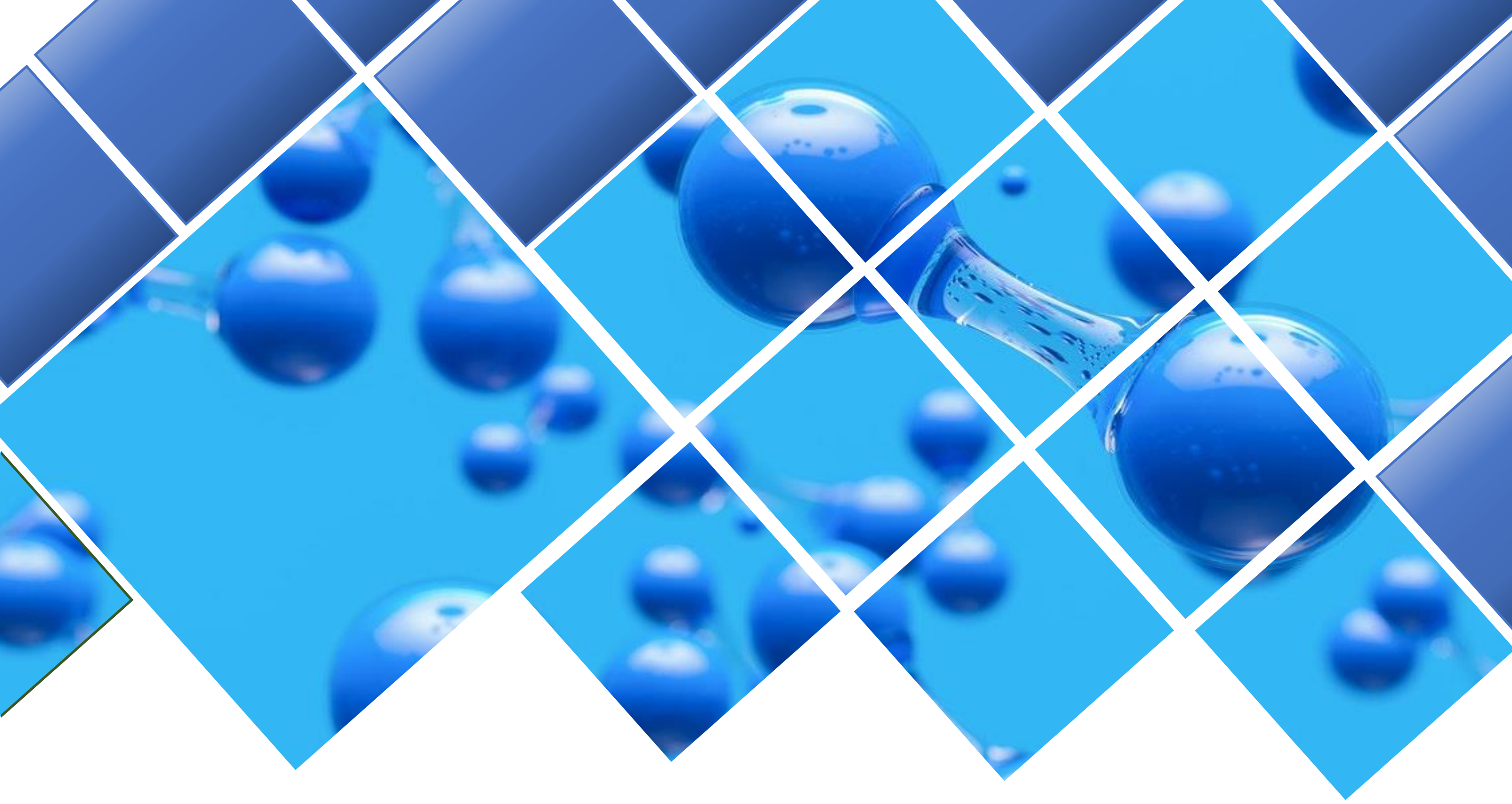

HASPOT SOLUTIONS: GREEN HYDROGEN TO DECARBONISE INDUSTRIES

H2ASPOT

Tutor - Jesús García Martín

Eduardo González Redondo

Jorge Bayona Ramón y Cajal

Juan Geisser Jorge

Manuel Queiro Blanco

Miguel Alonso de la Plaza

Table of contents

1. Introduction

In a world where the medium global temperature is raising without limits, droughts and acid rain are commonplace, and thousands of species are in danger of extinction, drastic changes are necessary. Between those changes the one that has brought more attention is green hydrogen, and that is based in his many applications. It can replace natural gas in nearly all his uses, is going to be an important fuel in the mid-term and is positioning as a future energy vector.

This broad range of options and the huge promotion of different governments and institutions have caused strong interest among large companies. Most of them are focusing their efforts on the production and distribution of green hydrogen that will initially be meant for the chemical and oil industries. This strategy follows the idea of removing natural gas from a lot of processes, especially ammonia production for fertilisers.

But since the beginning of our project, we have been thinking about other uses, other necessities that the market is not considering nowadays or maybe in a small portion. Therefore, **HASPOT SOLUTIONS** was born from the idea of making hydrogen a decarbonization solution for industries whose processes cannot stop emitting carbon dioxide, to help them achieve zero net emissions.

This need of cutting greenhouse gas emissions can be altruistic in many parts of the world, but in Europe is driven by the Emission Trading System (ETS), which the European Commission has developed. Many industries are suffering big costs due to this system and **HASPOT SOLUTIONS** has set its primary goal to reduce their emissions and give carbon dioxide a second life.

Therefore, we will be able to return the competitive advantage many industries are losing in the recent years, stopping them from leaving our continent on what is called nowadays the "carbon leakage". But how are we going to be capable of doing such a thing?

Our idea is to capture the carbon dioxide these companies emit and in combination with the green hydrogen, obtain synthetic natural gas. This solution generates a circular economy plan, eliminating the distribution costs and emissions, that helps the plants to become self-sustaining. Also, in the actual energy context, the chance of reducing markets' volatility is achieved.

So, without more hesitation, we are here to present **HASPOT SOLUTIONS**, a company that aims to decarbonise the economy using green hydrogen.

2. Green hydrogen

2.1 Fundamentals of green hydrogen production

Nowadays, there are several options to produce hydrogen. It can be obtained from natural gas, coal, or electrolysis. We will focus on technologies with less environmental impact, being the electrolysis the one whit less GHG footprint. To produce green hydrogen, it is necessary to water and electricity from renewable energy (wind or solar), obtaining as a products hydrogen and oxygen, as it is shown in Figure 1.

The electrolysis of the water molecule takes place on the electrolyser, being some different types of technologies. The existing ones are:

- PEM (Protonic Electrolyser Membrane)
- Alkaline electrolyser
- SOE (Solid Oxide Electrolysis)

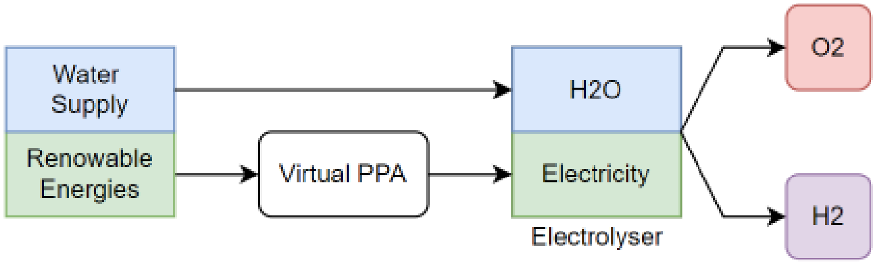

Figure 1. Scheme of the production of green hydrogen.

Analysing the hydrogen projects, the Alkaline and PEM technologies are the most mature and used technologies in the world. Figure 2 shows a scheme of the fundamentals of both technologies

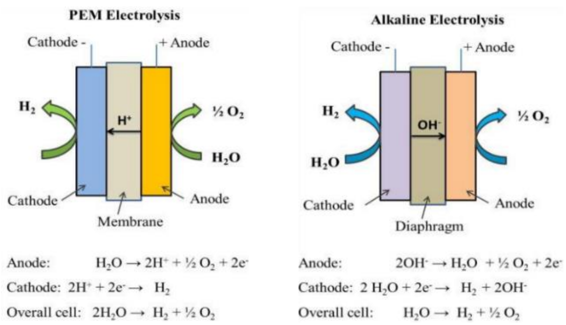

Figure 2. Fundamentals of PEM and Alkaline Electrolysis [1].

2.2 Technical Aspects

While the alkaline electrolyser highlights are the **energy efficiency, the higher life, the lesfewerpital costs**, the PEM electrolyser high highlightmakes forr it with **higher load flexibility, remote monitoring a,nd a lower carbon footprintimpact**.

Although both technologies could work well on an industrial application, the PEM technology is more linked to the goals of our project, as it will reduce even more the carbon footprint of our clients, reducing the costs to pay to the ETS. Table 1 resumes the main differences between both technologies.

Table 1. Main differences between PEM and Alkaline technologies [2].

	Proton Exchange Membrane (PEM)	Alkaline (ALK)
Technology Maturity	Under commercialization	Commercialized
Electrical efficiency (stack)	47-66 kWh/Kg H2	47-66 kWh/Kg H2
Electrical efficiency (system)	50-83 kWh/Kg H2	50-78 kWh/Kg H2
Lifetime (stack)	50 000-80 000 hours	60 000 hours
Stack unit size	1 MW	1 MW
Cold start (to nominal load)	< 20 minutes	< 50 minutes
Capital costs (stack) minimum 1 MW	$ 400/kW	$ 270/kW
Capital Costs (system) minimum 10 MW	700-1400 $/kW	$ 500-1 000/kW

2.3 Commercial development of the green hydrogen plants

The electrolyser capacity installation has grown more than forty-eight times to reach 288 MW in 2021 and is projected to grow at a CAGR (Compound Annual Growth Rate) of 37% between 2022 and 2026 [2].

Hydrogen M&A, venture finance deals, and partnerships have been increasing comparatively as part of increasing investments and opening the marInt. On this scenario a significant number of key electrolyser manufacturers are appearing over the world (see map below). In Europe, those key electrolyser manufacturers that stand out could be Nel hydrogen (Norwey), Siemens AG (Germany), Kumatec (Germany), ITM Power (UK) or H2B2 (Spain).

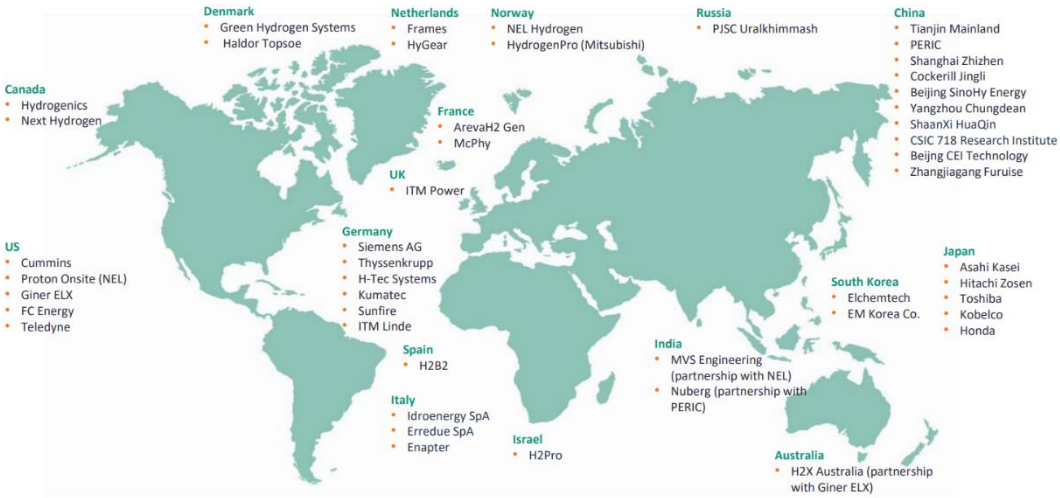

Figure 3. Main manufacturers of electrolysers in the world [2].

2.4 Technology licensors

There are a lot of Alkaline and PEM electrolyser licensors, that are taking position on the market, as it is shown in Figure 4. In case of PEM technology, both “**Plug Power**” and “**Nel Hydrogen**” are signing a lot of projects all over Europe, with 3 and 2GW manufacturing expansion plan by 2025, respectively [2].

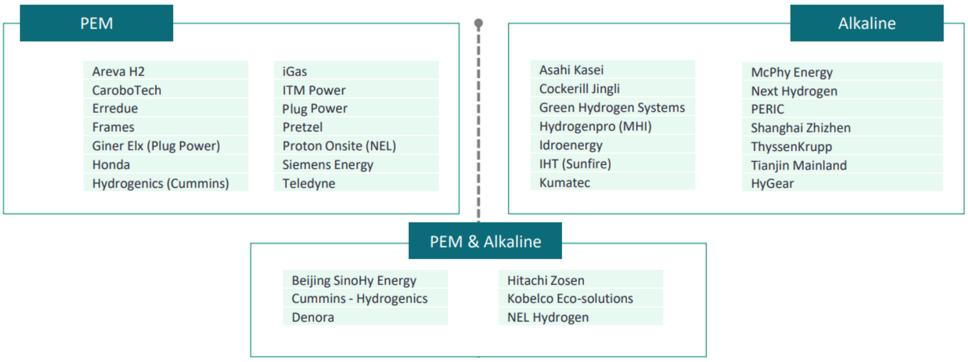

Figure 4. Main licensors of PEM and Alkaline technologies [2].

2.5 European Regulation

Europe is the leading region having specific funds for hydrogen development. There are at least 10 countries in Europe that have developed a national plan or Strategy to accelerate hydrogen development and transition into low carbon economies.

There are also the **ETS** to help developing low carbon industrial market solutions and low-carbon technologies to help decarbonize Europe in the transition pathway and the **EFSD** (European Fund of Sustainable Development) to help meeting UN 2030 agenda and boost economic growth for Europe-Africa regions [2].

3 Carbon capture technology (CCUS)

Carbon Capture Use & Storage (from now on, CCUS) stands for a bunch of technologies whose aim is to capture carbon dioxide from large emission points, known as heavy industry, such as cement, steel or chemicals.

The main objective of CCUS is to value waste, one of the principles of the circular economy. As a feedstock, carbon dioxide can be implemented in the production of synthetic fuels, chemicals, and other materials.

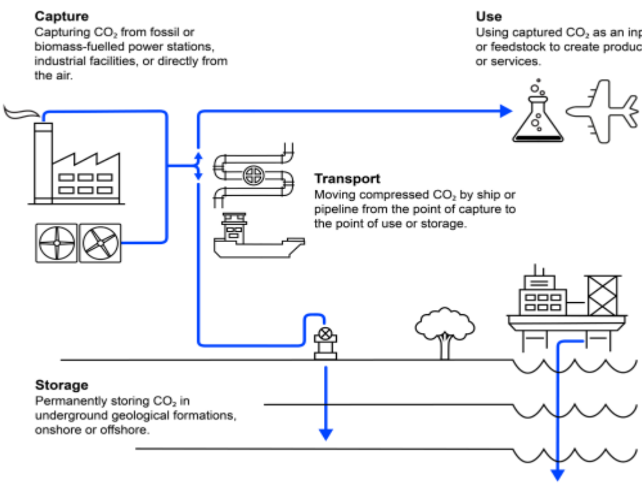

Figure 5. Schematic of CCUS [3]

In this chapter, the fundamentals of carbon capture, examples of commercial CCUS plants and technology licensors will be described. In addition, a deep report of how the European Emissions Trading System works and how the European Commission is developing tools to progressively reduce carbon dioxide emissions to reach net zero emissions are included.

3.1 Fundamentals of CCUS systems

In this section, commercial technologies to capture carbon dioxide from a gaseous stream in an industrial plant are presented.

- **Chemical Absorption** is an established technology at commercial scale based on the principle of chemical reaction. A chemical solvent, such as amine-based solvents, reacts with CO_2 and separates it from the gaseous stream. After that, the resulting stream can be heated to extract the CO_2 from the solvent and regenerate it to use it in a cycle. Figure 6 shows a schematic diagram of the chemical absorption process [4].

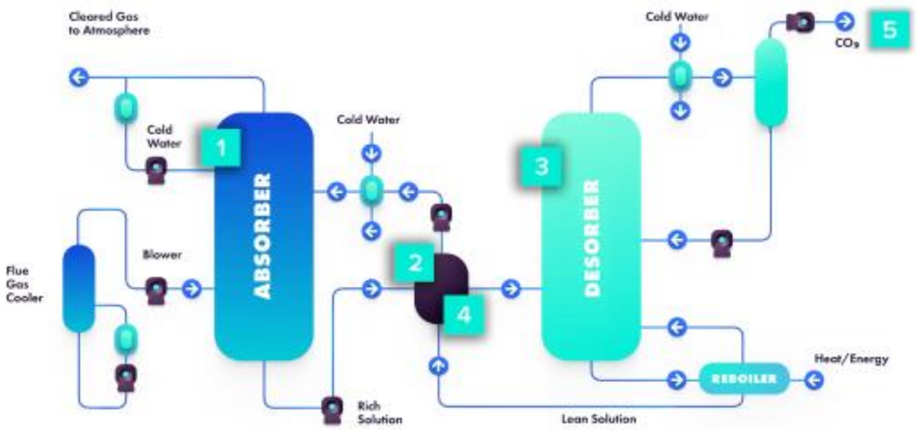

Figure 6. Schematic diagram of chemical absorption [4]

- **Physical Separation** are a bunch of technologies that are based in the separation processes of adsorption, physical absorption, or cryogenic separation. In the adsorption process, the carbon dioxide is caught by a solid surface of a material as alumina, activated carbon or zeolites, and then is released by increasing pressure (*Pressure Swing Adsorption* process, *PSA*) or temperature (*Temperature Swing Adsorption, TSA*). Physical absorption stands for the retention of carbon dioxide by a liquid solvent without chemical reaction. Both technologies are well-established for large-scale operations.
- **Oxy-fuel separation** is based on the combustion of a fuel with nearly pure oxygen, so that the flue gas stream is composed of carbon dioxide and water, making the separation process more accessible.
- **Membrane separation** is based on the selective retention of the carbon dioxide in the surface of a polymer, which lets the CO_2 pass through it and be separated from the gaseous mixture. This technology is not as well established as the ones presented before but is also developed at commercial scale.

3.2 Commercial development of CCUS plants

In 2020 [3], there were 21 CCUS plants around the world. The total capacity of those installations to capture carbon dioxide is 40 Mt CO_2. Mostly, the source of the captured carbon dioxide is from the upgrading of raw natural gas, which then is used for the petrochemical process of Enhanced Oil Recovery, *EOR.* Their capture capacity ranges from 0,5 Mt/year to 7 Mt/year and they are mostly based in North America, United States and Canada.

The reason why the United States concentrates most installations is because of the existence of an extensive carbon dioxide pipeline network and its demand for EOR, as well as Public Funds to support the development of the CCUS.

In these plants, the cost of capture is relatively low, around 15 USD per tonne of carbon dioxide, because of the high concentrated streams in the production of blue hydrogen, natural gas processing or chemical industry. In Figure 7, the evolution of the number of CCUS facilities and its carbon source is shown.

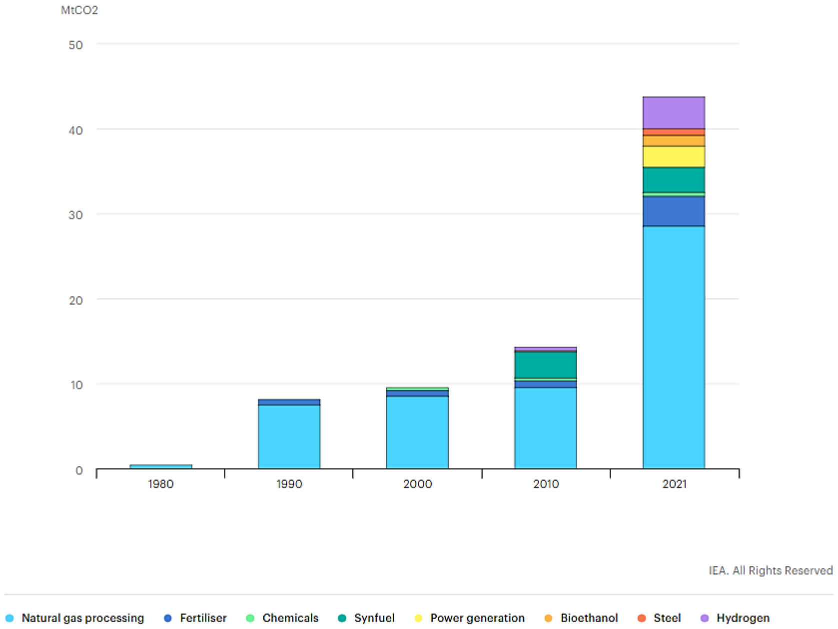

Figure 7. Number of Global CCUS plants by source and year [5]

The economy of the CCUS introduces the concept of *Levelized Cost of CCUS (LC CCUS)* , which indicates the needed investment to capture carbon dioxide from selected sources. Some examples are the capture from the production of Ammonia or natural gas processing, with a high concentrated stream and a *LC CCUS* from 25-35 and 15-25 USD/t. [6].

The installations presented before stand for operating plants but in the year 2020, there were 30 new installation projects in different countries and levels of development. The vast majority are in the US and Europe, but also in Australia, China and the Middle East.

The *International Energy Agency* in its publication *CCUS in Clean Energy Transition* [3] develops the idea of CCUS hubs, industrial centres where transport and storage of carbon dioxide can expand the potential of CCUS installations. In the present report, before this section it is shown the actual and future scenario of some examples of heavy industry such as steel, cement and chemical industry. With the dawn of the green hydrogen value chain, the integration with CCUS hubs opens the possibilities to develop synthetic fuels and chemicals (synthetic methane, methanol, etc.). The principal benefit of developing CCUS hubs is the possibility to share carbon dioxide related infrastructure. This fact can reduce costs and improve efficiency.

3.3 Technology licensors

The main commercial technologies are based on the operation of absorption. The developments achieved in the field came from the natural gas upgrading. Some examples of well-known technologies are as follow:

- In the field of **chemical absorption**, some examples are the *ADIP-X* technology from Shell, *Benfield* from Honeywell UOP and GAS/SPEC from INEOS. But the dawn of a company, which has Chevron as a shareholder, is Carbon Clean. This company is developing specific solutions for the decarbonization of heavy industry such as Cement and Steel, partnering with companies like CEMEX, LafargeHolcim or Tata Industry. Carbon Clean is developing pilot scale projects at facilities located in Spain (LafargeHolcim) and India (Tata Steel).

  Carbon Clean technologies are the *CDRMax* process and *CycloneCC* , whose development is reducing the costs of carbon capture.

- In the same way as chemical absorption, the **physical absorption** is a well-established technology, with proven licensors like *Selexol* from Dow Chemical/UOP and *Rectisol* from Air Liquide.
- Other proven technologies for **adsorption** are *M3100 Xebec Rotary-valve* de Xebec, *UOP MOLSIV* de UOP. In the case of **membrane separation** UOP developed the *Separex* membrane**.**

4 Synthetic natural gas

The development of the green hydrogen value chain opens a new horizon for the decarbonization of all sectors: industry, power generation, transport, buildings, and home residences, etc.

But there are some points that should be noticed about the hydrogen, that are related with its chemical characteristics. Some of those points are as follow:

- The **Heating Value** of hydrogen is higher than natural gas' in terms of energy per unit of mass. But the thing changes when the comparison is made in terms of energy per unit of volume, and this is because of the low density of the molecule. This chemical characteristic is a remarkable limiting to implement green hydrogen in industrial heat, because the pieces of equipment are designed for a certain volumetric flow. The same volumetric flow of natural gas and hydrogen does not provide the same amount of energy. Also, it is still under investigation the percentage of hydrogen that can be injected in the natural gas grid when all the green hydrogen value chain is deployed.
- As it was mentioned before, the low density of hydrogen also is a limitant for its **transport**. A huge amount of energy is needed to compress the hydrogen. Also, other approaches as *Liquid Organic Hydrogen Carriers* as Benzene, Toluene or the production of green Ammonia can solve this problem.

The limitations shown for hydrogen can be solved with the deployment of hydrogen-derivatives like synthetic natural gas, synthetic fuels, and methanol for specific applications.

In addition, Europe is facing a huge energy crisis with the Russia conflict in Ukraine. It shows the energy dependence of natural gas and other hydrocarbons. The solution to reduce Europe imports goes by supporting the renewable energy generation, energy vectors as green hydrogen, biomethane and the deployment of a consistent infrastructure of CCUS so that the green hydrogen produced can be used for synthetic fuels like synthetic methane and methanol for specific applications.

The basis of synthetic natural gas is to **help the decarbonization of heavy industry**, **reduce energy dependence** and **produce a synthetic fuel** that can be implemented in all sectors **to reduce emissions.**

4.1 Fundamentals of Synthetic Natural Gas Production

Synthetic Natural Gas is produced by the chemical reaction of Hydrogen and Carbon Dioxide in a well-known process called the Sabatier Reaction, as it is shown in Figure 8. The reaction is supported by a nickel catalyst to improve performance.

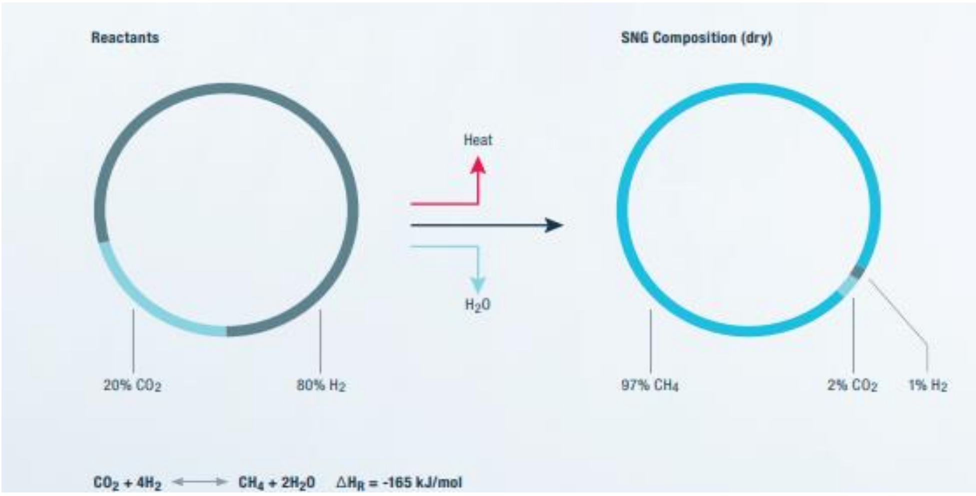

Figure 8. Chemical process to obtain SNG [7]

The Temperature and Pressure conditions to maximise the production of methane, as the reaction is exothermic, are low temperature values and high-pressure values. In addition, the reactor operates at isothermal conditions, so that the produced heat by the reaction can be recovered and used for heating applications in the industrial facility.

4.2 Commercial Development of SNG Plants

Synthetic natural gas value chain is still under development. The only commercial facility is in Werlte, Germany, where Audi partnering with MAN Energy Solutions developed a 1.000 t/yr synthetic natural gas installation, about 1,74 MW output of SNG. In Figure 9 it is shown a schematic diagram of the whole process.

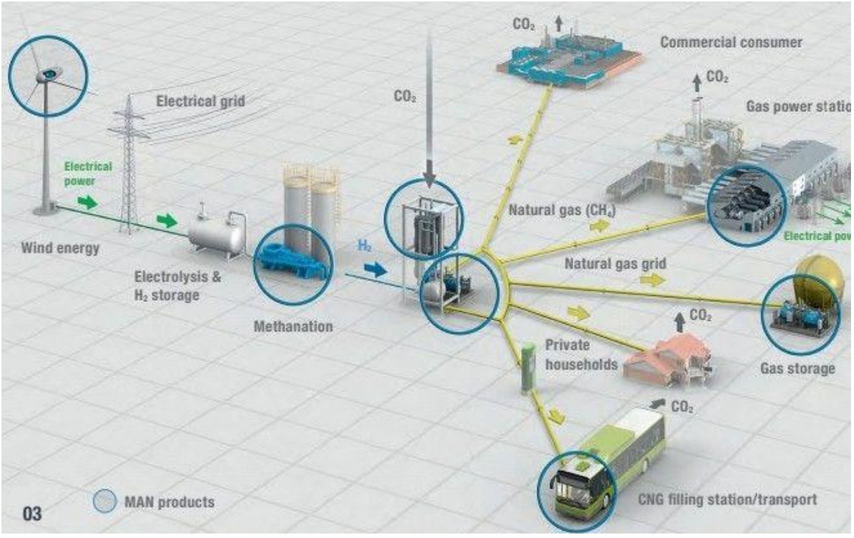

Figure 9. Schematic diagram of the whole SNG process [7]

As part of the development of pilot scale projects, the Store&Go project at Falkenhagen, Germany, is one of the most important achievements in this field. The Store&Go project had the participation of some remarkable companies like Uniper and ThyssenKrupp. In the web page of the project, there is access to some open-source information on techno-economical aspects of the methanation process [8]. The project runned for 1.186 h and produced 192 MWh of Synthetic Natural Gas, that were injected in the natural gas grid. In Figure 10, a layout of the Falkenhagen facility is shown.

Figure 10. Layout of the Falkenhagen plant [8]

4.3 Technology Licensors

The principal technology licensor is MAN Energy Solutions, with their DWE Reactors for the methanation process. This technology can be used for different inlet streams as it is shown in Figure 11.

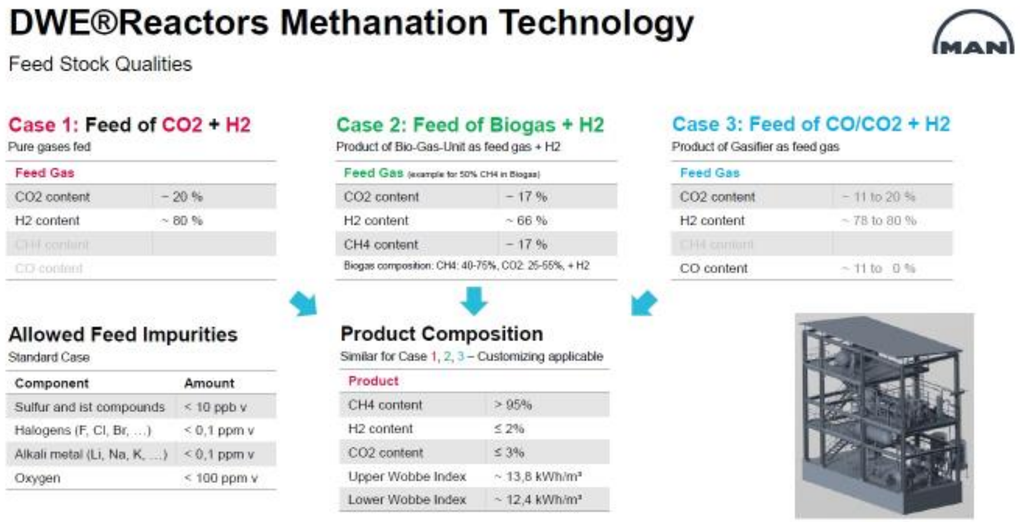

Figure 11. Applications DWE Methanation Technology of MAN Energy Solutions [7].

5. Industries to decarbonise

Between the industries that emit carbon dioxide nowadays there are some of them that can be our target as clients based in different aspects. We are looking for companies whose production plants are in the ETS system (that we will explain in the next chapter), and, production plants that use natural gas which can be substitute for the synthetic one.

Moreover, there are other considerations we are considering such as oxygen demand or future hydrogen consumption. This will ensure all the possible outputs are supplies to clients, increasing the value of our solution. And if this is not an option, another aspect we are going to analyse is the location of the plants, so that we have a strategic point from which distribute the products in the mid-term.

The next chart is based on ETS information, all companies inside the system must notify to the European Commission their tons of carbon dioxide emitted every year. We have included the aviation, aluminium production, and the refining oil industry to provide a good comparison between them.

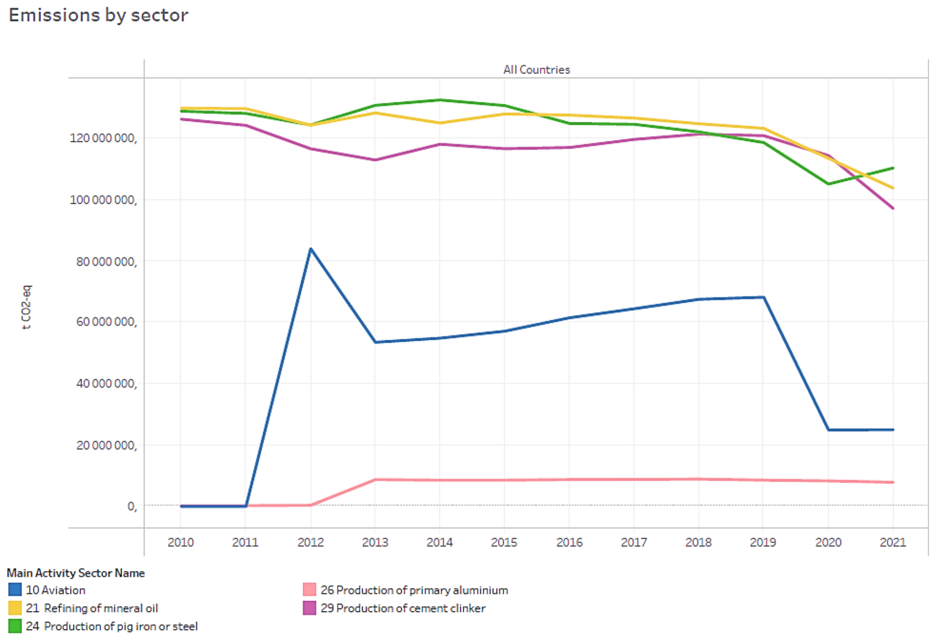

Figure 12. Comparison between carbon dioxide emitters Source European Comission

The industries we have consider based in the assumptions mentioned are the followed, and will be explain in this chapter:

- **Production of pig iron or steel:** As shown in the next chart is one of the industries that have the biggest emissions and its chemical demands fit perfectly with our outputs.
- **Production of cement clinker** is also one of the most polluted sectors, its technically more difficult to generate value for them, but we will see in the next sections.
- **Production of chemicals:** Even thought is not among the most polluted industries in Europe, certain companies in Spain are inside the system and its processes give our solution a great technical outcome.
- **Cogeneration plants** is not represented in the graphic because is mixed with all the combustion of fuels (the main emission source), but its use of natural gas and its capacity to combine it with hydrogen makes it a great target for us.

5.1 Steel industry

The **steel industry** is the most convenient one in terms of efficiency. As a commodity it is the most recycled material on the planet. This fact makes steel a sustainable material and allows the industry to implement some processes to set a circular economy.

On the other side, the industry is responsible for around 8-9% of the CO_2 global emissions, which is directly related with the huge investment that they will have to do to achieve the requests of the decarbonization agenda [9]

5.1.1 Actual Technology

Nowadays, the most widespread method to produce steel is the Blast Furnace (BF), as it is a mature technology, processes like the carbon capture will help the industry to reduce the CO_2 emissions. Other way would be the implementation of the Electric Arc Furnace (EAF), to eliminate the coke from the process, in combination with the Direct Reduction of Iron (DRI), a process which uses gases such as natural gas or hydrogen to produce steel.

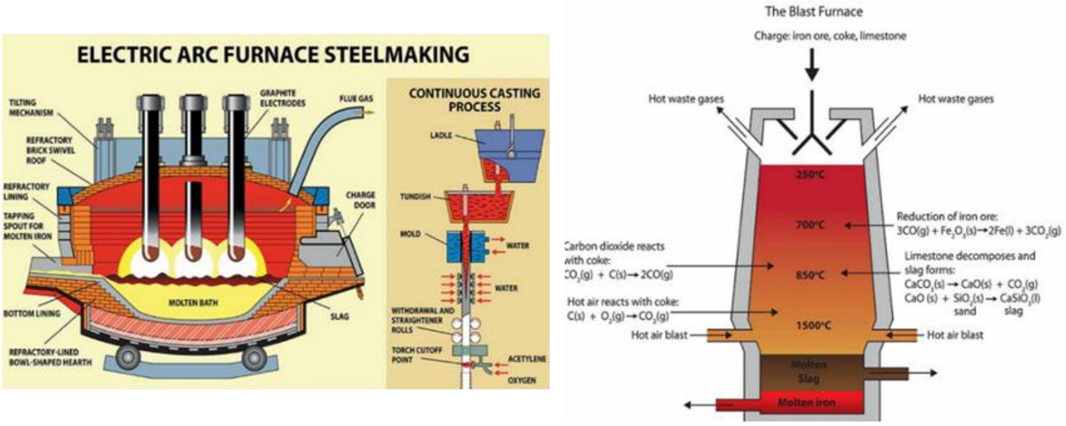

Figure 13. EAF and BF schemes

Almost all European steel producers are currently developing decarbonization strategies and running pilot plants to assess different production technologies, and the big companies are turning their old blast furnace into EAF where DRI process could be apply.

The ***transition from BF into EAF*** will be needed to reduce the emissions of the steel industry, and a strategy to reach it. Due to the actual procedures, the steps would be [10]:

- Combine the carbon capture technology with blast furnaces, could be a short-term solution to give a second live to the CO_2 emissions, reducing the amount of money to paid to the ETS.
- Combine the carbon capture (from the BF), with green H_2 produced near the steel industry (to reduce the transport investment) to get a CH_4 final product, which we could reuse on the same industry (or sell to other ones)
- Set an investment to replace the BF for the EAF technology, reducing even more the total emission of the process. Would be possible to use the green H_2 to implement DRI processes, improving the quality of the steel.

	CO_2 reduction			Full decarbonization possible		
	Blast furnace efficiency (BOF)	Biomass reductants	Carbon capture and usage	Electric arc furnace (EAF)	DRI plus EAF using natural gas	DRI plus EAF using H_2
Strategy	Make efficiency improvements to optimize BF/BOF operations	Use biomass as an alternative reductant or fuel	Capture fossil fuels and emissions and create new products	Maximize secondary flows and recycling by melting more scrap in EAF	Increase usage of DRI in the EAF	Replace fossil fuels in DRI process with renewable energy or H_2
Examples	Optimized BOF inputs (DRI, scrap), increased fuel injection in BF (e.g., hydrogen, PCI)	Tecnored process	Bioethanol production from CO_2 emissions	EAF – usage to melt scrap	Current DRI plus EAF plants using natural gas (NG)	MIDREX DRI process running on H_2 HYL DRI process running on H_2
Current outlook	Technology readily available at competitive cost	Process possible in South America and Russia, due to biomass availability	Not available on an industrial scale	Technology readily available at competitive cost	Technology readily available	Technology available at high cost

Figure 14. Decarbonization strategies from steel producers

At this point the future necessities of the steel industry on the short and long-term, could be [10]:

1. **Carbon capture Use and Storage (CCUS)** -> to reduce the CO_2 emissions, to pay less money to the ETS and to have the opportunity to reuse the CO_2 for other products.

2. **Low costs of distribution** -> setting the electrolyser near the factory, the supply will be assured reducing the costs derive from transportation.
3. **Supply of green H_2** -> on the short-term the supply will be assured by our plant. On the long-term we could sell the plant to the steel industry saving costs of the process.
4. **Saving costs** -> less money to pay to the ETS (reducing emissions), and giving a second live to the CO_2, the industry will increase the range of profits and will turn into a sustainable steel supplier.

5.1.2 Carbon Intensity and Age of Steel Plants by Region

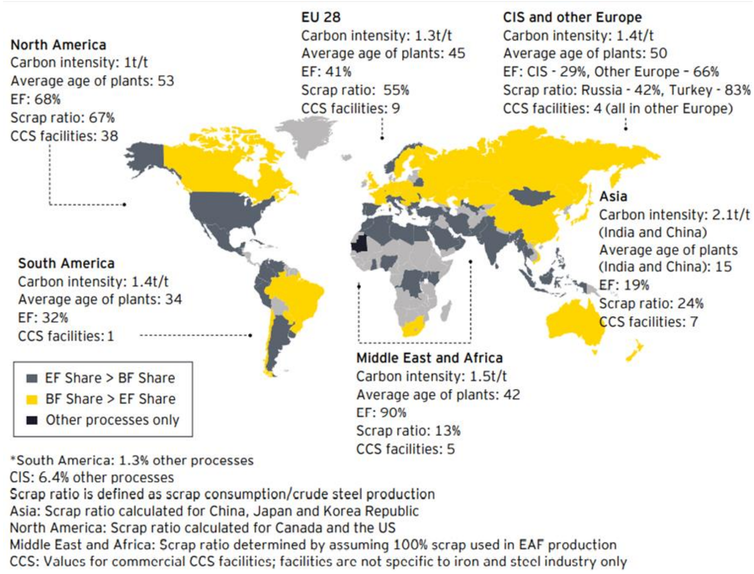

Figure 15. Carbon intensity and age of steel plants by region [9]

Analysing the EY study [9] and asking experts on the field as ***Hasan Akbulut***, in Europe there are multiple reasons to invest on CCUS technology (for BF technology) or in DRI processes (in case of EAF), as for example:

- 41% of the furnaces are already Electrics (EAF)
- Scrap ratio just lower than North America or Turkey
- 9 commercial CCUS facilities, just lower than North America
- The average age of plants is 45, so it is a perfect moment for the BF to EAF transition

Europe (like EEUU), as a Non-BRIC (***BRIC: Brazil, Russia, India and China***) region are better positioned to invest in sustainable steelmaking (map above). The increased costs of some commodities as carbon or natural gas, reduced the global competitiveness of Europe, but at the same time sustainability initiatives (***HIsarna, HYBRIT***) have appeared to lead the processes to lower production costs. Besides, there is a strong policy framework for green H_2 deployment, so the European funds will be insured till 2050 for hydrogen projects which will try to reduce carbon footprint [9]

For these reasons, Europe could be a perfect region to set new H_2 projects allowing the steel industry to reduce the total CO_2 emissions, saving costs and getting the transition (from BF to EAF) that they will need to perform the decarbonization agenda.

5.2 Cement industry

The cement is a commodity used in the infrastructure sector and the second most consumed product in the world after water, as accounts for between 4 – 8% of global man-made carbon emissions and the largest emitter of CO_2 in the built environment.

According to the Paris agreement, to achieve the target of 1.5ºC, the carbon emissions from cement production need to fall by at least 16% by 2030. Action is underway and incentives to accelerate this action are increasing. At COP26 a new Industrial Deep Decarbonisation Initiative (IDDI) was launched that seeks to create new markets for low carbon concrete and steel to help decarbonise heavy industry. [11]

The IDDI will disclose the embodied carbon of major public construction projects by 2025, achieve net zero in major public construction steel and concrete by 2050, and set an emissions reduction target for 2030.

For many cement companies, a key question is what to do with the captured CO_2. our idea is to transform the CO_2 captured into green hydrogen, and then use it again in the plant or sell it to other industries that need it as fuel. A cement plant's flue gas is also ideal for carbon capture given the high concentration of CO_2.

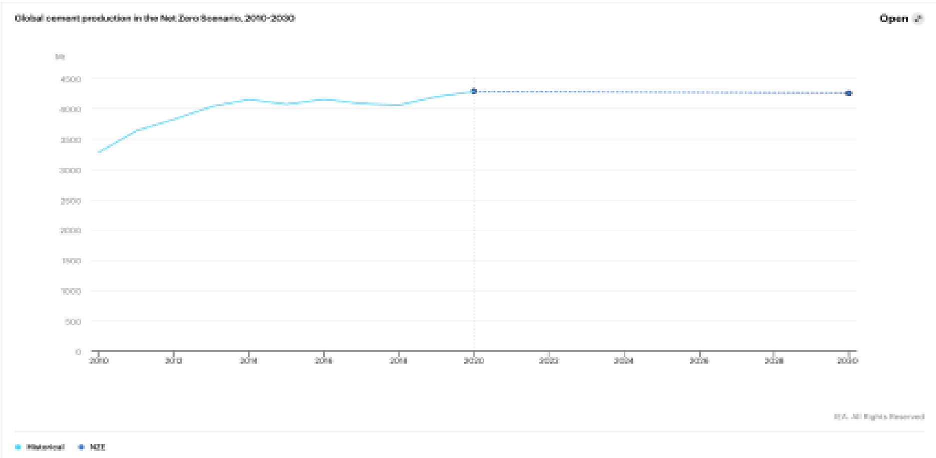

Figure 16. Global cement production in the Net Zero Scenario, 2010-2030. [11]

The Global Cement and Concrete Association aims for carbon neutrality by 2050, the direct CO_2 intensity of cement production increased 1.8% per year during 2015-2020. In contrast, 3% annual declines to 2030 are necessary to get on track with the Net Zero Emissions by 2050 Scenario. Sharper focus is needed in two key areas: reducing the clinker-to-cement ratio and deploying innovative technologies. [11]

Reducing CO_2 emissions while producing enough cement to meet demand will be challenging, especially since demand growth is expected to resume as the slowdown in Chinese activity is offset by expansion in other markets. Thermal energy intensity must fall considerably by 2030 and bioenergy use must expand for Net Zero Emissions by 2050 alignment. [11]

5.3 Chemical subsector

The chemical subsector is the third-largest industrial source of CO_2 emissions. Ammonia production accounts for 30% of total direct CO_2 emissions from the subsector, followed by high-value chemicals, which are olefins and aromatics (16%) and methanol (13%).

The higher amount of CO_2 Emissions comes from the production of urea and methanol, emitting around 130 Mt CO2, so using the CCUS in fertilizers facilities would have a direct application in both of the scenarios (RTS and CTS). The urea demand by 2060 would remain slightly higher than nowadays.

In the CTS background we can differentiate between two kinds of emissions streams of CO_2. The concentrated CO_2 emissions stream which is 45% of the CCUS capacity and the dilute stream which equate to 55% of the CCUS capacity. Concentrated CO_2 streams are targeted for early CCUS deployment, accounting for around 60% of cumulative chemical emissions captured before 2030.

In methanol and ammonia production the CO_2 separation is an inherent part of the process which means that these capture options are less costly and therefore more attractive, even though it limits the scope of the investment.

It is of major importance since chemical production is projected to rise at least 40% in the CTS by 2060, this rise would be lower than in the RTS because of plastic recycling.

It is expected that CCUS will take a critical role in the decarbonisation projection by 2060, A cumulative 15 Gt CO_2 are captured for use and storage in the CTS, it would mean the higher decarbonisation measure individually extracting around the 38% carbon captured in total. CCUS has a huge decarbonisation potential if it would be related to the coal-chemical plants, particularly in China.

5.3.1 Prospects for hydrogen in industry

Today, hydrogen is used in industry, primarily for ammonia production and refining, with almost all of this produced from natural gas and, to a lesser extent, coal. The potential for hydrogen to support the decarbonisation of industry and other sectors has recently gained increased attention.

There are two main routes for clean hydrogen production: hydrogen production from fossil fuels in combination with CCUS or from renewable electricity. The former is expected to be the least-cost low-carbon option in the medium term, especially in regions where inexpensive natural gas is readily available. Coal-based hydrogen production may also remain cost-competitive in countries such as China for some time, whereas electrolytic hydrogen will be most competitive in locations with favourable conditions for renewables and sufficient space. These locational considerations could suggest a need for the construction of significant transport infrastructure for hydrogen or other carriers such as ammonia, or the relocation of industrial production sites.

5.4 Cogeneration Plants

Also known as combined heat and power (CHP), the term cogeneration describes the simultaneous generation of electrical energy and usable heat from a single primary energy source like natural gas, oil, or other fuels. Several cogeneration system definitions exist, but overall, the term applies when a single fuel source produces two or more forms of energy. Cogeneration is also sometimes called recycled energy.

When a power plant generates electricity, it produces heat, if the plant releases that heat into the environment as an exhaust it represents a huge waste of energy. Most of that heat can be captured and used for other purposes. When that repurposing of heat occurs, the power plant is working as a cogeneration system.

The cogeneration process can increase overall energy efficiency, with typical systems ranging from 65 to 90 percent. Businesses that use cogeneration can lower operational costs and boost their self-sufficiency while reducing greenhouse gas emissions and pollutants. At the most basic level, a typical cogeneration plant has an electricity generator and a heat-recovery system. Here are some basic elements of a CHP setup:

- **Prime movers:** Converts fuel into heat and electrical energy that can be used to generate mechanical energy. Examples of prime movers include gas turbines and reciprocating engines.
- **Electrical generator:** Converts mechanical energy into electrical energy.
- **Heat recovery system:** Captures heat from the prime mover.
- **Heat exchanger:** Makes sure that the captured heat is put to use.

A variety of fuels can be used in cogeneration plants including natural gas, diesel, gasoline, coal, biofuels… The use of biofuels in cogeneration typically includes renewable resources, like waste gases from landfills and solid waste from agriculture. There are different types of plants:

- **Topping cycle plants:** A topping cycle system starts with electricity generation.
- **Bottoming cycle plants:** Generating heat is first — waste heat produces steam that is then used to generate electricity.

Bottoming cycle plants are found in industries that use very high-temperature furnaces. They're less common than topping cycle plants in part because it's easier to sell excess electricity.

In conclusion, a cogeneration plant is a perfect client to supply synthetic natural gas and green hydrogen, which can little by little substitute part of the gas reducing carbon dioxide emissions. So, from the 100% of natural gas consume previously, 90% would now be synthetic natural gas produced from CO_2 and 10% will be green hydrogen (until 15-20%) this limits guarantee that the turbine of gas used is appropriate and the combustion parameters of the fuel do not change the efficiency of the plant.

6 European Mechanisms to Achieve Net Zero Emissions

6.1 European Emissions Trading System (ETS)

As mentioned in chapter 5, the industries that are our target are those that emitted the most carbon dioxide, because they will be inside the ETS. This means that we can help our clients saving them money in allowances, as much as the tons capture. So, let's explain what the ETS is.

The European Union Emissions Trading System (EU ETS) it's the first large greenhouse gas emissions trading scheme in the world, it was launched in 2005 and it operates in all EU countries plus Iceland, Liechtenstein, and Norway (EEA-EFTA states). It limits emissions from around

10.000 installations in the power sector and manufacturing industry, as well as airlines operating between these countries, and it covers around 40% of the EU's greenhouse gas emissions.

The EU ETS Works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by the installations covered by the system. Within the cap, installations buy or receive emissions allowances, which they can trade with one another as needed.

The cap is reduced gradually every year so that total emissions fall, but the industries where "carbon leakage" is a risk, the cap is lower in every phase of the scheme. For the cap defined the company receive free allowances, but since the third phase (2013-2020) electricity generators must obtain all their permits in auctions.

In phase 3 the Union-wide cap for stationary installations decreased each year by a linear reduction factor of 1.74%. In phase 4 of the EU ETS (2021-2030), the cap on emissions continues to decrease annually at an increased annual linear reduction factor of 2.2%. The limit on the total number of allowances available ensures that they have a value, each allowance gives the holder the right to emit:

- One tonne of carbon dioxide (CO2).
- Or the equivalent amount of other powerful greenhouse gases, nitrogen oxide (NO_x) and perfluorocarbons (PFCs).

After each year, an installation must surrender enough allowances to cover fully its emissions, otherwise heavy fines are imposed. If an installation reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another installation that is short of allowances. The system covers the following sectors and gases, focusing on emissions that can be measured, reported, and verified with a high level of accuracy:

- Carbon dioxide (CO_2) from:
  - Electricity and heat generation.
  - Energy-intensive industry sectors including oil refineries, steel works, and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids, and bulk organic chemicals.
  - Commercial aviation within the European Economic Area.
- Nitrous oxide (N2O) from production of nitric, adipic and glyoxylic acids and glyoxal.
- Perfluorocarbons (PFCs) from production of aluminium.

Participation in the EU ETS is mandatory for companies in these sectors but in some of them only installations above a certain size are included:

- <u>Combustion energy</u> > **20 MW**
- <u>Steel production</u> > **2,5 tons/h**

The efficiency of the system is strongly linked to the price of the carbon permits, for example, during the last financial crisis the allowances cost were so low, companies could afford them and compensate their cost increasing production. But the situation nowadays is very different, carbon permits are in their all-time high generating huge pressure to the industries that emitted the most.

Figure 17. Evolution of carbon taxes. Source European Comission

Being that the case, we will study the past emissions of the companies we find adequate to be our clients, and, the free allowances they are going to receive in the fourth phase. With that information we will be able to estimate the amount of money our solution can save them.

6.2 Next Generation EU Funds

The next generation funds are a temporary instrument design to impulse the recovery of the European societies economy and social damages related to COVID 19 and help to make the European societies to be more sustainable, resilient, and prepared against the ecologic transition and digital challenges and opportunities.

There are 800 billion € funds in loans and grants available to support the reforms and investments deployed by European countries. Any person could take advantage of the UE Budget looking for financial proposals, taking information about procedures or applying to online financing.

Iberdrola has presented 175 projects to the Next Generation EU program to mobilize investments of €30 bn in Spain, involving 350 small and medium-size enterprises, institutions, technology partners, start-ups and the entire value chain. These projects are located in green hydrogen, innovative renewable energy, sustainable mobility, energy storage, smart power grids, heat electrification and component recycling with clean technologies areas.

Iberdrola and Fertiberia Will apply for the EU funds to support the Puertollano and Palos de la Frontera Hydrogen plant investment of 1,8 Billion €.

Iberdrola Will also apply to these funds to support its investment in decarbonization of industrial processes and co-generation green Hydrogen plant in Lada, which replaces the grey hydrogen.

Repsol also has started the Bilbao Port decarbonization hub, they Will build a plant which Will produce synthetic fuel and will provide car, truck and plane fuel fulfilling the energy demand with green hydrogen. This Project investment is expected to be 103 million €.

7 Cost analysis

7.1 Carbon capture costs

Carbon capture costs deeply depend on the studied process. The tool to evaluate and compare carbon capture costs is the Levelized Cost of Carbon Capture, which stands for Capital Expenditure and Operational Expenditure Costs of applying CCUS technologies in a process. More concentrated streams incur lower costs and vice versa.

For example, in the Fischer-Tropsch process, carbon dioxide must be removed from the syngas product stream, obtaining a nearly pure carbon dioxide stream. In the opposite case, applying carbon capture in the steel industry at the Blast Furnaces implies the separation of carbon dioxide from a more diluted gaseous mixture. Figure 18 shows some examples of LC CCUS.

CO_2 source/industry	CO_2 concentration (%)	Capture cost (USD/tCO_2)
Natural gas processing	96 - 100	15 - 25
Coal to chemicals (gasification)	98 - 100	15 - 25
Ammonia	98 - 100	25 - 35
Bioethanol	98 - 100	25 - 35
Ethylene oxide	98 - 100	25 - 35
Hydrogen (SMR)	30 - 100	15 - 60
Iron and steel	21 - 27	60 - 100
Cement	15 - 30	60 - 120

Figure 18. Levelized Cost of Carbon Capture of some industrial processes [3].

7.2 Green hydrogen costs

There are 3 main alternatives to produce hydrogen, as follow:

- Steam Methane Reforming (SMR) represents the most widely used way of producing hydrogen nowadays [12] . CCUS technology can be implemented to avoid inherent emissions of the process. Figure 19 shows the Levelized Cost of Hydrogen (LCO H_2) from SMR in different regions.

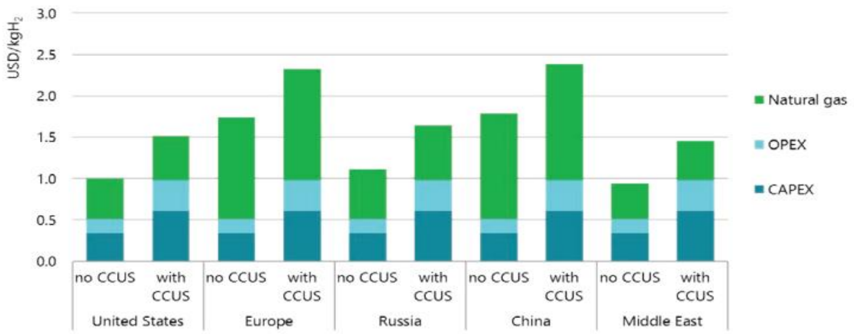

Figure 19. Levelized Cost of Hydrogen from SMR in different regions [12].

- Hydrogen from water and electrolysis, well-known as Green Hydrogen constitutes the renewable way of producing Hydrogen when the electricity sources are wind power, solar power, or other renewable sources. In the process, around 8 kg of high pure oxygen are produced per kg of hydrogen. This fact can help the development of this approach, because of the valuable resource of oxygen. The economic viability of this alternative clearly depends on the costs of electricity and the CAPEX of the electrolyser. In the next years, as Europe is firmly supporting the deployment of the green hydrogen value chain, economy of scale will make the $LCO\,H_2$ go down. Figure 20 shows the future $LCO\,H_2$, that depend on electrolyser CAPEX, full load hours and electricity costs.

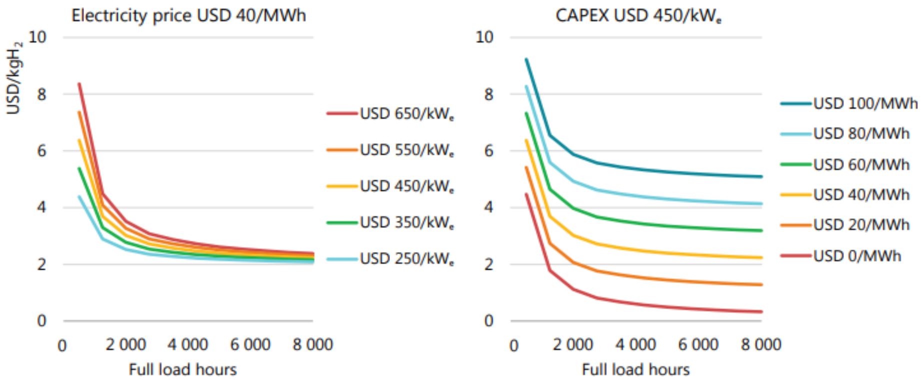

Figure 20. $LCO\,H_2$ by full load hours, electrolyser CAPEX and electricity price [12]

- Hydrogen from coal is a well-established technology, especially in China to produce Ammonia. The syngas produced from the gasification of coal is used to produce hydrogen. Levelized Cost of Hydrogen is around 1 USD/ kg of H_2 [11].

Figure 21 shows as an example of the Levelized Cost of Hydrogen from different sources in China, 2019.

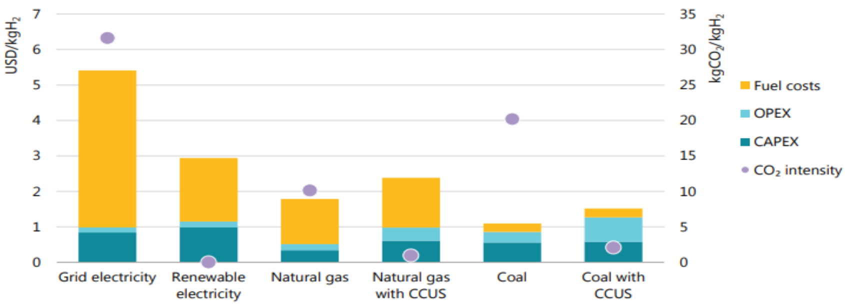

Figure 21. Comparison of LCO H_2 from different sources in China, 2019 [12].

Also, it is interesting to make a comparison between sources in the 2030 scenario in Europe, probably the region with more ambition to reduce emissions and achieve net zero carbon. Figure 22 shows the Levelized Cost of Hydrogen by 2030 in Europe.

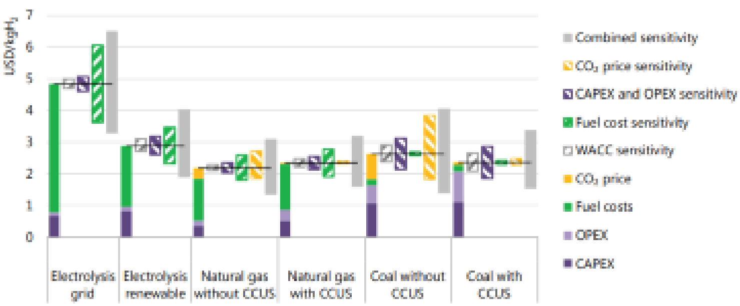

Figure 22. Levelized Cost of Hydrogen in Europe by 2030 from different sources sources [12].

7.3 Synthetic natural gas costs

Synthetic methane or Power-to-Gas is a solid alternative to convert hydrogen into hydrogen-based fuels that are easier to store, transport and use. Other alternatives are Ammonia and methanol.

The open-source information from the Store&Go project shown in Figure 23 indicates that in the next few years the economy of scale will make the investment costs go down for the methanation unit. OPEX is meant to be around 10 % of CAPEX.

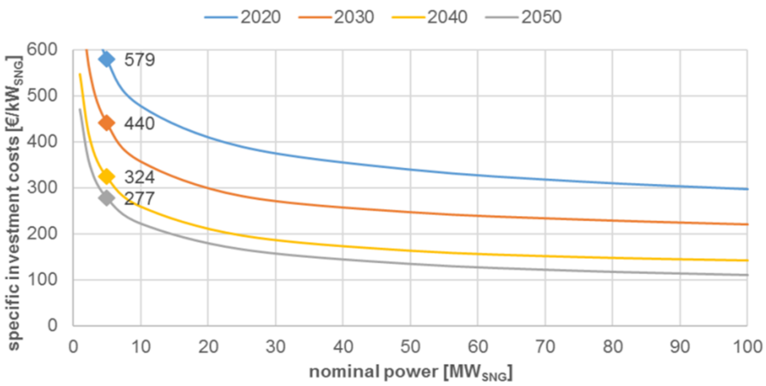

Figure 23. Specific investment costs of SNG over the years and nominal power [13].

In addition, Figure 24 shows the evolution of the Levelized Cost of SNG, which takes into account the hydrogen and carbon dioxide feedstocks, electricity, CAPEX and OPEX.

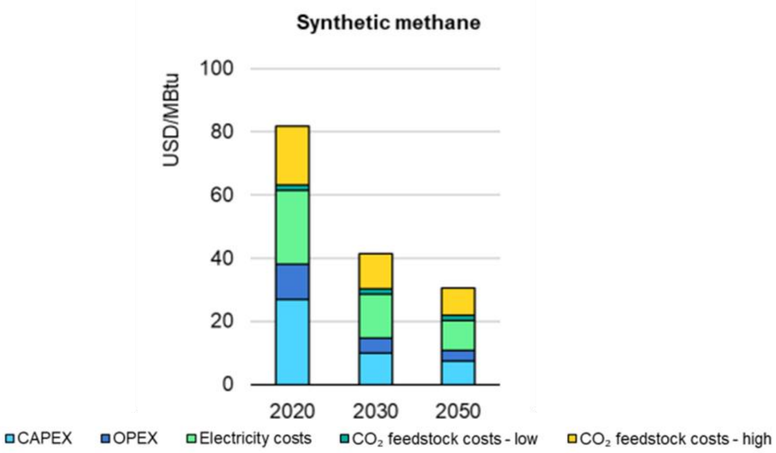

Figure 24. Evolution of SNG levelized cost over the years [14]

By 2030, considering the source of carbon dioxide the steel industry, with a carbon capture costs higher than other sources as ammonia or natural gas processing, the LCO_{SNG} is around 40 USD/MBtu, equivalent to 136,50 USD/MWh, so that for a 20 MW_{SNG} output facility with full load hours over 7.920 h (330 operation days, typical value in the chemical industry), the total cost is around 21.621.600 USD.

7.4 Sensitivity analysis: main parameters

To analyse how the variation in the value of the most important variables affects the total costs, a sensitivity analysis was performed. The analysis is performed considering the 2030 scenario. The main variables are as follow:

- Levelized Cost of Hydrogen, considered around 3,50 €/kg H_2
- Levelized Cost of Carbon Capture, considered around 60 €/t
- Emissions Trading System Taxes price
- Natural gas price, considered around 20-30 €/MWh

7.4.1 Model Basis

The model is based on the SNG output, considering 7.920 h of operation (330 operation days, typical value in the chemical industry). It is considered four SNG output capacities, 5 MW, 10 MW, 20 MW and 50 MW of SNG.

The mass balance to calculate all mass and molar fluxes are based on a 99% conversion of carbon dioxide. It is also considered that the water produced in the methanation process is separated from the synthetic natural gas stream, which meets the requirements to be injected in the Spanish natural gas grid.

The function to evaluate the profitability of the process depends on the following variables:

- Natural gas sell price, €/MWh (NG_{SALE})
- CAPEX SNG unit, €/kW_{SNG} ($CAPEX_{SNG}$)
- OPEX SNG unit, 10% CAPEX SNG ($OPEX_{SNG}$)
- Levelized Cost of Carbon Capture, €/t CO_2 (LCO_{CCUS})
- Emissions Trading System taxes, €/t CO_2 (ETS_{CO2})
- Levelized Cost of Hydrogen, €/kg H_2 (LCO_{H2})
- Complementary Hydrogen unit OPEX, 10 % LCO H_2 ($OPEX_{H2\ unit}$)*
- Oxygen sell price, €/t O_2 ($O_{2\ SALE}$)

*Related with the needed infrastructure to condition oxygen to medical grade.

All the described terms are involved in the following equation [1]

$$Profit = (NG_{SALE} - CAPEX_{SNG} - OPEX_{SNG}) + (ETS_{CO2} - LCO_{CCUS}) - (LCO_{H2} - OPEX_{H2\ unit} + O_{2\ SALE}) \quad [1]$$

* All terms depend on the respective fluxes of natural gas, carbon captured, hydrogen and oxygen

The sale price of oxygen is considered around 500 €/t, as prices fluctuate from 5€/kg for medical oxygen to 50€/t for industrial use. Dedicating around 10% of the total oxygen produced (8 kg O_2 per kg of H_2) to medical oxygen and the rest for industrial used, the obtained medium price is around 500 €/t O_2.

The CAPEX of the SNG unit is obtained from Figure 23 by 2030. Capacities from 5 MW, 10 MW, 20 MW and 50 MW of SNG.

The Levelized Cost of Hydrogen is considered by 3,50 €/kg for all SNG outputs, as it should go down with the economy of scale, but to build a more restrictive model, the value is not changed.

The Emissions Trading System taxes are considered around 100 €/t, as the value that the *International Energy Agency* uses in its reports.

The Levelized Cost of Carbon Capture is considered around 60 €/t. The deployment of CCUS in heavy industry and European Union regulation on this field can make the costs go down, but it is considered a value that can make the model more restrictive.

In addition, it is noticed that the SNG output implies a double power capacity for the electrolysis process. For example, for a 20 MW_{SNG} output, a total of 40 $MW_{electrolysis}$ is needed.

After the model is presented, the following headings will describe the performed analysis.

7.4.2 Analysis 1

The first analysis calculates from what natural gas sale price the process is profitable, with the following considerations:

- Levelized Cost of Hydrogen of 3,50 €/kg
- Emissions Trading System taxes of 100 €/t
- Levelized Cost of Carbon Capture of 60 €/t

The obtained results are included in Figure 25. Economy of scale makes the requirements lower to be profitable.

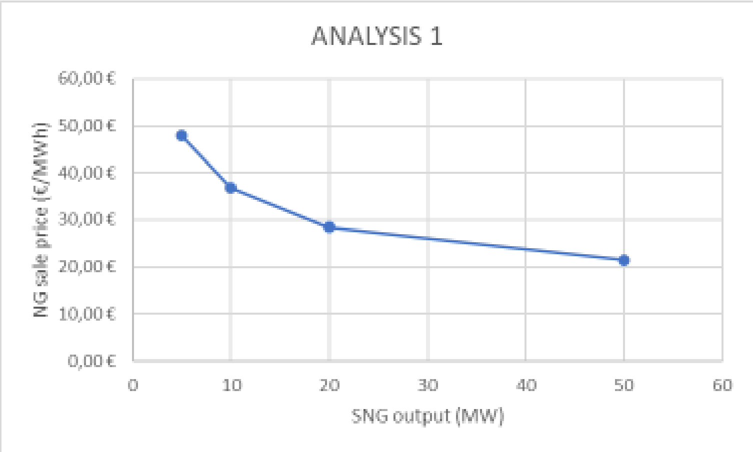

Figure 25. Evolution of NG sale price by SNG output to achieve profit.

7.4.3 Analysis 2

The second analysis calculates from what Emissions Trading System tax the process is profitable, with the following considerations:

- Levelized Cost of Hydrogen of 3,50 €/kg
- Natural Gas sale price of 20 €/MWh
- Levelized Cost of Carbon Capture of 60 €/t

The obtained results are included in Figure 26. Economy of scale makes the requirements lower to be profitable.

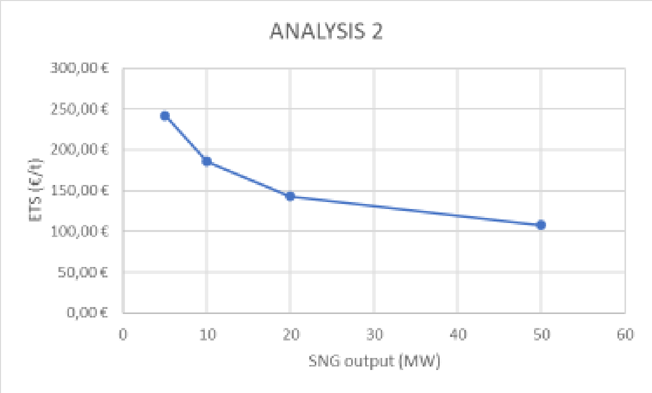

Figure 26. Evolution of ETS tax by SNG output to achieve profit.

7.4.4 Analysis 3

The third analysis calculates from what Levelized Cost of Carbon Capture the process is profitable, with the following considerations:

- Levelized Cost of Hydrogen of 3,50 €/kg
- Natural Gas sale price of 20 €/MWh
- Emissions Trading System taxes of 100 €/t

The obtained results shows that economy of scale makes the requirements lower to be profitable, as for 5 MW and 10 MW output of SNG the process is not profitable under the taken considerations. For 20 MW output, the maximum cost of carbon capture should be around 17 €/t, and for 50 MW output, the costs rise till 52 €/t. This last value is a very reasonable value, because lower capacities are more related to under-commercial projects like demonstration or pilot plants.

7.4.5 Analysis 4

The fourth analysis calculates from what Levelized Cost of Hydrogen the process is profitable, with the following considerations:

- Emissions Trading System taxes of 100 €/t
- Natural Gas sale price of 20 €/MWh
- Levelized Cost of Carbon Capture of 60 €/t

The obtained results are included in Figure 27. Economy of scale makes the requirements lower to be profitable. As it is shown in Figure 24, the sensitivity analysis performed by the *International Energy Agency* shows up that variation of ETS carbon taxes and electricity price are in line with the present analysis.

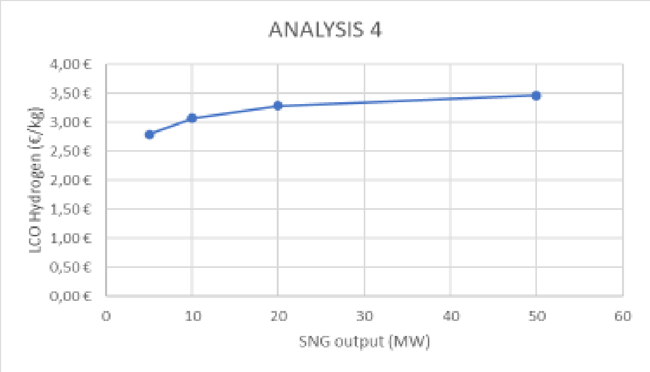

Figure 27. Evolution of Levelized Cost of Hydrogen by SNG output to achieve profit.

7.4.6 Conclusions

The lessons learned from the sensitivity analysis are as follow:

- **Natural Gas price** is the most volatile variable, values between 20-30 €/MWh cover the costs generating small profits. Being this range the most restrictive case, we can consider the option of closing a long-term contract between 40-55 €/MWh.
- Results of 50 MW SNG simulations are better from 5 MW SNG (**Economy of Scale**), even so in the first steps small models will be developed.
- Development of **CCUS technologies** have a huge potential even at a cost of 60€ per ton captured. And they will become more profitable considering the carbon allowances price that will increase over 100 € around 2030.
- **Levelized Cost of H_2** is the most important variable, and it is expected that with progressive development and EU regulations the price will decrease under **3,50 €/kg**, a value where profit is achievable already.

8. Marketing Plan

Because our idea is an industrial solution, the approach and the strategy used differs a lot from the common idea of marketing. Our final weapons are nothing more than economic aspects, such as savings, new incomes, profit… But we have several options in order to attract customers and start with them a long relationship.

As we have said, our main weapons are economic arguments, even so, if we combine them with flexible options, it will be easier to convince them. Therefore, we will offer to our potential partners different ways to close a deal with **Haspot Solutions**:

- We can stablish between the parts a normal **consumer-producer relationship**, making all the final investment as mentioned but we will also enjoy all the profits the project can generate. This option introduces a bigger reward but also a higher permitting and land acquisition risk.
- In case they are attracted by our solution, and they want to enter in our business, we are giving them the option to stablish a **Joint Venture (JV)** between both sides. This will

have several outcomes; in first place we will become partners so they will benefit from the expected profits making more attractive our solution for them. In our case, we will minimize our risks such as the technical ones due to a bigger involvement from their side, and we will reduce the amount of money we must invest. This solution makes sense specially in the first clients because of our low profile, once we have grown and our technical expertise is proven we will have the financial power and brand awareness to attract new businesses into our model.

- Besides these two options, we can give them a **buy-option** in a certain moment of the life duration of the project. Leaving them at a **preference position** in case the facility is sold, will give them a feeling of control that will add value to our offer. This option could be considered in both strategies, having more sense in the JV one thanks to the partnership created. This solution, whether the first or the second strategy is chosen, will give us the possibility of selling certain assets we are no longer interested in, and gaining the cash for future opportunities.

We are going to give a fast explanation of what a **joint venture (JV)** consists of. It is a business arrangement in which two or more parties agree to pool their resources to accomplish a specific task, and it can be a new project or any other business activity. In a JV, each of the participants is responsible for profits, losses, and costs associated with it. However, the venture is its own entity, separate from the participants' other business interests, and can be formed under any legal structure.

A joint venture can take advantage of the combined resources of both companies to achieve the goal of the venture. One company might have a well-established manufacturing process, while the other company might have superior distribution channels. A joint venture (JV) is not a partnership. That term is reserved for a single business entity that is formed by two or more people. Joint ventures join two or more different entities into a new one, which may or may not be a partnership. Once the joint venture (JV) has reached its goal, it can be liquidated like any other business or sold.

In the **consumer-producer relationship**, **Haspot** is the producer part, and our client is the consumer part. The customer has a need related to our product, for this need we will offer a unique and tailor-made solution that is adapted to the customer's own needs.

This measure will be delivered turnkey to the customer, who will not have to worry about anything, we will take care of the engineering project, financing, purchasing management, construction, and commissioning. The client will only have to provide the carbon dioxide emitted, taking care of the opex related to these facilities (CCUS), and we will supply the different products: SNG, hydrogen, oxygen…

8.1 Final strategy

We will build **Haspot Solutions** around the idea of giving our clients flexibility and control over their production process, but also giving our stakeholders the capacity of generating profit reducing the risk and uncertainties to the minimum. These are the reasons why we think the next company structures will be the best.

A parent company named **Haspot Solutions** will be founded and inside of it several SPVs (Special Purpose Vehicles) will own every project and its facilities (this kind of vehicle will be set fo the joint ventures). This will give us the chance to sell one plant separately and fast, to the client if he wants to (buy option mentioned) or to another investor.

With this scheme, we can grow in the first years by making good partnerships that will allow us to minimize the capital we invest and maximize the returns. Once we start earning money and generating profits, we can sell some of the assets (initial project plants that will surely be JV) and with the capital of the selling, develop new projects knowing that we can approach our new clients with expertise and financial power we did not have at the beginning.

Therefore, more options apart from the JV will be available and bigger returns and profits for the mid-term period. In order to achieve the goals commented we need to build a competitive team, and therefore, our different positions inside the company will be the next:

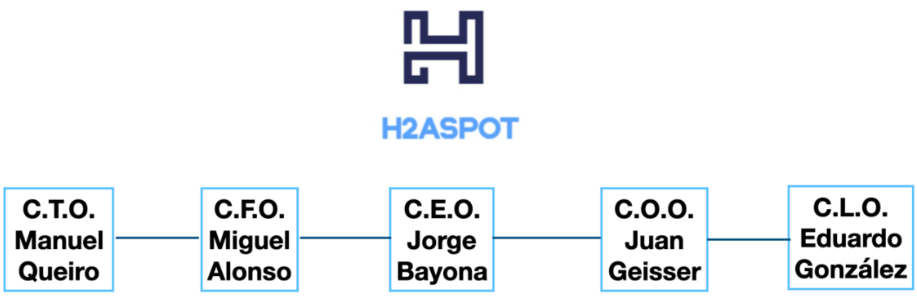

Figure 28. Border of Directors of **Haspot Solutions**

So, our global strategy will be divided into **three stages**:

- **Short-term strategy:** our idea is to find one or two clients (the ones we are going to show in models A & B), develop at least one project and once we have proven its efficiency, start gaining new clients by the same structure (**JV** if possible and small plants).

- **Mid-term strategy:** the previous period can last between 3-5 years, and we hope to close around 5 deals in that time. At that moment we will start analysing possibilities around Europe but considering bigger plants with bigger emissions that will allow us to produce more SNG and hydrogen. This expansion financial rounds can be helped by the selling of some initial projects (**SPV & JV**). This mid-term strategy can last 10 years, growing in the distribution channels and capturing new clients, we will also study the distribution options in this stage, plants bad ubicated will not be considered.

- **Long-term strategy:** if the mid-term strategy is well developed, we will have bigger projects and well located. This will give us the chance of producing and distributing huge amounts of synthetic natural gas and green hydrogen. But even so, competing with the main firms during that period can be complicated, in that case, selling the parent company to one of them will be considered.

9. Client business model: A & B

9.1 Introduction

Once we've studied the most polluting industries that are inside of the ETS it's time to apply our technical solutions to a specific client. But for our initial projects, we have discovered two different business models that will give us more flexibility to attract clients. In the first one, **"Model A"**, we will produce the exact amount of hydrogen that's needed to transform all the carbon dioxide into synthetic natural gas. In the second one, **"Model B"**, our client will demand hydrogen as well and therefore, we will produce more to fulfil his demand, creating a new source of income.

For both, the technical solution will follow the same scheme, except that on **"Model B"** a bigger electrolyser is installed in order to produce more green hydrogen. The different facilities and the equipment are described as the following:

- **Electrolyser: 20 MW** of power installed in order to produce the exact amount of **green hydrogen** that is necessary to transform all the SNG produced, 2.805 tons per year. (For the other model, 30 MW will be installed, and 4.208 tons will be produced).
- **SNG facilities: 10 MW** of power installed that will be able to produce 79.200 MWh/year.
- **CCUS facilities**: that will capture the **carbon dioxide** transforming 15.554 of tons per year into SNG.
- **Connection facilities**: their length and dimensions depend not only on the model but also in the client and the land available.
- **Oxygen facilities**: Inside this process **oxygen** is produced, around 22.440 tons per year (33.660 tons per year in the second model).

There is another point that both models will share and those are the savings our client will have because of capturing a percentage of their emissions. As we have mentioned, around 15.554 tons of carbon dioxide will be capture, and so, that number of allowances could be sold or not spend if they must buy them in an auction.

Based in all the information we have analysed; carbon permits price is only going higher. Being that the case, we have established an evolution of the price considering it grows as fast as inflation goes (3%), starting on 2023 at 85 € (actual price, so we believe is conservative). In the next table we show the savings generated to our client and their CCUS facility maintenance cost, for the first three years:

Table 2. Evolution of saving due to increase in carbon permits.

Actual years	2025	2026	2027
Project years	1	2	3
Carbon permits price	90,18 €	92,88 €	95,67 €
Carbon permits savings	1.361.774,27 €	1.402.627,50 €	1.444.706,33 €
OPEX - CCUS facilities	- 93.325,48 €	- 96.125,24 €	- 99.009,00 €
Total savings	**1.268.448,79 €**	**1.306.502,26 €**	**1.345.697,33 €**

9.2 Project Development

Regarding the project development, the same schedule is followed for both models. There is no official deadline right now, but we would like to be operating by 2025, which means having a COD (Commercial Operation Date) around Q4 OF 2024.

We divided the project into **8 stages**, starting by negotiating with the client to close an **agreement** (that can be a joint venture or a producer-consumer deal), and for that, we estimate a maximum of 6 months.

The initial **feasibility study** is already done (this report), but once we are close to signing an agreement with the client, we can develop this analysis in more detail. At that moment we will eliminate the uncertainty of selling prices or the infrastructure budget, so the economic model will be more precise.

The **engineering** will start once the feasibility is proven again and will last until the construction begins. Three projects will be done: the administrative one for the permitting (which will only have basic information), the bidding project (for the procurement process), and the detailed engineering (for construction).

For the **land lease and the government permits**, we don't expect to spend more than one year, being the main points (if needed):

- Change the land use of the plots.
- Environmental procedure.
- The building licenses by the council of the city.
- The administrative authorization from the regional government.

The **project finance** step begins once we have some certainty that the process is going to see the light, after applying to the administration, we expect it to be no longer than 6 months. The **procurement process** will take around 9 months because the technology used is very new and there are just a few suppliers with low manufacturing capacity.

The **construction stage** will last no more than one year, depending on the supply of the equipment and the difficulties that can turn up in this kind of project. The construction company and the equipment supplier will be chosen by a tender, but for the last one we won't offer only the actual project, but a mid-term deal of supply.

The reason why we are interested in closing a deal with them (electrolyzer company), apart from a good economical fixed price, is because a partnership will give technical support to our solutions. The final step will be the **commissioning** of the plant in order to start operation by 2025.

Table 3. Gant's Diagram of project tasks from Power point to start up

Year	2022		2023				2024			
Quarter	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Consortium agreement (JV)										
Feasibility Study										
Engineering										
Land lease and government permits										
Project finance										
Procurement process										
Construction										
Commissioning										

9.3 Model A: Steel company Megasa Siderúrgica S.L.

In this case, our two outputs will give us two-income routes and our ideal client will be the one that demands both. For this search, we've used the list of allowances assignation for the initial part of phase 4 (2022-2025) that was published last year by the MITECO, and we've tried to focus on steel plants consuming both products (SNG and oxygen).

During the process, we found the **Megasa Siderúrgica, S.L.,** focusing on their plant in Ferrol, where steel is transformed into different shaped products by extrusion, blowing… and cutting it. These processes demand a big amount of oxygen. Even though, their demand is lower than our oxygen production so we will only be able to sell them **85%** of it, at an index price beginning at **0,20 €/kg**. The rest of the oxygen will be distributed to other industries, applying a distribution cost and therefore, selling it at a higher price, but for this model this will not be consider. Being so, our income from oxygen will start around 4 million € and will finish at 6,5 million €.

But it is a different case for the **SNG**, where all the quantity produce will be sold to client, considering the option of closing a bilateral contract with them for 10 years for 52 €/MWh (based on the market actual price and the previous sensitive analysis). For the next 10 years another contract will be sign, but the price will be renegotiated (we expect to be lower around 44 €/MWh). Even so, obligation to buy all the amount produced by our facilities during the 20 years of life use will be signed.

Being so, our income from synthetic natural gas will be:

- 4.118.400 € for the first ten years.
- 3.484.800 € for the last ten years.

As we have mentioned in the marketing plan, we will assume that for our first projects and clients a JV will be closed, and therefore, we will have our client involved in the development. In this case, the space needed can be part of the contribution of the client.

In the case of **Megasa plant** there's little land available around it, and since it is located in a very populated area, we may have problems with the building permitting. But we have nearly one hectare inside their plot, ubicated at the north, that we believe is more than enough for our solution:

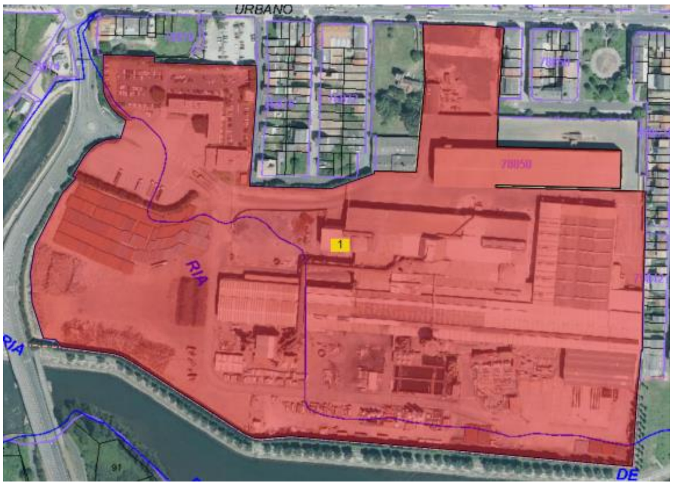

Figure 19. Plot owned by Megasa plant in Ferrol.

But in order to study the most restrictive case, we suppose a lease agreement with them for those 20 years at a price of 25.000 € per hectare, and the project will occupy around 0,6 hectares. Before we start discussing the fiscal assumptions or the initial CAPEX of the project, we are going to show the layout of the facilities, especially the connection infrastructure:

Figure 20. Production plant project.

The total investment this solution model requires, based on the costs mentioned in the last chapter, will be the following:

- CAPEX:

  - Hydrogen production: Cost of the 20 MW PEM electrolyzer based on IRENA report.
  - SNG production: 10 MW facilities to produce a final quantity of 79.200 MWh per year.
  - CCUS facility: at a cost of 60€ per tonne captured, as we have seen in chapter 7.
  - Connection infrastructures: that will connect the CCUS facilities with the SNG plant, the electrolyzer with the SNG plant and the SNG plant with their natural gas tanks and oxygen storage system to supply them.

- Another initial investment will be considered as development expenditures, inside of it will be de legal costs of creating the different societies (JV), the building and environmental permits, and detail engineering for the biding and building project.

Table 4. Initial Capital Expenditures.

Project budget	Value	Units
Hydrogen Electrolyser cost	500,00	€/kW
SNG facilities cost	360,00	€/kW
CCUS facilities cost	60,00	€/ton
CAPEX - H_2 Production: Electrolyser	10.000.000,00	€
CAPEX - SNG production	3.600.000,00	€
CAPEX - CCUS facilities	933.254,78	€
CAPEX - Connection infrastructures	750.000,00	€
CAPEX - Development	320.000,00	€
Total CAPEX	**15.603.254,78**	**€**

- **OPEX:**
  - The operational cost of hydrogen production is mainly electricity. The electrolyzer consumes 49,9 kWh per kg of H_2 produced and considering we sign two PPA contracts (10 years each of them, being cheaper the second one due to the estimated future prices). The prices considered are 36 €/MWh for the first period, and 30 €/MWh for the second.
  - For the SNG production the operational cost is again electricity and maintenance.
  - For the oxygen will be an extra purification of the product.
  - Another operational cost will be the salaries of the two workers that will be needed, one as the plant boss and the other as a worker for 55.000 per year.
  - There is also the land lease we mentioned above of 15.000 per year.

Table 5. Yearly Operational Expenditures (First period).

Project budget	Value	Units
OPEX - O_2 Purification (10%)	897.600,00	€
OPEX - SNG Production (20%)	720.000,00	€
OPEX - CCUS Facilities (10%)	93.325,48	€
OPEX - H_2 Electricity (years 1-10)	5.038.902,00	€
OPEX - H_2 Electricity (years 11-20)	4.199.085,00	€
OPEX – Water consumption	54.697,50	€
OPEX - Land lease	15.000,00	€
OPEX - Employees	55.000,00	€
Total OPEX – First year	**6.930.624,98**	**€**

- **Fiscal assumptions:**
  - We will suppose an amortization period of 12 years.
  - A profit tax of 25%.

- An inflation rate of 3%, that we found adequate knowing that nowadays is higher near to the 6-7% but this situation will last few more years and that it will stabilize around the 2% for the future years. Therefore 3% is a conservative number for us.

Table 6. Fiscal assumptions for the project.

FISCAL ASSUMPTION	
Profit tax	25%
CPI	3,0%
Amortization	1.300.271,23 €
Term (years)	12

- **Financial assumptions:** We consider that if we sign a JV and a selling contract with the client, and we can close the PPAs at a good price, the uncertainty of the project is reduced to very low levels. This will make the project bankable in some good conditions:
  - The project will be leveraged at 70%, with a commission of 2% and with an interest rate of 4%, having a maximum of 15 years period to return the money.
  - But we have used also the RCSD concept to make it even easier to finance the solution, considering a 1,3 rate. This means the capital returned every year will guarantee that we have enough income to pay the interest and the complete loan.

Table 7. Financing assumptions.

FINANCING	
Initial Cost	15.603.255 €
Interest rate	5%
Term (years)	14
Leverage rate	65%
Contribution	5.461.139 €
Loan	10.142.116 €
DSCR	1,3
Commission rate	2%

- **Income:** We will have two-income sources, the oxygen selling, and the SNG, so for the first three years it would be:

Table 8. Evolution of income.

Actual years	2025	2026	2027
Project years	1	2	3
O2 price (€/MWh)	0,20 €	0,21 €	0,21 €
O2 income	3.814.800,00 €	3.929.244,00 €	4.047.121,32 €
SNG price (€/MWh)	52,00 €	52,00 €	52,00 €
SNG income	4.118.400,00 €	4.118.400,00 €	4.118.400,00 €
Total income	**7.933.200,00 €**	**8.047.644,00 €**	**8.165.521,32 €**

- **Final outcomes:**

Table 9. Evolution of income.

PROJECT RESULTS	
Equity IRR	**9,31%**
Simple repay (years)	14,33
Project IRR	7,35%

9.4 Model B: Finsa Cogeneration Plant

In the second model "B" we will produce more hydrogen than is necessary to transform all the carbon dioxide into synthetic natural gas, having in this case three outputs, and therefore three-income routes. In this scenario, we will prioritize hydrogen consumption from oxygen demand, considering we can distribute the last one at a competitive price.

Using the list of allowances assignation mentioned, we found the **Finsa Cogeneration Plant** in Santiago de Compostela, where wood is transformed into different shaped products and for many years a cogeneration plant that burns fuel covers the electricity consumption of the plant and even sells to the grid. So, as we have seen in the cogeneration plants, part of their gas will be replaced by ours and by green hydrogen (at a low percentage).

All the **SNG** produce will be sold to client, considering the option of closing a bilateral contract with them for 10 years for around 52 €/MWh (based on the market actual price and the previous sensitive analysis). For the next 10 years another contract will be sign, but the price will be renegotiated (we expect to be lower around 44 €/MWh). Even so, obligation to buy all the amount produced by our facilities during the 20 years of life use will be signed. Being so, our income from synthetic natural gas will be:

- 4.118.400 € for the first ten years.
- 3.484.800 € for the last ten years.

All the surplus **hydrogen** that is produce will be sold to client, considering the option of closing a bilateral contract with them during the 20 years for around 3,5 €/kg.

As we have mentioned in the marketing plan, we will assume that for our first projects and clients a JV will be closed, and therefore, we will have our client involved in the development. In this case, the space needed can be part of the contribution of the client.

In the case of **Finsa** there's enough land available around it, we have nearly one hectare inside their plot, that we believe is more than enough for our solution. But even considering this option, we suppose a lease agreement with them for those 20 years at a price of 25.000 € hectare.

The total investment this solution model requires, based on the costs mentioned in the last chapter, will be the following:

- **CAPEX:**
  - Hydrogen production: Cost of the 20 MW PEM electrolyzer based on IRENA report.
  - SNG production: 10 MW facilities to produce a final quantity of 79.200 MWh per year.

- CCUS facility: at a cost of 60€ per tonne captured, as we have seen in chapter 7.
- Connection infrastructures: that will connect the CCUS facilities with the SNG plant, the electrolyzer with the SNG plant and the SNG plant with their natural gas tanks and oxygen storage system to supply them.
- Another initial investment will be considered as development expenditures, inside of it will be de legal costs of creating the different societies (JV), the building and environmental permits, and detail engineering for the biding and building project.

Table 10. Structure of CAPEX

Project budget	Value	Units
Hydrogen Electrolyser cost	500,00	€/kW
SNG facilities cost	360,00	€/kW
CCUS facilities cost	60,00	€/ton
CAPEX - H_2 Production: Electrolyser	15.000.000,00	€
CAPEX - SNG production	3.600.000,00	€
CAPEX - CCUS facilities	933.254,78	€
CAPEX - Connection infrastructures	1.038.000,00	€
CAPEX - Development	411.425,10	€
Total CAPEX	**20.982.679,88**	**€**

- **OPEX:**
  - The operational cost of hydrogen production is mainly electricity. The electrolyzer consumes 49,9 kWh per kg of H_2 produced and considering we sign two PPA contracts (10 years each of them, being cheaper the second one due to the estimated future prices). The prices considered are 36 €/MWh for the first period, and 30 €/MWh for the second.
  - For the SNG production the operational cost is again electricity and maintenance.
  - For the oxygen will be an extra purification of the product.
  - Another operational cost will be the salaries of the two workers that will be needed, one as the plant boss and the other as a worker for 55.000 per year.
  - There is also the land lease we mentioned above of 15.000 per year.

Table 11. Structure of OPEX

Project budget	Value	Units
OPEX - O_2 Purification (10%)	1.500.000,00	€
OPEX - SNG Production (20%)	720.000,00	€
OPEX - CCUS Facilities (10%)	93.325,48	€
OPEX - H_2 Electricity (years 1-10)	7.558.353,00	€
OPEX - H_2 Electricity (years 11-20)	6.298.627,50	€
OPEX – Water consumption	82.046,25	€
OPEX - Land lease	20.000,00	€
OPEX - Employees	75.000,00	€
Total OPEX – First year	**9.966.678,48**	**€**

- **Fiscal assumptions:**
  - We will suppose an amortization period of 12 years.
  - A profit tax of 25%.
  - An inflation rate of 3%, that we found adequate knowing that nowadays is higher near to the 6-7% but this situation will last few more years and that it will stabilize around the 2% for the future years. Therefore 3% is a conservative number for us.

Table 12. Fiscal assumptions for the project.

FISCAL ASSUMPTION	
Profit tax	25%
CPI	3,0%
Amortization	1.748.556,66 €
Term (years)	12

- **Financial assumptions:** We consider that if we sign a JV and a selling contract with the client, and we can close the PPAs at a good price, the uncertainty of the project is reduced to very low levels. This will make the project bankable in some good conditions:
  - The project will be leveraged at 70%, with a commission of 2% and with an interest rate of 4%, having a maximum of 15 years period to return the money.
  - But we have used also the RCSD concept to make it even easier to finance the solution, considering a 1,3 rate. This means the capital returned every year will guarantee that we have enough income to pay the interest and the complete loan.

Table 13. Financing assumptions.

FINANCING	
Initial Cost	20.982.680 €
Interest rate	5%
Term (years)	14
Leverage rate	65%
Contribution	7.343.938 €
Loan	13.638.742 €
DSCR	1,3
Commission rate	2%

- **Income:**

Actual years	2025	2026	2027
Project years	1	2	3
O2 price (€/MWh)	0,22 €	0,23 €	0,23 €
O2 income	2.962.080,00 €	3.050.942,40 €	3.142.470,67 €
H2 income	4.827.992,40 €	4.827.992,40 €	4.827.992,40 €
SNG price (€/MWh)	52,00 €	52,00 €	52,00 €
SNG income	4.118.400,00 €	4.118.400,00 €	4.118.400,00 €
Total income	**11.908.472,40 €**	**11.997.334,80 €**	**12.088.863,07 €**

Table 14. Evolution of income.

- **Final outcomes:**

PROJECT RESULTS	
Equity IRR	**9,94%**
Simple repay (years)	13,18
Project IRR	7,77%

10. Conclusion

Once we have seen the two business models and their financial outcomes, it is time to present our offer. In what we consider to be the first stage of **Haspot Solutions**, we will only develop **model A**, and for that we will need 6 million €, but considering we will come to an agreement with the client signing a JV:

Table 16. Stage I

	Construction Budget	Margin 2,00%	JV	Legal Expenses	Total
Stage I	5.461.139,17 €	5.570.361,96 €	2.785.180,98 €	50.000,00 €	**2.835.180,98 €**

Therefore, giving the construction budget a 2% margin and taking into account 50.000 € for legal expenses, nearly 3 million will be needed to start our business. In our first approach to early investors, we have been fortunate to have the interest of different funds or entities. We have closed and initial agreement with a family office from Aragon named **Serrablo Sicav,** with an equity capital around 12 million € they have asked for at least a 30% share with a 900.000 € valuation.

The founder team wants to maintain control of the parent company with at least a 51%, providing nearly 300.000 € each one. As a result of this, we need to close another funding round for the 450.000 € remaining for a 15% stake of the company. Having a more than attractive IRR, the project will guarantee our shareholders a return of 6 times their investment after the project lifetime.

Shareholders	Share	Investment	Return year 20
Miguel Alonso	10,48%	297.036,20 €	1.788.793,61 €
Eduardo González	10,48%	297.036,20 €	1.788.793,61 €
Manuel Queiro	10,48%	297.036,20 €	1.788.793,61 €
Juan Ign. Geisser	10,48%	297.036,20 €	1.788.793,61 €
Jorge Bayona	10,48%	297.036,20 €	1.788.793,61 €
Total founders	52,38%	1.485.180,98 €	8.943.968,03 €
Serrablo Sicav	31,74%	900.000,00 €	5.419.926,15 €
New investor	15,87%	450.000,00 €	2.709.963,07 €
Total	100,00%	2.835.180,98 €	17.073.857,25 €

In conclusion, the economic and technical feasibility of our project has been proven, even without taking into account any European Fund which is for sure an option. With **Haspot**

Solutions we offer our investors the opportunity to enter the green hydrogen industry adding more value to the product due to his application.

Reducing carbon dioxide emissions for these industries is a legal and financial obligation, and this need is yet to be covered by solutions like the one we are presenting. We believe that both business models are just the first step in a long journey to achieve zero net emissions for our clients. And while growing in Spain and Europe, emission systems like the ETS are going to be developed in other countries opening up the possibility of expanding to new markets.

11. References

[1] S. KumarV.Himabindu, «Hydrogen production by PEM water electrolysis».

[2] GlobalData, «Hydrogen Market - Riding the Sustainability Wave,» 2022.

[3] IEA (2020), CCUS in Clean Energy Transitions, IEA, Paris https://www.iea.org/reports/ccus-in-clean-energy-transitions

[4] CO_2 capture technology at industrial scale, Carbon Clean https://www.carbonclean.com/technology-licence

[5] IEA (2021), About CCUS, IEA, Paris https://www.iea.org/reports/about-ccus

[6] IEA (2019), Transforming Industry through CCUS, IEA, Paris https://www.iea.org/reports/transforming-industry-through-ccus

[7] Personal Communication Javier F. López Sotomayor, MAN Energy Solutions Europe Sales Manager.

[8] STORE&GO. Final report on evaluation of technologies and processes Avaliable in: https://www.storeandgo.info/fileadmin/downloads/deliverables_2020/20200713-STOREandGO_D5.9_DVGW_Final_report_on_evaluation_of_technologies_and_processes.pdf

[9] E. &. Young, «Towards Greener Steel. Steering the Transition».

[10] M. &. Company, «Decarbonization challengue for steel».

[11] IEA, Global cement production in the Net Zero Scenario, 2010-2030, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-cement-production-in-the-net-zero-scenario-2010-2030

[12] IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen

[13] STORE&GO. Analysis on future technology options and on techno-economic optimization Available in : https://www.storeandgo.info/fileadmin/downloads/deliverables_2020/Update/2019-07-04_STOREandGO_D7.7_accepted.pdf

[14] IEA (2021), Global Hydrogen Review 2021, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2021