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Towards a sustainable future in Campari Group

Decarbonization path of the Novi Ligure Plant’s

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ABSTRACT

This study focuses on the development of an energy model for a beverage production plant within the Food and Beverage sector, aiming to create a roadmap for achieving a reduction of C02 emissions by 2050. This industry sector is one of the largest consumers of energy and significantly contributes to global greenhouse gas emission, making the implementation of sustainable and energy-efficient strategies crucial.

A key component of this study involves the use of an Excel-based model to define and analyze the plant's primary energy vectors. By assessing the current state of the facility, the model will identify the specific energy needs and consumption patterns. This detailed analysis will serve as the foundation for implementing a comprehensive plan to transition the plant to reduce impact operation. Through this model, various decarbonization scenarios will be created, considering the supply and demand dynamics of the plant's energy requirements. Simulation models are used to evaluate various technical and managerial solutions, including adoption of renewable energy sources, optimization of production processes and the integration of innovative technologies.

The main aim of this research is the formulation of a clear and detailed roadmap that guides the plant towards carbon neutrality, aligned with global sustainability goals and European regulations. The roadmap outlines progressive steps, including investments in low-impact infrastructure, the transition to a cleaner energy and the reduction of energy intensity through operational efficiency.

1 FOOD AND BEVERAGE SECTOR ENERGETIC OVERVIEW

1.1 STATE OF ART OF FOOD AND BEVERAGE SECTOR

The food and beverage sector is a vital pillar of the global economy, deeply intertwined with cultural identities and the health of society. This industry includes a wide spectrum of activities, from agricultural production to the final consumer experience, making it essential for understanding both economic and social dynamics.

F&B includes activities related to the distribution of food products in hotels, restaurants, kiosks, bars, shopping centers and practically anywhere it is possible to buy food for immediate consumption.

F&B are quite different realities, all united by the serving of dishes and drinks in the same place (or in the immediate vicinity) where they are purchased and consumed. The expression, whose literal meaning is "food and drink", finds its more precise definition in the technical terminology HoReCa, an acronym for *Hotellerie*, *Restaurant*, *Cafè*. and coincides with the sector which includes the distribution of food products in hotels, restaurants and cafes (an item identified with catering activities), not to be confused with the large-scale retail sector (large-scale distribution Organized).

The food and beverage sector is a crucial element of the economy, made up of several phases that intertwine with each other to ensure that food and beverages are available and of quality to consumers.

First, there is primary production, which includes agriculture and livestock. Here, farmers grow a wide range of produce, from grains to fruits and vegetables, while ranchers are dedicated to the production of meat, milk, and eggs. This phase is crucial because it provides the necessary raw materials for the entire industry.

Once the products have been harvested, we move on to transformation and processing. This phase is managed by the food industry, where raw materials are processed into ready-to-eat foods. For example, meat is processed, fruit can be made into juices or preserves, and bread is made from flour. Packaging plays a crucial role in this process, as it must ensure that food remains fresh and safe until it is ready to eat.

Distribution is the next step, where wholesalers and distributors take care of getting the products from the manufacturers to the points of sale. Wholesalers supply large quantities of products to supermarkets, restaurants, and other retailers, while distributors handle logistics to make sure products arrive at their destination efficiently.

The last phase is retail, where consumers can buy food and beverages directly. Supermarkets and grocery stores offer a wide range of products, while catering, which includes restaurants, bars, and cafes, offers customers the chance to have meals and drinks in a social environment.

An important aspect of the sector is that of beverages, which are divided into non-alcoholic beverages, such as juices and soft drinks, and alcoholic beverages, such as wines, beers and spirits. Each category has its own production and distribution process, which is just as complex as that of food.

Finally, there is a growing focus on sustainability and innovation. Companies are increasingly looking to adopt sustainable practices, such as organic farming and the use of eco-friendly packaging. In addition, the introduction of advanced technologies, linked to the Fourth Industrial Revolution, is changing the way the sector operates, making processes more efficient and interconnected.

In summary, the food and beverage sector is a complex and dynamic system, constantly evolving to meet the needs of consumers and face the challenges of the future.

1.2 KEY COMPONENTS OF THE FOOD AND BEVERAGE SYSTEM

1. **Agricultural production**

    - This is the fundamental stage in which raw materials are grown. It includes agricultural activities for crops, livestock and aquaculture. The quality of agricultural products directly affects the entire food supply chain.

2. **Food Processing**

    - In this step, the raw ingredients are transformed into consumable products. This includes tasks such as canning, freezing, and packing. The processing industry must comply with strict safety and quality standards to ensure the health and satisfaction of consumers.

3. **Logistics and Distribution**

    - Efficient logistics are crucial to maintaining the integrity of food products throughout the supply chain. This includes storage, transportation, and inventory management. Cold chain logistics are especially important for perishable goods, requiring controlled temperatures during storage and transportation.

4. **Retail & Food Service**

    - This segment involves selling food products directly to consumers through various channels, including supermarkets, restaurants, and online platforms. Retailers must adapt to changes in consumer preferences, such as the growing demand for organic and specialty foods.

5. **Regulatory framework**

    - The food and beverage industry is heavily regulated to ensure food safety, quality, and environmental sustainability. Standards such as ISO 22000 provide guidelines for managing food safety throughout the entire supply chain.

1.3 INDUSTRY CHALLENGES

- **Supply Chain Disruptions**: Recent global events have highlighted vulnerabilities in supply chains, affecting everything from ingredient availability to distribution efficiency.
- **Sustainability Concerns**: There is increasing pressure on companies to adopt sustainable practices, reduce waste, and minimize their environmental impact. This includes initiatives to reduce food waste and improve resource efficiency throughout the supply chain.
- **Trends in Consumer Health**: The growing awareness of health and nutrition has led consumers to seek healthier options, prompting companies to innovate their product offerings.

As consumer preferences evolve and market competitiveness increases, it is crucial to examine the structure and composition of this industry. The agri-food industry is of fundamental importance in Italy, being the second manufacturing sector and contributing 13% to industrial production with a turnover of 132 billion euros (Ministry of Economic Development, 2021). This sector is constantly evolving and must adapt to the new preferences of consumers, who today prefer organic, nutritious and minimally processed foods (ANSA, 2018; Eurostat, 2019). It also addresses significant challenges, such as the demand for greater sustainability and the impact of the Fourth Industrial Revolution, characterized by the introduction of advanced technologies.

Sustainability, understood as a continuous process of care and conservation of resources, is a central objective. Sustainable development, defined in 1987 in the Bruntland Report, aims to meet current needs without compromising those of future generations, and is based on three dimensions: social, economic and environmental. Over the past 50 years, many efforts have been made to promote sustainable development, culminating in the 2030 Agenda approved by the United Nations in 2015, which sets 17 goals to be achieved by 2030.

The food sector has a significant impact, particularly at the environmental level, due to high greenhouse gas emissions, intensive land use and food waste, with one-third of the food produced globally ending up wasted (FAO, 2021). Packaging, often made of plastic, is essential to prevent food waste, but its inadequate disposal causes pollution.

In addition, the industry is facing the Fourth Industrial Revolution, which leads to increased digitization and automation of processes. Technologies such as augmented reality and collaborative robots are changing the manufacturing landscape. Food companies will therefore have to reinvent themselves and adopt new methods to remain competitive.

Within it, the food and beverage industry consist of various segments, including manufacturing, processing, distribution, and retail. Each of these components plays a significant role in ensuring the availability of diverse food products, while navigating complex supply chain dynamics. The interactions between these segments not only affect operational efficiency, but also pricing strategies and consumer access to goods.

Importance of Cost Structure

Understanding the cost structure of the food and beverage industry is equally important. The industry faces a multitude of cost factors, including raw materials, labor, marketing, and overhead. These costs are subject to fluctuations determined by economic conditions, regulatory changes, and changes in consumer demand. Analyzing these elements offers insights into the challenges and opportunities that companies face in maintaining profitability and sustainability.

1.4 RECENT TRENDS AND EXTERNAL IMPACTS

In recent years, the food and beverage industry has experienced notable performance trends influenced by various external factors. The COVID-19 pandemic, for example, has had profound impacts on consumer behavior and market dynamics, prompting companies to quickly adapt to new realities. As we move forward, it is essential to assess how these trends will continue to affect the industry and what challenges lie ahead. It is worth remembering that the sector we are considering has suffered serious repercussions during the pandemic emergency, if possible to an even greater extent than others, as it is specifically linked to outdoor activities and in company.

According to the Annual Report prepared by FIPE-Confcommercio for the year 2021, in the two-year period 2020-2021, 45 thousand companies ceased operations, while 34.1% of those still operating declare that they have a lower number of employees than in 2019.

However, there is no shortage of signs of recovery, which is inevitably expected to be massive, at least in the short term. In terms of turnover, the year 2021 closed with an increase of 22% compared to 2020 (although below 22.4% compared to 2019).

In addition, the sector is now facing another major challenge, a consequence of the generalized effort of companies towards the ecological transition and which will result in greater consumer attention to healthy food with low environmental impact.

Not to mention that in Italy the number of vegetarians and vegans, which has been growing for years, now amounts to 8.3% of the population, an impressive slice that cannot be ignored.

Also, according to the FIPE-Confcommercio report, the public sector employs 876 thousand workers in Italy, of which 796 thousand are employees. These are mainly young people: about 40% are under 30 years old and 62% under 40.

In general, 79% of the employment of the entire "Hotels and public establishments" sector is attributable to catering activities.

There are 112,751 registered businesses run by women (52.2% restaurants, 46.8% bars and 1% canteens and catering), equal to 28.5% of the total. Those managed by young people under 35 are 50,952, equal to 12.8% of the total, distributed as follows:

- 58.0% restaurants;
- 41.4% bar;
- 0.6% canteens and catering.

On the other hand, there are less than 50 thousand companies with foreign owners, equal to 12.6% of the total.

As far as distribution on the territory is concerned, public services are well present throughout the Peninsula, with 3 regions in particular in which a large number of companies are concentrated:

- Lombardy (14.8% of the total number of companies);
- Lazio (10.8%);
- Campania (10.1%).

The **costs of raw materials** represent one of the most significant items. Ingredients, such as grains, meat, fruits, and vegetables, form the basis for food and beverage production. The price of these commodities can vary greatly based on the season and market conditions. For example, a bountiful harvest can bring down prices, while adverse weather events can cause them to rise.

The **food cost**, which represents the cost of the raw materials used for the preparation of the dishes, affects on average 28-30% of the final sale price. It is crucial to monitor this value to ensure adequate profit margins. An ideal food cost should not exceed 30% of total turnover.

Similarly, **beverage cost** is about the costs associated with beverages, both alcoholic and non-alcoholic, and must be managed carefully, as it can significantly affect profit margins.

Moving on to the **production** phase, labor costs come into play here. The wages and benefits for workers involved in the production process, from processing to packaging, represent a significant investment. Added to these are the costs for **energy**, necessary to power the machines and maintain the operational facilities, and those for the **maintenance** of the equipment, which must always be in excellent condition to ensure efficiency.

We cannot forget about the **packaging costs**. Packaging is essential for the preservation and presentation of products and must comply with strict food safety regulations. These materials, therefore, are not just a cost, but a fundamental aspect for the quality of the final product.

When it comes to **distribution**, logistics costs are crucial. Transporting goods from production sites to points of sale involves significant expenses, as does managing the warehouses where products are stored. Proper management of these costs is essential for maintaining an efficient workflow.

Additionally, businesses must consider **marketing and sales costs**. Product promotion is vital to attracting consumers, and this involves investing in advertising and promotional campaigns.

Another key aspect concerns **compliance** and regulatory costs. Companies must comply with health and food safety regulations, which can result in expenses for audits and certifications necessary to operate legally and safely.

Finally, there are indirect **costs**, such as rent and utilities, which represent overhead operating expenses. These costs, while not directly related to production, significantly affect the company's balance sheet.

All of these factors not only affect operating costs, but also affect pricing strategies. Companies must be prepared to adapt to market fluctuations, which can increase costs and, consequently, consumer prices. In addition, there is a growing focus on sustainability, which, while it may initially increase costs, can lead to long-term savings and a better brand image.

In conclusion, cost management in the food and beverage industry is a complex but fundamental task. Every aspect, from production to distribution, must be monitored and optimized to ensure the profitability and competitiveness of the company in the market.

1.5 MARKET PERFORMANCE IN THE FOOD AND BEVERAGE SECTOR

Looking to the future, the food and beverage industry is poised for transformation, driven by emerging trends such as sustainability, health-conscious consumption, and technological innovation. These factors will not only redefine market strategies, but also shape consumer expectations. By exploring these themes, this chapter aims to provide a comprehensive foundation for understanding the complexities and evolving landscape of the food and beverage industry.

Over the last thirty years, the world demand for Food & Beverage has embarked on a path of rapid expansion, supported by the progressive demographic and income increase on the international scene. Particularly significant is the tone of growth inaugurated in the post-pandemic period, which, also thanks to inflationary dynamics, has brought the value of international trade in the segment closer to the threshold of 700 billion euros in 2023 (see Fig.1)

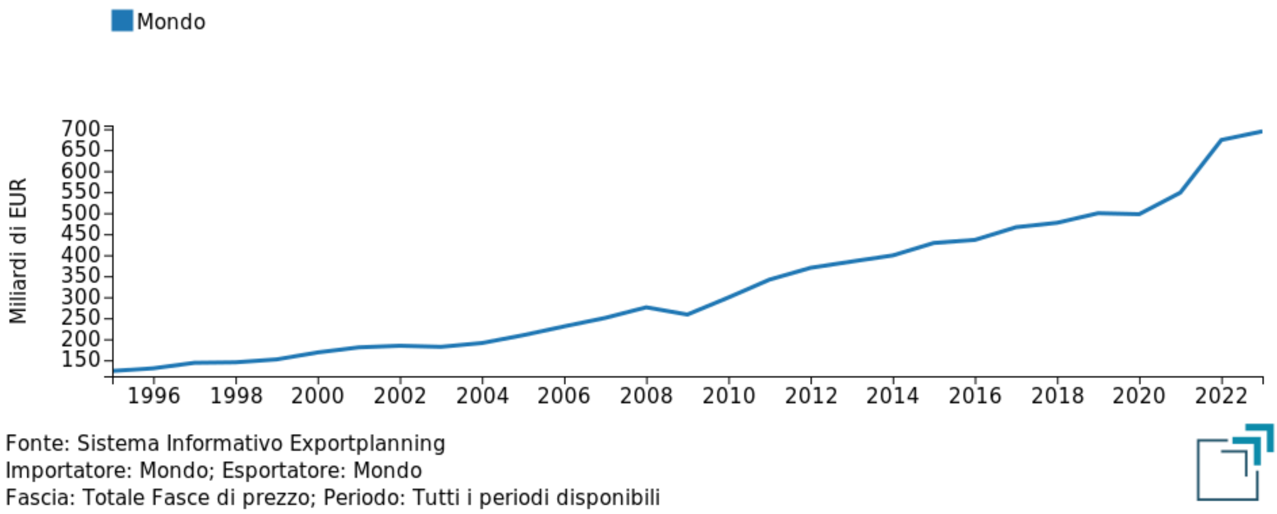

Figure 1 - World demand for Packaged Food and Beverages (1995-2023, billion euros)

Source: ExportPlanning calculations

The Packaged Food and Beverages segment has in fact shown resilience, containing losses in a decline in euros limited to -0.5%, and confirming its acyclical character. The most recent data, relating to 2023, also document a relative resilience of the sector in a context of slowing world trade. Demand for Food & Beverage closed last year with an increase of 3% in euros and a "contained" decline of 2.5 percentage points in real terms (at constant prices), i.e. net of inflationary effects (Fig.2). The result appears particularly significant, not only because it is part of a long-term dynamic of strong growth, but also because it follows a two-year period of sustained real increases.

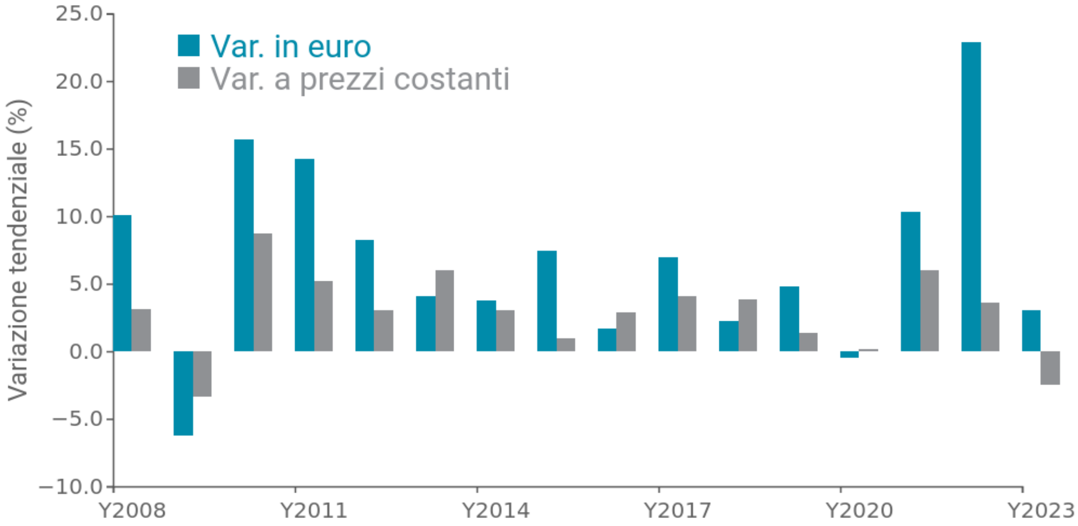

Figure 2 - Growth rates of world demand for Packaged Food and Beverages (annual change in euros and quantities)

Source: ExportPlanning calculations

In the face of the picture just described, the Export Planning forecasts for the current year also appear positive. Thanks to the gradual return to growth and the mitigation of inflationary effects, in 2024 world demand for Food & Beverage is expected to reach 734 billion euros, an increase of 6% compared to 2023.

However, the geography of growth will appear to be differentiated in terms of products and target markets. This will be a factor to be taken into consideration, also by virtue of the importance that the sector plays in being representative of Made in Italy in the world.

The graph below shows the major world geographies, ordered by an expected increase in imports of Packaged Food and Beverages in 2024 compared to 2023.

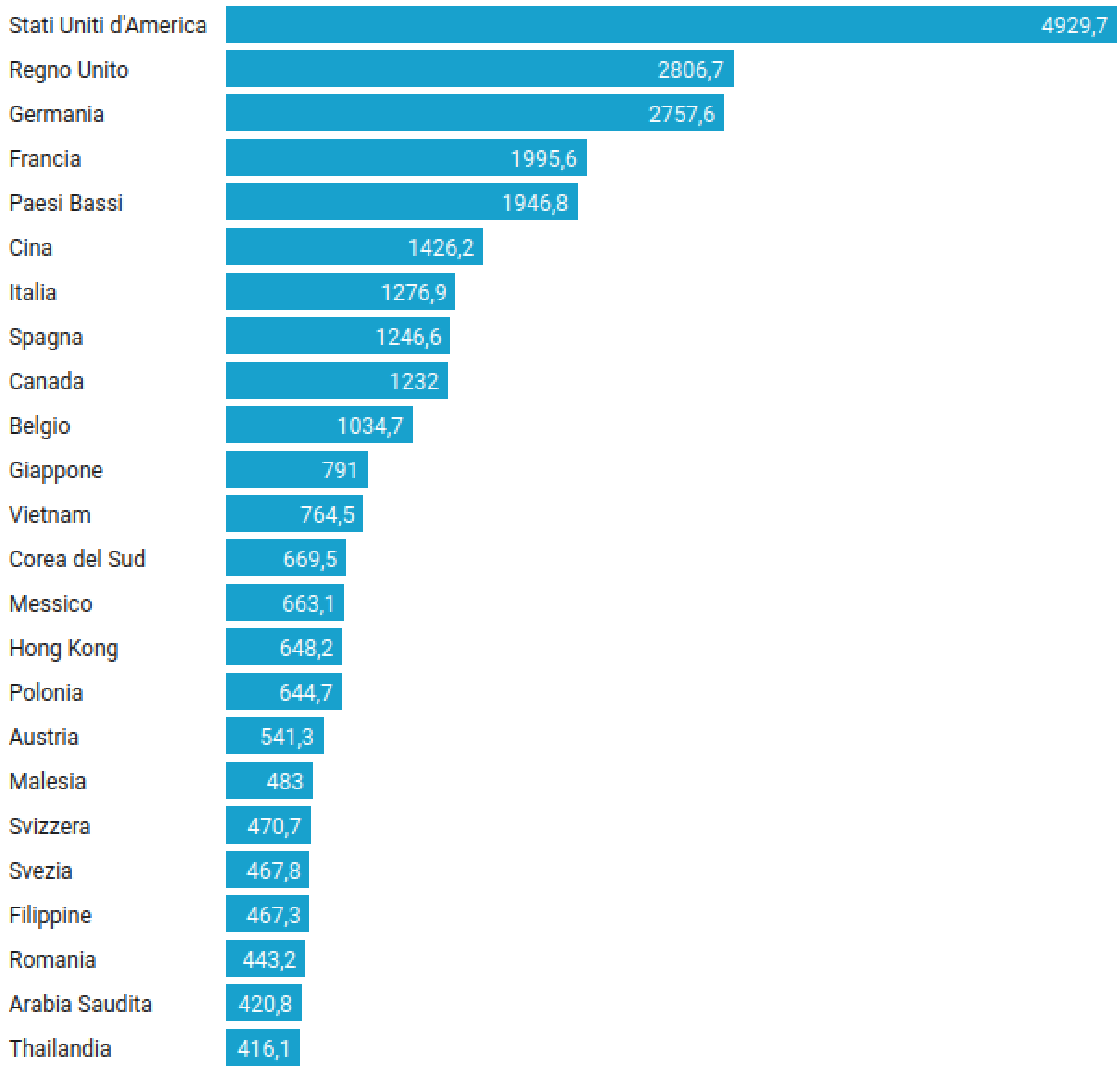

Figure 3 - Expected increases in 2024: absolute change in 2023 for the major markets (million euros)

Source: ExportPlanning calculations

In view of their importance, there are three markets that dominate the ranking: **the United States**, with an expected increase of about 5 billion euros, **the United Kingdom**, for an expected variation of 2.8 billion euros, and, almost equally, **Germany**.

In terms of dynamics, however, it will be the emerging geographies that will be characterized by the best growth rates. These include Vietnam and Mexico, for which an increase of more than 9% is expected, several ASEAN economies - such as Malaysia, the Philippines and Thailand - with variations of 7%, and finally Poland and Hong Kong, with variations above the overall reference average.

Asia: an increasingly significant role

Growth estimates therefore confirm the growing centrality of Asian economies in global demand for the segment, with significant room for growth in the near future, especially in terms of dynamism. From 1995 to today, imports from the Asian area have in fact experienced a significant expansion, with an acceleration at the dawn of the Great Recession. The most relevant aspect is that there has been a progressive and solid increase in the higher price ranges.

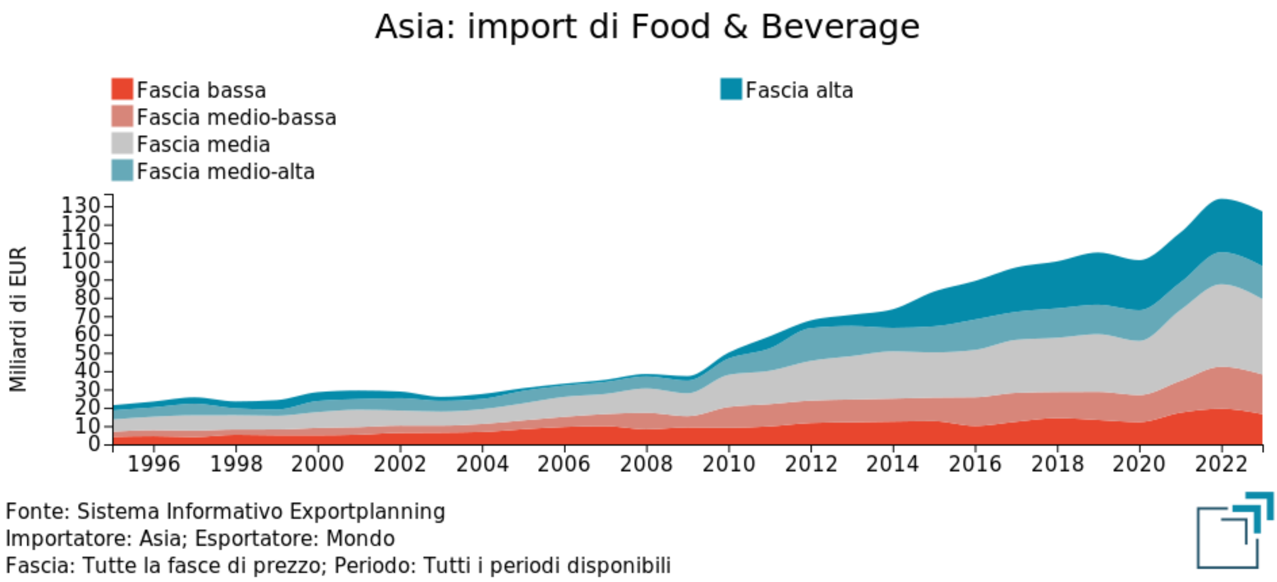

Figure 4 - Asia: import of Food & Beverage

Source: ExportPlanning calculations

China, Japan, South Korea, Hong Kong and Vietnam are the largest importers of Food & Beverage in the area, with an ever-increasing role carved out by the economies ASEAN. If the most recent quarters have seen a relative decline in Chinese imports, greater resilience has characterized the performance of Malaysia, the Philippines, Thailand and Taiwan.

ASEAN Insight and a proposal for a strategic approach to the markets of the area

Thailand, the Philippines, Malaysia, Indonesia, Singapore, Vietnam, Brunei, Laos, Myanmar, Cambodia are currently the 10 countries that adhere to the Association of Southeast Asian Nations: given the minimal growth of the European/Italian economy and the contraction of domestic consumption, ASEAN is increasingly capturing the attention of Italian and European exporters.

On the Italy/Europe side: governments and companies are working to probe markets, develop new commercial partnerships potentially able to cope with the economic instability of the moment. For this reason, attention to ASEAN has significantly increased in recent years as it is an area that continues to grow: over 600 million consumers, with an average age of around 30 and a GDP in full health also in 2023 (Philippines, +5.6%, Vietnam and Indonesia, +5% Malaysia, Thailand and Singapore respectively 3.8%, 2.5%, 1.2%). The political dialogue between the various governments resulted in the formalization of the acceptance of Italy's candidacy (2020) as a Development Partner of the Association of Southeast Asian Nations, a position that is part of a broader European scenario thanks to the free trade agreements signed by the European Union with Singapore and Vietnam.

On the ASEAN side: the Asian world is characterized by continuous change, thanks to the socio-political factors that affect domestic consumption and exports in the first place. In the face of frequent Sino-American tensions, many ASEAN countries are trying to maintain economic relations with China while maintaining political relations with the Americans, guaranteeing themselves freedom of action in the world's major markets. In this scenario, it is necessary to be quick in the adaptation processes otherwise there is a risk of being out of phase with respect to the critical issues and, likewise, to the opportunities that are generated.

The latter must be analyzed, in particular, country by country according to the wide and varied socio-cultural-economic geography to which fundamental factors such as:

1. local production and any protection;
2. composition of the population (age, income, education, etc.), mindset (experience, palate, cultural expressions, propensity for comparison), needs of the population in the light of long-term government plans which, for example, have the health and well-being of their citizens as a priority;
3. attitude towards Italy and the perception of the Italian product;
4. potential local Ambassadors (Chefs and/or others) and any presence/number of the Italian community on site;
5. other possible factors.

In short, we should go beyond the vision of the country to which we would like to export as a huge supermarket shelf, or as an endless table laden with all the PDO, PGI delicacies, DOCG. It has been done a more analytical job that involves, upstream, the collection and analysis of as much information as possible starting from the aspects characterizing one's product (selling points) and its natural price positioning.

A concrete example for an Italian producer of healthy F&B

If a country indicates, among its Guidelines, the opportunity to prioritize the trade of healthy food products to prevent the onset of diabetes and/or cardiovascular disease, the strategy could be to meet local nutritionists/dietitians, articulate arguments tailored to the needs of the population, develop ad hoc bundles, present them to retailers and/or Chefs (chosen by positioning) and, finally, meet importers with a good number of potential expressions of interest. In this way, the "best importer", future partner, is "offered" an interesting opportunity to increase his turnover and, finally, the expression WIN-WIN can be given shape. The timing and budget are obviously to be expected , but they would also be in the traditional way , and since they could be significant, it would be appropriate for our producers to work in a network also in order to become even more relevant in terms of the breadth and depth of the assortment, structured in a grid of opportunities for access to the market: from the entry price to the premium price.

In summary, the food and beverage sector present significant challenges in terms of energy consumption and sustainability, but also opportunities to improve efficiency and reduce environmental impact.

With an understanding of the dynamics of the food and beverage sector, it is essential to examine global energy consumption to better contextualize the challenges and opportunities.

1.6 GLOBAL ENERGY CONSUMPTION

1.6.1 Typical energy mix of an industrial plant

For the past 20 years, the European Union has been working towards the development and increase of the electricity production park from renewable sources to achieve these objectives and ensure responsible and competitive industrial production.

An industrial plant adopts an energy mix, i.e. a balance between different energy sources, optimized to maximize efficiency and minimize environmental impact. The energy mix, according to the Energy Services Manager (GSE) is the set of primary energy sources used for the production of electricity supplied by sales companies to end customers. It describes the origin of the electricity sold by a wholesaler to a customer over a certain period of time. That is, it lists the different sources used to produce the energy sold and indicates the percentage of contribution for each source.

The sources are divided into:

- **Primary:** i.e. those present in nature before being subjected to any transformation process. By custom, they are divided into renewable (or non-exhaustible) and non-renewable (or exhaustible). Renewable sources are, for example, hydraulic, solar, wind and geothermal. Non-renewables, on the other hand, are nuclear fuels and fossil fuels, such as oil, natural gas, coal, etc. Today, to reach the amount of electricity needed for Italian needs, sources of both kinds are used. And every year the National Energy Mix tells us which sources there are and in what percentage, compared to the total, each of them has been used.
- **Secondary**: i.e. energy sources also called derivative, since they are the result of the transformation of a primary energy source. Or the further process of transformation of a secondary source.

Going into detail, common energy sources can be classified as follows:

1. **Electricity**: It is one of the main sources of energy for industrial plants. It is used to power machinery, lighting, control systems, and other equipment. Electricity can come from a variety of sources, including fossil fuel, nuclear, hydroelectric, and renewable power plants such as solar and wind.

2. **Natural Gas**: Widely used for heating, steam production and as a fuel for some industrial processes. It is appreciated for its efficiency and lower CO2 emissions compared to other fossil fuels.
3. **Coal**: Although declining due to environmental concerns, coal is still used in some industries, especially those that require large amounts of thermal energy.
4. **Petroleum and Derivatives**: Mainly used in specific industries such as oil refining and chemical manufacturing. Oil can also be used for the generation of electricity and heat.
5. **Renewable Sources**: The use of renewable energies such as solar, wind, biomass and geothermal is growing. These sources are particularly important for reducing the environmental impact and improving the sustainability of industrial plants.

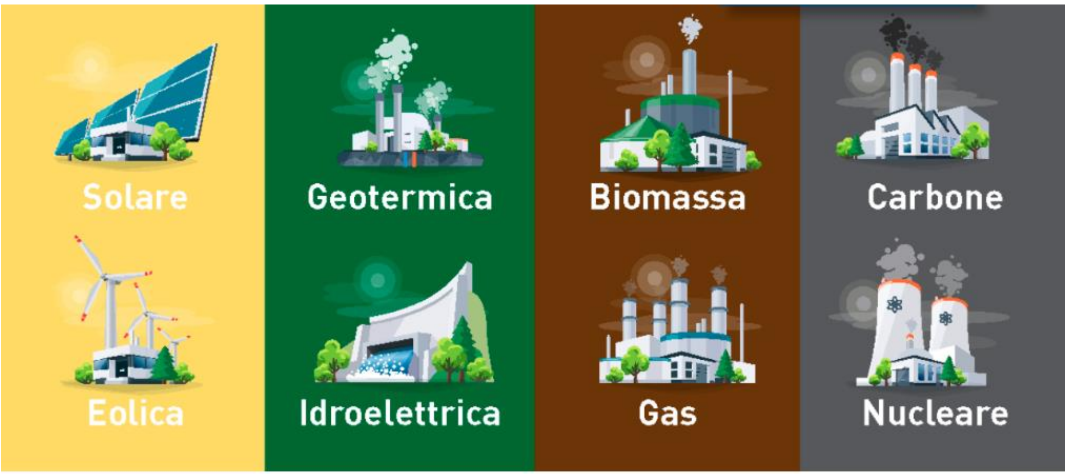

Figure 5 - The energy mix

Looking at the data, whose source is the national TSOs, of electricity production in 2019 of some of the main European countries (Italy – France – Germany – Spain), it is possible to understand some fundamental elements that characterize the different markets and the dynamics that are found on prices.

Italy: the main source for electricity production is natural gas (over 45%), renewables and hydroelectric produce almost 40% of total energy and coal has a role limited to less than 10%.

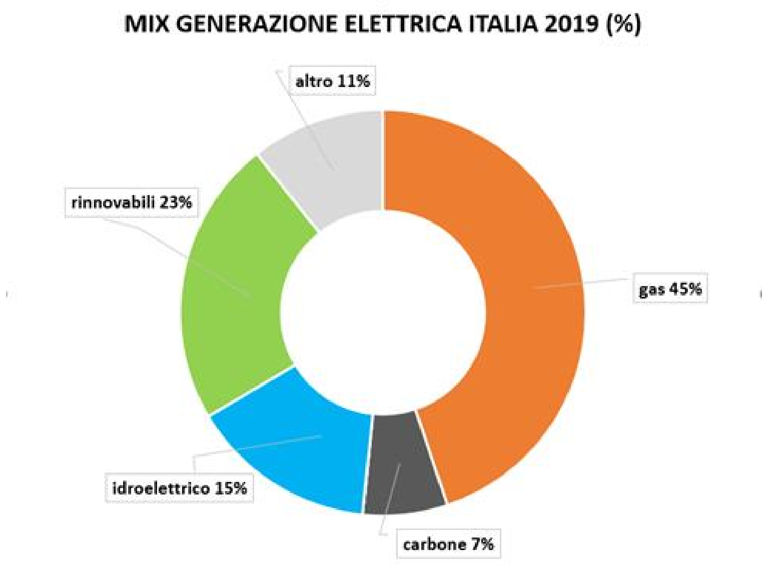

Figure 6 - Italian electricity generation mix 2019 (%)

France: more than 70% is produced by nuclear, renewables and Cuban hydroelectric almost 20%, while the remainder is produced by gas or other fuels.

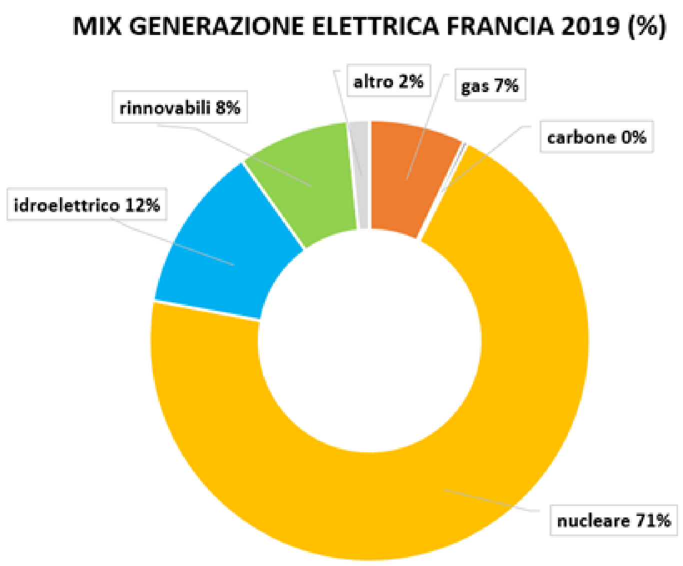

Figure 7 - French electricity generation mix 2019 (%)

Germany: more than 40% was produced from renewables and hydropower, coal has the role of primary fossil source (almost 35%), then nuclear and gas.

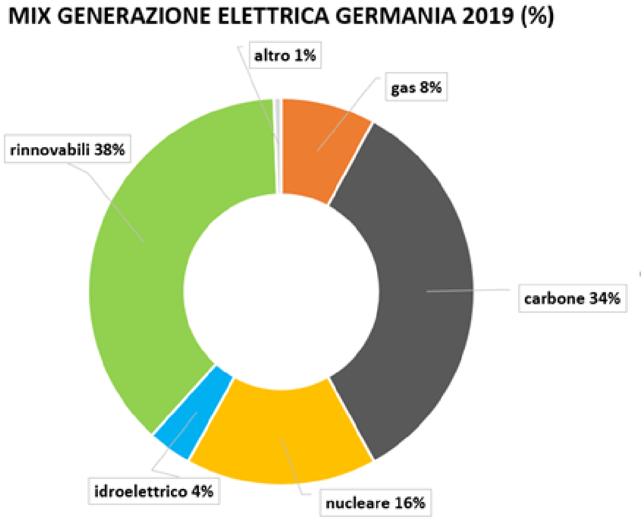

Figure 8 - German electricity generation mix 2019 (%)

From the graphs above we can see that the share of electricity production from renewable sources is significant (close to 40%) in all the countries considered, with the exception of France, where national policies aimed at maximizing nuclear profits have not yet allowed the green share to exceed 20%.

In a generation park so rich in non-programmable renewable sources (in particular photovoltaic and wind), however, it is not possible to assume, in the short term, a complete decommissioning of traditional fuel power plants.

Due to the non-programmability and frequent fluctuation of renewable output, in fact, it is necessary to combine renewables with programmable and flexible production plants, to meet demand at times when the sun or wind are not available. Precisely for this reason, natural gas is the preferable source of thermoelectric generation, both for the greater flexibility it offers compared to coal, for example, and for the lower amount of emissions produced in the combustion process.

The high share of renewables in the generation mix, in addition to the need for flexible resources to integrate, has other less obvious implications. If with gas and coal the impact of the weather factor is not significant compared to production, with renewables this takes on crucial importance. Sun or clouds, strong or light wind, rain or drought.

These elements become more important as the penetration of renewables in the electricity production mix progresses, and for this reason the weather factor becomes even more forcefully among the elements that determine prices in the short term.

The food and beverage sector is a major consumer of energy in industry, with a growing demand for sustainable energy solutions. This industry includes a wide range of activities, from food and beverage production to food and beverage processing and preservation. The adoption of renewable energy technologies can play a crucial role in reducing environmental impact and improving energy efficiency.

In 2030, the food and beverage industry is estimated to use approximately 4.2 EJ (exajoules) of fossil fuels for process heat generation. In addition, it is expected to use around 1.3 EJ of renewable energy, mainly biomass and combustible waste. This sector has one of the highest percentages of renewable energy use in the fuel mix, with more than 40% of total energy consumption coming from renewable sources.

Figure 9 - Energy consumption in industry by production sector (%)

Between 2005 and 2016, for all national production sectors, drops in energy consumption of up to over 30% were observed: for food the decrease was 18%. However, 2016 and 2017 seem to be turning points: almost all sectors, in fact, have achieved significant increases in final consumption.

To understand whether consumption trends are linked to greater or lesser efficiency or to production trends, however, it is necessary to analyze energy intensity, i.e. the ratio between the sector's final consumption and added value: the lower the energy intensity, the more virtuous the sector. For food in the years from 1996 to 2016, a limited reduction in energy intensity of 7.1% was observed, with a recovery (+1%) in the years 2015-2016. On balance, the sector shows a high energy intensity and, consequently, wide possibilities for efficiency.

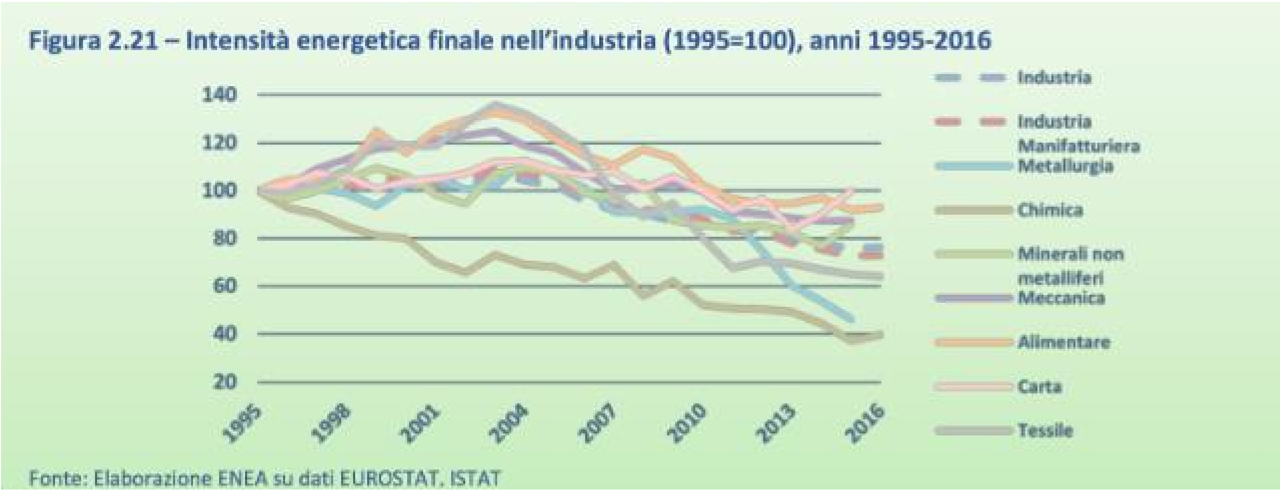

Figure 10 - Final energy intensity in industry

The food system brings together a complex set of activities that deal with the processing of raw materials, not to mention the agricultural sector and distribution. An idea of the variety of activities in the sector can be found in the following table for the end of 2017.

CLASSIFICAZIONE DELLE INDUSTRIE ALIMENTARI SULLA BASE DEL CODICE ATECO	NR. IMPRESE
Produzione di prodotti da forno e farinacei	35.448
Produzione di altri prodotti alimentari	5.416
Lavorazione e conservazione di carne e produzione di prodotti a base di carne	3.585
Industria lattiero-casearia	3.374
Produzione di oli e grassi vegetali e animali	3.344
Lavorazione e conservazione di frutta e ortaggi	1.785
Lavorazione delle granaglie, produzione di amidi e di prodotti amidacei	1.059
Produzione di prodotti per l'alimentazione degli animali	529
Lavorazione e conservazione di pesce, crostacei e molluschi	391

Figure 11 - Classification of food industries based on the Ateco code

The variety of activities in the food industry involves very diverse energy uses. Suffice it to say that according to RSE (Research on the Energy System) the energy consumption associated with 1 kg of ready-to-eat food varies from a minimum of 0.5 kWh to a maximum of 61 kWh, depending on the type of food (animal or vegetable), cultivation and processing techniques and transport.

This is followed by post-process operations, such as packaging and storage in a protected atmosphere, necessary to distribute food from the production sites to distributors and consumers.

The beverage and food sector is highly energy-intensive and water-intensive, with a significant impact on greenhouse gas emissions and the consumption of natural resources. However, the adoption of decarbonization and resource efficient management techniques can significantly reduce these impacts, contributing to a more sustainable future. The goal is ambitious: to achieve net zero emissions by 2050. This sector is crucial because it contributes significantly to global CO_2 emissions, and therefore its transformation is essential to address climate change.

Currently, the food and beverage sector in Europe generates around 94 million tons of CO_2 equivalent per year. This represents 11% of total food value chain emissions. To give an idea of the scale, these emissions are almost equivalent to those of the whole of Belgium. Most of these emissions come from energy use: about two-thirds of the energy consumed is in the form of heat, while one-third is electricity from the grid. Interestingly, a significant portion of electricity is used for cooling, a distinctive aspect of the food industry compared to other industries.

The food and drink sector also has great potential for the use of bioenergy and waste. Food waste can be converted into biogas through anaerobic digestion, a process that produces a mixture of methane and carbon dioxide. This biogas can be used to generate electricity and heat, reducing dependence on the electricity grid and contributing to energy sustainability.

Food is the most important sector of the manufacturing industry in the European Union, with a presence of small and medium-sized enterprises of over 90% distributed mainly in Southern Europe (only 1% of companies in the sector can be classified as "large companies"). Italy, in particular, is going through a positive period: in 2017 the turnover of the food industry reached 137 billion euros, with an increase of 2.6% compared to the previous year. A result that has no equal in the last decade, driven above all by exports (+6%), which confirms the appreciation for the quality of national products. The number of companies in the sector reached 58,413 (+0.2% on 2016 and +3.5% on 2010) and is worth almost 12% of the total industry.

In the coming decades, a major challenge arises for the sector worldwide. The FAO (Food and Agriculture Organization of the United Nations), in fact, has predicted that the world population will rise to over 9 billion in 2050 and that it will therefore be necessary to produce 70% more food.

The food sector, from agricultural production to distribution and consumption, has a significant impact on global energy consumption. Agriculture alone consumes about 200 Exajoules of energy per year, a value that exceeds the national energy demand of countries such as China or the United States. When considering the entire life cycle of food, from farm to fork, food production is responsible for about 30% of global energy consumption.

The graph shows the indicative energy consumption of the agri-food sector by type of energy source.

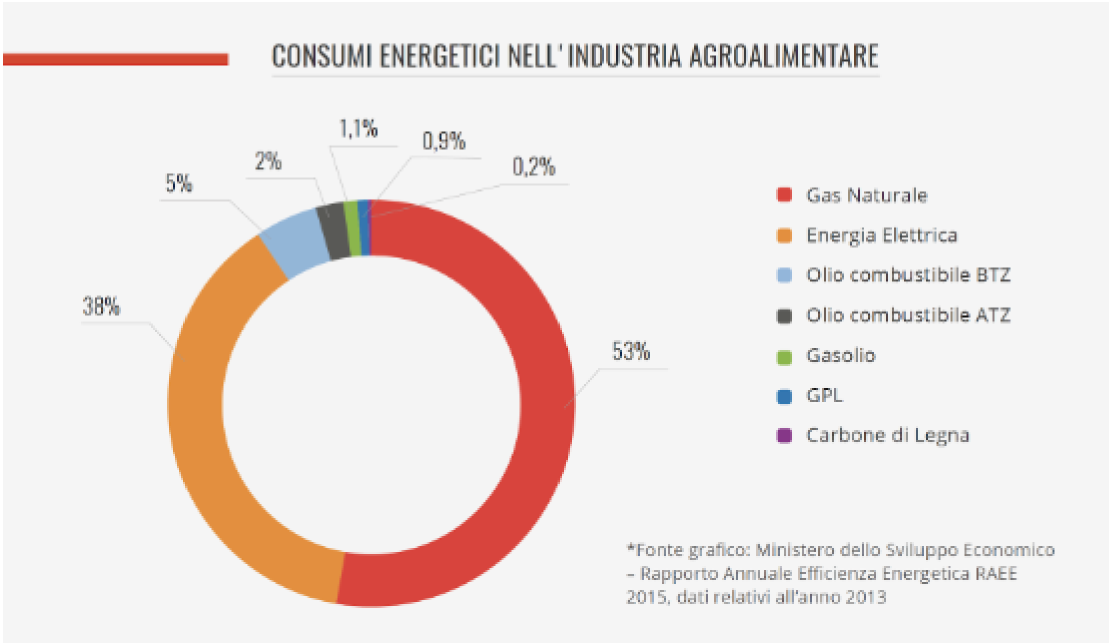

Figure 12 - Main consumption concerns gas and electricity.

Knowing the specific consumption values of one's business is essential not only to adopt efficiency actions, but, even before that, to assess the level of competitiveness and set up new growth strategies. The timely collection of consumption information relating to all machinery and processes, in order to identify any critical issues and assess the feasibility and economic convenience of the actions to be taken, is carried out through the energy diagnosis (or energy audit). With the energy audit it is possible to:

- Define the energy balance of the company or production site;
- Identify the inefficiencies of the plants/processes also following comparisons with industry benchmarks;
- Identify efficiency measures;
- Evaluate the technical feasibility and economic return of an intervention;

The energy audit, mandatory for large companies and energy-intensive companies (Legislative Decree 102/2014), can be requested by any structure that wants to focus on savings. The analysis must be carried out by an authorized figure such as an EGE (Energy Management Expert) or a certified ESCo.

In the face of growing demand and constant international competitiveness, the domestic food industry must also rethink products so that they use fewer resources (energy, water, raw materials) and have a low ecological footprint. Actions should focus on the following aspects:

• Sustainable procurement and full exploitation of agricultural raw materials;

• Efficient use of resources and reduction of emissions;

• Optimization of packaging and correct management of post-use packaging;

• Policies and actions aimed at preventing waste and promoting sustainable development.

The food system is the largest land user on the planet. For example, vineyards occupy about 7.5 million hectares of land, while cereals are grown on 700 million hectares, an area twice the geographical size of India. This intensive land use has a significant impact on the environment, contributing to biodiversity loss and land conversion.

From an energy point of view, the Italian agri-food sector has high consumption, equivalent to about 11% of industrial consumption (data from the Annual Report on Energy Efficiency of Enea 2018). The effort of companies in the sector, which have long been oriented towards diversifying energy sources and increasing the contribution of renewables, must therefore continue with the search for innovative solutions that allow energy consumption and costs to be lowered. The goal is to provide useful information to operators in the food industry to guide them towards efficiency. By analyzing the consumption of the sector in relation to the different processes, indicating how to carry out an energy diagnosis, an overview is provided of the recommended interventions to improve performance and the economic incentives available to reduce the cost of the investment.

Another critical aspect of the food sector is waste. More than a third of the food grown, procured and processed is wasted, representing an unacceptable loss of resources and nutrients. This waste occurs throughout the food supply chain, from agricultural production to distribution and final consumption.

Global food systems are directly implicated in some of the most pressing sustainability challenges. They contribute to 60% of biodiversity loss, 60% of land conversion, 70% of nutrient overload and 30% of climate change. In addition, the food system contributes to more than 50% of water eutrophication, a process in which lakes and rivers receive excess nutrients and begin to collapse.

In the food and beverage industry, the processes that consume the most energy vary from industry to industry. In some sectors, pumps and fans are responsible for the majority of consumption. For example, in agriculture these are ventilation systems for animals, while in the dairy industry they are cooling and refrigeration. In other segments, the most energy-intensive processes are grinding and machining, e.g. grinding and centrifuging in sugar processing, or grain grinding in the ingredient sector. In the confectionery industry, burrs, troughs, compressors and mixers are the machines that consume the most energy.

With a clear view of global energy consumption, we can now explore the European metrics adopted and the calculation of key performance indicators (KPIs).

1.6.2 European metrics adopted, calculation of KPI's.

The Paris Agreement, finalized at COP21 in December 2015, established a key objective: to cap global temperature increases well below 2°C above pre-industrial levels, while pursuing efforts to limit the rise to 1.5°C to prevent the most damaging effects of climate change. To meet this challenge, the European Union (EU) and the UK have pledged to achieve net-zero emissions by 2050. As part of this commitment, in September 2020, the European Commission proposed a target of reducing the EU's net greenhouse gas (GHG) emissions by at least 55% by 2030. This goal is designed to align with the EU's broader Green Deal ambitions of achieving net-zero emissions by 2050. The Commission's assessment affirmed that this reduction target is both feasible and achievable. Achieving this ambitious goal will require decarbonization across all sectors, including the food and beverage industry. The EU Emissions Trading System (ETS) is a cornerstone of this strategy. The ETS mandates that companies obtain permits for each ton of CO_2 they emit, which they must purchase through auctions, providing an economic incentive to cut emissions. Certain allowances are also granted to foster innovation in key sectors. Progress toward these objectives has been driven by improvements in energy efficiency, better water management, and more sustainable transportation and logistics. The shift to renewable energy, reduction of food waste, and a stronger emphasis on circular economic principles, including the use of eco-friendly packaging, are equally critical. ETS, which regulates around 40% of the EU's greenhouse gas emissions and encompasses about 11,000 power plants and industrial sites, is the world's largest carbon market. In April 2023, the system was reformed to further reduce emissions by 62% by 2030, compared to 2005 levels, to stay on track with the EU's climate objectives These updates reflect the EU's commitment to meeting its climate goals by ensuring that carbon-intensive industries transition toward more sustainable and low-emission practices.

To reduce energy waste, it is necessary to acquire information with the use of an energy efficiency plan that includes defining and calculating the specific energy consumption of the activity, the definition of annual KPIs and the planning of periodic improvement objectives.

The main steps to calculate KPIs are:

1. **Definition of Specific Energy Consumption**:
    a. Calculate the specific energy consumption of the activity in terms of MWh/tonne of product.
2. **Production Data Collection**:
    a. Multiply the production rates with the specific energy consumption to get the total annual energy consumption (MWh/year).
3. **Energy Consumption Breakdown**:
    a. Collect indicative data on the percentage breakdown of energy consumption in electricity and heat for each sub-sector.
4. **Estimation of Greenhouse Gas (GHG) Emissions**:
    a. Calculate the CO2e emissions generated by the electricity use of the grid by multiplying the electricity consumption by the CO2e intensity of the electricity grid.
5. **Planning of Improvement Objectives**:
    a. Define periodic improvement targets and related actions to reduce energy consumption and improve efficiency.

These steps provide a framework for determining energy efficiency and defining KPIs, ensuring continuous improvement of energy performance in the food and beverage industries.

In conclusion, European metrics and KPIs provide a clear framework for measuring and improving energy efficiency in the food and beverage sector.

Key parameters for water and energy consumption across the F&B sector

The FDM sector represents around 10% of the total industrial energy consumption in the EU-28. Below are described the Key parameters able to define the energy and water consumption across the F&B sector.

Energy consumption

The calculation of specific energy consumption is based on the following equation:

$$specific\ energy\ consumption = \frac{final\ energy\ consumption}{activity\ rate} \tag{1. 1}$$

Final energy consumption is the total amount of energy consumed by the specific processes concerned during the production period, in the form of heat and electricity, expressed in MWh/year.

Water consumption

The calculation of specific water consumption is based on the following equation:

$$specific\ water\ consumption = \frac{water\ consumption}{activity\ rate} \tag{1. 2}$$

Where water consumption is the total amount of water consumed by the specific processes concerned during the production period, expressed in m3/year.

Activity rate is the total amount of products or raw materials processed, depending on the specific sector, expressed in tonnes/year or hl/year. Packaging is not included in the weight of the product.

After examining the metrics and KPIs, it is useful to compare energy consumption across different industrial sectors to identify best practices and areas for improvement.

1.6.3 Analysis and Comparisons Across industrial sector

According to the 2018 Annual Report on Energy Efficiency by ENEA, which is based on Eurostat data, in 2016 the Italian agri-food industry absorbed a total of about 11% of the industry's final consumption, which is distributed as follows: 11.3% of electricity consumption, 11.3% of LPG and 7.8% of diesel. If we consider the different sectors that make up the production chain (primary production, agro-industry, trade and services), it is one of the most energy-intensive sectors in terms of total energy consumption, after mechanical, steel and chemicals.

The sector is extremely diverse, encompassing numerous sub-sectors such as bakery, meat and poultry processing, brewing and malting, fruit and vegetable processing and preservation, dairy and cheese production, sugar and confectionery production, and oil and fat production. Each sub-sector has specific energy needs, which vary according to the production processes used.

The food industry is characterized by significant energy consumption: at European level (EU-28), it is estimated that they are worth, including all processes from transformation to distribution of products, 12% of the primary energy consumed by the entire European industry.

The food sector is characterized by a great diversification of products, each with a specific energy requirement.

Here is a graphical representation of energy consumption in the different subsectors of food and beverages:

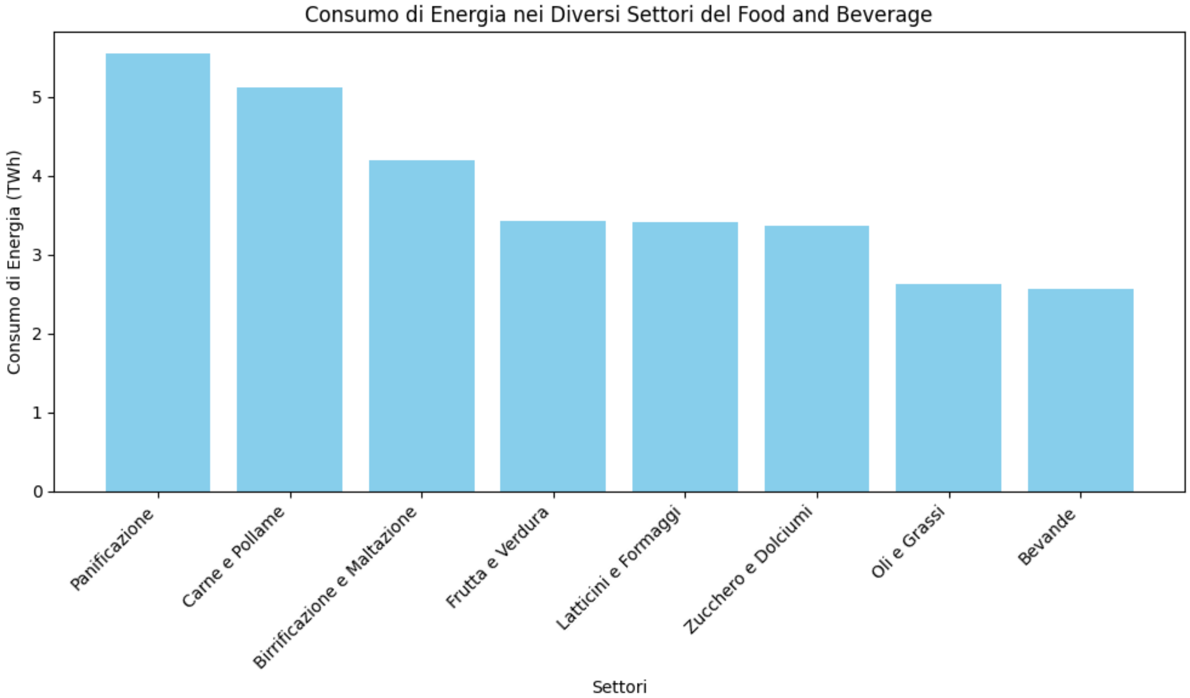

Figure 13 - Energy consumption in the various food and beverage sectors

Details of Energy Consumption by Subsector

- **Bakery**: 5.54 TWh
- **Meat and Poultry**: 5.11 TWh
- **Brewing and Malting**: 4.19 TWh
- **Fruits and Vegetables**: 3.42 TWh
- **Dairy products and cheeses**: 3.41 TWh
- **Sugar & Confectionery**: 3.37 TWh
- **Oils and Fats**: 2.63 TWh
- **Drinks**: 2.56 TWh

For example, in the bakery industry, a large amount of energy is used to power ovens, which require high temperatures to bake bread and other baked goods. In the meat and poultry industry, energy is primarily used for cooking and refrigeration, which are essential processes to ensure food safety and the quality of the final product. Brewing and malting require energy for malt cooking and fermentation, while dairy and cheese processing requires energy for pasteurization and refrigeration.

Agricultural production and the supply of raw materials are highly dependent on fossil fuel-based fertilizers. Modern agriculture uses fertilizers, pesticides, and herbicides to transform ecosystems, which has a significant impact on greenhouse gas emissions. For example, livestock production is responsible for 18% of global greenhouse gas emissions and 80% of anthropogenic land use. In addition, enteric livestock fermentation and manure management produce large amounts of methane. Agriculture is the largest consumer of water globally. Techniques such as precision irrigation can significantly reduce water consumption while improving crop efficiency. Efficient water management is crucial to reducing the environmental impact of agricultural production.

The production of fruit and vegetables, especially frozen ones, is a large consumer of electricity and natural gas. Deep freezing is the process that uses the most electricity, with energy consumption ranging between 80 and 280 kWh per ton of frozen vegetables. Water consumption for fruit and vegetable production varies greatly. Energy consumption is affected by various factors, including the type of food being frozen, the temperature of the food at the entrance to the freezing tunnel, and the surface area of the tunnel. For example, bulky vegetables like cauliflower are harder to freeze than smaller vegetables like peas or diced carrots.

For example, for the production of French fries, the specific water consumption ranges from 1.25 to 4.3 m^3 per tonne of raw potatoes. Other potato products show water consumption ranging from 2.7 to 5 m^3 per tonne of raw potatoes.

The production of animal feed is also an energy-intensive sector. Specific energy consumption varies between products, with relevant activities such as pelletizing and heat treatment for salmonella decontamination requiring a lot of energy. The data show that the specific energy consumption for compound feed production is generally low, thanks to the adoption of energy efficiency techniques. The specific water consumption to produce compound feed is generally low. This is due to the adoption of water efficiency techniques that help reduce overall water consumption and improve the sustainability of operations.

Food processing and processing are extremely energy-intensive processes. Food industries use energy for a wide range of applications, including steam or hot water production, drying, refrigeration, and cooking.

Steam plays a crucial role in many processes in the food and drink industry. It is used for cooking, sterilization, humidification, and drying. For example, steaming tunnels are used for cooking vegetables, rice, grains, seafood, and meat. Steam sterilization is essential to ensure that bottles and cans are free of contaminants before filling. Steam drying is used to remove excess moisture from foods such as fruits and vegetables, extending their shelf life.

Some of the most energy-intensive processes include:

- Cooking and Boiling: Used for the preparation of various foods, they require large amounts of thermal energy.
- Refrigeration and Freezing: Essential for preserving food, they represent a significant part of energy consumption.
- Drying and Evaporation: Used to remove water from food, they are energy-intensive processes.

It is possible to trace the manufacturing processes of the food industry to 4 main phases:

- Preparation of raw materials (sorting, washing, thawing, size reduction, mixing, extraction, etc.);
- Treatment processes (soaking, fermentation, drying, pickling, aging, etc.);
- Heat administration for cooking, pasteurization, sterilization, dehydration;
- Cooling, cold stabilization of food and freezing.

Food processing requires large amounts of water for cleaning, cooking, and other processes. For example, beer and beverage production requires water for bottle sterilization and for the fermentation process. The global food industry continues to produce highly processed foods, such as ready-to-eat meals, and sugary beverages, such as sodas. In addition, the production of these foods requires a significant amount of energy and natural resources.

Taking sugar processing as an example to understand the potential savings. Sugar production is very energy-intensive and, therefore, sugar factories are often equipped with their own energy plants. These are generally cogeneration plants, which produce both steam and electricity. The amount of energy used varies at each stage of the process: for example, the preparation and grinding of sugar cane uses about 40% of all the energy consumed by the plant. However, many old factories use a lot of steam from cogeneration boilers to power their processes, resulting in a high level of inefficiency. Converting steam processes to electrical processes can greatly improve energy efficiency.

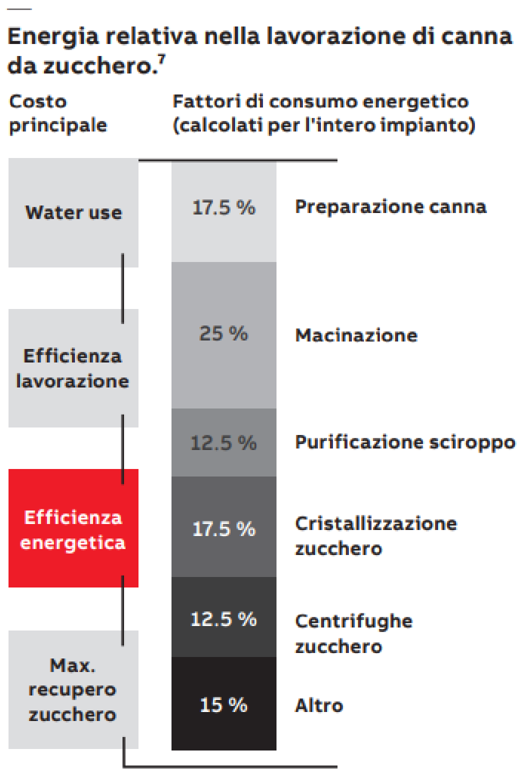

Figure 14 - Relative energy in sugarcane processing

The production of soft drinks and nectars requires significant energy consumption, which varies depending on the installations. The data collected show that specific energy consumption values are generally less than 0.035 MWh per hectolitre of product. This energy consumption is influenced by various factors, including the efficiency of the technologies used and the operating practices adopted.

Brewing is another industry with significant energy consumption. Breweries report a specific energy consumption of less than 0.6 MWh per hectolitre of product in most cases. The water recycling rate varies between 1% and 23%, depending on the operating practices adopted.

Food distribution and retail require energy for refrigeration, lighting, heating, and space cooling. In supermarkets, for example, refrigeration systems can account for between 30% and 60% of total electricity consumption. In addition, the transport of food, often over long distances, contributes significantly to greenhouse gas emissions.

By comparing energy consumption across sectors, we can now delve into industrial energy solutions to improve efficiency.

1.6.4 Main Energy sources in the industrial sector

In today's industrial landscape, understanding the main energy sources used in a plant is crucial for optimizing operations and ensuring sustainability. Energy is the lifeblood of any manufacturing facility, powering machinery, processes, and systems that transform raw materials into finished products. The choice of energy sources not only affects operational efficiency but also has significant implications for environmental impact and cost-effectiveness.

The primary energy sources utilized in plants can vary widely depending on the industry, geographical location, and technological advancements. Traditional sources, such as fossil fuels, have long dominated the energy mix, providing reliable power for various industrial applications. However, the growing emphasis on sustainability and carbon reduction has led to an increasing interest in renewable energy sources, such as solar, wind, and biomass.

Each energy source comes with its own set of advantages and challenges. Fossil fuels, while currently abundant and relatively inexpensive, contribute to greenhouse gas emissions and environmental degradation. Conversely, renewable sources offer cleaner alternatives but may require substantial initial investments and infrastructure changes.

As industries strive to reduce their carbon footprint and embrace more sustainable practices, the transition to a diversified energy portfolio becomes essential. This not only involves integrating renewable energy solutions but also optimizing energy efficiency within existing systems. By doing so, plants can enhance their resilience, reduce operational costs, and contribute to a more sustainable future.

In this context, we will explore the various energy sources commonly used in industrial plants, examining their characteristics, applications, and the potential for future developments in energy consumption. This analysis will provide valuable insights into how industries can adapt and thrive in an increasingly energy-conscious world.

1.6.4.1 Thermal energy

Thermal energy plays a fundamental role in the industrial sector, powering numerous production processes such as heating, sterilization, drying, and material melting. It is primarily generated from fossil fuels (such as natural gas, coal, and fuel oil) and, increasingly, from renewable sources (such as biomass and solar thermal energy).

The techniques currently adopted in the sector are summarized as follows:

Cogeneration Systems (CHP)

Cogeneration systems, also known as CHP (Combined Heat and Power), are highly efficient because they produce both electricity and useful heat. These systems can achieve energy efficiency of up to 90%, optimizing the use of fossil fuels and reducing CO2, NOx and SO2 emissions. For example, a CHP plant can generate 600 kWh of electricity and 600 kWh of thermal energy, with a total cost of about 1 million euros.

Heat Exchangers

Heat exchangers are devices that allow heat to be transferred from hot exhaust streams to cold incoming streams. Assume a pipe through which a hot fluid flows, such as wastewater from an industrial process. This pipe is surrounded by another pipe through which a cold fluid flows, such as water that needs to be heated for another process. The heat from the hot fluid is transferred to the cold fluid, heating it without the need for additional energy. This process significantly reduces the energy consumption required for heating.

Heat Pumps

Heat pumps are incredibly versatile devices that can extract heat from low-temperature sources, such as air or water, and raise their temperature for reuse in manufacturing processes. Assume a heat pump that takes heat from the outside air, even if it is cold, and compresses it to increase its temperature. This heat can then be used to heat water or air inside a building or industrial process. Heat pumps are particularly useful because they can work in both directions: they can heat in winter and cool in summer, making them extremely efficient.

Steam generator

Generally, in the food sector, medium-pressure steam generators (greater than 1 bar and up to 15 bar) with three smoke passes (a conformation that allows better seasonal efficiency and lower emissions from the chimney), with a power between 0.5 and 20 t/h of steam, are used. The integral insulation of the system (including the smoke box, doors and plumbing connections) is essential to limit heat loss. Equally fundamental is the provision of heat recovery systems such as economizers and condensers.

Hot water boiler

Similar to steam generators, the latest generation boilers that can be used for industrial processes and space heating are particularly efficient (up to 96%). Integral insulation and heat recovery devices take efficiency to the highest level (up to 100%).

Solar Thermal Collector

Solar thermal collectors consist of pipes or panels in which a heat transfer fluid circulates, usually water or a mixture of water and glycol. When sunlight hits the solar collector, the heat transfer fluid absorbs the heat, heating up. This hot fluid is then conveyed through a system of piping and heat exchangers, transferring the collected thermal energy to a storage tank or directly to the end uses.

In industrial settings, solar thermal systems can be used to heat fluids used in industrial processes, such as sterilization, pasteurization, or washing.

The use of this type of system leads to significant benefits such as energy savings, emission reduction and sustainability. As regards the first advantage, it reduces dependence on non-renewable energy sources and contributes to the reduction of energy costs in the long term as it refers to an unlimited resource. With respect to the second aspect, these plants contribute to the reduction of greenhouse gas emissions and air pollution, improving air quality and mitigating the effects of climate change. Finally, when it comes to sustainability, solar thermal systems are a clean and sustainable form of energy, contributing to the promotion of greener living practices and the transition to a low-carbon economy.

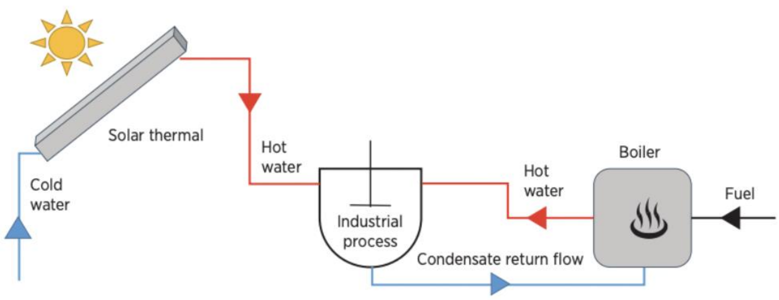

Figure 15 - A solar thermal system for direct heating to process equipment

Source: IRENA

1.6.4.2 Electrical energy

According to the Enea 2023 Annual Energy Efficiency Report, the food industry sector recorded a drop in consumption to 10.3% of the entire industrial sector. The food sector achieved a 27.1% reduction in energy intensity from 1995 to 2021, achieving the largest declines in the last year analyzed, i.e. 2021. A well-started optimization path that can be further refined, especially in the field of production. The indication comes from an in-depth analysis by the Energy & Strategy Group of the Politecnico di Milano, which in 2020 put the sector's needs under the magnifying glass. 56% of the total, in line with the industry average, is directed to production processes while 44% is associated with auxiliary services such as the use of technologies such as:

Inverter

Inverters are electronic devices that allow the bidirectional conversion of power between alternating current (AC) and direct current (DC). Although in common parlance the term "inverter" is often used to indicate devices that also include the rectification stage to interface with the AC grid, this meaning is formally incorrect. In fact, the true inverter is bidirectional, while the rectification stage is generally unidirectional**.** Inverters are high-efficiency machines, with efficiencies that can reach 99%. This makes them ideal for optimizing the operation of pumps, fans and other industrial machines, improving the overall efficiency of energy conversion and reducing pressure drops. The use of inverters also has significant environmental benefits. Regenerative braking, for example, reduces the need for mechanical brakes or electric rheostats, decreasing the footprint of cooling devices and improving overall energy efficiency.

Inverters are essential in various sectors:

- Industrial Drives: They allow you to adjust the torque, position, speed and power of rotating electric machines such as synchronous motors (traditional and brushless), asynchronous and dual power supply.
- Electric Traction: Used in railway locomotives, subways and electric cars, where regenerative braking feeds kinetic energy back into the grid.
- Power Generation and Distribution: Essential for extracting maximum power from renewable sources such as wind and photovoltaic, they stabilize power grids and allow power transmission over long distances with low losses (HVDC-VSC).

High efficiency motors

In Europe, the classification of the efficiency of electric motors has undergone a significant evolution. Initially, the classification was based on a voluntary agreement using the test methods of IEC 60034-2:1996. This standard defined three efficiency classes: EFF3 for low-efficiency motors, EFF2 for standard-efficiency motors, and EFF1 for high-efficiency motors.

However, in 2008, the IEC updated this standard, introducing three new efficiency classes:

- **IE1**: Standard efficiency, comparable to the old EFF2 class, but now outdated.
- **IE2**: High efficiency, similar to EFF1, with efficiency values ranging between 75% and 90%.
- **IE3**: Premium Yield, with efficiencies ranging from 80% to 96%.

Improvements in engine efficiency are mainly achieved by reducing losses in various components:

- Stator and rotor cores: Approximately 50% of total losses can be reduced by using low-loss steel or thinner foils.
- Electrical conductors: Approximately 20% of total losses can be reduced by using conductors with increased cross-section or by changing the shape of the motor casing.
- Friction in bearings and cooling system: Approximately 23% of total losses can be reduced by optimizing the geometry of the motors and reducing the size of the cooling system.

High-efficiency motors offer many advantages:

- Energy Saving: When coupled with inverters, they allow maximum energy savings and "soft start" of the motor, reducing peak absorption at start-up.
- Noise Reduction: Less leakage means less need for cooling and therefore less noise associated with the cooling fan. The sound level decreases by a few dB(A) for low-power engines and by about 10 dB(A) for larger engines.

An alternative to replacing a broken motor with a high-efficiency one is extraordinary maintenance with the complete replacement of the winding. However, the repair results in a reduction in engine efficiency, estimated at between 0.50% for professional repairs and 1% for standard repairs. In addition, the average life of engines subjected to maintenance is significantly reduced depending on the heat treatments to which they are subjected.

Trasformer

In the industrial context, chargers are often called rectifiers. These devices take alternating current (AC) from the mains, usually 220 or 380V, and transform it into direct current (DC) with voltages ranging from 12 to 80V and different amperages to recharge the batteries. A typical application of these chargers is to charge electric forklift batteries.

Traditional chargers consist of two main components: a transformer and a rectifier. The transformer, operating at mains frequency, is bulky and heavy. The rectifier, which operates at high currents, tends to dissipate a lot of power in the form of heat due to Ohm's law. On average, a traditional charger can dissipate up to 44% of the energy drawn from the electricity grid in the form of heat.

Another downside of traditional chargers is the lack of control over the voltage applied to the battery, which is directly proportional to the amplitude of the grid peak. This leads to a reduction in the useful life of the battery, a decrease in its capacity and a greater need for maintenance due to the evaporation of the electrolyte present inside it. However, these devices are reliable over time, easily repairable in the event of failures and have relatively low prices, often less than 1,000 euros.

Cogeneration

Various industrial processes require energy in the form of both electricity and heat. In 2014, Italian industry had an energy requirement of over 380 TWh, of which about two-thirds in the form of heat and the remainder in the form of electricity (source: Energy&Strategy Group, 2015). Cogeneration, also known as CHP (Combined Heat and Power), is the simultaneous production of electricity and heat. This technology represents an interesting way of energy efficiency, particularly useful when industrial processes require both forms of energy.

The most common technologies for cogeneration include:

- Steam turbines
- Gas turbines
- Internal combustion engines

Renewable

Renewable energy plants work thanks to energy sources from natural resources that do not run out over time and do not cause irreversible damage to the environment. This concept contrasts with non-renewable energy sources, such as oil and coal, which, in addition to being limited, produce emissions that are harmful to the environment.

Renewable sources, therefore, play a crucial role in the current energy landscape, offering clean, sustainable and cost-effective solutions.

Photovoltaic Systems in the Food Industry

Photovoltaic systems represent one of the most innovative and sustainable solutions to produce electricity, and their application in the food industry is gaining increasing attention. In this context, we will analyze what these systems are, how they are used, and the benefits they offer.

What Are Photovoltaic Systems

Photovoltaic systems are systems that convert sunlight into electricity using solar panels. These panels are made up of photovoltaic cells, usually made of silicon, which generate electricity when exposed to sunlight. The systems can be installed on rooftops, land, and dedicated structures, and they can vary in size, from small residential systems to large industrial installations.

How They Are Used in the Food Industry

In the food industry, photovoltaic systems can be used in various ways:

1. Self-Consumption of Energy: Food companies can use the energy produced by their systems to power machinery, refrigeration systems, and production lines, thereby reducing energy costs.

2. Sustainability and Corporate Image: The adoption of photovoltaic systems helps improve corporate image by demonstrating a commitment to sustainable and responsible practices.

Benefits of Photovoltaic Systems

The integration of photovoltaic systems in the food industry offers numerous advantages:

1. Reduction of Energy Costs: Self-generation of energy allows companies to significantly cut energy expenses, freeing up financial resources for other investments.

2. Energy Independence: Companies can reduce their dependence on external energy supplies, which may be subject to price fluctuations and availability.

3. Environmental Sustainability: Solar energy is a renewable and clean source, meaning that the adoption of photovoltaic systems helps reduce CO2 emissions and the overall environmental impact of industrial activities.

4. Incentives and Tax Benefits: Many governments offer incentives for the installation of photovoltaic systems, making the initial investment more accessible.

5. Increase in Property Value: Companies that invest in renewable energy may also see an increase in the value of their facilities due to the adoption of modern and sustainable technologies.

1.6.4.3 Water

Water is essential for production processes in various industrial sectors for several reasons:

Cooling

Many industrial processes generate heat, and water is often used as a cooling medium. For example, in power plants, chemical factories, and metal manufacturing processes, water absorbs excess heat, keeping equipment at safe operating temperatures.

Transport and Washing

Water is an excellent solvent and is used for transporting materials and washing equipment and products. In the food industry, for example, water is essential for cleaning plants and for processing food.

Chemical Processes

In many industries, water is a key component in chemical processes. It is used as a reagent in chemical reactions and as a means of dissolving substances, facilitating the reactions needed to produce chemicals, pharmaceuticals and foodstuffs.

Steam Production

Water is used to produce steam, which is crucial in numerous industrial processes, such as in electricity generation and heating buildings and plants. Steam is also used in sterilization and pasteurization processes in the food industry.

Hydration and Nutrition

In the agri-food industry, water is essential for agricultural production, influencing crop growth and food quality. In addition, it is necessary for food processing and storage.

In the sustainability path of the food and beverage industry, water management is a critical factor. Water waste not only undermines the environmental efficiency of production processes but also incurs substantial economic costs. As a result, techniques designed to minimize water waste are increasingly being adopted, including systems such as:

- **Water Recycling and Reuse**

Water recycling and reuse are essential practices to reduce water consumption. For example, recovered condensate water can be used as feed water for boilers or for cleaning equipment. Additionally, the use of dry-cleaning systems, such as compressed air or suction systems, can significantly reduce water consumption.

- **Water Flow Optimization**

Optimizing water flows through measurement and control can reduce waste and improve efficiency. Sensors such as photocells can detect the presence of materials and activate water only when needed, thus reducing consumption during product changeovers and production stoppages.

To summarize, global energy consumption varies significantly across industrial sectors, with the food and beverage sector representing a substantial portion of total consumption.

After exploring energy solutions, it is crucial to consider sustainable practices and energy efficiency technologies specific to the food and beverage industry.

1.7 SUSTAINABLE PRACTICES AND ENERGY EFFICIENCY TECHNOLOGIES IN F&B INDUSTRY

Annual investment in the energy sector is expected to grow between 2% and 4% per year, reaching between $2 trillion and $3.2 trillion in 2040, in line with global GDP growth. However, despite decarbonization efforts, a significant proportion of investment, between 25% and 40%, will still be allocated to fossil fuels in 2040.

Although the energy transition is already underway, the future of energy is permeated with uncertainties, ranging from technological advances to geopolitical risks, to consumption dynamics. As a result, the complexity in formulating resilient investment strategies increases, as entrepreneurs must reconcile long-term decarbonization goals with short-term economic return expectations.

Fossil fuels

Analyzing fossil fuels, forecasts indicate a peak in global demand by 2030. Although demand for coal is expected to decline sharply, natural gas and oil will show growth in the coming years, remaining indispensable in the global energy landscape for decades.

Renewable energy

Renewables are expected to make up the majority of the energy mix by 2050, driven by their economic competitiveness. They are expected to contribute between 45% and 50% to global generation by 2030 and between 65% and 85% by 2050, with solar energy leading the way followed by wind power.

To meet global climate commitments, it is therefore essential that businesses and governments make significant efforts to address the challenges related to the energy transition. These challenges include:

1. Development of energy infrastructure: Targeted investments are essential for the construction of energy infrastructure that enables the large-scale adoption of sustainable and low-carbon energy sources.
2. Accessibility for consumers: Eco-friendly solutions must be easily accessible and affordable for consumers to promote an effective transition to more sustainable practices.
3. Responsible sourcing of sustainable land and materials: Addressing the limited availability of land and materials needed for climate initiatives requires a responsible sourcing strategy based on the sustainable management of natural resources and the search for environmentally friendly alternatives.

The future of energy will be cleaner, it will be marked by new alternative energy sources that will bid farewell to the era of fossil fuels.

While it is already estimated that non-renewable resources will soon run out, it is also true that the development of energy storage systems is set to revolutionize the sector. And in this context, renewable energies will play an increasingly important role.

As part of the European Green Deal, which has estimated the achievement of zero climate impact for Europe by 2050 , one of the key targets to be achieved by 2030 to continue the actions undertaken with the 2020 Climate and Energy Package and accelerate the decarbonization process, include: the proposal to increase the intermediate emissions reduction target from the initial 40% to 55% (compared to 1990 levels); a share of at least 32% renewable energy; an improvement of at least 32.5% in energy efficiency.

Rapidly implementing the energy transition and seizing the opportunity to revolutionize the management of the energy sector is one of the greatest challenges of our time to which all economic sectors, led by energy production, must contribute with their intentions and concrete actions. The change will be driven by the penetration of renewable energy with the application of the principles of energy efficiency: a driver of growth and development that Esa Energie, through the construction and management of photovoltaic plants, has made its own in over fifteen years of experience.

In recent decades, emissions of carbon and other greenhouse gases have increased dramatically, exacerbating the climate emergency. The damage caused by climate change and achieved carbon neutrality by 2050, there is only one way to go: switch to renewable energy.

The European Union's green push has seen several countries, first and foremost Germany, plan an imminent exit from coal/lignite electricity production (fuels that are particularly harmful from the point of view of emissions) and Italy itself has declared the same goal, planning the conversion of some large coal-fired power plants to exploit natural gas as fuel.

Investments in renewables have been planned and sustained over time in order to make up for this future lower production from fossil fuels and to allow the reduction of emissions, in particular CO2, also in accordance with the EU's 2030 objectives.

In recent years, incentives for renewables, initially implemented by the governments of the various countries through forms of support for revenues from the sale of the energy produced, have been progressively replaced by indirect incentives, more focused on the economic disincentive of the most polluting fossil fuels (support for CO2 prices is an example). The goal is grid parity, i.e. the economic convenience of investments in renewables without the need for

government support to ensure their attractiveness and this goal seems to be getting closer and closer.
The push towards clean energy, however, is not only an impulse that comes from European or national policies but is becoming a need expressed by many consumers in recent years. The greater sensitivity to the issue of a sustainable future has meant that an increasingly significant share of customers, both civil and industrial, specifically request supply contracts with certification of the renewable origin of energy.
Those who do not have the opportunity to physically install photovoltaic panels or wind turbines to self-produce the renewable energy they need, in fact, can request their supplier to purchase energy produced 100% from renewable sources, the certification of which consists of guarantees of origin, or "labels" that ensure the origin of the energy from a specific renewable plant.
The future therefore is increasingly driven towards clean energy, sustainable choices, energy efficiency and attention to the environment. Although we will not be able to do without conventional technologies in the short term, we will see in the next 10-20 years the evolution of the energy mix, the development of renewable energy storage systems and the introduction of innovative technologies with a lower environmental impact such as hydrogen.

1.7.1 Energy efficiency techniques

In the food and beverage industry, there are several key technologies used to improve energy efficiency and reduce carbon emissions, such as heat recovery from condensing gases, the use of boiler economizers, the use of variable speed motors, and piping insulation. These techniques help reduce overall energy consumption and improve the sustainability of operations.

Breweries, for example, use techniques such as wort steam condensers, boiler economizers, and heat recovery at various stages of the process. These techniques help reduce overall energy consumption and improve the sustainability of operations. Water consumption for brewing varies depending on the type of beer, the number of beer brands, and the size of the brewery. Most of the values reported are less than 0.6 cubic meters per hectoliter of product. The water recycling rate varies between 1% and 23%, depending on the operating practices adopted.

Precision agriculture, on the other hand, uses advanced technologies to optimize the use of agricultural resources, such as fertilizers and water, improving crop efficiency and reducing greenhouse gas emissions. Here are some specific techniques:

- **Sensors and Satellite Imagery**: Used to monitor crop health and determine exactly where and how much fertilizer to apply.
- **Drip Irrigation Systems**: They provide water directly to plant roots, reducing waste and improving water efficiency.
- **Manure management**: Advanced manure management techniques can reduce methane emissions and improve soil quality.

A list of energy efficiency improvement technologies is illustrated below:

Process Automation and Optimization

- **Automation and Robotics**: The use of automated machines for cutting, forming, mixing and packaging food products. These technologies improve efficiency and reduce operating costs. For example, robots can be used for volumetric and weight filling of containers, ensuring precision and reducing waste.
- **Process Optimization**: Includes the use of advanced sensors and control systems to improve the management of production processes, reducing waste and improving the quality of the final product. Technologies such as remote condition monitoring and computer vision are used to improve operational efficiency.

Thermal Management and Heat Recovery

- **Heat Recovery**: Technologies that recover heat from production processes to reuse it in other stages of the production process. This includes the use of heat exchangers and exhaust gas heat recovery systems. For example, recovering heat from air compressors and refrigeration systems can significantly reduce energy consumption.

Refrigeration and Freezing Technologies

- **Magnetic Refrigeration**: An emerging technology that uses magnetocaloric cooling to reduce energy consumption. This technology is still under development but promises significant energy savings.

Sustainable Packaging Technologies

- **Active and Smart Packaging**: Packaging that can extend the shelf life of food and monitor product quality. For example, modified atmosphere packaging can limit the exchange of respiratory gases, prolonging the freshness of fresh produce.
- **Edible Packaging**: Packaging materials that can be consumed along with the food product, reducing waste. This packaging is made from biodegradable and edible materials.

Waste Management Technologies

- **Resource Recovery**: Technologies that allow valuable materials to be recovered and reused from production waste. For example, recovering protein from whey can reduce wastewater pollution and create new food products.

Monitoring and Control Technologies

- **Remote Monitoring**: Systems that allow you to monitor and control production processes remotely, improving operational efficiency. These systems use advanced sensors to collect real-time data and optimize processes.
- **Advanced Sensors**: Used to monitor critical parameters such as temperature, humidity, and air quality, ensuring optimal conditions for food production. Spectrometry sensors can detect foreign bodies in food, improving food safety.

Implementing sustainable practices is crucial, but it is equally important to quantify industry emissions to monitor progress towards decarbonization.

1.8 AMOUNT OF INDUSTRY EMISSIONS

The food & drink sector in the EU is responsible for the emission of 85 million tons of $CO2$ per year, most of which is due to energy use. Food waste is a fundamental issue, in 2021 58 million tons were wasted, equal to 16% of production, in 2022 there was a slight decrease, 57 million tons. This is equal to about 125 kg per inhabitant. The Waste2 Zero initiatives, promoted by FAO and other organizations, serve to induce companies to use suitable packaging, and citizens to make better use of the food they buy, 40% of plastic is recycled, with Italy, Spain and Slovenia leading the ranking, exceeding the European average. The percentage of agricultural land dedicated to organic production is also increasing, an area of 10% of the entire agricultural area.

The quantities of emissions from the food and beverage sector can be broken down by different categories of energy use; Below is a detailed overview:

1. **Boilers**: Boilers are responsible for 49% of the industry's emissions. This is mainly due to the generation of steam and hot water used in food production processes.
2. **Direct heating from fuel combustion**: This accounts for 19% of emissions. It includes processes such as cooking and pasteurization that require direct heat.
3. **Engines**: The engines used in the various production processes contribute to 16% of emissions. These motors are often used to drive machinery and equipment.
4. **Direct electric heating**: This type of heating is responsible for 8% of emissions. It is used in processes that require precise and controlled heat.
5. **Refrigeration and air conditioning**: These systems contribute to 6% of emissions. They are essential for keeping food products at safe temperatures during production and storage.
6. **Compressed air**: The use of compressed air accounts for 2% of emissions. It is used in various manufacturing processes to operate pneumatic tools and other equipment.

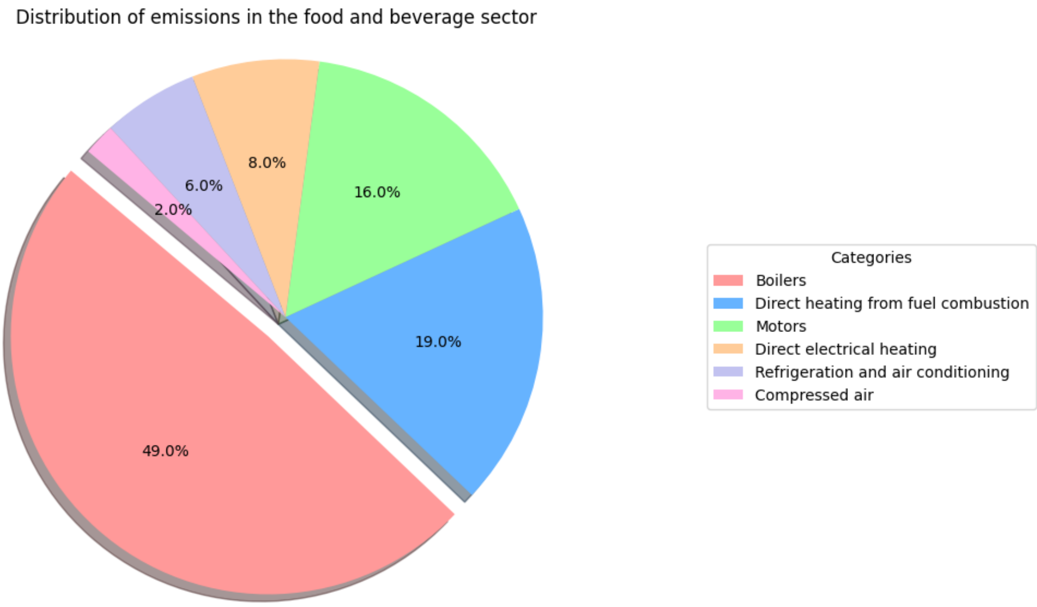

Figure 16 - Distribution of emissions in the food and beverage sector

In addition, food production processes such as canning and baking are particularly energy-intensive. For example, canning uses 70% of the energy for boilers, while baking requires about 60% of the total energy for ovens.

These figures indicate that the majority of carbon emissions in the food and beverage industry are closely linked to steam and heat generation processes. Therefore, implementing energy-efficient technologies, improving controls to ensure process optimization, and recovering and utilizing waste steam and heat can contribute significantly to reducing emissions.
According to the European Court of Auditors, 26% of global greenhouse gas emissions are caused by food production, with the agricultural sector responsible for 10.3% of the EU's climate-changing emissions. To make responsible and sustainable consumption choices, it is possible to consider the carbon footprint of food products. The carbon footprint is an indicator that calculates the greenhouse gas emissions of a product measured in carbon dioxide equivalent (CO_2e). In particular, the carbon footprint of a food product measures the total greenhouse gas emissions of a food, taking into account the entire life cycle (Life Cycle Assessment or LCA): production, packaging, storage, transport, sale, consumption and disposal. The global reference body is the Global Footprint Network, an international non-profit organization founded in 2003 that offers standardized and easy-to-access tools, metrics and indications.

To calculate the carbon footprint of food products, it is necessary to have a database of specific information and metrics, starting from reliable data to which mathematical formulas can be applied. In this way, it is possible to obtain the most accurate result possible, to correctly calculate the estimated greenhouse gas emissions of a food considering the entire life cycle of the product.

Obviously, there are other indicators to measure the sustainability of food. For example, it is important to know what the ecological footprint is in the food sector, i.e. the set of natural resources used in the life cycle of a food. Unlike the carbon footprint, the ecological footprint calculates not only greenhouse gas emissions but also the overall environmental impact of a food product, considering both the resources needed to produce it and the Earth's ability to regenerate these resources and dispose of the waste generated.

To understand which food the most environmentally friendly and which ones is involve the highest greenhouse gas emissions, consider a study recently carried out by the Financial Times based on data from CarbonCloud.

The analysis shows that the food that produces the most greenhouse gas emissions is beef, with 21 kg of CO2 equivalent for each kg of product (KgCO2eq/kg); however, frozen shrimp also has a considerable climate impact with 19.9 KgCO2eq/Kg.

Among food products based on milk and dairy products, cheese has an average carbon footprint of 14.2 KgCO2eq/Kg while mozzarella has an average carbon footprint of 8.7 KgCO2eq/Kg. Among the most sustainable foods there are of course plant-based foods, in fact products such as tomatoes (1.8 KgCO2eq/Kg), carrots (0.4 KgCO2eq/Kg) and apples (0.3 KgCO2eq/Kg) have a reduced carbon footprint. This clearly shows the environmental consequences of food consumption choices: reducing the consumption of animal-based foods and increasing plant-based foods has a positive effect on the planet.

As far as food production is concerned, according to the European Court of Auditors, 53% of greenhouse gas emissions come from animals, 29% from crops and 18% from the supply chain. In particular, just 5% of climate-changing emissions are caused by packaging, compared to 6% for transport, 8% for land use for human food and 31% for livestock farming and fishing. In any case, it is also possible to reduce the carbon footprint of food by intervening on food packaging, preferring eco-friendly alternatives such as eco-sustainable packaging.

Another sustainability indicator that can be used is the water footprint, i.e. the amount of fresh water used to produce a food, by examining all the different types of water used during the production process (e.g. drinking, groundwater, rainwater).

These metrics are developed by scholars and researchers and there is still a lack of a standardized process at global, European or even national level on the calculation of the carbon footprint. Most companies rely on organizations such as the Global Footprint Network, which provides easy-to-use tools that allow companies to calculate their carbon footprint and that of their products.

Considering CO2 emissions in the food and beverage sector, below is a list of foods with the greatest environmental impact:

- canned or otherwise preserved fruit and vegetables
- lentils (with an index of 1.7)
- Canned mushrooms (with an index of 2.4)
- butter (with an index of 11.5)
- cheeses (with an index of 7)

- cream (with an index of 5.3)
- eggs (with an index of 3)
- milk (with an index of 1)
- a kilo of beef (with an index of 13.6)
- chicken (with an index between 3 and 5)
- aquaculture fish (with an index around 5)
- wild fish (with an index of 3)
- frozen fish (with an index of 10)
- crustaceans (with an index greater than 12)

Global food production is responsible for greenhouse gas emissions equivalent to over 17 billion tons of CO2 per year: 57% comes from the production of foods of animal origin, while 29% is due to plant foods.

The environmental impact is greatest for cattle farms and rice crops, while the geographical areas that produce the most emissions are South America and Southeast Asia. The estimate is published in the journal Nature Food by an international group of experts led by the University of Illinois in which the Statistics Division of the FAO in Rome also participates.

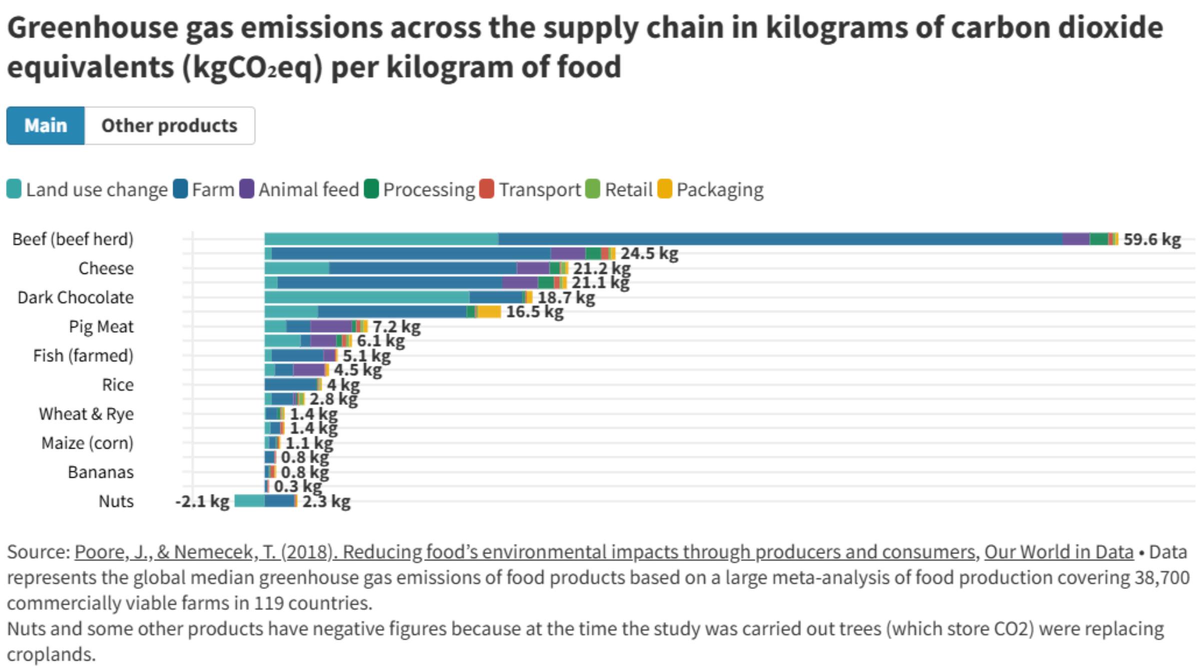

Figure 17 - Greenhouse gas emissions across the supplay chain in kilograms of carbon dioxide equivalents per kilogram of food

That is, the unit of measurement used to make the different climate-changing gases comparable. The European Data Journalism network, a data-driven journalism network of which InfoData is also a member, has tried to put the numbers of this phenomenon on paper.

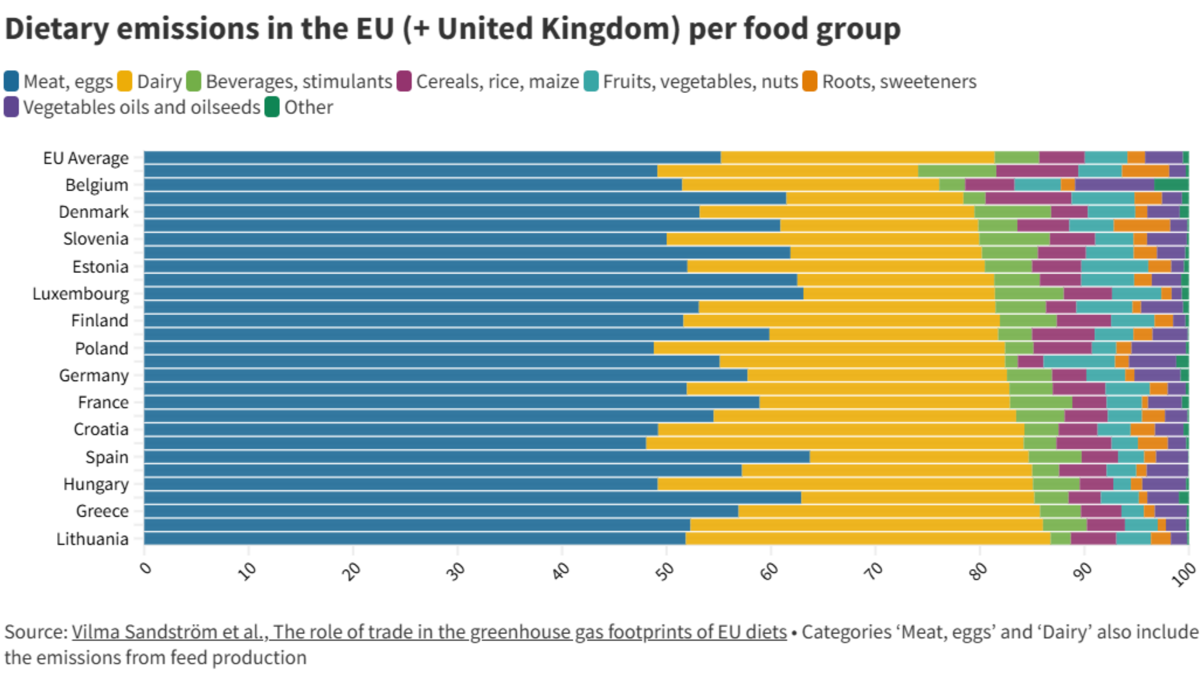

Figure 18 - Dietary emissions in the EU (+ United Kingdom) per food group

Pollution is affected, and a lot, by the global agri-food system, which is one of the main sources of greenhouse gas emissions, contributing more than 25% to the global problem. A problem that could be absolutely more contained. According to FAO data, 14% of food is lost before marketing, while 17% – equal to 931 million tons – is wasted by consumers and/or retail.

With a clear understanding of industry emissions, we can now explore decarbonization strategies to reduce environmental impact.

1.9 DECARBONIZATION

These technologies represent just a part of the innovations that are transforming the food and beverage sector, making it more sustainable and efficient.

The decarbonization of the food and beverage industry, for example, presents both challenges and opportunities. Among the main challenges are high capital and operating costs for some decarbonization measures, uncertainty about energy costs and the need for adequate infrastructure for new fuels such as green hydrogen. In addition, many of the technologies needed to achieve net-zero emissions are not yet mature or economically viable.

Decarbonizing the food and beverage sector can lead to numerous benefits, including energy and carbon savings, cost reduction, environmental protection, and improved worker health.

However, there are also many opportunities. For example, reducing greenhouse gas emissions in the industry can lead to reduced operating costs through more efficient use of energy. Additionally, consumers are increasingly environmentally conscious and value products with a reduced carbon footprint, which can translate into a competitive advantage for companies that adopt sustainable practices. Finally, there are a number of EU funding mechanisms available to support the transition to low-carbon technologies.

Despite the benefits, there are several barriers to decarbonizing the food and beverage industry. These include financial and economic barriers, such as high costs and long investment cycles, organizational and managerial barriers, such as industry fragmentation and skills shortages, and behavioral and consumer barriers, such as a preference for carbon-intensive foods.

To overcome these barriers, innovative policies and business models must be adopted. These can include carbon trading schemes, renewable energy incentives, feed-in tariffs, and sectoral agreements. In addition, business models such as financing through ESCOs (Energy Service Companies) and the use of green investment banks can help mobilize the financial resources needed for decarbonization.

The three decarbonization scenarios for the food and beverage sector by 2050:

1. **Baseline (S1):** This scenario envisages the continuation of current environmental policies without the implementation of the Green Deal. In this case, decarbonization would be limited and emissions would remain significant.

2. **Rapid Decarbonization (S2) scenario**: In this scenario, the Green Deal is successfully implemented, leading to a significant reduction in emissions through the adoption of clean technologies and the use of renewable energy.

3. **Slow decarbonization scenario (S3):** This scenario envisages a mixed implementation of the Green Deal, where some clean technologies only become economically viable in the long term.

The different categories of decarbonization can be summarized as follows:

- Energy management: This includes implementing energy management systems, regularly maintaining facilities, and training staff to optimize energy use.

- Decarbonization of combustion units: Use of cleaner fuels such as biogas and green hydrogen, and improvement of the efficiency of existing combustion units.
- Heat electrification: Using heat pumps and electric steam generators to reduce reliance on fossil fuels.
- Reduce heat demand: Implement heat recovery systems, thermal insulation, and optimize steam distribution systems.
- Decarbonizing cooling: Using more efficient cooling technologies and reducing storage time to decrease energy demand for cooling.
- On-site renewable energy generation: Installation of solar panels and other renewable energy production technologies directly at production sites.

For manufacturers, it is crucial to monitor new regulations, use decision support tools to select the most effective decarbonization technologies, and consider the impact of CO_2 emissions in decision-making processes. For national authorities, it is important to ensure the decarbonization of the electricity grid, support the electrification of heat and facilitate access to technical information for companies.

The proposed roadmap represents a key step in guiding the food and beverage sector towards a sustainable future, addressing the challenges of climate change and exploiting the opportunities offered by the transition to a low-carbon economy.

Decarbonization strategies are fundamental, but it is also important to look at future trends to further improve upon the current situation.

1.10 FUTURE TRENDS FOR IMPROVEMENT COMPARED TO THE CURRENT SITUATION

The food and beverage industry has a significant impact on energy consumption and the environment, but there are numerous opportunities to improve sustainability and reduce carbon emissions. Addressing these challenges will require an integrated approach involving technological innovations, behavioral changes and supportive policies.

More and more often it is often considered biogas and green hydrogen as a useful combination to reduce emissions and give resilience to the national and European economic system.

Biomethane and hydrogen will play a key role in the energy transition that Italy, but more generally the whole of Europe, is implementing and that will see it engaged in the coming years. The objective can be summarized in various points:

- Reduce greenhouse gas emissions, protecting the environment, health and the economy, the latter especially in relation to extreme weather events that will increasingly have a negative impact on national production (therefore GDP);
- Increasing the resilience of the Old Continent. In fact, the production of biomethane and hydrogen can ensure that production takes place on European soil, avoiding or at least limiting the degree of exposure to the risk that the supplier drastically reduces the production of the energy raw material in question. As an example, just think of the oil shocks in the second half of the twentieth century and what happened more recently with Russia;
- Stimulate domestic employment through public and private investments that can give new impetus to the European economy.

Biomethane

Biomethane is the result of the purification of biogas, the latter deriving from the decomposition process (technically anaerobic digestion) of organic waste materials, such as waste from the agricultural sector. Three aspects make this gas particularly useful for the transition:

- Zero impact. Biomethane is made up of gases produced by the decomposition process of organic waste. Once burned, no additional amounts of greenhouse gases are released into the environment;

- Valorization of waste products. These are used as useful resources in production;
- Implementation of the circular economy concept, with positive effects on employment.

According to the European Gas Association (EBA), there are 1,322 biomethane production plants in Europe, while in 2021 there were "only" 1,023. In just two years, there has therefore been an increase of about 30% in the total number of biomethane plants, a symptom of a solid demand that must be met.

Energy data management in the F&B sector presents several common challenges, even though each company has its own peculiarities.

First, there's the issue of compliance: manufacturers must follow strict standards and regulations to ensure food safety.

This involves continuously monitoring factors such as humidity and temperatures, as well as properly managing disposal and emissions, which requires information from different operational areas.

Another challenge is managing energy consumption. Reducing energy consumption is key to reducing costs and minimizing environmental impact, but it requires effective data management to be truly effective.

In addition, there is a need to synthesize energy data. Energy can be used in many ways, and companies need to develop innovative solutions to turn this information into useful and easily understandable data.

Finally, it is crucial to act on the data collected. If information is not translated into concrete actions, such as optimizing processes to reduce emissions or planning energy use during off-peak hours, its value decreases. Therefore, the ability to make informed data-driven decisions is essential for improving business operations and achieving sustainability goals.

The F&B sector accounts for a significant portion of global energy consumption. The increasing focus on sustainability and energy efficiency is driving companies to adopt more responsible practices, helping to both reduce operating costs and improve environmental impact.

The European Commission estimates that by 2030 , 350 TWh of biomethane could be produced per year, equivalent to 10% of natural gas consumption, which would help reduce CO2 emissions by about 110 million tons, thanks to the replacement of fossil fuels and the capture of methane emissions from organic waste and manure.

Biomethane is seen as a key component to achieving the European Union's climate goals, particularly those of the "Fit for 55" package and climate neutrality by 2050. This renewable gas, derived primarily from anaerobic digestion and gasification, is considered one of the cheapest and easily scalable forms of renewable energy available today.

The main biomethane production technologies are anaerobic digestion and gasification.

Anaerobic digestion is a biological process that decomposes organic matter in the absence of oxygen, producing biogas (composed mainly of methane and CO2) and digestate, an organic fertilizer.

Gasification, on the other hand, is a thermochemical process that converts dry biomass and municipal solid waste into syngas, which is then transformed into biomethane.

In addition to the significant reduction in greenhouse gas emissions, biomethane production can create numerous jobs in rural areas, contributing to local economic development. This is particularly relevant for the agricultural sector, where biomethane can be produced using agricultural residues and organic waste, improving the sustainability of agricultural practices.

The F&B sector is closely linked to the production of biomethane using organic waste and residues. Food waste from food and beverage production can be used as feedstock for anaerobic digestion, thereby reducing waste and uncontrolled methane emissions. Not only does this help to manage waste more sustainably, but it also contributes to the production of renewable energy.

In addition, the biogenic CO2 produced during anaerobic digestion can be captured and used in the food and beverage industry, for example for beverage carbonation, reducing the need for fossil CO2. This represents a further step towards sustainability, as it allows the carbon cycle within the sector to be closed.

The adoption of biomethane can improve the sustainability of the food supply chain, reducing the carbon footprint and promoting sustainable agricultural practices such as the "Biogas done right". This concept integrates sequential bioenergy crops and minimizes soil disturbance, improving soil quality and biodiversity. Sequential crops, grown between major crops, do not compete with food production and can be used to produce biomethane, thus increasing agricultural productivity without additional pressure on land resources.

These include increasing the capacity of anaerobic digestion and biogas upgrading plants to achieve economies of scale, and technological innovation to develop pretreatment technologies that unlock new feedstocks and improve process efficiency. In addition, it is crucial to implement long-term policies that incentivize biomethane production and reduce costs.

In conclusion, biomethane represents a versatile and sustainable energy solution, with significant benefits for the environment and the rural economy. The F&B sector can benefit from integrating biomethane into its operations, contributing to a more sustainable supply chain and an overall reduction in greenhouse gas emissions.

In addition to this energy raw material, which plays an important role in the energy transition, there is another that will see its degree of relevance and pervasiveness within the European economic and energy system increase in the coming years: hydrogen.

Hydrogen

Hydrogen is the most abundant element in the universe, but in its pure state it is not available on our planet. Most of the "convenient" hydrogen can be extracted from other substances with chemical and electrolytic procedures, or it can be produced from other fuels, using substances with a high energy content, such as fossil fuels (methane reforming and coal), but these methods, in addition to depleting non-renewable resources, generate CO_2 in greater quantities than conventional ones. Hydrogen can also be produced by electrolysis of water, using considerable amounts of electricity produced by large photovoltaic systems.

Hydrogen can be used as a feedstock, fuel, carrier or renewable energy storage, capable of absorbing fluctuations in electrical power supply from sources such as the photovoltaic cell and/or wind turbines and can also be used in energy-efficient devices, such as hydrogen turbines and fuel cells that are capable of using hydrogen to produce electricity with good efficiency.

In theory, the only emission from hydrogen cells is pure water. Hydrogen cells are more efficient than the internal combustion engine, diesel and, in cogeneration mode (electricity and heat) fuel cell plants will perhaps achieve energy efficiency of 80-85%. Other innovative technologies, competing with hydrogen fuel cells, demonstrate 50% electrical efficiency.

In Europe, interest in hydrogen as a solution to decarbonize industrial processes and economic sectors where reducing carbon emissions is most difficult is growing rapidly. All this makes it essential to support the European Union's commitment to achieve climate neutrality by 2050.

The strategic vision envisaged by the European *Green Deal* envisages the growth of the share of hydrogen in the European energy mix, currently below 2%, up to 13-14% by 2050. The EU's priority is to develop renewable hydrogen, mainly using wind and solar energy. The path identified provides for the installation of 6 GW of electrolyzers by 2024 to reach an installed capacity of 40 GW by 2030.

In our country, in order to start the development of the decarbonized hydrogen market, it is expected to install about 5 GW of electrolysis capacity by 2030, integrated with imports or other forms of low-carbon hydrogen. This will offer a concrete option for the decarbonization of processes to the synthetic chemistry and oil refining sectors that already use hydrogen obtained from fossil sources. In the industrial field, there are now numerous experiments underway in Europe and Italy, on the side of hydrogen production, pure or mixed use and its transmission through existing networks.

In Italy, the use of hydrogen in the industrial sector is already a reality: the current demand for hydrogen is about 0.5 Mil T per year. It is mainly used in the synthetic chemistry and petroleum refining sectors. In both cases, hydrogen is mainly produced on-site in its "grey" form, i.e. from natural gas, using *Steam Methane Reformers* – SMRs. In this process, natural gas, reacting with high-temperature water vapor, is separated into hydrogen (H2) and carbon dioxide (CO2)

In particular to produce ammonia and nitrogen fertilizers and in that of methanol: in this sector, about 200 million cubic meters of gas are currently used for the production of hydrogen.

Hydrogen stands out as a concrete alternative to clean fuels because, during combustion with oxygen, it produces only water vapor as a byproduct. This makes it unique compared to fossil fuels, which emit carbon dioxide and other harmful pollutants that are detrimental to human health and the environment. However, hydrogen is not easily found in nature in its free state (H2); it is primarily present in combination with other elements, such as in water (H2O) or in hydrocarbon compounds like methane (CH4). Its reactivity makes it difficult to find natural sources of pure hydrogen on the Earth's surface.

To produce hydrogen, it is necessary to separate it from the elements it is bonded with, a process that requires energy. Therefore, hydrogen is considered an energy carrier, capable of storing and transferring energy. However, one of the main current limitations of hydrogen is its low efficiency, due to significant energy losses during the phases of production, storage, transport, and conversion into kinetic energy in vehicles.

The interest in accelerated hydrogen development is also underlined in the PNRR where a total of €3.64 billion is the funds provided for in the measure and explicitly dedicated to the development of hydrogen-related projects.

Hydrogen is an energy carrier capable of storing and releasing large amounts of energy per unit mass (i.e. it has a certain density in terms of energy) without generating carbon dioxide emissions during the combustion process. The great advantage of this element is its abundance on the planet and, more generally, in the solar system.

However, the extreme simplicity with which hydrogen binds to other elements makes it complex to trace in its pure state. This raises the question of how to separate it from atoms of other elements while reducing greenhouse gas emissions.

Although it is still a colour less gas, the methods of hydrogen production are conventionally associated with different colours, which classify the level of environmental impact.

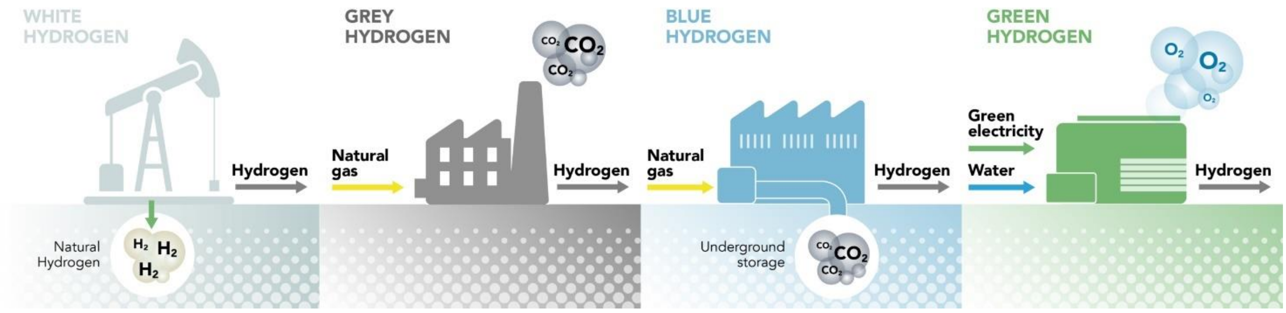

Figure 19 - Four colours of hydrogen

To date, 4 colours of hydrogen are mainly identified, based on the production process used:

- **Grey hydrogen**: obtained from the combustion of methane (this is currently the most common process); it is obtained through the steam reforming process of methane (SMR) or other hydrocarbons. This procedure uses the reaction between steam and methane at very high temperatures to create hydrogen. Currently, this method is used to produce about 48% of the world's hydrogen. It is a chemical reaction that generates carbon dioxide (CO2) as a waste product, releasing on average more than 9 kg of C02 into the atmosphere for every kg of hydrogen produced.
- **Blue hydrogen**: produced from methane but with an attached process for capturing polluting gases. The production process of "blue hydrogen" is the same as that used for Grey hydrogen but with a substantial difference: a part of the CO_2 emissions produced during the process are captured, stored and not directly released into the atmosphere.
- **Green hydrogen**: produced using energy from renewable sources, used to power the electrolysis process. It is the production method with the lowest environmental impact.

> In this production process, hydrogen is obtained by electrolysis of water, i.e. electricity is used to separate water (H2O) into its two constituent elements: hydrogen and oxygen. This is done through an electrolyzer which, when powered by renewable energy sources, results in the production of 100% zero-emission hydrogen. Today, green hydrogen is seen as a concrete option for decarbonization.

With a view to the energy transition, the goal becomes not to produce gray hydrogen, or in any case limit its production, as the pollutants produced would contribute to altering the climate with the spillover effects mentioned several times.

A further method of production is through the use of biomethane, i.e. the gas produced by the "recycling" of waste material with "zero impact" or, rather, "net zero emissions". The latter method could accompany renewable energy production to increase supply and make more available a resource that wants to become the protagonist of the energy future at European and, in some ways, global level.

According to ANIMA, between 2025 and 2030, green hydrogen is expected to become a substantial part of the European energy mix, with around 40 GW of electrolyzers installed, within its borders and as many outside them. At this stage, the investment by 2030 for this type of plant should reach a value of between 24 and 42 billion euros.

The infrastructure connected to this "new" energy carrier will have to be implemented and upgraded, in order to allow transport over long distances and a considerable storage capacity. Together with the upgrading of production plants and infrastructure, between 220 and 340 billion euros would be needed to increase the production of solar and wind energy, so as to allow a contribution of renewable energy to electrolysis plants and, consequently, the production of green hydrogen.

In addition to this, an investment of 11 billion euros is estimated to adapt the plants already in operation through carbon capture and storage (CCS) technology. This is a necessary measure in order not to lose production capacity in the field of hydrogen production and in view of a path characterized by net zero emissions.

Finally, again in the five-year reference period, 65 billion euros will be needed for transport, distribution and storage for hydrogen refueling stations.

For the 2030–2050-time frame, some maturity is expected with respect to green hydrogen production technologies, such that large-scale production should be possible, effectively contributing to the decarbonization of the European economy and the achievement of the emissions target.

The maturity envisaged, combined with the massive production of renewable energy, should allow the production of green hydrogen and the development of a strong supply chain of the energy sector.

In this direction, the PNRR also aims to finance, facilitate and implement projects related to hydrogen production, so as to develop a new market segment with positive effects on both employment and GDP, and increase the degree of resilience of the economy as a whole, becoming less dependent on external suppliers.

The total value of the investment financed by the PNRR is around 3.64 billion euros, of which 500 million allocated for the creation of 52 hydrogen valleys, with 26 projects located in the South.

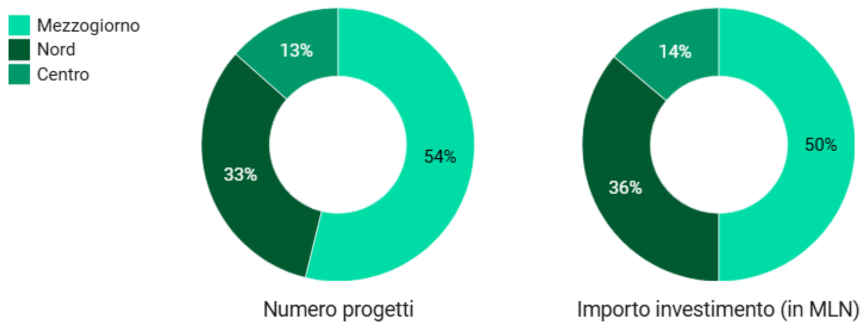

Figure 20 - Number of projects and investment amount divided by macro-area

It is worth adding that gas infrastructure can be used, at least in the short term, to transport a certain percentage of hydrogen in addition to gaseous hydrocarbon. In fact, in 2019 Snam experimented with the introduction of a mix of 5% hydrogen and natural gas, noting no problems in the measure implemented. It was verified that with that percentage of hydrogen introduced into the mix, it was possible to transport a quantity of this gas equal to 3.5 billion cubic meters, or the consumption of 1.5 million households. Such a proportion would avoid the emission of 2.5 million tons of carbon dioxide into the atmosphere.

If we assume a line whose extremes represent environmental impact and energy efficiency, we will find fossil fuels on the one hand (greater impact, lower efficiency) and, on the other, renewable electricity with direct use or battery storage (lower impact, greater efficiency). Hydrogen is in the middle of this line, constituting a compromise between reduced environmental impact and reduced efficiency. In the case of green hydrogen obtained from sustainable energy sources, due to its low environmental impact, this, on the line, is closer to electricity.

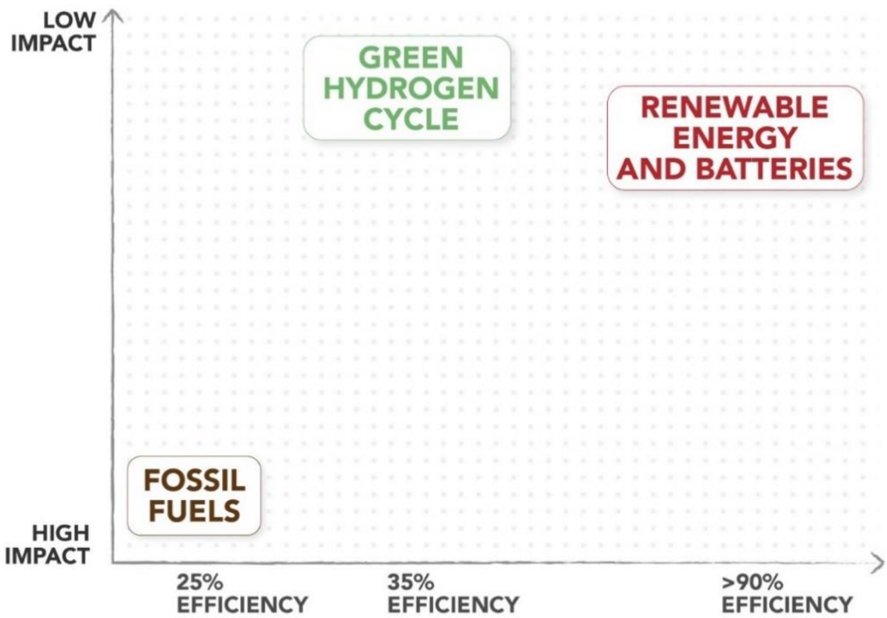

Figure 21 - Graph representative of the efficiency and impact of different energy sources

Hydrogen transport represents one of the most complex and fascinating challenges in today's energy landscape. Despite its enormous potential as a source of clean energy, there are several obstacles preventing its complete replacement of fossil fuels.

First of all, hydrogen is an extremely light gas, which means that it has a very low volumetric energy density. This means that, in order to transport significant amounts of energy, hydrogen must be compressed at very high pressures or liquefied at extremely low temperatures. Hydrogen compression requires specialized equipment and significant energy expenditure, while liquefaction involves cooling the gas to -253°C, a process that requires advanced and expensive technologies.

The infrastructure needed to transport hydrogen is another critical point. While existing pipelines can be retrofitted for methane, they need to be modified to prevent leaks and ensure safety, as hydrogen can easily diffuse through materials that would be impermeable to other gases. Additionally, road or sea transportation requires specialized containers that can keep compressed or liquefied hydrogen safely, further increasing the associated costs and risks.

Safety is a key aspect when it comes to hydrogen. Being highly flammable, hydrogen can form explosive mixtures with air, which requires strict safety protocols during transport and storage. Even though the industry has developed technologies to manage these risks, the public perception of hydrogen safety remains a significant barrier. People are often concerned about the risk of explosions, which can hinder the acceptance and large-scale adoption of this technology.

Another factor to consider is cost. Currently, transporting hydrogen is much more expensive than fossil fuels. The need for compression, liquefaction and specialized infrastructure contributes to making hydrogen less economically competitive. This is a significant problem, as to be a true alternative to fossil fuels, hydrogen must be not only sustainable, but also cost-effective.

Finally, energy efficiency is a crucial issue. The production, transport and storage of hydrogen result in significant energy losses. For example, electrolysis of water to produce green hydrogen requires a lot of energy, and additional losses occur during compression and liquefaction. This means that, at the moment, hydrogen is not yet a fully efficient energy solution.

Hydrogen has the potential to become a key component of a sustainable energy system, there are still many challenges to overcome. Significant investments in research and development, infrastructure and safety technologies are needed to make hydrogen a true alternative to fossil fuels. Only by addressing these challenges will we be able to harness the full potential of hydrogen and contribute to global decarbonization.

In conclusion, biomethane and hydrogen can contribute to meeting part of the overall energy demand and energy mix soon, with the possibility of exploiting, at least temporarily, existing infrastructures involving the distribution of natural gas.

2 ENERGY CONTEXT OF CAMPARI GROUP AND NOVI LIGURE PLANT

2.1 THE ROLE OF CAMPARI GROUP: ENVIRONMENTAL IMPACT SCOPE 1,2,3

The Group is committed to sustainable development by responsibly using resources and minimizing the environmental impact of its production activities. Campari Group understands that climate change is a significant challenge for the planet's future and recognizes the importance of limiting global temperature increases to 1.5°C, as outlined in the Paris Agreement. Therefore, the Group is dedicated to reaching net-zero emissions by 2050 or earlier. The goals are in line with the UN Sustainable Development Goals, focusing on environmental protection through the reduction of emissions and water usage at the Group's production facilities, as well as minimizing landfill waste from direct operations. These targets include both short-term, by 2025, and medium-term ,by 2030, commitments. The Group ensures transparency in tracking and reporting its progress, following internationally recognized standards. Campari Group is advancing its energy efficiency efforts through a global, multi-year program initiated in 2020. The program focuses on promoting energy-saving initiatives, implementing sustainable practices, and decarbonizing production activities. Beyond its strong commitment to reducing carbon emissions from its direct operations, Campari Group has broadened its efforts to encompass the entire supply chain. The goal is to reduce the overall intensity of Supply Chain GHG emissions, Scope 1, 2, and 3 by 30% by 2030, with the ambition of achieving net-zero emissions by 2050. Currently, Campari Group's GHG emissions footprint consists of 8% from Scope 1 and 2 emissions, and 92% from Scope 3 emissions.

Scope 1 and **Scope 2** consist in GHG emissions divided into:

- Combustion in thermal plants (t of CO2 e.)
- Refrigerants (t of CO2 e.)
- Purchased electricity location-based (t of CO2 e.)
- Purchased electricity market-based (t of CO2 e.)

As part of its strategy to reduce Scope 1 and Scope 2 GHG emissions, in 2023 the Group invested in local energy efficiency projects designed to lower energy demand at its manufacturing sites. These initiatives included optimizing utilities, replacing boilers, improving insulation, and installing LED lighting systems. Alongside boosting energy efficiency, Campari Group is also exploring technological solutions to support its transition to greener energy sources.

Scope 3

In 2023, Campari Group conducted its annual Scope 3 emissions analysis, assessing the fifteen categories outlined by the GHG Protocol standard. The analysis revealed that the largest contributors to Scope 3 emissions are the purchase of goods and services (71%), transport and upstream/downstream distribution (12%), and capital goods (10%), which together account for 93% of the total Scope 3 impact. During the same year, the Group strengthened its engagement with key suppliers, particularly those related to packaging and raw materials such as glass, closures, aluminum cans, sugar, and alcohol, as well as logistics. This enhanced engagement not only allowed Campari to gather detailed information on the specific emission reduction initiatives of these suppliers but also helped establish standards for smaller and less advanced suppliers. Campari Group is committed to implementing targeted emissions reduction initiatives throughout its value chain in collaboration with these suppliers. To drive this Scope 3 reduction program, the Group has established a cross-functional Steering Team, focusing primarily on Purchased Goods and Services, as well as Logistics.

Figure 22 - GHG emissions Scope

2.2 WATER AND WASTE MANAGEMENT

Campari Group acknowledges the critical importance of water and is dedicated to conserving and reducing its consumption through a responsible and sustainable water management program. As part of its global Water Reduction initiative, the Group has optimized water usage in its production processes, focusing on both the quantity and quality of water used. Additionally, Campari Group is investing in water recovery systems to minimize waste across its operations.

Main Target are:

- Reduce water usage intensity (liters withdrawn per liter manufactured L/L) by 60% by 2025 and by 62% by 2030
- Continue to ensure the safe return of wastewater from direct operations to the environment.

Campari Group is also dedicated to reducing overall waste from its production sites by adopting a circular approach. This involves various local initiatives focused on optimizing material usage and disposal, enhancing efficiency, and increasing recycling, recovery, and reuse processes. The Group aims to achieve zero waste to landfill across all its production sites by 2025. Production sites aim to increase the recovery and reuse rate of by-products generated during the production cycle by repurposing them as animal feed, biomass, or compost.

Main Target:

- Continue the global reduction program towards the zero waste to landfill target by 2025

2.3 ENERGETIC STRUCTURE OF NOVI LIGURE PLANT'S

2.3.1 Overview of the site

The site is located in an industrial area of Novi Ligure, in the province of Alessandria, at Via Nazioni Unite, 1. It covers a total covered area of approximately 60,000 square meters, where production processes, operations, and the storage of finished products take place before they are sold.

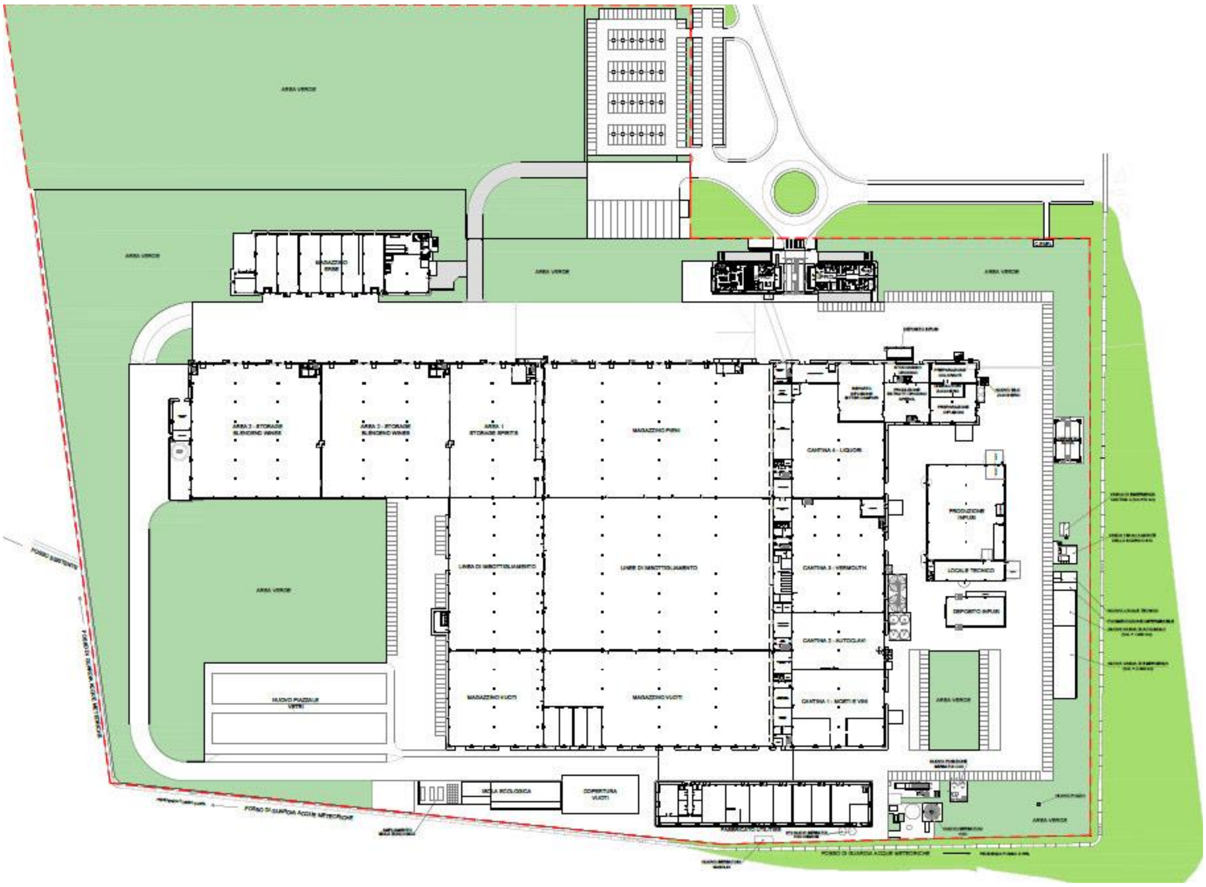

Figure 23 - Novi Ligure Layout

At the Novi Ligure site, Davide Campari Milano S.p.A. N.V. produces wines, sparkling wines, aromatized wines, vermouths, distilled liquors, hydroalcoholic infusions and extracts for both alcoholic and non-alcoholic products. The facility also handles bottling, packaging, storage, and shipment of finished goods.

Specifically, the Novi site produces four categories of products:

- **Sparkling Wines:** Including Asti Cinzano, Brachetto d'Acqui Cinzano, Cinzano Dry Edition, Cinzano Sweet Edition, Cinzano Rosé, Pinot Chardonnay Cinzano, Cinzano Pro-Spritz, Cinzano Gran Collezione, Prosecco Cinzano, Prosecco Riccadonna, Riccadonna Chardonnay Brut, Riccadonna Moscato Rosé, J.-Marc XO, Ruby.
- **Vermouth:** Such as Cinzano Bianco, Cinzano Rosso, Cinzano Dry, Cinzano Extra Dry, 1757 Vermouth di Torino, and aromatized wine-based beverages (Cinzano BAV).
- **Liquors:** Including Bitter Cinzano, Campari, Negroni, Cynar, BiancoSarti, Skyy Vodka.
- **Aperitifs:** Such as Crodino, Aperol Soda, Campari Soda, Aperol Spritz, Aperol Soda

Production is divided into two distinct areas:

- **Canteen Section**
- **Bottling Section**

There are seven production lines, each of which is independently powered by electricity:

Table 1 - Production data

	LINEA GAI	LINEA CAMPARI	LINEA APEROL	LINEA CAMPARI SODA VAP	LINEA LIQUORI (CY/BS/VTH)	LINEA SPUMANTI	LINEA CRODINO	Totale
gennaio	510.275,40	1.980.079,20	-	1235801,56	2.976.864,30	1.533.231,00	763.644,99	8.999.896,45
febbraio	501.539,40	5.575.002,00	-	1379833,14	3.474.197,40	1.519.978,50	1.034.485,20	13.485.035,64
marzo	693.301,50	2.211.588,60	28.980,00	1.997.351,72	3.392.110,50	1.421.802,00	1.546.548,19	11.291.682,51
aprile	334.513,50	2.478.644,40	688.745,40	1.516.280,50	2.601.059,40	1.437.030,00	535.335,30	9.591.608,50
maggio	398.084,40	4.417.528,20	1.445.671,20	1.690.549,98	4.204.425,60	1.211.143,50	1.402.907,26	14.770.310,14
giugno	636.943,80	3.985.569,60	1.784.928,60	1.175.995,10	4.090.001,40	1.375.195,50	986.599,25	14.035.233,25
luglio	574.652,40	1.301.392,20	2.976.559,20	786.020,76	3.881.769,00	603.297,00	1.356.986,75	11.480.677,31
agosto	598.686,30	1.504.031,40	1.314.737,40	419.824,16	2.256.004,80	386.631,00	930.969,66	7.410.884,72
settembre	609.115,80	1.901.492,99	1.008.502,81	1.088.358,60	2.313.073,20	706.104,00	1.138.581,60	8.765.229,00
ottobre	460.780,80	1.829.434,30	1.028.291,30	1.308.786,08	1.354.549,80	1.073.173,50	818.389,80	7.873.405,58
novembre	317.031,00	1.652.375,75	1.027.463,05	861.461,16	1.038.831,00	902.614,50	412.645,16	6.212.421,62
dicembre	393.289,80	337.712,84	555.727,36	-	227.006,40	656.734,50	410.143,20	2.580.614,10
	6.028.214,10	29.174.851,48	11.859.606,32	13.460.262,76	31.809.892,80	12.826.935,00	11.337.236,36	116.496.998,82

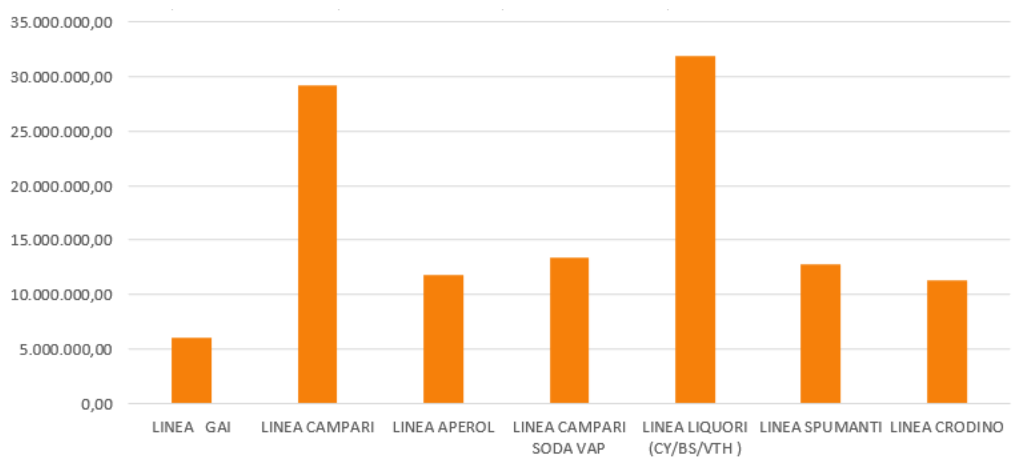

Figure 24 - Lines production trend

2.3.2 Site Facilities

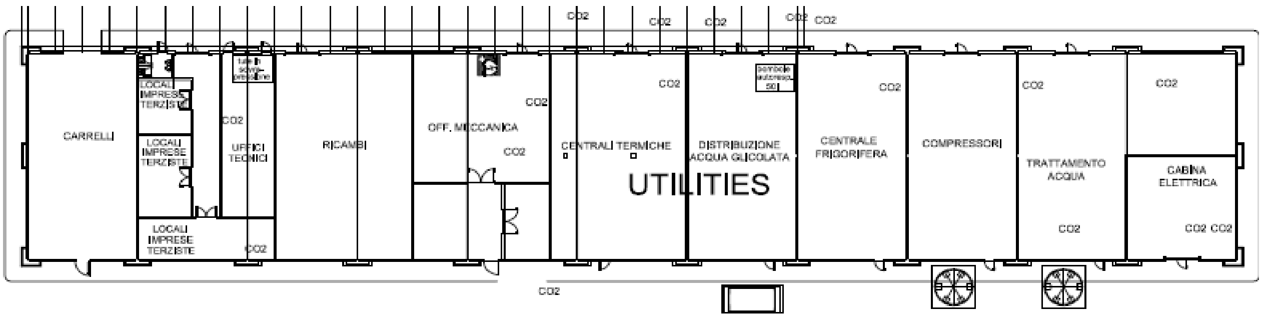

Figure 25 - Layout Utilities

2.3.3 Electrical system

The facility is supplied with three-phase medium voltage (15 kV) from the national Enel grid. The maximum available power under the current supply contract is 2,644 kW, delivered at a single point with a dedicated substation. Within the facility, there are three transformer substations (15,000V/400V)

2.3.4 Thermal power plant

There are four steam generators located in the thermal power plant. The steam is distributed to the main manifold positioned within the thermal power plant. The boilers operate in a cascade system based on set-point pressure levels configured in the system. They are composed of three smoke tubes with a capacity of 3 t/h of steam certificate for operation with an exemption every 72 hours. Once started, they are capable of functioning autonomously for 72 consecutive hours. After completing the cycle, the boilers will automatically shut down. In the same thermal power plant, there is a thermally insulated condensate recovery tank. The distribution system is located in an adjacent utility tunnel within the facility. Inside this tunnel, steam-to-water heat exchangers are installed to supply the production lines, along with steam pressure reduction stations. The condensate generated and recovered by the heat exchangers is pumped back to the thermal power plant using dedicated booster pumps.

Table 2 - Nameplate data of heat generators

	Brand	Year	Feeding	Output Vector	Flow rate [kg/h]	Useful thermal power [kWt]
Steam generator 1	HOVAL THD3-3000 HT2	2020	Natural Gas/Gasoline	Steam 6,5 bar	3000	2093
Steam generator 2	HOVAL THD3-3000 HT3	2020	Natural Gas/Gasoline	Steam 6,5 bar	3000	2093
Steam generator 3	HOVAL THD3-3000 HT4	2020	Natural Gas/Gasoline	Steam 6,5 bar	3000	2093
Steam generator 4	HOVAL THD3-3000 HT5	2020	Natural Gas/Gasoline	Steam 6,5 bar	3000	2093

From the manifold, the necessary amount of steam is drawn off for the following purposes:

- Supplying the shell and tube heat exchanger for the integration/heating of glycol to 30°C;
- Supplying the shell and tube heat exchanger for the integration/heating of process water in the Pasteurizer;
- Supplying the shell and tube heat exchanger for the integration/heating of the bottling department (air heaters);
- Other production uses

2.3.5 Cogeneration plant

The site is equipped with a cogeneration plant with a capacity of 851 kWe and 959 kWt. The generated electricity is fully consumed on-site, with any excess being fed into the grid. The thermal energy is produced in the following forms:

- **Steam:** At 6.5-7 bar, generated by a steam recovery boiler with a capacity of 419 kWt.
- **Hot Water:** At 90°C, produced using a heat exchanger with a capacity of 540 kWt.

Table 3 - Nameplate data of the cogenerator

Brand	Year	Feeding	Output Vector	Electric power [kWe]	Steam thermal power [kWt]	Hot water thermal power [kWt]
ASSEMBLATO AB	2019	Natural Gas	Steam and Hot water at 7 bar	851	419	540

The steam is directed into the main steam manifold located in the thermal power plant, while the hot water is used for:

- Heating the warehouse
- Heating the bottling area
- The pasteurization line for Crodino

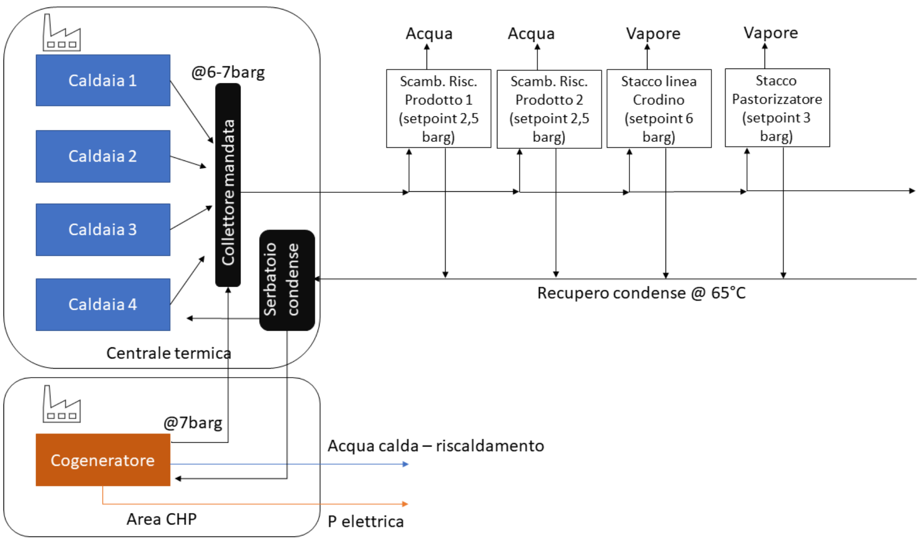

Figure 26 - Diagram of the thermal generation plant

2.3.6 Compressor station

The following compressors are present:

	Brand	Model	Size [kW]	Pressure [bar	FAD Capacity [m3/h]	Specific consumption [kWh/m3]
Compressor 1	Atlas Copco	ZR132/VSD	132	7	1231	0,1072
Compressor 2	Atlas Copco	ZR132	132	7	1321	0,099
Compressor 3	Atlas Copco	ZR160VSD+	160	7	5082	0,031

Table 4 - Nameplate of compressor

The station is composed by 3 compressors: one is a fixed speed compressor, the others are variable speed compressor VSD. They are able to work from 1500 to 3775 rpm.

	ZR 132/VSD: Nominal performance			
Speed	Input power	Capacity	Specific power	
[giri/min]	[kW]	[m3/min]	[m3/h]	[kWh/m3]
1500	48	7,62	457,2	0,105
3000	103	17,34	1040,4	0,099
3500	123	20,52	1231,2	0,100
3775	134	22,32	1339,2	0,100

Table 5 - Nominal technical specification of the variable speed compressor

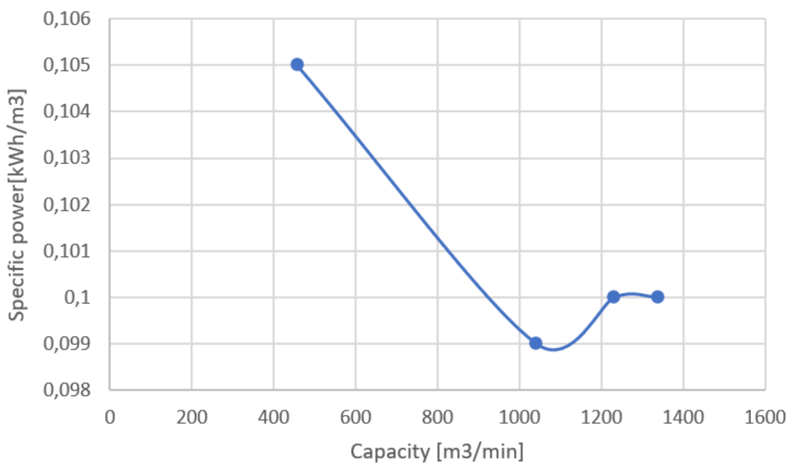

Figure 27 - Specific consumption trend of the variable speed compressor

The compressors operate with a fluctuating pressure between 6.70 bar and 7.40 bar. The station is equipped with storage tanks, where the produced air is accumulated before being delivered to production as needed. The ZR 132 VSD and ZR 160 VSD compressors have internal dryers, while the ZR 132 has an external dryer. These dryers are responsible for removing moisture from the air. During the compressed air production phase, the compressor tends to heat up. To ensure the proper functioning of the compressors, the compressor station operates within a closed-loop system that is cooled by an open-loop circuit, which is facilitated by a cooling tower. The supply water for the compressor comes from the cooling tower, which cools the compressor by using chilled water. This water is then routed through a heat exchanger that absorbs the heat generated by the compressor, warming the water. After the heat exchange, the heated water exits and continues its path through the closed circuit, maintaining a continuous flow.

2.3.7 Refrigeration station

The refrigeration plant operates with two closed circuits: one external circuit utilizing glycolated water and one internal circuit using ammonia. The glycolated water is cooled in a separator and stored in a tank. Pumps circulate this water through the circuit, where it is heated and then recirculated back into the system. The ammonia, passing through an expansion valve, changes state from liquid to gas. The gas, which absorbs heat, is directed to the evaporative condensers, where it releases the heat absorbed from the returning glycol. After releasing the heat, the ammonia is cooled and returned to its liquid state in a high-pressure receiver at ambient temperature.

This process occurs continuously within a closed circuit.
The refrigeration plant for producing glycolated water at **-10°C** is equipped with two ammonia chillers, MYCOM EUROPE N200VSD-M, with a total installed electrical power of 132 kWe + 186.5 kWe and a total cooling capacity of 1,250 kWf. The chillers operate in parallel using a cascade system. The distribution system for the propylene glycol solution at -10°C starts from the distribution center located in the utilities building, passing through the technological tunnel and autoclaves in cellars 1, 2, and 3: Lines No. 2-3.

The refrigeration plant for producing glycolated water at **0°C** is equipped with two ammonia chillers, MYCOM EUROPE N160VSD-M, with a total installed electrical power of 132 kWe + 186.5 kWe and a total cooling capacity of 1,350 kWf. Similarly, these chillers operate in parallel with a cascade system. The glycolated water at 0°C is distributed from the central plant through the technological tunnel to the tanks in cellar 1, and is also used for cooling the bottling department, pasteurizers, and other cellar utilities - Line No. 5.

For glycolated water at **+30°C**, distribution is also managed from the central plant through the technological tunnel to the steam-glycol heat exchangers for support and backup, and to the utilities in cellars 1, 2, and 3 - Line No. 4.

All chillers can operate together only in the production of glycolated water at -10°C, as the N160VSD chillers can be integrated into the -10°C circuit using specific sectioning valves.

Table 6 - Nameplate data of glycol water cooling unit -10°C/ 0°C

	Brand	Model	Cooling capacity [kWf]	Refrigeration capacity [kWe]	Refrigerant Gas	Services
Chiller 1 / -10°C	MYCOM EUROPE	N200VSD-M	1250 kW a -10°C	132+186,5	ammonia refrigeration unit	Autoclaves
Chiller 2 / -10°C	MYCOM EUROPE	N200VSD-M	1250 kW a -10°C	132+186,5	ammonia refrigeration unit	Cell
Chiller 3 / 0°C	MYCOM EUROPE	N160VSD-M	1350 kW a -0°C	132+186,5	ammonia refrigeration unit	Production
Chiller 4 / 0°C	MYCOM EUROPE	N160VSD-M	1350 kW a -0°C	132+186,5	ammonia refrigeration unit	Cellars

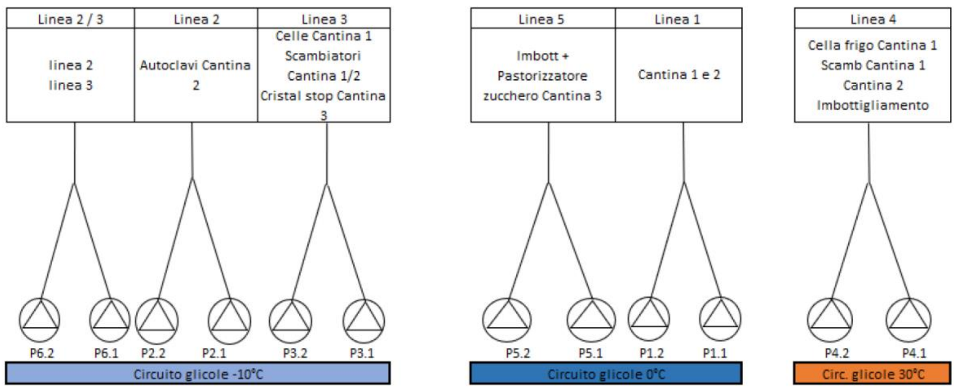

Figure 28 - Distribution of the water-glycol solution

The condensation of the chillers in the refrigeration plant is achieved through two BAC VXC-S.403 evaporative condensers installed on the roof. These condensers operate in parallel with a cascade system. Similar to the evaporative towers for compressed air, these condensers also utilize a closed circuit cooled by an open circuit.

The evaporative condensers operate in three stages, depending on the requirements:

1. **First stage**: The pump draws in ammonia and sends it to the nozzles, which spray water over the tube bundle, cooling the product inside.
2. **Second stage**: The motor, pulley, and rotor rotate the fans to further cool the ammonia. This stage combines the first stage with level 1 ventilation.
3. **Third stage**: Similar to the second stage but with enhanced ventilation.

The evaporative condensers contain tube bundles and require regular draining of water and ammonia when conductivity levels are too high to prevent damage to the piping. Internal deflectors facilitate the release of vapor.

On the roof of the facility, three additional chillers are installed to supplement the production of glycolated water at 0°C, used to cool bottled products on the Crodino and Campari Soda lines. An additional chiller, Systemair VLS 1204 BLN, is dedicated to cooling the Campari product, primarily used during the summer. The chillers operate in parallel with a cascade system.

2.3.8 Photovoltaic system

In Novi Ligure site's photovoltaic system is installed with a capacity of 996 kWp.

The system includes the following components:

- **2370 Monocrystalline PERC Silicon Photovoltaic Panels** with a peak power output of 420 Wp each and dimensions of 2066 x 998 x 35 mm, offering an efficiency of 20.4%.
- **100 kW String Inverters**

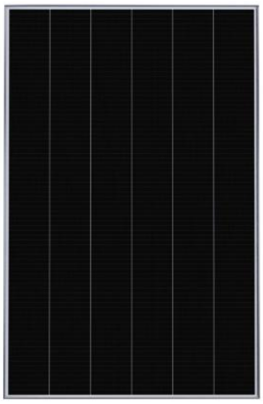

Figure 29 - Sunpower P6 module performance 420 W

Monocrystalline PERC Silicon	Data
Power	420 W
Dimensions	2066 x 998 x 35 mm
Efficiency	20,40%
Open Circuit Voltage (Voc):	54,4 V
Short Circuit Current (Isc)	9,92 A
Maximum Power Voltage (Vmp)	45,3 V
Maximum Power Current (Imp)	9,28 A
Temperature Coefficient of Powe	0.34 %/°C
Weight	22 kg
Glass	Anti-reflective tempered glass
Operating Temperature Range	-40°C to +85°C
Warranty	35 years

Table 7 - Nameplate data of Sunpower P6 - 420W

Source: Sun power from maxeon solar technologies

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
996 kWp	420 Wp	2370	5°/ 103° - 283°	4890 mq	-77°/103°	1.040.820 kWh/anno

LEGENDA:

Pannello fotovoltaico
dimensioni: 2066 x 998 x 35 mm.

metro di sicurezza per normativa Vigili del Fuoco

Sistema di sicurezza presente in copertura
Canalina di corrente continua
Canalina di corrente alternata

Inverter posizionati in esterno sulla
copertura del tetto piano

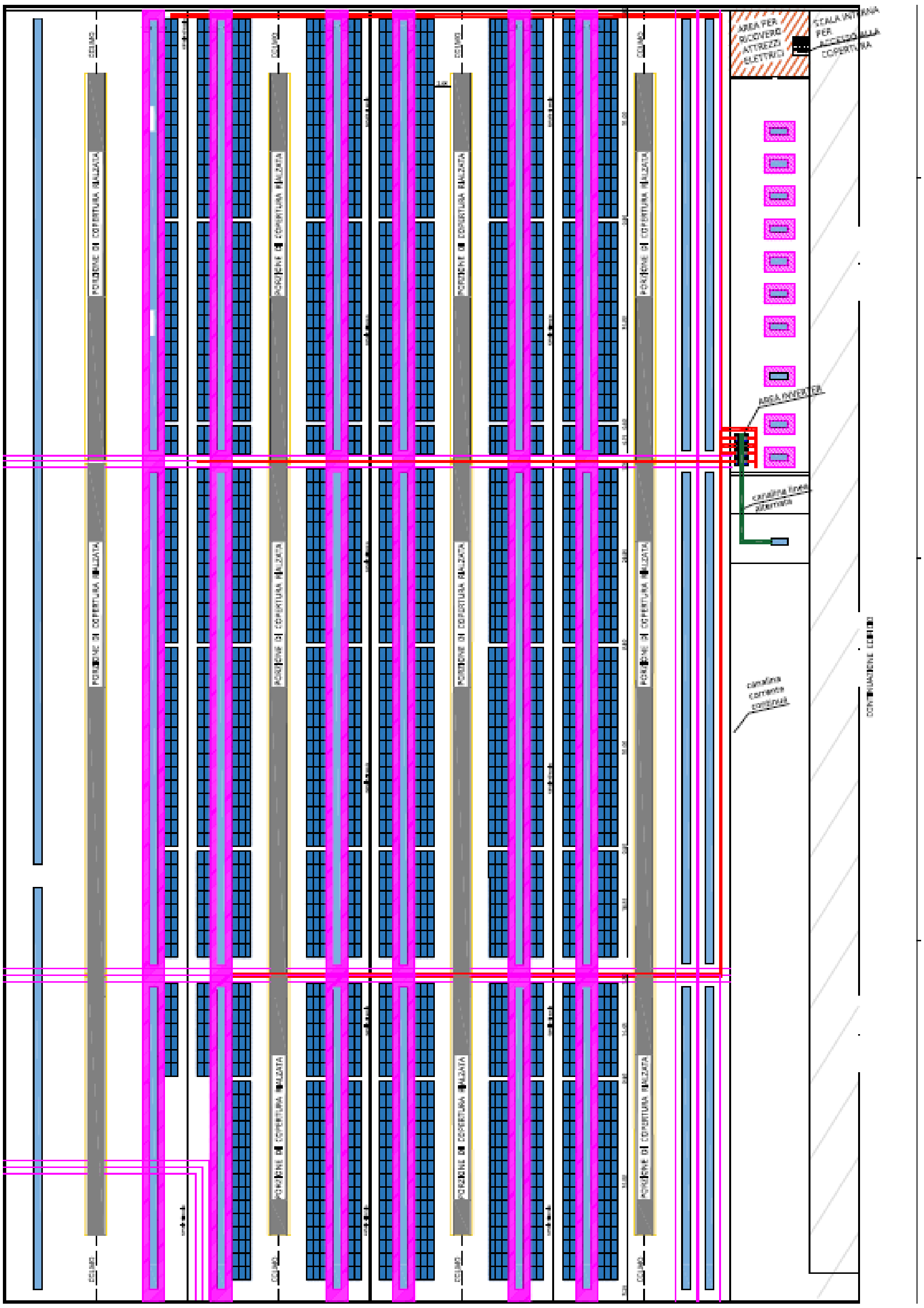

Figure 30 - Layout of Photovoltaic system 996 kWp

Source: Elmec Solar s.r.l.

In 2023, an offer was made for the extension of the existing photovoltaic system, adding a peak power of 360 kWp, and the installation of a new rooftop photovoltaic system with a peak power of 510 kWp in the new building. Currently, the new system is undergoing testing and is pending the required approvals before it can be fully operational.

The system includes :

- **817/51 Monocrystalline PERC Silicon Photovoltaic Panels** for the extension of the existing photovoltaic system
- **936 Monocrystalline PERC Silicon Photovoltaic Panels** for the new installation in the new building

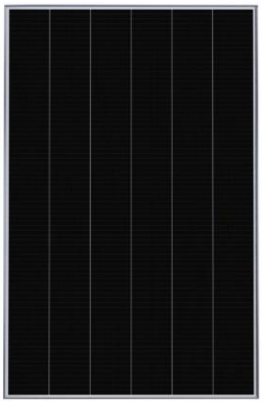

Figure 31 - Sunpower P6 module performance 545 W

Monocrystalline PERC Silicon	Data
Power	545 Wp
Dimensions	2384 x 1092 x 35 mm
Efficiency	21,00%
Open Circuit Voltage (Voc):	60,5 V
Short Circuit Current (Isc)	10,25 A
Maximum Power Voltage (Vmp)	50,5 V
Maximum Power Current (Imp)	9,90 A
Temperature Coefficient of Powe	0.34 %/°C
Weight	25 kg
Glass	Anti-reflective tempered glass
Operating Temperature Range	-40°C to +85°C
Warranty	35 years

Table 8 - Nameplate data of Sunpower P6 - 545W

Source: Sun power from maxeon

Table 9 - Data of Photovoltaic power system 996kWp

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
996 kWp	420 Wp	2370	5°/ 103° - 283°	4890 mq	-77°/103°	1.040.820 kWh/anno

Table 10 - Data of the extension Photovoltaic power system 360 kWp

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
360 kWp	415 Wp	817/51	5°/ 103° - 283°	1790 mq	-77°/103°	374.360 kWh/anno

Table 11 - Data of the new installation Photovoltaic power system 510 kWp

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
510 kWp	545 Wp	936	5°/ 103° - 283°	2437 mq	-77°/103°	530.518 kWh/anno

Table 12 - Data of the total Photovoltaic power system 1825 kWp

Total System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
1825 kWp	420 Wp/415 Wp/ 545 WP	4174	5°/ 103° - 283°	9117 mq	-77°/103°	1.945.698 kWh/anno

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
510 kWp	545 Wp	936	5°/ 103° - 283°	2437 mq	-77°/103°	530.518 kWh/anno

System Power	Panel Power	Number of Panel	Tilt / Azimuth (south 180°)	Area	Roof Orientation	Annual electricity production
360 kWp	415 Wp	817/51	5°/ 103° - 283°	1790 mq	-77°/103°	374.360 kWh/anno

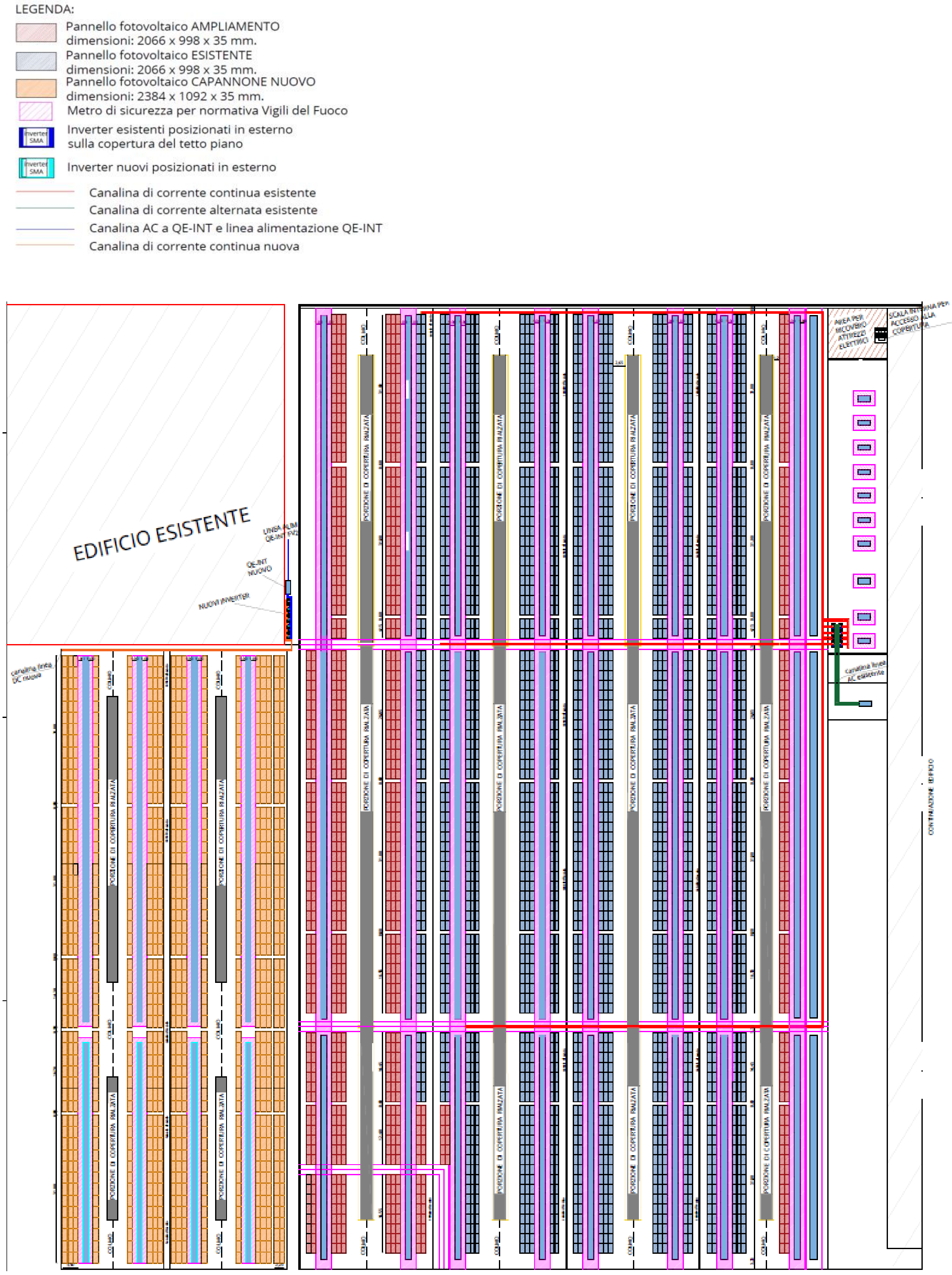

Figure 32 - Layout of the total Photovoltic system

Source: Elmec Solar s.r.l.

2.3.9 Water station

One of the most critical needs of the Novi site is water. The plant is equipped with a well approximately 250 meters deep, from which 70 m^3/h of water is drawn using dedicated pumps. In some cases, the production demand exceeds the well's supply capacity, water from the municipal network is utilized, allowing for a maximum extraction of up to 60 m^3/h.

The water undergoes an initial accumulation phase inside the "TK20" tank. Once stored, the water is directed to the "ZENON" trains 1 and 2. These trains are equipped with fine pores capable of filtering out impurities, expelling the dirty residue. The trains operate together, sharing the required water flow; however, each individual train can pump up to a maximum of 140 m^3/h, sufficient to supply the total demand. Every 3600 seconds, one train is stopped while the other remains operational, allowing for a backwash process. This backwash sends water from inside to the outside of the membrane pipes to clean them. The wastewater from this operation is discharged into the "Rio" river.

Once filtered, the water is transferred to the "350" tank, where chlorine dioxide is added to remove impurities and lower its conductivity. Pumps then push the water at a pressure of 4 bar into the central water distribution system.

The water plant is equipped with machinery capable of converting raw water into microfiltered, softened, and osmotized water.

Soften water:

Raw water contains high levels of salts, such as calcium, which need to be removed to produce softened water. Initially, the water passes through five filtration units with filters rated at 10 microsiemens, followed by an additional five units with 1 microsiemens filters. Once softened, part of the filtered water is directed to the boilers, while the majority is used in the production of Vermouth, replenishment of ammonia and compressed air evaporative towers, sanitization processes of autoclaves in the cellar, rinses and vacuum pumps on the production lines. The softened water is stored in two tanks. When one tank reaches a capacity of 400 m^3, a backwash is performed, emptying and refilling the tank with water and salt, which is held for a couple of hours before being flushed out. This process prevents the formation of preferential water pathways within the system.

Osmotized water:

The raw water exiting from the “350” tank is passed through a carbon filter. This water still contains chlorine dioxide, and the carbon filter, with pores of 1 microsiemens, effectively removes this compound. The filter is disinfected after every 10,000 m³ of water processed. The water is then sent to four reverse osmosis machines. In standard operation condition, each machine withdraw between 6-8 m³/h, retaining approximately 70% as permeate and discharging 30% as concentrate. This osmotized water, with low conductivity levels of 10-15 microsiemens, is used in the production of products like Aperol, Campari, Skyy Vodka, and Cinar and for the generation of sterile steam.

For the production of Campari Soda and Crodino, microfiltered water is used. This water is raw water that has undergone an additional microfiltration process.

For all other uses, such as CIP “Cleaning in Place” and COP “Cleaning out place” for sanitizing the bottling section, which is used for liquid changeovers that can occur on the same line, for floor washing, and for irrigating green areas, raw water is used.

Only for municipal services is the use of water from the public water supply mandatory.

2.4 PLANT ENERGY DEMAND

After describing the energy structure of the Novi Ligure site, we analyze the production volumes and energy consumption that form the basis of the energy model description.

Table 13- Production volume, Water and Energy consumption

		January	February	March	April	May	June	July	August	September	October	November	December
VOLUMES 2024	L	8.999.896,50	13.485.035,00	11.291.682,50	9.591.608,50	14.770.310,14	14.033.166,06	11.480.677,31	7.410.884,72	8.765.229,00	7.873.405,58	6.212.421,62	2.580.614,10
Electricity from Grid	kWh	509.776,00	503.901,00	552.969,00	484.824,00	431.510,99	474.815,98	716.732,98	728.764,48	785.563,25	695.649,63	663.528,56	569.766,83
Electricity from Photovolta	kWh	16.208,00	29.680,00	51.968,00	75.366,00	110.796,00	127.892,00	152.488,00	91.424,00	92.845,15	60.874,38	42.663,79	34.743,26
CHP (Electricity Produced)	kWh	333.040,00	362.616,00	220.892,00	184.100,00	264.568,00	385.148,00	359.828,00	146.596,00	274.819,50	280.211,91	279.986,21	151.437,07
Gas	Sm3	222.205,00	192.322,00	156.966,00	111.335,00	103.554,00	175.319,00	173.149,00	89.589,00	106.039,77	176.947,03	236.203,22	124.587,40
Total Water Withdrawn	m3	30.814,00	30.756,00	38.482,00	29.964,00	36.049,00	30.984,00	31.270,00	18.233,28	31.590,89	32.210,76	32.184,81	17.407,91
Well Water	m3	23.650,00	27.193,00	35.118,00	27.224,00	33.225,00	29.575,00	30.437,00	16.381,22	28.382,01	28.938,91	28.915,60	15.639,68
Municipal Water	m3	7.164,00	3.563,00	3.364,00	2.740,00	2.824,00	1.409,00	833,00	1.852,07	3.208,88	3.271,85	3.269,21	1.768,23

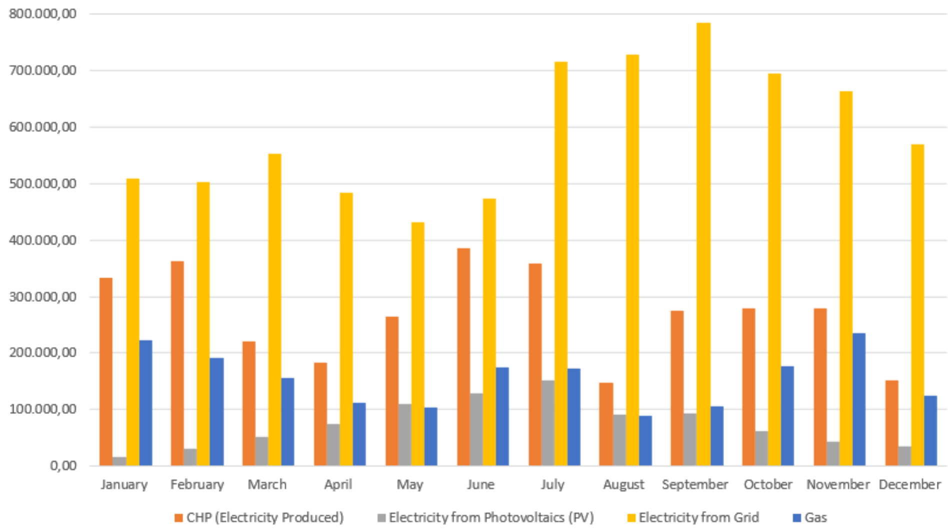

Figure 33- Energy demand

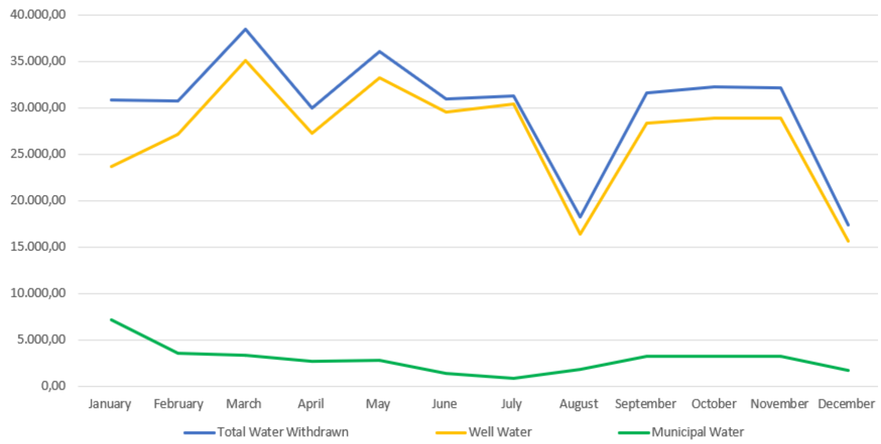

Figure 34 - Water demand

3 DEVELOPMENT AND APPLICATION OF THE ANALYTICAL MODEL

3.1 DESCRIPTION OF THE ANALYTICAL MODEL

Analyzing the energy consumption of an industrial facility is essential for understanding operational efficiency and identifying optimization opportunities. A mathematical model based on energy consumption allows for evaluating resource usage, measuring CO_2 emissions, and forecasting potential savings from the adoption of more efficient technologies or renewable energy sources. This model is constructed through the collection of both historical and real-time data related to production volumes, the specific technologies in use, and the facility's energy structure, including primary resources such as natural gas, electricity, steam, hot water, compressed air, refrigerant energy.

The analysis of this data enables the development of a mathematical model capable of monitoring energy usage and CO_2 emissions, providing a detailed view of the overall energy demand in relation to production demand. By simulating consumption dynamics, the model helps identify areas for improvement, such as optimizing energy flows, adopting more efficient technologies, or transitioning to renewable sources. This approach enables the company to meet regulatory requirements and achieve sustainability goals, while simultaneously reducing operational costs and environmental impact. The complex integration of different technologies and energy sources makes this model a powerful tool for energy planning, as it allows the simulation of future scenarios and informed decision-making on investments and energy management strategies, aligned with long-term decarbonization objectives.

The following energy analysis model represents the current situation of the Novi Ligure industrial facility and is divided into three main components: Power and Heat Production Technologies, Commodities, and Process Technologies.

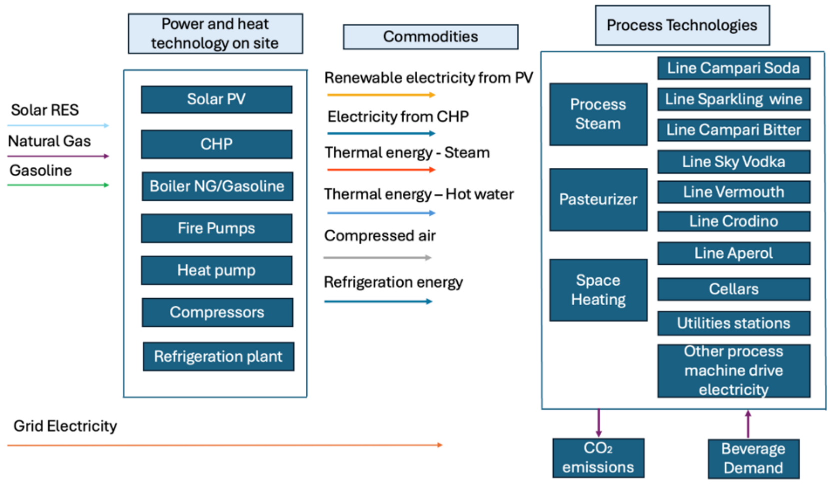

Figure 35 - Model Representation - Reference Energy System

Power and Heat Technologies On-site:

This section lists the primary technologies for energy generation and management that enable the facility to produce heat and electricity.

- **Solar PV**: Solar panels provide renewable electricity.
- **CHP (Combined Heat and Power)**: A cogeneration system that optimizes energy from fuel, simultaneously producing electricity and heat.
- **Boiler NG/Gasoline**: A boiler powered by natural gas or gasoline that produces thermal energy.
- **Fire Pumps and Compressors**: Critical for safety and powering pneumatic tools.
- **Heat Pump**: A highly efficient technology that uses thermal energy to provide heating or cooling.
- **Refrigeration Plant**: Cooling is essential in a beverage industry and represents one of the most significant energy consumption categories.

Commodities:

Commodities are the forms of energy and resources produced or utilized within the facility, necessary for various production processes:

- **Renewable Electricity from Photovoltaics:** Renewable energy generated from solar panels, used to power various processes and reduce reliance on grid electricity.
- **Electricity from CHP (Combined Heat and Power):** Electricity produced by the cogeneration system, intended to supply power to production lines and infrastructure. This contributes to maintaining energy independence and reducing costs.
- **Thermal Energy - Steam:** Steam is used for heating industrial processes, such as pasteurization, which is essential for the quality and safety of beverages.
- **Thermal Energy - Hot Water:** This is provided for heating requirements and other processes. Hot water is primarily generated through the cogenerator and represents a crucial resource for maintaining controlled temperatures in production processes.
- **Compressed Air:** Supplied by compressors, compressed air is used to power pneumatic equipment at various points in the production process.
- **Refrigeration Energy:** This is necessary to maintain optimal temperatures during production and storage processes, which is fundamental for preserving product quality.

Process Technologies

This section includes production lines and process technologies, which require various forms of energy:

- **Process Steam:** Steam used to heat or sterilize various components of the process, including tanks and pipes, ensuring that production is safe and compliant with standards.
- **Pasteurizer:** A specific facility for the pasteurization of beverages, which requires a significant heat input to eliminate any pathogens.
- **Space Heating:** Necessary to ensure a comfortable working environment and to maintain the equipment at optimal temperatures.
- **Beverage Production Lines:** Each line (e.g., Campari Soda, Sparkling Wine, Campari Bitter, Sky Vodka) has specific energy requirements, with both electrical and thermal energy used to power equipment and maintain consistent product quality.

- **Cellars:** These are specialized facilities where liquids are processed before bottling. They require controlled temperature and humidity conditions to ensure the stability and quality of the products during fermentation, aging, or blending processes. Specific energy needs for cooling, heating, and ventilation are essential to maintain optimal environmental conditions for the products.
- **Electricity for Other Processes:** Includes all other electrical needs, such as the operation of auxiliary equipment and machinery for processing.

3.2 DISTRIBUTION OF THE TOTAL PLANT PRODUCTION

Using meters installed in the facility and software that enables real-time data visualization, it was possible to extract the following allocation of facility energy consumption, which is distributed across various production processes.

Table 14 - Distribution of energy consumption

NATURAL GAS	1.868.216	Sm3	755.047	Sm3	Chp
			1.113.169	Sm3	Boilers

GASOLINE	100	L	Fire pumps

ELECTRICITY	11.247.994	kWh	886.949	kWh	Renewable PV	7,9%
			3.243.243	kWh	Electricity from CHP	28,8%
			7.117.803	kWh	Grid electricity	63,3%

Boilers	0,60%	67.488	kWh
Heat pump	1,56%	175.469	kWh
Compressors	7,94%	893.091	kWh
Refrigeration plant	15,05%	1.692.823	kWh
Line Campari soda	5,70%	641.136	kWh
Line sparkling wine	3,70%	416.176	kWh
Line campari bitter	2,40%	269.952	kWh
Line Sky vodka	0,90%	101.232	kWh
Line vermouth	1,50%	168.720	kWh
Line crodino	5,70%	641.136	kWh
Line aperol	1,60%	179.968	kWh
Cellars	8,10%	911.088	kWh
Utilities station	14,25%	1.602.839	kWh
Other process drive electr.	31,00%	3.486.878	kWh

THERMAL ENERGY -STEAM	10.976.723	kWht	Process steam	93,7%	10.356.012	kWht
			Space heating	6,3%	620.712	kWht

THERMAL ENERGY - HOT WATER	1.067.721	kWht	Pasteurizer	78,19%	834.851	kWht
			Process steam	21,81%	232.870	kWht

COMPRESSED AIR	5.821.868	m3	Cellars	27%	1593146	m3
			Line Campari soda	19%	1121103	m3
			Line sparkling wine	13%	727733	m3
			Line campari bitter	8%	472043	m3
			Line Sky vodka	3%	177016	m3
			Line vermouth	5%	295027	m3
			Line crodino	19%	1121103	m3
			Line aperol	5%	314696	m3

REFRIGERETION ENERGY	6.886.089	kWf	Cellars	85%	5853175,891	kWf
			Pasteurizer	15%	1032913,393	kWf

3.3 ANALYSIS AND ASSUMPTIONS OF THE ENERGY MODEL

The year 2024 has been established as the reference for maximum annual production, reaching a total volume of 116,494,931 liters. To achieve this output, the facility requires a total energy demand of 114,100,500 MJ, met through the consumption of 1,868,216 Sm³ of natural gas and 11,247,994 kWh of electricity.

Assuming that both production volume and the facility's energy demand remain constant from 2024 to 2050, this study focuses on analyzing the impact of technological replacements and the integration of new renewable energy sources. The objective is to reduce both the facility's overall energy demand and its reliance on external energy sources by increasing on-site energy generation.

The energy analysis is structured into two distinct models: a thermal model and an electrical model, each providing a detailed representation of the utilization and distribution of their respective energy vectors.

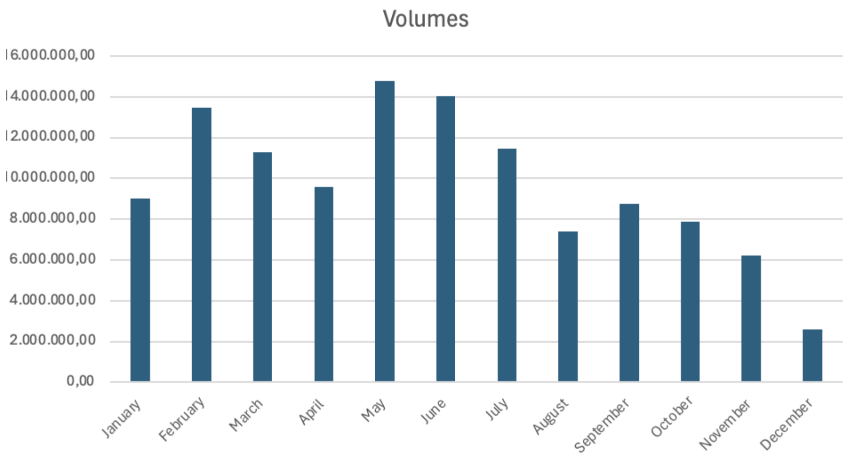

Figure 36 - Distribution Volumes

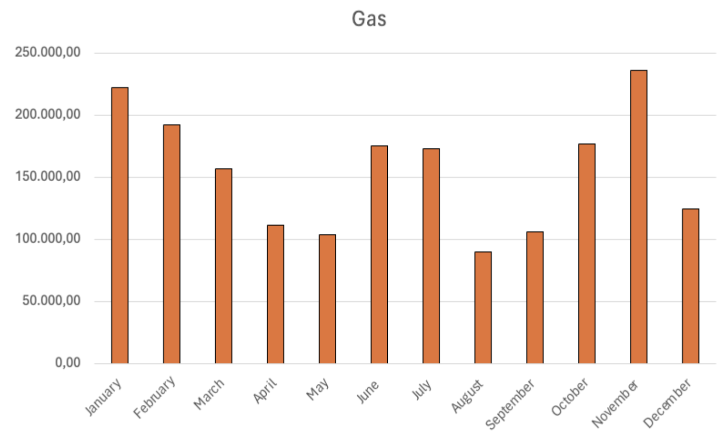

Figure 37- Gas trend

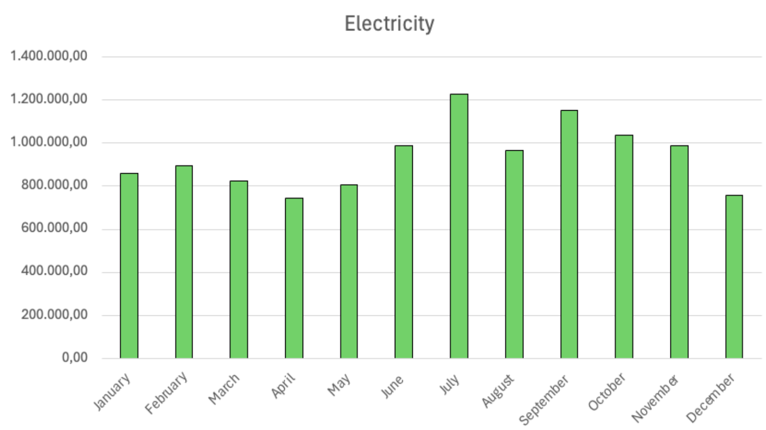

Figure 38 - Electricity trend

3.3.1 Thermal model

The thermal model is divided into two main components:

- Analysis of the cogeneration system's operation
- Evaluation of boiler performance, with the potential integration of a heat pump

Both analyses aim to reduce emissions and energy consumption by exploring the replacement of natural gas as the primary energy source with renewable alternatives. These include biomethane, obtained through anaerobic digestion and thermal gasification, and hydrogen produced via fuel cells. The model examines the period from 2024 to 2050, making it essential to accurately project the present and future availability of energy sources. This approach ensures a realistic feasibility study that can justify the replacement or integration of new sustainable technologies.

Data analysis:

Below are the two main parameters that primarily influence the model.

Fuel injected:

Gas Natural:

The table below presents fossil fuel import prices in €/MWh, adjusted for inflation. According to the European benchmark for natural gas prices, the current rate stands at €42.33/MWh. Based on the EU's Long-term Scenarios 2050, projections for 2030 and 2050 indicate a gradual decline in natural gas prices, with an expected decrease of approximately 0.28% annually from 2024 to 2050.

Table 15 - Cost variation of Gas Natural

GAS NATURAL	2024	2030	2050
€/Mwh	39,54	39,43	36,72
€/Sm3	0,428	0,427	0,398

Biomethane – Anaerobic digester:

According to the report "*The Optimal Role for Gas in a Net-Zero Emissions Energy System*" (Terlouw et al., 2019) , the current cost of biomethane production via anaerobic digesters is approximately 77 €/MWh, this can vary based on the type of biomass used. With the increase in biomethane production installations in the future, it is estimated that this cost could decrease by around 20 €/MWh by 2050 compared to 2024, reaching approximately 57 €/MWh.

Table 16 - Cost variation of Biomethane Anaerobic Digester

BIOMETHANE - ANAEROBIC DIGESTER	2024	2030	2050
€/Mwh	77,50	72,44	57,30
€/Sm3	0,775	0,724	0,573

The cost shown in the previous table does not include the connection expenses required to inject biomethane into the gas grid. The total connection cost is estimated at approximately 9.7 €/MWh, with 5 €/MWh attributed to biogas pipeline infrastructure and 4.7 €/MWh to grid connection and related expenses. The revised values, taking these additional elements into account, are provided below.

Table 17 - Cost variation of Biomethane Anaerobic Digester adding connection cost

BIOMETHANE - ANAEROBIC DIGESTER	2024	2030	2050
€/Mwh	87,20	82,14	67,00
€/Sm3	0,872	0,821	0,670

Biomethane – Thermal Gasification:

In agreement with the report by Terlouw et al. (2019), the current cost of biomethane production via thermal gasification is approximately 88 €/MWh, based on a mix of biomass feedstocks. The projected reduction in production costs from now until 2050 is primarily due to increased energy conversion efficiency, expected to rise from 65% to 75%, the benefits of economies of scale, and the development of a larger number of production plants. These advancements enhance infrastructure reliability and overall operational efficiency, leading to an estimated production cost of around 47 €/MWh by 2050.

Table 18 - Cost variation of Biomethane Thermal Gasification

BIOMETHANE - THERMAL GASIFICATION	2024	2030	2050
€/Mwh	88,00	77,44	47,00
€/Sm3	0,880	0,774	0,470

The production cost of biomethane from thermal gasification does not include the transportation costs of the gas and the connection to the grid. For this source, it is estimated that the costs associated with grid injection and connection will be minimal. This is because the biomethane, generated at a natural gas quality, is produced at high pressure, allowing for easy injection into the grid. Moreover, it is anticipated that the thermal gasification facilities will be situated near the existing gas grid, resulting in very low pipeline costs. The annual costs calculated for injecting gasification-based biomethane into the grid are 2 €/MWh.

Table 19 - Cost variation of Biomethane Thermal Gasification adding connection cost

BIOMETHANE - THERMAL GASIFICATION	2024	2030	2050
€/Mwh	90,00	79,44	49,00
€/Sm3	0,900	0,794	0,490

Hydrogen

For hydrogen fuel, the report "Un nuovo alleato, un'alternativa difficile" by Davide Tabarelli indicates that current costs are around 180 €/MWh, equivalent to approximately 6 €/kg. This high cost is attributed to several factors, including the price of electrolyzers, storage systems, and the costs of green electricity and water required for the production process. However, advancements in hydrogen production technologies, such as high-efficiency electrolysis and carbon capture techniques, along with an increase in renewable energy capacity, will contribute to a decrease in the cost of green electricity. These combined factors are expected to lead to a reduction in hydrogen costs by 2050, estimating them at around 120 €/MWh, or approximately 4 €/kg.

Table 20 - Cost variation of Hydrogen

HYDROGEN	2024	2030	2050
€/Mwh	180	164	120
€/Sm3	0,54	0,49	0,36

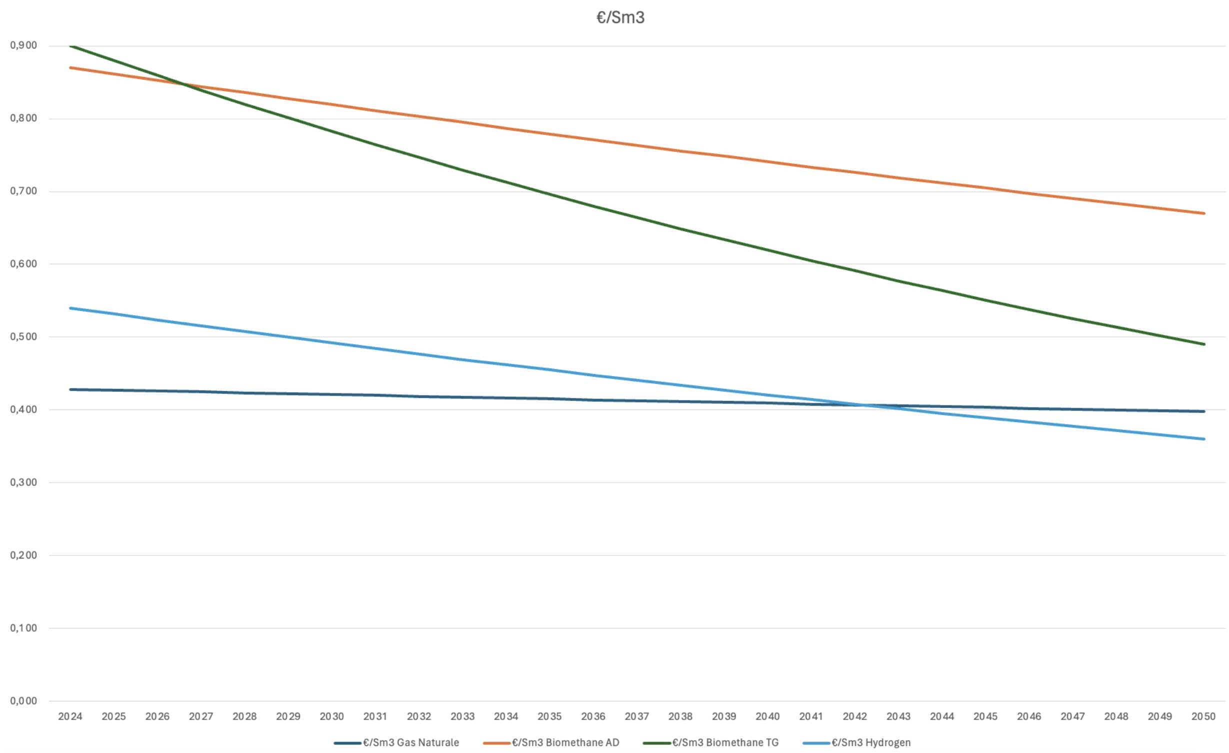

Figure 39 - Gas Trends

Emission factor:

Another parameter to consider in the mathematical model is the emissions generated per product.

Gas Natural:

The report "IPCC Guidelines for National Greenhouse Gas Inventories" (Dario R. Gomez et al., 2006) estimates methane gas emissions at 56,100 kg/TJ, a value essential for calculating the annual CO_2 emissions from the site.

Biomethane:

For biomethane, since it is produced from renewable sources, emissions are 0 kg/TJ.

Hydrogen

Similarly, hydrogen production, also based on renewable sources, is assigned an emission factor of 0 kg/TJ.

Once the total tons of CO_2 produced are known, it will be essential to assess the projected emission cost per ton from 2024 to 2050. According to "Il Sole 24 Ore", the current price of CO_2 emission allowances is 85 €/tCO_2. As shown in the table, this value is expected to rise sharply, reaching approximately 400 €/tCO_2 by 2050.

Table 21 - Emission Cost of CO2

EMISSION COST OF CO2	2024	2030	2050
€/t	85	122	400

In our data analysis, this value will be used to calculate the carbon tax, defined as:

$$\text{Carbon tax } [€] = CO_2 \text{ produced } [tCO_2] * \text{Emission cost of } CO_2 \ [€/tCO_2]$$

(3. 1)

This parameter will play a critical role in the model, as it will provide a projection of emission-related costs from 2024 to 2050, allowing us to determine the most effective technology for minimizing both costs and emissions.

Guarantee of Origin

Having defined the trend of the CO_2 price as previously mentioned and considering natural gas as the primary source of emissions, it was possible to calculate an additional parameter, defined as Guarantee of Origin (GO), to quantify the increase in the cost of gas in terms of €/MWh due to the carbon tax. In other words, the objective is to assess the economic impact of CO_2 emission taxation, expressed in €/MWh. To calculate the Guarantee of Origin, the following steps were necessary:

- Calculation of total CO_2 emissions by 2025.
- Determination of the unit cost of CO_2 emissions projected for 2050.
- Application of the CO_2 emission factor for natural gas, set at 0.0000561 tCO_2/MJ.

The resulting value in €/MJ is obtained using the following formula:

$$\text{Cost of CO2 emissions} \left[\frac{€}{\text{MJ}}\right] = \text{Emission cost of CO2} \left[\frac{€}{\text{tCO2}}\right] * \text{Emission factor CO2} \left[\frac{€}{\text{MJ}}\right] \tag{3. 2}$$

After calculating the emission costs of CO_2 in €/MJ, it was converted to €/MWh using the conversion factor, where 1 MWh = 3,600 MJ. This conversion allows for the calculation of the carbon tax impact in €/MWh. The total cost of natural gas for 2050 is obtained by summing the price of natural gas at the defined date and the calculated carbon tax value. The initial cost result, considering the model values, is 117 €/MWh. Considering specific market dynamics and regulations such as:

- **Supply and Demand**: The price of GOs depends on the availability of certificates in the market relative to demand; a surplus of certificates can lead to a significant price reduction.
- **Government Incentives**: Governments may offer incentives or subsidies for the purchase of certified renewable energy, thereby reducing the effective cost of GOs for consumers.
- **Market Efficiency**: Efficient markets for trading GOs can reduce transaction costs, leading to a lower price for certificates.

A 40% discount was applied to the value of the Guarantees of Origin (GO), resulting in 70.5 €/MWh, to obtain a more realistic value.

The introduction of the Guarantee of Origin ensures that the energy drawn from the grid is entirely renewable, thus eliminating CO_2 production. In the developed model, the obtained data was added to the initially defined costs for biomethane, derived from anaerobic digestion and thermal gasification, reinforcing the hypothesis that the analyzed fuels will not produce CO_2. Consequently, there will be no carbon tax cost, as the price increase will already be integrated into the total cost in €/MWh of biomethane.

Table 22 – Biomethane Anaerobic Digester with GO

BIOMETHANE - ANAEROBIC DIGESTER	2024	2030	2050
€/Mwh	157,70	152,64	137,50
€/Sm3	1,577	1,526	1,375

Table 23- Biomethane Thermal gasification with GO

BIOMETHANE - THERMAL GASIFICATION	2024	2030	2050
€/Mwh	160,50	149,94	119,50
€/Sm3	1,605	1,499	1,195

3.3.1.1 Cogeneration system

The analysis model for the cogenerator considers various parameters that influence its technical and economic performance, comparing different technologies under the same operating conditions. It identifies the optimal solution, allowing the replacement of the current technology with the one that offers the best €/kWht and €/kWhe ratio.

The analysis involves comparing four types of cogenerators (CHP):

1. CHP powered by natural gas
2. CHP powered by biomethane – anaerobic digestion
3. CHP powered by biomethane – thermal gasification
4. CHP powered by hydrogen

these differ in the type of fuel used and in:

- **Installation cost of the plant;**
- **Fuel cost**, calculated with the following formula:

$$\text{Cost of fuel } [\text{ € }] = \text{Gas cost of fuel } [\text{ €/Sm3 }] * \text{ Fuel injected } [\text{Sm3}]$$

(3. 3)

- **Useful life duration;**
- **Incentives obtainable** through white certificates (valid for a duration of 10 years) calculated with the formula:

$$\text{Incentives} = \text{White certificates price } \left[\frac{\text{€}}{\text{TOE}}\right] * \text{ Tons of oil equivalent } [\text{TOE}]$$

(3. 4)

The values of tons of oil equivalent are:

- 1000 Sm3 of Natural Gas corresponds to 0.836 Toe
- 1000 Sm3 of Biomethane corresponds to 0.55 Toe

- **Amount of CO_2** emitted (which will affect the carbon tax cost) calculated with the formula:

$$\text{Total C02 emission} = \text{CO2 emission factor} \left[\frac{\text{tCO2}}{\text{MJ}}\right] * \text{Net Calorif value} \left[\frac{\text{MJ}}{\text{Sm3}}\right] * \text{Fuel injected [Sm3]}$$

(3. 5)

Depending on the plant, the following is considered:

- the **Net Present Value (NPV)** of the capital is calculated from the installation cost defined as follows:

$$\text{NPV} = \frac{(\text{Cost of installation} \; * \; \text{Discount rate})}{(\,1 - \;(1 \; + \; \text{Discount rate})\;\hat{}\,(-\,\text{Years of operation})\,)}$$

(3. 6)

  where the discount rate is set at 5%.

- the **thermal and electrical** production of the cogenerators is constant from 2024 to 2050. The estimated values of thermal and electrical production of the cogenerators are 2,546,800 kWht and 3,243,247 kWhe, respectively, calculated based on the annual operating hours of the plant (equal to 5,500 hours/year); part of which includes maintenance hours (each maintenance hour generates a cost that contributes to the annual maintenance cost).

- the **amount of fuel used** varies depending on the type of fuel chosen, as it is directly related to the Net Calorific value. Once the amount of fuel needed to power the plant is determined, this value will remain constant from 2024 to 2050.

Operational and installation cost	
Cost of installation	€
Operation hours	h/y
Years of operation	year
Maintenance	%
Maintenance hour	h/y
Mantainance cost per hour	€/h
Mantainance cost	€
Plant production	
Production energy	MJ
Heating production	kWht
Electricity production	kWhe
Financial analysis	
Discount rate	
Present value of capital	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Net Calorific value	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO2/MJ
Total C02 emission	tC02
Emission cost of C02	€/tC02
Incentives	
Tons of oil equivalent (TOE)	TOE
White certificates price	€/TOE
Incentives	€

Figure 40 - Parameters for CHP analysis.

Once the type of gas used, the fuel cost, the costs associated with CO_2 emissions (carbon tax), the annual maintenance costs, and the incentives from white certificates are established, we can calculate the total annual cost for electrical and thermal production.

From the estimates of the cogeneration plant's production, 56% of the fuel is used for electricity production, while the remaining 44% is allocated to thermal production.

The formulas for calculating the total cost are as follows:

$$\text{TOTAL COST for heating} = \text{present value of capital } [€] + \text{Cost fuel for heating } [€] + \\ + \text{Matainance cost } [€] - \text{Incentives } [€] + \text{Carbon tax } [€] \tag{3. 7}$$

$$\text{TOTAL COST for electricity} = \text{present value of capital } [€] + \text{Cost fuel for electricity } [€] + \\ + \text{Matainance cost } [€] - \text{Incentives } [€] + \text{Carbon tax } [€] \tag{3. 8}$$

Once the quantities of electricity and heat produced are defined, we can calculate the production cost of each commodity, electricity and heating, for each year from 2024 to 2050. Comparing the obtained data will allow us to identify the technology with the best €/kWht and €/kWhe ratio.

The formulas for the unit production costs are:

$$\text{Cost of heating production}\left[\frac{€}{\text{kWht}}\right]=\frac{\text{Total cost for heating}}{\text{Heating production}}$$

(3. 9)

$$\text{Cost of electricity production}\left[\frac{€}{\text{kWhe}}\right]=\frac{\text{Total cost for electricity}}{\text{Electricity production}}$$

(3. 10)

Year	
Present value of capital	€
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Fuel for heating	Sm3
Fuel for electricity	Sm3
Cost of fuel for heating	€/year
Costo of fuel for electricity	€/year
Mantainance cost	€
Incentives	€
Emission cost of C02	€/tC02
Carbon tax	€
TOTAL COST for heating	€
TOTAL COST for electricity	€
Heating production	kWht
Cost of heating production	€/kWht
Electricity production	kWhe
Cost of electricity production	€/kWhe

Figure 41- Yearly evaluation of CHP cost.

Below are the values analyzed for each technology: The technologies differ in the amount of fuel injected because each fuel has its own Net Calorific Value.

CHP- Natural Gas:

Table 24 – Data for evaluation of CHP Natural Gas

Gas Natural Cogenerator		
Operational and installation cost		
Cost of installation	€	1.083.000
Operation hours	h/y	5.500
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	825
Mantainance cost per hour	€/h	15
Mantainance cost	€	12.375
Plant production		
Production energy	MJ	20.844.169
Heating production	kWht	2.546.800
Electricity production	kWhe	3.243.247
Financial analysis		
Discount rate		5%
Present value of capital	€	76.842
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,428
Fuel injected	Sm3	755.047
Net Calorific value	MJ/Sm3	33
Cost of fuel	€/year	323.424
C02 Emission factor	tCO_2/MJ	0,0000561
Total C02 emission	tC02	1.414
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	TOE	631
White certificates price	€/TOE	250
Incentives	€	157.805

Table 25 – Trend of CHP Natural Gas

Year		2024	2030	2050
Present value of capital	€	76.842	76.842	76.842
Gas cost of fuel	€/Sm3	0,428	0,421	0,398
Fuel injected	Sm3	755.047	755.047	755.047
Fuel for heating	Sm3	332.114	332.114	332.114
Fuel for electricity	Sm3	422.933	422.933	422.933
Cost of fuel for heating	€/year	142.261	139.852	132.115
Costo of fuel for electricity	€/year	181.164	178.096	168.243
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	157.805	157.805	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	120.219	171.869	565.735
TOTAL COST for heating	€	193.891	243.133	787.067
TOTAL COST for electricity	€	232.794	281.377	823.195
Heating production	kWht	2.546.800	2.546.800	2.546.800
Cost of heating production	€/kWht	0,08	0,10	0,31
Electricity production	kWhe	3.243.247	3.243.247	3.243.247
Cost of electricity production	€/kWhe	0,07	0,09	0,25

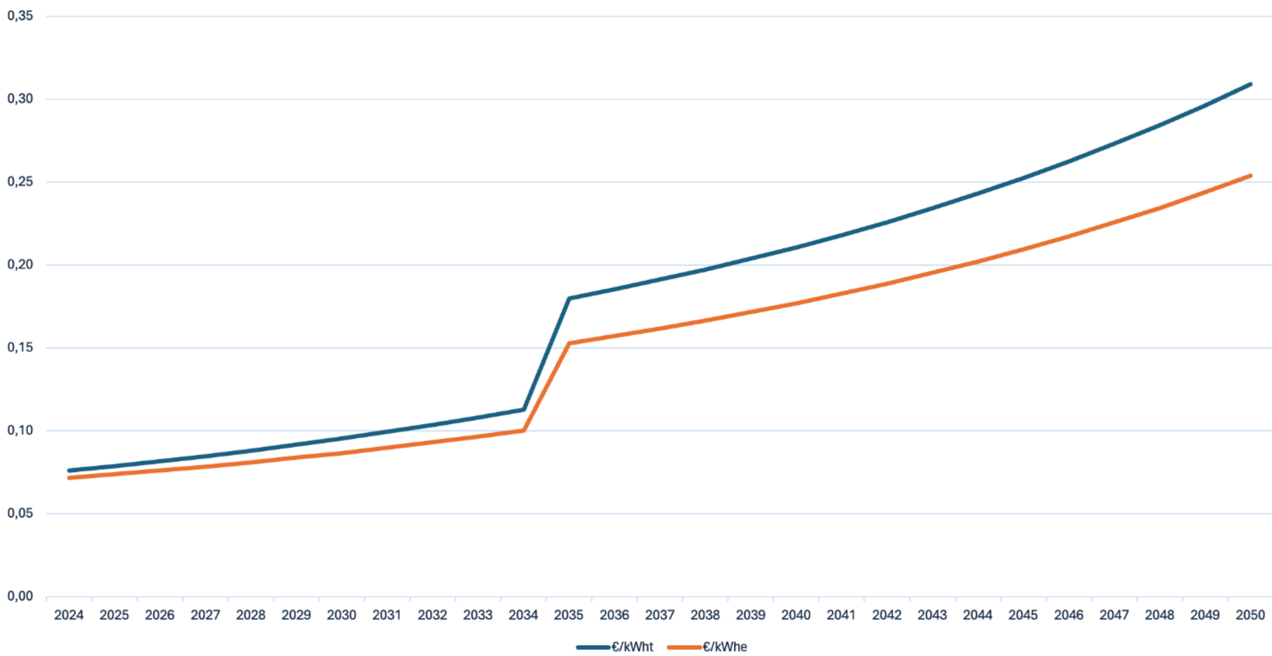

Figure 42 – Cost trend for CHP Natural Gas production

CHP- Biomethane Anaerobic Digestion

Table 26 - Data for evaluation of CHP Biomethane Anaerobic Digestion

Biomethane cogenerator - Anaerobic Digestion		
Operational and installation cost		
Cost of installation	€	3.620.000
Operation hours	h/y	5.500
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	825
Mantainance cost per hour	€/h	15
Mantainance cost	€	12375
Plant production		
Production energy	MJ	20.844.169
Heating production	kWht	2.546.800
Electricity production	kWhe	3.243.247
Financial analysis		
Discount rate		5%
Present value of capital	€	256.848
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,575
Fuel injected	Sm3	665.249
Net Calorific value	MJ/Sm3	39
Cost of fuel	€/year	1.047.767
C02 Emission factor	tCO_2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	tep	366
White certificates price	€/tep	250
Incentives	€	91.472

Table 27 – Trend of CHP Biomethane Anaerobic Digestion

Year		2024	2030	2050
Present value of capital	€	256.848	256.848	256.848
Gas cost of fuel	€/Sm3	1,58	1,53	1,38
Fuel injected	Sm3	665.249	665.249	665.249
Fuel for heating	Sm3	292.615	292.615	292.615
Fuel for electricity	Sm3	372.634	372.634	372.634
Cost of fuel for heating	€/year	460.869	446.650	402.346
Costo of fuel for electricity	€/year	586.898	568.791	512.371
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	91.472	91.472	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	0	0	0
TOTAL COST for heating	€	638.620	624.401	671.569
TOTAL COST for electricity	€	764.649	746.542	781.594
Heating production	kWht	2.546.800	2.546.800	2.546.800
Cost of heating production	€/kWht	0,25	0,25	0,26
Electricity production	kWhe	3.243.247	3.243.247	3.243.247
Cost of electricity production	€/kWhe	0,24	0,23	0,24

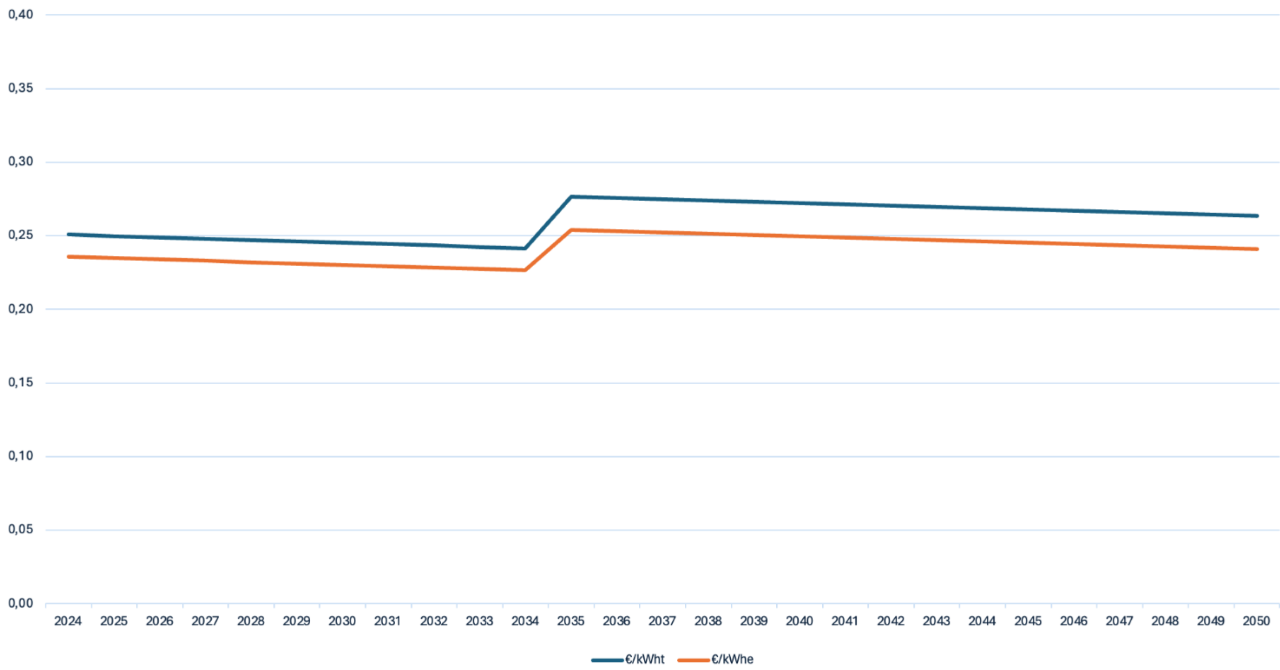

Figure 43 – Cost trend for CHP Biomethane Anaerobic Digestion production

CHP - Biomethane Thermal Gasification

Table 28 - Data for evaluation of CHP Biomethane Thermal gasification

Biomethane cogenerator - Thermal Gasification		
Operational and installation cost		
Cost of installation	€	3.620.000
Operation hours	h/y	5.500
Years of operation	year	20
Maintenance	%	15
Maintenance hour	h/y	825
Mantainance cost per hour	€/h	15
Mantainance cost	€	12375
Plant production		
Production energy	MJ	20.844.169
Heating production	kWht	2.546.800
Electricity production	kWhe	3.243.247
Financial analysis		
Discount rate		5%
Present value of capital	€	290.478
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,605
Fuel injected	Sm3	665.249
Net Calorific value	MJ/Sm3	39
Cost of fuel	€/year	1.067.725
C02 Emission factor	tCO_2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	tep	366
White certificates price	€/tep	250
Incentives	€	91.472

Table 29 - Trend of CHP Biomethane Thermal gasification

Year		2024	2030	2050
Present value of capital	€	290.478	290.478	290.478
Gas cost of fuel	€/Sm3	1,61	1,50	1,20
Fuel injected	Sm3	665.249	665.249	665.249
Fuel for heating	Sm3	292.615	292.615	292.615
Fuel for electricity	Sm3	372.634	372.634	372.634
Cost of fuel for heating	€/year	469.648	438.742	349.675
Costo of fuel for electricity	€/year	598.077	558.720	445.297
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	91.472	91.472	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	0	0	0
TOTAL COST for heating	€	681.029	650.123	652.528
TOTAL COST for electricity	€	809.459	770.101	748.150
Heating production	kWht	2.546.800	2.546.800	2.546.800
Cost of heating production	€/kWht	0,27	0,26	0,26
Electricity production	kWhe	3.243.247	3.243.247	3.243.247
Cost of electricity production	€/kWhe	0,25	0,24	0,23

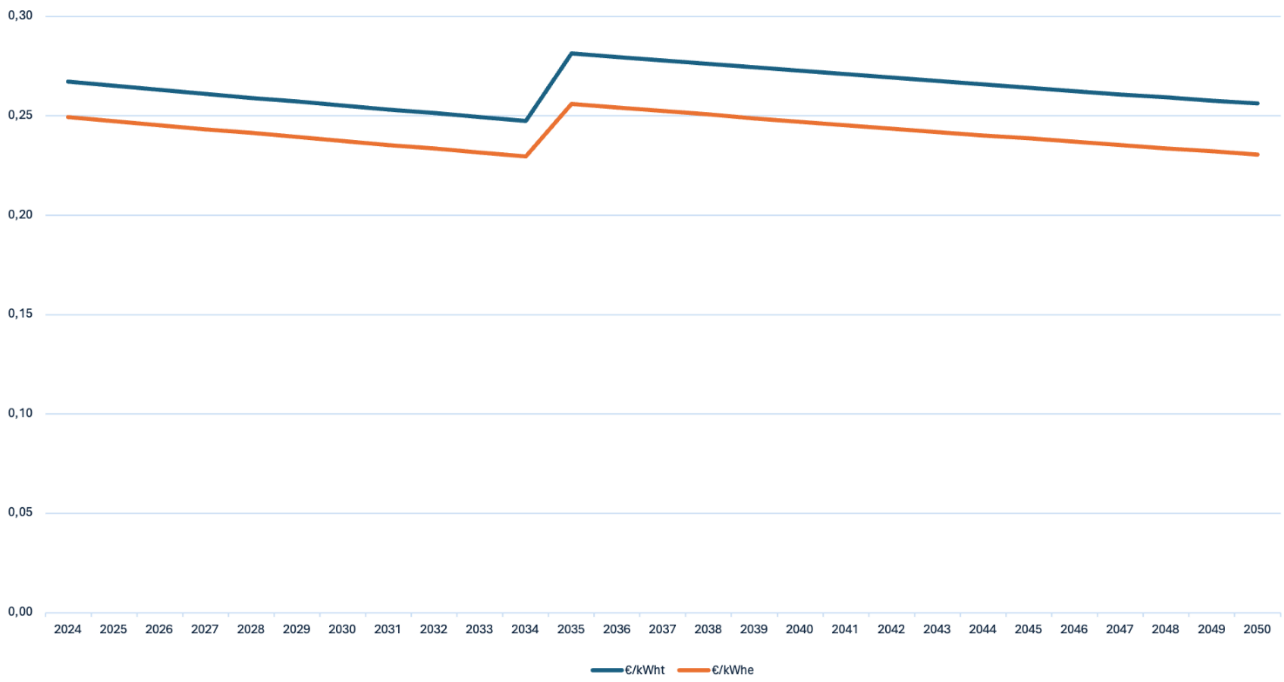

Figure 44 – Cost trend for CHP Biomethane Thermal gasification production

CHP - Hydrogen

Table 30 - Data for evaluation of CHP Hydrogen

Hydrogen Cogenerator		
Operational and installation cost		
Cost of installation	€	5.400.000
Operation hours	h/y	5.500
Years of operation	year	8
Maintenance	%	15
Maintenance hour	h/y	825
Mantainance cost per hour	€/h	15
Mantainance cost	€	12375
Plant production		
Production energy	MJ	20.844.169
Heating production	kWht	2.546.800
Electricity production	kWhe	3.243.247
Financial analysis		
Discount rate		5%
Present value of capital	€	835.498
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,54
Fuel injected	Sm3	2.060.799
Net Calorific value	MJ/Sm3	11
Cost of fuel	€/year	1.112.831
C02 Emission factor	tCO_2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	tep	1.133
White certificates price	€/tep	250
Incentives	€	283.360

Table 31 - Trend of CHP Hydrogen

Year		2024	2030	2050
Present value of capital	€	835.498	835.498	835.498
Gas cost of fuel	€/Sm3	0,54	0,49	0,36
Fuel injected	Sm3	2.060.799	2.060.799	2.060.799
Fuel for heating	Sm3	906.459	906.459	906.459
Fuel for electricity	Sm3	1.154.339	1.154.339	1.154.339
Cost of fuel for heating	€/year	489.488	445.765	326.325
Costo of fuel for electricity	€/year	623.343	567.663	415.562
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	283.360	283.360	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	0	0	0
TOTAL COST for heating	€	1.054.001	1.010.278	1.174.198
TOTAL COST for electricity	€	1.187.856	1.132.176	1.263.435
Heating production	kWht	2.546.800	2.546.800	2.546.800
Cost of heating production	€/kWht	0,41	0,40	0,46
Electricity production	kWhe	3.243.247	3.243.247	3.243.247
Cost of electricity production	€/kWhe	0,37	0,35	0,39

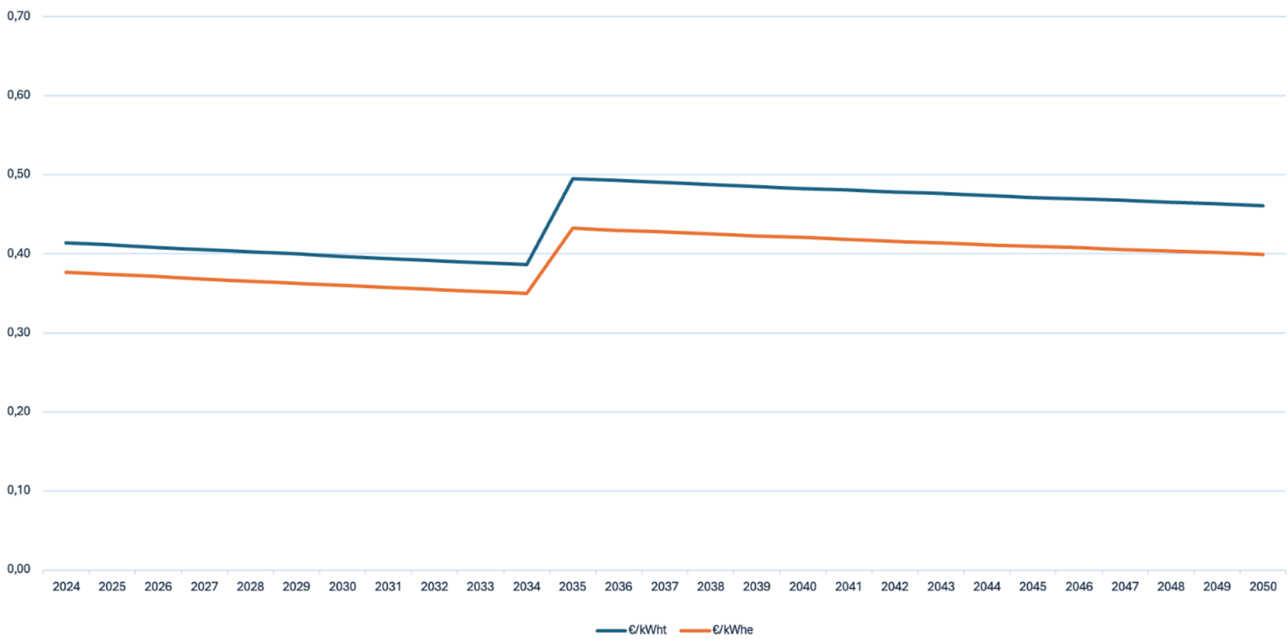

Figure 45 - Cost trend for CHP Hydrogen production

3.3.1.2 Boilers

The analysis of the boilers is focused exclusively on the heating phase of the site, which constitutes only a fraction of the overall thermal production. Given the small volume of energy considered, two distinct scenarios have been developed: the first involves the simple replacement of existing boilers with different types of fuel, while the second scenario extends this hypothesis by including the possibility of sustainable technological integration, such as the installation of a heat pump, which would offer environmental benefits. The two scenarios will be analyzed in detail below.

Boiler scenario

Similar to the analysis provided for the cogenerator, the thermal model compares different technologies under the same operating conditions, identifying the optimal solution, allowing the replacement of the current technology with the one that offers the best €/kWht ratio.

The types of boilers examined are three, as indicated below:

- Boilers powered by natural gas
- Boilers powered by biomethane – anaerobic digestion
- Boilers powered by biomethane – thermal gasification

these differ in the type of fuel used and in:

- **Installation cost of the plant;**
- **Fuel cost**, calculated with the following formula:

$$\text{Cost of fuel } [\,€\,] = \text{Gas cost of fuel } [\,€/\text{Sm3}\,] * \text{ Fuel injected } [\text{Sm3}]$$

(3. 11)

- **Useful life duration;**
- **Amount of CO_2 emitted**, which will affect the carbon tax cost, calculated with the formula:

$$\text{Total C02 emission} = \text{CO2 emission factor } \left[\frac{\text{tCO2}}{\text{MJ}}\right] * \text{Net Calorif value } \left[\frac{\text{MJ}}{\text{Sm3}}\right] * \text{Fuel injected } [\text{Sm3}]$$

(3. 12)

The values of tons of oil equivalent are:

- 1000 Sm3 of Natural Gas corresponds to 0.836 Toe
- 1000 Sm3 of Biomethane corresponds to 0.55 Toe

Depending on the plant, the following is considered:

- The **Net Present Value (NPV)** of the capital is calculated from the installation cost define as follows:

$$\text{NPV} = \frac{(\text{Cost of installation} \, * \, \text{Discount rate})}{(1 - (1 + \text{Discount rate})\,\hat{}\,(-\,\text{Years of operation}))} \tag{3. 13}$$

  where the discount rate is set at 5%.

- The **thermal production of the boilers** is constant from 2024 to 2050 (mainly for space heating). The estimated value of thermal production is 620,712 kWht annually. The boiler operates for about 6,240 hours per year, including maintenance hours, which generate a cost that is included in the annual maintenance cost.
- The **amount of fuel used** varies depending on the type of fuel chosen, as it is directly related to the Net Calorific Value. Once the amount of fuel needed to power the plant is determined, this value will remain constant from 2024 to 2050.

Operational and installation cost	
Cost of installation	€
Operation hours	h/y
Years of operation	year
Maintenance	%
Maintenance hour	h/y
Mantainance cost per hour	€/h
Mantainance cost	€
Plant production	
Heating production	kWht
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Net calorif value	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO2/MJ
Total C02 emission	tC02
Costo emissione C02	€/tC02
Tons of oil equivalent (TOE)	tep

Figure 46 - Parameters for Boiler analysis

Once the parameters are established and the fuel cost, type of gas used, costs associated with CO_2 emissions (carbon tax), and annual maintenance costs are determined, we will be able to calculate the total annual cost for thermal production using the following formula:

$$\text{TOTAL COST} = \text{present value of capital } [€] + \text{Cost of fuel } [€] + \text{Matainance cost } [€] + \\ + \text{Carbon tax } [€]$$

(3. 14)

Once the amount of heat produced is defined, we can calculate the production cost of the thermal commodity, ensuring total heating for each year from 2024 to 2050. Comparing the obtained data will allow us to identify the technology with the best €/kWht ratio.

The formula for the unit production cost is:

$$\text{Cost of heating production } \left[\frac{€}{\text{kWht}}\right] = \frac{\text{Total cost for heating}}{\text{Heating production}}$$

(3. 15)

Year	
Present value of capital	€
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Cost of fuel	€/year
Mantainance cost	€
Emission cost of C02	€/tC02
Carbon tax	€
TOTAL COST	
Heating production	kWht
Cost of heating production	€/kWht

Figure 47 - Yearly evaluation of Boiler cost.

Heat pump

The analysis model for the Heat pump considers various parameters that influence its technical and economic performance, namely:

- **Installation cost** of the technology;
- **Thermal production and electrical demand** of the machine: the estimated thermal production is 409,308 kWh, while the electrical demand is 162,625 kWh. These values are calculated based on the annual operating hours of the system, which are 5,000 hours/year, including maintenance hours (each maintenance hour incurs an additional cost that contributes to the total annual maintenance cost).
- **Useful life** duration;
- **Incentives** obtained from the production of thermal energy from a sustainable source. The calculation of incentives follows these steps:

    1. Definition of the thermal power produced, Qu, and the nominal power of the heat pump, Pn.
    2. Consideration of the machine's COP (Coefficient of Performance) value.
    3. Definition of a heat pump utilization coefficient Quf, which varies depending on the climatic zone of installation.

- **The incentivized thermal energy produced** in a year is calculated as:

$$\mathrm{Ei} = \mathrm{Qu} * (1 - 1/\mathrm{COP})$$

(3. 16)

Additionally, a thermal energy valorization coefficient, Ci, of 0.018 €/kWh is considered, as the nominal power falls within the range of 35 kW to 500 kW.

The total value of the incentives will therefore be given by:

$$\mathrm{Incentives} = \mathrm{Ei} * \mathrm{Ci}$$

(3. 17)

This methodology allows for the quantification of economic incentives related to the production of sustainable thermal energy, taking into account the efficiency and utilization of the heat pump in relation to the climatic context.

Operational and installation cost	
Cost of installation	€
Operation hours	h/y
Years of operation	year
Maintenance	%
Maintenance hour	h/y
Mantainance cost per hour	€/h
Mantainance cost	€
Technology production	
Heating production	kWht
Electricity required	kWh
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital	€
Gas and emission cost	
Electricity cost	€/kWh
Cost of electricity withdraw	€/year
C02 Emission factor	tCO2/MJ
Incentives	
Incentives	€

Figure 48 - Parameters for Heat pump analysis.

After establishing the above-mentioned parameters, it is possible to calculate the total annual cost for thermal production using the following formula:

$$\begin{aligned}\mathrm{TOTAL\ COST} &= \text{present value of capital } [€] + \text{Cost of electricity withdraw } [€] \\ &+ \text{Matainance cost } [€] - \text{Incentives } [€]\end{aligned}$$

(3. 18)

Once the amount of heat produced is defined, we can calculate the production cost of the thermal commodity, ensuring total heating for each year from 2024 to 2050. Comparing the obtained data will allow us to identify the technology with the best €/kWht ratio.

The formula for the unit production cost is:

$$\text{Cost of heating production}\left[\frac{€}{\text{kWht}}\right]=\frac{\text{Total cost for heating}}{\text{Heating production}}$$

(3. 19)

Year	
Present value of capital	€
Cost of electricity withdraw	€
Mantainance cost	€
Incentives	€
TOTAL COST	
Heating production	kWht
Cost of heating production	€/kWht

Figure 49 - Yearly evaluation of Heat pump cost.

Boiler with Heat pump scenario

The analysis model for the Boiler with Heat Pump utilizes both technologies simultaneously. We analyze the use of three different boilers along with the Heat Pump:

- Boilers powered by natural gas
- Boilers powered by biomethane – anaerobic digestion
- Boilers powered by biomethane – thermal gasification

The parameters influencing this model are:

- **Installation cost** of the technology, derived from the sum of the installation costs of both technologies.
- **Thermal production and electrical demand** of the machine: The estimated thermal production is 620,712 kWh, given by the sum of the thermal production of the boilers 211,404 kWh and that of the heat pump 409,308 kWh. These values are calculated based on the annual operating hours of the plant, which are 6,240 hours/year, including maintenance hours (each maintenance hour incurs an additional cost contributing to the total annual maintenance cost).
- **Useful life** duration;
- **Fuel cost**, calculated with the following formula:

$$\text{Cost of fuel } [\,€\,] = \text{Gas cost of fuel } [\,€/\text{Sm3}\,] * \text{ Fuel injected [Sm3]} \tag{3. 20}$$

- **Amount of CO_2** emitted (which will affect the carbon tax cost), calculated with the formula:

$$\text{Total C02 emission} = \text{CO2 emission factor } \left[\frac{\text{tCO2}}{\text{MJ}}\right] * \text{Net Calorif value } \left[\frac{\text{MJ}}{\text{Sm3}}\right] * \text{Fuel injected [Sm3]} \tag{3. 21}$$

The values of tons of oil equivalent are:

- 1000 Sm3 of Natural Gas corresponds to 0.836 Toe
- 1000 Sm3 of Biomethane corresponds to 0.55 Toe

- **Incentives** obtained through thermal energy production via the heat pump.

Depending on the plant, considered as the combination of boilers and the heat pump, the following is considered:

- **Net Present Value (NPV)** of the capital is calculated from the installation cost defined as follows:

$$\text{VAN} = \frac{(\text{Cost of installation} \ * \ \text{Discount rate})}{(\,1 - \ (\,1 \ + \ \text{Discount rate})\ \hat{}\,(-\,\text{Years of operation})\,)}$$

(3. 22)

where the discount rate is set at 5%.

- **Constant thermal production** from 2024 to 2050 (mainly for space heating). The estimated value of thermal and electrical production is 620,712 kWh annually. The boiler operates for about 6,240 hours per year, including maintenance hours, which generate a cost included in the annual maintenance cost.
- **Fuel quantity used** varies based on the type of fuel chosen, as it is directly related to the Net Calorific Value. Once the amount of fuel needed to power the plant is determined, this value will remain constant from 2024 to 2050.

Operational and installation cost	
Cost of installation	€
Operation hours boiler	h/y
Operational hours heat pump	h/y
Years of operation	year
Maintenance	%
Maintenance hour boiler	h/y
Maintenance hour heat pump	h/y
Mantainance cost per hour	€/h
Mantainance cost	€
Plant production	
Heating production	kWht
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
PCI	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO_2/MJ
Total C02 emission	tC02
Costo emissione C02	€/tC02
Tons of oil equivalent (TOE)	tep

Figure 50 - Parameters for Boiler with Heat pump analysis.

Once the above parameters are established and the fuel cost, type of gas used, CO_2 emission costs (carbon tax), and annual maintenance costs are determined, we can calculate the total annual cost for thermal production using the following formula:

$$\begin{aligned}\text{TOTAL COST } = & \text{ present value of capital [€]} + \text{Cost of fuel [€]} + \\ & + \text{Cost of electricity withdraw [€]} + \text{Matainance cost [€]} + \\ & + \text{Carbon tax [€]} - \text{Incentives [€]}\end{aligned}$$

(3. 23)

Given the amount of heat produced, we can calculate the production cost of the thermal commodity, ensuring total heating for each year from 2024 to 2050. Comparing the obtained data will allow us to identify the technology with the best €/kWh ratio. The formula for the unit production cost is.

The formula for the unit production cost is:

$$\text{Cost of heating production}\left[\frac{€}{\text{kWht}}\right] = \frac{\text{Total cost for heating}}{\text{Heating production}}$$

(3. 24)

Year	
Present value of capital	€
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Cost of fuel	€/year
Mantainance cost	€
Emission cost of C02	€/tC02
Incentives	€
Carbon tax	€
TOTAL COST	
Heating production	kWht
Cost of heating production	€/kWht

Figure 51- Yearly evaluation of Boiler with Heat Pump cost

Below are the values analyzed for each technology:

The technologies differ in the amount of fuel injected because each fuel has its own Net Calorific Value.

Boiler scenario:

Boiler - Natural Gas:

Table 32 – Data for evaluation of Boiler Natural Gas

BOILER-Gas naturale		
Operational and installation cost		
Cost of installation	€	240.000
Operation hours	h/y	6.240
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	936
Mantainance cost per hour	€/h	15
Mantainance cost	€	14040
Plant production		
Heating production	kWht	620.712
Production energy	MJ	2.938.544
Financial analysis		
Discount rate		5%
Present value of capital	€	17.029
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,42835
Fuel injected	Sm3	74.582
Net calorif value	MJ/Sm3	33
Cost of fuel	€/year	31.947
C02 Emission factor	tCO_2/MJ	0,0000561
Total C02 emission	tC02	165
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	62

Table 33 - Trend of Boiler Natural Gas

Year		2024	2030	2050
Present value of capital	€	17.029	17.029	17.029
Gas cost of fuel	€/Sm3	0,43	0,42	0,40
Fuel injected	Sm3	74.582	74.582	74.582
Cost of fuel	€/year	31.947	31.406	29.669
Mantainance cost	€	14.040	14.040	14.040
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	14.012	20.033	65.941
TOTAL COST		77.028	82.508	126.678
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,12	0,13	0,20

Boiler - Biomethane Anaerobic Digestion

Table 34 - Data for evaluation of Boiler Biomethane Anaerobic digestion

BOILER-Biomethane AD		
Operational and installation cost		
Cost of installation	€	240.000
Operation hours	h/y	6.240
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	936
Mantainance cost per hour	€/h	15
Mantainance cost	€	14040
Plant production		
Heating production	kWht	620.712
Production energy	MJ	2.439.763
Financial analysis		
Discount rate		5%
Present value of capital	€	17.029
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,575
Fuel injected	Sm3	61.923
Net calorif value	MJ/Sm3	39
Cost of fuel	€/year	97.529
C02 Emission factor	tCO2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	34

Table 35 - Trend of Boiler Biomethane Anaerobic digestion

Year		2024	2030	2050
Present value of capital	€	17.029	17.029	17.029
Gas cost of fuel	€/Sm3	1,58	1,53	1,38
Fuel injected	Sm3	61.923	61.923	61.923
Cost of fuel	€/year	97.529	94.520	85.144
Mantainance cost	€	14.040	14.040	14.040
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	0	0	0
TOTAL COST		128.597	125.588	116.213
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,21	0,20	0,19

Boiler - Biomethane Thermal Gasification

Table 36 - Data for evaluation of Boiler Biomethane Thermal gasification

BOILER-Biomethane TG		
Operational and installation cost		
Cost of installation	€	240.000
Operation hours	h/y	6.240
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	936
Mantainance cost per hour	€/h	15
Mantainance cost	€	14040
Plant production		
Heating production	kWht	620.712
Production energy	MJ	2.439.763
Financial analysis		
Discount rate		5%
Present value of capital	€	17.029
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,605
Fuel injected	Sm3	61.923
Net calorif value	MJ/Sm3	39
Cost of fuel	€/year	99.386
C02 Emission factor	tCO2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	34

Table 37 - Trend of Boiler Biomethane Thermal gasification

Year		2024	2030	2050
Present value of capital	€	17.029	17.029	17.029
Gas cost of fuel	€/Sm3	1,61	1,50	1,20
Fuel injected	Sm3	61.923	61.923	61.923
Cost of fuel	€/year	99.386	92.846	73.998
Mantainance cost	€	14.040	14.040	14.040
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	0	0	0
TOTAL COST		130.455	123.915	105.066
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,21	0,20	0,17

Boiler with Heat pump scenario

Boiler with Heat pump – Natural Gas

Table 38 - Data for evaluation of Boiler Natural Gas with heat pump

BOILER-Gas naturale + HEAT PUMP		
Operational and installation cost		
Cost of installation	€	375.000
Operation hours boiler	h/y	6.240
Operational hours heat pump	h/y	5.000
Years of operation	year	25
Maintenance	%	15
Maintenance hour boiler	h/y	936
Maintenance hour heat pump	h/y	500
Mantainance cost per hour	€/h	15
Mantainance cost	€	21540
Plant production		
Heating production	kWht	620.712
Production energy	MJ	998.130
Financial analysis		
Discount rate		5%
Present value of capital	€	26.607
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,42835
Fuel injected	Sm3	25.333
Net calorif value	MJ/Sm3	33
Cost of fuel	€/year	10.851
C02 Emission factor	tCO2/MJ	0,0000561
Total C02 emission	tC02	56
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	21

Table 39 - Trend of Boiler Natural Gas with heat pump

Year		2024	2030	2050
Present value of capital	€	26.607	26.607	26.607
Gas cost of fuel	€/Sm3	0,43	0,42	0,40
Fuel injected	Sm3	25.333	25.333	25.333
Cost of fuel	€/year	10.851	10.668	10.078
Mantainance cost	€	21.540	21.540	21.540
Emission cost of C02	€/tC02	85	122	400
Incentives	€	5.207	5.207	0
Carbon tax	€	4.760	6.804	22.398
TOTAL COST		58.551	60.412	80.623
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,09	0,10	0,13

Boiler with Heat pump - Biomethane Anaerobic Digestion

Table 40 - Data for evaluation of Boiler Biomethane Anaerobic digestion with heat pump

BOILER-Biomethane AD + HEAT PUMP		
Operational and installation cost		
Cost of installation	€	375.000
Operation hours boiler	h/y	6.240
Operational hours heat pump	h/y	5.000
Years of operation	year	25
Maintenance	%	15
Maintenance hour boiler	h/y	936
Maintenance hour heat pump	h/y	500
Mantainance cost per hour	€/h	15
Mantainance cost	€	21540
Plant production		
Heating production	kWht	620.712
Production energy	MJ	998.130
Financial analysis		
Discount rate		5%
Present value of capital	€	26.607
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,575
Fuel injected	Sm3	21.033
Net calorif value	MJ/Sm3	39
Cost of fuel	€/year	33.127
C02 Emission factor	tCO2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	12

Table 41 - Trend of Boiler Biomethane Thermal gasification with heat pump

Year		2024	2030	2050
Present value of capital	€	26.607	26.607	26.607
Gas cost of fuel	€/Sm3	1,58	1,53	1,38
Fuel injected	Sm3	21.033	21.033	21.033
Cost of fuel	€/year	33.127	32.105	28.921
Mantainance cost	€	21.540	21.540	21.540
Emission cost of C02	€/tC02	85	122	400
Incentives	€	5.207	5.207	0
Carbon tax	€	0	0	0
TOTAL COST		76.068	75.045	77.068
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,123	0,121	0,124

Boiler with Heat pump - Biomethane Thermal Gasification

Table 42 - Data for evaluation of Boiler Biomethane Thermal gasification with heat pump

BOILER-Biomethane TG + HEAT PUMP		
Operational and installation cost		
Cost of installation	€	375.000
Operation hours boiler	h/y	6.240
Operational hours heat pump	h/y	5.000
Years of operation	year	25
Maintenance	%	15
Maintenance hour boiler	h/y	936
Maintenance hour heat pump	h/y	500
Mantainance cost per hour	€/h	15
Mantainance cost	€	21540
Plant production		
Heating production	kWht	620.712
Production energy	MJ	998.130
Financial analysis		
Discount rate		5%
Present value of capital	€	26.607
Gas and emission cost		
Gas cost of fuel	€/Sm3	1,605
Fuel injected	Sm3	21.033
Net calorif value	MJ/Sm3	39
Cost of fuel	€/year	33.758
C02 Emission factor	tCO2/MJ	0
Total C02 emission	tC02	0
Emission cost of C02	€/tC02	85
Tons of oil equivalent (TOE)	tep	12

Table 43 - Trend of Boiler Biomethane Thermal gasification with heat pump

Year		2024	2030	2050
Present value of capital	€	26.607	26.607	26.607
Gas cost of fuel	€/Sm3	1,61	1,50	1,20
Fuel injected	Sm3	21.033	21.033	21.033
Cost of fuel	€/year	33.758	31.537	25.135
Mantainance cost	€	21.540	21.540	21.540
Emission cost of C02	€/tC02	85	122	400
Incentives	€	5.207	5.207	0
Carbon tax	€	0	0	0
TOTAL COST		76.699	74.477	73.282
Heating production	kWht	620.712	620.712	620.712
Cost of heating production	€/kWht	0,124	0,120	0,118

The following graphs show a comparison between the two evaluated scenarios for the different fuels considered:

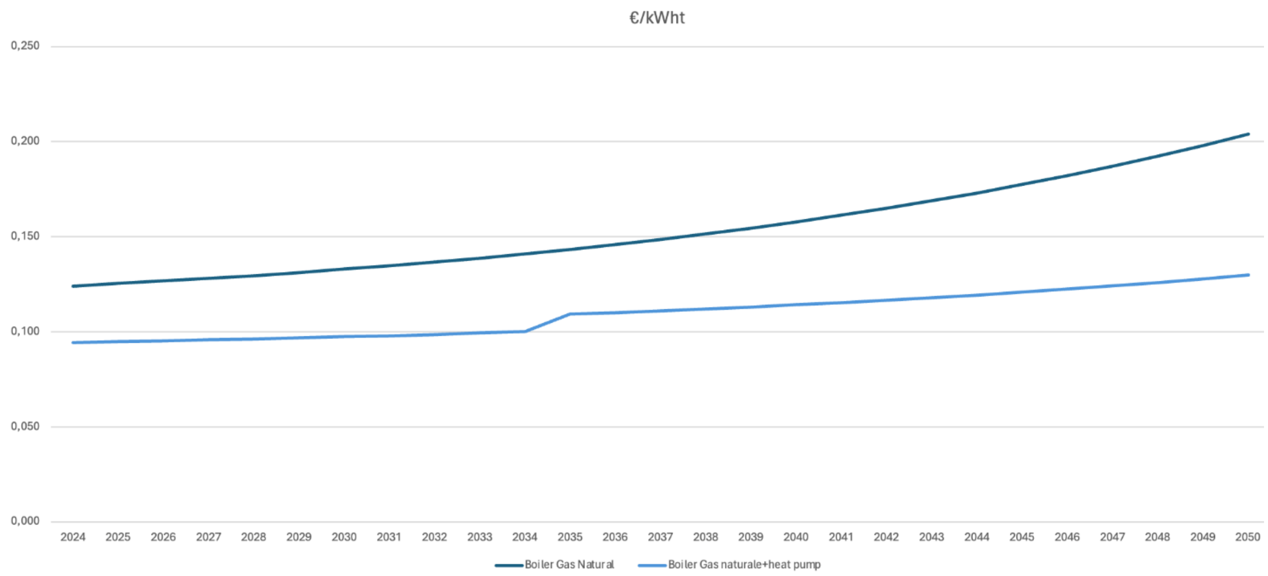

Figure 52 – Comparison of cost trend of different scenario for boiler Natural Gas

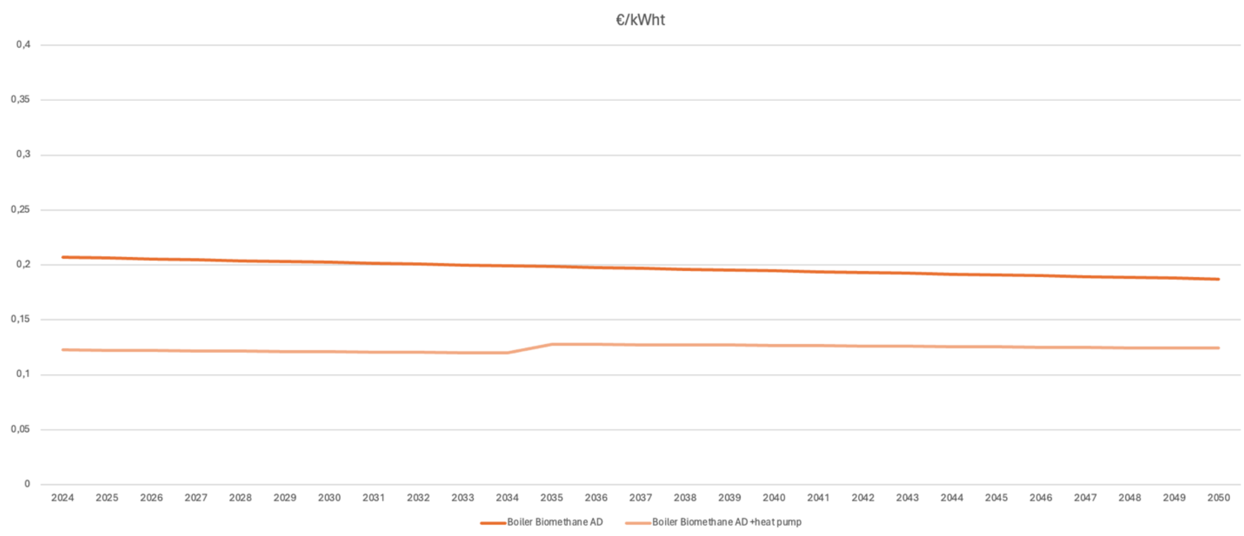

Figure 53 - Comparison of cost trend of different scenario for boiler Biomethane Anaerobic digestion

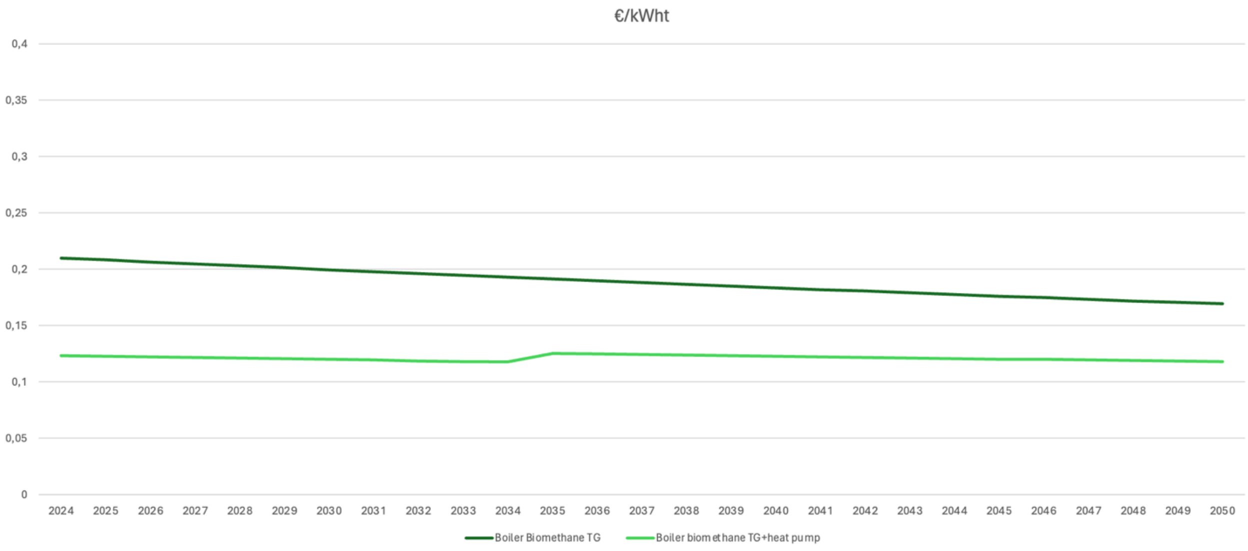

Figure 54 - Comparison of cost trend of different scenario for boiler Biomethane thermal gasification

3.3.2 Electrical model

The analysis of the electrical model compares two scenarios:

- **First scenario**: Evaluates the electricity demand using the technologies already present in the plant, such as the existing photovoltaic system, the cogenerator, and the electricity supplied by the grid.
- **Second scenario**: Extends the first scenario by including an additional photovoltaic installation, which reduces the demand for energy from the grid, generating savings in terms of consumption.

The following table shows the trend of electricity costs, expressed in €/MWh, between 2024 and 2050.

Table 44 - Cost variation of Electricity

ELECTRICITY	2024	2030	2050
€/Mwh	158,00	136,94	85,00
€/kWh	0,158	0,137	0,085

In this model, a linear trend of electricity cost reduction is assumed, with an average annual decrease of 2.36%. This reduction is attributable to an increase in energy production capacity from renewable sources over the period from 2024 to 2050. The expansion of renewable plants, such as photovoltaic, wind, and hydroelectric, indeed promotes greater availability of electricity at lower costs, contributing to a reduction in the average energy price in the long term.

Before analyzing the scenarios, we define the parameters considered in the technology analysis:

Cogenerator heat and power :

The technology has already been defined in the thermal model mentioned earlier.

Operational and installation cost	
Cost of installation	€
Operation hours	h/y
Years of operation	year
Maintenance	%
Maintenance hour	h/y
Mantainance cost per hour	€/h
Mantainance cost	€
Plant production	
Production energy	MJ
Heating production	kWht
Electricity production	kWhe
Financial analysis	
Discount rate	
Present value of capital	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Net Calorific value	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO2/MJ
Total C02 emission	tC02
Emission cost of C02	€/tC02
Incentives	
Tons of oil equivalent (TOE)	TOE
White certificates price	€/TOE
Incentives	€

Figure 55 - Parameters for CHP analysis.

Year	
Present value of capital	€
Gas cost of fuel	€/Sm3
Fuel injected for electricity	Sm3
Cost of fuel	€/year
Mantainance cost	€
Incentives	€
Emission cost of C02	€/tC02
Carbon tax	€
TOTAL COST	
Electricity production	kWhe
Cost of electricity production	€/kWhe

Figure 56 - Yearly evaluation of CHP cost.

Photovoltaics:

The parameters considered for photovoltaic technologies are:

- **Installation cost of the plant**, from which the Present Value of Capital is defined, considering a discount rate of 5%.
- **Nominal and actual production of the plant**. Once the production values of the plant are defined, an annual maintenance value will also be considered.
- **Emissions avoided through the renewable plant**, with estimates taken from Elmec s.r.l.

Operational and installation cost	
Cost of installation	€
Years of operation	year
Maintenance	%
Mantainance cost per hour	€/h
Mantainance cost	€
CO2 Avoidance	tC02
Electricity cost	€/kWh
Plant production	
Plant production	MW
Nominal Electricity production	kWhe
Effective Electricity production	kWhe
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital	€

Figure 57 - Parameters for photovoltaics analysis

Additionally, a decrease in the efficiency of photovoltaic plants of 0.55% is considered from 2024 to 2050.

Year	
Present value of capital	€
Mantainance cost	€/Sm3
Efficiency	%
TOTAL COST	€/year
Electricity production	kWhe
Cost of electricity production	€/kWhe

Figure 58 – Yearly evaluation of photovoltaic cost.

The electrical analysis model was developed to evaluate the annual cost of electricity, expressed in €/kWh, in the two scenarios under consideration.

3.3.2.1 Current situation

The model considers the following parameters for the analysis:

- **Installation cost of the plants**: cost of the various technologies present in the plant, such as the photovoltaic system and the cogeneration unit (CHP).

For each plant, the following is calculated:

- **Net Present Value (NPV)** of the invested capital, determined by the installation cost according to the formula:

$$\text{VAN} = \frac{(\text{Cost of installation} * \text{Discount rate})}{(1 - (1 + \text{Discount rate})\ \hat{}\ (-\text{Years of operation}))}$$

(3. 25)

where the discount rate is set at 5%.

- **Total electricity production**: An overall electricity production of 11,247,997 kWh has been estimated, maintained constant from 2024 to 2050. The analysis considers the production estimates of the individual plants, with the photovoltaic system generating 886,949 kWh and the cogenerator 3,243,247 kWh, while the remaining part is supplemented by the grid.

It is expected that the share of electricity required from the grid will progressively increase each year due to the reduction in the efficiency of the photovoltaic system. The annual operating hours of the plants, including maintenance hours, have also been considered; each maintenance hour contributes to the total annual maintenance cost.

The current situation assumes that the cogeneration technology in use is based on natural gas. Here, it will also be important to define:

- **Fuel cost**, calculated with the following formula:

$$\text{Cost of fuel } [\ €\ ] = \text{Gas cost of fuel } [\ €/\text{Sm3}\ ] * \text{ Fuel injected } [\text{Sm3}]$$

(3. 26)

- **Useful life** duration;
- **Amount of CO_2 emitted**, which will affect the cost of the carbon tax, calculated with the following formula:

$$\text{Total C02 emission} = \text{CO2 emission factor } \left[\frac{\text{tCO2}}{\text{MJ}}\right] * \text{Net Calorif value } \left[\frac{\text{MJ}}{\text{Sm3}}\right] * \text{Fuel injected } [\text{Sm3}]$$

(3. 27)

- **Incentives obtainable through white certificates**, valid for a duration of 10 years, calculated with the formula:

$$\text{Incentives} = \text{White certificates price } \left[\frac{€}{\text{TOE}}\right] * \text{ Tons of oil equivalent } [\text{TOE}]$$

(3. 28)

The value of the equivalent tons is 0.836 Toe, which corresponds to 1000 Sm^3.

Operational and installation cost	
Cost of installation CHP	€
Cost of installation FTV1	€
Years of operation	year
Mantainance cost per hour	€/h
Mantainance cost Cogenerator	€
Mantainance cost FTV1	€
Electricity cost	€/kWh
Plant production	
Electricity production CHP	kWhe
Electricity production FTV1	kWhe
Grid electricity	kWhe
Total electricity	kWhe
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital CHP	€
Present value of capital FTV1	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
PCI	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO_2/MJ
Total C02 emission	tC02
Emission cost of C02	€/tC02
Incentives	
Tons of oil equivalent (TOE)	tep
White certificates price	€/tep
Incentives	€

Figure 59 - Parameters for analysis of Current situation

Once the type of gas used, the fuel cost, the costs associated with CO_2 emissions (carbon tax), the annual maintenance costs, the incentives from white certificates, and the net present value of each plant are established, we can calculate the total annual cost for electricity production.

The formula for calculating the total cost is:

$$\begin{aligned}\text{TOTAL COST for eletricity} = {} & \text{present value of capital CHP [€]} + \\ & + \text{Cost fuel for electricity[€]} + \\ & + \text{Matainance cost for CHP [€]} + \\ & - \text{Incentives [€]} + \text{Carbon tax [€]} + \\ & + \text{present value of capital FTV1 [€]} + \\ & + \text{Matainance cost for FTV1 [€]} + \\ & + \text{Cost of electricity from grid [€]}\end{aligned}$$

(3. 29)

Once the annual electricity demand of the plant is defined, the cost of producing electricity in €/kWh in the current situation can be calculated:

$$\text{Cost of electricity production} \left[\frac{€}{\text{kWht}}\right] = \frac{\text{Total cost for electricity}}{\text{Electricity production}}$$

(3. 30)

Year	
Present value of capital CHP	€
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Cost of fuel	€/year
Mantainance cost	€
Incentives	€
Emission cost of C02	€/tC02
Carbon tax	€
Present value of capital FTV1	€
Mantainance cost	€
Degradation from nominal performance	%
Grid electricity	kWhe
Cost of electricity	€/kWh
Cost of grid electricity	kWh
TOTAL COST	€
Electricity production	kWhe
Cost of electricity production	€/kWhe

Figure 60 – Yearly evaluation of Current situation

3.3.2.2 Situation with new photovoltaic system

The model considers the following parameters for the analysis:

- **Installation cost of the plants**: The installation cost of the various technologies present in the plant is examined, such as both photovoltaic systems and the cogeneration unit (CHP).

For each plant, the following is calculated:

- **Net Present Value (NPV) of the invested capital**, determined by the installation cost according to the formula:

$$\text{VAN} = \frac{(\text{Cost of installation} * \text{Discount rate})}{(1 - (1 + \text{Discount rate})\hat{}(-\text{Years of operation}))}$$

(3. 31)

where the discount rate is set at 5%.

- **Total electricity production**: An overall electricity production of 11,247,997 kWh has been estimated, maintained constant from 2024 to 2050. The analysis considers the production estimates of the individual plants that generating, with the first photovoltaic system 886,949 kWh, the new photovoltaic system 771.104 kWh and the cogenerator 3,243,247 kWh, while the remaining part is supplemented by the grid.

It is expected that the share of electricity required from the grid will progressively increase each year due to the reduction in the efficiency of the photovoltaic system. The annual operating hours of the plants, including maintenance hours, have also been considered; each maintenance hour contributes to the total annual maintenance cost.

The current situation assumes that the cogeneration technology in use is based on natural gas. Here, it will also be important to define:

- **Fuel cost**, calculated with the following formula:

$$\text{Cost of fuel } [\,€\,] = \text{Gas cost of fuel } [\,€/\text{Sm3}\,] * \text{ Fuel injected [Sm3]}$$

(3. 32)

- **Useful life** duration;

- **Amount of CO_2 emitted**, which will affect the cost of the carbon tax, calculated with the following formula:

$$\text{Total C02 emission} = \text{CO2 emission factor}\left[\frac{\text{tCO2}}{\text{MJ}}\right] * \text{Net Calorif value}\left[\frac{\text{MJ}}{\text{Sm3}}\right] * \text{Fuel injected [Sm3]}$$

(3. 33)

- **Incentives obtainable through white certificates**, valid for a duration of 10 years, calculated with the formula:

$$\text{Incentives} = \text{White certificates price}\left[\frac{€}{\text{TOE}}\right] * \text{Tons of oil equivalent [TOE]}$$

(3. 34)

The value of the equivalent tons is 0.836 Toe, which corresponds to 1000 Sm^3.

.

Operational and installation cost	
Cost of installation CHP	€
Cost of installation FTV1	€
Cost of installation FTV2	€
Years of operation	year
Mantainance cost per hour	€/h
Mantainance cost Cogenerator	€
Mantainance cost FTV1	€
Mantainance cost FTV2	€
Electricity cost	€/kWh
Plant production	
Electricity production CHP	kWhe
Electricity production FTV1	kWhe
Electricity production FTV2	kWhe
Grid electricity	kWhe
Total electricity	kWhe
Production energy	MJ
Financial analysis	
Discount rate	
Present value of capital CHP	€
Present value of capital FTV1	€
Present value of capital FTV2	€
Gas and emission cost	
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
PCI	MJ/Sm3
Cost of fuel	€/year
C02 Emission factor	tCO2/MJ
Total C02 emission	tC02
Emission cost of C02	€/tC02
Incentives	
Tons of oil equivalent (TOE)	tep
White certificates price	€/tep
Incentives	€

Figure 61 - Parameters for analysis of Situation with new photovoltaic system

Once the type of gas used, the fuel cost, the costs associated with CO_2 emissions (carbon tax), the annual maintenance costs, the incentives from white certificates, and the net present value of each plant are established, we can calculate the total annual cost for electricity production.

The formula for calculating the total cost is:

$$
\begin{aligned}
\text{TOTAL COST for eletricity} = {} & \text{present value of capital CHP } [€] + \\
& + \text{Cost fuel for electricity } [€] + \\
& + \text{Matainance cost for CHP } [€] - \text{ Incentives } [€] + \\
& + \text{Carbon tax } [€] + \text{ present value of capital FTV1 } [€] + \\
& + \text{Matainance cost for FTV1 } [€] + \\
& + \text{present value of capital FTV2 } [€] + \\
& + \text{Matainance cost for FTV2 } [€] + \\
& + \text{Cost of electricity from grid } [€]
\end{aligned}
$$

(3. 35)

Once the annual electricity demand of the plant is defined, we can calculate the cost of producing electricity in €/kWh in the analyzed situation.

Year	
Present value of capital CHP	€
Gas cost of fuel	€/Sm3
Fuel injected	Sm3
Cost of fuel	€/year
Mantainance cost	€
Incentives	€
Emission cost of C02	€/tC02
Carbon tax	€
Present value of capital FTV1	€
Mantainance cost	€
Efficiency	%
Present value of capital FTV2	€
Mantainance cost	€
Grid electricity	kWhe
Cost of electricity	€/kWh
Cost of grid electricity	kWh
TOTAL COST	€
Electricity production	kWhe
Cost of electricity production	€/kWhe

Figure 62 – Yearly evaluation of Situation with new photovoltaic system

Below are the analyzed values for each technology:

CHP – Natural Gas

Table 45 - Data for evaluation of CHP Natural Gas

Gas Natural Cogenerator		
Operational and installation cost		
Cost of installation	€	1.083.000
Operation hours	h/y	5.500
Years of operation	year	25
Maintenance	%	15
Maintenance hour	h/y	825
Mantainance cost per hour	€/h	15
Mantainance cost	€	12.375
Plant production		
Production energy	MJ	20.844.169
Heating production	kWht	2.546.800
Electricity production	kWhe	3.243.247
Financial analysis		
Discount rate		5%
Present value of capital	€	76.842
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,428
Fuel injected	Sm3	755.047
Net Calorific value	MJ/Sm3	33
Cost of fuel	€/year	323.424
C02 Emission factor	tCO2/MJ	0,0000561
Total C02 emission	tC02	1.414
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	TOE	631
White certificates price	€/TOE	250
Incentives	€	157.805

Table 46 - Trend of CHP Natural Gas

Year		2024	2030	2050
Present value of capital	€	76.842	76.842	76.842
Gas cost of fuel	€/Sm3	0,43	0,42	0,40
Fuel injected for electricity	Sm3	422.933	422.933	422.933
Cost of fuel	€/year	181.164	178.096	168.243
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	157.805	157.805	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	120.219	171.869	565.735
TOTAL COST		232.794	281.377	823.195
Electricity production	kWhe	3.243.247	3.243.247	3.243.247
Cost of electricity production	€/kWhe	0,07	0,09	0,25

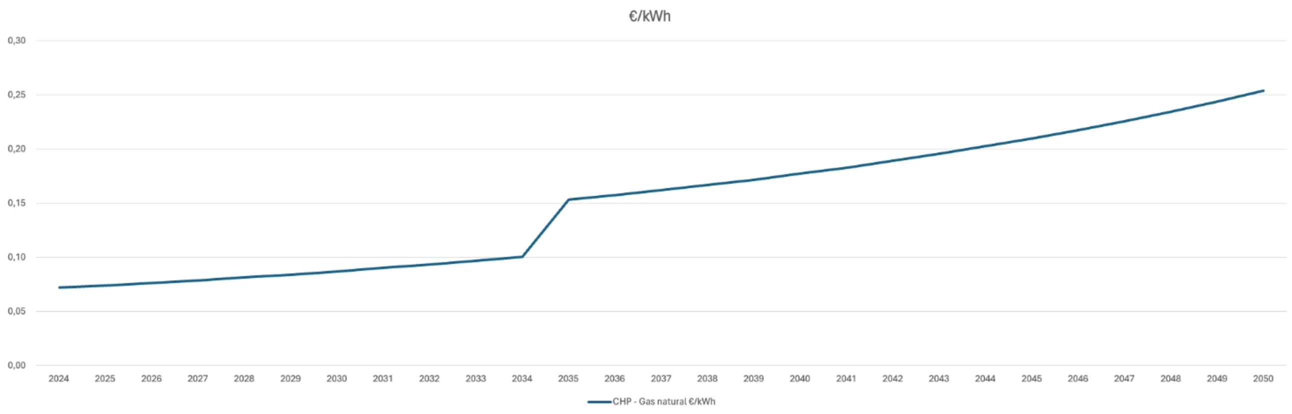

Figure 63 - Cost trend for CHP Natural Gas production

FTV1 – Photovoltaic system

Table 47 - Data for evaluation of Photovoltaic system

FTV1-Electricity		
Operational and installation cost		
Cost of installation	€	1.200.500
Years of operation	year	25
Maintenance	%	15
Mantainance cost per hour	€/h	15
Mantainance cost	€	15000
CO2 Avoidance	tC02	837,73
Electricity cost	€/kWh	0,158
Plant production		
Plant production	MW	0,96
Nominal Electricity production	kWhe	1.040.820
Effective Electricity production	kWhe	886.949
Production energy	MJ	3.193.015
Financial analysis		
Discount rate		5%
Present value of capital	€	85.178

Table 48 - Trend of Photovoltaic system

Year		2024	2030	2050
Present value of capital	€	85.178	85.178	85.178
Mantainance cost	€/Sm3	15000	15000	15000
Efficiency	%	0,98	0,9483374	0,85
TOTAL COST	€/year	100.178	100.178	100.178
Electricity production	kWhe	1.040.820	987.049	884.697
Cost of electricity producti	€/kWhe	0,096	0,101	0,113

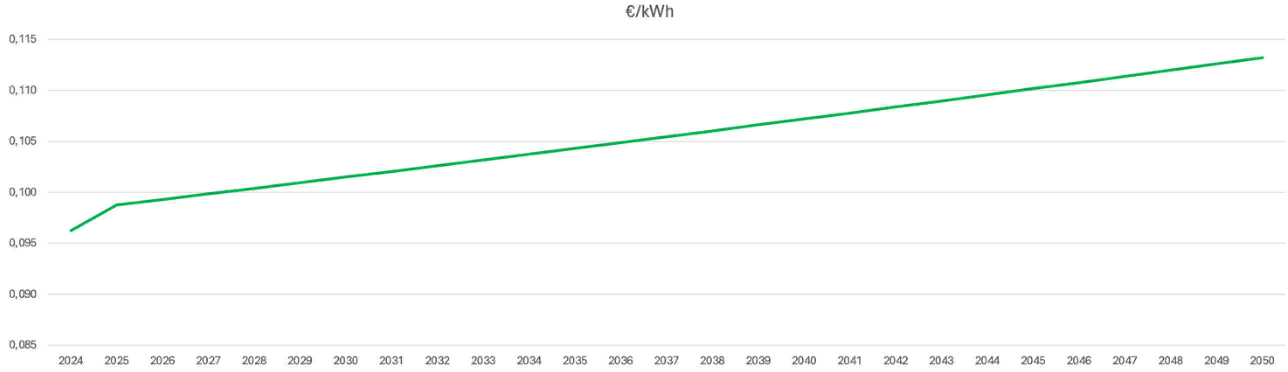

Figure 64 - Cost trend for Photovoltaic system production

FTV2 – Photovoltaic system

Table 49 - Data for evaluation of new Photovoltaic system

FTV2-Electricity		
Operational and installation cost		
Cost of installation	€	1.108.000
Years of operation	year	25
Maintenance	%	15
Mantainance cost per hour	€/h	15
Mantainance cost	€	15000
CO2 Avoidance	tC02	728,31
Electricity cost	€/kWh	0,158
Plant production		
Plant production	MW	0,87
Nominal Electricity production	kWhe	904.878
Effective Electricity production	kWhe	771.104
Production energy	MJ	3.257.561
Financial analysis		
Discount rate		5%
Present value of capital	€	78.615

Table 50 - Trend of new Photovoltaic system

Year		2024	2030	2050
Present value of capital	€	78.615	78.615	78.615
Mantainance cost	€	15000	15000	15000
Efficiency	%	0,98	0,948337419	0,85
TOTAL COST		93.615	93.615	93.615
Electricity production	kWhe	904878	858129,6674	769146,3
Cost of electricity production	€/kWhe	0,103	0,109	0,122

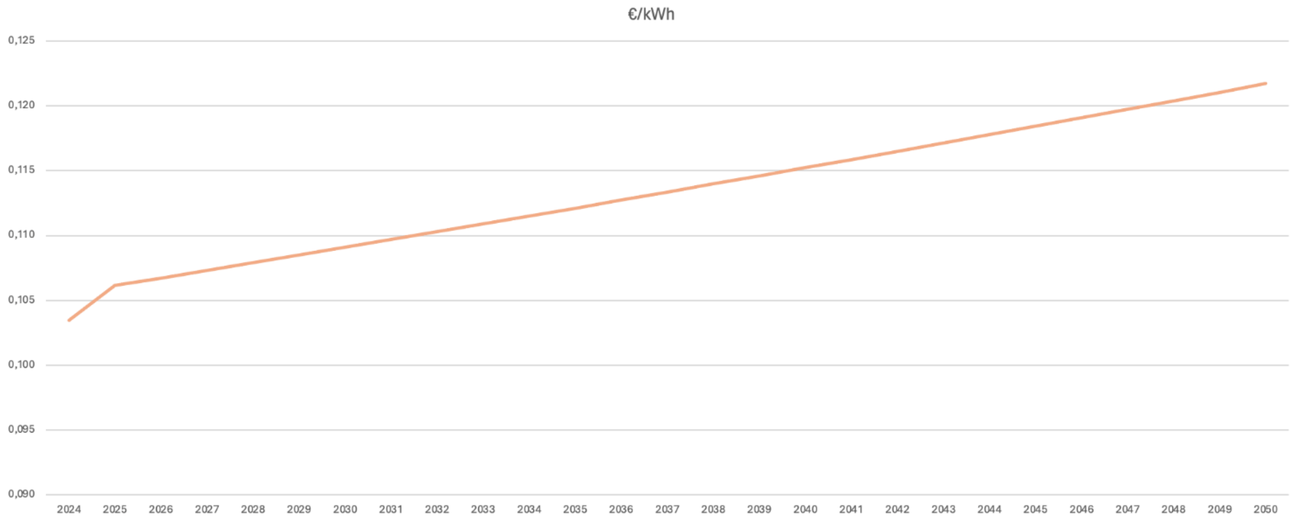

Figure 65 - Cost trend for new Photovoltaic system production

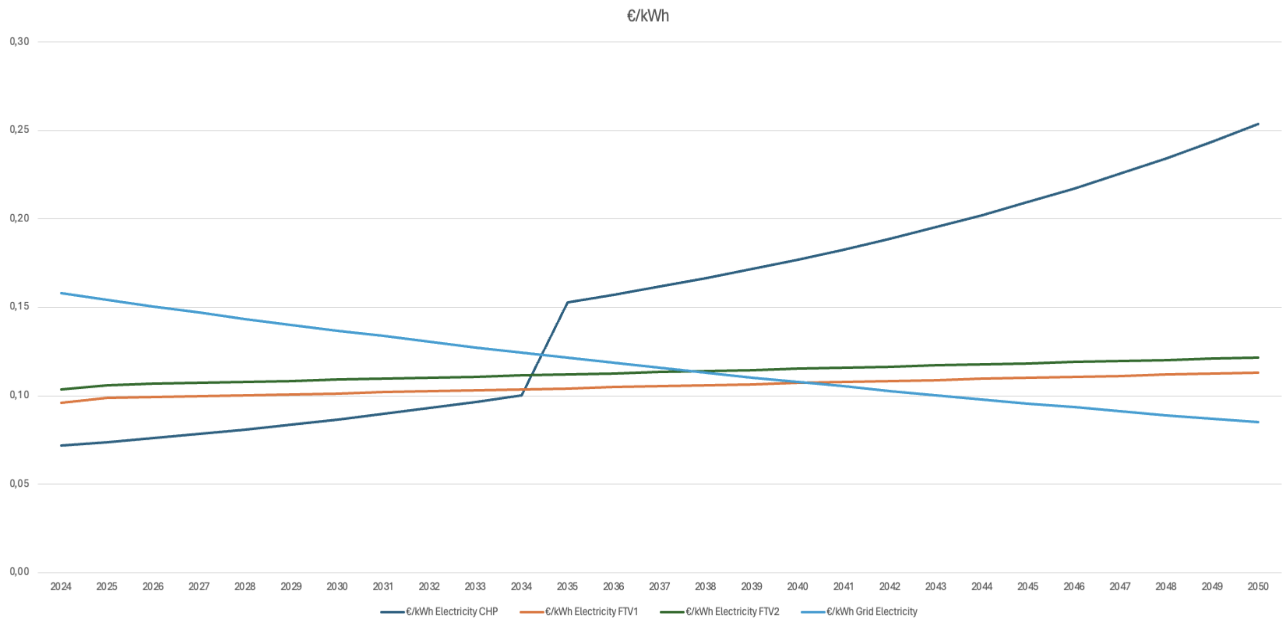

Figure 66 – Comparison of different cost trend

Current situation

Table 51 - Data for evaluation of Current situation

Operational and installation cost		
Cost of installation CHP	€	1.083.000
Cost of installation FTV1	€	1.200.500
Years of operation	year	25
Mantainance cost per hour	€/h	15
Mantainance cost Cogenerator	€	12375
Mantainance cost FTV1	€	15000
Electricity cost	€/kWh	0,158
Plant production		
Electricity production CHP	kWhe	3.243.247
Electricity production FTV1	kWhe	886.949
Grid electricity	kWhe	7.117.802,70
Total electricity	kWhe	11.247.997,97
Production energy	MJ	40.492.793
Financial analysis		
Discount rate		5%
Present value of capital CHP	€	76.842
Present value of capital FTV1	€	85.178
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,42835
Fuel injected	Sm3	422.933
PCI	MJ/Sm3	33
Cost of fuel	€/year	181.164
C02 Emission factor	tCO2/MJ	0,0000561
Total C02 emission	tC02	792
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	tep	354
White certificates price	€/tep	250
Incentives	€	88.393

Table 52 - Trend of Current situation

Year		2024	2030	2050
Present value of capital CHP	€	76.842	76.842	76.842
Gas cost of fuel	€/Sm3	0,43	0,42	0,40
Fuel injected	Sm3	422.933	422.933	422.933
Cost of fuel	€/year	181.164	178.096	168.243
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	88.393	88.393	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	67.340	96.271	316.892
Present value of capital FTV1	€	85.178	85.178	85.178
Mantainance cost	€	15.000	15.000	15.000
Degradation from nominal performance	%	0,98	0,95	0,85
Grid electricity	kWhe	7.135.542	7.163.625	7.250.845
Cost of electricity	€/kWh	0,16	0,14	0,085
Cost of grid electricity	kWh	1.127.416	980.975	616.322
TOTAL COST	€	1.476.920	1.356.344	1.290.852
Electricity production	kWhe	11.247.998	11.247.998	11.247.998
Cost of electricity production	€/kWhe	0,13	0,12	0,11

Situation with new photovoltaic system

Table 53 – Data for evaluation of Situation with new photovoltaic system

Operational and installation cost		
Cost of installation CHP	€	1.083.000
Cost of installation FTV1	€	1.200.500
Cost of installation FTV2	€	1.108.000
Years of operation	year	25
Mantainance cost per hour	€/h	15
Mantainance cost Cogenerator	€	12375
Mantainance cost FTV1	€	15000
Mantainance cost FTV2	€	15000
Electricity cost	€/kWh	0,158
Plant production		
Electricity production CHP	kWhe	3.243.247
Electricity production FTV1	kWhe	886.949
Electricity production FTV2	kWhe	771.104
Grid electricity	kWhe	6.364.438
Total electricity	kWhe	11.265.737
Production energy	MJ	40556653
Financial analysis		
Discount rate		5%
Present value of capital CHP	€	76.842
Present value of capital FTV1	€	85.178
Present value of capital FTV2	€	78.615
Gas and emission cost		
Gas cost of fuel	€/Sm3	0,428
Fuel injected	Sm3	422.933
PCI	MJ/Sm3	33
Cost of fuel	€/year	181.164
C02 Emission factor	tCO_2/MJ	0,0000561
Total C02 emission	tC02	792
Emission cost of C02	€/tC02	85
Incentives		
Tons of oil equivalent (TOE)	tep	354
White certificates price	€/tep	250
Incentives	€	88.393

Table 54 – Trend of Situation with new photovoltaic system

Year		2024	2030	2050
Present value of capital CHP	€	76.842	76.842	76.842
Gas cost of fuel	€/Sm3	0,43	0,42	0,40
Fuel injected	Sm3	422.933	422.933	422.933
Cost of fuel	€/year	181.164	178.096	168.243
Mantainance cost	€	12.375	12.375	12.375
Incentives	€	88.393	88.393	0
Emission cost of C02	€/tC02	85	122	400
Carbon tax	€	67.340	96.271	316.892
Present value of capital FTV1	€	85.178	85.178	85.178
Mantainance cost	€	15.000	15.000	15.000
Efficiency	%	0,98	0,95	0,85
Present value of capital FTV2	€	78.615	78.615	78.615
Mantainance cost	€	15.000	15.000	15.000
Grid electricity	kWhe	7.135.542	6.424.309	6.588.192
Cost of electricity	€/kWh	0,158	0,14	0,085
Cost of grid electricity	kWh	1.127.416	879.734	559.996
TOTAL COST	€	1.570.536	1.348.719	1.328.141
Electricity production	kWhe	11.247.998	11.247.998	11.247.998
Cost of electricity production	€/kWhe	0,140	0,120	0,118

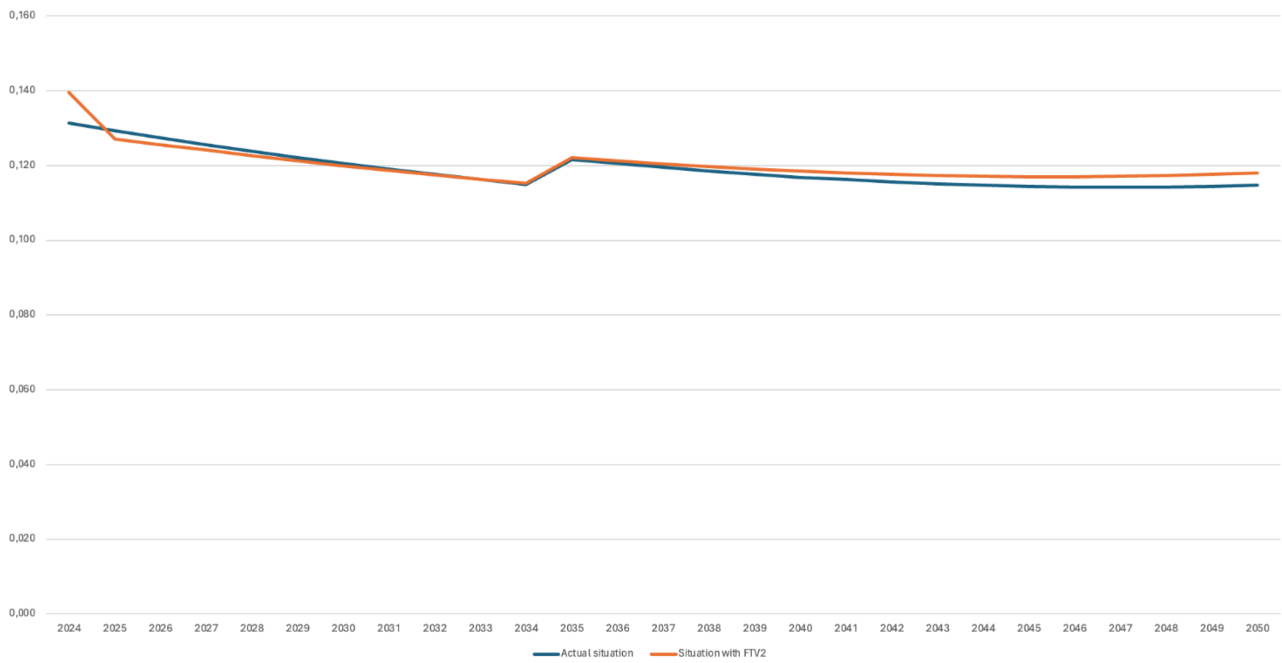

Figure 67 – Comparison between different scenario

4 RESULT'S ANALYSIS AND SUSTAINABILITY STRATEGIC PLAN

After analyzing the analytical model in the previous chapter, the results are presented graphically, along with the relevant observations.

4.1 COGENERATOR MODEL RESULTS

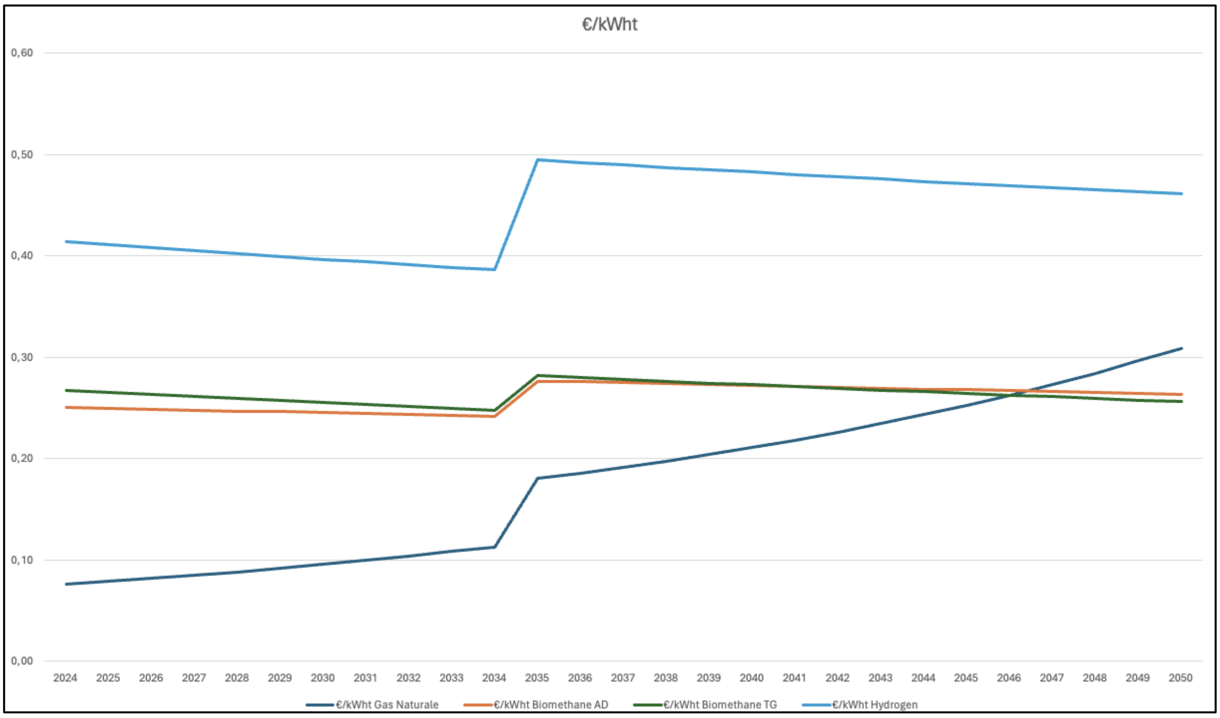

Figure 68 – Result's trend of Congenator technology in terms of €/kWht

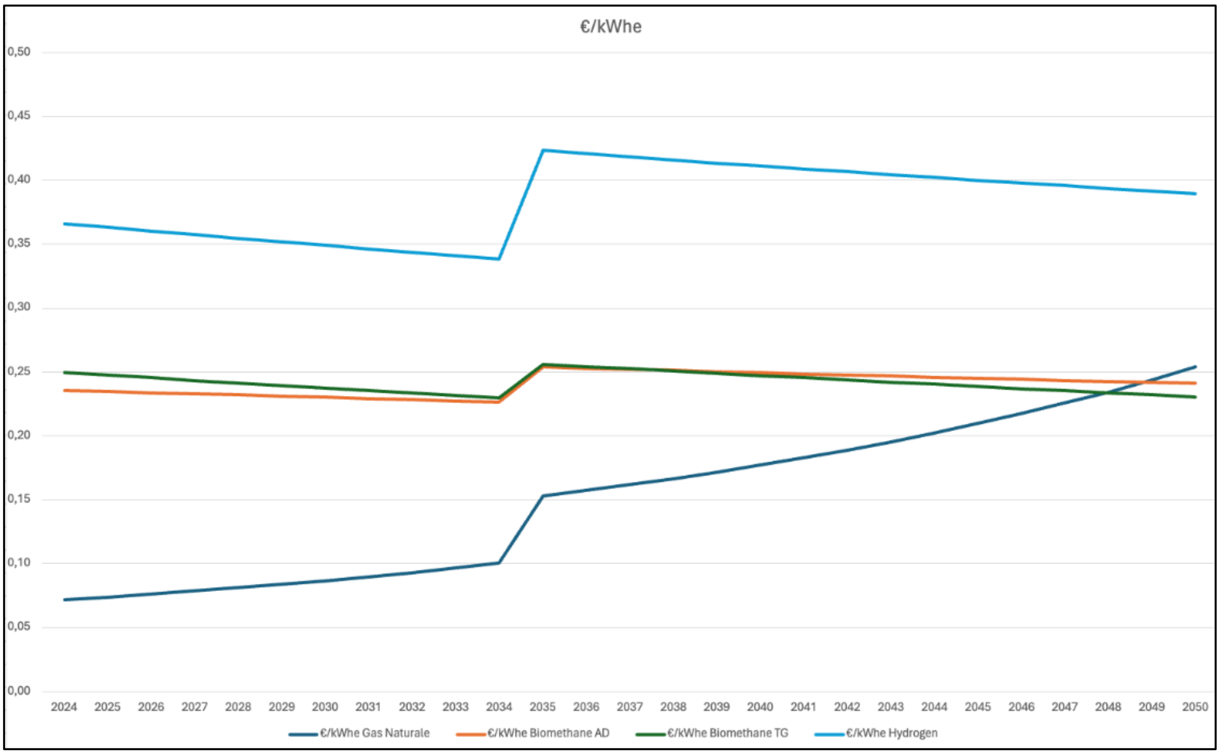

Figure 69 - Result's trend of Congenator technology in terms of €/kWhe

The graphs show that the cogenerator powered by biomethane produced through thermal gasification, in the year 2046, will allow to produce thermal energy more conveniently in terms of €/kWht. Subsequently, it will also achieve the goal from the perspective of electrical production expressed in €/kWh; for this reason, the technology of the cogenerator powered by biomethane produced through thermal gasification is the best to replace the cogenerator powered by natural gas.

The trend of the curves related to biomethane and hydrogen is decreasing during the observation years but is interrupted by a cost increase between 2034 and 2035 due to the discontinuation of incentives. Nevertheless, the decreasing trend of the curves is sufficient to allow for the replacement of the machinery.

The trend of the curve related to the cogenerator powered by natural gas is increasing. Again, the discontinuation of incentives strongly contributes to the rise in costs, which continue to grow due to the costs of the carbon tax resulting from the production of carbon tones.

Due to its high costs, hydrogen cannot be considered for technological replacement regarding the cogenerator.

From the analysis of the provided graphs, one can observe a detailed comparison between various cogeneration technologies to produce electrical and thermal energy, powered by natural gas, biomethane (both from anaerobic digestion and thermal gasification), and hydrogen.

Natural Gas: The first element to consider is the trend of the production costs of the cogenerator powered by natural gas. The graphs show a rising cost trend from 2024 to 2050. This increase is mainly influenced by the cessation of incentives and the rising costs associated with the carbon tax, which progressively burdens systems with high CO_2 emissions like natural gas. This increase makes this technology economically less sustainable in the long term, pushing the search for less expensive and less polluting alternatives.

Biomethane: Biomethane, especially that produced through thermal gasification, emerges as the most promising alternative to replace the natural gas cogenerator. Starting in 2024, both biomethane technologies (anaerobic digestion and thermal gasification) benefit from government incentives for renewable energy. This initial support makes biomethane production costs more competitive and allows for a descending trend in the early years.

- For biomethane produced through thermal gasification, this initial phase of cost reduction is particularly significant: between 2024 and 2034, the costs per energy unit steadily decrease, making the technology increasingly accessible.
- This phase temporarily halts in 2035, when the cessation of incentives leads to a cost increase for all renewable technologies.
- However, biomethane from thermal gasification continues to be advantageous even after this critical phase. Unlike natural gas, whose cost is heavily influenced by fossil fuel price variations and carbon tax policies, biomethane produced by thermal gasification benefits from continuous improvements in its production and availability, progressively reducing unit costs.

After 2035, even without incentives, the costs of this technology resume their downward trend. This effect is mainly due to technological efficiency improvements and the increased spread of biomethane production plants, which favor economies of scale. The long-term stability and cost reduction make thermal gasification of biomethane not only sustainable but also economically competitive. In 2046, biomethane from thermal gasification reaches a turning point: the costs per kWh (electrical energy) and per kWht (thermal energy) become competitive enough to surpass those of natural gas.

Hydrogen: Hydrogen, while theoretically representing a clean and low-emission technology, is not economically competitive. The production and distribution costs of hydrogen remain high throughout the analyzed period, making this option unsuitable for replacing the natural gas cogenerator. Even after the end of incentives for other technologies, hydrogen continues to maintain prohibitive costs, reducing its ability to compete economically.

4.2 BOILERS MODEL RESULTS

Boiler:

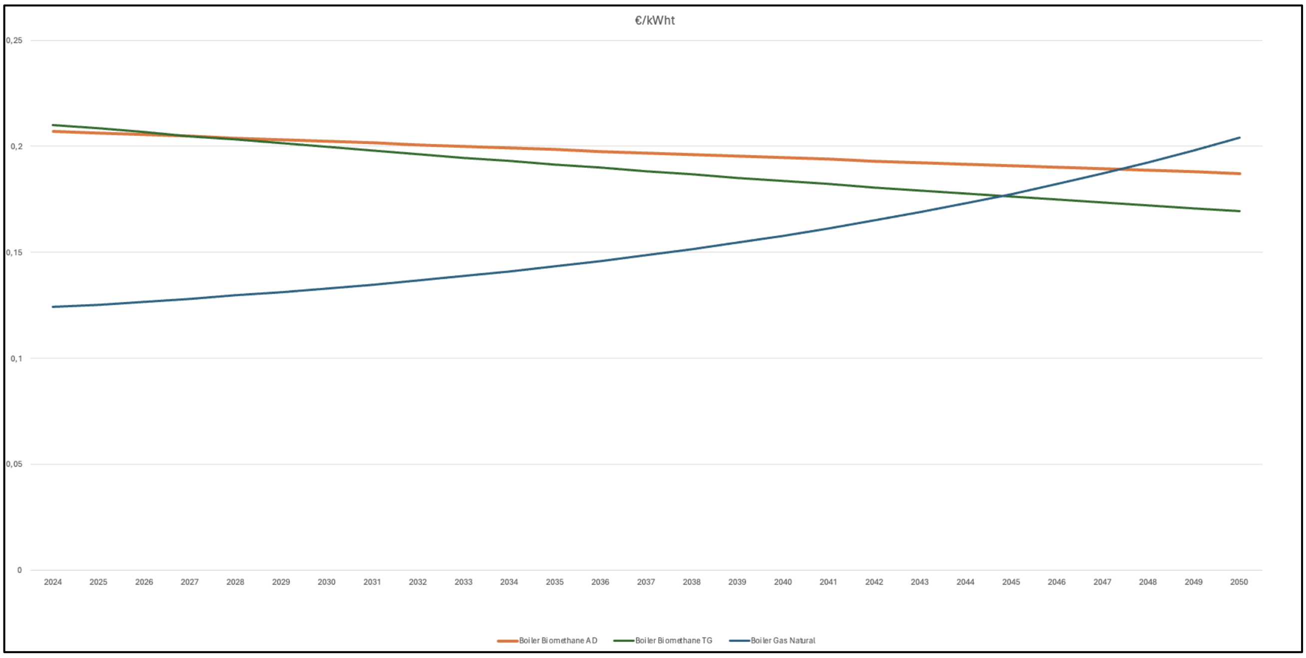

Figure 70 - Result's trend of Boiler technology in terms of €/kWht

Boiler with heat pump:

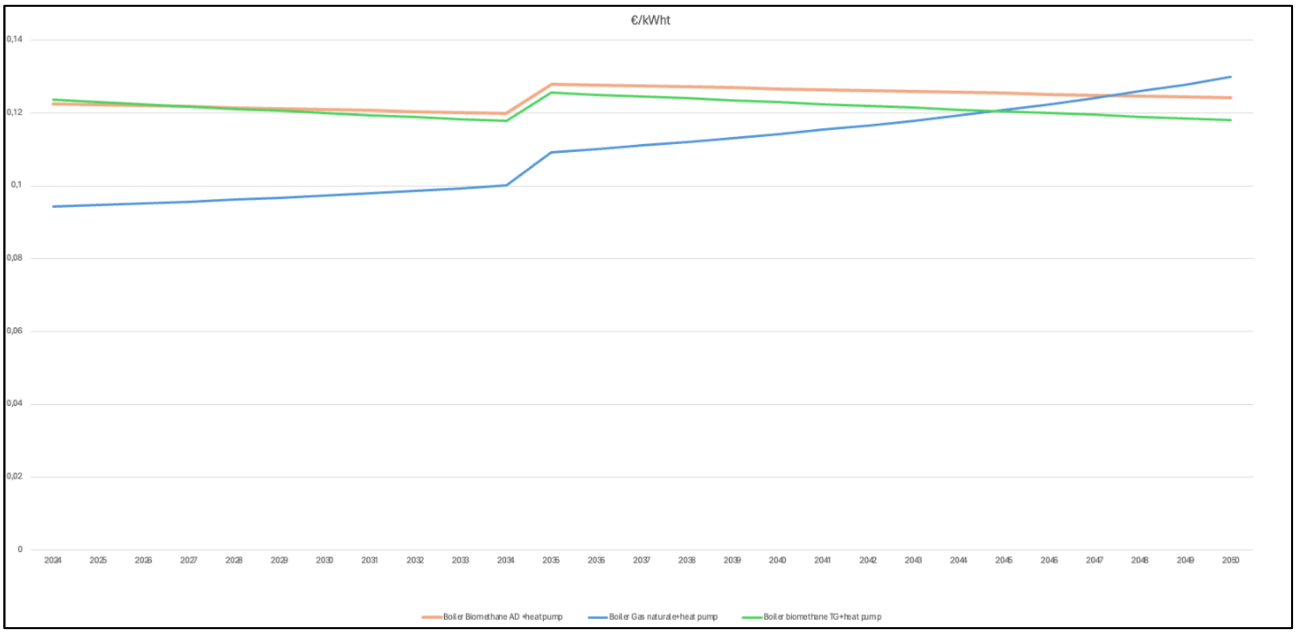

Figure 71 - Result's trend of Boiler with heat pump technology in terms of €/kWhe

The graphs above highlight the costs of thermal technologies based on biomethane and natural gas, considering different energy sources and the integration of heat pumps. The data show how these costs evolve up to 2050, providing an overview of future trends.

Regarding **natural gas**, a steady increase in costs is observed in the long term. This increase is probably due to CO_2 emission-related costs, such as carbon taxes, making this technology progressively less sustainable. Even with the adoption of heat pumps, which improve the overall system efficiency, natural gas costs continue to rise. This means that despite an improvement in efficiency, the use of natural gas becomes less competitive compared to renewable alternatives, especially in a context where environmental costs play a significant role.

Moving on to **biomethane from anaerobic digestion**, initially, the costs are higher than those of natural gas. However, in the scenario related to the installation of heat pumps, the incentives for renewable energies tend to further decrease the thermal production costs in the early years. Around 2040, a stabilization or slight increase in costs is observed, due to the cessation of incentives. Despite this, biomethane from anaerobic digestion manages to maintain some competitiveness compared to natural gas, both in the version that considers only boilers and in the one that includes the installation of heat pumps.

Finally, the most promising technology seems to be **biomethane from thermal gasification**. This technology shows a cost trend similar to that of anaerobic digestion, but with a more marked reduction in the early years. It becomes economically advantageous compared to natural gas over a shorter time frame, thanks to continuous improvements in production processes and greater efficiency, which favor a progressive reduction in costs per kWht. Even with the integration of heat pumps, biomethane from thermal gasification shows lower costs compared to natural gas, positioning itself as one of the most competitive and sustainable options in the long term.

In summary, biomethane, especially that produced through thermal gasification, emerges as a more sustainable and competitive solution compared to natural gas, especially considering environmental costs and future trends.

4.3 MODEL EFFECT

Table 55 – Constant distribution volumes analyzed

Months	Volumes
January	8.999.897
February	13.485.035
March	11.291.683
April	9.591.609
May	14.770.310
June	14.033.166
July	11.480.677
August	7.410.885
September	8.765.229
October	7.873.406
November	6.212.422
December	2.580.614
	116.494.931 L

Once the consumption has been defined, the technological changes implemented are analyzed over a timeline:

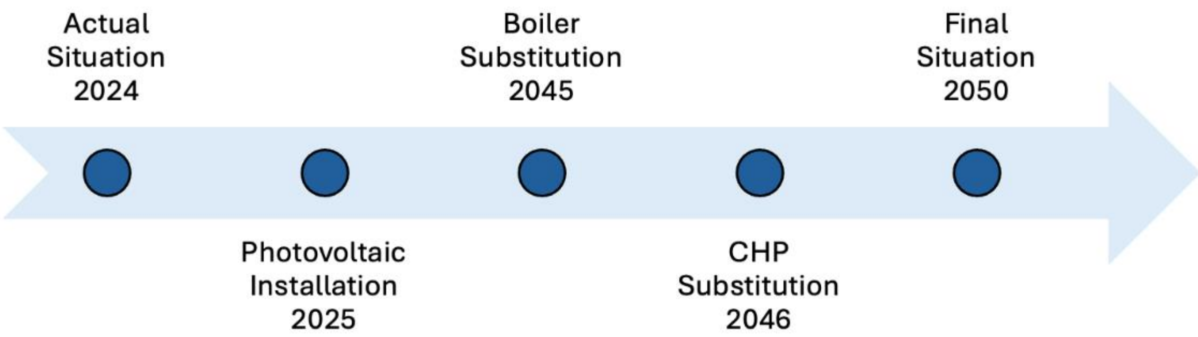

Figure 72 – Timeline

Below is presented the analysis of the yearly temporal evolution for each project implemented, which has provided environmental sustainability benefits to the plant.

This analysis considers the initial situations of the plant and evaluates the final state under three distinct scenarios: no project implementation; implementation of the planned projects; and implementation of the planned projects with the addition of a heat pump.

In detail, when the projects include the installation of a heat pump, the plant's overall electrical demand increases by 162,625 kWh, which corresponds to the additional energy requirement of the heat pump itself. All analysis results are presented as KPIs (Key Performance Indicators), defining both the plant's annual energy demand and the annual energy demand from grid-supplied sources.

The KPI related to the total consumption of the plant is calculated by relating the annual reference energy demand to the liters produced in the same year.

$$\mathrm{KPI} = \frac{\text{Energy consuption for the reference year}}{\text{Liters produced in the reference year}}$$

(3. 36)

The calculation of the plant's energy demand is determined as follows:

$$\text{Energy consuption} = \text{Total Gas [Sm3]}*\ 39{,}4\ \left[\frac{\text{Sm3}}{\text{MJ}}\right] + \text{Total electricity [kW]}*\ 3{,}6\ \left[\frac{\text{kW}}{\text{MJ}}\right]$$

(3. 37)

The KPI related to the consumption from external sources is determined by relating the energy demand of external sources to the reference year.

$$\mathrm{KPI} = \frac{\text{Energy consumption from external sources for the reference year}}{\text{Liters produced in the reference year}}$$

(3. 38)

The calculation of the external sources required by the plant is as follows:

$$\text{Energy consumption from external sources} = \text{Total Gas [Sm3]} * 39{,}4 \left[\frac{\text{Sm3}}{\text{MJ}}\right] + \text{Grid electricity [kW]} * 3{,}6 \left[\frac{\text{kW}}{\text{MJ}}\right] \quad (3.\ 39)$$

Table 56 – Energy consumption of the plant for 2024 Scenario and calculation of KPI total consumption

SCENARIO 2024		
TOTAL GAS	1.868.216	Sm3
TOTAL ELECTRICITY	11.247.994	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	114100500	MJ
KPI TOTAL CONSUMPTION	0,979	MJ/L

Table 57 - Energy consumption of the plant for 2024 Scenario and calculation of KPI external consumption

TOTAL GAS	1.868.216	Sm3
GRID ELECTRICITY	7.117.803	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	886.949	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	99.231.812	MJ
KPI EXTERNAL CONSUMPTION	0,852	MJ/L

Table 58 - Energy consumption of the plant for 2025 Scenario and calculation of KPI total consumption

SCENARIO 2025 With FTV2- project		
TOTAL GAS	1.868.216	Sm3
TOTAL ELECTRICITY	11.247.998	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	114100515	MJ
KPI TOTAL CONSUMPTION	0,979	MJ/L

Table 59 - Energy consumption of the plant for 2025 Scenario and calculation of KPI external consumption

TOTAL GAS	1.868.216	Sm3
CHP	755.047	Sm3
BOILER	1.113.169	Sm3
GRID ELECTRICITY	6.369.183	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	864.465	kW
FTV2 ELECTRICITY	771.104	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	96.536.780	MJ
KPI EXTERNAL CONSUMPTION	0,829	MJ/L

Table 60 - Energy consumption of the plant for 2045 Scenario and calculation of KPI total consumption

SCENARIO 2045 With Boiler project		
TOTAL GAS	1.855.557	Sm3
TOTAL ELECTRICITY	11.247.994	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	113601719	MJ
KPI TOTAL CONSUMPTION	0,975	MJ/L

Table 61 – Energy consumption of the plant for 2045 Scenario and calculation of KPI external consumption

TOTAL GAS	1.855.557	Sm3
CHP	755.047	Sm3
BOILER	1.100.510	Sm3
Gas for Steam process	1.038.586	Sm3
Gas for Heating process	61.923	Sm3
GRID ELECTRICITY	6.548.887	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	774.825	kW
FTV2 ELECTRICITY	681.039	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	96.684.936	MJ
KPI EXTERNAL CONSUMPTION	0,830	MJ/L

Table 62 - Energy consumption of the plant for 2045 Scenario with heat pump installation and calculation of KPI total consumption

SCENARIO 2045 With Boiler project and Heat pump installation		
TOTAL GAS	1.814.667	Sm3
TOTAL ELECTRICITY	11.410.619	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	112576116	MJ
KPI TOTAL CONSUMPTION	0,966	MJ/L

Table 63 – Energy consumption of the plant for 2045 Scenario with heat pump installation and calculation of KPI external consumption

TOTAL GAS	1.814.667	Sm3
CHP	755.047	Sm3
BOILER	1.059.620	Sm3
Gas for Steam process	1.038.080	Sm3
Gas for Heating process	21.540	Sm3
GRID ELECTRICITY	6.711.512	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	774.825	kW
FTV2 ELECTRICITY	681.039	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	95.659.333	MJ
KPI EXTERNAL CONSUMPTION	0,821	MJ/L

Table 64 – Energy consumption of the plant for 2046 Scenario and calculation of KPI total consumption

SCENARIO 2046 With CHP - project		
TOTAL GAS	1.765.759	Sm3
TOTAL ELECTRICITY	11.247.994	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	110063680	MJ
KPI TOTAL CONSUMPTION	0,945	MJ/L

Table 65 – Energy consumption of the plant for 2046 Scenario and calculation of KPI external consumption

TOTAL GAS	1.765.759	Sm3
CHP	665.249	Sm3
BOILER	1.100.510	Sm3
Gas for Steam process	1.038.586	Sm3
Gas for Heating process	61.923	Sm3
GRID ELECTRICITY	6.556.835	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	770.595	kW
FTV2 ELECTRICITY	677.322	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	93.175.506	MJ
KPI EXTERNAL CONSUMPTION	0,800	MJ/L

Table 66 - Energy consumption of the plant for 2046 Scenario with heat pump installation and calculation of KPI total consumption

SCENARIO 2046 With CHP - project and Heat pump installation		
TOTAL GAS	1.724.869	Sm3
TOTAL ELECTRICITY	11.410.619	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	109038076,8	MJ
KPI TOTAL CONSUMPTION	0,936	MJ/L

Table 67 - Energy consumption of the plant for 2046 Scenario with heat pump installation and calculation of KPI external consumption

TOTAL GAS	1.724.869	Sm3
CHP	665.249	Sm3
BOILER	1.059.620	Sm3
Gas for Steam process	1038080,2	Sm3
Gas for Heating process	21540	Sm3
GRID ELECTRICITY	6.719.460	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	770.595	kW
FTV2 ELECTRICITY	677.322	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	92.149.903	MJ
KPI EXTERNAL CONSUMPTION	0,791	MJ/L

Table 68 - Energy consumption of the plant for 2050 Scenario without project and calculation of KPI total consumption

SCENARIO 2050 Without project		
TOTAL GAS	1.868.216	Sm3
TOTAL ELECTRICITY	11.247.994	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	114100500	MJ
KPI TOTAL CONSUMPTION	0,979	MJ/L

Table 69 - Energy consumption of the plant for 2050 Scenario without project and calculation of KPI external consumption

TOTAL GAS	1.868.216	Sm3
CHP	755.047	Sm3
BOILER	1.113.169	Sm3
Gas for Steam process	1.038.586	Sm3
Gas for Heating process	74.582	Sm3
GRID ELECTRICITY	7.250.845	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	753.906	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	99.710.764	MJ
KPI EXTERNAL CONSUMPTION	0,856	MJ/L

Table 70 - Energy consumption of the plant for 2050 Scenario and calculation of KPI total consumption

SCENARIO 2050 With project		
TOTAL GAS	1.765.759	Sm3
TOTAL ELECTRICITY	11.247.994	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	110063679,8	MJ
KPI TOTAL CONSUMPTION	0,945	MJ/L

Table 71 - Energy consumption of the plant for 2050 Scenario and calculation of KPI external consumption

TOTAL GAS	1.765.759	Sm3
CHP	665.249	Sm3
BOILER	1.100.510	Sm3
Gas for Steam process	1.038.586	Sm3
Gas for Heating process	61.923	Sm3
GRID ELECTRICITY	6.588.192	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	753.906	kW
FTV2 ELECTRICITY	662.653	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	93.288.393	MJ
KPI EXTERNAL CONSUMPTION	0,801	MJ/L

Table 72 - Energy consumption of the plant for 2050 Scenario with heat pump installation and calculation of KPI total consumption

SCENARIO 2050 with projects and Heat pump		
TOTAL GAS	1.724.869	Sm3
TOTAL ELECTRICITY	11.410.619	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	109038077	MJ
KPI TOTAL CONSUMPTION	0,936	MJ/L

Table 73 – Energy consumption of the plant for 2050 Scenario with heat pump installation and calculation of KPI external consumption

TOTAL GAS	1.724.869	Sm3
CHP	665.249	Sm3
BOILER	1.059.620	Sm3
Gas for Steam process	1038080,2	Sm3
Gas for Heating process	21540	Sm3
GRID ELECTRICITY	6.750.817	kW
CHP ELECTRICITY	3.243.243	kW
FTV1 ELECTRICITY	753.906	kW
FTV2 ELECTRICITY	662.653	kW
THERMAL ENERGY -STEAM	10.969.877	kWht
THERMAL ENERGY - HOT WATER	1.067.721	kWht
COMPRESSED AIR	5.821.868	m3
REFRIGERETION ENERGY	6.886.089	kWf
	92.262.790	MJ
KPI EXTERNAL CONSUMPTION	0,792	MJ/L

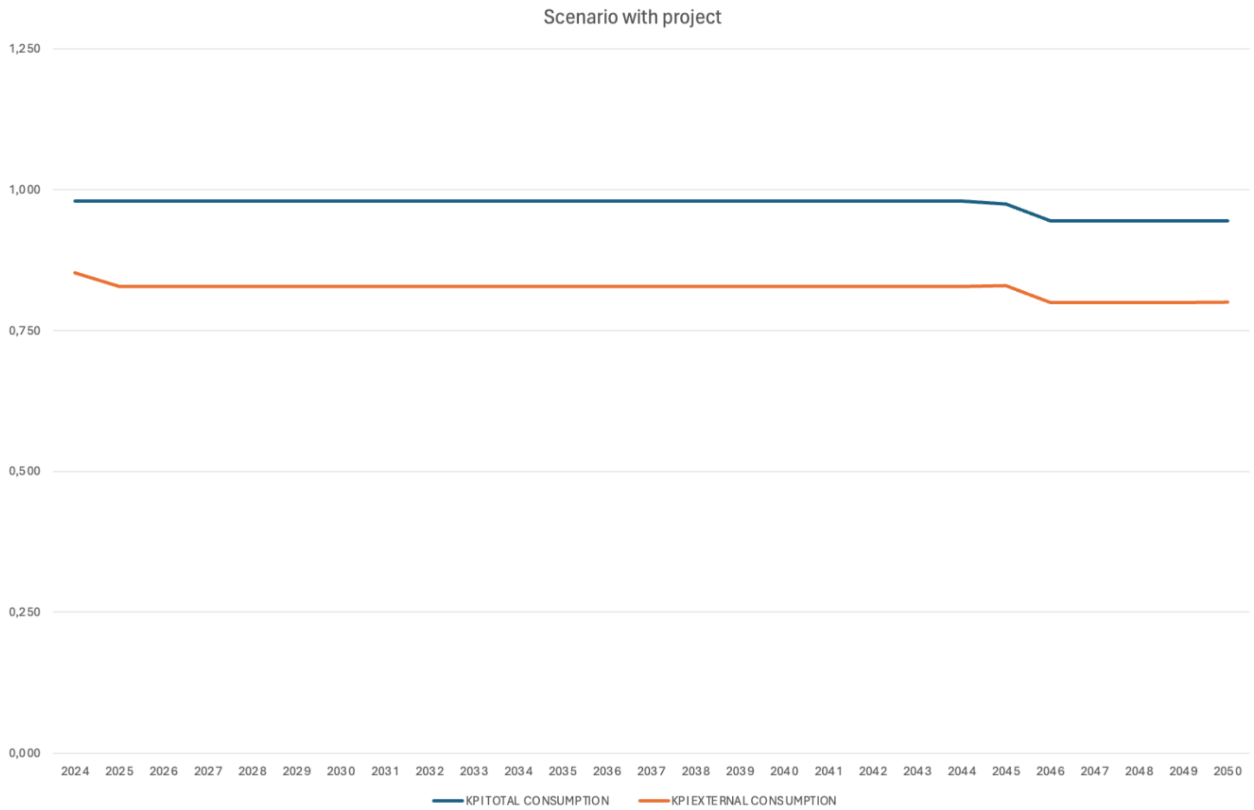

Figure 73 – Comparison between KPI consumption considering project

Table 74 – Trend of KPI consumption for Scenario with project

Scenario with project		
	KPI TOTAL CONSUMPTION	KPI EXTERNAL CONSUMPTION
SCENARIO 2024	0,979	0,852
SCENARIO 2025 With FTV2- project	0,979	0,829
SCENARIO 2045 With Boiler project	0,975	0,830
SCENARIO 2046 With CHP - project	0,945	0,800
SCENARIO 2050 With project	0,945	0,801

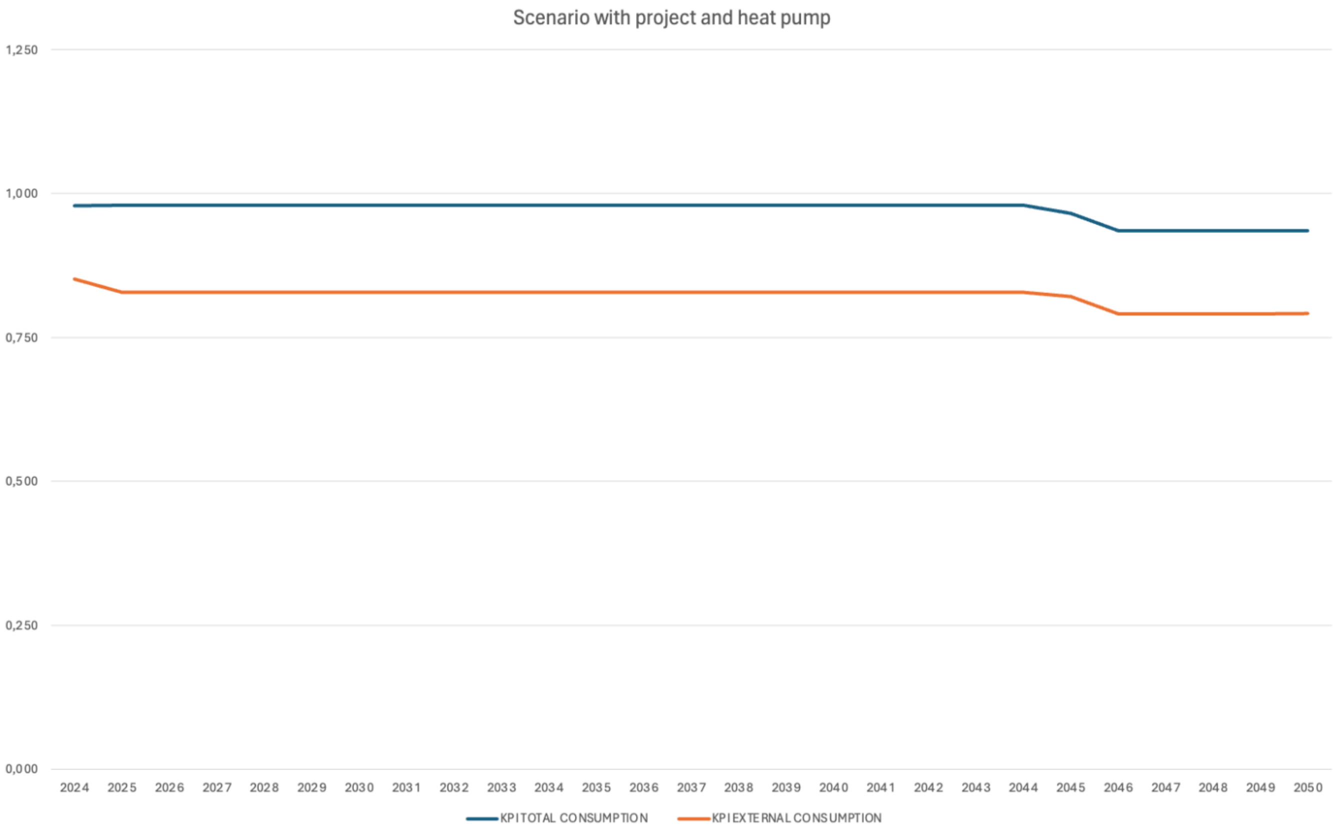

Figure 74 - Comparison between KPI consumption considering project with heat pump

Table 75 - Trend of KPI consumption for Scenario with project and heat pump

Scenario with project and heat pump		
	KPI TOTAL CONSUMPTION	KPI EXTERNAL CONSUMPTION
SCENARIO 2024	0,979	0,852
SCENARIO 2025 With FTV2- project	0,979	0,829
SCENARIO 2045 With Boiler project	0,966	0,821
SCENARIO 2046 With CHP - project	0,936	0,791
SCENARIO 2050 With project	0,936	0,792

The illustrated graphs highlight the energy consumption of the Novi Ligure plant, comparing total consumption and consumption from external sources, expressed as KPIs (Key Performance Indicators). These consumptions are evaluated in two scenarios: one that considers only standard projects and one that includes the installation of a heat pump. In both cases, a decreasing trend in consumption is observed, indicating that the energy needs of the plant are set to be reduced thanks to new technologies.

Total and External Source Consumption The graphs show that the total consumption of the plant and consumption from external sources decrease over time. This is due to the adoption of new technologies that improve energy efficiency. In particular, the installation of the photovoltaic system and the heat pump significantly contribute to this reduction.

Reduction in Imported Network Consumption The reduction in consumption is even more evident in KPIs related to the consumption imported from the network, both for gas and electricity. Starting from the 2024 scenario, the model predicts a series of interventions that will lead to a substantial reduction in energy demands by 2050. These interventions include:

- Installation of a new photovoltaic system: This will contribute to generating renewable energy directly on-site, reducing dependency on the grid.
- Replacement of boiler fuel: The use of biomethane instead of natural gas will reduce CO_2 emissions and energy costs.
- Conversion of the cogenerator to biomethane from thermal gasification: This will further improve energy efficiency and reduce emissions.

Impact on CO_2 Emissions Energy savings not only reflect in terms of energy consumption (MJ) but also in a significant reduction in CO_2 emissions. In 2050, without interventions, the plant is estimated to produce 1,414 tons of CO_2 annually from the cogenerator and 165 tons annually from the boilers, for a total of 42,642 tons of CO_2 produced over the analysis period.

The implementation of the thermal model will start reducing CO_2 emissions from 2045, with the first significant replacement, leading to a savings of 6,482 tons of CO_2. Additionally, the electrical model, thanks to the new photovoltaic installation, will allow an annual savings of 728 tons of CO_2. The existing photovoltaic system already allows avoiding about 837 tons of CO_2 per year. Overall, the photovoltaic systems will ensure an annual reduction of 1,565 tons of CO_2 for 25 years, allowing savings of about 39,000 tons of CO_2. This, added to the savings generated by the thermal model, will lead to a total reduction of about 45,000 tons of CO_2.

These interventions will make the plant more sustainable, aligning it with European Commission regulations for future energy scenarios. The model will prepare the plant for the challenges of decarbonization, improving the company's image from a sustainability perspective.

5 CONCLUSION ON MODEL APPLICATION IN NOVI PLANT AND GENERAL SUSTAINABILITY VISION FOR CAMPARI GROUP

The conclusion of the energy analysis model for the plant outlines a path of radical transformation, oriented towards environmental sustainability achieved through the adoption of advanced technologies and the progressive replacement of fossil fuels with renewable sources. A key element that emerged from the results is biomethane, particularly that produced through thermal gasification processes. This fuel proves to be the most suitable solution to replace current technologies based on natural gas. The transition is driven not only by the rising costs associated with natural gas, influenced by carbon taxes and CO_2 emission reduction policies, but also by the competitive advantages of biomethane, supported by state incentives for renewable energy.

The analysis shows how biomethane from thermal gasification maintains a decreasing cost profile in the long term, eventually stabilizing at levels that make it not only an ecological choice but also economically advantageous compared to traditional sources. Despite a temporary interruption of economic benefits due to the cessation of incentives in 2035, the competitiveness of biomethane is quickly regained thanks to technological advancements and the greater diffusion of production plants, which promote efficiency increases and create economies of scale. From 2045, the production of thermal and electrical energy through biomethane from thermal gasification becomes economically advantageous compared to the use of natural gas, making it a solid and sustainable solution for the plant in the long term.

The decarbonization process of the plant also involves the introduction of new technological installations. The integration of heat pumps, particularly effective in combination with biomethane from thermal gasification, is crucial for improving the overall energy efficiency of the system. Heat pumps, applied to thermal production plants, allow for the optimization of energy consumption and the reduction of procurement costs from the grid, using renewable energy or less carbon-intensive sources. This strengthens the plant's ability to save energy and improve its ecological profile.

In parallel, the expansion of photovoltaic systems also plays a decisive role in this transition. Photovoltaic systems not only reduce the demand for energy from the grid but also contribute to increasing the plant's energy resilience, reducing vulnerability to energy price fluctuations, and promoting greater energy independence. Overall, these systems ensure a considerable annual CO_2 savings, which adds to the emission reductions resulting from the adoption of biomethane and the energy efficiency of cogeneration systems.

The reduction of CO_2 emissions stands out as one of the most significant results of the analysis. The planned interventions lead to a significant decrease in the plant's carbon footprint. From the early years of model implementation, with the expansion of photovoltaic systems, a gradual reduction in overall energy demand is observed. These savings translate into a substantial decrease in annual emissions, consolidating the plant's path towards an increasingly sustainable scenario. The analyses indicate that, between the thermal and electrical systems, the overall annual CO_2 savings will be significant and in line with the standards of European regulations for industrial decarbonization.

In summary, the results of the model demonstrate how the plant can achieve significant energy optimization through a series of planned interventions. These include the replacement of fossil fuels with biomethane in systems currently powered by natural gas, such as cogenerators and boilers, and the integration of innovative technologies such as photovoltaic systems and heat pumps. The outlined strategy is not only effective for environmental sustainability but also positions the plant at the forefront of global energy challenges. This transition model is set to transform the plant into a facility aligned with environmental regulations, consolidating the company's image towards

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