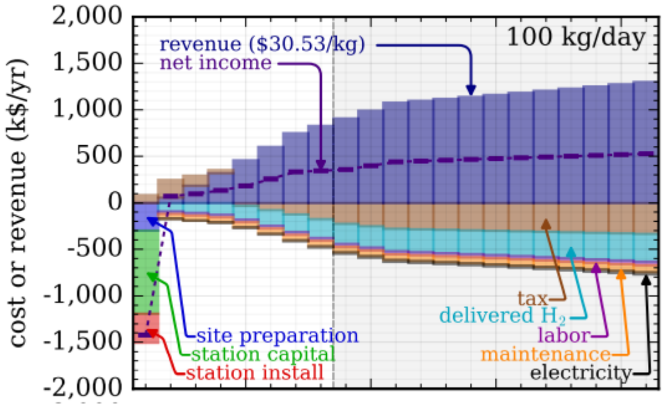

Figure 6: Breakdown of a potential evolution of revenue year on year from hydrogen sales (k$/year). (S. Hecht & Pratt, 2017)

According to the Association of Belgian fuel retailers (BRAFCO), a payback period of 7 years on alternative fuel sales in acceptable. Mr. Neirynck states that "when [fuel retailers] renovate a service station, [they] generally start with an investment of 12 to 15 years. For compressed natural gas (CNG), since the investment is [lower], between 250,000 and 300,000 €, the return on investment is much faster: 3 years at the most." (Neirynck, 2021). Adapting to market conditions is not free and without risks. As distributing hydrogen is seen as highly risky for now, a payback period of 7 to 8 years is foreseeable and would reward enough the risk that a fuel station owner exposes himself to.

5.2.5 Incentives to launching a hydrogen offering within a fuel station.

Launching a hydrogen offering within a fuel station is yet to be done in Belgium. This would be a novel idea, therefore, the following incentives for launching such a business model are theoretical and are subject to the test of reality.

According to Mr. H, "it is necessary to support any new investment in this type of energy, whether it is hydrogen or electricity, because at present it is not financially interesting. When such systems become more common, the subsidies will decrease and eventually reach the level of the one of fossil fuels." (H, 2021). The reality of running a business is that as long as there is no potential for a profit, no company will fight for it.

Despite a willingness to fight climate change, "in any company, money is the most important thing." (H, 2021). Protection of the earth does not justify the death of the company; therefore, subsidies might play a significant role in the offering of hydrogen. Subsidies might apply in different areas to incentivise the launch of a hydrogen offering within a fuel station. Sustaining forecourt retailers directly in the form of tax cuts, or grants delivered for the construction of hydrogen distribution infrastructure. Criteria and conditions will have to be set by local authorities to ensure that the path to distributing hydrogen is monitored.

Indirectly, subsidies already applied on the sale of hydrogen vehicles could further impact positively hydrogen sales as this would boost hydrogen vehicle sales further sustaining hydrogen demand.

This is an indirect incentive to fuel retailers seeking to start selling hydrogen which to be kept into consideration.

The protection of market share could be a valid reason for a manager to add the distribution of hydrogen to his fuel station. While expanding its fuel mix, this would attract a new customer base that could contribute to enhance its' competitive advantage in comparison to fuel stations that offer solely fossil fuels. Mr. Neirynck states "that in the long run we will have to do it if we don't want to lose customers." (Neirynck, 2021). This shows that Belgian fuel retailers understand that the fuel mix is changing. According to Mr. Neirynck, multiple members of BRAFCO have already started diversifying by offering electric chargers on their fuel station's premisses.

5.2.6 Disincentives to launching a hydrogen offering within a fuel station.

As mentioned previously, launching a hydrogen refuelling service comes at a risk. This is represented by the financial value of the initial investment. This upfront investment amounts to $1.51M and is considerably higher than the one required for equivalent works for a fossil fuel distribution infrastructure.

Political decisions will guide the future of hydrogen both at the European and Belgian level. As explained by Mr. Neirynck the electric "mobility policy has not had much luck at the moment and is very poorly coordinated and thought out." (Neirynck, 2021). If this would be applied to hydrogen, this could represent a major hurdle for a fuel retailer to launch a hydrogen offering. Additionally, uncertainties about fiscality are too large and "too many questions about the tax system [are present], but also about the consumer's choice in relation to the purchase of a hydrogen car. For the moment, hydrogen cars are not very "democratic" and are "de facto" reserved to the wealthy class of the population. It is possible that leasing companies start offering them to their customers, but the [policy of offering] company cars is seriously questioned at the moment; so it is a question to ask." (Neirynck, 2021). The discussion about how hydrogen vehicles might get more popular is essential. Traditionally, the Belgian fiscality has favoured car leasing over private buyers by permitting companies to supply vehicles to their employees at a reduced cost. Favourable taxation has made it possible to renew the car fleet at short intervals. In recent years, a political trend towards increased taxation of leased cars in Belgium shows a will to no longer favour this type of locomotion. The risk of slowing down the renewal of the Belgian car fleet could be one of the brakes on the owners of service stations for the potential distribution of hydrogen.

On a practical side, no infrastructure including dispensers and other essential materials for the distribution is readily available. As an example, a large portion of fuel retailers in Belgium are partners with a company that supplies them the dispensers. Being a gas, hydrogen is not able to pass through the fossil fuels dispensers. This situation exemplifies the fact that new partners must be found by fuel retailers or further development for the company that sells fuel dispensers will be necessary. As explained by Mr. H, such uncertainties do not let him know if this system (the existing stations) can dispense hydrogen when it can already do so with CNG or LNG. It remains to be seen how these systems will evolve. It is very likely that hydrogen producers will invest in the development of hydrogen dispensers but, for the moment, it is difficult to know who we will be working with since new, more experienced players, are [already] present [on the world market]." (H, 2021)

Finally, security wise the installation of an appropriate infrastructure might stand as a disincentive. The Belgian government is not yet fully aware of the implication of the sale of hydrogen. On a security perspective, the government seeks to cover all risks. Unfortunately, on this perspective fuel retailers are "convinced that it will be almost impossible to incorporate a hydrogen station into any type of petrol station. The stations in the centre or around Brussels have very little possibility to accommodate hydrogen pumps on their site. Especially in terms of safety and return on investment. The biggest discussion is about safety, the second discussion is about the type of hydrogen station." (H, 2021)

5.3 Setting up a business framework and answering the question

5.3.1 Business framework

The third and last operational objective set out for this research is the establishment of a framework for fuel stations' managers to take future strategic decisions regarding the developing hydrogen distribution network. As such, the nine building blocks of the Business Model Canvas will be developed for a fuel station that would include a hydrogen offering. The following details of each building block would add to those already present as the hydrogen offering would be an added service.

1) Customer segments

Similarly, to fossil fuels sales, hydrogen stations will target customers that own or drive hydrogen vehicles. Tucks and other commercial vehicles using hydrogen would be targeted by stations as well. However, this research does not include such commercial vehicles. Therefore, revenues and costs computations are not adapted for such a possibility.

2) Value proposition

Shopping in the backcourt would be a facility that fuel stations would boast in the event they choose to distribute also hydrogen to their newly acquired hydrogen customers. Comments about the type of fuel station are still valid and apply as well for hydrogen refuelling offering and, as a result, to its value proposition.

3) Channels

With an added hydrogen offering, fuel stations' communication should not evolve extensively. Customer touch points would be like those already in place. However, partnerships with hydrogen databases which map out the hydrogen distribution network could be an effective way to communicate to any potential customer.

4) Customer relationships

The customer relationship building block in a hydrogen sale business model would be equivalent to the one of a traditional fuel station. It would highly depend on the type of fuel station and whether it has a backcourt offering.

In the absence of any backcourt activity, hydrogen stations would offer self-service and a round-the-clock service. In this case, the customer relationship is minimal compared to the personal service which is linked to a backcourt.

5) Revenue streams

As explained above, revenue streams are mainly the sale of hydrogen. Additionally, as said by Mr. E (2021), synergies might appear between hydrogen sale and backcourt sales. This is in sharp contrast to electric charging as filling up a hydrogen vehicle takes minutes whereas electric vehicles can be charged in approximately one hour. As a result, hydrogen sale should not boost as much backcourt sales as electric vehicles, but synergies could, nonetheless, appear between the two segments of the fuel station.

6) Key resources

Similar to traditional fuel stations, hydrogen stations require financial, physical, intellectual and human resources. In addition to covering other needs, financial resources are necessary to cover costs. These are explained in the cost structure building block of this Business Model Canvas. Physical resources will have to be acquired in the form of new infrastructures to enable hydrogen distribution. These are extensively laid out above, under stations' capital investment point (see Table 3 above).

Intellectual resources in the form of knowledge and know-how of hydrogen distribution will need also financial means to buy expertise. Being a relatively niche market in Belgium, the fuel industry still must learn how to market and sell hydrogen. This process could impose itself as a hurdle to fuel station managers.

Finally, human resources should not change much. However, added training of staff on hydrogen distributing practices could be required. In the case where the fuel station already offers a backcourt, added personnel should not be hired as hydrogen distribution is not particularly personnel intensive.

7) Key activities

Key activities added by the sale of hydrogen are the purchase and sale of hydrogen, contacting new suppliers and partnering with new players in the hydrogen environment. Of course, maintaining the infrastructure will be a key aspect of this building block.

8) Key partnerships

Key partnerships to sustain a hydrogen sale business model are similar to those necessary for fossil fuel sale. New partners include all necessary suppliers for installation on the hydrogen distribution infrastructure from acquiring to installation. Partners to acquire the delivered hydrogen are needed. These include a hydrogen truck leasing company, a hydrogen producer and deliverer, etc.

Additionally, a potential partnership with other hydrogen distributors that have the knowledge to teach hydrogen distribution could be a strategic decision to speed the process of learning and avoid potential pitfalls. Furthermore, a partnership for co-investment of upfront costs is an example of a partnership studied in this research. Details on such a co-investment have been discussed in section 5.1.2.

9) Cost structure

As previously laid out, costs linked to hydrogen sale can be separated in to two types: upfront, fixed costs and variable costs linked to activities. Fixed costs include station capital, site preparation and station installation, and amount to $1.51M for a hydrogen sale capacity of 100Kg/day (S. Hecht & Pratt, 2017).

Variable costs are linked to sales and materialise only after the site installation. These include sales taxes, hydrogen delivered (including delivery of hydrogen, lease of tube trailers and production of hydrogen), maintenance and electricity. Note that labour is not included as adding a hydrogen offering to an already existing fuel station could mean that no additional labour must be considered.

Here below, table 4 takes stock of the main additional elements of a business model of a fuel stations offering hydrogen. These elements result from the addition of the hydrogen sale activities.

<table>
<tr><th colspan="5">Business Model Canvas for a fuel station offering hydrogen sale
(Solely additional elements brought by hydrogen sale)</th></tr>
<tr><td>Key Partners</td><td>Key Activities</td><td>Value Proposition</td><td>Customer Relationships</td><td>Customer Segments</td></tr>
<tr><td rowspan="3">Hydrogen-specific partners. (production and delivery companies)
Contractors to build infrastructure.
Hydrogen distributors
Co-investor</td><td>Purchase and sale of hydrogen.
Contacting hydrogen-specific partners.</td><td rowspan="3">Supplying hydrogen fuel while being able to shop in the backcourt.</td><td></td><td rowspan="3">Hydrogen vehicle owners/drivers</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td>Human.
Financial.
Hydrogen sale knowledge.
Physical infrastructure.</td><td>Hydrogen network maps</td></tr>
<tr><td colspan="2">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="2">Initial fixed costs
Variable costs</td><td colspan="3">Hydrogen sales
Backcourt sales</td></tr>
</table>

Table 4: Business Model Canvas for a fuel station offering hydrogen sale (Solely additional elements brought by hydrogen sale)

5.3.2 Recommendations: decisions to be taken

Strategic decisions that must be taken by fuel retailers in Belgium regarding hydrogen distribution depend vastly on the timeframe that is considered. While observing the state of the hydrogen market, undoubtably, we see that opportunities might arise from a very niche market where very little development is yet to take place. We are in the presence of a market that still requires development. Therefore, the fuel retailer must answer the question about comfort to risk. Indeed, entering early in such market is equivalent to getting exposed to a considerable amount of risk as uncertainties are plentiful. His answer to comfort to risk will dictate how early he will enter in the market of hydrogen distribution. As a result, recommendations will be formulated while keeping in mind two timeframes: decisions to be taken in the next 10 years and decisions to be taken later than 10 years from now (i.e., as from 2030). This will guide two profiles of fuel station owners: the risk tolerant and the risk averse.

1) Decisions to be taken during the next 10 years.

In the timeframe of the next 10 years, the aim is to understand the market and the prerequisites of a good location for hydrogen distribution. Large Belgian retailers are considering hydrogen as a potential future investment. A rationale approach first foresees a study of the hydrogen environment in order to take an informed decision. For example, economic reasons might guide the choice to establish a hydrogen distribution service not far from a hydrogen production site as this would lower its cost of delivery. As seen previously, one of the largest cost drivers is the delivery of hydrogen. A lower delivery distance would reduce insurance and maintenance costs of tube trailers as well as labour delivery cost.

Additionally, discussions with politics will have to be engaged to understand their plans. The position of the Belgian government is still very unclear. Indeed, fiscal regimes applicable to alternative fuels such as hydrogen is unclear. Fuel retailer should initiate discussions on taxation applicable to the sale of hydrogen.

Observation of technological progresses in hydrogen distribution will have to be carried out and a preparation of a legal groundwork to enable hydrogen distribution within a fuel station would be an ideal accomplishment. On a more practical level, fuel retailers will have to build new relationships with suppliers in order to acquire all station capital (see table 3 above for details)

Long term strategic decisions include a change in the vision and the mission of the fuel stations to adapt its value proposition and create a link to a new customer segment. This represents a total overhaul of a strategy as most of the Business Model Canvas' building blocks will require a change.

Other decisions are more practical such as assembling necessary resources explained above. In the case of financial resources, fuel retailers should favour 100% self-investing as oil companies might not consider this kind of investment early in a developing market.

2) Decisions to be taken 10 years from now.

In the timeframe later than 10 year from now, the aim is to evaluate business opportunities that are left untouched by early investors. As the more risk tolerant would have taken earlier opportunities, more risk-averse will have to take quicker actions in order to gain market shares. Fortunately, these will benefit from a more mature and developed market which will boost sales quicker.

Strategic decisions also include a change in the vision and the mission of the company to adapt its value proposition and create a link to a new customer segment. As the market would have matured, it will be necessary to build a strategy dedicated to each building block of its new business model. This will create a stable framework which will enable the fuel retailer to advance with more certainty and, thus, more quickly.

Other decisions are more practical such as assembling necessary resources explained in section 5.3.1. In the case of financial resources, fuel retailers should favour co-investing with an oil company that might consider this kind of investment. Such companies could have had the chance to understand the hydrogen market in Belgium, making it easier for them to enter in a co-investment agreement with fuel retailers.

Additionally, approaching partners to enable activities linked to hydrogen distribution will be a strategic decision made by fuel retailers. In this timeframe, the aim is to enter in partnerships rather than just understanding the environment. As time will be scarcer, the necessity to find appropriate suppliers is even more important.

Finally, partnering with a fuel retailer that already took the decision to distribute hydrogen could, strategically, be the right decision. This is to fill the gap of knowledge that was created by the years of wait.

Conclusion

Hydrogen is about to experience a major boost in popularity. On the one hand, hydrogen has never been as much at the centre of alternative energy press, almost rivalling the EV press. This increase in popularity could be largely explained by the longer milage of hydrogen vehicles compared to battery-powered vehicles, or by the time saved in charging them. These observations only make public opinion more favourable to the renaissance of this technology. Furthermore, the European Commission has highlighted the work done by the hydrogen market players and identified the opportunities for development in the transport sector. Despite the very low number of hydrogen cars on the road, the installation of hydrogen stations progress. At present, three hydrogen stations are under construction and should open by the end of this year.

Unfortunately, the lack of key players in the hydrogen market poses a serious threat to its widespread adoption. The production, transport and distribution of hydrogen to the consumer are the three main steps in the hydrogen supply chain. Unfortunately, they are all problematic. The development of these stages still needs to take place before we can hope for a democratisation of this energy.

My research aimed to identify the incentives and disincentives to the introduction of a hydrogen fuelling service within a fuel station and to propose, to fuel station managers, a commercial framework for the implementation of such a service within their existing infrastructure. To this end, a proposed financial plan was submitted to the opinions of key players in the fuel market. The results show that the role of mobility policies is crucial for the attractiveness of a potential hydrogen distribution service within a fuel station. Potential subsidies or state aids are important incentives. On the side of the disincentives, two of them emerge. One focuses on the uncertainty of the future due to the lack of clarity in the government's position on the hydrogen issue. The other, more pragmatic, reflects the youth of the hydrogen market and its cruel lack of key players capable of facilitating hydrogen distribution.

Further developments of my research revolve around the limited resources available to me. A more detailed analysis should identify elements that enter in the decision-making process of investment in a hydrogen offering within fuel stations with different locations: urban, rural and along highways. The impact of location on hydrogen distribution should therefore be studied.

Additionally, the fact that all calculations are based on standalone hydrogen fuel sales might skew numbers. I believe that it would have been interesting to factor in the financial resources that could be saved by fuel retailers when installing a hydrogen pump on the premises of their business. As often happens, it is expected that overall cost numbers would decrease massively when the infrastructure already present in a fuel stations can be used for hydrogen delivery. Hence, decreasing unit costs.

Finally, a more detailed discussion of the level of future potential tax burden would be beneficial for the completeness of this research. Currently, all taxes linked to vehicles amount to 30 billion euros in Belgium. Approximately 60% of the price fuel is made up of excise duties and VAT. The question is whether politicians will take the decision to apply such taxes on hydrogen in the future.

Understanding each region's approach to hydrogen fiscality could also add precision into a potential future analysis.

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