PROGRAMME **Official Master´s Degree in Industrial Engineering and MBA**

Repsol strategic proposal to develop green hydrogen filling stations in Spain

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Master final project

Madrid
May 2023

REPSOL STRATEGIC PROPOSAL TO DEVELOP GREEN HYDROGEN FILLING STATIONS IN SPAIN

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EXECUTIVE SUMMARY

Hydrogen has emerged as a promising source of energy for the transition to a more sustainable and environmentally friendly power system. It has been recognized as a key element in the transition to a low-carbon economy. One of its main applications is the production of electricity through hydrogen fuel cells. This technology is used in various sectors such as transport, stationary power generation and portable electronic devices, among others. Hydrogen fuel cells produce electricity through a chemical reaction between hydrogen and oxygen, generating only water as a byproduct. Therefore, an important application of hydrogen is as a fuel in transportation. The use of hydrogen as fuel in vehicles can significantly reduce greenhouse gas emissions. In addition, hydrogen fuel cells have a higher efficiency than traditional internal combustion engines, making them a promising alternative for vehicles.

The development of green hydrogen vehicles in Spain presents great opportunities for growth and development in the transportation sector. The availability of renewable energy in the country can support the production of clean hydrogen fuel, reducing dependence on imported fossil fuels and improving air quality in urban areas. Spain is also witnessing the introduction of fuel cell buses powered by green hydrogen, with plans for their deployment in Madrid and Barcelona. Heavy vehicles, such as trucks and buses, are also suitable for renewable hydrogen as a fuel source.
The factors that support this new technology are strong government and international support for green hydrogen development, financial opportunities from Spain and Europe, rising social awareness of climate change, positive technological advancements and environmental benefits in terms of reduced greenhouse gas emissions. However, there are challenges to overcome, such as the high cost of hydrogen production and infrastructure investment. Investor skepticism and uncertainty may also pose obstacles. Continued industry support, funding and government initiatives will be crucial to address these challenges and unlock the full potential of hydrogen vehicles in Spain.

Repsol S. A. is a Spanish multinational energy and petrochemical company specialized in oil and gas exploration, exploitation, production, transportation and refining activities. It also produces, distributes and markets petroleum derivatives, petrochemical products, liquefied gas and sells natural gas. Since 2018 it also markets gas and electricity in the Spanish retail market.
Repsol advocated its transformation into a multienergy firm in 2020, solidifying its leadership in the energy transition. The company is committed to become net zero emissions by 2050. Repsol has been at the forefront of developing environmentally friendly fuel alternatives using the latest technologies. Only in 2022, Repsol avoided 3,400 tons of C02 emissions and installed 3,870MW low-emission generation capacities with an investment of €770M in renewables. In 2025, Repsol expects to achieve 6GW of renewable production, by 2050 20GW will be available. Among Repsol's different business units, this strategic proposal will focus on the Commercial and Renewables area, more specifically in the mobility activities.

The objective of this project is to develop a strategic plan for the implementation of hydrogen filling stations in Repsol's service stations. To do so, the hydrogen market and technological solutions will be analyzed. The evolution of the hydrogen energy in the automotive sector in Spain is crucial to estimate de number of filling stations needed.

The targeted clients that will use Repsol's hydrogen stations are private customer with their own hydrogen car. These are citizens that are concerned about the environment and the air contamination. They usually perform urban and short transportation; the use will be for their daily life travels. These clients need refueling stations inside the cities and near their homes.
The first public hydrogen filling station arrived at Spain in 2022 and previously there were already 5 private filling station, the supply of this type of dispenser now is practically minimal. Since there is little data on the expected growth of hydrogen-powered vehicles, it is estimated that the growth will be comparable to the development of electric vehicles. To estimate the market for hydrogen cars, three different scenarios have been identified. Assuming that in 2021 there were 15 hydrogen cars in Spain and in 2009 there were only 17 electric cars, the same annual growth rate is applied to calculate the growth of new hydrogen car registrations. With this calculated data, it is possible to estimate the total number of cars that will grow each year. These obtained data, which follow the same growth trend as the one of electric cars, will be identified as the first growth case (scenario 1). This first scenario is the highest volume considered. For the following two cases, each annual growth rate of the total hydrogen cars is expected to decrease by 12.5% for scenario 2 and 25% for scenario 3. With this study, three possible market size cases are obtained, starting from a scenario with a very large market size to a much smaller third estimate.

In order to establish coherent hydrogen stations development objectives for Repsol, the market share of hydrogen sales is estimated. In the electric mobility and gasoline refueling market, Repsol is one of the companies that captures the highest market share. However, in the hydrogen filling stations market, these companies are not the only ones investing in this infrastructure. This gives Repsol a strong sales advantage due to its consumer stronger approach at its service stations. Nevertheless, its market share does not seem to become as high as in its traditional gasoline refueling stations market. Therefore, it is assumed that Repsol will have a market share of 10% in the sale of hydrogen at its filling stations.

Considering the market growth expectations estimated, the amount of hydrogen that Repsol will be able to sell at its refueling stations is estimated for each proposed scenario. The hydrogen filling station that will be installed is a 480kg/day dispenser with external supply of hydrogen gas. For this type of model, an installation investment of €2.2M per unit will be taken and it will be able to dispense 175,200 kg of H2 per year, which is equivalent to 80 car refills per day. Finally, with the estimated Repsol sales of hydrogen and the hydrogen stations capacity, it is possible to propose the number of filling stations to be installed for Repsol to meet the estimated demand according to the three types of scenarios. By 2050, the number of required hydrogen filling stations will vary significantly depending on the demand scenario, ranging from 658 to 56 dispensers needed.

The economic feasibility of the proposed number of hydrogen filling stations depending on each scenario has been made. The first two scenarios are the most financially interesting while proceeding with caution regarding scenario 3 due to its unfavorable financial outlook. However, scenario 1 evolution seems idealistic, making scenario 2 a more realistic option adapted to the uncertainties and challenges associated with hydrogen technology. It is not clear that the evolution of hydrogen cars beyond 2021 will follow the same path as the history of electric cars since 2009. While there may be lessons learned and technical breakthroughs that will accelerate hydrogen vehicle adoption, there are special problems and limits connected with hydrogen technology, such as large-scale hydrogen generation and transportation, that may limit its expansion.

Therefore, scenario 2 is the best option: it has a positive net present value with an interesting internal rate of return of 12% while its selling evolution and market capacity are more reachable. Repsol is advised to move on with investment in this scenario 2. It strikes a balance between market growth and feasibility. Its projected market evolution is more attainable, aligning with the current state of hydrogen technology and market.

It is very important for Repsol to position itself as a leader of the benchmark in clean mobility. Partners are identified in two categories: suppliers and producers of hydrogen filling stations' technologies and producers of hydrogen. Repsol has the option to collaborate with either well-known international companies like Air Liquide or Linde Group or small Spanish companies specializing in hydrogen technologies. Establishing alliances with Spanish companies, such as Calvera Hydrogen, Clantech and Hiberbaric, would enhance Repsol's image in national industrial and technological development while leveraging synergies and market knowledge. This would reduce costs and minimize the risks associated with importing technology. A recommended partner could be Clantech, combining Repsol's energy sector expertise with Clantech's experience in designing hydrogen stations. Additionally, Repsol could form alliances with hydrogen car manufacturers like Hyundai, Toyota or BMW, as well as transportation company Uber. Collaborative projects could focus on research, innovation, joint sales, vehicle distribution, and maintenance. They could explore new business models and invest in infrastructure, expanding their presence in the sustainable mobility market. This partnership would maximize the potential of hydrogen technology in transportation and open new geographic opportunities for both companies.

To implement the installation of green hydrogen filling stations, Repsol's implementation plan should follow these steps. Firstly, suitable locations must be identified, focusing on high-traffic areas in major cities such as Madrid, Barcelona, Valencia, Sevilla, Zaragoza, and Malaga. Then, strategic alliances with the already mentioned partners should be established. Construction plans, equipment acquisition and obtaining necessary permits must be executed, followed by the recruitment and training of station personnel. Finally, awareness and marketing campaigns should be implemented to promote the product.

During this execution plan, Repsol should consider the potential cannibalization of hydrogen cars over other transportation methods and explore the production and sale of low-emission fuels, such as sustainable aviation fuels and biofuels, to mitigate the impact on their refining and petroleum products businesses. As the market evolves, Repsol will need to transform its gas stations into mixed-energy service stations, providing a combination of electric vehicle, hydrogen and biofuel refueling services while maintaining their existing services to enhance the customer experience and maintain market share. By adapting to the changing energy landscape and meeting customer expectations, Repsol can retain its market leadership.

KEYWORDS

Hydrogen filling stations, Repsol, green hydrogen energy, service stations

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CAGR - Compound Annual Growth Rate

CO2 - Carbon dioxide

EHB - Hydrogen Backbone

EU - European Union

FCEV - Fuel cell electric vehicles

H2 - Hydrogen

IRR - Internal Rate of Return

LHV - Lower Heating Value

LOHC - Liquid organic hydrogen carrier

LPG - Liquified petroleum gas

MWh - Megawatt hours

NPN - Net Present Value

PEM - Polymer Electrolyte Membrane

SDG - Sustainable development goals

SOEC - Solid Oxide Electrolyzer

1. Introduction

a. What is hydrogen energy?

Hydrogen has emerged as a promising source of energy for the transition to a more sustainable and environmentally friendly energy system. There are two main sources for obtaining hydrogen: fossil fuels and electricity. Fossil fuels such as petroleum, natural gas and coal can be decomposed into hydrogen molecules through a process known as steam reforming. This process generates carbon dioxide as a byproduct, which contributes to greenhouse gas emissions. On the other hand, hydrogen can be produced through the electrolysis of water using electricity. Although this process does not produce direct emissions, the source of the electricity used must be taken into account. If the electricity used is generated from non-renewable sources such as coal or natural gas, then the production of hydrogen still contributes to greenhouse gas emissions. The emissions associated with hydrogen must be considered throughout the entire life cycle of the product, not just during its use. Therefore, two methods can be used to reduce emissions: (Asociación Española de Operadores de Productos Petrolíferos, 2020)

- Carbon capture: The carbon dioxide emitted during hydrogen production can be captured and stored, reducing greenhouse gas emissions. However, the current technical limit for carbon capture is only 90%, so additional actions such as reforestation are required to achieve net zero emissions.
- Renewable electricity: The use of 100% renewable electricity to produce hydrogen can greatly reduce greenhouse gas emissions, leading to so-called "green hydrogen" that is considered renewable and clean.

The goal is to achieve renewable hydrogen with zero or nearly zero emissions throughout its life cycle. Although this goal requires further technological development, achieving it would greatly contribute to the transition towards a more sustainable and low-carbon energy system.

According to the scientific community, there are different types of hydrogen energy, depending on the production sources and emissions, which are summarized on Table 1.

Type	Characteristics
Green	Green hydrogen is the cleanest type of hydrogen produced through electrolysis using renewable electricity. It is emission-free but currently more expensive than gray or blue hydrogen, requiring substantial investments in renewable energy and electrolysis technology.
Grey	Grey hydrogen is the predominant type of hydrogen produced globally, comprising approximately 75% of production. It is created via steam methane reforming, emitting carbon dioxide as a byproduct. This method is environmentally unfriendly due to CO2's contribution to climate change.

Blue	Blue hydrogen is produced by using a process similar to grey hydrogen but incorporates carbon capture, utilization, and storage. This technology captures and stores or reuses carbon emissions, resulting in a significantly reduced carbon footprint. Blue hydrogen is regarded as a low-carbon fuel and holds potential for facilitating the transition towards a more sustainable energy system.
Brown	Brown hydrogen, similar to grey hydrogen, is generated from coal instead of natural gas. This type of hydrogen production is even more polluting than grey hydrogen and contributes significantly to greenhouse gas emissions.
Turquoise	Turquoise hydrogen is derived from renewable natural gas obtained through organic waste decomposition. It exhibits lower carbon emissions compared to blue hydrogen and is recognized as a cleaner alternative.
Purple	Purple hydrogen is generated by utilizing nuclear power to generate the necessary electricity for electrolysis. It is a carbon-free hydrogen variant; however, its use is controversial due to concerns surrounding nuclear power safety.
Yellow	Yellow hydrogen is produced by utilizing electricity from the grid, which can come from various energy sources. As a result, the carbon emissions associated with yellow hydrogen vary depending on the mix of energy sources powering the grid.
Gold	Gold hydrogen is produced using renewable energy for electrolysis and has the potential to capture and store CO2 emissions, achieving negative emissions. This technology is currently in the experimental phase and not widely employed for commercial hydrogen production.

Table 1. Types of hydrogen energy. Source: (Pérez, 2022)

Hydrogen has been recognized as a key element in the transition to a low-carbon economy, thanks to its multiple applications. One of its main applications is the production of electricity through hydrogen fuel cells. This technology is used in various sectors such as transport, stationary power generation, and portable electronic devices, among others. Hydrogen fuel cells produce electricity through a chemical reaction between hydrogen and oxygen, generating only water as a byproduct. Another important application of hydrogen as a fuel is in transportation. The use of hydrogen as fuel in vehicles can significantly reduce greenhouse gas emissions, as the only byproduct of this reaction is water. In addition, hydrogen fuel cells have a higher efficiency than traditional internal combustion engines, making them a promising alternative for vehicles, especially in heavy-duty transport such as buses, trucks, and trains. Hydrogen can also be used as a raw material for industrial processes. The production of industrial chemicals such as ammonia, methanol, and hydrocarbons can be achieved through hydrogenation processes. This provides an opportunity for the chemical industry to move towards more sustainable and environmentally friendly production methods. Moreover, hydrogen can be used in the reduction of metals, a process used to obtain various types of metals such as iron, steel and aluminum. This process involves the use of hydrogen to remove oxygen from the metal ores, resulting in pure metals. Renewable energy storage is another important application of hydrogen. Hydrogen can be used to store energy from intermittent renewable energy sources such as solar and wind power, as it can be produced through the electrolysis of water using renewable energy sources and stored in tanks or underground storage facilities. In addition, hydrogen can be used for thermal and electrical power generation in various industrial sectors, such as the production of cement, glass and paper. This provides an opportunity for these sectors to reduce their carbon footprint and promote a more sustainable production process. (Gallego, 2018) Summing up, hydrogen energy offers numerous advantages, such as its exceptional energy density that allows it to store more energy per unit of weight or volume than other fuels like gasoline or diesel. Nevertheless, there are also several hurdles associated with hydrogen production, storage, and transportation. The production of hydrogen from fossil fuels can lead to the release of greenhouse gases into the environment and generating it from renewable sources such as water through electrolysis can be costly and require high energy input. Furthermore, due to its low density and the need for specialized equipment, storing and transporting hydrogen can be challenging.

b. Project motivation

Our energy system is in a time of change and uncertainty. The global situation is developing, pushed by international agreements, solutions and technologies against climate change, as stated in the development of the SDGs (Sustainable Development Goals) by the United Nations, and the 2021 Glasgow and the 2016 Paris. Both governments and companies all around the world have agreed to fight this climate problem and have started to invest in renewable energies. The photovoltaic, wind, hydropower and geothermal energies are already well known and widely developed. However, in recent years, a new technology has emerged: hydrogen energy. Hydrogen energy refers to the use of hydrogen as a fuel source to generate energy. Hydrogen is the most abundant element in the universe and has a high energy density, making it an attractive alternative to fossil fuels. Therefore, the production and use of hydrogen require careful consideration of the environmental and economic implications.

Repsol is a Spanish multinational energy and petrochemical company that has been at the forefront of developing environmentally friendly fuel alternatives using the latest technologies. The company's interest in investing in green hydrogen is in line not only with its global commitment to combating climate change, but also with its long-term strategic vision to diversify the range of energy sources and reduce dependence on fossil fuels. Repsol recognizes the importance of investing in green hydrogen to achieve sustainable development and zero emissions by 2050. By investing in green hydrogen projects in Spain, Repsol can contribute to the country's decarbonization goals and position itself as an important player in the emerging market. Additionally, given that demand for green hydrogen is expected to grow rapidly, this investment could create new business opportunities and generate shareholder value. With its expertise and capabilities, Repsol can become a leading supplier of green hydrogen solutions both at home and abroad.

c. Project goals

The goals of the project are summarized as follows:

- Analyze the green hydrogen sector worldwide, in Europe and in Spain. The study will be focused on green hydrogen cars, supply hydrogen filling stations and green hydrogen generation.
- Identify the technological solutions that could be implemented.
- Study the evolution of the hydrogen energy in the automotive sector in Spain.
- Identify an implementation plan.
- Study the economic viability for green hydrogen filling stations, considering the evolution of hydrogen cars and the implementation of green hydrogen cars in Spain.
- Propose a strategic plan for Repsol's business development of this technology.

d. Methodology

The methodology of the project will be:

- Data capturing for understanding the green hydrogen cars and buses, energy production and hydrogen filling stations markets and technologies. Websites from consulting firms, renewable energy companies and car suppliers will be consulted.
- All the markets and Repsol analysis will be done with internal and external frameworks studies. External frameworks such as PESTEL and Porter's five forces will be used for the international and national market studies. The internal framework SWOT will be used for analyzing and proposing assessment to Repsol.
- The economic viability for the businesses plan will be studied through a capital budgeting evaluation. An estimation of general revenues and costs, IRR (Internal Rate of Return), NPN (Net Present Value) and discounted payback will be calculated.
- Finally, with all this data recollection, analysis and calculation, the strategic proposal for Repsol will be reasoned.

2. Hydrogen market analysis

a. Renewable energy evolution

Renewable energies' evolution has been impressive, over the past years the use of renewable energy has increased significantly as these energies, such as solar, wind, hydro and geothermal, are an important replacement for fossil fuels. This is mainly due to lower production costs and the rise in social and climate awareness. Nowadays in our society, the climate and environmental consequences are considered a priority in the development of cleaner technologies and industries. Renewable energy represents a pillar in this green development. Therefore, as shown in Figure 1, the investment in these energies has been increasing considerably each year: a very high CAGR (Compound Annual Growth Rate) is obtained in the last decade, whose value is 8.5%. (IRENA (International Renewable Energy Agency), 2023) The energies with higher investment are solar photovoltaic plants and onshore wind, they represent more than the 80% of the renewable energy investments in 2022.

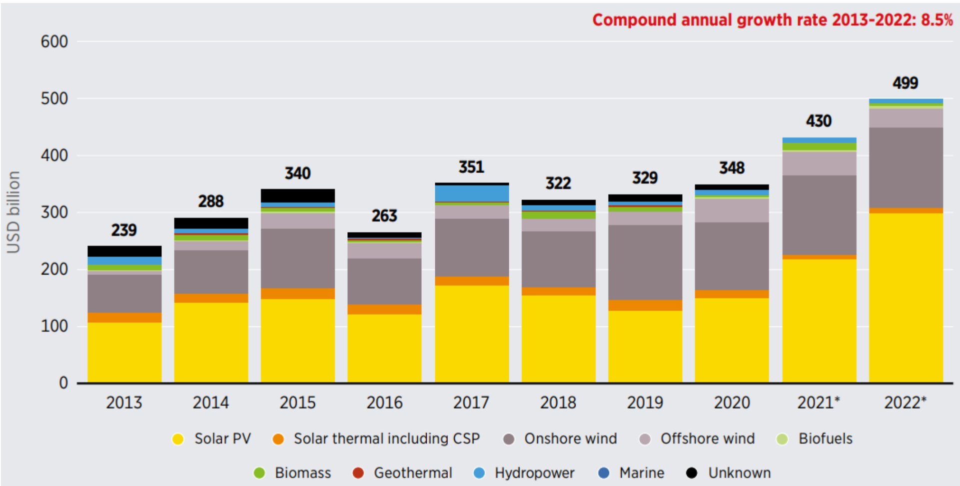

Figure 1. Annual financial commitments in renewable energy, by technology, 2013-2022. Source: (IRENA (International Renewable Energy Agency), 2023)

In Spain, the development of renewables is even greater: the country continues to demonstrate its renewable potential. Wind and photovoltaics energies have broken their own production records in 2022. Photovoltaics is the technology that has increased the most and this year has already managed to surpass hydraulics, currently ranking third in the ranking of sources with more power: it already accounts for almost 16%. The renewable generation capacity amounts to be around the 58% of the total production in Spain in 2022. In fact, the installed renewable power continues to grow, accounting for 60% (70,000 MWh) of the total installed power in Spain. (Red Eléctrica Española, 2022)

b. International hydrogen market

Being such a recent technology, the development of the hydrogen market is very recent. As of 2017 with Japan as the first country involved, governments are developing routes and strategies to implement this new energy vector. Most European countries stablished their strategies in 2020.

According to a study by the research agency Transparency Market Research (Figure 2), the green hydrogen market will grow by 50% over the decade. And the size of the market will increase from 2.1 billion euros today to 133.58 billion euros in 2031. The market for electrolyzers will also grow exponentially and will reach 240 GW of total capacity. Therefore, the expected CAGR for the next 10 years will be around 40%. This strong growth will take place mainly in two regions, Europe and Asia which will lead this new energy business worldwide.

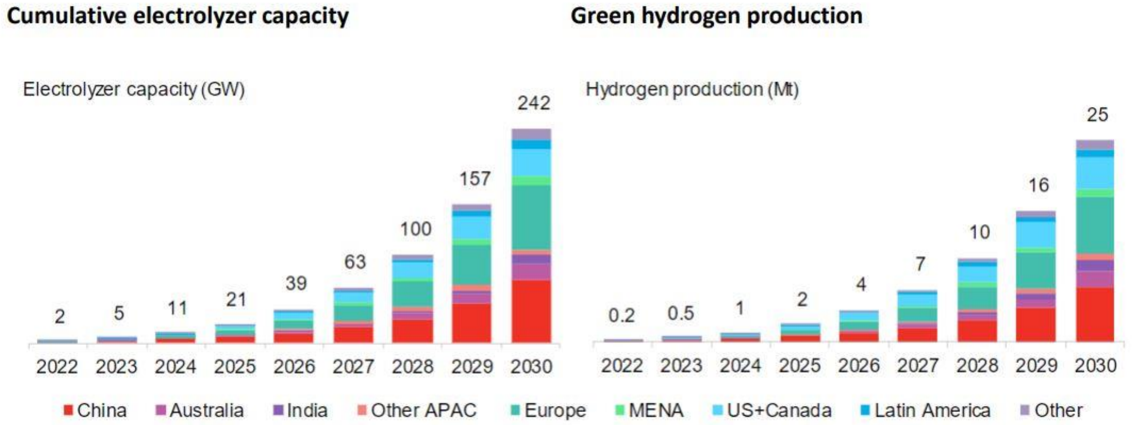

Figure 2. Expected hydrogen market growth in 2030. Source: (BloombergNEF, 2022)

The increasing presence of chemical and steel industries in several countries may prove to be a growth highlight in the green hydrogen market in Asia. Among others, France has big green hydrogen economy deployment plans. China and Japan are probably the most advanced market for green hydrogen worldwide. Norway has huge potential to create hydrogen from hydropower as well as pioneering the use of fuel cells on ferries and the UK is one of the world's leading offshore wind markets. Other countries moving towards a hydrogen economy include Australia, which wants to utilize its large renewable capacity to start producing and exporting green hydrogen. The USA, Canada and India will follow them but will be far behind. (BloombergNEF, 2022) China has the potential to become one of the major powers in hydrogen production, local governments are pushing the development of hydrogen clusters all over the country. In addition, they have been able to develop electrolyzers with the lowest production cost on the market, making their installation even more cost-effective. The main sectors that will demand this energy in 2050 are transportation and industrial energy, as it is indicated in Figure 3. This shows the high peak and development that hydrogen transportation will undergo, becoming the main hydrogen consumer sector. A great deal of investment is needed at the international level in order to meet this high demand.

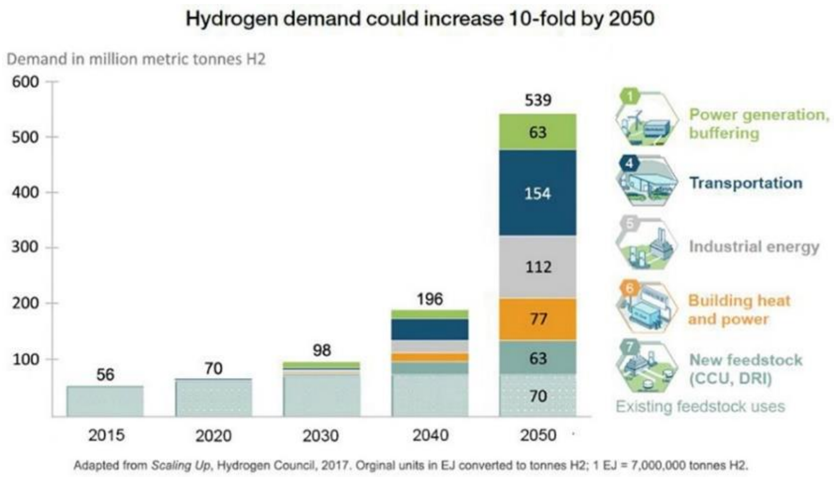

Figure 3. Hydrogen expected growth demand. Source: (Kazi & Eljack, 2021)

One of the main promoters of hydrogen development projects is the European Union, which aims to achieve climate neutrality by 2050 and reduce greenhouse gas emissions by at least 55% compared to 1990 levels by 2030. To achieve this goal, the EU has established an interim agreement on European Climate Law which is the basis for the European Green Pact. The EU hydrogen strategy foresees a phased path to accelerate clean hydrogen development over three strategic phases between 2020 and 2050. The first phase, until 2024, will concentrate on early deployment near demand centers. The next phase, through 2030, will focus on cost reduction and infrastructure development. After 2030, renewable hydrogen technology will reach maturity with large-scale deployment and demand. The European Clean Hydrogen Partnership, launched in July 2020, is a forum that brings together industry, public authorities and civil society to coordinate investments. (European Commission, n.d.)

A proposal in the EU is to promote the development of hydrogen valleys. Hydrogen valleys are ecosystems where hydrogen production and consumption are facilitated locally. This concept describes how the hydrogen economy will be implemented in Europe, starting from small neighborhoods where large amounts of hydrogen are produced for different consumers. While seeking energy independence with these valleys, the EU is also searching to create a hydrogen network to unify the countries. Europe's leading energy infrastructure operators have joined forces to create the European Hydrogen Backbone (EHB) initiative with the aim of jointly developing a low-carbon hydrogen market for the entire EU. (European Hydrogen Backbone, 2023) Figure 4 shows the infrastructure interconnection that the EHB expects to be developed by 2040. In some cases, new pipelines will be built, and some existing ones will also be rehabilitated. In addition, new storage facilities are expected to be developed at natural geological sources.

Figure 4. Expected hydrogen infrastructure connections in Europe by 2040. Source: (European Hydrogen Backbone, 2023)

In addition to agreements between private companies in the sector, the European Union also plans to support the energy sector with subsidies to develop this new technology. In May 2022, they presented the REPowerEU plan, a plan to rapidly reduce dependence on fossil fuels and make rapid progress in the ecological transition. Among other targets, they include the objective of obtaining 10 million tons of domestic production of renewable hydrogen and 10 million tons of imports by 2030 to replace natural gas, coal and oil in industries and transport sectors that are difficult to decarbonize. To this end, additional funding of EUR 200 million is earmarked for research, and the Commission is committed to completing the assessment of the first major projects. (European Commission - Press release, 2022)

c. Spanish hydrogen market

As a member of the European Union, Spain is also committed to the investment of green hydrogen. To this end, they have developed a Hydrogen Roadmap as a result of the participation of various economic agents, administrations and citizens who have made their contributions, in particular through the proposal of numerous innovative projects at the different stages of the renewable hydrogen value chain. In line with the SDGs and the European hydrogen strategy, the Spanish government has set targets for its own development by numerous funding to Spanish green hydrogen projects. At least 4 GW of electrolyzers power is planned to be installed in Spain. In addition, a minimum renewable hydrogen contribution of 25% of the total hydrogen consumed in 2030 is estimated. Regarding the transport sector, at least 5,000 to 7,500 light and heavy hydrogen fuel cell vehicles for freight transport in 2030 and at least 150 to 200 renewable hydrogen fuel cell buses are estimated.

From an international point of view, the country is also leader in the development of H2Med, a future pipeline that will connect Portugal, Spain, France and Germany, and will serve to supply the EU with green hydrogen. The macro-project, which will be carried out with 50% of the funds coming from the European Union, is expected to be completed by 2030. H2Med is the first hydrogen pipeline that will connect the Iberian Peninsula with the rest of the continent. The project includes two cross-border infrastructures. The first, between Celorico da Beira, in Portugal, and the Spanish province of Zamora and the second, underwater, between Barcelona and Marseille.

Other main hydrogen projects in Spain are local clusters spread over several communities. They include the Basque Hydrogen Corridor (BH2C), the Hydrogen Valley of Aragon, the Hydrogen Valley of Catalonia, the Hydrogen Cluster of Castilla-La Mancha and the Green Hydrogen Valley of the Region of Murcia. Furthermore, there are research projects led by the Clean Hydrogen Partnership organization. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020) This association is funding investigation projects in Spain such as:

- H2PORTS: This is a European-scale pilot project located in the Port of Valencia that develops and validates the transformation to H2 of two machines real operating conditions. The project includes the development of a hydrogen generator, as well as the study and development of H2 supply logistics in ports.
- SUN2HY: Pre-commercial full-scale demonstrator for the direct conversion of solar energy into hydrogen using photoelectrochemical cells.
- SEAFUEL: Its objective is to demonstrate the feasibility of powering local transportation networks using fuels produced from renewable sources and seawater. It is a sustainable integration of renewable fuels in local transportation systems. The project includes a renewable energy facility (51 MW) associated with a hydrogen plant that will be directly connected to the wind turbines and will be supplied by seawater, producing hydrogen from available natural resources. The hydrogen generated will be used to replace part of the diesel vehicle fleet with hydrogen cars.
- HIGGS (Hydrogen In Gas GridS): The objective is to analyze the existing potential and requirements on infrastructure, components and management involved in injecting

hydrogen into existing high pressure natural gas transmission networks.

- GREEN HYSLAND: This project is for industrial-scale production of renewable hydrogen, up to 7.5 MW of electrolysis, from photovoltaic power generation in Mallorca. The uses are related to the energy demand of the tourist sector: hydrogen supply for trucks, a fleet of 5 buses of the public transportation of Palma and 10 vehicles of a rent-a-car fleet, also it will be used for electricity generation in the Port of Palma and to satisfy thermal uses in hotel and administrative buildings. The objective of this project is to demonstrate the viability of local production and energy independence in islands.

Currently, there are several Spanish companies that are investing in the development and implementation of hydrogen as an energy source. Some of the main Spanish companies are: Repsol, Iberdrola, Endesa, Acciona, Enagás and Naturgy. These companies, leaders in the energy sector, are investing in different aspects of the hydrogen value chain, from production to storage and distribution, with the aim of promoting a more sustainable energy transition in Spain. The investment in green hydrogen in Spain is very broad, the main stakeholders support the research and implementation of this energy vector. Always bearing in mind that the development of green hydrogen is fully linked to renewable development, Spain has a great expectation of increasing investment in renewable energy, which will even support higher hydrogen development.

d. Hydrogen in the Spanish transportation market

Hydrogen has been recognized as a key element in the transition to a low-carbon economy, thanks to its multiple applications. One of its main applications is the production of electricity through hydrogen fuel cells, which can positively impact the transportation sector. The development of renewable energy and green hydrogen will encourage investment and development of hydrogen vehicles. Renewable hydrogen production in Spain, driven by the large amount of renewable energy available in the country, can provide the clean fuel source needed to power these hydrogen vehicles. This could help reduce the country's dependence on imported fossil fuels and improve air quality in urban areas. There are already projects lead by public transportation companies to implement hydrogen vehicles, the next step is the arrival of hydrogen cars to the private consumer. To do so, the infrastructure and the hydrogen network must be ready and able to meet the demand. From all the aspects analyzed, it can be concluded that there are great opportunities for growth and development in the long-term for the implementation of hydrogen filling stations in Spain. Currently, the technologies of the hydrogen vehicles are very advanced, focusing the study on the media in which its application is most advisable. The status is detailed for each of the options in the mobility sector:

- Road transport: This category includes both light vehicles (passenger cars and vans) and heavy vehicles (trucks and buses). In 2019, the global fleet of light hydrogen fuel cell vehicles amounted to 12,000 operational units. These vehicles were mainly located in Japan, Canada and Germany. In the case of Spain, according to data from the Spanish General Directorate of Traffic, there are 10 vehicles belonging to research projects. Regarding to heavy vehicles, it is positioned as the segment in which the use of renewable hydrogen as fuel is more convenient. In Spain, several pilot programs are being carried out to analyze the feasibility of using renewable hydrogen in commercial vehicles such as buses and trucks. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020) Among them, the Municipal Transport Company of Madrid has just announced a tender for the supply of 10 fuel cell buses powered by green hydrogen, which will circulate on the streets of Madrid in 2023 (Empresa Municipal de Transporte de Madrid, 2022). The technical specifications of this public tender detail that these are 10 standard buses (12 meters long) with fuel cells powered by green hydrogen. The vehicles must have sufficient autonomy to complete a full day's work, at least 280 kilometers or 20 hours, and an estimated recharge time of 5 to 10 minutes. (European Commission - Press release, 2022) Similar projects are being undertaken in Barcelona.
- Rail transport: currently, the railway sector uses electric energy as its main energy resource, although there are still some unelectrified tracks with trains powered by diesel locomotives. It is precisely in the latter niche, and specifically where electrification is not feasible, where fuel cells powered by renewable hydrogen could have a clear application. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020)
- Maritime transport: the application of renewable hydrogen for maritime transport encompasses not only the use of fuel cells in ships, but also in machinery used in ports and harbors. In relation to ships, the use of fuel cells for maritime transport is currently limited to demonstration projects on small vessels, but their feasibility is expected to be tested on large vessels. In Spain, the H2Ports initiative stands out, dedicated to the development of a pilot project located in the Port of Valencia. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020)
- Aviation: In line with what is happening in maritime transport, fuel cells are expected to be an alternative means of propulsion for aircraft and machinery used in aviation. At present, only demonstration projects have been developed for use in non-commercial flights. In addition, in the aviation sector, the application of renewable hydrogen for the manufacture of synthetic fuels, such as biokerosene, is particularly relevant in the aviation

sector. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020)

A PESTEL framework (Table 2) study has been carried out to understand the general trends and highlight the most relevant aspects of the hydrogen cars sector in Spain. The development of green hydrogen is supported strongly by the Spanish government and international organizations, among other political and legal factors. Financial opportunities from the governments of Spain and Europe as well as ongoing investment in renewable energy are other favorable economic factors. However, the industry may face difficulties in the economic factors due to the high cost of producing hydrogen, the uncertainty of investors' ability to recover from their investments and the high hydrogen filling stations infrastructure cost. With the trend toward a regular green energy consumption, the social factor of rising sensitivity to climate change. Finally, technological and environmental factors are positive for the sector, with research and development being essential to the advancement of renewable hydrogen technology. Spain's energy system will become more environmentally friendly and greener as a result of the use of hydrogen-powered vehicles, which will help cut greenhouse gas and CO2 emissions. In conclusion, the PESTEL analysis overall reveals promising opportunities for the growth of green hydrogen and hydrogen vehicles in Spain. Even so, there are still difficulties and obstacles to get over, especially regarding the price of production and investor skepticism, but these can be done so with continued industry support and funding, what are already doing European and Spanish governments.

PESTEL Framework	Very Negative	Negative	Neutral	Positive	Very Positive
Political & Legal					x
The Spanish government is committed to support the COP21 Paris Agreement, SDGs and the European hydrogen strategy					x
The Spanish government published 'Hoja de Ruta del Hidrógeno: apuesta por el hidrógeno renovable' in 2020 to support green hydrogen activities					x
European Union also supports green hydrogen in the medium- and long-term development with a new European Climate Law based on clean energies					x
The Spanish government has devoted and declared a climate emergency: creation of the Ministry of Ecological Transition in 2018					x
Support from international organizations such as the Clean Hydrogen Partnership or the European Hydrogen Backbone project.				x	
The Spanish government has established tax incentives and fundings for companies that want to invest in renewable hydrogen projects				x	
The Spanish government approved 'Estrategia de Movilidad Segura, Sostenible y Conectada 2030' to transform transport, logistics and mobility policies.					x
Economic		x			
Renewable hydrogen production costs in Spain are still high compared to fossil fuels.	x				
Very high infrastructure investments are required, and it is not certain that investors will be able to recover them.	x				
Hydrogen cars tend to have higher costs compared to battery electric vehicles, due to the production and development costs of fuel cell technologies.		x			
Major investment in development of hydrogen car projects by Spain's leading private energy companies.					x
Financing through European and Spanish government's funds				x	
Social					x
Spanish society is highly sensibilized with climate change					x
Social movements supporting climate activists					x
Trend in the daily consumption of green energies					x
Technological				x	
Renewable hydrogen production technology is constantly evolving and improving worldwide					x
Research and development in the field of hydrogen cars is essential to improve existing technologies and develop new solutions. Spain is leader in developing and research new technologies					x
Hydrogen cars are yet very expensive and only few models are available in the market.		x			
Ecological					x
Reduce greenhouse gas emissions					x
Reduce CO2 emissions					x
Making the Spanish energy system as green and eco-friendly as possible.					x

Table 2. PESTEL framework analysis

e. Market sizing of hydrogen cars in Spain

To further analyze the hydrogen car market development, its market size has been calculated. Since there is little data on the expected growth of hydrogen-powered vehicles, it is estimated that the growth will be comparable to the development of electric vehicles. The number of electric cars registered each year from 2009 to 2038 is shown in Table 3. The annual growth rate of new registrations compared to the previous year is also calculated.

Electric cars estimation				
Year	New car matriculations		Total cars	
	Nº	Annual rate	Nº	Annual rate
2009	17	-	17	-
2010	79	365%	96	465%
2011	377	377%	473	393%
2012	549	46%	1.022	116%
2013	893	63%	1.915	87%
2014	1.405	57%	3.320	73%
2015	2.248	60%	5.568	68%
2016	3.654	63%	9.222	66%
2017	7.448	104%	16.670	81%
2018	11.813	59%	28.483	71%
2019	17.474	48%	45.957	61%
2020	41.237	136%	87.194	90%
2021	66.916	62%	154.110	77%
2022	78.335	17%	232.445	51%
2023	114.725	46%	347.170	49%
2024	125.612	9%	472.782	36%
2025	129.612	3%	602.315	27%
2026	165.520	28%	767.756	27%
2027	187.420	13%	954.799	24%
2028	213.283	14%	1.167.533	22%
2029	243.559	14%	1.410.199	21%
2030	279.819	15%	1.688.613	20%
2031	321.792	15%	2.008.157	15%
2032	370.061	15%	2.374.563	15%
2033	418.169	13%	2.785.284	13%
2034	472.530	13%	3.246.001	13%
2035	524.509	11%	3.753.036	11%
2036	582.205	11%	4.294.004	11%
2037	628.781	8%	4.855.869	8%
2038	679.084	8%	5.456.618	8%

Table 3. Electric cars: market estimation. Source: (GANVAM, 2023); (Europa Press, 2010)

To estimate the market for hydrogen cars, three different scenarios have been identified. Assuming that in 2021 there were 15 hydrogen cars in Spain (Martín, 2021) and in 2009 there were only 17 electric cars (Europa Press, 2010), the same annual growth rate is applied to calculate the growth of new hydrogen car registrations. With this calculation, it is possible to estimate the total number of cars that will grow each year. These obtained data, which follow the same growth trend as that of hydrogen cars, will be identified as the first growth case (scenario 1). This first scenario is the highest volume considered. For the following two cases, each annual growth rate of the total hydrogen cars is expected to decrease by 12.5% for scenario 2 and 25% for scenario 3. With this study, three possible market size cases are obtained, starting from a scenario with a very large market size to a much smaller third estimate. All the results are indicated in Table 4. It should be noted that the third case estimates that in 2030 there will be about 7,000 hydrogen cars, this data corresponds to the estimate made by the Spanish Ministry of Ecological Transition.

Hydrogen cars estimation						
Year	Scenario 1		Scenario 2		Scenario 3	
	New H2 car matriculations	Total H2 cars	Annual rate	Total H2 cars	Annual rate	Total H2 cars
2021	15	15	-	15	-	15
2022	70	85	406,6%	76	348,5%	67
2023	333	417	343,6%	337	294,5%	265
2024	484	902	101,6%	679	87,1%	497
2025	788	1.690	76,5%	1.199	65,5%	822
2026	1.240	2.929	64,2%	1.969	55,0%	1.274
2027	1.984	4.913	59,2%	3.135	50,8%	1.921
2028	3.224	8.137	57,4%	4.935	49,2%	2.867
2029	6.572	14.709	70,7%	8.423	60,6%	4.603
2030	10.423	25.132	62,0%	13.646	53,1%	7.050
2031	15.418	40.550	53,7%	20.971	46,0%	10.293
2032	36.386	76.936	78,5%	37.436	67,3%	17.221
2033	59.044	135.979	67,2%	62.575	57,6%	27.132
2034	69.119	205.099	44,5%	90.407	38,1%	37.476
2035	101.228	306.326	43,2%	129.450	37,0%	51.348
2036	110.834	417.146	31,7%	170.432	27,1%	65.283
2037	114.364	531.439	24,0%	211.291	20,5%	78.697
2038	146.047	677.154	24,0%	262.072	20,6%	94.909
2039	165.371	842.040	21,3%	317.938	18,3%	112.251
2040	188.191	1.029.443	19,5%	379.922	16,7%	131.008
2041	214.905	1.243.108	18,2%	449.016	15,6%	151.430
2042	246.899	1.488.024	17,3%	526.584	14,8%	173.853
2043	283.934	1.768.734	13,1%	595.698	11,3%	193.411
2044	326.524	2.088.686	13,1%	673.883	11,3%	215.170
2045	368.972	2.447.235	11,4%	750.537	9,8%	236.149
2046	416.939	2.848.755	11,4%	835.911	9,8%	259.174
2047	462.802	3.275.172	9,6%	916.367	8,3%	280.556
2048	513.710	3.729.838	9,6%	1.004.568	8,3%	303.701
2049	554.807	4.215.526	7,0%	1.074.888	6,0%	321.924
2050	599.191	4.713.489	7,0%	1.150.130	6,0%	341.239

Table 4. Hydrogen cars: market estimation calculation.

3. Technological outline of green hydrogen's value chain and implications in the transportation industry

a. Hydrogen production, transport and storage

The production and delivery of green hydrogen as a clean energy source involve different stages in its value chain. The first stage is the production of feedstock, which are raw materials or resources that are used as inputs in the manufacturing process. In the case of green hydrogen, water is the feedstock, and it is split into hydrogen and oxygen using renewable energy sources like solar or wind power. This process is known as electrolysis and is made by electrolyzers. After hydrogen production, the compression and transportation of the hydrogen is made. Compressing the hydrogen makes the transport easier. Large tanks store the compressed hydrogen until ready for use. The final stage involves distributing hydrogen to users. This value chain process is represented on Figure 5.

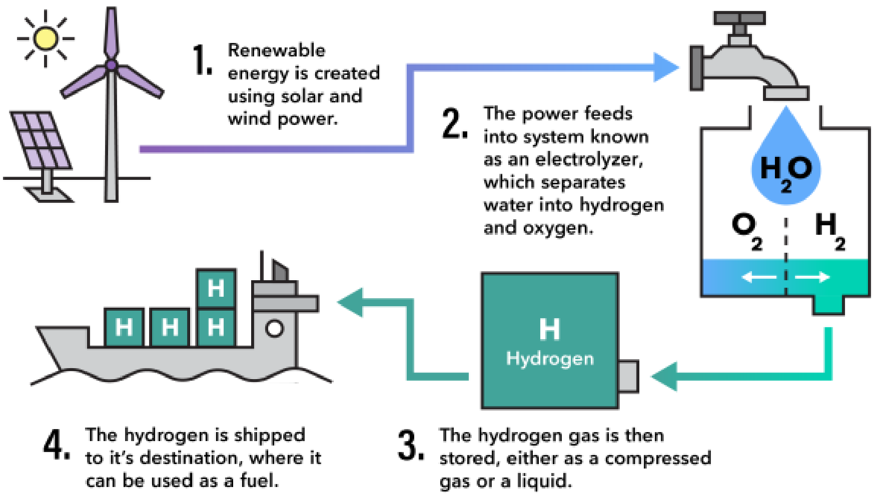

Figure 5. Green hydrogen value chain. Source: (Lee, 2021)

Electrolyzers are devices that use electricity to split water into hydrogen and oxygen through a process called electrolysis. The electrolyzer has two electrodes, an anode and a cathode, and are separated by a membrane. Electricity is applied to the electrodes: water molecules are split into hydrogen ions and oxygen molecules. The hydrogen ions are attracted to the cathode, where they combine to form hydrogen gas. Meanwhile, the oxygen molecules are attracted to the anode, where they combine to form oxygen gas. The gases are then collected and stored. There are three main electrolyzer technologies: (Retuerto, 2021)

- Alkaline Electrolyzer is the most used technology for large-scale hydrogen production. It uses an alkaline electrolyte, typically potassium hydroxide, and the electrodes are usually made of nickel. Alkaline electrolyzers are relatively simple to operate, cheap and have an easy maintenance. Despite that, its electrodes end up corroding, so they must be replaced to maintain its requirements.

- Polymer Electrolyte Membrane (PEM) Electrolyzer uses a solid polymer membrane as an electrolyte. PEM electrolyzers are capable of responding quickly to changing loads and the hydrogen produced is very pure. However, one drawback is that its electrodes are based on valuable metals, such as titanium, whose price is high and might have supply and scarcity issues.
- Solid Oxide Electrolyzer (SOEC) uses a solid ceramic electrolyte to facilitate the electrolysis process. However, this technology is not yet very commercialized. SOECs can produce both hydrogen and oxygen simultaneously. The energy efficiency is almost 100%, and it doesn't require valuable metals, but there are still doubts regarding the durability of its components.

Each type of electrolyzer has its own unique advantages and disadvantages, and the choice of electrolyzer depends on the specific application and requirements. Alkaline electrolyzers are the most used technology for large-scale hydrogen production, while PEM electrolyzers are suitable for smaller-scale applications and for applications where quick response and changes are required. The main techno-economic characteristics of each electrolyzer are summarized in Table 5.

In terms of efficiency and lifespan, solid oxide electrolyzers (SOECs) are superior. However, in terms of projected capital cost, proton exchange membrane electrolyzers (PEM) are more economical. The choice depends on the specific needs and priorities of each application.

-	Alkaline electrolyzer			PEM electrolyzer			SOEC electrolyzer		
Period	Today	2030	Long term	Today	2030	Long term	Today	2030	Long term
Electrical efficiency (LHV, %)	63-70	65-71	70-80	56-60	63-68	67-74	74-81	77-84	77-90
Stack lifetime (operating hours)	60 000 – 90 000	90 000 – 100 000	100 000 – 150 000	30 000 – 90 000	60 000 – 90 000	100 000 – 150 000	10 000 – 30 000	40 000 – 60 000	75 000 – 100 000
Plant footprint (m^2/kWe)	0,095	-	-	0,048	-	-	-	-	-
CAPEX (USD/kWe)	500 - 1400	400 - 850	200 - 700	1100 - 1800	650 - 1500	200 - 900	2800 - 5600	800 - 2800	500 - 1000

Table 5. Techno-economic characteristics of different electrolyzer technologies. Source: (International Energy Agency, 2019)

To determine the optimal option for transportation and storage of the hydrogen, different factors must be taken into account, such as the flow rate produced and consumed at each point (measured in Nm3/h) and the distance from the production plant to the consumption points, among others. Hydrogen can be transported in a pure state, either as a liquid or gas, or through other carriers such as ammonia or liquid organic hydrogen carrier (LOHC), the hydrogen's states during the value chain are summarized in Figure 6. As hydrogen is a gas with very low density, cost of its large-scale storage and long-distance transportation is very high. However, this same property facilitates its storage under pressure in the form of compressed hydrogen. Nevertheless, hydrogen can be transported in the gaseous state through dedicated pipelines (hydrogen pipelines). It can also be injected into the gas network once additional processes have been carried out. Liquid hydrogen is useful for high quantity storage, but it is not recommended if the hydrogen is going to be storage for a long period of time, as it requires a high energy input to keep hydrogen in a liquid state. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020)

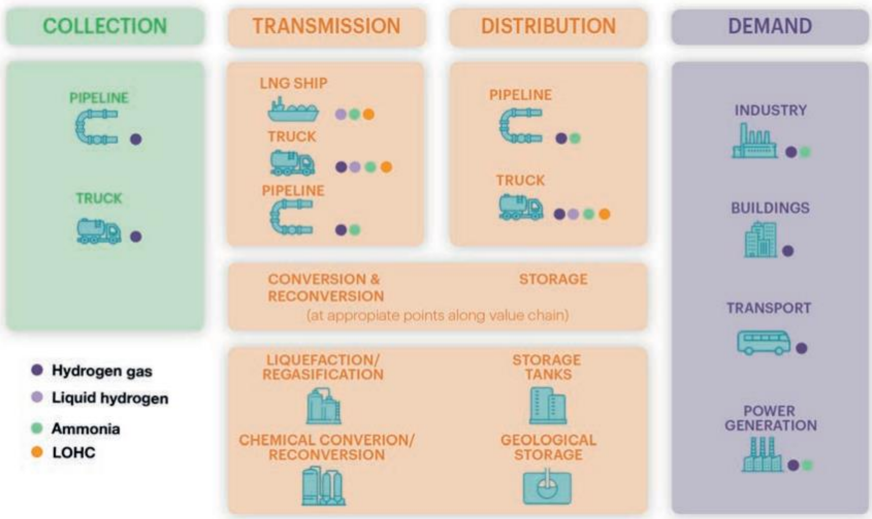

Figure 6. Transmission, distribution and storage elements of hydrogen value chains. Source: (International Energy Agency, 2022)

The long-term storage is very important to secure the network supply: ensure stability due to the varying renewable electricity production for electrolyzers and provide energy security in the event of supply disruptions due to trade disputes or natural disasters. For small-scale hydrogen storage and short-term use, the most plausible possibilities considering its current degree of development and manageability are high-pressure tanks and solid materials that absorb the hydrogen. Storage tanks, applied to liquified and compressed hydrogen, have a high efficiency and discharge rates. Regarding long-term storage, these facilities are not viable. Therefore, for a prolonged period, natural geological storage methods such as salt caverns, aquifers, and depleted natural gas or oil deposits are used. The main technologies are compared on Table 6 . The geographically limited gas storages are underground natural resources, which are already used for natural gas. Salt caverns have been used to storage hydrogen for the past decades in the United States, since it was used for petrochemical industry (ammonia and methanol production). This method is widely developed and easy to implement, but its availability is reduced. With similar characteristics, depleted natural gas fields and aquifers have been used for decades for gas storage. Gas fields represent 75% of the gas storage and aquifers represent about 11% of the storage. Due to a higher compressibility factor of hydrogen, there are still challenges to be solved to storage hydrogen in these two underground resources. (International Energy Agency, 2022)

H2 state	**Gaseous state**				**Liquid state**			**Solid state**
Technology	Salt Caverns	Depleted gas fields and aquifers	Rock caverns	Pressurized containers	Liquid hydrogen	Ammonia	LOHCs	Metal hydrides
Volume	Large	Large	Medium	Small	Medium	Large	Large	Small
Cycling	Month-weeks	Seasonal	Month-weeks	Daily	Days-weeks	Month-weeks	Month-weeks	Days-weeks
Actual LCOS ($/kg)	0,23	1,9	0,71	0,19	4,57	2,83	4,5	-
Possible future LCOS ($/kg)	0,11	1,07	0,23	0,17	0,95	0,87	1,86	-
Geographical availability	Limited	Limited	Limited	Not limited	Not limited	Not limited	Not limited	Not limited

Table 6. Hydrogen storage. Source: (BloombergNEF, 2020)

The hydrogen transportation cost of each technology is summarized in Figure 7. Due to lower proportional cost, transmission and distribution pipelines are a good choice for large quantities and long distances. Although this can significantly increase the cost, trucks are suitable for small volumes and LOHC for longer distances. Despite being useful for large quantities and long distances, ammonia is the most expensive option and is not very cost-effective.

In general, the best option might be to supply hydrogen through a large-scale local supply chain that serves clusters of customers through dedicated pipeline networks, supported by a larger-scale storage facility to smooth the cluster's energy supply. There is a high need of infrastructure investment in order to provide all the expected hydrogen supply. Therefore, already existing pipelines could be used to boost the development of the hydrogen infrastructure.

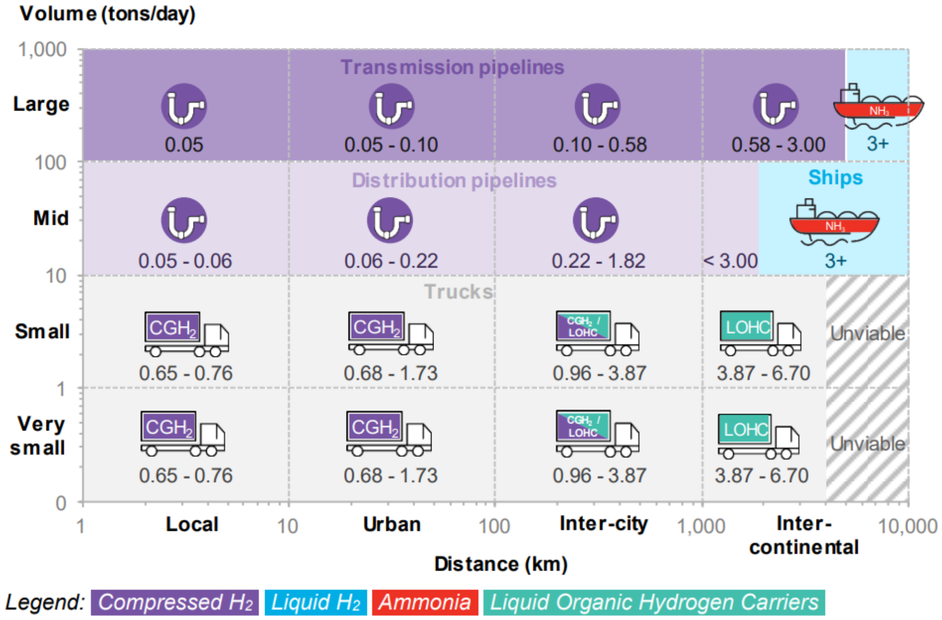

Figure 7. Hydrogen transport costs in \$/kg, based on distance and volume. Source: (BloombergNEF, 2020)

On the one hand, one possibility is repurposing gas pipelines for hydrogen, by transforming underutilized parallel pipelines. These pipelines are normally kept in case of contingency and emergency supply of the principal pipeline. This will allow the conversion of one line to pure hydrogen, and the other one would be able to meet the current demand for natural gas. With the intention of adapting existing pipelines, the most important technological investment and change are the compressors' adaptation: as the volumetric density of hydrogen is higher than for natural gas at the same pressure, the technology must be adapted. Due to the hydrogen and other gases different chemical properties, the deterioration of pipelines might be sped because it causes cracks in the steel, this process known as hydrogen embrittlement. Other adverse effects are the reduction of transmission capacity, efficiency reduction and gas losses. Unfortunately, some reconfigurations and adaptations must be performed to adjust the pipeline network. Depending on the pipeline technology, some research and further development must be carried out. Nevertheless, the adaptation of existing pipelines could cut the investment cost between 50% and 80% compared to the construction of new pipelines. (International Energy Agency, 2022)

On the other hand, a second technological alternative that takes advantage of existing pipelines is hydrogen injection into natural gas steams of the distribution grid, this is knows as blending. This solution can quickly provide hydrogen production into the network, without making high investments. It is a great solution for short-term implementation, while the hydrogen grid and market are growing. For a better implementation the hydrogen production must be strategically situated close to the gas transmission network and end users. If only 5% by volume of hydrogen were added to natural gas European grids, it would result in a 2.5 MtH2/yr increase in low-carbon hydrogen demand. For this so, almost 25 GW of water electrolysis capacity would be needed. However, the blending method would mean losing the intrinsic value of the renewable hydrogen present in the mixture, and it also creates technical challenges for later separating the two gases at the point of consumption. As is demonstrated, blending activities can boost the development of hydrogen distribution, but technology efficiency improvements and international regulations are needed. Although operational costs will be increased, this innovative hydrogen implementation is an interesting solution to be implemented for building heat supply and metal productions (iron and steel). (International Energy Agency, 2019)

Furthermore, if the reuse of the pipelines is not possible, the construction of new hydrogen pipelines alongside existing natural gas pipelines can benefit from the existence of rights-of-way and siting permits that can lower costs and reduce pipeline construction.

With the aim of putting into practice the knowledge gained in R&D projects through recommendations and guidelines for the adaptation of natural gas infrastructures to hydrogen injection, the HyReady partnership was made. The project is supported by GERG (The European Gas Research Group) and more than 20 worldwide industrial partners. Other relevant studies that support the development of these activities are a hydrogen lab test by ROSEN or the PosHYdon project launched by Dutch energy industrialists. (International Energy Agency, 2022)

b. Technological overview of hydrogen in the transportation industry

The application of hydrogen in the transport sector is materialized in the use of fuel cells, which are devices in which a reverse process to the one carried out by electrolyzers is performed. The hydrogen produced is used to generate electricity to drive the fuel cell electric vehicles (FCEVs). These fuel cells are usually installed in combination with electric batteries that recharge themselves during vehicle operation, either during the regenerative braking process or through the battery itself, which can produce energy for recharging and maintain it at optimum charge levels.

The use of fuel cells combined with batteries in vehicles (FCHV) provides a significant competitive advantage over electric vehicles with electric batteries. FCHV reduce recharging times and increase the distance traveled by the vehicle before refueling, while at the same time reducing the weight of the vehicle by reducing the size of the batteries. Vehicle weight is reduced by reducing the size of the batteries. However, the energy efficiency of these vehicles is lower than that of electric vehicles: the energy consumed to obtain the hydrogen must be taken into account, as well as the energy required to compress and store it in the vehicle tanks. (Ministerio para la Transición Ecológica y el Reto Demográfico , 2020)

A fundamental difference compared to other electric vehicles is that hydrogen cars produce their own electricity. They do not extract energy from an integrated battery, as in pure electric or plug-in hybrid vehicles that can be recharged from an external source. In contrast, hydrogen cars carry their own efficient power plant, in the form of a fuel cell on board. In the fuel cell, a process called reverse electrolysis takes place, whereby hydrogen reacts with oxygen. The hydrogen comes from one or more tanks in the vehicle, while the oxygen is taken from the ambient air. All that results from this reaction is the electrical energy generated, heat and water, which is expelled as steam from the exhaust pipe. Therefore, the hydrogen car generates no harmful emissions at the local level. The energy generated in hydrogen fuel cells travels two paths, depending on the demand of the specific driving situation: it can flow to the engine and drive the vehicle directly, or it can charge a battery, which is used as a buffer store for the energy until it is needed to drive the engine. This drive battery, as it is called, is much smaller and lighter than that of all-electric cars, as it is constantly recharged from the fuel cell.

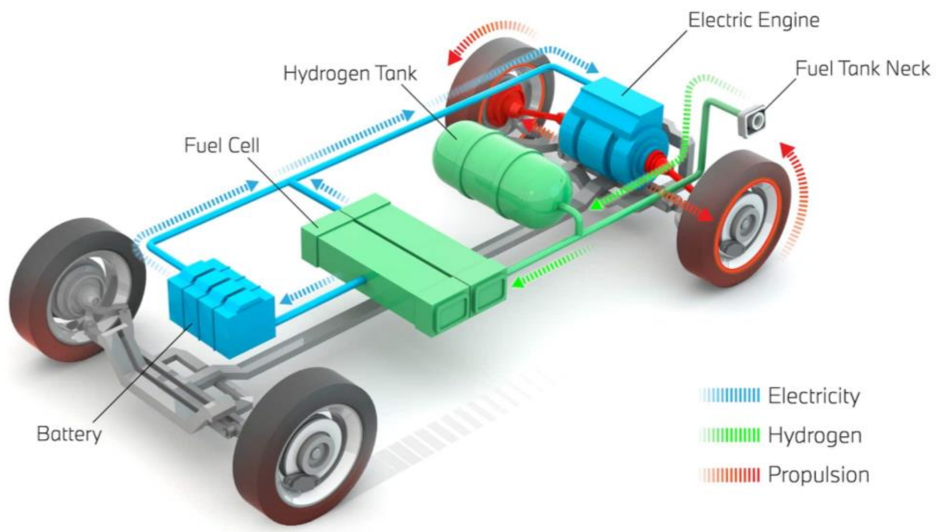

Figure 8. Hydrogen engine. Source: (BMW Group, 2019)

The process in specified in Figure 8. Like other electric cars, hydrogen vehicles can recharge from braking energy. To do this, the electric motor converts the car's kinetic energy into electrical energy and feeds it to the storage battery. (BMW Group, 2019)

Aspect	Hydrogen Cars	Electric Cars
Refueling Time	Hydrogen cars can refuel in a few minutes, similar to gasoline or diesel cars.	Electric cars require a longer time to recharge, usually taking more than an hour and a half.
Range	Hydrogen cars have a greater range, typically between 600 and 700 kilometers without refueling.	Electric cars generally have a shorter range compared to hydrogen cars, although it varies by model.

Resistance to Extreme Temperatures	Hydrogen cars have superior resistance to extreme temperatures, and their range remains independent of the outside temperature.	Electric cars may experience a reduction in range in extreme temperatures.
Maintenance	Hydrogen cars have lower and cheaper maintenance due to the exposure of the engine to water vapor.	Electric cars also have lower maintenance costs compared to traditional internal combustion engine vehicles.
Driving Experience	Hydrogen cars provide an all-electric operation with a similar driving sensation to conventional electric cars.	Electric cars offer an all-electric driving experience with instant torque and no engine noise.
Car Price	Hydrogen cars are relatively expensive, with prices around 70,000 euros, almost double the cost of comparable electric or hybrid cars.	Electric cars are generally more affordable compared to hydrogen cars.
Availability of Models	There is a shortage of hydrogen car models available in the market.	Electric cars have a wider variety of models and options available from various manufacturers.
Availability of Filling Stations	There are limited hydrogen filling stations, with only 11 points of sale in Spain.	Electric charging stations are more widespread and accessible, with a larger network available in many countries.
Space Efficiency	Hydrogen cars require space for large components, especially the hydrogen tanks, which may sacrifice trunk space.	Electric cars tend to have more space-efficient designs and offer better trunk space compared to hydrogen car
Price efficiency	With current models, it is possible to travel 100km with 1kg of H2, which currently costs 8€/kg. (Benito, 2021)	For an electric car, traveling 100 kilometers will cost around 2.054€. Now, the cost per kilometer traveled in an electric car is four times cheaper. (ENDESA, 202O)

Table 7. Comparison between Hydrogen Cars and Electric Cars. Source: (Franco, 2022)

The pioneers in the development of hydrogen cars are Toyota (2014) and Hyundai (2018). Toyota sells in Spain the Mirai model since 2019. It starts at a price of 68,900 euros (without discounts) for the normal finish and 75,900 euros for the luxury finish. It has a capacity of 5.6 kilos of hydrogen in its three tanks, with a theoretical range close to 700 kilometers. Its combined power is 182 hp (horsepower), which is the result of the energy from the fuel cell of 128 kW (174 hp) and the battery of 25.5 kW (34.6 hp). This allows it to reach a top speed of 175 km/h and go from 0 to 100 km/h in nine seconds. Its battery has a nominal voltage of 310.8 V, a capacity of 1.24 kWh and a peak power of 25.5 kW for 10 seconds. The total weight of this Toyota is 1,975 kilograms.

In the case of the Hyundai model, which was the first hydrogen car sold in Spain, Nexo's price is somewhat higher than the Toyota's Mirai, since it starts at 73,450 euros. But almost its main difference with respect to the Toyota is that this Hyundai has an SUV body type. It is smaller and lighter, weighing 1,889 kilograms. Its combined power is also lower, at 163 hp. The power of the fuel cell is 95 kW (129 hp) and that of the battery, 40 kW (54 hp). Its battery has a slightly higher capacity than the Mirai, thanks to its 1.56 kWh. And it also has three hydrogen tanks that allow a range of almost 670 kilometers, in line with the Toyota. With this, it accelerates from 0 to 100 km/h in 9.5 seconds and reaches a top speed of 179 km/h. (Rueda, 2022)

In addition, it is worth noting that other well-known brands of cars are also developing their own hydrogen car. We find the Honda Clarity and the BMW iX5 Hydrogen. Despite being one of the pioneers in the development of hydrogen cars, whose research began in 2007, Honda decided to stop manufacturing its Clarity model in 2021 due to low demand. It seemed that the company had left aside the market for these vehicles, however, they have announced the launch of a new hydrogen car model in 2024. As for the BMW model, its development is very recent, with a prototype launched in 2019. At the beginning of 2023, BMW has just put into operation about 100 units of the iX5 Hydrogen, for demonstration and testing purposes in the public. Its sale to private consumers has not yet been established. The BMW iX5 Hydrogen has the hydrogen cell located in the front area, and generates 125 kW, equivalent to 170 hp. For its part, the BMW eDrive electric motor delivers 275 kW (374 hp). It can cover a distance of 700 kilometers, at a refueling rate of 4 minutes in a hydrogen station. (BMW Group, 2019)

We have seen that hydrogen car models are developing successfully, major producers are investing in this new technology, the market has great potential. The next objective of these producers is to optimize their production cost to reduce the price of the vehicle and make it more affordable to the small consumer.

Regarding the filling process at a hydrogen station, there is not much difference from a conventional refueling station, although there are some details that make the experience slightly different. As hydrogen is delivered under high pressure, and because it is an extremely volatile gas, the connection between the receptacle or vehicle connection point and the pump must be watertight. Unlike conventional refueling stations, hydrogen is sold by the kilo, not by the liter, and the refueling time for a conventional bus, which typically has a capacity of 30 to 37.5 kilos, does not exceed 12 minutes. (Iberdrola, 2021)

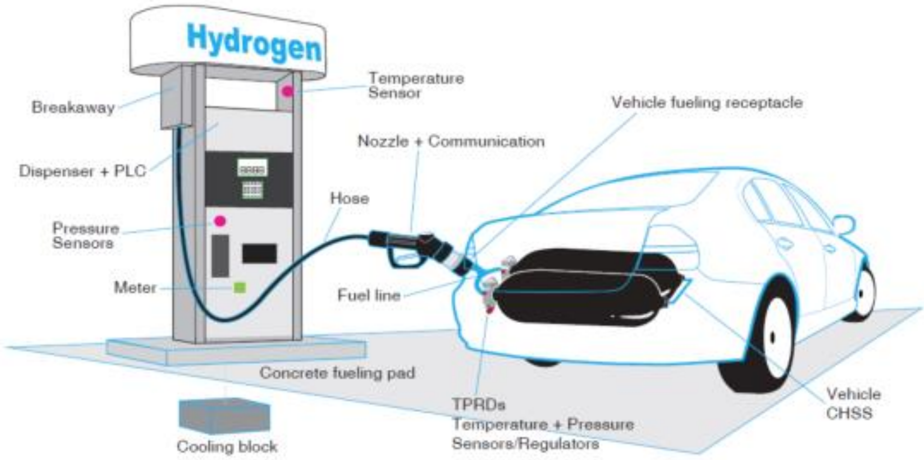

Figure 9. Hydrogen fueling station. Source: (International Organization for Standardization, 2022)

According to the technical Specification ISO/TS 19880-1, for gaseous hydrogen and fueling stations (Part 1: General requirements), which is a key document for the building of hydrogen fueling stations worldwide, the hydrogen fueling station must have the elements indicated in Figure 9.

The hydrogen plant can be supplied by the company itself or externally. If it is in-house, the hydrogen is produced directly from an electrolyzer connected to the installation. If it is external, the hydrogen plant is supplied by means of hydrogen cylinders from a generating plant, which can be supplied as compressed or liquid gas. In both cases, this hydrogen is stored at low pressure. Then, the hydrogen pressure is raised from the initial pressure to the desired pressure of the high-pressure storage, this is the pressure required for the tank of the cars. This high-pressure storage consists of cylinders that allow storing the hydrogen coming from the compressor at sufficient pressure for subsequent refueling of the vehicle by pressure transfer. However, before reaching the vehicle's tank, the hydrogen passes through a cooling system: there is equipment in charge of cooling the hydrogen transferred to the vehicle before it passes through the dispenser. (Velatia, 2022)

The first public hydrogen filling station arrived to Spain in 2022, previously there were already 5 private filling station. Thanks to a project carried out by Gasnam, 8 public filling station are expected to arrive in 2023. The goal is for Spain to have a network of more than 100 filling station by 2030. (GASNAM neutral transport, 2020) The main supplier of filling station in Spain is the Spanish company Calvera Hydrogen, the first manufacturer of complete filling station in the country. This company was the first to manufacture and deliver the first 700 bar car filling station in Spain and has also developed filling station for the largest buses in Spain. (Roca, 2021)

4. Repsol: business overview and current strategy

a. Main activities

Repsol S. A., founded in 1987, is a Spanish multinational energy and petrochemical company headquartered in Madrid. The company specializes in oil and gas exploration, exploitation, production, transportation and refining activities. It also produces, distributes and markets petroleum derivatives, petrochemical products, liquefied gas and sells natural gas. Since 2018 it also markets gas and electricity in the Spanish retail market. Therefore, the Repsol group is divided in four main areas: exploration and production, refining and marketing, chemicals and gas and electricity. The refining activity consists of the supply and trading of crude oil and products, oil refining, marketing of petroleum products, distribution and marketing of liquefied petroleum gas (LPG), production and marketing of chemical products and development of new energies. The group operates six refineries, five of them in Spain (Escombreras, La Coruña, Musques, Puertollano and Tarragona) with a combined distillation capacity of 896,000 barrels of oil per day. The sixth one is located in Peru. Its products are marketed under the Repsol, Campsa and Petronor brands. In terms of its international aspects, Repsol has a significant presence in Latin America, where it has important exploration and production operations in countries such as Brazil, Bolivia, Colombia, Peru and Venezuela. In addition, it also has a presence in Africa, Asia and Europe, making it one of the largest and most diversified energy companies in the world. (Repsol Group, 2023) Repsol corporate structure is indicated in Figure 10 with its main companies. The core business is composed of 300 companies across more than 36 countries.

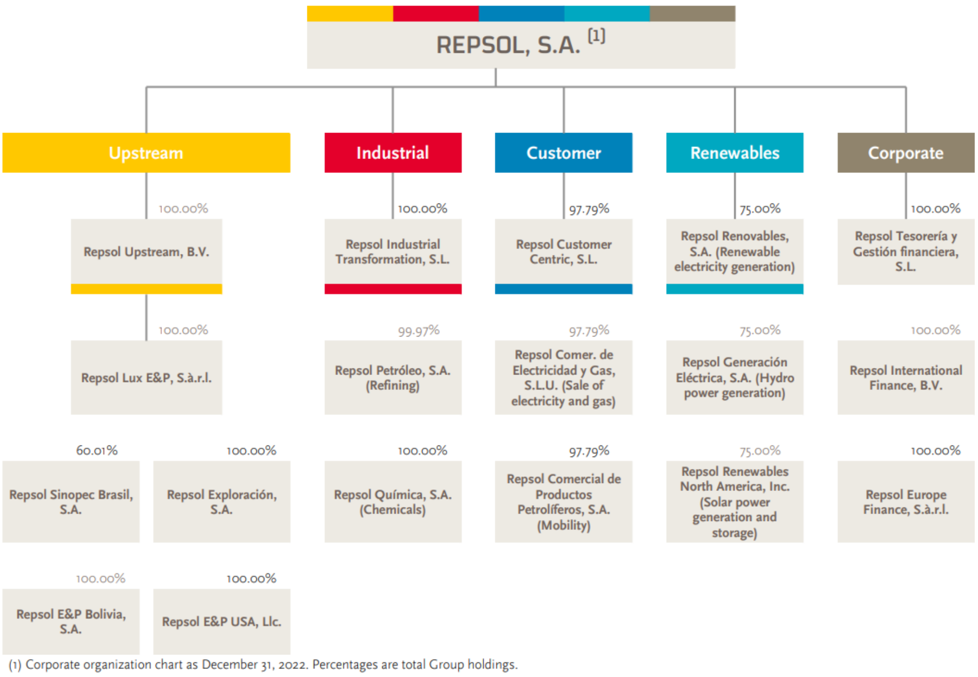

Figure 10. Repsol's corporate structure. Source: (Repsol Group, 2022)

b. Repsol key figures

Repsol is a listed company in the Spanish stock exchange IBEX35 with a market capitalization of 17.527B€. (Yahoo! Finance, 2023) The company's stock market evolution price is indicated in Figure 11.

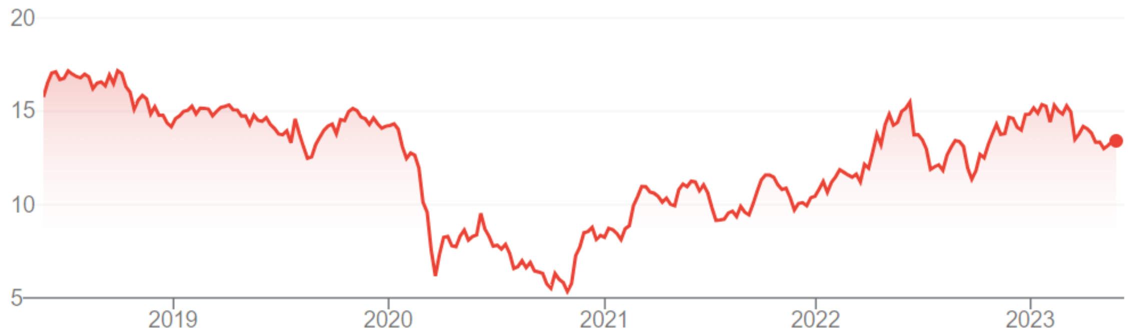

Figure 11. Repsol's stock price chart. Source: (Yahoo! Finance, 2023)

Repsol invested €4.182 billion in 2022, 40% more than the previous year, to advance its transformation, primarily in the Iberian Peninsula and the United States. It intends to allocate historic organic investments totaling more than €5 billion in 2023 with the aim of enhancing its multi-energy profile. Additionally, the year-long net debt reduction was 61 percent thanks to cash generation. Repsol also disclosed an increase in cash compensation for shareholders of 11% in 2023. The overall results of Repsol are indicated in Table 8. (Repsol Group, 2022)

	Upstream		Industrial		Customer and Renewables		Repsol	
Year	2021	2022	2021	2022	2021	2022	2021	2022
EBITDA	4,429	7,485	2,654	5,223	1,219	1,248	8,170	13,813
Net income	1,687	3,029	606	3,150	542	540	2,499	4,251
Investments	1,223	2,127	1,025	859	829	925	2,994	4,182
Cashflow from operations	3,355	5,706	1,031	2,639	1,288	770	5,453	8,923
Net debt							5,762	2,256
ROE (Return on equity)							10,97	25,27

Table 8. Repsol's main key figures. Source: (Repsol Group, 2022)

With the table, we can verify that the company's EBITDA has increased significantly in all business areas, especially in Upstream and Industrial. Also, it is since Repsol has increased its investment in Upstream and Industrial but has reduced its investment in Customer and Renewables. Overall, there is a growing in the company's total investment. Repsol has reduced its net debt over the last two years, which is a good sign for investors. Repsol's ROE has also increased significantly, suggesting a good return for shareholders.

c. Current sustainable strategic plan

Repsol advocated its transformation into a multienergy firm in 2020, solidifying its leadership in the energy transition. The company is committed to become net zero emissions by 2050. To do so, the steps that they targeted are reducing 25% by 2025, 28% by 2030 and 55% by 2040 their emissions. The environmental policy is implemented using the United Nations SDGs, which is based on best practices in environmental, social, and governance issues. It is divided into six pillars: climate change, environment, innovation and technology, safe and secure operation, people, and ethics and transparency. The main targets to achieve these objectives are investments in:

- Decarbonization of facilities and the portfolio by reducing scope 1+2 and methane emissions.
- Renewable electrification by increasing solar, wind and hydro electricity generation capacity.
- Renewable fuel and low carbon product production (biofuels, synthetic fuels and hydrogen)
- Carbon sinks by CO2 carbon capture and storage.

Only in 2022, Repsol avoided 3,400 tons of C02 emissions and installed 3,870MW low-emission generation capacities with an investment of €770M in renewables. In 2025, Repsol expects to achieve 6GW of renewable production, by 2050 20GW will be available.

In 2022, Repsol has made major business operations. The Repsol Renewables company is valued at €4,383 million under the terms of the agreement. Finally, a deal was struck to acquire Asterion Energies, a development renewable projects in Spain, Italy and France. The portfolio will control 7,700 MW of renewable assets. The asset portfolio of Asterion Energies includes 4,900 MW of solar photovoltaic energy and 2,800 MW of wind generation, with 2,500 MW in advanced development or under construction. The addition of partners to Repsol Renewables and the purchase of new renewable energy assets demonstrate the company's commitment to investing in its future growth. Regarding green hydrogen, Table 9 indicates the main projects led by Repsol Renewables for the development of green hydrogen, the company could also become a key leader in the production of this new energy vector.

Hydrogen projects	Description
Renewable hydrogen hub in Meirama	Repsol has launched a project with Naturgy and Reganosa to develop a renewable hydrogen production center in Galicia. This project includes the installation of an electrolysis plant with an initial capacity of 30 MW, expandable in different phases with a total capacity of 200 MW. It will produce more than 4,000 tons of renewable hydrogen per year and will bring its total production to 30,000 tons per year.
Electrolyzers in industrial complexes	Installing the electrolysis machine in the environment of industrial areas. The first will be installed at the Petronor refinery in Bilbao and will have a capacity of 2.5 megawatts. The plant will start operating in the first half of 2023.
R&D to boost renewable hydrogen	Researchers from Repsol and Enagás have developed a cutting-edge technology to produce renewable hydrogen directly from solar energy using photocatalysis. This innovative method simplifies the traditional electrolysis process by using photoactive materials to generate an electric charge from solar radiation, which separates oxygen and hydrogen molecules. The next stage is the construction of a pilot plant in the Repsol Industrial Park of Puertollano, with the aim of reaching commercial viability by 2030
SHYNE Project (Spanish Hydrogen Network)	SHYNE is the largest renewable hydrogen group in Spain, consisting of 33 members across the board. Its mission is to pilot renewable hydrogen projects in the Spanish economy and to facilitate decarbonization in challenging sectors such as steel, aviation and shipping. In addition, SHYNE aims to connect existing regional hydrogen clusters, such as the Basque Hydrogen Corridor, the Hydrogen Valley of Catalonia and the Hydrogen Valley of the Murcia region. The alliance will also create two new innovation centers in Castilla-La Mancha and Madrid to promote technology development.

Table 9. Repsol's hydrogen projects. Source: (Repsol Group, 2023)

d. Repsol: Commercial and Renewables

Among Repsol's different business units, the strategic proposal and the development of hydrogen filling stations will be implemented in the Commercial and Renewables area. This unit deals with the marketing and distribution of energy products, such as fuels, natural gas and electricity. In addition, it also focuses on the development and marketing of renewable energies, such as wind and solar energy. The main activities of this part of the business are shown in Table 10. In particular, the strategic proposal will focus on mobility, where direct oil sales are carried out in the service areas.

By the end of 2022, Repsol had 4 651 service stations, located all over Spain, Portugal, Peru and Mexico. Repsol's main objective for its service stations is to create spaces where customers can tune up their vehicles, rest and buy any quality product they need. This is achieved by:

- Seeking the customer's comfort: its professionals are available to solve any of the customer's needs or those of their vehicle.
- Taking care of the environment: protecting the environment and reducing possible impacts as much as possible.
- Taking care of safety: gas stations are designed to achieve a high level of safety in every detail.

Activities	Description
Mobility	Marketing and selling of petroleum and other products through service stations (direct selling), providing differentiated value to industries such as shipping, heavy industry and end consumers.
Lubricants, aviation, asphalts and specialties	Manufacturing and selling lubricating oils, lubricant base, bitumen for asphalt, jet fuel, expansion oil, coke, sulfur, paraffin and propellants.
LPG (Liquified Petroleum Gases)	Buying, selling, producing, distributing, storing and wholesale and retail of LPG.
Retail electricity and gas	Retail (residential and businesses) of electricity and gas in Spain.
Renewables and low-carbon generation	Low-emission power generation and development of renewable energy generation projects.

Table 10. Commercial and Renewable's main activities

In order to provide quality service and comfort to its customers, Repsol gas stations offer a wide variety of services: (Repsol Group, 2023)

- 30 cents credit on used cooking oil: when clients bring used cooking oil to a Repsol gas station, they will be paid a 30-cent credit at their app Waylet, which will convert to 100% renewable fuel.
- Car wash services.
- Sprint Store with a wide range of high-quality traditional products to meet the needs of customers on the go.
- SuperCor Stop & Go Stores: Repsol offers a wide range of El Corte Inglés products in their stores.
- Repsol Online Store through app Waylet clients can buy quality products and pick them up at your nearest gas station.
- Amazon locker services.
- Charging stations: Repsol has an extensive network of more than 1,700 charging stations in the Iberian Peninsula, allowing you to charge your electric vehicle with ease.
- Moto Stop: Repsol offers exclusive motorcycle maintenance facilities and services, including easier refueling, convenience areas and special products.

- The Repsol rest areas are equipped with a variety of services to make the rest hours an enjoyable and relaxing experience.
- Starbucks on the go: clients can enjoy the Starbucks experience at Repsol gas stations.
- Way & Go is a service that allows to make purchases in the Repsol store, scan the code and validate the purchase without having to go to the cashier, thus facilitating client's daily work.

In terms of sustainable mobility, for the moment Repsol service stations are committed to the mobility of electric cars and have: (Repsol Group, 2022)

- Extensive recharging network with more than 400 operational recharging points. Its goal is to have a Repsol recharging point every 50 km. The network of charging stations for electric vehicles continues to grow, with more than 1,000 public charging stations installed by the end of 2022.
- Clean energy with a recharging system based on 100% renewable energy, with intelligent installations and terminals.
- Experience and innovation with more than 10 years of experience thanks to the collaboration with its technological partner IBIL.
- Unification of management thanks to its mobility app Waylet. It allows customer to search for the nearest point, reserve it, start the recharge and pay for everything from the app.

e. Competitive situation

A SWOT study was carried out to determine the current situation and identify possible obstacles and risks to the organization. With this framework, Repsol's threats, strengths, weaknesses and opportunities of the hydrogen car sector are analyzed (Table 11).

Internal factors	
Strengths (+)	**Weaknesses (-)**
1. International presence: Repsol operates in more than 30 countries, which enables it to diversify its operations and lower the risks that could be led from one single market. **2. Extensive network of service stations:** The company has an extensive network of service stations throughout Spain, giving it a competitive advantage in implementing hydropower infrastructure by capitalizing on its strategic location and distribution capacity. **3. Investments in the development of renewable energy technologies**: such as solar and wind, positioning it to benefit from the expanding clean energy market and hydrogen production. **4. Brand image:** Well-known company throughout the world and with a good reputation in the energy industry.	**1. Dependence on hydrogen prices**: Repsol depends heavily on the production and sale of hydrogen, making it vulnerable to price fluctuations of the market. **2. High costs:** The process of producing hydrogen is expensive. **3. Physical space limits:** Some service stations may have physical space constraints while adding more hydrogen filling stations. Its installation requires additional room for storage equipment, compressors, and other components, which might be difficult at existing service stations with limited space. **4. Dependence on international partners:** It can make Repsol vulnerable to changes in commercial and political relations and government regulations between these countries.
External factors	
Opportunities (+)	**Threats (-)**
1. Growth in the renewable energy market: the growing interest in renewable energy gives Repsol the opportunity to increase its presence in hydrogen market. **2. Growth in sustainable mobility:** Environmental consciousness and emission-reduction policies increase demand for hydrogen and electric vehicles. Repsol has the opportunity to capitalize on its growth and establish itself as a major player in the electric mobility industry. **3. Regulatory changes:** Government regulations and policies may create new advantages for Repsol to develop new solutions and services that meet new regulatory requirements. **4. Sector consolidation**: Consolidation in the energy sector can create new strategic assets for the company. **5. Diversification and growth potential:** Opportunity to diversify its energy portfolio and extend its mobility options. Repsol may tap into a booming market and position itself as a leader in the sustainable mobility solutions.	**1. Strong Competition:** The hydrogen industry is highly competitive that might affect profitability. **2. Limited infrastructure for hydrogen distribution:** There is a scarcity of broad hydrogen distribution infrastructure. The installation of hydrogen stations needs the construction of an extensive network of pipelines to provide hydrogen to the stations. **3. Limited consumer awareness and acceptance:** Hydrogen fuel cell cars are still relatively new and less known to the general public. **4. Technological advancements:** The rapid advancements in battery technology for electric cars present a threat to the adoption of hydrogen fuel cell vehicles, whose development is slower. **5. Competition from other clean energy sources:** Alternative clean energy sources such as battery electric cars, biofuels, and other renewable energy technologies compete with hydrogen as a fuel source.

Table 11. Repsol SWOT analysis

5. Strategic proposal to implement hydrogen filling stations

Hydrogen energy is a technology with great potential and growth expectations. It has been proven that hydrogen cars are emerging as a possible alternative to vehicles powered by fossil fuels. However, despite their potential, the growth of hydrogen cars is slow, and their implementation and establishment in the market is long term. In part, this slow development is because hydrogen infrastructure is limited and expensive to build. Therefore, multinational energy companies such as Repsol are promoting and investing in its development. For the moment, Repsol has only invested in the production of green hydrogen, but not in its distribution to private vehicles. The objective of this chapter is to propose a strategy for implementing green hydrogen filling stations at Repsol's gas stations.

a. Sector description

Before developing a detailed strategy, the attractiveness of the green hydrogen filling stations market in Spain will be briefly analyzed. For this purpose, Porter's 5 forces framework will be used:

- Threat of new entrants: LOW

  As it has been indicated, green hydrogen development is at an early stage of development. High investment in renewable energy infrastructure and technology is needed to provide enough green hydrogen to the market. Therefore, even though there are opportunities for new companies wishing to enter the green hydrogen filling stations market, they could enter only if they have sufficient capabilities. Furthermore, it should be taken into account that the sale to hydrogen cars will cannibalize the sale of gasoline at the fueling station itself.

- Threat of substitutes: MEDIUM-HIGH

  The threat of new products coming to market that can provide clean and renewable energy for transportation is high. Because hydrogen car technology is so new, it is less clear whether this technology will be the future of green transportation or whether if new and more efficient technologies will emerge. For example, cars powered directly by solar energy are being developed. Nevertheless, it is certain that hydrogen cars are the most advanced and most promising technology.

- Power of suppliers: VERY HIGH

  Due to the limited number of suppliers in the market, the power of technology and equipment suppliers is very high. This is partly because the technologies required are very specialized and modern, which limits the number of experts in the industry focused on this technology. In addition, due to their low demand, the different businesses interested in these suppliers will compete for their products, increasing their bargaining power.

- Power of clients: LOW

  For now, because the number of hydrogen vehicles and the number of available hydrogen plants is so low, consumers have no bargaining power. However, when the demand for hydrogen and hydrogen cars increases, customers will have more choice between different hydrogen suppliers, which will increase their power. The market will become more competitive.

- Competitive rivalry: VERY HIGH

  As already noted, the production of green hydrogen is currently low. However, several Spanish companies are already investing heavily in this technology. Among them, some noticeable Spanish companies are Repsol, Iberdrola, Endesa, Acciona, Enagás and Naturgy. Although there are not many companies, these companies have the power, infrastructure and capacity to capture the entire market, which makes the competitive rivalry between them very high.

This study shows that hydrogen car market in Spain presents many challenges and opportunities. There are high barriers to entry, due to the initial investment in technology, infrastructure and the need to obtain licenses and permits. Despite this, the market has great long-term growth prospects for companies such as Repsol, which makes it an interesting market.

b. Recommended actions

i) Objectives

First of all, in order to establish coherent hydrogen stations development objectives for Repsol, the market share of hydrogen sales is estimated. In the electric mobility and gasoline refueling market, Repsol is one of the companies that captures the highest market share. Its main competitors are Cepsa, BP, and Galp. These four major players in the oil and gas sector in Spain collectively capture around 50% of the market. (EFE, 2022) However, in the hydrogen filling stations market, these companies are not the only ones investing in this infrastructure; other companies in the Spanish energy sector such as Iberdrola and Naturgy are also entering in the market. This gives Repsol a strong sales advantage due to its consumer stronger approach at its service stations. Nevertheless, its market share does not seem to become as high as in its traditional gasoline refueling stations market. For all these reasons, it is assumed that Repsol will have a market share of 10% in the sale of hydrogen at its filling stations.

Considering the market growth expectations calculated above in the market size, the amount of hydrogen that Repsol will be able to sell at its refueling stations is estimated for each proposed scenario. The assumed range and fuel consumption characteristics of a hydrogen car are shown in the Table 12. By applying the estimated annual consumption of a hydrogen car and assuming a market share of 10% Repsol, it is possible to estimate the annual hydrogen sales that Repsol will have in the hydrogen car market. The results for each scenario are indicated in Table 14.

H2 car characteristics		**Source**
Average tank volume in kg	6	(Alabajos, 2022)
Average recharge time in minutes.	8	(Benito, 2021)
Range in km of a car	600	(Benito, 2021)
Average mileage in km of car per year	20 000	-
Number of car refills per year	33	-
Total H2 in kg consumed by a car per year	200	-

Table 12. Hydrogen car characteristics

Once the sales volume in kg of hydrogen that Repsol will be able to reach is calculated, the number of hydrogen filling stations needed to supply all this demand is estimated.

Hydrogen filling station capacity (kg H2/day)	**Installation costs of a hydrogen distribution station (M€)**			
	Onsite Steam Methane Reforming (SMR)	Onsite electrolysis	With hydrogen gas supply	With hydrogen liquid supply
100	0,9-2,6	1-2,6	1,1-1,8	0,7-2,1
480	1,9-4,6	1,9-5,4	1,9-2,4	1,59-2,9
1000	3,2-4,8	4-7,9	3,2	2,4

Table 13. Hydrogen stations installation costs. Source: (Fundación Naturgy, 2020)

There are several models of hydrogen filling station available, each with a capacity to provide different amounts of H2 per day. These data are presented in Table 13. In this case, it is decided to take a 480kg/day hydrogen station with external supply of hydrogen gas. For this type of model, an installation investment of €2.2M per unit will be taken. With the car and filling stations characteristics provided, it can be estimated that a hydrogen refueling station will be able to dispense 175,200 kg of H2 per year, which is equivalent to 80 car refills per day. Finally, with all this information, it is possible to estimate the number of hydrogen filling stations required to provide all the necessary hydrogen for Repsol's market. All the results are indicated in the following Table 14:

Year	Expected selling H2 in kg per year			Total number of filling stations needed		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2023	8.347,06	6.742,37	5.308,77	1	1	1
2024	18.035,29	13.589,86	9.930,09	1	1	1
2025	33.794,12	23.980,06	16.437,60	1	1	1
2026	58.588,24	39.374,57	25.482,57	1	1	1
2027	98.258,82	62.702,81	38.423,41	1	1	1
2028	162.741,18	98.707,95	57.334,93	1	1	1
2029	294.176,47	168.462,85	92.064,16	2	1	1
2030	502.641,18	272.919,66	140.994,30	3	2	1
2031	811.005,88	419.423,66	205.868,12	5	3	2
2032	1.538.717,65	748.727,18	344.411,49	9	5	2
2033	2.719.588,24	1.251.503,74	542.647,37	16	8	4
2034	4.101.970,59	1.808.131,98	749.520,46	24	11	5
2035	6.126.529,41	2.588.997,12	1.026.969,10	35	15	6
2036	8.342.911,76	3.408.647,34	1.305.650,24	48	20	8
2037	10.628.788,24	4.225.812,08	1.573.942,17	61	25	9
2038	13.543.076,47	5.241.447,17	1.898.184,35	78	30	11
2039	16.840.800,00	6.358.767,00	2.245.015,33	97	37	13
2040	20.588.858,82	7.598.436,50	2.620.165,83	118	44	15
2041	24.862.164,71	8.980.322,00	3.028.607,28	142	52	18
2042	29.760.476,47	10.531.675,00	3.477.058,17	170	61	20
2043	35.374.673,82	11.913.957,34	3.868.227,22	202	69	23
2044	41.773.720,19	13.477.664,24	4.303.402,78	239	77	25
2045	48.944.699,76	15.010.748,55	4.722.984,55	280	86	27
2046	56.975.107,09	16.718.221,20	5.183.475,55	326	96	30
2047	65.503.432,28	18.327.349,99	5.611.112,28	374	105	33
2048	74.596.762,72	20.091.357,42	6.074.029,04	426	115	35
2049	84.310.517,47	21.497.752,44	6.438.470,78	482	123	37
2050	94.269.786,72	23.002.595,12	6.824.779,03	539	132	39

Table 14. Repsol expected selling hydrogen estimation and number of hydrogen stations.

Knowing that the refueling of a hydrogen car takes about 8 minutes, this translates to the refueling station being in use for approximately 11 hours per day. This utilization rate appears to be quite high, so a 20% margin has been added to the final proposed number of dispensers. Table 15 indicates the proposed filling stations to be installed for Repsol to meet the estimated demand according to the three types of scenarios. It can be observed that in 2050, the number of required hydrogen filling stations will vary significantly depending on the demand scenario, ranging from 658 to 56 dispensers needed.

Year	Proposed filling stations to be installed each year			Total number of filling stations proposed		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2023	2	2	2	2	2	2
2024	2	2	2	5	4	4
2025	2	1	1	7	5	5
2026	2	1	1	9	6	6
2027	2	1	1	11	7	7
2028	2	1	1	13	8	8
2029	1	1	1	14	9	9
2030	1	1	1	15	10	10
2031	2	1	1	18	11	11
2032	5	2	1	22	14	12
2033	8	4	2	31	17	14
2034	10	4	1	40	21	16
2035	13	5	1	54	26	17
2036	16	6	2	69	32	19
2037	16	6	1	85	38	20
2038	20	6	2	105	44	23
2039	23	8	2	128	52	25
2040	25	8	2	153	61	28
2041	29	10	4	182	70	31
2042	34	11	2	216	81	34
2043	38	10	4	254	91	37
2044	44	10	2	298	100	40
2045	49	11	2	348	111	42
2046	55	12	4	403	123	46
2047	58	11	4	460	134	49
2048	62	12	2	523	146	52
2049	67	10	2	590	155	54
2050	68	11	2	658	166	56

Table 15. Proposed number of hydrogen filling stations to be installed.

ii) Clients' analysis

The main segments and customers that Repsol could count on in its business development have been identified:

- Private customer with their own hydrogen car: citizens that are concerned about the environment and the air contamination. They usually perform urban and short transportation; the use will be for their daily life travels. These clients need refueling stations inside the cities and near their homes.
- Long distance travelers: medium and long-distance travelers in Spain are common. Due to the high autonomy expectations of hydrogen cars, long distance users will also be interested in these vehicles. For this reason, they will need to

find recharging stations at strategic points to be able to move around the country without any problem.

- Transportation companies: Some public transportation companies have already shown interest in implementing hydrogen buses in cities such as Madrid and Barcelona. More Spanish cities will be interested to implement this method of transport. Moreover, private Spanish bus transportation companies, such as Alsa, could also be interested in using hydrogen buses.
- Private companies and institutions: Many companies and government institutions will seek to reduce their environmental impact and improve their corporate image.

The first two client segments represent the possible clients estimated for Repsol in Table 14. After identifying potential customers, it is found that in order to have a total presence in the market, Repsol should establish public hydrogen stations in its gas stations for private users and get possible private agreements with companies to become their main supplier of hydrogen for their corporate vehicles.

iii) Marketing and partnerships' strategies

It is very important for Repsol to position itself as a leader of the benchmark in clean mobility. For this purpose, the company must be highly present in promoting the benefits of having green hydrogen energy: such as lower environmental impact and the possibility of obtaining transportation from renewable sources. This is related with consumer education. It is essential to educate consumers about the benefits of fuel cell and hydrogen technology, as well as the vehicle options that are available on the market, to increase demand and accelerate adoption.

- Repsol could launch a loyalty program to reward users who use its hydrogen filling stations, as it already does with its regular gas customers with Waylet. Clients could accumulate points every time they use the service station and redeem them for discounts on fuel and maintenance services.
- Repsol could organize events to publicize its product and to allow potential customers to discover hydrogen filling stations. These events could include demonstrations of the technology, test drives of fuel cell vehicles, and informative talks.
- Repsol could sponsor cultural and sporting events to increase its presence in the community and generate a positive image in the market.

- Presence in social networks and other communication channels to reinforce its presence and leadership in the market. These proposals could be related to the above-mentioned events and awareness campaigns.
- Discounts on the installation of hydrogen stations to companies that request their services. As it was identified in the client's analysis, transportation companies will be interested in using hydrogen buses, for these businesses the installation of private filling stations is crucial. Also, other types of private and governmental businesses that want to promote the use of hydrogen cars among their employees, have been identified as potential customers for the private installation of filling stations. In both cases, hydrogen stations will need to be installed in their facilities, Repsol could provide installation discounts to these potential customers.

These development proposals will be easier to achieve with agreements and strategic alliances with different market stakeholders. Partners are identified in two categories: suppliers and producers of hydrogen filling stations' technologies and producers of hydrogen cars. Among potential hydrogen filling stations producers, Repsol could rely on well-known international companies, such as Air Liquide or Linde Group; or rely on small Spanish companies that are specializing in this sector. The local Spanish companies that have developed high-quality and innovative hydrogen technologies are Calvera Hydrogen, Clantech and Hiberbaric. Repsol would benefit more in having alliances with Spanish companies, because it would favor its image in the national industrial and technological development. In addition, it would be a collaboration between Spanish companies that share a strategic vision and common values on the energy future. Synergies and complementarities between both companies, which have extensive experience and knowledge of the Iberian market, could be exploited. Finally, it could reduce costs and lower the risks of importing technology from other countries, making the supply more secure. For example, one company to be recommended would be Clantech, combining the experience of Repsol in the energy sector with Clantech's expertise in the design and commissioning of hydrogen stations. (Clantech, 2023) Furthermore, Repsol could establish alliances with hydrogen car manufacturers to collaborate on joint research and innovation projects focused on sustainable mobility. They could also work together to promote joint sales to their potential customers: the vehicle manufacturing company could provide the car, while Repsol would be responsible for hydrogen production and distribution. The potential producers with whom Repsol could establish alliances are Hyundai, Toyota or BMW, which are the main sellers of hydrogen cars in Spain. A proposal from a transport company that Repsol could also work with is Uber. Joint marketing could be developed: Uber will offer hydrogen cars on its transport platform, and Repsol will provide the hydrogen needed to operate the vehicles. In addition, both companies could establish collaborative arrangements for vehicle distribution and maintenance, which would allow users to have access to a complete and efficient infrastructure. Under the partnership, Repsol and Uber could also explore new business opportunities related to sustainable mobility, such as the development of shared mobility services based on hydrogen cars. The two companies could work together to develop innovative business models to maximize the potential of hydrogen technology in transport. As part of the partnership, both companies could commit to joint investments for the construction and upgrading of necessary infrastructure. In addition, this alliance could allow both companies to expand their geographic presence in the sustainable mobility market.

iv) Business plan

In order to evaluate the economic feasibility of the project for the installation of all the hydrogen stations proposed, estimates of revenues and profitability have been made for each scenario. The baseline data indicate that the investment cost for the hydrogen filling station is 2.2 million euros, with a production capacity of 480 kg H2/day. For the calculation, it is estimated that Repsol manages to sell on average all the hydrogen estimated by the demand, in addition to being able to keep some inventory of 30 days in their tanks.

Financial assumptions		Source
CAPEX in 2023	2,2 M€	(Fundación Naturgy, 2020)
O&M costs	4€/kg H2	(Muñoz, 2022)
Hydrogen selling price to customer in 2023	8 €/kg H2	(Hidrogeno-verde.es, 2022)
Price variation each year	-5%	-
Production of hydrogen	480 kg H2/day	(Fundación Naturgy, 2020)
Days in inventory	30 days	-
Payables Due	30 days	-
Accrued Due	30 days	-
WACC	8,5%	-
Tax	10%	-

Table 16. Assumptions for the business plan.

All values used for the calculation are shown in Table 16. A few values have been assumed:

- Days in inventory, Payables Due and Accrued Due of 30 days as it is considered that hydrogen production and agreements with suppliers and customers are made in an efficient manner.

- The quantity of hydrogen sold each year is the estimation of the expected selling hydrogen of Repsol with a 10%, this data is indicated in Table 14.
- The current market selling price is very high; however, it is expected to decrease significantly in the coming years. Experts aim for it to reach €2/kg by 2030 (Aragón, 2021). For this reason, a gradual 5% reduction in the selling price of hydrogen has been applied.
- As for the production cost, operating and management expenses also account for production and distribution prices. In this case, it is assumed that the initial production costs will be 4€/kg in 2023. The variable costs of this type of project are considered to be low, 20% compared to total costs. To estimate the costs for the following years, it is considered that the ratio between variable and fixed costs does not change. The new costs will be based on the revenues of those years.
- The CAPEX of each dispenser is also expected to gradually decrease in the coming years, making the installation of a hydrogen refueling station cheaper in the future. It starts with an initial cost of €2.2M, which will decrease by 1% each year. For each year, the CAPEX will depend on the number of estimated hydrogen stations that must be installed each year.

Business plan results			
-	**Scenario 1**	**Scenario 2**	**Scenario 3**
PV (€)	34.520.777,15	7.777.767,65	- 866.348,60
NPV (€)	30.120.777,15	13.377.767,65	- 5.266.348,6
Payback period	16,7 years	16,8 years	19,9 years
IRR	13,5%	12,0%	6,3%

Table 17. Results of businesses plan.

The business plans calculations are presented from Figure 12 to Figure 17, the calculation has been made three times, for each scenario. In conclusion, the results from the business plan analysis provide valuable insights (Table 17). Scenario 1 demonstrates the most favorable financial outcome, with a higher present value (PV) and net present value (NPV), along with a relatively shorter payback period and a higher internal rate of return (IRR). This suggests that scenario 1 presents a more promising opportunity for profitability and return on investment. On the other hand, scenario 3 exhibits a negative PV and NPV, indicating potential financial loss and challenges. The payback period for all scenarios is significant, ranging from 16.7 to 19.9 years, reflecting a considerable time frame for recouping the initial investment. Considering these factors, the first two scenarios are the most financially interesting while proceeding with caution regarding scenario 3 due to its unfavorable financial outlook. However, scenario 1 evolution seems idealistic, making scenario 2 a more realistic option adapted to the uncertainties and challenges associated with hydrogen technology. It is not clear that the evolution of hydrogen cars beyond 2021 will follow the same path as the history of electric cars since 2009. While there may be lessons learned and technical breakthroughs that will accelerate hydrogen vehicle adoption, there are special problems and limits connected with hydrogen technology, such as large-scale hydrogen generation and transportation, that may limit its expansion. Therefore, scenario 2 is the best option: it has a positive NPV with an interesting IRR of 12% and its selling evolution and market capacity are more reachable.

Finally, to determine the weighted average cost of capital (WACC), data provided in (Zhou & Searle, 2022) establishing the cost of renewable hydrogen produced on-site at hydrogen refueling stations in Europe has been used. This document includes the following financial assumptions:

- Inflation: 2%
- Corporate tax rate of 10%
- Debt-to-equity ratio of 60% to 40%
- Loan interest rate of 4%
- Return on equity of 16%.

The WACC is calculated using the following formula:

$$WACC = E/V * Re + D/V * Rd * (1 - Tc)$$

Where:

E: market value of the company's equity or stocks

D: market value of the company's debt

V: total value of the company, which is the sum of E and D

Re: expected rate of return on the company's equity or stocks

Rd: interest rate on debt

Tc: corporate tax rate

D/E: debt/capital ratio, meaning the percentage of financing that comes from debt and the percentage that comes from equity or stocks.

By replacing the given values in the formula, we get:

$$WACC = 0.4 * 0.16 + 0.6 * 0.04 * (1 - 0.10) = 8.5\%$$

	Year 2023	Year 2024	Year 2025	Year 2026	Year 2027	Year 2028	Year 2029	Year 2030	Year 2031	Year 2032	Year 2033	Year 2034	Year 2035	Year 2036
Period	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Quantity sold (kg H2/year):		18.035	33.794	58.588	98.259	162.741	294.176	502.641	811.006	1.538.718	2.719.588	4.101.971	6.126.529	8.342.912
H2 price (€/kg):		8,00	7,60	7,22	6,86	6,52	6,19	5,88	5,59	5,31	5,04	4,79	4,55	4,32
Price variation:			*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*
Revenues		144.282,35	256.835,29	423.007,06	673.957,27	1.060.429,64	1.821.025,16	2.955.899,62	4.530.845,24	8.166.533,80	13.712.151,04	19.648.010,52	27.878.163,96	36.065.412,26
- COGS		14.428,24	25.683,53	42.300,71	67.395,73	106.042,96	182.102,52	295.589,96	453.084,52	816.653,38	1.371.215,10	1.964.801,05	2.787.816,40	3.606.541,23
- SG&A		57.712,94	54.827,29	52.085,93	49.481,63	47.007,55	44.657,17	42.424,32	40.303,10	38.287,94	36.373,55	34.554,87	32.827,13	31.185,77
EBITDA		**72.141,18**	**176.324,47**	**328.620,42**	**557.079,91**	**907.379,13**	**1.594.265,47**	**2.617.885,34**	**4.037.457,62**	**7.311.592,48**	**12.304.562,39**	**17.648.654,60**	**25.057.520,44**	**32.427.685,26**
- Depreciation														
Pretax Profit		**72.141,18**	**176.324,47**	**328.620,42**	**557.079,91**	**907.379,13**	**1.594.265,47**	**2.617.885,34**	**4.037.457,62**	**7.311.592,48**	**12.304.562,39**	**17.648.654,60**	**25.057.520,44**	**32.427.685,26**
- Taxes		7.214,12	17.632,45	32.862,04	55.707,99	90.737,91	159.426,55	261.788,53	403.745,76	731.159,25	1.230.456,24	1.764.865,46	2.505.752,04	3.242.768,53
NOPAT		**64.927,06**	**158.692,02**	**295.758,38**	**501.371,92**	**816.641,21**	**1.434.838,92**	**2.356.096,81**	**3.633.711,86**	**6.580.433,23**	**11.074.106,15**	**15.883.789,14**	**22.551.768,39**	**29.184.916,74**
CapEx	(4.400.000,00)	(4.334.000,00)	(4.268.990,00)	(4.204.955,15)	(4.141.880,82)	(4.079.752,61)	(2.411.133,79)	(2.374.966,79)	(4.678.684,57)	(9.217.008,60)	(15.887.818,57)	(17.885.144,34)	(24.223.192,36)	(28.197.998,02)
Taxes														
NCS	**(4.400.000,00)**	**(4.334.000,00)**	**(4.268.990,00)**	**(4.204.955,15)**	**(4.141.880,82)**	**(4.079.752,61)**	**(2.411.133,79)**	**(2.374.966,79)**	**(4.678.684,57)**	**(9.217.008,60)**	**(15.887.818,57)**	**(17.885.144,34)**	**(24.223.192,36)**	**(28.197.998,02)**
Inventory		1.185,88	2.110,98	3.476,77	5.539,37	8.715,86	14.967,33	24.295,07	37.239,82	67.122,20	112.702,61	161.490,50	229.135,59	296.428,05
Acc. Receivable														
Cash		2.371,76	2.646,93	3.103,12	3.842,54	5.031,80	7.455,11	11.112,80	16.220,96	28.107,66	46.276,89	65.732,25	92.733,49	119.596,50
Payables		1.185,88	2.110,98	3.476,77	5.539,37	8.715,86	14.967,33	24.295,07	37.239,82	67.122,20	112.702,61	161.490,50	229.135,59	296.428,05
Accrued		4.743,53	4.506,35	4.281,04	4.066,98	3.863,63	3.670,45	3.486,93	3.312,58	3.146,95	2.989,61	2.840,13	2.698,12	2.563,21
- *NWC*		*2.371,76*	*1.859,42*	*1.177,91*	*224,44*	*(1.168,16)*	*(3.784,66)*	*(7.625,87)*	*(12.908,38)*	*(24.960,71)*	*(43.287,28)*	*(62.892,12)*	*(90.035,37)*	*(117.033,29)*
- **ΔNWC**		**2.371,76**	**(512,34)**	**(681,51)**	**(953,47)**	**(1.392,60)**	**(2.616,50)**	**(3.841,21)**	**(5.282,51)**	**(12.052,33)**	**(18.326,57)**	**(19.604,84)**	**(27.143,24)**	**(26.997,92)**
OCF		64.927,06	158.692,02	295.758,38	501.371,92	816.641,21	1.434.838,92	2.356.096,81	3.633.711,86	6.580.433,23	11.074.106,15	15.883.789,14	22.551.768,39	29.184.916,74
NCS	(4.400.000,00)	(4.334.000,00)	(4.268.990,00)	(4.204.955,15)	(4.141.880,82)	(4.079.752,61)	(2.411.133,79)	(2.374.966,79)	(4.678.684,57)	(9.217.008,60)	(15.887.818,57)	(17.885.144,34)	(24.223.192,36)	(28.197.998,02)
ΔNWC		2.371,76	(512,34)	(681,51)	(953,47)	(1.392,60)	(2.616,50)	(3.841,21)	(5.282,51)	(12.052,33)	(18.326,57)	(19.604,84)	(27.143,24)	(26.997,92)
Free Cash Flow	**(4.400.000,00)**	**(4.266.701,18)**	**(4.110.810,32)**	**(3.909.878,28)**	**(3.641.462,38)**	**(3.264.504,00)**	**(978.911,37)**	**(22.711,18)**	**(1.050.255,22)**	**(2.648.627,70)**	**(4.832.039,00)**	**(2.020.960,04)**	**(1.698.567,21)**	**959.920,80**
Other (Opp, Erosion, ...)														
FCF	**(4.400.000,00)**	**(4.266.701,18)**	**(4.110.810,32)**	**(3.909.878,28)**	**(3.641.462,38)**	**(3.264.504,00)**	**(978.911,37)**	**(22.711,18)**	**(1.050.255,22)**	**(2.648.627,70)**	**(4.832.039,00)**	**(2.020.960,04)**	**(1.698.567,21)**	**959.920,80**

Figure 12. Scenario 1: business plan (part 1)

	Year 2037	Year 2038	Year 2039	Year 2040	Year 2041	Year 2042	Year 2043
Period	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Quantity sold (kg H2/year):	10.628.788	13.543.076	16.840.800	20.588.859	24.862.165	29.760.476	35.374.674
H2 price (€/kg):	4,11	3,90	3,71	3,52	3,34	3,18	3,02
Price variation:	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*
Revenues	43.649.634,36	52.836.956,28	62.417.559,59	72.493.646,76	83.163.013,13	94.570.299,03	106.790.084,85
- COGS	4.364.963,44	5.283.695,63	6.241.755,96	7.249.364,68	8.316.301,31	9.457.029,90	10.679.008,48
- SG&A	29.626,48	28.145,16	26.737,90	25.401,00	24.130,95	22.924,41	21.778,19
EBITDA	**39.255.044,45**	**47.525.115,49**	**56.149.065,73**	**65.218.881,08**	**74.822.580,86**	**85.090.344,72**	**96.089.298,18**
- Depreciation							
Pretax Profit	**39.255.044,45**	**47.525.115,49**	**56.149.065,73**	**65.218.881,08**	**74.822.580,86**	**85.090.344,72**	**96.089.298,18**
- Taxes	3.925.504,44	4.752.511,55	5.614.906,57	6.521.888,11	7.482.258,09	8.509.034,47	9.608.929,82
NOPAT	**35.329.540,00**	**42.772.603,94**	**50.534.159,16**	**58.696.992,97**	**67.340.322,78**	**76.581.310,25**	**86.480.368,36**
CapEx	(27.775.028,05)	(35.776.372,66)	(39.385.577,32)	(42.878.456,15)	(49.003.949,88)	(57.171.274,86)	(65.338.599,85)
Taxes							
NCS	**(27.775.028,05)**	**(35.776.372,66)**	**(39.385.577,32)**	**(42.878.456,15)**	**(49.003.949,88)**	**(57.171.274,86)**	**(65.338.599,85)**
Inventory	358.764,12	434.276,35	513.021,04	595.838,19	683.531,61	777.290,13	877.726,72
Acc. Receivable							
Cash	144.479,67	174.635,86	206.087,47	239.170,38	274.205,99	311.669,73	351.806,69
Payables	358.764,12	434.276,35	513.021,04	595.838,19	683.531,61	777.290,13	877.726,72
Accrued	2.435,05	2.313,30	2.197,64	2.087,75	1.983,37	1.884,20	1.789,99
- *NWC*	*(142.044,62)*	*(172.322,56)*	*(203.889,83)*	*(237.082,62)*	*(272.222,63)*	*(309.785,53)*	*(350.016,70)*
- ΔNWC	**(25.011,33)**	**(30.277,95)**	**(31.567,27)**	**(33.192,79)**	**(35.140,00)**	**(37.562,91)**	**(40.231,16)**
OCF	35.329.540,00	42.772.603,94	50.534.159,16	58.696.992,97	67.340.322,78	76.581.310,25	86.480.368,36
NCS	(27.775.028,05)	(35.776.372,66)	(39.385.577,32)	(42.878.456,15)	(49.003.949,88)	(57.171.274,86)	(65.338.599,85)
ΔNWC	(25.011,33)	(30.277,95)	(31.567,27)	(33.192,79)	(35.140,00)	(37.562,91)	(40.231,16)
Free Cash Flow	**7.529.500,63**	**6.965.953,34**	**11.117.014,57**	**15.785.344,03**	**18.301.232,89**	**19.372.472,47**	**21.101.537,35**
Other (Opp, Erosion, ...)							
FCF	**7.529.500,63**	**6.965.953,34**	**11.117.014,57**	**15.785.344,03**	**18.301.232,89**	**19.372.472,47**	**21.101.537,35**

	Year 2044	Year 2045	Year 2046	Year 2047	Year 2048	Year 2049	Year 2050
Period	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Quantity sold (kg H2/year):	41.773.720	48.944.700	56.975.107	65.503.432	74.596.763	84.310.517	94.269.787
H2 price (€/kg):	2,87	2,72	2,59	2,46	2,34	2,22	2,11
Price variation:	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*
Revenues	119.802.324,92	133.349.492,40	147.466.866,98	161.063.438,18	174.251.487,72	187.094.867,61	198.735.864,81
- COGS	11.980.232,49	13.334.949,24	14.746.686,70	16.106.343,82	17.425.148,77	18.709.486,76	19.873.586,48
- SG&A	20.689,28	19.654,81	18.672,07	17.738,47	16.851,55	16.008,97	15.208,52
EBITDA	**107.801.403,15**	**119.994.888,34**	**132.701.508,21**	**144.939.355,89**	**156.809.487,40**	**168.369.371,88**	**178.847.069,81**
- Depreciation							
Pretax Profit	**107.801.403,15**	**119.994.888,34**	**132.701.508,21**	**144.939.355,89**	**156.809.487,40**	**168.369.371,88**	**178.847.069,81**
- Taxes	10.780.140,32	11.999.488,83	13.270.150,82	14.493.935,59	15.680.948,74	16.836.937,19	17.884.706,98
NOPAT	**97.021.262,84**	**107.995.399,51**	**119.431.357,39**	**130.445.420,30**	**141.128.538,66**	**151.532.434,69**	**160.962.362,83**
CapEx	(75.547.756,07)	(83.715.081,05)	(93.924.237,28)	(98.007.899,77)	(106.175.224,75)	(114.342.549,73)	(116.384.380,97)
Taxes							11.638.438,10
NCS	**(75.547.756,07)**	**(83.715.081,05)**	**(93.924.237,28)**	**(98.007.899,77)**	**(106.175.224,75)**	**(114.342.549,73)**	**(104.745.942,88)**
Inventory	984.676,64	1.096.023,23	1.212.056,44	1.323.809,08	1.432.204,01	1.537.766,04	1.633.445,46
Acc. Receivable							
Cash	394.550,85	439.055,48	485.436,45	530.106,81	573.435,63	615.632,74	653.878,19
Payables	984.676,64	1.096.023,23	1.212.056,44	1.323.809,08	1.432.204,01	1.537.766,04	1.633.445,46
Accrued	1.700,49	1.615,46	1.534,69	1.457,96	1.385,06	1.315,81	1.250,02
- *NWC*	*(392.850,36)*	*(437.440,01)*	*(483.901,76)*	*(528.648,86)*	*(572.050,57)*	*(614.316,93)*	*(652.628,18)*
- ΔNWC	**(42.833,67)**	**(44.589,65)**	**(46.461,75)**	**(44.747,10)**	**(43.401,71)**	**(42.266,36)**	**614.316,93**
OCF	97.021.262,84	107.995.399,51	119.431.357,39	130.445.420,30	141.128.538,66	151.532.434,69	160.962.362,83
NCS	(75.547.756,07)	(83.715.081,05)	(93.924.237,28)	(98.007.899,77)	(106.175.224,75)	(114.342.549,73)	(104.745.942,88)
ΔNWC	(42.833,67)	(44.589,65)	(46.461,75)	(44.747,10)	(43.401,71)	(42.266,36)	614.316,93
Free Cash Flow	**21.430.673,10**	**24.235.728,81**	**25.460.658,36**	**32.392.773,44**	**34.909.912,20**	**37.147.618,60**	**56.830.736,89**
Other (Opp, Erosion, ...)							
FCF	**21.430.673,10**	**24.235.728,81**	**25.460.658,36**	**32.392.773,44**	**34.909.912,20**	**37.147.618,60**	**56.830.736,89**

PROJECT	**PV: 34.520.777,15**
	WACC 8,5%
	NPV: 30.120.777,15
	Payback Period: 16,7 years
	IRR: 13,5%

Figure 13. Scenario 1: business plan (part 2)

	Year 2023	Year 2024	Year 2025	Year 2026	Year 2027	Year 2028	Year 2029	Year 2030	Year 2031	Year 2032	Year 2033	Year 2034	Year 2035	Year 2036
Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Quantity sold (kg H2/year):		13.590	23.980	39.375	62.703	98.708	168.463	272.920	419.424	748.727	1.251.504	1.808.132	2.588.997	3.408.647
H2 price (€/kg):		8,00	7,60	7,22	6,86	6,52	6,19	5,88	5,59	5,31	5,04	4,79	4,55	4,32
Price variation:			*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*
Revenues		108.718,91	182.248,45	284.284,38	430.078,60	643.185,91	1.042.826,71	1.604.968,24	2.343.193,48	3.973.767,27	6.310.075,95	8.660.763,24	11.780.974,41	14.735.175,82
- COGS		10.871,89	18.224,84	28.428,44	43.007,86	64.318,59	104.282,67	160.496,82	234.319,35	397.376,73	631.007,60	866.076,32	1.178.097,44	1.473.517,58
- SG&A		43.487,56	41.313,19	39.247,53	37.285,15	35.420,89	33.649,85	31.967,36	30.368,99	28.850,54	27.408,01	26.037,61	24.735,73	23.498,94
EBITDA		**54.359,45**	**122.710,42**	**216.608,42**	**349.785,59**	**543.446,43**	**904.894,19**	**1.412.504,06**	**2.078.505,15**	**3.547.540,00**	**5.651.660,35**	**7.768.649,31**	**10.578.141,24**	**13.238.159,29**
- Depreciation														
Pretax Profit		**54.359,45**	**122.710,42**	**216.608,42**	**349.785,59**	**543.446,43**	**904.894,19**	**1.412.504,06**	**2.078.505,15**	**3.547.540,00**	**5.651.660,35**	**7.768.649,31**	**10.578.141,24**	**13.238.159,29**
									3.547.540,00					
- Taxes		5.435,95	12.271,04	21.660,84	34.978,56	54.344,64	90.489,42	141.250,41	207.850,51	354.754,00	565.166,03	776.864,93	1.057.814,12	1.323.815,93
NOPAT		**48.923,51**	**110.439,38**	**194.947,58**	**314.807,03**	**489.101,78**	**814.404,77**	**1.271.253,66**	**1.870.654,63**	**3.192.786,00**	**5.086.494,31**	**6.991.784,38**	**9.520.327,11**	**11.914.343,37**
CapEx	(4.400.000,00)	(4.334.000,00)	(2.134.495,00)	(2.102.477,58)	(2.070.940,41)	(2.039.876,31)	(2.009.278,16)	(2.374.966,79)	(2.339.342,28)	(4.608.504,30)	(6.809.065,10)	(6.706.929,13)	(8.808.433,59)	(10.845.383,85)
Taxes														
NCS	**(4.400.000,00)**	**(4.334.000,00)**	**(2.134.495,00)**	**(2.102.477,58)**	**(2.070.940,41)**	**(2.039.876,31)**	**(2.009.278,16)**	**(2.374.966,79)**	**(2.339.342,28)**	**(4.608.504,30)**	**(6.809.065,10)**	**(6.706.929,13)**	**(8.808.433,59)**	**(10.845.383,85)**
Inventory		893,58	1.497,93	2.336,58	3.534,89	5.286,46	8.571,18	13.191,52	19.259,12	32.661,10	51.863,64	71.184,36	96.829,93	121.111,03
Acc. Receivable														
Cash		1.787,16	1.957,41	2.224,96	2.639,77	3.279,11	4.534,77	6.327,59	8.702,08	14.012,95	21.646,54	29.329,77	39.545,20	49.216,98
Payables		893,58	1.497,93	2.336,58	3.534,89	5.286,46	8.571,18	13.191,52	19.259,12	32.661,10	51.863,64	71.184,36	96.829,93	121.111,03
Accrued		3.574,32	3.395,60	3.225,82	3.064,53	2.911,31	2.765,74	2.627,45	2.496,08	2.371,28	2.252,71	2.140,08	2.033,07	1.931,42
- *NWC*		*1.787,16*	*1.438,19*	*1.000,86*	*424,76*	*(367,80)*	*(1.769,03)*	*(3.700,14)*	*(6.206,00)*	*(11.641,67)*	*(19.393,83)*	*(27.189,70)*	*(37.512,13)*	*(47.285,56)*
- **ΔNWC**		**1.787,16**	**(348,97)**	**(437,33)**	**(576,10)**	**(792,56)**	**(1.401,23)**	**(1.931,11)**	**(2.505,87)**	**(5.435,67)**	**(7.752,15)**	**(7.795,87)**	**(10.322,43)**	**(9.773,44)**
OCF		48.923,51	110.439,38	194.947,58	314.807,03	489.101,78	814.404,77	1.271.253,66	1.870.654,63	3.192.786,00	5.086.494,31	6.991.784,38	9.520.327,11	11.914.343,37
NCS	(4.400.000,00)	(4.334.000,00)	(2.134.495,00)	(2.102.477,58)	(2.070.940,41)	(2.039.876,31)	(2.009.278,16)	(2.374.966,79)	(2.339.342,28)	(4.608.504,30)	(6.809.065,10)	(6.706.929,13)	(8.808.433,59)	(10.845.383,85)
ΔNWC		1.787,16	(348,97)	(437,33)	(576,10)	(792,56)	(1.401,23)	(1.931,11)	(2.505,87)	(5.435,67)	(7.752,15)	(7.795,87)	(10.322,43)	(9.773,44)
Free Cash Flow	**(4.400.000,00)**	**(4.283.289,33)**	**(2.024.404,59)**	**(1.907.967,33)**	**(1.756.709,48)**	**(1.551.567,08)**	**(1.196.274,62)**	**(1.105.644,24)**	**(471.193,52)**	**(1.421.153,97)**	**(1.730.322,94)**	**277.059,38**	**701.571,10**	**1.059.186,08**
Other (Opp, Erosion, ...)														
FCF	**(4.400.000,00)**	**(4.283.289,33)**	**(2.024.404,59)**	**(1.907.967,33)**	**(1.756.709,48)**	**(1.551.567,08)**	**(1.196.274,62)**	**(1.105.644,24)**	**(471.193,52)**	**(1.421.153,97)**	**(1.730.322,94)**	**277.059,38**	**701.571,10**	**1.059.186,08**

Figure 14. Scenario 2: business plan (part 1)

ICADE BUSINESS SCHOOL
COMILLAS ICADE

	Year 2037	Year 2038	Year 2039	Year 2040	Year 2041	Year 2042	Year 2043	Year 2044	Year 2045	Year 2046	Year 2047	Year 2048	Year 2049	Year 2050
Period	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Quantity sold (kg H2/year):	4.225.812	5.241.447	6.358.767	7.598.437	8.980.322	10.531.675	11.913.957	13.477.664	15.010.749	16.718.221	18.327.350	20.091.357	21.497.752	23.002.595
H2 price (€/kg):	4,11	3,90	3,71	3,52	3,34	3,18	3,02	2,87	2,72	2,59	2,46	2,34	2,22	2,11
Price variation:	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*	*-5,0%*
Revenues	17.354.297,40	20.448.981,13	23.567.687,90	26.754.196,36	30.038.841,96	33.466.656,85	35.966.197,79	38.652.423,18	40.896.679,50	43.271.242,96	45.064.295,09	46.931.646,82	47.706.018,99	48.493.168,30
- COGS	1.735.429,74	2.044.898,11	2.356.768,79	2.675.419,64	3.003.884,20	3.346.665,69	3.416.788,79	3.865.242,32	4.089.667,95	4.327.124,30	4.506.429,51	4.693.164,68	4.770.601,90	4.849.316,83
- SG&A	22.324,00	21.207,80	20.147,41	19.140,04	18.183,03	17.273,88	16.410,19	15.589,68	14.810,20	14.069,69	13.366,20	12.697,89	12.063,00	11.459,85
EBITDA	**15.596.543,66**	**18.382.875,22**	**21.190.771,71**	**24.059.636,69**	**27.016.774,73**	**30.102.717,28**	**32.532.998,81**	**34.771.591,19**	**36.792.201,36**	**38.930.048,98**	**40.544.499,38**	**42.225.784,24**	**42.923.354,09**	**43.632.391,62**
- Depreciation														
Pretax Profit	**15.596.543,66**	**18.382.875,22**	**21.190.771,71**	**24.059.636,69**	**27.016.774,73**	**30.102.717,28**	**32.532.998,81**	**34.771.591,19**	**36.792.201,36**	**38.930.048,98**	**40.544.499,38**	**42.225.784,24**	**42.923.354,09**	**43.632.391,62**
- Taxes	1.559.654,37	1.838.287,52	2.119.077,17	2.405.963,67	2.701.677,47	3.010.271,73	3.253.299,88	3.477.159,12	3.679.220,14	3.893.004,90	4.054.449,94	4.222.578,42	4.292.335,41	4.363.239,16
NOPAT	**14.036.889,30**	**16.544.587,70**	**19.071.694,54**	**21.653.673,02**	**24.315.097,25**	**27.092.445,56**	**29.279.698,93**	**31.294.432,07**	**33.112.981,22**	**35.037.044,08**	**36.490.049,44**	**38.003.205,82**	**38.631.018,68**	**39.269.152,46**
CapEx	(10.682.703,09)	(10.522.462,55)	(14.510.475,85)	(14.292.818,72)	(16.334.649,96)	(18.376.481,21)	(16.334.649,96)	(16.334.649,96)	(18.376.481,21)	(20.418.312,45)	(18.376.481,21)	(20.418.312,45)	(16.334.649,96)	(18.376.481,21)
Taxes														1.837.648,12
NCS	**(10.682.703,09)**	**(10.522.462,55)**	**(14.510.475,85)**	**(14.292.818,72)**	**(16.334.649,96)**	**(18.376.481,21)**	**(16.334.649,96)**	**(16.334.649,96)**	**(18.376.481,21)**	**(20.418.312,45)**	**(18.376.481,21)**	**(20.418.312,45)**	**(16.334.649,96)**	**(16.538.833,09)**
Inventory	142.638,06	168.073,82	193.707,02	219.897,50	246.894,59	275.068,41	280.831,96	317.691,15	336.137,09	355.654,05	370.391,47	385.739,56	392.104,27	398.573,99
Acc. Receivable														
Cash	57.789,16	67.926,77	78.145,19	88.588,26	99.355,63	110.595,27	112.872,30	127.589,00	134.941,75	142.724,19	148.596,02	154.713,29	157.238,30	159.806,36
Payables	142.638,06	168.073,82	193.707,02	219.897,50	246.894,59	275.068,41	280.831,96	317.691,15	336.137,09	355.654,05	370.391,47	385.739,56	392.104,27	398.573,99
Accrued	1.834,85	1.743,11	1.655,95	1.573,15	1.494,50	1.419,77	1.348,78	1.281,34	1.217,28	1.156,41	1.098,59	1.043,66	991,48	941,91
- *NWC*	*(55.954,31)*	*(66.183,66)*	*(76.489,24)*	*(87.015,11)*	*(97.861,14)*	*(109.175,50)*	*(111.523,51)*	*(126.307,65)*	*(133.724,47)*	*(141.567,77)*	*(147.497,43)*	*(153.669,63)*	*(156.246,82)*	*(158.864,45)*
- ΔNWC	**(8.668,75)**	**(10.229,35)**	**(10.305,58)**	**(10.525,87)**	**(10.846,03)**	**(11.314,36)**	**(2.348,01)**	**(14.784,14)**	**(7.416,82)**	**(7.843,30)**	**(5.929,66)**	**(6.172,20)**	**(2.577,19)**	**156.246,82**
OCF	14.036.889,30	16.544.587,70	19.071.694,54	21.653.673,02	24.315.097,25	27.092.445,56	29.279.698,93	31.294.432,07	33.112.981,22	35.037.044,08	36.490.049,44	38.003.205,82	38.631.018,68	39.269.152,46
NCS	(10.682.703,09)	(10.522.462,55)	(14.510.475,85)	(14.292.818,72)	(16.334.649,96)	(18.376.481,21)	(16.334.649,96)	(16.334.649,96)	(18.376.481,21)	(20.418.312,45)	(18.376.481,21)	(20.418.312,45)	(16.334.649,96)	(16.538.833,09)
ΔNWC	(8.668,75)	(10.229,35)	(10.305,58)	(10.525,87)	(10.846,03)	(11.314,36)	(2.348,01)	(14.784,14)	(7.416,82)	(7.843,30)	(5.929,66)	(6.172,20)	(2.577,19)	156.246,82
Free Cash Flow	**3.345.517,45**	**6.011.895,80**	**4.550.913,11**	**7.350.328,43**	**7.969.601,26**	**8.704.649,99**	**12.942.700,96**	**14.944.997,96**	**14.729.083,20**	**14.610.888,33**	**18.107.638,58**	**17.578.721,17**	**22.293.791,53**	**22.886.566,20**
Other (Opp, Erosion, ...)														
FCF	**3.345.517,45**	**6.011.895,80**	**4.550.913,11**	**7.350.328,43**	**7.969.601,26**	**8.704.649,99**	**12.942.700,96**	**14.944.997,96**	**14.729.083,20**	**14.610.888,33**	**18.107.638,58**	**17.578.721,17**	**22.293.791,53**	**22.886.566,20**

PROJECT	
	PV: 17.777.767,65
	WACC 8,5%
	NPV: 13.377.767,65
	Payback Period: 16,8 years
	IRR: 12,0%

Figure 15. Scenario 2: business plan (part 2)

	Year 2023	Year 2024	Year 2025	Year 2026	Year 2027	Year 2028	Year 2029	Year 2030	Year 2031	Year 2032	Year 2033	Year 2034	Year 2035	Year 2036
Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Quantity sold (kg H2/year):		9.930	16.438	25.483	38.423	57.335	92.064	140.994	205.868	344.411	542.647	749.520	1.026.969	1.305.650
H2 price (€/kg):		8,00	7,60	7,22	6,86	6,52	6,19	5,88	5,59	5,31	5,04	4,79	4,55	4,32
Price variation:			-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%
Revenues		79.440,69	124.925,73	183.984,13	263.546,18	373.597,30	569.899,95	829.150,16	1.150.123,08	1.827.916,95	2.736.025,47	3.590.124,67	4.673.120,96	5.644.170,24
- COGS		7.944,07	12.492,57	18.398,41	26.354,62	37.359,73	56.990,00	82.915,02	115.012,31	182.791,69	273.602,55	359.012,47	467.312,10	564.417,02
- SG&A		31.776,28	30.187,46	28.678,09	27.244,18	25.881,98	24.587,88	23.358,48	22.190,56	21.081,03	20.026,98	19.025,63	18.074,35	17.170,63
EBITDA		**39.720,34**	**82.245,70**	**136.907,63**	**209.947,38**	**310.355,59**	**488.322,08**	**722.876,66**	**1.012.920,21**	**1.624.044,22**	**2.442.395,95**	**3.212.086,57**	**4.187.734,52**	**5.062.582,59**
- Depreciation														
Pretax Profit		**39.720,34**	**82.245,70**	**136.907,63**	**209.947,38**	**310.355,59**	**488.322,08**	**722.876,66**	**1.012.920,21**	**1.624.044,22**	**2.442.395,95**	**3.212.086,57**	**4.187.734,52**	**5.062.582,59**
									1.624.044,22					
- Taxes		3.972,03	8.224,57	13.690,76	20.994,74	31.035,56	48.832,21	72.287,67	101.292,02	162.404,42	244.239,59	321.208,66	418.773,45	506.258,26
NOPAT		**35.748,31**	**74.021,13**	**123.216,86**	**188.952,64**	**279.320,03**	**439.489,87**	**650.588,99**	**911.628,19**	**1.461.639,80**	**2.198.156,35**	**2.890.877,91**	**3.768.961,06**	**4.556.324,33**
CapEx	(4.400.000,00)	(4.334.000,00)	(2.134.495,00)	(2.102.477,58)	(2.070.940,41)	(2.039.876,31)	(2.009.278,16)	(1.979.138,99)	(1.949.451,90)	(1.920.210,12)	(4.539.376,74)	(2.235.643,04)	(2.202.108,40)	(4.338.153,54)
Taxes														
NCS	**(4.400.000,00)**	**(4.334.000,00)**	**(2.134.495,00)**	**(2.102.477,58)**	**(2.070.940,41)**	**(2.039.876,31)**	**(2.009.278,16)**	**(1.979.138,99)**	**(1.949.451,90)**	**(1.920.210,12)**	**(4.539.376,74)**	**(2.235.643,04)**	**(2.202.108,40)**	**(4.338.153,54)**
Inventory		652,94	1.026,79	1.512,20	2.166,13	3.070,66	4.684,11	6.814,93	9.453,07	15.023,97	22.487,88	29.507,87	38.409,21	46.390,44
Acc. Receivable														
Cash		1.305,87	1.403,18	1.547,72	1.762,15	2.079,18	2.682,01	3.493,92	4.510,78	6.702,66	9.653,57	12.428,65	15.957,91	19.120,69
Payables		652,94	1.026,79	1.512,20	2.166,13	3.070,66	4.684,11	6.814,93	9.453,07	15.023,97	22.487,88	29.507,87	38.409,21	46.390,44
Accrued		2.611,75	2.481,16	2.357,10	2.239,25	2.127,29	2.020,92	1.919,88	1.823,88	1.732,69	1.646,05	1.563,75	1.485,56	1.411,28
- *NWC*		*1.305,87*	*1.077,98*	*809,38*	*477,10*	*48,11*	*(661,09)*	*(1.574,05)*	*(2.686,90)*	*(4.969,98)*	*(8.007,52)*	*(10.864,90)*	*(14.472,35)*	*(17.709,41)*
- **ΔNWC**		**1.305,87**	**(227,89)**	**(268,60)**	**(332,29)**	**(428,99)**	**(709,20)**	**(912,96)**	**(1.112,85)**	**(2.283,08)**	**(3.037,54)**	**(2.857,38)**	**(3.607,45)**	**(3.237,06)**
OCF		35.748,31	74.021,13	123.216,86	188.952,64	279.320,03	439.489,87	650.588,99	911.628,19	1.461.639,80	2.198.156,35	2.890.877,91	3.768.961,06	4.556.324,33
NCS	(4.400.000,00)	(4.334.000,00)	(2.134.495,00)	(2.102.477,58)	(2.070.940,41)	(2.039.876,31)	(2.009.278,16)	(1.979.138,99)	(1.949.451,90)	(1.920.210,12)	(4.539.376,74)	(2.235.643,04)	(2.202.108,40)	(4.338.153,54)
ΔNWC		1.305,87	(227,89)	(268,60)	(332,29)	(428,99)	(709,20)	(912,96)	(1.112,85)	(2.283,08)	(3.037,54)	(2.857,38)	(3.607,45)	(3.237,06)
Free Cash Flow	**(4.400.000,00)**	**(4.296.945,82)**	**(2.060.701,77)**	**(1.979.529,31)**	**(1.882.320,06)**	**(1.760.985,26)**	**(1.570.497,49)**	**(1.329.462,95)**	**(1.038.936,56)**	**(460.853,41)**	**(2.344.257,92)**	**652.377,49**	**1.563.245,22**	**214.933,73**
Other (Opp, Erosion, ...)														
FCF	**(4.400.000,00)**	**(4.296.945,82)**	**(2.060.701,77)**	**(1.979.529,31)**	**(1.882.320,06)**	**(1.760.985,26)**	**(1.570.497,49)**	**(1.329.462,95)**	**(1.038.936,56)**	**(460.853,41)**	**(2.344.257,92)**	**652.377,49**	**1.563.245,22**	**214.933,73**
Acc. FCF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Payback		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Figure 16. Scenario 3: business plan (part 1)

	Year 2037	Year 2038	Year 2039	Year 2040	Year 2041	Year 2042	Year 2043	Year 2044	Year 2045	Year 2046	Year 2047	Year 2048	Year 2049	Year 2050
Period	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Quantity sold (kg H2/year):	1.573.942	1.898.184	2.245.015	2.620.166	3.028.607	3.477.058	3.868.227	4.303.403	4.722.985	5.183.476	5.611.112	6.074.029	6.438.471	6.824.779
H2 price (€/kg):	4,11	3,90	3,71	3,52	3,34	3,18	3,02	2,87	2,72	2,59	2,46	2,34	2,22	2,11
Price variation:	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%	-5,0%
Revenues	6.463.766,03	7.405.576,10	8.320.767,33	9.225.638,87	10.130.578,33	11.049.098,34	11.677.515,81	12.341.674,52	12.867.738,40	13.416.225,75	13.796.911,16	14.188.398,51	14.287.717,30	14.387.731,32
- COGS	646.376,60	740.557,61	832.076,73	922.563,89	1.013.057,83	1.104.909,83	1.109.364,00	1.234.167,45	1.286.773,84	1.341.622,58	1.379.691,12	1.418.839,85	1.428.771,73	1.438.773,13
- SG&A	16.312,10	15.496,49	14.721,67	13.985,59	13.286,31	12.621,99	11.990,89	11.391,35	10.821,78	10.280,69	9.766,66	9.278,32	8.814,41	8.373,69
EBITDA	**5.801.077,33**	**6.649.521,99**	**7.473.968,93**	**8.289.089,40**	**9.104.234,19**	**9.931.566,52**	**10.556.160,92**	**11.096.115,72**	**11.570.142,78**	**12.064.322,48**	**12.407.453,38**	**12.760.280,34**	**12.850.131,16**	**12.940.584,50**
- Depreciation														
Pretax Profit	**5.801.077,33**	**6.649.521,99**	**7.473.968,93**	**8.289.089,40**	**9.104.234,19**	**9.931.566,52**	**10.556.160,92**	**11.096.115,72**	**11.570.142,78**	**12.064.322,48**	**12.407.453,38**	**12.760.280,34**	**12.850.131,16**	**12.940.584,50**
- Taxes	580.107,73	664.952,20	747.396,89	828.908,94	910.423,42	993.156,65	1.055.616,09	1.109.611,57	1.157.014,28	1.206.432,25	1.240.745,34	1.276.028,03	1.285.013,12	1.294.058,45
NOPAT	**5.220.969,60**	**5.984.569,79**	**6.726.572,03**	**7.460.180,46**	**8.193.810,77**	**8.938.409,87**	**9.500.544,83**	**9.986.504,15**	**10.413.128,50**	**10.857.890,24**	**11.166.708,05**	**11.484.252,30**	**11.565.118,05**	**11.646.526,05**
CapEx	(2.136.540,62)	(4.208.985,02)	(4.145.850,24)	(4.083.662,49)	(6.125.493,74)	(4.083.662,49)	(6.125.493,74)	(4.083.662,49)	(4.083.662,49)	(6.125.493,74)	(6.125.493,74)	(4.083.662,49)	(4.083.662,49)	(4.083.662,49)
Taxes														408.366,25
NCS	**(2.136.540,62)**	**(4.208.985,02)**	**(4.145.850,24)**	**(4.083.662,49)**	**(6.125.493,74)**	**(4.083.662,49)**	**(6.125.493,74)**	**(4.083.662,49)**	**(4.083.662,49)**	**(6.125.493,74)**	**(6.125.493,74)**	**(4.083.662,49)**	**(4.083.662,49)**	**(3.675.296,24)**
Inventory	53.126,84	60.867,75	68.389,87	75.827,17	83.265,03	90.814,51	91.180,60	101.438,42	105.762,23	110.270,35	113.399,27	116.616,97	117.433,29	118.255,33
Acc. Receivable														
Cash	21.787,03	24.856,57	27.839,95	30.790,67	33.742,82	36.740,77	36.866,46	40.949,88	42.660,68	44.446,13	45.680,80	46.951,83	47.263,11	47.577,43
Payables	53.126,84	60.867,75	68.389,87	75.827,17	83.265,03	90.814,51	91.180,60	101.438,42	105.762,23	110.270,35	113.399,27	116.616,97	117.433,29	118.255,33
Accrued	1.340,72	1.273,68	1.210,00	1.149,50	1.092,03	1.037,42	985,55	936,28	889,46	844,99	802,74	762,60	724,47	688,25
- *NWC*	*(20.446,31)*	*(23.582,89)*	*(26.629,95)*	*(29.641,17)*	*(32.650,80)*	*(35.703,35)*	*(35.880,91)*	*(40.013,60)*	*(41.771,22)*	*(43.601,15)*	*(44.878,06)*	*(46.189,23)*	*(46.538,63)*	*(46.889,18)*
- ΔNWC	**(2.736,90)**	**(3.136,58)**	**(3.047,06)**	**(3.011,22)**	**(3.009,63)**	**(3.052,55)**	**(177,56)**	**(4.132,69)**	**(1.757,61)**	**(1.829,93)**	**(1.276,92)**	**(1.311,16)**	**(349,41)**	**46.538,63**
OCF	5.220.969,60	5.984.569,79	6.726.572,03	7.460.180,46	8.193.810,77	8.938.409,87	9.500.544,83	9.986.504,15	10.413.128,50	10.857.890,24	11.166.708,05	11.484.252,30	11.565.118,05	11.646.526,05
NCS	(2.136.540,62)	(4.208.985,02)	(4.145.850,24)	(4.083.662,49)	(6.125.493,74)	(4.083.662,49)	(6.125.493,74)	(4.083.662,49)	(4.083.662,49)	(6.125.493,74)	(6.125.493,74)	(4.083.662,49)	(4.083.662,49)	(3.675.296,24)
ΔNWC	(2.736,90)	(3.136,58)	(3.047,06)	(3.011,22)	(3.009,63)	(3.052,55)	(177,56)	(4.132,69)	(1.757,61)	(1.829,93)	(1.276,92)	(1.311,16)	(349,41)	46.538,63
Free Cash Flow	**3.081.692,08**	**1.772.448,19**	**2.577.674,73**	**3.373.506,75**	**2.065.307,41**	**4.851.694,82**	**3.374.873,53**	**5.898.708,97**	**6.327.708,40**	**4.730.566,57**	**5.039.937,39**	**7.399.278,65**	**7.481.106,15**	**8.017.768,44**
Other (Opp, Erosion, ...)														
FCF	**3.081.692,08**	**1.772.448,19**	**2.577.674,73**	**3.373.506,75**	**2.065.307,41**	**4.851.694,82**	**3.374.873,53**	**5.898.708,97**	**6.327.708,40**	**4.730.566,57**	**5.039.937,39**	**7.399.278,65**	**7.481.106,15**	**8.017.768,44**

PROJECT	
	PV: (866.348,60)
	WACC 8,5%
	NPV: (5.266.348,60)
	Payback Period: 19,9 years
	IRR: 6,3%

Figure 17. Scenario 3: business plan (part 2)

v) Implementation plan

It should be noted that different types of facilities could be developed: those with green hydrogen production in situ and others with hydrogen provided by established hydrogen (Table 13). In the case of direct production, these would be installations with sufficient space to be able to install a small renewable generation plant, such as solar panels. In fact, the company already carries out projects to install this type of renewable generation in its gas stations. In this case, the installation of solar panels should be further promoted. In terms of facilities without direct production, they would be useful for the development of the network in the interior of cities, where space is more reduced. It is considered that Repsol will be able to produce the green hydrogen needed to sell it in these stations without supply problems.

Scenario 2 seems to be the best choice for the long-term investment in the construction of hydrogen filling stations. With a positive NPV and an IRR of 12%, it provides good financial performance. Scenario 2 is a good option since it is more plausible and better suited to the risks and difficulties connected with hydrogen technology. So, while retaining a long-term view and carefully observing market trends and technical improvements in the hydrogen vehicle industry, Repsol is advised to move on with investment in scenario 2. It strikes a balance between market growth and feasibility. Its projected market evolution and capacity are more attainable, aligning with the current state of hydrogen technology.

Finally, to develop these green hydrogen filling stations, the implementation plan will be similar in the three scenario cases identified and should follow these steps:

1. Identify the most suitable locations for hydrogen stations. Strategic locations must be chosen to ensure adequate coverage of the country and meet the needs of identified customers. The focus should be on high traffic area. Depending on the phase, the locations of each station will be set differently.

   During the first ten years, hydrogen filling stations will be located in the biggest cities in Spain: stating by Madrid and Barcelona, and then following its installation in Valencia, Sevilla, Zaragoza and Malaga. Once these cities are well provided, the network could be expanded. By 2050, there should be located at least a hydrogen station every 50km in the most populated areas.

2. Establish partnerships with suppliers of hydrogen station technology. Repsol could work with Clantech as a supplier, as it has already been proposed.

3. Design the construction plan for the hydrogen stations. Designs and plans must be developed for the construction of hydrogen stations at selected locations. In

addition, Repsol must acquire the necessary equipment to build and operate hydrogen stations.

4. The necessary permits must be obtained from the competent authorities to build and operate the hydrogen stations.
5. Recruit and train the necessary personnel to operate the stations.
6. Establish agreements with potential partners that have already been identified.
7. Implement the awareness and marketing campaigns proposed to publicize the product.

Another aspect to be taken into account in the implementation of hydrogen generators at refueling stations is the cannibalization of hydrogen cars over other transportation methods, such as electric or combustion cars. Customers who start using this method of transport will no longer consume the other energy sources, causing loss of sales. The refining and petroleum products businesses, which are currently the most profitable, may be negatively affected. To solve this problem, Repsol is also focusing its research on low-emission fuels. Leveraging their expertise in refinery technology, they can focus on the production and sale of low-emission fuels, such as sustainable aviation fuels and biofuels. These new types of products will allow the combustion car to stay on the market longer, which will benefit the company. Despite these cleaner and renewable proposals, there will come a time when consumers will adopt hydrogen and other electric vehicles, affecting their sale at the pump. At some point, Repsol might make a strategic move and change traditional pump points into hydrogen filling stations. Faced with this situation, Repsol will have to consider the most radical transformation of its gas stations, converting them into mixed-energy service stations. Service stations will have to provide all possible sources of energy for mobility: a combination of electric vehicle refueling services and gas, hydrogen and biofuels supply. As indicated in previous sections, Repsol service stations also have a series of parallel services, which allow them to create a comfortable environment and enhance the customer experience. These services are paramount as they allow them to improve their profitability and add value to their service. In future mixed-energy service stations, they will have to maintain these proposals, which will encourage all types of customers to go to their stations and they will not lose market share.

To summarize, Repsol must adjust its service stations to the changing energy environment by offering a variety of energy sources for mobility, emphasizing low-emission fuels and maintaining high-quality services. Repsol will be able to maintain its market leadership and fulfill changing client expectations with this method.

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