POLITECNICO DI MILANO

School of Industrial and Information Engineering

Department of Management, Economics and Industrial Engineering

Master of Science in Management Engineering

Master Thesis for Energy Management (ENM) course:

Implementation of Energy Management Systems according to UNI CEI EN ISO 50001 procedures: drivers, barriers, and benefits analysis with a real case study application

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to my family, my mentors, my friends and foes,

I would not be here without you

"Remember that all models are wrong; the practical question is how wrong do they have to be, to not be useful."

(George E.P. Box, *Empirical Model-Building and Response Surfaces*, p.74, 1987

Summary

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List of Acronyms and Symbols

EMS: Energy Management System

GHG: Green House Gas

SDG: Sustainable Development Goals

EU: European Union

IT: Italy

ISO: International Organization for Standardization

CEC: Collarini Energy Consulting s.r.l.

EN: European Normative

CEN: Comité Européen de Normalisation

CEI: Comitato Elettrotecnico Italiano

CTI: Comitato Termotecnico Italiano

UNI: Ente Italiano di Normazione

EnPI: Energy Performance Indicators

EnB: Energy Baselines

PDCA: Plan-Do-Check-Act

SEU: Significant Energy Uses

ATECO: Attività Economiche

ENEA: Ente per le Nuove tecnologie, per l'Energia e l'Ambiente

GRI: Global Reporting Initiative

CO_2: Carbon Dioxine

Kg: Kilograms

KW: KiloWatt

KWh: KiloWatt*hour

PET: Petrol Equivalent Tons

FIRE: Italian Federation for the Rational use of Energy

PBT: Payback time

NPV: Net Present Value

GSE: Gestore dei Sistemi Elettrici

DSO: Distribution System Operator

EEF: Energy Efficiency Titles

TSO: Transmission System Operator

DC: Direct Current

AC: Alternate Current

HV: High Voltage

MV: Medium Voltage

LV: Low Voltage

O&M: Operation and Maintenance

EFA: Energy Functional Area

ICT: Information and Communication Technologies

WIP: Work in Progress

COO: Chief Operations Officer

EMT: Energy Management Team

CHP: Combined Heat and Power

HLS: High Level Structure

PI: Probability-Impact

EM: Energy management

BREF: Baseline Reference

PBT: Pay Back Time

NPV: Net present value

IRR: Internal rate of return

SME: Small medium enterprise

EME: Energy Management Expert

KSF: Key Success Factor

Abstract

The thesis aims to demonstrate which are the main drivers, barriers and benefits given by an effective implementation of an Energy Management System (EMS), according to the UNI CEI EN ISO 50001 (2018) procedures.

The thesis presents a brief introduction on the importance of the topic energy efficiency, both from an operational and strategic point of view, which justifies the motivation of the thesis.

In Chapter 1, the thesis shows which guidelines to follow in order to achieve ISO 50001 certification by correctly implementing an EMS, according to a PDCA cycle that aims at continuous improvement of energy performance.

In the "Planning" phase, the organisation must indicate the energy context, the energy management team, the energy policy with its objectives, energy risks and opportunities, but it also provides an initial energy picture of the organisation through an energy analysis.

In Chapter 3, a real case study of the implementation of an EMS according to UNI CEI EN ISO 50001 procedures is presented. Thanks to the energy analysis and the comparison in the "Check" phase with the monitoring data, it is possible to identify the areas that have energy efficiency intervention priorities, marked as "Significant Uses of Energy" (SEU).

In the final “Act” stage, top management analyses the results of the previous stages and defines priorities for action to ensure continuous improvement of the energy performance.

In Chapter 2, an analysis of drivers, barriers and benefits is presented, putting together the results of a questionnaire on ISO 50001 and other data collected by scholars on the subject.

This analysis is taken up in Chapter 4, while presented to the top management of the case study. Therefore, in Chapter 4, the results of a survey sent to CEC s.r.l.'s client companies are presented. The energy consultant has an energy management role for these clients.

The same role that CEC s.r.l. has for SKI s.r.l. in the real case that led the organisation to become ISO 50001 certified in 2021.

The survey analyses the same drivers, barriers and benefits considered in Chapter 2.

These results are compared with those of the questionnaire previously presented, to which data from the FIRE report (2021), which analysed the state of SGE implementation in Italy and ISO 50001 certification, and those of the real case study are added.

Both Chapter 4 and the conclusions show the results of this survey.

Estratto

La tesi ha l'obiettivo di dimostrare quali sono i principali driver, barriere e benefici dati da un efficace implementazione di un Sistema di Gestione dell'Energia (SGE), secondo le procedure UNI CEI EN ISO 50001 (2018).

La tesi presenta una breve introduzione sull'importanza del tema efficienza energetica, sia dal punto di vista operativo che strategico, che giustifica la motivazione della tesi.

Nel capitolo 1, la tesi mostra quali sono le linee guida da seguire al fine di conseguire la certificazione ISO 50001 implementando correttamente un SGE, secondo un ciclo PDCA che mira al miglioramento continuo della prestazione energetica.

Nella fase di "Pianificazione", l'organizzazione deve indicare quali sono il contesto energetico, il team di gestione dell'energia, la policy energetica con i suoi obiettivi, i rischi e le opportunità energetiche, ma anche fornire un primo quadro energetico dell'organizzazione grazie ad una analisi energetica.

Come si vedrà nel capitolo 3, in cui è presentato un caso reale di studio di implementazione di un SGE secondo le procedure UNI CEI EN ISO 50001, grazie a tale analisi e al confronto nella fase di "Verifica" con i dati di monitoraggio, è possibile identificare le aree che presentano priorità di intervento di efficientamento energetico, segnalati come "Usi Significativi dell'Energia" (USE). Nell'ultima fase di "Azione", il top management analizza i risultati delle fasi precedenti definendo le priorità di intervento per garantire il miglioramento continuo della prestazione energetica.

Nel capitolo 2 è presentata una analisi di driver, barriere e benefici, collezionando i risultati di un questionario sulla ISO 50001 e altri dati raccolti da studiosi del tema.

Tale analisi viene ripresa nel capitolo 4, oltre che presentata al top management del caso di studio. Pertanto nel capitolo 4 vengono illustrati i risultati di un questionario, presentato alle aziende clienti della CEC s.r.l., che ha seguito come energy manager la SKI s.r.l. nel caso reale che ha portato l'organizzazione a certificarsi ISO 50001 nel 2021.

Tale questionario riprende gli stessi driver, barriere e benefici considerati nel capitolo 2.

Tali risultati vengono confrontati con i medesimi del questionario precedentemente presentato, ai quali vengono aggiunti i dati da report della FIRE (2021), che ha analizzato lo stato di implementazione dei SGE in Italia e delle certificazioni ISO 50001, e quelli del caso reale di studio.

Sia il capitolo 4 che le conclusioni mostrano i risultati di tale indagine.

Introduction

Manufacturing companies must improve their production processes to increase industrial plants' energy efficiency, especially for those with high-energy consumption.
There are two main reasons behind such a call to action: reduction of greenhouse gas (GHG) emissions [1] and energy price increase. [2]

Drivers for energy efficiency

The Green Deal signed in 2019 enhances several actions at the European level to reduce GHG emissions to reduce climate change. In particular, the Commission redefined the net-zero carbon emissions target for 2050. An impact assessment plan is still in development, in order to reduce gas emissions in 2030 to at least 50% and towards 55% compared with 1990 levels. Further targets are going to be defined for 2030-2050 for energy production and use since they are responsible for at least 75% of GHG emissions. [1]
In addition, by implementing energy efficiency measures, companies are contributing to some Sustainable Development Goals. More specifically, they are tackling Goal 12 (ensure sustainable consumption and production patterns) and Goal 13 (take urgent action to combat climate change and its impacts). [3]
The energy price increase is another driver calling for energy efficiency.
For the thesis purposes, we are considering electricity and natural gas retail prices, because they are the most used energy sources for industrial consumers.
In 2021, the average price for natural gas in Europe increased up to 48 €/MWh, compared to 10 €/MWh in 2020 (decreased compared to 15 €/MWh in 2019, due to COVID).
The electricity market in 2021 registered an increase of more than 200% compared to 2020 and more than 100% in 2019.
Spain, France and Germany registered 111,93 €/MWh, 109,17 €/MWh and 96,85 €/MWh, respectively. In Italy, the electricity spot market accounted for an average price of 125,46 €/MWh (38,92 €/MWh in 2020; 52,32 €/MWh in 2019).
Italian highest daily price was reached on 22 December 2021, with 184 €/MWh for natural gas and 438 €/MWh for electricity. Thanks to national policies, prices have been lowered in January 2022 up to 87 €/MWh for natural gas and 225 €/MWh for electric energy. [2]

ISO 14001 and ISO 50001

The International Organization for Standardization (ISO) develops standards on a worldwide basis that are process-oriented. In fact, they help organizations ensure compliance with industry or regulatory limits, establishing management system guidelines and procedures, without imposing any goals or thresholds. [4]

Considering previous assumptions regarding energy trends, the thesis is showing the opportunities, challenges, benefits, and savings related to the adoption of an Energy Management System (EMS), according to "UNI CEI EN ISO 50001 – Energy Management Systems: requirements with guidance for use" (2018) [5]

In order to analyse the effects of its adoption, it is also necessary to evaluate the contribution of an important antecedent of energy and environmental international guidance: "ISO 140001 - Environmental Management Systems: specification with guidance for use" (1996).

The aim of this ISO is to declare the Carbon Footprint of the company, by following some procedures to track them. Then each adopter should try to reduce them with energy efficiency measures and environmental management procedures, aimed to reduce GHG emissions in industrial processes, transportation, and other business-related activities. [4]

According to the results of Carbon Footprint standards (ISO 14001) applications, there are some environmental benefits related to emissions management that are in line with ISO 50001 purposes, making its study relevant for the thesis.

From an empirical point of view, Bansal and Roth (2000) suggested three clusters of motives that lead companies to ISO 140001 standards: legitimation, competitiveness, and ecological responsibility. [6] Neumayer and Perkins (2005) mention other two motivations: an internal one related to efficiency, and an external one related to social pressures in adopting eco-friendly practices. [7]

GHG emission saving is the main benefit for the environment.

Operational benefits can be proven too, in terms of cycle time, efficiency, flexibility, cost, plant safety, product innovation, quality and performance, process optimization, quality assurance, defects reduction, and overall productivity increase. [8]

Another study developed by Chavan (2005) showed that ISO 14001 adoption lead companies to improve both their environmental performance and their business efficiency.

Environmental performance improvement is achievable by minimizing environmental liabilities, reducing waste, creating awareness in employees about environmental issues, and gaining more consciousness of company activities' impact.

Other benefits of Carbon Footprint measures leading to higher business efficiency are better corporate image, maximization of efficient use of resources, and increased profits thanks to more efficient operations. [9] Seen ISO 14001 results, other management standards dealing with other energy and environmental aspects have been developed: the ISO 14064 (2012) standard for quantification and reporting of greenhouse gases, the ISO 14006 (2020) standard for eco-design and the ISO 14031 (2021) standard for environmental performance evaluation.
Good results are expected also with ISO 50001 implementation, regarding EMS benefits, especially when the maturity model is quantitatively managed or optimized, according to Jovanovic and Filipovic (2015). [10]
As stated by Amundsen (2000), integration of EMS gives good results for energy conservation measures, securing also continuous improvements. [11]
Since it has applicability in several economic sectors, Marimon (2017) estimated that the standard could influence up to 60% of the world's energy use. [12]

Thesis motivation

The thesis initially explains the UNI CEI EN ISO 50001 procedures to implement efficiently an Energy Management System.
After this explanation, an analysis of drivers, barriers and benefits of adoption is taken from other studies regarding UNI CEI EN ISO 50001 procedures.
Then, thanks to Collarini Energy Consulting s.r.l. (CEC) know-how on energy management and its knowledge on EMS topics, the thesis is presenting a real business case of EMS implementation and certification achievement.
By analysing drivers, barriers and benefits perceived by some CEC's clients certified UNI CEI EN ISO 50001, results of such questionnaire are compared with other studies illustrated before, using them as benchmark.
On one side, the thesis aims at illustrating how the certification and the related procedures are implemented in a real case, showing some drivers, barriers and benefits.
Then, by putting together the results of the case study and the questionnaire ones, the thesis aims at showing the importance of achieving such certification and implementing an Energy Management System.

1. UNI CEI EN ISO 50001 – Energy Management Systems: requirements with guidance for use

The European Normative (EN) on Energy Management system ISO 50001 has been published in 2011, but the last version have been released by the “Comité Européen de Normalisation” (CEN) in 2018.
After being analysed and adapted to the Italian context by the “Comitato Elettrotecnico Italiano” (CEI) and by the “Centro Termotecnico Italiano” (CTI), it has been ratified by the “Ente Italiano di Normazione” (UNI), gaining the official status of a national norm: “UNI CEI EN ISO 50001 – Energy Management Systems: requirements with guidance for use”.
Each organization can adopt EMS following UNI CEI EN ISO 50001 procedure.
There are no restrictions or obligations, it is a certification that ensure commitment to energy efficiency topics. Companies from any sector can commit to gain this certification.

The whole content of this chapter is taken directly from the official Italian normative. [5]. Everything that is going to be mentioned, will be referenced with the section related (e.g.: (Sec. 0.1.))

1.1. Introduction to UNI CEI EN ISO 50001

The normative has the goal to support companies in defining systems and processes that are necessary to improve their energy performance in a continuous way.
It requires working on energy efficiency, energy use and energy consumption, therefore it is necessary to define requirements and specifications about an EMS adoption.
The main goal of the ISO is to specify requirements to establish, apply, maintain and improve an EMS. (Sec. 0.1). UNI CEI EN ISO 50001 is adoptable in combination with other ISOs, if normative requirements are respected, as if for all other ISOs. (Sec. 0.4)
The expected results should allow companies to follow a systemic approach to foster continuous improvement of both energy performance and EMS itself. (Sec. 0.2)
As mentioned in the official document, the success in the implementation of an EMS foster a continuous improvement culture inside the organization. Very good results are

achievable only if there is a commitment on all organizational levels, which could require changes in the company culture and operations. (Sec. 0.1)
EMSs manage activities that are controllable internally: planning, supply and control of plants, tools, systems, or processes inside the organization that consumes energy.
The development of an efficient EMS has to include an energy policy, objectives, energy goals and an action plan about energy efficiency, energy use and energy consumption.
Once defined the direction to focus on, the EMS would allow taking all the necessary actions to improve the company's energy performance, demonstrating conformity to the UNI CEI EN ISO 50001, if well implemented. (Sec. 0.1)
It has to be a systematic process, based on data and facts and focused on continuous improvement of energy performance: only in this way, results are measurable and effective. By defining some Energy Performance Indicators (EnPI) and some Energy Baselines (EnB), it is possible to show improvements in energy performance, use, and consumption. (Sec. 0.2)

1.1.1. PDCA methodology

The EMS described in the normative considers a Plan-Do-Check-Act (PDCA) cycle (also known as Deming cycle), focused on energy management inside the company. (Sec. 0.3)
The PDCA cycle has to be applied inside an energy application field, internal to the organization, even if could be influenced both by the opinion of relevant stakeholders and the impact of external or internal factors or drivers.
Relevant stakeholders could influence the activities of the company, which therefore should be in line with their expectations, also from an energy management point of view.
Internal factors are mainly due to managerial decisions like product innovation, changes in logistics and operations, changes in roles and responsibilities… etc., thus every endogenous factor related to the management of the company that can influence the efficiency of the plant and its energy management.
External factors could be an increase in energy prices, an increase in prices of raw materials, or a fall in market shares… etc., thus every exogenous factor that could have an impact on the company value chain, which could ultimately reflect on the energy profile of the company.
Focusing on the PDCA cycle, the UNI CEI EN ISO 50001 defines the four phases of the loop. (Sec. 0.3)

“Planning” is about:

- Understanding the organizational context;
- Establishing an energy policy and an energy management team;
- Taking into account risk and opportunities defining actions to react;
- Conducting an energy audit and an energy assessment (phases of an energy analysis);
- Identifying Significant Energy Uses (SEU);
- Defining EnPI and EnB;
- Defining energy objectives and goals, with the action plans related;

Before moving to the “Do” phase, the company should verify that needs and expectations of relevant stakeholders are accomplished, without creating issues in the energy management plan.

“Doing” is about supporting the energy management plan and doing operating activities by:

- Actuating action plans, operative and maintenance checks;
- Communicating actions properly;
- Ensuring competences;
- Considering energy performance in planning and supply of energy activities.

After the “Do” phase, expected results of the EMS should be estimated.

“Checking” is about evaluating the EMS performance:

- Monitoring consumption profiles and energy performance;
- Measuring, analysing and evaluating data of energy performance;
- Conducting energy audits;
- Re-examining energy performance measures and EMS implemented.

Once the “Check” phase is over, expected results of the EMS should be compared with the ones measured during the phase.

“Acting” is about improving the EMS and the energy performance by:

- Taking actions to overcome non-conformity results;
- Continuously improving energy performance and EMS.

Before moving again to the “Plan” phase and re-start the PDCA cycle, the company should consider other internal and external factors or drivers that can influence the EMS. (Sec. 0.3)

To let the PDCA work efficiently for the EMS to improve energy performance, a strong leadership act has to be kept for the whole cycle duration. This is due to the need of changing the company's culture to be successful. An energy management team has to be defined, as well as some leaders to report to the top management and be responsible for results. (Sec. 0.1)

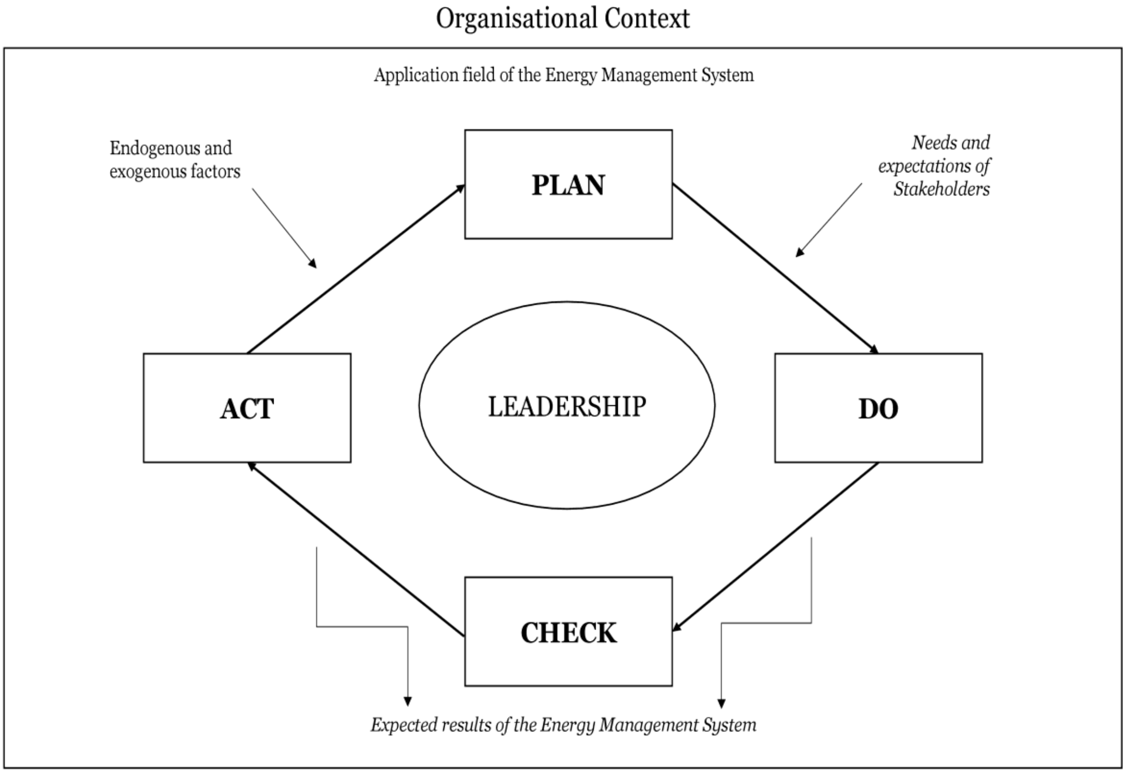

Figure 1 - PDCA methodology according to ISO 50001 procedures

An efficient application of the Deming cycle about energy performance and EMS is strongly beneficial for the adopting company.
This systemic approach for energy management changes the way organizations manage energy. Integrating such measures inside the company routines, they could establish an effective continuous improvement of energy performance.
Energy performance would improve, as well as energy costs reduced, allowing companies to be more competitive.
Furthermore, the application of such measures is giving positive contribution to international objectives, like climate change mitigation and GHG emissions reduction. (Sec. 0.5)

Since the topics mentioned in this introduction will be all taken into account in the business case, the thesis now is focusing on the different components of the UNI CEI EN ISO 50001, analysing them deeply.

1.2. The organizational context

UNI CEI EN ISO 50001 states that the company has firstly to understand the organization and its context. In particular, it has to identify the relevant internal and external aspects influencing the expected results of its EMS, which can also interfere with the energy performance improvement. (Sec. 4.1)

Another important step is to understand the needs and expectations of stakeholders, by defining:

- Relevant stakeholders for energy performance and EMS;
- The requirements that stakeholders identify as relevant;
- Needs and expectations of relevant stakeholders to accomplish by adopting an EMS.

The organisation has also to be compliant with the law and with the other requirements related to energy efficiency, energy use and energy consumption, declaring how they will be accomplished. After that, the company should grant that these requirements are truly considered, re-examining them periodically to understand which are not. (Sec. 4.2)

It is necessary to define the application field of the EMS. Therefore, the limits and the applicability area of the EMS has to be declared in order to determine the application field, taking also into account both internal and external aspect and relevant stakeholders' needs and expectations.

Of course, the organization must have permission to control his own energy efficiency, use and consumption internally, without excluding any kind of energy used in the application field designed. Once determined, the application field has to maintained as it is, providing information and communicating them properly, as analysed in Sec. 7.5. (Sec. 4.3)

The last step to define the organizational context regards establishing, applying, maintaining, and continuously improving the EMS, evaluating not only the model itself but also all the necessary processes to be done and the interactions generated from the cascade of implementation steps, always ensuring coherency and conformity to the UNI CEI EN ISO 50001 requirements.

Certainly, processes and interactions will change according to the dimension of the company, its activities, processes, products, and services; but also according to the complexity of processes and their interactions and according to the employees' competencies. (Sec. 4.4)

1.3. Leadership

This section of the UNI CEI EN ISO 50001 focuses on the importance of leadership in the implementation of an EMS. In particular, it deals with three different aspects: commitment, energy policy, and roles and responsibilities. (Sec. 5)

1.3.1. Leadership and commitment

The first important step has to be done by the top management: they must show leadership and commitment on continuous improvement of the energy performance and of the EMS.
This implies to ensure that application fields and limits of the EMS are well defined, that the energy policy with energy objectives and goals are clear and that they are coherent with the top management business strategy. Commitment has to be shown also by approving and applying action plans, ensuring availability of the needed resources to implement the EMS, also by communicating to the employees the importance of an effective energy management.
The top management has also to verify that expected results of the EMS are reached, promoting continuous improvement too.
It also has to nominee an energy management team in charge of energy performance and EMS, training these resources and declaring one or more responsible for the output. The energy management team has to be guided and supported by the top management, to achieve commitment in making the EMS effective. Energy responsible have to be supported too, especially to enhance leadership in energy management activities, showing how to apply it in the different responsibility areas.
Last important step about commitment regards energy performance: EnPI must reflect properly the energy performance of the company, while processes to identify changes in EMS has to be put in place and verified. (Sec. 5.1)

1.3.2. Energy policy

The top management has also to identify a proper energy policy for the company. (Sec.5.2)
It has to:

- Be coherent with company's strategic goals;
- Be a reference for energy goals' definition and revision;
- Grant information and resources availability to reach the fore mentioned energy objectives;
- Satisfy legal requirements on energy efficiency, use and consumption;
- Be focused on continuous improvement;
- Include supply of products and services that are energetically efficient, with a positive impact on energy performance.
- Support planning activities regarding energy performance improvement (PDCA: Plan)

The energy policy must also be available for all stakeholders, in the sense that information must be documented and shared among the organisation members, therefore it has to be communicated in the right way to create commitment and updated after feedbacks or results (if needed). (Sec. 5.2)

1.3.3. Roles, responsibilities and authorities inside the organization

The top management is the authority that assigns roles and responsibilities for the energy management team, ensuring that they are well assigned and communicated inside the organization. The energy team has to establish the EMS and to put it in place. Then, after the end of the PDCA, it has to be maintained and continuously improved, always granting conformity to the UNI CEI EN ISO 50001.
The energy team has also to put in practice the energy plan, in a continuous improvement logic, establishing criterion and methods that are necessary to ensure an effective functioning and controlling of the EMS.
Energy and EMS performance must be reported periodically to the top management. (Sec. 5.3)
There are no strict rules about how many energy responsible to identify or how to develop the energy team. There are no restrictions on how many people involve and in which roles, especially concerning how they should coordinate and collaborate. This is due to the diversity of businesses that can adopt the UNI CEI EN ISO 50001 and to the diversity of management styles.

1.4. PDCA: Plan

The “Plan” phase of the PDCA methodology divides in two main clusters of activities: Planning and Support.

Regarding the “Planning”, it has four main steps: (Sec.6)

1. Defining energy goals and facing risks and opportunities;
2. Conducting an energy analysis;
3. Defining EnPI and EnB;
4. Planning energy data collection according to SUE.

The “Support” activities distinguishes between: (Sec. 7)

1. Resources and competences
2. Awareness and communication
3. Documentation

1.4.1. Planning: energy goals and risks & opportunities

Planning of the energy policy and the activities related (Sec. 6.1), must be coherent to the internal and external factors influencing the energy performance, according to expectations and needs of relevant stakeholders (Sec. 4.1 and 4.2).

The organisation trying to certificate ISO 50001 has to determine risks and opportunities related to the energy performance of the organisation itself, by adopting and EMS and by modifying the energy structure of its business models.

Risks and opportunities should be identified in order to: (Sec. 6.1.1)

- Grant that the EMS can reach the expected results (energy performance continuous improvement included);
- Prevent or reduce the unexpected effects and other externalities;
- Obtain continuous improvement of the EMS and of the energy performance.

The company has to plan actions to face these risks and opportunities, reducing the first and exploiting the second ones.

It has also to identify in which way it can integrate and apply the EMS inside the business model of the company, increasing the energy performance and evaluating the effectiveness of the energy actions planned. (Sec. 6.1.2)

After identifying risks and opportunities related to the EMS adoption, the organisation must define energy goals at different levels, declaring the different functions involved and their sub-goals. (Sec. 6.2.1)

Energy goals must be measurable and coherent with the energy policy (Sec. 5.2), it must consider all the requirements, the SEU (Sec. 6.3), and energy opportunities to improve the energy performance (Sec. 6.3). Also, they must be monitored, communicated and updated properly, keeping track energy goals and objectives in appropriate documentation to be shared too. (Sec. 6.2.2)

While planning energy goals and objectives, the organisation has to define some action plans to maintain over time, declaring:

- What has to be done;
- When it is expected to be completed;
- Which resources are necessary;
- Who is responsible for the specific activity;
- How results are evaluated, including the methods used to verify an effective improvement of the energy performance.

All activities included in the action plan must be coherent with the business model of the company, especially to its operational processes (day-by-day activities).

These activities have to be tracked in some documentation (Sec. 7.5) in order to be formalized and then shared among employees. (Sec. 6.2.3)

1.4.2. Planning: energy analysis

The company adopting ISO 50001 standards has to develop and conduct an energy analysis. It can de done fully internally or partially externally, by getting help of an external energy auditor (as CEC does in the business case). (Sec. 6.3)

To develop a proper energy analysis, it is necessary to analyse uses of energy and the related consumption on the basis of measurements and other energy data, identifying the current uses of energy (Sec. 3.5.1.) and evaluating past and present energy uses and consumption.

Starting from the results of the energy analysis, the organisation has to understand which are SEU. (Sec. 3.5.6.)

For each SEU it is necessary to:

- Determine the pertinent variables (those influencing directly the energy performance; e.g. t of output produced per year);
- Define the static factors (those that influence the production rate, but that are usually constant; e.g. kg of raw material / kg of product)
- Determine the actual energy performance;
- Identify people in charge of the activities in which a SEU is present, including the influence and effects that employees can provoke regarding SEU.

It is also important to determine and give priority to the opportunities related to continuous improvement of energy performance, and it is beneficial to estimate future energy uses and consumption.

The energy analysis has to be frequently updated; the frequency is decided by the company itself (usually it is done each year).

By doing so, it is possible to keep track of important changes in plants, tools, systems and processes. In this way, the organisation establish methods and criterions to develop the energy analysis, that should be documented as well, becoming an energy management know-how. (Sec. 6.3)

1.4.3. Planning: EnPI and EnB

The organisation trying to certificate ISO 50001 has to determine its EnPI, which can vary according to the industry (ATECO code in Italy) and the specific company processes.

EnPI should reflect energy performance of the company, being measurable and allowing its monitoring; they should be a measure to evaluate and show the improvement of the energy performance itself.

Data allowing EnPI calculations must be documented, especially regarding the pertinent variables influencing significantly the energy performance. Starting from these data, EnPI are defined.

The value of each EnPI has to be benchmarked with the corresponding EnB, as declared by ENEA (Ente per le Nuove tecnologie, per l’Energia e per l’Ambiente), according to the ATECO code reflecting company business structure.

EnB has to be identified correctly, in order to make the benchmarking reasonable. This is done using the information obtained with the energy analysis, considering a meaningful period (usually one year) in which the same EnPI are re-evaluated after an improvement.
If the mentioned pertinent variables are not in line with the unit of measures present in the corresponding baseline, the EnPI has to be normalized or converted, according to the different unit of measure (e.g. EnPI in kWh/kg, while EnB in TEP/t).
EnB has to be revised and eventually changed, if one or more of these situations occur:

- EnB are no more reflecting the energy performance of the company (business model has changed);
- There are significant changes in the static factors (usually occurs only if business model changes);
- Methods for EnPI calculations are pre-determined (according to industry standards), while the EnB considers different variables.

The organisations has to keep information about EnB references, as well as it must document every modifications both in the pertinent variables (therefore in the EnPI calculations) and in the EnB. (Sec. 6.5)

1.4.4. Planning: energy data collection and SEU

The company has to ensure that the key characteristics of its operations influencing the energy performance are identified, measured, monitored and analysed in defined periods. (usually monthly and yearly). (Sec. 6.6)
In order to do that, it has to define and apply a plan for energy data collection adequate to its dimension and complexity, according to its resources and its monitoring tools.
The collection plan has to specify the data necessary for evaluating the energy performance, indicating also the frequency of collection.
Data to be collected must include:

- Pertinent variables for SEU;
- Energy consumption related to both SEU and the whole company;
- Operative criteria related to SEU (data about processes);
- Static factors;
- All other data sources declared in the action plans.

Of course, any variation in the collection plan (e.g. different data to be collected) has to be properly updated, documented and finally communicated.
The company must also ensure that tools for data collection are measuring them in an accurate way, keeping documentation also about how monitoring system works (how and which data collects; e.g. level of aggregation of data). (Sec. 6.6)

1.4.5. Support: resources and competences

Resources that are necessary to define, adopt and maintain and EMS has to be defined, since they contribute to the continuous improvement of the energy performance. (sec. 7.1)
In order to decide which resources to be allocated to the EMS, key competences has to be defined, and then, according to the resources available, they should met these skills requirements.
Therefore, the organisation has to: (Sec. 7.2)

- Determine the competences that the resource must have to positively influence the energy performance and the EMS management;
- Ensure that these resources are well trained and capable to understand energy topics;
- Create know-how to establish the necessary competences inside the organisation (training for resources);
- Keep information about competences required, allocated resources and training sessions, as a proof of competence presence inside the organisation.

1.4.6. Support: awareness and communication

People belonging to the organisation (employees, managers and other stakeholders) must be aware of the energy policy (sec. 5.2) applied inside the company.
They must know how they contribute to the energy performance of the company and on the correct utilisation of the EMS.
By doing so, they must be aware of which data to control and how to behave: they should be aware of the impact of their activities.
Therefore, they must know how they contribute on the EMS effectiveness, included benefits of a better energy performance and energy goals achievement (sec. 5.2).

Awareness should also include implications regarding non-conformity of the EMS, especially about which behaviours are leading to non-conformity (that would prevent the certification achievement). (Sec. 7.3)

Both internal and external communication about EMS is important.

The company has to define what to communicate, when, how, who is in charge of communication and the addressers of it.

When establishing a communication process, the organisation has be sure that all the relevant information are coherent with the ones extrapolated by the EMS, ensuring trustworthiness of data.

Each person contributing to the energy performance should inform and suggest the top management advices for improving EMS and energy performance.

Each documentation involved in the communication process has to be stored in some database. (Sec. 7.4)

1.4.7. Support: documentation

As mentioned in previous paragraph, each information regarding the EMS must be documented and available for every stakeholder. (Sec. 7.5)

Each step of the PDCA has to be reported to the top management and communicated to the whole company, especially the ones directly involving some personnel (identified as key resource for that energy activity).

Every other information regarding the EMS that is not mentioned in the UNI CEI EN ISO 50001, has to be reported as well, if useful for EMS effectiveness.

The level of detail of information varies according to the dimension of the organisation, its complexity, it kind of activities, processes, products and services… as well as according to the employees training level, their competences and the level of interactions among employees and with the EMS. (Sec. 7.5.1)

When creating any informational document they should define some “documental standards” that has to be maintained. Thus, coherence of information occurs if some updates of documentation are applied.

Documental standards regards description of the document (title, data, author, ID number), its format (language, graphics, software) and its type (paper based or digital).

While defining these document or during update, it is necessary an approval from the top management, to grant conformity and adequacy of documentation. (sec 7.5.2)

All information requested by the UNI CEI EN ISO 50001, or any other regarding the EMS not mentioned in the normative, has to be checked periodically.

This to ensure that they are always available and ready to use and to protect them properly (to ensure privacy of data and integrity).

Thus, the organisation is in charge of:

- Distribution, access, availability and utilisation of information;
- Archiving and conservation of information (including readability);
- Checking modification (updating);
- Memorization of new versions and eliminations of old ones.

External information that influence planning and working of the EMS has to be properly formalized and kept as well. (Sec. 7.5.3)

1.5. PDCA: Do

The “Do” phase of the PDCA cycle regarding EMS deals with operating activities, according to UNI CEI EN ISO 50001.

This phase is divided into two main activities:

1. Planning execution and operative control
2. Design and supply

1.5.1. Planning execution and operative control

The organisation has to create a planning & control cycle related to its processes, especially for the ones identified as USE.

At first, the company has to establish the criteria to evaluate energy performance of its processes. This allows doing a gap analysis after the monitoring phase, comparing expected and real energy performance. The organisation itself (or its energy auditor) freely decide the criteria to label a gap in energy use as significant. These criteria should include both the working of machinery and maintenance of plants, tools and any other system or process consuming energy.

People operating or responsible for that use must be properly informed.

After planning how to do an evaluation of energy uses, such criteria are used in the control phase to conduct a gap analysis.

Gap analysis information has to be formally collected and communicated, to let members of the organisation know which SEU are identified.

Thanks to the gap analysis, changes in the planning might occur, as well as some mitigations actions to reduce the impact of negative energy performance must properly be defined. Each SEU must be correctly monitored to ensure data trustworthiness. (Sec. 8.1)

1.5.2. Design and supply

Opportunities for improving the energy performance and the operative control structure has to be defined.
Therefore, in the design of new plants, tools, system or processes consuming energy, their impact during the whole life cycle of the item has to properly considered.
Since they can have a significant impact on the energy performance, re-design of existing plants, tools, system or processes has to be take into account as well.
If possible, results regarding the energy performance evaluation should translate into design and supply activities, and properly communicated. (sec. 8.2)
Criteria regarding the energy performance evaluation has to be defined also when purchasing products, tools or services consuming energy, for which a significant impact on the energy performance is expected.
In fact, when purchasing a product, tool or service consuming energy, the organisation should be aware about its possible impact on SEU. Therefore, the company has to inform their suppliers that the energy performance of their supply is one of the decisional criteria while selecting a supplier.
If possible, the company has to provide to supplier specifications regarding the energy performance related to each item purchased.
Furthermore, the energy supply policy must be defined and communicated properly. (sec. 8.3)

1.6. PDCA: Check

The “Check” phase of the PDCA methodology concerns the evaluation of the energy performance.

This phase of the cycle regards the monitoring, measuring, analysis and evaluation of both the energy performance and the EMS. Furthermore, it requires an internal energy audit and a re-assessment by the top management. (Sec. 9)

1.6.1. Monitoring, measuring, analysis and evaluation

In this phase, the company has to consider several aspect about the energy performance and the EMS.

Firstly, it has to determine the “what” to monitor and measure, considering the following key aspects:

- Effectiveness of energy plans in achieving the energy objectives;
- The EnPI;
- The functioning of SEU;
- The real energy consumption compared to the expected one.

Then the organisation should define methods for monitoring, measuring, analysing and evaluating, to ensure trustworthiness of results.

It has also to define the “when”, so the frequency of monitoring and measuring (usually hourly, weekly or monthly) and the frequency of analysis and evaluation of the monitored and measured data (usually monthly or yearly).

Defined the “what” and the “when”, the company has to define the “how”.

Therefore, an energy analysis of the company in its status quo occurs.

The way the company decide to conduct this analysis, especially regarding the level of analysis (e.g. manufacturing company: from single machinery to production lines), has to be properly defined and declared, coherently with the “Plan” and “Do” phases.

At this stage, the evaluation phase can start.

Evaluation should give several results, which ultimately give a whole picture of the energy performance and of the EMS effectiveness.

The improvement of the energy performance must be evaluated benchmarking the value of the EnPI with the reference EnB.

By doing so, the organisation can identify and evaluate some significant gaps in its energy performance. Once defined, documentation and communication of them becomes necessary, especially regarding the impact on company performance. (sec 9.1.1)

Legal requirements regarding energy efficiency, energy use, energy consumption and regarding the EMS must be checked with a pre-defined frequency.

The organisation must keep track of these information, communicating results of conformity evaluation and about every actions taken after the evaluation. (sec. 9.1.2)

1.6.2. Internal audit and re-assessment by the top management

Internal audits about the EMS must be done with a pre-defined frequency.

This in order to ensure some results about the EMS implementation: (sec. 9.2.1)

- Improvement of the energy performance;
- Conformity regarding legal requirements, company processes, energy policy, energy goals and regarding the UNI CEI EN ISO 50001 procedure;
- Effective realization and maintenance of EMS.

To conduct correctly an internal audit it is necessary to: (sec. 9.2.2)

- Plan, establish, apply and maintain one or more audit scheduling, including its frequency, methods, responsibilities, requirements and relationships among stakeholders involved in the energy performance and in previous audits;
- Define criteria to conduct the audit properly, defining also the application field for each audit conducted;
- Select the auditors and conduct the audit in a way ensuring objectivity and impartiality during the audit process;
- Ensure the reporting of audit results to the top management in a proper way;
- Keep track and document the information related to the audit, as a proof of both the audit scheduling and the audit results.

Once the internal audit is over, a re-assessment by the top management is necessary.

Indeed, the top management must re-assess the EMS periodically, to ensure constantly its suitability, adequacy and effectiveness, guaranteeing coherency with the company strategic goals. (sec. 9.3.1)

Such re-assessment must consider: (sec. 9.3.2)

- The state of corrective actions (if executed or not) coming from previous re-assessments;
- Changes in internal and external factors influencing the energy performance or changes in risks and opportunities related to the EMS;
- Information about EMS performance, also including non-conformities and corrective actions related, results of monitoring and measuring, audit results, conformity and legal requirements evaluation results.
- Opportunities for continuous improvement, including also opportunities for new competences to englobe in the company know-how;
- The energy policy.

Inputs regarding the energy performance and the top management re-assessment must include a scale of achievement of energy goals, EnPI and state of action plans.

Inputs regarding energy performance has to consider not only EnPI, but also other data coming from monitoring that contributes to the improvement of energy performance (in case they do not directly impact on the EnPI considered). (sec. 9.3.3)

Output of the re-assessment phase must include a set of decisions made by the top management regarding opportunities for improvement or needs for change about the EMS including:

- Opportunities to improve the energy performance;
- The energy policy;
- EnPI and/or EnB;
- Energy goals, objectives, action plans and corrective actions in case of misalignment or non-achievability;
- Opportunities to improve the integration of EMS with company processes;
- Allocation of resources;
- Improvement of competences, awareness and communication.

Even result of the re-assessment has to be documented and communicated to the rest of organisation, especially with people directly involved. (sec. 9.3.4)

1.7. PDCA: Act

The “Act” phase of the PDCA methodology, necessary to achieve the UNI CEI EN ISO 50001 certification, deals with taking actions for energy performance’s and EMS’ improvement. (sec. 10)

There are three topics linked each other: non-conformities, corrective actions and continuous improvement.

When a non-conformity occurs, the ISO suggests to:

- React to the non-conformity, by taking controlling and correcting actions, also facing the consequences (if present);
- Evaluate corrective actions that eliminate causes of non-conformity, so that it will not occur again in the future. It is done by re-evaluating the non-conformity, determining the causes leading to it and detecting if similar non-conformities could arise as well;
- Take every corrective actions needed;
- Evaluate the effectiveness of such corrective actions;
- Modify the EMS structure if needed.

Corrective actions should be designed properly to prevent effects of the non-conformities detected.

The organisation has to keep information about the nature of each non-conformity and each related corrective action taken, but also about the results of each corrective action. (sec. 10.1)

The last point regards continuous improvement.

The organisation must commit to improve continuously suitability, adequacy and effectiveness of the EMS.

The company must demonstrate continuous improvement of the energy performance, also documenting the results. (sec. 10.2)

2. Factors influencing ISO 50001 adoption and state of art for Italian SMEs

As mentioned in the introduction, a first draft version of ISO 50001 has been published in July 2011.

As stated by the International Organization for Standardization (ISO), the standard could influence up to 60% of the world's energy use, due to its broad applicability across national economic sectors. [13]

In 2015, state of adoption worldwide accounted for 11,985 registered organizations. The adoption of this certification grew rapidly (from 459 in 2011 to 1981 in 2012), accounting for a total annual growth of 332%.

Considering increase of energy prices, need of reduction for GHG emissions and the need of producing more clean energy [14] , the adoption of ISO 14001 and 50001 has become more and more frequent.

Before seeing a real case study of adoption, in order to understand the real implications of the ISO 50001 certification, it is necessary to analyse the causal relation between motivations, difficulties and benefits linked to EMS implementation. [12]

2.1. Motives and Drivers

As mentioned in the introduction, motives for certificate ISO 50001 are very similar to ISO 14001 ones.

By collecting several studies made by questionnaires worldwide, it can be defined motives and drivers leading company to adopt ISO 14001 and 50001.

Bansal and Roth identified legitimation, competitiveness and ecological responsibility as three main motives for adopting ISO 14001. [6]

Neumayer and Perkins stated that also internal need for efficiency and external social pressure to adopt environmental management practices. [7]

Pan identified corporate image, environmental improvement, marketing advantage and improved relations with communities as major drivers. [15]

Psomas studies' results identified competitive advantage, social requirements and environmental-friendly policy. [16]

Gonzalez-Benito differentiated four different clusters of drivers for the adoption of environmental management systems: operational competitive motivations (costs and productivity), commercial competitive motivations (market, image, customers), ethical motivations, and relational motivations (regulators, local organizations). [17]

Marimon claims that companies are often adopting ISO 14001 just for "cleaning their dirty image". That's why he states that Global Reporting Initiative (GRI) is a common tool to disclose information about environmental practices also for the energy sector. [18]

Frederic Marimon and Martì Casadesus created a statistical model to evaluate motives and benefits. Due to the scarcity of empirical literature related to ISO 50001, some aspects are taken from authors that analysed motivations and benefits of other related standards, like ISO 14001. [12]

They started from a survey, made of 4 main sections:

1. Background information about the organization (Organization Data);
2. Organization motivations to adopt ISO 50001 (Input);
3. Adoption process of ISO 50001 (Implementation);
4. Results of the implementation (Output).

Chapter	Contents
1. Organization Data	Organization classification
	International Scope
2. Input	Motivations
3. Implementation	Commitment leadership
	Human resource
	Other resources
	Time and cost
	Difficulties
	Integration
4. Output	Operational benefits
	Financial benefits
	Innovation

Table 1 - ISO 50001 Surveys sections

In order to create a weighted model, a one-to-five Likert scale has been assigned to each question, according to the degree of agreement: (1) no effect, (2) a little important, (3) important, (4) very important, (5) totally important.

The sample is composed by Spanish organizations, since they account for the second-highest share of ISO 50001 certification throughout the world, next to Germany. Furthermore, estimates tell that Spain is contributing to increase massively energy efficiency, according to EU target for reducing energy demand by 20% in 2020.

From 87 questioned companies, only 57 responded (65% response rate).

Once the surveys' answers have been collected, three latent factors (F1, F2, F3) regarding motives of adoption has been labelled:

- F1 – Social requirements: incentive given by public administration, pressure from professional associations;
- F2 – Ecology drivers: improve energy efficiency, reduce GHG effects, enhance employee energy awareness, the rise of energy prices, the impacts of climate change;
- F3 – Competitive advantage: competitors' pressure, clients' requirements, image improvement.

Starting from these three factors, they conducted an exploratory factor analysis.

		Variables	Mean Value
F1	**Social requirements**	Incentive given by public administration	2,19
		Pressure from professional associations	2,30
F2	**Ecology Drivers**	Improve energy efficiency	4,42
		Reduce GHG effects	3,49
		Enhance employee energy awareness	4,02
		The rise of energy prices	3,67
		The impacts of climate change	3,39
F3	**Competitive Advantage**	Competitors pressure	2,51
		Clients' requirements	2,67
		Image improvement	3,67

Table 2 - Exploratory factor analysis for the motives in adopting ISO 50001

Looking at survey's results, ecological drivers (mean value: 3,80) represent the main cluster of factors inducing companies in certificate ISO 50001.

More specifically, improvement of energy efficiency (4,42) and enhancement of employee energy awareness (4,02) are the most relevant, with a high importance.

Energy efficiency improvement is the most important driver, but it requires energy awareness of employees to be achieved: investments are not enough, and organizations are well aware of it.

Also rise of energy prices (3,67) is considered by organizations a quite important driver for certificating ISO 50001, due to the instability of energy market prices.

GHG effects reduction (3,49) and impacts of climate change (3,39) are valuable too, in line with the EU decarbonisation path.

Competitive advantage is the second relevant factor (mean value: 2,95).

Indeed, image improvement is considered by organizations the most important variable for gaining advantage with competitors (3,67). Instead, pressure coming from clients (2,67) and competitors (2,51) are less valuable.

Social requirements have the lowest perception of importance (2,25), with a slightly higher value of pressure from associations (2,30) compared to incentives given by public administration (2,19).

These results are in line with ISO 14001 ones made by Psomas [16].

Indeed, he conducted a factor analysis as well, in which the internal factor of constructing an "environmental-friendly policy" resulted in a much higher significance than the external factors, represented by "competitive advantage" and "social requirements".

2.2. Barriers of implementation

High costs of certification, lack of available resources, lack of leadership commitment and uncertainty of ISO 14001 benefits has been signalled by Babakri as main obstacles for the environmental management standards. [19]

Regarding barriers strictly linked to ISO 50001, there are some studies defining some barriers or difficulties in implementing an EMS, thus achieving an ISO 50001 certification.

Wessels identified lack of managerial and leadership commitment as the major barrier of adoption. This is due to unawareness of EMS benefits, since employees do not perceive an impact on safety, quality or production cycle time. [20]

Another study by Velazquez stated some hurdles in determining the energy baselines (EnB) and the energy performance indicator (EnPI), due to data complexity: there is high variability of production data and interacting processes in the same site, making the calculations less reliable. According to his studies, another technical issue comes from monitoring activities. There are technical issues in installing an automated real-time energy measurement. [21]

Liyin stated that the increased cost, time and resource consumption strongly reduced commitment on energy and environmental performance improvement. [22]

Starting from these assumptions coming from previous studies, Marimon and Casadesus created another model for barriers, very similar to the one related to drivers of adoption, using some results of the fore mentioned (sec. 2.1.) survey. [12]

Again, they conducted an exploratory factor analysis. As a result, they defined two main factors or clusters:

- F6 – Operational difficulty: necessity of continuous measurement tools, data complexity, lack of economic resources, norm complexity;
- F7 – Organizational difficulty: changing mindset, internal communication, lack of leadership commitment and benefits uncertainty.

		Variables	Mean Value
F6	**Operational difficulty**	Necessity of continuous measurement tools	3,34
		Data complexity	3,04
		Lack of economic resources	3,02
		Norm complexity	2,26
F7	**Organizational difficulty**	Changing mindset	2,77
		Internal communication	2,40
		Lack of leadership commitment	2,28
		Benefits uncertainty	2,57

Table 3 - Exploratory factor analysis for the difficulties in adopting ISO 50001

Looking at the previous table, barriers of adoption are quite low: operational ones have a mean value of 2,92, while organizational ones mean value account for 2,50.

In detail, some operational difficulties have a higher importance in preventing the adoption of ISO 50001. Necessity of a continuous measurement tools, with the technical issues and investments related, have the highest value (3,34).

It is followed by data complexity and lack of economic resources, which have similar values (3,04 vs 3,02). Norm complexity is not perceived as a strong barrier (2,26).

Organizational complexity is given by the need of changing mindset (2,77), followed by benefits uncertainty (2,57). Slightly lower values for internal communication (2,40) and lack of leadership commitment (2,28).

According to the authors, previous experience in adopting international standards such as ISO 9001 and 14001 may facilitated conformity with ISO 50001 ones. This could affect the perception of some barriers, especially organizational ones, since the adoption of previous standards may have initiated a change of mindset and organizational culture towards efficiency topics. Indeed, 85% of the organization answering to the survey have yet adopted either ISO 9001 or 14001, or both.

2.3. Benefits of adoption

Operational benefits can be identified dealing with ISO 14001, and similarly, to ISO 50001. According to different authors, operational benefits in establishing an environmental management system are lower cycle time and costs, higher efficiency and flexibility, better plant safety, better productivity, higher rate of product innovation, performance and quality, lower defects rate, quality assurance and process optimization. [8] [23]

ISO 14001 has proven a powerful tool for improving environmental performance and business efficiency.

According to Chavan [9], it helps in minimizing environmental liabilities, maximizing efficient resource utilization and reducing waste. It is also beneficial for improving corporate image, building awareness on environmental topics. Lastly, his study showed better understanding of environmental impact on business activities and an increase in profits, thanks to more efficient operations.

In all the analysis regarding strictly ISO 50001 adoption, EMS showed improvement of the energy performance, resulting in a very powerful tool.

Wessel showed success of the implementation of an EMS in Toyota SA, with a strong improvement of some energy indicators, especially “energy saving/year” and “kg of CO2 savings/year”. [20]

In another Velazquez regarding some oil companies based in Seville, estimated a huge saving in energy consumption: 2,82 GWh per year. [21]

In his analysis about the Bentley Group, Lambert estimated a yearly saving of at least 180 kW of absorbed power, resulting in 1,532,768 kWh savings for electrical energy consumption. [24]

Jabbour made an analysis regarding the impact of ISO 50001 practices on the supply chain. [25] He discovered that 50001 standards creates positive impact for green supply chain management. Indeed, the integration-energy-practice model necessary to introduce the EMS, efficiently meets demand for EnPI calculations, with results showing savings.

Marimon and Casadesus conducted a third exploratory factor analysis also regarding benefits of adoption, considering the mentioned results of previous ISO 14001 and 50001 case studies. [12]

According to the survey results, they labelled two factors:

- F4 – Ecological benefits: energy savings, improvement of environmental performance, improvement of environmental impact, and increase of environmental awareness;
- F5 – Production benefits: increase plant safety, increase overall productivity, process optimization, and improvement of product performance.

		Variables	Mean Value
F4	**Ecological benefits**	Energy saving	4,43
		Improvement of environmental performance	4,02
		Improvement of environmental impact	3,83
		Increase of environmental awareness	3,55
F5	**Production benefits**	Increase plant safety	2,47
		Increase overall productivity	3,04
		Process optimization	3,49
		Improvement of product performance	2,38

Table 4 - Exploratory factor analysis of the benefits for adopting ISO 50001

Ecological benefits mean value is the highest (3,96), while production benefits scored a much lower value (2,76). Thus, production benefits' impact is perceived less.

Indeed, the adoption of ISO 50001 procedures, is mainly beneficial for energy consumption and environment, rather than process related activities.

Energy saving is the highest benefit perceived (4,43), followed by improvement of environmental performance (4,02) and impact (3,83). These three benefits result in reduced energy consumption (KWh or PET) and less pollution (kg of CO_2).

Also increase of environmental has good importance (3,55).

Regarding production benefits instead, process optimization is the most perceived benefit (3,49), to a more efficient energy consumption due to better machinery utilization.

Increase overall productivity is quite relevant too (3,04), while increase plant safety (2,47) and improvement of product performance (2,38) benefits are less perceived.

2.4. Link between drivers, barriers, and benefits: a path analysis

By analysing results of the three explanatory factor analyses, Marimon and Casadesus conducted a path analysis, linking the three dimensions: drivers, barriers and benefits. [12] Through results they identified six factors:

- Social requirements (F1), ecology drivers (F2), and competitive advantage (F3) as clusters of drivers;
- Ecological benefits (F4) and operational benefits (F5) as clusters of benefits;
- Organizational difficulties (F7) and operational difficulties (F8) as clusters of barriers.

By conducting a path analysis they correlated among each other all the mentioned factors, using a maximum likelihood method, as shown in the following figure.

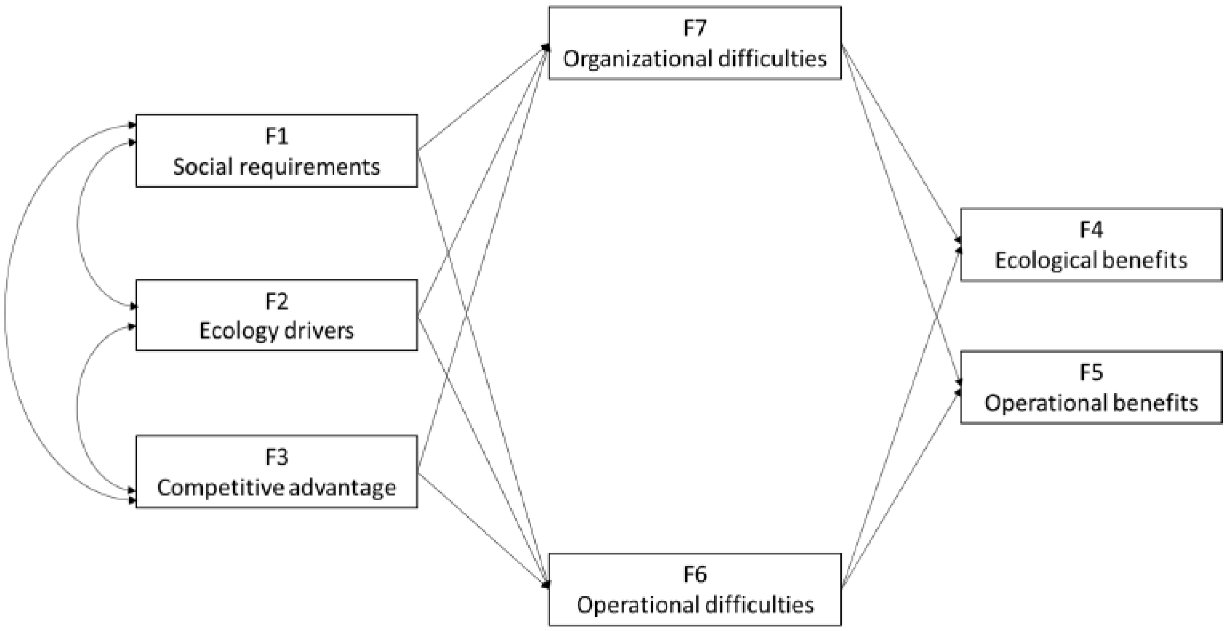

Figure 2 - Exploratory path analysis graphical representation

Without going in detail with the statistical reliability of results (shown in the analysis made by the two authors), it is possible to understand the reasoning of such links and their relationships. Some of them have been deleted, when seeing no significant value of relationship between one another.

Different links, according to their importance, have been assigned with a 5% or 10% of significance level (according to a Lagrange Multiplier Test with Comparative Fit Indices (CFI) model), as shown in the following figure.

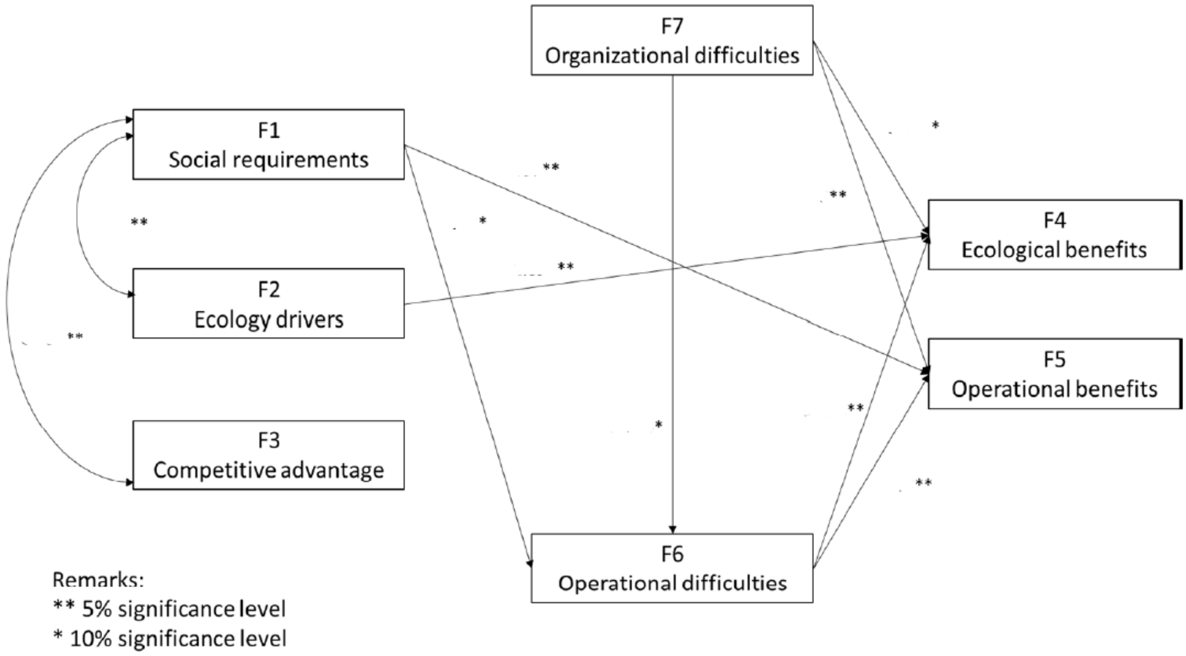

Figure 3 - Final path analysis with significance level

Now the implications of the path analysis' results are analysed.

During the implementation process, some operational difficulties arise, due to social requirements (incentives by public administration and professional associations).

On the other hand, social requirements enable organization to exploit operational benefits like safety, productivity, performance, quality, and optimization; while they have no impact on ecological benefits.

Ecological benefits are achievable thanks to ecology drivers. Therefore, without such drivers, only operational benefits are attainable.

It can be said that drivers (or motivations) have a positive influence for the overall benefits for adopting ISO 50001 standard.

Organizational barriers have an inverse relationship with operational and ecological benefits, compared to drivers.

Indeed, change management is initiated on both organizational and managerial activities, and afterwards it comes to the operational side.

Consequently, organizational difficulties (changing mindset, internal communication, lack of leadership commitment, and benefits uncertainty) limits the positive impact of both operational and ecological benefits.

By reducing such barriers, the organization becomes faster and more suited for adopting EMS procedures, therefore increasing their operational and ecological benefits.

Operational barriers due to necessity of continuous measurement tools, data complexity, lack of economic resources, and norm complexity, have a negative impact on operational and ecological benefits too.

Due to the need of meeting requirements of the energy policy by fixing targets, managing energy data and measuring results, some operational difficulties can arise.

The more seriously organizations consider ISO 50001 implementation, the more ecological benefits manifests, due to the higher effort in energy management activities.

Also in this case, operational difficulties are not beneficial both for operational and ecological benefits, therefore must be reduced as much as possible. The lower these barriers are, the more beneficial the adoption of ISO 50001 is, on both sides.

Competitive advantage drivers are not reducing barriers, neither have a positive impact on ecological or operational benefits. They can have an impact on the strategic goals of the company, and ultimately in the energy strategy, but they have not a very strong link with production or ecological benefits.

2.5. State of Art of UNI CEI EN ISO 50001 adoption in Italy

The Department of Mechanical and Aerospace Engineering of the Sapienza University in Rome published the most recent article regarding state of Art of UNI CEI EN ISO 50001 in Italy in 2015. This analysis has been developed also by using some data coming from FIRE (Italian Federation for the Rational use of Energy). [26]

The document provides a big picture of Italian companies' state of adoption.

By using data coming from the ISO Survey 2013, the Figure below shows top ten countries in the world for ISO 50001 certifications issued between 2011 (year of first publication) and 2013.

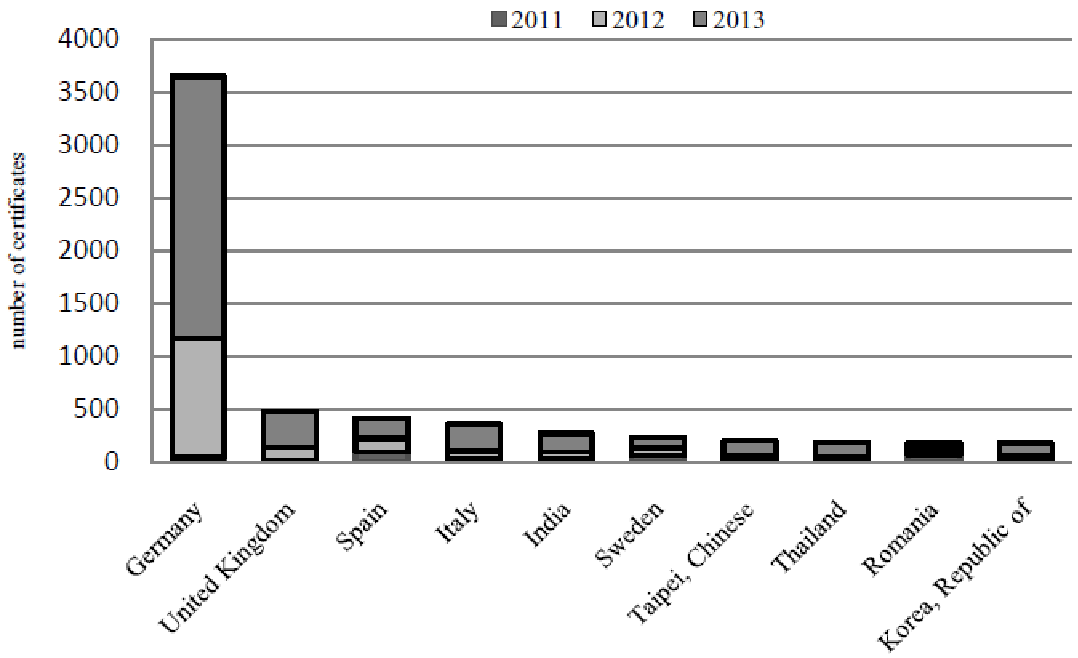

Figure 4 - The top ten countries for number of ISO 50001 certificates issued

Italy accounted for 2992 energy intensive companies in 2015, for which the adoption of the ISO 50001 is strongly beneficial. Italy is the fourth place for total certificates issued in 2015 (362 sites), even if there is a huge gap with Germany (3652 sites) due to tax reliefs introduced by the German government for ISO 50001 certified companies. [27]

Considering an S-curve maturity model, the document states that ISO 50001 penetration in Italy is still on an early stage of development. Considering the three stages (introduction, growth and maturity), penetration in Italy is still in the introduction stage. It should reach the maturity one in 2018.

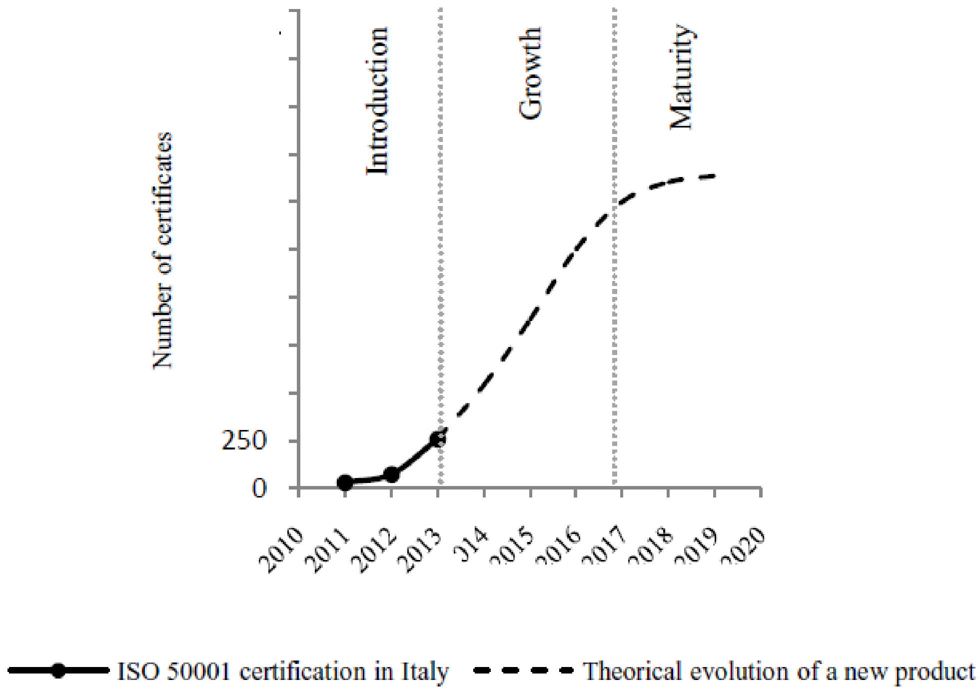

Figure 5 - S-Curve maturity model for ISO 50001 adoption

In a very recent data published by FIRE in 2020 (shared in a training course on ISO 50001 procedures), around 3000 sites are certified ISO 50001.

Most of them belonging to the Lombardia region (26%), followed by Lazio (18%) and Piemonte (10%). All other regions account for less than 10% each, with Emilia-Romagna (9%) and Liguria (8%) highest rate. [28]

Considering more than 3000 energy intensive companies in Italy nowadays (with an average of two production sites each), the adoption for 50001 certificates has not yet reached the maturity stage: it is still on a growth stage.

This is another reasoning behind the new version of UNI CEI EN ISO 50001 published in 2018, in which leadership, commitment and communication are emphasized (more than in the previous version of 2011).

To understand the reasons why the adoption rate is growing slowly, the analysis made by the Sapienza University in 2015 is providing some answers.

They issued a survey to three different actors participating in the certification process:

- 40 companies: organizations that certified ISO 50001;

- 18 consultants: energy service company that helps organizations in achieving the certification;
- 14 certification bodies: actors in charge of evaluating non-conformities that issue the certification after an audit and verification process.

The survey was composed by several multiple-choice questions about perception of critical issues in implementing and EMS.

Questions were about the main requirements of an EMS:

- Definition of an energy policy;
- Identification of the energy management team;
- Definition of the Baseline;
- EnPI calculations;
- Monitoring planning and results.

Answers ranged from a difficulty level 1 (very easy) to 5 (very difficult).

After collecting the results, seeing different percentage of energy savings, they decided to cluster results with four categories of energy savings level: less than 1%, between 1% and 3%, between 3% and 5% and greater than 5%.

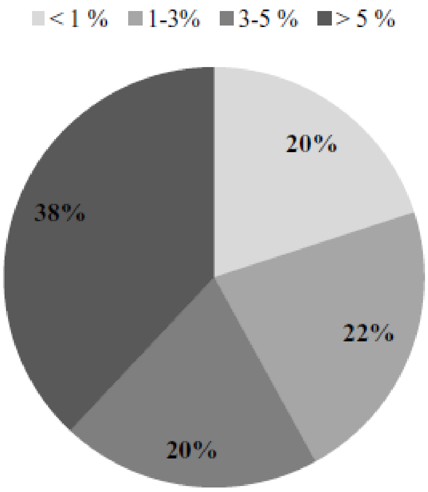

Figure 6 - Energy savings obtained by companies with an EMS implementation

Companies saving less than 1% of energy represent the 20% of the sample. The 22% of the sample are companies with energy savings between 1-3%. Organization with energy savings between 3-5% are the 20% again, while the ones with energy savings higher than 5% are the 38% of the sample. (Figure 7)

The first part of the survey was about motivations for implementing an EMS, sent only to companies and consultants.

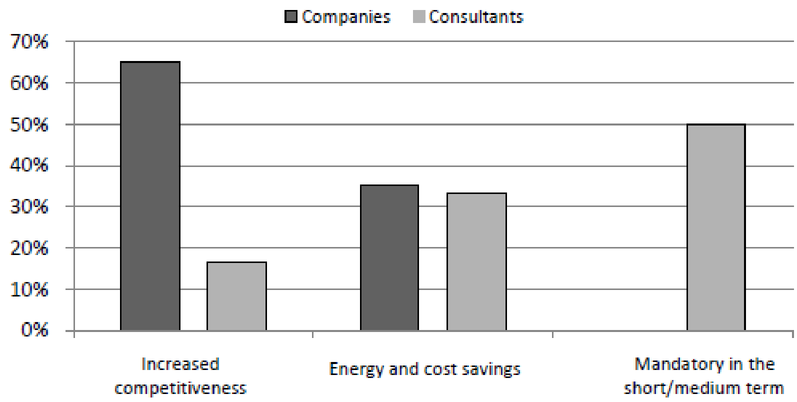

Figure 7 - Background motivations for an EMS

As the previous figure shows, increased competitiveness is the most relevant motivation for companies, followed by energy and cost savings.

Results for companies and consultants are now analysed.

Level 4 (difficult) and level 5 (very difficult) answers have been reported in Figure 8.

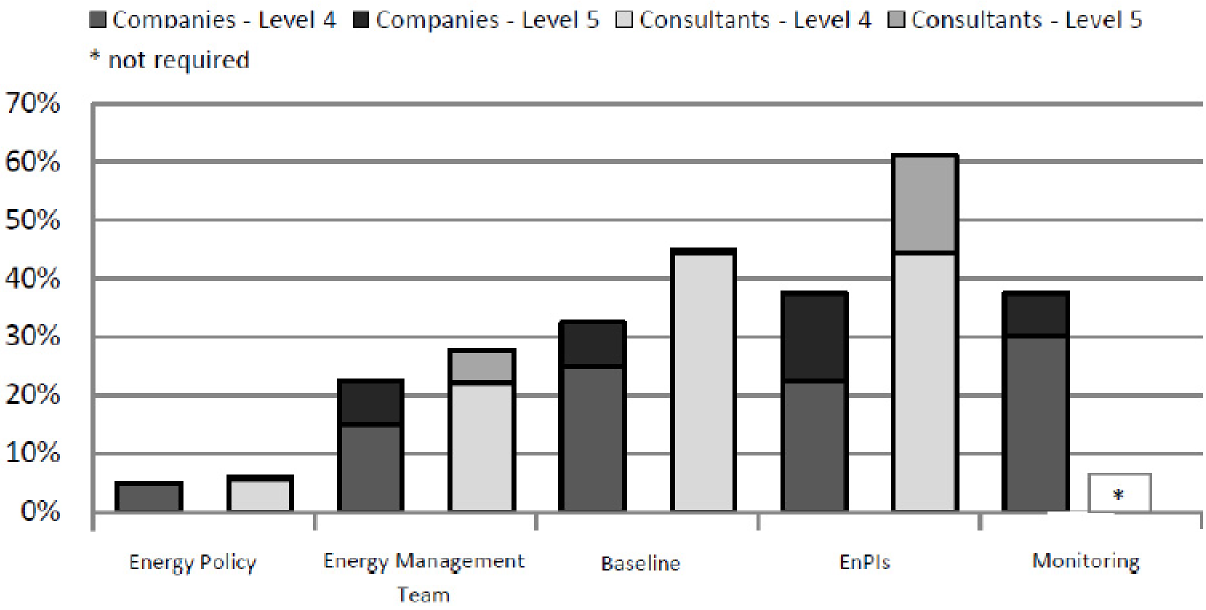

Figure 8 - Requirements of an EMS more difficult to satisfy

Looking at Figure 8, EnPI calculation is the most though stage. Harder on consultancy side, since they usually calculate them for the organizations, even it is though also on companies' side. This is mainly due to variability of production rate and correct understanding of consumptions along all processes.

The correct selection of a EnB to benchmark EnPI is another relevant issue.

Since companies do monitoring, they are the only that can perceive their issues.

Indeed, monitoring is hard to manage as EnPIs calculations, especially due to its reliability that sometimes fail. Being monitoring not often reliable, also EnPI follows the same unreliability.

Analyzing answers coming from certification bodies, there are some patterns with the previous answers.

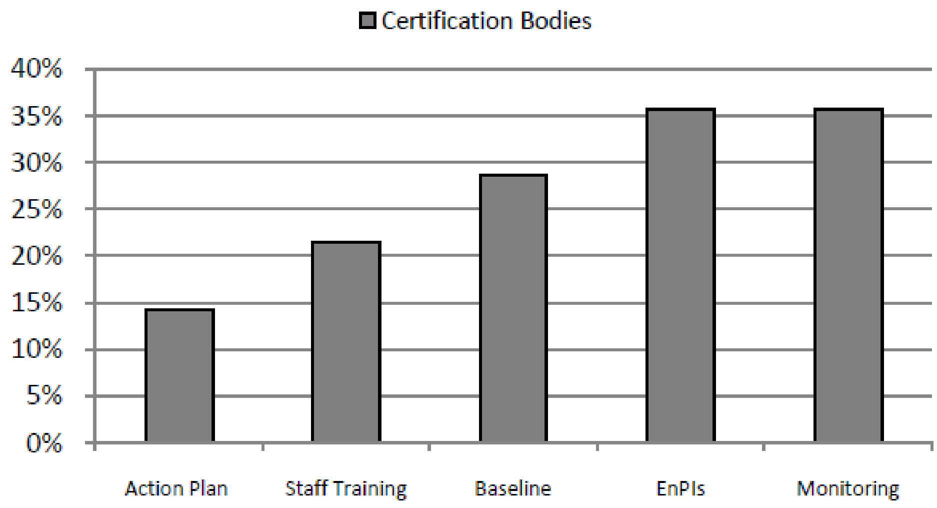

Figure 9 - Most disregarded elements of an EMS identifies by certification bodies

The previous figure shows the 5 main categories of activities that organizations has to do in order to certify ISO 50001.
Certification bodies were asked to declare which of these activities are giving more troubles in achieving the certification. In other words, the higher the percentage is, the more probable that activity would lead to non-conformities.
Again, EnPI and monitoring has been identified as the more difficult one, leading more likely to non-conformities. Then the other quite relevant issue is the baseline definition.
The results are perfectly aligned with companies and consultants' perception, therefore ensuring the reliability of results.
Even if the study has been done in 2015, data can be assumed as reliable also for the thesis.
This is due to no further incentives about EMS implementation coming from the Italian Government in the following years.

A more recent study done by FIRE in 2021 shows the state of adoption of UNI CEI EN ISO 50001 (2018) in Italy. [29] The research is based on a dataset collected by Accredia.
Through the implementation of an EMS, an organization is able to implement a High Level Structure (HLS) by integrating in a unique management system:

- Quality management system (ISO 9001);
- Security and safety management system (ISO 45001);
- Environmental management system (ISO 14001);
- Energy management system (ISO 50001).

Therefore, the implementation of an EMS becomes more beneficial if the organization implemented along the years the previous certifications of the HLS.
For such reason, the state of adoption of the UNI CEI EN ISO 50001 strongly increased in the last years (almost 4000 plants certified), as shown in the following figure.

Figure 10 - Implementation trend for ISO 50001 certified sites (Italy, FIRE)

Nowadays, most of companies have implemented a Quality management system (ISO 90001) and a Security and Safety management system (ISO 45001), due to previous incentives or due to market restrictions (clients/suppliers' requirements).

Environmental management systems (ISO 14001) are more recent, but they are strongly increasing in their adoption rate. EMS (ISO 50001) are expected to face a similar growth in future years, according to FIRE previsions.

Figure 11 shows a clear state of art of the four ISO implementation belonging to the HLS.

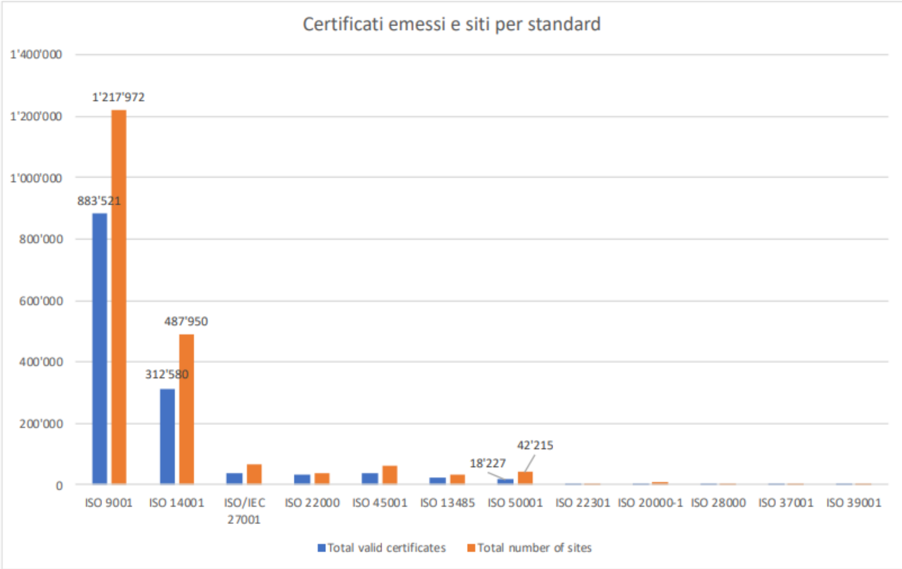

Figure 11 - HLS management systems' implementation (state of art, 2019) (FIRE)

Due to the need of defining an energy context (chapter 1.2), organisations can freely decide to certify just some of their production sites. Usually, it is more convenient to certify those plants that have a high-energy consumption profile, for which energy efficiency is more beneficial also in economic terms (energy savings).

When there is a strategic purpose behind the decision to certify UNI CEI EN ISO 50001 as organization (like competitive advantage or clients/suppliers' requirements), such companies decide to implement an EMS in more than one production sites.

In the following Figure, a comparison between certified organizations and sites, showing what previously stated.

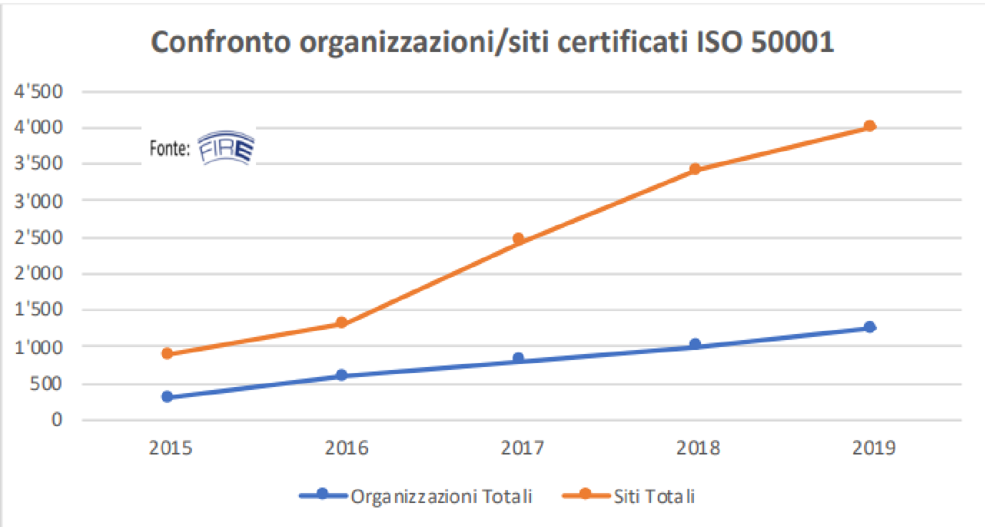

Figure 12 - Comparison organizations vs sites certified ISO 50001 (FIRE)

Comparing Italy with other countries, it is possible to observe a massive grow in the rate of adoption due to the new version of 2018.

With the previous version (2011) Italy was at the fourth place for EMS implementation, far from Germany and behind United Kingdom and Spain.

As can be noticed in the following Figure, Italy is nowadays at the third place for EMS implementation, even if still far from Germany and France (in which incentives played a key role).

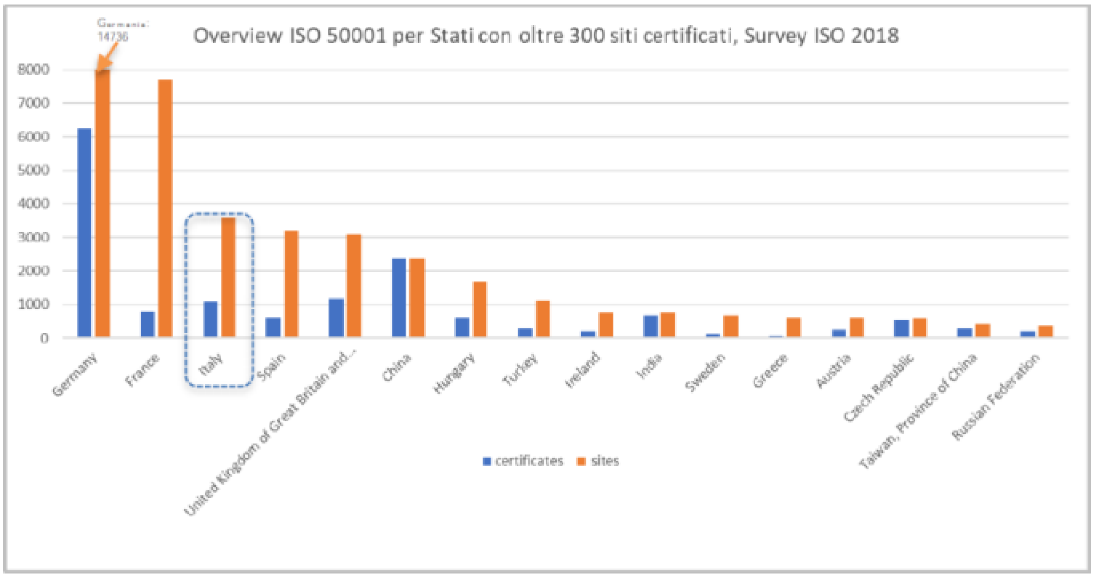

Figure 13 - Adoption rate for ISO 50001 worldwide (FIRE)

Such result shows the importance of reviewing the UNI CEI EN ISO 50001, enhancing leadership and commitment on energy efficiency topics.

Increase of energy prices in Italy played for sure a key role in such growth in the adoption rate. However, the presence of clear and proved benefits not only on energy savings gave a boost in the adoption in recent years. Organizational and managerial benefits of implementing an HLS, has been a very important factor according to the FIRE analysis.

3. A business case of ISO 50001 certification: Smurfit Kappa Italia s.r.l. - Verzuolo plant

In 2021, Smurfit Kappa Italia s.r.l. decided to certify the Verzuolo plant according to UNI CEI EN ISO 50001 (v. 2018).
The plant manufactures paper, and it has a huge amount of energy consumption.
In order to reduce their consumption level, the top management committed to implement an EMS, and apply the PDCA cycle necessary to certificate ISO 50001.
Having not enough knowledge in energy management, while being supported by Collarini Energy Consulting s.r.l. in energy trading activities, they asked to the energy consultancy company in to let them achieve the certification.
This section shows, after a short presentation of both CEC s.r.l. and SKI s.r.l. – Verzuolo plant, the ISO 50001 certification path.
In particular, this chapter focuses on:

- Energy audit conducted by CEC s.r.l. for the Verzuolo plant;
- Context, leadership and responsibilities assigned to the plant;
- The energy policy of the company;
- Energy goals, risks and opportunities linked to energy consumption for the paper manufacturing industry;
- The energy analysis, which focuses on three dimensions: the electric energy model (an estimation of the electric consumption profile), the thermal energy model (the energy production profile of the company), and the primary energy model (that considers all energy flows);
- EnPI calculation and SEU identification;
- The monitoring phase, with an R^2 significance test useful for a gap analysis between monitored data and estimations.

3.1. Collarini Energy Consulting s.r.l. know-how and operating models

Collarini Energy Consulting s.r.l. is an Italian energy consultancy company, based in Garlasco (PV). The company deals with energy services aimed at optimizing energy costs and consumption for its clients.

Clients come mainly from manufacturing industries, since they have energy intensive processes.

CEC s.r.l. activities can be synthetized in three main clusters:

- Trading and contracting;
- Carbon footprint activities;
- Energy management.

3.1.1. CEC s.r.l. activities: trading, contracting and carbon footprint

Regarding trading and contracting, CEC s.r.l. does some activities.

The contracting activities are one of the most relevant and requested by clients, since CEC looks for the most convenient contract for energy supply, both for electric and thermal energy (if present).

Trading activities strictly connects to contracting ones. Indeed, while signing or re-defining an energy contract, CEC tries to find an agreement with an energy distributor for a fixed or variable pricing, according to the opportunities that the energy market shows looking at its futures.

In this way, when the client is not satisfied with the energy contract, the consultancy company tries to identify better market conditions, trading with the same client (renegotiating) or contracting with a new one.

In order to show the amount of energy consumption and the costs associated, the company does a monthly report of the energy profile.

Each month CEC updates the energy profile and send it to the client, both for electric energy consumption and natural gas consumption (if present).

By doing so, the client can keep track of its consumption profile and understand its energy costs.

Then, CEC shows to the client if there are more convenient energy contracts.

The consulting company looks also at energy futures, thus making predictions about the energy costs that the client will face for the next twelve months. This is very important for energy intensive companies.

CEC is also dealing with carbon footprint activities.
Indeed, starting from the energy consumption profile and defining some indicators (e.g. ton of CO_2 produced / kWh consumed), CEC is able to calculate the amount of CO_2 produced by the client in its operations.
By calculating the amount of energy savings, it can estimate the amount of CO_2 saved by the client, that is important to show environmental improvements for ISO 14001 certificated companies.
In fact, clients often request for such activities, since it has a positive impact on the environmental profile of the company, and on the whole client supply chain ultimately.

3.1.2. Energy management in CEC s.r.l.

There are several energy management activities done by CEC s.r.l.
Such activities are mandatory for some manufacturing companies that are considered in Italy as energy intensive companies (the ones overcoming a certain consumption threshold, according to the ATECO code).
Anyway, all companies that wants to manage energy in a more efficient way can issue for energy management activities, even if not obliged.
The first activity is the energy audit.
Doing an energy audit means doing an inspection of the plant, trying to understand all the energy flows and all the consuming sources (light, machinery, heating, air flows, logistics… etc.).
Again, this activity is obliged for energy intensive companies (at least one energy audit each four years), while it is a free choice for the others.
After conducting an energy audit, CEC has a whole picture of:

- The production process;
- All energy flows and sources;
- The energy consumption profile (light, machinery, heating, air flows, logistics…)

Then, the energy analysis take place.
Starting from data collected in the audit phase, CEC starts modelling a framework (the so called “energy diagnosis”) that is useful to conduct an energy analysis.
The most relevant sections of the energy diagnosis are:

- Identification of the whole production process (material flows);

- Subdivision of activities according to the "energy functional area" (EFA): principal activities (those directly contributing to the output realization – e.g. production machinery), auxiliary services (those that influence the production process and the consumption profile, but that are not strictly necessary for the output realization), and general services (all other energy consuming activities that are not linked to the output);
- Estimation of the production profile (e.g. number of units produced monthly)
- Electric, thermal and water consumption profile (monthly);
- Self-consumed energy by photovoltaics or other sources (if present);
- Definition of an electrical model (a list of all consuming tools with their nominal power, load factor and yearly estimated consumption);
- Definition of a thermal model (a list of machinery producing or consuming heat with the related estimation according to nominal power and load factor)
- Definition of possible future interventions that can help the client in saving energy, with all the energy savings related (kWh, PET and CO_2)
- Economic analysis with PBT and NPV for each intervention suggested;
- Definition of EnPIs linked to energy efficiency improvements.

After the diagnosis, the last part of the energy analysis occurs.

By collecting data in the monitoring phase (for energy consumption and production, if present), the benchmark between estimations and real data take place.

By doing so:

- Real energy consumption is defined and compared with expectations;
- EnPI are compared with the reference EnB to understand criticalities.

After the analysis is over, the output of the energy analysis is showed to the client.

In this phase, if results are not in line with expectations, a re-assessment from the top management can take place.

Such re-assessment could be a consequence of bad energy performance, leading to some improvement actions:

- Investments in more efficient machinery (production);
- Investments in more efficient lighting system;
- Investments in more efficient heating, air flows or air conditioning;
- Changes in the operations;
- Changes in the energy policy;

- Changes in the business strategy.

The last important activity is the calculation of “Energy Efficiency Titles”, an incentive for energy efficiency improvements. EEFs are issued only if investments take place and if they satisfy some conditions defined by the GSE – Gestore dei Sistemi Energetici (the Italian DSO – Distribution System Operator). Therefore, they are not included in the economic analysis of interventions as positive cash flow.

Since the energy analysis is one the most important step for certifying ISO UNI CEI EN 50001, it will be analysed in depth in the business case.

3.2. Smurfit Kappa Italia s.r.l.

Smurfit Kappa Group is an international group that works in the paper industry, both for paper realization (both primary and recycled one according to the plant) and packaging.

There are four main kind of output realization, according to the site:

- Primary paper realization from cellulose;
- Recycled paper realization from wastes;
- Solid paper for packaging purposes;
- Wood pulp realization;
- Packaging realization.

The Italian firm is managed by some responsible belonging to the top management of the group, and it has eleven different plants just in Italy.

The business strategy of the group is to vertically integrate the whole packaging value chain.

Since they produce very few volumes of packaging compared to paper, the main activity is the realization of paper, which is sold in European markets or transferred to the packaging realization sites.

Smurfit Kappa is one of the leading industry for paper realization, especially for recycled paper.

All the eleven sites of the group are certified ISO 14001, as a proof of their sustainability strategy. Indeed, they are converting most of their sites from primary paper or wood pulp production to recycled paper, as happened for the Verzuolo (CN) site, which now fully dedicates to recycled paper realization.

Only three of the eleven production sites are considered by the GSE as energy intensive sites: Toscolano (BS), Avezzano (AQ), and Verzuolo (CN) (since they are large plants with high-energy consumption profile).

Each four years these three sites must conduct an energy audit, according to the D. Lgs. 102/2014 announced by the Italian government in 2014. [29]
The Verzuolo (CN) site has a dimension of 113.201 m^2, with a total volume of 1.132.013 m^3.
The plant has been established by the eng. Burgo Luigi in 1897 (Burgo s.p.a.).
He started to produce firstly only wood pulp from the near hoods. Then the business moved also towards primary paper realization after the second world war, and faced a very fast growth, showed by the enlargement of the production site. Indeed, there were two separated production lines, one for wood pulp and another one for paper. This growth lead to the acquisition of the near steam turbine station, which is still part of the plant nowadays.
During the 1980's, part of the group has been acquired by the Marchi Group (75% of shares), that englobed also the Toscolano (BS) and Avezzano (AQ) sites. After such acquisition, another huge line only dedicated to recycled paper has been established in 2001 (PM9). In order to maintain a sustainable profile, the group installed also a bark boiler dedicated to biomass energy production coming form production wastes (muds).
Seeing a slowing demand in primary paper and wood pulp, the Marchi Group faced a slow-down in their market shares. For these reasons, they decided to be acquired by an international competitor in the paper industry: the Smurfit Kappa Group (2018), which now fully manages the site.
Smurfit Kappa top management decided to close the two lines dedicated to primary paper and wood pulp, for a twofold reason. The first is a change in the mission: making paper production sustainable. The second are pressures from north-European customers that started requesting more and more recycled paper.
Verzuolo has another peculiarity compared to most of paper manufacturing sites: it is energetically independent thanks to the englobed steam turbine, fed with turbo-gas cycles or biomass energy. Indeed, they self-produce their energy through a cogeneration system (thus producing both electrical and thermal energy), and even sell electricity to the capacity market, when issued by Terna Group (the Italian TSO).

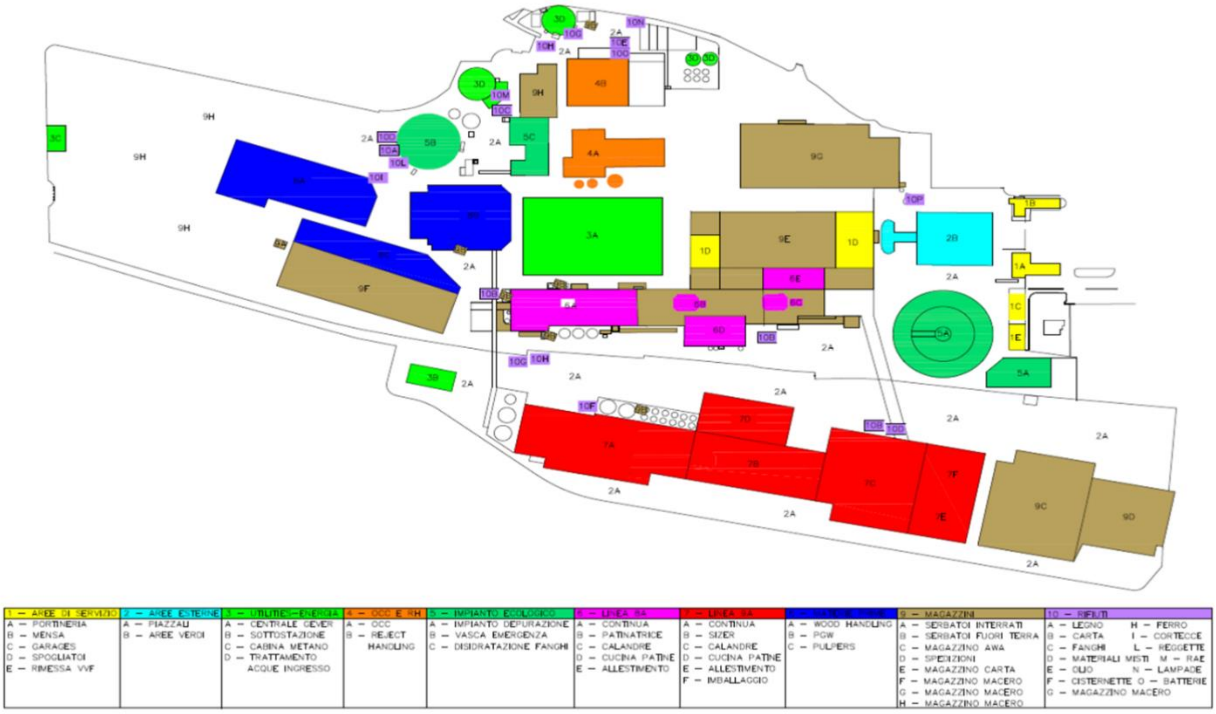

Figure 14 - SKI s.r.l. Verzuolo (CN) planimetry

3.2.1. Activities and production process in Verzuolo (CN)

As mentioned in the previous chapter, we can distinguish two main activities done in the Verzuolo plant:

- Production of recycled paper;
- Production of energy.

The production of recycled paper starts with the recollection of paper wastes from waste management companies and discards from other companies using paper as input.

Paper is not the only component of the input waste.

Indeed, bales of paper mixed with residual metal or plastic arrives in storages through trucks. (raw material storage phase)

Some forklifts are in charge of moving the bales to the pulp area (raw material handling phase), where the separation between paper and the other components occurs (HC cleaning phase). This is done through some rollers that move the mixture of materials allowing the separation with the paper. Hot water and some chemicals additives are added to the paper in order to obtain a pulp (pulping phase).

The pulp is compressed with high-pressured air to drip the exceeding water of the “paper mud” (coarse screening phase).

By doing so, two different flows of material are present.

The dryed mixture of paper is sent to some rollers and enter in the production process (LC cleaning phase).

Wastes of such process identified as “production muds” go directly to the “mud treatment area”. Here, the wet mixture of waste is dried and compressed to be burned in a bark boiler to produce energy from these biomasses.

The input paper is now ready to enter in the paper production area.

Here, the main area is the “PM9” production line.

Such line has a high degree of automation, and operators only intervene in the setup phase of some machinery, while they check the correct flow of materials through computers in operational offices.

The dried paper goes through a series of coils, where the paper starts to roll out (fractionation phase).

In the first coils, the paper starts to assume the form of thick paper rolls (thickening phase). Only for shorter paper rolls, a quality check occurs in a dedicated machine (fine screening phase). Longer paper rolls’ defects are checked by operators through their computers instead, since they have a very low degree of error.

Going on with the line, some chemical additives are progressively added to the paper rolls, making them more malleable and resistant. Before becoming paper reels ready to be stocked, some colorants are added to obtain the typical brown colour of the recycled paper. Then the paper roll is progressively stretched and dried.

Once ready, a huge cutting machine divides the paper reel according to the specifications set up in the computers that control the process (cutting phase).

Then, paper rolls are stocked into two storages (fiber storage phase - one for shorter paper and another for longer ones), where trucks transport them to the final customer or to another production site of Smurfit Kappa for packaging purposes.

Such process is strongly energy intensive and requires the utilization of different kind of machines.

Starting from the beginning of the process, hot vapour at medium pressure (7 bar) is required to create the paper pulp.

Then, to obtain a dry paper bulk, some compressed air is necessary, and therefore some compressors are used.

Such compressors are strongly necessary also in the production line, due to the need of drying and stretching the rolling paper.

Low-pressured vapour (4 bar) and chemical additives wet the rolls. Therefore, such vapour must be captured by the steam turbine for the good realization of the process.

All other machinery that presses the roll and makes it with the desired specification require electrical energy.

Since the process creates very high temperature due to the mechanical friction between paper and rolls, there is no need to flow hot air in the production site (for heating purposes). Therefore, there is no thermal energy consumption associated to heating. Thermal energy is used only to create vapour for the process.

The following figure shows the whole production process.

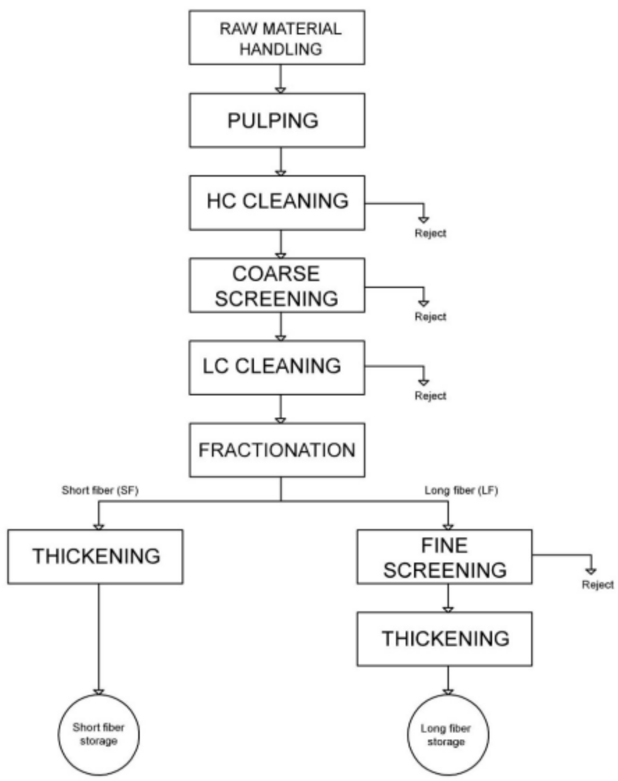

Figure 15 - Production flow

The energy production system is composed by:

- Two turbo-gas turbines (TG1, TG2: 40 MW nominal power) cycles burning methane, thus generating HV electricity;

- Two post-combustors burning methane (5 combustors after each TG), to recover some heat (medium pressure (7 bar) vapour) from the turbo-gas cycle;
- Two boilers (GVR: 20 MW nominal power) cycles producing high (15 bar) and low pressure (4 bar) vapour using the heat produced by TGs and post-combustors;
- A bark boiler (19 MW nominal power) producing few high pressure vapour (15 bar) from biomass energy;
- A steam turbine (80 MW nominal power) producing electricity (DC for HV) and releasing some vapour for the production process (low (4 bar) and medium pressure (7 bar)).

The energy plant follows a Combined Heat and Power (CHP) cycle.

The two turbo-gas turbines (TG1, TG2) burn methane, producing work as result. Such work is then transformed into Direct Current (DC) and sent to a High Voltage (HV) station, that is present inside the plant.

Two boilers (GVR) are located after TG1 and TG2 respectively to recover some heat from the turbo-gas cycle that would be wasted otherwise.

Part of the heat sent to the steam turbine is recollected as vapour (both in medium (7 bar) and low pressure (4 bar)) and used directly into the production process. While high pressure vapour (15 bar) is used in the steam turbine for electricity production, where some heat is recovered and used again in the production process. The work generated by the steam turbine is converted into DC and sent to the HV station. While exceeding vapour condenses in a cooling tower, and water is recollected in a large collection pool to be re-used in the production process.

If both turbo-gas works constantly, the amount of energy produced would be too high compared to the need of Verzuolo plant. For this reason, one of the two turbo-gas works for the capacity market (TG2), only if issued by Terna.

Biomass energy is obtained through a Bark Boiler, by recovering the “production muds” and feeding the system with methane. Such energy is useful to produce high-pressured vapour for the steam turbine, thus contributing to the electricity and vapour production.

The following figure shows the energy production process.

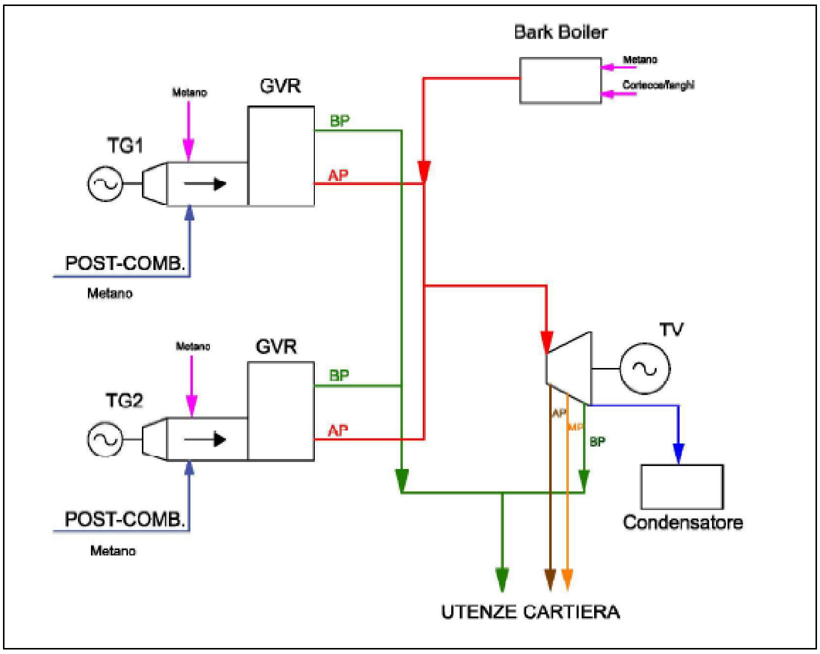

Figure 16 - Cogeneration system

3.2.2. Energy Audit in Verzuolo plant

The approach for conducting an energy audit follows the guidelines defined by the UNI CEI EN ISO 16247 (2014). [30]

The following framework summarizes the approach adopted by CEC during the energy audit conducted for SKI – Verzuolo.

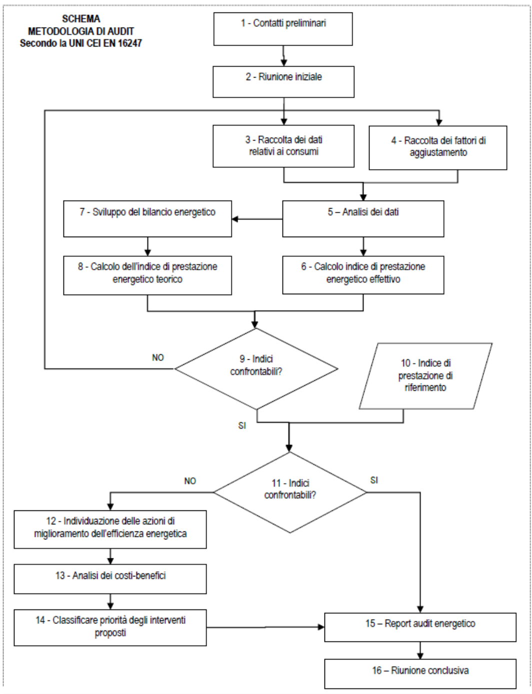

Figure 17 - Energy audit methodology according to UNI CEI EN ISO 16247

The preliminary contact starts when the client (SKI - Verzuolo) asks for an energy audit to a certified auditor (CEC).

Then an initial meeting take place, in which the two actors finds an economic and methodological agreement. Indeed, there is a contract proposal by the auditor, in which activities to be done and the economic conditions related are written.

In the next phase the auditor has to visit the plant for which the energy audit is requested. During the visit, the auditor has to understand all the energy flows and all the energy sources, in order to understand all the operations that require energy (not only related to production, but also to heating, lightening, logistics… etc.).

At this point the client has to give to the auditor all the consumption data (coming from all energy bills related to each energy flow) and all other "adjustment factors".

Such factors are applied to all those activities for which the consumption is not so easy to define precisely.

For example, dealing with a machinery in a production line, nominal power is well known. Anyway, just looking to the electricity bill gives only a whole picture. Without applying a load factor (a percentage of utilization of a machine) there would be an estimated consumption profile that will not reflect correctly the consumption. This is particularly important for all those utilities that have not a monitoring system dedicated.

In this case, without applying load factors or similar corrective factors (e.g. the efficiency of a boiler), it would be impossible to estimate correctly the consumption profile of each tool or machine consuming energy.

At this point the data analysis starts, in which the auditor applies its specific know-how to create an energy diagnosis framework.

Regarding CEC specific know-how, the whole framework is present in the annexes as *"Annex 1 – Energy Diagnosis – SKI s.r.l. Verzuolo (CN)"*.

The energy diagnosis is composed by the following sections:

- "Generalities" sheet: in this excel sheet all generalities regarding the site object of the audit are present. It includes general data about the company (name, address, ATECO code, VAT number, total income of the year, year of audit), total internal and external surface, total internal volume, number of employees, work scheduling (opening hours and operating hours).

CLIENT DATA *Consultancy by CEC s.r.l. - Luglio 2022*		
Auditing company name	Smurfit Kappa Cartiera di Verzuolo s.r.l.	
Legal address	Via Giacomo Leopardi 2 - 20123 Milano	
VAT number	11939280969	
ATECO 2007 Code	17.12.00	"Paper and paper-related production"
Revenues (2021)		Revenues at 31.12.2021
Audit Mandatory	Yes	UNI CEI EN ISO 50001:2018
Reference year for the energy diagnosis	**2021**	

SITE CHARACTERISTICS *Consultancy by CEC s.r.l. - Luglio 2022*		
Site	Via Roma 26 - 12039 Verzuolo (CN)	
Point of Delivery (POD) code	IT001E00100656	
Redelivery Point (PDR) code	36082501	
Production	67.921	m^2
Storage	33.960	m^2
Offices, laboratories and services	6.792	m^2
Technical rooms	4.528	m^2
Total INTERNAL surface	**113.201**	m^2
Loading zones and other internal areas	153.630	m^2
Green areas	2.695	m^2
Total EXTERNAL surface	**156.326**	m^2
Production	679.208	m^3
Storage	339.604	m^3
Offices, laboratories and services	67.921	m^3
Technical rooms	45.281	m^3
Total INTERNAL volume	**1.132.013**	m^3
Average working days/year	355	days/year
Operating hours (production)	24	hours/day
Operating hours (offices and laboratories)	8	hours/day
Working personell	207	people/day
Total production	**417.094**	**ton**

Figure 18 - "Generalities" sheet: "Energy diagnosis: SKI Verzuolo"

This section also includes an important subdivision of "energy uses": production, conditioning system, air flow, chiller systems, air compressed, internal lightening, external lightening, movement systems, pumping systems, ICT, various consumption, losses (production and energy losses). Such clustering is very important, especially to understand how the electrical consumption profile splits among these consumption areas. It is also important to understand criticalities and possible areas of improvement. For each "energy use", an Energy Funcitonal Area is assigned as shown in the next figure.

USE		ENERGY FUNCTIONAL AREA (EFA)	
	ILLI	General services	Internal lighting
	ILLE	General services	External lighting
	CDZ	General services	Winter/Summer climatization
	FAN	General services	Air flow systems
	CHL	Auxiliary services	Process chiller group
	ACO	Auxiliary services	Air compressed motors
	MOV	Auxiliary services	Handling and movimentation of raw material and products
	PROD	Principal activities	Production lines
	PMP	Auxiliary services	Pumping systems
	ICT	General services	Information and communication technologies
	VAR	General services	Various applications/uses
	LOSS	General services	Electric and process losses

Figure 19 - Energy Uses and Energy Functional Areas (EFA)

As ENEA states in the Energy Audit methodology, each energy use can be clustered according to the EFA where it belongs:

- "Principal activities": those activities directly contributing to the production process that would prevent the output realization if not working; (e.g.: production lines)
- "Auxiliary services": those activities that are not directly contributing to the production process, but that contributes to a correct output realization (e.g.: air compressors, chillers, handling system, pumping system, etc. …);
- "General services": those activities that give no contribute to the output realization, but that are present in the plant (e.g.: ICT, lighting, air conditioning, air flow, etc. …).

Another cluster is present in this sheet. It is about the site "areas": production, storage, offices and service, technical rooms, external area. It is important to understand which areas has highest impact on the consumption profile.

PLANT AREAS	PRODUCTION	Production area
	STORAGE	Area for stocking raw materials and products
	TECHNICAL ROOMS	Technical rooms to support production
	OFFICES AND SERVICES	Offices, Laboratories, Changing rooms, toilets
	EXTERNAL AREA	External areas

Figure 20 - Areas

This sheet also contains some "sum-up tables and figures" that comes from other sheets' results. Such tables contain information about the energy flows consumed (electricity (kWh/year), thermal energy (smc/year), etc…) and about the amount of CO_2 produced during the year.

ENERGY CONSUMPTION PROFILE *Consultancy by CEC s.r.l. - Luglio 2022*		
Reference year	2021	
Electric energy consumption	245.014.087	kWh/year
Electric energy purchased from the grid	1.336.941	kWh/year
Thermal energy consumption	1.085.148.068	kWh/year
Natural gas purchased	110.341.744	Sm3/year

Table 5 - Consumption profile

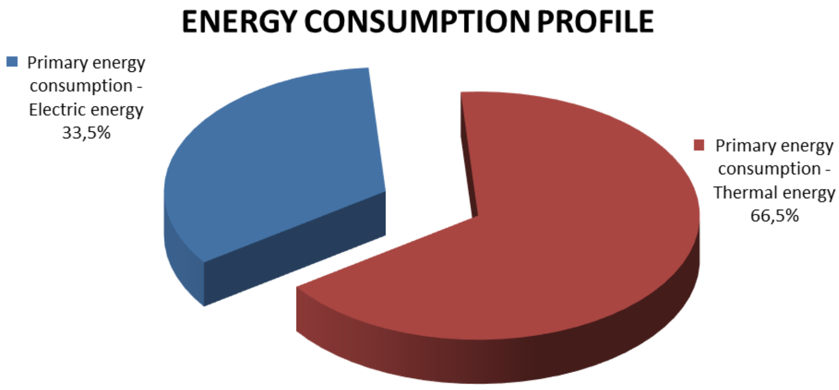

Figure 21 - Energy consumption

ENERGY COSTS PROFILE *Consultancy by CEC s.r.l. - Luglio 2022*		
Electric energy	320.866	€/year
Thermal energy	59.153.072	€/year
Total purchase	**59.473.937**	**€/year**

Table 6 - Energy costs profile

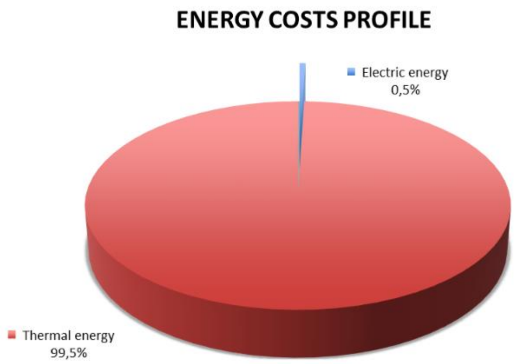

Figure 22 - Energy costs profile

PRIMARY ENERGY AND CO2 EMISSIONS *Consultancy by CEC s.r.l. - Luglio 2022*		
Electric energy consumption	882.051	GJ/year
Thermal energy consumption	3.906.533	GJ/year
Total energy consumption	**4.788.584**	**GJ/year**
Primary energy consumption - Electric energy	45.818	PET/year
Primary energy consumption - Thermal energy	91.032	PET/year
Total primary energy consumption	**136.850**	**PET/year**
CO2 emissions due to eletric energy	70.564	ton/year
CO2 emissions due to thermal energy	217.594	ton/year
Total CO2 emissions	**288.158**	**ton/year**

Table 7 - Energy flows and CO2 consumption

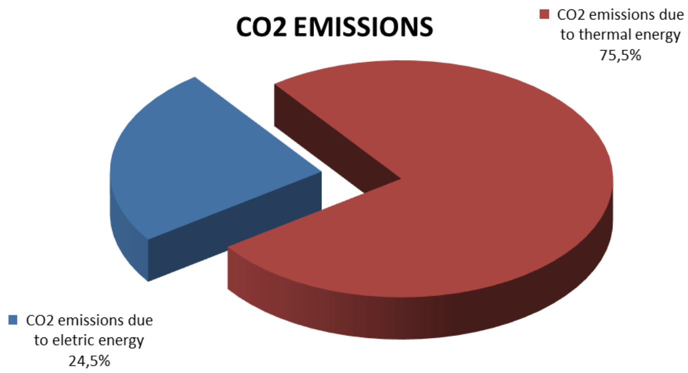

Figure 23 - CO2 emissions

- "Production" sheet: in this sheet the output production profile is present. It contains a simple graph of the production process and a table containing the monthly production rate of the site (in tons), for the accounting year (2021) and the two previous (2019 and 2020). By doing so, a graph is created, benchmarking production of the accounting year with the previous ones.

ton	2019	2020	2021
JAN	25.181	22.000	31.476
FEB	24.537	14.000	30.671
MAR	28.306	25.000	35.383
APR	25.764	30.000	32.205
MAY	29.173	24.000	36.467
JUN	27.436	15.000	34.294
JUL	27.054	22.000	33.818
AUG	30.771	27.000	38.464
SEP	27.650	30.000	34.562
OCT	29.495	33.000	36.868
NOV	28.682	34.000	35.852
DEC	29.627	31.500	37.033
TOTAL	**333.675**	**307.500**	**417.094**

Table 8 – Production

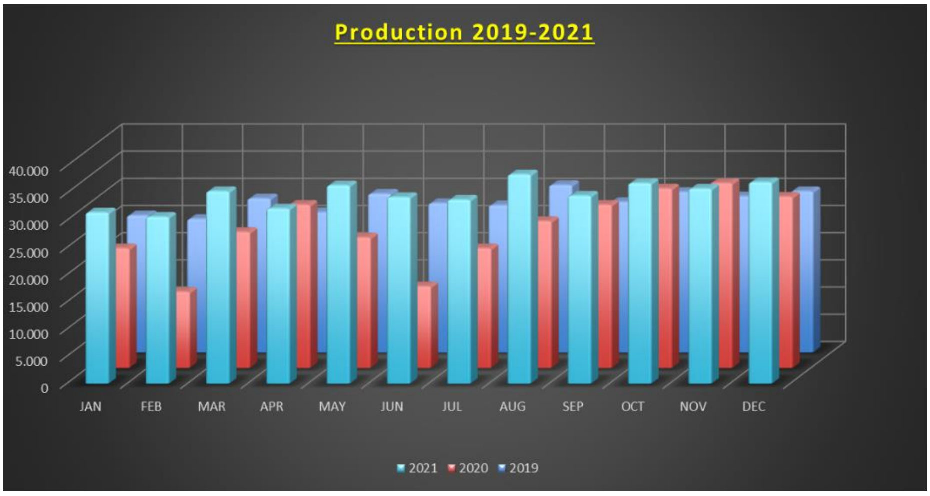

Figure 24 - Production profile

- “Electric Energy” sheet: it contains the monthly electrical energy consumption profile, coming from the energy bill of the electricity distributor. Having knowledge of the monthly energy cost, it also calculates the energy cost (€/kWh) as it follows:

$$Electric\ Energy\ Cost\ \left[\frac{€}{kWh}\right] = \frac{Energy\ Bill\ [€]}{Energy\ Consumed\ [kWh]}$$

ELECTRIC ENERGY CONSUMPTION PROFILE *Consultancy by CEC s.r.l. - Luglio 2022*	2021		
Month	energy consumed [kWh]	purchasing cost [€]	energy cost [€/kWh]
January	19.729.969	73.922	0,240
February	18.638.111	110	0,240
March	21.599.639	0	0,240
April	19.209.601	68.296	0,240
May	21.490.087	23.290	0,240
June	19.928.020	0	0,240
July	19.991.210	70.904	0,240
August	22.154.011	0	0,240
September	20.117.938	0	0,240
October	20.990.930	0	0,240
November	20.379.822	84.345	0,240
December	20.784.748	0	0,240
TOTAL	**245.014.087**	**320.866**	**0,240**

Table 9 - Energy consumed and energy cost

Also, electric consumption of each month is synthetized into a graph, according to the energy source (from grid or self-produced (both from photovoltaics or CHP).

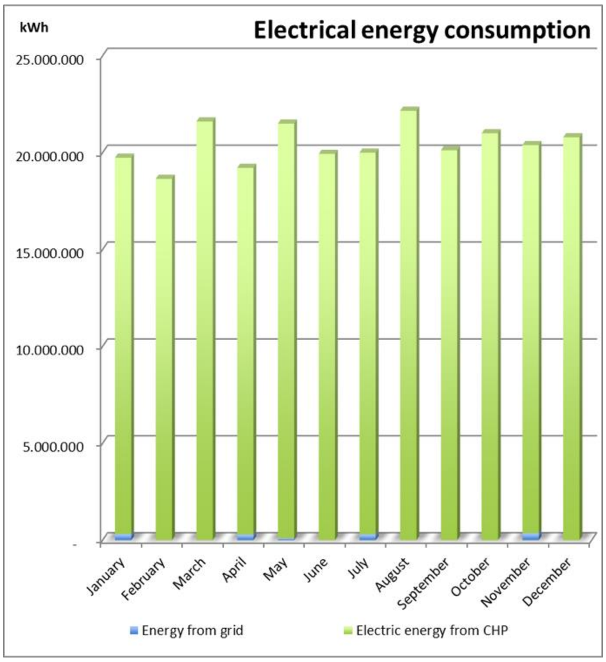

Table 10 - Electric energy consumption profile

This section also contains information about other the electric energy consumption profile. Starting from electricity bills, it is possible to estimate the maximum, minimum and average power consumed.

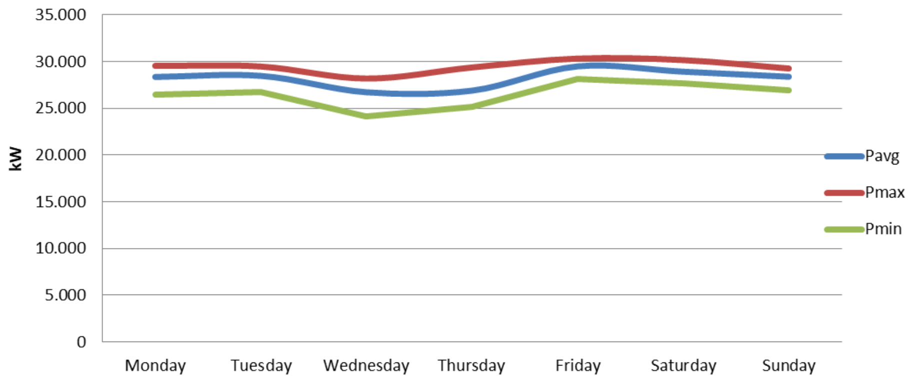

Figure 25 - Consumption profile

It is also possible to estimate the weekly electricity consumption profile, using an average consumption of the day of the week during the whole year.

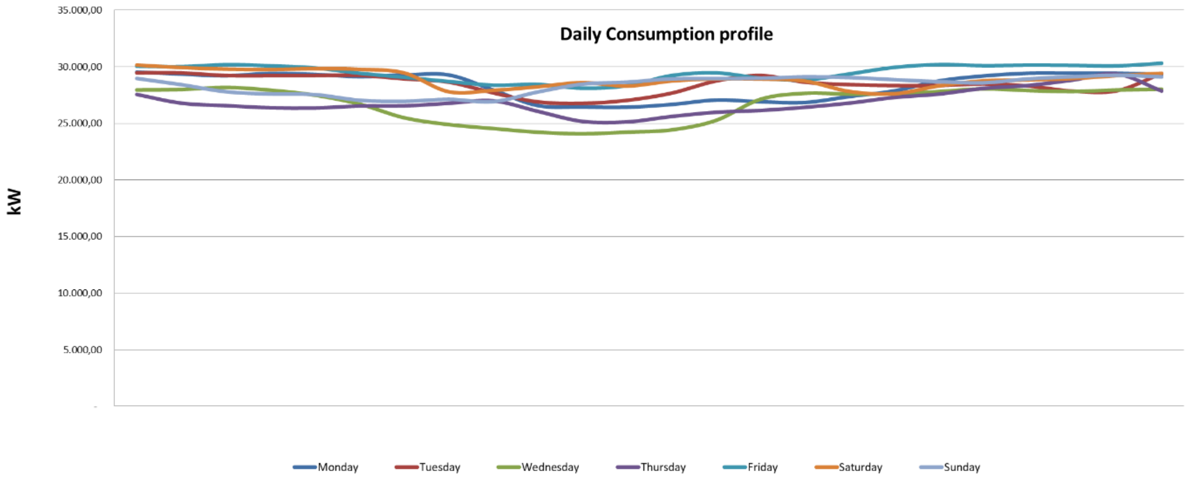

Figure 26 – Daily consumption profile

- “Thermal Energy” sheet: this excel sheet is very similar to the previous one. Indeed, it calculates the amount of methane consumed starting from the natural gas bills. Having knowledge of the thermal energy cost, it also calculate the unitary cost as it follows:

$$Thermal\ Energy\ Cost\ \left[\frac{€}{smc}\right] = \frac{Energy\ Bill\ [€]}{Energy\ Consumed\ [smc]}$$

It is important to keep in mind that natural gas is consumed in the Verzuolo plant only for CHP energy production. Therefore, methane is burned to let the two turbo-gas turbines, the post-combustors, and the bark boiler work.

NATURAL GAS CONSUMPTION PROFILE *Consultancy by CEC s.r.l. - Luglio 2022*			
	2021		
Month	Natural gas [Sm3]	Purchasing cost [€]	Energy cost [€/Sm3]
January	9.507.300	2.425.330	0,255
February	9.056.400	2.158.114	0,238
March	9.889.472	2.350.145	0,238
April	8.871.787	2.357.695	0,266
May	9.528.581	2.923.696	0,307
June	8.943.504	3.036.512	0,340
July	8.868.574	3.776.606	0,426
August	9.091.066	4.541.631	0,500
September	8.695.254	6.225.647	0,716
October	9.079.479	8.760.631	0,965
November	8.911.565	8.097.587	0,909
December	9.898.762	12.499.480	1,263
TOTAL	**110.341.744**	**59.153.072**	**0,536**

Table 11 - Natural gas consumption (smc) and cost (€/smc)

As shown in the previous table, the whole amount of methane burned accounts for 110.341.744 smc.

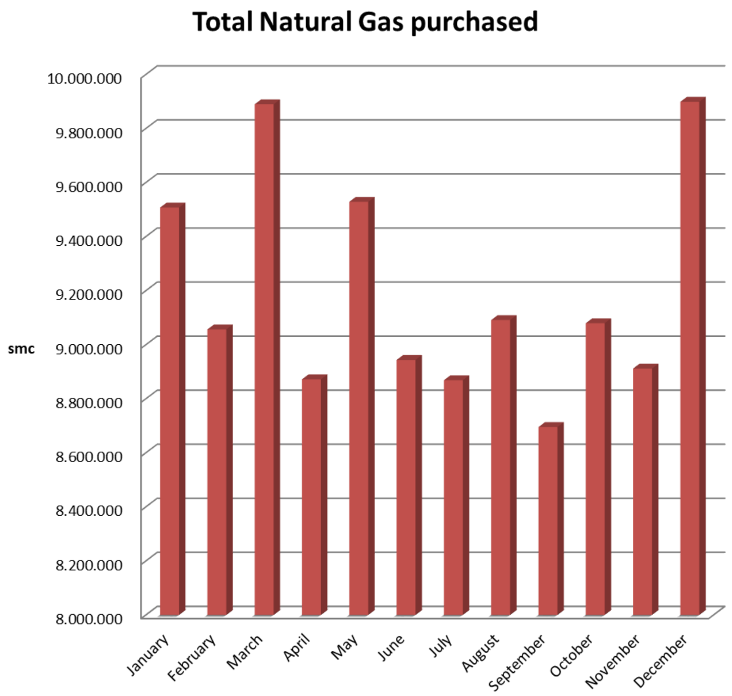

Figure 27 - Natural gas consumption profile (smc)

By appling a conversion factor (1 smc = 9,593 kWht), it is possible to estimate the natural gas consumption of the site in kWht.

NATURAL GAS CONSUMPTION PROFILE *Consultancy by CEC s.r.l. - Luglio 2022*	2021		
Month	Thermal energy [kWh]	Purchasing cost [€]	Energy cost [€/kWh]
January	93.498.869	2.425.330	0,0259
February	89.064.524	2.158.114	0,0242
March	97.257.312	2.350.145	0,0242
April	87.248.961	2.357.695	0,0270
May	93.708.155	2.923.696	0,0312
June	87.954.257	3.036.512	0,0345
July	87.217.363	3.776.606	0,0433
August	89.405.445	4.541.631	0,0508
September	85.512.860	6.225.647	0,0728
October	89.291.493	8.760.631	0,0981
November	87.640.155	8.097.587	0,0924
December	97.348.674	12.499.480	0,1284
TOTAL	**1.085.148.068**	**59.153.072**	**0,05**

Table 12 - Natural gas consumption (kWht) and cost (€/kWh)

As shown in Table 11, the total amount of methane burned accounts for 1.085.148.068 kWht (1.085,148 MWht).

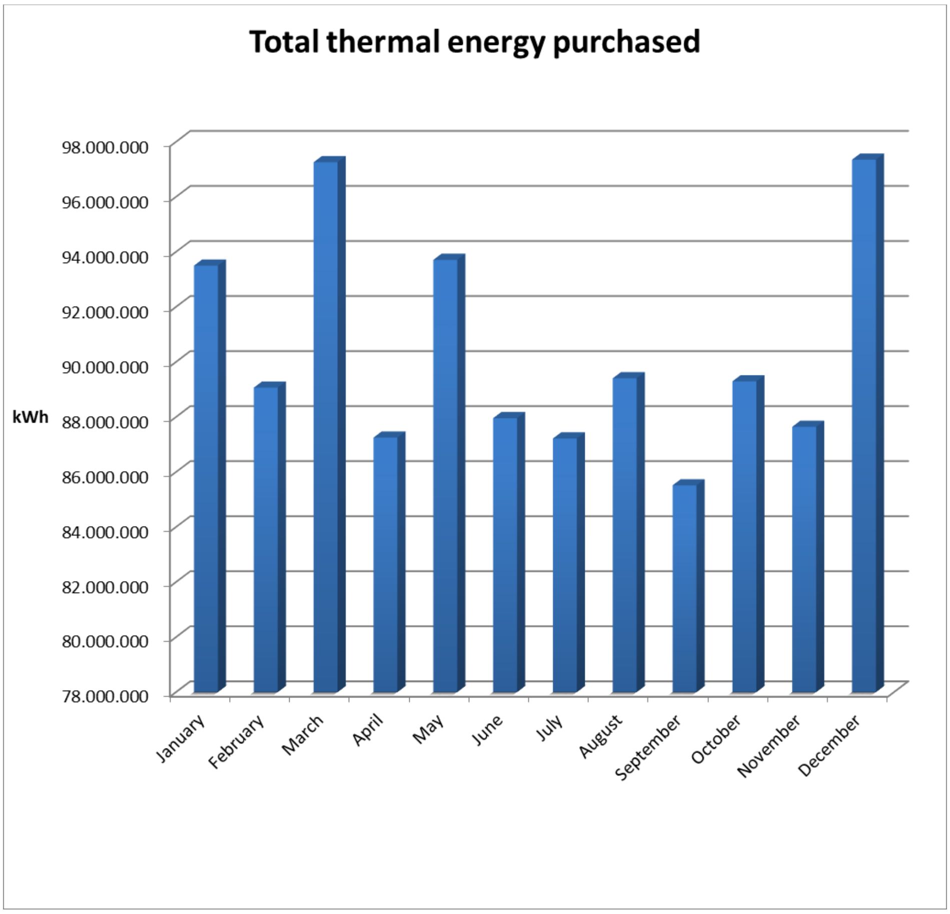

Figure 28 - Natural gas consumption profile (kWh)

Once concluded energy data collection, the energy analysis focuses on the estimation of the theoretical electrical and thermal consumption.

This section is indicated in Figure 12 (Energy audit methodology) as "Development of the energy balance".

- "Electrical energy model": it contains a list of all electrical energy machines and tools that consumes electricity.
  For each item listed, a yearly annual consumption is estimated (kWh). By summing them, the total amount of electricity should reflect the total amount of the "Electrical energy" sheet. This is one of the most important part of the analysis, and will be deeply analysed in the following chapter.
- "Thermal energy model": it contains the framework to calculate the amount of natural gas consumed in order to produce thermal energy.
  This sheet of the excel file will be better analysed in the following chapter too.

Once these models are finished, "Sankey" sheet is filled.

Sankey is a graphical representation of the energy flow inside the organization.

Starting from all energy sources, it splits graphically all the energy flows.

They can not be drawn without knowing in which area the energy will be consumed.

That is the reason why they are done after the "electrical" and "thermal model".

There are three different typologies of Sankey: (taken from: *"Annex 1 – Energy Diagnosis SKI s.r.l – Verzuolo (CN).docx", "Sankeys" sheet*)

- Energy flow in %;
- Energy flow in PET;
- Energy flow in MWh.

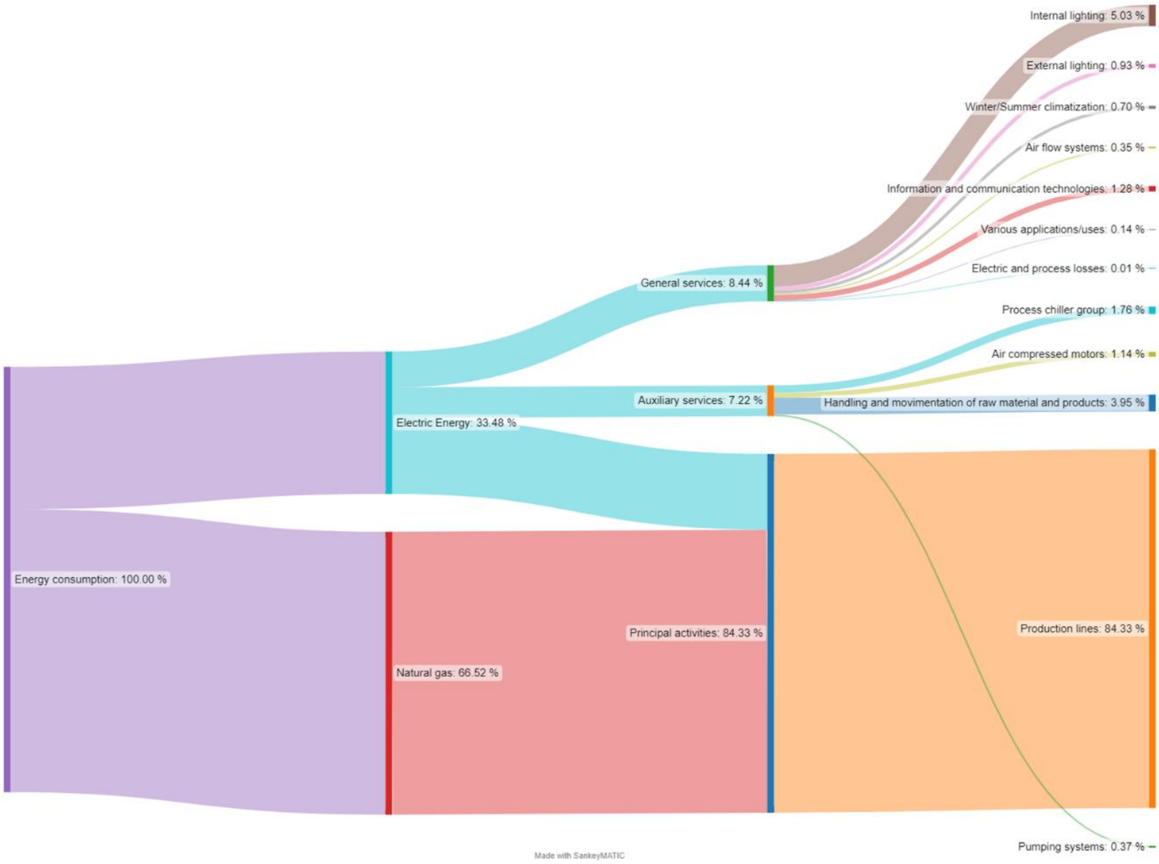

Figure 29 - Energy flows in %

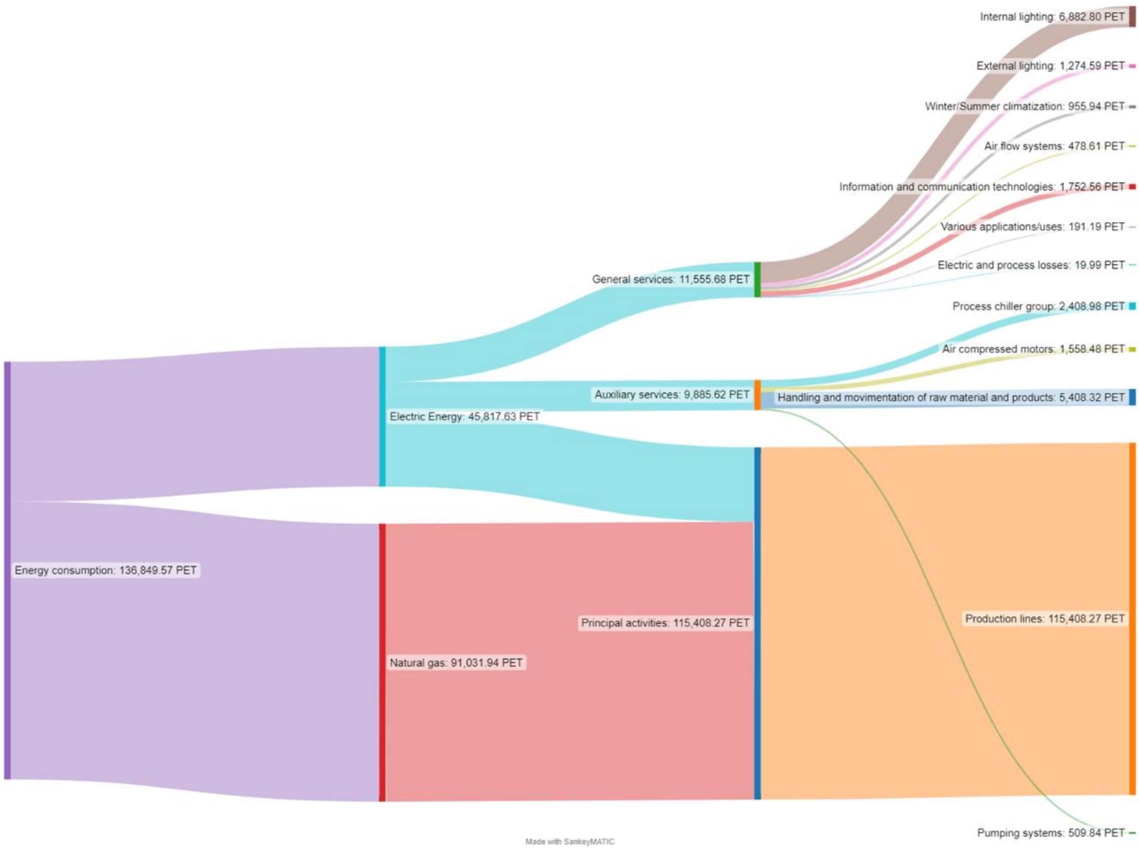

Figure 30 - Energy flows in PET

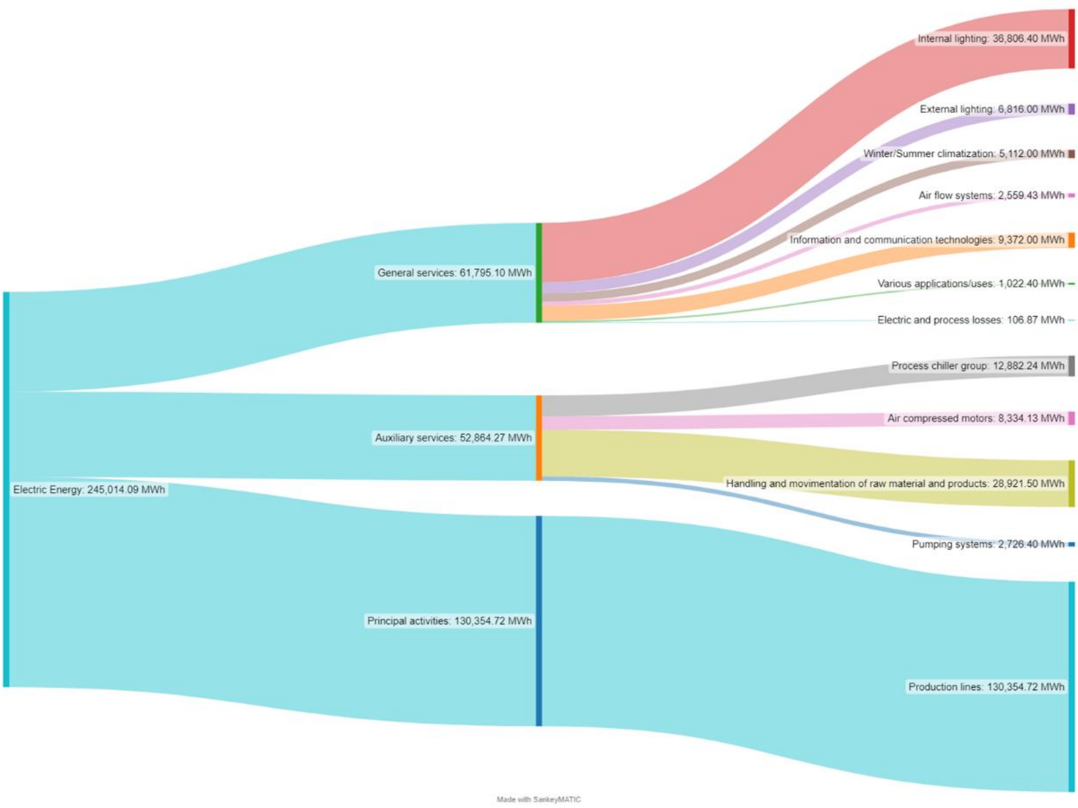

Figure 31 - Energy flows in MWh

As shown in figure 18 (Energy audit metholodogy), the following steps of the energy audit are:

- Calculation of the theoretical EnPIs;
- Calculation of the effective EnPIs.

The difference between the two is given by the difference between theoretical and real consumption profile.

Once adjusting the theoretical profile through load factors or adjustment factors (see chapter 3.3.4 and 3.3.5.), the theoretical model should be reflecting the real consumption profile, making EnPIs comparable.

If this would not happen, the framework suggests to step back to the data analysis.

By doing so, the auditor should work again on load factors or adjustment factors in order to make the EnPIs relevant for the analysis. (EnPIs for the Verzuolo site are analysed deeply in chapter 3.3.6)

Once EnPIs are adjusted, they have to be compared to the reference EnB (according to the ATECO code).

If the two are not comparable, EnPIs must be modified through some conversion factors (e.g., kWh in PET).

Once they have the same unit of measure, they should be comparable.

Doing such benchmarking, ENEA suggests some acceptable thresholds for the specific EnPI, according to the consumption profile of the company.

If some EnPI is not satisfying the EnB threshold, some improvement actions must be considered.

Even if the energy analysis has a section of possible interventions to improve the energy efficiency (with an economic analysis included), some interventions can be postponed. In fact, if an EnPI reflects good energy performance compared to the EnB, such interventions are not obliged in the short-term.

Instead, if an EnPI reflects bad energy performance, such interventions must be done in the following years (see chapter 3.3.9.).

The analysis of each intervention must include:

- A description of the intervention;
- The total cost for the intervention;

$$Total\ cost\ of\ intervention\ [€] = Purchasing\ cost\ [€] + Manufacturing\ cost\ [€]$$

- The energy savings (electricity or thermal energy), both in kWh and PET;

- The economic savings (due to less energy consumption) in €/year;
- The O&M (Operation and Maintenance) savings (due to less frequent and less costly maintenance) in €/year;
- The CO_2 avoided (comparing CO_2 consumption before and after the intervention) in tons/year;
- A PBT analysis (simple PBT);

$$PBT\ simple\ [years] = \frac{Total\ cost\ of\ the\ intervention\ [€]}{Economic\ savings\ \left[\frac{€}{year}\right] + O\&M\ savings\ \left[\frac{€}{year}\right]}$$

INTERVENTION FOR ENERGY CONSUMPTION REDUCTION - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*										
INTERVENTION CHARACTERISTICS		*INVESTMENT*	SAVINGS (Incentives excluded)				ECONOMIC RETURN	*EMISSIONS*	*COMPLEXITY*
DESCRIPTION		*TOTAL [€]*	ECONOMIC [€/year]	ELECTRIC ENERGY [MWh/year]	THERMAL ENERGY [Sm^3/year]	*PRIMARY ENERGY [PET/year]*	PBT SIMPLE	*CO2 avoided [t/year]*	*Indice 1-5*
1	NEW MACHINES FOR CONTINUOUS LINE PM9	9.600.000	1.199.200	2.997,01	-	560	8,00	1.303,70	5
2	NEW LAYOUT OF CHP PLANT	2.600.000	7.030.900	1.940,04	11.034.174	9.466	0,37	21.996,43	4
TOTAL		**12.200.000**	**8.230.100**	**4.937**	**11.034.174**	**10.026**	---	**23.300**	---

Table 13 - Interventions

To make the economic analysis relevant, CEC includes also a NPV analysis to calculate both the real PBT and the real economic value of the intervention.

NPV is calculated with the Excel formula:

$$+NPV(Discount\ Rate; sum\ of\ all\ Cash\ flows\ from\ year\ 0)$$

(The whole framework is included in *"Annex 1 – Energy Diagnosis – SKI s.r.l. Verzuolo (CN)"*, in the "*Economic Analysis*" sheet).

Once the needed interventions are analysed, if all EnPIs post-intervention are in line with the EnB, the auditor sends an "Audit Report" to the auditing company.

Once sent to the client, a final meeting occurs, in which the auditor and the auditing discuss about the prioritization of the fore mentioned interventions.

Once the final meeting is over, the audit phase is concluded.

3.3. UNI CEI EN ISO 50001 in SKI s.r.l. - Verzuolo

Trying to certify UNI CEI EN ISO 50001 requires some further steps compared to the Energy Audit methodology (figure 18).
Indeed, it requires to define the energy context, leadership commitment and responsibilities.
An energy policy has to be defined and has to be reflected by EnPIs and by the related interventions.
Energy goals, risks and opportunities must be shared in the organisation and must be reflected by EnPIs and interventions.
The energy analysis should focus mainly on the electrical and thermal model.
In order to align theoretical and real EnPIs, it is not enough to look at energy bills (as stated by the energy audit methodology).
Being mandatory to have a monitoring system, the auditing company must provide data coming from the monitoring system.
If they reflect the energy bill, it means that the monitoring system is well-working. Otherwise, there can be two issues:

- Monitoring system is not monitoring all energy flows;
- Monitoring system is not working well.

Especially in large plants, monitoring systems are dedicated mostly to the production. All other energy flows (heating, lighting, handling… etc.) are often estimated. Anyway, it is unusual that the monitoring system does not work properly.
Once theoretical and real consumption are in line, EnPIs are calculated.
Comparing them with an EnB, SEUs are identified.
A Gap analysis (R^2 significant model) is done to understand if SEUs are identified correctly.
Then, EnPIs are compared to the reference EnB.
If they are not in line, improvement actions and energy efficiency interventions are suggested to the auditing company.
A re-assessment from the top management occurs, and the auditor has the role of a consultant, suggesting them a prioritization of interventions.
Once all steps are done, a certification body verifies that there are no conformities in:

- The procedures adopted by the auditing company (must be in line with UNI CEI EN ISO 50001);
- The results of the energy audit (all EnPI must be in line with the EnB).

If there are no conformities, the UNI CEI EN ISO 50001 is issued to the certifying (auditing) company.

3.3.1. Context, leadership and responsibilities

Defining an energy context is very important in the "Plan" phase.

It helps determining what to monitor to achieve the UNI CEI EN ISO 50001 certification.

In the Verzuolo case, the whole plant is considered. In order to simplify the model, the energy context clusters all the different section of the plant according to the "area" mentioned in the Energy audit methodology (chapter 3.2.2.):

- "Production": it considers all the plant sections dedicated to production. Machines are clustered according to how they are going to be monitored. Even though in the "electric model" most of machines' consumption is estimated, their sum should be equal to the monitoring value of the production line. Indeed, production has five different production lines: (names are taken from the monitoring platform)
  - "1.1.2. OCC Pulp preparation": all machines dedicated to the pulp formation;
  - "1.1.3. Continuous production line - PM9": all machines dedicated to the recycled paper roll production;
  - "1.1.4. Final product activities - Line 9": All final operations like cutting, rolling, colouring and stocking of the paper rolls;
  - "1.2.2. Air Compressors": other air-compressed motors (some of them are monitored in "macchina continua PM9" and "lavorazioni finali linea 9", because they contribute to these processes);
  - "1.2.4. Water Depuration": all water depuration machines;
  - "1.2.5. Muds dehydration": all machines that dry pulp wastes to create biomass to be burned in the bark boiler;
  - "1.2.6. Reject Handling": all machines dedicated for handling and moving the WIP from pulp generation to continuos machine or to biomass generation;
  - "1.3.2. Internal lighting and industrial facility": all lighting systems present in the whole plant and other industrial facility monitored consumption.
- "Storage": it includes all areas for stocking raw materials, WIP or finished products;
- "Technical rooms": all rooms that contains machines that support production, but not included in "Production" area;
- "Offices and services": offices, laboratories, changing rooms, toilets, dining room… etc.

- “External area”: all areas included in the energy context that are external to the plant.

These four areas include most of the “2.1. Other energy uses”, which are listed in the “Electric energy model”.

Defining an energy context means also to identify all problems that are misaligned with:

- Relevant internal and external aspects influencing the expected results of its EMS;
- Relevant needs and expectations of stakeholders.

In order to define them, the COO of Verzuolo developed a table in collaboration with CEC s.r.l. according to ENEA guidelines (Tables 12, 13, 14) (taken from “*Annex 3 - Energy context.docx*”)

1. **External aspects:**

Potential issues	**Relevant details for the organization**
Misalignment between stakeholders’ interests and national or industry objectives, requirements or normative.	The sustainability strategy of producing recycled paper and recovering raw materials and energy from wastes is perfectly in line with the European Agenda 2030 and the Italian energy and environmental policies.
Restrictions of energy supply, security and trustworthiness	Since energy is self-produced in the plant, there is no risk of lack of energy supply.
Energy costs or different energy sources availability	Since energy is self-produced in the plant, a strong increase in natural gas price (input for bark boiler and turbines) is the only risk.
Time effects	The top management wants to keep the same core business with the same activities. A strong change in clients’ requirements could be an issue. Different operations may require a different energy profile.
Climate change effects	They would not directly affect both the power plant and the production site.

Effects on GHG' emissions	The pollution generated from the turbines could be an issue if CO2 emissions must be reduced.
Any other issues	

Table 14 – External aspects influencing the expected results of an EMS

2. Internal aspects:

Potential issues	**Relevant details for the organization**
Objectives and Core business strategy	The core business strategy to sell mostly in northern Europe (due to higher revenues) and the sustainability strategy of the organization are in line with the requirements of the ISO 50001 certification.
Investments and Budget plan	The group has no intention to invest in other sites, but to improve the machinery to reduce energy consumptions and pollution. Such investments are the ones needed to achieve the ISO 50001 certification.
Financial or working resources	The organisation has availability of capital, but few human resources to be allocated. Some extra-effort is requested to some responsible and there is a budget allocated for energy consultancy to help the energy management team.
Energy management, maturity and culture	Dealing with power and heat production, the plant has deep experience in energy management. The "power plant department" is working on the plant since many years. The company culture has shifted to energy efficiency topics since the "natural paper" production has been closed.
Sustainability issues	There are no sustainability pressures related to the company objectives.

Contingency plans for energy supply interruption	There is no risk due to self-production of energy. In case the power plant has to do maintenance, the organisation would directly take HV electricity from the grid.
Maturity of the technology used	The main production line of the site has been modernized in recent years. There is no risk of technology obsolescence.
Operationational risks and considerations	There are no operational risks linked to the implementation of an EMS or due to its management. Personnel in charge of the production line are not dedicated to energy management.
Any other issue	

Table 15 – Internal aspects influencing the expected results of an EMS

3. Stakeholders' needs and expectations:

Stakeholders	**Needs**	**Expectations**
Governative departments (Energy / Environment / Forests / Renewable energy, ecc.)	Reducing CO2 emissions, circular economy, industry 4.0	Verzuolo site should be in line with these targets (certified ISO 14001)
Personnell	Safety and quality of jobs	Verzuolo site should be in line with these targets (certified ISO 9001)
Owners	Increase of market shares and sustainability of production	Verzuolo site should be in line with these targets (according to market results)
Suppliers and tools' owner (products, machine or services for the plant)	No needs. There is no leasing of machines, they are fully owned by the company	No expectations. There is no leasing of machines, they are fully owned by the company
Electric energy suppliers (Terna)	Constant energy supply	Constant energy supply. Monthly prevision of energy need.

Fossil fuel suppliers (Snam)	Constant energy supply. If not possible, a monthly prevision of the supply.	Variations according to the TG2 activation (Capacity market)
Environmental associations	Keep producing paper from wastes and applying circular economy	Keep producing paper from wastes and applying circular economy
Any other stakeholder		

Table 16 – Needs and expectations of stakeholders

As mentioned in chapter 1.3.1., leadership and commitment on energy topics is essential to achieve an effective implementation of the EMS.

To show such leadership on the personnel, Smurfit Kappa Italia must define an Energy Management Team (EMT).

In defining the EMT, the company assigns some specific responsibilities.

The following table shows the personnel belonging to the EMT, but the full name of the resource is not shown for privacy issues (e.g., "Mario Rossi" is shown as "M.T.").

Resource name	**SKI role**	**EMT role**	**Responsibilities in the EMT**
T. G.	COO	Energy Team Leader	• Responsible of all energy management activities • Coordinator • Communication to all other members
D. O.	Facility Manager	Energy Manager	• Monitoring responsible • Lines efficiency responsible
A. C.	Top management	Communication and information manager	• Informed of all energy management activities • Communication with top management

L. B.	Production Line PM9 supervisor	Team member	• Monitoring of PM9 line • Line PM9 efficiency controller
M. A.	Pulp formation supervisor	Team member	• Monitoring of pulp formation • Pulp formation efficiency controller
T. C.	Power plant manager	Team member	• Monitoring of combined heat and power (CHP) plant • Capacity market management
P. B.	Cutting and stocking supervisor	Team member	• Monitoring of final product activities • Quality controller and line efficiency controller
N.C.	External consultant (Collarini Energy Consulting s.r.l.)	Consultant and Energy Manager	• Energy supply management • Energy contracts management • Capacity market consultant • Energy auditor • EMS management (monitoring consultancy) • UNI CEI EN ISO 50001 certification consultant

Table 17 - Energy Management Team roles and responsibilities

Looking at Table 15, it is possible to understand the organization chart of the energy Team.
The monitoring of consumption and the control of process efficiency are assigned to the specific process supervisor (Pulp formation, production line, final product activities and power plant). These resources have to report directly to the facility manager, that assumes the role of the energy manager in the EMT.
He has to be informed of any monitoring activity; both on the procedures applied and on the results (especially if there are some measurement issues).
He is also in charge of keeping the production process the more efficient as possible (low time-to-product and high production rate).
He has also to elaborate such data and report them to the energy team leader.

The team leader is in charge of communicating to the other team members mentioned before which activities have to be done. He also has to provide a scheduling of the energy activities to execute, while the energy manager is in charge of their results.
Therefore, the team leader has an important role of coordination between all the energy team resources.
He is the ultimate responsible for energy efficiency and monitoring activities.
For these reasons, he directly communicates with the top manager belonging to the team, which must be informed of the EMS results. He has the role of communication and information manager, because he must communicate results to the top management (bottom-up), while communicating also on the other side the activities to do (top-down).
The last member is external to the company but has a crucial role in the team.
Usually most of companies adopting an EMS directly manage these activities internally, but it requires investments in training or in hiring new resource with energy management competences.
CEC s.r.l. manages energy supply contracts and energy audits (as auditor) since more than ten years. For this reason, SKI s.r.l. decided to enlarge the consultancy activities integrating Eng. N.C. inside the team.
This resource is now in charge of consultancy concerning the monitoring performance and the Capacity market management, evaluating how the monitoring platform is working (and if can be improved) and how the power plant is working (so if when it is convenient to produce CHP).
Lastly, he has to ensure that the company is able to achieve the UNI CEI EN ISO 50001 certification, suggesting procedures to follow and resources to assign to each energy management or monitoring activity.
If any resource has no sufficient know-how to do the fore mentioned tasks, the organisation has to schedule training sessions for the specific resource.
Documentation regarding trainings (data, time, employees, topics) must be carefully kept in a database, accessible for the team leader and the top management.
In the Verzuolo case, no training sessions have been scheduled due to a strong know-how in the production lines management.

3.3.2. The energy policy and energy goals

Defining an energy policy is another essential point in the "Plan" phase, which is fundamental to achieve an efficient EMS implementation.

The energy policy must align with the company strategic goals.

Looking at SKI s.r.l. energy context (chapter 3.3.1.), the strategic goals of the company seems to be completely in line with the energy efficiency aim of UNI CEI EN ISO 50001.

Indeed, the organization focuses strongly on sustainability, industry 4.0, circular economy and waste management. They also self-produce their energy while contributing to supply HV electricity to the grid.

This is a first important key-point: SKI s.r.l. decides to commit on EMS because it is perfectly in line with the company goals.

In many cases, organization fails in achieving the certification because of a company culture that does not focus on energy efficiency management.

However, often because the company has no strategic goals regarding energy objectives.

Therefore, an energy policy reflecting purposes of UNI CEI EN ISO 50001 is impossible to apply. Consequently, energy goals often fails.

Moving on, there are some steps to follow to define an energy policy.

For each department or function involved (in SKI s.r.l.: Pulp formation, production line, final product activities, power plant, energy supply), the organisation must declare:

- One or more energy goals;
- "What" to do to achieve each energy goal;
- "Who" is in charge of doing each activity (team members or consulant);
- "Who" is responsible for such activity (energy manager or team leader);
- "When" activities are executed and when they are supposed to end;
- "How" results are measured (declaring also EnPI related);
- "How" activities to reach an energy goal are matching with company operations.

Before discussing specific energy goals, the energy team has to consider directives coming from top management, especially regarding its energy strategy (top-down):

- Sustainability strategy: production from wastes and biomass recovery and heat production from biomass;
- Energy efficiency: reduce energy consumption per unit produced;

- Product quality: save energy by reducing number of scraps (therefore reducing utilization of machines);
- CHP plant: maximize self-production and maximize revenues participating to the capacity market.

After several meetings between the energy team leader, the energy manager, the information and communication manager, and the consultant, the energy policy and all the goals for each function are designed.

The following tables shows each energy goal in the five departments/functions considered. (taken from "*Annex 3 - Energy Policy and EMS.docx")*

1. Department/Function: Pulp formation and biomass generation (drying production muds)

#ID	**Energy Goal**	**"What" to do**	**"Who": resources**	**"Who": responsible**	**"When": end of activity**	**"How" to evaluate results (EnPI)**	**How EM activities integrates with company operations**
G1	Minimize consumption from "cleaning process"	Control and increase efficiency of the "cleaning process"	Pulp formation supervisor (Team member)	• Facility manager (energy manager) • COO (team leader)	• Monthly report • End of the year (EnPI evaluation)	kWh (pulp formation) / tons output	• Daily monitoring of consumption • Monthly reporting
G2	Minimize consumption from "muds' drying" process	Control and increase efficiency of the "drying process"	• Pulp formation supervisor (Team member) • Facility manager (energy manager)	• Facility manager (energy manager) • COO (team leader)	• Monthly report • End of the year (EnPI evaluation)	kWh (drying process)	• Daily monitoring of consumption • Monthly reporting

Table 18 - Pulp formation and biomass generation's energy goals

2. Department/Function: Production line PM9

#ID	Energy Goal	"What" to do	"Who": resources	"Who": responsible	"When": end of activity	"How" to evaluate results (EnPI)	How EM activities integrates with company operations
G3	Minimize consumption from "PM9"	Control and increase efficiency of the "line PM9"	• Line PM9 supervisor (Team member) • Facility manager (energy manager)	• Facility manager (energy manager) • COO (team leader)	• Monthly report • End of the year (EnPI evaluation)	kWh (line PM9) / tons output	• Daily monitoring of consumption • Monthly reporting

Table 19 - Production line PM9's energy goals

3. Department/Function: Final product activities (colouring, cutting and stocking)

#ID	Energy Goal	"What" to do	"Who": resources	"Who": responsible	"When": end of activity	"How" to evaluate results (EnPI)	How EM activities integrates with company operations
G4	Minimize consumption from "final production"	Control and increase efficiency of "colouring, cutting and stocking"	• Final production line supervisor (Team member) • Facility manager (energy manager)	• Facility manager (energy manager) • COO (team leader)	• Monthly report • End of the year (EnPI evaluation)	kWh (final production) / tons output	• Daily monitoring of consumption • Monthly reporting

Table 20 - Final product activities' energy goals

4. Department/Function: Power plant (CHP) management

#ID	Energy Goal	"What" to do	"Who": resources	"Who": responsible	"When": end of activity	"How" to evaluate results (EnPI)	How EM activities integrates with company operations
G5	Maximize heat production from turbines	Monitoring efficiency of CHP cycle (turbogas, post-burners, turbines)	• Power plant manager (team member) • Facility manager (energy manager)	COO (team leader)	Monthly report	kWht produced / smc of natural gas burned	• Daily monitoring of heat generation • Monthly reporting
G6	Maximize electricity production from turbines	Monitoring efficiency of electricity generation (turbines)	• Power plant manager (team member) • Facility manager (energy manager)	COO (team leader)	Monthly report	kWhe produced / smc of natural gas burned	• Daily monitoring of electricity generation • Monthly reporting
G7	Maximize heat production from Biomass	Monitoring efficiency of bark boiler	• Power plant manager (team member) • Facility manager (energy manager)	COO (team leader)	Monthly report	kWht produced / smc of natural gas burned	• Daily monitoring of heat generation • Monthly reporting

Table 21 - Power plant (CHP) management's energy goals

5. Department/Function: Energy supply and capacity market management

#ID	Energy Goal	"What" to do	"Who": resources	"Who": responsible	"When": end of activity	"How" to evaluate results (EnPI)	How EM activities integrates with company operations
G8	Minimize cost of heat produced from turbines	Minimizing cost of natural gas supply	• Consultant and energy manager (external consultant) • Power plant manager (team member)	COO (team leader)	Monthly report	• €/ smc of natural gas burned • € / kWht generated	• Monthly monitoring of costs and reporting • Energy trading activities
G9	Minimize cost of electricity produced from turbines	• Minimizing cost of natural gas supply • Increasing efficiency of turbines	• Consultant and energy manager (external consultant) • Power plant manager (team member)	COO (team leader)	Monthly report	• € / kWht used • € / kWhe generated	• Monthly monitoring of costs and reporting • Energy trading activities
G10	Minimize unitary cost of heat produced from biomass	Minimizing cost of natural gas supply	• Power plant manager (team member) Facility manager (energy manager)	COO (team leader)	Monthly report	• €/ smc of natural gas burned • € / kWht generated	• Monthly monitoring of costs and reporting • Energy trading activities

Table 22 - Energy supply and capacity market management's energy goals

By putting together all energy goals for each department, it is possible to define a proper energy policy (considering also the strategic goals of the company):

- Minimize consumption of production machines by controlling and increasing process and energy efficiency (monitoring daily, reporting monthly, and evaluating EnPI yearly);
- Maximize production of heat and electricity (with daily monitoring and monthly reporting)
- Minimize cost of natural gas supply (with monthly reporting and energy trading);

Due to the purposes of achieving the UNI CEI EN ISO 50001 certification, maximizing production of heat and electricity and minimizing cost of natural gas supply are not considered in the EnPI calculation. There is lack of an EnB referred to energy production, which is controlled by Terna instead (also through the Capacity market).
Therefore, CHP's EnPIs have no meaning for the certification purposes, while they are interesting to monitor both for Terna and for the plant efficiency itself.
Minimizing consumption of production machines become the ultimate and most important goal for each production department.
The organization calculates their EnPIs yearly and benchmarks them with the reference EnB.

3.3.3. Energy risks and opportunities

The next step of the "Plan" phase regards the identification of energy risks and opportunities. (see "*Annex 5 – Risks and opportunities assessment.docx")*
The energy risks identification follows a risk management approach, adapted to the energy field. Indeed, the organisation identifies a Probability-Impact (PI) matrix that contains:

- The risk description;
- The probability of occurrence (P) of the risk;
- The impact (I) if the risk occurs;
- The level of control (C), which means how to control the risk;
- Legal requirements (L), which means if it is required by law to do some actions linked to the risk;
- The risk management style, which means how to face the risk;
- The mitigation plan in order to reduce the potential impact of the risk;
- The responsible for each risk management style or mitigation plan;

In order to assign a correct weight to probability of occurrence, impact, level of control, and legal requirements, the organisation defined a score guideline:

Value	Probability of occurence (P)	Impact (I)	Level of control (C)	Legal requirements (L)
1	Very unlikely (0-5%)	Low impact on costs, performance and planning	Control avoidable by taking risk mitigation actions	No legal requirements
2	Less likely (5-25%)	Medium impact on costs, performance and planning	Easily controllable by taking risk mitigation actions	
3	Good probability (25-60%)	Valuable impact	Hard to control by taking risk mitigation actions	
4	High probability (60-80%)	Strong impact	Almost impossible to control by taking risk mitigation actions	
5	Almost real (>80%)	Very strong impact (failure)	Uncontrollable with risk mitigation actions	Legal requirements

Table 23 - Score guidelines for risk assessment

There are different risk management styles applicable for each risk identified:

(a) Risk avoidance;

(b) Risk seeking (chasing opportunities);

(c) Risk source elimination;

(d) Probability of occurrence reduction;

(e) Impact reduction;

(f) Risk sharing;

(g) Keep the risk (people informed).

Before commenting each risk identified, it is necessary to show the whole PI matrix:

ID	**Risk description**	**Probability of occurrence (P)**	**Impact (I)**	**Level of Control (C)**	**Legal requirements (L)**	**Risk management style**	**Mitigation Plan**	**Responsible**
R1	Natural gas price increase	4	4	3	0	(g)	Sign a fixed price contract	COO (Team leader) and Energy Consultant
R2	Electric energy request reduction for the Capacity market	2	3	3	5	(f)	Ask Terna to guarantee a minimum for yearly energy production	COO (Team leader) and Energy Consultant
R3	Clients requiring energy production or consumption from renewable sources	2	5	5	0	(d, c)	Avoid clients with such requirements or change the supply chain downstream	COO (Team leader)
R4	Insufficient energy management know-how	3	2	2	0	(b)	Train resources or hire new ones with know-how	COO (Team leader) and Facility manager (Energy manager)
R5	Difficulties of integration between EMS practices and operations	2	4	1	0	(c)	Find solutions to eliminate integration issues	COO (Team leader) and Facility manager (Energy manager)
R6	Cultural issues in applying EMS practices	1	2	2	0	(c)	Invest in training to eliminate cultural misalignment	COO (Team leader) and Facility manager (Energy manager)

Table 24 - Probability - Impact matrix

An increase of natural gas prices would mean extra costs to produce heat and power (P: 60-80%).
Due to the very high-energy need of the plant, this would reflect in extra millions of euros in order to produce the paper.
Such risk must be shared among the EMT, but can not be avoided, eliminated or mitigated in any way, because it depends on market and supply conditions.
The only mitigation action is signing an energy contract with a fixed price, thanks to the external consultancy.
Another risk could happen if Terna would strongly reduce the amount of energy produced by the TG2 for the Capacity Market (P: 5-25%).
This would mean high costs for maintenance and setup of the turbine cycle, without any revenue coming from the energy production. This would mean having half of the energy plant unused, although it requires maintenance costs (even if the turbine is not working).
The only way to face this risk is to share the scheduling of Terna requests, asking to the TSO to guarantee a yearly minimum amount of energy produced.
Clients could maybe require the production line to be fed with electric energy coming from renewables, due to sustainability policies (P: 5-25%).
This would be a disaster for the Verzuolo plant, since the energy production comes from turbogas cycles and steam turbine. The amount of biomass burned is significantly low compared to the main CHP cycle components. Therefore, the plant can not change the energy supply policy without incurring in very high energy costs, which could strongly impact on the company costs.
This risk can be reduced or eliminated by choosing clients without such requirements.
An insufficient know-how in energy management topics could slow down the planning activities (P: 25-60%). This would also increase the probability of errors in managing the EMS. Such risk must be seek because otherwise the certification is not achievable. The way to mitigate its impact is to train resources or hire new ones, which would have not a strong impact on company costs.
Some difficulties of integration between EMS activities and operations may arise (P: 5-25%). This would slow down the production rate or it would mean a wrong application of EMS activities. In both cases, it would reflect in an economic and performance loss for the company, which has a very strong impact on company costs and planning. This risk has to be eliminated with solutions that foster such integration. For instance, a correct task

division, new roles assignment, or hiring new resources dedicated for EM activities, with other resources fully dedicated to production activities.

The last risk identified regards cultural issues. It has been assigned a very low probability of occurrence (P: 0-5%), because the company is committed in EM activities since they have been acquired by SKI s.r.l. They have a strong sustainability strategy, also reflected by the request to certify UNI CEI EN ISO 50001.

This risk can be eliminated by training the misaligned resources, explaining them the importance to monitor and control the energy profile of the organisation.

At this point the thesis focuses on the energy opportunities identified by the organisation, linked to an EMS implementation (or other energy opportunities if present).

The opportunity analysis' output is a table containing the following aspects:

- Opportunity description;
- Expected result of the opportunity:
  (a) Advantage for the company
  (b) Energy performance improvement;
- Expected outcome;
- Action plan for the opportunity;
- EMS integration with company operations (what is necessary to do):
  - OFI: Opportunity For (process) Improvement
  - MSC: Management System Changes (required)
  - RN: Resource Need

Before explaining in detail each opportunity, Table 25 shows the whole picture:

#ID	**Opportunity description**	**Expected result of the opportunity**	**Expected outcome**	**Action Plan for the opportunity**	**EMS Integration with company operations**	**Responsible**
O1	Reduce operational costs linked to energy consumption	(a, b)	Reduced energy need of production lines	Monitoring of energy consumption	Daily and weekly report of energy consumption profile (MSC)	Energy manager (Facility manager)
O2	Improve management system (HLS)	(a)	Better facility management (not only on environment, quality and	Integrate energy data with environmental, quality and safety in a unique database	Daily and weekly report of management systems outputs (MSC)	COO (Team leader) and Energy manager (Facility manager)

			safety, but also energy)			
O3	Gain energy management competences	(a)	Increased know-how on EMS topics and better facility management	Train resources or hire new ones	Weekly or monthly training sessions (MSC, RN)	COO (Team leader) and Energy manager (Facility manager)
O4	Increase brand image	(a)	Higher sales	Achieve the ISO 50001 certification	Commitment for an efficient EMS (OFI)	COO (Team leader)
O5	New clients/suppliers requiring 50001 certification	(a)	New markets for paper	Ask to purchase and sales departments to search for such clients/suppliers	Sell the same product in different markets (changing product would change operations) (OFI)	COO (Team leader)
O6	Increase energy efficiency	(b)	Detection of SEU and consumption improvement	Apply EMS principles and invest in more efficient machines	Adapt the production to new machines (OFI, MSC)	Energy manager (Facility manager)
O7	Increase production lines efficiency	(b)	Higher production rate or reduced consumption	Apply EMS principles and invest in more efficient machines	Adapt the production to new machines (OFI, MSC)	Energy manager (Facility manager)
O8	Reduce wastes	(b)	Higher production rate or reduced consumption	Apply EMS principles and invest in more efficient machines	Adapt the production to new machines (OFI, MSC, RN)	Energy manager (Facility manager)

Table 25 - Opportunities' assessment

Opportunities can be clustered according to the expected result.

The first cluster regards opportunities that give an advantage to the organisation as a company. The second one regards an improvement of the energy performance.

Reduce operational costs linked to energy consumption is the first and most relevant. It requires monitoring of energy consumption, and it would result in reduced energy need of production lines. This can be integrated into company operations through daily and weekly reporting of the energy consumption profile.

This first opportunity is the only one that has benefits both on the company as a whole (cost reduction) and on the energy performance of the company (reduced consumption).

Advantages for the organisation can be identified in the following opportunities (O2-O5).

Integrating energy data with environmental, quality and safety ones in a unique database allows to have a whole picture of the company management system (HLS). Therefore, this is an opportunity for improving the HLS management system. Through daily and weekly reports, it is expected to obtain a better facility management as result.

The company could also gain energy management competences by training resources in weekly or monthly scheduled sessions, resulting in increased know-how on EMS topics and in a better facility management.

By achieving the UNI CEI EN ISO 50001 certification, the company would improve its brand image. This can be done if there is commitment in implementing an effective EMS. By improving its image, the company can increase their sales, gaining higher market shares.

New clients/suppliers may requires the UNI CEI EN ISO 50001 as mandatory for sustainability policies purposes.

This would mean new potential markets for the SKI s.r.l., and therefore increased sales. It is important to mention that the company should not change its product type (that is recyclable and therefore sustainable), otherwise it would incur in high extra costs for changing the production lines, which may be not beneficial.

An improvement of the energy performance can be achieved by facing other opportunities (O6-O8).

This is possible by applying EMS principles on energy efficiency (especially about monitoring and reporting) and investing in more efficient machines. Of course, in case of investment in new production lines or in other energy tools, such items must be adapted to the company operations (especially regarding production lines and CHP production).

Energy efficiency can be increased consequently, allowing to detect SEUs and improving the consumption rate.

Production lines efficiency can be improved too, resulting in a higher production rate or in a reduced consumption profile of the lines.

The same results come also from a wastes reduction opportunity.

3.3.4. Energy analysis: electric, thermal, and primary energy models

The energy analysis focuses on three main directions: electric energy flow, thermal energy flow and primary energy flow.

Starting from the electric energy flow, it is important to mention two important sheets that are present in the "*Annex 1: Energy Diagnosis SKI s.r.l. – Verzuolo (CN).xlsx*".

The "*Electric energy model*" contains a list of all electric energy machines and tools that consumes electricity.

For each item are listed the "energy functional area", the "area", the nominal power (kW) and the number of units.

"Total nominal power" [kW] of each listed item is calculated as it follows:

$$Total\ nominal\ power\ [kW] = Nominal\ power\ [kW] * Number\ of\ units$$

For the sake of simplicity, a production line is often considered with n° units=1, considering the whole line as a unique machine.

Then, to obtain a more precise "absorbed power", some load factors have been applied, according to the "Use" of the specific machine group:

Internal lighting	ILLI	60%
External lighting	ILLE	80%
Winter/Summer climatization	CDZ	40%
Air flow systems	FAN	40%
Process chiller group	CHL	30%
Air compressed motors	ACO	40%
Handling and movimentation of raw materia	MOV	40%
Production lines	PROD	40%
Pumping systems	PMP	20%
Information and communication technologie	ICT	50%
Various applications/uses	VAR	15%
Electric and process losses	LOSS	100%

Table 26 - Load factors (estimated)

Absorbed power [kW] has been calculated as it follows:

$$Total\ absorbed\ power\ [kW] = Total\ nominal\ power\ [kW] * Load\ factor\ [\%]$$

By multiplying the absorbed power for each item, the theoretical “energy absorbed” [kWh/year] has been calculated:

$$Energy\ absorbed\ [\frac{kWh}{year}] = Total\ absorbed\ power\ [kW] * Working\ hours\ [\frac{h}{year}]$$

All the items consuming electricity that are listed in the Electric energy model are monitored.

For SEU evaluation, the macro area is considered to simplify the model.

For this reason, the theoretical electric consumption profile have been clustered according to the macro area in which the item belongs, in order to have more simple and manageable data.

The following table contains a whole picture of the theoretical electric energy model.

THEORETICAL ELECTRIC ENERGY MODEL - Smurfit Kappa Cartiera di Verzuolo s.r.l. - Via Roma 26 - 12039 Verzuolo (CN)

Consultancy by CEC s.r.l. - Luglio 2022

Description	Use	Area	EFA	Nominal Power	n. units	Total nominal Power	Load factor	Power Absorbed	Opening hours	Working Days	Working Hours	Energy Absorbed	Percentage
				kW		kW	%	kW	h	girono/anno	h/anno	kWh/anno	%
MACRO AREAS													
1.1.2. OCC Pulp preparation												**55.243.680**	
Pulp preparation 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp preparation 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp preparation 3	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
OCC machine PM9 1	PROD	PRODUCTION	Principal activities	560,00	1	560,00	40,0%	224,00	24	355	8.520	1.908.480	0,44%
OCC machine PM9 2	PROD	PRODUCTION	Principal activities	610,00	1	610,00	40,0%	244,00	24	355	8.520	2.078.880	0,48%
Refiner Cell 2	PROD	PRODUCTION	Principal activities	1.680,00	1	1.680,00	40,0%	672,00	24	355	8.520	5.725.440	1,31%
Refiner Cell 3	PROD	PRODUCTION	Principal activities	1.680,00	1	1.680,00	40,0%	672,00	24	355	8.520	5.725.440	1,31%
Pulp preparation Line 8 - Trasformer "K"	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	40,0%	640,00	24	355	8.520	5.452.800	1,25%
OCC Machine	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
1.1.3. Continuous production line - PM9												**182.430.240**	
Canvas section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Canvas section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Roll compression - Canvas section	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Roll compression - press section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Roll compression - press section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Dryers 5-8	ACO	PRODUCTION	Auxiliary services	2.340,00	1	2.340,00	40,0%	936,00	24	355	8.520	7.974.720	1,82%
Dryers 1-4	ACO	PRODUCTION	Auxiliary services	350,00	1	350,00	40,0%	140,00	24	355	8.520	1.192.800	0,27%
Compressors of press section	ACO	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Umid pulp 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Umid pulp 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Umid pulp 3	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Umid pulp 4	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Umid pulp 5	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp and dry section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp and dry section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Coater Optireel	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Continouus line 8 - Trasformer "C"	MOV	PRODUCTION	Auxiliary services	2.000,00	4	8.000,00	40,0%	3200,00	24	355	8.520	27.264.000	6,23%
Roll compression - pump section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Roll compression - pump section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Paper roller	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
1.1.4. Final product activities - Line 9												**65.092.800**	
Pulp cooking 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp cooking 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Ausiliari Supercooler	CHL	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	30,0%	756,00	24	355	8.520	6.441.120	1,47%
Ausiliari Supercooler	CHL	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	30,0%	756,00	24	355	8.520	6.441.120	1,47%
Roll compression - Coils section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Roll compression - Coils section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Preparation	MOV	STORAGE	Auxiliary services	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Winding machine line 8	PROD	PRODUCTION	Principal activities	800,00	1	800,00	40,0%	320,00	24	355	8.520	2.726.400	0,62%
Preparation lighting	ILLI	STORAGE	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	1,50%
1.2.2. Air Compressors												**5.452.800**	
Continuous line 8 - Compressor "ZRC"	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	40,0%	640,00	24	355	8.520	5.452.800	1,25%
1.2.4. Water Depuration												**37.079.040**	
Exit water	PMP	PRODUCTION	Auxiliary services	800,00	2	1.600,00	20,0%	320,00	24	355	8.520	2.726.400	0,62%
PGW9 Transformer 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
PGW9 Transformer 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Turbocompressors	PROD	PRODUCTION	Principal activities	2.520,00	2	5.040,00	40,0%	2016,00	24	355	8.520	17.176.320	3,93%
1.2.5. Muds dehydration												**5.452.800**	
PGW9 Transformer 3	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	40,0%	640,00	24	355	8.520	5.452.800	1,25%
1.2.6. Reject Handling												**8.588.160**	
Reject Handling	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
1.3.2. Internal lighting and industrial facility												**55.618.560**	
PM9 Lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	1,50%
PGW + OCC Lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	1,50%
Continuous lighiting line 8	ILLI	PRODUCTION	General services	800,00	1	800,00	60,0%	480,00	24	355	8.520	4.089.600	0,94%
Plant Air flow	FAN	PRODUCTION	General services	1.600,00	1	1.600,00	40,0%	640,00	24	355	8.520	5.452.800	1,25%
Bridge crane - pulp section	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Pulp machine - Transformer "L"	PROD	PRODUCTION	Principal activities	800,00	1	800,00	40,0%	320,00	24	355	8.520	2.726.400	0,62%
Bark movementation	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	40,0%	1008,00	24	355	8.520	8.588.160	1,96%
Bark area lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	1,50%
Preparation lighting	ILLI	STORAGE	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	1,50%
2.1. Other energy uses												**22.429.272**	
External lighting	ILLE	EXTERNAL AREA	General services	1.000,00	1	1.000,00	80,0%	800,00	24	355	8.520	6.816.000	1,56%
ICT tools (computers, printings, and other ICT)	ICT	OFFICES AND SERVICES	General services	2.200,00	1	2.200,00	50,0%	1100,00	24	355	8.520	9.372.000	2,14%
Split hot/cold in offices	CDZ	OFFICES AND SERVICES	General services	1.500,00	1	1.500,00	40,0%	600,00	24	355	8.520	5.112.000	1,17%
Other offices' tools	VAR	OFFICES AND SERVICES	General services	800,00	1	800,00	15,0%	120,00	24	355	8.520	1.022.400	0,23%
TRAFO Losses	LOSS	TECHNICAL ROOMS	General services	7,20	1	7,20	100,0%	7,20	24	365	8.760	63.072	0,01%
Process losses	LOSS	TECHNICAL ROOMS	General services	5,00	1	5,00	100,0%	5,00	24	365	8.760	43.800	0,01%
TOTAL						**125.732**	**40,8%**	**51.336**	**---**	**---**	**8.520**	**437.387.352**	**100,00%**

Table 27 - Electric energy model (theoretical)

The theoretical electric energy consumption of the plant accounts for 437.387.352 kWh/year.

Both “Area” and “EFA” are assigned to each item listed in the electric energy model.
By doing so, it is possible to evaluate all the consumption profile, according to:

- The energy “Use”;
- The plant “Area”;
- The “EFA”.

These clustering are presented in the “*EE Model Synthesis*” sheet.
All graphs and tables related to this sheet are presented in the “Monitoring phase” chapter, since they have been re-calculated according to the real electric consumption profile of the plant.

The “*Thermal energy model*” is another relevant model.
Usually it contains some data regarding natural gas consumption (e.g. amount of smc burned by a boiler for heating purposes, with the thermal energy produced).
In this specific case, being the facility also a CHP plant, this model presents a different configuration.
The CHP plant is seen as a black box, considering just all the input and output energy flows. Data belonging to this sheet have been taken by the energy production data of the company.
Thermal production is divided into:

- Low pressure vapour (LP): 4 bar;
- Medium pressure vapour (MP): 7 bar.

Then, having knowledge of...:

- The whole amount of natural gas (smc) burned to let work the two TGs, the post-combustors, and the bark boiler;
- The amount of vapour (tons) produced in LP and MP;
- The vapour enthalpy (kWht/tons) both for LP and MP vapour;

... the consultancy company have been able to calculate the thermal energy produced as it follows:

$$Thermal\ energy\ produced\ [kWht] = Vapour\ produced\ [tons] * Vapour\ enthalpy\ [\frac{kWht}{tons}]$$

The yearly amount of thermal energy produced has been 10.628.020,91 kWht in 2021.

Looking at the steam turbine production data, it has been possible to understand the amount of electric energy produced (388.008.060,00 kWhe in 2021) .

Such data are taken directly from the production plant, and they are not changing after the monitoring phase.

The following table resumes all the topics presented before.

ENERGY AND VAPOR COGENERATION MODEL - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN)								
Consultancy by CEC s.r.l. - Luglio 2022						*pci Gas Naturale:*	35.403,95	*kJ/Smc*
Machines	*Vapour pressure*	*Natural gas consumption*	*Vapour produced*	*Average vaporu production (nominal rate)*	*Vapour enthalpy*	*Thermal energy produced*	*Electric energy produced*	*percentage*
CHP plant: TG1+TG2+GVR+BB+TV	bar	smc/year	t	t/h	kWh/t	kWht	kWhe	%
Thermal Power Plant: Low Pressure	4,00	110.341.744,00	530,75	0,06	786,76	417.569,60	388.008.060,00	4%
Thermal Power Plant: Medium Pressure	7,00		13.222,03	1,55	772,23	10.210.451,31		96%
Total		**110.341.744,00**	**13.752,78**	**0,81**	**1.558,99**	**10.628.020,91**	**388.008.060,00**	**100%**

Table 28 - CHP plant production data

The "*Primary energy model*" sheet contains a sum-up of all energy flows that are present in the facility, converting all of them in PET.

The next table illustrates all the conversion factors that will be applied in the "Primary energy model". (see "Generalities" sheet of *Annex 1*)

Conversion factors		
Consultancy by CEC s.r.l. - Luglio 2022		
1 MWh electric	0,187	PET
1 Sm3 of natural gas	9,593	kWht
1 Sm3 of natural gas	34,53	MJ/Sm3
1 Sm3 of natural gas	0,000825	PET
1 MWh thermal	0,085985	PET
1 MWh thermal	3.600	MJ
1 MWh electric	288	kg of CO_2
1 Smc of gas	1,97	kg of CO_2

Table 29 - Conversion factors

The primary energy model contains a clustering of the energy consumption profile of the plant according to:

- The plant "Area";
- The "EFA".

Also these tables and graphs are presented in the "Monitoring phase" chapter, since they have been re-calculated after the real consumption profile calculation.

3.3.5. Theoretical Energy Performance Indicators' calculation and EnB comparison

The EnPIs give a whole picture of the energy performance of the company. (see "*EnPI and EnB*" sheet – *Annex 1*).

EnB for the comparison have been sent to SKI s.r.l. directly by ENEA (confidential document), according to the ATECO code and other facility data of the company (therefore ensuring trustworthiness)

Considering…:

- The "Electric energy" and the "Electric energy model" sheets;
- The "Thermal energy" and "Thermal energy model" sheets;
- The "Generalities" sheet (regarding internal surface (m²));
- The "Production" sheet (regarding tons of paper produced);

… it is possible to estimate all the theoretical EnPIs, as shown in the next table:

Theoretical EnPI per EFA (Benchmark EnB - BREF) - ENERGY PERFORMANCE INDICATOR	unit	EnB	EnPI	NOTES
Total per energy flow		Max value		
Electric Energy / tons of paper produced	kWh/t	350 - 450	1.048,65	Out of control
Vapour / tons of paper produced	kWh/t	1.100 - 1.500	930,27	Ok
Natural gas / tons of paper produced	kWh/t	1.100 - 1.500	1.167,13	Ok
Principal activities		50%		
Electric Energy / tons of paper produced	kWh/t	175 - 225	665,84	Out of control
Vapour / tons of paper produced	kWh/t	550 - 750	930,27	Out of control (but Ok, Vap. only for P.A.)
Natural gas / tons of paper produced	kWh/t	550 - 750	1.167,13	Out of control (but Ok, NG only for P.A.)
Auxiliary services		30%		
Electric Energy / tons of paper produced	kWh/t	105 - 135	227,72	Out of control
Vapour / tons of paper produced	kWh/t	330 - 450	-	Ok
Natural gas / tons of paper produced	kWh/t	330 - 450	-	Ok
General services		20%		
Electric Energy / tons of paper produced	kWh/t	70 - 90	155,09	Out of control
Vapour / tons of paper produced	kWh/t	220 - 300	-	Ok
Natural gas / tons of paper produced	kWh/t	220 - 300	-	Ok

Table 30 - EnPI vs EnB

Starting from a maximum threshold value for each EnPI, such value splits according to (source: ENEA):

- Principal activities (50%)
- Auxiliary services (30%)
- General services (20%).

As it can be observed in Table 30, "Electric energy produced/tons of paper produced" is "Out of control", which means that it has a much higher value compared to the baseline.

This is an important initial warning, that allows to understand that the facility has an overutilization of electric energy compared to the average need of similar plants.

Such amount must be reduced. In order to do so, it is important to do a SEU evaluation, to understand which "macro area" present an "out of control" situation.

If there will be any, it means that the company should think about an energy efficiency intervention, in order to reduce the energy need of that "macro area".

Vapour and natural gas consumption seem to be “Ok” in the total energy flow, while they are too high for principal activities purposes.

It is important to mention that in the Verzuolo case the production plant is also an energy plant, and it has no vapour or natural gas as auxiliary or general service.

EnB about vapour and natural gas regard plants that are not contributing to the national grid or to the capacity market. Therefore, being in control has a whole, and being entirely dedicated to production activities (principal activities), it can be assumed that vapour and natural gas EnPIs are perfectly under control.

In the SEU identification it will be very important to identify which areas are contributing the most to such “out of control” situation, allowing to find some prioritization of intervention.

Then the consultancy company is going to look at monitoring data in order to:

- Create a “real electric energy model”;
- Create a “real primary energy model”;
- Calculate “real EnPIs” to be benchmarked with the reference EnB.
- Identify SEUs and energy efficiency interventions;
- Calculate “Post-intervention EnPIs”, to understand the improvements due to the interventions suggested.

3.3.6. Monitoring phase: real electric and primary energy models with real EnPIs' calculation

Before going in deep with the monitoring phase, the company has to "Do" all the activities mentioned in the planning phase:

- Respect the energy policy;
- Commit to reach the energy goals;
- Take actions to foster each energy goal, while accomplishing all responsibilities in respect of the role in the EMT;
- Identify correctly the EnPIs and benchmark them with the right EnB;
- Identify SEUs and take continuous improvement actions (also by doing energy efficiency interventions).

Planning requires long time to be well-defined and executed, and it is revised only after a "Doing" and "Check" (and eventually "Act") sub-cycle.

It means that it is necessary to apply what stated in the "Plan" phase, checking the output by monitoring consumption and eventually "Act" by improving the EMS.

If top management retains that the action plan is no more sustainable and it must be re-assessed, the cycle restarts by modifying the "Plan" phase.

As mentioned before, the monitoring phase is the main core of the "Check" phase.

Here, some theoretical energy profiles are revised, especially:

- The electric energy model;
- The thermal energy model;
- EnPIs.

Such revision is done by benchmarking the theoretical consumption profile with the real one, taken by the monitoring system (Schneider monitoring software).

This monitoring system has an interesting dashboard that can show to the user different layouts.

Going back to the Electric energy model, it can be defined a real one, according to the monitoring data taken from the Schneider platform:

Description	*Monitoring Data*	*Difference*
MACRO AREAS	**kWh**	**kWh**
1.1.2. OCC Pulp preparation	25.930.175	29.313.505
1.1.3. Continuous production line - PM9	85.628.765	96.801.475
1.1.4. Final product activities - Line 9	40.860.785	24.232.015
1.2.2. Air Compressors	2.559.425	2.893.375
1.2.4. Water Depuration	18.850.778	18.228.262
1.2.5. Muds dehydration	2.559.425	2.893.375
1.2.6. Reject Handling	4.031.094	4.557.066
1.3.2. Internal lighting and industrial facility	42.164.367	13.454.193
2.1. Other energy uses	22.429.272	0
TOTAL	**245.014.087**	**192.373.265**

Table 31 - Monitoring data

Note well: "Difference" has been calculated as:

$$Difference\ [kWh] = Energy\ absorbed\ (theoretical)[kWh] - Monitoring\ data\ (consumption)[kWh]$$

In order to obtain an energy absorbed value equal to each monitoring one (so having difference equal to "0"), it is important to work on the load factors.

The methodology applied is very simple:

1. Look at the most important load factor (the one of the "Use" with higher electric energy consumption)
2. Apply the "Goal seeking" Excel function to the most important load factor, in order to make the difference between "Electric consumption from monitoring" and "Total estimated consumption" equal to "0".

The following table shows "load factors adjusted", in order to let the model work properly according to monitoring data.

Internal lighting	ILLI	60%
External lighting	ILLE	80%
Winter/Summer climatization	CDZ	40%
Air flow systems	FAN	19%
Process chiller group	CHL	30%
Air compressed motors	ACO	19%
Handling and movimentation of raw material and products	MOV	19%
Production lines	PROD	19%
Pumping systems	PMP	20%
Information and communication technologies	ICT	50%
Various applications/uses	VAR	15%
Electric and process losses	LOSS	100%

Table 32 - Load factors (adjusted)

The following table contains the “real electric energy model”:

REAL ELECTRIC ENERGY MODEL - Smurfit Kappa Cartiera di Verzuolo s.r.l. - Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*													
Description	Use	Area	EFA	Nominal Power	n. units	Total nominal Power	Load factor	Power Absorbed	Opening hours	Working Days	Working Hours	Energy Absorbed	Percentage
				kW		kW	%	kW	h	girono/anno	h/anno	kWh/anno	%
MACRO AREAS													
1.1.2. OCC Pulp preparation												**25.930.175**	
Pulp preparation 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp preparation 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp preparation 3	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
OCC machine PM9 1	PROD	PRODUCTION	Principal activities	560,00	1	560,00	18,8%	105,14	24	355	8.520	895.799	0,37%
OCC machine PM9 2	PROD	PRODUCTION	Principal activities	610,00	1	610,00	18,8%	114,53	24	355	8.520	975.781	0,40%
Refiner Cell 2	PROD	PRODUCTION	Principal activities	1.680,00	1	1.680,00	18,8%	315,42	24	355	8.520	2.687.396	1,10%
Refiner Cell 3	PROD	PRODUCTION	Principal activities	1.680,00	1	1.680,00	18,8%	315,42	24	355	8.520	2.687.396	1,10%
Pulp preparation Line 8 - Trasformer "K"	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	18,8%	300,40	24	355	8.520	2.559.425	1,04%
OCC Machine	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
1.1.3. Continuous production line - PM9												**85.628.765**	
Canvas section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Canvas section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Roll compression - Canvas section	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Roll compression - press section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Roll compression - press section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Dryers 5-8	ACO	PRODUCTION	Auxiliary services	2.340,00	1	2.340,00	18,8%	439,34	24	355	8.520	3.743.159	1,53%
Dryers 1-4	ACO	PRODUCTION	Auxiliary services	350,00	1	350,00	18,8%	65,71	24	355	8.520	559.874	0,23%
Compressors of press section	ACO	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Umid pulp 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Umid pulp 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Umid pulp 3	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Umid pulp 4	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Umid pulp 5	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp and dry section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp and dry section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Coater Optireel	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Continouus line 8 - Trasformer "C"	MOV	PRODUCTION	Auxiliary services	2.000,00	4	8.000,00	18,8%	1502,01	24	355	8.520	12.797.125	5,22%
Roll compression - pump section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Roll compression - pump section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Paper roller	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
1.1.4. Final product activities - Line 9												**40.860.785**	
Pulp cooking 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp cooking 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Ausiliari Supercooler	CHL	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	30,0%	756,00	24	355	8.520	6.441.120	2,63%
Ausiliari Supercooler	CHL	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	30,0%	756,00	24	355	8.520	6.441.120	2,63%
Roll compression - Coils section 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Roll compression - Coils section 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Preparation	MOV	STORAGE	Auxiliary services	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Winding machine line 8	PROD	PRODUCTION	Principal activities	800,00	1	800,00	18,8%	150,20	24	355	8.520	1.279.713	0,52%
Preparation lighting	ILLI	STORAGE	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	2,67%
1.2.2. Air Compressors												**2.559.425**	
Continuous line 8 - Compressor "ZRC"	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	18,8%	300,40	24	355	8.520	2.559.425	1,04%
1.2.4. Water Depuration												**18.850.778**	
Exit water	PMP	PRODUCTION	Auxiliary services	800,00	2	1.600,00	20,0%	320,00	24	355	8.520	2.726.400	1,11%
PGW9 Transformer 1	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
PGW9 Transformer 2	PROD	PRODUCTION	Principal activities	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Turbocompressors	PROD	PRODUCTION	Principal activities	2.520,00	2	5.040,00	18,8%	946,27	24	355	8.520	8.062.189	3,29%
1.2.5. Muds dehydration												**2.559.425**	
PGW9 Transformer 3	PROD	PRODUCTION	Principal activities	1.600,00	1	1.600,00	18,8%	300,40	24	355	8.520	2.559.425	1,04%
1.2.6. Reject Handling												**4.031.094**	
Reject Handling	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
1.3.2. Internal lighting and industrial facility												**42.164.367**	
PM9 Lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	2,67%
PGW + OCC Lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	2,67%
Continuous lighiting line 8	ILLI	PRODUCTION	General services	800,00	1	800,00	60,0%	480,00	24	355	8.520	4.089.600	1,67%
Plant Air flow	FAN	PRODUCTION	General services	1.600,00	1	1.600,00	18,8%	300,40	24	355	8.520	2.559.425	1,04%
Bridge crane - pulp section	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Pulp machine - Transformer "L"	PROD	PRODUCTION	Principal activities	800,00	1	800,00	18,8%	150,20	24	355	8.520	1.279.713	0,52%
Bark movementation	MOV	PRODUCTION	Auxiliary services	2.520,00	1	2.520,00	18,8%	473,13	24	355	8.520	4.031.094	1,65%
Bark area lighting	ILLI	PRODUCTION	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	2,67%
Preparation lighting	ILLI	STORAGE	General services	1.280,00	1	1.280,00	60,0%	768,00	24	355	8.520	6.543.360	2,67%
2.1. Other energy uses												**22.429.272**	
External lighting	ILLE	EXTERNAL AREA	General services	1.000,00	1	1.000,00	80,0%	800,00	24	355	8.520	6.816.000	2,78%
ICT tools (computers, printings, and other ICT)	ICT	OFFICES AND SERVICES	General services	2.200,00	1	2.200,00	50,0%	1100,00	24	355	8.520	9.372.000	3,83%
Split hot/cold in offices	CDZ	OFFICES AND SERVICES	General services	1.500,00	1	1.500,00	40,0%	600,00	24	355	8.520	5.112.000	2,09%
Other offices' tools	VAR	OFFICES AND SERVICES	General services	800,00	1	800,00	15,0%	120,00	24	355	8.520	1.022.400	0,42%
TRAFO Losses	LOSS	TECHNICAL ROOMS	General services	7,20	1	7,20	100,0%	7,20	24	365	8.760	63.072	0,03%
Process losses	LOSS	TECHNICAL ROOMS	General services	5,00	1	5,00	100,0%	5,00	24	365	8.760	43.800	0,02%
TOTAL						**125.732**	**22,9%**	**28.757**	**---**	**---**	**8.520**	**245.014.087**	**100,00%**

Table 33 - Electric energy model (real)

As it can be observed looking at the table, the total amount of electric energy consumed by the facility accounts for 245.014.087 kWh/year (-44% compared to estimations).

At this point, it is possible to evaluate also the electric consumption in the “EE model synthesis”, according to the “Use”, the “Area” and the “EFA”:

ELECTRIC MODEL - SYNTHESIS PER ENERGY USE (EFA) - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*						
USE	Code	kW_{inst}	load factor /efficiency	kWabs	kWh/year	split %
Internal lighting	ILLI	7.200	60,0%	4.320	36.806.400	15,0%
External lighting	ILLE	1.000	80,0%	800	6.816.000	2,8%
Winter/Summer climatization	CDZ	1.500	40,0%	600	5.112.000	2,1%
Air flow systems	FAN	1.600	18,8%	300	2.559.425	1,0%
Process chiller group	CHL	5.040	30,0%	1.512	12.882.240	5,3%
Air compressed motors	ACO	5.210	18,8%	978	8.334.128	3,4%
Handling and movimentation of raw material and products	MOV	18.080	18,8%	3.395	28.921.503	11,8%
Production lines	PROD	81.490	18,8%	15.300	130.354.718	53,2%
Pumping systems	PMP	1.600	20,0%	320	2.726.400	1,1%
Information and communication technologies	ICT	2.200	50,0%	1.100	9.372.000	3,8%
Various applications/uses	VAR	800	15,0%	120	1.022.400	0,4%
Electric and process losses	LOSS	12	100,0%	12	106.872	0,0%
TOTALE		**125.732**	**22,9%**	**28.757**	**245.014.087**	**100,0%**

Table 34 - EE model synthesis (per Use)

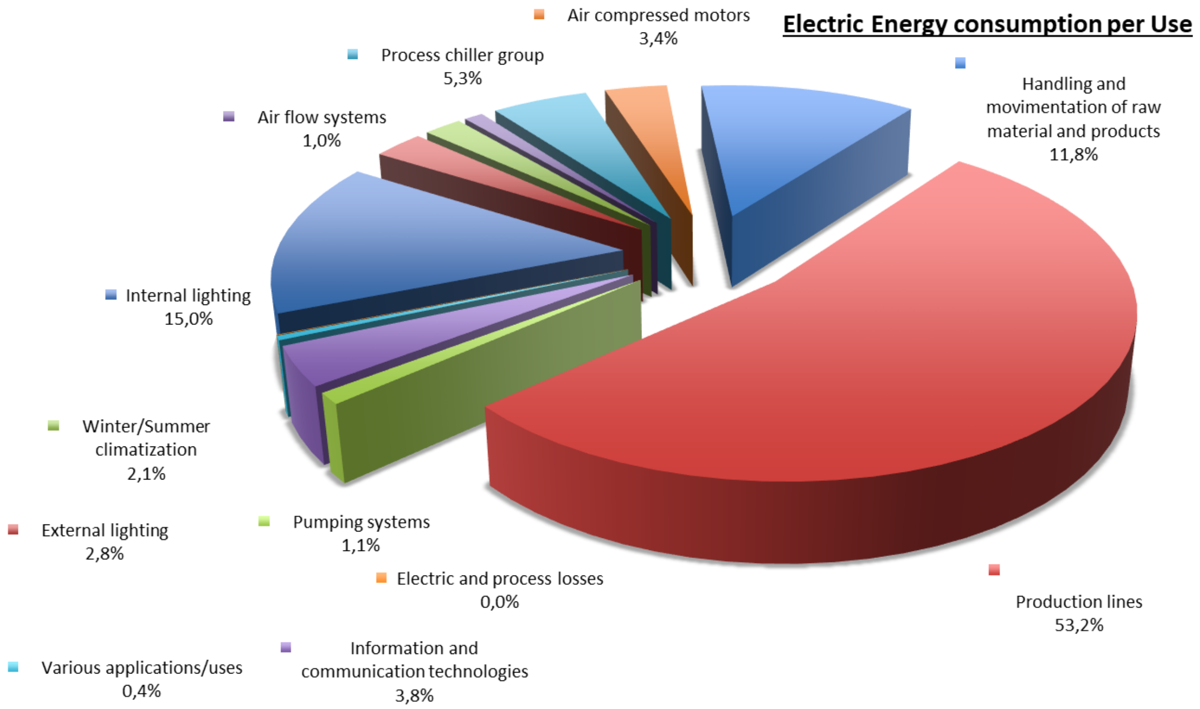

Figure 32 - Electric energy consumption per Use

ELECTRIC MODEL - SYNTHESIS PER PLANT AREA - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*						
AREA	Code	kW_{inst}	fattore di carico/ rendimento	kWass	kWh/anno	ripartizione%
Production area	PRODUCTION	115.140	20,9%	24.116	205.467.000	83,9%
Area for stocking raw materials and products	STORAGE	5.080	39,5%	2.009	17.117.814	7,0%
Technical rooms to support production	TECHNICAL ROOMS	12	100,0%	12	106.872	0,0%
Offices, Laboratories, Changing rooms, toilets	OFFICES AND SERVICES	4.500	40,4%	1.820	15.506.400	6,3%
External areas	EXTERNAL AREA	1.000	80,0%	800	6.816.000	2,8%
TOTALE		**125.732**	**22,9%**	**28.757**	**245.014.087**	**100,0%**

Table 35 - EE model synthesis (per Area)

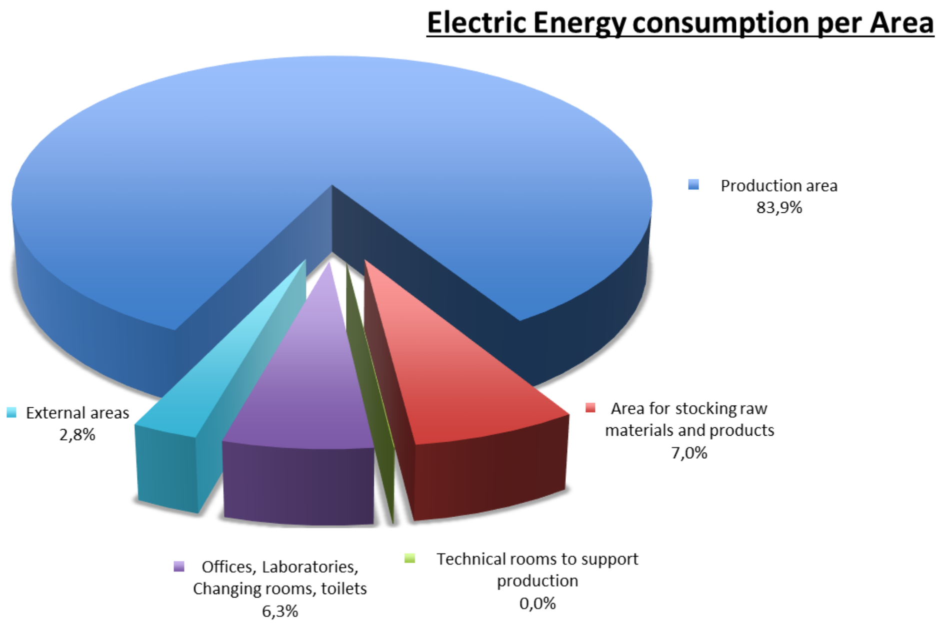

Figure 33 - Electric energy consumption per Area

ELECTRIC MODEL - SYNTHESIS PER EFA (Real) - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*						
EFA	kW_{inst}	load factor / efficiency	kWabs	kWh/year	PET/year	split %
PRINCIPAL ACTIVITIES	81.490	18,8%	15.300	130.354.718	24.376	53,2%
AUXILIARY SERVICES	29.930	20,7%	6.205	52.864.271	9.886	21,6%
GENERAL SERVICES	14.312	50,7%	7.253	61.795.097	11.556	25,2%
TOTAL	**125.732**	**22,9%**	**28.757**	**245.014.087**	**45.818**	**100%**

Figure 34 - EE model synthesis (per EFA)

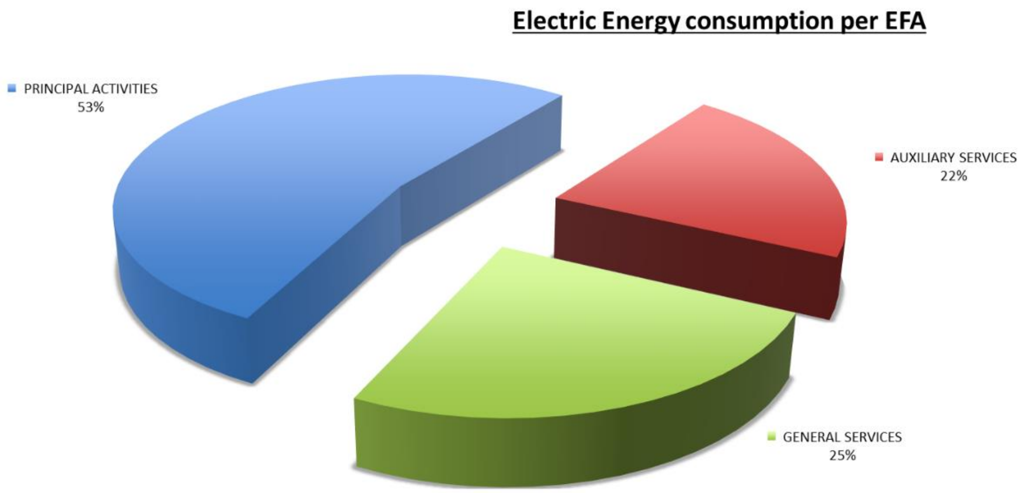

Figure 35 - Electric energy consumption per EFA

As explained before, the "Thermal energy model" have not been revised, due to the fact that data have been directly taken from the plant management system (and therefore assumed reliable).

Instead, the "Primary energy model" has been re-designed properly.

As mentioned before, it consider all the energy flows of the facility, according to facility "Area" and to the "EFA".

The following tables and graph give a clear picture of the company status quo.

(Total consumption: 136.849,57 PET in 2021)

CONSUMPTION - SYNTHESIS PER AREA - Primary Energy Consumption *Consultancy by CEC s.r.l. - Luglio 2022*					
AREA	Code	Thermal Energy Smc/year	Electric Energy MWh_e/year	Primary Energy PET/year	Percentage %
Production area	PRODUCTION	110.341.744	205.467	129.454	94,6%
Area for stocking raw materials and products	STORAGE	-	17.118	3.201	2,3%
Technical rooms to support production	TECHNICAL ROOMS	-	107	20	0,0%
Offices, Laboratories, Changing rooms, toilets	OFFICES AND SERVICES	-	15.506	2.900	2,1%
External areas	EXTERNAL AREA	-	6.816	1.275	0,9%
TOTAL		**110.341.744**	**245.014**	**136.849,57**	**100,0%**

Table 36 - Energy consumption per Area

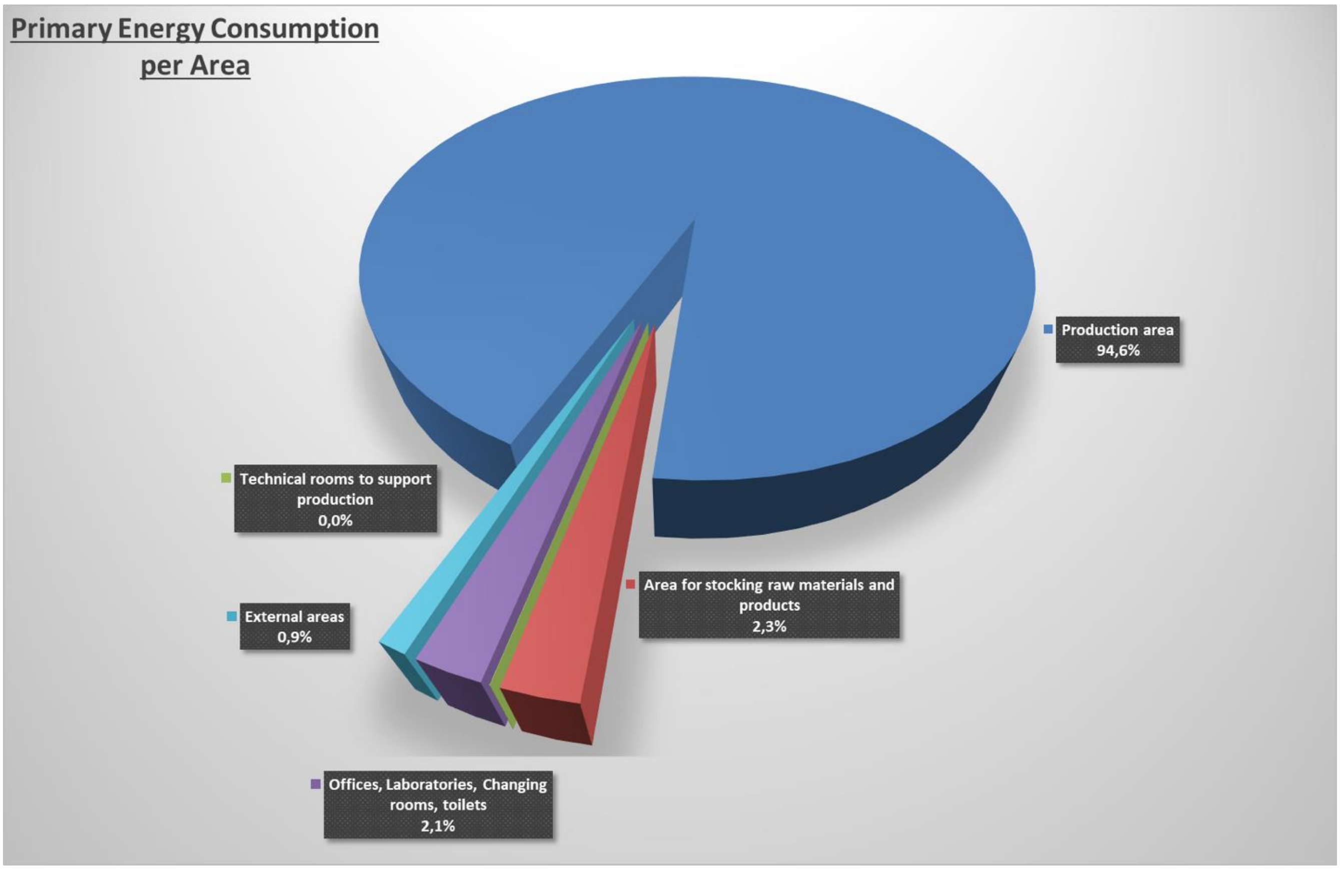

Figure 36 - Primary energy consumption per Area

CONSUMPTION - SYNTHESIS PER EFA - Primary Energy Consumption *Consultancy by CEC s.r.l. - Luglio 2022*				
ENERGY FUNCTIONAL AREA (EFA)	Thermal Energy	Electric Energy	Primary Energy	Percentage
	Smc/year	MWh_e/year	PET/year	%
PRINCIPAL ACTIVITIES	110.341.744	130.355	115.408	84,3%
AUXILIARY SERVICES	-	52.864	9.886	7,2%
GENERAL SERVICES	-	61.795	11.556	8,4%
TOTAL	**110.341.744**	**245.014**	**136.849,57**	**100,0%**

Table 37 - Energy consumption per EFA

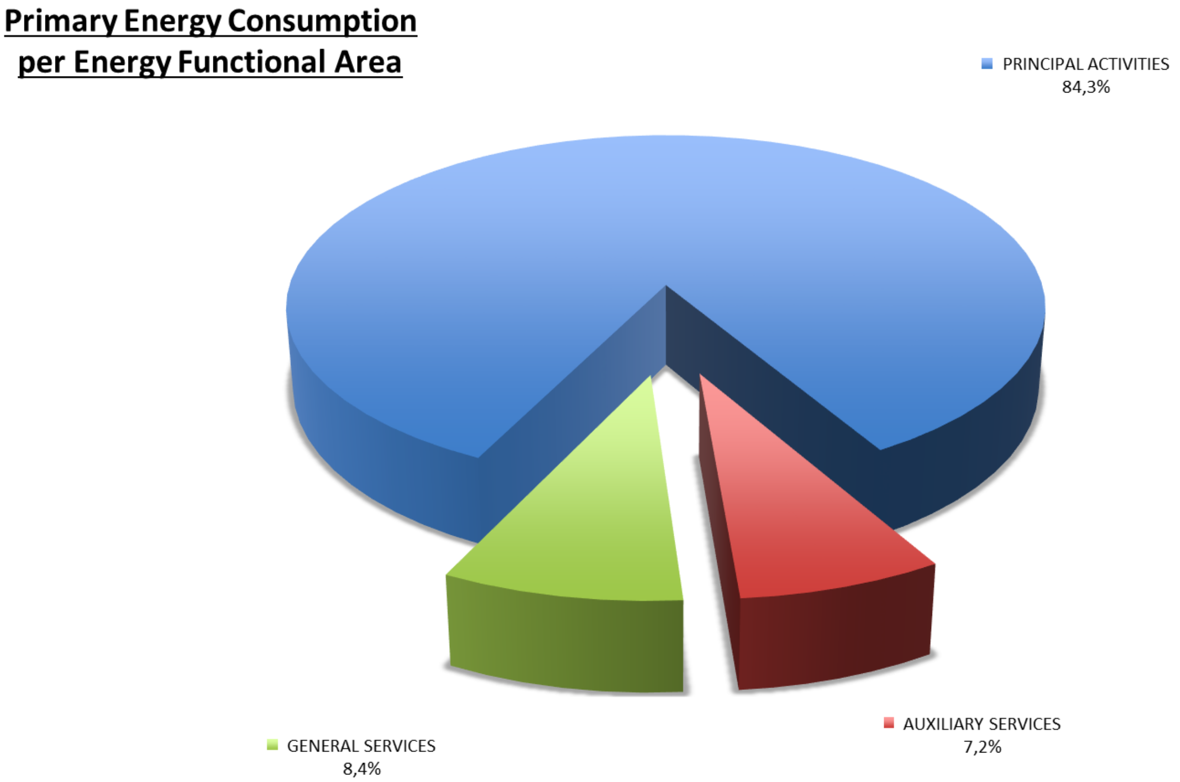

Figure 37 – Primary energy consumption per EFA

The last important revision to be done after the monitoring phase regards the EnPIs' calculation (based on real monitoring data).

The results are shown in the following table:

Real EnPI per EFA (Benchmark EnB - BREF) - ENERGY PERFORMANCE INDICATOR	unit	EnB	EnPI	NOTES
Total per energy flow		Max value		
Electric Energy / tons of paper produced	kWh/t	350 - 450	587,43	Out of control
Vapour / tons of paper produced	kWh/t	1.100 - 1.500	930,27	Ok
Natural gas / tons of paper produced	kWh/t	1.100 - 1.500	1.167,13	Ok
Principal activities		50%		
Electric Energy / tons of paper produced	kWh/t	175 - 225	312,53	Out of control
Vapour / tons of paper produced	kWh/t	550 - 750	930,27	Out of control (but Ok, Vap. only for P.A.)
Natural gas / tons of paper produced	kWh/t	550 - 750	1.167,13	Out of control (but Ok, NG only for P.A.)
Auxiliary services		30%		
Electric Energy / tons of paper produced	kWh/t	105 - 135	126,74	Ok
Vapour / tons of paper produced	kWh/t	330 - 450	-	Ok
Natural gas / tons of paper produced	kWh/t	330 - 450	-	Ok
General services		20%		
Electric Energy / tons of paper produced	kWh/t	70 - 90	148,16	Out of control
Vapour / tons of paper produced	kWh/t	220 - 300	-	Ok
Natural gas / tons of paper produced	kWh/t	220 - 300	-	Ok

Table 38 - EnPIs' calculations (real)

Vapour and natural gas look in control, since they have not changed after the monitoring phase.

Being total electric consumption of the site much lower that estimations, each EnPI considered has a much lower value compared to the theoretical one.

Anyway, even if such values are lower than before, "electric energy / tons of paper" is always an "out of control" EnPI.

Differently from before, it seems to be much higher only in “Principal activities” and “General services”, while it seems “Ok” for “Auxiliary services”.
Therefore, it is expected that a SEU is going to be identified in:

- a production line (PROD - principal activity);
- a lighting system (ILLI/ILLE - general service).

Due to the low amount of “kWh” consumed by all the other general services (ICT, CDZ, FAN, VAR, LOSS), they will not surely be a potential SEU, as well as all auxiliary services (CHL, ACO, MOV, PMP).

In the next chapter a “Gap analysis” is taking place through an R^2 significance test, to evaluate which macro area can be defined as a SEU, therefore improvable from an energy efficiency point of view.

3.3.7. SEUs' identification and gap analysis

Once available monitoring data, it is necessary to identify the SEUs.

This phase belongs to the "Plan" phase, even if it is done after the monitoring activity.

Indeed, it has no meaning to evaluate a SEU with theoretical consumption data, because those data would not be reliable.

Therefore, even if the UNI CEI EN ISO 50001 suggests to do it before monitoring activities, it is more precise to do it after such activities.

The identification of SEUs and the gap analysis are strictly connected.

Indeed, the consultancy company used a unique Excel file in order to do both. (see "*Annex 2 – Gap analysis.xlsx*")

The whole content of this chapter is an extract from "*Annex 2*".

The "Gap analysis" document is structured as follows:

- "*Analysis*" sheet: it contains all monitoring data (filled manually) for the reference year (2021). All monitoring data are clustered according to the energy flow ("electric energy", "methane (natural gas)", "vapour"). It also contains some "production" data (ton, g/m^2) and an "EnPI general" calculation;
- "*Monitoring*" sheet: it shows the SEUs of the plant starting from monitored data filled in the "Analysis" sheet. It creates some graphs automatically, showing which energy use are identified as SEUs. Such graphs uses some Baseline with a superior and an inferior limit, coming from an R^2 significance test. The different baselines with the related limits are calculated in the "*BLN x.x.x.*" sheets. If some monitored data is above or below the fore mentioned limits, the monthly energy use shows a message "Significant gap" with the related % of threshold overcome. The monitoring sheet sum-up all the energy uses identified as SEU, with the gap related. If an energy use presents a "gap", it means that there is an anomaly in the system that must be detected, which is signal of an over/underutilization of the machines present in the macro-area.
- "*Budget and expected consumption*" sheet: it shows if data coming from the "Analysis" sheet have been considered as expected consumption (monitored) or as budget ones (theoretical). (All data used in the case study comes from monitoring, therefore they are "expected consumption" ones).

- "BALANCE AND SEU (21)" sheet: it contains the energy balance for the reference year (2021), summing for each energy flow all the data coming from the "Analysis" sheet. It makes a first comparison of the EnPI general with the reference EnB (BREF). Then, for each activity, it calculates the % of incidence on total consumption, and if it is a SEU or not. For each activity, the sheet shows if the energy use is monitored (yes, no, or partially), the data monitoring frequency, and the formula for calculating the related EnB ("y" and "x" variables of the regression model applied in the "R^2 significance test")
- "*Significance test*" sheet: it calculates if an energy use is a SEU or not. This is done by assigning a "Significance score" for each activity, according to the importance of the activity (linked to the energy consumption for that specific activity). If the % of incidence on the EFA to which the activity belongs is higher than the pre-defined score, the energy use is labelled as a SEU. If it is so, the activity with the related consumption would show up in the "Monitoring" and "BALANCE AND SEU (21)" sheets.
- "*BLN x.x.x.(21)*" sheets: these sheets are used to calculate each Baseline to apply for each SEU. It is based on a "R^2 significance test" based on a "linear regression model". Therefore, starting from a baseline formula "$y=ax^2+b$", the user has to decide how to define the "x" variable, usually using a production data (ton), because it can be assumed as a fixed variable with scarce variability. So, this sheets contain all data to create a "linear regression model" for each SEU, like "R multiple"," R^2", "standard error deviation", "Square average", "F significance factor". It also shows the superior and inferior limits of the baseline, calculated as +/-15% of the average baseline (the value of the stochastic variable "y").

The results of the R^2 significance test and of the gap analysis, are presented in the following tables and graphs, coming from the "*Annex 2*".

The following table considers SEUs identified for "electric energy" flow.

SEU - ELECTRIC ENERGY														
1.1	PRINCIPAL ACTIVITIES	u.m.	gen-21	feb-21	mar-21	apr-21	mag-21	giu-21	lug-21	ago-21	set-21	ott-21	nov-21	dic-21
1.1.2	OCC PULP PREPARATION	kWh	4.814.693	4.796.232	5.710.463	5.224.872	5.224.872	4.036.993	5.488.921	6.513.789	6.787.150	7.006.348	7.094.615	7.104.548
			ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
1.1.3	CONTINUOUS PRODUCTION LINE	kWh	9.019.201	8.607.974	9.745.599	8.093.981	8.093.981	6.434.702	9.120.957	9.465.801	9.615.652	10.017.961	10.081.224	10.131.688
			ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
1.1.4	FINAL PRODUCT ACTIVITIES	kWh	1.686.938	1.486.636	1.616.383	1.044.871	1.044.871	934.926	1.120.527	1.173.262	1.163.767	1.185.118	1.179.339	1.206.012
			SIGNIFICANT GAP	SIGNIFICANT GAP	SIGNIFICANT GAP	ok	ok	ok	ok	ok	ok	ok	ok	ok
			GAP 16,7%	GAP 6,3%	GAP 8,8%									

Table 39 - SEU - Electric energy

As we can see in the previous table, there are three electric energy uses (kWh) that are identified as a SEU. All of them belong to "principal activities" as EFA:

- 1.1.2. OCC PULP PREPARATION;
- 1.1.3 CONTINUOUS PRODUCTION LINE;
- 1.1.4 FINAL PRODUCT ACTIVITIES.

While "OCC Pulp preparation" and "Continuous production line" consumption profiles are inside the Baseline limits, for "Final product activities" it is another pair of shoes.

This activity register a "Significant gap" for the first three months of analysis:

- Jan-21: +16,7%;
- Feb-21: +6,3%;
- Mar-21: +8,8%.

Therefore, this is a first important result for SKI s.r.l.: the "final product activities" line has a relevant overutilization compared to the baseline. Hence, the consumption coming from these activities must be reduced with an energy efficiency intervention. Also for the other two activity an energy efficiency intervention is suggested, but with a lower priority of intervention.

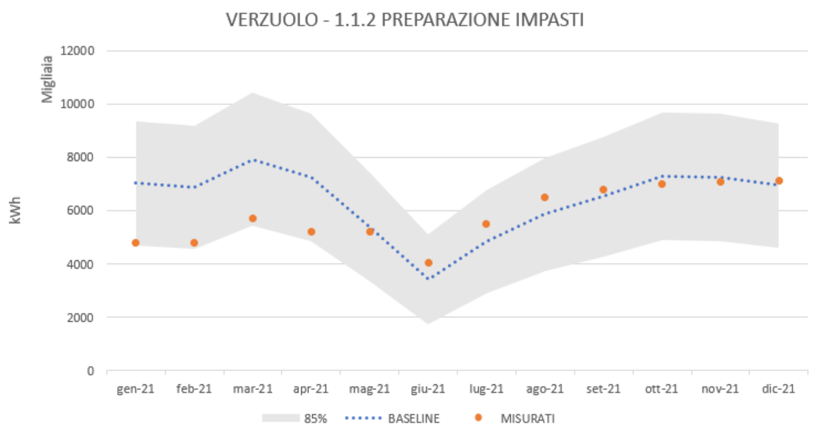

Figure 38 - OCC Pulp preparation (Electric energy)

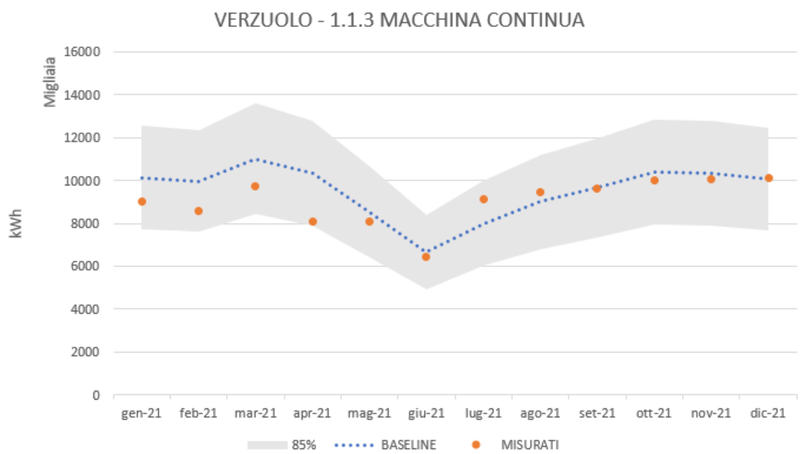

Figure 39 - Continuous production line (Electric energy)

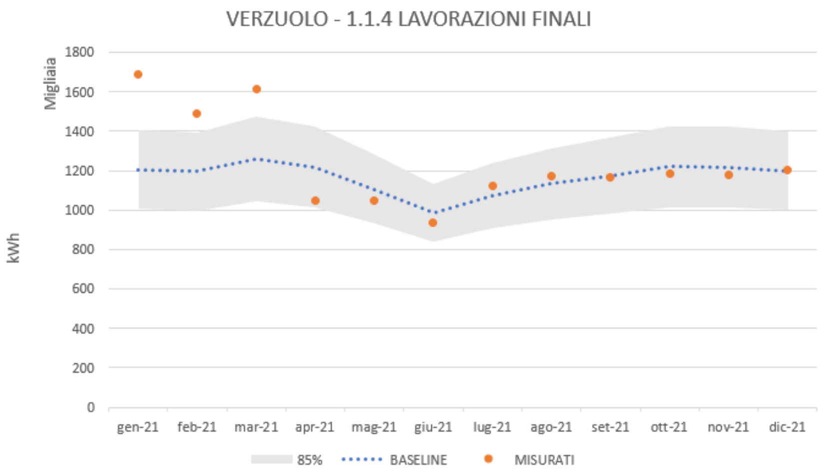

Figure 40 - Final product activities (Electric energy)

Considering "natural gas" energy flow there are no energy uses identified as SEU.

Regarding "vapour" energy flow (ton), there is a SEU in "principal activities" (EFA):

- 3.1.3. CONTINUOUS PRODUCTION LINE

This energy use refers to the vapour utilization inside the "Continuous production line". It allows to make the dried paper more malleable, so that it can be enrolled according to the production specification without damaging the canvas.

Even if identified as SEU, there is no "Significant gap" coming from the R^2 analysis.

This data is very important, since it gives a confirmation of what stated looking at electric energy consumption: the "Continuous production line" must be improved also from the vapour utilization point of view.

SEU - VAPOUR														
3.1	PRINCIPAL ACTIVITIES	u.m.	gen-21	feb-21	mar-21	apr-21	mag-21	giu-21	lug-21	ago-21	set-21	ott-21	nov-21	dic-21
3.1.3	CONTINUOUS PRODUCTION LINE	kWh	37.249.815	34.512.147	40.424.203	37.166.073	27.715.963	15.797.966	26.046.101	26.582.973	32.412.679	36.304.593	37.961.168	40.764.942
		Log(ton)	5	5	5	5	5	4	5	5	5	5	5	5
			ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok

Table 40 - SEU – Vapour

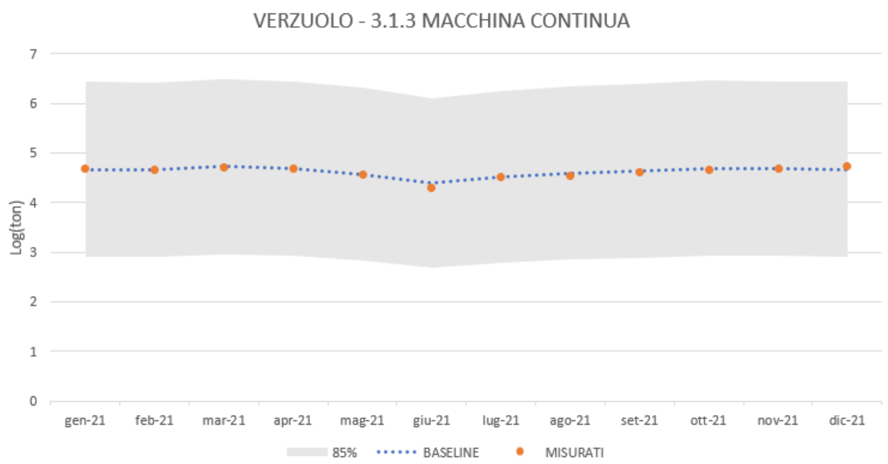

Figure 41 - Continous production line (Vapour)

Coming back to the BREF signalling that “Consumption of the plant are not in line with the Baseline”, the R^2 significance test have been applied also to the plant as a whole (PET). The plant of Verzuolo is a SEU in general, and therefore some energy efficiency interventions represent a priority in order to be more efficiency from a consumption point of view.

TOTAL PLANT CONSUMPTION													
	u.m.	gen-21	feb-21	mar-21	apr-21	mag-21	giu-21	lug-21	ago-21	set-21	ott-21	nov-21	dic-21
PET TOTAL	PET	7.374	6.890	8.000	7.222	5.826	4.118	5.949	6.292	6.924	7.392	7.546	7.827
		ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok

Table 41 – SEU - PET total Verzuolo

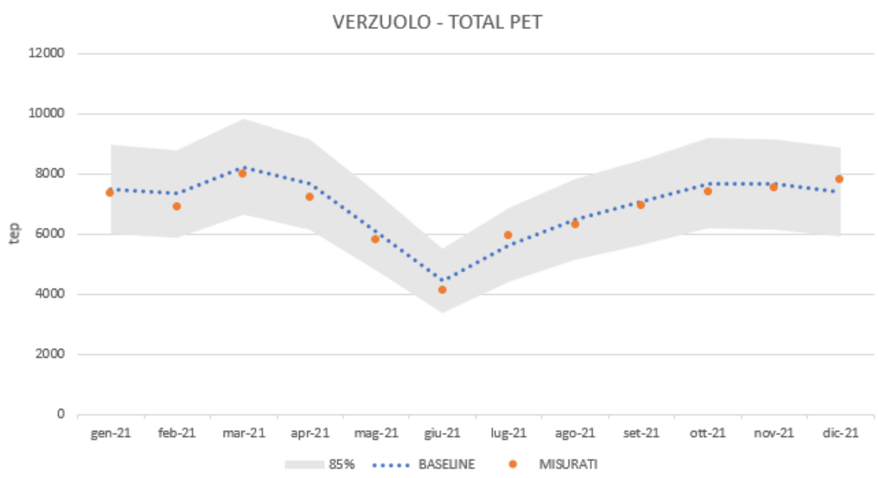

Figure 42 - Total PET Verzuolo

3.3.8. Re-assessment from top management and interventions for continuous improvement

From previous chapter analysis, the consultancy company signalled some SEUs and some potential interventions for energy efficiency improvement.

For each intervention, it has been enhanced (see "*Interventions*" sheet – "*Annex 1*"):

- Name (and type) of intervention;
- Purchasing costs [€];
- Manufacturing costs [€] (estimated as 20% of purchasing costs);
- Total investment costs [€], calculated as:

$$Total\ investment\ cost\ [€] = Purchasing\ cost\ [€] + Manufacturing\ cost\ [€]$$

- Economic savings (€/year) linked to the intervention. They have been calculated as it follows:

$$Economic\ saving\ \left[\frac{€}{year}\right] =$$

$$= Electric\ savings\ \left[\frac{MWh}{year}\right] * Electric\ energy\ price\ \left[\frac{€}{MWh}\right] + Thermal\ savings\ \left[\frac{smc}{year}\right] * Natural\ gas\ price\ [\frac{€}{smc}]$$

- Electric energy savings (MWh/year) linked to the intervention;
- Thermal energy savings (smc/year) linked to the intervention;
- Primary energy saving (PET/year) linked to the intervention. PET savings have been calculated as it follows:

$$PET\ savings\ \left[\frac{PET}{year}\right]$$

$$= Electric\ savings\ \left[\frac{MWh}{year}\right] * Conversion\ factor\ (0{,}187)\left[\frac{PET}{MWh}\right] + Thermal\ savings\ \left[\frac{smc}{year}\right] * Conversion\ factor\ (\ 0{,}000825\ )\ [\frac{PET}{smc}]$$

- O&M savings [€/year], due to the new machine lower need for maintenance (more efficient and new);
- PBT simple (number of years where Positive Cash Flow = Negative Cash Flow):

$$PBT\ simple\ [years] = \frac{Total\ investment\ [€]}{Economic\ savings\ \left[\frac{€}{year}\right] + O\&M\ savings\ [\frac{€}{year}]}$$

- CO_2 avoided [tons/year], calculated as:

$$CO2\ avoided\ \left[\frac{tons}{year}\right]$$
$$= (Electric\ savings\ \left[\frac{MWh}{year}\right] * Emission\ factor\ (288)\ \left[\frac{kgCO2}{Mwh}\right]$$
$$+ Thermal\ savings\ \left[\frac{smc}{year}\right] * Emission\ factor\ (1{,}97)\ \left[\frac{kgCO2}{smc}\right])/1000$$

For each intervention, it is also present a more structured "*Economic analysis*" sheet, that calculates:

- PBT (structured), with the "PBT" Excel formula;
- NPV, with the "NPV" Excel formula;
- IRR, with the "IRR" Excel formula.

As mentioned in the previous chapter there are two main interventions to improve the energy efficiency profile of the plant:

- A new line of machines for the "Final product activities" (9,6 M€ total investment).
- A new line of machines for the "Continuous product line" (16,8 M€ total investment);

INTERVENTION FOR ENERGY CONSUMPTION REDUCTION - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*									
INTERVENTION CHARACTERISTICS		*INVESTMENT*	SAVINGS (Incentives excluded)				ECONOMIC RETURN	*EMISSIONS*	*COMPLEXITY*
DESCRIPTION		*TOTAL [€]*	ECONOMIC [€/year]	ELECTRIC ENERGY [MWh/year]	THERMAL ENERGY [Sm^3/year]	*PRIMARY ENERGY [PET/year]*	PBT SIMPLE	*CO2 avoided [t/year]*	*Indice 1-5*
1	NEW MACHINE FOR FINAL PRODUCT ACTIVITIES	9.600.000	1.219.200	2.997,01	-	560	7,87	1.303,70	5
2	NEW MACHINES FOR CONTINUOUS LINE PM9	16.800.000	3.148.600	1.940,04	2.206.835	2.183	5,34	5.074,42	4
TOTAL		26.400.000	4.367.800	4.937	2.206.835	2.744	---	6.378	---

Table 42 - Sum up table for energy efficiency interventions

Going in detail, the savings for each intervention have been estimated as it follows:

- New machine for "Final product activities":
  - Electric energy savings: -20% of "final product activities" consumption;
  - O&M savings: 500.000 €/year (due to less maintenance need and new machine)
- New machine for "Continuous product line":
  - Electric energy savings: -20% of "Continuous production line" consumption;
  - Thermal energy savings: -2% of "natural gas" consumption (reduced need of vapour production in CHP)
  - O&M savings: 1.500.000 €/year (due to less maintenance need and new machine)

The following table resumes the intervention savings.

INTERVENTION FOR ENERGY CONSUMPTION REDUCTION - Smurfit Kappa Cartiera di Verzuolo s.r.l.Via Roma 26 - 12039 Verzuolo (CN) *Consultancy by CEC s.r.l. - Luglio 2022*												
INTERVENTION CHARACTERISTICS		*INVESTMENT*			SAVINGS (Incentives excluded)						ECONOMIC RETURN	*EMISSIONS*
DESCRIPTION		*Purchasing Cost [€]*	*Manufacturing Cost [€]*	*Total Investment [€]*	ECONOMIC [€/year]	ELECTRIC ENERGY [MWh/year]	THERMAL ENERGY [Sm^3/year]	*OTHER ENERGY SAVINGS (PET/year)*	O&M [€/year]	*PRIMARY ENERGY [PET/year]*	PBT SIMPLE	*CO2 avoided [t/year]*
1	NEW MACHINE FOR FINAL PRODUCT ACTIVITIES	8.000.000,00 €	1.600.000,00 €	9.600.000,00 €	**719.281,63 €**	2.997,01	-	-	500.000,00	560,44	**7,87**	1.303,70
2	NEW MACHINES FOR CONTINUOUS LINE PM9	14.000.000,00 €	2.800.000,00 €	16.800.000,00 €	**1.648.671,10 €**	1.940,04	2.206.835	-	1.500.000,00	2.183,43	**5,34**	5.074,42
TOTAL		22.000.000	4.400.000	26.400.000	2.367.953	4.937	2.206.835	-	2.000.000	2.744	---	6.378

Table 43 - Interventions for energy consumption reduction

Looking at the “Economic analysis” sheet, the two interventions give the following results:

- New machine for “Final product activities”:
  - PBT: 9,33 years;
  - NPV: 1.909.941 € (in 15 years);
  - IRR: 7%.

NEW MACHINE FOR FINAL PRODUCT ACTIVITIES

Actual electric consumption	245.014.087	[kWh/year]
Expected electric consumption	242.017.080	[kWh/year]
Actual thermal consumption	110.341.744	[Smc/year]
Expected thermal consumption	110.341.744	[Smc/year]
Investment Cost	9.600.000	€
New maintenance cost	200.000	€/year
Savings from maintenance	500.000	€/year
Electric energy price	0,240	€/kWh
Natural gas price	0,536	€/Smc
Inflation Rate	1,0%	
Discount Rate	4%	

PBT	9,33	years
NPV	1.909.941	€
IRR	7%	%

		anno 0	anno 1	anno 2	anno 3	anno 4	anno 5	anno 6	anno 7
ACTUAL	Electric energy expenditures		58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381
ACTUAL	Natural gas expenditures		59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
ACTUAL	TOTAL expenditures		117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452
POST INTERVENTION	Electric energy expenditures		58.084.099	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099
POST INTERVENTION	Natural gas expenditures		59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
POST INTERVENTION	Purchase and Maintenance	9.600.000	- 303.000	- 306.030	- 309.090	- 312.181	- 315.303	- 318.456	- 321.641
POST INTERVENTION	TOTAL expenditures	9.600.000	116.934.171	116.931.141	116.928.081	116.924.990	116.921.868	116.918.715	116.915.530
	NET CASH FLOW (YEAR)	- 9.600.000	1.022.282	1.025.312	1.028.372	1.031.463	1.034.585	1.037.738	1.040.922
	NET CASH FLOW (CUMULATED)	- 9.600.000	- 8.577.718	- 7.552.407	- 6.524.035	- 5.492.572	- 4.457.987	- 3.420.250	- 2.379.327

		anno 8	anno 9	anno 10	anno 11	anno 12	anno 13	anno 14	anno 15
ACTUAL	Electric energy expenditures	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381
ACTUAL	Natural gas expenditures	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
ACTUAL	TOTAL expenditures	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452
POST INTERVENTION	Electric energy expenditures	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099	58.084.099
POST INTERVENTION	Natural gas expenditures	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
POST INTERVENTION	Purchase and Maintenance	- 324.857	- 328.106	- 331.387	- 334.701	- 338.048	- 341.428	- 344.842	- 348.291
POST INTERVENTION	TOTAL expenditures	116.912.314	116.909.065	116.905.784	116.902.470	116.899.123	116.895.743	116.892.329	116.888.880
	NET CASH FLOW (YEAR)	1.044.139	1.047.387	1.050.668	1.053.982	1.057.329	1.060.710	1.064.124	1.067.572
	NET CASH FLOW (CUMULATED)	- 1.335.189	- 287.802	762.867	1.816.849	2.874.178	3.934.888	4.999.011	6.066.584

Figure 43 - Economic analysis: New machine for final product activties

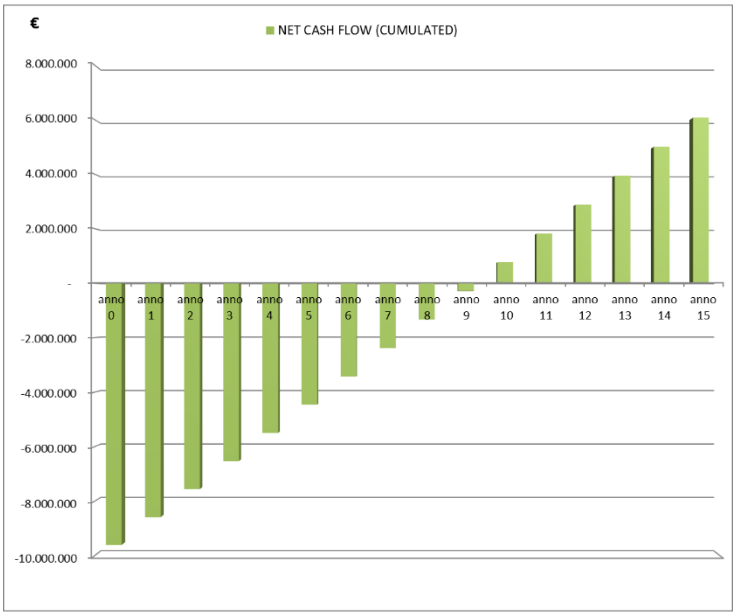

Figure 44 - NCF: New machine for final product activities

- New machine for “Continuous product line”:
  - PBT: 5,95 years;
  - NPV: 14.700.703 € (in 15 years);
  - IRR: 15%.

NEW MACHINES FOR CONTINUOUS LINE PM9

Actual electric consumption	245.014.087	[kWh/year]
Expected electric consumption	243.074.046	[kWh/year]
Actual thermal consumption	110.341.744	[Smc/year]
Expected thermal consumption	108.134.909	[Smc/year]
Investment Cost	16.800.000	€
New maintenance cost	350.000	€/year
Savings from maintenance	1.500.000	€/year
Electric energy price	0,240	€/kWh
Natural gas price	0,536	€/Smc
Inflation Rate	1,0%	
Discount Rate	4%	

PBT	5,95	anni
NPV	14.700.703	€
IRR	15%	%

		anno 0	anno 1	anno 2	anno 3	anno 4	anno 5	anno 6	anno 7
ACTUAL	Electric energy expenditures		58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381
	Natural gas expenditures		59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
	TOTAL expenditures		117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452
POST INTERVENTION	Electric energy expenditures		58.337.771	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771
	Natural gas expenditures		57.970.010	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010
	Purchase and Maintenance	16.800.000	- 1.161.500	- 1.173.115	- 1.184.846	- 1.196.695	- 1.208.662	- 1.220.748	- 1.232.956
	TOTAL expenditures	16.800.000	115.146.281	115.134.666	115.122.935	115.111.087	115.099.120	115.087.033	115.074.826
	NET CASH FLOW (YEAR)	- 16.800.000	2.810.171	2.821.786	2.833.517	2.845.366	2.857.333	2.869.419	2.881.627
	NET CASH FLOW (CUMULATED)	- 16.800.000	- 13.989.829	- 11.168.043	- 8.334.526	- 5.489.160	- 2.631.827	237.592	3.119.219

		anno 8	anno 9	anno 10	anno 11	anno 12	anno 13	anno 14	anno 15
ACTUAL	Electric energy expenditures	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381	58.803.381
	Natural gas expenditures	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072	59.153.072
	TOTAL expenditures	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452	117.956.452
POST INTERVENTION	Electric energy expenditures	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771	58.337.771
	Natural gas expenditures	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010	57.970.010
	Purchase and Maintenance	- 1.245.285	- 1.257.738	- 1.270.315	- 1.283.019	- 1.295.849	- 1.308.807	- 1.321.895	- 1.335.114
	TOTAL expenditures	115.062.496	115.050.043	115.037.466	115.024.763	115.011.933	114.998.974	114.985.886	114.972.667
	NET CASH FLOW (YEAR)	2.893.956	2.906.409	2.918.987	2.931.690	2.944.520	2.957.478	2.970.566	2.983.785
	NET CASH FLOW (CUMULATED)	6.013.175	8.919.584	11.838.571	14.770.261	17.714.781	20.672.259	23.642.825	26.626.611

Figure 45 - Economic analysis: new machine for continuous line PM9

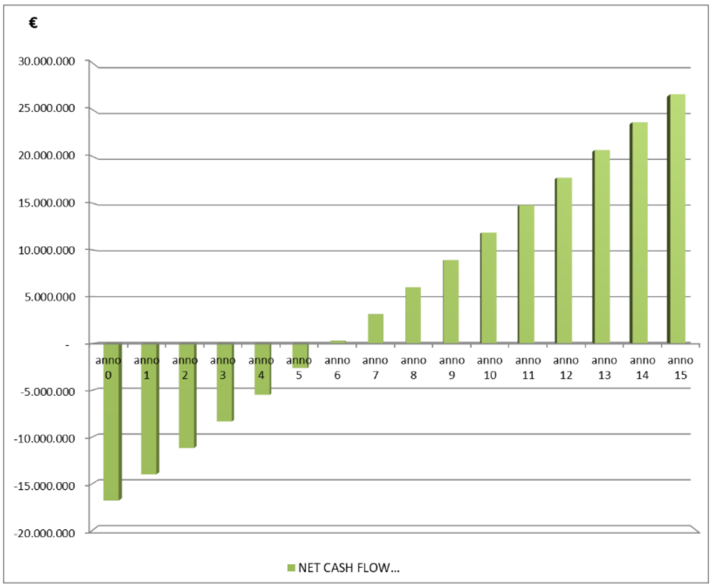

Figure 46 - NCF: new machine for continuous line PM9

The knowledge of the savings linked to these two interventions allows to calculate the "EnPI post interventions", which shows the improvement of the energy performance of the site.

The following EnPIs are considering the combined effects of both interventions illustrated before.

Real EnPI - ENERGY PERFORMANCE INDICATORS - Interventions	unit	Pre-intervention	Post-intervention	%
General indexes				
Electric energy consumption on total internal surface	kWh/m^2	2.164,41	2.120,80	-2,02%
Primary energy consumption on total internal surface	PET/m^2	1,209	1,185	-2,01%
Global production indexes				
Electric energy consumption on yearly production	kWh/t	587,43	575,59	-2,02%
Natural gas consumption on yearly production	Smc/t	264,55	259,26	-2,00%
Primary energy consumption on yearly production	PET/t	0,328	0,322	-2,01%
Energy cost on yearly production	€/t	142,59	132,12	-7%

Table 44 - EnPIs post-interventions

As can be seen in the previous table, general EnPIs like "electric energy consumption / total surface" or "primary energy consumption / total surface" will have a -2,02% and -2,01% of improvement (if the value of % is "<0" it means an improvement of that percentage).

Global production EnPIs follow a similar path:

- Electric energy consumption / yearly production: -2,02%
- Thermal energy consumption / yearly production: -2,00%

- Electric energy consumption / yearly production: -2,01%

"Energy cost / yearly production" has the most relevant improvement, with an expected improvement of -7%.

After a re-assessment meeting with the top management, the company decided to foster continuous improvement of the energy performance by ("Act" phase):

- Investing in a new production line for "Continuous line PM9" in 2022 (due to an higher IRR and NPV, with a lower PBT);
- Investing in a new production line for "Final product activities" in 2023.

4. Benchmarking: drivers, barriers, and benefits' analysis

The last part of the thesis is focusing on the results of a questionnaire sent to some clients of CEC s.r.l. that are certified UNI CEI EN ISO 50001, and for which the consultancy company is having an energy management role.

Results are benchmarked thanks to FIRE data (2021) about UNI CEI EN ISO 50001 certified companies. [29]

4.1. Questionnaire modelling and data source

The questionnaire focuses on the three dimensions analysed in chapter 2: drivers, barriers and benefits. (see "*Annex 6: Drivers, benefits and barriers of adoption survey*")
The analysis is considering different data sources:

- Results of the survey;
- Results of the questionnaire of chapter 2;
- Results of the FIRE analysis (2021) about EMS implementation in Italy [29].
- Results of the case study;

All these data are benchmarked each other to come to meaningful conclusions.

The survey has been sent to 18 clients of CEC s.r.l. that are certified UNI CEI EN ISO 50001. The response rate has been 83,3% (15/18). All of them are considered "Big companies" ("Grandi imprese"), according to the Italian legislation (none of them is a SME).
The survey is composed by three introductory questions:

- Is your organization an energy-intensive company?
- Are you an "obliged subject" for energy audit? (ISO 16247: 2014)
- Does your company have other HLS (High Level Structure) certification?

The whole cluster resulted being "obliged subjects".

Instead, the 73,3% of them (11/15) are "energy-intensive companies" ("energivori").

Regarding the HLS, the cluster splits as it follows:

- 86,7% (13/15): companies that already have a certified “Quality management system” (ISO 9001);
- 93,3% (14/15): companies that already have a certified “Safety and security management system” (ISO 45001);
- 66,7% (10/15): companies that already have a certified “Environmental management system” (ISO 14001).

The result of the question is perfectly in line of what stated in the “State of art” chapter (2.5): the possibility of integrating all management systems in a unique database (HLS) boosts the adoption of an EMS that is certified according to UNI CEI EN ISO 50001 procedures.

HLS is one of the main driver pushing organizations to implement a EMS, according to the FIRE report. This statement is confirmed by the result of the question.

Once set this introductory database, the core of the survey takes place.

For each category (drivers, barriers, and benefits), the clients have been asked to assign a score from “1” to “5”, according to the importance of the specific “variable” (the same as chapter 2 questionnaire) in being a driver, barrier, or benefit of adoption for an EMS:

1: no effect

2: a little important

3: important

4: very important

5: totally important

At the end of questions for each category, the clients have been asked to list the three most important drivers, benefits and barriers.

For each “variable” (the driver, barrier, or benefit belonging contributing to a “factor”), an average of the results has been made (“mean value”).

In the following paragraphs, drivers, barriers and benefits are analysed.

Results are then compared to the ones coming from chapter 2 questionnaire (“Old value”), showing also the difference in % (“Delta %”).

They are also benchmarked with results of the questionnaire of chapter 2, including some comments about what stated by the FIRE in their EMS implementation (ISO 50001) analysis (2021).

For each category, there are some considerations according to the results of the “SKI s.r.l. – Verzuolo site” case study.

4.2. Drivers' analysis

The following table shows the results of the questions linked to the drivers of adoption for an EMS, according to UNI CEI EN ISO 50001 procedures.

		Variables	Mean Value	Old value	Delta %
F1	**Social requirements**	Incentive given by public administration	1,73	2,19	-21%
		Pressure from professional associations	1,93	2,30	-16%
F2	**Ecology Drivers**	Improve energy efficiency	3,53	4,42	-20%
		Reduce GHG effects	3,60	3,49	3%
		Enhance employee energy awareness	3,00	4,02	-25%
		The rise of energy prices	4,73	3,67	29%
		The impacts of climate change	3,67	3,39	8%
F3	**Competitive Advantage**	Competitors pressure	2,87	2,51	14%
		Clients' requirements	3,33	2,67	25%
		Image improvement	4,27	3,67	16%

Table 45 - Results of the survey: Drivers analysis

Through an exploratory factor analysis with equal weights for each variable, it is possible to estimate the value of each factor as the average of all its variables:

- F1 – Social requirements: 1,83;
- F2 – Ecology drivers: 3,71;
- F3 – Competitive advantage: 3,49.

Looking at the results, the "Ecology drivers" (F2) have the highest impact on the decision to adopt an EMS.

In particular, the main driver influencing the decision is "the rise of the energy prices" (4,73). It seems that the energy futures, in which prices are expected to strongly increase in future years, frighten most of organisations. For this main reason, adopting an EMS becomes fundamental to monitor consumption, and therefore reduce as much as possible the risks linked to a price increase.

This result is much higher compared to the value of the questionnaire in chapter 2 (+29%). This is mainly due to the different cost of energy (much lower in the years when that study has been published), but also to the different prospect of energy futures.

However, the previous result (3,67) was still one of the highest, even if not that high.

Also in the FIRE analysis, energy cost reduction driver is one of the most relevant. It is linked to an expected increase of the energy prices. It is therefore in line with the result of the survey.

In the analysis presented in chapter 2, the "improvement of energy efficiency" was the most relevant variable (4,42). Such variable is reduced by -20% in the thesis analysis, even if it is still one of the highest value (3,53). It seems that organisations are not interested in the improvement of the energy efficiency of the plant per se. They are more frightened by the increase of the energy price.

According to the FIRE analysis, this is mainly due to the economic impact of energy efficiency improvements. Even if the 50001 procedure helps in identifying SEUs and therefore areas of improvement, the surveyed organisations are "obliged subjects". It means that they have to conduct the energy audit each four year according to the Italian legislation. In certifying UNI CEI EN ISO 50001, they give priority to the adoption of an EMS (with the related investment), rather than to an energy efficiency improvement per se (less costly and more beneficial). Indeed, they can identify some energy efficiency interventions even without the certification.

The value of energy efficiency improvement is very similar to "reduction of GHG effects" (3,60) and to "impacts of climate change" (3,67). Such values increased by +3% and +8% respectively, confirming the more and more importance of such themes for organisations.

"Enhance employee energy awareness" (3,00) is not considered so much valuable as before (4,02). Indeed, the mean value is reduced by -25%. This is due to a better awareness of sustainability and efficiency topics on companies' side.

As stated by the FIRE analysis, organisations identify the presence of leadership commitment as a Key Success Factor (KSF) of the EMS implementation. For this reason, employees' energy awareness is a consequence of the top management commitment. Therefore, it is not a strong driver for EMS implementation.

Going back to the survey, "Competitive advantage" (F3) has a similar relevance compared to the "Ecology drivers" (F2). Indeed, this factor has a mean value of 3,49 (vs 3,71 of F2). The variables composing this factor had a strong increase compared to the older analysis of chapter 2:

- Competitors' pressure: +14% (2,87)
- Clients' requirements: +25% (3,33)
- Image improvement: +16% (4,27)

Such results are strong evidence of the increasing importance of an EMS, from a strategic point of view. Indeed, in previous years it was more as an operational advantage, linked just to a better facility management, guaranteeing a reduction of consumption. As stated also by the FIRE analysis, the adoption of UNI CEI EN ISO 50001 procedure is mainly due for competitive advantage purposes.

Its adoption allows organisations to:

- Open to new markets requiring the certification;
- Increase the sustainability strategy of the group;
- Improve the image of the company.

Such statements are confirmed by the survey results too. “Image improvement” (4,27) is only second to “increase of energy price”, showing the importance of the certification nowadays.

“Clients’ requirements” (3,33) and “Competitors’ pressure” (2,87) have a much lower value.

According to the FIRE analysis, the presence of competitors having the certification is not a threat. Instead, it is very beneficial to enforce the core business. Having care of energy topics is beneficial on the final product and on the market, giving more importance to the product in the market, due to a sustainable operations’ policy (especially if adopting an HLS).

This is perfectly in line with the survey results. In fact, “clients’ requirements” have an higher value compared to “competitors pressure”. This result shows that the benefits linked to an EMS adoption reinforce the core business (and the relationships with clients ultimately).

Looking at the FIRE analysis, the “competitive advantage” linked to an EMS implementation is the most important driver. Even more important than the energy prices influence and the environmental impact improvement.

The thesis shows a very similar influence of both “ecology drivers” (F2) and “competitive advantage” (F3). While it is a different speech for “Social requirements” (F1).

As stated in the questionnaire of chapter 2, they have a very low influence in the EMS implementation. Nor “incentives given by public administration” (1,73) or “pressures from professional associations” (1,93) seems to have any relevant impact on the decision of certifying UNI CEI EN ISO 50001.

Also in the FIRE analysis, they are not even mentioned as a driver pushing organisations towards achieving the certification.

The Italian energy entity states that companies seem more forced than incentivized. Indeed, being mandatory to conduct an energy audit each four years, they see the certification as a further step to improve the energy audit results.

Organisations do not see convenient incentives (like “White certificates” or “EETs”) from a 50001 perspective. They see this kind of incentives more linked to energy efficiency interventions, as required by law through the energy audit. This is confirmed by the FIRE analysis, which do not consider the issue of "white certificates" as a relevant driver. They are more easily obtainable with an energy efficiency intervention than with an EMS implementation, according to the FIRE.

The following figure shows the three most relevant drivers, according to the CEC s.r.l. clients that answered to the survey.
Results are perfectly in line with the drivers' analysis explained before.

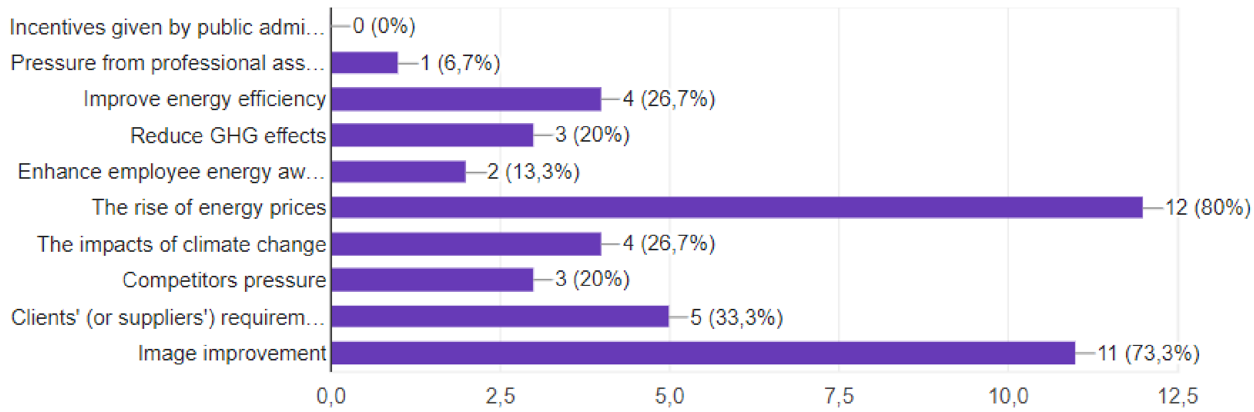

Figure 47 - Most relevant drivers according to the thesis survey

Also in the Verzuolo case, "the rise of energy prices" has been identified as a strong driver. Anyway, the company has more attention on the "image improvement" linked to the certification achievement. In particular, SKI s.r.l. wants to export paper in North-Europe, in which "clients require" the ISO 50001 certification. However, there are no "pressures from competitors".

They also want to "improve the energy efficiency" of the plant, in order to foster their sustainability strategy. But there are few motivations linked to "enhancing employee energy awareness".

"Reduce GHG effects" and the "impacts of climate" are therefore relevant too, according to the group strategy fostering sustainability.

There are no motivations linked to "public administration incentives" or due to "pressure from professional associations".

4.3. Barriers' analysis

The following table shows the results of the questions linked to the barriers of adoption for an EMS, according to UNI CEI EN ISO 50001 procedures.

		Variables	Mean Value	Old value	Delta %
F6	**Operational difficulty**	Necessity of continuous measurement tools	3,60	3,34	8%
		Data complexity	3,60	3,04	18%
		Lack of economic resources	3,33	3,02	10%
		Norm complexity	2,40	2,26	6%
F7	**Organizational difficulty**	Changing mindset	2,87	2,77	3%
		Internal communication	2,80	2,40	17%
		Lack of leadership commitment	3,07	2,28	35%
		Benefits uncertainty	2,20	2,57	-14%

Table 46 - Results of the survey: Barriers analysis

Through an exploratory factor analysis with equal weights for each variable, it is possible to estimate the value of each factor as the average of all its variables:

- F6 – Operational difficulty: 3,23;
- F7 – Organizational difficulty: 2,74;

Looking at the survey of chapter 2, "Operational difficulty" had a mean value of 2,92, while 2,51 for "Organizational difficulty". Similarly, they follow this trend in the thesis' survey, with "Operational difficulties" considered more relevant in preventing the adoption of an EMS. However, the two values increased by +11% and +9% respectively.

As stated in the previous questionnaire, the most relevant barrier was the "necessity of continuous measurement tools" (3,34). In the survey such value is increased by 8% (3,60), but it is still the most valuable barrier.

This barrier is confirmed as the most relevant also by the FIRE analysis. According to the Italian energy entity, the "absence of time and economic resources" is the main difficulty in the implementation of an EMS, followed by the "adaptability of resources to the EMS".

The absence of economic resources is strongly linked to the need of implementing an EMS, due to the investment cost. But it also refers to the costs for assuming an "Energy Management Expert" (EME) and to the costs of training or hiring new resources.

This statement perfectly reflects the survey results, in which "Lack of economic resources" (3,33) has the third score for barriers.

"Data complexity" (3,60) has the same value of "necessity of continuous measurement tools". This is in line with what stated by the FIRE analysis. Indeed, the need of hiring new resources, or the need to hire partially an EME for the EMS implementation path, are strong evidence that the data management linked to monitoring activities is often critical.

A bad monitoring of consumption could leave to non-conformities (therefore preventing the certification), but also to wrong evaluations of the consumption profile of the organisation (therefore giving misleading results).

“Norm complexity” (2,40) is one of the lowest barriers, according to the survey results.

This is confirmed also by the FIRE analysis, in which it is considered as one of the lowest. The FIRE identifies “internal bureaucracy” as more relevant.

The survey confirms such statement. Indeed, going on with “Organizational difficulty” (F6) analysis, it can be observed that “Changing mindset” (2,87) and “Internal communication” (2,80) are more relevant than “norm complexity” (2,40).

In fact, “changing mindset” and habits is really though for well-structured organisations. The way they used to operate, and therefore how they used to communicate internally too, has a strong impact if not in line with UNI CEI EN ISO 50001 procedures.

It may require changes in the company culture and in the employee day-by-day activities, which could be not well accepted. Resources are maybe unable to modify their activities to follow the procedure for managing an EMS. Inability of energy management or responsibilities misalignment could be consequences of a relevant internal bureaucracy. As a confirmation, the FIRE considers the second and the third most relevant barriers the “absence of specific competences” and the “employees’ adaptation to the EMS”.

This is perfectly in line with the thesis survey results.

“Lack of leadership commitment” (3,07) is not seen as a barrier by the FIRE.

Instead, the “presence of leadership commitment” is seen as one of the most important KSF for a meaningful EMS implementation. If absent, the EMS implementation is still achievable, but would not give the expected results and benefits.

“Benefits uncertainty” (2,20) has reduced along the years (-14% compared to previous analysis of chapter 2).

This is due to a better communication of the importance of the UNI CEI EN ISO 50001 procedures, also reflected by the results of the organizations that have implemented it in previous years.

The following figure shows the three most relevant barriers, according to the CEC s.r.l. clients that answered to the survey.

Results are totally in line with the barriers analysis shown before.

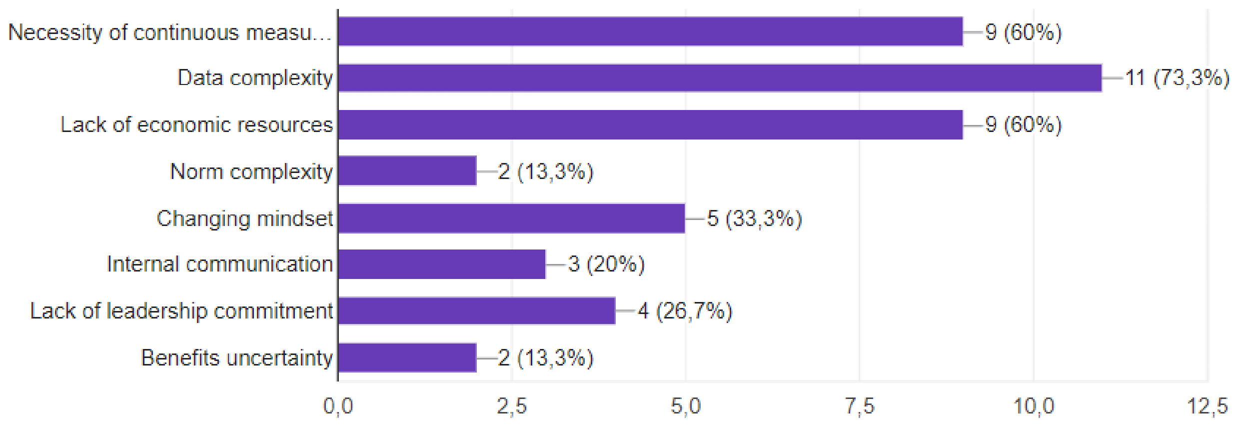

Figure 48 - Most relevant barriers according to the thesis survey

In the Verzuolo case, having a good knowledge on EM activities, there are no issues of "changing mindset" or "internal communication".

Procedures of monitoring started years ago, even if not collected in a unique HLS database.

This novelty could lead to the "data complexity" barrier, therefore the company asked the help of CEC s.r.l. as energy consultancy company. The group strategy shows that there is no "lack of leadership commitment" and no "lack of economic resources", justified by the decision of investing in energy efficiency interventions in the following two years.

The decision to invest in an EMS two years ago justify that "necessity of continuous measurement tools" is not a barrier for the company.

The presence of an energy consultant eliminates the barriers linked to "norm complexity" and "benefits uncertainty", which are therefore absent.

4.4. Benefits analysis

The following table shows the results of the questions linked to the benefits of adoption for an EMS, according to UNI CEI EN ISO 50001 procedures.

		Variables	Mean Value	Old value	Delta %
F4	Ecological benefits	Energy saving	4,20	4,43	-5%
		Improvement of environmental performance	3,73	4,02	-7%
		Improvement of environmental impact	3,40	3,83	-11%
		Increase of environmental awareness	3,13	3,55	-12%
F5	Production benefits	Increase plant safety	2,13	2,47	-14%
		Increase overall productivity	2,27	3,04	-25%
		Process optimization	3,07	3,49	-12%
		Improvement of product performance	2,93	2,38	23%

Table 47 - Results of the survey: Benefits analysis

Through an exploratory factor analysis with equal weights for each variable, it is possible to estimate the value of each factor as the average of all its variables:

- F4 – Ecological benefits: 3,62;
- F5 – Production benefits: 2,60;

"Ecological benefits" (F4) have a much higher value compared to "Production benefits" (F5). Even though they are reduced by -8,6% (3,96) and -8,7% (2,85) respectively, they follow a very similar trend compared to the questionnaire of chapter 2.

"Energy saving" is the most perceived benefit (4,20). Indeed, an EMS allows to monitor the consumption profile of the company. It gives the possibility to reduce utilization of machines, reducing setup time or production time of machines. It also gives some insights of which area to improve (thanks to the SEU identification and the prioritization of interventions). According to the FIRE analysis, organizations can benefit from an energy saving just by monitoring activities, as shown in the following figure.

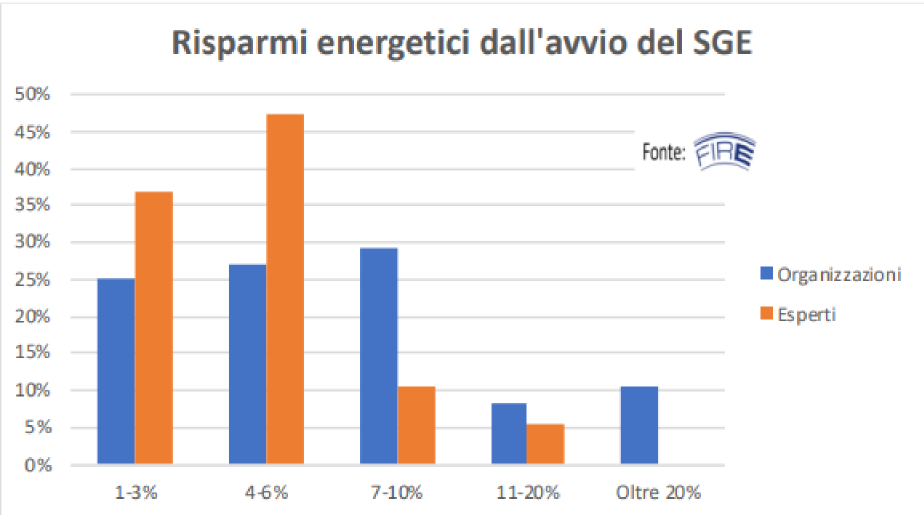

Figure 49 - Energy saving % according to the FIRE analysis (2021)

On average, most of organizations can achieve 5-10% of energy savings just by implementing an EMS.
“Improvement of environmental performance” (especially reduction of GHG emissions) is another relevant benefit perceived by organizations in implementing an EMS (3,73). Indeed, it was the second value for importance also in the questionnaire illustrated in chapter 2.
The FIRE analysis confirms the perception of environmental performance improvement, especially regarding the savings due to a reduced consumption of climate machines (chiller or air conditioning). According to the analysis, the environmental impact reduction is also due to a lower utilization of production machines, which therefore reduce the total emissions of the plant. Consequently, there is an improvement of the company image and a better management of resources in the plant.
“Improvement of the environmental impact” is another relevant benefit (3,40). It is strictly linked to a better plant management, that allows to do economies of scale, circular economies, or a better waste management. Therefore, an EMS is beneficial also from the environmental impact point of view, since it allows a better plant management.
“Increase of environmental awareness” is another important benefit (3,13). It refers not only to a consciousness of the environmental impact of the company, but also to a good energy management, which allows to foster sustainability.
This benefit has been perceived mostly by the organizations that had not a very structured energy management before the EMS implementation, according to the FIRE analysis.
In the FIRE analysis, it is also mentioned an improvement of the SDGs due to a better EM. The Italian energy entity states that the improvement of environmental awareness due to an EMS implementation creates more consciousness on sustainability topics, which ultimately reflects on a higher rate of SDGs accomplishment.
“Production benefits” are not as relevant as “Ecological” ones.
Anyway, they have their importance, also according to the FIRE analysis.
Referring to the survey results, “Process optimization” (3,07) is the most important for this category. Even if the value is lower than the previous analysis (-12%), also the FIRE analysis confirms that organizations implementing an EMS perceive an innovation of processes, linked to an improvement of the utilization of machine. This reduced utilization has an impact on the time of processing products in all production machines, which can ultimately reflect on a better productivity or into an increased quality of product.

Indeed, also “improvement of product performance” is an important production benefit (2,93). It is the only benefit that has been improved compared to previous analysis of chapter 2 (+23%). As mentioned before, the energy saving is also due to a more conscious utilization of machines. It allows to increase productivity and product quality, thanks to a better monitoring of the production lines. It helps in detecting scraps, or out-of-control situations for production machines. An EMS also reduces setup times, which is beneficial on the production Lead Time. Often, it has a good impact also on the product quality, according to the FIRE analysis.

“Increase overall productivity” (2,27) has a much lower value (-25%) compared to the previous analysis (3,04). The FIRE analysis confirms this result, since they collected a lower number of organizations perceiving this benefit, compared to the analysis they made in 2016 on ISO 50001 implementation in Italy.

“Increase plant safety” (2,13) is the lowest perceived benefit. Even though an EMS improves the performance of the plant, in terms of consumption, productivity and quality, it has little impact on the plant safety. It is not even mentioned in the FIRE analysis, since a better plant safety is much more linked to a “Safety and security management system”, according to ISO 45001 procedures.

A non-energy benefit that is not considered in the survey is the “image improvement”.

It has been considered as a driver of adoption, but of course, it is also a benefit.

The thesis decided to use it as driver, since it is something that pushes organizations towards an EMS implementation, even it is also a benefit in terms of market and supply chain performance.

According to the FIRE analysis, it is the second for importance as benefit, only behind the “energy savings” and the related “cost reduction” achievable.

The perception of cost reduction is another important aspect to mention.

As FIRE states, most of organizations are used to focus on minimizing the unitary cost of the product (to increase unitary margin) without caring of the energy consumption.

The energy cost has been considered by most of the organization has a whole plant cost, without splitting it on the production. Instead, applying UNI CEI EN ISO 50001 procedures, companies must calculate the EnPI related to the production rate (e.g. kWh/ton).

Thanks to this EnPI, organizations understand the impact that energy has on the single piece produced. Therefore, they gain a better consciousness of the impact of the energy

consumed in the single unit produced, allowing them to reduce the unitary cost of the product just through a better monitoring of energy consumption.
According to the FIRE analysis, this is the most important externality linked to an EMS implementation according to UNI CEI EN ISO 50001 procedures.

The following figure shows the three most relevant benefits, according to the CEC s.r.l. clients that answered to the survey.
Results are in line with the benefits analysis illustrated before.

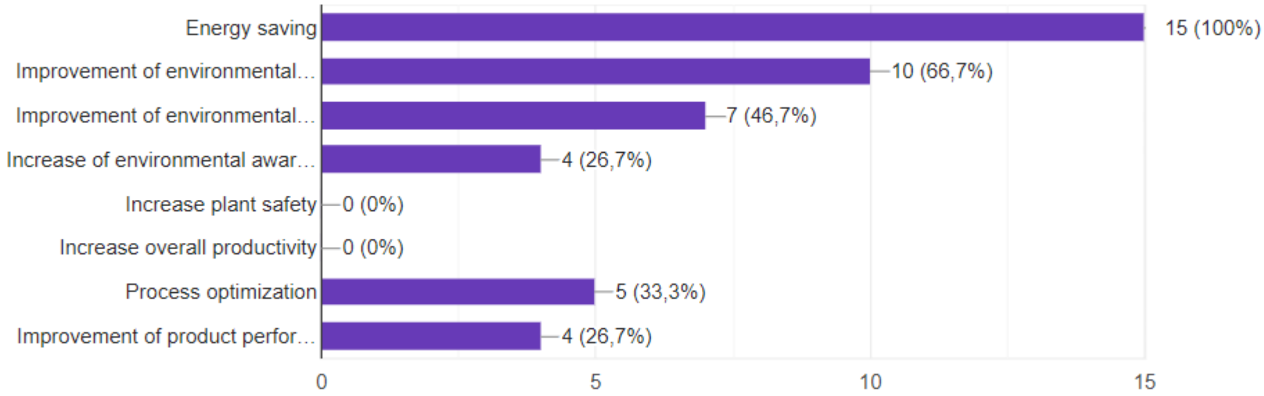

Figure 50 - Most relevant benefits according to the thesis survey

Also in the Verzuolo case, there are no benefits perceived as "increased plant safety" or "increased overall productivity", which are more linked to ISO 45001 and to ISO 9001 management systems respectively.
The "improvement of product performance" is perceived (in particular in the product quality), as well as "process optimization" (especially in reduced setup time).
The "increase of environmental awareness" and "impact" are more linked to the benefits of ISO 140001, according to the top management. Anyway, environmental impact and awareness are present in the company, because of their sustainability strategy (recycled input, circular economies, and biomass production).
Instead, they retain that the there is an "improvement of environmental performance" linked to the UNI CEI EN ISO 50001 procedures, due to a reduced utilization of machines (and therefore a reduction of GHG emissions).
The "Energy saving" is the most perceived benefit. They declared to have perceived an energy saving of 5% in the year (2019) they implemented a monitoring system (even if was not yet a structured EMS).

The improved value of EnPIs, especially considering “EnPIs post-intervention” (calculated with energy savings due to energy efficiency interventions) is a proof of what declared by the company.

5. Conclusions

The thesis shows an interesting real case study of implementation of an EMS, according to UNI CEI EN ISO 50001 guidelines.

The "SKI s.r.l. – Verzuolo (CN)" case study demonstrates how to introduce an effective PDCA cycle for an Energy Management System.

After defining the energy context, the EMT, the energy policy with all energy goals, and the energy risks and opportunities, the thesis shows a real case of energy analysis.

By applying monitoring and control, the thesis illustrates the SEU identification with a prioritization of energy efficiency interventions. It also demonstrates the positive impact of an EMS in terms of energy consumption through the calculation of EnPIs, comparing theoretical and real ones (also showing their improvement post-interventions).

The survey issued to CEC s.r.l. clients that have implemented an EMS according to UNI CEI EN ISO 50001 procedures gives interesting results, which confirms what stated in the chapter 2 analysis.

Also comparing the results with the FIRE analysis (2021) and applying the survey to the case study of Verzuolo plant, the thesis comes to some conclusions regarding drivers, barriers and benefits of the certification.

Implementing an EMS is an act of leadership commitment, which must translate into employee awareness on energy topics. Such commitment should also reflect into the energy policy and the company sustainability strategy.

The presence of other management systems like environment (ISO 14001), quality (ISO 9001), and safety and security (ISO 45001) allows to create a unique database for managing the plant (HLS). The adoption of an EMS is strongly beneficial for companies that have achieved these other certifications since they can manage the plant with more effectiveness and efficiency.

The two main drivers pushing organisations towards the certification are the image improvement and the increase of energy prices.

Adopting an EMS is beneficial on the market, on the supply chain, and enforces the core business, acquiring clients and supplier that requires it. It does not give a clear advantage on the competitors but creates competitive advantage in the market and in the supply chain.

The increase of energy prices could reflect ultimately on the product unitary cost.

Adopting an EMS means reduce the energy consumption of the plant; therefore it would reduce the energy consumption linked to production.

Increasing the energy efficiency is not the main goal, but it is important as well.

It is more a consequence of energy audit activities than a driver for the implementation of an EMS.

Reducing GHG effects and the impacts of climate change is a relevant driver for companies that have a strong sustainability strategy, especially for the ones also achieving ISO 14001 certification.

The main barrier for an effective EMS implementation is the lack of economic resources.

It has impact on both the decision of investing in an EMS and on the cost of training or hiring new resources, to gain EM competences.

Monitoring data is another relevant difficulty due to their complexity in managing them.

This could be a consequence of scarce know-how on energy management.

It could be also due to an organisational culture that requires to change the employee mindset or the internal communication style, otherwise it would prevent an effective EMS implementation.

The main benefit perceived is the energy saving. Just by implementing a monitoring system, the whole plant consumption is reduced due to a better consciousness of the consumption profile. By implementing an EMS, the energy saving is more and more relevant.

Other relevant benefits are the improvement of the environmental performance (reduced GHG emissions) and the improvement of the environmental impact (applying also circular economies). The increase of environmental awareness among employees is another tangible benefit, reflected also in higher energy management competences and awareness.

Benefits about the product performance (quality but also productivity) and the process optimization (reduced consumption) can be noticed.

Image improvement and the related competitive advantage is not only a driver, but also a benefit for organisations in the supply chain and in the market.

Bibliography

[1] European Commission, The European Green Deal - COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, Bruxelles, 2019, pp. 2-14.

[2] Autorità di Regolazione per Energia Reti e Ambiente (ARERA), "RISPOSTA ALL'AUMENTO DEI PREZZI DELL'ENERGIA: UN PACCHETTO DI MISURE D'INTERVENTO E DI SOSTEGNO" (ATTO 660/2021), 2022, pp. 5-9.

[3] General Assembly (United Nations), Transforming our world: the 2030 Agenda for Sustainable Development, 2015, pp. 14, 22-23.

[4] A. Quazi, K. Yee-Koon, T. Chin-Meng and W. Poh-Seng, Motivation for ISO 14000 certi cation: development of a predictive model, 29 ed., Singapore: Omega, 2001, pp. 525-542.

[5] Ente Italiano di Normazione (UNI), Comitato Elettrotecnico Italiano (CEI), Comité Européen de Normalisation (CEN), International Organization for Standardization (ISO), European Normative: Energy management systems - requirements with guidance for use, 2018-2019.

[6] P. Bansal and K. Roth, Why companies go green: A model of ecological responsiveness, Acad. Manag. J., 2000, pp. 43, 717-736.

[7] E. Neumayer and R. Perkins, Uneven Geographies of Organizational Practice: Explaining the Cross-National Transfer and Diffusion of ISO 9000, vol. 85, 2005, pp. 237-259.

[8] O. Perez, Y. Amichai-Hamburger and T. Shterental, The Dynamic of Corporate Self-Regulation: ISO 14001, Environmental Commitment, and Organizational Citizenship Behavior, Law Soc. Rev, 2009, pp. 43, 593-630.

[9] M. Chavan, An appraisal of environment management systems: A competitive advantage for small businesses, Manag. Environ. Qual. Int. J., 2005, pp. 16, 444-463.

[10] B. Jovanovic and J. Filipovic, ISO 50001 standard-based energy management maturity model - proposal and validation in industry, 2015.

[11] A. Amundsen, Joint management of energy and environment, 2000, pp. 1-2.

[12] M. Casadesús and F. Marimon, Reasons to Adopt ISO 50001 Energy, http://www.mdpi.com/journal/sustainability, 2017.

[13] ISO Central Secretariat, Win the Energy challenge with ISO 50001, Geneva, Switzerland: ISO (International Organization for Standardization), 2011.

[14] V. Dobes, New tool for promotion of energy management and cleaner production on no cure, no pay basis, vol. 39, J. Clean. Prod., 2013, pp. 255-264.

[15] J. Pan, A comparative study on motivation for and experience with ISO 9000 and ISO 14000 certification among Far Eastern countries, vol. 103, Ind. Manag. Data Syst., 2003, pp. 564-578.

[16] Psomas, Motives, difficulties and benefits in implementing the ISO 14001 Environmental Management System, 22 ed., Manag. Environ. Qual. Int., 2011, pp. 502-521.

[17] J. Gonzalez-Benito and O. Gonzalez-Benito, An analysis of the relationship between environmental motivations and ISO 140001 certification, 16 ed., Br. J. Manag., 2005, pp. 133-148.

[18] F. Marimon, M. Alonso-Almeida, M. Rodriguez and K. Alejandro, The worldwide diffusion of the global reporting initiative, 33 ed., J. Clean. Prod., 2012, pp. 132-144.

[19] K. Babakri, R. Bennet and M. Franchetti, Critical factors for implementing ISO 14001 standard in United States industrial companies, 11 ed., J. Clean. Prod., 2003, pp. 749-754.

[20] A. Wessels, Energy Management System adoption at Toyota SA. In proceeding of the 8th Conference on the Industrial and Commercial Use of Energy, Cape Town, South Africa, 2011.

[21] D. Velazques, R. Gonzalez-Falcon, L. Perez-Lombard, L. Marina Gallego, I. Monedero and F. Biscarri, Development of an energy management system for a naptha reforming plant: a data mining approach, 67 ed., Energy Convers. Manag., 2013, pp. 217-225.

[22] S. Liyin, Y. Hong and A. Griffith, Improving environmental performance by means of empowerment of contractors, 17 ed., Manag. Environ. Qual. Int. J., 2006, pp. 242-257.

[23] S. Zeng, C. Tam, V. Tam and Z. Deng, Towards implementation of ISO 14001 environmental management systems in selected industries in China, 13 ed., J. Clean. Prod., 2005, pp. 645-656.

[24] G. Lambert, Never Tire of Saving Energy! ISO 50001 is a Win-Win for Bridgestone, Geneve, Switzerland: ISO Central Secretariat, 2013.

[25] A. Jabbour, J. Verderio, C. Jabbour C, F. Leal, L. Souza and R. Castro, Toward greener supply chains: Is there a role for the new ISO 50001 approach to energy and carbon management?, 10 ed., Energy Effic., 2017, pp. 777-785.

[26] Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Industrial Energy Management Systems in Italy: state of art and perspective, Rome, 2015.

[27] American Council for an Energy-Efficient economy, The 2014 International Energy Efficiency Scorecard, 2014.

[28] FIRE Formazione , Corso intensivo ISO 50001, Andrea Grava, 2022.

[29] FIRE, Indagine sullo stato di attuazione dei sistemi di gestione dell’energia ISO 50001, 2021.

[30] Italian Governement, DECRETO LEGISLATIVO 4 luglio 2014, n. 102 - Attuazione della direttiva 2012/27/UE sull'efficienza energetica, che modifica le direttive 2009/125/CE, Roma: Gazzetta Ufficiale della Repubblica Italiana, 2014.

[31] International Organization for Standardization, Energy Diagnosis guidelines - p.5: Energy Audit, 2014.

Annexes

Annex 1: Energy Diagnosis SKI s.r.l. – Verzuolo (CN).xlsx

Annex 2: Gap analysis.xlsx

Annex 3: Energy context.docx

Annex 4: Energy policy and EMS.docx

Annex 5: Risks and opportunities assessment.docx

Annex 6: Drivers, benefits and barriers of adoption survey

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