Energy Transition Audits towards Decarbonization

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3.3	26/08/2023	UTC	Final document

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List of Acronyms

Acronym	Meaning
AIoT	Artificial Intelligence of Things
BECCS	Bioenergy with carbon capture and storage
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture, Utilization, and Storage
CDP	Carbon Disclosure Project
CFLs	Compact Fluorescent Lamps
CH4	Methane
CHP	Combined Heat and Power
CO2	Carbon dioxide
COT	Carbon Tracing Platform
DAP	Decarbonization Action Plan
DERs	Distributed Energy Resources
DESFA	National Natural Gas System Operator in Greece
DHW	Domestic Hot Water
DRM	Decarbonization Roadmap
EC	European Commission
EGR	Enhanced Gas Recovery
EGS	Engineered Geothermal Systems
EOR	Enhanced Oil Recovery
ESCO	Energy Service Company
ESG	Environmental, Social, and Governance factors
ETA	Energy Transition Audit
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse Gas
GoO	Guarantee of Origin
GWPs	Global Warming Potentials
HDVs	Heavy-Duty Vehicles
HEREMA	Energy Resources Management Company. Greece
HVAC	Heating, Ventilation, and Air Conditioning
KPI	Key Performance Indicators
LCFFES	low-carbon fuels, feedstocks, and energy sources
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
LMD	Laser Metal Deposition
MMBI	Mining and Metals Blockchain Initiative’s
N2O	Nitrous oxide
NECP	National Energy and Climate Plan

NZE	Near Zero-Emission
OEMs	Original Equipment Manufacturers
OPEX	Operating Expenditure
P2X	Power-to-X
PI	Process Intensification
PNIEC	Energy and Climate National Integrated Plan
PNRR	National Recovery and Resilience Plan in Romania
PV	Photovoltaic
RES	Renewable Energy Sources
ROP	Regional Operational Program
SBTi	Science Based Targets Initiative
SME	Small and Medium – sized Enterprise
WP	Work Package

Executive summary

This Report has been developed through the implementation of the 'EnTRAINER' project, funded by the Programme for Environment and Climate Action (LIFE) under the Grant Agreement No 101076424. The EnTRAINER project aims to introduce a paradigm shift from conventional energy audits through a new, holistic and complete methodology of 'Energy Transition Audits' (ETA). With this new approach, the focus is not only to provide energy efficiency action plans, but to provide also decarbonization action plans with a complete multi-benefit scheme evaluation of the audited sites.

The document aims to define detailed guidelines for the implementation of decarbonization actions which are proposed as a result of the **E**nergy **T**ransition **A**udits (**ETA**). These actions will be incorporated into a **D**ecarbonization **A**ction **P**lan (**DAP**) and will be shaped into a complete **D**ecarbonization **R**oadmap (**DRM**), tailored to the specific needs of the audited companies.

This report serves as a deliverable for WP2 *Paradigm shift towards a holistic energy transition audit methodology*, which focuses on the development methodology for ETA actions. Led by the TECHNICAL UNIVERSITY OF CLUJ-NAPOCA (UTC), this collaborative effort involves contributions from all project partners: ARISTOTELIO PANEPISTIMIO THESSALONIKIS (AUTH), UNIVERSITAT POLITECNICA DE VALENCIA (UPV), SERVELECT SRL (SERVELECT), AGENZIA PER L'ENERGIA ALTO ADIGE – CASACLIMA (CASACLIMA), PANEPISTIMIO DYTIKIS MAKEDONIAS (UOWM), BEON GESTIONA SOCIEDAD LIMITADA (BEON) and USE EFFICIENCY ASSOCIATION (USEEFF).

Deliverable D2.2 *Decarbonization roadmap* describes how the actions proposed by the auditor and the working group defined for ETA should be embedded in a well-defined internal strategy, which aims to lead towards the achievement of company's short, medium and long-term decarbonization targets. In the framework of EnTRAINER project, this document:

- outlines the directions that will be addressed in the development of training materials for the education and training activities to be implemented under WP5.
- will be improved significantly considering the conclusions drawn by the auditors after the ETA implementation phase foreseen in WP3. The improved version of the deliverable will also contain details of ETA deployment and lessons learned through real case studies, obtained in WP3 following ETA deployment in different industries from partner countries.
- is completed by an additional resource, i.e., Deliverable D2.1 *Holistic Energy Transition Audit Methodology.* To ensure comprehensive understanding and optimal utilization, it is highly recommended to utilize both documents in conjunction. This report acts as a complementary companion to D2.2, making frequent references to its subchapters throughout various sections.

Deliverables *D2.1 Holistic Energy Transition Audit* and *D2.2 Decarbonization roadmap* was applied, tested and improved through the implementation of the ETA actions within the EnTRAINER WP3, and the training activities in WP5. By the conclusion of the EnTRAINER project, this reports act as the improved version of these Deliverables, reflecting the experience gathered from the ETA implementation and the design of roadmaps for the audited companies.

Compared to the previous version, this edition is supplemented with concrete examples to clarify key ETA concepts - collective approach and multiple benefits - and highlights how the proposed methodology advances a company's decarbonization efforts.

More information about the EnTRAINER project can be found at https://entrainer-project.eu

1. Introduction

1.1. Importance of decarbonization

The importance of decarbonization lies in its critical role in addressing the mandatory global challenge of climate change. Decarbonization refers to the process of reducing or eliminating greenhouse gas (GHG) emissions, particularly in the scope of this project the carbon dioxide (CO2), from various sectors such as energy, transportation, industry, agriculture etc. There are several key reasons why DECARBONIZATION is highly important, as highlighted in Figure 1.

Figure 1: Key reasons for decarbonization.

Overall, decarbonization is crucial for safeguarding the environment, addressing climate change, promoting sustainable development, improving public health, driving innovation, and ensuring a resilient and secure energy future. It requires collective action, policy support, technological advancements, and international cooperation to achieve a sustainable, low-carbon society.

The plan of European Union (EU) to transform its industry for the net-zero era is built upon the European Green Deal, which is the EU's comprehensive strategy for sustainable growth. This plan requires the active involvement of the industrial sector to achieve climate neutrality and circularity in the EU economy. The European Climate Law, established in 2021, legally obligates the EU to achieve climate neutrality by 2050 and sets a target of reducing domestic GHG emissions by at least 55% by 2030 compared to 1990 levels [1-3].

To meet these goals, the 'Fit for 55 package' was introduced in 2021, consisting of various legislative proposals aimed at reforming EU policies and aligning them with the objectives of the climate law. Notable initiatives within this package include the updated emissions trading system (ETS) and the newly implemented carbon border adjustment mechanism, both of which became law on May 10, 2023. These measures play a significant role in regulating emissions and ensuring a level playing field for industries.

There has been a growing recognition of the urgency to expedite both the green and digital transitions while reducing strategic dependencies on critical products. This has led, in recent years, to widespread calls for increased government intervention in the economy and a resurgence of industrial policies. Presently, almost all countries are implementing some form of industrial policy, with the EU specifically embracing a more proactive industrial policy agenda.

In 2020, the European Commission (EC) adopted a new industrial strategy for Europe with the aim of making EU industry more environmentally sustainable, digitally advanced, and globally competitive, while also strengthening Europe's industrial and strategic independence. This strategy introduced an ‘ecosystem approach’ which involves closely monitoring strategic dependencies in 14 key industrial ecosystems representing 70% of the EU economy. These ecosystems include energy-intensive industries and renewable energies [1-3].

In the 2021 update of the industrial strategy, the focus shifted towards addressing the impacts of the pandemic, adapting to the evolving global competitive landscape, and accelerating the twin transitions of green and digital. Additionally, the updated strategy proposed a range of supplementary actions to tackle strategic dependencies.

In 2022, the REPowerEU plan was devised to reduce the EU's reliance on Russian fossil fuels. The plan focuses on deploying renewable energy sources (RESs) such as photovoltaic and wind capacities, as well as heat pumps, and aims to decarbonize the industrial sector. Recent amendments to EU energy legislation, proposed under this plan, have been agreed upon by the Council and Parliament. These amendments aim to accelerate the adoption of renewable energy sources, promote energy efficiency, and encourage energy savings.

Member States have been given the opportunity to include REPowerEU chapters in their recovery and resilience plans, with the Commission actively encouraging them to incorporate measures that foster the production of net-zero technologies. This demonstrates the EU's commitment to driving sustainable manufacturing practices and facilitating the transition to a carbon-neutral industry.

Overall, there has been a growing recognition of the need for government involvement in the economy to facilitate the green and digital transitions and reduce strategic vulnerabilities. The EU, through its industrial strategy, is actively working towards these objectives by adopting an ecosystem approach and implementing measures to enhance Europe's industrial and strategic autonomy.

The Net-Zero Industry Act proposed legislation to promote decarbonization and the transition to an industry with net zero GHG emissions. The Act aims to impose clear obligations and firm commitments on the industrial sector to reduce emissions and contribute to the achievement of set climate targets.

The legislative proposals include regulations on the standardization and implementation of cleaner production technologies and practices, supporting innovation and investment in low-emission technologies, and fostering collaboration between the public and private sectors to facilitate the transition to more sustainable and environmentally sustainable industries. The objective of enacting this legislation is to ensure that the industrial sector assumes accountability and actively participates in reducing GHG emissions, aligning with the global climate objectives [1-3].

The Green Deal Industrial Plan is a strategic initiative of the European Union that is part of the European Green Deal. This plan aims to transform the European industrial sector into a driver of sustainability and the transition to a low-carbon economy. The Green Deal Industrial Plan focuses on promoting innovation, productivity and competitiveness in industrial sectors, while reducing environmental impact and supporting sustainability.

The initiative aims to create green jobs, invest in clean and energy-efficient technologies, implement more sustainable production processes, promote the circular economy and reduce GHG emissions generated by industry. Through the Green Deal Industrial Plan, the EU aims to strengthen Europe's leadership in sustainability and ensure a sustainable transition to a green and globally competitive industry.

As a result, EU Member States are obligated to formulate national long-term strategies outlining their intended actions to achieve the necessary reductions in GHG emissions. These strategies should align with the commitments made by Member States and incorporate some of the recommendations put forth in European directives. In the future, certain recommendations from these directives are expected to become mandatory for EU Member States to ensure consistent progress towards meeting their climate targets and fulfilling their obligations under the Paris Agreement and EU objectives [3].

In this context, addressing the issue of climate change is increasingly becoming a top priority in business strategy, as there is growing political and social pressure for a swiftly transition towards a sustainable, low-carbon economy [4, 5].

Decarbonization is defined as the process of reducing CO2 emissions resulting from human activities. There are many paths to decarbonization, and it is very important not to mix decarbonization up with de-industrialization.

There are six pillars of climate mitigation, all needed to reach zero net emissions of GHGs by 2050 and negative emissions thereafter. The first five pillars aim to eliminate CO2 emissions from the energy system, hence ‘decarbonization’. The sixth aims to eliminate GHGs emissions from agriculture: CO2, methane (CH4), and nitrous oxide (N2O).

Industry is responsible for a large share of global GHG emissions, because industrial processes employ high temperatures and depend on high energy densities to enable the technical processes involved. The industry sector in 2022 was directly responsible for emitting 9.0 Gt of CO2, accounting for a quarter of global energy system CO2 emissions. Annual emissions slightly declined in both 2020 and 2022, but not enough to align with the Net Zero Emissions (NZE) by 2050 Scenario, in which industrial emissions fall to about 7 Gt CO2 by 2030 [6].

Although there have been some modest advancements in energy efficiency, renewable energy adoption, international collaboration, and innovation, progress in these areas has been slow and insufficient. To achieve significant milestones in line with the NZE Scenario by 2030, there is a pressing need for greater improvements in materials and energy efficiency, quicker adoption of low-carbon fuels, and faster development and implementation of near zero-emission production processes such as carbon capture, utilization, and storage (CCUS) as well as hydrogen technologies. Government policies play a major role in expediting progress by mitigating risks associated with emerging technologies and implementing mandatory CO2 emission reduction measures. [6]

1.2. Purpose of the report and project context

When a company starts on its sustainability transformation and decarbonization actions, the road can take many unexpected turns. To achieve timely and cost-effective results, it is crucial for companies to have a phased plan that clearly delineates actionable measures for integrating suitable technologies, accessing financing options, and overcoming organizational barriers.

The primary goal of this report is to offer guidance on creating a decarbonization roadmap that outlines the necessary actions for a company to decarbonize its operations and establish net zero strategies.

This deliverable in its current form is intended to be a digital document utilized by energy auditors during the Energy Transition Audit (ETA) process, along with the audited Clients – energy managers, top decision makers and other stakeholders. It can be tailored to suit the specific needs of audited industries and appended to energy transition audit reports.

Additionally, this report aims to contribute to raising awareness about the importance of creating a decarbonization roadmap, as follows:

- A roadmap provides a **clear and structured pathway** for achieving decarbonization goals. It outlines the specific steps, targets, and milestones necessary to transition to a low-carbon future. It helps in aligning efforts, setting priorities, and providing a sense of direction to policymakers, businesses, and stakeholders.
- Decarbonization is a complex and long-term process that requires **planning and coordination** across various sectors and stakeholders. A roadmap allows for strategic planning, enabling the identification of technological, policy, and financial requirements and ensures that actions are coordinated and integrated to maximize the effectiveness and efficiency.
- A roadmap provides policymakers with valuable **guidance for developing effective policies and regulations**. It helps in identifying policy gaps, assessing the impact of existing policies, designing new ones to support decarbonization efforts and facilitates policy coherence and consistency across different levels of governance.

- Decarbonization requires substantial investments in clean technologies, infrastructure, and innovation. A roadmap provides investors, financiers, and businesses with a clear vision of the decarbonization trajectory, fostering confidence and facilitating investment decisions, and also helps in attracting **funding and mobilizing resources** towards low-carbon projects and initiatives.
- Developing a roadmap involves **engaging and collaborating** with various stakeholders, including government agencies, businesses, civil society organizations, and the public. It creates a platform for dialogue, consensus-building, and collective action ensuring that diverse perspectives are considered, fostering ownership and buy-in from stakeholders, thereby increasing the chances of successful implementations.
- A roadmap serves as a **monitoring and evaluation** tool, enabling the tracking of progress towards decarbonization goals. It allows for periodic assessments, identifying potential blockages, and making necessary adjustments to ensure the effectiveness of decarbonization strategies. It facilitates accountability and transparency in the implementation process.
- Designing a decarbonization roadmap can foster **international cooperation and collaboration**. It provides a framework for sharing best practices, knowledge, and experiences across countries, enhances coordination in addressing global climate change challenges and facilitates the exchange of technology, expertise, and financial support.

The outputs of this report will be used as input to other project activities:

- It will be a document that completes the ETA methodology proposed within the EnTRAINER project.
- Within WP3, auditors will use it as a primary tool during the implementation of ETAs in high-intensive industrial companies. Following these actions, it will undergo validation and enhancement to ensure its adaptability in its final version. Ultimately, it will be designed to accommodate ETAs conducted in various industries and company's types, making it a versatile and comprehensive tool.
- This report will serve as a fundamental element for the development of training materials in WP5, specifically for the training and educational programs targeting energy managers, aspiring energy professionals, and company's employees. The content of this document will be used to create comprehensive training resources for these individuals.

1.3. Delineation

The purpose of the decarbonization roadmap is to present an evidence-based and experience-based perspective of how the outcomes of the energy transition audit should be transposed in short, medium or long term decarbonization actions. This ensures that both the Beneficiary company and the ETA auditor, acting as an energy transition expert and consultant, as well as external stakeholders, have a lucid and transparent trajectory to understand expectations and potential benefits for them.

The roadmap is not meant to be and will not be a substantial handbook or officially approved by any law methodology.

As a working definition, EnTRAINER project focuses on those companies operating within industrial sectors that significantly contribute to the overall quantity of CO2 emissions through their activities.

In the current version of this report, a considerable share of the information is dedicated to the decarbonization technologies from the partner countries in the project. This is intended to assist those drafting the decarbonization roadmap in selecting strategies that best fit the needs of the companies being audited. The final version of this report, due at the conclusion of the EnTRAINER project, will be completed and balanced with examples of roadmaps for companies from various industries, made following the implementation of ETAs.

1.4. Guidance in reading the deliverable

The project aims to shift the paradigm from the traditional energy audit process by introducing a holistic and comprehensive methodology known as ‘Energy Transition Audits’. This innovative approach shifts the emphasis towards a multi-faceted approach, offering a range of benefits and delivering a comprehensive action plan for achieving complete decarbonization of the audited sites. For this purpose, an audit methodology was designed, described in detail in a report that constitutes as a project deliverable, with the title D2.1 *Holistic Energy Transition Audit Methodology*.

The present report entitled as D2.2 *Decarbonization roadmap* serves as a supplementary resource to D2.1 report, providing guidance to energy auditors and beneficiary companies. Its purpose is to assist in the development of a decarbonization roadmap, outlining the essential steps for companies to decarbonize their operations and establish strategies aligned with achieving net zero emissions.

For thorough comprehension and optimal utilization, it is recommended to use both documents in tandem. This document, acting as a complementary report to D2.1, makes frequent references to subchapters from D2.1 across various sections. Consequently, employing these two reports together will enable a more comprehensive and cohesive approach to the subject matter, promoting better integration of the information provided.

D2.2 *Decarbonization roadmap* report is structured in three main chapters, completed with a section of conclusions.

In the first chapter, a review is made. The context in which large, energy-consuming industries had to initiate decarbonization actions is presented. This highlights the actuality and necessity of this document, which is ultimately intended to be a working document for energy professionals, but not only for them.

The second chapter supports a better understanding of the decarbonization actions that large, energy-consuming companies have at hand to reach their proposed CO2 reduction targets.

The review of the technologies that allow the reduction of CO2 emissions available for energy intensive industries is useful for energy auditors in defining the plan of decarbonization measures as a result of the ETA. Auditors can review the available technologies and suggest the use of the ones that are the most appropriate, considering the available resources of the company, the targeted economic sector and the national/international regulations in place.

Chapter 3 serves as a comprehensive guide for both auditors and beneficiary companies of an ETA, assisting them in designing and implementing a decarbonization roadmap. This chapter is closely interconnected with the ETA methodology described in detail into D2.1.

This chapter emphasizes and outlines the key stages that companies should undertake to achieve their net zero objectives. The highlighted steps are interconnected with subchapters from D2.1 and additional tools developed specifically for energy auditors are emphasized, as illustrated in Figure 2.

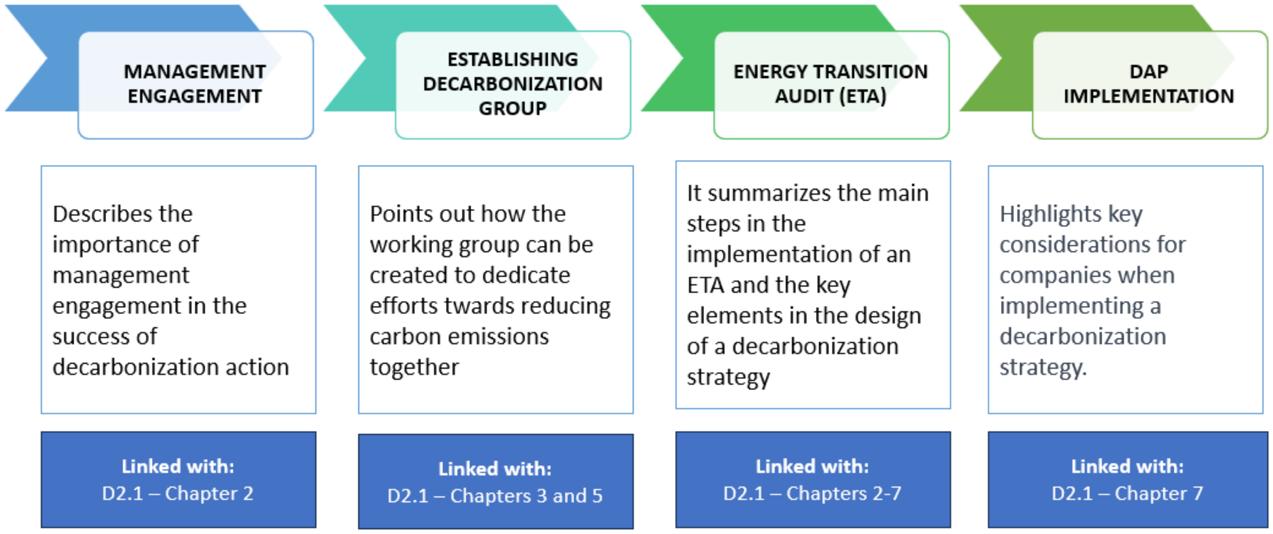


Figure 2: Main steps of decarbonization roadmap implementation.

2. Understanding decarbonization - Definition and strategies

Decarbonization is the process to reduce human-caused CO2 to limit the unprecedented, life-threatening impacts of global warming and climate change. Decarbonization requires a coordinated global shift to alternative energy sources other than fossil fuels (oil, gas, and coal).

At present, energy use is the main source of CO2 emissions–contributing 83% of CO2 emissions globally. Over 34 billion metric tons of CO2 emissions are emitted every year into the atmosphere. The endeavour to mitigate climate change and shift to a low-carbon economy by reducing or eliminating CO2 emissions from diverse sectors, involves decreasing the reliance on fossil fuels, which are major contributors to GHG emissions, and moving towards cleaner, renewable energy sources, along with adopting energy-efficient technologies and practices [7, 9].

Achieving complete decarbonization in complex and interconnected industrial environments needs a comprehensive and multifaceted approach and should focus on the key action areas emphasized in Figure 3.

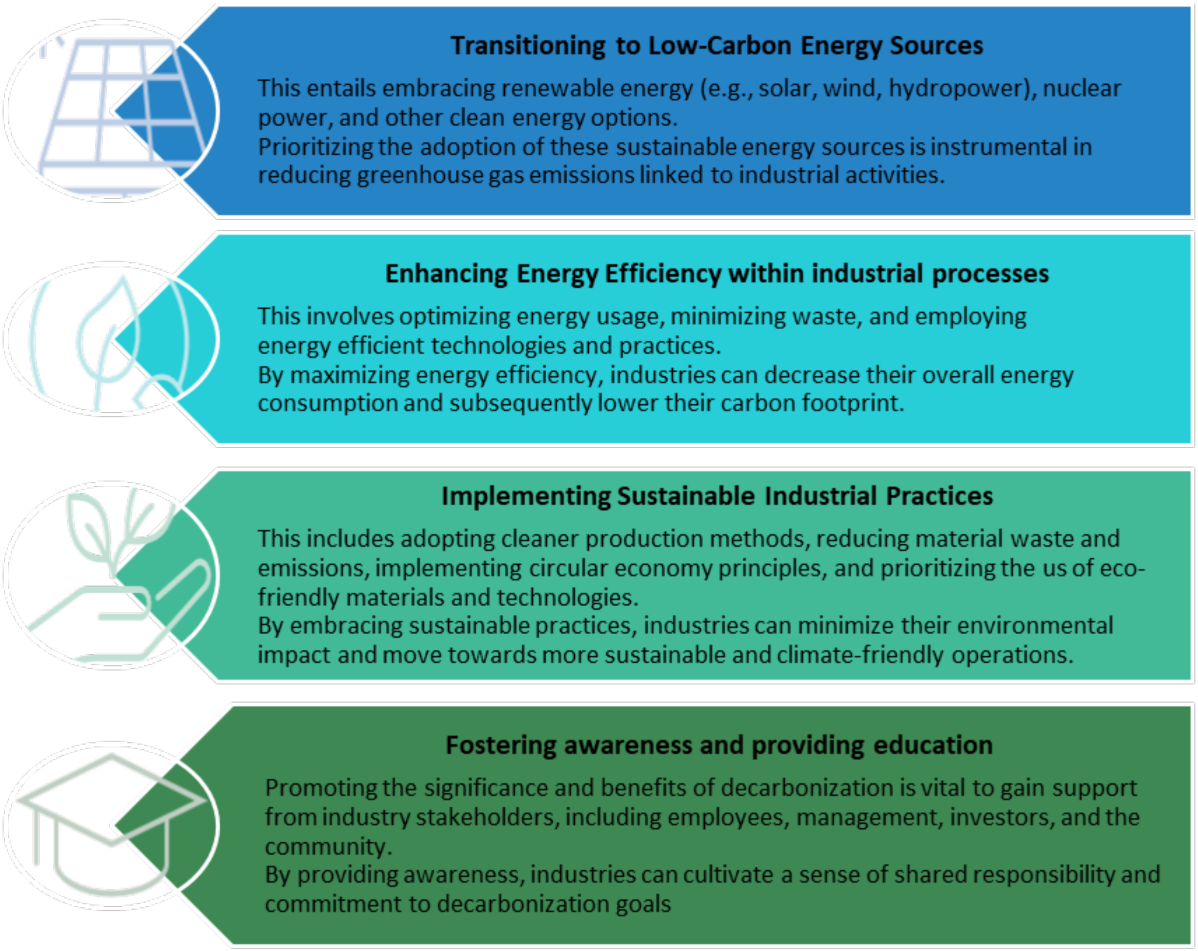


Figure 3: Key areas for decarbonization.

By focusing on these action areas—(a) transitioning to low-carbon energy sources, (b) enhancing energy efficiency, and (c) implementing sustainable industrial practices—the industry sector can make significant strides towards achieving full decarbonization. This multidimensional approach addresses the interconnected challenges of reducing emissions and fostering a sustainable future for industrial operations and represents also the EnTRAINER project main concept.

Cross-disciplinary research emphasizes that decarbonizing the industrial sector is widely regarded as the costliest endeavour. This is primarily because many of the available options for reducing emissions in this sector are either prohibitively expensive or not yet available at a large scale.

Because supply side constraints would limit the transportation and buildings sectors contributions to the 2030 reduction target, industrial companies would have to implement more expensive decarbonization technologies, such as electric boilers and CCS, to get the EU to the 55% reduction target [6, 10].

After 2040, when power, transportation, and buildings reach almost their full abatement potential, industry would need to abate another 40% of its last, most expensive emissions. Part of the very hard-to-abate industrial emissions are offset by bioenergy with carbon capture and storage (BECCS) on processes like ammonia or cement production. As a result, industry emissions could be reduced by more than 95% in 2050. The residual emissions would be offset outside the sector, for example by natural carbon sinks such as reforestation [10].

A net zero strategy comprises of two components, i.e., a pathway for reductions and a pathway for removals. While these pathways can be pursued simultaneously, the primary focus should be on reductions initially. The reductions pathway establishes the pace of decarbonization in accordance with scientifically grounded trajectories. On the other hand, the removals pathway offers additional measures to offset unavoidable residual emissions when reductions alone are inadequate to achieve climate goals aligned with the Paris Agreement.

Thus, a credible net zero target: (1) covers all relevant emissions, (2) prioritizes a reduction in emissions in line with climate science, and (3) neutralizes the residual balance of emissions through carbon removals. Companies should take a phased approach to build their net zero pathways [11]:

1. **Establish a baseline**: Calculate a full value chain emissions baseline.
2. **The reduction pathway**: Develop a Science-Based Targets initiative (SBTi) - approved target to deliver absolute reductions in scopes emissions.
3. **The removal pathway**: Develop a credible emission removal strategy to offset residual emissions.

Therefore, a well-designed decarbonization strategy is essential for providing a clear pathway, guiding policy decisions, attracting investments, fostering collaboration, and ensuring effective monitoring and evaluation. It serves as a vital tool in achieving the necessary transformation to a low-carbon and sustainable future.

2.1. Essential Insights into evaluating CO2 emissions

Net-zero emissions, as defined, refers to the significant reduction of GHG emissions to the lowest feasible level. Any remaining emissions are counterbalanced by absorption methods such as those provided by oceans and forests. A business achieves net-zero when it has successfully eliminated all possible carbon emissions and then offsets any remaining emissions through additional mitigation measures beyond its value chain.

The net-zero process starts with calculating emissions across Scope 1, 2, and 3, setting science-based targets, developing decarbonization pathways until 2030, and gradually moving towards long-term carbon capture, storage, and sequestration for those emissions which cannot be reduced.

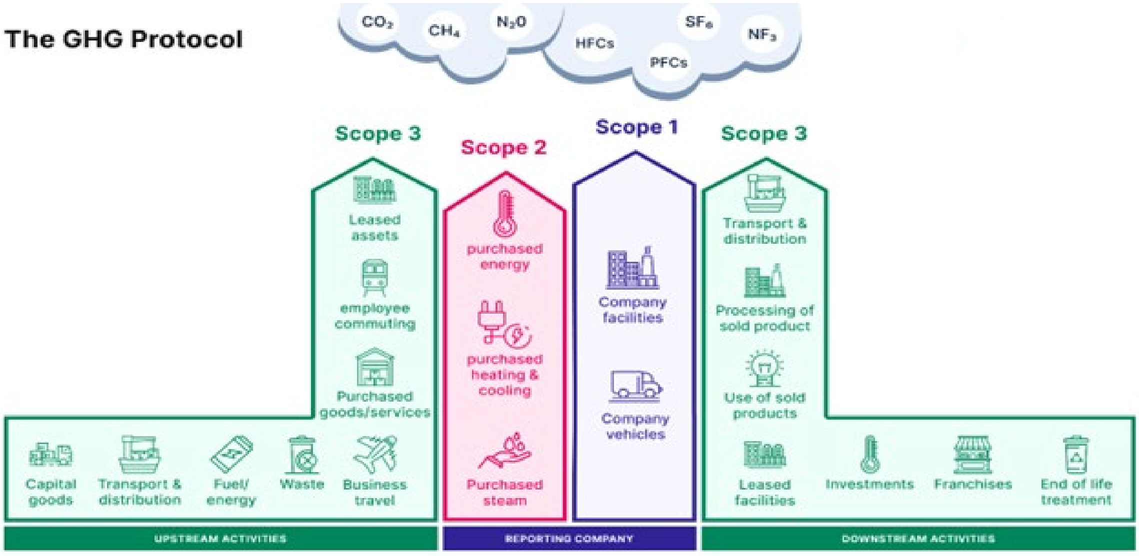


Figure 4: Mapping of Scopes 1, 2 and 3 [12].

These Scopes identify the location within the value chain to calculate a carbon footprint that the emission generating activity occurs:

- **Scope 1** – direct emissions occurring from sources owned or controlled by a company. Examples are fuels (stationary and mobile) use and refrigerant losses.
- **Scope 2** – indirect emissions associated with the purchase of electricity, steam, heat, or cooling, generated by the producer(s) and provider(s).
- **Scope 3** – indirect emissions associated with activities occurring across a company's value chain – outside of its direct influence. This covers a variety of tertiary activities.

While all three scopes are important, the EU recommends prioritizing emissions reduction efforts in the following order:

- Scope 1: Focus on reducing direct emissions from owned or controlled sources, as they have the most immediate impact and are within the company's direct control.

- Scope 2: Address indirect emissions from purchased electricity, heat, or steam, which can be reduced through sourcing renewable or low-carbon energy options.

- Scope 3: Identify and address significant indirect emissions from the value chain, including supply chain emissions, business travel, and customer use of products or services. These emissions require collaboration with external stakeholders and may involve more complex measurement and reduction strategies.

To evaluate CO2 emissions, companies should follow several steps. Firstly, they need to conduct a thorough assessment of CO2 emissions by considering all pertinent scopes and sources within the company. This involves collecting data on energy consumption, fuel usage, transportation activities, and other relevant metrics from various departments and sources.

To obtain accurate estimates, companies should employ standard emission factors or calculate site-specific emission factors. Monitoring and measurement tools like energy meters, emission tracking software, or data management systems should be utilized to track and report emissions continuously. Lastly, it is crucial to regularly review and update emission data to maintain data accuracy and reliability.

The EU provides guidelines for reporting CO2 emissions, including the European Union Emissions Trading System (EU ETS), which covers Scope 1 emissions from certain industries. Companies subject to EU ETS are required to monitor, report, and verify their emissions annually.

Once emissions are identified and assessed, companies can set reduction targets aligned with EU regulations or international frameworks like the Paris Agreement. Targets should be ambitious, time-bound, and consider the prioritization of scopes based on the company's context.

Visibility into CO2 emissions from direct and indirect sources enables enterprises to commit to a sustainable business framework, and devise policies to reduce the carbon footprint.

2.1.1. Practical approaches to calculating CO_2 emissions

The process of calculating CO_2 emissions typically involves four steps:

1. **Data collection** – gathering activity data on fuel use, purchased electricity, transport activity, or material inputs;
2. **Application of emission factors** – multiplying activity data by appropriate emission factors;
3. **Consolidation by scope** – categorizing emissions according to Scope 1, Scope 2, and Scope 3 boundaries;
4. **Verification and updating** – reviewing calculations periodically to ensure accuracy and alignment with evolving standards.

Example
A company consumes 10,000 liters of diesel for on-site operations (Scope 1). Using an emission factor of 2.68 kg CO_2 per liter, this results in 26.8 tCO_2. *Purchased electricity of 500,000 kWh (Scope 2) is multiplied by the grid emission factor (e.g., 0.25 kg CO_2/kWh, resulting in 125 tCO_2.* *If outsourced logistics amount to 200,000 km of truck transport, applying a freight transport emission factor (e.g., 0.9 kg CO_2/km yields 180 tCO_2), reported under Scope 3.*

Table 1: Emission Factors

Nr.	Fuel	Emission Factor	Unit
1	Natural gas	0.202	kgCO2/kWh
2	Liquid gas - Liquefied Petroleum Gases	0.23	kgCO2/kWh
3	Liquid Gas - Natural Gas Liquids	0.23	kgCO2/kWh
4	Diesel	0.268	kgCO2/kWh
5	Gasoline	0.25	kgCO2/kWh
6	Lignite	0.365	kgCO2/kWh
7	Coal - Anthracite	0.356	kgCO2/kWh

8	Biogas	0.197	kgCO2/kWh
9	Biomass (wood)	0.4	kgCO2/kWh
10	Solar thermal	0	kgCO2/kWh
11	Geothermal	0	kgCO2/kWh
12	Electricity renewable - wind	0	kgCO2/kWh
13	Electricity renewable - Photovoltaics	0	kgCO2/kWh
14	Electricity	as per table below	kgCO2/kWh
15	District heating	depends on each country if applicable	kgCO2/kWh

Table 2: Country-Specific Electricity Emission Factors

Country	Electricity	Unit
Greece	0.416	kgCO2/kWh
Italy	0.252	kgCO2/kWh
Romania	0.247	kgCO2/kWh
Spain	0.205	kgCO2/kWh

Additional information about emission factors and emission inventory are available in Deliverable *D3.2 – Report on engagement of the clients and initial energy scans* and can be access using this: link

Additional relevant sources for emission factors:

1. EFDB emission factor database. Available online: link
2. Greenhouse gas reporting: conversion factors 2023. Available online: link
3. Greenhouse gas emission intensity of electricity generation in Europe. Available online: link

Tools for data collection and footprint calculation

A wide range of initiatives are available to facilitate data collection and emissions accounting, and these can be grouped into three categories:

*1. **Data collection tools***

Smart meters provide real-time monitoring of electricity, gas or water use and transmit this data wirelessly to utility operator, while sub-metering systems based on long-range networks allow granular, remote measurement of consumption at the level of individual units within a building. These systems are often integrated into broader energy management platforms and IoT-based monitoring infrastructures.

*2. **Carbon accounting frameworks and calculation tools.***

For emissions accounting, several widely adopted frameworks and software tools offer standardized methods. The GHG Protocol's suite of tools enables organizations to develop comprehensive and reliable inventories of their greenhouse-gas emissions, and standards such as ISO 14064 or reporting platforms like CDP build on similar principles. Free, open-source LCA software such as openLCA, developed since 2006 and widely used across sectors, provides footprint calculations with a broad range of features and databases. Emerging platforms like Climatiq offer AI-powered carbon calculation engines and claim to host extensive databases of carbon impact data, enabling Scope-1-to-3 calculations via an API.

*3. **Sector-specific and EU-level resources. High-quality emission-factor databases and sectoral guidelines support more detailed analyses.***

The *Ecoinvent Database* contains over 25 000 datasets modelling activities and processes, enabling users to trace environmental impacts across supply chains. The IPCC's Emission Factor Database (EFDB) serves as a recognized library of emission factors and related parameters, complete with background documentation for estimating emissions. In the United States, the EPA's GHG Emission Factors Hub supplies a regularly updated set of default emission factors for organizational reporting. EU-level resources, such as the European Environment Agency's emission inventories and national greenhouse-gas inventory reports, provide additional reference data for region-specific analyses.

Together, these tools and resources the EnTRAINER suite can enhance data collection, expand calculation capabilities, and improv the accuracy of carbon inventories across different sectors and jurisdictions.

Other recommendations for practical approaches

- Establish a reliable baseline by starting with Scopes 1 and 2, progressively expanding to Scope 3 where relevant.
- Use simplified estimation methods where precise data are unavailable, while planning for continuous improvement in data accuracy.
- Combine technical tools with organizational capacity building, training energy managers and engineers to maintain consistent monitoring and reporting.
- By adopting this structured approach, companies can ensure that their decarbonization roadmaps are not only aligned with international standards but also reflect the full range of their carbon impacts.

2.2. Pillars of decarbonization

A decarbonization roadmap should assess four keys 'pillars' of industrial decarbonization: energy efficiency; industrial electrification; low-carbon fuels, feedstocks, and energy sources; and carbon capture, utilization, and storage. Each represents a high-level element of an industrial decarbonization action plan, and a cohesive strategy will require all four pillars to be pursued in parallel. Application of these pillars can enable the industrial sector to reach near-zero CO2 emissions, with the balance of reductions required for an overall net-zero outcome achieved through the application of alternative strategies reaching beyond the four pillars (such as negative emissions technologies) [13].

1. **Energy efficiency** is a foundational, crosscutting decarbonization strategy. Reducing the energy consumption of the industrial sector directly reduces CO2 emissions associated with fossil fuel combustion.
2. **Industrial electrification** enables industries to shift from combustion fuels to electric power, capitalizing on advancements in low-carbon electricity from both grid and onsite generation sources. For grid-purchased electricity, this strategy is predicated on the assumption of 'greening of the grid' – i.e., parallel advancements made in the electric power sector to

increase use of nuclear, renewable, and low-carbon fuel sources and reduce combustion emissions.
3. **Substitution with low-carbon fuels, feedstocks, and energy sources (LCFFES)** such as hydrogen, biofuels, or solar thermal power, can further reduce combustion-associated GHG emissions for industrial processes.
4. **Carbon Capture, Utilization, and Storage (CCUS):** is a comprehensive approach to reduce challenging emissions sources by capturing and utilizing CO2 and storing it securely to prevent its release into the atmosphere. [3]

2.3. Available technologies for energy-intensive industries

2.3.1. Energy efficiency

Energy efficiency actions should be the priority and stay like this, as even from the conventional energy audits, the main outcome is the energy efficiency action plan. Moreover, the continuous dynamic of the technology results in significant improvements, both in productivity and lower specific energy use. Therefore, all the industries will continue to be interested in strengthening their economic competitiveness by implementing energy efficiency measures.

A variety of energy efficiency measures and technologies can be employed to reduce energy use. The best technology choice is determined by a combination of energy savings, availability, supporting policies, and other important factors. A sample list of common options appears below [14].

Motors and Pumps (industrial, agricultural, and commercial) represent a substantial opportunity for energy efficiency improvements. It is estimated that electric motors account for 69% of electricity use in the industrial sector, 38% in the commercial sector, 22% in the residential sector, and 39% in the transportation and agriculture sectors combined [15].

Variable-Speed Drives (VSD) and High-Efficiency Motors are used to control motor speed and torque by varying motor input frequency and voltage. Installing a VSD makes it feasible to closely correlate demand on the motor with the energy consumption by the motor and results in significant energy savings.

Lighting is often the first stop for energy improvements, due to its short investment payback period. Light-emitting diode (LED) bulbs are considered top-tier in terms of energy efficiency, and their prices have recently become more competitive with other efficient lighting technologies such as compact fluorescent lamps (CFLs). Other types of efficient lamps are: **High Performance T8s, HID Lamps** and **T5Hos.** Automated control technology enables building managers and owners to reduce the need for lighting, heating, or cooling during low-occupancy hours of operation. **Occupancy Sensors and Timers** are used to turn the lights on or off automatically. **Dimming controls** are devices used to lower the brightness of a light.

Heating, Ventilation, and Air Conditioning (HVAC): Programmable Thermostats are designed to adjust the temperature according to a series of programmed settings that take effect at different times of the day. **HVAC: Building Automation Systems** can reduce energy consumption and operating costs by centralizing automated control of the heating, ventilation, air conditioning, lighting, and other systems.

Process Equipment: Automatic Scheduling determines how long equipment is required to operate, turning it on and off as needed.

Smart Meters are electronic devices that record the consumption of electric energy in intervals of an hour or less and communicate that information to the utility for monitoring and billing. Since smart meters allow consumers to monitor their electricity consumption rates in real time, they can be paired with other behavioural incentives (i.e., price signals during peak-consumption hours) to positively reinforce energy conservation.

Table 3: Specific actions related to energy efficiency in each project partner's country.

GREECE
In Greece, various technologies for increasing energy efficiency are mainly used through existing financial support schemes. The National Energy and Climate Plan (NECP) set out a set of energy efficiency improvement measures, the most ambitious ones related to buildings and transport. According to the available final energy consumption figures, cumulative energy savings of at least 7.3 Mtoe should be achieved over the period 2021-2030. In addition, an objective is set for the annual energy renovation of a total floor area of the thermal zone of central public administration buildings equal to 5,400 square meters, representing 3% of the total floor area. Also, a central quantitative objective is going to be established for the renovation and replacement of residential buildings with new nearly zero-energy buildings, which could be translated in aggregate amount to 12-15% of all residential buildings by 2030. The annual objective is to have an average of 60,000 buildings or building units upgraded in terms of energy and/or replaced with new more energy-efficient ones. Moreover, in the past few years and in compliance with the EU targets for decarbonization, Greece has announced several actions that are related to decarbonization activities and technologies, including provisions for the crucial part of decarbonizing the industry sector. To start with, the 'Green transition of SMEs' program has been published on the 6th of March 2023 by the Special Management Agency for Operational Program 'Competitiveness, Entrepreneurship & Innovation'. It includes a set of eligible actions for providing support to SMEs by subsidizing certain expenses. It comprises of 2 actions, i.e., 'Action 1: Green Transformation of SMEs' with budget from EUR 200,001 to EUR 1 million, and 'Action 2: Green Productive Investment of SMEs' with budget between EUR 30,000 and EUR 200,000. Among others, eligible are costs for equipment (GREEN) for energy efficiency/energy savings improvement, with up to 50% funding. In this category, eligible are costs related to commissioning, transport, installation of equipment including the corresponding necessary ICT (hardware & software), which aim to improve energy efficiency and save energy. Moreover, within the 'National Plan for Recovery and Resilience – Greece 2.0', several actions for the 'Green Transition' have been announced, including 'Energy and entrepreneurship' in component '1.2 Renovate' , which describes investments for energy efficiency improvement of buildings, energy efficiency upgrade of the production process, including waste heat recovery, installation of new or replacement of existing heating or cooling system as well as hot water supply with RES system, high efficiency cogeneration for self-consumption. Also, the installation of smart systems and IT equipment, electrical vehicles for the distribution of products and raw materials within and outside the production area and charging points, and the installation of energy efficient equipment. Finally support actions (energy Audit, energy and technical consulting, Energy

Performance Certificate, monitoring and management of the implementation of the investment plan) can be also financed. Finally, the 'Green Businesses' and 'Support to Improve Energy Efficiency in Industrial Processes' programmes aim at the deployment of environmentally friendly products and the energy consumption and cost reduction within the industrial processes.
ITALY
Regarding energy efficiency in the sectors subject to the Energy Audit obligation (energy-intensive companies and large enterprises), Italy is quite far ahead, as these companies are forced to install monitoring systems for energy consumption, to send an annual report on energy consumption to ENEA and to improve at least one of the energy efficiency measures identified by the auditor within four years after the first energy audit. The very high cost of almost all energy vectors and the incentive system of so-called white certificates have also pushed large companies and energy-intensive businesses to make their plants more efficient to be more competitive by lowering production energy costs.
ROMANIA
Romania established coherent and effective investment schemes to prioritize energy efficiency measures, enabling a successful transition to a decarbonized economy aligned with their Paris Agreement commitments and energy union objectives, as national long-term strategies in April 2023 [16-17]. Sustainable Development Operational Program 2021-2027 - a program dedicated to sustainable development that targets energy efficiency in the industrial sector and supports large enterprises and SMEs in improving their energy efficiency. The financial allocations for this type of investment amount to approximately EUR 470 million. Regional Operational Programs (ROP) 2021-2027 - Energy efficiency works targeting residential and public buildings as well as the district heating systems will be eligible for finance in the new ROP as part of priority axe 3 – A region with environment friendly cities. The approximate budget available for these interventions amounts to EUR 870 million, divided between 8 regions of Romania [17]. Long-term national renovation strategy proposes measures to improve energy efficiency, to reduce GHG emissions and to increase the renewable energy share in the total energy consumption through renovation of the national stock of buildings. The measures developed under the strategy are designed to reduce energy poverty (currently estimated at 1.7 million households), to improve thermal comfort and the level of safety in buildings, and to support the development of skills and innovation in the energy efficiency sector. The budgetary implications for the implementation of the Strategy are estimated at EUR 5 billion by 2030, which will be covered by the state budget and European funds available through the new operational programs for 2021-2027 and the Recovery and Resilience Facility – approximately EUR 870 million will come from the ROP 2021-2027, and EUR 2.2 billion are available through the allocations of the national recovery and resilience plan.
SPAIN
Spain is conducting a national plan towards decarbonization and energy efficiency (Energy and Climate National Integrated Plan, PNIEC 2021-2030), which includes different measures and policies promoting CO2 emissions-free technologies that are being currently implemented. Public administration is handing economic advantages for new renewable plants, considering the competitive aspect of traditional generation plants in the transition towards a more sustainable electrical system. Other incentive and funding programs, such as the IDAE grants, support energy efficiency projects and the implementation of management systems.

In 2022, Spain registered 254.5 M tons of CO2 emissions from energy through consumption of oil, gas and coal for combustion related activities and process emissions, which shows a 2.2% decrease from 2011.
The sector with the highest level of GHG emissions was transportation (27%), followed by industrial activities (20.8%), agriculture (14%) and electricity generation (11.8%). Out of the total emissions, 77% were attributed to CO2. Also, various policies promoting CO2 emissions-free technologies are applied.

2.3.2. Technologies dealing with electrification

Battery Technologies optimize the energy-power trade-off and maximize energy density through advanced materials and designs. Engineering analytics are applied to cut development costs. Further, sustainability requires the elimination of heavy metals like cobalt and cadmium. Recycling or disposal of batteries is also a key to ensure a minimal impact on the environment.

Electric Vehicle (EV) Charging Infrastructure improvements in charging time, affordability, and convenience greatly affect the adoption of electric vehicles.

Grid-scale Storage plays an important role in electrification as it improves the operating capabilities of the grid and lowers costs. Innovations in grid storage technologies, such as pumped hydro, compressed air energy, thermal energy, fuel cells, flywheel storage and batteries, offer more flexibility with variable power sources and higher energy demands, allowing higher penetration of renewables, thus accelerating the integration of renewable energy sources.

Energy Intelligence offers predictive analytics solutions for EVs. Big data analytics also drives better decision-making in planning for new EV infrastructure development and integrations.

Thermal Management Systems are crucial for electric devices to ensure their optimal performance and efficiency. This electrification trend includes all innovative heat management solutions that maintain batteries, power electronics, and electric motors at optimal temperatures.

Internet of Things is a key enabler of asset digitization, data collection, and computational capabilities in electrification efforts to better manage interconnected assets. It enables the real-time transfer of information and allows EV manufacturers to stay competitive.

Off-grid Energy Generation offers a more cost-effective alternative to extending existing grids in remote locations. These solutions allow end users to easily move away from grids that utilize fossil generation and adopt renewable energy sources. This aids sustainable electrification.

Microgrids and Energy Communities technology supports the development of a flexible and efficient electric grid by integrating distributed energy resources (DERs), such as solar and geothermal energy, together with batteries and intelligent demand response techniques.

Lightweight Technology solutions applied to electric vehicles improve efficiency and increase the range. Advances in lightweighting include developing new composite materials and innovative structural designs. Moreover, lightweight technologies translate to compact and power-saving solutions, leading to reduced cost of EV ownership and improved performance.

Sector Coupling: Energy storage technologies, power-to-X (P2X) applications, and demand-response solutions interlink the power-producing sector with power-demanding sectors.

New energy sources: floating offshore wind, solar trackers and floating solar, mini nuclear facilities [18].

Table 4: Specific actions related to technologies dealing with electrification in each project partner's country.

GREECE
The electrification concept is massively targeted, with the increase of the renewable energy sources integration into the existing electrical networks. Aim is to increase the exploitation of the generated clean energy, by PVs and wind power, combined with energy storage. In 2020 energy and climate targets, the country's energy policy focuses on boosting the use of renewable energy, especially for electricity generation, in tandem with increasing the share of energy demand covered by electricity, especially for transport and heating and cooling. Greece recently made several significant changes to its support scheme for renewable electricity generation to increase the rate of deployment. Greece is also taking steps to reduce the time needed for licensing and permitting projects for renewable energy, electricity infrastructure and energy storage. In August 2022, Greece approved its first Offshore Wind Law, which aims at 2 GW of offshore wind capacity by 2030. Greece is a global leader in the use of solar thermal to cover domestic hot water demand. There are also major investments planned to boost transmission and distribution capacity to support much higher levels of generation from wind, solar PV and hydro. The government also aims to connect the most populated islands to the mainland electricity grid by 2030. As for specific actions, the 'Green transition of SMEs' program has been published on the 6th of March 2023 by the Special Management Agency for Operational Program 'Competitiveness, Entrepreneurship & Innovation'. It includes a set of eligible actions for providing support to SMEs by subsidizing certain expenses. It comprises of 2 actions, i.e., 'Action 1: Green Transformation of SMEs' with budget from EUR 200,001 to EUR 1 million, and 'Action 2: Green Productive Investment of SMEs' with budget between EUR 30,000 and EUR 200,000. Among the eligible costs relative to the GREEN transition are costs for the installation of PV plants and storage systems to improve the self-consumption, including, commission and installation of PV plant with up to 10kW installed capacity, commission and installation of electric storage systems with minimum useful capacity equal to the energy produced by the corresponding PV station for a hour, installation of EV charging units, smart energy meters and telemetry (smart metering). Regarding the transport sector, as the stock of vehicles on Greek roads is also among the oldest in the EU, subsidies and fiscal measures aim to increase the adoption of EVs. Within the 'Green transition of SMEs' action, eligible are costs for the electrification of transport means (GREEN) with up to EUR 50,000 maximum amount of granted budget. Moreover, within the 'National Plan for Recovery and Resilience – Greece 2.0', several actions for the 'Green Transition' have been announced, including the 'Framework for installation and operation of EV charging infrastructure' in component '1.3 Recharge and refuel', which is compliant with the Law 4710/2020 'Promotion of e-mobility in Greece'. This law promotes the installation of publicly accessible e-vehicle charging infrastructure by 2022.
ITALY

The main technology for electrification of thermal needs is the heat pump. For example, in the industrial sector, if there is production of waste heat at low temperatures, heat pump systems can be used to generate hot water for other processes and consequently to reduce the consumption of natural gas. Through these systems it is also possible to obtain incentives such as White Certificates. Moreover, waste heat recovery systems from compressors (of compressed air systems) that recover heat to produce hot water for DHW use or for washing tanks and machinery in the food industry are quite common. However, large-scale implementation of these heat recovery processes is still uncommon, despite several studies that have demonstrated their potential.
ROMANIA
Companies and municipalities in Romania are researching and implementing the latest technologies dealing with electrification: - The number of charging stations for electric cars is now up to 950 in Romania but growing constantly (as the number of electric cars is also growing and the need for high-capacity EV chargers is increasing as well). - Companies are interested in creating new generations of higher capacity batteries but also recycling the lead from used batteries. - Microgrids that ensure onsite power generation and onsite battery energy storage are also being more and more used in Romania. The scalable microgrid control platform with island-mode capability, comprehensive energy conservation and load reduction measures also contribute to the energy security of the electro-energetic system.
SPAIN
Spain is actively promoting electrification in industrial sectors as part of its decarbonization efforts. The government provides incentives, grants, and tax benefits for industries to invest in electrification projects, integrated within the framework of the PNIEC program. These incentives aim to encourage industries to replace fossil fuel-based systems with electric alternatives with the use of electric machinery, equipment, and processes in manufacturing, production, and other industrial activities. In terms of renewable energy sources, 58% of the installed capacity of the Spanish generation system is renewable, a percentage that continues increasing every year. During 2022, 5,663 MW were connected to the grid (1,382 MW wind power and 4,281 MW photovoltaic), to which 2,649 MW were added in self-consumption projects. Renewable energies represent a very significant percentage of the energy mix, accounting for 42.1% of the country's electricity production. Last year, wind energy covered 22.1% of demand, while photovoltaic and hydroelectric energy covered 10.1% and 8% respectively. Technologies using biomass have a significant potential in Spain, with over 857 MW of installed power. Biomass power plants, both exclusively dedicated and co-firing with coal, contribute nationally to renewable energy generation and there is a Biomass Technology Platform and research institutions who support the development of this kind of energy source. On the other hand, technologies for deep geothermal energy are null due to the lack of high temperature deposits. Some plants use medium temperature; however, their prevalence is restricted due to geological and economic factors, as well as insufficient institutional support. Finally, solar thermal energy has slowly increased its capacity in recent years, although to a much lesser extent than photovoltaic energy. Currently, the installed capacity in the country is around 2,304 MW. However, several subsidies to increase these technologies are foreseen in the national plan, especially for the residential sector, so a considerable increase is foreseen in the coming years. Measures to promote renewable energies aim to reach 74% of the total energy production with these technologies, with the consequent contribution to the decarbonization plan.

2.3.3. Technologies for deep geothermal energy

Geothermal energy is a natural form of renewable energy generated from the heat of the earth core. Developments in drilling technology and geophysical techniques mean that systems can be engineered at depths more than 5km. Boreholes are drilled to access natural reservoirs of hot water and transferred to heat exchangers for use as direct heat. In the case of ‘hot rocks’ or ‘Engineered Geothermal Systems (EGS)’ schemes, water is pumped from the surface into rock formations where it is heated and returned to the surface. Old mine workings are another source of heat and are a good resource if located close to a heat load. The heat is then used to generate electricity via a turbine/engine and, if a heat load is present, the residual heat can be used via a combined heat and power (CHP) process. After the heat has been exploited, the water is recycled back down into the ground via a second borehole. Deep geothermal energy can be used for electricity production, or to provide heat for commercial, industrial and residential buildings. It can also be used in industrial processes, such as cooling, or in aquaculture and horticulture.

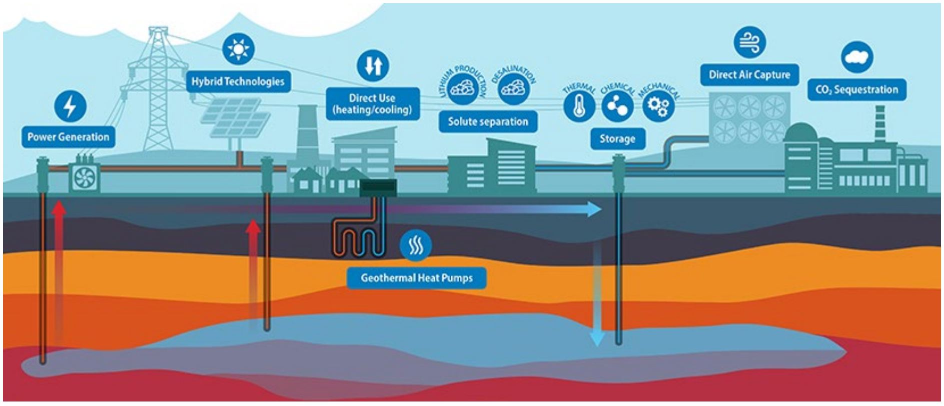


Figure 5: Geothermal Energy’s full potential [21].

Table 5: Specific actions related to technologies for deep geothermal energy in each project partner’s country.

GREECE
The contribution of geothermal energy to cover the thermal needs in Greece is low, identified mainly in the tertiary and the agricultural sector. However, the participation of geothermal energy in the final thermal energy consumption is expected to be increased together with the share of other RES. Within the next period, biomass and geothermal energy district heating networks of 30-40 MWth are envisaged to be developed. With regards to domestic electricity production, geothermal plants are expected to contribute by 1.1% in the future. All the above are to be supported by various institutional actions, such as laws, ministerial decisions and financing programmes, targeting to increase the geothermal energy share into the Greek energy mix. Currently, aiming at improving energy efficiency, the programme ‘Promotion of RES systems for heating and cooling and for cogeneration of heat and power for own consumption’ promotes thermal energy, among other RES, for heating/cooling and power production for self-consumption by financing relevant projects. In addition, there are various regional operational programmes implemented or planned concerning projects for heating/cooling using energy generated from RES. An indicative example is

the district heating project in the Municipality of Alexandroupolis with a maximum heat transfer capacity of 10 MWth, taking advantage of the geothermal field of Traianoupolis. Furthermore, the obligation that all the new private buildings as of 2021 and all the new public buildings as of 2019 should be nearly zero energy buildings is expected to increase the share of RES, including geothermal energy, for heating/cooling by 2030. Regarding the regulatory framework concerning geothermal applications, Law 3175/2003 on the utilization of geothermal energy and various Ministerial Decisions facilitate the rational use of geothermal energy, determine the conditions and procedures for their designation, exploration and management, as well as the authorizations for the construction of heating/cooling projects for own use and the exploitation of low-temperature fields for agricultural holdings. Finally, the Ministry of the Environment and Energy created a working group in charge of recommending a draft law on addressing all the issues preventing the promotion of geothermal applications.
ITALY
Italy has an historical record: it has been the first country in the world to produce electricity from geothermal energy, more than a century ago. Today, it is still among the top producers in the world and in first place in Europe. In 2021 in Italy, electricity production from geothermal energy was 0.51 Mtoe and thermal production was 0.14 Mtoe. Production data are as follows: 34 active plants and 817 MW of installed power. All the plants are installed in the provinces of Pisa, Siena and Grosseto. Condensing (85% of MW installed) and single flash (14% MW installed), plants are mainly used for electricity production. Only 1 MW is produced by binary cycle plants. The contribution to the national energy capacity is 1%, while the contribution to the national energy demand is 1.7%. Regarding direct heat use, 226 plants are installed, producing 5,885 TJ, subdivided as follows: 1,602 TJ for room air-conditioning, 2,451 TJ for thermal use, 620 TJ for agricultural use, 1,157 TJ for aquaculture and 57 TJ for industrial processes. The main district heating plants are installed in the Tuscan geothermal areas. In fact, 72.1% of heat consumption from geothermal energy is concentrated in Tuscany and Veneto. The geological characteristics of the Italian territory are favourable to the development of geothermal energy and could allow the exploitation of this resource through almost all available technologies, being able to exploit low-, medium- and high-enthalpy resources at different depths and in numerous areas of the country. An official estimate of the geothermal potential referring to the entire territory is lacking, but the MiSE has published the geothermal zoning of the Italian territory on a municipal scale, which can be a valuable aid in identifying the most favourable areas.
ROMANIA
Romania is third or fourth in Europe in geothermal energy potential. Exploration is currently being conducted at 24 sites. The sites are in the counties of Arad, Bihor, Harghita, Ilfov, Satu Mare, Timiș and Vâlcea. Selected operators are entitled to 49-year concession contracts for exploitation. Exploration for hydrocarbons has already uncovered over 200 wells with temperatures of up to 120 degrees Celsius. The optimal level for heating homes is 90 degrees, while at 45 degrees, the water can be used for thermal baths. Public funds have been invested in projects for heating public buildings. There is a long way before establishing accurate data, but the country is scattered with underground sources of geothermal waters and the Geological Institute of Romania estimated that, in geothermal energy potential, Romania is third or fourth in Europe. Italy, Greece and Iceland being at the top of the list [22].
SPAIN

Geothermal energy has not been prioritized in Spain as the focus has so far been on wind and solar energy. According to the Spanish geological and mining institute, the potential of high temperature geothermal resources for electricity generation is very limited and concentrated in some places (such as the volcanic archipelago of the Canary Islands). On the other hand, the medium and low temperature (50-90°C) geothermal energy is available in almost half of the territory and very low temperature resources (0-30°) is everywhere, which can be used to air-condition and DHW for dwellings. However, lack of knowledge, high initial cost and lack of regulation have slowed down the take-off of geothermal energy in Spain over the past years. From an industrial point of view, medium-temperature resources may be the most interesting, although currently these resources are only partially exploited and only to a small extent in some heating and DHW of buildings (including hotels and residential areas), swimming pools, spas or some few greenhouses. Nevertheless, recently this year, grants have been approved for feasibility studies for innovative projects to exploit deep geothermal energy, within the framework of the EU-funded NextGenerationEU Recovery, Transformation and Resilience Plan. It is hoped that this will begin to further exploit the country's geothermal potential and that industry will also begin to harness this resource where it is available.

2.3.4. Technologies using biomass

Biomass can be converted into several useful forms of energy using different conversion technologies. Bioenergy is the term used to describe energy derived from biomass feedstocks. To convert raw biomass into useful energy, three main process technologies are available: bio-chemical, thermo-chemical, and physio-chemical. Bio-chemical conversion encompasses two primary process options: anaerobic digestion (to biogas) and fermentation (to ethanol). For the thermo-chemical conversion routes, the four main process options are pyrolysis, gasification, combustion, and hydrothermal processing. Physio-chemical conversion consists principally of extraction (with esterification) where oilseeds are crushed to extract oil.

Bioenergy consists of solid, liquid, or gaseous fuels which can be obtained from the available technologies. Liquid fuels are commonly used in transportation vehicles but can also be used in stationary engines. Solid fuels are directly combusted to obtain heat, power, or CHP. Gaseous fuels can be applied to the full range of end-uses.

Several factors affect the choice of conversion process including the type, quantity, and characteristics of biomass feedstock, end-use requirements, environmental regulations, economics, location, and project-specific factors. It is the form in which the energy is required, and feedstock availability determines the process route. How biomass conversion technologies are implemented and operated will affect the GHG emissions that may arise from their use.

Table 6: Specific actions related to technologies using biomass in each project partner's country.

GREECE
The use of biomass for energy generation and/or fuel production in Greece is limited in relation to the availability of residual biomass. According to the estimations by the Greek Ministry of Development, the energy equivalent of the agricultural and forest residues available annually is ranging from 1,000,000 to 7,500,000 tons. The corresponding contribution of bioenergy amounts to 8% of the total, with the goal through the NECP to be 12% on the way to 2050, which is a milestone year for achieving climate neutrality in

the EU. More specifically, in the industrial heating sector, about 190,000 tons of olive stons, 73,000 tons of residues from agricultural industries (cotton ginning plants, kernels from fruit processing industries, almond shells, rice husks, industrial pellets, and 106,000 tons of wood residues (wood industries, industries non-metallic minerals) were consumed. In total, approximately 2,300,000 tons of biomass were consumed, corresponding to energy production of 9.4TWh. On the other hand, in the power generation sector, there are 25 power stations with total installed capacity of 15.5 MWe, ranging from 100 kWe to 5 MWe each. The use of bioenergy (primary solid biomass) will continue to make a significant contribution to heating and cooling, but without a significant increase until 2030, mainly due to the reduction of its use in the urban centres on environmental grounds. The doubling of the installed capacity of bioenergy plants, which is expected to reach and exceed 0.3 GW of installed capacity by the end of 2030 with the simulations of both energy models, is of particular interest. Respectively, the forecast for the use of bioenergy increases marginally both in absolute terms and in percentages and is estimated from 18% in 2020 to 21% of final energy consumption of the residential sector in 2030. The participation of biomass in thermal demand coverage is estimated to be up to 1,087 ktoe by 2025, 1,086 ktoe by2027 and 1,142 by 2030. Finally, as part of the national strategy to promote biofuels, any investment in the field is subsidized from Law 3299/2004 on promotion of investment. Subsidies vary from 40-55% according to region, and the type of the enterprise (in case of SMEs and specific regions they can reach up to 55%).
ITALY
Legambiente's Renewable Municipalities 2022 census indicates that solid biomass and biogas plants are present in 4,105 municipalities, with a total installed capacity of respectively 1,540 MWe and 3,409 MWe. To these should be added more than 2 million modern, high-efficiency domestic biomass installations fuelled by wood, wood chips or pellets (estimating the number of installations is extremely difficult). In Italy, the potential for unused woody residues is very large. ENEA estimates that the agricultural sector produces 4 million tons of (unused) residues annually. These are generated by the management of orchards, olive groves and vineyards (pruning and explants). The forestry sector, whose use for energy purposes is more established, may still contribute about 2.5 million tons annually. These values, when related to potentially available energy, yield approximately 19 TW of available thermal energy capacity per year. The best use of biomass in our country involves small-to medium-sized plants, well located to minimize the fuel supply pool (biomass transport). District heating systems (heat only) provide maximum energy efficiency. Combined heat and power systems, even if connected to a network of utilities for heat utilization, inevitably have low overall efficiency. In fact, the power plants are in operation even in seasons when there is no demand for heat, which must be dissipated without use. Different is the case of cogeneration plants linked to industries, which absorb heat all year round. Well-designed and sized plants, if fuelled by locally produced biomass, bring positive spin-offs to the area by improving the economy of agricultural and forestry activities. Such plants are very present in the alpine regions, even if they are not always fed by local biomass, which would otherwise be available. In Italy in 2021, biogas production, in terms of electricity (obtained mainly in cogeneration) was 8,142 GWh, while thermal energy production was 13,663 TJ. 83.3% of total national biogas power generation is provided by northern Italian regions. The main one is Lombardy, which concentrates 34.4% of the national production, followed by Veneto (15.3%), Emilia Romagna (14.8%) and

Piedmont (12.7%). Most of the energy produced by biogas plants in Italy comes from plants fuelled by agricultural and forestry activities (69.5%) and animal manure (16%).
ROMANIA
In Romania, the consumption of firewood will register a reduction of about 20% compared to the level of 2018 until 2030. As firewood has the highest share in the biomass, the decrease, because of the reduction in the consumption of firewood, the total consumption of energy resources coming from biomass will decrease until 2030 to the value of 39 TWh. The consumption of biofuels will increase until 2030 to the value of 4.1 TWh/year, enough to reach the national target for 2020 of 10% SRE share in the transport sector. Biogas will register rapid growth, up to a production of 3,500 GWh in 2030, due to the development of the agricultural sector and, to a lesser extent, the modernization of wastewater treatment plants. By 2030, small power plants fuelled exclusively with biomass, bioliquids, biogas, waste and waste and sludge fermentation gases will be developed, until such plants will have a total installed power of 139 MW. The boilers of some of the current thermoelectric plants will be adapted to allow the burning of additional biomass. Overall, a total of 0.9 TWh of electricity will be produced in 2030 by burning biomass. Complete regulations regarding the use of biomass to produce electricity will be developed, to prevent the irrational use of this resource.
SPAIN
In Spain, biomass is one of the main renewable energy sources, along with wind and solar energy, and there are more than 30 biomass power stations in rural regions and a few others that are under construction. According to the 2021 report of Red Eléctrica Española (REE), from 2014 to 2019, the total installed biomass capacity has grown by 9%. Specifically, there is an installed capacity of 857 MW of biomass. On the other hand, according to data from the Biomass Observatory, biomass production in Spain in 2020 was approximately 11.6 million tons and the number of pellet and biomass fuel plants is also increasing every year. However, biomass utilization in Spain is well below its potential and the European average, as it has abundant agricultural and forestry residues. There are several government incentives for the production and use of biomass, such as subsidies and grants for the installation of biomass systems in homes and buildings. Biomass is mainly used to produce heat in rural regions. In industry, biomass is used for example in paper production and furniture manufacturing. Biomass furnaces also exist in some Spanish industries. However, not many companies are using biomass and there is still a large remaining potential to be unlocked in the country.

2.3.5. Technologies using hydrogen

Hydrogen technologies are those related to the production and use of hydrogen, as a part hydrogen economy. Hydrogen technologies are applicable for many uses. Some hydrogen technologies are carbon neutral and could have a role in preventing climate change and a possible future hydrogen economy. Hydrogen is a chemical widely used in various applications including ammonia production, oil refining and energy. The most common methods for producing hydrogen on an industrial scale are steam reforming, oil reforming, coal gasification and water electrolysis.

Hydrogen is not a primary energy source, because it is not naturally occurring as a fuel. It is, however, widely regarded as an ideal energy storage medium, due to the ease with which electricity can convert water into hydrogen and oxygen through electrolysis and can be converted back to electrical power using a fuel cell. There is a wide number of different types of fuel and electrolysis cells. As an energy buffer, hydrogen produced via water electrolysis and in combination with underground hydrogen storage or other large-scale storage technologies, could play an important role for the introduction of fluctuating renewable energy sources like wind or solar power.

The potential environmental impact depends primarily on the methods used to generate hydrogen as a fuel.

Among increased investment, government support, engineering development and a skilled workforce, digital technology is one of the critical levers for accelerating the transition to green hydrogen – especially artificial intelligence of things (AIoT) – a combination of artificial intelligence and internet of things technology that enables the optimization and automation of systems through enhanced data management and analytics.

Here are four areas in which digital technology could help expedite the green hydrogen transition:

1. *Digital twins*. Before committing capital, investors want to know which system configuration will optimize their return. From PV to electrolyzer capacity, to buffers (such as energy and hydrogen storage), multiple variables will be considered. Digital twins can model multiple designs and scenarios, including variables such as weather, off-takers demand volatility and local infrastructure (current and future), optimizing each design to maximize return on investment and minimize risk. Estimates indicate that digital twin analysis can optimize capital expenditure (CAPEX) by 10-15% whilst reducing risk by 30-50%, along with a marginal change in operating expenditure (OPEX) [23].

2. *Monitoring and control*. Energy consumption, plant performance, production rates, purity and storage are among the key performance indicators (KPI) for hydrogen production which require visibility to ensure efficient production. AIoT can offer rapid anomaly detection using intelligent alarms, sensors on assets to monitor KPIs, and asset health and cloud-based remote monitoring beyond control rooms. Providing real-time monitoring of plant operations and asset health, coupled with remote control of assets, can reduce costs by 10-20% through lower energy consumption and a streamlined workforce. Leveraging monitoring models, consistent with design digital twins, allows investors to see where they stand regarding the business plan and to take actions to reduce eventual losses.

3. *Advanced analytics*. Analytics can transform data into business intelligence with actionable insights. For green hydrogen, churning and learning through data from plants, tanks, pipes, energy off-takers and even the weather, and the application of plant level or fleet level analytics can provide corrective action recommendations to maximize yields. Energy losses can be prevented by forecasting failures and optimizing electrolyzer uptime, thus increasing revenues and decreasing OPEX. Leveraging analytics models consistent with their digital twins allows investors and bankers to 'close the design loop' and take strategic and tactical decisions to optimize their returns.

4. *Certificates of origin*. Guarantee of origin (GoO) is a prerequisite for monetizing green hydrogen by certifying the renewable nature of all consumed electricity. AIoT-monitored installations can leverage near real-time data to automate input to GoO issuers – this avoids manual processing, offers more confidence and reliability, and increases futureproofing as more certifications evolves towards real-time and automation. AIoT can also ensure end-to-end traceability along the entire life cycle of the green hydrogen, from cradle to grave.

Table 7: Specific actions related to technologies using hydrogen in each project partner's country.

GREECE
Hydrogen is under development and incentivized in Greece, but not only for industry applications. The first step in Greece towards the regulation of hydrogen use as an alternative fuel in the transport sector was introduced by Law 4439/2016 on the adoption of Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the development of alternative fuel infrastructures and simplification of licensing procedure. Currently, there are already available hydrogen stations. In the framework of the NECP, it is mentioned that through pilot activities the generation of green hydrogen via RES will be promoted for the better exploitation of the RES potential. Moreover, in the NECP the coupling of electricity and gas sectors is proposed (power-to-gas) through storage applications that include the use of electricity generated by RES to produce gases, such as hydrogen. In 2020, the Committee for the National Strategy for hydrogen has been established, launched by the Greek Ministry of Environment & Energy, towards the development of the 'National Strategy for the Promotion of Technologies – Applications of Hydrogen and Renewable Gases'. The establishment of the Committee coincided with the adoption of the first Regulation for the European Hydrogen Strategy by the European Council. Aim of the Committee is to assess the risk and estimate the costs of various technological applications for the production and use of hydrogen with particular emphasis on the role of hydrogen transport/storage networks and infrastructures in relation to the existing natural gas network and the views of the energy industry. The Committee has calculated the effects of the development program on an annual basis in 2030 as follows: - Reduction of CO2 emissions: 750 ktoeCO2, or 1.5% of the total GHG emissions for 2030; - Reduction of gas and oil imports equal to 500 ktoe, which corresponds to a reduction of 10% and a reduction of import costs by EUR 230 million; - Total investments in the hydrogen supply chain of about EUR 3-4 billion; - Jobs in the hydrogen supply chain 3,000-4,000; - Domestic added value: 90-110 million euros. It is expected that the total turnover of the hydrogen supply chain in Greece will be in the order of EUR 10 billion per year in 2050. By then, approximately 60 GW of renewable energy sources will be required to power electrolysis units (30 GW by 2040). The National Strategy envisages fast-tracking renewable energy project licensing procedures for hydrogen production, licensing and grid connection and government subsidies until 2030 due to the immaturity of the technology, a factor that makes investment costs very high. The National Natural Gas System Operator (DESFA) S.A. has already started the construction of the first pipeline in Greece to transport 100% hydrogen. In addition, all new DESFA pipelines are designed and constructed to be able to transport 100% hydrogen. Moreover, DESFA is participating in the European natural gas managers to create a pan-European hydrogen network. In April 2021, the General Secretariat for Industry, which falls under the Hellenic Ministry of Economy and Development, issued a call for the submission of proposals related to investments in the hydrogen value chain, i.e., the safe and sustainable productions of low-carbon hydrogen, industrial equipment, solutions for storage, transport and distribution, and industrial applications of hydrogen. Finally, currently, in Greece there are many projects related to hydrogen. The most mature ones have already received approval from the EU under the Important Projects of Common European Interest (IPCES) in the hydrogen sector. In fact, Greece is one of the 23 European countries which signed the 'Manifesto for the development of a European Hydrogen Technologies and Systems value chain'.
ITALY

In 2021 ENEA and Confindustria (the most representative industry association) published a position paper regarding the 'Action Plan for Hydrogen in the Industrial Sector'. It shows that there already exist on the market some equipment that can run on hydrogen or with a hydrogen-methane mix, such as:

● Steel sector → the existing plants could operate without modification with 10% hydrogen mixtures

● Paper industry → there are already components on the market, such as burners and combustors, suitable to be fuelled either with hydrogen mixtures around 20 %

● Chemical industry → in processes using thermal energy, there are already burners and combustors on the market, suitable to be fuelled either with hydrogen mixtures around 20 %

● Ceramics sector → there are already products and solutions that allow the use of hydrogen mixed with natural gas in high percentages (over 50 %).

Vice versa, for some sectors hydrogen may not be a good solution. For example:

● Cement sector → there are many doubts about the actual availability of hydrogen in the quantities required by the production process, plus the large amounts of water vapor produced by hydrogen combustion could adversely affect the product. In addition, the production process relies on calcination, which releases CO2; so, the most appropriate way to decarbonize is to adopt CO2 capture, separation and storage or utilization (CCUS).

● Refineries sector → Refineries already use hydrogen in their production processes; however, it is produced by steam reforming and the remaining part by catalytic reforming processes of Virgin Naphtha (so-called grey hydrogen). Unfortunately, it seems very difficult to switch to the use of green hydrogen.

For other sectors (i.e., glass, food industry), further study is needed.

Right now, the Italian government has allocated 2 billion EUR of PNRR funds to fostering the transition to green and zero-emission hydrogen for those industries that are today most polluting and difficult to convert (hard-to-abate), EUR 230,000,000 to promote the creation of fuel stations for hydrogen experimentation in road transport and EUR 300,000,000 to test the conversion to hydrogen of non-electrified railway lines with high passenger traffic and heavy use of diesel trains, as in Lombardy, Puglia, Sicily, Abruzzo, Calabria, Umbria, and Basilicata.

ROMANIA

The Romanian Ministry of Energy announces the initiation of the development process of the 'National Hydrogen Strategy and Action Plan', part of the National Recovery and Resilience Plan (PNRR). The strategy will aim to achieve the targets of the energy transition process and decarbonization of the economic sectors, as well as the realization of the legal framework for facilitating investments in hydrogen along the entire value chain. The Ministry of Energy will subsequently ensure the adoption and entry into force of the changes to the legislative and regulatory framework that led to the implementation of Reform 4 of Component 6 (milestone #126) of the Recovery and Resilience Plan of Romania and the successful implementation of some key measures within the national hydrogen strategy and action plan. The changes will need to remove any legislative and administrative obstacles to the development of renewable and low-carbon hydrogen technology, so that the entire hydrogen value chain can be developed, including the mandatory use of hydrogen-ready appliances and equipment by end-users.

In Romania, the most promising hydrogen uses are in industry (steel, ammonia, fertilizers, refineries, and high value chemicals), transport (long-haul aviation, maritime shipping, HDVs and some railway segments), existing district heating systems and, potentially, long-term or seasonal energy storage beyond 2030. Other uses, such as gas blending or green hydrogen use in CCGTs are rather a waste of economic value, given the comparatively high costs of producing hydrogen.

SPAIN
In Spain, the economic potential of green hydrogen to reduce carbon footprint has been embraced with some enthusiasm by the national government, regional administrations, the private sector and, to some extent, civil society. A National Hydrogen Roadmap has been created to promote the deployment of these technologies across the industrial sector, setting a target of achieving at least 25% renewable hydrogen out of the total hydrogen used in industrial applications by 2030, either as a feedstock or for energy-calorific purposes. Spain could have one of the most competitive renewable hydrogen prices in the EU thanks to the possibility of developing projects that hybridize solar and wind power generation, the availability of land and experience in the development of renewable projects [24]. Various pilot projects and initiatives are underway, but there is still much to develop.

2.3.6. Technologies for carbon capture, utilization and storage (CCUS)

CO2 is one of many gases in the exhaust streams of power stations and industrial processes. To be used or stored, it first needs to be separated. This can be done in a number of ways, such as passing the exhaust fumes through solvents or across catalysts and other substances that selectively bind to CO2.

One way to strip the carbon out is through chemical absorption. This is when waste gases are passed through solvents like ammonia, which absorb the CO2 in a chemical reaction. This absorption is then reversed by blasting the ammonia with high temperature steam, releasing the purified CO2. This type of capture can be retrofitted onto existing buildings. This makes it the most popular CCUS technology trailed to date.

Another way to strip out CO2 is by oxyfuel combustion. This is when the fossil fuels are burned (e.g., during power generation) in a purer mixture of air. This mix contains just oxygen and CO2, with the nitrogen removed. Burning the fuel in purer air means that the exhaust gases are more concentrated with CO2, making it easier to capture and store the waste gases after burning. Oxyfuel combustion is slightly simpler than chemical absorption as no solvent is required. The unit that carries out this process is also relatively small. This means there is a possibility of retrofit to an existing plant with some alterations.

CCUS will be useful in decarbonizing industries that are likely to have residual emissions by 2050. Obvious examples are heavy industries like steel making and power generation that use natural gas or biomass. CCUS capture rates are not 100% efficient, so there will still be some residual emissions. Today, around 5kg of CO2 can be captured per person per year across the world, to a total of around 39.5 million tons. Yet, global CO2 emissions are around 33 billion tons. So, a significant gap remains. Although, planned pipeline will double the amount that can be captured per person, a much greater scale up is needed – around a thousand times the current level per person – to sequester the global average person’s carbon emissions of five tons (5,000 kgs) per year [25].

Transporting and using CO2: Before it can be used or stored, captured CO2 has been transported, usually via pipelines. For this, it is compressed into a liquid state and can then be moved through the pipelines, by ships or in road tankers. Sharing infrastructure such as pipelines between multiple emissions sources, creating 'industrial clusters', is becoming increasingly attractive. Clustering can combine emissions from power stations and industry into a single pipeline, cutting costs and providing the scale needed to make CCUS projects viable. Captured CO2 can be used to make a multitude of materials. It can be converted to building materials such as concrete (mineralization), used to make plastics via polymerization as a feedstock for microalgae that is converted to biofuels, among others. These processes can be very energy intensive. The additional cost of using CO2, as well as the waste produced in making new materials, can impact the viability of CCU projects.

CO2 can also be used directly in commercial processes such as food and drink, horticulture and in enhanced oil recovery. In food and drink, CO2 can be used to carbonate drinks, freeze and chill food and in packaging. In horticulture, it can be added to greenhouses to enhance the production of crops that use CO2 in photosynthesis.

The main use for CO2 today is enhanced oil recovery, a process to increase the maximum amount of oil and gas that can be extracted from a site. By injecting CO2 into the reservoir, more hydrocarbons are forced out than would be otherwise. The additional revenue of these fuels imparts a value on the CO2 used to extract them.

Storing captured CO2 – geologically, minerally or in oceans – prevents it from entering the atmosphere and contributing to climate change. Geological storage, in sedimentary rocks in old oil and gas fields or saline formations (porous rocks), can include re-using existing oil and gas infrastructure. Europe has several areas that have significant storage capacity potential, such as Spain (up to 14 GtCO2) and Norway (134 GtCO2). One often-cited concern around geological storage is that CO2 will leak out over time. However, studies have found this is unlikely, stating that even if there is a 50% probability of 0.0008% leakage per year, if 'well-regulated' over 98% of the stored CO2 would remain in the subsurface for over 10,000 years. For this reason, geological storage is the most credible option for CO2 examined to date [26].

Ocean storage is another option. While technically possible, injecting CO2 into the ocean and either letting it diffuse or trapping it in a specific location, would lead to the formation of carbonic acid, a direct cause of ocean acidification. For this reason, it is not seen as a credible means of storing CO2.

Mineral storage is also used. This is where CO2 is chemically bound to calcium and magnesium-rich rocks, holding it in place at specific sites. As calcium and magnesium are stable and abundant, the CO2 will not be released into the atmosphere. However, this reaction can be slow under normal temperatures and so would need to be heated (using more energy) to increase the speed.

Table 8: Specific actions related to technologies for CCUS in each project partner's country.

GREECE
Carbon Capture is under development and incentivized. Within the 'National Plan for Recovery and Resilience – Greece 2.0', several actions for the 'Green Transition' have been announced, including 'Produc-E Green' in component '1.3 Recharge and refuel'. The investment aims at establishing sustainable urban mobility and promoting storage of CO2 emissions, operating without using oil extraction/ recovery activities. Extensive study work had been undertaken to identify locations in Greece that can be developed to store CO2 captured from current emitters and the work had

concluded that currently the only site that can be developed in the immediate term is located at the Kavala fields. Towards the effort for CCS in Greece, the Hellenic Hydrocarbons and Energy Resources Management Company (HEREMA), fully owned by the Greek state, plays an important role in realizing Greece's potential as a leading energy and carbon abatement resource. In April 2022, HEREMA was appointed as the licensing authority for the geological storage of CO2, including the issuance of exploration and storage permits. This also includes the overall management of the rights of the Hellenic state for the storage of CO2 and other gases and liquids, such as natural gas and hydrogen (Law 4920/2022, Government Gazette A '74/ 15.04.2022). Important steps have been taken as there is already an institutional framework and the first approved application for CO2 storage in Prinos (Kavala). The Prinos CCS project concerns in the first phase the storage of 0.5-1 million tons of CO2 per year and has been included in the Recovery Fund. CO2 captured from local emitters (up to 150 km distant) will arrive at the facility by pipeline whilst CO2 captured at remote sites would arrive by ship and enter a buffer storage facility. HEREMA plans to study other potential sites for CO2 storage in Greece, such as in Grevena, Magnesia and in western part of Thessaloniki. CCS is at the centre of interest for industries with significant emissions (e.g., cement industry, metallurgy, power generations, refineries), especially in view of the further increase in the cost of purchasing CO2 emission rights expected in the following years. It should be noted that annual CO2 emissions by large industries in Greece, such as refineries, cement producers, electricity and metal groups are estimated at 30 million tons. Moreover, the Centre for Renewable Energy and Sources (CRES) had been participating in a project called DigiMon (Digital monitoring of CO2 storage projects), which aimed at accelerating the implementation of CO2 capture and geological storage by developing and demonstrating an affordable, intelligent, flexible and socially acceptable integrated early warning measurement system to monitor any CO2 geological storage project.
ITALY
To date, there are no large-scale CO2 capture and storage plants in Italy. Eni plans to build a plant with a storage capacity of 500 Mt of CO2 in Ravenna starting in 2024.
ROMANIA
Now, large-scale implementation of CCUS in Romania faces the challenge of defining a viable business case which can be achieved through utilization of captured CO2 for EOR (Enhanced Oil Recovery) and EGR (Enhanced Gas Recovery), as well as the establishment of a transport infrastructure. CO2-EOR operations have traditionally focused on optimizing oil production, not the storage of CO2. However, CO2-EOR can nonetheless result in very effective storage. In general, nearly 100% of the initially acquired/purchased CO2 for CO2-EOR operations (not that which is recycled) will be stored at the end of active injection. Multimodal transport of CO2 consists in a smart usage of pipelines and ships. At the scale of Danube - Black Sea area and, why not, for a large part of Europe, promoting the multimodal transport of CO2 could surpass the difficulties of building pipelines everywhere as well as, for example, those of public acceptance and transboundary cooperation, apart others. Instead of a unique network of pipelines, multimodal transport of CO2 means a large usage of specialized ships on the inland waterways, and short pipelines between the emission sources as well as suitable storage locations with the closest harbours.

Related to the Southern part of Romania, from previous and present CCUS studies, the industrial CO_2 emissions (verified on 2017), the appropriate geological structures for CO_2 storage as well as oil and gas deposits for EOR and EGR, are well documented. More information about CCUS in Romania were gathered by the H2020 project under the grant agreement 837754, Strategic planning of regions and territories in Europe for low carbon energy and industry through CCUS. The results are available online at [27].
SPAIN
Over the past decade, Spain has been standing out both for its facilities and its participation in projects of great relevance at European level for carbon capture, its utilization and storage. The progress is carried out through the CO_2 Capture, Transport, Storage and Use Management Plan by PTECO (CO_2 Technologic Spanish platform). It is focused on improving technologies aiming at decarbonization that are applied in industries where the cost of the capture is low and have access to transportation and storage lines. The facilities of the CO_2 Capture Technology Development Centre in Spain allow research with all types of coals and incorporate different oxy-combustion technologies. CCUS are also implemented along with biomass, accomplishing CO_2 capture efficiencies around 70-80%. In addition, in Spain, the carbon footprint of most industries will start to be registered on a mandatory basis, establishing limits with financial penalties and giving companies the opportunity to offset their emissions through their participation in national CO_2 absorption projects that are responsible, among other things, for the recovery, protection and management of ecosystems. In addition, companies in the industry will be obliged to develop their emission reduction plan for the coming years.

2.3.7. Technologies dealing with process intensification (PI)

Process intensification (PI), a technique aimed at modifying conventional chemical processes into more cost effective, productive, greener and safer processes offers the opportunity to address some of the challenges encountered in CO_2 capture and conversion. PI technologies are characterized by equipment size reduction through enhanced and targeted mixing, and mass/heat transfer, leading to improved selectivity, high energy efficiency, reduced capital cost and waste reduction. The smaller processing volumes handled in intensified systems offer the potential to reduce material costs and improve safety. Even greater intensification levels can be realized by astutely combining synergies of equipment, materials and methods, and by combining two or more technologies in each process. Such combinations can utilize the specific advantages of each component, whilst aiming to suppress any associated constraints of a particular aspect of the process. For instance, in the case of CO_2 reduction, electrochemical reduction can be incorporated with photo catalysis, which provides the driving force to initiate the process. Similarly, replacing an intensive energy source with a more efficient and ideally renewable source can lead to intensification of CO_2 reduction. For instance, compared to CO_2 activation using high-cost thermal energy, high-energy non-thermal plasma has shown an improved performance. For such combinations or substitutions to be effective, it is important to understand the important properties in material and/or devices that will efficiently and affordably reduce CO_2 to value-added products. Herein, the intensification of carbon capture and of key CO_2 reduction methods including photocatalytic, electrochemical, biochemical and thermochemical processes is reviewed, focusing on the integration of the three PI approaches of equipment, materials and methodology.

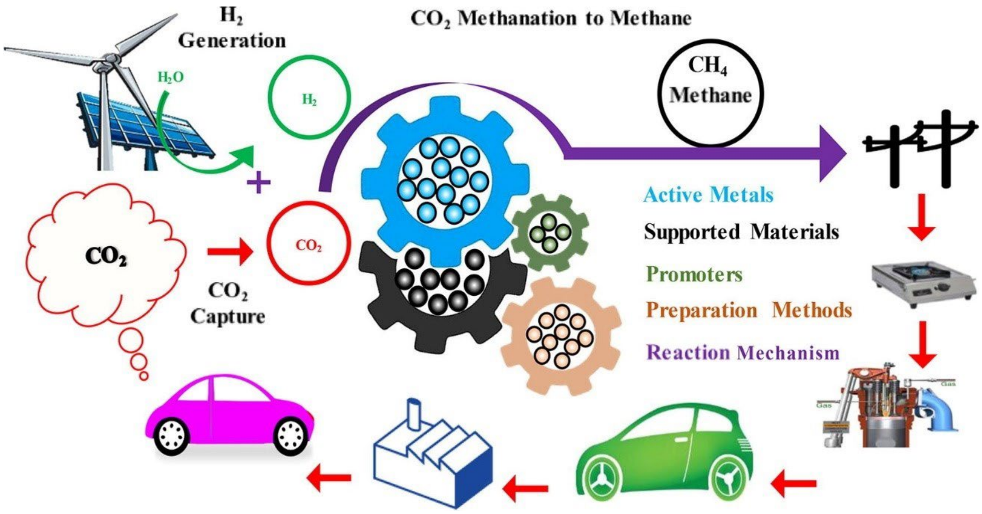


Figure 6: CO2 conversion cycle [28].

Process intensification can be achieved by four approaches [29]:

Low thermal budget transformative technologies (mid- to long-term): Technologies that may use alternative energy sources while offering disruptive changes in the current production methods (e.g., electrolysis and electrodialysis)

Alternative thermal processing (near- to mid-term): Technologies that use an alternative source of energy while maintaining the current production methods to gain more flexibility/control (e.g., induction and resistance furnaces)

Transformative supplemental technologies (near-term): Emerging energy efficiency and supplemental technologies that reduce thermal demand (e.g., smart Internet of Things devices for system optimization)

Waste heat management technologies (near-term): Emerging waste heat reduction, recycle, and recovery technologies (e.g., thermoelectric devices and heat pipes)

Table 9: Specific actions related to technologies dealing with PI in each project partner's country.

GREECE
Technologies dealing with process intensification are also incentivized for adaptation, as part of the energy efficiency improvement measures. Within the context of the strategy plan 'Industry 4.0', efforts are made to motivate industries towards digital transition, to achieve better efficiency of the processes and adopt cutting-edge technologies and digital skills that are compliant with the term of the Fourth Industrial Revolution.
ITALY
In Italy, PI are mainly applied in energy-intensive industries, where process heat can be recovered and reused. Besides this, another key sector for Italy where intensification plays a key role in decarbonization is agriculture. Agricultural emissions gradually decreased between 1990 and 2010 from about 34.5 MtCO2e to 30.1 MtCO2e. Therefore, intensification of the agricultural sector can result in a significant reduction of GHG emissions [30].
ROMANIA

Technologies dealing with process intensification are also incentivized for adaptation, as part of the national energy efficiency plan.
SPAIN
Technologies dealing with process intensification are also incentivized for adaptation, as part of the energy efficiency improvement measures.

2.3.8. Technologies concerning the circular economy

The concept of the circular economy is fundamentally based on the creation of a single extraction, production and consumption system; materials and products are kept within the cycle as long as possible, with losses minimized or ideally eliminated. This can overcome the limitations of classic decarbonization processes, which, being linear and therefore partial, do not allow for complete carbon neutrality, as can be observed in Figure 7.

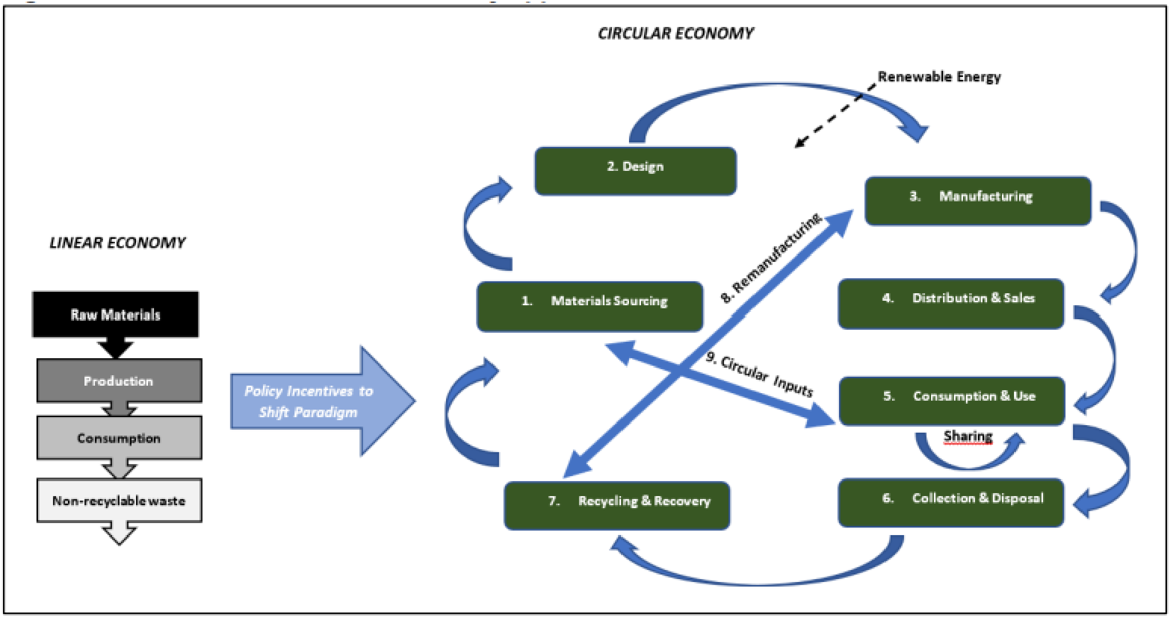


Figure 7: The concept of the circular economy [31].

Circular Economy trends in 2023 [32]:

1. Waste-to-Resource: The world generates tons of waste annually, most of which end up in landfills. The circular economy retains the value of products or resources by putting them back into the product cycle after use. Besides mechanical recycling, one of the biggest circular economy trends is to upcycle this waste to energy by incineration, gasification, anaerobic digestion, and pyrolysis. This allows waste management companies to get rid of the waste effectively as well as provide an additional stream of clean energy for power utilities. While every industry produces waste, some industries, like energy, food, agriculture, and fashion, are larger contributors than others. Startups are working on waste upcycling solutions that focus on waste from such polluting industries.

2. Reusing products extends their lifecycle while reducing waste and the use of new raw materials, thus, making it one of the top circular economy trends. However, there is often a lack of information about the products available for reuse. To tackle this issue, various types of sharing platforms are on the rise. For instance, asset sharing platforms allow businesses to earn revenue by lending materials or machines that otherwise mostly remain unused. Similarly, food sharing applications reduce food waste while preventing losses from unsold food. Apart from reusing materials, there is a shift away from single-use packaging to reusable packaging. The latter is made with durable materials to survive multiple lifecycles.

3. Internet of Waste: In traditional waste management systems, municipalities and waste management companies often end up spending a lot of money and effort to collect waste. The collection system usually works on fixed schedules, without considering the trash capacities of dumpsters. As a result, garbage trucks often visit dumpsters that are not yet full or those which overflow with garbage. Therefore, IoT-based smart waste management solutions reduce the inefficiencies in trash collection. Smart bins transmit real-time fill level information to waste collectors and eliminate inefficient visits to near-empty trash bins, saving time, fuel, and labour.

4. Artificial Intelligence: Separating or sorting garbage is as important as an effective waste collection to ensure that the right materials are sent for recycling. Unfortunately, this process is still a bottleneck for many waste management facilities as most of them follow a single-sort system in which all the recyclables end up in the same box. But the recyclables like plastic and cardboard need to be separated. AI-powered sensors differentiate among items made from different materials as well as nuances among the ones of the same materials. It also detects chemical contamination in the items. This is why the use of AI in waste management is one of the emerging circular economy trends. Moreover, AI-driven machines sort recyclables much faster than humans using computer vision and deep learning algorithms. AI enables waste management companies to reduce the need for manual labour, thus, cutting costs and maximizing efficiency.

5. Bio-Based Materials: Products made from non-renewable resources largely contribute to environmental pollution and reach the end of their lifecycle very quickly. Therefore, companies are producing new bio-based materials obtained from renewable resources, making it an important circular economy trend. Bio-based materials are generally compostable and easier to recycle, allowing companies and consumers to reduce their carbon footprints. They find applications in packaging, construction, healthcare, and automotive sectors.

6. Remanufacture: Both recycling and remanufacturing reduce solid and hazardous waste, but the former uses more energy to dismantle a product. Moreover, recycling implies breaking down a product to convert it into raw materials that are used for making new products. But remanufacturing involves rebuilding a product to its original condition with reused, repaired, and some new parts, making it as good as new. Advanced technologies like Laser Metal Deposition (LMD), an additive manufacturing process, not only restore a component but also add extra features for improved performance. This allows Original Equipment Manufacturers (OEMs) to cut down their capital expenditures while also reducing the carbon footprint.

7. Blockchain secures its position as a top emerging trend by enabling two important functions in the circular economy — providing transparency and traceability and incentivizing circular behaviour. Startups use blockchain's immutability to verify the origin of products, assuring that they meet their sustainability claims. For example, The World Economic Forum's Mining and Metals Blockchain Initiative's (MMBI) Carbon Tracing Platform (COT) — a unique proof of concept, traces carbon emissions across the supply chain. This enables mining companies to meet Environmental, Social, and Corporate Governance (ESG) demands.

8. Repair: Reusing products extends their lifecycle, but products often become unfit for reuse. Repair solutions address this, extending the life of products. Moreover, it reduces waste and the use of new raw materials. Take for example the tons of electronic waste globally. Repair solutions hold the potential to bring much of it back to the cycle. This is why repair solutions are an important circular economy trend and companies are adopting them to reduce their carbon footprint and save costs on raw materials.

Table 10: Specific actions related to technologies concerning the circular economy in each project partner's country.

GREECE
The concept of circular economy is widely elaborated in Greece through technologies and processes. Within the 'Green transition of SMEs' programme, which has been published on the 6th of March 2023 by the Special Management Agency for Operational Program 'Competitiveness, Entrepreneurship & Innovation', eligible are costs that aim to minimize and save resources utilizing practices of reuse and recycling of raw materials, while minimizing the use of natural resources in the framework of the circular economy. Some examples of eligible equipment are listed below: - Units for the management of liquids & solids of waste, - Systems that limit the soil, subsoil, water and air pollution, - Equipment to reduce water consumption and losses, - For recycling, such as mechanical waste bins, metal waste compactor, etc., - Equipment for waste, such as waste loading and sorting machines, waste shredders, drilling, sandblasting, primary sedimentation equipment, secondary treatment equipment-activated sludge and biological/chemical method removal, - Equipment to reduce defective products, such as production control x-ray machines, - Equipment to optimize water consumption resources/water reuse, such as water filtration systems (osmosis, desalination, etc.), and smart water saving systems.
ITALY
In 2020, the last available year of data, in the EU, the circular material utilisation rate was 12.8%. In Italy the value reached 21.6%, second only to that of France (22.2%) and almost ten percentage points higher than that of Germany (13.4%). It is interesting to note that for this specific indicator, Italy is in fourth position compared to all 27 EU countries. Furthermore, Italy has experienced a trend of growth in the rate of circular use of matter practically continuously over the years, starting from 11.6% in 2011 to 21.6% in 2020. In Italy, the recycling rate of all waste has almost reached 68%, which is the highest figure in the EU. The ranking overall of circularity in the top five economies of the EU is based on 7 indicators, i.e., the rate of overall recycling of municipal and special waste; the rate of utilisation of material from recycling; the resource productivity; the ratio of waste generation and material consumption; the share of energy from renewable sources in the total gross energy consumption; repair; land consumption. Italy and France are the countries with the best circularity performance, each scoring 19 points.
ROMANIA
The EC supported Romania in developing a circular economy strategy, which was officially adopted by the Romanian government on September 21, 2022. The adopted strategy provides an overview of the circularity potential of 14 economic sectors in Romania (including automobile industry, chemical industry, metallurgic industry, construction materials, etc.), establishing a clear general direction aimed at accelerating the transition from a linear economic model to a circular one. The

priorities for the development of policies aimed at promoting circularity in Romania focus on: reducing the consumption of virgin raw materials through sustainable extraction, recycling and recovery activities; reducing the consumption of consumer goods by extending the life of the products; reducing the impact of production activities on the environment; reducing the environmental impact of waste and wastewater management and disposal activities and improving policy coherence and governance, communication and collaboration between local, regional and national authorities.
SPAIN
In line with European policies, Spain has a circular economy strategy and different action plans that outline the path to achieve the objectives set for 2030 aimed at reducing national consumption of materials, waste generation, efficiency in water use or increasing the reuse of waste, among others. In addition, to achieve these objectives, the Strategic Project for Economic Recovery and Transformation (PERTE) for Circular Economy was approved last year, which will provide significant subsidies to industries with the aim of improving the competitiveness and innovation of the industrial fabric through the reduction of the consumption of virgin raw materials; eco-design; waste management and digitalization.

3. Design of the Decarbonization Roadmap

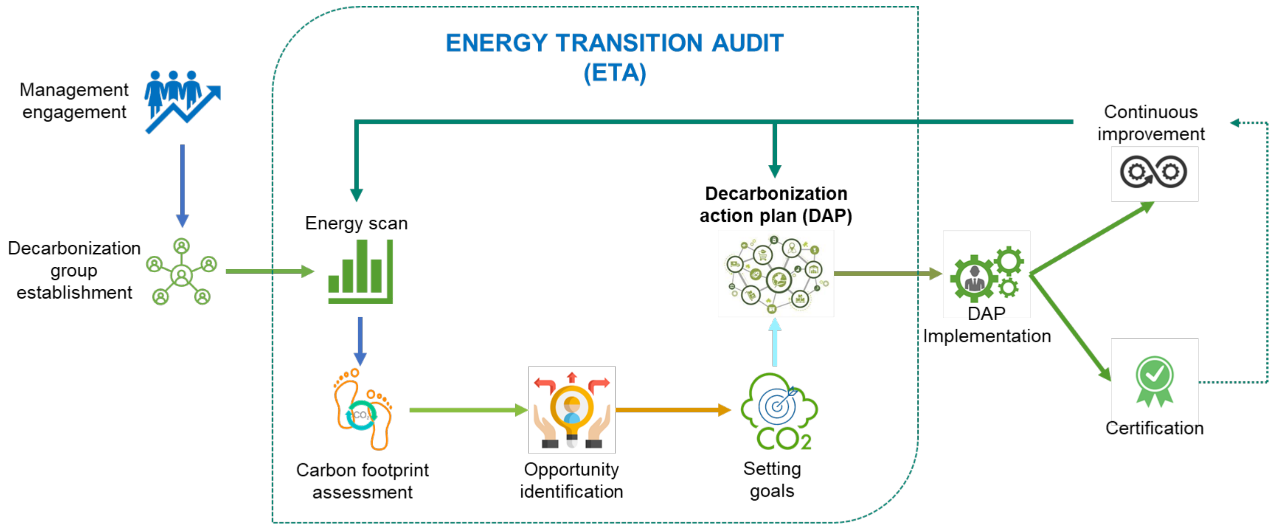


Figure 8: Decarbonization roadmap workflow.

3.1. Obtaining top management commitment/engagement

The **D**ecarbonization **R**oadmap (**DRM**) starts at the governance and strategy level of the company, launched by the top decision makers, but with the clear involvement and technical assistance of the energy professionals – energy managers. For real change and progress to be made, there is need for a clear mandate that sustainability and carbon reduction are prioritized and integrated within all business plans. All the aspect of the DRM continues throughout the entire process as the decisions made at this level significantly influence how each step is approached and the success of the entire process.

In this context, the top management engagement is crucial for the success of decarbonization actions, for at least the following reasons:

- ✓ Management's vision and guidance provide a framework for aligning business operations with long-term sustainability goals.
- ✓ Since management controls the allocation of resources, including financial, human, and technological resources, their engagement ensures that adequate resources are dedicated to decarbonization efforts. This includes funding for renewable energy projects, energy efficiency upgrades, research and development of clean technologies, and training programs for employees.
- ✓ When management demonstrates a strong commitment to decarbonization, it sets a positive example for employees and encourages their active participation and support. This fosters a culture of sustainability and creates a sense of shared responsibility towards achieving carbon reduction targets.

Top management engagement for decarbonization can be triggered by various sources that can differ depending on the industry, market conditions, regulatory landscape, and societal expectations:

- Awareness campaigns on climate change, sustainability, and the importance of decarbonization can prompt management to act for it.
- Changes in environmental regulations and legal frameworks related to carbon emissions.
- Pressure from investors and shareholders to address climate-related risks and sustainability issues.
- The emergence of cost-effective clean technologies and innovative solutions that could provide opportunities for companies to reduce carbon emissions while achieving operational efficiencies.
- Demands from customers, business partners, and supply chain stakeholders for sustainability commitments can impact management engagement.
- The presence of dedicated energy managers or sustainability professionals within a company due to their expertise in energy efficiency, renewable energy, and emissions reduction strategies.

In case of energy auditors or ESCO companies to persuade the top management of a company to design and implement a Decarbonization Roadmap, the following aspects can serve as arguments:

- **Engage in dialogue:** Initiate open and transparent discussions with top management to understand their perspectives, concerns, and priorities. Listen actively, address their questions and doubt, and emphasize the potential positive impact of decarbonization on the company's financial performance and reputation.
- **Building a compelling business case**: Development of a comprehensive presentation of the potential risks and opportunities associated with decarbonization. Presentation of a compelling business case that highlights the long-term benefits, such as cost savings, improved brand reputation and social responsibility, access to new markets, reduced of dependence on external energy sources and mitigated regulatory risks.

- **Align with organizational goals:** Demonstrating how decarbonization aligns with the company's overall mission, vision, and strategic objectives. Showing how it can enhance competitiveness, drive innovation, and create long-term value for the company.
- **Improved working environment:** The decision makers consider and aim to create good working environment, which could lead to improved productivity.
- **Multiple benefits identification and highlight:** The benefits which are not directly related to energy savings and the possible outcomes of implementing the ETA methodology could enhance the companies' management engagement.
- **Demonstrate quick wins:** Start with small-scale decarbonization projects that can deliver quick wins and showcase the benefits of taking actions. Celebrate these achievements and use them as examples to reinforce the importance of decarbonization efforts.
- **EU and national regulations**: Through providing insights into the existing regulations and specifically the ones related to energy audits and the environmental impact of the companies, the managerial staff could be approached.
- **Brand reputation**. Businesses who do not have a plan for how to thrive in a net zero economy will fall behind their competitors and face reputational risk. Maintaining a leading position by setting a credible net zero strategy ensures that your stakeholders, employees, and clients recognize your company's contribution to the global emissions reduction challenge. In addition, improving confidence with investors by demonstrating strong sustainability credentials could attract new sources of green investment.
- **Customer & employee expectations**. Increasingly, stakeholders at every level are putting pressure on businesses to take actions toward reducing their waste, emissions, and environmental impact. Present and future employees expect companies to show leadership and bold action on climate change mitigation, biodiversity protection, emissions reductions, and environmental stewardship.
- **Involve top management in decision-making:** Actively involve top management in the decision-making process related to decarbonization. Seek their input and involvement in the development and implementation of carbon reduction initiatives. This will help create a sense of ownership and commitment among top leaders.
- **Educate and raise awareness:** Providing educational resources and conduct awareness sessions to help top management understand the urgency and significance of addressing climate change. Share relevant data, reports, and case studies that highlight the economic, environmental, and social implications of carbon emissions.

3.2. Establishing a decarbonization working group

Establishing a decarbonization group involves bringing together a dedicated team of individuals with the expertise and willingness to drive the company's efforts towards reducing carbon emissions.

Figure 9: Main pillars of a decarbonization working group.

By considering the following aspects, the company could establish a dedicated decarbonization group that will play a crucial role in driving the efforts of company to reduce carbon emissions and transition towards a more sustainable future (Figure 9):

- The management should clearly articulate the **objectives and scope** of the decarbonization group, to determine whether the group will focus on a specific area or encompass the entire decarbonization efforts of company.
- The management will **identify the key stakeholders** who should be involved in the decarbonization group. This may include representatives from various departments such as operations, sustainability, finance, human resources, and technology with relevant expertise, knowledge, and a passion for sustainability and decarbonization.
- The working group should be a **cross-functional team** that represents different areas of the company. This diversity will ensure a holistic approach to decarbonization, with input from various departments and stakeholders. It is also important to select a capable and passionate **individual to lead** the decarbonization group. This person should have the necessary skills to drive the group's initiatives, coordinate efforts, and act as a liaison between the group and top management.
- To ensure a well-coordinated and efficient team, **clear roles and responsibilities** for each member of the decarbonization group should be defined by assigning specific tasks and areas of focus.
- The decarbonization group will be granted the **necessary resources**, including budget, tools, and support, to effectively carry out their initiatives.
- Regular **communication channels** within the decarbonization group to facilitate collaboration and information sharing will be set up. This may include regular meetings, email updates, shared project management tools, or dedicated communication platforms.

- To help ensuring accountability and maintaining visibility of the group's efforts a mechanism must be established to **monitor the progress** of decarbonization initiatives and regularly report outcomes to key stakeholders and top management.
- **Engaging with external stakeholders** can provide valuable insights, best practices, and support for the group's initiatives.
- The company should encourage a **culture of continuous learning** and improvement within the decarbonization group by staying updated on emerging technologies, regulations, and industry trends related to decarbonization, and adjust strategies and actions accordingly.

3.3. Performing preliminary energy scan

In summary, the Preliminary Energy Scan (or Walk-through Audit) involves a simple study of some major equipment and major energy sources, while the Detailed Audit involves a thorough study of practically all equipment/systems and all the energy sources.

For companies considering the implementation of an ETA and having already undergone a conventional energy audit can utilize their existing energy audit as a starting point and build upon that foundation.

For those companies that do not already have an existing energy audit, the Preliminary Energy Scan should focus on the major consumers, covering at least 70% of the total energy consumption. Only the directly available data are used for a simple analysis of the energy consumption profile and performance of the technical systems, therefore it can be completed with limited diagnostic instruments. It is essential to perform a preliminary data collection and analysis to establish a baseline for the decarbonization process.

The Energy Scan does not require measurements and detailed data collection. It is not time-consuming, and results are rather generic and include simple calculations. During the Energy Scan the auditors rely on their experience together with all the relevant written, oral visual information that can lead to a quick investigation of the industry’s energy consumption profile, and the identification of opportunities to improve energy efficiency. Audits may deploy minimum resources to simply check for energy saving opportunities, that are readily identifiable and to implement them to achieve savings immediately. It is the simplest type of energy audit and is the most basic requirement of the energy audit. Economic analysis is typically limited to the calculation of a simple payback period through the accomplished energy savings.

Preliminary Energy Scan is a relatively quick practice to:

- Develop the energy consumption profile of the company.
- Identify the energy sources, the cost per source and the emissions per source.
- Examine the possibility of limiting/eliminating the usage of fossil fuels and the installation of RES systems.
- Set the energy baseline, as ‘reference point’.
- Identify immediate actions for savings, especially those without or with low-cost.
- Prioritize the areas of attention.
- Detect areas suitable for more detailed study and measurements.

The performance of a Preliminary Energy Scan is essential to assess whether to proceed with a detailed energy audit in industry.

3.4. Energy Transition Audit

3.4.1. Carbon footprint assessment

Performing a carbon footprint assessment for a company involves measuring and analysing the company's CO2 emissions across its operations, including direct and indirect emissions and compute the total CO2 emissions. Considering that the EnTRAINER project focuses more on the first two Scopes, but to the extent that the collected data allows, it could be expanded to include the third Scope as well.

The process on how to conduct a carbon footprint assessment should consider the following aspects:

1. **Set of boundaries and objectives:** Define the boundaries of the assessment, considering all relevant operational activities, facilities, and value chain components. Determine the goal of the assessment, including whether it will cover only direct emissions (Scope 1) or also include indirect emissions from purchased energy (Scope 2) and emissions from the entire value chain (Scope 3).
2. **Data collection**: Gather relevant data on energy consumption, fuel usage, transportation, waste management, water consumption, and any other activities with the potential to generate CO2 emissions. Ensure data accuracy and consistency by using utility bills, fuel consumption records, financial reports, and other reliable sources.
3. **Identification of emission sources**: Categorize the data into emission sources based on the GHG Protocol's scopes. Common emission sources include combustion of fossil fuels, electricity consumption, transportation, waste generation, and business travel. Identify both direct emissions from owned or controlled sources and indirect emissions from purchased energy.
4. **Calculation of the emissions:** Calculate CO2 emissions using recognized emission factors or emission calculation tools specific to each emission source. Emission factors provide conversion rates to estimate emissions based on the quantity of fuel consumed or energy used. Consider using widely accepted protocols such as the GHG Protocol, ISO 14064, or other relevant industry-specific standards.
5. **Emissions and hotspots analyses**: Analyse the emissions data to identify significant emission sources, emission hotspots, and areas where emissions reduction opportunities exist. This analysis will help prioritize efforts for emission reduction strategies and set meaningful reduction targets.
6. **Benchmarking and comparing**: Compare the emissions data of the company with industry benchmarks or similar organizations to gain insights into its performance and identify areas for improvement. Benchmarking can provide valuable context and help identify opportunities to achieve best practices within the sector.
7. **Report and disclose**: Prepare a summarizing report that summarizes the carbon footprint assessment findings, including emission inventories, emission sources, and hotspots.

3.4.2. Opportunity Identification

To identify the existing opportunity available in the external environment, the working group should identify the relevant stakeholder which can be involved in the company's decarbonization process.

The main steps for opportunity identification are:

1. Organizing a **workshop** involving important stakeholders to create a process or business flow.
2. Creating a schematic for a **process or business flow**.
3. Identifying opportunities for **enhancing efficiency and technology**, typically with lower capital requirements.
4. Exploring options for significant **process changes or transitioning to alternative fuels and/or energy carriers**, often involving higher capital investments.

3.4.3. Setting a Goal/Reduction Target

Identifying a carbon footprint and announcing a reduction target is an important first step in developing a Decarbonization Roadmap and involves establishing specific and measurable objectives to reduce carbon emissions within a defined timeframe.

Process on how to set a decarbonization target is:

1. **Assess the baseline:** Determine the current carbon emissions of the company obtained during the comprehensive carbon footprint assessment. This will serve as the baseline against which progress will be measured.
2. **Consider science-based targets**: Generally, science-based target setting methods have three components: a carbon budget, which defines the overall amount of CO2 that should be emitted, an emissions scenario, defining the magnitude and timing of emissions reductions and an allocation approach, defining how the carbon budget is allocated to individual companies.
3. **Determine the target scope:** Decide whether the target will focus on specific emission sources or cover the entire company's emissions. It could include direct emissions (Scope 1), indirect emissions from purchased energy (Scope 2), and (if decided that way) emissions from the value chain (Scope 3).
4. **Set an ambitious yet achievable target**: Consider the company's current emission levels, available resources, industry benchmarks, and the urgency to address climate change. Set a target that is both ambitious enough to drive significant change and feasible to achieve within the chosen timeframe.
5. **Define the target type**: Determine the type of target that will be set. It can be an absolute target, aiming for a fixed reduction in emissions, or an intensity-based target, which focuses on reducing emissions per unit of activity (e.g., emissions per unit of revenue or production).
6. **Establish the time frame**: Define the timeframe within which the target will be achieved. Consider long-term goals as well as intermediate milestones to track progress and maintain momentum.
7. **Consult internal stakeholders:** Engage relevant stakeholders, including internal departments, senior management, sustainability teams, and external experts, to gather input and ensure alignment with organizational priorities. Seek their perspectives on target feasibility and potential strategies to achieve it.

8. **Determine the reduction pathway:** Develop a roadmap or plan outlining the strategies and actions required to reach the target. Identify specific initiatives, such as energy efficiency measures, renewable energy adoption, supply chain optimization, or process improvements. Consider collaborating with suppliers and partners to address Scope 3 emissions.
9. **Define KPIs** and metrics to measure emissions reductions regularly.

Setting a decarbonization target requires careful consideration of the emissions of the company, industry context, available resources, and stakeholder input. By following these aspects, a company can establish a clear and meaningful target to guide its decarbonization efforts and contribute to a sustainable future.

3.4.4. Decarbonization action plan →Decarbonization roadmap

Transposing a decarbonization action plan into a decarbonization roadmap involves taking the specific actions identified and organizing them into a structured timeline and framework. As a result, the company will have a structured framework that outlines the timeline, responsibilities, and resources required for successful implementation. This roadmap will serve as a guide for driving progress and achieving the desired emissions reduction targets.

The steps to transpose the action plan provided by an Energy Transition Audit into a Decarbonization roadmap should be as follows:

Review of Decarbonization Action Plan (DAP)

- Assess the feasibility, effectiveness, and alignment of these actions with the company's goals and targets.
- Assess whether these targets are specific, measurable, attainable, relevant, and time-bound (SMART).
- Ensure that they are aligned with the company's overall decarbonization objectives and any external commitments or regulations.

Prioritizations of the actions

- Prioritize the identified actions based on their importance, potential impact, feasibility, and interdependencies.
- Consider the sequence in which actions need to be implemented, considering any dependencies or prerequisites for certain initiatives.
- Assess the cost-effectiveness of each action by considering the potential emissions reduction achieved relative to the resources required for implementation. Prioritize actions that provide substantial emissions reductions while optimizing resource allocation.

Establish Timelines

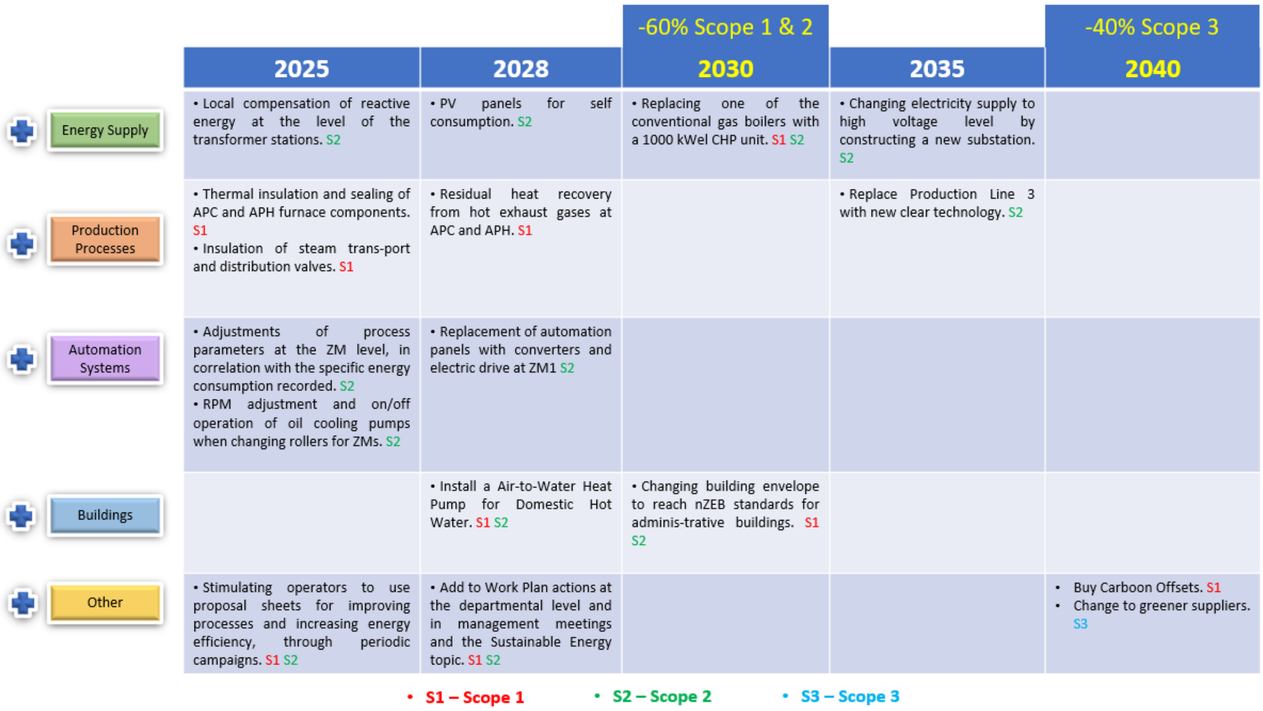
- Assign estimated timelines or deadlines to each action or milestone within the roadmap. This could include start dates, completion dates, or specific timeframes for different phases of implementation.
- Ensure that the timelines are realistic and achievable. These may include specific milestones, timelines, responsible parties (groups), resource allocation, metrics for tracking progress, and any external factors or dependencies that need to be considered.

Allocate Resources	• Determine the necessary resources, including financial, technological, and human resources, for implementing each action. • Assess the budget and funding requirements for each initiative and allocate resources accordingly.
Consider Dependencies and Constraints	• Consider any dependencies or constraints that may impact the implementation of certain actions. These could include regulatory requirements, availability of technology or expertise, stakeholder engagement, or external factors such as market conditions or policy changes.
Develop Tracking Mechanisms	• Establish KPIs and metrics to track the progress of each action and the overall decarbonization efforts. • Determine how progress will be measured and reported and establish a system for regular monitoring and reporting. Regularly review and refine the decarbonization roadmap as new information becomes available or circumstances change. • Continuously assess progress, evaluate the effectiveness of actions, and adjust as necessary to ensure alignment with goals and objectives.

3.5. Implementation - Energy Transition Pathway

The company should consider its internal strategies and guidelines to determine the best way to proceed with the implementation of the decarbonization action plan. These strategies may involve budget allocation, resource allocation, project prioritization, and alignment with organizational goals.

Visual representations, such as Gantt charts, timelines, or other graphical formats, should be created to present the roadmap for decarbonization (Figure 10). These visuals clearly illustrate the sequencing and interdependencies of the planned actions, making it easier for involved persons to comprehend the plan and provide their support.



	2025	2028	-60% Scope 1 & 2 2030	2035	-40% Scope 3 2040
Energy Supply	• Local compensation of reactive energy at the level of the transformer stations. S2	• PV panels for self consumption. S2	• Replacing one of the conventional gas boilers with a 1000 kWel CHP unit. S1 S2	• Changing electricity supply to high voltage level by constructing a new substation. S2	
Production Processes	• Thermal insulation and sealing of APC and APH furnace components. S1 • Insulation of steam trans-port and distribution valves. S1	• Residual heat recovery from hot exhaust gases at APC and APH. S1		• Replace Production Line 3 with new clear technology. S2	
Automation Systems	• Adjustments of process parameters at the ZM level, in correlation with the specific energy consumption recorded. S2 • RPM adjustment and on/off operation of oil cooling pumps when changing rollers for ZMs. S2	• Replacement of automation panels with converters and electric drive at ZM1 S2			
Buildings		• Install a Air-to-Water Heat Pump for Domestic Hot Water. S1 S2	• Changing building envelope to reach nZEB standards for adminis-trative buildings. S1 S2		
Other	• Stimulating operators to use proposal sheets for improving processes and increasing energy efficiency, through periodic campaigns. S1 S2	• Add to Work Plan actions at the departmental level and in management meetings the Sustainable Energy topic. S1 S2			• Buy Carboon Offsets. S1 • Change to greener suppliers. S3

• S1 – Scope 1 • S2 – Scope 2 • S3 – Scope 3

Figure 10: Example of decarbonization strategy representation.

Effective communication of the decarbonization roadmap is crucial. The company should engage with relevant stakeholders, including employees, management, investors, and external partners, to ensure their understanding and buy-in. By effectively communicating the benefits of the plans and demonstrating its feasibility through visual representations, stakeholders can be more engaged and supportive to the decarbonization efforts.

3.6. Continuous improvement

A key trait of the DRM is iteration, creating continuous improvement. It is a living and breathing document that will need to be amended to reflect changes in the company's business, technology, or the operational environment.

Conducting a periodical strategic review can reveal that certain opportunities have generated higher savings than anticipated, while others may have fallen short. This assessment might lead to changes in the company's operational approach or target markets. Furthermore, as renewable technologies continue to witness substantial investments across various industries, the evolving landscape can redefine what constitutes best practices in a rapidly changing environment. It is important to consider and address these factors from the Decarbonization Action Plan to achieve optimal carbon-related outcomes and, equally importantly, favourable economic results within the DRM. It is also needed to regularly update and report the carbon footprint on an annual basis, taking full advantage of the enhanced data collection methods that have been implemented. This may involve modifying existing actions, adding new initiatives, or realigning priorities to ensure the plan remains relevant, effective, and aligned with organizational goals and external developments.

Hence, it is important to motivate the company to undertake such actions by considering the following key aspects, which embody the fundamental principles of sustainability:

Periodical review of DRM

- Decarbonization Roadmap should be periodically reviewed to assess its progress and effectiveness.
- This review process involves evaluating the implementation of actions, tracking the achieved outcomes, and identifying any gaps or areas for improvement.

Feedback mechanisms

- Establish feedback mechanisms that allow stakeholders to provide input, suggestions, and observations regarding the decarbonization initiatives.
- Encourage open communication and collaboration to gather insights from employees, suppliers, customers, and other relevant parties.

Performance evaluation

- Conduct thorough evaluations to measure the performance and impact of the implemented actions.
- Assess the progress made towards emissions reduction targets, analyze data and metrics, and identify areas where adjustments or enhancements are required.

Incorporate lessons learned

- Learn from successes and challenges encountered during the implementation of the action plan.
- Capture and document lessons learned to avoid repeating past mistakes and capitalize on effective strategies. Use these insights to refine future actions and approaches.

Technological advancements

- Keep abreast of emerging technologies, scientific advancements, and industry best practices in decarbonization.
- Regularly assess the suitability of new technologies and innovative solutions that can enhance the effectiveness and efficiency of emissions reduction efforts.

Evolving regulatory landscape

- Stay informed about evolving regulations, policies, and market mechanisms related to decarbonization.
- Monitor changes in carbon pricing, emissions trading schemes, or government incentives that can influence the strategic direction of the action plan. Ensure compliance with new requirements and seize opportunities that arise.

Benchmarking and collaboration

- Engage in benchmarking exercises to compare the organization's performance and progress against industry peers or leaders.
- Identify areas where the company can learn from others or collaborate on joint decarbonization initiatives to achieve mutual benefits and accelerate progress.

Set stretch goals

- Continuously challenge and set stretch goals within the decarbonization action plan.
- Encourage ambitious targets that push the boundaries of emissions reduction efforts. This drives innovation, fosters creativity, and promotes a mindset of continuous improvement throughout the company.

3.7. Certification

Decarbonization certification refers to the process by which companies or organizations are formally recognized and certified for their efforts and achievements in reducing carbon emissions and transitioning to a low-carbon or carbon-neutral state. These certifications provide credibility and assurance to stakeholders, demonstrating a commitment to environmental responsibility and sustainability.

In some cases, the end goal of this process is obtaining formal certification. Pursuing a Carbon Roadmap and obtaining certification are entirely independent processes, and there is no reason why they cannot be run in parallel. Many businesses are now choosing to do both.

Certification schemes related to decarbonization may exist at different levels, such as national, regional, or industry-specific initiatives, each with its own specific criteria and standards. Some commonly recognized certifications include:

1. **Carbon Neutral Certification**: This certification confirms that a company or organization has achieved net-zero carbon emissions by offsetting or balancing their carbon footprint through activities such as investing in renewable energy projects or supporting carbon sequestration initiatives.

2. **Carbon Disclosure Project (CDP)**: CDP is a global platform that assesses, and rates companies based on their disclosure and management of climate-related risks and opportunities. CDP certification signifies a company's transparency and proactive approach in addressing climate change.

3. **ISO 14001: 2015** is an internationally recognized environmental management standard. It certifies that a company has implemented an effective environmental management system, including measures to reduce GHG emissions and mitigate environmental impacts.

4. **LEED Certification**: LEED (Leadership in Energy and Environmental Design) certification is specific to the building and construction industry. It evaluates the environmental performance and sustainability aspects of buildings, including energy efficiency, water conservation, and emissions reduction.

5. **Science-Based Targets** (SBT): The Science-Based Targets initiative ensures that a company's emissions reduction targets align with the latest climate science and contribute to keeping global temperature rise well below 2 degrees Celsius. SBT certification confirms that a company's emissions targets are scientifically credible.

These certifications, among others, provide tangible evidence of a company's commitment to decarbonization and sustainability. They can enhance the company's reputation, attract environmentally conscious customers, investors, and partners, and demonstrate compliance with regulatory requirements or industry best practices.

4. Concluding remarks and lessons learned

EnTRAINER project introduces a paradigm shift from conventional energy audits to a new, holistic, and complete methodology of Energy Transition Audits. This innovative approach prioritizes a multi-benefit framework and delivers a comprehensive action plan aimed at achieving complete decarbonization of the audited sites.

This report serves as a deliverable for WP2 *Paradigm shift towards a holistic energy transition audit methodology*, which focuses on the development of methodology for ETA actions.

Deliverable D2.2 Decarbonization roadmap, was tested and improved through the implementation of the ETA actions within EnTRAINER WP3, and the training activities in WP5.

Following ETA deployment across four countries, several cross-cutting insights emerged on the design and use of Decarbonization Roadmaps (DRM) and on how to strengthen Deliverable D2.2.

- **Barriers in DRMs design after ETA deployment**

Italy. In several cases, the roadmaps lean heavily on technologies that are not yet mature or affordable, such as high-temperature heat pumps, green hydrogen, or CCS, on the assumption that costs will fall or availability will improve. This creates a real risk of slippage against targets and of investments that never materialize. A second weakness is organizational: DRMs and DAPs are too often developed in parallel to, rather than inside, the corporate investment process. Without that integration, internal sponsorship is thin, change management is weak, and execution suffers.

Spain. Many DRMs arrive without a structured plan for measurement, verification, and scheduled adjustment. As corporate strategies evolve and national/EU funding windows and regulations shift, the absence of a built-in update cycle leaves the roadmap increasingly out of step with reality.

Greece. The current roadmaps rely predominantly on on-site renewable generation. While credible, this emphasis pushes investment requirements high and can make adoption harder to justify. A more balanced approach, explicitly assessing power purchase agreements (PPAs) alongside on-site options, would de-risk the path to low-carbon electricity and broaden the appeal of the DRM.

Romania. Companies face a shortage of local, sector-relevant examples. Without familiar case studies, it is harder for teams to picture the transition pathway, test assumptions, and build confidence in the recommended measures.

- **Shortcomings found in existing roadmaps**

Italy. Too few roadmaps are co-created with the people who must live with them, maintenance staff and line managers. When their input is missing, projects can be misaligned with operational constraints and prove difficult to implement on the shop floor.

Spain. Roadmaps often lack crisp, measurable KPIs tied to baselines and targets, as well as a clear governance framework for monitoring, reporting, and course correction. Without these elements, progress tracking becomes ad hoc and momentum fades.

Greece. Many DRMs are technically sound but organizationally thin. They give limited attention to readiness, behaviors, and roles, and they underuse training and capacity-building as levers to sustain change.

Romania. A common template is missing. The absence of a standard structure slows adoption, complicates comparison across sites, and makes portfolio-level oversight more difficult.

- **Lessons to inform future DRM iterations**

Italy. Start with data that truly represents normal operations. Where datasets are short or atypical, apply tools such as CUSUM and document variability analyses, ideally in an annex, to avoid over-optimistic savings claims. Just as important, design for persistence: specify post-intervention O&M and routine performance checks (frequencies, parameters, and ownership) so that assets like heat pumps and PV systems continue to deliver.

Spain. Treat each DRM as a strategic instrument tailored to the site's business trajectory. Whether the company anticipates downsizing, a new product mix, or expansion, the roadmap should reflect that direction so it guides decision-making rather than sitting on the shelf as a theoretical list.

Greece. Build capability into the plan. Embed training modules, simple operating procedures, and knowledge-transfer steps that help teams prioritize, sequence, and execute measures, not just identify them.

Romania. No additional lessons have been reported yet. Upcoming pilots should translate the identified needs, standard templates and illustrated examples, into practical implementation aids.

- **Closing note**

Across countries, the most effective DRMs share three traits: they rest on reliable, representative data; they pair technology choices with financing, governance, and capability-building; and they include a clear mechanism for monitoring, verification, and periodic revision, keeping the plan aligned with evolving markets, policies, and company strategy.

To make Decarbonization Roadmaps (DRMs) truly investable and deliverable, policy should require a data-first foundation - process-level sub-metering, normalized baselines, and basic QA rules (gap/outlier flags, calibration logs) - then standardize how DRMs are built and governed through a national template that includes measure sheets, NEB taxonomy, business-case mini-dossiers, and an annual refresh protocol. Funding should hinge on bankable cases, not technical wish lists, with IPMVP-aligned M&V plans made a condition of grants and loans. Appraisals must capture multiple benefits - productivity, O&M (Operations and Maintenance) performance, quality, resilience -so projects are scored on total value, while power-sourcing rules should balance on-site renewables with streamlined Standardize corporate PPA (Power Purchase Agreement) contracts to de-risk clean electricity.

DRMs need board-level sponsorship and alignment with capex cycles, backed by capability-building (operator training, ISO 50001) to sustain savings. A living library of anonymized case studies and sector benchmarks can accelerate uptake while secure digital rails (portals/APIs) automate data submissions, dashboards, and verification. Sequenced over three years—template and guidance first, M&V-ready DRMs for funded projects next, and full adoption for large users thereafter—these measures turn DRMs from static documents into managed programs that deliver verified savings and durable decarbonization.

Appendix A. Case study – Greece

The purpose of the present Energy Transition Audit (ETA) report is to present the current energy situation through a detailed energy analysis and to propose a personalized Decarbonization Action Plan for the audited company, aiming to significantly reduce the CO2 emission level of the company with 100% until 20045, compared to 2023 level.

1. General information

The audited company is an urban wastewater treatment, including:
- Reception and pretreatment of sewage water
- Primary and secondary sedimentation
- Biological treatment and sludge management
- Biogas production and energy recovery via cogeneration

The Wastewater Treatment Plant covers approximately 30,000 m² including a sewage inlet well, primary settling tanks, blowers, outlet pumping station, biogas production and sludge processing line.

Based on the data provided by the company for the period 2021 -2023, the average annual electricity consumption from the grid was 15,229,315kWh, while the production, i.e., import of sewage water, was 52,748,137 m^3. Additionally, since May 2023 the company produced electricity from cogeneration units.

For the implementation of ETA we utilized the following data, covering a period from January 2021 to December 2023, with monthly granularity:

- Electricity consumption from the power supply (kWh)
- Electricity production from cogeneration (kWh)
- Total electricity consumption (kWh)
- Import of sewage water (m^3)
- Biogas production (By-product) (m^3)

1.1. Proposed approach

The baseline year was formulated considering the above data. The electricity consumption was the dependent variable while the sewage water import and the biogas production were the dependent variables. Considering the targets of European Union, the proposed measures were in line with the targets of European Green Deal. Specifically, the measured included in DAP was separated in short-term, medium-term and long-term measures as follows:
- Short term measures: 30% CO_2 reduction until 2026
- Medium-term measures: 50% CO_2 reduction until 2030
- Long-term measures: 100% CO_2 reduction until 2050

This approach enhances the effectiveness of the DAP, by setting intermediate targets aligned with EU targets.

2. Description of the company and technological processes

2.1. Energy Contour

The plant's total installed electrical power amounts to 9.107 kW, while the total installed thermal power is 15,856 kW. The facility operates 24/7 for industrial processes, while administrative offices operate 12–16 hours daily, 5 days per week. The main energy sources are electricity from the grid and, since May 2023, self-generated electricity from biogas cogeneration.

2.1.1. Technical Characteristics of Installations

The installation includes the following key infrastructure:

1. Sewage inlet well, primary settling tanks
2. Blowers
3. Outlet pumping station
4. Biological treatment stage (including an intermediate lifting pumping station and biological reactors),
5. Secondary sedimentation tanks
6. Full biogas production
7. Sludge processing line

The following picture presents the individual components of the wastewater treatment plant.

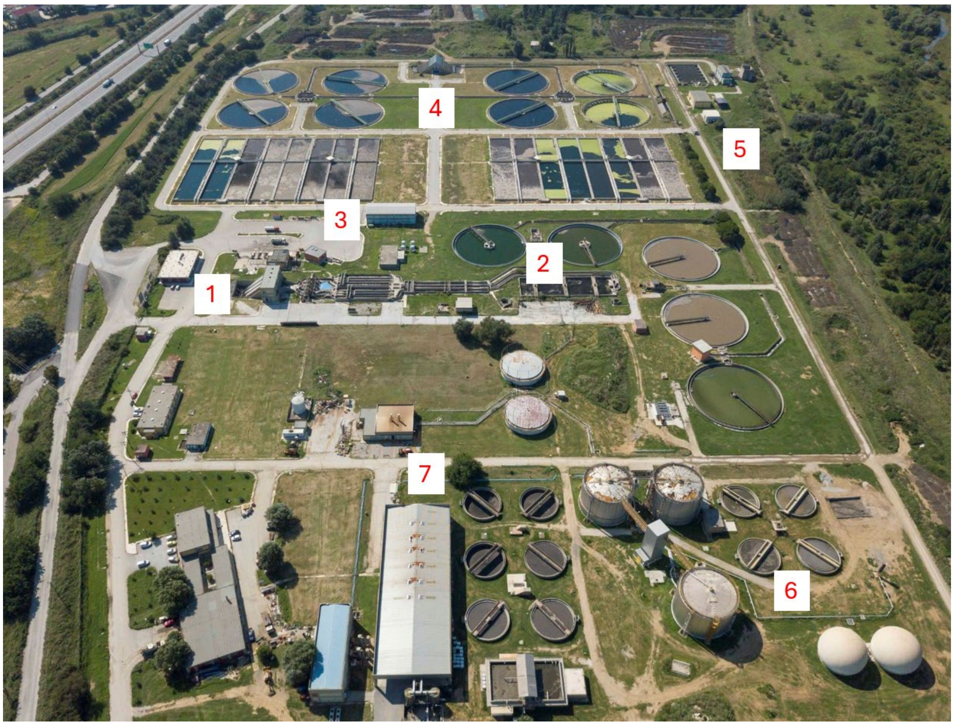


Figure 11: The Wastewater treatment plant of Thessaloniki

2.2. Technological Flow

The main operational activity of the facility is the treatment of urban wastewater, encompassing both the reception and pre-treatment of sewage water. In this process, incoming wastewater first undergoes primary treatment in sedimentation tanks with a total volume of 15,600 m^3, where heavier solids are separated. The partially treated water is then directed to rainwater tanks and pumped through a system for intermediate lifting, sludge recirculation, and excess biological sludge handling before being distributed to secondary sedimentation tanks via manual gate valves. A central pumping station further manages the lifting of primary treated wastewater and the recirculation of sludge, with two dedicated recirculation channels serving the secondary treatment phase.

2.2.1. Measuring Instruments

The assessment of the energy contour and the current situation of the company was based on information and measurements obtained during site visits, as well as data provided by the company. During the visits, operating data such as air conditioner setpoints and process machine capacities were recorded to establish the baseline. The company also validated the data reflecting typical and frequent operating conditions when the plant operates at maximum production. Where certain values were unavailable, the audit team made estimates.
The emission factors for each energy supplier used in the energy scan were based on the coefficients published in 2023 by the Ministry for Ecological Transition and the Demographic Challenge, in conjunction with data from the electricity supplier.

2.3. Decarbonization Action Plan & energy efficiency measures and environmental impact

The DAP outlines the prioritized measures and strategic steps required for the Thessaloniki Wastewater Treatment Plant to achieve substantial reductions in CO_2 emissions by 2030 and fully decarbonization by 2050. The proposed plan focuses on short-term, medium-term, and long-term actions, each contributing to the overall target of a 60% reduction in emissions by 2030 and an 100% reduction by 2050. It should be noted that those estimations are based on the baseline year.
Short-term measures (2024–2026) focus on high-impact and quick-payback interventions. These measures include:

- Installation of an 8.3 MWp photovoltaic park (M2) to offset grid electricity consumption.
- Replacement of fluorescent and halogen lighting with LED technology (M1).
- Initial replacement of IE2 motors with IE4 high-efficiency models (M3).

Medium-term measures (2027–2035) aim to optimize processes and integrate advanced energy efficiency solutions, such as:

- Full-scale replacement of remaining motors with IE4 models.
- Installation of variable frequency drives (VFDs) on process motors to improve load control and reduce energy use (M4).
- Process optimization to maximize biogas utilization for electricity production.

Long-term measures (2036–2050) target full decarbonization through.

- Achieving 100% renewable electricity supply.
- Advanced energy recovery systems and complete electrification of processes.
- Offsetting any residual emissions through verified schemes.

Each measure in the DAP is assessed in terms of energy savings, CO_2 reductions, investment costs, payback period, and multiple benefits, ensuring an integrated approach that combines environmental, economic, and operational gains. The plan will be periodically reviewed and updated to reflect technological advancements, regulatory changes, and operational feedback.

2.4. Main stages of the work

The Energy Transition Audit (ETA) was conducted in two main stages:

Stage 1 – Preliminary Assessment and Data Collection

- Setting the decarbonization targets in alignment with the company'ssustainability objectives and the European Green Deal.
- Collecting primary data for the period 2021–2023, including electricity consumption from the grid, electricity generation from cogeneration, sewage water intake, and biogas production.
- Identifying the key production processes of the wastewater treatment facility, including wastewater inflow, sedimentation, biological treatment, sludge processing, and biogas utilization.
- Identifying the types of energy carriers used, with electricity as the primary source and biogas as an internally generated renewable source.
- Categorizing the main energy users, including process motors, air compressors, lighting systems, and auxiliary equipment.
- Reviewing available measurement data from installed meters, supplemented with energy invoices and operational records.

Stage 2 – Analysis and Decarbonization Planning

- Preparing a detailed description of the company, the wastewater treatment technological processes, and the facility's electricity contour.
- Conducting an energy analysis to determine specific consumption patterns and seasonal variations.
- Developing an emissions inventory based on Scope 1 (direct emissions from on-site biogas combustion) and Scope 2 (indirect emissions from purchased electricity).
- Proposing a Decarbonization Action Plan (DAP), including four prioritized measures:
- Installation of a photovoltaic (PV) park within the plant area.
- Replacement of IE2 motors with IE4 high-efficiency motors.
- Installation of Variable Frequency Drives (VFDs) on selected motors.
- Replacement of existing lighting with LED technology.
- Preparing a roadmap for short-, medium-, and long-term implementation of the proposed measures, targeting a progressive CO_2 reduction up to 100% in the long term.

1.3. General description of the work

The Energy Transition Audit (ETA) was conducted to assess the current energy performance of the Wastewater Treatment Plant, identify opportunities for energy efficiency improvements, and propose measures to support the company's decarbonization pathway.

The work included the collection and analysis of operational and energy-related data for the period 2021–2023, an evaluation of electricity and thermal energy contours, and the preparation of a Decarbonization Action Plan (DAP) with a clear implementation roadmap. The assessment considered both the technical characteristics of the installations and the operational regime of the facility, with the aim of maximizing energy savings, reducing CO_2 emissions, and ensuring long-term sustainability.

1.3.1. Description of the electricity contour

The facility is supplied with electricity from the national grid via connections managed by the Hellenic Electricity Distribution Network Operator (HEDNO). Since May 2023, part of the electricity demand has been met through on-site cogeneration using biogas produced during the wastewater treatment process. Annual electricity consumption for the plant ranges between 15–17 GWh, with the highest demand attributed to process motors, air compressors, and pumping systems.

1.3.2. Energy assessment contour

The assessment covers the plant's full operating regime, with industrial processes operating 24 hours per day, 7 days per week, 365 days per year, and administrative offices operating 12–16 hours per day, 5 days per week, 252 days per year. The analysis included the plant's main operational profile, energy use by major process stages, and seasonal variations.

The time period considered for input data was January 2021 – December 2023. The sources of input data included:

- Direct measurements from on-site meters and monitoring systems.
- Historical consumption records from electricity and water invoices.
- Operational logs and technical records provided by the facility.
- Estimates made by the audit team for parameters not directly measured.

The overall annual operating hours for the main industrial facilities are approximately 8,760 hours/year, reflecting continuous operation, while offices operate approximately 3,024 hours/year.

1.3.3. Energy analysis

The wastewater treatment plant relies primarily on electricity as its main energy carrier. Electricity is used for:

- Operation of process motors (pumps, blowers, mixers)
- Air compressors for aeration processes
- Lighting systems in industrial areas, offices, and outdoor zones
- Auxiliary systems such as control panels and monitoring equipment

The annual electricity consumption for 2021, 2022 and 2023 is presented in Figure 12. For the period 2021–May 2023, all electricity was purchased from the grid. However, since May 2023, part of the electricity demand has been met by locally produced electricity from the combustion of biogas in a cogeneration unit. As a result, 24% of the total electricity consumption was covered by the cogeneration unit (Figure 13) and the electricity consumption from the grid was significantly reduced as presented in Figure 14.

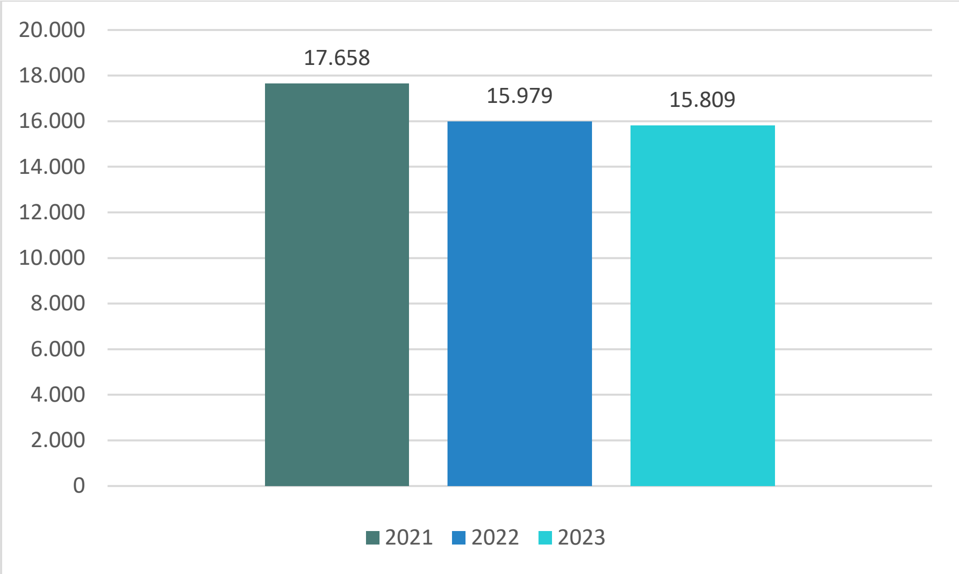


Figure 12: Annual electricity consumption

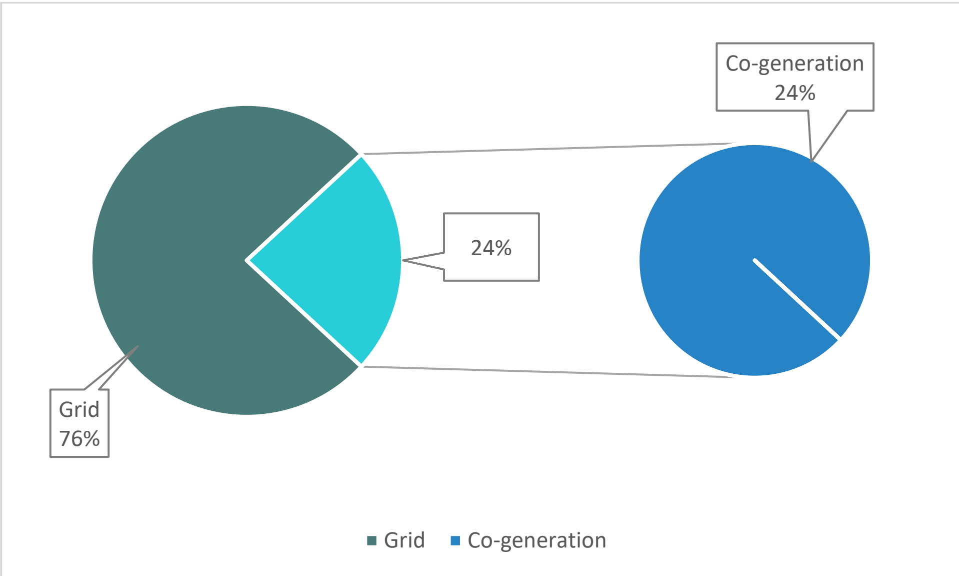


Figure 13: Electricity source of facility for the year 2023

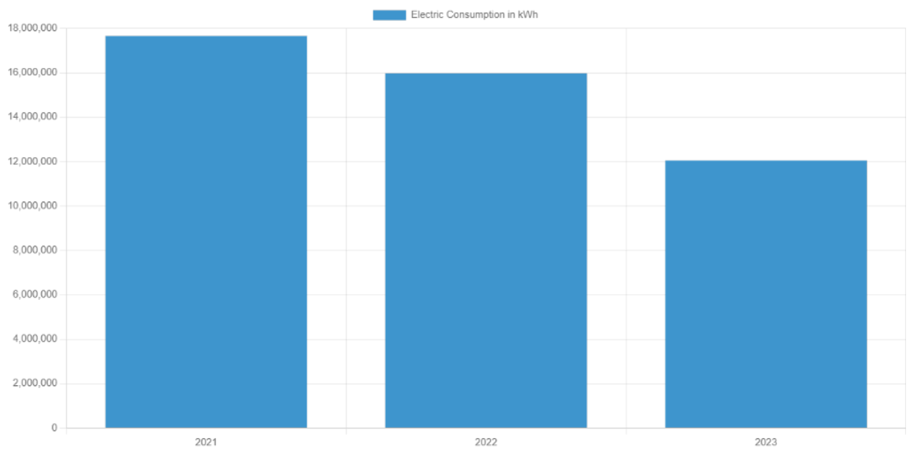


Figure 14: Aggregated annual electricity consumption from the grid.

The following figures illustrate the total electricity consumption and the electricity consumption from the grid per month. Except for the period from August 2022 to April 2023, the facility's energy consumption shows relatively stable variations over time (Figure 15). However, due to the operation of the co-generation unit, the electricity purchased from the grid was significantly reduced after May 2023.

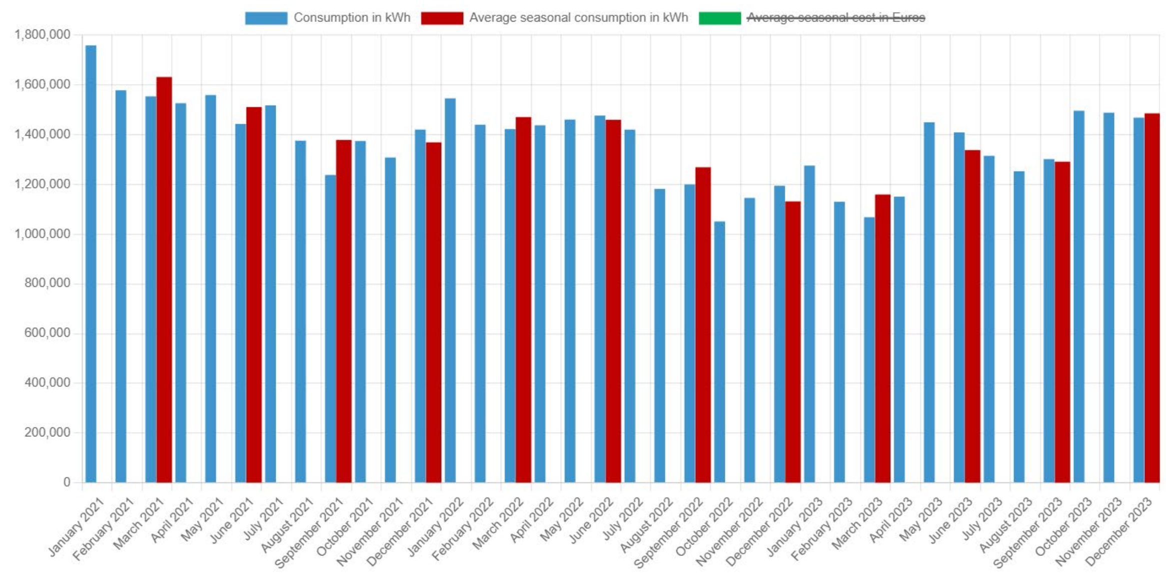


Figure 15: Total electricity consumption per month for the years 2021-2023 [kWh]

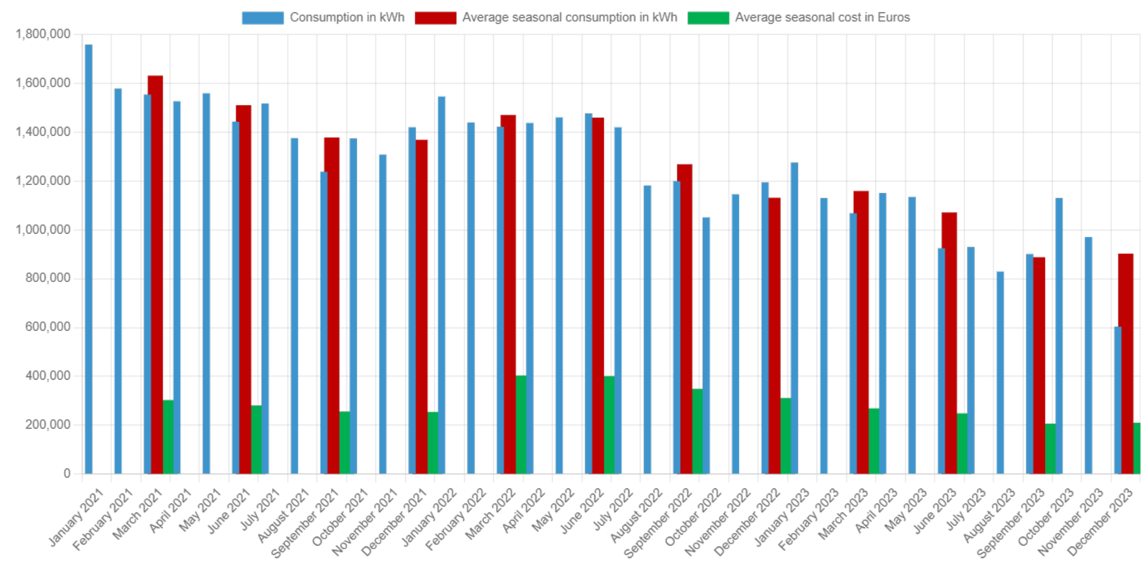


Figure 16: Electricity consumption from the grid for the years 2021-2023 [kWh]

Based on the analysis of energy consumption we can conclude that:

- Electricity is the only energy carrier in use, making the plant's carbon footprint directly dependent on the grid emission factor.

- Biogas utilization has already delivered measurable reductions in purchased electricity and associated CO_2 emissions.

1.3.4. Specific energy consumption

The monthly import of Sagewater is presented in the following figure. In total, the WWTP production for the years 2021 until 2023 is estimated up to 54,554,056 m^3. On the other hand, the total electricity consumption for the same period is about 15,808,529 kWh$_e$. It should be noted that this consumption includes the electric energy produced by biogas. As a result, the specific consumption of the audited company is estimated as follows:

$$\text{Specific electricity consumption } [kW_eh/m^3] = \frac{15.808.529\ kWh}{54.554.056\ m3} = \mathbf{0,29\ kW_eh/m^3}$$

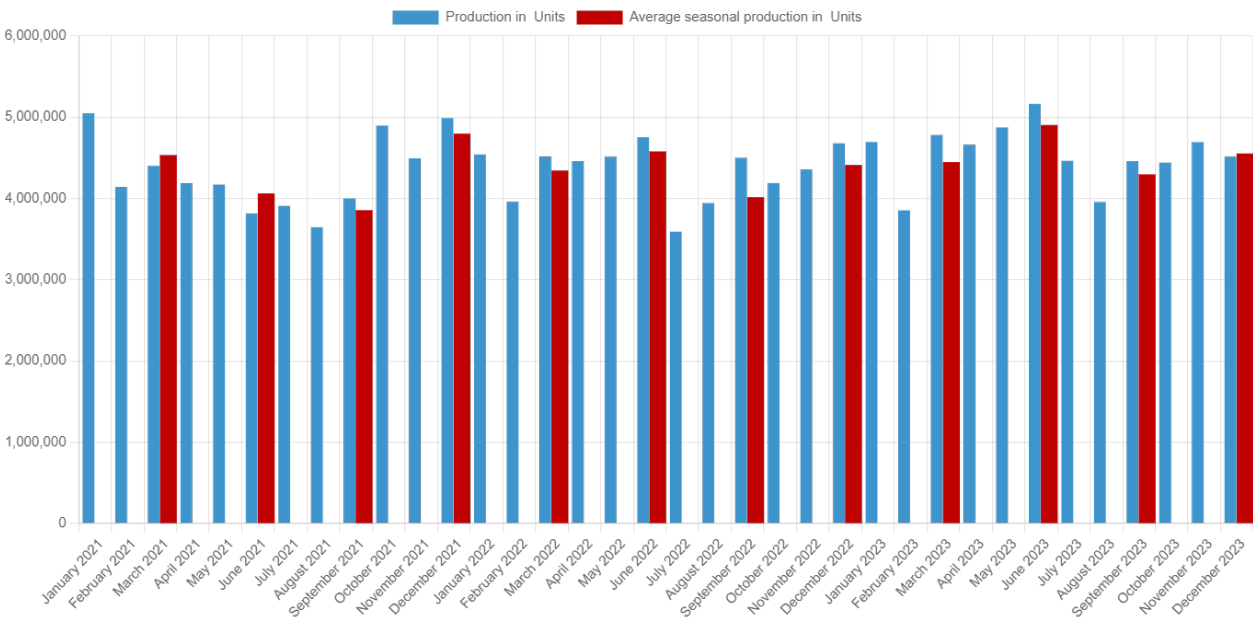


Figure 17: Monthly Import of Sewage Water [m3]

1.4. Emission inventory

The assessment of the emission profile of the company is done according to the GHG Protocol categorization, as follows:

- Definition of the scopes specific to the company's situation and according to the available data

The following CO2 emission inventory follows the five main principles of the GHG protocol:
For the present inventory, the following emission factors have been used for each energy carrier assessed:

Table 11: Emission factor

Energy carrier	Emission factor	U.M
Electricity from the grid	0.416	kgCO2/kWh

Electricity produced by biogas	0	kgCO2/kWh

The monthly CO2 emission for three consecutive years is presented in the following figure. The analysis shows that:

- 2021 recorded the highest annual CO_2 emissions, totalling approximately 7,346 tCO_2, entirely attributable to grid electricity consumption (Scope 2).
- 2022 emissions decreased to 6,647 tCO_2, a reduction of about 9.5% compared to 2021. This decline reflects slightly lower grid electricity demand, as the energy supply source remained exclusively grid based.
- 2023 shows a further and more substantial reduction to 5,013 tCO_2, equivalent to 24.6% lower than 2022 and 31.8% lower than 2021. This sharp decrease is due to the commissioning of the cogeneration system in May 2023, which replaced part of the grid electricity demand with renewable biogas-based electricity (accounted for as zero emissions).

Monthly interpretation indicates relatively steady emissions in 2021 and 2022, ranging between ~437–732 tCO_2 per month. From mid-2023 onwards, however, there is a clear downward shift, with emissions falling to as low as 251 tCO_2 in December 2023. This coincides with the gradual integration of biogas-based self-generation, which displaced grid electricity consumption.

Multiannual perspective highlights that between 2021 and 2023, the company achieved a cumulative reduction of more than 2,300 tCO_2. This confirms the significant impact of on-site renewable integration and underlines the effectiveness of biogas utilization in lowering indirect emissions.

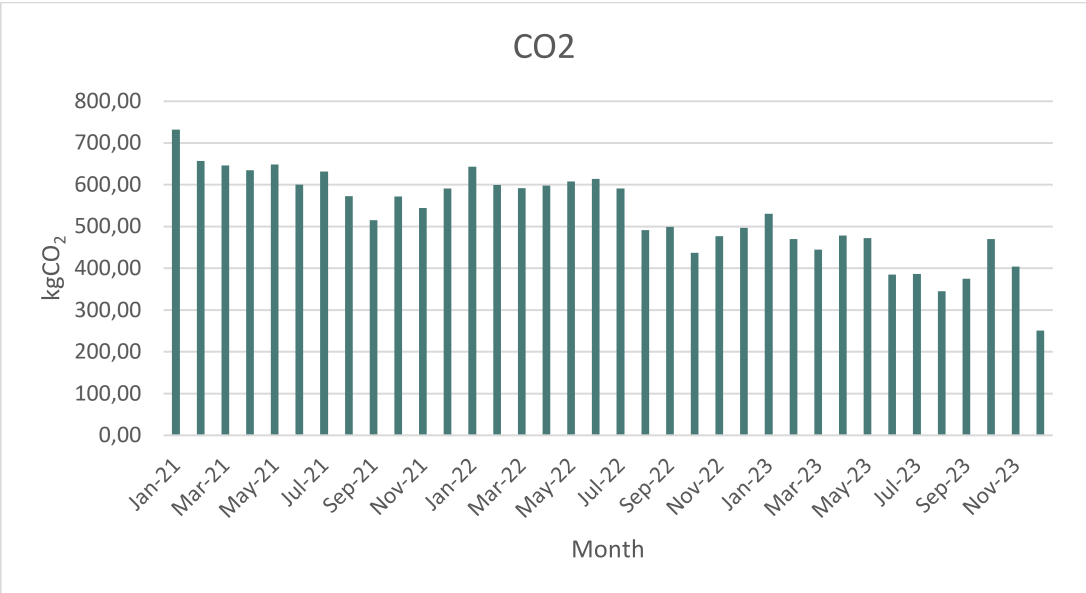


Figure 18: Monthly CO2 emissions

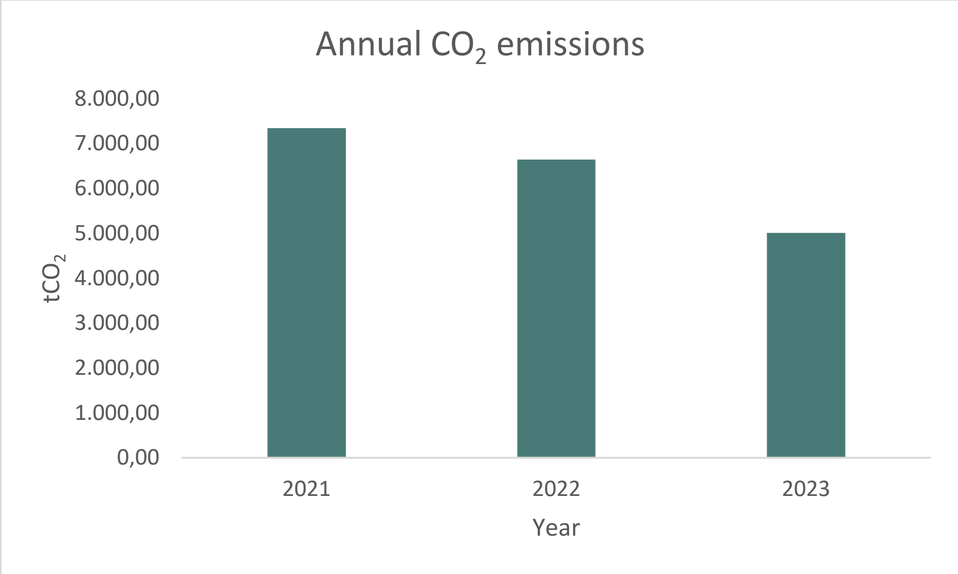


Figure 19: Annual CO2 emissions

1.5. Decarbonization action plan

The target of the audited site was to achieve full decarbonization by 2050. Based on the analysis of the energy carriers and the production process, four measures were proposed, as presented in the following table.

Table 12: Measures proposed by the auditor

Measure	Change to apply
M1	**REPLACEMENT OF FLURICIENT LAMPS AND HALOGEN LAMPS WITH MODERN LED LAMPS**
M2	**INSTALLATION OF RES-PHOTOVOLTAICS WITHIN THE FACTORY UNIT**
M3	**REPLACEMENT OF CLASS IE2 MOTORS WITH THE CORRESPONIND CLASS IE4 MOTORS**
M4	**REPLACEMENT OF CONVENTIONAL SPEED MOTORS WITH CORRESPONDING VFD**

Based on the multi-benefit analysis the proposed measures are classified as follows:

- M2: Installation of res-photovoltaics within the factory unit
- M3: Replacement of class IE2 motors with the corresponding class IE4 motors
- M4: Replacement of conventional speed motors with corresponding VFD
- M1: Replacement of fluorescent lamps and halogen lamps with modern LED lamps

The DAP of the audited company is presented in the following table. According to the DAP, short-term actions are expected to deliver a 30% reduction in CO_2 emissions, medium-term actions aim for a 50% reduction, while the long-term objective is to achieve 100% decarbonization by 2047. The total CO2 emissions reduction at the intermediate target years and the final target year period are presented in Table 13, while Figure 20 and Figure 21 illustrate the decarbonization progress and the decarbonization target, respectively.

If all proposed measures are implemented the company could achieve:

- Energy savings of about 13.5 GWh/year
- CO_2 savings of approximately 5,615 tones/year,
- Economic savings of nearly 3.1M €/year

Table 13: Proposed DAP

	FIRST APPROACH TO THE DECARBONISATION ACTION PLAN							
	Short term			Medium term			Long term	
Strategic environmental objectives	· Reduce their carbon footprint · Include renewable energies			· Move away from natural gas ·Improve their energy efficiency.			· Become a leading company i the Water Treatmen	
Decarbonizacion KPIs (% CO2 to be reduced)	→		30%	→		50%	→	
Decarbonizacion KPIs (tn CO2 to be reduced)			1503,94			1754,60		
MEASURE CATEGORY	**2024**	**2025**	**2026**	**2028**	**2030**	**2032**	**2037**	**2042**
Energy Supply decarbonization	M2		M3		M4			M1
Production processes performance	M3							
Automation systems								
Building								
Repair and maintenance								
Staff habits								
Organizational								
Others								

Table 14: Emission targets

Baseline year:	**2023**
Baseline emission level [tones of CO2 eq.]	5,013.13
Intermediate target year	2028
Intermediate target emission level [%]	- 30%
Intermediate target emission level [tones of CO2 eq.]	1503,94
Intermediate target year	2028
Intermediate target emission level [%]	- 30%
Intermediate target emission level [tones of CO2 eq.]	3,258.54
Final target year	2047
Final target emission level [%]	-100%
Final target emission level [tones of CO2 eq.]	**5,013.14**

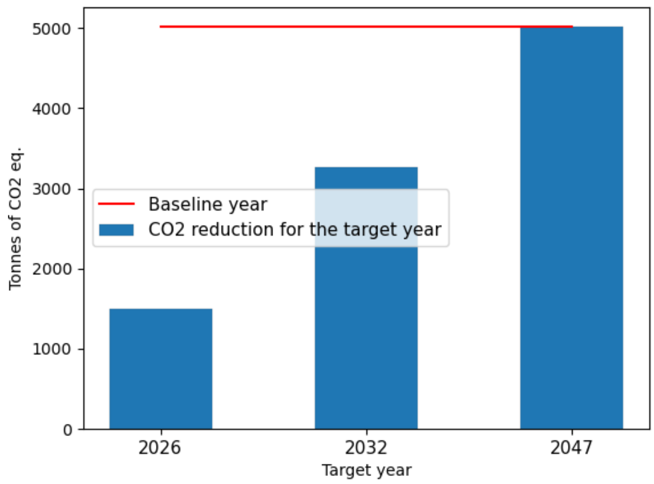


Figure 20: Decarbonisation progress

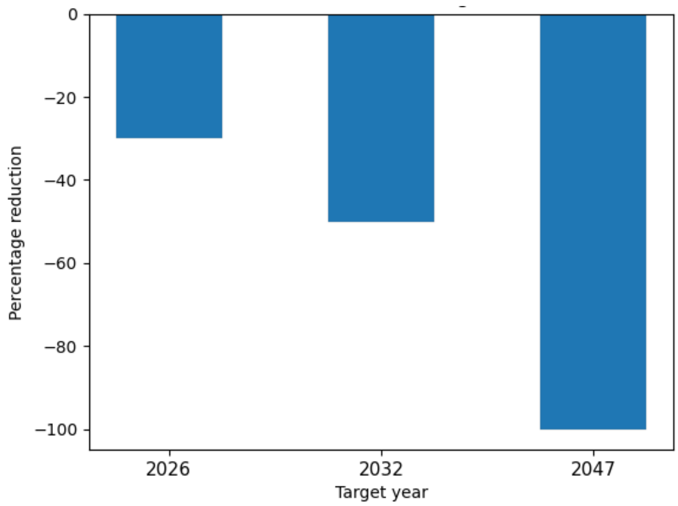


Figure 21: Decarbonisation targets

1.6. Multiple benefits analysis

The multi-benefit analysis that was conducted for the audited company is presented in the following table.

Table 15: Multi-benefit analysis of the proposed measures

Assess which benefits apply to each proposed measure, indicating their relevance (high, medium, low) according to the company's strategy and objectives. Leave empty if not applicable.	Energy Transition Audit Measures			
MULTIBENEFITS	**M1**	**M2**	**M3**	**M4**
Value proposition	0	2	0	2
New green products		Medium		Medium
Intellectual property				
Competitive financial advantage				
Performance	11	11	14	1
Workforce productivity				
Increase production performance	Medium	Medium	Medium	
Improve equipment performance	High	High	High	
Improve asset utilization	Low	Medium	Medium	
Reduce malfunctions and/or lengthen equipment life (due to reduced wear and tear)	Low	Medium	High	Low
Reduce maintenance needs	Low	Medium	Medium	
Water footprint			Medium	

Improve staff safety or reduce injuries				
Reduce raw material consumption				
Reduce waste to improve recycling				
Reduced waste heat				
Reduced CO2 and energy price risks	High			
Staff, customers and partners	0	1	0	1
Improve employee comfort (e.g. reducing noise, improving thermal comfort, better lighting, etc.)		Low		Low
Improve employee satisfaction				
Improve employee health (e.g. thanks to air quality improvement of ambient air, improving workplace conditions, etc.).				
Improve customer service quality				
Improve the share of green products/services				
Attract new customers				
Improve customer satisfaction and loyalty				
Improve Supplier Environmental Sustainability Index				
Improve stakeholder relationships				
Regulatory compliance				
Other				
Other				
Rating	11	14	14	4
MB Ranking	**3**	**1**	**1**	**4**
CONVENTIONAL BENEFITS	**M1**	**M2**	**M3**	**M4**
CO2 reduction	Low	High	Medium	Medium
Energy consumption reduction	Medium	High	High	Low
Cost savings	Low	Medium	Medium	Medium
Investment	High	Medium	Medium	Low
Rating	2	7	6	5
CB Ranking	**4**	**1**	**2**	**3**
Final Ranking	**4**	**1**	**2**	**3**

Based on the analysis, the proposed measures provide a balanced mix of environmental, performance, and economic benefits, aligned with the company's decarbonization strategy. Regarding the value position only measures M2 and M4 are considered since they could contribute to the production of green products. Additionally, based on the analysis all measures were considered to affect the performance of the company with measures M1, M2, and M3 having the highest impact. Moreover, regarding the Staff, customers and partners category, only measures M2 and M4 were considered. Despite their low impact, they could contribute to the improvement of employee's comfort.

In terms of conventional benefits, all measures contribute to reducing CO_2 emissions and energy consumption, with M2 and M3 offering the most significant impact. M1 (LED lighting) further reduces indirect emissions through efficiency, while M4 (VFDs) supports optimization of energy use. Moreover, all measures lead to cost savings, though at varying scales. M2 yields the greatest long-term economic advantage through self-generation of renewable electricity. M3 and M4 generate medium-level cost reductions through efficiency improvements, while M1 has a smaller but steady contribution.

The evaluation of the proposed measures highlighted clear priorities for the company's decarbonization strategy. The installation of PV system (M2) ranked first, as it could deliver the most significant environmental and financial benefits. Moreover, the replacement of IE2 motors with IE4 motors (M3) could offer strong improvements in energy efficiency and equipment performance, with a balanced investment profile. The replacement of conventional motors with variable frequency drives (M4) was ranked third, providing cost-effective and performance-oriented benefits that could contribute moderately to overall savings. Finally, the replacement of fluorescent and halogen lamps with LED lighting (M1) was the last measure in the ranking list with smaller energy and economic impacts.

1.7. Cost-benefit analysis / Financial analysis

Table 16: Description of the proposed measure

#	Proposed measure	Lifetime (years)	Analysed period (years)	Description of the measure	Type of action	Addressed Scope	Alignment with other initiatives	Dependencies and/or constrains	Barriers and risk to be considerer
M1	Replacement of fluorescent lamps with LED ones	-	1	Replacement of fluorescent lamps with LED ones		Reduce electricity cost	EU Green Deal	-	-
M2	Installation of res-photovoltaics within the factory unit	20	20	Installation of res-photovoltaics within the factory unit		Reduce electricity cost	EU Green Deal	-	High investment cost
M3	Replacement of class IE2 motors with the corresponding class IE4 motors	-	1	Replacement of class IE2 motors with the corresponding class IE4 motors		Improve efficiency and reduce electricity cost	EU Green Deal	-	-
M4	Replacement of conventional speed motors with corresponding VFD	-	1	Replacement of conventional speed motors with corresp. VFD		Improve efficiency and reduce electricity cost	EU Green Deal	-	-

Table 17: Costs of the proposed measures

#	CAPEX (Euro)	OPEX (Euro)	Required investment (Euro)
M1	67,665	-	67,665
M2	5,050,000	101,000	5,050,000
M3	-	Does not increase the OPEX	N/A
M4	-	Does not Increase the OPEX	N/A

Table 18: Short evaluation of the measures

#	Energy saving (MWh/year)	CO2 emission reduction (tons/year)	Cost saving (Euro/year)	Multiple benefits (Euro/year)
M1	106.203		25,486	-
M2	12,046.484		2,770,691.34	-
M2	131.050		28,736	-
M4	1,214.070		279,236	-

Table 19: Financial evaluation of the measures

#	Payback period (year)	IRR (%)	NPV (Euro)	Payback period with MB (year)	IRR with MB (%)	NPV with MB (Euro)	By Energy Savings (Euro/MWh)	By CO2 Reduction (Euro/tons)
M1	2.65	-	-	-	-	-	230	
M2	1.2	-	48,754,520.43	-	-	-	230	
M3	-	-	-	-	-	-		
M4	-	-	-	-	-	-		

1.8. Funding sources for energy efficiency and decarbonization

At the national level, several funding schemes have been launched to support the energy efficiency and green transition of businesses in Greece. One of the key programs was "Exoikonomo for Businesses", which targeted small, medium, and large enterprises with measures such as:

- Installation of heat pump systems for heating.
- Deployment of solar heating systems.
- Use of smart energy consumption meters (behind-the-meter).
- Other energy-saving interventions in production, storage, product distribution, and company operations through modern energy-efficient equipment and systems.

In parallel, two additional funding programs were dedicated to small and medium-sized enterprises: "Green Productive Investment for SMEs" and "Green Transition of SMEs." Both actions promoted projects aimed at adopting modern technologies, upgrading products and services, and enhancing energy efficiency and circular economy practices. The Green Productive Investment for SMEs program had a total budget of €400 million, with particularly favourable conditions for less developed regions.

Currently, the active national programs include "Storage Systems for Businesses" and "I Move Electrically". The first supports the installation of battery energy storage systems in existing PV installations of enterprises, thereby enhancing self-consumption and grid flexibility. The second initiative promotes e-mobility by providing subsidies for the purchase or lease of electric vehicles, motorcycles, bicycles, and light commercial vans, as well as for the installation of smart charging points. By addressing both businesses and individuals, this program contributes directly to the decarbonization of road transport and the achievement of Greece's national climate objectives.
Furthermore, Western Macedonia, where University of Western Macedonia (UOWM) is located, has been designated as a Just Transition region due to its ongoing lignite phase-out. These regions will benefit from further funding opportunities aimed at supporting a successful green transition. According to the regional Just Transition Plan of Western Macedonia, at least EUR 1 trillion will be mobilized over the next decade to facilitate this transformation, while almost EUR 6 million will be allocated for energy efficiency and demonstration projects in SMEs or large enterprises. This will create significant funding opportunities for local industries to invest in clean technologies, renewable energy, and other green transition projects in Western Macedonia.

Additionally, national banks also provide loans under favourable conditions for enterprises aiming to improve their energy performance. A prominent initiative is the European Investment Bank (EIB) program for green financing in Greece, which is designed to:

- Support businesses operating in sectors related to climate action and environmental sustainability.
- Enable investments in renewable energy, energy efficiency, and other green projects across all sectors by SMEs and Mid-Caps.
- Promote youth employment and gender equality in the workplace.

To date, more than 350 Greek businesses have benefited from this program. Since the EIB requires recipient banks to match its funding, the total financing mobilized for green projects in Greece is expected to reach €2 billion.
In addition, for the installation of RES systems, national banks offer dedicated financing covering up to 75% of the total investment cost, with a maximum loan amount of €1.5 million per customer. Loans

may be issued with either a variable interest rate (linked to the 3-month Euribor) or a fixed interest rate, in both cases subject to an additional margin and the statutory levy under Law 128/75.

1.9. Decarbonisation Roadmap

The RMD of the audited site is based on five main scopes:

- S1: Reduce the carbon footprint (Short-term measure)
- S2: Include RES (Short-term measure)
- S3: Improve energy efficiency (Medium-term measure)
- S4: Decarbonization of the company (Long-term measure)

Table 20: Decarbonisation Roadmap

		-30% Scope 1, 2 & 3	-35% Scope 1 & 3	-35% Scope 4
	2024	2026	2030	2042
Energy Supply	Installation of RES (S1, S2)			
Production Processes	Replacement of class IE2 motors with the corresponding class IE4 motors (S1, S3)	Replacement of class IE2 motors with the corresponding class IE4 motors (S1, S3)	Replacement of conventional speed motors with corresponding VFD (S1, S3)	
Buildings				Replacement of fluricient lamps and halogen lamps with modern LED lamps (S4)
Other	Recommendations for conducting additional studies for the proposed measure (S1) Available funds and program cycles (S1)	Organizational measures - education and training measures (S1, S3) Guidance for monitoring & verification and standard recommendations to reach the targets set (S1, S3)	Organizational measures - education and training measures (S1, S3)	

S1: Reduce the carbon footprint S3: Improve energy efficiency
S2: Include RES S4: Decarbonization of the company

Appendix B. Case study – Italy

The purpose of the present Energy Transition Audit (ETA) report is to present the current energy situation through a detailed energy analysis and to propose a personalized Decarbonization Action Plan for the audited company, aiming to significantly reduce the CO2 emission level of the company with 35% until 2030 and with 88% until 2050, compared to 2023 level.

1.1. General information

Founded in December 1954, the Company's mission was to offer the market high-quality, innovative products made from fresh milk collected every morning from South Tyrol's mountain farms. In 1987, the Company began producing yoghurt, which would become its flagship product, in addition to bottling fresh milk and cream. Then, in 2000, in response to consumer demand, it started producing yoghurt and probiotic drinks.
Over the years, the Company has distinguished itself through its commitment to sustainability and innovation by using renewable energy sources and implementing energy-saving measures. The company now employs 180 people.

The Company is already aware of the importance of energy efficiency and mindful of its impact on climate-changing gas emissions. The following measures had already been implemented by August 2024:

- Replacement of fluorescent and incandescent lamps with LED systems.
- Installation of presence sensors in ramps, storage and packaging areas.
- Installation of three photovoltaic systems with a total peak power output of around 1 MWp.
- Increasing the EER of the ammonia refrigeration unit.
- Increased efficiency of the compressed air production system.
- Reduction in the operating pressure of the steam generators.
- Heat recovery from compressors for integration into the domestic hot water production system.
- Periodically checking the average monthly power factor and the need for power factor correction.
- Monitoring of compressed air and gas circuit leaks.

The analysis revealed that the most critical aspect is the use of gas to produce steam for production processes. In contrast, the Company is already highly efficient in its use of electricity. In addition to maximizing the self-consumption of energy produced by photovoltaics, a series of measures have been implemented over the years to make processes using this energy source as efficient as possible, such as the production of cold and compressed air.

The data was collected in collaboration with company staff, who provided the necessary information and documents for preparing the ETA. These included the following:

- Electricity consumption and costs for the last three years (2021–2023).
- Natural gas consumption and costs for the last three years (2021–2023).
- Diesel consumption and costs for the last three years (2021–2023).
- Refrigeration unit consumption, operating temperatures and EER.
- Consumption and air volumes processed by the compressed air production line.

- Photovoltaic data, such as the amount of electricity produced and sold to the grid.
- Nameplate data of installed steam generators.
- A list of the most energy-intensive systems and machinery.
- Production data, i.e. the number of kilograms of yoghurt produced between 2021 and 2023.

The reference year for the energy analysis was 2023.
For each energy carrier, the data obtained from supplier bills was compared with the total consumption obtained by adding up the monitoring data from the various plant services, taking into account the machines' actual operation and the company's work shifts. Where monitored data was unavailable, estimates were made of the operating modes of the machinery (e.g. load and utilisation factors) and the resulting consumptions.

Proposed approach:

- Baseline year - 2023
  Target year - 2050, in line with the European Green Deal.
- Setting intermediate targets:
  - Short- and medium-term measures: 35% reduction until 2030
  - Long term measures: 88% reduction until 2050

1.2. Short description of the company

Since 2000, the Company has produced probiotic drinks, as well as yogurt and bottled fresh milk and cream. The Company processes approximately 45 million liters of Italian milk each year.
The milk is delivered by truck, weighed, inspected, and stored according to the production line on which it will be used. There are three different storage tanks:

- a tank for raw milk.
- a tank for standard milk.
- a tank for "special" milk, i.e., milk used for particular products or as a reserve.

The milk is then pasteurized using heat exchangers and centrifuges for yogurt production. For some products, such as creamy yogurts, evaporators are used for milk, but not for yogurt-based drinks. After pasteurization, the milk is sent to maturation tanks where the temperature is maintained at 35-45°C. The product then undergoes various treatments, such as being mixed with fruit, before finally being sent to the packaging lines.

Additional processes involving significant energy consumption include washing tanks with water and soda cycles, which usually occur after each milk load, depending on the tank and line. Another example is the cleaning and sterilization process for drinkable yogurt bottles, which requires a lot of energy and water. Finally, after the packaging of finished products, there are two pallet transport lines and a packaging line dedicated to the pallets themselves.

The products processed are yogurt, drinkable yogurt, fresh milk, and cream. There are nine packaging lines in total, two of which are unmonitored: cream and fresh milk. The finished products are stored and shipped in an automatic refrigerated warehouse with two robots, as well as in two other warehouses where pallets are prepared for loading onto refrigerated trucks at 2-4 °C.
The company uses electricity and natural gas for its production processes and diesel fuel for its vehicle fleet. There is also significant consumption of tap water and untreated well water.
Regarding monitoring, checks are carried out for leaks in the compressed air circuit and gas line.

Regarding renewable energy sources, the Company has three photovoltaic systems with a total installed capacity of approximately 1 MWp. The amount of electricity produced and fed into the grid is recorded for each system.

Work is divided into three shifts over five days (Monday through Friday, with shifts at 1:00 a.m., 9:00 a.m., and 5:00 p.m.) and ends at 5:00 a.m. on Saturday morning.

For data protection reasons it is not possible to provide the address of the company. The site is in the norther part of the Trentino Alto-Adige region. It consists of several buildings covering an area of approximately 10.880 m². The total area, including loading areas and parking lots, is approximately 17.000 m².

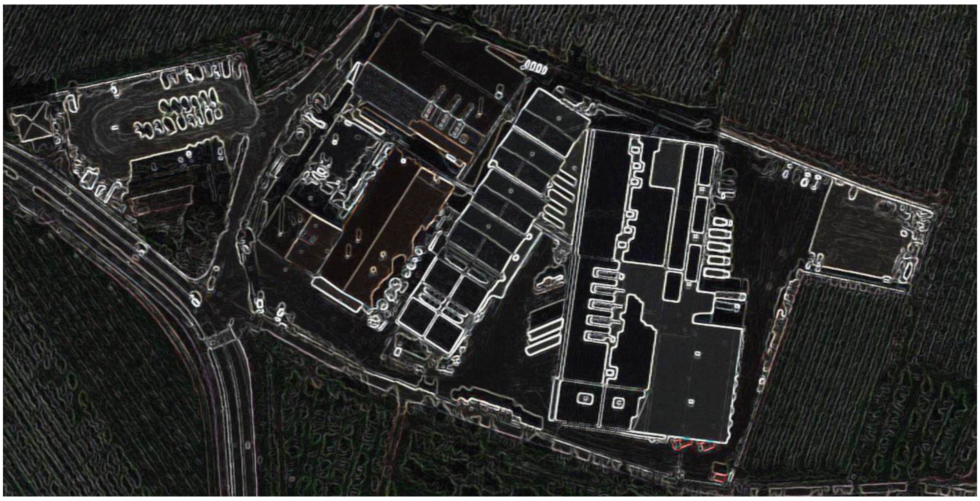


Figure 22: Location of the industrial site

1.3. Description of the technological processes

The minimum structure of the ETA report according to the EnTRAINER ETA methodology includes the following elements:

- Defining the energy contour
- Technical characteristics of installations contained in the outline;
- Description of the company/site and the technological flow;
- Measuring instruments used (if the case)
- Decarbonization action plan
- Calculation of efficiency savings and environmental impact, including targeted reduction.
- Roadmap for DAP implementation (Annex)

1.3.1. Description of the electricity contour

The input voltage at the plant is 20 kV, which is then converted to low voltage by two transformers, one of 1250 kVA and the other of 1600 kVA. The average monthly power factor is also checked to minimize penalties resulting from the injection of reactive power into the grid.

1.3.2. Description of the thermal energy contour

Two gas-fired steam generators, each with a nominal power of 1950 kW, supply the thermal energy used in production processes. They operate 24 hours a day. Only a small proportion of the heat produced (around 1%) is used in winter to supplement the heating and domestic hot water (DHW) circuits. An ammonia refrigeration unit consisting of two machines with a total capacity of approximately 1.6 MW generates the cold used for production processes and for the storage of finished products.

1.3.3. Energy assessment contour

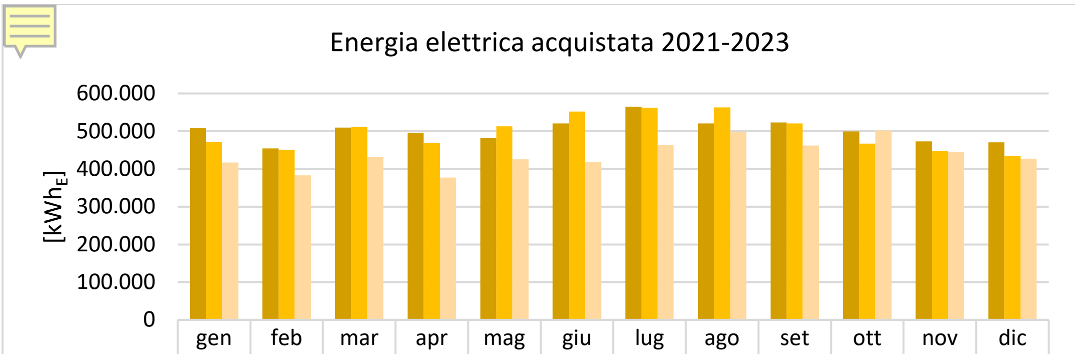
The reference year for this energy analysis was 2023. Data on energy consumption and production, as well as benchmark indices, were assessed for the same year. Data from supplier bills were used for both natural gas and electricity. The latter were added to the self-consumption data for electricity produced by the photovoltaic system to provide a comprehensive overview of the plant's electricity consumption. This data was then compared with the total electricity consumption obtained by adding the monitoring data from the various plant services, taking the actual operation of the machinery and the company's work shifts into account. Where monitored data was unavailable, estimates were made of the operating modes of the machinery (e.g. load and utilization factors) and the resulting consumptions.

Based on an analysis of the Company's services and activities, several functional areas were defined for the purposes of this ETA to better represent and schematize the different energy uses, which are also reflected in the organization of spaces within the company.
Regarding the data used for consumption parameterisation, it was decided that the quantity of yoghurt produced in kilograms would be used.
The plant operates for around 240 days a year, working in three 8-hour shifts.
The energy consumption inventory was carried out using data provided by the Company. This consisted of measured data, such as that from continuously monitored compressors for electricity consumption and compressed air volume produced, and estimated data, such as load and utilisation factors for the rest of the machinery.

1.4. Energy analysis

a. *Electrical Energy*

Based only on monitored data, it is clear that the departments consuming the most electricity are those involved in compressed air and cooling. These departments account for approximately 18% and 19% of total consumption, respectively. Extending the analysis to include departments for which operating regimes, and therefore consumption, have been hypothesised, it is evident that packaging finished products is the most energy-intensive process, accounting for around 25% of total consumption. The figure below shows the trend in monthly consumption of electricity purchased in the period of analysis. The graph shows that in the three years the energy purchased has dropped by a percentage of about 13% thanks to the entry into operation of an additional photovoltaic system that has reduced the withdrawal from the grid.



	gen	feb	mar	apr	mag	giu	lug	ago	set	ott	nov	dic
2021	508.1	454.4	509.9	495.8	481.6	520.7	564.8	520.2	522.7	499.2	473.4	470.6
2022	471.2	450.7	511.1	468.6	513.0	552.4	562.3	563.3	520.5	466.9	447.2	435.1
2023	416.7	382.7	431.0	376.8	425.6	418.4	462.5	498.7	462.4	502.1	445.0	427.3

Figure 23: Monthly electricity purchased for the three-year period 2021-2023

Below is the evolution of the unit cost of electricity (net of VAT) for the three-year period 2021-2023 for the plant, which shows that in 2022 there was a sharp increase in the cost of supply due to the energy crisis triggered by the Russian-Ukrainian conflict.

Table 21: Average annual unit electricity costs for the three-year period 2021-2023

Reference year	Utility bill withdrawal [kWh]	Average unit cost [€/kWh]
2021	6,021,929	0.13 €
2022	5,962,867	0.34 €
2023	5,249,834	0.21 €

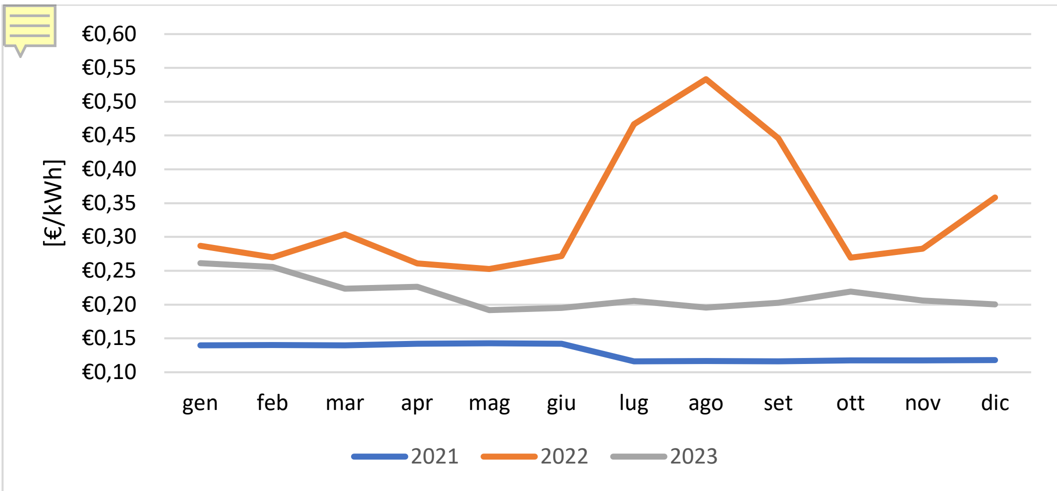
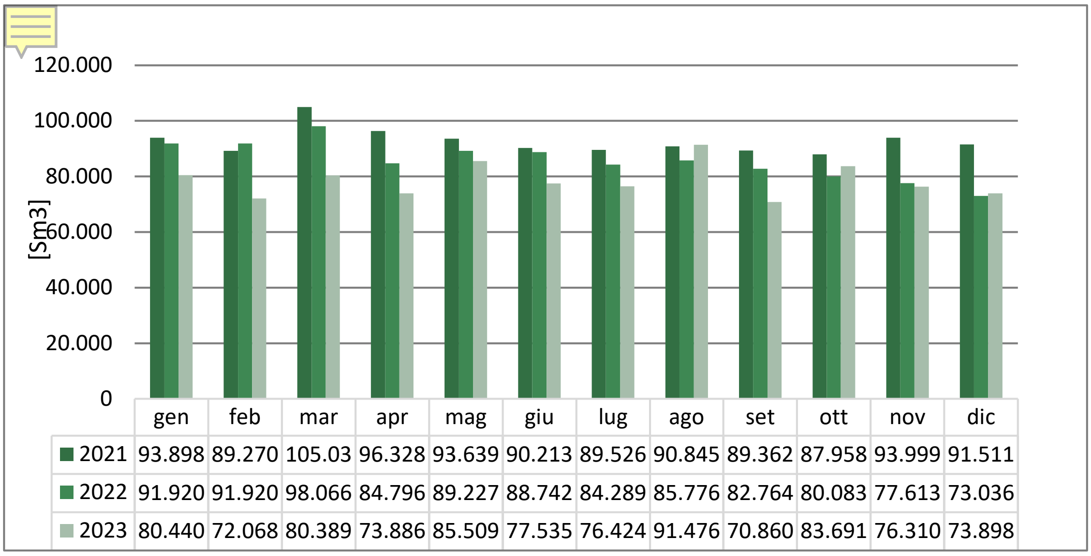


Figure 24: Trend in the average monthly unit cost of electricity in the three-year period 2021-2023

b. *Natural Gas*

Monthly natural gas consumption was calculated from bills provided for the three-year period 2021-2023. Consumption trend does not depend on the outside temperature but on production, as heat is used almost exclusively for production processes (99.95%) and only to a very small extent (0.05%) for space heating and DHW production.

Similarly to what was seen for electricity, the trend in monthly natural gas consumption in the period of analysis is shown below. The graph shows that the purchase of fuel has fallen, from 2021 to 2023, with a percentage of about 15% even though production has remained almost constant. This testifies to the Company's commitment to energy efficiency.



	gen	feb	mar	apr	mag	giu	lug	ago	set	ott	nov	dic
2021	93.898	89.270	105.03	96.328	93.639	90.213	89.526	90.845	89.362	87.958	93.999	91.511
2022	91.920	91.920	98.066	84.796	89.227	88.742	84.289	85.776	82.764	80.083	77.613	73.036
2023	80.440	72.068	80.389	73.886	85.509	77.535	76.424	91.476	70.860	83.691	76.310	73.898

Figure 25: Trend in natural gas consumption in the three-year reference period 2021-2023

Finally, a comparison of the average annual unit cost of natural gas is proposed, which shows that there has been, from 2021 to 2023, a considerable increase in the cost of purchasing fuel due to the Russian-Ukrainian war.

Table 22: Average annual unit costs of natural gas for the three-year period 2021-2023

Reference year	Utility bill withdrawal [Sm³]	Average unit cost [€/Sm³]
2021	1,111,587	0.246 €
2022	1,028,231	0.335 €
2023	942,486	1.020 €

c. Diesel

Diesel is used for the movement of the vehicle fleet and therefore for the transport of the raw material.

Table 23: Average annual unit costs of diesel for the three-year period 2021-2023

Reference year	Utility bill withdrawal [litres]	Average unit cost [€/litre]
2021	167,331	1.342 €
2022	172,119	1.642 €
2023	174,119	1.532 €

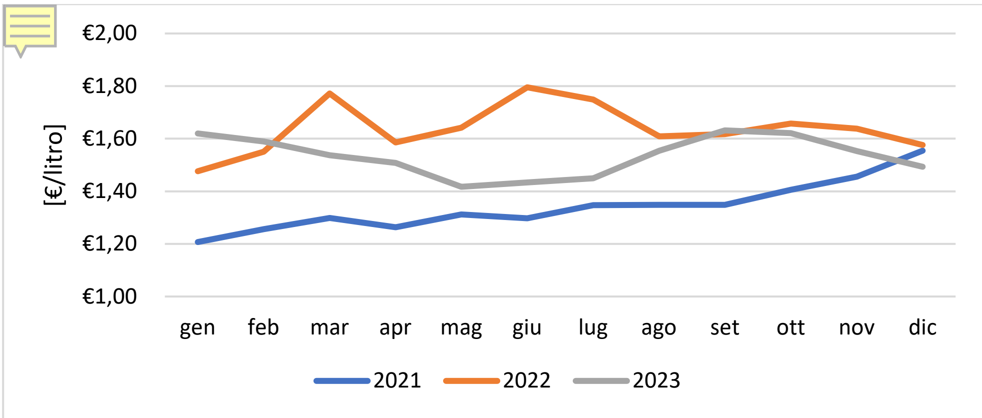


Figure 26: Trend in the average monthly unit cost of diesel in the three-year period 2021-2023

From 2021 to 2023, there was a small increase in diesel consumption, while the unit cost increased slightly in 2022 and decreased the following year.

d. *Electricity produced by RES*

The industrial site is equipped with three separate photovoltaic systems called PV 1, PV 2 and PV 3, respectively of 391.69 kWp, 124.33 kWp and 464.12 kWp. For the first two, daily production and sales data are available on the grid starting from January 2020, while the third plant went into operation at the end of October 2023.

Table 24: Monthly data on electricity produced by photovoltaics in 2021, 2022 and 2023

	Electricity produced – PV system 1			Electricity produced – PV system 2			Electricity produced – PV system 3		
Month	Year 2021 [kWh]	Year 2022 [kWh]	Year 2023 [kWh]	Year 2021 [kWh]	Year 2022 [kWh]	Year 2023 [kWh]	Year 2021 [kWh]	Year 2022 [kWh]	Year 2023 [kWh]
January	1,507	5,924	4,839	5,289	17,900	14,835	0	0	0
February	7,019	7,691	7,807	22,351	23,757	24,851	0	0	0
March	11,951	11,876	10,506	38,554	37,810	34,525	0	0	0
April	14,125	14,024	14,137	45,484	44,616	45,446	0	0	0
May	16,595	15,720	14,901	52,305	50,212	43,056	0	0	0
June	17,744	17,168	17,875	53,627	54,411	56,978	0	0	0
July	15,520	18,375	16,702	46,281	57,028	53,321	0	0	0
August	14,825	16,147	14,802	46,668	50,861	47,160	0	0	0
September	12,547	11,594	11,889	39,480	36,433	38,277	0	0	0
October	8,774	8,608	7,738	27,326	25,949	24,872	0	0	0
November	4,818	5,262	5,514	14,987	15,155	18,014	0	0	5,641
December	3,530	3,262	3,752	10,476	8,959	11,908	0	0	3,775

Table 25: Monthly data on electricity sold to the grid in 2021, 2022 and 2023

Month	Electricity sold		
	Year 2021 [kWh]	Year 2022 [kWh]	Year 2023 [kWh]
January	0.00	0.00	121.04
February	0.00	0.00	868.70
March	0.00	2.04	3,223.88
April	6.12	97.92	8,414.66
May	66.64	5.10	3,817.52
June	3.74	0.00	6,462,07
July	3.40	0.00	5,810.91
August	8.16	11,720.48	2,489.48
September	0.00	13.94	1,950.24
October	0.00	70.38	352.58
November	0.00	8.84	145.18
December	0.00	0.00	2.72

In 2023, the plant reached a self-consumption rate of about 94%, which means that almost all of the electricity produced by photovoltaics was self-consumed in situ. The latter, in particular, corresponds to 10% of the plant's total electricity consumption. It should also be noted that the share of energy sold to the grid is linked to photovoltaic production that takes place during weekends, in which there is a surplus of production compared to the plant's electricity needs.

For a breakdown of the monthly values, relating to 2023, of the electricity purchased, produced by the photovoltaic system, the self-consumed electricity and the annual total, please refer to the table and graph below.

Table 26: Data on electricity purchased and produced by photovoltaics in 2023

	Total electricity purchased [kWhE]	Total electricity produced PV [kWhE]	Total self-consumed electricity [kWhE]	Total consumption 2023 [kWhE]
gen.23	416,748	19,674	19,553	436,301
feb.23	382,712	32,659	31,790	414,502
mar.23	431,038	45,031	41,807	472,845
apr.23	376,816	59,583	51,169	427,985
mag.23	425,677	57,958	54,140	479,817
Jun.23	418,445	74,853	68,391	486,836
Jul.23	462,564	70,023	64,213	526,777
ago.23	498,781	61,962	59,472	558,253
set.23	462,420	50,167	48,217	510,637
there.23	502,164	32,610	32,258	534,422
nov.23	445,095	29,169	29,024	474,119
Dec.23	427,374	19,436	19,433	446,807
TOTAL [kWh]	**5,249,834**	**553,125**	**519,466**	**5,769,300**

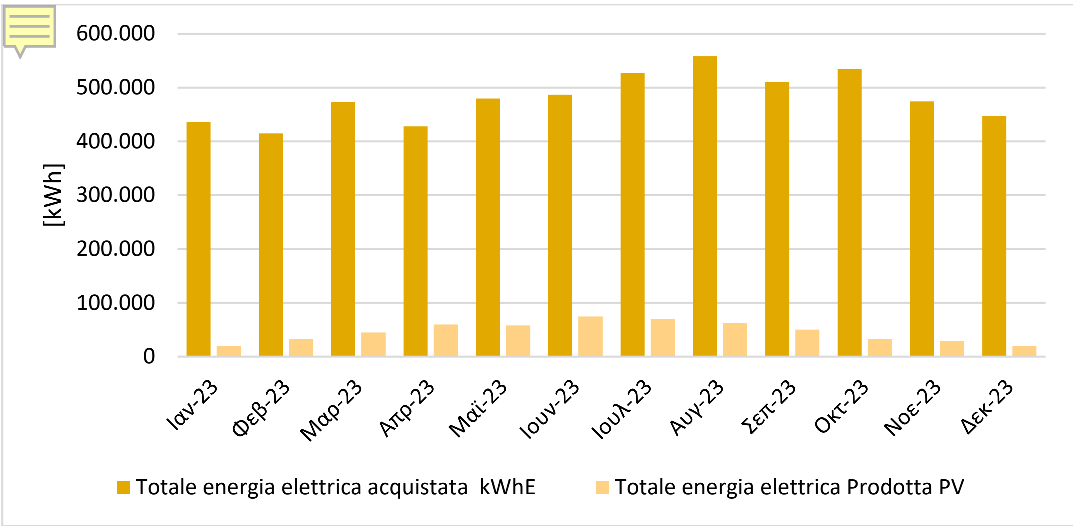


Figure 27: Comparison of electricity purchased and produced by PV in 2023

Summary and comparison of energy carriers

The breakdown of total energy costs over the last three years is summarised in the following figures, which show that electricity always has the greatest weight, although from 2021 to 2023 there was a drop in incidence from 61% to 48%, partly due to changes in energy costs and partly to the increase in photovoltaic production.

With reference to 2023, the high share assumed by natural gas (41%) underlines the importance of making processes involving this energy carrier more efficient, in order to reduce both energy costs and related emissions.

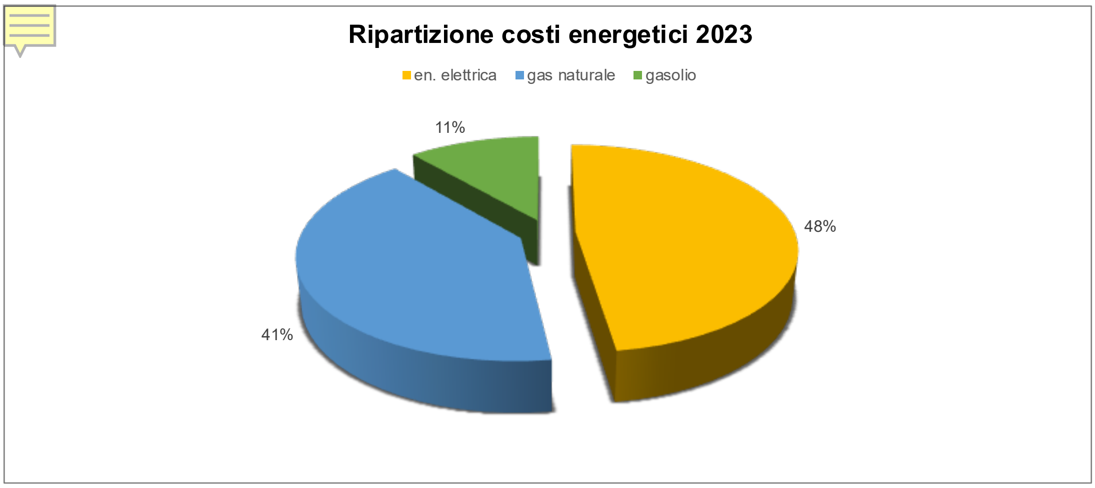


Figure 28: Breakdown of energy costs in 2023

Figure 29: Breakdown of energy costs in 2022

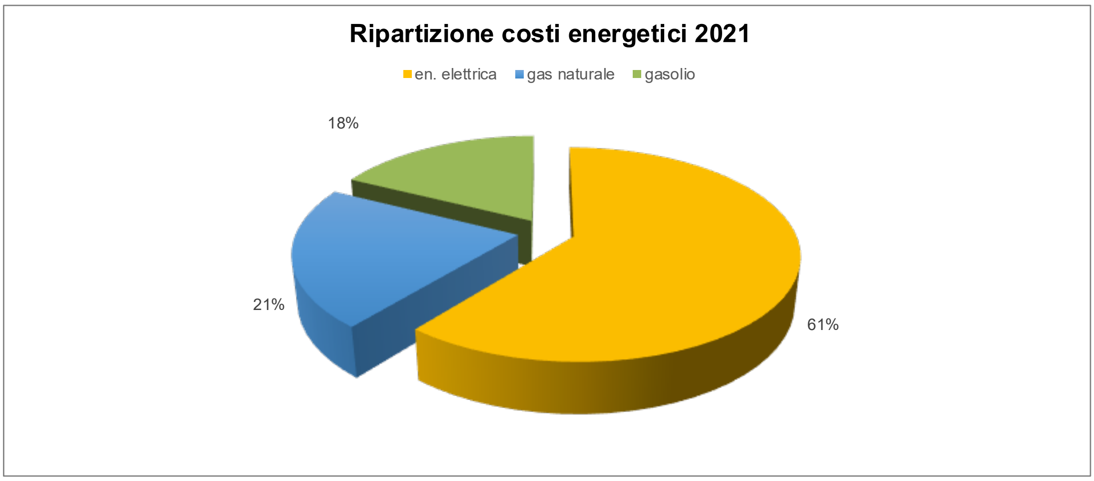


Figure 30: Breakdown of energy costs in 2021

1.4.1. Energy Indicators

Consumption data and energy inventory results for the various carriers were processed into a series of summary energy indicators. These indicators allow values to be normalised using variables defined for each functional area. These indicators enable immediate comparisons of consumption under the same conditions, as well as the calculation of annual variations and savings, net of factors that may have affected the energy demand of the various consumption items.

Please note that if new data or measurements become available, or if there are future expansions, interventions or changes to departments, activities or services, it may be necessary to revise the indices to take these changes into account.

The variables on which to base the indices have been discussed and agreed with the Company representative. In this regard, it has been decided that the quantity of yoghurt produced in kilograms or tonnes will be used as an indicator for all main activities and auxiliary services. For general services, however, the indicators used will vary depending on the service in question.
The following tables show the indicators calculated according to the different functional areas and energy carriers, based on the considerations set out above.

Table 27: Summary of the indicators for electricity consumption (here "." is used as separator for thousands)

Indice	Reparto	Energia Elettrica kWh$_e$	variabile	u.d.m.	indicatore	u.d.m.
D. g.	Intero stabilimento	5.178.596	41.505	t,tot	124,8	kWh/t,tot
	Attività principali	**2.055.685**				
D. a. 1	Pastorizzazione	377.653	41.505	t,tot	9,1	kWh/t,tot
D. a. 2	Confezionamento Prodotti	1.415.232	41.505	t,tot	34,1	kWh/t,tot
D. a. 3	Immagazzinamento	262.800	41.505	t,tot	6,3	kWh/t,tot
	Servizi Ausiliari	**2.767.745**				
D. s. 1	Produzione vapore	119.808	41.505	t,tot	2,9	kWh/t,tot
D. s. 2	Produzione freddo	1.068.474	41.505	t,tot	25,7	kWh/t,tot
D. s. 3	Produzione aria compressa	1.047.213	41.505	t,tot	25,2	kWh/t,tot
D. s. 4	Trasformatori	104.997	41.505	t,tot	2,5	kWh/t,tot
D. s. 5	Acqua di pozzo	224.640	41.505	t,tot	5,4	kWh/t,tot
D. s. 6	Movimentazione prodotti	202.613	41.505	t,tot	4,9	kWh/t,tot
	Servizi Generali	**355.167**				-
D. g. 1	Uffici/CED e spogliatoi	47.068	180	n. addetti	261,5	kWh/addetti
D. g. 2	Riscaldamento e ACS	9.539	676	GG·m^2·10^{-3}	14,1	kWh/m^2 GG
D. g. 3	Raffrescamento uffici	1.296	310	m^2	4,2	kWh/m^2
D. g. 4	Illuminazione interna	209.664	10.880	m^2	19,3	kWh/m^2
D. g. 5	Illuminazione esterna	87.600	6.120	m^2	14,3	kWh/m^2

Table 28: Summary of the indicators for natural gas consumption (here "." is used as separator for thousands)

Area funzionale	Gas naturale Sm^3	variabile	u.d.m.	indicatore	u.d.m.
Intero stabilimento	959.395	41.505	t,tot	23,12	Sm^3/t,tot
Servizi Ausiliari	**958.870**				
Produzione vapore	958.870	41.505	t,tot	23,10	Sm^3/t,tot
Servizi Generali	**524**				
Riscaldamento e ACS	524	676	GG·m^2·10^{-3}	0,78	Sm^3/GG·m^2

Table 29 Summary of the indicators for diesel consumption (here "." is used as separator for thousands)

Area funzionale	gasolio l	variabile	u.d.m.	indicatore	u.d.m.
Intero stabilimento	171.190	41.505	t,tot	4,12	l/t,tot
Servizi Ausiliari	**171.190**				
Trasporti	171.190	7	n	24.455,66	l/n camion

Analysis of these tables reveals comparable consumption indices that will enable the Company's energy efficiency in various sectors to be analysed and monitored for improvements in the coming years and during any subsequent energy audits.

In relation to transport, it should be noted that the high consumption of diesel by the vehicle fleet is due to the high positive differences in height (even over 1500 meters) that the vehicles are obliged to cover every day to reach the farms of South Tyrol for milk collection.

1.5. Emission inventory

The assessment of the emission profile of the company is done according to the GHG Protocol categorization. For the present inventory, the following emission factors have been used for each energy carrier assessed:

Table 30: Emission factor by energy carrier

Energy carrier	Emission factor	U.M
Electricity	0.252	kgCO2/kWh
Natural gas	0.202	kgCO2/kWh
Diesel	0.268	kgCO2/kWh

The graph below provides an in-depth analysis of CO_2 emissions for 2023, showing the contributions of different energy sources.

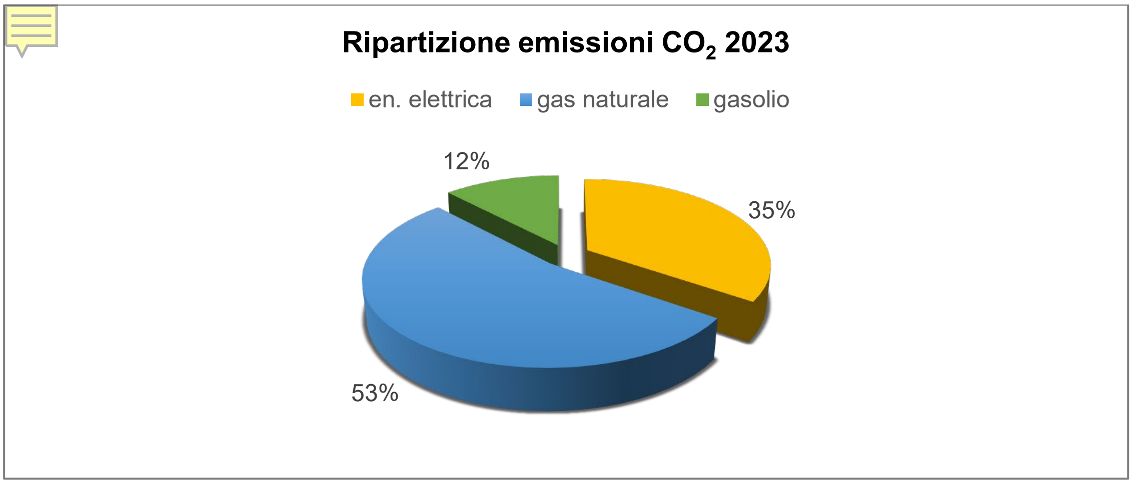


Figure 31: Breakdown of CO2 emissions across the three energy carriers for the year 2023

In 2023, the energy carrier with the greatest impact on the plant's overall carbon footprint is natural gas, accounting for 53% of total emissions. Therefore, in the definition of the interventions and in the decarbonization plan, we will try to identify solutions aimed at reducing the impact of this energy vector on total energy consumption and therefore on CO2 emissions.

The following graphs show the trend in Scope 1 and Scope 2 emissions over the three years analysed:

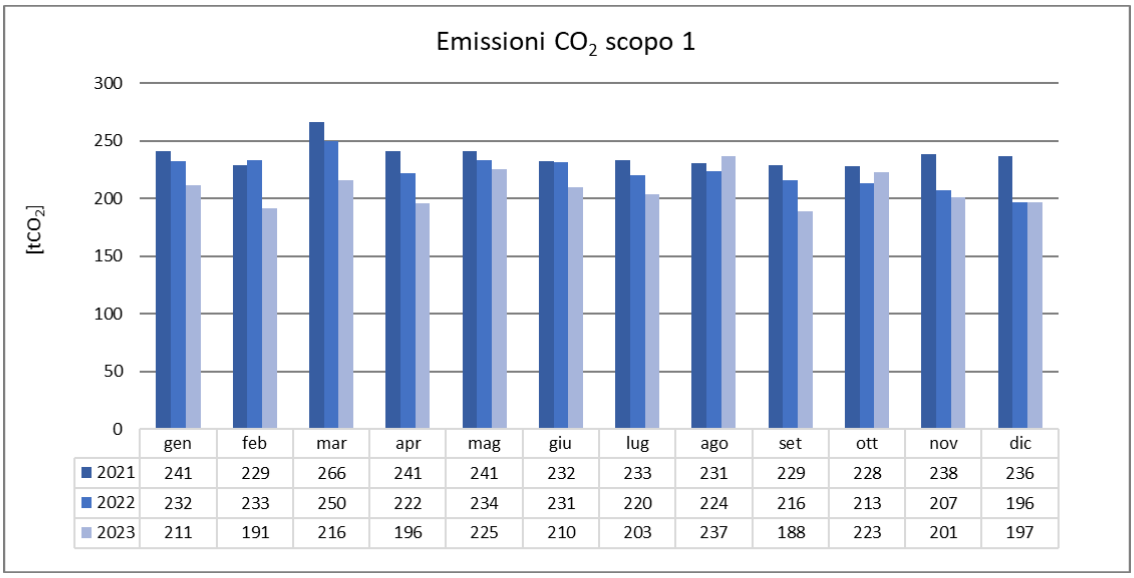


Figure 32: Trend in Scope 1 CO_2eq emissions over the three-year period from 2021 to 2023

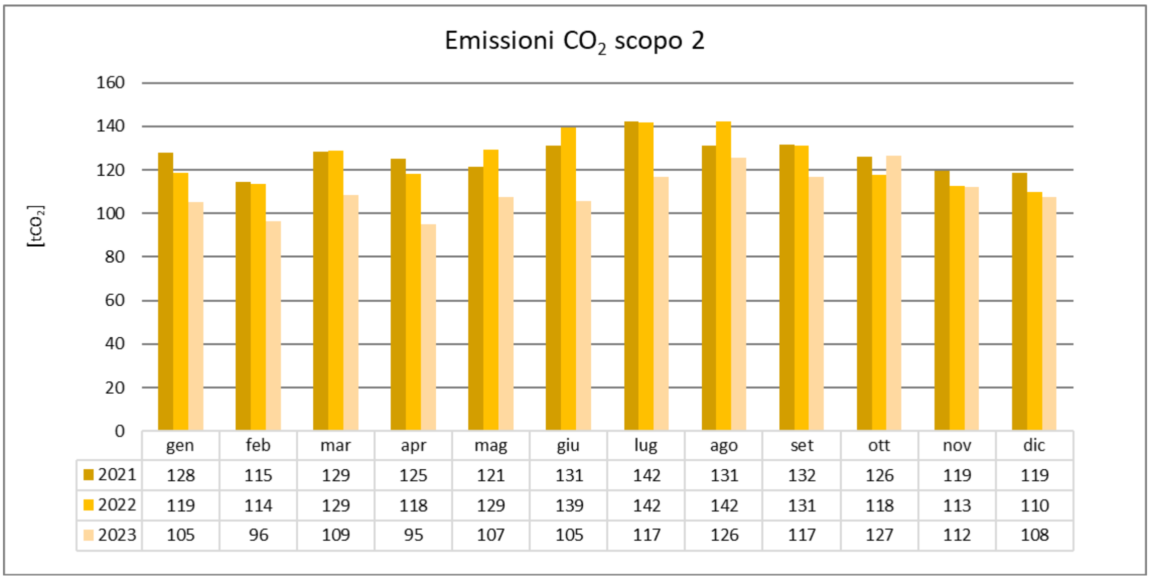


Figure 33: Trend in Scope 2 CO_2eq emissions over the three-year period from 2021 to 2023.

Furthermore, the graph below shows the breakdown of CO2 emissions over the three years according to the Purpose to which they belong:

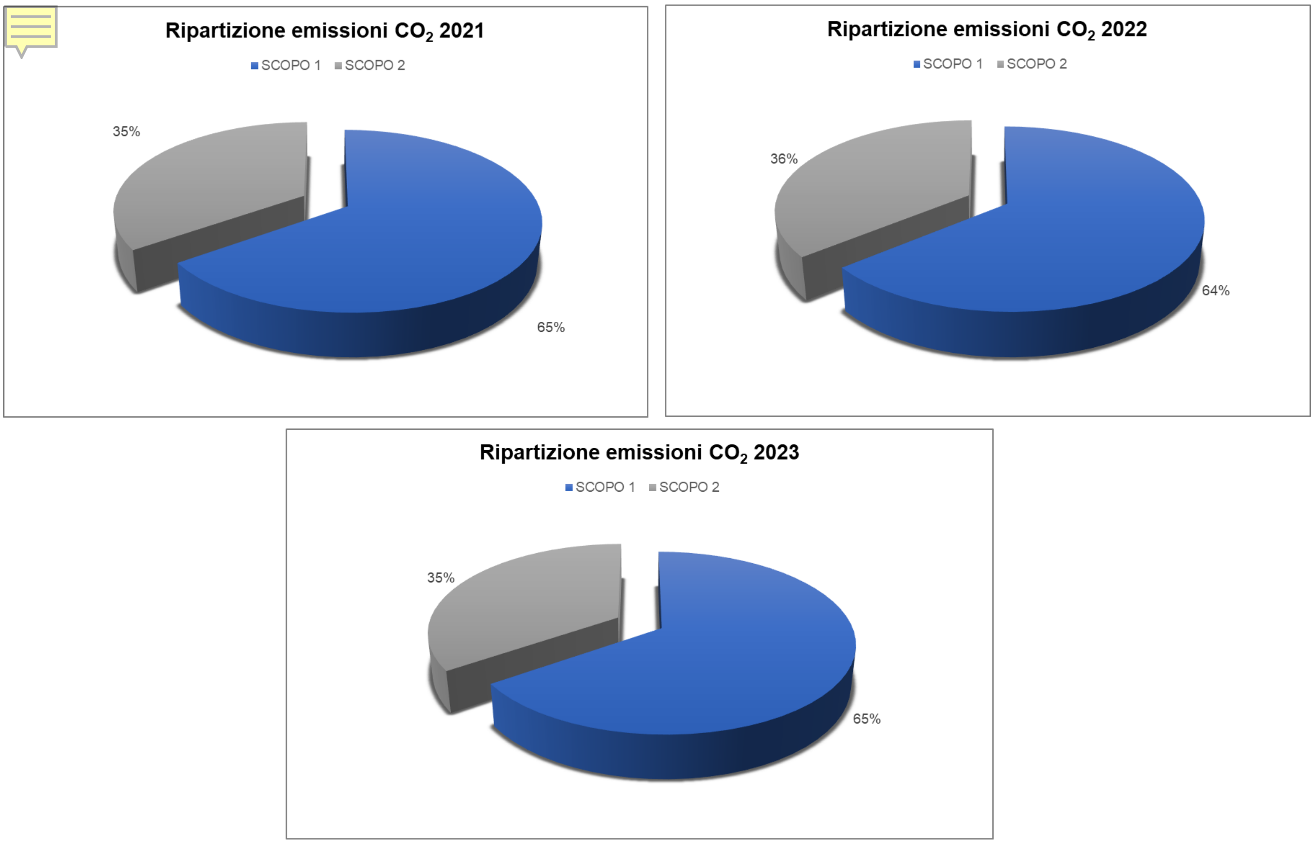


Figure 34: Country-Specific Electricity Emission Factors of CO2 emissions across the three different years

It is clear that Scope 1 emissions, attributable to the consumption of natural gas and diesel are approximately twice as high as Scope 2 emissions, which are associated with electricity consumption.

1.6. Decarbonization action plan

Showcasing the summary of the decarbonization action plan (DAP) and associated KPIs: the total electrical and thermal savings, CO2 savings, total economic savings, total investment, and global payback if all measurements are implemented.

Table 31: Costs of the proposed measures

#		OPEX (€)	CAPEX (€)	REQUIRED INVESTMENT (€)
1	Signing a contract for the supply of certified green energy	-	-	-
2	Installation of a 306 kWp photovoltaic system	5,600	367,200	479,200
3	Replacement of steam generators with a 3.9 MW heat pump	49,056	975,000	1,956,119

Table 32: Summary of financial, energetic benefits and GHG savings

#	Energy saving (MWh/year)	CO_2 emission reduction (tons/year)	Cost saving (Euro/year)	Payback (anni)	TIR (%)	VAN (Euro)	Specific energy saving (€/MWh)
1	-	1,323	-	-	-	-	-
2	0	0	61,745.5	6,5	14%	284,404	93.4
3	0	2,035	*	*	*	*	*

* negative or insignificant values

Table 33: Emission targets

1. Baseline year:	1.6.2. 2023
1.6.3. Baseline emission level [tones of CO2 eq.]	1.6.4. 3,820
1.6.5. Intermediate target year	1.6.6. 2030
1.6.7. Intermediate target emission level [%]	1.6.8. - 35%
1.6.9. Intermediate target emission level [tones of CO2 eq.]	1.6.10. 2,497
1.6.11. Final target year	1.6.12. 2050
1.6.13. Final target emission level [%]	1.6.14. -88%
1.6.15. Final target emission level [tones of CO2 eq.]	1.6.16. **462**

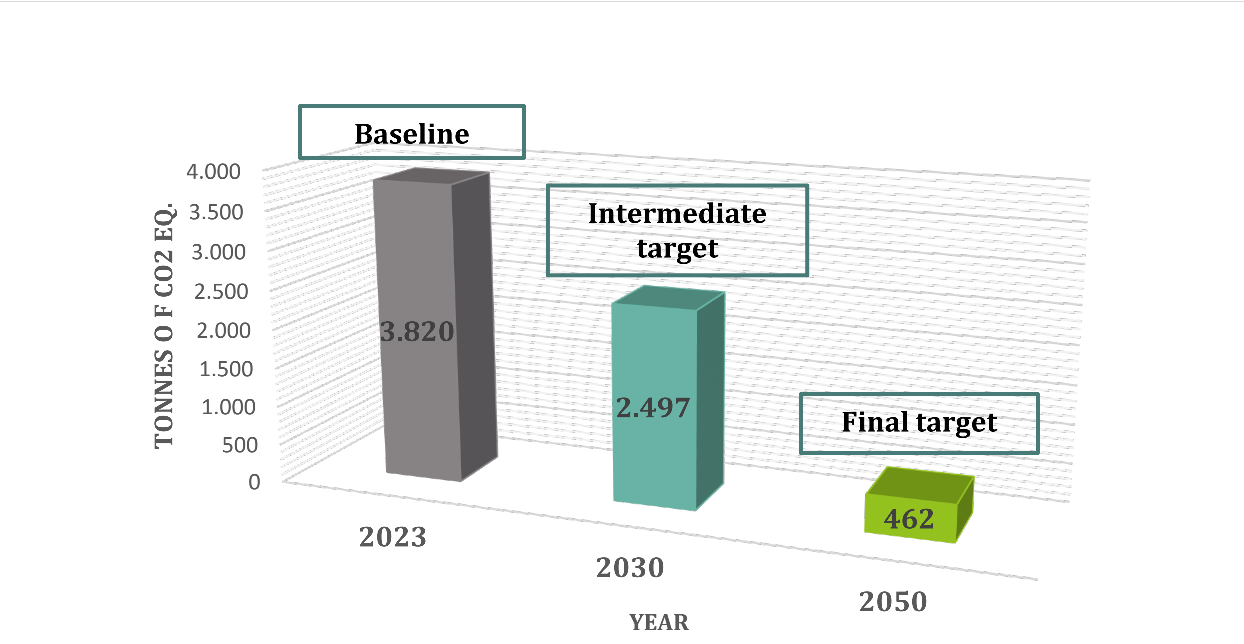


Figure 35: Decarbonization progress

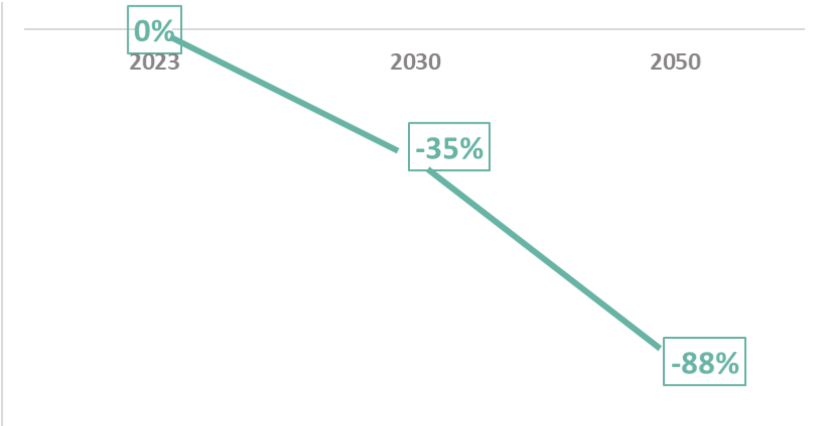


Figure 36: Decarbonisation targets

Table 34: Proposed measures

#	Description of the measure	Lifetime (years)	Analysed period (years)	Addressed Scope	Alignment with other initiatives
1	Signing a contract for the supply of certified green energy	-	-	Scope 2	-
2	Installation of a 306 kWp photovoltaic system	20	20	Scope 2	Measure 3
3	Replacement of steam generators with a 3.9 MW heat pump	20	20	Scope 1	Energy renovation of building envelope

Table 35: Costs of the proposed measures

#	CAPEX (Euro)	OPEX (Euro)	Required investment (Euro)
1	-	-	-
2	367,200	5,600	479,200
3	975,000	4,056	1,956,119

Table 36: Summary of financial, energetic benefits and GHG savings

#	Energy saving (MWh/year)	CO2 emission reduction (tons/year)	Cost saving (Euro/year)
1	-	1,323	-
2	0	0	61,745.5
3	0	2,035	*

* negative or insignificant values

Table 37: Financial analysis of the measures

#	Payback period (year)	IRR (%)	NPV (Euro)	By Energy Savings (Euro/MWh)
1	-	-	-	-
2	6.5	14%	284,404	93.4
3	*	*	*	*

* negative or insignificant values

1.7. Multiple benefits analysis

Table 38: Multiple benefits analysis

	Energy Transition Audit Measures		
MULTIBENEFITS	**M1**	**M2**	**M3**
Value proposition	3	5	4
New green products	Low	Low	Low
Intellectual property	Low	Low	Low
Competitive financial advantage	Low	High	Medium
Performance	14	15	15
Workforce productivity	Low	Low	Low
Increase production performance	Low	Low	Low
Improve equipment performance	Low	Low	Low
Improve asset utilisation	Low	Low	Low
Reduce malfunctions and/or lengthen equipment life (due to reduced wear and tear)	Low	Medium	Medium
Reduce maintenance needs	Low	Low	Low
Water footprint	Low	Low	Low
Improve staff safety or reduce injuries	Low	Low	Low
Reduce raw material consumption	Low	Low	Low
Reduce waste o improve recycling	Low	Low	Low
Reduced waste heat	Low	Low	Low
Reduced CO2 and energy price risks	High	High	High
Staff, customers and partners	17	17	17
Improve employee comfort (e.g. reducing noise, improving thermal comfort, better lighting, etc.)	Low	Low	Low
Improve employee satisfaction	Low	Medium	Medium
Improve employee health (e.g. thanks to air quality improvement of ambient air, improving workplace conditions, etc.)	Low	Medium	Medium
Improve customer service quality	Low	Low	Low
Improvev the share of green products/services	High	Medium	Medium
Attract new customers	Medium	Low	Low
Improve customer satisfaction and loyalty	Medium	Low	Low
Improve Supplier Environmental Sustainability Index	Medium	Medium	High
Improve stakeholder relationships	Medium	Medium	Medium
Regulatory compliance	Medium	High	Medium
Other			
Other			
Rating	34	37	36
MB Ranking	**3**	**1**	**2**

CONVENTIONAL BENEFITS	**M1**	**M2**	**M3**
CO2 reduction	High	High	High
Energy consumption reduction	Low	Low	Medium
Cost savings	Low	High	Medium
Investment	None	Medium	Medium
Rating	8	6	6
CB Ranking	**1**	**2**	**2**
Final rating	114	97	96
Final Ranking	**1**	**2**	**3**

Table 39: Proposed measures

M1	Signing a contract for the supply of certified green energy
M2	Installation of a 306 kWp photovoltaic system
M3	Replacement of steam generators with a 3.9 MW heat pump

1.8. Cost-benefit analysis / Financial analysis

No.	Proposed measure	Fiancial Indicators				
		Without MB			Specific Costs	
		Payback period [year]	IRR [%]	NPV [Euro]	By Energy Savings [Euro/ MWh]	By CO2 Reduction [Euro/tons]
1	Sottoscrizione di un contratto di fornitura di energia verde certificata	-	-	-	-	-
2	Installazione impianto PV da 306 kWp	6,5	14%	284.404,0	93,4	-
3	Sostituzione dei generatori di vapore con pompa di calore da 3,9 MW	-	-	-1.511.006,0	-	-11,1

For this case study, the monetization of multiple benefits has not been performed.

1.9. Funding sources for energy efficiency and decarbonization

a. *White certificates*

The Italian legislative framework provides for several incentives for the promotion of energy efficiency that can be linked to certain measures identified in the ETAs. Below is a list of those currently in force: ***WHITE CERTIFICATES***.

White certificates (also called Energy Efficiency Certificates or TEE) are a form of incentive recognized for energy efficiency interventions, which is managed directly by the GSE on whose website you can find in-depth information (at https://www.gse.it/servizi-per-te/efficienza-energetica/certificati-bianchi).

The incentives are disbursed in the form of securities that can be traded on the GME (Energy Market Manager) platform and certify the achievement of energy savings in energy end uses through interventions and projects to increase energy efficiency.
White certificates cannot be combined with other incentives (however denominated) charged to electricity and gas tariffs and with other state incentives, except for access to guarantee funds, revolving funds, interest subsidies, tax relief on business income for the purchase of machinery and equipment.

They are disbursed for a period of years that varies depending on the type of intervention and cannot be directly requested from the GSE by individuals or companies, but only through certain entities, including accredited E.S.Co. (acronym for Energy Service Company).
Some of the most interesting interventions that can be incentivized with the white certificate mechanism are reported for information:

- installation of cogeneration plants;
- installation of inverters on electric motors, fans, pumping systems, etc.;

- efficiency interventions in the industrial sector (heat recovery, replacement of generators, installation of more energy-efficient production machinery);
- installation of air-cooled and water-cooled chillers for industrial applications;
- replacement of lighting systems with high-efficiency systems (LEDs, etc.).

It is possible to apply for the incentive for a good number of energy efficiency interventions (the complete list is available on the GSE website). The savings achieved, however, must be measurable and significant and must be able to achieve the minimum amount of energy savings required by the GSE annually.

b. *Conto termico*

The "**Conto Termico 2.0**" is a form of support introduced by the Ministerial Decree of 28/12/12, strengthened by the Ministerial Decree of 16/02/16 and entered into force on 31 May 2016 for the incentive of small-scale interventions carried out to increase energy efficiency and for the production of thermal energy from renewable sources. The GSE is also in this case the entity responsible for the implementation and management of the mechanism, including the provision of incentives to the beneficiaries.

The subjects admitted are the following:

- Public administrations (including the former Autonomous Institutes of Public Housing, inhabitants' cooperatives, publicly-owned companies and social cooperatives);
- Private subjects (citizens and companies).

These entities can also make use of a E.S.Co. for the implementation of the interventions, signing an energy service contract (both for public administrations and private entities) or energy performance (only for public administrations).

The legislation and the Application Rules define the procedure for requesting and accessing the incentive mechanism, which provides either direct access (application to be sent to the GSE within 60 days of the conclusion of the intervention) or (only for public administrations and E.S.Co. operating on their behalf) the possibility of booking the incentive before the execution of the intervention.

The incentive is a contribution to the expenses incurred, paid, in the case of direct access, in annual instalments for a duration varying between 2 and 5 years (for public administrations and in general for incentive amounts up to € 5,000, it is paid in a single instalment) depending on the interventions carried out. In the case of booking the incentive, on the other hand, it is possible to request the payment of a deposit at the start of the works and the balance at their conclusion.

The amount of the incentives is not calculated in proportion to the cost incurred for the intervention, but on the basis of certain coefficients and parameters such as the nominal power (or surface area for solar collectors), the climatic zone and other technical characteristics of the system.

The incentive can only be assigned to interventions that do not access other state incentives, with the exception of guarantee funds, revolving funds and interest rate subsidies. Only public administrations (excluding inhabitants' cooperatives and social cooperatives) are allowed to combine the incentive with other capital incentives, including state ones, up to covering 100% of eligible expenses.

The interventions that can be incentivized for all subjects (public and private) are the following:

- Replacement of existing air conditioning systems with high-efficiency systems (electric or gas heat pumps, including geothermal) with a power of up to 2,000 kW;
- Replacement of existing air conditioning systems with biomass systems with a power of up to 2,000 kW;
- Installation of solar thermal collectors, also combined with solar cooling systems;
- Replacement of electric water heaters with heat pump water heaters;
- Replacement of existing air conditioning systems with hybrid heat pump systems.

Finally, it should be noted that the Conto Termico 2.0 provides that for interventions carried out on the building envelope or on buildings served by air conditioning systems with a power ≥ 200 kW, a pre-intervention Energy Diagnosis and a post-intervention Energy Performance Certificate (APE) must be carried out. The amount for the preparation of these documents is incentivized at 50% for private entities (including companies).

c. *Tax breaks for energy saving*

The **tax relief** consists of deductions from IRES (Corporate Income Tax) and is granted if interventions are carried out that increase the level of energy efficiency of existing buildings. In particular, the deductions are recognized if the expenses have been incurred for the following interventions:

- global energy upgrading of existing buildings, with a reduction of the energy performance index for winter air conditioning below certain thresholds;
- improvement of the efficiency of the dispersing surfaces of the building envelope such as walls, roofs, windows and doors;
- installation of solar thermal panels;
- replacement of air conditioning systems with condensing or biomass-fuelled ones;
- replacement of air conditioning or DHW production systems equipped with heat pumps;
- purchase and installation of solar shading;
- installation of *building automation technologies*;
- micro-cogenerators to replace existing plants.

The maximum limit of economic savings that can be obtained with the deduction varies from € 100,000 to € 30,000 depending on the type of intervention. The deductions, to be divided into ten annual instalments of the same amount, are currently recognized as 50% of the expenses incurred.

d. *Other forms of contribution for energy savings*

Transizione 5.0: A plan to incentivise, through a tax credit, goods that are part of an innovation project that allows to reduce energy consumption. In particular, such projects must lead to a reduction of at least 3% in the energy consumption of the production facility or, alternatively, to a reduction of at least 5% in the energy consumption of the processes involved in the investment.

Nuova Sabatini: scheme to help small and medium-sized enterprises to purchase new machinery, plant and equipment for productive use;

Energy Release 2.0: Incentives for energy-intensive companies for the installation of renewable energy systems. This mechanism allows energy-intensive companies to request a three-year advance of 50% of the energy at competitive prices generated as a result of investments in renewable energy systems, for which priority is also given to the use of public areas. The new generation capacity can be realized through: new photovoltaic, wind and hydroelectric plants with a minimum capacity of 200 kW each; upgrading or renovation of photovoltaic, wind and hydroelectric plants that allow an increase in capacity of at least 200 kW.

e. *Provincial and regional contributions*

Currently, the Autonomous Province of Bolzano incentivises:

- Energy renovation of buildings.
- Hydraulic balancing of existing heating and cooling systems.
- Solar thermal systems.
- Installation of electric heat pumps with photovoltaic systems.
- Energy audits.

Applications must be submitted before the start of the works and in any case by 31 May 2025.

The incentive is paid following the reporting of the expenses incurred by the end of the year following the one in which the application was submitted.

The redevelopment of the envelope that could be interesting for the Company, for example, has a cost ceiling per square meter for the insulation of dispersing surfaces that varies with the type of surface and the thickness of the insulation.

Each intervention also has a maximum percentage of incentive depending on the type of intervention and the size of the company.

Normativa comunitaria di riferimento	Intervento e articolo di riferimento nei criteri	Tipo di impresa	Percentuale sui costi ammissibili
Regime "de minimis", ai sensi dei regolamenti (UE): - n. 2023/2831 - n. 1408/2013	Art. 9 Risanamento energetico di edifici con certificazione CasaClima B o di classe superiore dell'involucro dell'edificio o con certificazione CasaClima R dell'edificio	Piccola impresa	50%
		Media impresa	40%
		Grande impresa	30%

For further information, please visit the dedicated page: https://news.provincia.bz.it/it/news/incentivi-energetici-2025-domande-aperte-per-richieste-di-contributo

1.10. Decarbonisation Roadmap

The main steps of the decarbonization roadmap are exemplified below:

Table 40: Proposed decarbonization roadmap

		-35%scope 2		-88%scope 1 e 2
TYPE OF INTERVENTION	**2025**	**2030**	**2035**	**2050**
Energy supply	Signing of a certified green electricity supply contract **S2**	installation of an additional 306 kWp of photovoltaics **S2**		
Production processes				

Automation systems				
Energy efficiency of the building				Replacement of the two steam generators with heat pump **S1**

Appendix C. Case study – Romania

The purpose of the present Energy Transition Audit (ETA) report is to present the current energy situation through a detailed energy analysis and to propose a personalized Decarbonization Action Plan for the audited company, aiming to significantly reduce the CO_2 emission level of the company by 60% until 2050, compared to 2024 level. It is important to note that this case study does not represent a literal example of an audit conducted for audited companies, as there are differences between the two approaches. Instead, this study serves as a guiding example, reflecting the working method derived from the applied methodology.

The company is specialized in the production of ceramic products through high-temperature firing, including tiles, bricks, refractory tiles, ceramic tiles, faience, ceramic objects or porcelain.

- NACE code: 2392 - Manufacture of bricks, tiles, and construction products, in baked clay
- Total nr of employees: 303

The company has an Energy Manager.

Electrical energy consumption in 2023: 10,474.25 [MWh]

Thermal energy consumption in 2023: 42,764.45[MWh]

1.1. Short description of the company

The brick manufacturing company was designed to produce high-quality clay bricks using modern, energy-efficient processes. The factory integrates traditional production methods with automated systems to ensure consistent output, reduced environmental impact, and compliance with construction industry standards.

Figure 37: Examples of products offered by the company

1.1.1. Location

The company is located in Zalau, Sălaj country.

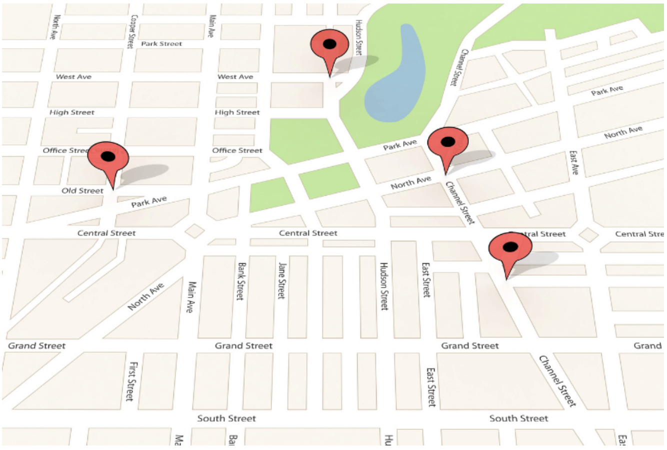


Figure 38: Location of the company

1.1.2. Buildings description

	Total net surface	300,00	sqm
	Total surface (buildings + outdoor premises)	320,00	sqm
Number of the administrative buildings	**Number of the buildings for production**	**Number of the buildings dedicated for warehouses**	**Total number of the buildings**
1	1	1	3

The facility is divided into distinct sections, as follows:

- Raw material preparation and storage building covering 7,000 sqm.
- Production buildings spanning 12,280 sqm.
- An administrative building measuring 300 sqm.

The built-up area of the production site, including halls and platforms, is totalling 60,000sqm.

1.2. Description of the technological processes

The technological process is described in the following diagram:

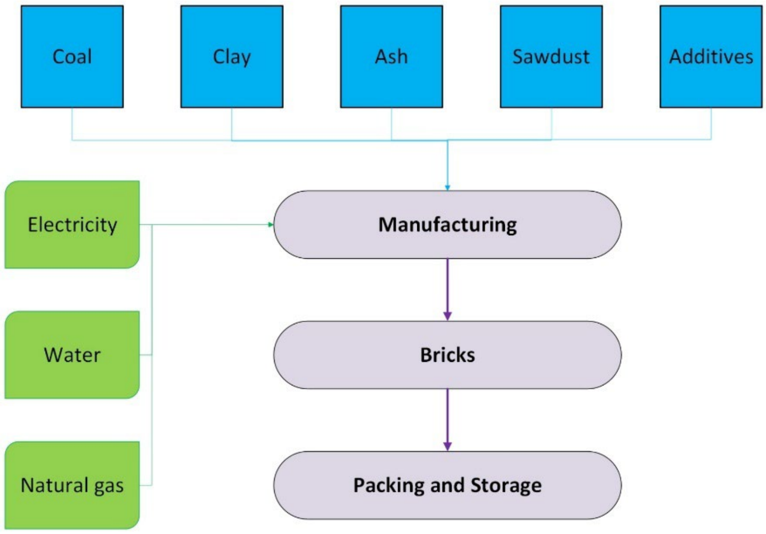


Figure 39: Technological process within the company

Manufacturing process by technological phases:

1) Extraction of raw materials
2) Clay mass preparation
3) Product shaping
4) Drying of semi-finished products
5) Firing of products
6) Unloading, sorting, packaging, and storage of finished products

In presented case-study Electricity is supplied at medium voltage via two 1600 kVA and one 2000 kVA transformers (20/0.4 kV) in a shared station.

The factory's electrical energy input comes from both the national grid and its own cogeneration system. Useful energy output includes electricity delivered to equipment, mechanical energy from electric motors, and heat used in production processes and for heating. Losses occur in motors, transformers, and the compressed air system. Lighting system is partially with LED Technology.

The thermal energy input is methane gas used to power key installations. Useful output is the heat used to bring products to required process temperatures. Heat losses occur via flue gas, radiation, convection, and other sources. The thermal energy equipment included in the system consists of a dryer, cogeneration plant for dryer, tunnel oven and heating installations, and heating machines for administrative buildings.

The reference year for the energy analysis was considered to be 2024. From the information specified by the Beneficiary, an approximate number of 8,760 operating hours per year is estimated, corresponding to a full year of continuous operation.

1.3. Energy analysis

The energy carriers that support the company's operations and production processes are as follows*:*

Table 41: Types of energy used

Type of energy	Carrier	Usage in the company
1. Electrical energy	Energy supplier	Production area, administrative
2. Thermal energy	Gas supplier	Technological processes, heating spaces, hot water
3.Water	Water supplier	Technological processes, consumption

Table 42: Monthly energy analysis of the company

Year	Month	Electrical Energy Consumption [MWh]	RES production [MWh]	Grid consumption [MWh]	Electrical Energy Cost [EUR]	Thermal Energy Consumption [MWh]	Thermal Energy Cost [EUR]	Production [PCS]
2024	January	1,140.60	206.54	934.06	149,095.18	3,568.85	182,011.35	520,000.00
	February	1,121.70	236.04	885.66	141,368.73	2,828.35	144,245.85	580,000.00
	March	1,187.60	354.06	833.54	133,049.18	3,276.70	167,111.70	740,000.00
	April	1,089.10	472.08	617.02	98,488.09	3,029.30	154,494.30	570,000.00
	May	1,137.43	490.00	647.43	103,343.31	3,333.15	169,990.65	700,000.00
	June	1,152.13	690.21	461.92	73,732.20	3,434.40	175,154.40	710,000.00
	July	1,158.80	674.01	484.79	77,382.18	3,557.05	181,409.55	660,000.00
	August	1,147.37	658.06	489.31	78,103.13	3,312.90	168,957.90	610,000.00
	September	1,125.03	534.01	591.02	94,339.14	3,300.50	168,325.50	690,000.00
	October	1,162.97	461.59	701.38	111,953.74	4,266.75	217,604.25	740,000.00
	November	1,143.23	279.72	863.51	137,834.00	4,248.00	216,648.00	710,000.00
	December	1,164.53	234.42	930.11	148,464.69	4,608.50	235,033.50	460,000.00
TOTAL		**13,730.50**	**5,290.75**	**8,439.75**	**1,347,153.57**	**42,764.45**	**2,180,986.95**	**7,690,000.00**

1.3.1. Electrical energy

Electrical energy price from grid: 156.60 EUR/ MWh

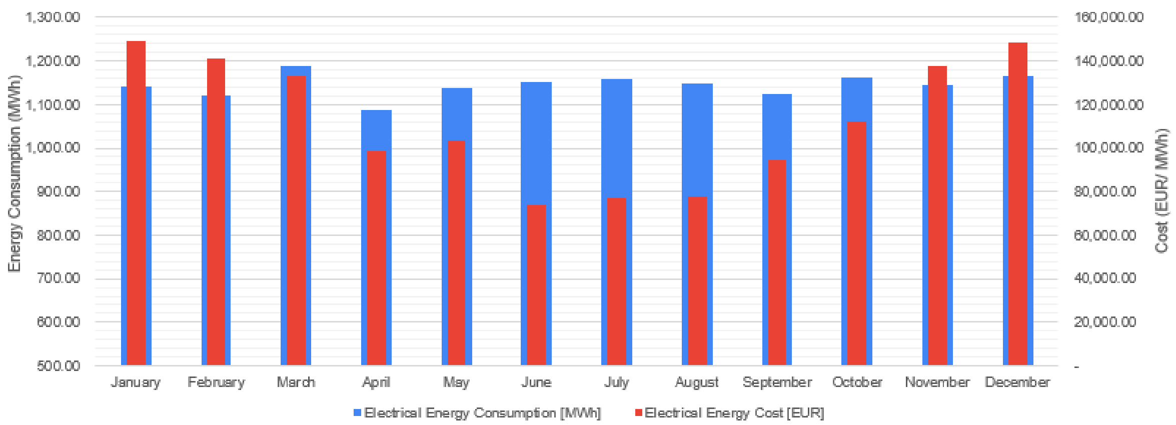


Figure 40: Monthly electrical energy consumption [EUR/MWh]

The chart reveals that energy consumption from grid remains relatively stable between 1,100 and 1,200 MWh for most months, with slight dips in April and September. However, costs fluctuate more significantly, peaking in January and December, suggesting higher energy prices during these months. Notably, despite similar consumption levels, some months like June and July show substantially lower costs, indicating seasonal price variation.

1.3.2. Thermal energy

Thermal energy (Methane gas) price: 51 EUR/MWh

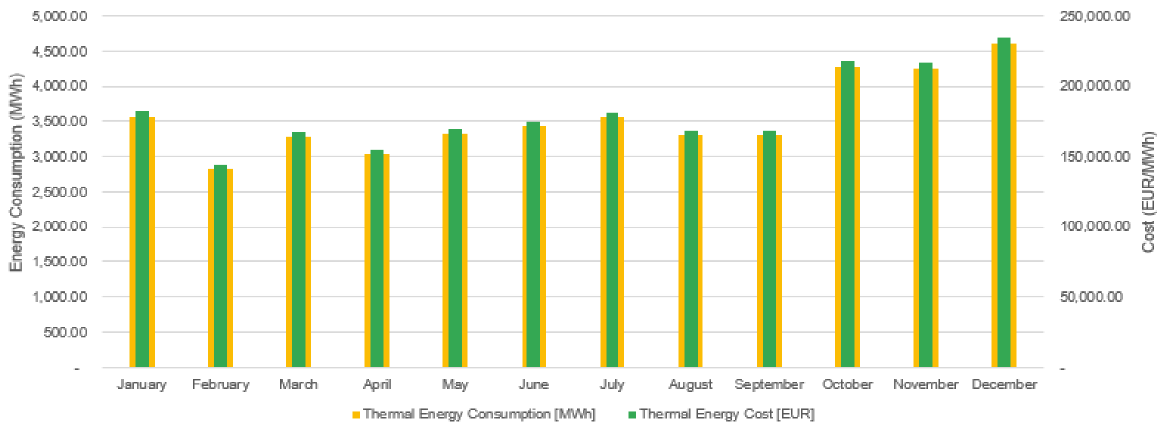


Figure 41: Monthly thermal energy consumption and costs [EUR]

Thermal energy usage fluctuates moderately throughout the year, with notable peaks in the colder months of January, October, November, and December-coinciding with higher heating demand. Costs generally follow the same trend as consumption, with December showing the highest values in both categories. In contrast, February records the lowest consumption and cost. Overall, the chart highlights a clear seasonal pattern, with increased thermal energy demand and expense during winter months.

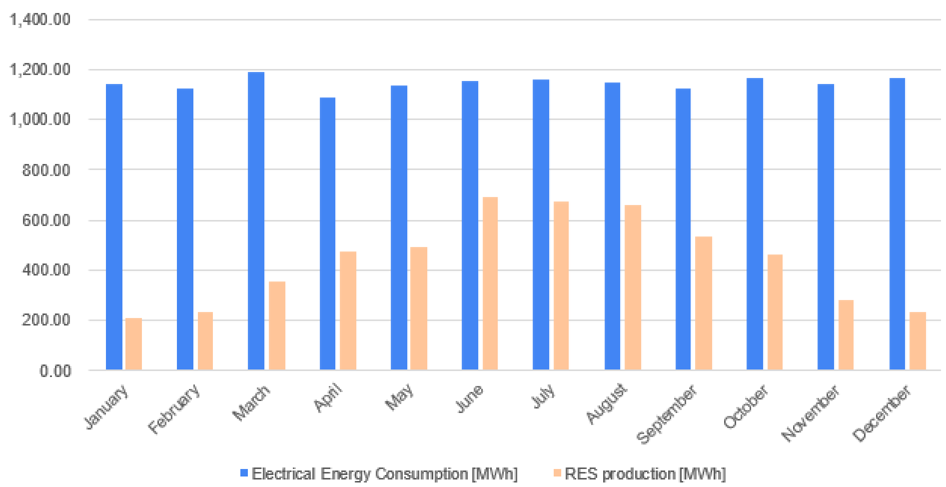


Figure 42: Electrical energy consumption and RES production

1.3.3. Water

Water price: 2.4 EUR/ m^3

Year	Month	Water Consumption [m^3]	Water cost [EUR]
2024	January	5,047.50	12,114.00
	February	4,710.00	11,304.00
	March	5,705.00	13,692.00
	April	5,075.00	12,180.00
	May	5,160.00	12,384.00
	June	5,415.00	12,996.00
	July	5,407.50	12,978.00
	August	5,212.50	12,510.00
	September	5,175.00	12,420.00
	October	5,287.50	12,690.00
	November	5,085.00	12,204.00
	December	5,297.50	12,714.00
TOTAL		**63,657.50**	**152,778.00**

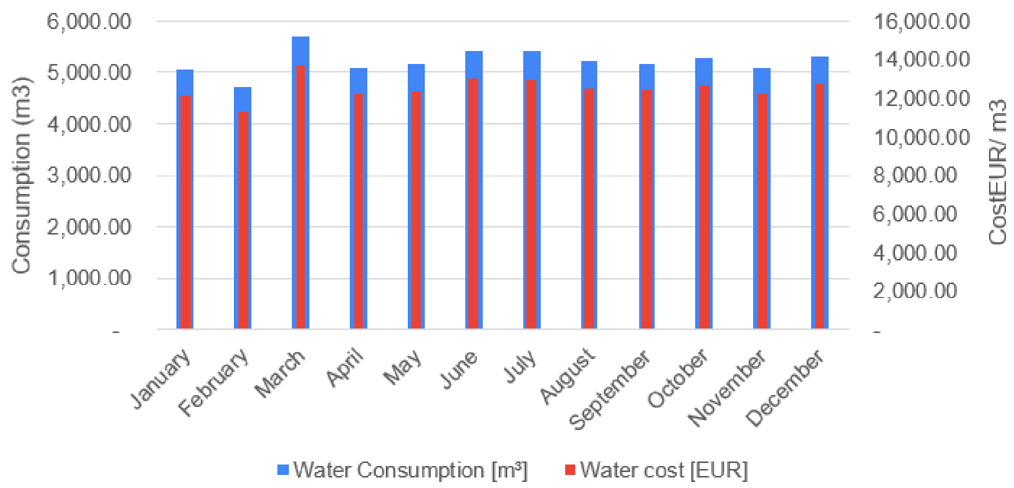


Figure 43 Monthly water consumption and costs [EUR]

The chart illustrates relatively stable consumption and cost trends throughout the year, with slight variations, peaking in months like March and July.

1.3.4. Diesel

Diesel price: 1.5 EUR /L

Year	Month	Diesel Consumption [L]	Diesel cost [EUR]
2024	January	810.00	1,215.00
	February	730.00	1,095.00
	March	1,120.00	1,680.00
	April	1,440.00	2,160.00
	May	1,500.00	2,250.00
	June	1,750.00	2,625.00
	July	1,800.00	2,700.00
	August	1,850.00	2,775.00
	September	1,600.00	2,400.00
	October	1,400.00	2,100.00
	November	1,100.00	1,650.00
	December	900.00	1,350.00
TOTAL		**16,000.00**	**24,000.00**

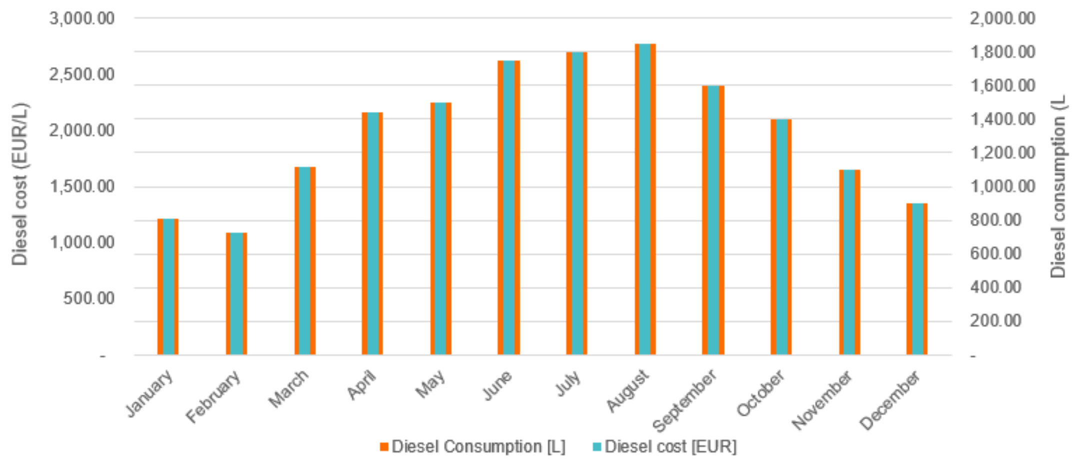


Figure 44: Monthly diesel consumption and costs [EUR]

In the previous chart both consumption and cost rise steadily from February, peaking in July and August, which suggests higher operational activity or fuel use during summer months. After August, both metrics decline steadily through December. The chart shows a strong correlation between diesel usage and cost, with closely aligned bar heights throughout the year, indicating relatively stable pricing per litter.

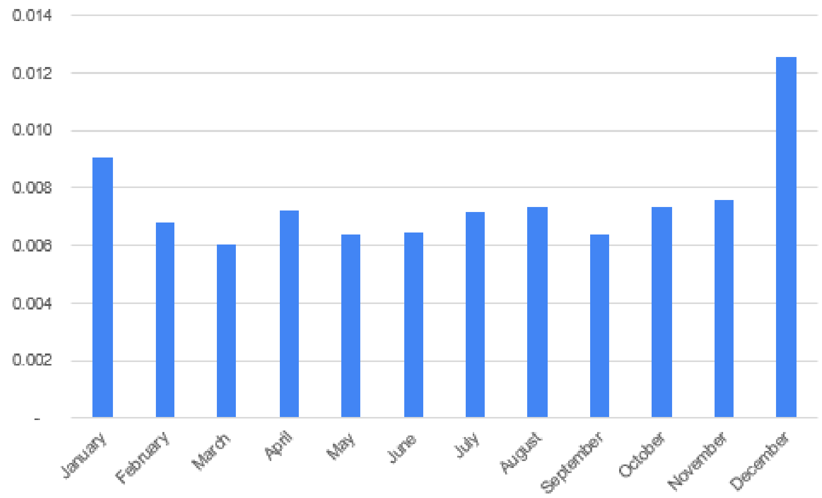


Figure 45: Monthly specific consumption [MWh/PCS]

The bar chart illustrates monthly energy consumption values across the year, measured in megawatt-hours (electric and thermic) per PCS unit. The data shows higher specific consumption during winter months, with December peaking at just over 0.012 MWh/PCS, followed by January, which is also notably high at around 0.009 MWh/PCS. The lowest consumption is observed in May, at slightly below 0.006 MWh/PCS. In general, consumption dips during the warmer months (May–September) and rises during colder periods, suggesting a seasonal dependency, likely due to heating needs. The trend is consistent with typical gas or energy usage patterns in climates with cold winters and mild summers.

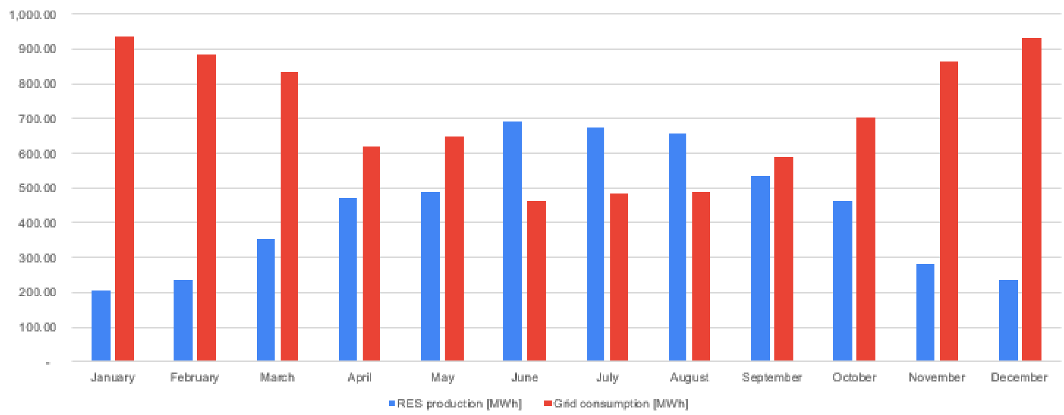


Figure 46: Energy produced and purchased

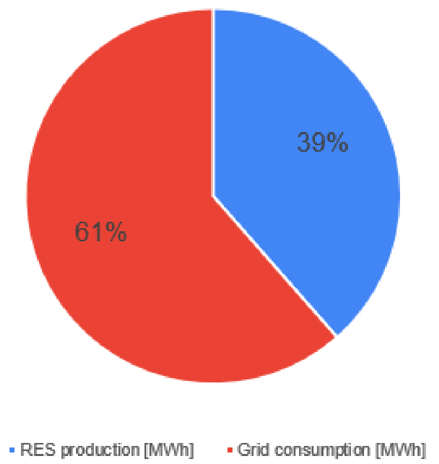


Figure 47: Energy produced vs purchased from grid

Based on the data from charts, in winter months (Jan–Mar), grid consumption is much higher than RES production. From May to October, RES production exceeds grid use, with grid reliance dropping sharply, especially in July–October. In December, RES production peaks while grid use is nearly zero, highlighting strong seasonal self-sufficiency from renewables.

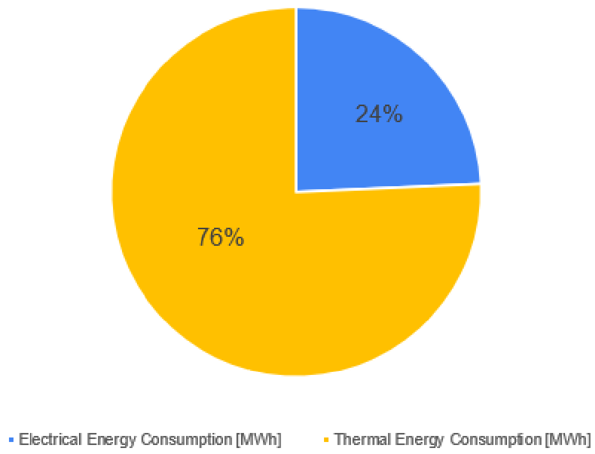


Figure 48: Share of energy consumption

The pie chart entitled "Share of energy consumption" illustrates the distribution between two energy carriers shows that fossil energy consumption constitutes the majority, accounting for 80% of the total energy use, while electrical energy consumption makes up the remaining 20%. This highlights a heavy reliance on fossil fuels compared to electrical sources.

Data reveals clear seasonal patterns and disparities in energy consumption, cost, and source reliance. Thermal energy remains the dominant source, representing 80% of total consumption, and consistently surpasses electrical usage throughout the year, particularly peaking in winter months like December. Despite lower consumption, electrical energy often incurs higher costs, especially in the colder months, suggesting efficiency or pricing issues. Specific energy consumption per unit also spikes in winter, indicating increased operational demands. However, the growing role of renewable energy sources (RES), especially from May onward, demonstrates a shift toward sustainability, with RES covering most needs from summer through fall. This comprehensive analysis emphasizes both the seasonal impact on energy dynamics and the importance of transitioning toward cleaner, more efficient energy systems.

Following the energy analysis, most energy is consumed in the production process. Even though the company has implemented some decarbonization measures, like PV panels installation and cogeneration installation at the dryer machine, there is still room for improvement and cost optimization. Therefore, there is a real need for a new decarbonization plan.
The table below shows the amount of energy used by type:

Table 43: Consumptions and production

2024	Electricity (Grid)	Methane gas	Diesel for transport	Heating Diesel	Energy produced and consumed locally from RES	Energy produced and sold from RES
Unit of measure	MWh	MWh	L	N/A	MWh	MWh
Consumption	8,439.75	42,764.45	16,000	0	5,290.75	0

Where are used:

Table 44: Energy Consumption Sources and Applications

Electricity		Yes/No/DK
	Technological process	YES
	Lighting	YES
	Compressed air	YES
	Ventilation	DK
	Pumps	DK
	Drives	NO
	Electrical heat	NO
	Air conditioning	YES
	Offices: PCs, printer, copier etc.	YES

Heat (Methane gas)		Yes/No/DK
	Technological process	YES
	Room heating	YES
	Domestic hot water preparation	YES

1.4. Emission inventory

The assessment of the emission profile of the company is done according to the GHG Protocol categorization. For calculating the equivalent CO_2 emissions, the following general equation has been used:

$$Emission = Activity\ data\ \times emission\ factor$$

Table 45: Emission factors

Energy carrier	Emission factor	U.M
Electrical energy	306	kgCO2/MWh
Methane Gas	1.9	kgCO2/m^3
Diesel Fuel	2.64	kgCO2/L

Table 46: Scope 1 - Equivalent CO2 Emissions

Scope 1 - Equivalent CO2 Emissions			
Fuel / Energy Carrier	**Quantity**	**Units**	**CO2 emissions [tonnes/year]**
Methane Gas**	4,053,214.57	[m^3]	7,701.11
Diesel Fuel	16,000	[L]	42.24
TOTAL Scope 1			**7,743.35**

***Note 1MWh=94.78 m^3; 1 m^3=10.5 kWh.*

Table 47: Scope 2 - Equivalent CO2 Emissions

Scope 2 - Equivalent CO2 Emissions			
Energy Carrier	**Quantity**	**Units**	**CO2 emissions [tonnes/year]**
Electricity-from grid	8,439.75	[MWh]	2,582.56
Electricity-from PV	5,290.75	[MWh]	0
TOTAL Scope 2			**2,582.56**

Total CO2 emissions: **10,325.91 [tonnes/year]**

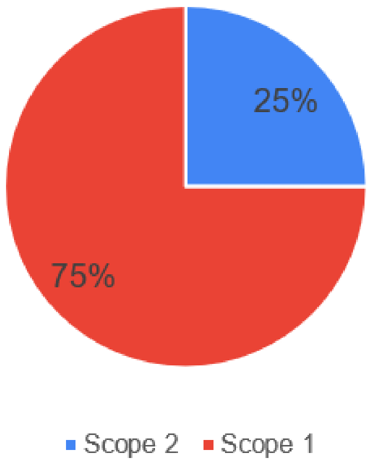


Figure 49: Emission inventory by scopes

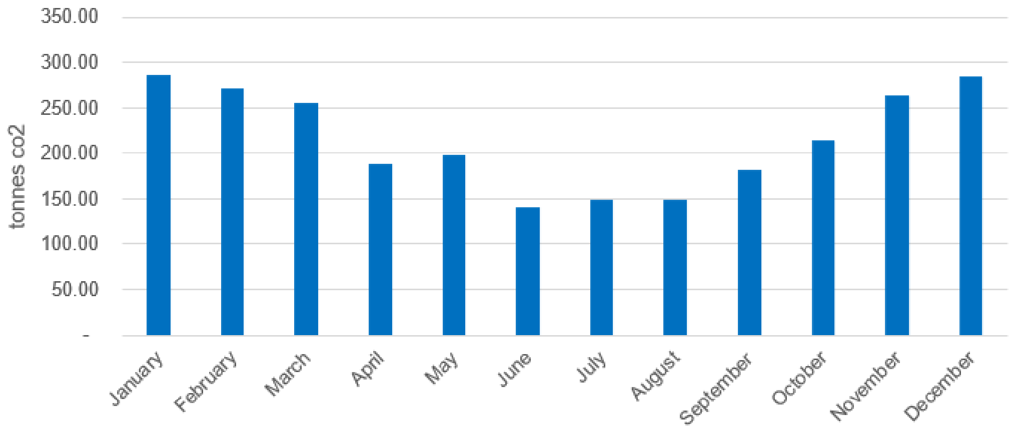


Figure 50: Equivalent monthly CO2 emission from electrical energy

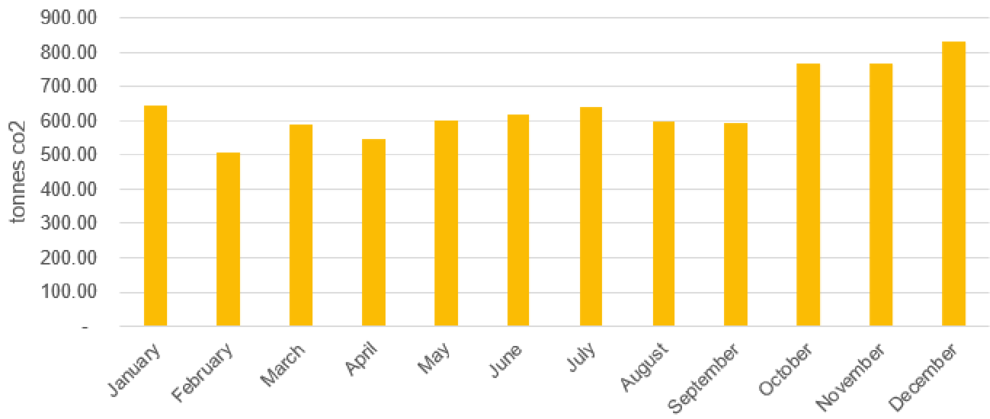


Figure 51: Equivalent monthly CO2 emission from methane gas

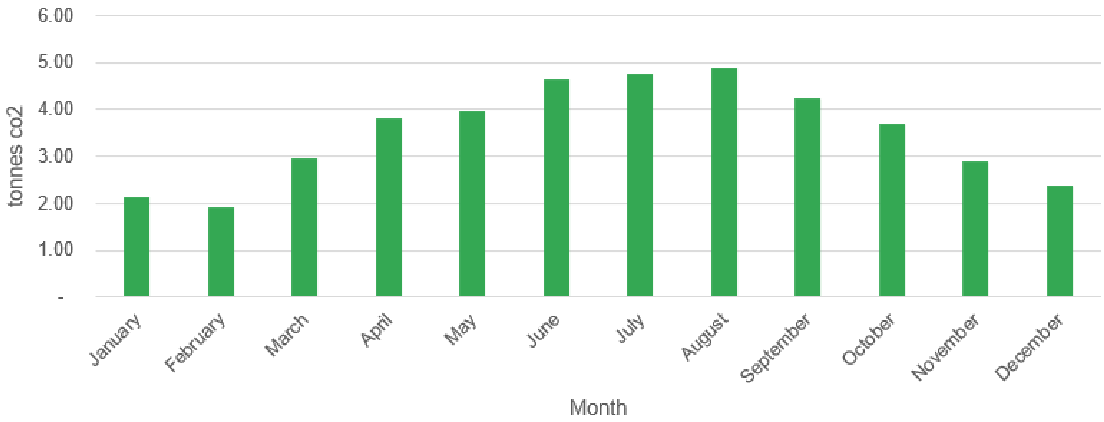


Figure 52: Equivalent monthly CO2 emission from diesel

As seen above, Scope 1 emissions are 75% out of the total emissions and Scope 2 emissions are 25%. The rising energy costs constrain the company to reduce even more the energy bought from carriers and to produce its own electrical energy therefore, there is a real need for a new decarbonization plan.

1.5. Decarbonization action plan

The following targets are assumed to be fulfilled at the end of 2023 and 2050 in DAP.

Table 48: Emissions targets

Baseline year:	**2024**
Baseline emission level [tones of CO2 eq.]	**10,325.91**
Intermediate target year	2030
Intermediate target emission level [%]	40%
Intermediate target emission level [tones of CO2 eq.]	**6,195.55**
Final target year	2050
Final target emission level [%]	-60%
Final target emission level [tones of CO2 eq.]	**4,130.36**

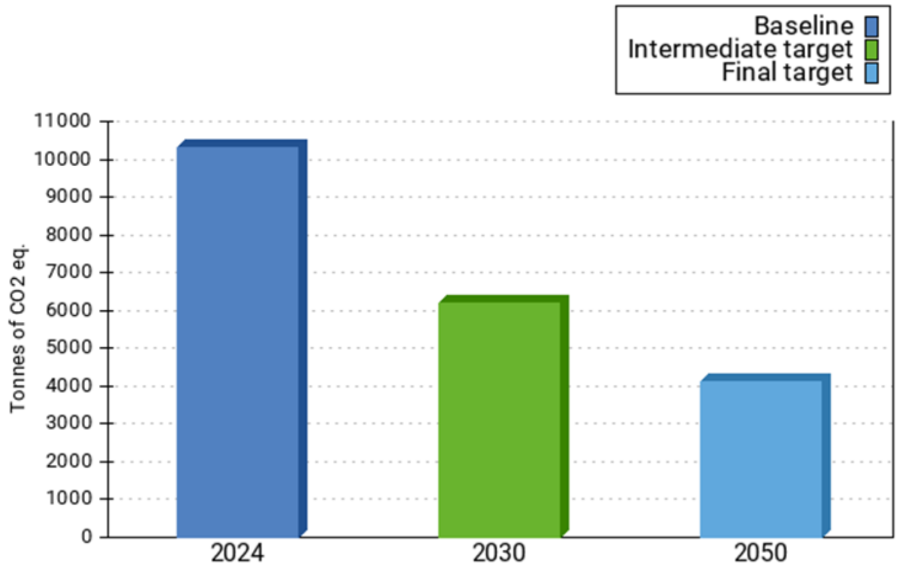


Figure 53: Decarbonisation progress

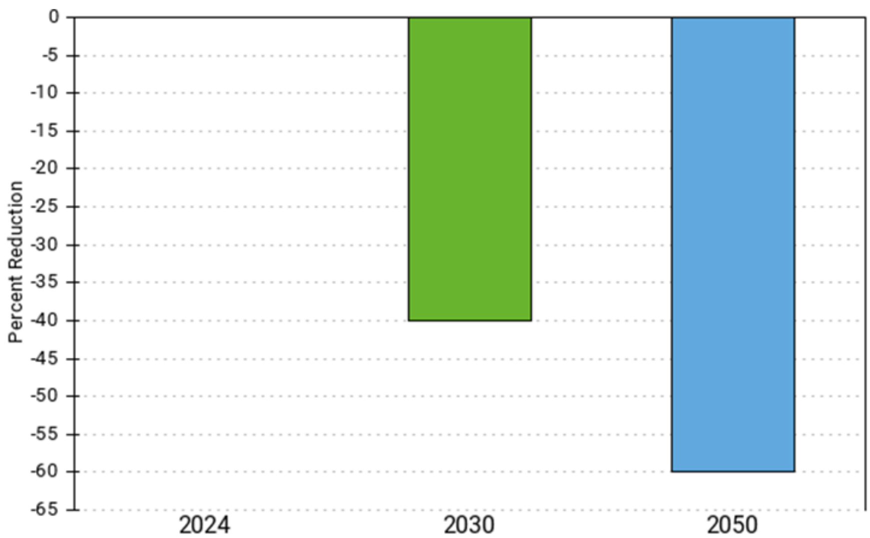


Figure 54: Decarbonisation targets

Table 49: Description of the proposed measure

#	Proposed measure	Lifetime (years)	Analysed period (years)	Description of the measure	Type of action	Addressed Scope	Alignment with other initiatives	Dependencies and/or constrains	Barriers and risk to be considerer
1	Installation of PV panels for self-consumption	20	25	Add more PV panels for self-consumption	Technical - Energy Efficiency	Scope 2	Contributes to 2030 fit for 55 targets	Available space, budget availability	High Initial Cost
2	Green energy acquisition	25	22	Change energy supplier	Technical - Energy Efficiency	Scope 2	Contributes to 2030 fit for 55 targets	Availability of Green Tariffs, Grid Infrastructure	Limited Market Competition, Lack of Transparency
3	New compressor with variable speed and centralized compressor control	15	24	Replace fixed-speed compressor with variable-speed unit and add centralized control to optimize usage	Technical - Energy Efficiency	Scope 2	Contributes to 2030 fit for 55 targets	Compressed-air piping modifications	Potential production downtime
4	Retrofit lighting devices	15	25	Replace fluorescent lighting with LEDs	Technical - Energy Efficiency	Scope 2	Contributes to 2030 fit for 55 targets	High ambient temperatures may reduce LED efficiency	Visual comfort concerns; high upfront cost

5	Additional turbine in cogeneration plant	25	25	Add a gas turbine to existing CHP to improve efficiency and cost savings	Technical - Energy Efficiency / Cogeneration	Scope 2	Contributes to 2030 fit for 55 targets	Integration works	Technical complexity
6	Residual heat recovery from combustion gases	20	15	Install heat recovery system in tunnel furnace using stainless steel exchangers	Technical - Waste Heat Recovery	Scope 1	Contributes to 2030 fit for 55 targets		
7	Upgrade of existing industrial dryer	15	10	Retrofitting the current tunnel dryer with advanced process controls	Technical-Thermal energy efficiency	Scope 1	Contributes to 2030 fit for 55 targets	Integration with existing ducting; potential production downtime during installation	Upfront capital availability; commissioning complexity

Table 50: Costs of the proposed measures

Measure	CAPEX (Euro)	OPEX (Euro)	Required investment (Euro)
M1	3,000,000	40,000	3,040,230
M2	-	-	-
M3	28,000	2,500	30,500
M4	3,500	300	3,775
M5	1,380,000	61,000	1,441,082
M6	9,000	1,000	10,000
M7	36,500	3,500	40,000

Table 51: Short evaluation of the measures

Measure	Energy saving (MWh/year)	CO2 emission reduction (tons/year)	Cost saving (Euro/year)	Multiple benefits (Euro/year)
M1	9,523.34	2,914.14	1,520,115.53	1,782,388
M2	-	1,287.39	-	115,865
M3	19.30	5.91	3,080.66	3,612
M4	63.30	19.37	10,103.95	11,842
M5	-	-	256,260.00	256,260
M6	630	143	45,300.00	58,170
M7	800	481	48,800.00	92,290

1.6. Multiple benefits analysis

This chapter evaluates the measures proposed in the Decarbonization Action Plan (DAP) not only in terms of their direct energy and cost savings but also through their broader environmental, social, and operational impacts.

The solutions detailed in Chapter 4 – Decarbonization Action Plan, for which the multiple benefits analysis has been done are the following:

- M1: PV panels for self-consumption
- M2: Green energy acquisition
- M3: New compressor with variable speed and centralized compressor control
- M4: Retrofit lighting fixtures
- M5: Cogeneration plant with an additional turbine
- M6: Residual heat recovery from combustion gases
- M7: Upgrade of industrial dryer

1.6.1. Evaluation and quantification

M1 – PV panels for self-consumption

The first measure in the DAP focuses on expanding photovoltaic (PV) capacity for self-consumption. With an investment of over €3 million, this measure enables the company to generate clean, renewable electricity on-site, significantly decreasing dependence on grid-supplied electricity and fossil fuel-based sources.

This solution directly addresses both environmental and financial performance by reducing Scope 2 emissions and stabilizing long-term energy costs. With a short payback period and high internal rate of return, this measure is a key component in the decarbonization roadmap.

Table 52: Summary of key benefits of M1

Category	Key benefit	Impact
Energy	Energy savings	9,523.34MWh/year
	CO_2 savings	2,914.14 t CO_2 eq./year
	Efficiency improvement	Increase the RES production.
Non-energy	Maintenance savings	No.
	Improved process stability	Energy production will be used in the process.
	Workplace comfort	No.
Financial	NPV	€3,586,891.14
	IRR	41.04%
	Payback period	~2 years

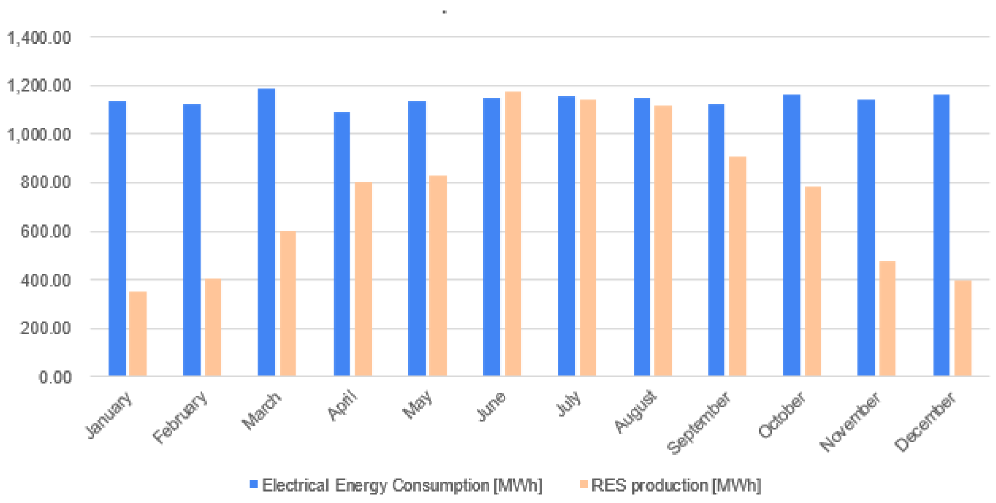


Figure 55: Electrical energy consumption vs. RES production after implementation of the Measure 1

Table 53: Quantifiability of benefits as a matrix of M1

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Cost savings; CO_2 emissions reduction	Cost savings; CO_2 emissions reduction
MEDIUM	Operational visibility; grid impact	Operational visibility; grid impact
LOW	None	Supply chain resilience; reputational benefits

Time

M2 – Green energy acquisition

The second measure consists of switching to electricity sourced entirely from certified renewable energy suppliers. Though it requires no capital investment, this measure brings significant environmental benefits by displacing emissions associated with conventional power generation.

This solution is especially valuable for its simplicity, speed of implementation, and contribution to emission reduction targets. It’s lined with green procurement and ESG standards and with a low-barrier, high-impact action contributing to climate goals.

Table 54: Summary of key benefits of M2

1.6.1. Category	Key benefit	Impact
1.6.4. Energetic	Energy savings	Green electrical energy is paid and consumed by the company.
	CO_2 savings	1,287.39 t CO_2 eq./year
	Efficiency improvement	Reduce the CO_2 eq. of Scope 2.
Non-energetic	Maintenance savings	No
	Improved process stability	No
	Workplace comfort	No
Financial	NPV	-
	IRR	-
	Payback period	-

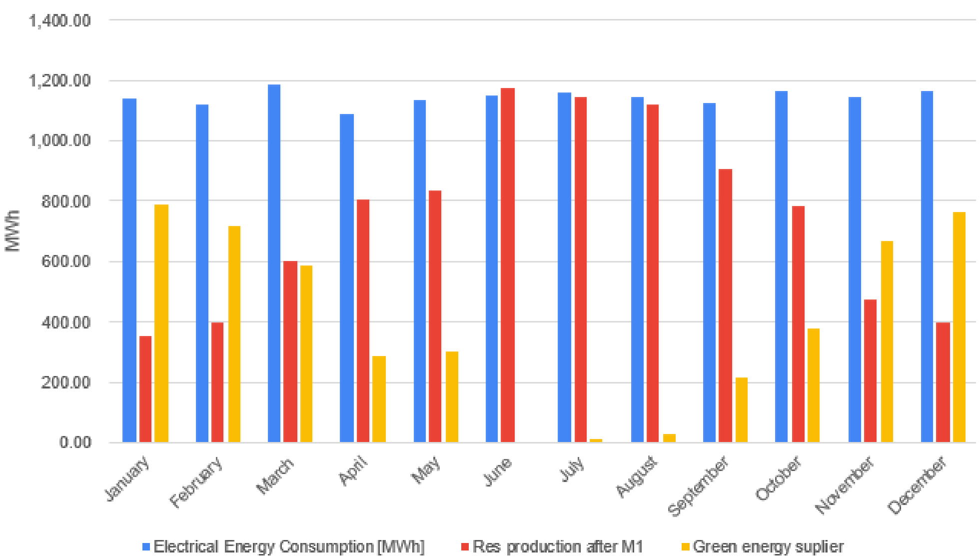


Figure 56: Energy analysis after implementation the Measure 1 and 2.

Table 55: Quantifiability of benefits as a matrix of M2

QUANTIFIABILITY		SHORT TERM	LONG TERM
	HIGH	CO_2 emissions reduction; Scope 2 decarbonization	No capital expenditure; Rapid implementation
	MEDIUM	Ease of implementation; procurement alignment	ESG compliance; supply-chain transparency
	LOW	None	Market differentiation;

Time

M3 – New compressor with variable speed and centralized compressor control

This measure involves replacing the existing fixed-speed compressor with a variable-speed compressor, integrated with a centralized control system. This action addresses inefficiencies in compressed air production by optimizing energy use and reducing idle time. By aligning compressed air generation with actual production demands, this measure promises significant energy savings, reduced carbon emissions, and enhanced operational reliability.

This measure offers a wide array of benefits spanning energy efficiency, operational reliability, environmental sustainability and financial profitability, making it a pivotal step toward achieving decarbonization and business objectives:

Table 56: Summary of key benefits of M3

Category	Key benefit	Impact
Energetic	Energy savings	63.3 MWh/year
	CO_2 savings	19.37 t CO_2 eq./year
	Efficiency improvement	Reduced idling and optimized demand
Non-energetic	Maintenance savings	Lower operating hours
	Improved process stability	Consistent air pressure
	Workplace comfort	Lower noise levels
Financial	NPV	13,245.00
	IRR	19.90%
	Payback period	~3 years

Table 57: Quantifiability of benefits as a matrix of M3

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Energy savings; flexibility in energy use;	Improved energy efficiency; lower maintenance costs; CO_2 savings;
MEDIUM	Operational reliability; energy independence	improved equipment lifespan;
LOW	Workplace comfort; community impact	Support for corporate sustainability goals;

Time

This measure not only delivers quantifiable energy and cost savings but also significantly enhances operational efficiency and workplace conditions. Its high return on investment and short payback period make it a financially sound decision, while its contribution to reducing emissions and improving sustainability further underscores its strategic importance.

M4 – Retrofit lighting fixtures

This measure aims to address the dual objectives of reducing energy consumption and minimizing operational costs while delivering multiple additional benefits. By replacing outdated fluorescent and sodium vapor lamps with modern LED technology, the company expects to achieve significant energy savings, enhance workplace safety and comfort, and contribute to its broader sustainability goals. The retrofit not only aligns with company's commitment to environmental stewardship but also provides a high-return investment opportunity with a short payback period, making it a compelling step in the company's transition to a greener, more efficient operation.

Table 58: Summary of key benefits of M4

Category	Key benefit	Impact
Energetic	Energy savings	19.3 MWh/year
	CO_2 savings	5.91 t CO_2 eq./year
	Efficiency improvement	Significant reduction in power demand
Non-energetic	Maintenance savings	LED lifespan is 3-5x longer
	Improved safety and comfort	Enhanced lighting conditions
	Environmental impact	Reduced hazardous waste
Financial	NPV	€9,563
	IRR	37%
	Payback period	<2 years

Table 59: Quantifiability of benefits as a matrix of M4

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Improved lighting quality;	Energy savings, improved energy efficiency; reduced maintenance costs; cost savings; high investment returns
MEDIUM	Operational reliability; modernized infrastructure	Reduction in hazardous waste; CO2 savings; resource efficiency
LOW	Workplace safety and comfort; community impact	Energy independence; alignment with sustainability goals;

Time

In conclusion, the lighting retrofit measure represents a pivotal step in the company's decarbonization journey, delivering a multifaceted range of benefits that transcend traditional energy efficiency gains. With tangible energy and cost savings, enhanced workplace safety, and alignment with global sustainability goals, this measure exemplifies how targeted investments in energy efficiency can yield significant value across environmental, social, and economic dimensions.

M5 – Cogeneration plant with an additional turbine

The fourth measure in the DAP involves the installation of an additional turbine in the existing cogeneration plant. This measure is designed to optimize energy production efficiency by utilizing waste heat more effectively, thereby reducing reliance on grid electricity and lowering operational costs. By integrating advanced cogeneration technology, this initiative aligns with the company's goals of improving energy efficiency, reducing greenhouse gas emissions, and strengthening energy security. Although the measure involves a significant upfront investment (€ 1,449,924), the multiple benefits it offers across environmental, operational, and financial dimensions justify its inclusion as a cornerstone of the company's decarbonization efforts.

Table 60: Summary of key benefits of M5

Category	Key benefit	Impact
Energetic	Increased efficiency	Optimized waste heat utilization
	Energy savings	Reduced grid reliance
Non-energetic	Energy security	Stable and predictable energy costs
	Operational reliability	Fewer disruptions
	Sustainability alignment	Strengthened environmental profile
Financial	NPV	€ 159,764
	IRR	10.6 %
	Payback period	-

Table 61: Quantifiability of benefits as a matrix of M4

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Increased energy efficiency; cost-effectiveness of energy use	Energy savings;
MEDIUM	Operational reliability	Improved energy security; long-term value creation
LOW		

Time

M6 – Residual heat recovery from combustion gases in an industrial tunnel furnace

The fifth measure in the DAP involves implementing a residual heat recovery system for combustion gases in the industrial tunnel furnace. While the data provided for this measure is generic and not yet tailored to specific operations, it highlights the potential for significant energy savings and environmental benefits through innovative heat recovery solutions. This measure exemplifies the company's commitment to exploring advanced efficiency techniques and adopting sustainable practices that align with its long-term decarbonization goals.

Table 62: Summary of key benefits of M6

Category	Key benefit	Impact
Energetic	Energy savings	~ 630 MWh/year
	CO_2 emissions reduction	~ 143 t CO_2 eq./year
	Improved efficiency	Reduced thermal losses
Non-energetic	Scalability	Future adaptability
	Operational reliability	Stabilized furnace performance
	Resource usage reduction	Circular energy practices
Financial	Cost savings	~ € 45,300/year
	IRR	~22.3%
	Short payback period	< 1 year

Table 63: Quantifiability of benefits as a matrix of M6

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Lower operational costs	Energy savings, CO_2 emissions; scalability and adaptability
MEDIUM	Operational benefits	Lower operational costs; short payback; reduction in resource usage
LOW		Alignment with

Time

While the data supporting this measure is generic and not tailored specifically to the facilities, it underscores the significant potential of residual heat recovery systems to enhance energy efficiency and reduce operational emissions. The projected benefits, including substantial energy savings, reduced CO2 emissions, and rapid cost recovery, suggest that implementing such a system is a promising step toward achieving the company's sustainability objectives.

M7 – Upgrade of existing industrial dryer

The sixth measure in the DAP targets the plant's tunnel dryer, one of the largest continuous thermal loads on site. By retrofitting advanced process controls (temperature & humidity sensors), improved insulation, exhaust-air heat recovery, and an optional heat-pump module, this upgrade can unlock substantial efficiency gains and environmental benefits.

Table 64: Summary of key benefits of M7

Category	Key benefit	Impact
Energetic	Energy savings	~ 800 MWh/year
	CO_2 emissions reduction	~ 481 t CO_2 eq./year
	Improved efficiency	Reduced thermal losses
Non-energetic	Scalability	Future scalability
	Operational reliability	Stabilized drying performance
	Resource usage reduction	Circular energy practices
Financial	Cost savings	~ € 48,800/year
	IRR	21.25%
	Short payback period	< 1 year

Table 65: Quantifiability of benefits as a matrix of M7

QUANTIFIABILITY	SHORT TERM	LONG TERM
HIGH	Energy savings; CO_2 reductions; cost savings	Cost savings; short payback; operational gains
MEDIUM	Operational benefits; resource usage reduction; short payback	Short payback; reduction in resource usage
LOW	Alignment with sustainability objectives	LONG TERM (energy & CO_2 savings; scalability

Time

1.7. Cost-benefit analysis / Financial analysis

The implementation of these measures is projected to yield substantial energy savings, and significant environmental benefits by reducing CO_2 emissions. The following table includes a summary of these benefits, alongside the most relevant financial indicators to underline the financial viability of the measures. Since M5, regarding residual heat recovery from combustion gases does not entail tailored costs and savings data, it will not be included in the total of investments, costs and saving.

Table 66: Summary of financial, energetic benefits and GHG savings

No.	Energy efficiency solutions proposed in the DAP	Investment (€)	Cost savings (€/year)	PP (years)	NPV (€)	IRR (%)	Energy savings (MWh/year)	CO2 savings (t CO_2 eq. / year)
M1	PV panels for self-consumption	3,040,230	1,520,115.53	2	3,586,891.14	41.04%	9,523.34	2,914.14
M2	Green energy acquisition	-	-	-	-	-	-	1,287.39
M3	New compressor with variable speed and centralized compressor control	30,500	10,103.95	3.02	13,245	19.90%	63.3	9.369
M4	Retrofit lighting fixtures	3,775	3,080.66	1.23	9,563	76.90%	19.3	5.905
M5	Cogeneration plant with an additional turbine	1,441,082	-	-	-	-	-	-
M6	Residual heat recovery from combustion gases	10,000	45,300	0.22	186,125	22.3%	630	143
M7	Upgrade of industrial dryer	40,000	48,800	0.82	171,279	21.25%	800	481
TOTAL / year (*without M5*)		**4,565,587**	**1,627,400.14**	**7.28**	**3,967,103.14**	**152.09.36%**	**11,035.94**	**4,850.81**

The integration of these actions into factory operations forms a comprehensive roadmap to sustainability, balancing immediate energy savings with long-term environmental and operational gains. While some measures prioritize financial efficiency, others emphasize their transformative impact on CO2 emissions and energy independence.

1.8. Funding sources for energy efficiency and decarbonization

Several funding programs can support the implementation of proposed energy efficiency and renewable energy measures

1. **Romanian Fund for Energy Efficiency (FREE)**

The Fund promotes commercial financing for projects that improve energy use and develop renewable sources. It offers loans under competitive conditions, complementing traditional banks, and provides professional, customer-oriented services to overcome barriers in financing. By 2025, FREE concluded 53 contracts totaling USD 30.65 million.

2. **National Recovery and Resilience Plan (PNRR)**

At the beginning of 2025, no new calls are open, but a recent example is Investment Measure I5 – “Ensuring energy efficiency in the industrial sector.” The scheme supported modernization, monitoring, and efficiency measures across companies of all sizes. Grants covered up to €2 million for eligible equipment such as production line components, motors, compressors, pumps, boilers, ventilation, heating/cooling systems, and energy management tools. This call closed in April 2024, with no similar opportunity available at present.

3. **Sustainable Development Program (PDD/SDP)**

For 2025, a competitive call is announced for industrial energy efficiency projects (Priority 4, Action 4.1). Eligible applicants include large enterprises and industrial companies consuming over 1,000 toe/year (as defined in Law 121/2014). The applicant’s guide is expected in March 2025, with the call opening around 15 March 2025.

1.9. Decarbonisation Roadmap

The EnTRAINER Roadmap for the present ETA provides a clear and structured pathway to achieve the decarbonization goals. It outlines the specific steps, targets and milestones needed to make the transition to a low-carbon future. The Roadmap helps to align efforts, prioritize and provide a sense of direction for policy makers, business and stakeholders. It also serves as a monitoring and evaluation tool, allowing tracking progress against decarbonization targets. It allows for regular assessments, identifying potential bottlenecks and making the necessary adjustments to ensure the effectiveness of decarbonization strategies. It facilitates accountability and transparency in the implementation process.

Table 67: Distribution of measure implementation in time

Year of implementation	2025	2028	2035	2040
	M1. PV panels for self-consumption			
	M3. New compressor			
	M4. Retrofit lighting fixtures			
		M2. Green energy acquisition		
		M5. Cogeneration plant with an additional turbine		
			M6. Residual heat recovery from combustion gases	
				M7. Upgrade of industrial dryer

Table 68: Targets of emission levels archived in time

Year	2024	2028	2030	2040	2050
Target emission level [%]	**0%**	**-30%**	**-40%**	**-50%**	**-60%**
Target emission level [tones of CO2 eq.]	**10,325.91**	**7,228.14**	**6,195.55**	**5,162.96**	**4,130.36**
M1. PV panels for self-consumption	*Baseline*	2,914.14	2,914.14	2,914.14	2,914.14
M2. Green energy aquisition	*Baseline*	*TBI*	1,287.39	1,287.39	1,287.39
M3. New compressor	*Baseline*	19.37	19.37	19.37	19.37
M4. Retrofit lighting fixtures	*Baseline*	5.91	5.91	5.91	5.91
M5. Cogeneration plant with an additional turbine	*Baseline*	-	-	-	-
M6. Residual heat recovery	*Baseline*	*TBI*	*TBI*	143.00	143.00

from combustion gases					
M7. Upgrade of industrial dryer	*Baseline*	*TBI*	*TBI*	*TBI*	481.00
TOTAL / year (*without M5*)	*Baseline*	**2,939.42**	**4,226.81**	**4,369.81**	**4,850.81**
Emission reduction level [tones of CO2 eq.]	10,325.91	7,386.49	6,099.10	5,956.10	5,475.10
Emission reduction level [%]	0%	-28.47%	-40.93%	-42.32%	-46.98%

Note: TBI -To Be Implemented

This table outlines a progressive roadmap for reducing CO_2 emissions from 2024 to 2050 through the implementation of multiple energy and efficiency measures. It presents year-by-year targets in terms of emission reduction levels—starting with no reduction in 2024 (0%) and reaching a 50% reduction goal by 2050. The baseline emission level is set at 10,325.91 tonnes of CO_2 equivalent per year. Across the years, various measures contribute to reducing emissions, including PV panels for self-consumption (constant at 2,914.14 tonnes saved annually), green energy acquisition (implemented from 2028 onward), new compressor systems, retrofitting lighting fixtures, and other measures like residual heat recovery and upgrading industrial dryers. Some initiatives, such as cogeneration and industrial dryer upgrades, remain unimplemented in earlier years, marked as TBI (To Be Implemented). Over time, the cumulative effect of these measures significantly reduces total emissions, reaching a projected 5,475.10 tonnes by 2050—equating to a 46.98% reduction. The data highlights a phased and strategic deployment of technologies aligned with defined decarbonization targets.

Appendix D. Case study – Spain

The purpose of the present Energy Transition Audit (ETA) report is to present the current energy situation through a detailed energy analysis and to propose a personalized Decarbonization Action Plan for the audited company, aiming to significantly reduce the CO2 emission level of the company 24% until 2030 and 48% until 2050, compared to the 2023 baseline.

1.1. General information

The audited site is a century-old Spanish company based in Valencia that processes and packs honey and other bee products under its own and private-label brands. It operates in an industrial building that has been progressively modernized, most recently in 2022, plus a raw material warehouse.

The year 2023 will be set as a baseline year, against which decarbonization targets will be compared. In 2023, the company consumed 1,647 MWh as total final energy, of which 1,230 MWh come from natural gas and 417.4 MWh from electricity from the grid. Moreover, the company has a photovoltaic installation that covers part of the electricity demand of the facility. As for CO_2 emissions, 74% are considered Scope 1, and the rest are considered Scope 2.

The main input data used for the ETA is historical electricity consumption records, distributor readings, specifications of the equipment used during the production process, water flow and bills (both electricity and natural gas), annual production data, among others. This information is completed with on-site measurements.

As a result of the analysis, a Decarbonization Action Plan is presented, following the *GHG Protocol* and in line with the *European Green Deal*, with final targets for 2050 and intermediate milestones for 2030, covering technical measures as well as organizational measures, aiming to improve the company's sustainability short and long term.

1.2. Short description of the company

The audited company is a Valencian honey processor and packager (*Manufacture of other food products n.e.c; NACE 10.89*). It was founded in 1912; with more than 100 years' experience in the industrial sector, it is currently owned by the same family that started the business. They operate at an international level and obtain raw material from different locations, mainly Spain and other countries in Europe, but also: Guatemala, El Salvador, Nicaragua, Cuba, Mexico or Republica Dominicana. The company has its own brand selling bee products, but it also supplies large supermarket companies with private label in Spain and other 35 countries. Nowadays, it supplies about 25% of Spain's domestic honey market. Their supply chain stimulates local economies – approximately 100 families earn their livelihood from the company's honey procurement, including a large network of Spanish beekeepers.

The main building is a 2,000 m^2 industrial building with north-west orientation. It was built in 1912 and in 2022 it underwent a significant renovation project. The facility consists of the production area, offices, storage, as well as a small laboratory dedicated to the quality control of the final product. There is also another building for the storage of raw materials.

Around 50 people work in the audited facility from Monday to Friday in 3 shifts that cover 24 hours a day from October to May, and 2 shifts cover 16 hours a day the rest of the year.

The company has never carried out an Energy Audit similar to the present one. They are conscious of their use of energy, as they installed energy management software and a photovoltaic system in 2022, but do not have specific goals in terms of energy savings nor decarbonization efforts.

Location

Indicate the exact location of the audited company/site. You can include a map for more visual representation. The audited site is located in Montroi, Valencia.

Figure 57: Satellite view of the audited site

1.3. Description of the company and technological processes

The company is an energy-intensive business that specializes in processing and packaging various varieties of honey and pollen, handling more than 10,000 t/year in formats such as jars, bulk containers, single-serve doses, squeezer bottles, and more.

It has 4 production lines encompassing 9 processes, including the following:

- Pre-heating in heating tunnel. Honey tanks are moved through this tunnel in order to break the crystals in the honey and achieve a liquid texture. The tanks spend approximately 5-10 minutes in this station, depending on the initial state of the raw product. The tunnel processes around 300 kg of honey a day.
- Crushing. This process is only necessary if the honey is too solid and needs additional help in crushing the crystals. It also uses thermal energy.
- Turnover. The tanks are tipped into a homogenizing tank surrounded by hot water.
- Melting. The extracted honey passes through a shell and tube exchanger (water-honey-water).
- Homogenization. The honey goes to an underground chamber in which it is homogenized for 40 minutes with moving blades. It requires heat treatment with water at approximately 50 ºC.
- Pasteurization. The honey is heated through a plate heat exchanger.

- Cooling through a plate heat exchanger.
- Storage, with or without heat treatment.

As for energy-consuming installations, they have electric installation, HVAC, lighting and production process machinery. Hot water is provided by two natural gas boilers (889 kW and 565 kW); the smallest one is only used when a process needs extra power, which does not happen often.

The energy-related data was collected from their energy management system which monitors HVAC, gas, electricity and water use. 2023 is used as the baseline year.
In 2023, the company had an electricity consumption of 528 MWh. Since 2022, part of it, about 20 % in 2023, is covered by renewable energy: a 175kW photovoltaic system. The following graph shows a general decrease in electric consumption from 2022 to 2023 and the contribution of the PV installation. It is important to note that in May there seems to be a deviation due to a failure of the distribution company in the consumption records.

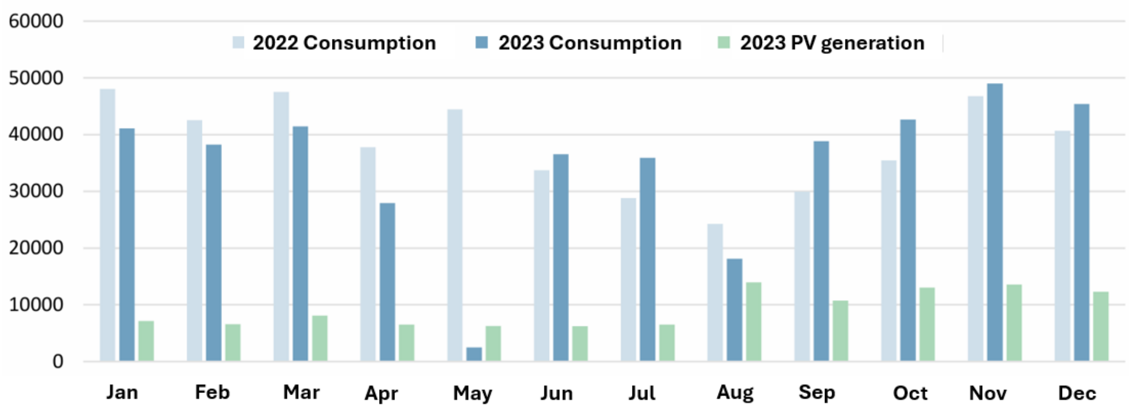


Figure 58: Total electric consumption and generation [kWh]

The equipment used to carry out the production process requires both hot water, provided by the natural gas-fired boilers, and electricity to power them.
The company's energy consumption consists of electricity and natural gas. The billed annual electricity consumption in 2023 is 417.4 MWh, so that grid electricity accounts for 79% of the total electricity demand in 2023. In addition, considering that natural gas consumption in 2023 was 1230 MWh.

In order to break down consumption by process line, Energy and Power Quality Analyzers along with data loggers were installed for the period between 19th October 2023 and 30th October 2023 at the following points:

- Homogenization
- Pre-heating
- HVAC system (Biocool)
- Pasteurization
- Charging of forklift batteries

In addition, analyzers were also installed on the general switchboard, which includes all of the above, as well as lighting, other machinery, chillers, boiler burners and all other equipment operating in the audited site during said time period. By extrapolating the data to a whole year, with 250 working days, considering a correcting factor of 0.75, the results are shown in the following table.

Table 69: Annual consumption according to energy analyzers, extrapolated and corrected

Measured point	Annual consumption (MWh)
Pre-heating	7.72
Homogenization	1.5
Biocool	1.34
Pasteurization	1.91
Charging forklift batteries	0.72
Other process lines	86.91
General consumption	535.19
Remaining consumption	435.09

With the results obtained, the following indicators are defined in Table 73.

Table 70: Annual energy indicators

Indicator	
Total consumption per 500 g dispenser	0.28 (kWh/dispenser·year)
Total consumption per area	630.7 (kWh/m^2 ·year)
Total consumption per employee	28,668 (kWh/employee·year)

During the on-site visit, it was also possible to detect heat loss from water pipes using a thermographic camera, as shown in Figure 58. Part of the pipe system is not insulated, and as a result the superficial temperature is higher than the insulated sections.

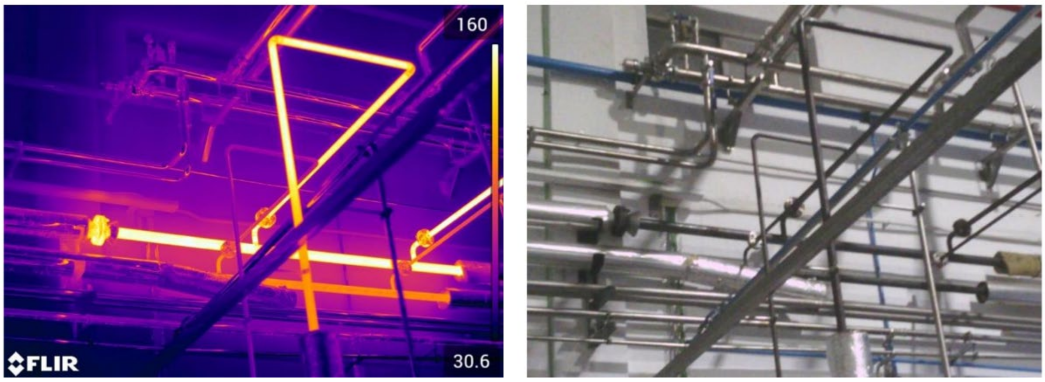


Figure 59: Images provided by the thermographic camera in the production area

To obtain the surface temperature of the pipes, it has been considered that the external surface is copper, resulting in high emissivity (0.9). Likewise, the emissivity of the rock wool insulation is considered to be close to 0.9. In the thermal imaging, is it possible to differentiate the pipe sections with and without any type of insulation.

1.3.1. Carbon footprint assessment

Regarding CO_2 emissions, the company has an emission profile mainly within Scope 1 and Scope 2. The emission factor considered is 0.202 kg CO_2/kWh for natural gas, and 0.205 kg CO_2/kWh for electricity. Following Equation 1, the company's industrial activities resulted in 248.46 t CO_2 from natural gas and 85.56 t CO_2 from electricity, emitted in 2023.

$$CO2\ emissions\ [kg] = Consumption\ [kWh] \cdot Emission\ factor\ \left[\frac{kg}{kWh}\right]$$

Equation 1: CO2 emissions from energy consumption

This leads to the defining of the following emission indicators in Table 74.

Table 71: Annual emission indicators

Indicator	
Emissions per honey dispenser	$5.8 \cdot 10^{-5}$ (tCO_2/dispenser·year)
Emissions per area	0.167 (tCO_2/m^2 ·year)
Emissions per employee	7.59 (tCO_2/employee·year)

The following sections will explore the implementation of energy efficiency measures and DAP.

1.4. Main stages of the work

The work was carried out in two main stages:

Stage 1:
- *Setting the decarbonization target(s);*
- *Collection of primary data related to the objective assessed;*
- *Identification of production/technological activities and/or processes;*
- *Identification of the types of energy carriers used in the current activity;*
- *Identification of the types of energy users, classification;*
- *Carry out energy measurements and assessments (if the case);*

The initial phase focused on understanding the baseline scenario, both in terms of energy performance and emission profile, which is then used as a baseline to set the decarbonization targets. Along the same lines, a detailed data collection process is conducted, involving electricity and natural gas bills, historical energy use, production lines, equipment specifications, working habits and more. This is then analyzed to identify the main areas of improvement, deficiencies and trends.
Understanding the production process is a key step to get a comprehensive view of energy flows within the facility. Auxiliary processes, main lines and technological activities can lead to operational gaps that may have a major impact on the whole process. This helps define focus areas for decarbonization and identify and classify energy users and their relevance during the production process. On this issue, major energy-consuming systems were categorized by their function: production, thermal usage, lighting, HVAC, office equipment, etc. Moreover, it provides a clear view of all energy inputs used on-site (electricity and natural gas, in this case), including quantities, usage patterns and energy flows.

Once all the above is considered, the team carried out relevant, real-time measurements that would help fill the gaps in the collected data and expand the detail on energy consumption or energy waste across the facility. This is useful especially to verify consumption patterns and detect anomalies or inefficiencies.

Taking into account all the work done during stage 1, the current EU's and Spain's climate goals, sector-specific benchmarks and the company's strategic vision, individual targets were set for each emission scope (Scope 1 and 2). It is important to ensure that these goals are realistic and achievable, which makes it necessary to understand the company's needs and priorities, encourage their commitment with the decarbonization plan and clearly communicate the benefits of it. Tools like the ones provided by EnTRAINER were also used to carry out a preliminary energy analysis and draw the main conclusions from this initial stage.

Stage 2:

- *Description of the company and the technological processes carried out;*
- *Description of the electricity and thermal energy contour;*
- *Preparation of the energy analysis and specific consumption;*
- *Preparation of the emission analysis/inventory based on Scope 1 and 2;*
- *Proposal of a decarbonization action plan;*
- *Roadmap outlining.*

The following stage comprises a comprehensive diagnostic that quantifies emissions and energy use, translating data and insights into a structured decarbonization strategy tailored to the site's specific context.

The team prepared a short description of the company, and the technological processes carried out, including the company's sector, production capacity, operating schedule and any energy-related issue they may have identified. Next, the electricity and thermal energy contour was defined through a quantitative analysis of generation, consumption and end-use points of each energy carrier, leading to identification of major energy losses and saving opportunities. This procedure also helps with visualizing the interaction between energy systems and the main activity of the facility.

Then, hourly electricity consumption from both historical records and own on-site measurements (extrapolated and corrected) were graphed and broken down by process and carrier. This builds the energy balance in the company and the energy and emission related KPI, which are crucial to benchmark and monitor the company in these aspects.

Following the *Greenhouse Gas Protocol*, total CO_2 carbon footprint is classified into Scope 1 and 2 (direct and indirect emissions, respectively) that require different decarbonization targets. The total emissions are calculated using the emission factor assigned to each energy carrier: 0.202 $kgCO_2/kWh$ and 0.205 $kgCO_2/kWh$ for the electricity trader of the company. The inventory is built with the collected data of energy use and forms the baseline for decarbonization.

Consequently, the decarbonization action plan for this company aims to reduce the total CO_2 emissions in alignment with their goals. The targets of this plan are carefully studied to ensure that they are specific, measurable and realistic. They are also evaluated in terms of technical feasibility, emission reduction potential, estimated investment and payback period. This includes assessing the necessary resources, including financial, technological and human resources, to implement each action. To this end, it was necessary to communicate with top decision makers of the company and consider their expectations and their ability to allocate resources accordingly.

Finally, a Decarbonization Roadmap is developed to guide the company towards the achievement of the proposed targets, in a structured and realistic way. The roadmap includes a timeline of actions, responsible departments and expected energy/emission outcomes. This roadmap is intended to be used as a tool to clearly identify the baseline position of the company and the actions that need to be taken that lead to successful decarbonization.

1.5. General description of the work

1.5.1. Description of the electricity contour

- *Power supply*
- *Information about Power transformers*

The electricity required for the operation of the company's activities is provided through electricity from the grid and its own photovoltaic generation.
The contracted power from the electricity trader is as follows:

Type of contract and tariff	6.1 TD					
Contracted power for each tariff period (kW)	P1	P2	P3	P4	P5	P6
	180	180	180	180	180	180

1.5.2. Description of the thermal energy contour

- *Thermal energy supply/sources*
- *Thermal energy equipment*

In addition to electricity, the company also has natural gas supply.

Hot water used throughout the process is obtained from the two tanks in which it is stored, located on the outside of the building, and from a closed circuit installed throughout the facility it is supplied to the different equipment that requires it.

Overall, the two boilers operate approximately 5,000 hours a year. One of them, the oldest one (installed in 2016) has 565 kW of thermal power. It serves as a back-up system and only works sporadically. The other one, installed in 2023, covers the demand of hot water most of the time, and has 889 kW of thermal power.
The following table specifies which process equipment uses thermal energy.

Table 72: Water flow and water temperature for thermal energy consuming equipment

Equipment	Water flow (l/h)	Estimated water temperature (ºC)
Crusher	10,000	80
Melter	13,000	80

Homogenizing tank	10,000	80
Tank cleaner	3,000	80

1.5.3. Energy assessment contour

• Reference conditions for carrying out the energy assessment, including, type of profile included, timeframe, operating regime, etc.
• Description of the time period considered for the input data, and the source of the input data (measures, estimated or obtained from historic measurements). The overall operating hours/year should be mentioned, along with the location operating schedule.

The industrial facility follows an operation regime with production typically taking place Monday to Friday, across two or three shifts (June-September and October-May, respectively). 250 working days/year and 115 non-working days/year are considered in the ETA. The timeframe of analysis covers years 2021, 2022 and 2023 depending on the available data of each year, offering a recent and representative baseline of energy use and operating patterns. The data was obtained from historical records from the distribution company. In addition, short-term electrical measurements were conducted on-site during 12 days in October 2023.

After collecting the necessary data, the type of load profile considered includes base load during non-production hours, daily shift-related variations and seasonal and monthly fluctuations. As for the first one, the energy analysis includes nights (out shift: June-September), weekends and bank holidays, to detect primarily standby consumption. The second profile reveals power peaks, shift changes and the contribution of PV generation. Lastly, seasonal and monthly fluctuations show the link between consumption and HVAC use or changes in demand, for example.

Graph 2 displays only one of all the measurements the audit team carried out on-site for 11 days. Along with the other graphs that have been produced from the measurements, the data obtained from the energy analyzer equipment provides detailed insight into the power demand patterns of part of the machinery from the facility. The orange curve is the sum of all the measures included in the chart. It can be observed that power demand varies considerably between weekdays and weekends and is mainly cyclical.

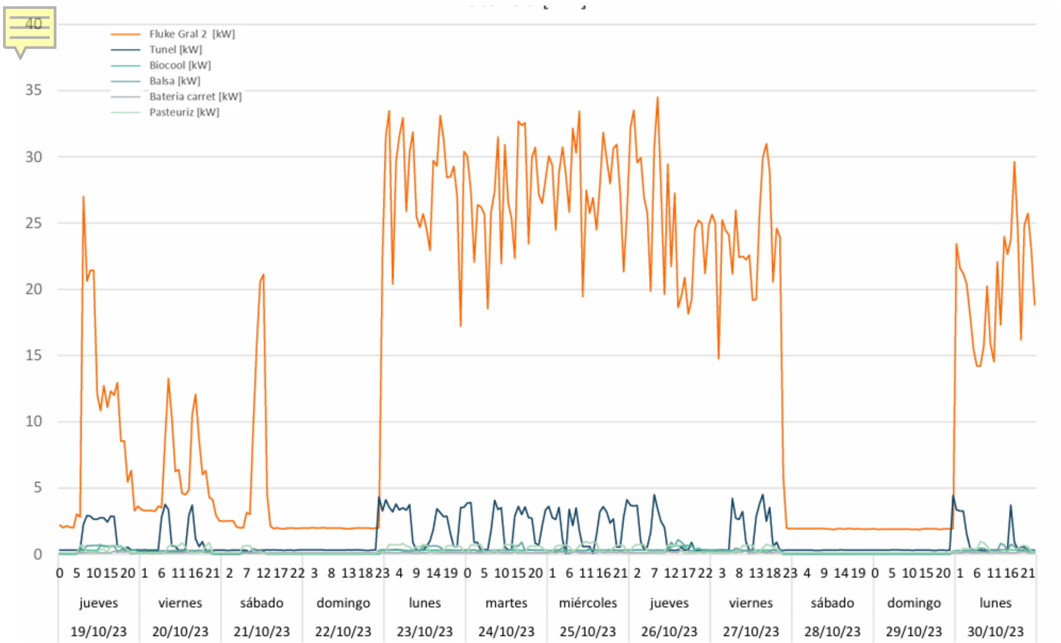


Figure 60: Measurements made for the electricity demand of the main equipment

1.6. Energy analysis

The present chapter should present the energy analysis done within the energy scan, and additional elements described below:

• Description of the energy carriers and their usage in the company.

• Presentation of the monthly consumption and cost analysis of each energy carrier for at least 3 consecutive years. Analysis (monthly and multiannual) of the situation. Interpretations in the form of text.

• Specific cost of the different energy carriers. Presenting the multiannual trend.

• If the case: presentation of the energy produced locally. E.g. electrical energy produced from RES.

• If RES is available, show the total electric energy, the energy purchased by the grid and the one produced locally, numerically, and by share.

• Share of energy consumption

• Main conclusions of the energy analysis and presentation of the need for a decarbonization action plan.

• Specific energy consumptions

There are two main energy carriers in the company: thermal energy and electricity. Natural gas is used to fuel two boilers, which generate hot water for key stages of the honey processing line, while electricity is used by process equipment, HVAC systems and lightning, among others.

Melting and pasteurization depend heavily on steam and hot water circuits, fed by a pipe system from the boilers. It is also used to maintain process temperatures, especially where honey needs to be in a liquid state, in heat exchangers.

Table 76 displays the electricity consumption billed during the year 2021 and 2022 (there was a reading error during 2023 from the distributor company). The cost includes the energy cost, billing for contracted power, electricity tax, transmission and distribution charges, metering equipment rental and VAT at 21%.

Table 73: Electricity billing 2021-2022

	2021			2022		
Month	Consumption [kWh]	Cost [€]	Specific Cost [€/kWh]	Consumption [kWh]	Cost [€]	Specific Cost [€/kWh]
January	59,848	7,476.57	0.12493	48,051	6,152.22	0.12803
February	54,167	6,679.9	0.12332	42,532	5,619.16	0.13211
March	58,009	7,162.75	0.12348	45,341	20,702.95	0.4566
April	50,401	6,391.11	0.12681	39,946	12,648.71	0.31664
May	50,604	6,584.65	0.13012	44,445	13,318.94	0.2996
June	46,890	6,134.22	0.13082	33,723	11,850.85	0.35141
July	41,938	6,978.98	0.16641	28,834	12,346.01	0.42817
August	46,858	6,218.83	0.13272	24,225	12,385	0.5112
September	49,108	5,667.91	0.11542	29,942	12,294.06	0.4105
October	42,742	4,451.08	0.10756	35,471	10,562.5	0.2977
November	49,813	5,357.64	0.10756	46,773	10,403	0.2224
December	48,825	5,459.86	0.11183	40,643	8,056.49	0.1982
TOTAL	**599,203**	**74,563.5**	**0.124**	**459,875**	**136,340**	**0.3**

The specific cost increased notably in 2022, mostly due to the energy term, as the contracted power remained the same during both years. This steep rise can be attributed to several factors such as an overall volatility in the European energy system that affected the Spanish electricity market in 2022. The trend is shown in Graph 3.

On the other hand, consumption from the grid has decreased since 2021, likely due to the photovoltaic installation in 2022; in 2023, it was even lower: 417.4 MWh, while tonnes of production have remained constant.

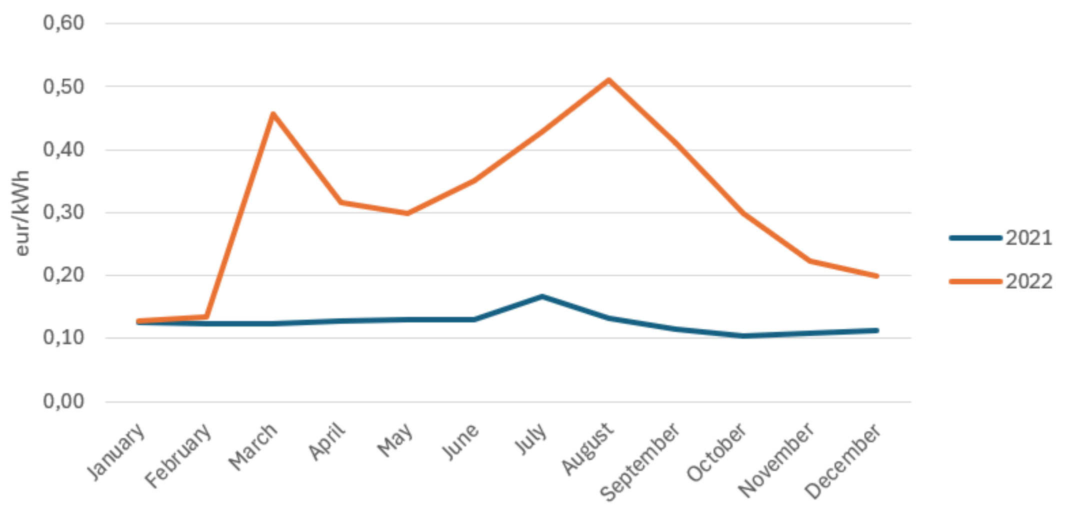


Figure 61: Evolution of specific cost in 2021 and 2022

Moreover, in 2022 the company consumed 844 MWh from natural gas. In 2023, billings are only available up to the month of June, so information on the last half of the year is not available. In general, the months with the highest demand are those corresponding to winter. At the same time, there is a clear decrease in consumption during summer, and an increase as winter approaches. This is due to the combined effects of both the decrease in temperature corresponding to the winter months, as well as possible changes in production. The trend can be seen in Graph 4.

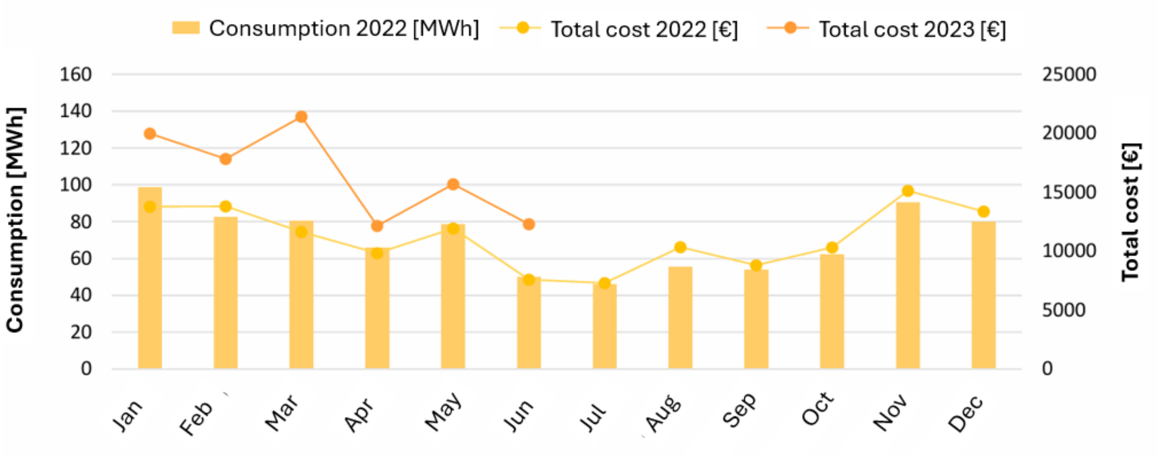


Figure 62: Monthly natural gas consumption and billing

The average specific cost for natural gas in 2022 with 21 % VAT is 0.1575 €/kWh.
Considering the billing in 2022, the company spent a total 267,879.4 € in energy supply.

Photovoltaic production contributed to the decrease in electricity consumption from the grid. Graph 5 shows the average hourly interaction between electricity demand, PV generation and grid electricity consumption from 2023. Although peaks occur during morning (7-8h) and evening (19-20h) aligning with shift changes or production ramp-ups, and midday demand slightly dips, grid demand reductions during PV hours are visible and consistent, supporting the economic and environmental value of the solar installation.

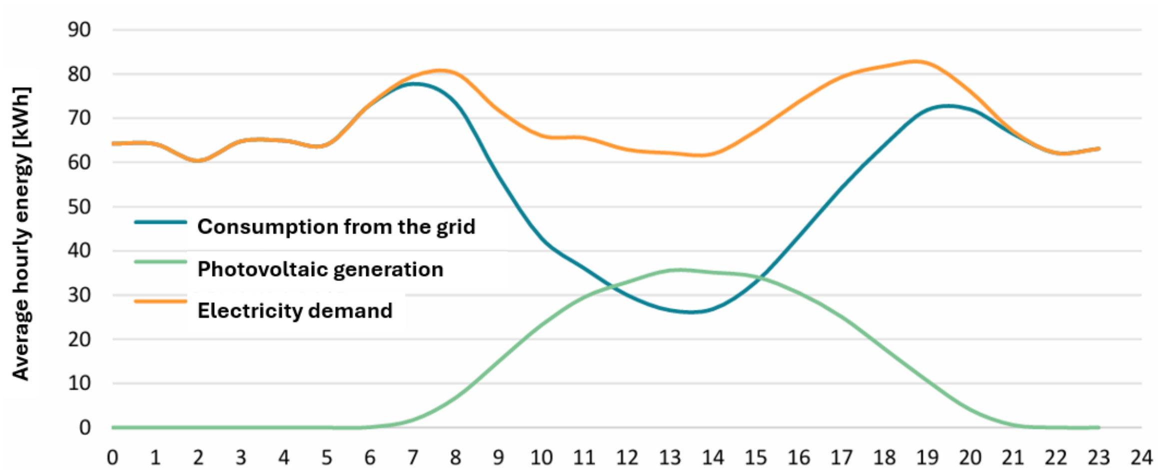


Figure 63: Average hourly consumption, generation and demand

There remains a substantial night-time base load, indicating room for efficiency gains, for example with battery storage to absorb excess midday generation.

The share of energy consumption by source can be seen in the following chart.

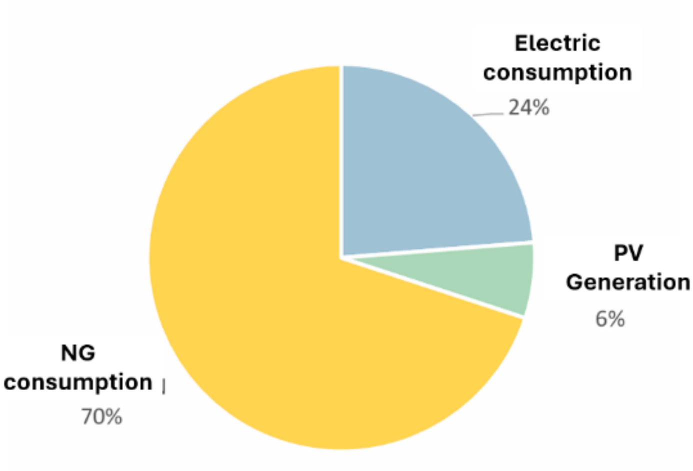


Figure 64: Distribution of energy consumption/generation by source

Consequently, based on the audit findings and associated data from the industrial facility, energy consumption patterns, performance and emission profile justify the development and implementation of a decarbonization action plan. Natural gas, which comprises Scope 1 emissions, represents the dominant share (70 %), primarily used for thermal processes via two boilers. Electricity accounts for the remaining 30 %, partially supplied by the 175 kWp rooftop photovoltaic system, which contributes to approximately 6 % of the site's needs and effectively reduces mid-day grid dependency.

Detailed hourly load profile indicates high night-time and weekend base load, suggesting significant consumption from equipment such as refrigeration units, compressors and battery chargers. In addition, there are limited energy management measures actively practiced with no advanced control or scheduling tools currently in place to avoid unnecessary consumption and optimize demand. Lastly, specific costs for electricity supply are volatile and have increased during the years under analysis.
Given the above, the need for a decarbonization action plan is both environmentally and economically justified.

In terms of the interaction between energy consumption and production, honey production, which is the main item produced in the factory, is what impacts energy demand the most, over other bee products (pollen, jam, etc). This influence can be observed in Graph 7.

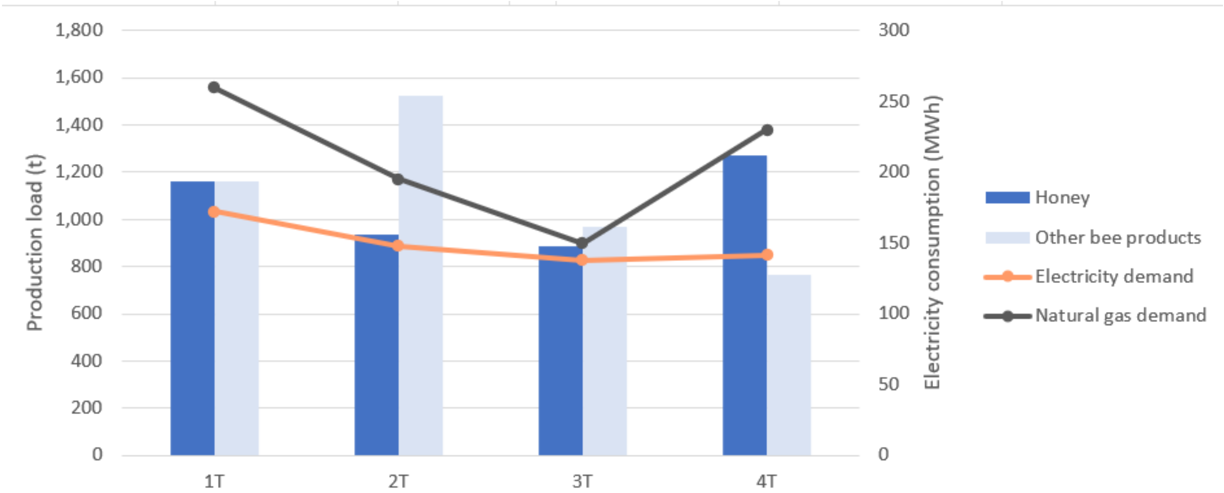


Figure 65: Production and energy demand

1.7. Emission inventory

For the present inventory, the following emission factors have been used for each energy carrier assessed:

Table 74: Emission factors

Energy carrier	Emission factor	U.M
Electricity	0.205	kgCO2/kWh
Natural gas	0.202	kgCO2/kWh

The emission inventory will be completed using Spain's Ministry for Ecological Transition *Carbon Footprint Calculator Tool for Organizations* (https://www.miteco.gob.es/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/calculadoras.html). This calculator allows for a simple estimation of greenhouse gas emissions associated with an organization's activities, including both direct emissions and indirect emissions from electricity consumption. It does not include the calculation of Scope 3 emissions.

Inserting the data related to the company's industrial activities, results are shown in Graph 8. The analysis extends to the years 2022 and 2023, as these are the latest years which complete yearly electricity and natural gas consumption data are available.

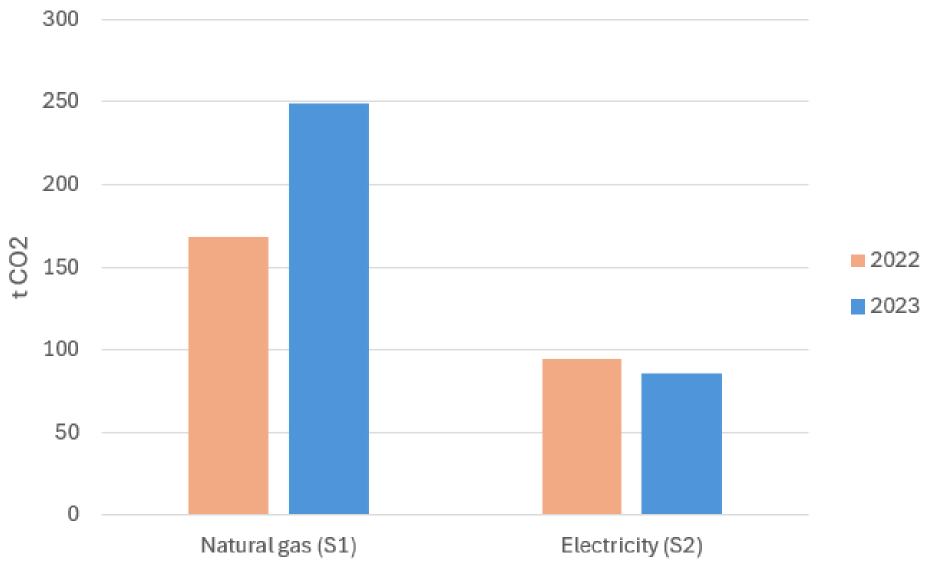


Figure 66: Emission profile (Scope 1 and 2) for 2022 and 2023

Natural gas use and therefore emissions coming from natural gas have notably increased from one year to another, while electricity has slightly decreased.

Furthermore, an additional annual 78 t CO_{2eq} are estimated to come from *fugitive emissions*. That is, emissions from air conditioning equipment present in the facility, which use refrigerant gases (mainly R-410A, HFC-32, HCFC-22) and occur during their use or during their maintenance.

1.8. Decarbonization action plan

Once all the data is analysed, the aim is to identify energy efficiency measures that can contribute to the overall sustainability of the company.
The proposed measures are detailed in Table 78. In each of them, there is a brief description of the implementation, the annual energy savings that would come after its implementation, as well as the associated reduction in CO_2 emissions. This information will later be further developed
They have been tailored to match the expectations of the company, their future plans and their current needs.

The annual economic savings are calculated according to equations 2 and 3, for natural gas and electricity consumption, respectively.

$$Annual\ economic\ savings\ (GN)\ [€] = Energy\ savings\ (GN)[kWh] \cdot 0.13\ \left[\frac{€}{kWh}\right]$$

Equation 2: Economic savings from energy efficiency measures targeting NG use reduction

$$Annual\ economic\ savings\ (elect.)\ [€] = Energy\ savings\ (elect.)[kWh] \cdot 0.3\ \left[\frac{€}{kWh}\right]$$

Equation 3: Economic savings from energy efficiency measures targeting electricity use reduction

Table 75: Energy Efficiency measures

Energy Efficiency Measure	Description	Savings
Stand-by consumption reduction	Based on the values obtained from the energy analyzers, the average power on non-working days is 22 kW, which should be minimized. Extrapolating to a year, non-productive consumption ends up being about 60.7 MWh. The measure proposes reducing this parasitic consumption by 50 %. It involves turning on timers, smart control systems and activating shutdown protocols. Investment: 0 €	30.3 MWh/year 6.21 tCO_2 /year 9,108 €/year
PV extension + storage system	Results obtained from the analysis of the PV generation indicate 21 % of annual excess generation, while only 20 % of total consumption is covered by the RES. This measure proposes extending the PV installation (additional 175 kWp) and including a storage system (500 kWh). Investment: 350,000 €	191 MWh/year 39.15 tCO_2/year 58,020 €/year Payback: 6 years
Hot water pipe insulation	Some process equipment requires hot water during operation, which is provided by a system of pipes running through the building, from the boiler room to each individual equipment. Estimating heat loss in 42.8 kW (considering pipe length, diameter, interior and exterior temperature, emissivity and Stefan-Boltzmann constant), around 237.8 MWh are wasted. Investment: 13,500 €	172 MWh/year 34.8 tCO_2/year 22,400 €/year Payback: 0.6 years
Replacing a NG steam boiler with an electric boiler + PV extension with storage system	Steam is essential in the production process of the company. To fulfill the decarbonization goals, it is proposed to replace one of the steam boilers (the oldest one, 565 kW) with an electric boiler (600 kW) and use it as the main one. In this sense, the new boiler will be powered by renewable energy obtained from an extension of the PV installation (an additional 425 kWp with 500 kW storage system). Note that electricity consumption will rise, but gas consumption will decrease. Investment: 42,000 € + 425,000 €	50.4 MWh/year (thermal) 80 tCO_2/year 58,894 €/year Payback: 30 years
Considering preheating of hot water needed during operation	NG consumption of the boiler is directly related to the temperature of the inlet water to be heated. This measure proposes to use the excess energy from PV installation from the previous measure to preheat the water used in the production process. Calculations are made considering a surplus of 100 MWh.	85 MWh/year 17.5 tCO_2/year 11,050 €/year

	Investment: 0 €	

Additionally, the following recommendations are presented to the company.

- Closely monitor energy consumption through EMS to detect any anomalies/peaks.
- Employee training in low-impact operational practices: efficient equipment use, smart shutdown protocols, etc.
- Demand-side management. Study whether demand can be shifted to off-peak hours or when PV surplus can be used.
- Conduct regular internal energy scans to identify areas for improvement. Establish channels to communicate detected inefficiencies.
- Replace any equipment that needs to be upgraded with one of high efficiency.
- Consider replacing the other gas boiler with an electric boiler.
- Consider reducing Scope 3 emissions. Examine the reception of raw material, distribution, logistics, etc.

The next step is to design a Decarbonization Action Plan. It is focused on the transition to low-carbon energy sources and enhancing energy efficiency within industrial processes, which account for most of the annual consumption and therefore emissions. Implementing sustainable industrial practices and fostering awareness about the climate situation and their impact on the planet.

The initial situation in 2023 establishes a baseline, a 'reference point', in which 334 tCO_2 are emitted (74 % Scope 1, 26 % tCO_2 Scope 2). An intermediate decarbonization target is set for 2030, and a long-term decarbonization is set for 2050.

The main challenge for this industry is to reduce emissions associated with Scope 2. The first goal sets a 24 % reduction as intermediate target emission level, with 253.84 t CO2eq remaining. This is the first milestone that will help the company to plan, do, check and act towards the final decarbonization goal. The final target emission level aims to reduce 48 % of emissions both from Scope 1 and 2.
The following graph shows the projected decrease according to the DAP.

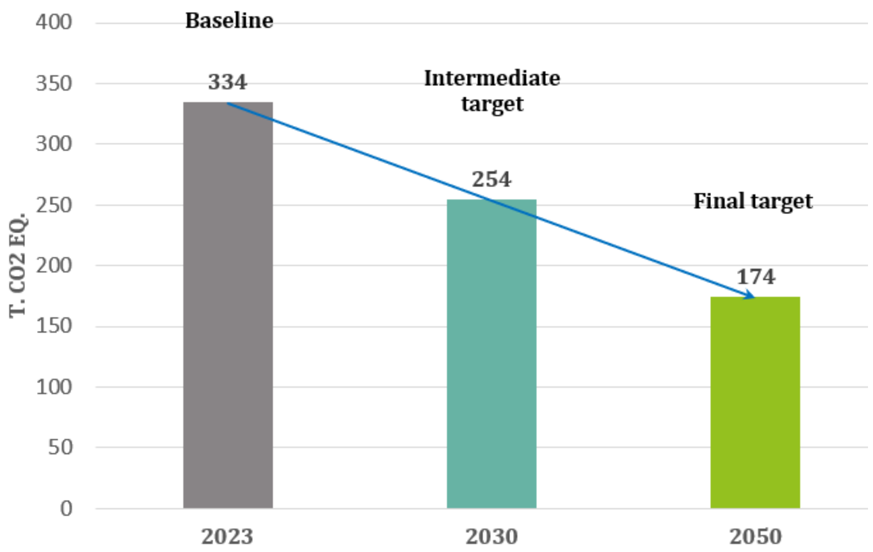


Figure 67: Decarbonization targets; short- and long-term

During the process, it is important to keep track of the progress being made. Energy management systems or an energy manager can help with this task, using indicators.

In order to drive the company's efforts towards reducing carbon emissions, it is also key to establish a decarbonization working group, with representatives from various departments to ensure that different areas of the company are working together to achieve the milestones on the plan. For this matter, strong and regular communication channels should be set up, and a sense of responsibility, willingness to learn and improve should be encouraged across the company.

The Roadmap includes EEM and additional recommendations for the company.

- Roadmap for DAP implementation

Table 76: Emission targets

Baseline year:	**2023**
Baseline emission level [tones of CO2 eq.]	334
Intermediate target year	2030
Intermediate target emission level [%]	- 24%
Intermediate target emission level [tones of CO2 eq.]	253.84
Final target year	2050
Final target emission level [%]	- 48%
Final target emission level [tones of CO2 eq.]	**173.84**

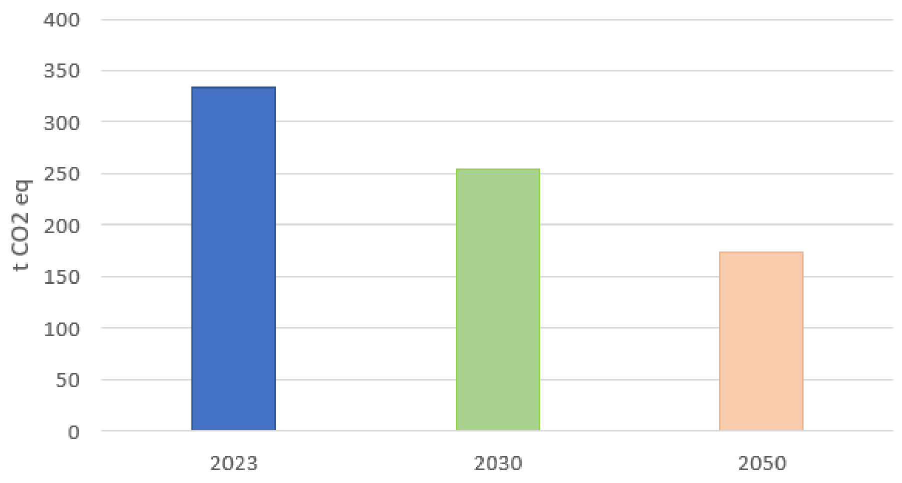


Figure 68: Decarbonisation progress

Figure 69: Decarbonisation targets

The Decarbonization Action Plan is developed by total investment required:

1. Stand-by consumption reduction
2. Hot water pipe insulation
3. Photovoltaic system extension + storage system
4. Preheating hot water using PV excess
5. Replacing NG steam boiler with electric boiler + PV extension with storage system

Measure #1 has null investment; so does #4, but it is dependent on #3.

However, focusing solely on decarbonization targets, the company should implement the measures in the following order:

1. Replacing NG steam boiler with electric boiler + PV extension with storage system
2. Photovoltaic system extension + storage system
3. Hot water pipe insulation
4. Preheating hot water using PV excess
5. Stand-by consumption reduction

Considering the strategic vision of the company and their needs, the audit team along with the energy manager of the company agreed on the first categorization being the most suitable for them.

Table 80 shows the proposed decarbonization measures, and Table 82, Table 83 and Table 84 in *7.Cost-benefit analysis / Financial analysis* will explore the investment requirements, annual savings and key financial indicators, such as NPV, IRR and payback period associated with each measure.

Table 77: Proposed decarbonization measures

#	Proposed measure	Lifetime (years)	Analysed period (years)	Description of the measure	Type of action	Addressed Scope	Alignment with other initiatives	Dependencies and/or constrains	Barriers and risk to be considerer
1	Stand-by consumption reduction	15	15	Reducing 50% non-productive consumption through programmable timers and smart control systems	Others	Scope 2	Compatible with ongoing digitalization efforts	Minor adjustments may be needed in operational practices	Lack of user engagement, potential need for additional sensors
2	Hot water pipe insulation	15	15	Application of high-efficiency insulation material to hot water circuits serving honey processing	Production processes performance	Scope 1	Aligns with the company's objective to improve process efficiency	Installation should be planned during maintenance shutdowns	Long-term degradation of insulation materials if improperly maintained
3	Photovoltaic system extension + storage system	15	15	Extend the PV installation by 175 kW and include storage system (500 kWh)	Energy Supply decarbonization	Scope 2	Available funding source in 2024 at national level	-	-
4	Preheating hot water using PV excess	15	15	Preheat incoming cold water using excess PV from measure #3	Production process performance	Scope 1	Complements pipe insulation and boiler electrification	Dependent on PV excess generation	-
5	Replacing NG steam boiler with electric boiler + PV extension with storage system	15	15	Electrification of one thermal generation unit to eliminate natural gas use, integrated with PV expansion to maximize self-consumption	Energy Supply decarbonization	Scope 1 & Scope 2	Aligned with decarbonization roadmap and Spain's national funding for industrial electrification in 2024	Requires reinforcement of electrical infrastructure	-

1.9. Multiple benefits analysis

Table 78: Multiple Benefit Matrix

MULTIBENEFITS	M1	M2	M3	M4	M5
Value proposition	2	2	6	3	5
New green products			High	Low	Medium
Intellectual property					
Competitive financial advantage	Medium	Medium	High	Medium	High
Performance	6	19	9	18	21
Workforce productivity		Medium		Medium	Medium
Increase production performance		Medium	Low	Medium	Medium
Improve equipment performance	Low	Medium	Low	Medium	Medium
Improve asset utilisation		Medium	Medium	Medium	High
Reduce malfunctions and/or lengthen equipment life (due to reduced wear and tear)	Medium	Medium		Medium	Medium
Reduce maintenance needs	Medium	Medium	Medium	Medium	Medium
Water footprint					
Improve staff safety or reduce injuries		Medium		Medium	Medium
Reduce raw material consumption					
Reduce waste o improve recycling					
Reduced waste heat		High		Low	High
Reduced CO2 and energy price risks	Low	Medium	High	High	High
Staff, customers and partners	2	2	17	5	15
Improve employee comfort (e.g. reducing noise, improving thermal comfort, better lighting, etc.)	Low	Low	Low	Low	Low
Improve employee satisfaction					
Improve employee health (e.g. thanks to air quality improvement of ambient air, improving workplace conditions, etc.)	Low	Low			Low
Improve customer service quality					
Improvev the share of green products/services			High	Medium	High
Attract new customers			Medium		Low
Improve customer satisfaction and loyalty			Medium		Low
Improve Supplier Environmental Sustainability Index			High		High
Improve stakeholder relationships			High		Medium
Regulatory compliance			High	Medium	High
Other					
Other					
Rating	10	23	32	26	41
MB Ranking	**5**	**4**	**2**	**3**	**1**

CONVENTIONAL BENEFITS	M1	M2	M3	M4	M5
CO2 reduction	Medium	High	High	Medium	High
Energy consumption reduction	Medium	Medium	High	Medium	Medium
Cost savings	Medium	High	High	Medium	High
Investment	Low	Medium	High	Low	High
Rating	6	7	7	6	6
CB Ranking	**3**	**1**	**1**	**3**	**3**

Final Ranking	**5**	**3**	**1**	**4**	**2**

Measures number 3 and 5 (PV system and replacing natural gas boiler, respectively) are the most impactful in terms of energy, CO2 emission and multiple benefit analysis. Also, they stand out in benefits regarding company image towards customers and investors, as they can be seen as a more sustainable industry. However, they are also the ones that require the greatest investment.

The final ranking is as follows:

#3 Photovoltaic system extension + storage system
#5 Replacing NG boiler with electric boiler + PV extension with storage system
#2 Hot water pipe insulation
#4 Preheating hot water using PV excess
#1 Stand-by reduction consumption

This multiple benefit analysis is presented to the company as part of the Energy Transition Audit. While this analysis highlights the broader long-term value of high-investment measures like the PV system and boiler replacements, the proposed implementation for the Decarbonization Action Plan has been prioritized based on investment cost, financial feasibility and progressive impact, ensuring the decarbonization roadmap remains realistic and sustainable. Implementing low or zero-investment measures first allows the organization to achieve quick wins in energy savings and emissions reduction without requiring upfront capital. This decision aligns with the company's budget for energy efficiency measures. However, in *8. Funding sources for energy efficiency and decarbonization*, several funding sources will be presented for the company to assess their budget allocation possibilities.

1.10. Cost-benefit analysis / Financial analysis

A detailed financial analysis was conducted for each decarbonization measure – key indicators (PP, NPV, IRR) show that measures 1 through 5 are all financially acceptable, with all Net Present Values positive and all Internal Rate of Return (IRR) greater than the discount rate. Moreover, measures with null or low investment present the best IRR, so they are the most attractive projects in this sense. Table 82, Table 83 and Table 84 include the results from the ETA Tool "*DAP_detailed"*.

#1 Stand-by reduction consumption
#2 Hot water pipe insulation
#3 Photovoltaic system extension + storage system
#4 Preheating hot water using PV excess
#5 Replacing NG boiler with electric boiler + PV extension with storage system

Table 79: Analysis of investment for EEM implementation

#	CAPEX (Euro)	OPEX (Euro)	Required investment (Euro)
1	-	-	-
2	13,500	-	13,500
3	350,000	5,000 eur/year	355,000
4	-	-	-
5	467,000	6,000 eur/year	473,000

Table 80: Analysis of savings derived from EEM implementation

#	Energy saving (MWh/year)	CO2 emission reduction (tons/year)	Cost saving (Euro/year)	Multiple benefits (Euro/year)
1	30.3	6.21	9,108	500
2	172	34.8	22,400	1,000
3	191	39.15	58,020	7,000
4	85	17.5	11,050	1,000
5	50.4	80	58,894	2,000

Note: below are the estimated quantified economic savings from multiple benefits.

#1 – Extended equipment lifespan and reduced maintenance (500 euro/year).
#2 – Reduced boiler load – longer boiler lifespan (1,000 euro/year from reduced maintenance).
#3 – Reduced grid dependence avoiding downtime costs (5,000 euro/year lost in production during outages) + storage used during high-tariff periods (2,000 euro/year).
#4 – Higher ROI on existing PV infrastructure, process stability (1,000 euro/year in maintenance).
#5 – Improved operational costs (2,000 euro/year) and preparing for future regulations.

The following indicators in Table 84 confirm the order of implementation for the decarbonization measures.

Table 81: Financial analysis of EEM implementation

#	Payback period (year)	IRR (%)	NPV (Euro)	Payback period with MB (year)	IRR with MB (%)	NPV with MB (Euro)	By Energy Savings (Euro/MWh)	By CO2 Reduction (Euro/tons)
1	-	-	94,537	-	-	99,728	3,120	15,223
2	0.6	-	220,000	0.57	-	229,384	1,279	6,321
3	6	12	200,329	5.38	15	272,988	1,049	5,117
4	-	-	115,000	-	-	125,074	1,352	6,571
5	30	7.4	82,021	29.7	8	102,780	1,627	1,025

Note: NPV with 5% discount, 15 years.

$$NPV = \sum_{t=1}^{v} \frac{NCF_t}{(1+i)^t} - C_0$$

1.11. Funding sources for energy efficiency and decarbonization

a. *Property tax rebates*

Both SMEs and large companies in Spain can claim a reduction in property tax (IBI) for the installation of solar panels for their business. Both the amount of money and the duration of the subsidy received depends on the municipality. On average, the deduction is 50 %. (https://sede.valencia.es/sede/registro/procedimiento/HA.BI.55?lang=1).

b. Construction Tax (ICIO) Deductions

Companies that undertake renewable energy or energy efficiency projects, particularly PV installations, can apply for up to 95% rebates on the ICIO (*Tax on Construction, Installations and Works)* – a local tax on construction work. This incentive significantly lowers the cost of structural and electrical upgrades. (https://sede.valencia.es/sede/registro/procedimiento/HA.CO.30?lang=1).

c. IVACE grants

The IVACE (*Valencian Institute for Business Competitiveness*) launches the *Aid for Energy Efficiency in SMEs and large companies in the industrial sector* in the Valencian Community, which includes grants targeting SMEs and industrial enterprises aiming to:

- Improve industrial processes and equipment
- Implement Energy Management Systems (EMS)
- Invest in renewable energy systems, electric boilers and storage technologies

The grants often cover 20-40% of eligible costs and are especially relevant for PV installations and storage systems, which align with the proposed measures for the company. The current grants can be consulted on the IVACE website: https://www.ivace.es/index.php/es/ayudas/ayudas-vigentes.

d. Recovery and Resilience Facility (RRF) – NextGenerationEU

Spain's PERTE (*Strategic Projects for Economic Recovery and Transformation*) channels EU funds into strategic decarbonization and digitalization of industry. They are directed to develop technology, industrial capacities and new business models that reinforce the country's position in the field of clean energy.

Companies can receive direct grants for:

- Renewable energy installations
- Electrification of thermal uses (replacing gas boilers for electric boilers)
- Energy storage systems
- Energy efficiency audits and management systems

Useful link: https://www.prtr.miteco.gob.es/es/perte/perte-de-energias-renovables-hidrogeno-renovable-y-almacenamiento.html.

e. National Energy Efficiency Fund – ERDF (EU)

This fund is managed by IDEA (*Institute for Energy Diversification and Saving*) and channels EU and national resources into energy efficiency, especially in the industrial sector. The types of action include:

- Electricity generation with renewable sources, highlighting the development of renewable power linked to storage and self-consumption applications.
- Thermal energy production

Useful link: https://www.idae.es/ayudas-y-financiacion/lineas-de-ayudas-la-inversion-en-renovables-fondos-feder.

f. LIFE Programme (EU)

This European programme co-finances innovative climate action projects that promote energy efficiency, decarbonization or circular economy solutions. Useful link: https://cinea.ec.europa.eu/programmes/life_en.

1.12. Decarbonisation Roadmap

Table 82: Decarbonization Roadmap

	2026	2030	2045	2050
Energy Supply		**Photovoltaic system extension + storage system**	**Replacing gas boiler with electric boiler + PV extension with storage system**	Consider replacing the other gas boiler with an electric boiler
Production Process	**Hot water pipe insulation**	**Preheating hot water using PV excess**		
Other	**Stand-by consumption reduction**	Demand-side management. Study whether demand can be shifted to off-peak hours or when PV surplus can be used	Replace any equipment that needs to be upgraded with one of high efficiency	Consider reducing Scope 3 emissions. Examine the reception of raw material, distribution, logistics, etc.
	Closely monitor energy consumption through EMS to detect any anomalies/peaks	Conduct regular internal energy scans to identify areas for improvement. Establish channels to communicate detected inefficiencies		
	Employee training on low-impact operational practices: efficient equipment use, smart shutdown protocols, etc.			

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