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Exit from the ETS system for an Iveco Group Plant: possibilities offered by district heating from renewable sources

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Preface

This thesis developed at IVECO Group, deals with the application of a decarbonization model to a company plant located in Italy.

The exact geographical location will not be specified for company policy reasons, referring to the plant analyzed as the "Plant".

Summary

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Abstract

Modern industry faces increasing pressure to reduce greenhouse gas emissions and adopt more sustainable solutions. Among the most interesting projects is district heating: the study focuses on the technical and economic analysis of this technology in place of traditional heating through a thermal plant in an industrial plant of Iveco Group.

The thesis begins with an overview of the global context of climate change concerning the latest reports that framed the problem. Particular attention was given to the European Union and its strategic position in the energy transition through the European Green Deal; in detail, the ETS quota system has been deepened concerning its impact on industry and the need for reducing emissions.

After a brief introduction to the reality of Iveco Group and its role in today's automotive market, a pilot plant was chosen to focus on the analysis for the realization of an efficient project that could lead, on the one hand, to the exit from the ETS system and on the other to the achievement of the company's sustainability targets.

Based on monitoring the primary and secondary energy vectors in the thermal power plant, it was decided to develop an efficient project that would replace traditional heating using a boiler with central heating connected to the city's district heating.

A section dedicated to district heating in Italy provides an overview of the energy sources used and the associated environmental benefits. In addition, a particular focus has been made on the system in the city by deepening the power plants that provide the design and the prices that follow for individuals and companies.

The project has been deepened through two studies on two different aspects: initially, the technical point of view has been developed, analyzing the connection to the net and the characteristics of the distributed fluid; the economic aspect was then addressed through different scenarios and with some sensitivity analyses. Finally, a chapter dedicated to the project's future explores future challenges and opportunities for implementing district heating.

The results indicate that district heating can be an environmentally advantageous solution, allowing the company to achieve ambitious decarbonization targets.

Introduction

Climate change is one of the most difficult challenges facing humanity today, as these events are changing the environment in which we live, the economy, cultures, and, not least, our health.

The consequences of these changes are visible worldwide, with effects both on the environment, with the loss of biodiversity and the fragmentation of ecosystems, but also on humans, with an increase in deaths due to extraordinary catastrophic events and, in general, heat and cold.

To address this problem, many associations and more and more countries are moving through international meetings and action plans to mitigate the effects of pollution and climate change.

Among the most active countries on this issue, the European Union has set very ambitious goals to become a leader in the energy transition in the world.

The most ambitious plan is the European Green Deal, which aims to get to net zero carbon 2050 through targeted actions in different sectors, especially the industrial one.

The most significant measure of this package is the emission allowance scheme (EU ETS), with which the European Union aims to reduce emissions in the sector, one of the most energy-intensive and polluting. The price of these quotas is very volatile and, in recent years, has reached very high prices, leading companies to prioritize efficient projects that could allow the exit from the system with consequent economic savings.

Among the companies most sensitive to this issue is Iveco Group, which, after the split from CNH Industrial, is implementing a decarbonization program to 2040, ten years before the Paris agreements, along with other very ambitious objectives.

It is essential to analyze the consumption of plants and implement practical decarbonization projects to reduce polluting emissions and energy consumption to achieve this goal.

This study will deal with a plant of the Iveco Group in central Italy, going to analyze the production processes and consumption related to them. In addition, an efficient project will be studied and analyzed: the transition from current traditional heating, operating through a thermal power plant, to a central heating system, that is, district heating, a project that would allow the plant under analysis to leave the ETS system.

The district heating technology, how much it weighs in the Italian energy market, and its advantages will deepen the operation in the city where the plant is located, with particular attention to the thermal power plant and its prices.

The aim of this work will, therefore, be to analyze the technology and apply it to an Iveco Group plant, focusing on the technical and economic aspects of the offer to understand whether this system would satisfy the current thermal supply and whether it is economically viable for the company, without forgetting the ultimate goal of the project: decarbonize the plant and the production processes to achieve the sustainability objectives without affecting the quality of the final product.

1. Objective of the study

In the current context, where climate change is an unprecedented global challenge, industries increasingly focus on strategies that promote environmental sustainability and reduce carbon emissions without affecting product quality.

This paper will analyze an efficient energy project applied to an Iveco Group plant to combat climate change and achieve the company's sustainability objectives.

1.1. Global Climate Change

Undoubtedly, climate change is among the issues most debated today and most felt by people worldwide. Every day, we hear news about global warming and its effects in every part of the world.

1.1.1. Current situation

The first definition of climate change was given in 1992 during the United Nations Framework Convention on Climate Change (UNFCCC) [1], commonly called the Rio Accords, where they defined climate change as:

> *A change in climate that is attributed directly or indirectly to*
> *Human activity that alters the composition of the global atmosphere and*
> *is in addition to natural climate variability observed over comparable*
> *periods.*

This treaty did not set limits on emissions but included the possibility of restricting future conventions.

From the definition given, it is clear how human activities significantly affect climate change, and events such as the Industrial Revolution, deforestation, and the development of livestock farming have affected and continue to affect the climate, causing irreversible damage.

A recent study by the journal *Nature* [2] has calculated the number of deaths in Europe due to the increase in temperatures, then of the heat in the year 2022, the hottest summer ever recorded in Europe.

Last summer, there were temperature peaks, drought, and fires in the old continent. In particular, the highest temperature peaks were in France (+2.43 °C) and Switzerland

(+2.30 °C), but overall, the whole of Europe has experienced temperature increases, as can be seen from Figure 1, where each shade represents a more or less marked increase in temperature compared to the average temperature of the same area in the same period.
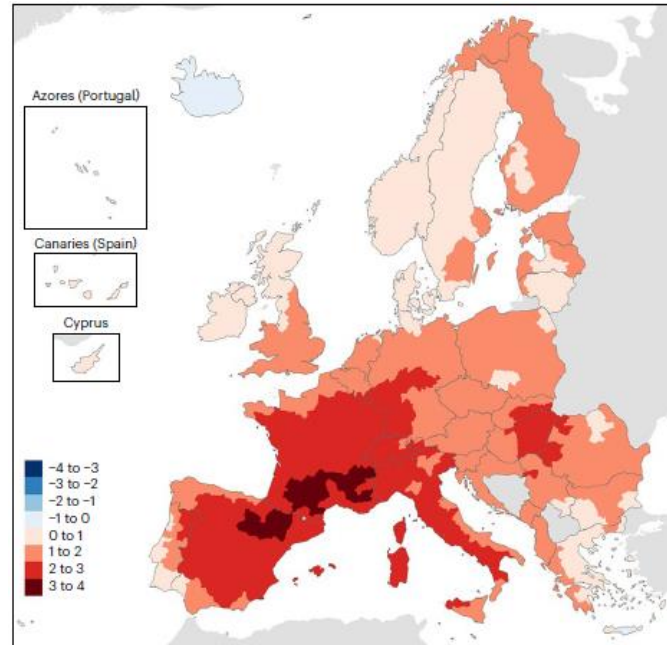
Figure 1: average temperature rises in Europe in 2022 [2]

Overall, 61.672 people died in the heat on the continent; the most affected country was Italy, with 18.000 deaths, followed by Spain (11.324) and Germany (8.173).

These poor results were also certified by the latest report of the World Meteorological Organization (WMO) released in May 2023 [3].

This organization estimates when the global temperature will exceed the pre-industrial average temperature by 1,5 ºC or before the start of CO_2 emissions worldwide. The temperature delta of 1,5 ºC has always been indicated as a minimum increase that would cause increased risks to health, livelihoods, food security, water supply, human security, and economic growth; it was signed in the Paris Agreements of 2015, and it has always had a more political than scientific value but with a great symbolic significance.

The latest report is much more pessimistic than the previous versions and estimates that there are two chances out of 3 that the increase will take place by 2027 and will last for at least a year; to make a comparison, in 2015, the odds were 0, between 2017 and 2021

were 10%, in 2022, last year, they were 50% and, as mentioned, today they have reached 75%.

In addition, the organization states that there is a 98% chance that at least one year, between 2023 and 2027, will be the hottest ever, beating the record of 2016; to demonstrate this, the 3 July 2023 was recorded as the hottest day in the world, with a world average temperature of 17,01 °C, breaking the previous record of 16,92 ºC in August 2016.
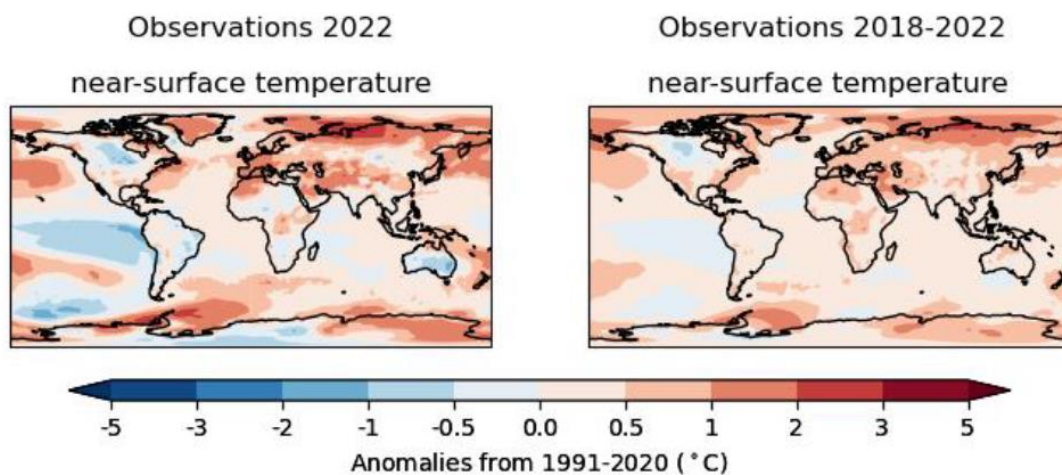
Figure 2: world average surface temperature in 2022 and 2018-2022 [3]

Figure 2 shows the temperature difference observed in 2022 in the world compared to the highest temperatures observed between 2018 and 2022; it is pretty clear that the average temperature is higher, especially in the continental zone of Eurasia. Overall, however, all areas will increase in temperature.

1.1.2. European Green Deal

To address this problem, almost all countries worldwide are working to limit their emissions and promote an ecological transition. The European Union plays an essential role in this context with its ambitious European Green Deal plan.

The European Green Deal is a roadmap signed in November 2019 with the goal of carbon neutrality in 2050 to stop global warming below 1,5 ºC.

To achieve this goal, a European law called *Fit for 55* was signed on 24 June 2021, which aims to reduce emissions by 55% by 2030, confirming the EU's leadership in the fight against climate change [4].

Figure 3: European Green Deal scheme [5]

Figure 3 shows the European Commission's roadmap for achieving all the targets set, particularly the importance of the Social Fund ETS for climate change to help those most affected by climate change.

1.1.2.1. European Emission Trading Scheme (EU ETS)

Among the primary measures of the *Fit for 55,* there is undoubtedly the *Emissions Trading System* (ETS), an instrument used to combat and reduce CO_2 emissions at the industrial level, whose economic and political weight increases from year to year; think that in 2021 it was the most extensive cap-and-trade program in the world for traded value [6].

The EU ETS was launched in 2005 and is active in 31 EU and non-EU countries (such as Norway), with over 12.000 plants, including industrial plants and power plants, covering over 40% of total greenhouse gas emissions within the EU.

ETS are emission permits that companies must apply for when they release CO_2 into the atmosphere in their production processes; these certificates represent a cost for companies that are therefore tempted to emit less to limit or eliminate a significant cost within the production processes.

To a lesser extent, these permits are partly guaranteed to companies and partly sold on the market at very volatile prices that change very quickly.
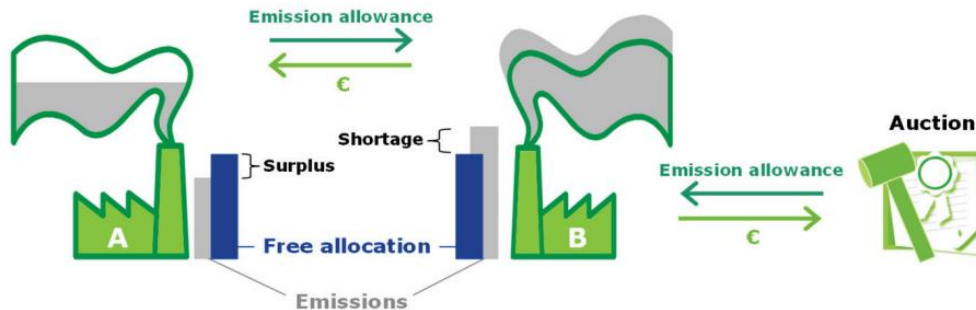
Figure 4 shows a simple scheme of operation of the ETS: Company A consumes fewer CO_2 allowances than those due from the free assignment; this can keep them for the future or resell them on the market; on the contrary, Company B needs more quotas to cover the delta between its consumption and those protected by free quotas, the company will be free to use percentages accumulated over the years, if present, or will be obliged to buy them from other operators (company A) or through auctions, in Italy the latter are managed by the GSE (*Gestore dei Servizi Energetici*).

Since it entered into force in 2005, the ETS has been implemented in several stages; in the first phase, which lasted until 2007, the cap of the issue was 2298 Mt of CO_2 per year, which was a transitional phase to introduce the measure. Where it was forbidden to accumulate ETS for subsequent years, almost all allowances were guaranteed free of charge, not burdening economically the companies that had to enter the scope of this measure [8].

The second phase (2007-2012) was the first real phase of this policy: free allowances fell to 90%, forcing companies to adapt, auctions for the purchase of shares began, and fines for those who did not comply increased from 40€/ton CO_2 to 100€/ton CO_2.

The financial crisis of 2008 led to a significant reduction in production and, consequently, emissions, leaving many free quotas on the market and having a significant impact on the price of them.

The third phase, from 2013 to 2020, was crucial and led to several changes: the limit of quotas at the national level was replaced by a single limit at the level of the European Union, and the inclusion within the system of other types of pollutants.
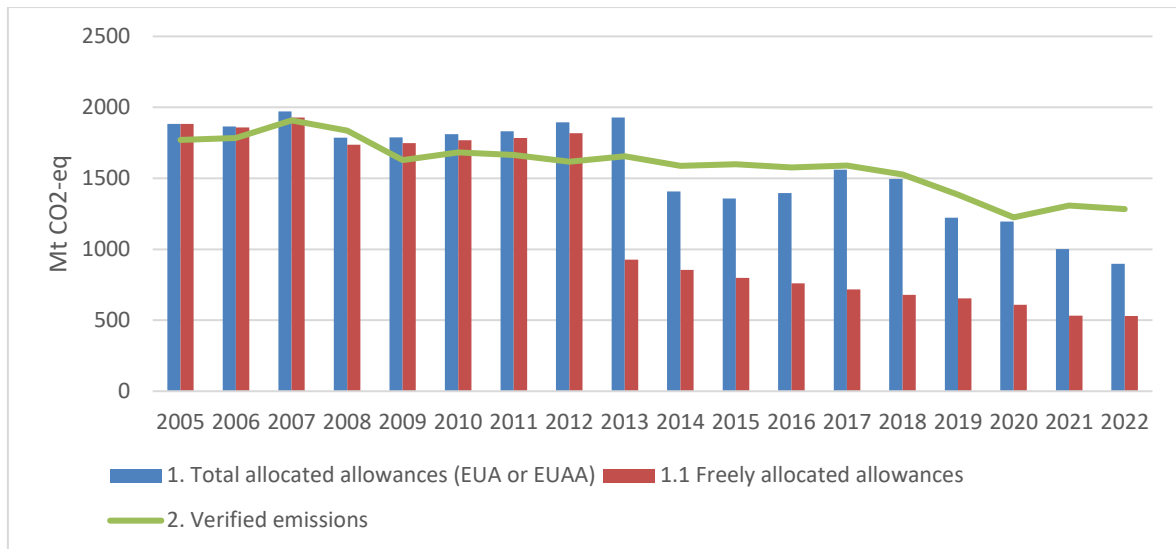
Figure 5: emissions from ETS countries and allowances sold [7]

Figure 5 shows the total ETS allowances used from 2005 to 2022 (blue bar) compared to the free allowances issued by the EU (orange bar) and the verified emissions in the European Union (green line).

In the first two phases, until 2012, the allowances issued were almost totally covered by the free allowances; this led to a not-too-significant reduction in emissions and was mainly due to the financial crisis 2008. On the contrary, since 2012, with the reduction of free allowances, there has been a decrease in emissions and, consequently, in the quotas used by industries; excluding the short growth for the years 2017 and 2018, it can be concluded that since the entry into force in 2005, the allowances used are more than halved, while verified emissions are reduced by about 30%.

Free allowances were allocated to cover about 80% of emissions until 2013, while later, they covered 30%; the goal, as mentioned above, is to reach 0% by 2034.
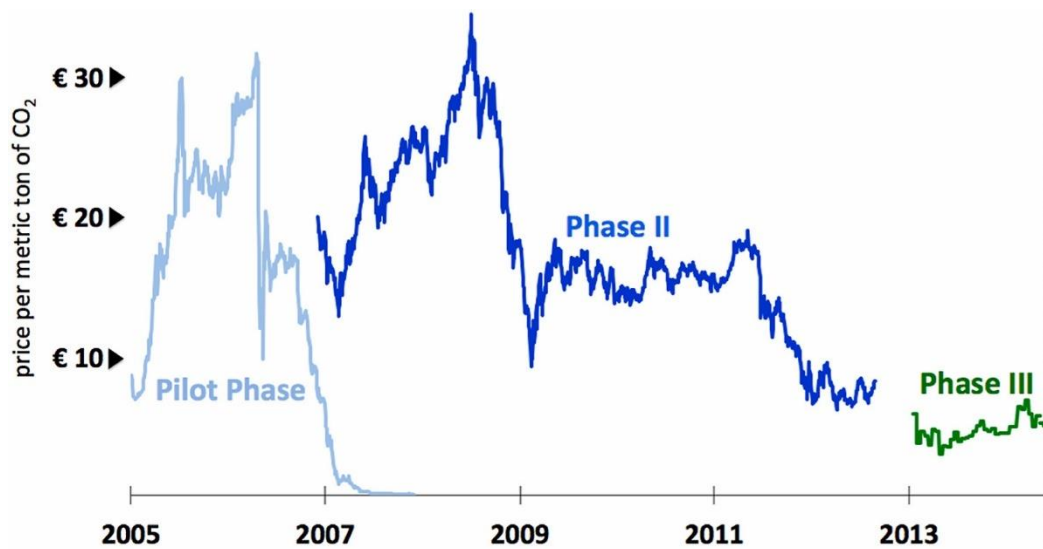
Figure 6: ETS price with evidence of the various stages [9]

Figure 6 shows the evolution of prices in the three phases explained above. The effect of the financial crisis of 2008 is visible when a reduction in production and, as a result, emissions led prices to drop dramatically.

The drastic decrease of 2008 pushed the European Union in 2015 to create the stabilizing reserve of the market MSR (*Market Stability Reserve*) in order to align better the supply and the question of quotas, placing 24% of all the quotas ETS in reserve, from which they can be unblocked in case of shortage. This measure has been extended from 2023 until 2030 as protection from events that can damage the price of quotas, such as COVID-19 [10].

In December 2022, the European Union, to comply with the ambitious reduction plan wanted by the European Grand Deal, implemented changes to the ETS system that aim to reduce industrial emissions by 62% by 2030.

The signed update will bring the following changes:

- Further reduction of market shares;
- Creation of an Innovation Fund and a Modernisation Fund to increase funding for innovative technologies and modernization of the energy system, and part of the economic revenue from the ETS will go to the Social Fund for Climate. This fund protects families and businesses affected by energy poverty.
- The phasing-out of free allowances for the industry by 2034 (Table 1) and the entry into force of the carbon adjustment mechanism at the EU border in the same year to apply to incoming products a surcharge equal to the price of the carbon emitted

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for the production of the goods, in such a way as not to favor imports to the detriment of domestic production;

- Extension of the scheme to maritime transport;

- Inclusion of emissions from waste incineration plants from 2024;

- The creation of a similar but parallel ETS system (ETS II) to include all commercial buildings and road transport from 2027 with the aim of including private buildings from 2029.

Table 1: percentage reduction of free allowances

Year	2026	2027	2028	2029	2030	2031	2032	2033	2034
% Reduction	2,5%	5%	10%	22,5%	48,5%	61%	73,5%	86%	100%

In the years, the price of the quotas available on the market has significantly varied, as demonstrated in Figure 7; the general tendency is to increase following an almost exponential course.
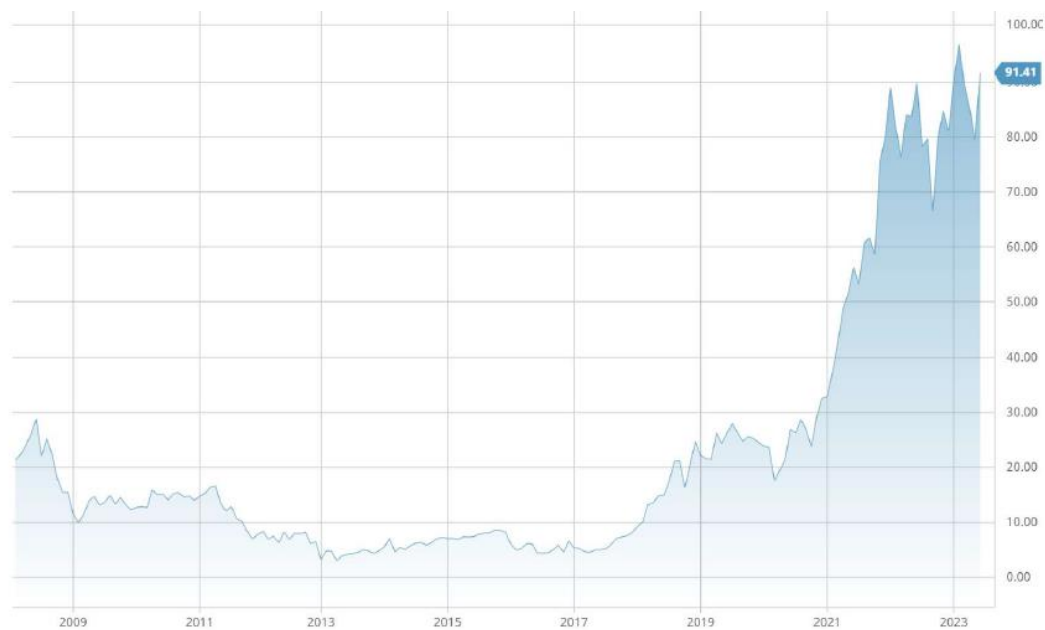
Figure 7: ETS price from 2008 to 2023 [11]

Excluding 2008, the first year of the ETS policy, where the price has almost reached 30€ per ton of carbon dioxide emitted, for several years, from 2009 to 2017, the price has always been constant on less than 10€/ ton of CO_2, making this measure insignificant for

the coffers of industries and therefore less impactful than when it could potentially be. On 22 April 2013, the all-time low of €2.97/ ton of CO_2 was reached.

Starting from 2017, the price of quotas has increased exponentially, except for the pandemic to fall for the same consequences that occurred in 2008, reaching over € 30/ ton of CO_2 in late 2020. This growth is due to the consequences of the environmental measures implemented by the EU and, consequently, increased market demand. Moreover, the ETS is strongly influenced by the general price of energy. In turn, they affect the cost of energy by generating a chain effect that is difficult to control: the rise in the price of energy and gas, which the invasion of Ukraine in 2022 has further affected, has made a splash on the price of the quotas, making to go from the approximately 30€ of 2021 to beyond 90€ of 2022, this increase has remarkably widened the weight of this measure on the chests of the industries[11].
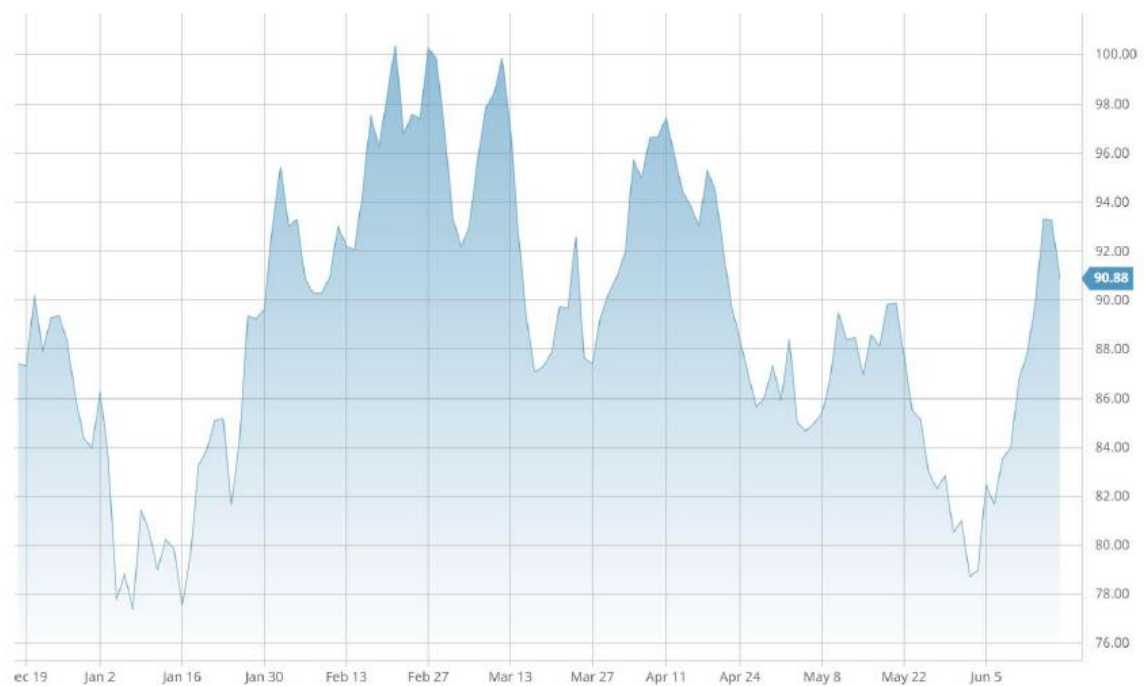
Figure 8: ETS price in 2023 [11]

Analyzing the specific course of the quotas from the beginning of 2023, Figure 8 shows that the price is now fixed above 78 €/ ton of CO_2 with an average little inferior to 90€. During the year, there were times when the threshold of 100 € was reached, ten times the average value of six years before.

Today, many companies are looking for the best time to buy shares to use in the future as the price will increase significantly in the coming years as a response to the decreasing quotas and the approach to eliminating free quotas.

1.1.2.2. The importance of industries in the Green Deal

An important piece of the European Green Deal was recently approved on 12 July 2023. During this time, the European Parliament passed a law to protect 20% of the European Union's land and sea surface by 2030 to prevent commercial exploitation. This victory is significant because it was the most critical law in the package and because, if it had been rejected, it would have substantially compromised the law's approval by the end of the legislature [12].

This law is among the most ambitious of the Green Deal package, along with decarbonization as of 2050 and a ban on selling cars with thermal engines from 2035.

The following steps of the European Union concern the Farm to Fork, that is, the plan of the European Commission to push the agricultural sector to more sustainable investments and approaches, and especially the *Industrial Plan* [13].

This last measure, which the Commission presented in February 2023, aims to facilitate the energy transition in the industrial sector without losing competitiveness with other world markets through a simplification of regulations, faster access to funding, the establishment of courses to encourage the teaching of specific skills and strengthening trade by the principles of green transition [14].

It is clear that, within this transition, industry plays a crucial role in the growth and competitiveness of the European Union globally to become a leader in the green transition.

In this context, it is essential that every company, large or small, understands the importance of the battle against climate change through actions that reduce emissions and energy consumption; among the companies that have a sustainability plan is Iveco Group, which for some years has presented its ambitious decarbonization plan to 2040.

1.2. IVECO GROUP

Iveco Group is an Italian group leader in producing light, medium, and heavy commercial vehicles, but also for public transport and special vehicles. Officially born in 2022 from the split with CNH Industrial of some of those companies that until then were part of. [15].

However, its history began much earlier, when Conrad Magirus founded his company in 1864; over the years, the company passed under Fiat Veicoli Industriali (1929) and officially became IVECO in the 70s. Subsequently, Astra and FPT joined the Group before the industrial sectors were separated in 2011 by the Fiat group. On 1 January 2022, Iveco Group was officially born, and from 3 January 2022, the Group is listed at Euronext Milan, the Italian stock exchange (Figure 9).
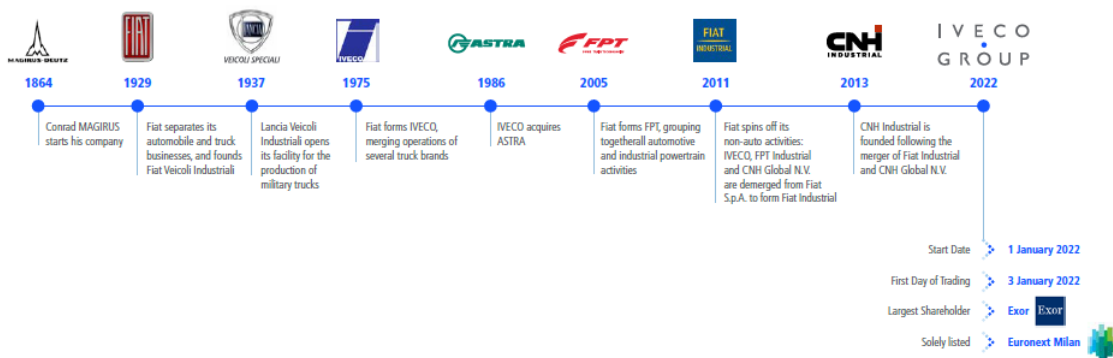
Figure 9: history of Iveco Group [15]

The companies that today are part of the Group (Figure 10) are:

- Iveco Capital, the organization of financial services of companies belonging to the Group, provides financial assistance and advice requirements for the sale, purchase, or use of all vehicles and their engines or spare parts;
- Heuliez, the market leader in electric urban buses in France with more than 90 years of history;
- Iveco Bus, a brand specializing in the construction of passenger transport and today highly focused on the concept of sustainable mobility;
- Iveco, a brand specialized in the production of commercial vehicles (light, medium, and heavy);

- FPT Industrial, the world leader in industrial powertrains and alternative propulsion for road and off-road vehicles and marine and power generation applications.

- Iveco Defence Vehicles, it provides a means of transport for defense and civil protection;

- Astra, specialized in the development of industrial vehicles for extreme off-road conditions;

- Magirus GmbH, entirely dedicated to the manufacture of firefighting vehicles.

Figure 10: brands of Iveco Group [15]

Today, Iveco Group has 20 industrial sites worldwide and 29 development centers where more than 35.000 employees work. The range of vehicles and engines produced is extensive, and overall, the Group deals with producing thousands of vehicles per year and various components.

1.2.1. The sustainability objectives of the Group

Within such an important reality, sustainability plays a primary role.

The sustainability objective has different purposes and is related to Scope 1, Scope 2, and Scope 3. Scope 1 emissions include direct emissions of sources owned or controlled by the company, Scope 2 emissions include indirect greenhouse gas emissions from purchased or acquired energy, and Scope 3 emissions include all indirect emissions occurring in the value chain of a reporting company.

Iveco Group has set very ambitious targets in the field of sustainability related to emissions in Scope 1 and 2, among which there is certainly the net zero carbon 2040, that is, the zero setting of CO_2 emissions ten years before the deadline set by the Paris agreement. These objectives are:

- -30% of energy consumption referred to Total Manufacturing Hours [GJ/TMH];

- -50% of tonnes of CO_2 emissions in all plants;

- 100% of electricity consumed from renewable sources.

The company's commitment to sustainability is also demonstrated by the fact that twenty-three plants are now certified ISO 50001, which guarantees the commitment to applying an energy system.

To achieve these objectives, Iveco Group has invested heavily in several efficient projects in recent years; for example, in 2022, more than EUR 2 million were invested in projects that reduced 64 TJ of energy and about 4.500 tons of CO_2.

Figure 11 shows the 2022 trend of 2030 targets.
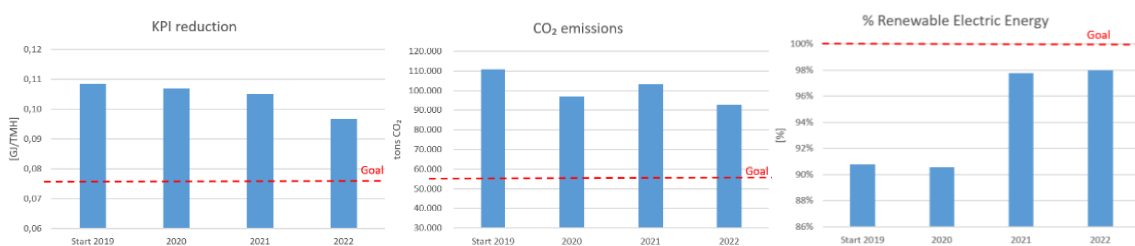
Figure 11: trend of targets from 2019

1.2.2.   L'Energy Department and internal benchmark

The Energy Department pursues these objectives within the Group through the development and implementation of an energy management system based on the monitoring of EnPI indicators (*Energy Performance Indicator*).

These indicators are fundamental for Iveco Group to monitor the effective efficiency deriving from each project, to understand how and which measures to implement, and to establish new targets related to the Manufacturing area only, which include all the production processes that transform the raw materials, while the non-manufacturing area is not the competence of the department and includes all the offices.

To monitor all consumption, the EMT platform, *Energy Monitoring & Targeting*, is used, where all Plants charge their consumption monthly, which allows a global vision and comparison of consumption and emissions of the various plants.

This monitoring is carried out by the central body to keep consumption and emissions so that they are in line with the budget set by the department at the beginning of each year for each Plant.

To better carry out the objectives of the Group, the department carries out important work on internal and external benchmarks to be implemented in the work of monitoring and sharing at various intervals.

In particular, the internal benchmark consists of sharing data and projects of the various Plants to obtain a constructive comparison. It allows for better exploiting the efficient projects, aiming to implement them in other plants.

One of the department's tasks is to identify efficient projects for Plants to reduce energy consumption and, consequently, emissions without losing the quality of the final product that distinguishes the company in the world market.

Particular importance is given to projects that reduce natural gas consumption for sustainability reasons. Emissions come almost entirely from this energy carrier for economic reasons because they would allow the exit from the ETS.

1.2.3.   The impact of the ETS system on the Group

The economic weight of the ETS has become increasingly evident, and companies today can no longer ignore the economic weight of this measure.

As stated above, the ETS is becoming increasingly important, and industries must consider this. Fourteen Iveco Group plants in Europe fall within the ETS circuit, and their weight varies greatly depending on the site's size and the thermal systems' size.

At the industrial level, the equipment subject to the emissions trading system shall be all those (boilers, burners, turbines, ovens and dryers, engines) with a nominal power sum of more than 20 MW; the calculation for inclusion or not in the ETS excludes thermal installations with a thermal input of less than 3 MW.

If we analyze only the Italian plants, they all fall into the system in question, and for these, Iveco Group, in 2022, paid about EUR 3 million for the ETS expenditure.
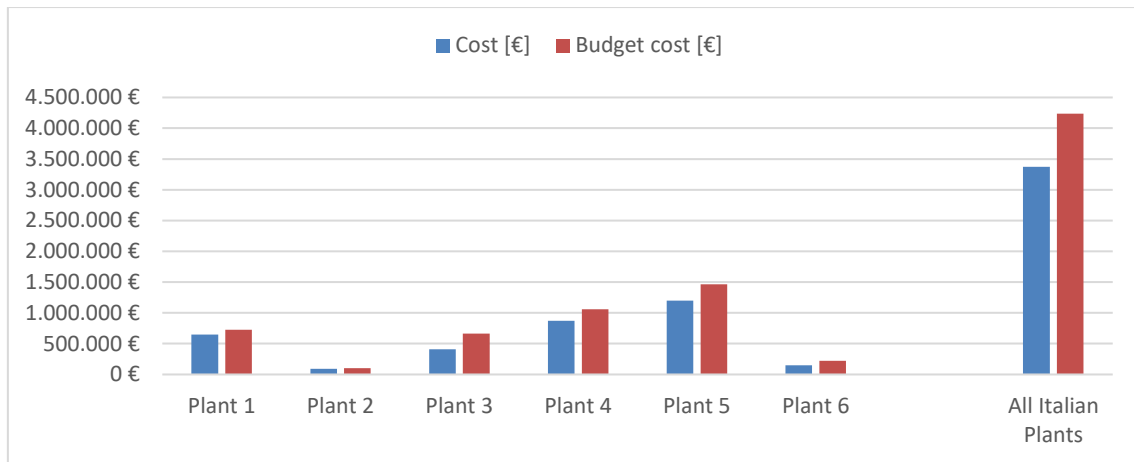
Figure 12: ETS fees for Italian plants

Figure 12 shows the breakdown of expenditure for ETS in Plants located on Italian territory; their weight is very different and depends on the size of the Plant, their thermal demand, and how this is met. It is crucial, however, to stress that these costs are not negligible and have a bearing on the coffers of the establishments.

Compared to the budget expenditure allocated to the ETS system, almost a quarter of the money initially allocated was saved, as is also shown by Figure 12, where the red column represents the expenditure allocated to the budget for the purchase of quotas while the blue column represents the expenditure made; this thanks to a very accurate market share buying strategy, constantly monitoring trends and buying them in the most advantageous periods.

Figure 13: ETS spending performance with and without a defined exit strategy

Some internal estimates, Figure 13, showed that, following the trend of recent years, the difference between a business strategy aimed at efficiency with the objective of exit from the ETS can lead to a saving of almost three million euros per year compared to a situation where projects are not implemented and passively suffer the effects of the market and of the ETS in general. Therefore, it is crucial to act on thermal installations responsible for emissions and falling within the ETS system to limit, if not zero, emissions into the atmosphere.

It is helpful to underline that it is not always necessary to replace the systems to exit the system; in some cases, it is sufficient to re-modulate the heating units by lowering or switching off some boilers to remain below 20 MW, the minimum threshold to enter the system. This strategy is helpful in the short term but does not lower the costs of natural gas consumption; it is also linked to the shutdown of backup systems and, in general, to a reduction in the thermal energy required by the Plant, details not always easily achievable. It is, therefore, essential to find, where possible, alternative solutions upstream of the problem, that is, in the generation of heat, and the transition to district heating could meet this need.

2. Energy consumption and emissions analysis of an Iveco plant

This work will analyze an efficient project applying it to an Iveco plant; in particular, two of the Group's industries located in the same area of the same city in central Italy have been chosen and have been active since 1930. The two Plants belong to two different brands (Magirus and Iveco CV) and produce different end products but share the area in which they are located.

Despite sharing the thermal power plant, they are two independent plants, each with its legal entity, its organization, and within the Energy Department are analyzed independently with separate budgets and consumption analysis.

Consequently, two separate analyses will be developed with the same objective: reducing natural gas consumption.

Figure 14 shows an aerial view of the two factories, in the blue box is highlighted the part of Iveco CV, commercial vehicles, while in the red box Magirus.

Figure 14: aerial view of the two factories

2.1.   IVECO CV: introduction

The most significant part of the Plant belongs to Iveco CV (*commercial vehicles*). It occupies an area of 667.000 m² of which 297.000 m² are covered, inside which are produced medium-range industrial vehicles, employing about 1800 employees.

The area on which the Plant extends (Figure 15) consists of several plants used for different tasks.

The production process starts from the welding shop area where the sheet is welded, then, always in the same building, the painting, and the harnessing take place; the components are transported by size to the adjacent Plant thanks to automated scales, where the vehicle is assembled (finishing and assembly shop). Once finished, the vehicle is taken to a large open-air warehouse, always in the factory area, ready for sale or delivery.

Overall, there is also a warehouse (logistic area), where the new Iveco Daily electric and minibuses are produced, the administrative offices (headquarters), and finally, an area where electric cables of vehicles (wire & pipes) are assembled from scratch.
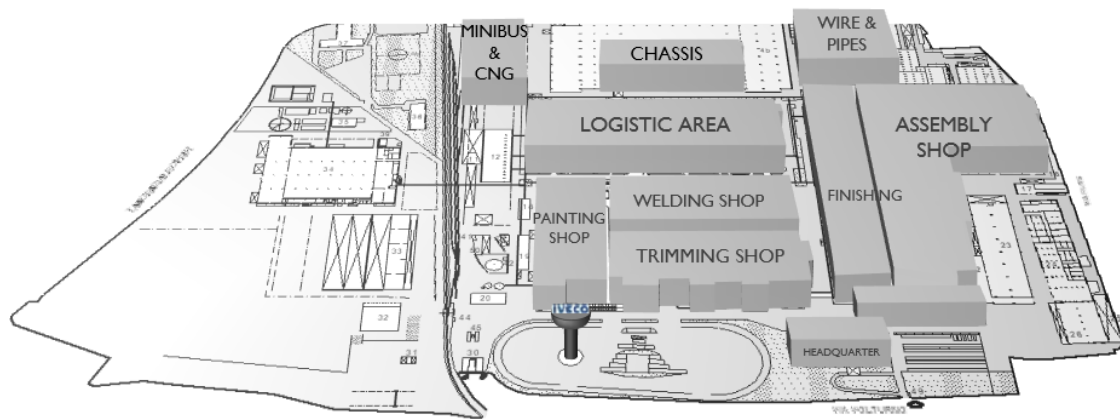
Figure 15: division of Plant Iveco CV

The Iveco Group plant in question is a body shop, which, through processes of nailing, paving, painting, harnessing, and assembly of parts, produces medium commercial vehicles called EUROCARGO, medium-range vehicles weighing between 7.5 tonnes and 15.99 tonnes.

In addition, part of the components of the heavy middle classes are produced and subsequently destined for other plants of the Group located in Europe; there are also third-

party companies that deal with the management of ecological plants (technological water treatment, waste management) and all energy carriers (electricity distribution, industrial water, and compressed air).

As mentioned above, the flagship vehicle of the Plant under study is EUROCARGO, a medium-sized freight truck produced since 1991 and winner of the 1992 and 2016 Truck of the Year awards, the latter thanks to the fourth generation of the vehicle, still sold today[15]. In addition, minibuses have also been produced since 2016, and from 2022 the DAILY vans in the electric version and the classic 4x4 version.

Figure 16 shows three examples of vehicle types produced.

Figure 16: vehicles produced in the factory [15]

The number of vehicles produced per year peaked in 2007 with almost 25.000 vehicles produced, after the 2008 crisis brought production down to 10.000 in 2009. Today, the Plant produces about 18.000 Eurocargos and nearly 8.000 electric Daily vans.

Every vehicle needs a medium of approximately 70 hours of job.

2.1.1. Manufacturing processes

The production process consists of several consecutive construction phases that will now be deepened to understand the energy consumption better:

- **Slabbing**: The unit produces, with complete cycle, welded sub-assemblies of sheet metal for the cabins destined for painting and external customers. This production cycle is divided into two phases: the first is to create subgroups and complete cabins through automated systems, and the second is to revise and

deliberate the product. The automated welding activity is preceded by preparation activities performed on manual stations where several operators operate.

This process mainly needs electricity from a low-voltage cabin and uses thermal energy, industrial water, and compressed air to a lesser extent.
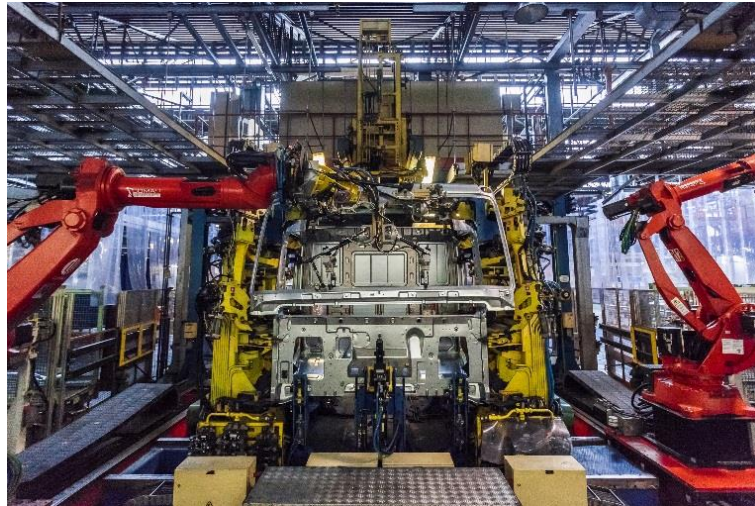
Figure 17: slabbing process

Figure 17 is an example of the paving of the doors in the factory.

- **Painting:** The Plant's cabin painting operation unit is structured to produce painted bodies for Iveco trucks.

  The painting cycle is two layers high in thickness; that is, the sheet is covered by a first layer that has the function of preserving from oxidation and a second layer of enamel to finish.

  Initially, the cab bodies are sent to the painting plant from the paving department through an air convoy, where they will be pre-treated and undergo a cataphoresis process. A layer of PVC underbody will be applied, the joints will be extruded, and the colored enamel will be applied. After a testing area, which determines whether a second layer of enamel is necessary or not, a polishing/ retouching phase takes place and then continues toward the harnessing phase.

  This phase mainly uses electricity, using a low-voltage electrical cabin, and methane to power the ovens at 0.5 bar. Thermal energy, compressed air, industrial water, and demineralized water are also used to a lesser extent.

Figure 18: painting room

In Figure 18 the process of painting the plant.

- **Assembly:** The assembly operating unit is structured for vehicle production, quality control, and resolution. The drive boxes, axle, drive shaft, engines, and cab are lowered to be connected to the chassis system. Finally, fluids are filled, and vehicles are set in motion before mounting the wheels.

  Within the department are sub-departments such as the harness, with the task of saddling the cabins, the sub-group responsible for quality control, and the finishing department performing the final tests.

  This operating unit uses mainly electricity, output in low voltage from an electric cabin, and methane, which feeds the technological users with gas at the pressure of 0.5 bar. Compressed air, thermal energy, and industrial water are also used to a lesser extent.

  Figure 19 shows an example of the final assembly phase in an Iveco plant.

Figure 19: assembly phase

Overall, the primary and secondary energy carriers used in the Plant are:

- **Electric energy:** distributed inside the area with systems of first (up to 1000 V in c.a.), second (up to 30.000 V in c.a.), and third category (tensions in c.a. greater than 30.000 V).

- **Methane:** used for technological use and direct heating; the distribution company delivers it as a 12-bar gas, which is then decompressed in unique booths first at 4 bar and then at 0.5 bar, pressure appropriate to the use.

- **Compressed air:** produced inside the thermal Plant with a group of compressors and distributed at a pressure of 6 bar.

- **Thermic Energy:** produced inside the power plant using a group of generators (boilers) as superheated water at 130 ºC.

- **Industrial water:** taken from wells and used for production (abatement of powder painting and cooling).

- **Demineralized water:** generated by a special plant and used mainly in painting and as food for boilers for heat generation.

2.1.2. Energy consumptions and emissions

We will now analyze in more detail the consumption of energy carriers of the Plant; this research is helpful to understand better the operation of the Plant from the energy point of view and allows us to understand which are the most energy-intensive production units and where, consequently, it is appropriate to operate in energy efficiency to reduce emissions and reduce electricity consumption, in line with the objectives of the Iveco Group.

The Group's Energy Department collected these data to monitor consumption and work annually to create the energy budget for the following year. Furthermore, to have a clear idea of which carriers are affected by the production processes and to what extent it allows better development of the decarbonization strategy through more targeted efficient projects.

Since 2017, Iveco has had an agreement with an external company that manages energy carriers; this agreement concerns some plants in Italy and two in Spain. The two Plants in question are covered by the deal, which means that energy carriers and wastewater are

managed by an external company that has the task of transforming primary energy carriers into secondary energy carriers and the distribution of these within the plants.

Working in synergy with this company, Iveco can propose projects; the external company will formulate an offer that follows an analysis of technical and economic feasibility by the Energy Department.

Primary energy carriers

The 2022 energy consumption of the Iveco CV plant is shown in Table 2, where the three primary carriers purchased by the plant in their technical unit of measurement are highlighted.

Table 2: Iveco's primary consumption in 2022 with technical units

Primary energy carrier	Unit of measure	Consumption in 2022
Electricity	kWh	32.187.734
Natural gas	Sm³	5.220.401
Diesel	t	31,37

The energy needed for the Plant comes from electricity, natural gas, and, to a lesser extent, diesel.

They were later converted to GJ using the appropriate conversion factors to better compare these vectors.

The conversion was made using the conversion coefficients calculated by the IEA [16] (Table 3).

Table 3: conversion factors provided by the IEA [16]

Energy carriers	Parameter	Conversion	Value
Electricity	EE conversion coefficient	kWh → GJ	277,778
Natural gas	NG conversion coefficient	Sm³ → t	0,0007395
	PCS natural gas	t → GJ	48
Diesel	PCS diesel	t → GJ	43

The results obtained can be seen in Table 4.

Energy carrier	Unit of measure	Consumption in 2022
Electricity	GJ	115.876
Natural gas	GJ	185.303
Diesel	GJ	1.349

From Table 4, it is easy to see that methane gas is the plant's most widely used energy carrier.

Then, the trends of individual energy carriers over the years began in 2017. In recent years, several events have impacted the evolution of prices and general consumption, such as the pandemic; however, it is essential to analyze annual trends to understand future developments better and to choose a better efficiency strategy.

The diesel is not monitored monthly at the software level by the plants, and its consumption is reported annually, so it will not be subject to further analysis; moreover, its use is minimal and mainly concerns the testing of vehicles and not their production.

❖ **Natural gas**
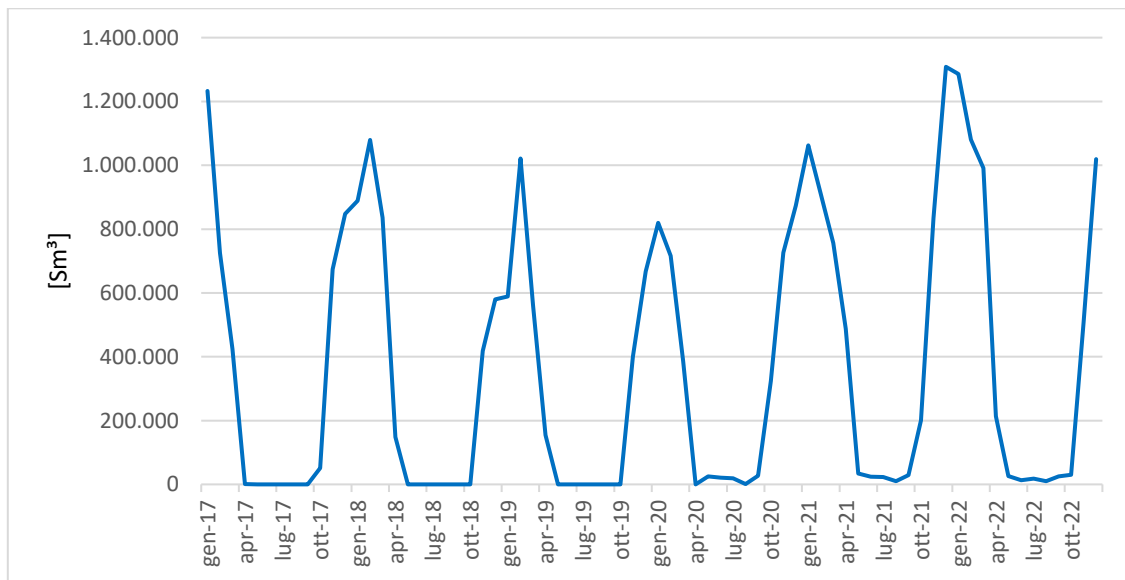
Figure 20: natural gas consumption from 2017 to 2022

Figure 20 shows the trend of natural gas consumption from 2017 to 2022; this trend is zero between May and October of each year and then a peak in January. This is because almost all natural gas is used to heat environments in winter. However, in the summer of

2020, consumption was not zero but still had little impact; this could be due to its industrial use.

If we analyze the month of January, the peak month of each year, we can see that consumption decreased in the years of Covid (mainly 2019 and 2020), but then consumption rose again and reached peaks even higher; it is no coincidence that the maximum monthly consumption is in January 2022 with a value of 1.285.608 Sm³ of natural gas.

❖ **Electricity**

For electricity, Figure 21 shows the trend over the same period.
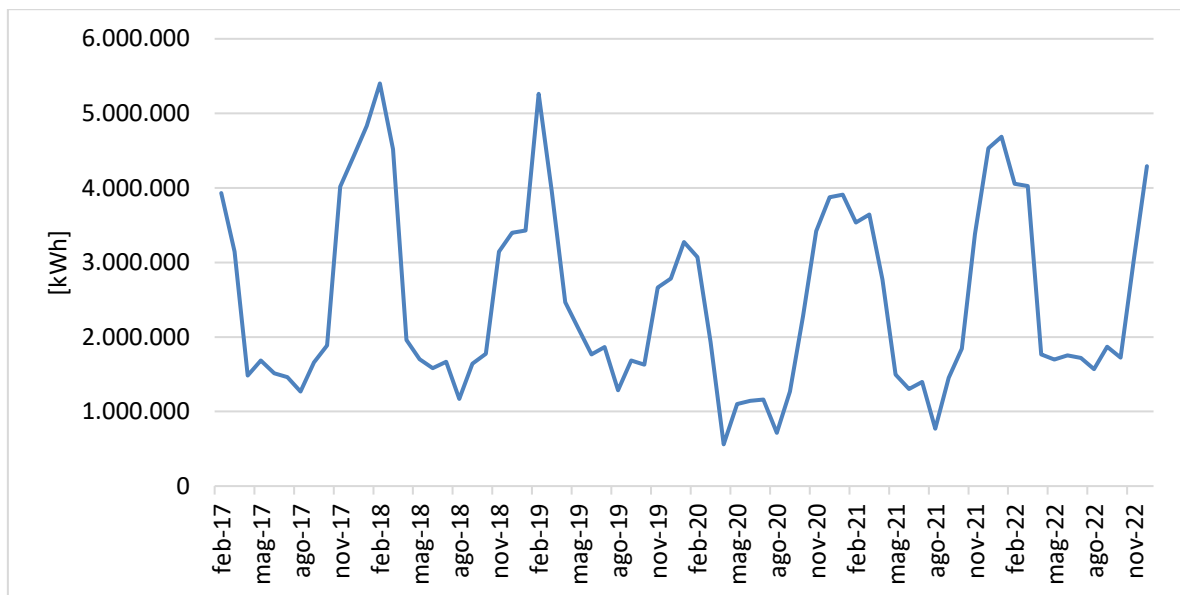
Figure 21: electricity consumption from 2017 to 2022

The trend of electricity consumption is similar to that of natural gas, with peaks in the winter months when electricity is also used for boilers; unlike the previous graph, consumption is never zero because electricity is also used for production systems and the driving force. It is even more evident that the COVID period lowered consumption between 2019 and 2020, while in the following years, consumption growth was less significant due to several efficiency projects implemented in the Plant.

Analyzed primary vectors, it is important to understand how these are used in the Plant to identify the most energy-intensive sectors and determine the best energy efficiency strategies and solutions.

Secondary energy carriers

The consumption of secondary carriers in 2022 for the Iveco CV plant is shown in Table 5.

Table 5: secondary consumption of Iveco in 2022 with technical units

Secondary vector	Unit of measure	2022 Consumption
Compressed air	Nm3	13.361.440
Heating	MJ	152.424.365
Electricity driving force	kWh	14.016.440
Electricity lighting	kWh	6.273.895
Heat for superheated water	MJ	11.596.653
Natural gas	Sm^3	1.204.329
Natural gas for decentralized heating	Sm^3	188.850
Industrial Water for Technological Use	m^3	537.397
Demineralized water	m^3	23.662
Wastewater technology	m^3	178.269

Also, in this case, the energy consumption has been converted into GJ to be able to compare them with each other and see how much they impact the plant; the conversion has been done with the conversion coefficients updated to the reference year. Excluded from this table are water consumption not included in energy reporting.

Table 6: secondary consumption of Iveco in 2022

Secondary energy carrier	Unit of measure	Consumption in 2022
Compressed air	GJ	6.520
Heating	GJ	152.424
EE driving force	GJ	50.459
EE lighting	GJ	22.586
Heat for superheated water	GJ	11.597

Table 6 shows that almost all the consumption is for heating heat, more than 90%. Significant is also the consumption of technological heat for overheating of water. In contrast, the consumption of compressed air and electricity used for matrix force and lighting are present but more marginal.

There are two separate natural gas consumptions from the gas used for heating the heading natural gas, which is used in the painting industry, and natural gas for decentralized heating, which is used in decentralized installations and is not part of the reporting of the thermal power plant. These two consumptions will not be deepened monthly because they are marginal and do not re-enter the consumptions of the thermal power plant.

Subsequently, the consumption of electricity, heat for heating, heat for overheated water, and compressed air were considered, analyzing the monthly trend from 2017 to 2022.

❖ **Compressed air**
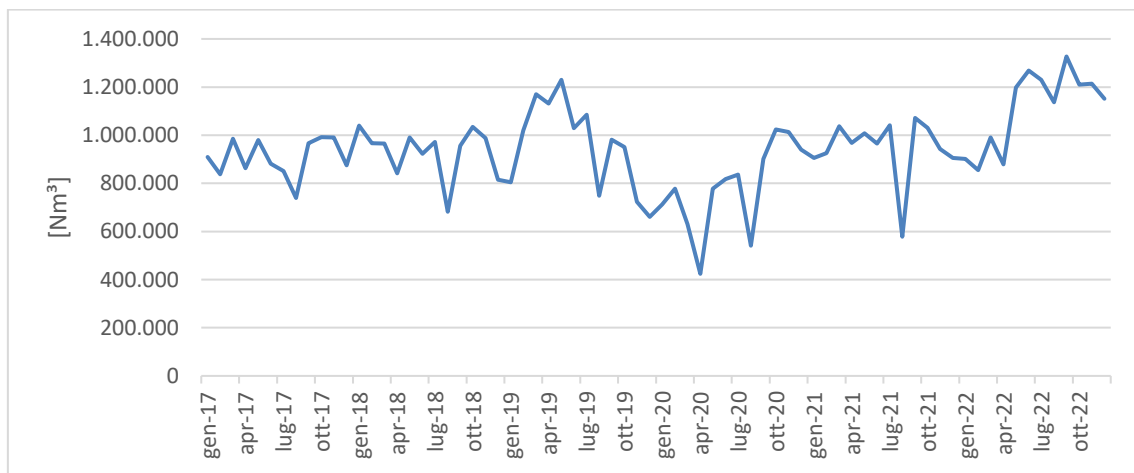
Figure 22: compressed air consumption from 2017 to 2022

Table 22 shows the trend of compressed air consumption in Nm³ from 2017 to 2022; the movement is almost constant, with a decrease between 2019 and 2020 due to the pandemic. In the last period, consumption has grown except for a slight decrease in recent months. The causes of this growth are still unknown; the company that manages the distribution of the carrier as a result of several measures has excluded problems in the production plant, and more in-depth analysis is underway in distribution where there may be losses or new connected users.

❖ Heat for heating
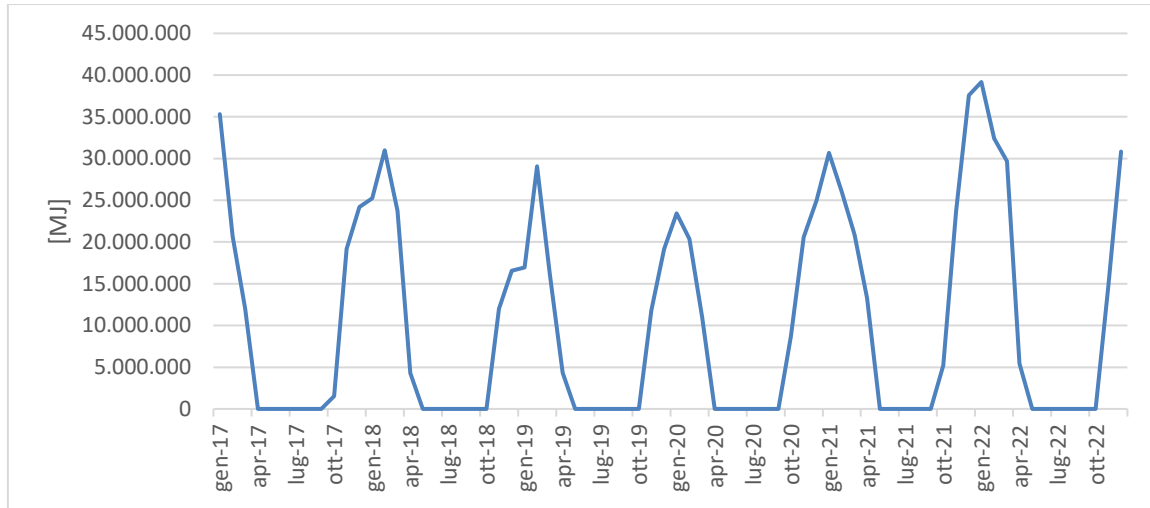
Figure 23: heat consumption for heating from 2017 to 2022

Heat for heating, Figure 23, follows a cyclical pattern used only in winter. To better analyze this trend, being also the most energy-intensive, a kpi, *Key Performance Indicators*, has been studied, that is, the relationship between the heat consumption for heating and the average value of the degrees per day in this plant in the months under consideration; this is because it allows comparing the consumption at the average outdoor temperature allowing to identify the consumption due to colder temperatures and the consumption due to waste or worse efficiencies. The analysis was made from 2020 to 2022; the results are illustrated in Figure 24.
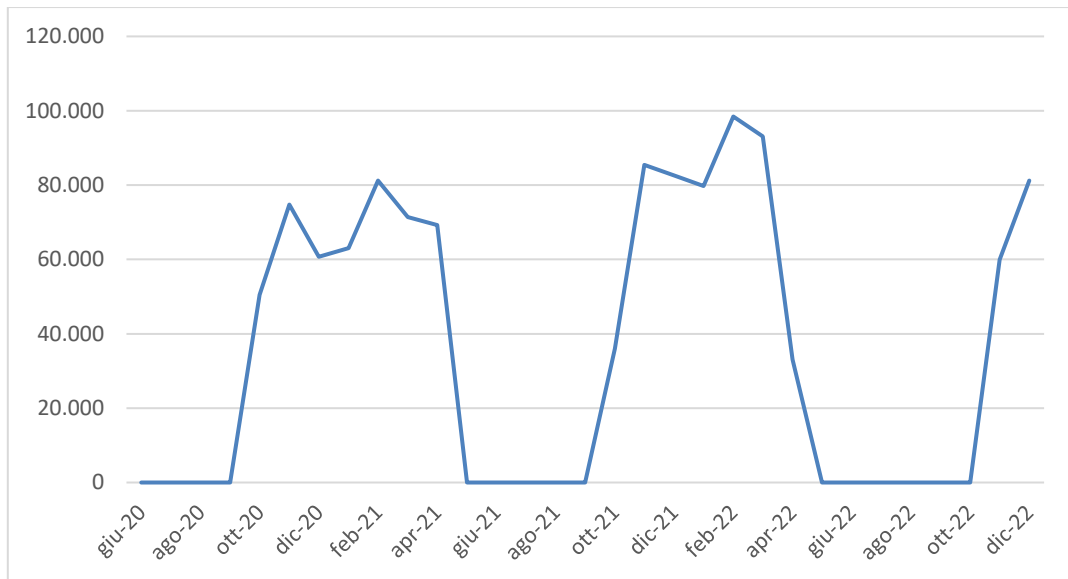
Figure 24: heat kpi for heating from 2020 to 2022

Figure 24 shows that the trend is also growing about the external temperature, demonstrating that the external climate also influences this trend.

❖ **Electricity**
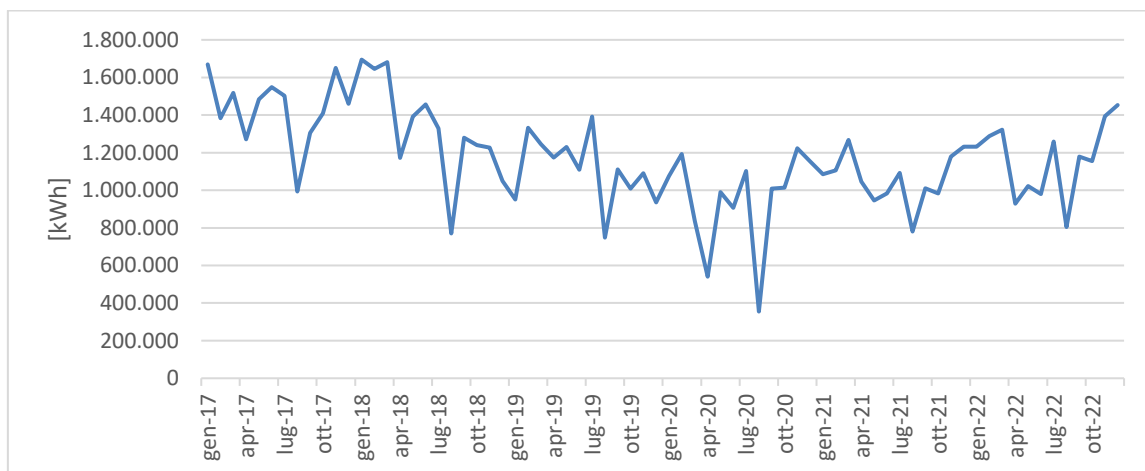
Figure 25: electricity consumption by motive power from 2017 to 2022
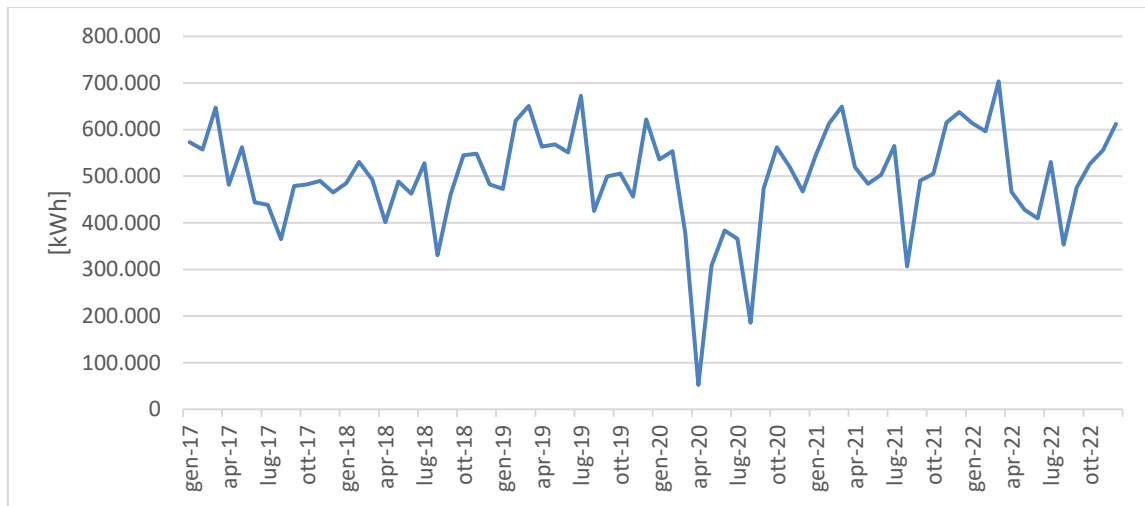
Figure 26: electricity consumption from 2017 to 2022

Figure 25 and Figure 26 show the trend of electricity consumption by motive power; therefore, for production machinery and lighting, the values are almost constant during the years, with a decrease in 2020, particularly in April of that year, lockdown month, lighting is almost nothing since the staff was unable to come to work.

❖ **Heat for overheating water**

Finally, the last analyzed consumption is related to heat for overheating water (Figure 27).
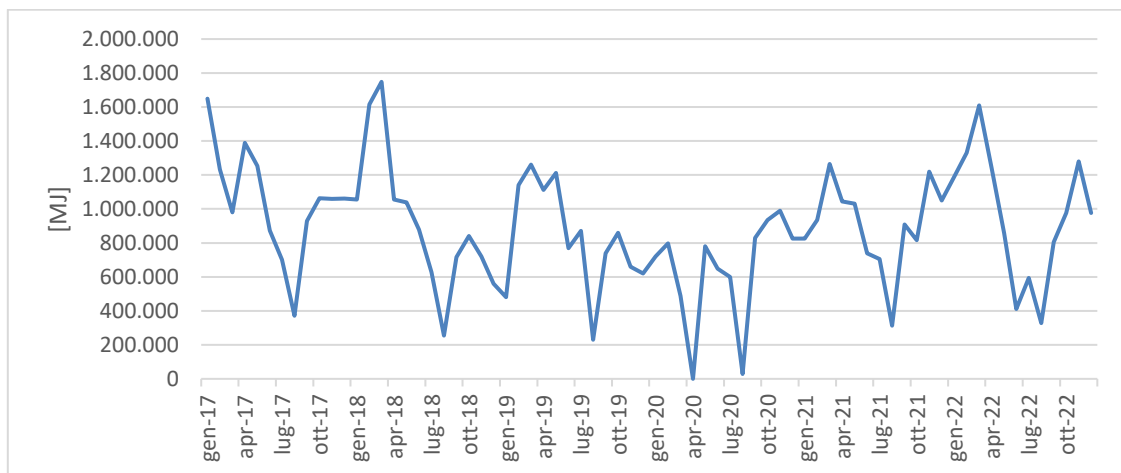
Figure 27: technological heat consumption for overheated water from 2017 to 2022

This consumption depends on two main factors: the total manufacturing hours, that is, the working hours, and the heating degrees day, which is a measure of how cold the temperature was on a given day or during days; all this because the painting is linked to the production, an increase in production needs more working hours and therefore more

painted pieces, also higher temperatures needs less heat to bring the water to temperature and therefore in summer we expect a lower consumption.

To demonstrate this, two analyses were made, comparing the post-Covid consumption (starting from June 2020) with TMH and HDD.
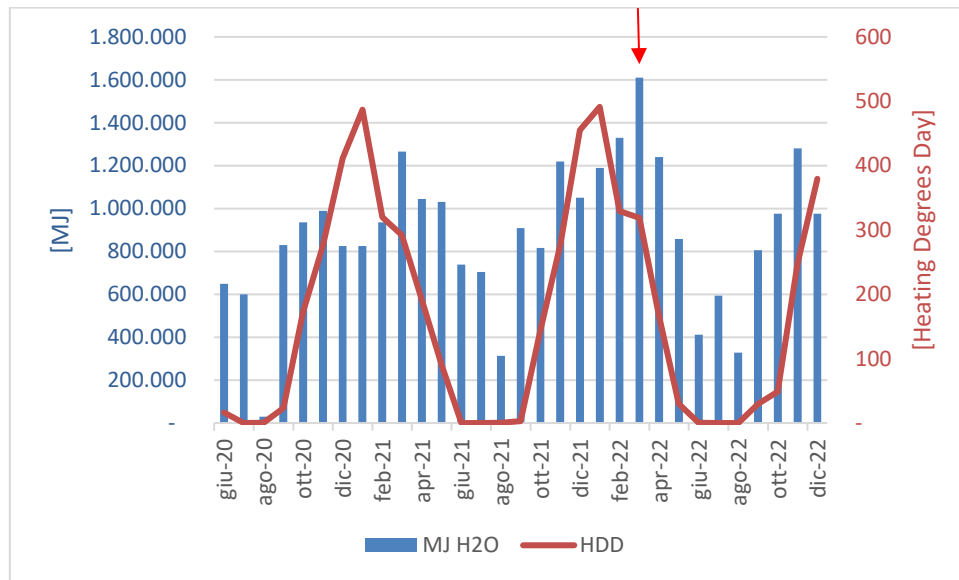
Figure 28: technological heat for overheated water compared with HDD
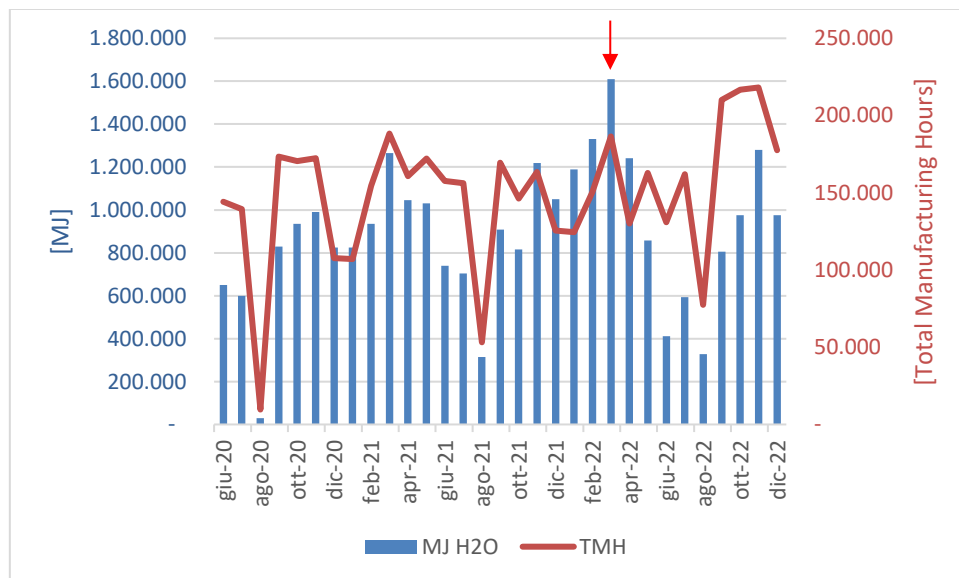
Figure 29: technological heat for superheated water compared with TMH

Figure 28 shows the heat consumption to generate superheated water compared with the degrees day; the graph shows that both data are cyclical, with a maximum in winter and a minimum in summer. This is because when the climate is more rigid, the thermal shock is more significant, and therefore, more heat is needed to bring the water to temperature.

Taking, for example, the data of March 2022 (indicated by the red arrow), the peak is not justifiable with the day degrees, having a high consumption but a temperature not particularly rigid because, as written above, there is a dependence even with the total hours of work.

This comparison can be observed in Figure 29, where consumption is compared with TMH. However, it is less cyclical; it is possible to find points of comparison, especially in maxima and minimums of consumption. There are two examples of this in the Covid period, where the hours are minimum and in the same way the consumption, and also the month of March 2022 (here also indicated by a red arrow) where we find two maximum consumption and working hours, probably due to a more significant number of orders or a period, in general, of more outstanding production.

Emissions

The consumption analyzed in the previous chapter is responsible for the Plant's emissions. Iveco Group purchases electricity with guarantees of origin for almost all plants worldwide; this ensures the Plant consumes only electricity from renewable sources.

Guarantees of origin are electronic certificates attesting to the renewable origin of the sources used by energy plants. These certifications can be sold and bought freely on the market, guaranteeing the absence of emissions in the production of energy purchased from the network, even with certificates produced by plants in other territories.

As a result, the emissions produced are only an effect of natural gas and diesel consumption.

Emissions were calculated considering the consumption analyzed in the previous chapter and the conversion factors (Table 12), using those provided by the IPCC (*Intergovernmental Panel on Climate Change*) in the Emission Factor Database. This document uses the company also at the level of internal reporting.[17].

Table 7: CO_2 conversion factors [17]

Energy carrier	Unit of measure	Value
Natural gas	gCO_2/GJ	56.100
Diesel	gCO_2/GJ	74.100

CO_2 emissions from the installation are shown in Table 13.

Table 8: CO₂ emissions in 2022

2022	Unit of measure	Natural Gas	Diesel	Total
Iveco CV	Tons of CO$_2$	10.396	100	10.496

The emissions generated by natural gas consumption have been monitored for many years, making a more precise analysis possible and allowing us better to frame the emission trend during the last years.
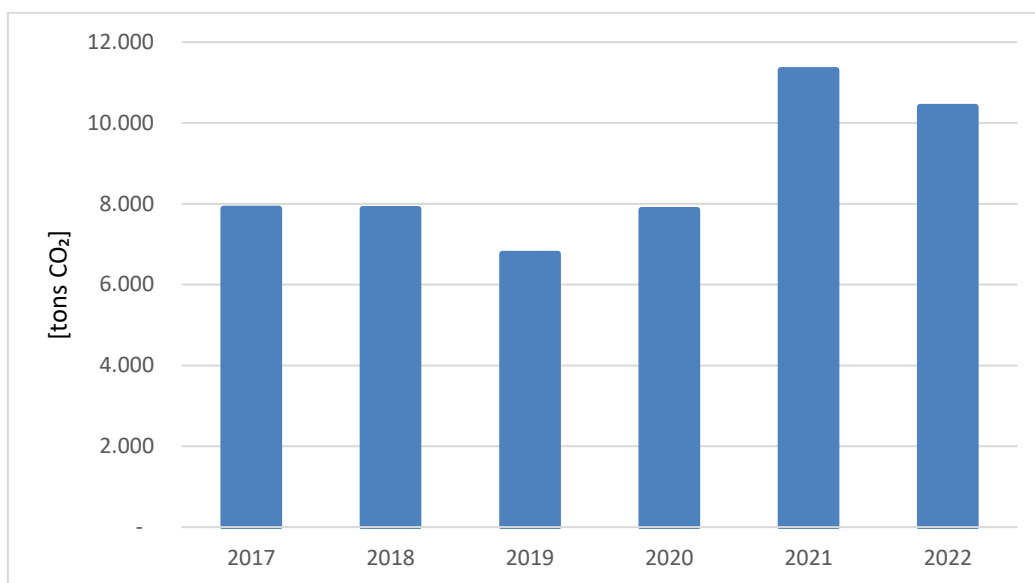
Figure 30: CO₂ emissions of Iveco CV from 2017 to 2022

Figure 30 shows the trend of emissions from 2017 to 2022 for the Iveco CV plant. Until 2020, emissions were constant, with a slight reduction in 2019 due to the pandemic. In 2021, emissions soared due to an increase in the production perimeter, while the following year, the decrease was split to halve them to 2030 compared to the baseline set for 2019. As previously written, these issues are linked to the expenses for the purchase of ETS quotas; in particular, the figure shows the expenses of the Group for the quotas of the Italian plants in which the weight of Iveco CV is evidenced.
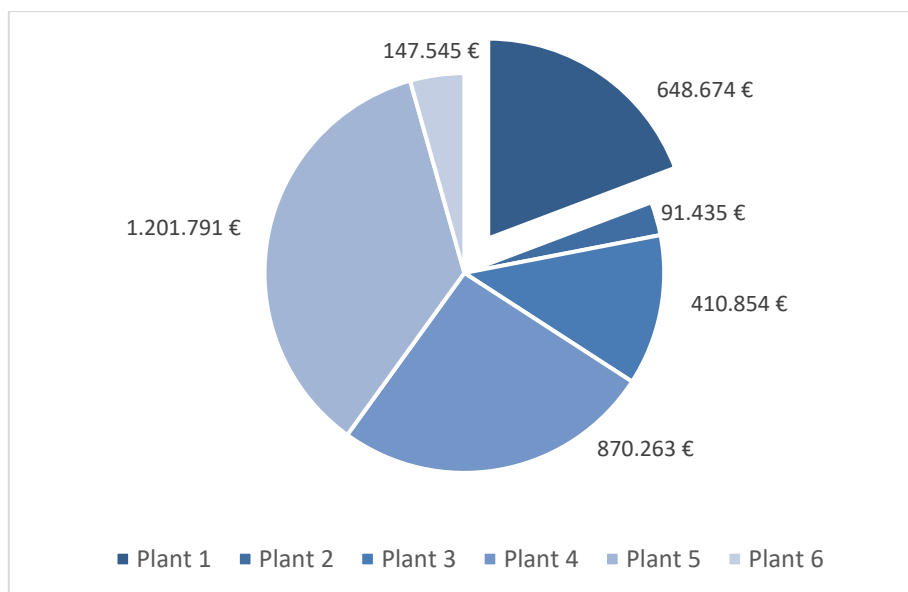
Figure 31: Iveco CV ETS spending in 2022 on total in Italy

Figure 31 shows the expenditure of the Italian plants for the ETS quotas in 2022, within prominence plant 1, that is, the Plant of Iveco CV just analyzed, which weighs 19% on the total expense.

Over the years, several efficiency projects have been carried out to reduce emissions and reduce the plants' energy consumption in line with the Group's sustainability plan.

The most significant project was constructing a photovoltaic system of more than 4000 kWp capable of generating about 5000 MWh of totally renewable energy. This project, combined with the inclusion of heat pumps in the factories, has allowed a small part to reduce emissions and energy consumption.

Therefore, the objective of this work will be to focus on an efficient project that can reduce CO_2 emissions or reduce (or, at best, cancel) the consumption of natural gas and, consequently, emissions.

2.2.   MAGIRUS: introduction

The other brand in the Plant belongs to Magirus and occupies the western part of the Plant.

Magirus is a manufacturer of firefighting equipment owned by Iveco Group since 1975. The brand was invented 150 years ago in Germany and deals mainly with fire engines and ladder trucks.

In Figure 32, the part of the Plant occupied by Magirus highlighted the main buildings.
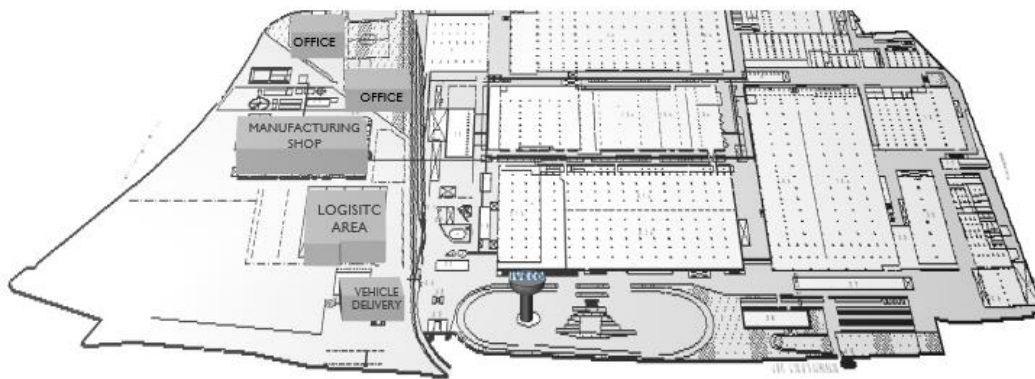
Figure 32: division of Plant Magirus

The Magirus plant, also called Iveco MS (special vehicles), occupies an area of 51,950 m² of which 23,950 m² are covered, divided into several areas visible in Table 9.

Table 9: division of the covered areas

Zone	Area
Office	2.080 m²
Warehouse	7.700 m²
Manufacturing	14.170 m²

There are several buildings, including a production area (manufacturing shop), a warehouse (logistic area), a vehicle delivery area, and offices.

The Plant produces, in particular, about 40 Dragon vehicles per year (Figure 33), just over 200 Magirus standard vehicles, and various components.

Figure 33: Magirus Dragon produced in the factory [15]

2.2.1. Manufacturing processes

The activity carried out by the company consists of the preparation of special vehicles, mainly used for use by VVFs and Civil Protection. In these activities, the vehicles coming from the Iveco group are completed through the following fundamental activities:

- External reception of chassis and various parts (tanks, components);
- Body construction using sheet metal/cross-cutting machines, pneumatic tools, and several pieces of equipment;
- Construction and installation of water, pneumatic, and electrical systems;
- Assembly and assembly of pumps, monitors, power sockets, bumpers, noses, mixers, multipliers;
- Air crash prototypes assembly with chassis and cab set-up and assembly of axles, engines, pneumatic, and hydraulic sub-assemblies;
- Painting of various details;

Overall, the primary and secondary energy carriers used in the Plant are:

- **Electric energy:** distributed within the district with systems of first (up to 1000V in c.a.), second (up to 30.000V in c.a.), and third category (tensions in c.a. greater than 30.000V).
- **Methane:** used for technological use and direct heating; the distribution company delivers it in the form of a 12-bar gas, which is then decompressed in unique

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booths first at 4 bar and then at 0.5 bar, pressure appropriate to the use that is made;

- **Compressed air:** produced inside the thermal Plant with a group of compressors and distributed at a pressure of 6 bar;
- **Thermic energy:** produced inside the power plant using a group of generators (boilers);

Although they are two plants of the same group, adjacent to each other and with the same type of energy carriers used, they will be considered separately because the internal benchmark of the group considers them independent and because, from the design point of view, it is correct to analyze them as two separate and independent intervention opportunities.

2.2.2. Energy consumptions and emissions

As previously done, the Plant's energy consumption will now be analyzed with particular attention to primary and secondary energy carriers, that is, the output from the thermal Plant. Moreover, they will be taken in examination the emissions and the quotas ETS that the Plant acquires to cover them.

Primary energy carriers

Initially, the primary energy consumption of Magirus, or those purchased from the plant that will be used or processed by the thermal plant, is essential to note that the plant in question is smaller than the plant of Iveco CV. Consequently, consumption is lower but no less significant.

Table 10: primary consumption of Magirus in 2022

Energy carrier	Unit of measure	2022	Unit of measure	2022
Electricity	kWh	1.329.560	GJ	4.786
Natural gas	Sm3	376.347	GJ	13.359
Diesel	t	28	GJ	1.204

Table 10 shows the consumption of electricity and methane gas for the Magirus plant in 2022 in the unit of technical measurement and converted into GJ; the latter allows a comparison between the two carriers and shows that here, the majority is methane gas, more than triple the electricity. As mentioned above, these consumptions are lower than

the Iveco plant; an example is natural gas, whose demand by Magirus is equivalent to about 7% of the same carrier required by Iveco in 2022.

Again, the consumption of diesel will not be further analyzed.

❖ **Electricity**

If we analyze the trend of the two carriers from 2017 to 2022, the trend is similar; in Figure 34, we can see the trend of electricity. The trend is periodic, with peaks in the winter months and a fixed consumption of about 80.000 kWh; the absolute minimum is in April 2020, the pandemic peak period.
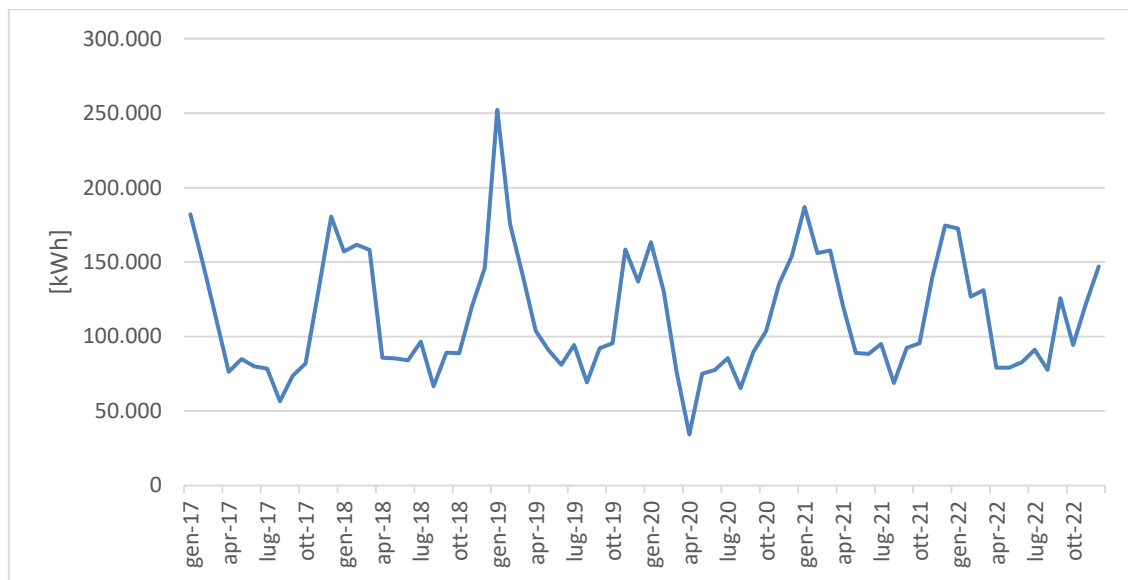
Figure 34: electricity consumption from 2017 to 2022

❖ **Natural gas**

The trend of natural gas (Figure 35) is similar to that of electricity, with the maximum peaks in the winter months, i.e., the coldest months; from about May to October, the consumption of methane gas is zero because the plant does not need heating.
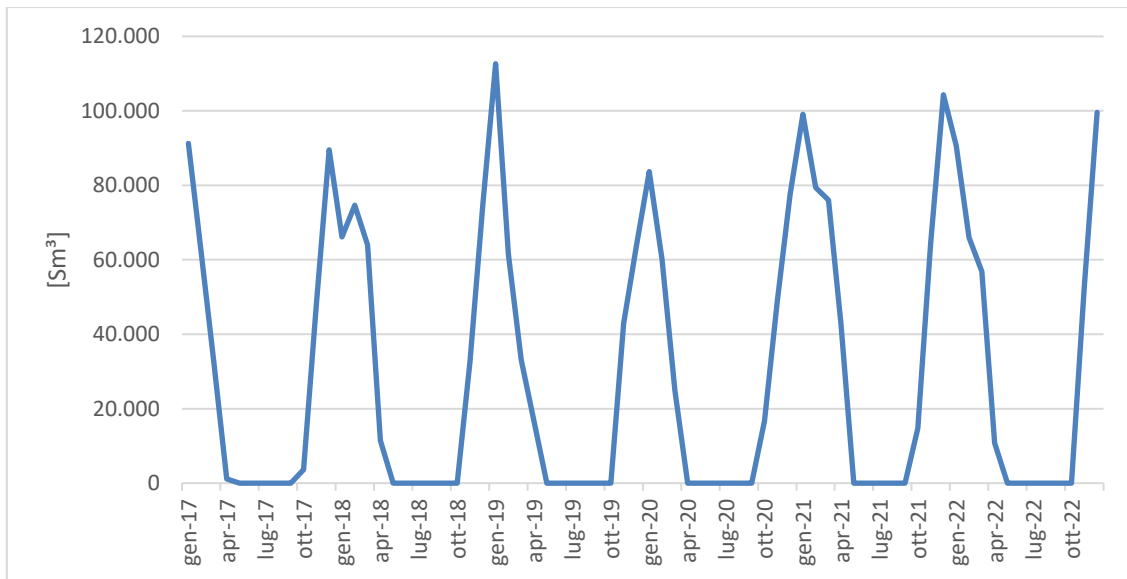
Figure 35: natural gas consumption from 2017 to 2022

The Energy Department is responsible only for the Manufacturing area and does not monitor the non-manufacturing sectors; for example, the offices, which are already heated with district heating, will not be analyzed and will not be the subject of this study.

Secondary energy carriers

After the primary energy vectors needed by the plant, secondary vectors were analyzed. Table 11 shows consumption in 2022 in both technical and GJ units for a better comparison.

Table 11: secondary consumption of Magirus in 2022

Energy carriers	Unit of measure	Consumption in 2022	Unit of measure	Consumption In 2022
Electricity	kWh	1.206.343	GJ	4.343
Compressed air	Nm3	172.002	GJ	84
Heating	MJ	11.600.106	GJ	11.600

The table shows that heating consumption is almost all of the consumption of the plant; this could already be inferred from the consumption of primary carriers and their seasonal dependence.

There is also the consumption of compressed air and energy for motive power.

❖ **Electricity**

Unfortunately, this plant does not have the precise details of electricity consumption by motive power and lighting; the value presented in Table 11 is the sum of the two consumptions and does not allow a more precise analysis.

Subsequently, the consumption of these carriers was analyzed over the years, starting from 2017, to understand the performance and possible future scenarios better.
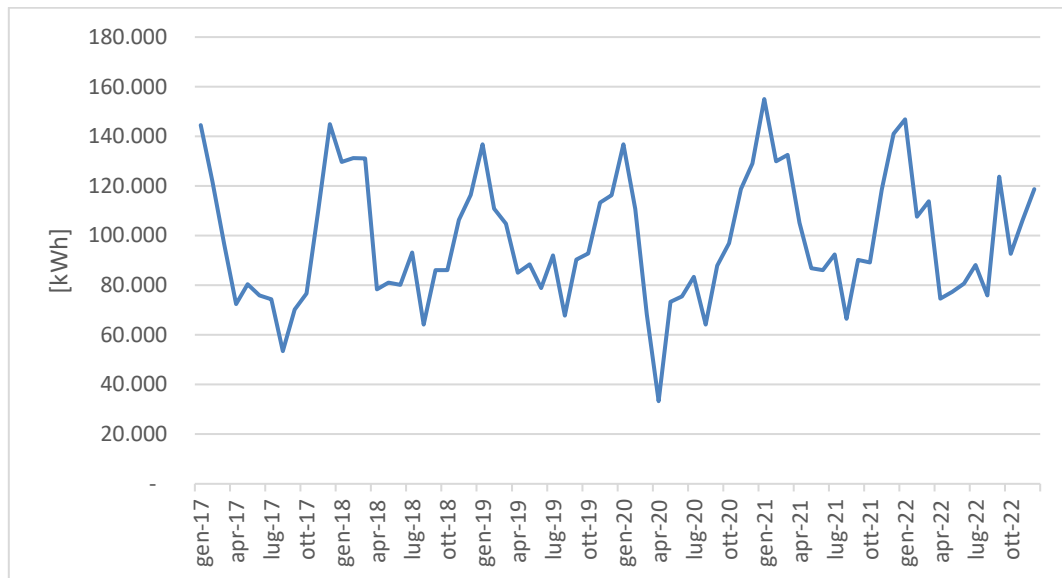
Figure 36: electricity consumption from 2017 to 2022

Figure 36 shows the trend of electricity over time; the trend is similar to the consumption previously examined, with peaks in the winter months and very similar values from year to year except in 2020.

❖ **Heat for Heating**

The same can be said for heating (Figure 37), which is zero in the summer months and peaks in the year's first month.
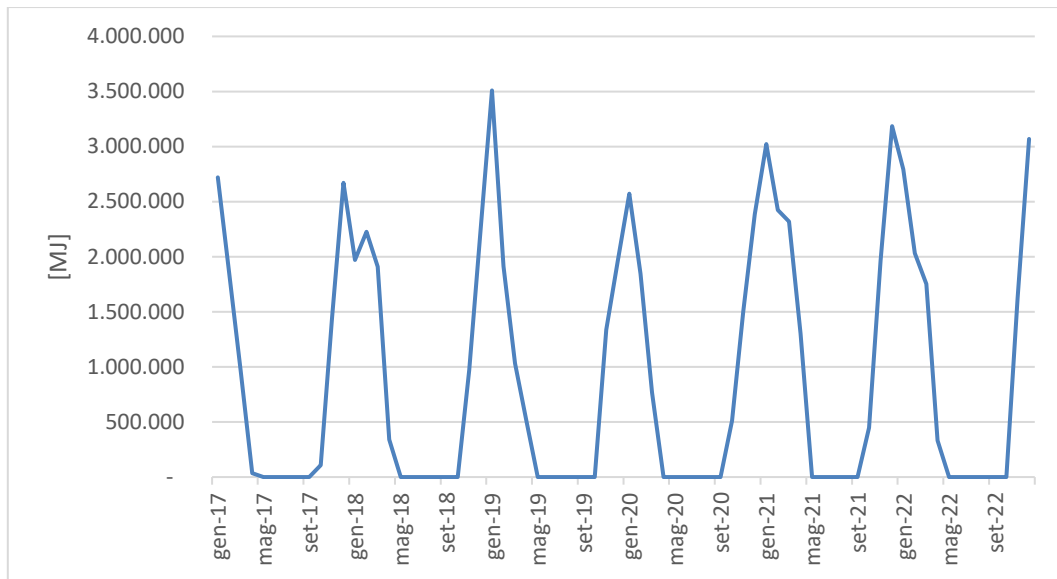
Figure 37: heating consumption from 2017 to 2022

❖ Compressed air

Of greater interest is Figure 38, which shows the evolution of compressed air over the years.

The trend up to 2020 is decreasing; this decrease is due to the identification and repair of some losses in the generation and distribution system. The record low was reached in March 2020, concomitance with the pandemic; subsequently, the trend returned to growth, stabilizing the values post-repair works.
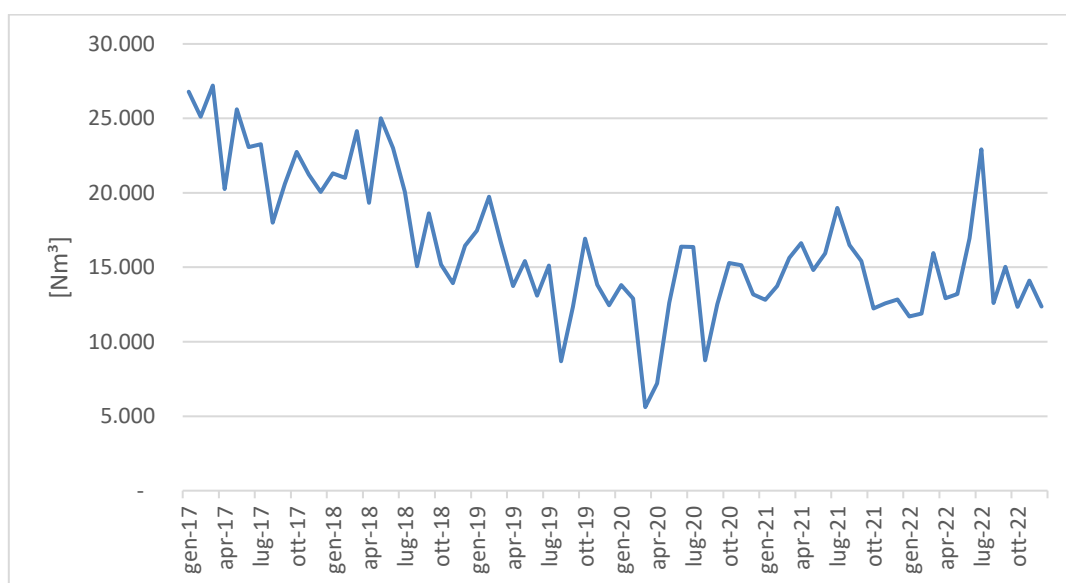
Figure 38: compressed air consumption from 2017 to 2022

Emissions

Magirus emissions are lower than the Iveco CV emissions analyzed above because they are proportionate to the gas consumption.

Also, this plant applies the concept of guarantees of origin for electricity that excludes possible emissions from electricity use.

The conversion factors used are the same as those presented above and are shown in Table 12.

Table 12: CO_2 conversion factors [17]

Energy carrier	Unit of measurement	Value
Natural gas	gCO_2/GJ	56.100
Diesel	gCO_2/GJ	74.100

CO_2 emissions from the installation are shown in Table 13.

Table 13: CO_2 emissions in 2022

2022	Unit of measure	Natural Gas	Diesel	Total
Magirus	Tons CO_2	749	-	749

Magirus issues, as already written, are lower than the same of Iveco CV, about 7%.

Figure 39 shows the trend of emissions from 2017 to 2022 for the Magirus plant. Until 2020, emissions were about constant, minus a slight reduction in the last year under consideration for the pandemic. In 2021, emissions soared due to a change in the production perimeter, while the following year, the decrease was split to halve them to 2030 compared to the baseline set for 2019.
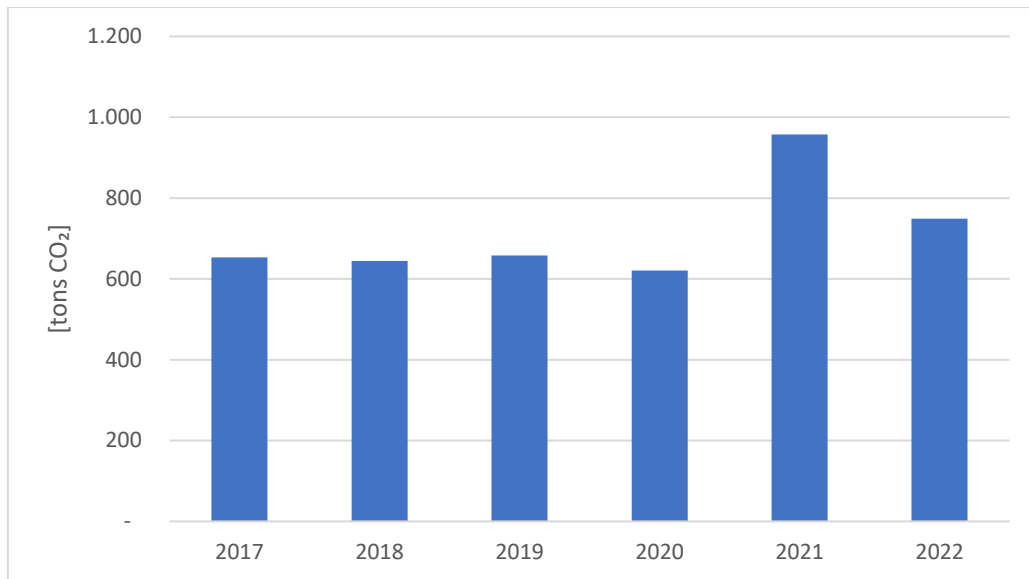
Figure 39: CO₂ Magirus emissions from 2017 to 2022

As mentioned several times, these emissions are covered by the ETS quotas; Figure 40 shows that in 2022, the plant quotas weighed just over 3% of the Group's total expenditure on emission allowances.
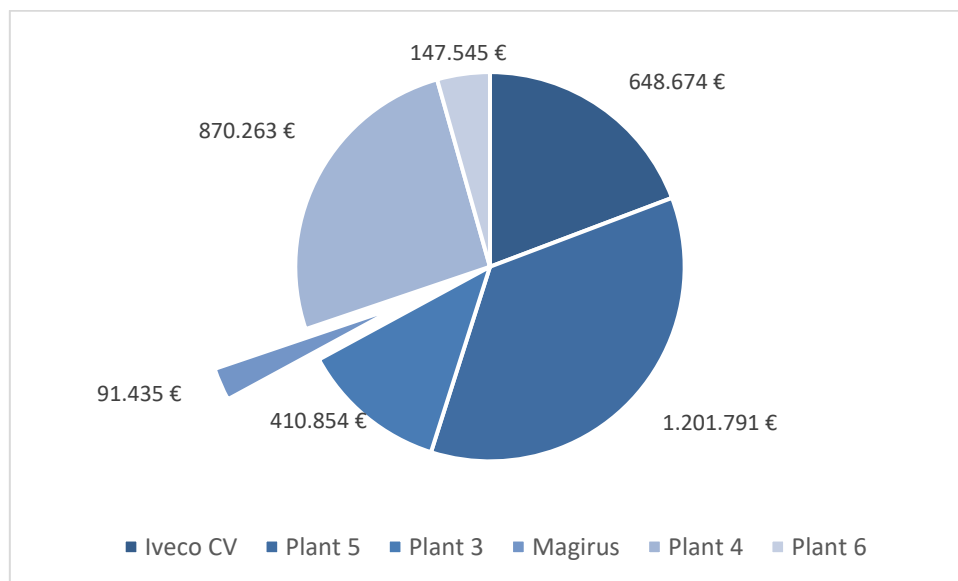
Figure 40: Magirus ETS spending in 2022 on total in Italy

3. The efficiency project: district heating

From the consumption analysis, it is clear how the efficiency project must go to reduce the consumption of natural gas because it is very significant and mainly because it weighs in the ETS discourse.

Precisely, the exit from the European measure is one of the prerogatives of the Department of Energy because it would bring a double effect: zero-emission, in line with the group's sustainability objectives, and significant economic savings due to the failure to purchase emission allowances.

Among the analyzed projects of particular interest is district heating, a technology present in the city and already exploited for some offices.

The technology will be briefly analyzed to analyze the project and how to develop it within the plant.

3.1.   District Heating in Italy

District heating in Italy is defined by D.L. 102/2014 [18] as:

> *Thermal energy transport system, built mainly on public land, aimed at allowing anyone interested, within the limits allowed by the extension of the network, to be connected to it for the supply of thermal energy for heating or cooling of spaces, for working processes and for the coverage of domestic hot water needs.*

This means remote heat transport for heating, cooling, and domestic hot water production; the use of a particular energy source in a production plant is not specified, but the overall heat production and distribution system.

The power plants generate hot water (80-90 ºC) or superheated water (120-130 ºC), which is then transported through a network of pre-insulated pipes to the connected buildings where the heat is transferred to the substations through exchangers (Figure 41) to the user system. In contrast, the cooled water returns to the power station to be heated again. [19].
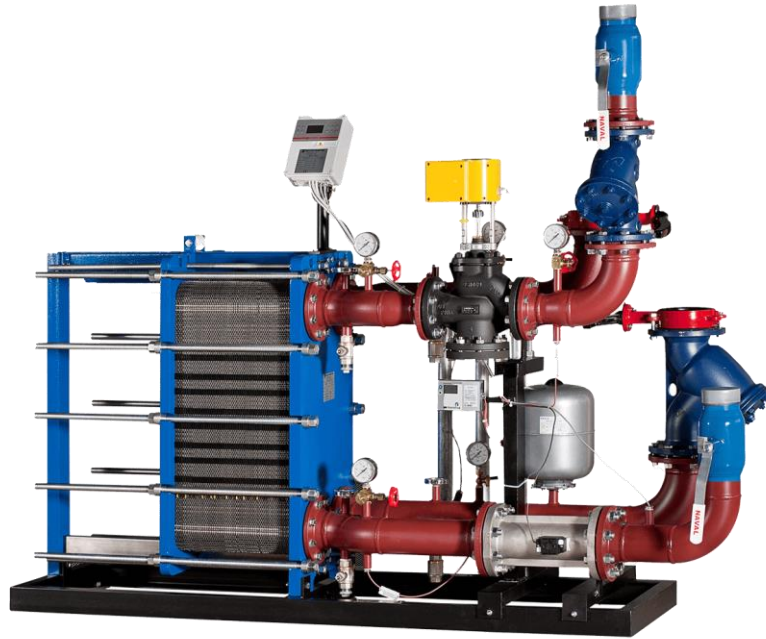
Figure 41: substation for district heating [19]

This technology reduces the amount of emissions produced (CO_2, Nox, and fine dust) while maintaining high efficiency, as they can exploit residual heat sources or cogeneration processes to produce thermal energy, reducing waste in traditional heating systems. In addition, using this heat to produce cold water to cool the rooms through trigeneration and increasing the advantages of use is possible.

The district heating sector has been growing for several years; in Figure 42, it is possible to observe the growth of energy input and the overall extension of the networks. These two data are growing strongly compared to the beginning of 2000, but to a different extent; energy has tripled while the extension of the networks has quadrupled. This

difference in development is probably due to the growth of the sector but also to disconnected factors such as the improvement of the energy performance of buildings.

Figure 42: trend of energy input from district heating [20]

To date, it plays an increasingly important role in the heat market: according to the GSE report on district heating of 2022 in the country, there are about 340 networks in operation, equivalent to 5000 km of extension and just under 10 GW of installed thermal power, 2% of the country's total demand [20].

This technology affects 284 municipalities, located chiefly in northern Italy, as shown in Figure 43.
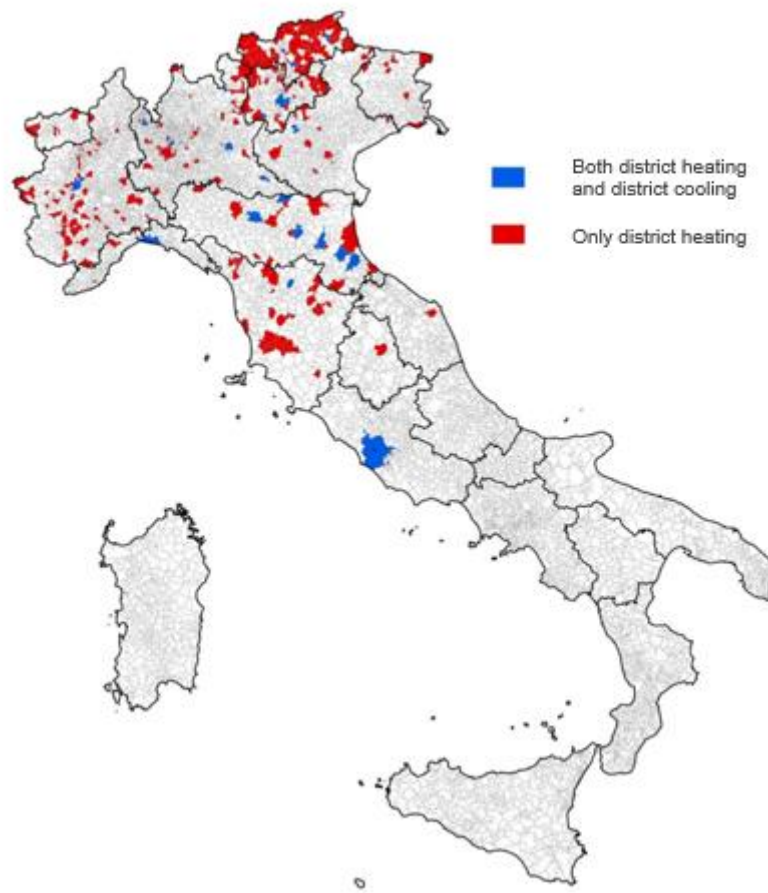
Figure 43: map of municipalities with district heating in Italy [20]

The importance of this technology is also demonstrated by its presence in *the Integrated National Plan for Energy and Climate* (PNIEC) presented by the Italian government to the European Commission in 2020 to extend the networks; also, the inclusion in the *National Recovery and Resilience Plan of Italy* (PNRR) demonstrates its importance, distributing resources of 200 million euros.

Table 14: data on district heating in Italian regions [20]

Regions	Number of municipalities	Number of systems	Installed Thermal Power (MW)	Total extension of networks (km)	Number of user substations	Heated volume (mln of m3)
Piemonte	54	63	3.041	1.168	13.419	105,7
Valle d'Aosta	7	8	173	77	930	4,2
Lombardia	60	54	3.427	1.391	36.238	162,2
Prov. Aut. Bolzano	54	76	853	1.117	20.698	28,3
Prov. Aut. Trento	29	32	311	199	3.406	9,7
Veneto	12	11	402	146	2.227	17,0
Friuli Venezia	9	9	83	30	332	1,6
Liguria	4	5	93	16	92	4,3
Emilia-Romagna	21	32	1.171	673	8.560	45,5
Toscana	31	44	177	186	6.320	3,0
Umbria	1	1	18	11	72	0,6
Marche	1	1	15	15	411	0,7
Lazio	1	1	83	26	565	3,5

As it can be seen from Table 14, published in the last monitoring of the GSE released in June 2022 [20], the networks in operation at the end of 2020 were 337 operating in 284 municipalities located in the north of the country, mainly between Piedmont and Lombardy; the network extends for more than 5000 km giving heat to over 93.000 users, most in Lombardy (39%) and exchanging a volume of over 300 m³ of heat. 63% of the volume is destined for residential users, followed by the tertiary sector (34%) and industrial users (3%).

The heat production plants are divided between plants of thermal production only (68%) and cogeneration plants, capable of producing both heat and electricity (32%). At the same time, Figure 44 shows the division of production of the energy carrier, today primarily derived from fossil fuels (81.7%), mainly from natural gas. In comparison, the remaining is produced from renewable sources (10.9%), waste (6.8%), and a small part from heat recovery (0.6%).
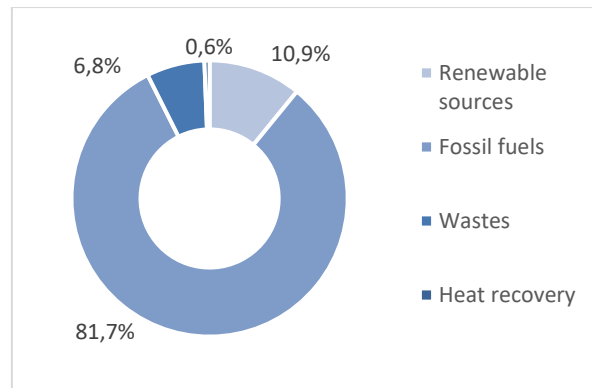
Figure 44: primary energy sources of district heating in Italy [20]

Figure 45 shows all municipalities using district heating by dividing them by energy source (fossil, renewable, or waste) and by energy (MWh) produced.
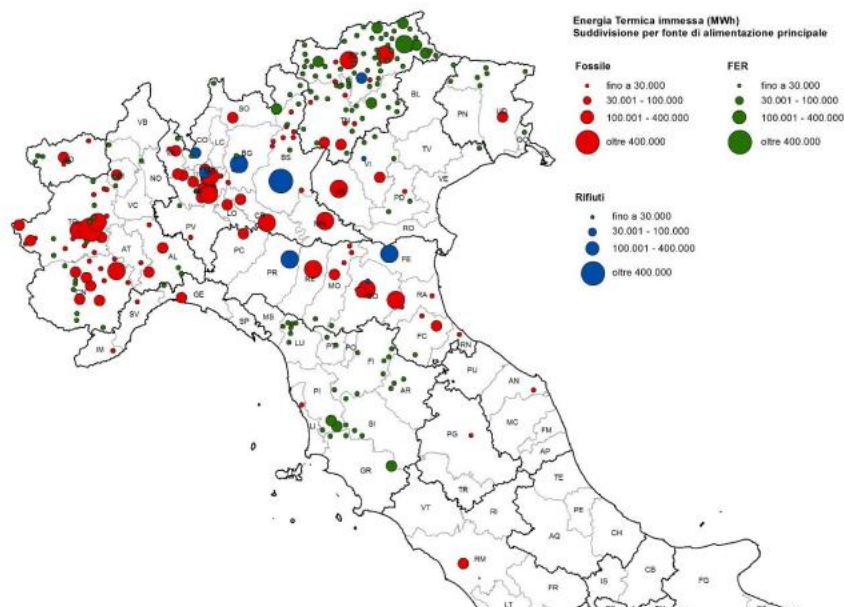
Figure 45: size of district heating systems in Italy [20]

It can be noted that production varies from region to region; for example, there are almost renewable regions such as Tuscany and Trentino, which are, however, an exception since most plants produce through fossil fuels. Moreover, it is possible to observe how the renewable plants are numerous but generally of small size while the exploitation of energy from waste takes place from few plants capable of producing much energy.

Consideration will now be given to the city where the plant is located to deepen the characteristics of district heating and its development.

This city covers about 90 km² and has just under 200.000 inhabitants. The district heating has been present in the area since 1972 and today has more than 20.000 buildings connected thanks to 679 km of double pipes that can serve almost 200.000 apartments.

About 70% of the city's heat demand is met by district heating, which avoids more than 69.000 tons of CO_2, 2.6 tons of fine dust (PM10), and more than 100 tons of nitrogen oxides (NOx).

In 2021, the heated volume was 42.787.099 m³ divided between residential (23.233.395 m³), tertiary (16.644.182 m³), and industrial (2.909.523 m³) with an overall increase of 0.3% compared to the previous year [21].

The system is based on seven production plants whose characteristics are shown in the table below (Table 15).

Table 15: district heating plants in the city concerned [21]

Type	Number of units	MW_e	MW_{th}	Year of installation
Steam turbines under back pressure	1	75.000	130.000	1987-1992
Integration boiler	3		255.000	2015-2016
Waste-to-energy plant	1	117.300	180.000	1998
Integration and reserve boilers	10	-	184.180	1981-2020
Heat recovery from steelworks	2	-	247.000	2016-2021

As we can see from the table, the primary plants are four different types. The first is a gas-fired combined heat and power plant capable of producing 75 GW of electricity and 385 GW of heat, also considering the integrated and reserve boilers; there is also a waste-to-energy plant capable of producing 600 GWh of electricity per year and 900 GWh of thermal energy per year dealing with 730.000 tons of waste. In addition, ten other auxiliary and reserve boilers and a share of thermal energy are recovered from steelworks. Overall, the energy comes mainly from the waste-to-energy plant, with a share of 63%, followed by fossil fuels (36%) and heat recovery (1%). At the same time, there is no share of energy from renewable sources.

The heat recovery energy that comes from the electric furnaces of steelworks is the first case in Italy of thermal energy recovery from industry for use in district heating.

Despite this, the thermoelectric power plant uses biogas fuel of natural origin, and this has allowed the GSE to include the plant in the list of plants capable of generating GO (*Guarantees of Origin*), that is, the certification certifying the origin of the source used by the plants to produce each MWh of electricity, for the plant in question is certified 95 MW.

The GOs allow certification of the use of only renewable sources during the purchase of electricity or heat; these certificates can be purchased, sold, and traded on the market, allowing companies to communicate their environmental commitment and stand out on the market.

The switch to district heating has several advantages, mainly from an environmental point of view, because it is possible to use renewable sources and because, in general, large plants generate fewer pollutants than the same production but with smaller plants; moreover, it is very convenient because the purchase costs are eliminated, maintenance and overhaul of the boiler, as well as the verification and cleaning and the costs of construction of the flues, with apparent benefits also in terms of safety (absence of combustion and open flames in boiler rooms, of hazards from gas leakage or poor combustion and risks of explosion or fire).

In addition, district heating has several advantages from the economic point of view: on average, it is estimated that between 10% and 25% savings in bills for individuals [22].

We will now analyze the economic offers for the district heating of this city, freely available on the site, both for individuals and industries.

Considering a request for high-temperature water, the prices provided by the responsible company are shown in Table 16 and updated to March 2023.

Table 16: district heating cost in the city concerned [21]

Descriptions	Fixed part [€/year *m³/h]	Proportional part [€/kWh$_t$]
The alternative of individual users	1.515,55	0,088286
Central user	3.907,35	0,082328
Tertiary	1.453,54	0,093080

We will now analyze the economic offers for the district heating of this city, freely available on the site, both for individuals and industries.

Considering a request for high-temperature water, the prices provided by the responsible company are shown in (Table 17).

Table 17: current cost of energy establishment

Energy carrier	Price	Unit of measure
Electricity	0,2530	€/kWh
Natural gas	0,4212	€/Sm³

By analyzing offers for individuals in the same city, prices are shown in Table 18 and are estimates between different suppliers.

Table 18: current energy cost for private [23]

Energy carrier	Fixed part	Proportional part
Electricity	7,60 €/month	0,168 €/kWh
Natural gas	12,50 €/month	0,570 €/Sm³

District heating prices are related to the consumption of thermal energy because the service directly delivers the heat through a heat exchanger and is ready for use; on the contrary, the two following tables show the prices of electricity and natural gas because they are the two energy carriers that are then used to generate heat, generally through the use of boilers.

In the following chapters, an economic analysis of the case study in question will calculate how much the savings in the bill actually and on the convenience of the project.

3.2.   Thermal power plant descriptions

Currently, the two plants are fed by the same power plant composed of the boilers listed in Table 19.

Table 19: boilers of the power plant

Boiler	Production	Power load [MW$_t$]	Year	Use
Idrotermici	Superheated steam	21	-	Back-up
Ruths	Saturated steam	36	1975	Routine
C.C.T.	Saturated steam	11,6	1990	Routine
Viessmann	Superheated water	2,09	-	For technological use in summer

The total power of the power plant is 70.69 MW$_t$, without 13 MW$_t$ of the boiler PENSOTTI, a boiler that produced saturated steam but was abandoned for some years. Other boilers in the plant are not part of the power plant but are still used for heating and sanitary facilities in some specific areas.

Table 20: other boilers in the Plant

Boiler	Production	Power load [MW$_t$]	Place of use
Belleli	Hot water for heating	0,43	Delivery vehicles
R.B.L.	Hot air for heating	1,2	Refurbishing
Blowtherm	Hot air for heating	1,06	Plank department
Atag	Domestic hot water	0,0973	VVF
Caldaietta	Domestic hot water	-	Chassis department

Table 20 shows the other boilers in the two plants but not included in the thermal power plant. Their power is much lower than that of the plant, less than 3 MWt, and their use is purely related to HVAR, *Heating, Ventilation, and Air Conditioning*, and not for industrial use. These boilers are not part of the ETS but are still responsible for the consumption of natural gas; therefore, it is essential to try to replace them as soon as possible to eliminate their emissions and reduce the consumption of the primary energy carrier.

Going to analyze the power plant, it is helpful to deepen the scheme of general operation of the plant in which the boilers are included.
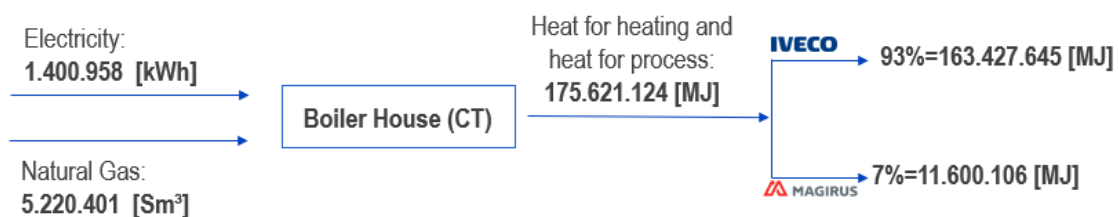
Figure 46: energy balance of thermal power plant in 2022

Figure 46 shows the total energy balance of the power plant in 2022 for the plant. The primary vectors used are natural gas and, to a lesser extent, electricity, which, through the thermal power plant, was spent on generating heat in the form of superheated water and steam, which in turn were divided between the Iveco CV plant, 93% and the Magirus plant, the remaining 7%.

In particular, this energy conversion occurs through the power plant's boilers.

Boilers are equipment that consumes electricity and methane gas to generate saturated steam that can be used directly or subsequently overheated for industrial use [24].

The steam generator consists of a large metal box divided into two zones, one radiant and one convective, connected to at least two external tanks called cylindrical bodies.

The radiant zone acquires heat by radiation and is also called the combustion chamber, while the convective zone is so called because it receives heat from conduction and is formed by several benches of tubes.
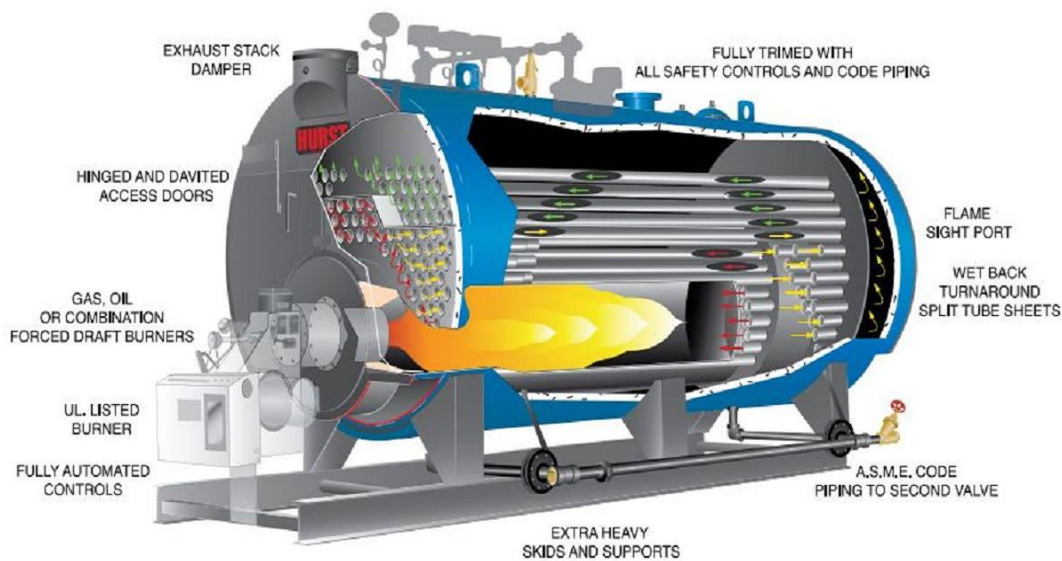
Figure 47: scheme of a boiler [24]

Figure 47 shows a simplified diagram of a steam generator where the tubes of the convective zone and the tank of the radiant zone are visible.

The combustion zone, in particular, is where natural gas is burned to evaporate water; there are also electric fans for air used as oxidizers.

The tube banks are divided in order between *economizers* (ECO), with the task of heating the water; *evaporators* (EVA), with the mission of making it evaporate; and *superheaters* (SH), with the task of overheating it.

There are two other cylindrical bodies, one lower to collect the evaporated water and one upper to separate the water from the saturated steam.

In total, three circuits can be distinguished in a boiler: the water-steam circuit, where the first is heated until the phase changes and is sent to the users; the fuel circuit, where it is sent at the necessary pressure and in sufficient quantity to be burned and heat the water, and the air-smoke circuit, where the air is pushed by a fan to the combustion chamber, Then the fumes will be expelled, previously undergoing processes to reduce emissions.

The boilers' objective is to generate saturated or superheated steam; the difference between these two end products is the temperature. Saturated steam is a consequence of the complete vaporization of the liquid at a specific temperature and a certain pressure. In contrast, a further increase in temperature, at constant pressure and without exceeding the critical temperature, leads the steam to become overheated.

3.3.   Thermal power plant scheme
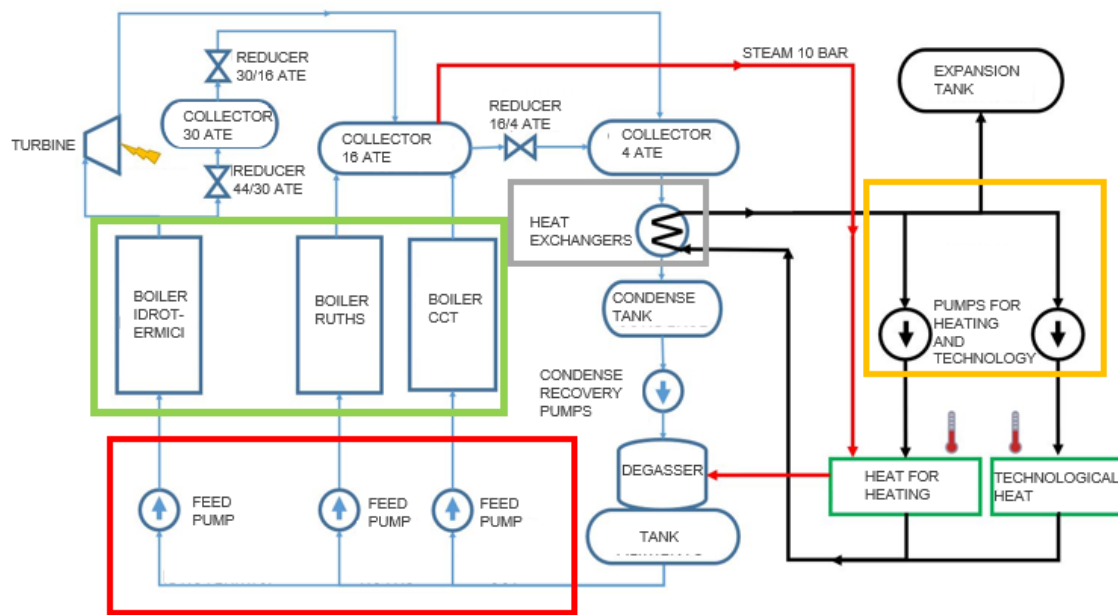
Figure 48: diagram of the power plant

Figure 48 shows the diagram of the power plant: in the green box are highlighted the three boilers in Table 19; the first produces steam at 45 bar while the other two produce steam at 15 bar and a total of 70 MW_t. Each of these boilers receives the water to heat thanks to a food pump (red box); also, in the diagram, there is a turbine of 2.5 MW_{el}, no longer active.

The steam produced by the generators feeds directly:

- 3 AHUs (Air Handling Units) of Door Cladding Building;
- 2 AHUs covering partially manufactured where pre-assembly of frames takes place;
- 1 AHU of Manufactured Cables.

The characteristics of these AHUs are shown in Table 21.

Table 21: AHU features

Description	Value
Power	$0{,}9 \, MW_t$
Flow rate	75.000 m³/h
Maximum input temperature in TPP	130°C
Temperature return to TPP	20°C

In addition, steam feeds several heat exchangers (grey box) with a potential of about 17 MW each; three of them are used simultaneously to produce superheated water in winter with a maximum block temperature of 158 ºC.

Subsequently, the heat exchanged is distributed through dedicated AHUs with incoming water, usually at 120 ºCs to about 400 unit heaters distributed and located in more critical areas.

This overheated water is divided between two circuits differentiated by use, technology, and heating, each with a personal electric pump (orange box); in the most critical periods, the contemporaneity of the uses is about 2000 m³/h.

It is helpful to remember that the new buildings use high-temperature heat pumps for environmental heat, and in summer, they are prepared for the cooling cycle. In contrast, the office buildings are already heated through the city's district heating.
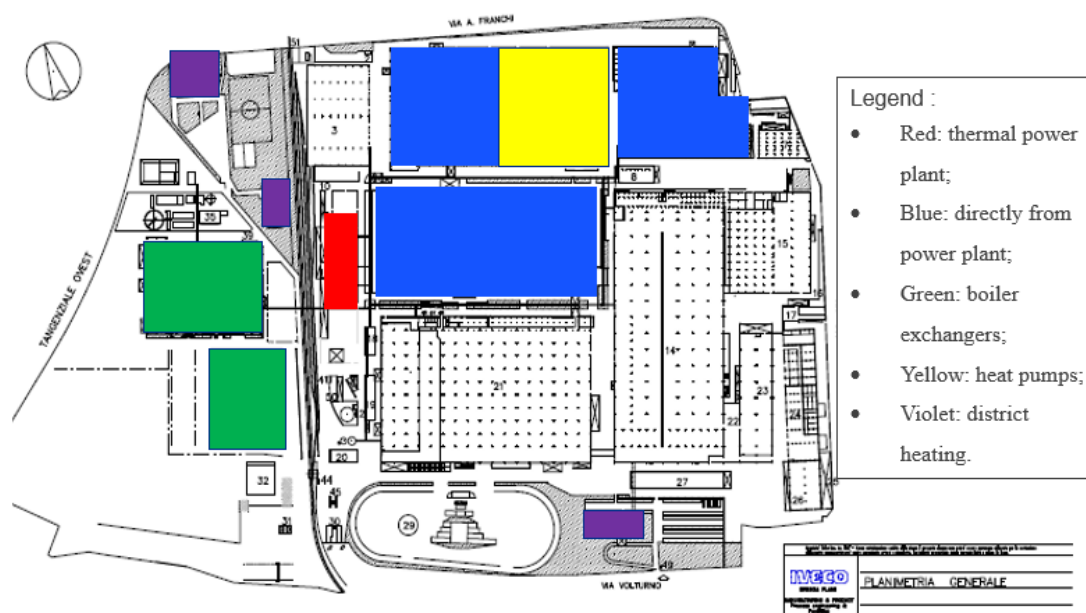
Figure 49: current heating system plant

Figure 49 summarizes the heating methods of some buildings in the plant to date:

- in red is the power plant;
- in blue, the buildings connected directly to the boilers;
- green buildings heated by heat from heat exchangers;
- in yellow, the building half uses heat pumps;
- in violates offices already connected to the district heating.
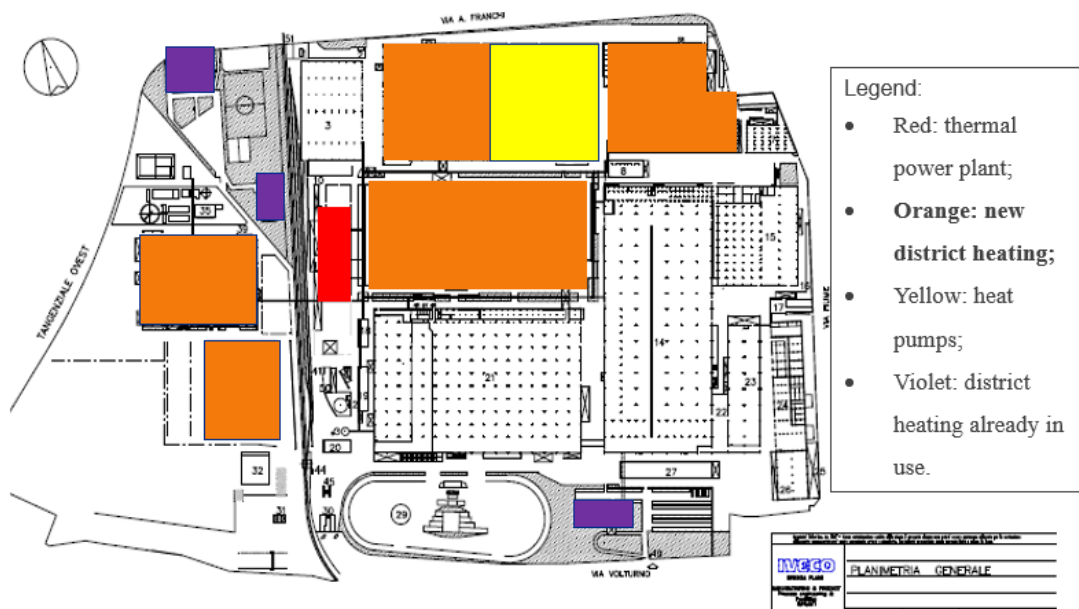
Figure 50: heating system plant after the project

Figure 50 shows the map of the plant highlighting the buildings that would be heated by district heating with the project present in this study, differentiating the buildings already heated today with this technology.

3.4.   Analysis of the current heating of some buildings

Two buildings were taken as examples to deepen the heating system and show the systems.

The first building considered is one of the buildings heated by heat from the heat exchanger.
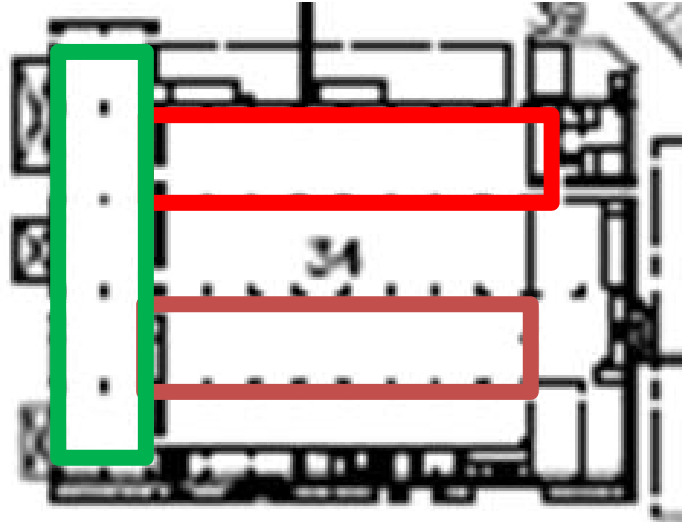
Figure 51: diagram of a building connected to the thermal power plant

Figure 51 shows the scheme of the building, a construction of about 110.000 m³, divided into three zones: the green box highlights an area heated by five vertical thermals, six large AHUs heat the blue zone, and three smaller AHUs and the red zone by six large AHUs.

Altogether, the 12 large AHUs are for heating the workshops, while the three small AHUs (Figure 52) are for various services with summer/winter sections and exchange through fan coils.

More specifically, four large AHUs 40.000 m³/h (Figure 53), nine 30.000 m³/h, and one 27.000 m³/h, all of them are equipped with a cooling battery and all date from the period between 1989 and 1999. The air distribution in the workshop takes place through metal ducts as the partial recovery.
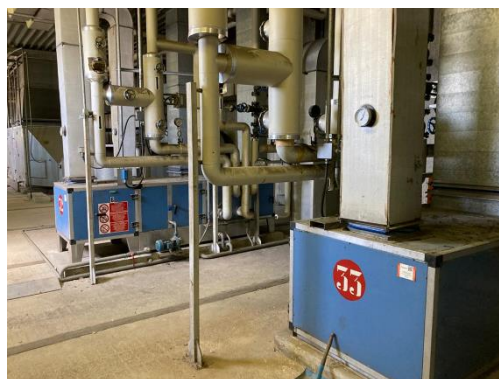
Figure 52: AHU for small services

Figure 53: example of AHU of 40.000 m³/h

Taking an example of a building already connected to district heating, it is possible to observe the dedicated AHU and the heat exchanger to which water arrives from the urban line of district heating.

Figure 54: heat exchanger for district heating already active in the plant

In particular, the exchanger, the model shown in Figure 54, has dimensions of about 1 m high and 32 cm wide, is from 2006, and the technical characteristics are shown in Table 22.

Table 22: technical characteristics heat exchanger for district heating [25]

Description	Primary circuit	Secondary circuit
Fluid inlet temperature	120 °C	55°C
Fluid outlet temperature	105°C	70°C
Design temperature	140 °C	90°C
Max nominal pressure	16 bar	16 bar

3.5. Technical analysis of the offer

Once the current structure of the thermal power plant has been analyzed, it is necessary to examine the technical offer for district heating, highlighting the design requirements of the technology and its feasibility.

As mentioned, district heating is provided through heat distribution through steam, which is transferred to users through a heat exchanger.

Therefore, the first step is to analyze the current district heating network in the city to see if it is well connected and if the Plant is close to networks already in use, resulting in less investment from the distribution point of view.
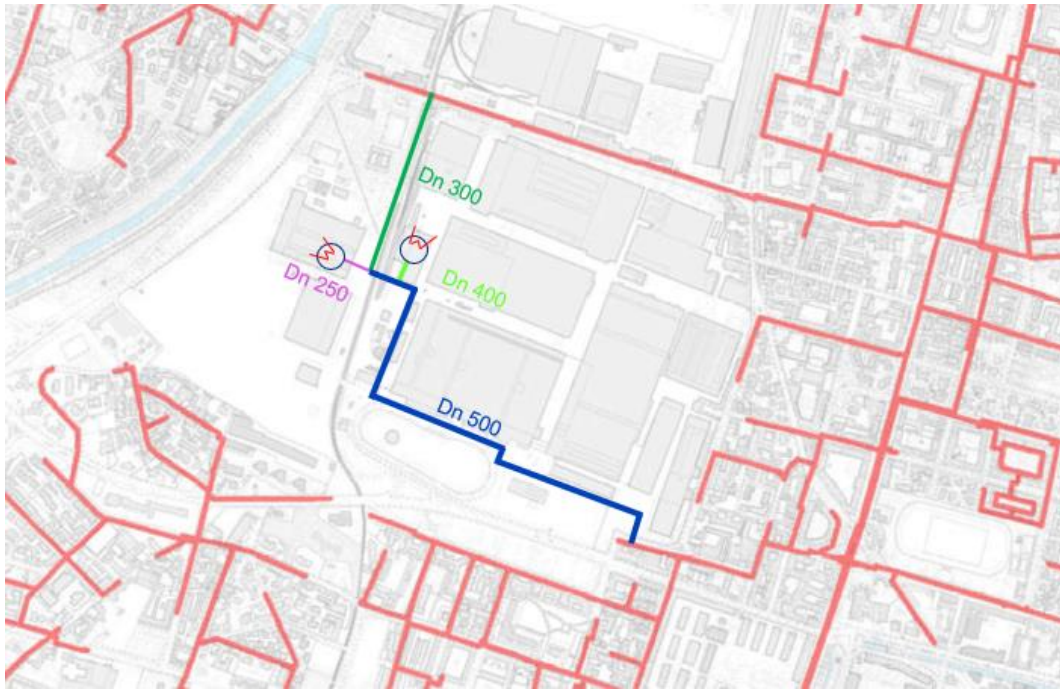
Figure 55: distribution network of the city and possible connection with plant

Figure 55 is taken from the district heating distributor of the city: the red lines represent the distribution network of district heating present today in the territory. Since the Plant is located in the city center, many networks are adjacent to the area, and the connection to these networks is simple logistically.

In the image, there is also a possible solution to the connection to the distribution network proposed by the energy company.

This proposal includes two connections: a pipeline located to the southeast of the Plant connected to a pipeline already present to the north of the Plant. All this would allow the creation of a closed circuit with fewer complications in ordinary and extraordinary maintenance and would lighten the thermal load, dividing the total flow of fluid required. The company, analyzing consumption, estimated a round-trip pipe with a diameter of 500 mm (in blue), starting from the southeast up to near the thermal Plant. Here, the Iveco CV and Magirus plants would be served by two dedicated pipes with a diameter of 400 mm and 250 mm, respectively, up to the two exchangers. Finally, to complete the mesh, it would always be connected with round-trip but with a smaller diameter, or 300 mm.

Once the technical feasibility of the connection to the existing network had been established, the technical characteristics of the fluid coming from the district heating network were examined to see if they were sufficient to meet the thermal requirements of the two plants. The characteristics are shown in Table 23.

Characteristic of the energy carrier	Value
Maximum cold fluid outlet temperature	120 °C
Minimum cold fluid inlet temperature	60 °C
Minimum hot fluid outlet temperature	70 °C
Maximum hot fluid inlet temperature	130 °C

Table 23 shows that district heating heat is distributed using a hot fluid at a temperature between 70 ºC and a maximum of 130 ºC. The fluid will then reach the exchanger, transferring heat to a secondary fluid whose maximum temperature is 120 ºC. Finally, the return temperature of the primary fluid after exchanging heat with the secondary is 60 ºC. With the data provided by the energy supplier, it is possible to analyze the potentially exchanged calories and evaluate the feasibility of the projects.

Let us analyze the delivery and return temperatures. We can see that for the Magirus plant, there are no significant problems because the temperature required by the user today is 120 ºC and is supplied through the exchanger. On the contrary, there are problems with the Iveco CV plant because the temperature required for some utilities is 130 °C, higher than the maximum 120 °C district heating, and the return temperature is 20 °C well lower than the 60 ºC return temperature required by the energy company.

As for the volumetric flow rates of the fluid, no standard values are required because these will be calibrated and calculated to meet the required thermal load following Equation 1.

$Q = m * c * \Delta T$	(1)

The equation describes the law of calorimetry, where Q [J] is the heat released by district heating, m is the mass of the fluid [kg], c is the specific heat [J/kg/K], and ΔT is the temperature difference between the inlet and outlet fluid. In this case, the heat is fixed to the value required by the Plant, and the specific heat is the characteristic value of the water. Consequently, the energy company needs to determine the temperature difference; the only fixed parameter to be analyzed in the case study is mass, from which the required volumetric flow rate will be obtained.

To cope with this problem, we must proceed with an adjustment of the AHU going to increase the number of heating batteries because this number depends on the temperature of the hot fluid, and being less will need more batteries to maximize the exchange.

This change would make it possible not to completely replace the AHUs by reducing the initial investment cost and still allowing to meet the demand for the temperature of 45 ºC at the exit from the air handling unit; the increase of the batteries will have to be made taking into account the current power of the fans trying to avoid further changes also in the electric components.

3.6.   Economic analysis of the offer

To analyze the costs and the economic feasibility, it is first necessary to study the evolution of the price of energy and gas for the Plant in the last few years in the city under consideration, that is, the two energy carriers used in the thermal Plant. This analysis can help understand past trends and how these prices will vary in the future.
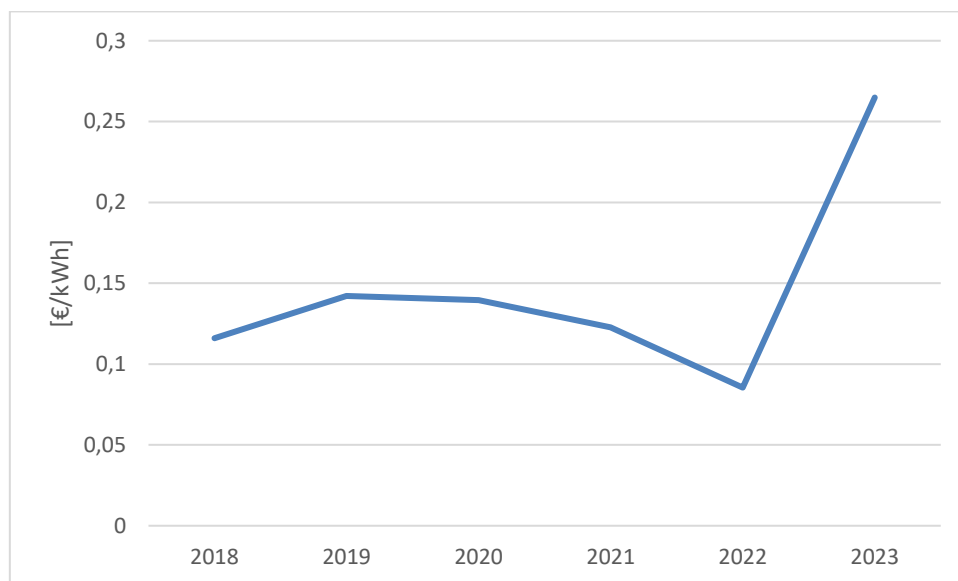
Figure 56: evolution of electricity price over the years

Figure 56 shows the trend of the price of electricity from 2018 to 2023, where the current year is the forecast value 5+7, i.e., the budget prices of 2023 and the actual prices updated in May of the same year. The trend is growing in the first two years due to the Covid and then decreasing until 2022 and increasing by almost 70% in the current year; this surge is due to the war in Ukraine that caused prices to soar in 2022. However, the purchasing

office of Iveco deals with energy prices the previous year, closing the contracts in November, and consequently, the effects are visible from the following year.
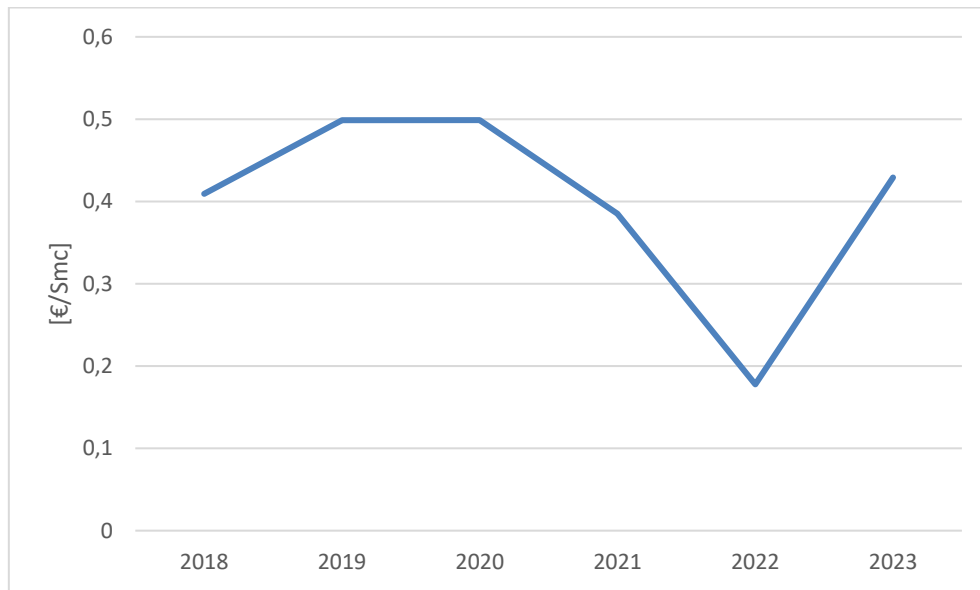
Figure 57: evolution of natural gas price over the years

Figure 57 shows the evolution of the price of natural gas from 2018 to 2023, following the same reasoning as Figure 56. Also, in this case, the trend is similar to that of electricity, with growth until 2019 and a decrease until last year; in 2023, the price is again back to grow by almost 60%. The difference with electricity is visible in the years 2019 and 2020, where the price is flatter, while for 2023, the price has risen but is lower than the highs of previous years.

Considering the consumption and prices of the carriers in 2022 and the ETS quotas bought by the factory, almost EUR 2 million was paid. Table 24 details the costs related to Iveco CV and Magirus.

Table 24: expenditure for the thermal power plant in 2022

Description cost	Cost in 2022 [€]
Electricity	119.719
Natural gas	927.886
ETS	740.109
Total	**1.787.714**

This figure has risen sharply since 2023 due to increased electricity and gas prices seen in the previous figures. As an example, it has been calculated how much the Plant would spend maintaining the same consumption of 2022 but updated to the prices of 2023, and

the total would amount to about € 3,3 million with an increase of almost 70% in a single year.

From these costs were excluded the costs of maintenance of the Plant and the staff who work there, employees of the energy supplier, the cost of which is within the terms of the contract, for a total of about 500.000 €; however, these costs will not be eliminated but will be present to a different extent also for district heating.

Table 25: initial investment cost of the project

Capex	Expenditure
Grid connection	545 k€
AHU adjustment	1.000 k€
Total	**1.545 k€**

Table 25 shows the initial costs for the project; the total is 1.545.000 € divided between the connection to the network and the adaptation of AHUs.

The first, which weighs about a third of the total Capex, was calculated by the district heating distribution company and included the costs of installing the pipes and laying up the heat exchangers inside the buildings.

The remaining million euro is the cost of adjustment of AHUs; this expenditure was assumed by the energy company that manages the energy carriers and includes all the necessary changes to air handling units, particularly batteries.

In addition, by analyzing the thermal load consumed by the Plant, the energy company calculated the peak volume flow required to fully meet the heat demand or 700 m³/h, of which 615 m³/h for Brescia CV and the remaining 85 m³/h in Magirus.

The economic analysis has been made by calculating the cash flow and the Simple Payback Time of the plan, that is, the number of years to return on the investment. Overall, the calculation was made considering the extraordinary expenses, the initial Capex, and the ordinary expenses, that is, the expense to acquire the heat from district heating.

The costs of district heating have been calculated based on a fixed fee and a variable fee; the fixed fee is given by the volume required and is summarized in Table 26; its value is given in €/m³/h and is updated every 1 October of the year according to the annual percentage change in the index of consumer prices calculated by the *National Institute of*

Statistics, ISTAT. In this study, this value will be kept constant while it will vary only the price of the primary carriers.

Table 26: composition of the fixed fee

Fixed fee	Required volume flow rate	Total fixed fee
1453,54 €/year/(m³/h)	700/(m³/h)	1.017.478 €/year

Instead, The variable considerations are updated monthly and formed by an essential variable part shown in Table 27, together with the thermal load to be met.

Table 27: variable share and thermal load

Description	Value	Unit of measure
Thermal load	52.874	MWh
Variable share base	93,08	€/MWh

This variable price is then updated monthly, adding a proportional fee that considers the energy prices on the market [21].

$$ITTLR\left[\frac{€}{MWh}\right] = [ICNF * \Delta PUN_m + (1 - ICNF) * \Delta TTG_m]/8,154$$	(2)

Equation 2 is used to calculate the variable share of the price of district heating; these prices depend on the following:

- ICNF: percentage of supply or production of heat from non-fossil sources that feeds the district heating networks; in 2023, this percentage is equal to 52,80%;
- ΔPUN_m: change in the reference price of electricity calculated by the GME (*Gestore dei mercati energetici* in Italian);
- ΔTTG_m: monthly change in the reference price of natural gas supply costs; this cost depends on the day-ahead PSV price calculated by the *Regulatory Authority for Energy Networks and Environments*, ARERA, and the ESA, that is the monthly average of the environmental cost, established by *Intercontinental Exchange*, ICE, and calculated by applying an emission factor of 0.00196 ton/Sm³;
- 8,154: fixed coefficient that takes into account the energy transformation processes involved in the provision of the service;

The initial values used for the analysis are given in Table 28.

Table 28: initial values of different parameters and ITTLR value

Parameter	Value	Unit of measure
PUN	136,38	€/MWh
TTF	0,672442	€/Sm³
EUA	99,8	€/ton CO_2
TTG	0,86805	€/Sm³
ITTLR 03/23	**48,130**	**€/MWh**
ITTLR 07/23	**36,705**	**€/MWh**

The values for March 2023, the month of study start, and the final value of the ITTLR compared with the most recent value are given, that is July 2023; this figure is significantly lower because in summer, the heat demand is much lower, and because in summer generally, energy prices are lower.

The thermal energy prices from the final district heating were then calculated according to Equation 3.

$$DH_{price} \left[\frac{€}{MWh} \right] = Var_{price} + ITTLR + \frac{Fix_{price}}{Thermal_{load}} \qquad (3)$$

In particular:

- Var$_{price}$ is the basis of the variable quota (93,08 €/MWh);
- ITTLR has been calculated with the equation 2;
- Fix$_{price}$ is the fixed fee equal to 1.017.478 €/year;
- Thermal load is the thermal load of the Plant (52.874 MWh).

The final price of district heating energy for the first year is summarised in Table 29.

Table 29: final price of energy with district heating

Description	Unit of measure	Price
Final energy price with DH	€/MWh	108,50

At the same time, the energy price was calculated in the current situation with the thermal power plant to compare it with the price of district heating, following formula 4.

$$Boiler_{price} \left[\frac{€}{MWh} \right] = (PUN + Com_{ee}) * k_{ee} + \left(TTF + EUA + Com_{ng} \right) * k_{ng} \qquad (4)$$

In particular:

- Com_{ee}: price of commodities for electricity;
- k_{ee}: coefficient of consumption of the boiler in MWhee/MWhth;
- Com_{ng}: price of commodities for natural gas;
- k_{ng}: coefficient of consumption of the boiler in MWhng/MWhth;

The prices of commodities depend on the contract between Iveco and the energy supplier, while the consumption coefficients are characteristic of the thermal power plant and are shown in Table 30.

Table 30: coefficients to calculate boiler energy price

Parameter	Unit of measure	Value
Com_{ee}	€/MWh	38,645
k_{ee}	MWh_{ee}/MWh_{th}	0,026496
Com_{ng}	€/MWh	8,74
k_{ng}	MWh_{ng}/MWh_{th}	1,0625
Final energy price	**€/MWh**	**88,006**

They were then multiplied by the same thermal load, shown in Table 27, to obtain the total expenditure for district heating and the case of a thermal power plant with a boiler. The difference between the two costs of the two technologies corresponds to the savings obtained that year thanks to the transition to district heating; this saving was added to the initial Capex, and the cumulative sum over the years corresponds to the project's cash flow. The Simple Payback Time of the project corresponds to the year the cash flow becomes 0 when the investment is returned and the project begins to earn actively.

Three different scenarios were developed: in the first, the price of electricity and gas were kept constant; in the second case, they were increased by 2% annually; and in the third case, they decreased by 2% constantly. These three analyses cover all the market eventualities in case of improvement and worsening of the world energy situation. On the contrary, the price of EUA, relative to the ETS, is constantly increasing in all three scenarios; this increase is assumed to be the 5% anniversary online with the analyses of the group's finances.

3.6.1. Analysis with fixed price

Table 31 shows the variables of the present case, namely the price of gas on the market (FTT), the price of energy on the market (PUN), and the price of the ETS (EUA) with the related annual increases or decreases.

Table 31: calculation variables and consequent annual variation

Parameter	Unit of measure	Initial value	Annual variation
TTF	€/Sm³	0,67	+0%
PUN	€/MWh	136,38	+0%
EUA	€/ ton CO_2	92,20	+5%

Table 32 shows the calculations made in the case of constant energy price over the years; in particular, the values of TTF and PUN remain constant while the value of EUA grows constantly, as previously written.

It can be observed that saving in the first years is negative because the price of district heating is higher than the price of energy; in the twelfth year, the price of the ETS becomes more substantial and brings a positive annual saving that invests in 2048, to the 24th year after installation.

It is helpful to remember that from 2030, the free ETS will end, and we expect a surge in prices due to the increased research of certifications on the market; the establishment should not undergo significant changes since it does not own free titles and will not have to go to buy more certificates but would be affected by the market price.

Table 32: cash flow with fixed price

Year	Price energy from boiler [€/MWh]	Price energy from DH [€/MWh]	Total expenditure with CT [k€]	Total expenditure with DH [k€]	Saving [k€]	NPV [k€]
2024	99,58	111,46	5.265	5.893	-628,32	-1.545,00
2025	100,48	112,85	5.313	5.967	-653,60	-2.173,32
2026	101,44	112,87	5.363	5.968	-604,62	-2.826,92
2027	102,44	112,90	5.416	5.969	-553,19	-3.431,58
2028	103,49	112,93	5.472	5.971	-499,19	-3.984,74
2029	104,59	112,96	5.530	5.973	-442,49	-4.483,94
2030	105,75	112,99	5.591	5.974	-382,96	-4.926,43
2031	106,96	113,02	5.656	5.976	-320,45	-5.309,39
2032	108,24	113,06	5.723	5.978	-254,81	-5.629,83
2033	109,58	113,10	5.794	5.979	-185,89	-5.884,64
2034	110,99	113,13	5.868	5.981	-113,52	-6.070,53
2035	112,47	113,18	5.947	5.984	-37,54	-6.184,05
2036	114,02	113,22	6.029	5.986	42,24	-6.221,59
2037	115,65	113,26	6.115	5.989	126,02	-6.179,35
2038	117,36	113,31	6.205	5.991	213,98	-6.053,33
2039	119,15	113,36	6.300	5.994	306,34	-5.839,33
2040	121,04	113,41	6.340	5.996	403,31	-5.533,02
2041	123,02	113,47	6.505	5.999	505,13	-5.129,70
2042	125,10	113,52	6.614	6.002	612,06	-4.624,56
2043	127,28	113,58	6.730	6.006	724,32	-4.012,51
2044	129,57	113,65	6.851	6.009	842,20	-3.288,19

3.6.2.   Analysis with increasing price

The second study has assumed a constant increase of the TTF and the PUN of 2%; this figure has been chosen in agreement with the finance of the group and represents the best possible case because the price of the energy of the thermal power plant mainly suffers from the market prices (Table 33).

Table 33: calculation variables and consequent annual variation

Parameter	Unit of measure	Initial value	Annual variation
TTF	€/Sm³	0,67	+2%
PUN	€/MWh	136,38	+2%
EUA	€/ton CO_2	92,20	+5%

The results of this analysis are visible in Table 34, where it can be seen that saving becomes positive after six years, and the investment begins to generate profits in 2037, after thirteen years.

Table 34: cash flow with rising price

Year	Price energy from boiler [€/MWh]	Price energy from DH [€/MWh]	Total expenditure with CT [€]	Total expenditure with DH [€]	Saving [€]	NPV [€]
2024	99,58	111,46	5.265	5.893	-628,32	-1.545,00
2025	103,28	113,82	5.461	6.018	-556,89	-2.173,32
2026	105,72	113,86	5.590	6.020	-430,77	-2.730,22
2027	108,22	113,91	5.722	6.023	-300,65	-3.160,98
2028	110,81	113,96	5.859	6.025	-166,39	-3.461,63
2029	113,48	114,01	6.000	6.028	-27,82	-3.628,02
2030	116,24	114,06	6.146	6.031	115,22	-3.655,83
2031	119,09	114,12	6.297	6.034	262,92	-3.540,61
2032	122,03	114,17	6.452	6.037	415,43	-3.277,69
2033	125,07	114,23	6.613	6.040	572,97	-2.862,26
2034	128,21	114,29	6.779	6.043	735,73	-2.289,29
2035	131,45	114,36	6.951	6.047	903,91	-1.553,56
2036	134,81	114,42	7.128	6.050	1.077,73	-649,66
2037	138,28	114,49	7.311	6.054	1.257,43	428,08
2038	141,86	114,57	7.501	6.057	1.443,23	1.685,50
2039	145,57	114,64	7.697	6.061	1.635,39	3.128,73
2040	149,41	114,72	7.900	6.066	1.834,16	4.764,12
2041	153,38	114,80	8.110	6.070	2.039,81	6.598,28
2042	157,49	114,88	8.327	6.074	2.252,64	8.638,09
2043	161,74	114,97	8.552	6.079	2.472,92	10.890,72
2044	166,14	115,06	8.785	6.084	2.700,98	13.363,65

3.6.3.   Analysis with decreasing price

Finally, Table 35 shows the last case, with the energy price decreasing over time.

Table 35: calculation variables and consequent annual variation

Parameter	Unit of measure	Initial value	Annual variation
TTF	€/Sm³	0,67	-2%
PUN	€/MWh	136,38	-2%
EUA	€/ ton CO_2	92,20	+5%

The results in Table 36 show that this case is the worst because the price of power plant energy is more affected by the market and will have better prices.

This possibility would not be economically sustainable not having positive cash flow since the annual saving is negative and decreases over the years instead of increasing.

Table 36: cash flow with decreasing price

Year	Price energy from boiler [€/MWh]	Price energy from DH [€/MWh]	Total expenditure with CT [k€]	Total expenditure with DH [k€]	Saving [k€]	NPV [k€]
2024	99,58	111,46	5.265	5.893	-628,32	-1.545,00
2025	97,79	111,94	5.171	5.919	-747,91	-2.173,32
2026	96,04	111,21	5.078	5.880	-802,11	-2.921,23
2027	94,33	110,47	4.986	5.841	-853,29	-3.723,34
2028	92,65	109,70	4.899	5.800	-901,42	-4.576,64
2029	91,00	108,90	4.812	5.758	-946,45	-5.478,06
2030	89,39	108,08	4.726	5.715	-988,34	-6.424,51
2031	87,81	107,23	4.643	5.670	-1.027,03	-7.412,84
2032	86,26	106,35	4.561	5.623	-1.062,49	-8.439,88
2033	84,74	105,44	4.480	5.575	-1.094,63	-9.502,36
2034	83,25	104,50	4.402	5.525	-1.123,42	-10.596,99
2035	81,79	103,52	4.325	5.473	-1.148,76	-11.720,41
2036	80,36	102,50	4.249	5.420	-1.170,60	-12.869,17
2037	78,96	101,44	4.175	5.364	-1.188,84	-14.039,77
2038	77,59	100,35	4.102	5.306	-1.203,41	-15.228,62
2039	76,24	99,20	4.031	5.245	-1.214,22	-16.432,03
2040	74,92	98,02	3.961	5.183	-1.221,15	-17.646,25
2041	73,63	96,78	3.893	5.117	-1.224,12	-18.867,40
2042	72,36	95,49	3.826	5.049	-1.223,00	-20.091,51
2043	71,12	94,15	3.761	4.978	-1.217,68	-21.314,51
2044	69,91	92,75	3.696	4.904	-1.208,02	-22.532,19

3.6.4.   Comparison of the three analyses

These results can be compared by reporting the different cashflows in a single time graph. The results, observable in Figure 58, highlight that in the case of fixed and increasing prices, cash flow becomes positive and has a growing trend over the years, while if the price were decreasing, the cash flow would reduce year by year, resulting in wrong investment.
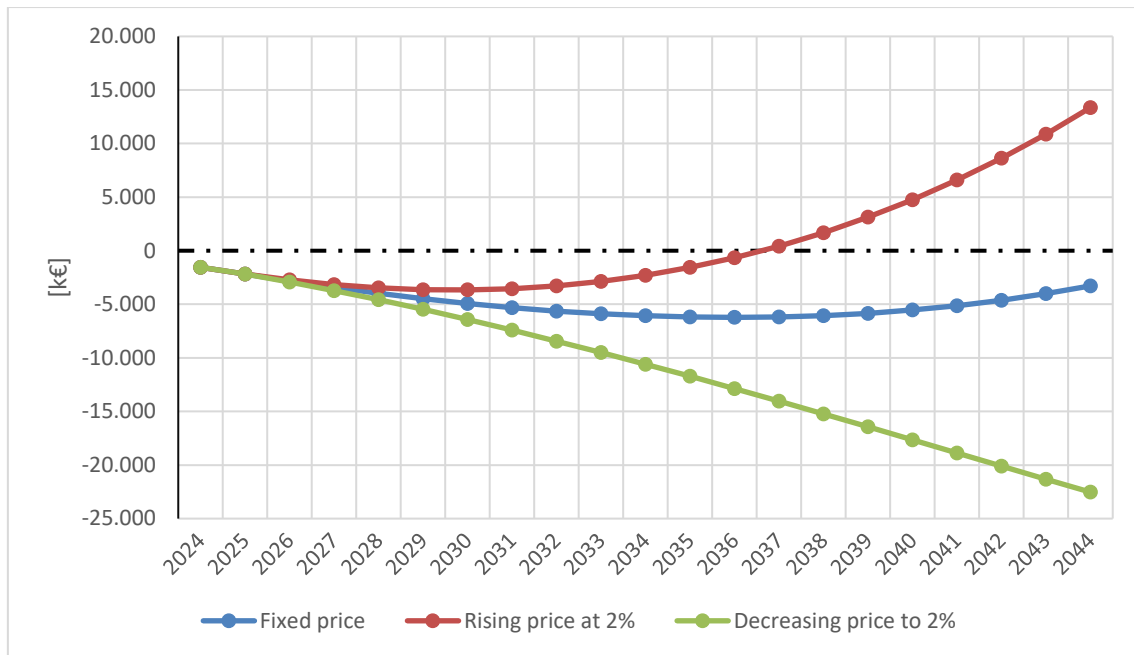
Figure 58: cash flow in the three cases

Usually, the simple payback time of efficient projects considered by the department is about three years; the results obtained from this study are all three worst and theoretically not acceptable; however, this project would allow to zero the CO_2 emissions of the plant in line with the objectives of Iveco Group and would make the plant a green Plant, that is a plant without emissions with a consequent return of image.

3.7.   Sensitivity Analysis

To better analyze the feasibility of this technology, several sensitivity analyses have been developed to study the dependence of district heating on some factors involved and to understand better what scenarios are desirable for the project to be economically sustainable.

3.7.1.   Dependence on the price of natural gas

This analysis shows that the costs' dependence on the gas price is evident since consumption mainly depends on this energy carrier. In this regard, a cost analysis was made regarding district heating and the present issue of gas prices on the market.
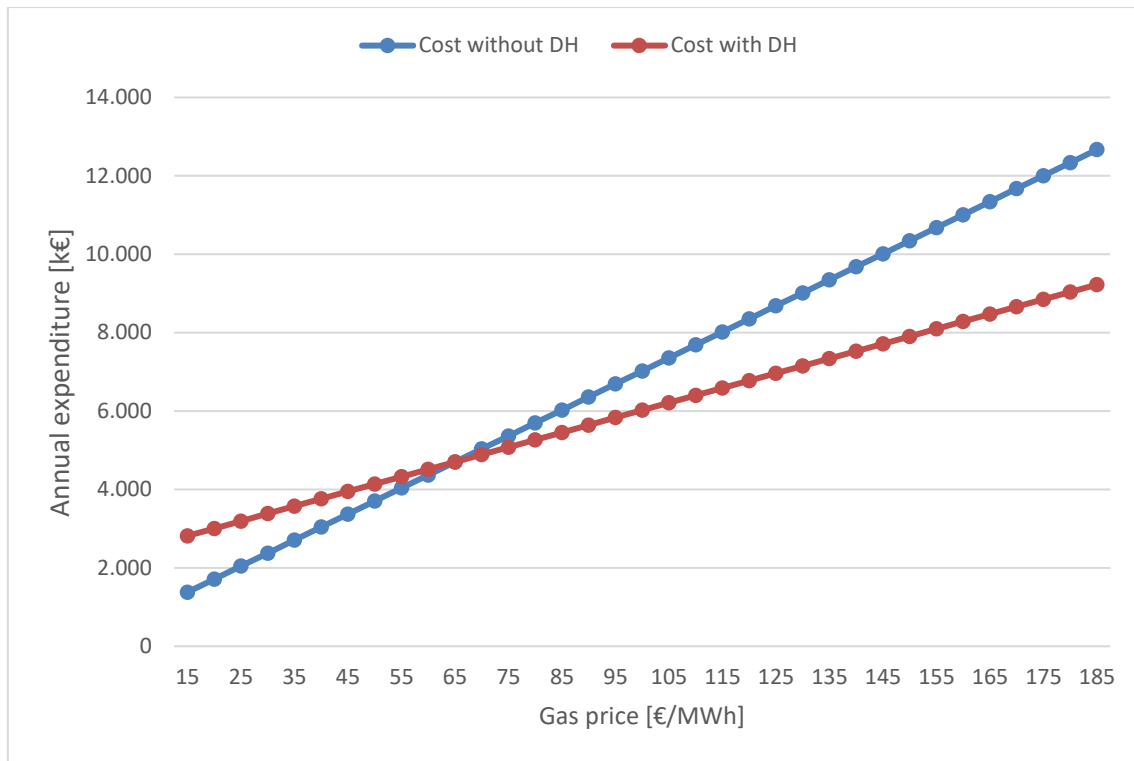
Figure 59: dependence of DH costs on gas price

As seen in Figure 59, the costs are proportional to the price of natural gas, and we notice a price watershed for the diagram reading. When the price is less than 65€/MWh, the district heating is inconvenient and is more expensive than the current thermal plant; on the contrary, if the price is higher, this technology is more economically reliable, and increasing the price also increases the gap between the two prices.

3.7.2.   Dependence on thermal load

The analysis carried out in the previous chapters was made considering the entire thermal load of the plant, or 52.874 MWh; however, this amount includes heat for heating buildings and heat for technological use; the latter is now served to users at temperatures much higher than those achievable by district heating and should be excluded.

The analysis was done including this heat, because it is the best case possible. After all, the saving is more significant and allows us to cover the Capex faster, bringing profit; instead, satisfying a lower thermal load would involve the same initial investment but with a lower volume of heat and, therefore, saving.

To prove this, a further analysis was made to cover only the thermal load from heating, and cash flows were compared, considering the best possible case, that is, with increasing

energy prices. In particular, the boilers listed in Table 37 have been excluded, where the Hydrothermal boiler will still weigh the ETS system, while the Viessmann boiler will not be less than three MW_t.

Table 37: boilers for technological use

Boiler	Production	Power
Idrotermici	Superheated steam	21 MW_t
Viessmann	Superheated water	2,09 MW_t

Table 38 shows the coefficients used in the first analysis and their present value for this further study.

Table 38: coefficients dependent on thermal load

Thermal load	Full load	Only heating	Unit of measure
EE consumption	1.401	1.367	MWh
NG consumption	51.473	44.195	MWh
Total consumption	52.874	45.562	MWh
Volume	700	600	m³/h
Fixed fee	1.017.478	872.124	€/y

Initially, the thermal heat for technological uses was subtracted from the total supplied by the thermal power plant, re-proportioning the consumption of electricity and natural gas in the boiler inlet; this was followed by a change in the volume flow rate necessary to meet the requirements and, consequently, the fixed quota to be granted to the energy company.

The calculations were then made again, considering the amount of heat supplied by the district heating system, as revised above, and the use of the thermal power plant for the remainder. It is important to note that, in the latter case, the ETS will also be paid, which has been re-proportioned to the emissions issued and counted in the expenses.
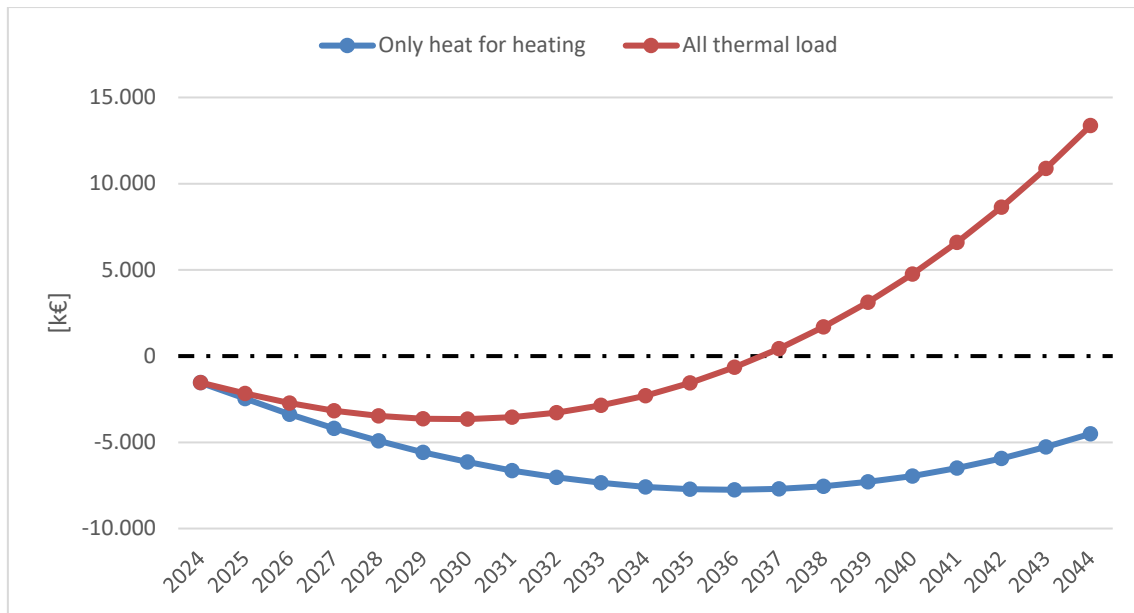
Figure 60: cash flow with total and partial load

Figure 60 shows the results obtained; in particular, it can be noted that covering only partially the thermal load results in a higher SPBT, or 25 years, compared to the 13 years of the first case study. This shows that the objective must be to completely decommission the power plant and fully meet the demand for district heating because the lower the percentage of energy connected to the network, the higher the return time of the project with the increased expenditure of money and the risk of not returning the investment made.

3.7.3.   Dependence on the price of the ETS

Previous analyses have shown that the project is mainly dependent on the price of gas (FTT) and the price of European trading quotas (EUA). Therefore, an analysis has been made to study the project's feasibility at varying prices of these two.
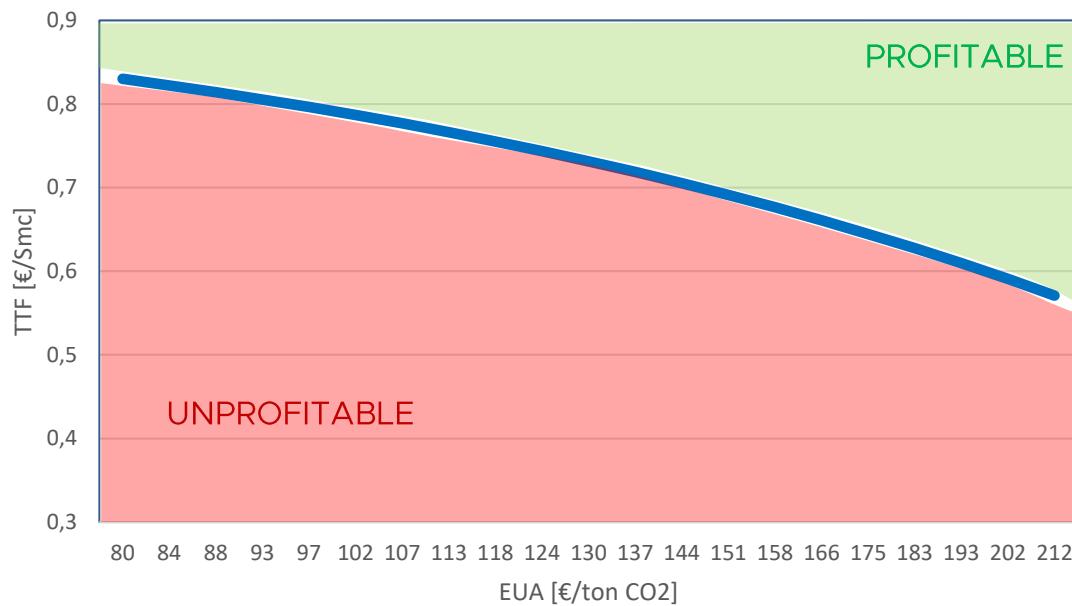
Figure 61: feasibility analysis of the project to change the TTF and EUA

Figure 61 shows the line of equality between energy prices in district heating and in the current thermal power plant as the price of gas (TTF) varies in the European market and the ETS (EUA) shares.

The figure allows us to identify two well-defined areas: the green area represents the area where the project is profitable, and the saving is positive. In contrast, the second red one represents the area where the project is unsuccessful and has a negative saving.

It is clear that the red area is much larger than the green area, and therefore there is less chance of the project being economically viable; however, it must be considered that from September 2021 to January 2023 the FTT has always been higher than 0,7 €/Smc with an average value of 1,19 €/Smc and a peak of 2,38 €/Smc in August 2022, while subsequently began to fall by lowering the average of the last two years to 0,85 €/Smc.

The same goes for the price of ETS allowances, as already mentioned since the price is constantly increasing and to date is about 90 €/ ton CO_2.

Conclusion

This study aimed to identify and analyze an efficient project applicable to an Iveco Group plant to continue the company's decarbonization process in line with the sustainability objectives set for 2030.

Initially, a general overview of climate change was made, which highlighted the need for immediate action through actions that could eliminate polluting emissions. In this context, the European Union is playing an essential role in the Green Deal, with which it wants to lead the transition. In particular, great emphasis is given to the industries primarily responsible for the climate crisis, and more in detail was deepened Iveco Group, an automotive multinational and leader in the industrial and special vehicles sector.

Among the measures of the Green Deal was the emissions trading system (EU ETS) through an in-depth analysis of the functioning of the ETS scheme and the future steps that the European Union wants to take in support of this measure, including the cancellation of the accessible shares in 2034; moreover, the economic weight of these shares for the Group was analyzed, highlighting the very volatile price that has now reached 90 €/ton CO_2, much higher than the almost 3 €/ton CO_2 of 2013 and future savings if you leave the system or not.

Subsequently, a Group plant was chosen, located in central Italy, to use as a pilot for the efficiency project; the plant chosen is divided between two brands of the same Group, Iveco CV and Magirus, specializing in special vehicles, and for both have been deepened production processes and consumption related to them, both for primary energy carriers for both secondary carriers analyzing their trends in the past years. This analysis has shown that the most widely used energy carrier is natural gas, mainly used for heating and, in part, for technological use. Furthermore, emissions from natural gas and their trend over the years were analyzed.

The efficient project chosen was district heating, a system already active in the city. A general overview of the operation of this technology on the Italian territory has shown that to date, district heating covers 2% of the national energy needs, mainly in the north of the country, with much difference between the power plants, divided between gas plants, using waste and renewable.

The current power plant with four active boilers and the connected heating circuit was subsequently examined.

The analysis of the project was first developed through the technical aspect, in which the connection to the current network of the city and deepened the characteristics of the fluid coming to the exchanger from the district heating, such as inlet and outlet temperatures imposed by the energy company; this first analysis has shown that for the Iveco Magirus plant, there are no problems to implement the technology and the thermal demands are easily satisfied while there would be problems for Iveco CV because the demand for heat for technological use needs higher temperatures, challenging to implement by the current conditions of district heating. The solution to this problem could be the adaptation of the AHUs by increasing the heating batteries, whose state of obsolescence would require more deepened analyses.

Then, the economic analysis of the plan is made, in which the simple payback time and the revenues that would follow from it are calculated. This study has been made through three different hypotheses that differ for the evolution of the prices of primary energy carriers over the years. This choice has been made because accurately predicting energy price developments in the coming years is a complex challenge due to the variability of economic factors, geopolitics, and environment that affect the global market, and the consequence is difficult to make accurate predictions since the unknowns are many and often sudden.

Moreover, the national incentives available to companies have yet to be considered because they depend on the start-up period and are challenging to apply; however, any economic aid could affect the project and make it economically more sustainable.

The greater dependence of the thermal power plant on energy prices compared to the district heating system has meant that the best possible case is the one with gas and electricity prices rising over the years, as demonstrated by the smaller SPBT, 14 years, while on the contrary, the worst possible case is with prices falling, with a net cash flow consistently negative and always worse, year after year. Finally, the issue with constant prices is positioned in the middle, with a positive cash flow after 24 years, several years after the best case.

For a better analysis, three further studies have been made; in the first, cost dependence on the price of natural gas has been demonstrated, finding the minimum price, 65 €/MWh, beyond which district heating is advantageous. Subsequently, an analysis was made by decreasing the thermal load satisfied by district heating, from which it became clear that the project is valid if the entire thermal demand is met while satisfying it only partially

would lead to an increase in recovery time the investment made; however, to date, it is difficult to think of satisfying all the demands with district heating.

One solution could be modifying the two plants' internal heat distribution. This option, combined with the adaptation of the AHU, could allow a change in the internal thermal loads, and it is not excluded that it would allow to satisfy the thermal load through district heating fully; however, this option is costly, it would further lengthen the time needed to implement the project and, in addition, to modify ancient distribution systems, could lead to further problems as production processes would also change.

Iveco and the energy company are working on the issue of temperatures to understand if there are solutions that allow us to meet the maximum possible energy share.

Finally, the last analysis highlighted the dependence of technology on the price of ETS quotas, identifying prices that, combined with the market value of gas, would generate revenue.

In conclusion, the detailed analysis carried out in this research has highlighted the complexity and the importance of the transition to district heating for the Iveco plant. Although the return on investment time may be relatively long and influenced by a variety of factors, it is clear that the adoption of sustainable practices and the transformation of the plant into a "green plant" represent critical steps towards reducing emissions, achieving sustainability targets and combating global warming, where the industry has a crucial role to play.

In a context where the importance of corporate social responsibility is constantly growing, and consumers and investors are increasingly paying attention to sustainability, adopting eco-friendly solutions is a far-sighted strategic choice. In this transformation process, the company demonstrates its commitment to global challenges, acting as an industry leader and actively helping to build a more sustainable future for all.

This thesis not only provides a comprehensive overview of the technical and economic implications of the transition to district heating for the Iveco plant but also stresses the importance of environmental considerations in business decisions. The road to sustainability may be extended and demanding, but it is a road that deserves to be traveled for the good of present and future generations and the health of our planet.

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