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"Procedure for Energy Management and Optimization of Renewable Energy Integration for Public Administrations in Small and Medium-Sized Municipalities"

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Pas	Public Administration
EnMS	Energy Management System
PNRR	National Recovery and Resilience Plan
RECs	Renewable Energy Communities
ISO	International Organization for Standardization
EnPIs	Energy Performance Indicators
LED	Light Emitting Diode
SECAP	Sustainable Energy and Climate Action Plan
EnBs	Energy Baseline
FIRE	Italian Federation for the Rational Use of Energy
CDD	Cooling Degree Days
CEA	City Energy Analyst
PV	Photovoltaic
UCL	Upper Control Limit
LCL	Lower Control Limit
CO₂	Carbon dioxide
KPI	Key Performance Indicator

ABSTRACT

In the context of the energy transition in PAs, this research proposes and tests a replicable methodology for implementing an Energy Management System (EnMS) compliant with the ISO 50001 standard in small- to medium-sized municipalities. The case study focuses on the Municipality of Mascalucia, with which a formal agreement was signed for energy auditing and management. On-site inspections and monthly consumption data collection were carried out to perform energy audits across multiple public buildings. Bill analysis and anomaly detection via CUSUM curves made it possible to identify consumption peaks and irregularities, guiding targeted efficiency measures—particularly lighting retrofit (relamping). Microsoft Power BI was used for dynamic data visualization and monitoring, while advanced modelling was conducted with City Energy Analyst. To assess the potential contribution of renewable energies, estimates were made of the coverage rate achievable by photovoltaic installations on the audited buildings. Results show that, although efficiency measures theoretically deliver significant savings, operational variations, occupancy fluctuations, and unforeseen anomalies often affect actual performance. The study underscores the importance of continuous monitoring, dynamic performance indicators, and stakeholder engagement—key elements for the sustainability and resilience of public infrastructures. The developed model offers an operational framework applicable to other municipalities, contributing to integrated energy management strategies for local administrations.

INTRODUCTION

Energy management and the integration of renewable energy sources into the urban fabric are critical issues in the formulation of action plans aimed at improving the energy performance of municipal building stocks. From a regulatory standpoint, the National Recovery and Resilience Plan (PNRR) represents a key economic and social policy instrument adopted by the Italian government to address the consequences of the COVID-19 pandemic and to foster the country's economic recovery, with particular emphasis on sustainability and digital transformation. PAs play a central role in the implementation of the PNRR, as they are responsible for executing the proposed measures and coordinating actions at both local and national levels. Notably, a significant portion of the plan's investments is allocated to the energy retrofit of public buildings, and four of the six missions outlined in the PNRR directly involve PA activities.

A long-term strategic vision requires the development of an Energy Management System (EnMS), structured through a set of procedures specifically tailored to the energy needs and operational characteristics of PAs. Within this framework, the present research project is situated, aiming to define standardized procedures for energy management in PAs of small and medium-sized Italian municipalities. These procedures are designed to systematize energy auditing processes and to optimize the integration of renewable energy sources in the relevant urban areas, thus also facilitating the potential creation of Renewable Energy Communities (RECs). Energy Management Systems (EnMS) integrate the actions of various stakeholders within the organization, including top management, technological systems, internal staff, external suppliers, and the broader social and territorial context. Each of these actors can influence—and potentially improve—overall energy performance. As previously mentioned, EnMS represent an integrated approach to managing and optimizing energy use within an organization. They involve all the aforementioned elements that affect energy performance. The involvement of top management is essential, as the definition of energy objectives and policies at the strategic level provides the direction and support necessary for the effective implementation of the EnMS. This involvement is crucial for resource allocation and the adoption of key strategies aimed at improving energy efficiency. The technological system plays a central role in EnMS, as advanced technologies enable the monitoring, control, and optimization of energy consumption. Sensors, remote monitoring systems, and automation tools can help identify and reduce energy waste, thereby enhancing overall performance. Staff engagement is also critical to the success of an EnMS. Raising employee awareness about the importance of energy efficiency and involving them in the identification and implementation of energy solutions can foster stronger commitment and adoption of best practices. External suppliers constitute another key component, as relationships with suppliers that embrace sustainable practices can significantly impact an organization's energy performance. Selecting commercial partners who share similar values regarding energy efficiency can contribute to reducing the overall environmental footprint. Finally, considering the social and territorial context is important for understanding the impact of the organization's activities on the surrounding environment and local community. This awareness can influence energy-related decisions, encouraging, for example, investments in energy efficiency projects that benefit both the organization and the broader community.

Overall, the integration of these actions and stakeholders within an Energy Management System (EnMS) enables a comprehensive and holistic approach to optimizing energy use, resulting in both economic and environmental benefits for the organization and for society as a whole.

The definition of clear and measurable energy objectives is a fundamental element for the successful implementation of an EnMS in accordance with ISO 50001 standards. The primary goal set by the Municipality of Mascalucia is to reduce energy consumption across all PA buildings by 10% over the next three years, as an initial step towards achieving ISO 50001 certification. This target not only ensures significant economic savings but also aligns with local environmental commitments, contributing to the reduction of greenhouse gas emissions and the overall improvement of energy efficiency. A thorough analysis of energy consumption for each building represents the starting point for defining specific targets. This phase involves:

- Collection and historical tracking of consumption data: Detailed monitoring of energy use to gain a clear understanding of each building's energy profile.
- Energy audits: Identification of inefficiencies and potential areas for energy savings.
- Benchmarking analysis: Comparing energy consumption across buildings with similar functions and sizes to identify room for improvement.
- Identification of technical solutions: Evaluation of possible interventions, such as thermal insulation upgrades, lighting system optimization, and the integration of renewable energy sources.

1. STATE OF ART

The publication of the International Standards ISO 50001 and ISO 50006 has significantly raised awareness of the benefits deriving from the adoption of a well-structured Energy Management System (EnMS). These standards have consolidated the principle of continuous improvement of energy performance and provide organizations with a framework to define an energy policy, set objectives, and monitor their achievement through specific Energy Performance Indicators (EnPIs) (ISO, 2018; ISO, 2014). The standards are deliberately general, requiring the energy manager to adapt them to the specific organizational context. In industry, this task is supported by sector expertise and by the ease of linking energy consumption to production outputs (O'Donnell et al., 2013; Richert, 2017). For this reason, much of the literature has focused on industrial applications, including the development of energy benchmarking methods (Sola & Mota, 2019; Swiatek & Imbault, 2017), aggregated indicators (Jemmad et al., 2019), or efficiency indexes tailored to manufacturing companies (Siebert et al., 2014). However, the application of ISO 50001 is increasingly relevant also for organizations providing intangible services, such as universities, research centres, and public administrations (Dzene et al., 2015; European Commission, 2017). In these cases, buildings—rather than processes or technologies—represent the main energy cost centres, thus attracting growing interest in the development of building-specific EnPIs. Several studies have addressed this issue by applying ISO 50001 to assess energy and carbon savings in educational buildings (Castrillón-Mendoza et al., 2019; Ocampo Battle et al., 2019), to identify relevant stakeholders and indicators at the district scale (Li et al., 2017), or to evaluate the role of ICT in energy efficiency improvements (Janez Moran et al., 2016). Other contributions have focused on energy audits (Dermentzis et al., 2019) and methodologies for retrofit planning (Dall'O' et al., 2020).

Although much of the research has concentrated on industry and education, the application of ISO 50001 within municipalities is gaining attention, due to the complexity of public building stocks and the potential benefits in terms of energy efficiency and sustainability.

1.1 ISO 50001 in Municipalities

The adoption of energy management standards, such as ISO 50001, is driven by a range of motivations and factors that vary depending on the organizational context and business objectives. However, empirical literature specifically focused on ISO 50001 is still limited, which is why many studies refer to models developed for other environmental standards, such as ISO 14001.

In this context, Frederic Marimon and Martí Casadesus (Casadesús & Marimon, 2017), developed a statistical model to analyse the motivations and benefits of adopting ISO 50001. Since empirical research on this certification is still evolving, their study also relies on data and theories previously applied to ISO 14001, a widely adopted environmental management system. To better understand the dynamics that drive organizations to adopt ISO 50001, Marimon and Casadesus structured their survey into four main sections:

Organization Data – basic information about the company and its operating environment;
Input – motivations leading the organization to implement ISO 50001;
Implementation – process of adoption and integration of the standard into business systems;
Output – results obtained following the implementation of the certification.

Through this approach, it is possible to identify the key drivers that encourage organizations to pursue ISO 50001 certification, providing a clearer understanding of the dynamics that govern its adoption and effectiveness.

Table 1_ ISO 50001 Survey sections

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

In the research conducted by Frederic Marimon and Martí Casadesús ([Casadesús & Marimon, 2017](#)), a system was developed to systematically analyse the motivations and benefits of adopting ISO 50001. To create a weighted model, a one-to-five Likert scale was assigned to each question based on the degree of agreement: (1) no effect, (2) a little important, (3) important, (4) very important, (5) totally important.

The sample consists of Spanish organizations, as they represent the second-highest share of ISO 50001 certifications worldwide, following Germany.

Furthermore, estimates indicate that Spain is making a significant contribution to increasing energy efficiency, in line with the EU target of reducing energy demand by 20% by 2020.

Out of the 87 companies surveyed, only 57 responded, resulting in a 65% response rate.

Once the survey responses were collected, three latent factors (F1, F2, F3) related to adoption motives were identified:

F1 – Social demands: incentives from PA, pressure from professional associations;

F2 – Environmental drivers: improving energy efficiency, reducing greenhouse gas emissions, raising employee awareness about energy, rising energy costs, and the impacts of climate change;

F3 – Competitive edge: pressure from competitors, customer demands, and the desire to enhance company image.

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

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

		Variables	Mean Value
F1	Social requirements	Incentive given by PA	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

The survey results show that ecological drivers (mean value: 3.80) are the primary factors motivating companies to adopt ISO 50001 certification, with energy efficiency improvement (4.42) and employee

energy awareness (4.02) being the most significant. However, when it comes to PA, social requirements are perceived as the least important motivator (mean value: 2.25). Among these, pressure from associations (2.30) is slightly more influential than incentives offered by PA (2.19). This indicates that while public sector involvement is acknowledged, it plays a less significant role in driving ISO 50001 adoption compared to ecological and competitive factors.

The implementation of an EMs compliant with the ISO 50001 standard represents a strategic opportunity for PAs, enabling more efficient energy consumption management and a reduction in environmental impacts. However, the certification process can encounter several difficulties that often hinder or slow down the adoption of the standard within public entities. The main barriers can be categorized into three macro-areas: economic, organizational, and technical. On one hand, the initial certification costs and the lack of dedicated funding represent significant obstacles, especially for entities with limited resources. Increased costs, time, and resource consumption required for system implementation strongly reduce commitment to improving energy and environmental performance. On the other hand, the lack of specific skills and the limited involvement of leadership make it difficult to integrate an EMs within administrative structures.

The lack of awareness of EnMS benefits has been identified as one of the main barriers to ISO 50001 adoption, as employees do not perceive a direct impact on safety, quality, or production cycle times (Wessels, 2022).

Based on these premises, Marimon and Casadesus ([Casadesús & Marimon, 2017](#)) developed a model to classify the barriers to ISO 50001 implementation, dividing them into two main factors:

Operational difficulties (F6): necessity of continuous measurement tools, data complexity, lack of financial resources, regulatory complexity.

Organizational difficulties (F7): need for a mindset shift, internal communication issues, lack of leadership commitment, and uncertainty regarding certification benefits.

Table 3_Exploratory factor analysis for the difficulties in adopting ISO 50001

		Variables	Mean Value
F6	Operational difficulty	Necessity of continuous measurements 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 uncertainly	2.57

According to the study, operational barriers have an average value of 2.92, while organizational ones stand at an average value of 2.50. Specifically, the need for continuous measurement tools is perceived as the most significant obstacle (3.34), followed by data complexity and lack of financial resources (3.04 and 3.02, respectively). Regulatory complexity, however, is not considered a major obstacle (2.26). Regarding organizational difficulties, the main challenge is the need for a mindset shift (2.77), followed by uncertainty about the standard's benefits (2.57). Issues related to internal communication (2.40) and lack of leadership commitment (2.28) are perceived as less significant.

Finally, according to the authors, prior experience in adopting international standards such as ISO 9001 and ISO 14001 can facilitate compliance with ISO 50001. In fact, 85% of the organizations analysed have already implemented at least one of these standards, which has contributed to a cultural shift toward greater energy efficiency. However, for PAs that have no prior experience with certified management systems, organizational barriers may be more significant and harder to overcome.

1.2 Examples of Municipalities implementing ISO 50001

Municipality of Milan (Italy)

Another of the most significant examples identified during the literature review is the case of the Municipality of Milan. The Municipality of Milan's path toward ISO 50001 certification was a structured and complex process. It all began with a thorough energy audit aimed at evaluating energy use in public buildings and infrastructure. This analysis allowed for the identification of critical points and the establishment of an energy baseline to serve as a reference for measuring future progress. The Municipality then developed clear energy policies, which included goals for energy efficiency and sustainability. Concrete targets were set, such as reducing energy consumption and CO2 emissions, and a dedicated team was assigned to manage and monitor energy performance. The practical actions taken included projects to upgrade public buildings to improve energy efficiency, such as thermal insulation and the replacement of windows and doors. The Municipality also upgraded heating and cooling systems, opting for low-energy consumption versions. Another initiative was the introduction of LED lighting for streets and squares, which led to a significant reduction in energy consumption. In addition, photovoltaic systems were installed on the roofs of municipal buildings to increase renewable energy production. A crucial aspect of the process was the implementation of an advanced monitoring system to track energy consumption and compare it with established performance indicators. Periodic reports were produced to document progress and make strategic adjustments if necessary. The Municipality also invested in staff training, raising awareness of the importance of efficient energy management, and promoted campaigns to engage and inform citizens about the measures adopted.

The final phase involved the intervention of an accredited external body, which conducted an audit to verify the Municipality's EMs compliance with ISO 50001 requirements. After successfully passing the audit, the Municipality of Milan obtained certification. Thanks to this process, the Municipality achieved significant benefits, including reduced energy consumption and costs, lower greenhouse gas emissions, and an overall improvement in sustainability. Additionally, the economic savings from energy efficiency allowed funds to be allocated to other projects. This approach strengthened the Municipality's image as an entity committed to sustainability and environmental innovation.

Municipality of Daugavpils (Latvia)

One of the most significant cases emerging from the literature concerns the application of the ISO 50001 standard in the Municipality of Daugavpils, Latvia. This project involved a wide range of initiatives aimed at improving energy efficiency and reducing emissions within the municipal sector.

As part of this project, energy efficiency improvements were planned and implemented in twelve school buildings, four social care facilities, three sports facilities, and four municipal buildings, as well as interventions in public transport and street lighting. The primary goal was to transform these infrastructures into low-energy consumption facilities, reduce costs associated with public lighting, and mitigate emissions from public transportation. However, despite its ambitious goals, the project encountered several challenges during implementation:

- **Lack of political support:** One of the main difficulties encountered was the lack of adequate political backing. Without clear commitment and support from local authorities, it was challenging to secure the necessary resources and drive the required changes.
- **Limited experience in implementing an EnMS:** Given the relative novelty of EMs (EnMS) implementation in Latvian municipalities, the personnel involved may not have had prior

experience with such projects. This resulted in a steep learning curve and difficulties in effectively applying the recommended practices.

- Challenges in identifying the causes of energy consumption deviations: During the monitoring and evaluation process of energy performance, identifying the reasons behind energy consumption deviations proved to be a significant challenge. This made it difficult to implement targeted and timely corrective measures.
- Difficulty in changing deeply rooted societal habits: One of the most significant challenges was addressing and overcoming ingrained societal habits. Behavioural change is often one of the most complex aspects of implementing energy efficiency projects, requiring awareness efforts and active community engagement.

Despite these challenges, the Daugavpils project provides valuable lessons learned and highlights the importance of addressing not only the technical aspects but also the political, organizational, and behavioural ones in the implementation of EMs in municipalities. Its experience can serve as a reference point for future similar projects, contributing to informing more effective and sustainable strategies for improving energy efficiency at the local level.

The implementation of the EnMS in the municipality of Daugavpils was organised into four key phases, ensuring a systematic and comprehensive approach. Phase 1 – Motivation and initial support: focused on the city’s decision to develop both the EnMS and the Sustainable Energy and Climate Action Plan (SECAP). Community engagement and awareness-raising were prioritised, alongside securing external financial resources, technical expertise, and specialised support. The approval of the 2016 energy efficiency law gave the project further legitimacy. Phase 2 – Definition of objectives and boundaries: involved setting clear goals and limits, initially targeting interventions on numerous public buildings, public lighting, and public transport. This required analysing needs, resources, and the municipality’s capacities to establish realistic priorities. Phase 3 – Introduction and organisation: structured the implementation into three steps—developing detailed procedural manuals, issuing formal responsibility assignments, and delivering training to ensure staff competence. Phase 4 – Evaluation: focused on reviewing the monitoring process, communication between departments and stakeholders, and progress against objectives, highlighting successes, identifying challenges, and defining improvements to ensure long-term continuity.

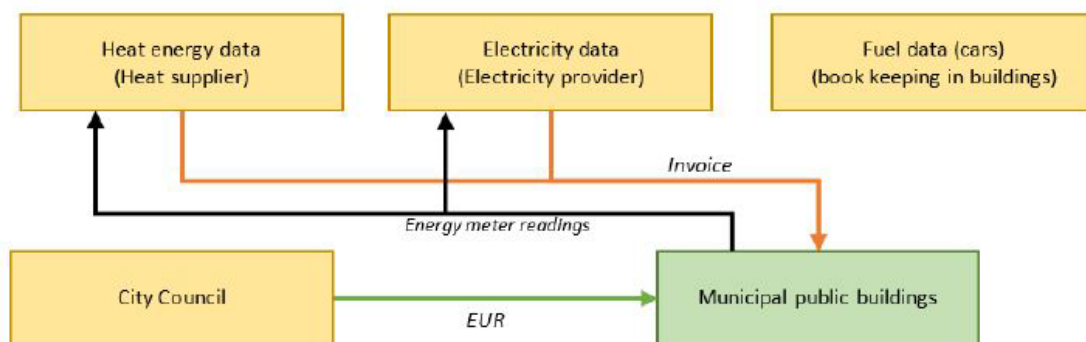


Figure 1_ Energy consumption data management system in Daugavpils municipal buildings before EnMS ([A. Jekabsone, A. Kamenders, M. Rosa, 2020](#))

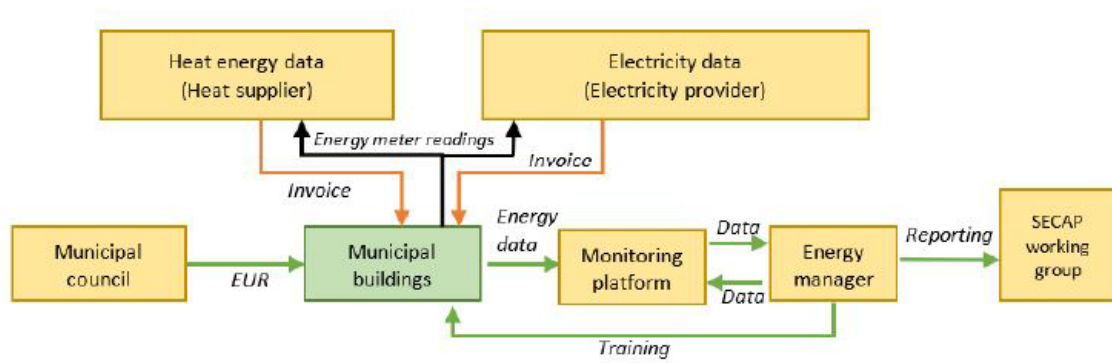


Figure 2_.Energy consumption data management system in Daugavpils municipal after EnMS ([A. Jekabsone, A. Kamenders, M. Rosa, 2020](#))

2. UNI CEI EN ISO 50001: ENERGY MANAGEMENT SYSTEM

2.1 Overview and requirement

The ISO 50001 standard, first published in 2011 by the International Organization for Standardization, provides a framework for establishing, implementing, maintaining, and improving an Energy Management System (EnMS). Its aim is to enable organisations to follow a systematic approach to continually improve energy performance, including energy efficiency, energy use, and energy consumption. Improved energy performance can also lead to a reduction in greenhouse gas emissions and other related environmental impacts ([International Organization for Standardization, 2018](#)).

ISO 50001 certification is voluntary and not mandatory for organisations but can be integrated with other standards such as ISO 9001, ISO 14001 and OHSAS 18001 ([International Organization for Standardization, 2018](#)). The purpose of the standard is not to impose penalties for non-compliance with energy parameters, but rather to provide a framework for the implementation of systems and processes aimed at improving energy performance, with a focus on energy efficiency, use and consumption ([International Organization for Standardization, 2018](#)). This approach brings economic benefits to businesses and advantages to society, in line with European and national environmental regulations. A concrete example is energy auditing: adopting an ISO 50001-compliant EMs can help solve the problems highlighted by this analysis or achieve the energy efficiency targets imposed by law for certain sectors, such as PA. According to historical data from ACCREDIA, in January 2017 a total of 17,924 sites were certified to ISO 50001. According to historical data from ACCREDIA, in January 2017 a total of 17,924 sites were certified to ISO 50001. More recent global statistics from the *ISO-CASCO_ 3. ISO Survey 2023 – comparison with 2022 – using data from providers taking part both years* (ISO, 2017) indicate that in 2022 there were 23,621 valid certificates worldwide. While these figures are not limited to Italy, they clearly illustrate a growth trend in the adoption of the standard at an international level ([ACCREDIA, 2017](#); [ISO, 2017](#); [European Commission, 2020](#)).

Since August 2018, the new edition of the ISO 50001 standard, ISO 50001:2018, has come into effect. While maintaining the fundamental principles of the original 2011 version, this revision has introduced significant improvements. Among the main changes, the role of the “Management Representative” has been eliminated and replaced by the Energy Management Team. Energy Baselines (EnBs) and Energy Performance Indicators (EnPIs) are key elements in this framework, providing reference values and measurable indicators to assess changes in energy performance over time. The EnB serves as the quantitative benchmark against which improvements are evaluated, while EnPIs represent the metrics used to consistently monitor and compare energy performance. The new edition provides a clearer definition of the concept of energy performance improvement, introducing the determination of the Energy Baseline (EnBs) and Energy Performance Indicators (EnPI – Energy Performance Indexes) ([International Organization for Standardization, 2018](#)).

The updated text specifies energy objectives, targets, and the action plan to achieve them with greater precision. Another important change concerns the replacement of the previous measurement plan with a more detailed energy data collection plan, aimed at monitoring key operational parameters that influence energy performance. Additionally, the new version allows the inclusion of procurement specifications, not only for products and services but also for energy carriers ([International Organization for Standardization, 2018](#)). According to the schedule established by the International Accreditation Forum ([IAF, 2018](#)), the three-year transition period ended on August 20, 2021. From this date onward, all certificates compliant with the 2011 version have either expired or must be updated. However, as of

February 20, 2020, all initial, surveillance, and recertification audits must be conducted in compliance with the ISO 50001:2018 requirements (IAF, 2018).

2.2 PDCA Cycle

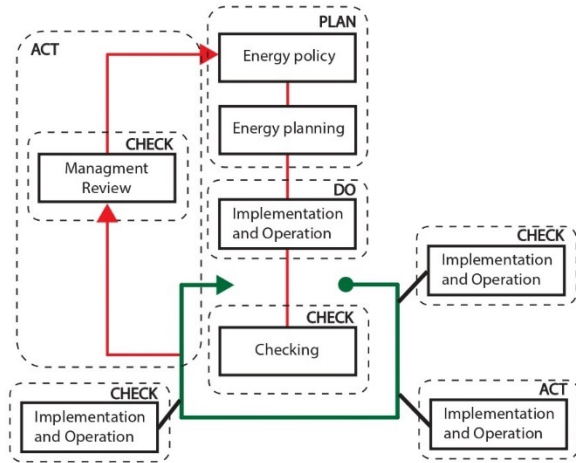


Figure 3__PDCA Cycle

The PDCA cycle represents the methodological backbone of this research, providing a structured framework for the implementation of ISO 50001 in the context of public buildings in the Municipality of Mascalucia. Each phase of the cycle has been explicitly operationalized within the research design to ensure consistency, traceability, and practical applicability. **Plan:** In this phase, an accurate energy diagnosis of all municipal buildings was carried out. Monthly consumption data from utility bills were collected, cleaned, and structured into dedicated Excel worksheets, which formed the basis for defining the energy baseline in line with ISO 50006:2014. Statistical normalization techniques,

such as the use of Cooling Degree Days (CDD), were applied to ensure comparability over time. Based on this analysis, realistic yet ambitious energy performance targets were set, and an action plan was developed to reduce energy consumption by at least 10% over a three-year period.

Do: The planned measures were implemented both at the methodological and technological levels. This included the development of monitoring tools in Excel and Power BI, scenario simulations (e.g., relamping with 50% reduction of lighting demand), and the estimation of renewable integration through the City Energy Analyst platform. Furthermore, site inspections were conducted to identify energy-intensive systems, thus creating the basis for targeted efficiency measures.

Check: Continuous monitoring was carried out through statistical tools such as Control Charts and CUSUM analysis, implemented in dedicated Excel worksheets. These tools allowed deviations from the baseline to be detected, particularly in the summer season when cooling loads dominate energy use. The comparison between measured and expected consumption provided evidence of the actual performance achieved, supporting a data-driven evaluation of efficiency improvements. KPIs were defined to quantify results, enabling systematic verification of progress towards the set targets.

Act: The insights derived from the monitoring phase were used to refine the action plan, identify new priorities, and consolidate best practices. This stage also included the design of a web-based platform aimed at increasing transparency and stakeholder engagement by making municipal energy consumption data available to the local community. Such communication strengthens citizen trust, promotes awareness, and fosters an organisational culture aligned with energy efficiency and sustainability.

By structuring the research methodology according to the PDCA cycle, this work not only complies with ISO 50001 requirements but also demonstrates its practical applicability in a real municipal context. As explicitly stated in ISO 50001:2018, the standard is “based on the Plan-Do-Check-Act (PDCA) continual improvement framework and incorporates energy management into everyday organizational practices” (ISO, 2018, p. vi). The cyclical approach ensures that the implementation does not stop at the achievement of initial targets but initiates a continuous improvement process with long-term benefits

in terms of environmental sustainability, energy cost reduction, and climate change mitigation, in line with the principle of continual improvement emphasized in ISO 50001:2018 ([ISO, 2018](#)).

2.3 ISO 50001

The UNI CEI EN ISO 50001 provides a comprehensive framework for energy management in organizations, aiming to improve energy efficiency and reduce environmental impact. Public Administrations (PAs), as entities responsible for managing public resources and delivering essential services to the community, play a crucial role in adopting such standards. While not all PAs are formally required to implement ISO 50001, establishing an Energy Management System (EMS) based on this standard is considered good practice to promote efficiency and sustainability. ([ASviS – Alleanza Italiana per lo Sviluppo Sostenibile, n.d.](#))

To be effective, an energy management approach should consider the broader context in which the organization operates. This includes identifying internal and external factors that influence energy performance, such as environmental regulations, energy efficiency goals, and sustainability policies at both national and international levels. In many countries, the adoption of energy-efficient practices and structured management systems is also encouraged through tax incentives or dedicated funding for energy renovation projects.

Understanding the expectations of stakeholders—especially citizens and public service users—is also essential. PAs are increasingly called upon to demonstrate transparency, improve operational efficiency, and reduce energy consumption. This involves identifying key stakeholders and integrating their expectations into the overall energy strategy, while also ensuring compliance with all applicable legal and regulatory requirements.

An effective energy management system should clearly define its scope and be applicable to all relevant areas under the responsibility of the public administration, including public buildings, transport, and infrastructure. It is important that the EMS covers all types of energy used and that the administration has sufficient authority and resources to manage and improve energy performance internally.

Moreover, the energy management process should be continuously reviewed and improved. This allows Public Administrations to adapt to changing circumstances, evolving community needs, regulatory updates, and technological advancements. A continuous improvement approach supports better governance of energy resources, increases the reliability of public services, reduces long-term energy costs, and strengthens local sustainability. ([International Organization for Standardization, 2018](#)).

3. ISO 50001 AND P.A.

3.1 State of Art of UNI CEI EN ISO 50001 adoption in Italy

In the current context of increasing environmental awareness and the need to promote energy efficiency, PAs play a fundamental role in fostering sustainable practices and reducing the environmental impact of their activities. In this regard, the adoption of the ISO 50001 standard represents a key tool for implementing effective and targeted EMS within PAs. Through an in-depth literature review, various studies and articles have been identified that explore the application of ISO 50001 in PAs, providing valuable insights into the practices and challenges encountered during this process. These studies highlight the importance of adopting structured, data-driven approaches to improve the energy efficiency of public buildings and reduce associated costs.

This chapter will examine and analyse the key findings from the literature regarding the application of ISO 50001 in PAs, with a particular focus on the methodological approaches adopted, the results achieved, and the challenges faced.

Since the introduction of various standards and the publication of ISO 50001, the implementation of EMs by Italian organizations has been steadily increasing over the years. Through the data available from ACCREDIA's databases ([ACCREDIA, 2017](#)), it has been possible to track a trend in the implementation of ISO 50001 regarding certified sites (keeping in mind that many organizations certify more than one site), as shown in [Figure 4](#):

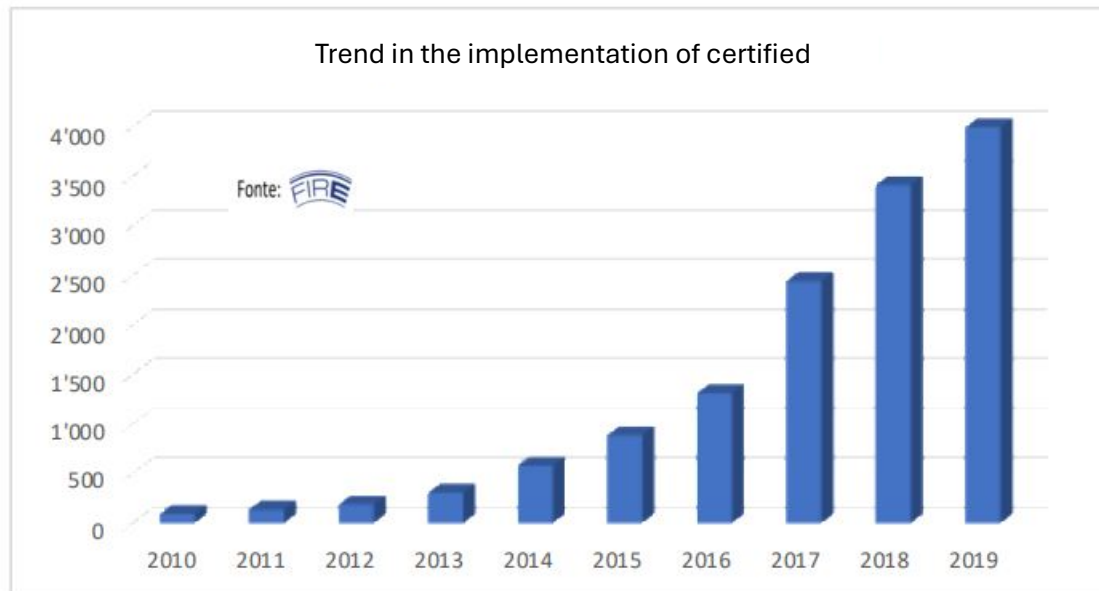


Figure 4_Trend of implementation for ISO 50001 certified sites over the years – Source: FIRE elaborations on ACCREDIA database (FIRE, 2021).

The strong growth in the years following 2014 is due to the push introduced by Legislative Decree 102/2014, which required energy-intensive companies to conduct energy audits every four years or implement an EMs that includes an audit, thus making them aware of the impact of their energy consumption on their business operations.

In recent years, the trend has continued to grow, with annual increases. However, many organizations that decide to certify themselves are multi-site, which creates a significant discrepancy between the implementation trends for the two different categories.

For this reason, a comparison between certified organizations and the total certified sites has been presented in [Figure 5](#):

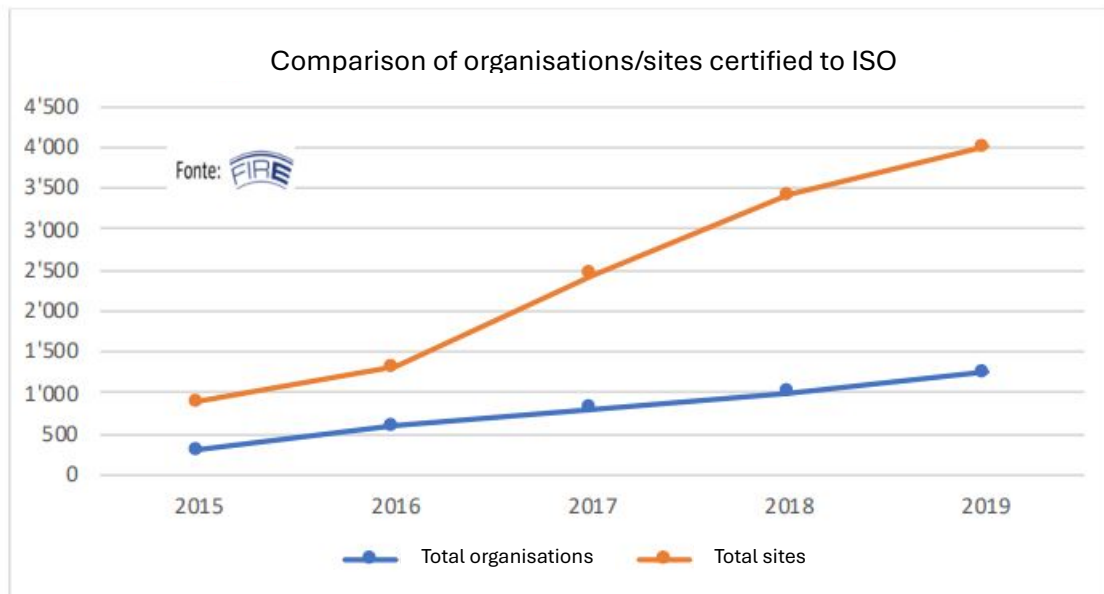


Figure 5_ Comparison between the implementation trend for ISO 50001 certified sites and organizations over the years – (FIRE, 2021).

According to a report prepared by FIRE (Italian Federation for the Rational Use of Energy) in 2016, a total of 54 organizations held an ISO 50001 certified EMS, of which only 6% belonged to the PA category. In the chart included in the report, the distribution of certifications across various sectors is clearly visible. ([FIRE, CEI, & CTI, 2016](#))

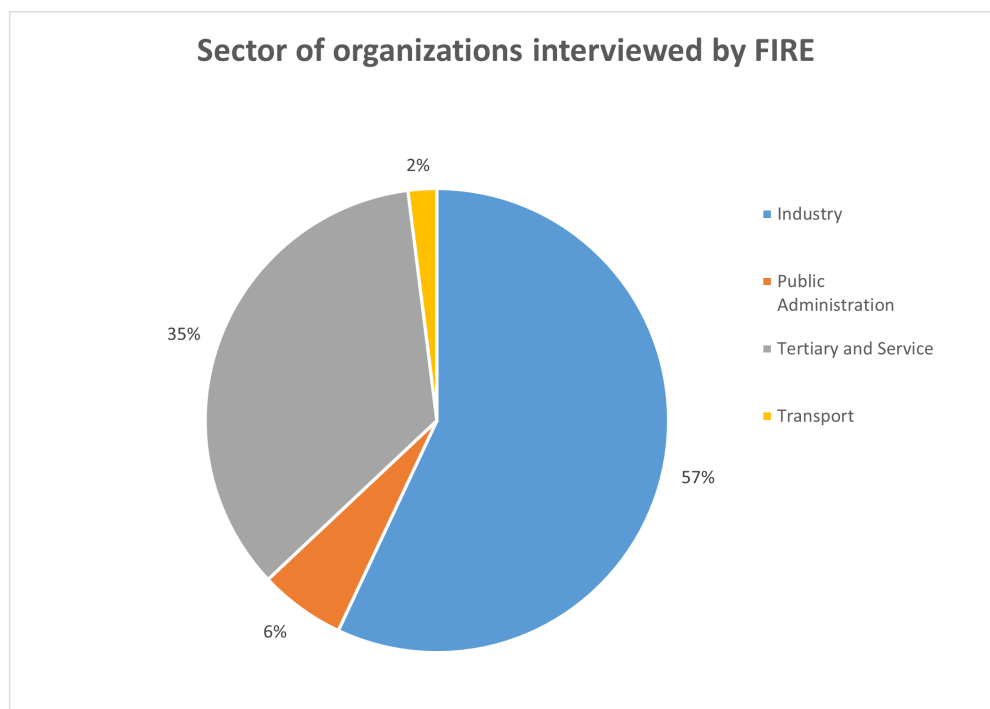


Figure 6_ Sector of organizations interviewed (FIRE, 2021).

To obtain a more detailed analysis of the types of organizations that have adopted an EMS, the entire sample was divided according to the classification shown in [Figure 7](#). The analysis clearly reveals that the survey mainly involved entities required to implement an energy audit or an EMS in accordance with

Article 8 of Legislative Decree 102/2014 ([Italy, 2014](#)). The sample examined is made up of 84% large companies or energy-intensive enterprises. Small and medium-sized enterprises (SMEs), which are not subject to this obligation, account for only 9% of the total ([FIRE, 2021](#)). This finding is not surprising, as most end-users with high absolute energy consumption, meaning those who are the first to consider adopting an EMs, do not fall into the SME category.

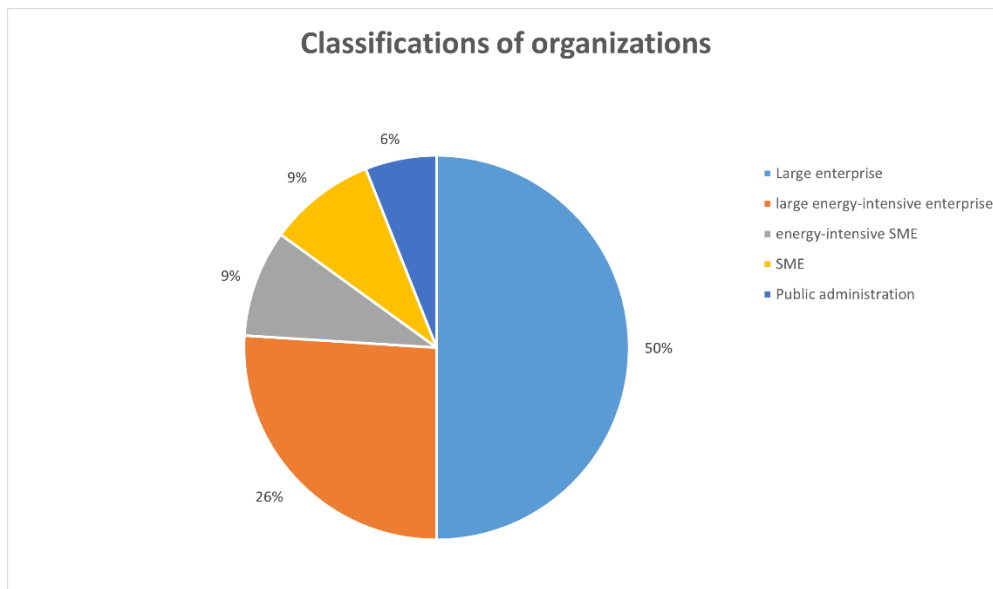


Figure 7_Classifications of organizations (FIRE, 2021).

In 2017, the following year, FIRE published a new list of organizations that had obtained ISO 50001 certification for their EMs. This update allowed for an analysis of the evolution of such certifications over the year. The data analysis clearly showed that the number of PAs that had obtained certification decreased compared to the previous year, marking a negative trend that deserves further reflection. In the following section, this trend will be examined in more detail, highlighting the factors that may have influenced this decline ([FIRE, 2021](#)).



Figure 8_ Organizations certified according to ISO 50001 (FIRE, 2021).



Figure 9_ Certificates issued and certified sites for different standards worldwide (FIRE, 2021).

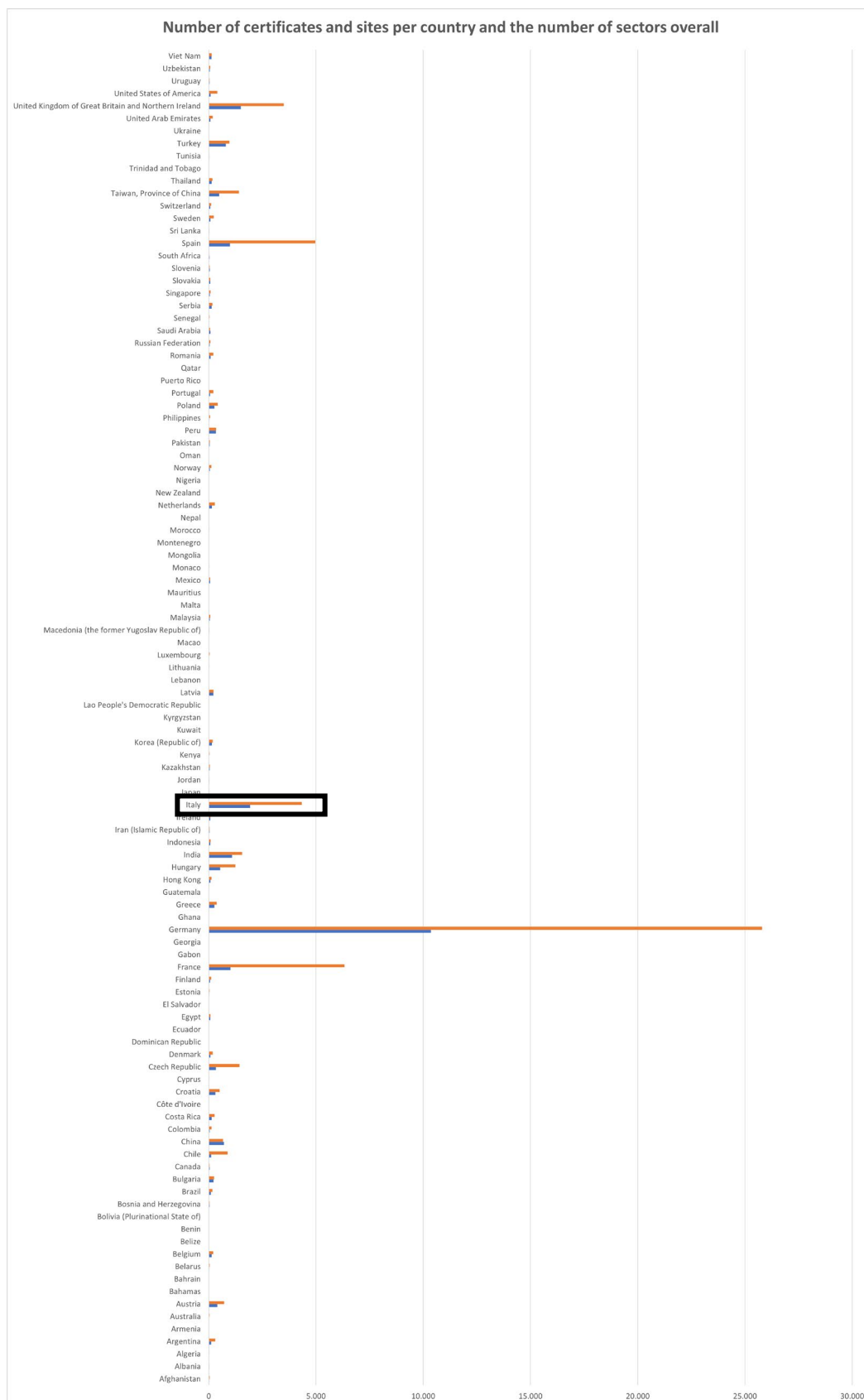


Figure 10_ Number of ISO 50001 certifications worldwide, 2021 data. (FIRE, 2021).

3.2 Drivers and barriers

The adoption of energy management standards, such as ISO 50001, is driven by a range of motivations and factors that vary depending on the organizational context and business objectives. In this context, Ane Laskurain, et al. ([Laskurain et al., 2017](#)) highlight that, before the emergence of ISO 50001, energy management practices were largely derived from environmental management standards such as ISO 14001 and EMAS. Similarly, Tobias Knayer ([Knayer, 2025](#)) underlines that ISO 14001-based Environmental Management Systems have served as methodological foundations for the development and diffusion of ISO 50001.

In this context, Frederic Marimon and Martí Casadesus ([Casadesús & Marimon, 2017](#)), developed a statistical model to analyse the motivations and benefits of adopting ISO 50001. Since empirical research on this certification is still evolving, their study also relies on data and theories previously applied to ISO 14001, a widely adopted environmental management system. To better understand the dynamics that drive organizations to adopt ISO 50001, Marimon and Casadesus structured their survey into four main sections:

Organization Data – basic information about the company and its operating environment;

Input – motivations leading the organization to implement ISO 50001;

Implementation – process of adoption and integration of the standard into business systems;

Output – results obtained following the implementation of the certification.

Through this approach, it is possible to identify the key drivers that encourage organizations to pursue ISO 50001 certification, providing a clearer understanding of the dynamics that govern its adoption and effectiveness.

3.3 Benefits of adoption

Energy management in PA represents an opportunity not only in terms of reducing consumption and costs, but also in improving the quality of services provided to citizens. The main benefits of energy management in PAs include:

1. Reduction of operating costs: Through energy efficiency interventions, PAs can significantly decrease costs related to energy consumption, freeing economic resources to be allocated to essential services for the community.
2. Minimisation of greenhouse gas emissions: Reducing energy consumption translates into a direct decrease in CO₂ emissions, thus contributing to national and international targets for reducing greenhouse gas emissions and combating climate change.
3. Enhancement of the public building stock: Energy efficiency measures improve the performance and quality of public buildings, increasing user comfort and prolonging the life of the structures.
4. Raising awareness and involvement: By implementing energy management measures, PAs can raise awareness among citizens and public employees themselves on the importance of energy efficiency and sustainability.

The EMs represents a highly relevant tool, particularly for small and medium-sized municipalities. Through the adoption of the ISO 50001 standard, it is possible to achieve numerous measurable benefits, both in economic terms and in energy performance.

The standard provides a systematic approach to optimizing energy performance, promoting a more efficient and sustainable management of resources. By obtaining ISO 50001 certification, a Municipality could:

- Gain an in-depth understanding of its internal energy consumption.
- Monitor and reduce energy demand, contributing to more sustainable management.
- Improve its environmental reputation by demonstrating a commitment to sustainability.
- Measure, document, and transparently communicate energy consumption, ensuring greater accountability as a PA.
- Enhance overall energy performance, including energy efficiency, usage, and consumption, through targeted actions or the adoption of high-efficiency technologies.

This certification not only allows for a reduction in energy costs but also represents a significant step toward continuous improvement and environmental sustainability.

4. METHODOLOGY

In line with the conclusions drawn in the previous chapters, it is clear that the adoption of energy management systems, such as ISO 50001, requires a well-structured methodological approach based on systematic data analysis. The experiences and theoretical models discussed, while essential for understanding the motivations and benefits of certification, highlight the need for concrete operational tools that guide organizations in the collection, processing, and interpretation of energy information.

The purpose of this chapter is to propose a systematic and replicable approach to energy data analysis, aimed at supporting public administrations in the process of implementing ISO 50001. This approach will then be applied to a real case study, demonstrating its effectiveness in practice and providing an operational tool to support strategic decision-making in the field of energy management.

The methodological approach consisted of:

1. **Establishing the Energy Baseline (EnB)** – The year 2022 was defined as the baseline for comparison. This allowed the quantification of performance changes in subsequent years and the evaluation of the influence of climatic conditions through correlation with monthly CDD values, in line with ISO 50001 and ISO 50006 guidelines ([ISO, 2014; ISO, 2018](#)) and with similar applications in public organizations ([Fichera et. al 2020](#)).
2. **Scenario development** – Two main scenarios were analysed:
 - *Current scenario*: based on measured electricity consumption.
 - *Relamping scenario*: simulating a 50% reduction in lighting electricity demand, to estimate potential savings from energy efficiency upgrades. ([International Energy Agency \[IEA\], 2018](#)).
3. **Performance monitoring tools** – Statistical control methods, such as Control Charts, were used to detect anomalies or deviations from the baseline, while CUSUM analysis was applied to identify cumulative trends over the cooling season (May–October). ([Borgstein et. al 2016](#))
4. **Renewable integration analysis** – The City Energy Analyst (CEA) software was used to estimate the potential monthly photovoltaic (PV) production for each building, calculate the coverage rate of electricity demand, and assess possible energy surpluses.
5. **Identification of major energy-consuming systems** – On-site inspections were carried out to inventory lighting systems, HVAC units, IT equipment, and other appliances. The theoretical energy demand of each was estimated based on technical specifications and operational schedules, and then compared with measured consumption to validate data and prioritise interventions.

By integrating climatic indicators, measured consumption data, statistical monitoring, and renewable energy potential analysis, this methodology provides a robust framework for applying ISO 50001 principles in the public sector. It supports both the assessment of current performance and the design of targeted, measurable actions for continuous improvement.

4.1 Energy management methodology

Energy management control contributes to achieving the objectives set by the organization for improving its energy performance, as outlined in the energy policy. Specifically, the control process is structured in three main phases:

1. Measuring the Energy Performance Indicators (EnPIs),

2. Comparing the measured values with the reference baseline, and
3. Identifying, if necessary, corrective actions aimed at continuous improvement.

The main steps of the proposed Energy Management System (EMS) follow the same methodology described by Fichera et al. (2020). The first step consists in defining the boundaries for the Energy Performance Indicator (EnPI), which essentially determine the physical perimeter of the department, process, or system that the organization intends to control. According to the standards, when selecting the boundaries for each EnPI, the perimeter should be easily isolatable. Furthermore, particular care should be taken at this stage, as it is essential to define the boundary not only from a physical perspective, but also by clearly identifying responsibilities and energy uses ([International Organization for Standardization, 2018](#)); [ISO, 2014](#)).

In the case study described by Fichera et al. (2020), the EnPI boundary is represented by the building in which an energy supervisor (coordinated by the organization's energy manager) has been appointed and where energy use—such as lighting, heating/cooling, and similar services—has been clearly identified. In the present study, while following the same methodological approach, no energy supervisor was appointed, and the analysis focused exclusively on electricity consumption from lighting and cooling. After defining the boundaries, the energy flows crossing them are identified. In this case, the analysed energy flows refer exclusively to electricity used for the two aforementioned services. As this is a case study that can be replicated in other municipalities, it will be the responsibility of the local administration to appoint a person in charge of energy management and monitoring.

The following steps listed above are applied to each individual building. The ISO 50001 standard, as previously mentioned, requires the implementation of a series of actions aimed at reducing electricity consumption. Since in this case we are conducting an analysis strictly focused on electrical consumption—which largely includes lighting—we have planned a complete relamping of all energy-intensive elements identified during the energy audit. This will allow us to effectively assess the potential energy savings that would result from replacing the old lamps currently installed in the buildings with modern LED bulbs. Such an intervention would lead to a reduction in consumption of at least 50–60%. However, for the sake of simplicity and to avoid underestimating the results, this study will consider a 50% reduction in all consumption values recorded in the energy bills.

The initial step involves establishing the boundaries for the Energy Performance Indicator (EnPI). These boundaries essentially define the physical scope of the department, process, or system that the organization intends to monitor. According to the standards, each EnPI should be associated with a clearly delineated and easily isolatable area. Special attention is required at this stage, as it is crucial to not only outline the physical limits but also clearly assign responsibilities and define energy usage. In the EMS approach presented here, the boundary for the EnPI is set as the building where an energy supervisor (under the coordination of the organization's energy manager) has been appointed, and where energy consumption—such as lighting, heating, and cooling—has been specifically identified. ([Fichera et al., 2020](#)).

This chapter presents, for each building under analysis, the baseline energy consumption graph referring to the year 2022, the control chart including data from the years 2022, 2023, and 2024, a table reporting the predicted energy consumption values calculated using the formula:

$$Y = mx + c \quad (1)$$

and the CUSUM chart based on cooling degree days (CDD). Each of these representations will subsequently be repeated under the hypothetical scenario of a relamping intervention, with the aim of

quantitatively and visually highlighting the potential benefits resulting from the implementation of such an energy efficiency measure.

After defining the boundaries, it is necessary to identify the energy flows crossing these boundaries. In the case study considered, the flows of electricity and natural gas were identified, and dedicated measurement points provide information on the amount of energy crossing each boundary, that is, the energy consumed by each building (both electrical and thermal).

Once the boundaries and flows have been identified, the next step is to quantify which variables influence the energy consumption of the buildings. These variables should be able to highlight trends and deviations. To verify if the choice is consistent, the energy manager can plot the variable over time and observe whether it affects the energy consumption trends through a simple x-y diagram. Once the trends have been identified, it is necessary to assess whether the correlation is significant; for this purpose, the use of linear regression can be helpful. Generally, the form of the equation resulting from this correlation process is as follows:

$$Y = mx + c \quad (1)$$

The baseline period plays a crucial role in evaluating improvements achieved in relation to the organization's energy objective. It is considered good practice to define a baseline capable of minimizing variability and accounting for seasonal fluctuations; for this reason, a 12-month period is generally suitable. During this timeframe, Energy Performance Indicators (EnPI) are monitored and used to validate the chosen reference period.

To assess the evolution of energy performance, EnPIs must be quantified and compared to baseline values. This comparison provides an initial indication of the effectiveness of the actions taken in pursuing the targets set by the organization's energy policy.

There are several tools available to monitor energy performance. In this study, conducted on public buildings in the Municipality of Mascallucia, control charts and the CUSUM method are used. Both are well-established statistical approaches for analysing variations in processes. Control charts, introduced by Shewhart in 1929, are widely applied due to their ability to detect deviations from expected values.

To construct these tools, it is necessary to define a reference period – which in this case corresponds to the energy baseline identified for the Municipality of Mascallucia – collect energy consumption data and calculate key statistical parameters such as the mean and standard deviation. A typical control chart features three main lines: the mean, representing the average energy consumption during the reference period, and two limits – the Upper Control Limit (*UCL*) and the Lower Control Limit (*LCL*) – which are calculated as follows:

$$MEAN = \bar{X} \quad (2)$$

$$UCL = \bar{X} + 3\sigma_2^1 = \bar{X} + 3\sqrt{\frac{\bar{X}(1-\bar{X})}{n}} \quad (3)$$

$$LCL = \bar{X} - 3\sigma_2^1 = \bar{X} - 3\sqrt{\frac{\bar{X}(1-\bar{X})}{n}} \quad (4)$$

In the equations presented above, the symbol $\bar{X}$ represents the mean value of energy consumption measured during the baseline period, n refers to the size of the statistical population, and σ is the standard deviation, typically multiplied by a factor of 3. Once the control chart is structured based on

these parameters, the recorded energy consumption values of the buildings are plotted within the chart to identify any deviations from expected behaviour. A process is considered out of control when one or more of the following conditions are observed:

- Outliers, i.e., data points falling outside the control limits;
- Consistent increasing or decreasing trends;
- Most data points located above or below the mean, even if still within the control limits.

While control charts are effective in detecting statistical anomalies, they do not indicate whether the energy performance of a building is improving or deteriorating over time. Furthermore, any shifts in consumption patterns are not directly linked to past observations, which limits the ability to track long-term changes.

In this study, carried out on public buildings in the Municipality of Mascalucia, it was observed that these conditions were not consistently met across all buildings analysed. This highlights the usefulness of control charts as an initial diagnostic tool, but also the necessity of complementary methods such as trend analysis or CUSUM for a more in-depth evaluation of performance over time.

4.2 Energy management technologies and tools

The application of an energy management system in accordance with ISO 50001 requires the use of tools and methodologies capable of supporting the definition of the energy baseline, the continuous monitoring of performance, and the evaluation of improvement scenarios. To this end, within the framework of this study, several spreadsheets were developed in Microsoft Excel, structured according to the main methodological phases.

4.3 Excel spreadsheets

4.3.1 Energy Baseline (EnB)

The EnB worksheet was designed for the definition of the Energy Baseline (EnB), taking the year 2022 as the reference period, in accordance with the ISO 50006:2014 guidelines. In this worksheet, the monthly electricity consumption data (kWh) were normalized as a function of the Cooling Degree Days (CDD), calculated based on local meteorological data. This approach is widely adopted in the literature to correlate energy consumption with climatic conditions and to ensure consistent comparisons over time ([Dzene et al., 2015](#); [Dall'O' et al., 2020](#); [Fichera et al., 2020](#)).

4.3.2 Scenario Development

To assess the effectiveness of energy efficiency measures, a tool for scenario simulation was developed. In particular, in addition to the current consumption, a relamping scenario was hypothesized, with a 50% reduction in consumption attributed to artificial lighting. This assumption is based on international guidelines and benchmarks that highlight the potential savings resulting from the replacement of traditional light sources with high-efficiency LEDs ([International Energy Agency \[IEA\], 2018](#)).

4.3.3 Statistical Performance Monitoring

The energy baseline (EnB) was established by correlating monthly electricity consumption with the climatic variable of Cooling Degree Days (CDD), following the procedure recommended in ISO 50006

(ISO, 2014) and applied in several studies on public buildings (Fichera et al., 2020; Dall'O' et al., 2020). A linear regression model of the form $Y = mX + c$ was developed, where Y represents electricity consumption and X the corresponding CDD values. The baseline equation obtained from this regression was then used as a reference to estimate expected consumption under standard climatic conditions. This normalization allowed energy use to be adjusted for weather variations, thus providing a robust benchmark for performance monitoring.

To further assess deviations from the expected trend, statistical monitoring tools were applied. In particular, Cumulative Sum (CUSUM) control charts were employed, following the methodological approach proposed by Fichera et al. (2020). The method consists in calculating the cumulative sum of the differences between the actual consumption values and the baseline values predicted by the regression model. Positive slopes of the CUSUM curve indicate increases in consumption compared to the baseline, while negative slopes highlight reductions. This technique enables the detection of consumption variations attributable to operational changes or the implementation of energy efficiency measures. In this study, CUSUM analysis was specifically applied to the summer period (May–October), when cooling loads exert the most significant impact on electricity use, thereby enhancing the ability to capture meaningful deviations from the baseline.

4.3.4 Renewable Energy Integration

The “Grid Feed-in” worksheet was developed to evaluate the integration of photovoltaic (PV) systems on public buildings. The input data were derived from simulations carried out with the City Energy Analyst (CEA) software, which allows the estimation of monthly electricity production from PV at the building scale. Through this worksheet, the Coverage Rate was calculated, defined as the ratio between renewable energy production and electricity consumption, as well as the possible surplus fed into the grid. This methodology is consistent with approaches found in the literature for assessing renewable potential at the urban scale (Allegrini et al., 2015; Fonseca et al., 2016).

4.3.5 Identification of Major Energy-consuming Systems

Finally, the “Identified Energy-Intensive Elements” worksheet compiles the results of on-site inspections carried out on the buildings under study. For each system (lighting, HVAC, IT equipment, household appliances), the following are reported:

- Nominal power,
- Usage profile,
- Estimated theoretical demand.

These values were compared with the measured consumption in order to validate the data and identify the areas with the highest energy intensity. This approach is consistent with the guidelines for energy audits in public buildings and represents an essential preliminary step for the planning of targeted interventions.

4.4 City Energy Analyst

“City Energy Analyst (CEA) is a unique urban-scale energy simulation software, as it combines a UBEM (Urban Building Energy Modelling) and a USEM (Urban Scale Energy Modelling) tool in a single platform.”

([CEA Team, 2025](#)) . This integrated approach focuses on the optimisation, design, and in-depth analysis, both qualitative and quantitative, of energy services for the residential sector. Aimed at urban and energy planners, CEA includes a modern 4D interface designed to make visualisation of results more intuitive. CEA's methodology is based on the implementation of a hybrid model for energy demand analysis, integrated in ArcGIS. By means of two bottom-up calculation models - one statistical and one analytical - and using georeferenced data related to current or future urban scenarios, the software enables the estimation of hourly power and temperature energy demand for the required services. The City Energy Analyst (CEA) is an advanced energy analysis tool designed to support sustainable urban planning through simulations and assessments of energy performance at the city level. Developed in response to the growing need for greener cities, CEA offers a powerful interface to assess the effectiveness of energy interventions, optimise renewable resources and estimate the energy demand of buildings and neighbourhoods. Among its main functionalities is the possibility to analyse scenarios related to CO₂ emissions reduction, heat distribution and renewable energy production, such as photovoltaics, at the city level.

Photovoltaic (PV) electricity generation can play a valuable role in a municipality's EnMS aligned with ISO 50001, enhancing both energy efficiency and sustainability. Within the ISO 50001 framework, PV generation supports energy policy by enabling municipalities to set concrete renewable energy targets and reduce reliance on conventional electricity sources ([International Organization for Standardization, 2018](#)).

PV data must be integrated into the EnMS's Energy Baseline (EnB) and Energy Performance Indicators (EnPIs) to facilitate effective monitoring of energy improvements. Tools like City Energy Analyst (CEA) are instrumental in this process, as they enable estimation of potential rooftop PV output at building or campus scale—providing realistic metrics for renewable integration and informing strategic planning ([Fonseca et al., 2016](#); [CEA Team, 2025](#)). For example, CEA combines urban building energy modelling (UBEM) with urban-scale energy modelling, enabling analysis of generation potential and energy balance at district levels ([Fonseca et al., 2016](#)).

By integrating PV simulation outputs into performance monitoring, municipalities can update baseline and KPI values in response to renewable production, enabling adaptive management of energy targets and continuous improvement ([International Organization for Standardization, 2018](#)).

4.5 Microsoft Power BI

The main purposes and functionalities for which Power BI was applied in this research are:

- a) Data visualisation: Interactive dashboards and reports were created to display monthly and annual electricity consumption, costs, Cooling Degree Days (CDD), and photovoltaic coverage rates for each building. Various visualisations were employed, including time series graphs, comparison charts, and performance maps, to make complex energy data immediately understandable for decision-makers. ([Fig. 12](#))

The screenshot displays the COMPI-HIO software interface. The top menu bar includes 'File', 'Home', 'Guida', and 'Strumenti tabella'. Below the menu, there are icons for 'Contrassegna come tabella data', 'Gestisci relazioni', 'Nuova Misura', 'Nuova misura rapida colonne tabella', and 'Calcoli'. The main area shows a table with columns: Edificio, Anno, Mese, Giorno, Orario, HDD, Consumi, Produzione, and Immissione in rete. The table contains 30 rows of data for August 2021, with all values being 0. The right sidebar has a 'Dati' section with a search bar and a list of 'Foglio1'.

Edificio	Anno	Mese	Giorno	Orario	HDD	Consumi	Produzione	Immissione in rete
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	1	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	2	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	3	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	4	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	5	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	6	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	7	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	8	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	9	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	10	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	11	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	12	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	13	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	14	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	15	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	16	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	17	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	18	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	19	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	20	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	21	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	22	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	23	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	24	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	25	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	26	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	27	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	28	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	29	01:00	0	0	0	0
Plesso I.C.S. Fava - Via A. Reina	2021	Agosto	30	01:00	0	0	0	0

Figure 11_ Screenshot of the interface dedicated to presenting the entered data

- b) In-depth analysis: Power BI's advanced features enabled time series analysis, correlation between CDD and electricity consumption, and scenario comparison (current vs. relamping). Forecasting tools were also applied to project expected trends based on the Energy Baseline (EnB).
- c) Data integration: In this thesis, Power BI retrieved and combined data from multiple sources: Excel spreadsheets with utility bill data, CEA simulation outputs, and climate datasets from reference meteorological stations. This integration allowed the creation of a unified and consistent analytical environment. (Fig. 13)
- d) Customised Reports: Customised dashboards were developed for each of the fifteen analysed buildings, enabling municipal staff to explore both aggregated and detailed data views.

- e) **Data security:** Even though the dataset was limited to the municipal administration, Power BI's role-based access control was considered to ensure that sensitive cost-related data remained accessible only to authorised personnel.

- f) **Automation and Planning:** Power BI was configured to update reports automatically when new consumption data became available, ensuring real-time monitoring and reducing manual processing workload.

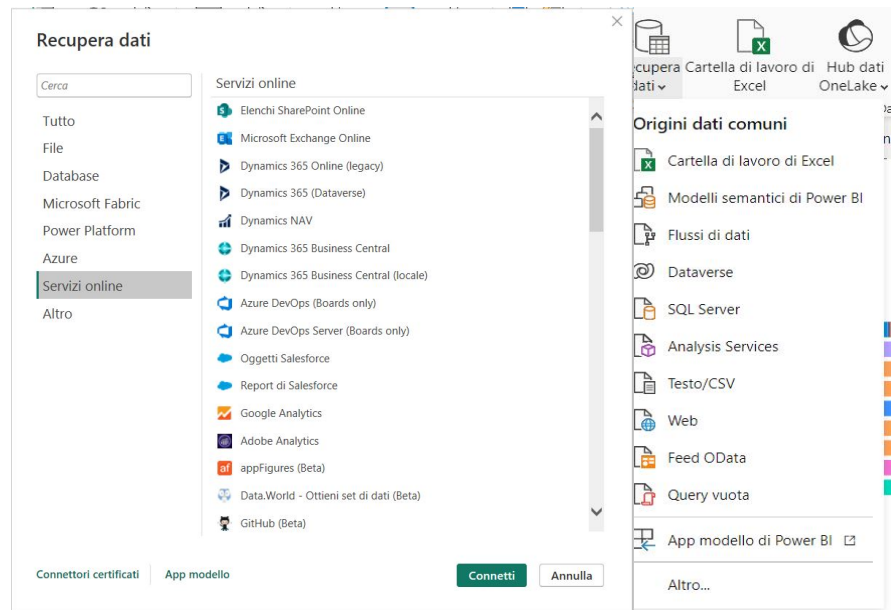


Figure 12_Integrating data from different sources

- g) **Machine Learning and Predictive Analytics** Predictive analysis functions, such as time series forecasting, were used to identify deviations from the baseline and to estimate the impact of energy efficiency measures. This feature allowed the municipality to anticipate potential inefficiencies and evaluate the return on investment of proposed interventions.

Monitoring the energy consumption of Mascalucia's public buildings was fundamental for identifying opportunities for energy savings, detecting inefficiencies, and improving resource management. With the growing relevance of renewable energy in the municipality's strategy, monitoring potential photovoltaic production became equally important to maximise on-site utilisation and reduce reliance on conventional energy sources. The integration of Power BI into this thesis therefore provided a decision-support platform, combining energy monitoring, simulation results, and performance indicators, in line with the continuous improvement principles of ISO 50001. The developed Power BI platform will be made available to the staff of the Municipality of Mascalucia, enabling them to continuously monitor energy performance, evaluate the impact of efficiency measures, and plan future interventions based on reliable, up-to-date data.

5. CASE STUDY AND ENERGY ANALYSIS

The case study selected for this research concerns the Municipality of Mascalucia, located in the Metropolitan City of Catania, Sicily, on the southern slopes of Mount Etna. The municipality covers an area of approximately 16.31 km², lies at an average altitude of 420 m above sea level, and has a population of around 32,022 inhabitants. It is characterised by a Mediterranean climate, with mild, wet winters and hot, dry summers. According to the Italian climatic classification ([DPR 412/1993](#)), Mascalucia belongs to climate zone C, with a total of 1,098 Heating Degree Days (HDD) annually (DPR 412/1993). The municipality owns a diverse portfolio of public buildings, including schools, administrative offices, and civic facilities, which together represent a significant share of local public energy consumption. For this study, all public buildings under municipal ownership were initially considered. A preliminary screening was conducted to identify those accessible for on-site surveys and with sufficient historical consumption data for analysis. This process led to the selection of fifteen buildings, forming the core sample for the energy audit. Given the unavailability of natural gas consumption data, the analysis focused exclusively on electricity consumption, which also accounts for cooling loads in the summer months. To account for climatic variability, Cooling Degree Days (CDD) were calculated monthly, using data from the nearest meteorological station. This ensured that seasonal changes in cooling demand could be correlated with observed variations in electricity use. As the available energy consumption data refer exclusively to electricity, CDDs represent a particularly relevant climatic parameter for the purposes of this study ([DegreeDays.net, n.d.](#)). Such an approach has been widely adopted in the scientific literature on energy management systems in public organizations ([Dzene et al., 2015](#); [Dall'O' et al., 2020](#); [Fichera et al., 2020](#)), confirming its suitability for this case study.

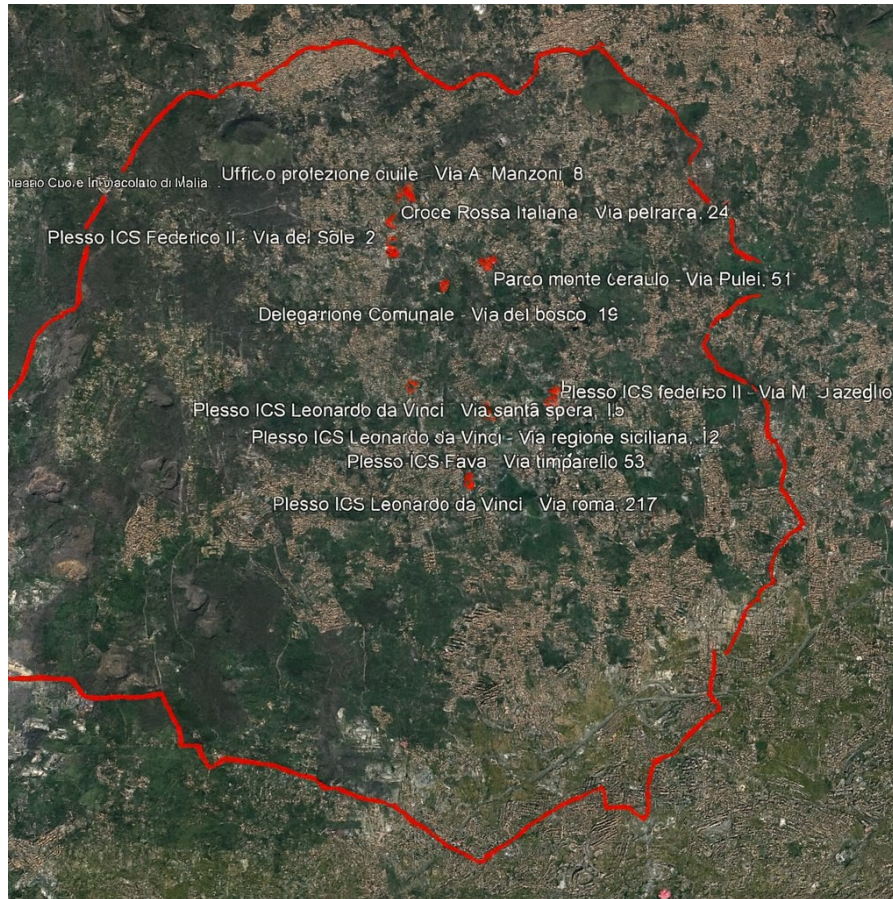


Figure 13_ Satellite map of the Municipality of Mascalucia showing the public buildings analysed and the municipal boundaries (Elaboration on Google Earth, 2025).

5.1 Overview of the buildings analysed

The Technical Office of the Municipality of Mascalucia provided a detailed list of all buildings under municipal management. However, during the analysis, it emerged that not all listed buildings were relevant for our study, leading to a targeted selection of those to be examined.

Below is the final list of buildings examined, with information on their location, contract power and specific voltage value:

Table 4_ List of buildings included in the case study

Building	Localization	Contractual Power	Voltage
Plesso ICS Fava	Via dei Villini, 19	30	380
Plesso ICS Fava	Via Timparello, 53	43	380
Plesso ICS Federico II	Via Massimo D'Azeglio, 14	33	380
Plesso ICS Federico II	Via del Sole, 2	90	380
Plesso ICS Leonardo Da Vinci	Via Roma, 217	33	380
Plesso ICS Leonardo Da Vinci	Via della Regione Siciliana, 12	90	380
Plesso ICS Leonardo Da Vinci	Via Santa Spera, 15	6	220
Municipio	Corso San Vito, 2	53	380
Ufficio Protezione civile	Via Manzoni, 8	20	380
Delegazione COM	Via del Bosco, 19	30	380
Croce Rossa Italiana	Via Petrarca, 24	6	220
Auditorium	Via San Nicolò	30	380

Parco Monte Ceraulo	Via Pulei, 51	15	380
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The buildings analysed have a heterogeneous nature, reflecting the variety of their intended uses within the Municipality of Mascalucia. Among these are school complexes, which include elementary and middle schools, many of which remain operational during the summer period, serving as a venue for summer camp activities for children. There are also municipal buildings intended primarily for offices, including the municipal delegation, used both for community events and presentations and as a library. The civil protection office, on the other hand, is activated only occasionally based on needs.

The list also includes the two municipal cemeteries and the auditorium, which is open to the public only for specific events. Even the Monte Ceraulo Park, despite being an important resource for the community, is mainly frequented on weekends. This variety of buildings and infrastructures implies differentiated approaches to energy management, requiring tailor-made strategies to optimize consumption based on the specific use of each structure. All the listed buildings are managed by HERACOMM.

In three of the buildings analysed, the Municipality has already installed photovoltaic systems. Specifically, at the ICS Fava complex (Via Avvocato Reina 14) a 10-kW system was installed, and at the ICS Federico II complex (Via Massimo D'Azeglio) a 22 kW system. However, for the purposes of this study, the analysis will assume the absence of photovoltaic installations in all buildings. This assumption is necessary because the existing systems have only been in operation for approximately one year, making it difficult to obtain reliable and representative production data. Consequently, the study will simulate the potential photovoltaic generation for each building under standardised conditions, ensuring a uniform and comparable assessment across the entire sample.

5.2 Consumption analysis

Consumption refers exclusively to electricity, distributed according to the different intended uses of the buildings examined, namely:

- School buildings
- Buildings for cultural and recreational activities
- Buildings for PA
- Green areas and public parks

5.3 Electricity billing

The electricity bills analysed are related to a good part of the public buildings in the municipality of Mascalucia; unfortunately, due to logistical reasons, it was not possible to have consumption for the same periods for all the buildings, but a good part of them coincide. Considering the Covid-19 pandemic relating to the years 2020/2021, the relative reduction in consumption for that period was considered, especially for school buildings. All detailed electricity consumption data extracted from utility bills are reported in [Annex I](#).

5.3.1 Electricity bill analysis

In Italy, electricity tariffs are divided into time slots defined by the national electricity authority (ARERA), which determine the cost per kWh based on the time of day and the day of the week. This structure incentivises shifting consumption to off-peak hours when electricity is generally cheaper and the demand on the grid is lower.

- **F1 – Peak hours:** This is the most expensive time slot, as it coincides with the highest demand for electricity.
- **F2 – Mid-peak hours:** The tariff in this slot is intermediate between F1 and F3.
- **F3 – Off-peak hours:** This is the cheapest time slot, due to lower overall demand.

Table 5_ Electricity consumption time slots (F1–F3)

Electricity consumption time slots	
F1	Monday-Friday 08:00/19:00
F2	Monday-Friday 07:00/08:00-19:00/23:00
F3	Monday-Friday 23:00/07:00+weekend

The analysed electricity bills report consumption separately for each time slot (F1, F2, F3), enabling a more accurate assessment of usage patterns and potential opportunities for load shifting towards lower-cost periods.

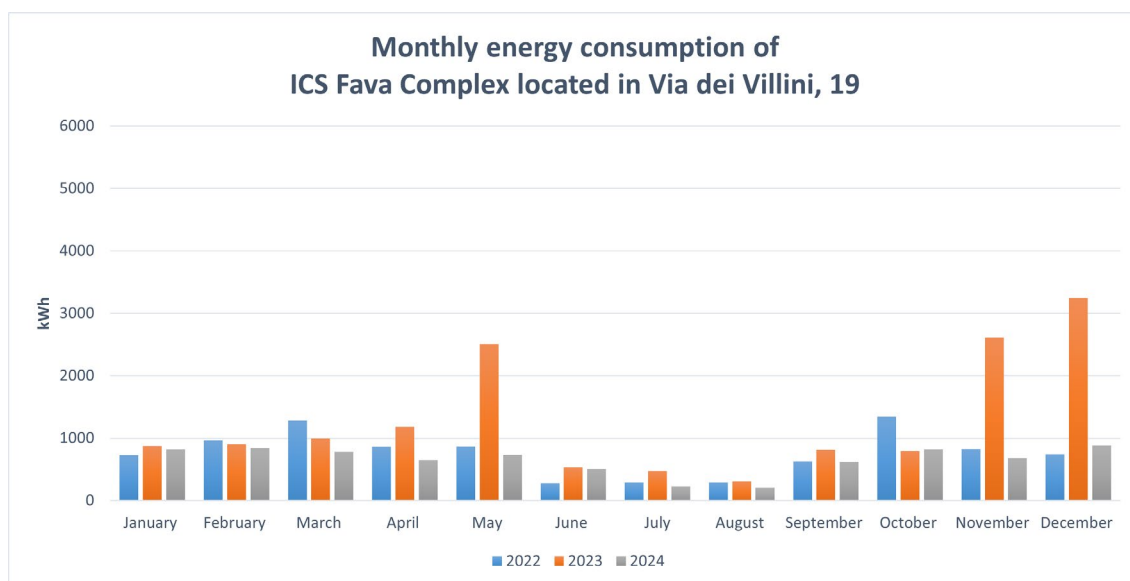


Figure 14_ Electricity consumption from 2022 to 2024 of ICS Fava Complex located in Via dei Villini, 19.

The chart illustrates the monthly electricity consumption (in kWh) of the ICS Fava Complex in Via dei Villini, 19, over the years 2022, 2023, and 2024. It is evident that 2023 recorded significantly higher consumption peaks compared to the other two years, particularly in May, November, and December, with values exceeding 2,500–3,000 kWh. In contrast, 2022 and 2024 show more moderate consumption levels, generally below 1,500 kWh per month, following a more consistent pattern. Summer months (June–August) display low consumption across all years, likely due to school closure during the holidays. The spike in May 2023 is particularly anomalous, being nearly triple the value of May 2022, which could be related to extraordinary events, changes in space usage, equipment malfunctions, or specific weather conditions. The increases observed in November and December 2023, absent in the other years, might indicate more intensive use of lighting and other electrical systems during the winter months or increased building activity. The more uniform trend in 2024, without marked peaks, may

suggest better consumption control, or reduced operational activity. These findings highlight the need for targeted analysis in spring and winter months to determine whether variations are due to unavoidable operational requirements or avoidable inefficiencies.

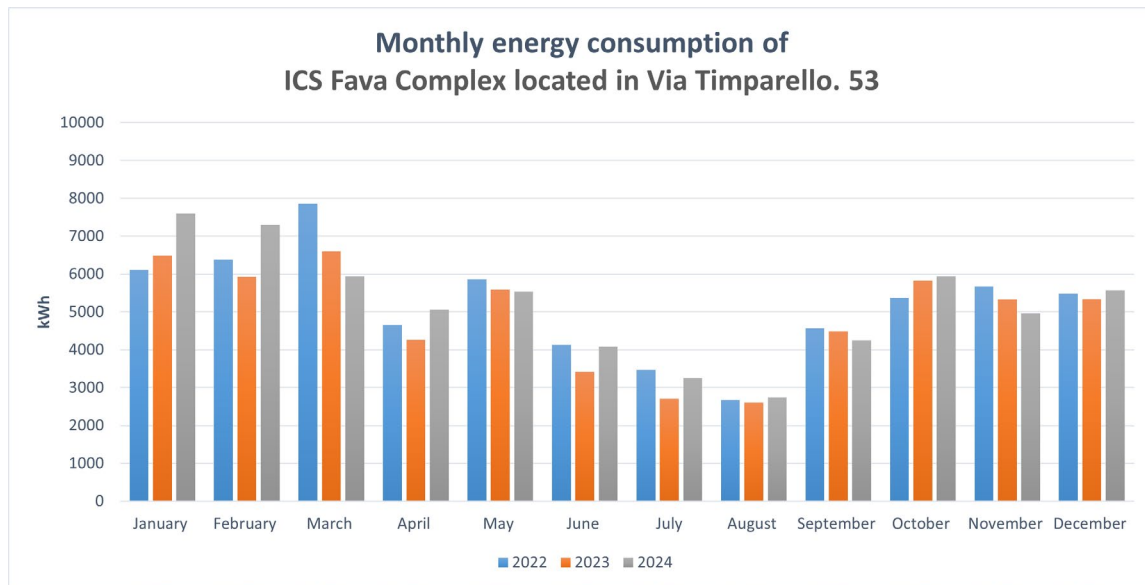


Figure 15_Electricity consumption from 2022 to 2024 of ICS Fava Complex located in Via Timparello, 53.

The chart depicts the monthly electricity consumption (in kWh) of the ICS Fava Complex in Via Timparello, 53, for the years 2022, 2023, and 2024. The data show a relatively stable and consistently high consumption profile throughout the year, with peak values in the winter months (January–March) and autumn months (October–December), frequently exceeding 6,000 kWh and reaching almost 8,000 kWh in March 2022. During the summer months (July–August), there is a marked decrease, with values around 2,500–3,500 kWh, likely due to the school closure during the summer holidays and reduced internal activities. Notably, 2024 records particularly high consumption in January and February, exceeding those of the other two years, whereas 2023 shows slightly lower-than-average values in spring and summer months. The steady consumption in most other months suggests that a significant share of the energy demand is related to equipment and systems operating regardless of the season, such as internal lighting, IT equipment, and winter heating systems. However, year-to-year differences indicate potential variations in space usage patterns or climatic conditions, warranting targeted analysis to identify possible efficiency improvements.

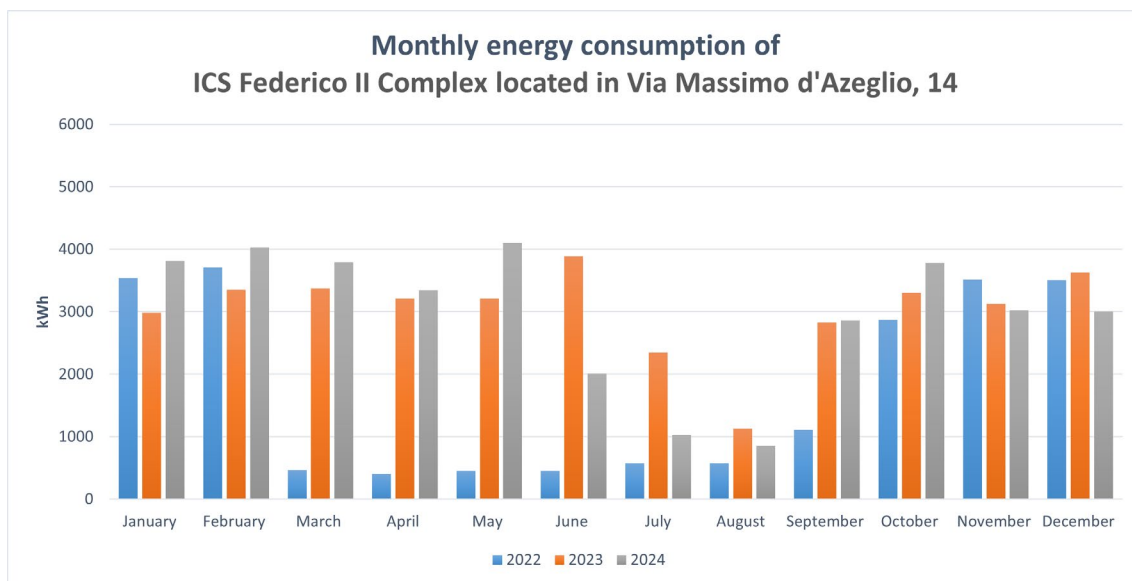


Figure 16_ Electricity consumption from 2022 to 2024 of ICS Federico II Complex located in Via Massimo D'Azeglio, 14.

The chart shows the monthly electricity consumption (in kWh) of the ICS Federico II Complex in Via Massimo D'Azeglio, 14, for the years 2022, 2023, and 2024. The data reveal different patterns across the three years, with relatively stable winter consumption (January–February and November–December) ranging between 3,000 and 4,000 kWh, and more variable trends in spring and summer. In 2022, consumption dropped sharply from March to July, reaching values below 1,000 kWh, likely due to partial closures or changes in operational schedules. Conversely, 2023 displays an unusual summer peak, exceeding 3,800 kWh in June and showing a significant increase in July, which may indicate intensive use of air conditioning systems or extraordinary activities during the summer period. In 2024, spring and summer consumption is generally higher than in 2022 but lower than the 2023 peaks, suggesting a more balanced use of the facilities. Overall, the year-to-year differences could be linked to climatic conditions, internal management, and possible technical or organisational interventions.

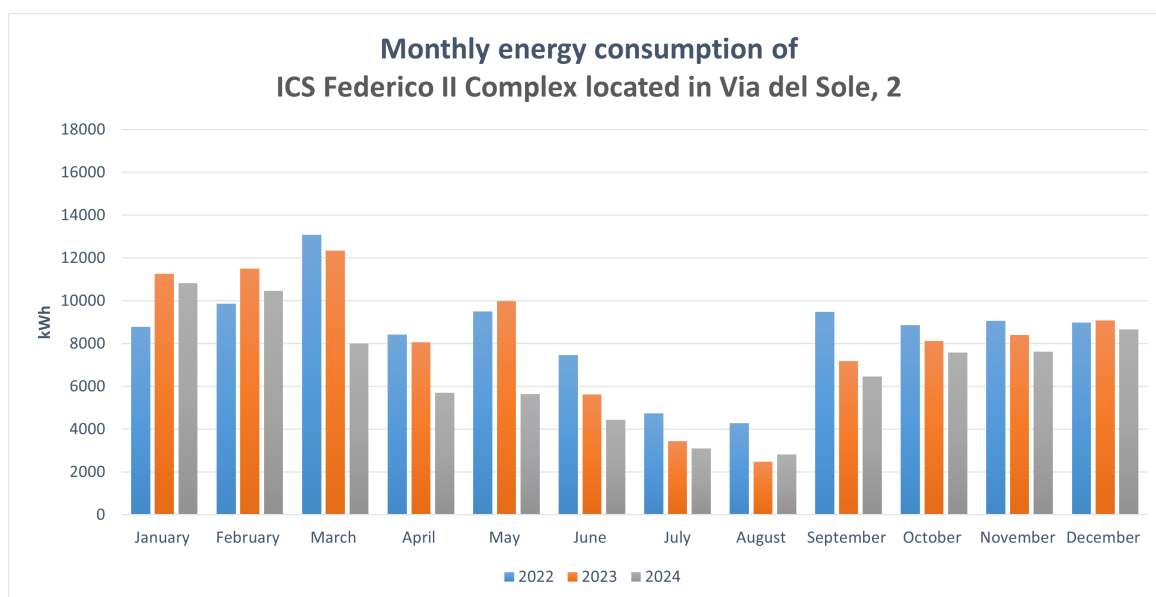


Figure 17_ Electricity consumption from 2022 to 2024 of ICS Federico II Complex located in Via del Sole, 2.

The chart shows the monthly electricity consumption (in kWh) of the ICS Federico II Complex in Via del Sole, 2, for the years 2022, 2023, and 2024. The data reveal high consumption during winter and spring

months, with significant peaks in March (over 12,000 kWh in both 2022 and 2023) and consistently above 8,000 kWh in the early months of the year. A marked decrease is observed in the summer months, with consumption dropping below 3,000 kWh in August across all years, likely due to the school's summer closure and reduced equipment usage. However, 2024 stands out for having lower values from April to September compared to previous years, with particularly sharp drops in May and June (around 5,600 and 4,300 kWh respectively), suggesting improved resource optimisation or reduced activity levels. From September to December, the trend shows relative stability between years, with a gradual increase towards the winter season. These variations may be linked to climatic differences, air-conditioning use, or changes in the school's operational schedule.

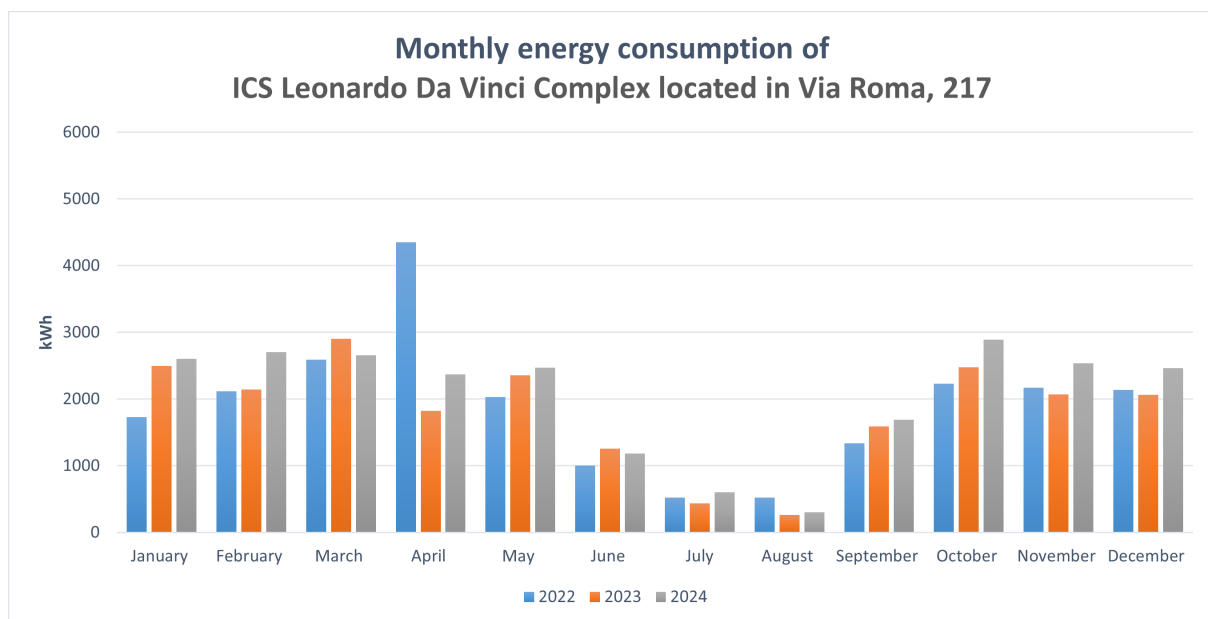


Figure 18_Electricity consumption from 2022 to 2024 of ICS Leonardo Da Vinci Complex located in Via Roma, 217.

The chart displays the monthly electricity consumption (in kWh) of the ICS Leonardo Da Vinci Complex in Via Roma, 217, for the years 2022, 2023, and 2024. The trend shows moderate winter consumption, ranging between 2,000 and 2,700 kWh, and a sharp peak in April 2022 (over 4,300 kWh) not present in other years, possibly linked to intensive equipment use or extraordinary events. During the summer months, particularly July and August, there is a steep decline (values near or below 500 kWh), likely due to the school's summer closure and reduced activity. In 2024, from October to December, consumption is slightly higher than in previous years, especially in October (almost 2,900 kWh), suggesting increased use of systems, possibly for heating needs or other indoor activities. The overall pattern reflects the typical seasonality of school buildings, with higher consumption during teaching periods and reductions during holiday months.

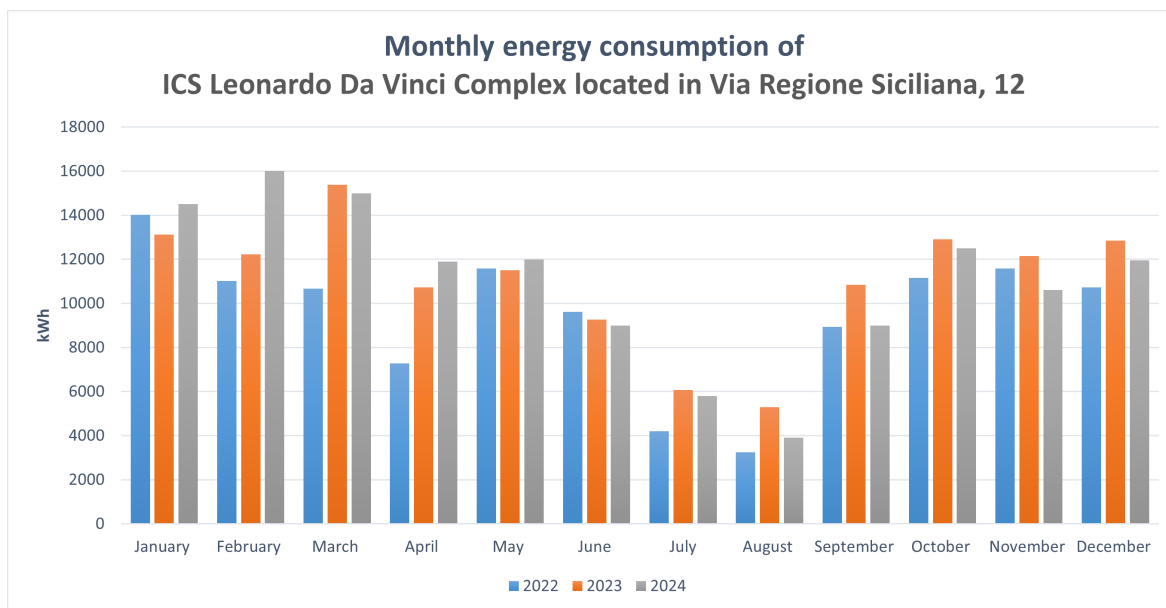


Figure 19_ Electricity consumption from 2022 to 2024 of ICS Leonardo Da Vinci Complex located in Via Regione Siciliana, 12.

The chart illustrates the monthly electricity consumption (in kWh) of the ICS Leonardo Da Vinci Complex located in Via Regione Siciliana, 12, for the years 2022, 2023, and 2024. The trend shows very high consumption during winter and spring months, with values exceeding 10,000 kWh and notable peaks in February 2024 (over 16,000 kWh) and March 2023 (over 15,000 kWh). The summer months, especially July and August, display a sharp decline (ranging from 3,000 to 6,000 kWh), likely due to the school's summer closure and reduced activity. September marks a significant rebound, with values again exceeding 9,000–11,000 kWh and remaining high until December. Such pronounced peaks in colder months may be linked to intensive use of electric heating or other energy-demanding equipment during school operations.

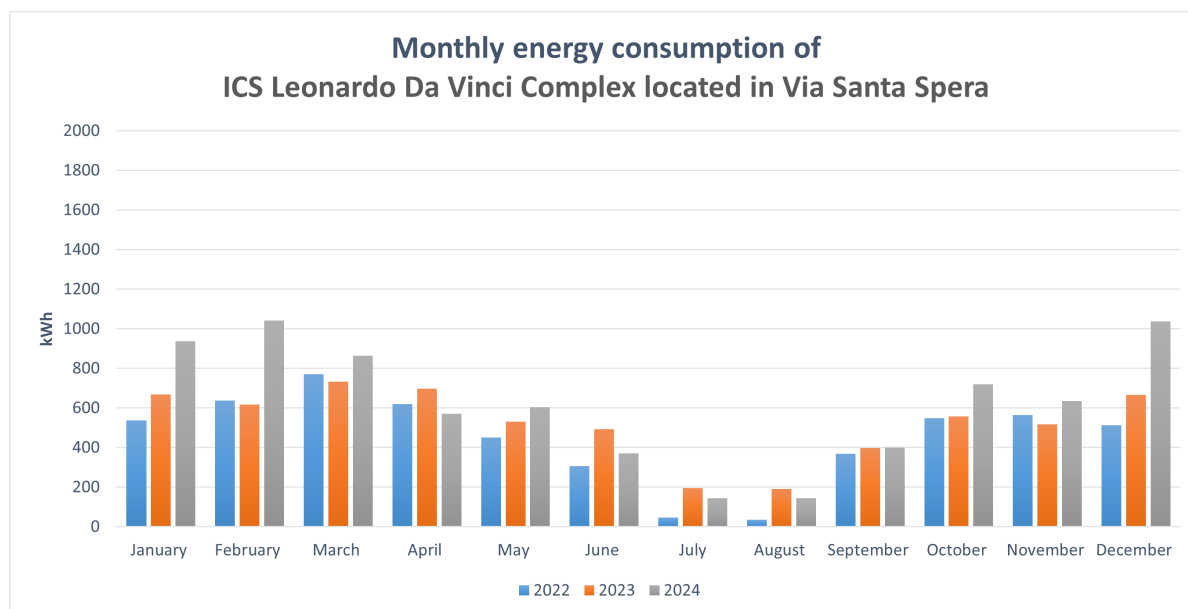


Figure 20_ Electricity consumption from 2022 to 2024 of ICS Leonardo Da Vinci Complex located in Via Santa Spera, 15.

The chart presents the monthly electricity consumption (in kWh) of the ICS Leonardo Da Vinci Complex located in Via Santa Spera for the years 2022, 2023, and 2024. The recorded values are generally low compared to other school buildings analysed, ranging from approximately 500 to 1,000 kWh during peak activity months. A noticeable peak occurs in February 2024 (around 1,040 kWh) and a significant

increase is seen in December of the same year (over 1,000 kWh). During the summer months, particularly July and August, consumption drops sharply to below 200 kWh, likely due to the school’s summer closure and the absence of academic activities. Consumption starts to recover in September, gradually increasing until December, suggesting a progressive rise in space and equipment usage.

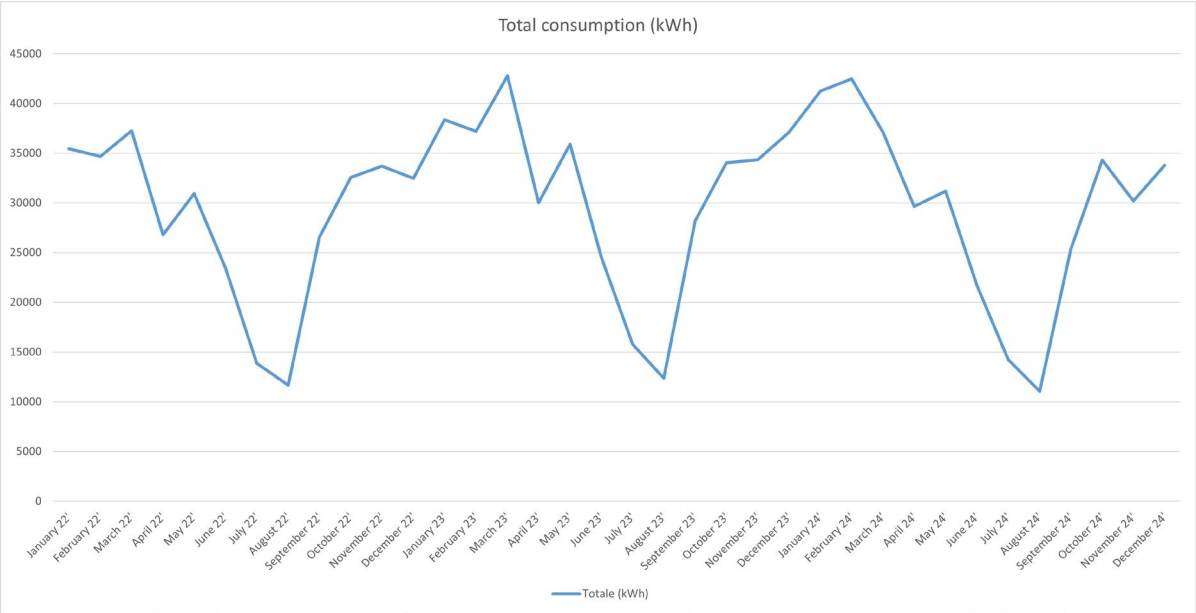


Figure 21_ Electricity consumption in school buildings from 2022 to 2024.

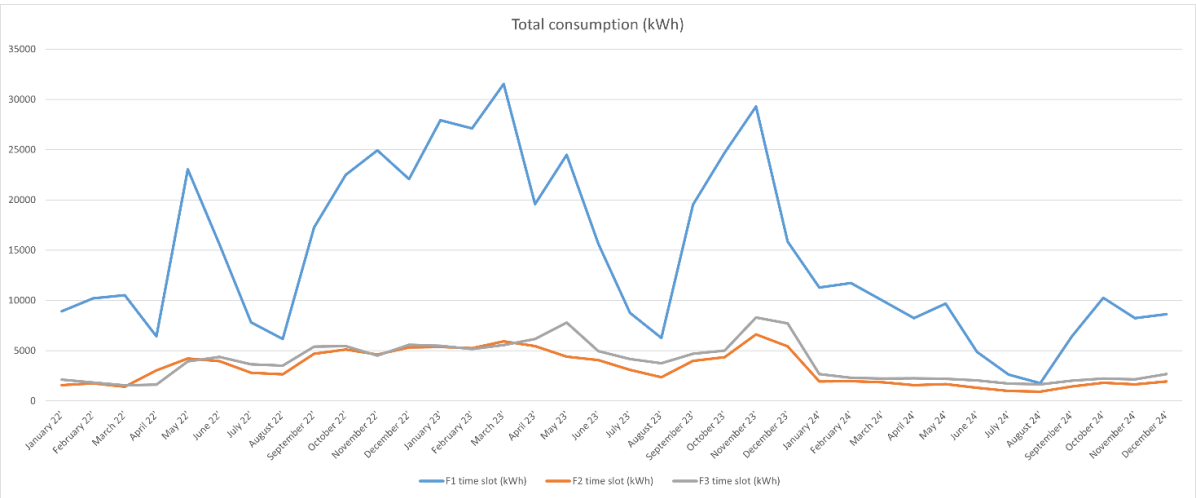


Figure 22_ Electricity consumption in school buildings divided by time slots from 2022 to 2024

The first chart illustrates the overall monthly electricity consumption of school buildings from 2022 to 2024. A strong seasonal pattern emerges, with peaks during the winter months (January–March and October–December) and minimum values in the summer (July–August). This trend aligns with the school calendar and the reduced operation of facilities during summer holidays. The most pronounced drops occur mid-year, likely reflecting school closures and the absence of teaching activities. The second chart, broken down by F1, F2, and F3 time slots, shows that most of the energy consumption occurs in F1 (working hours), confirming that energy use is mainly driven by daytime school activities. F2 and F3, while significantly lower, display a relatively constant trend, indicating baseline consumption (emergency lighting, equipment on standby, possible night-time or maintenance climate control). The sharp contrast between F1 and the other time slots highlights the dominant role of daytime school operations in total consumption.

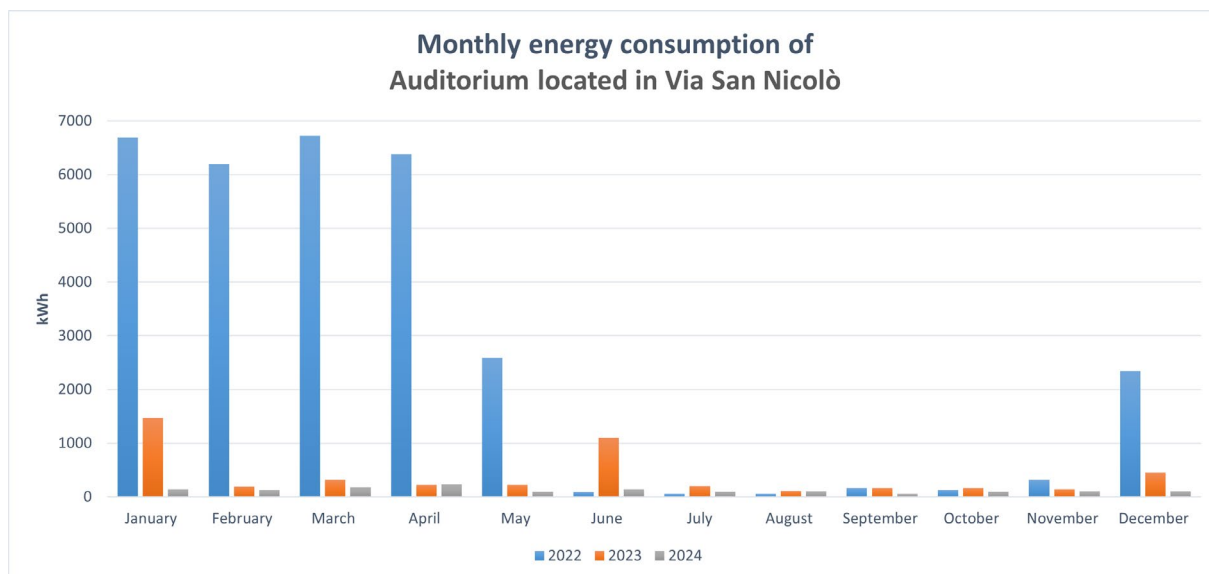


Figure 23_Electricity consumption from 2022 to 2024 of Auditorium located in Via San Nicolò

The chart illustrates the monthly electricity consumption of the Auditorium in Via San Nicolò for 2022, 2023, and 2024. The data show that 2022 recorded significantly higher values compared to the following years, with pronounced peaks in the winter and spring months (January–April) and a notable increase in December. Starting in 2023, consumption drops drastically, remaining at very low and nearly constant levels throughout the year, with only minor occasional increases (e.g., June 2023).

This trend suggests a substantial change in the building’s use, such as a reduction in activities, a change in its function, or the implementation of energy efficiency measures. The stark difference between years is unlikely to be solely the result of seasonal variation, instead pointing to a structural change in the auditorium’s operation.

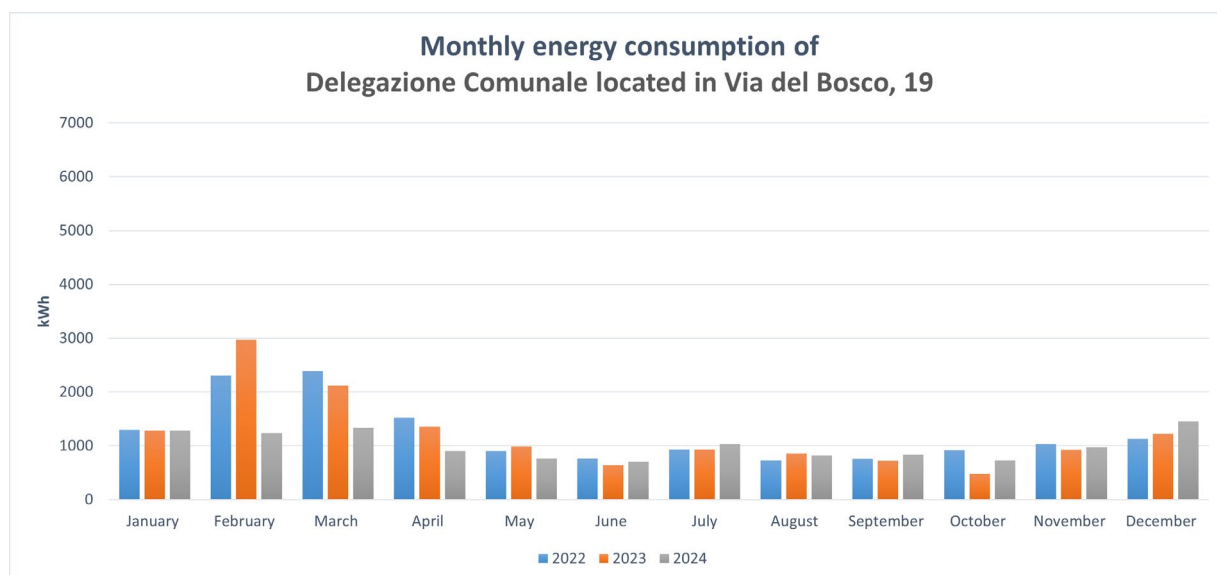


Figure 24_Electricity consumption from 2022 to 2024 of Delegazione Comunale located in Via del Bosco, 19

The chart shows the monthly electricity consumption of the Municipal Delegation located in Via del Bosco, 19 for the years 2022, 2023, and 2024. A marked peak is visible in the winter months, particularly in February 2023, when consumption exceeds 3000 kWh, followed by a gradual decrease during spring and summer. In the summer period (June–September), consumption remains low and relatively constant, before slightly increasing in autumn and more noticeably in December.

Comparing the three years, the monthly distribution pattern remains similar, although the absolute values vary. In 2023, there are higher peaks in the early months, whereas 2024 shows generally lower and more stable consumption, except for December. Seasonality appears to play a key role, likely linked to more intensive use of the facility in the colder months and a significant reduction in activity during the summer.

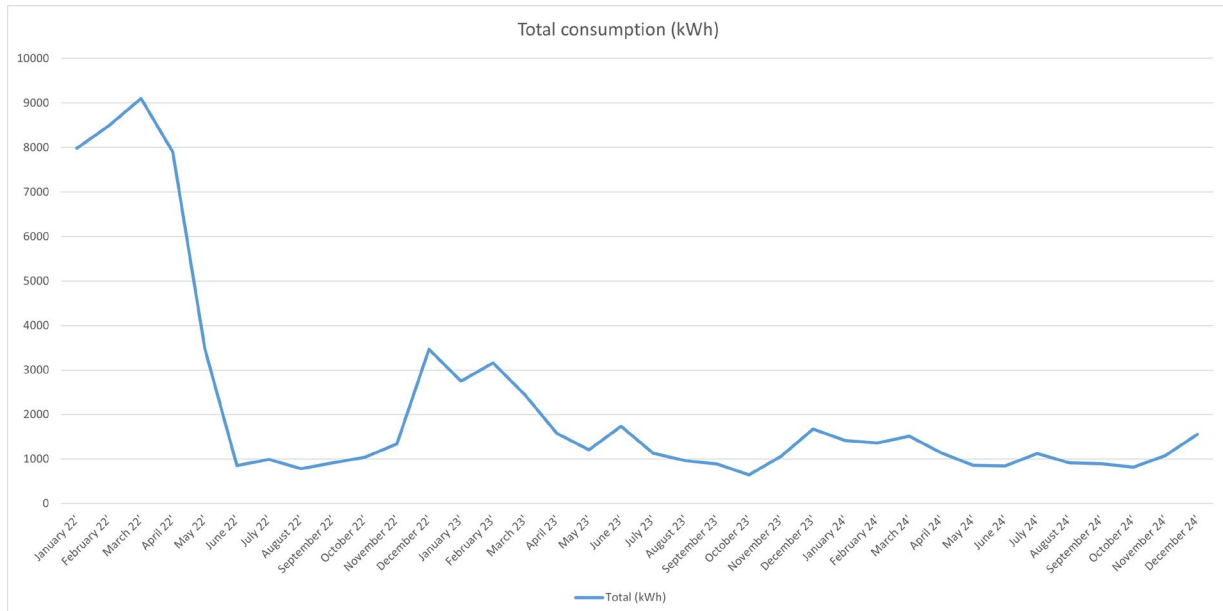


Figure 25_Electricity consumption buildings for cultural and recreational activities from 2022 to 2024

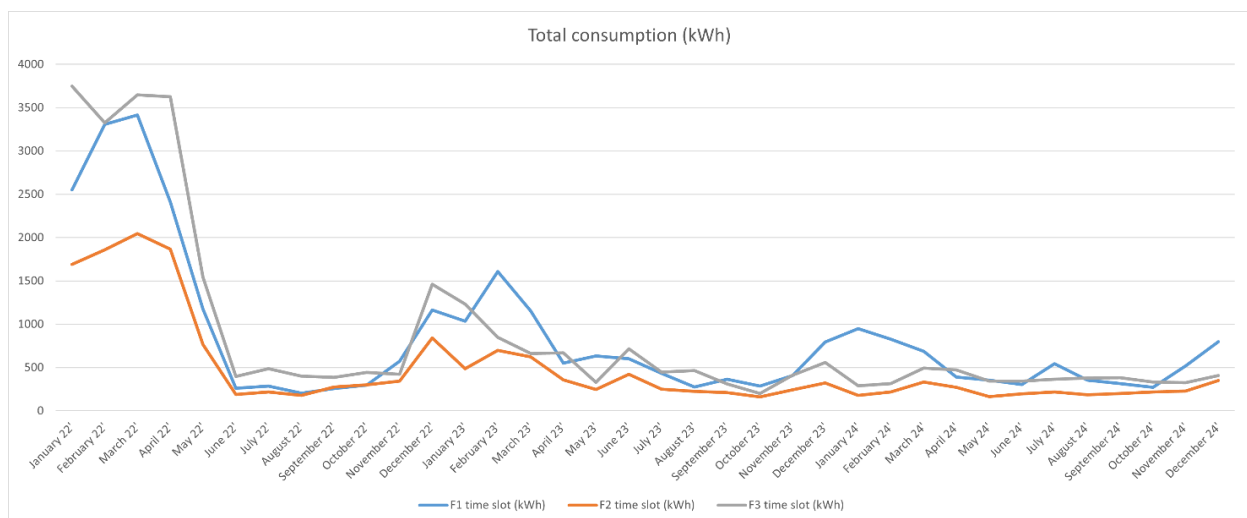


Figure 26_Electricity consumption buildings for cultural and recreational activities divided by time slots from 2022 to 2024

The charts show the overall electricity consumption trend for recreational buildings, specifically the auditorium and the municipal delegation hall. The data highlight very high consumption in the first months of 2022 (above 8,000–9,000 kWh per month), followed by a sharp decrease starting in May 2022, reaching monthly values generally below 2,000 kWh in the following years. This change can be attributed to more sporadic use of the facilities, a reduction in events and conferences, or the implementation of consumption rationalisation measures, such as improved system management and stricter shutdown policies during idle periods.

The second chart, which breaks down consumption by time slots (F1, F2, F3), shows that in early 2022 the F3 slot (night-time and weekends) recorded significant usage, likely due to systems being left on outside of operational hours (lighting, HVAC, equipment). After the May 2022 drop, all time slots

decreased significantly and uniformly, with F1 slightly prevailing during active periods, confirming that current consumption is mainly concentrated during actual usage for events or public access.

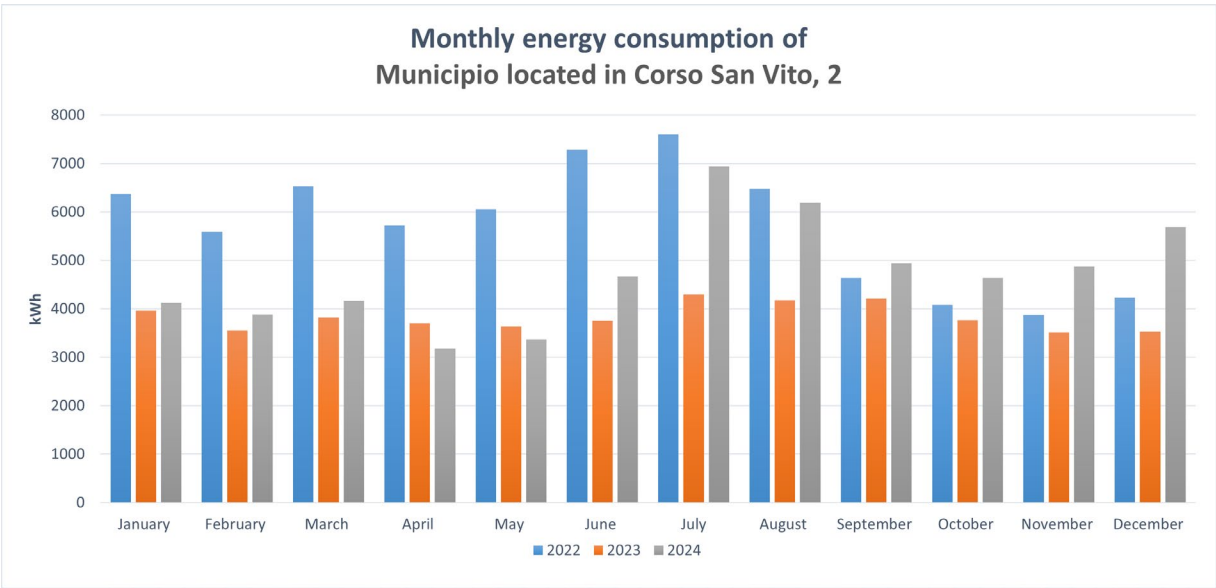


Figure 27_Electricity consumption from 2022 to 2024 of Municipio located in Corso San Vito, 2

The chart presents the monthly electricity consumption of the Town Hall located in Corso San Vito, 2, for the years 2022, 2023, and 2024. In 2022, consumption levels are significantly higher than in the following years, with peaks in June (over 7,000 kWh) and July (around 7,500 kWh), likely due to intensive air conditioning use or increased administrative activity. In 2023, there is a marked and more consistent decrease, with values remaining between 3,500 and 4,500 kWh, suggesting improvements in energy management practices, or reduced operating hours. In 2024, the trend is intermediate: lower consumption in the first half of the year but a notable spike in July (nearly 7,000 kWh), indicating that high summer loads persist. Overall, the data show progress compared to 2022, but the summer peak remains a critical point. Targeted actions—such as improving air conditioning efficiency or implementing better operational strategies during hot months—could help reduce seasonal demand.

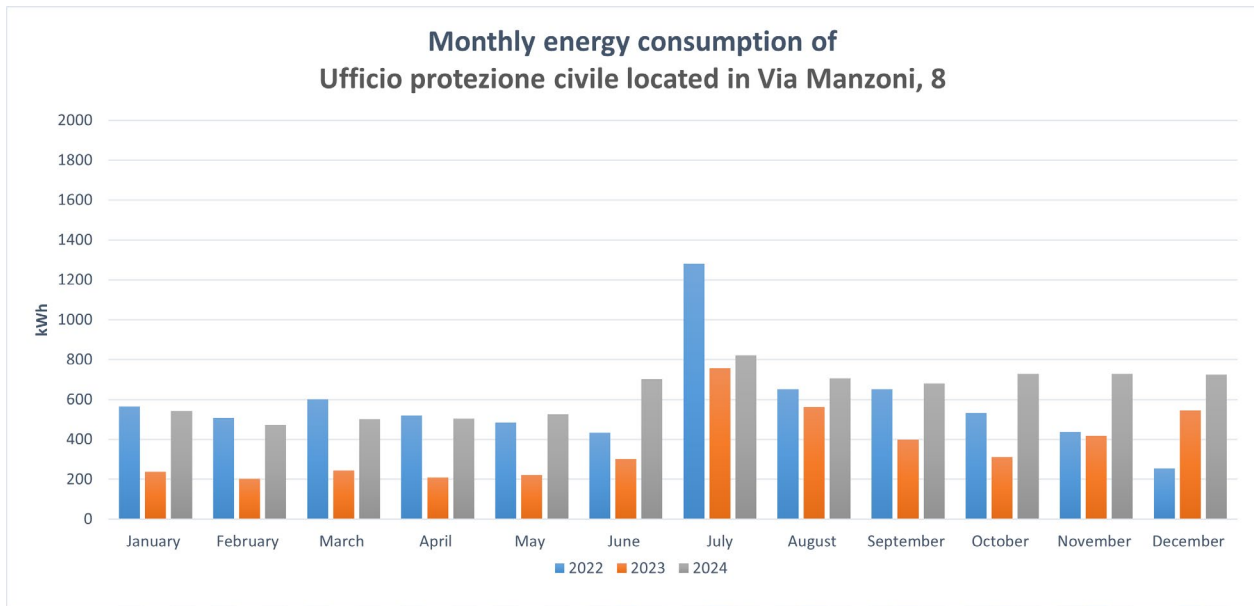


Figure 28_Electricity consumption from 2022 to 2024 of Ufficio Protezione civile located in Via Manzoni, 8

The chart shows the monthly electricity consumption of the Civil Protection Office in Via Manzoni, 8, for the years 2022, 2023, and 2024. In 2022, consumption remained stable throughout the year, with a significant peak in July (over 1,200 kWh), possibly linked to intensive air conditioning use or extraordinary operational activities. In 2023, there was an overall decrease compared to 2022, with lower values and a maximum in July (around 750 kWh). The 2024 trend appears more regular, with average values higher than in 2023 but lower than in 2022 and increases during the summer and early autumn months (June–September) that could reflect more consistent building use or new operational needs. Overall, the trend indicates improved energy efficiency compared to 2022, but also highlights the need for better management during high-demand months—particularly in summer—to prevent peaks not justified by regular activity.

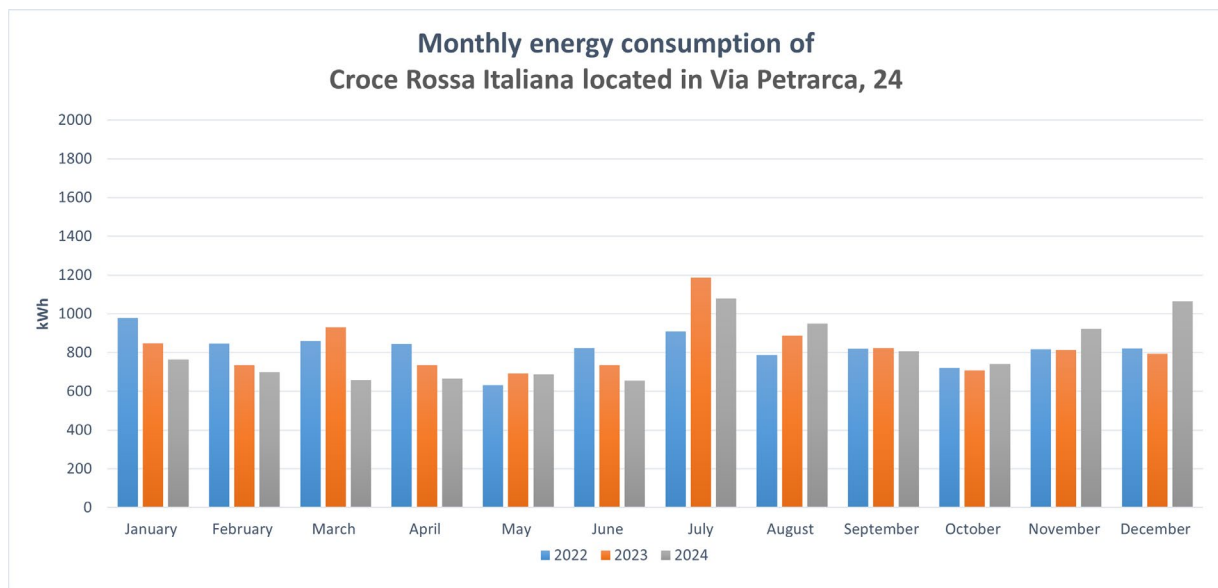


Figure 29_Electricity consumption from 2022 to 2024 of Croce Rossa Italiana located in Via Petrarca, 24

The chart shows the monthly electricity consumption of the Italian Red Cross headquarters in Via Petrarca, 24, for the years 2022, 2023, and 2024. In 2022, consumption remained relatively constant, ranging between 700 and 1,000 kWh, with no significant peaks, suggesting regular space usage. In 2023,

there was an increase in summer months, with a peak in July (nearly 1,200 kWh), likely due to intensive air conditioning use or extraordinary activities. In 2024, values were lower than in previous years during the first months, but rose towards the end of the year, peaking in December (over 1,100 kWh), possibly linked to increased winter usage or special events. Overall, the trend shows general stability but with seasonal variations, highlighting the need to monitor and manage consumption during periods of high attendance or intensive cooling system use.

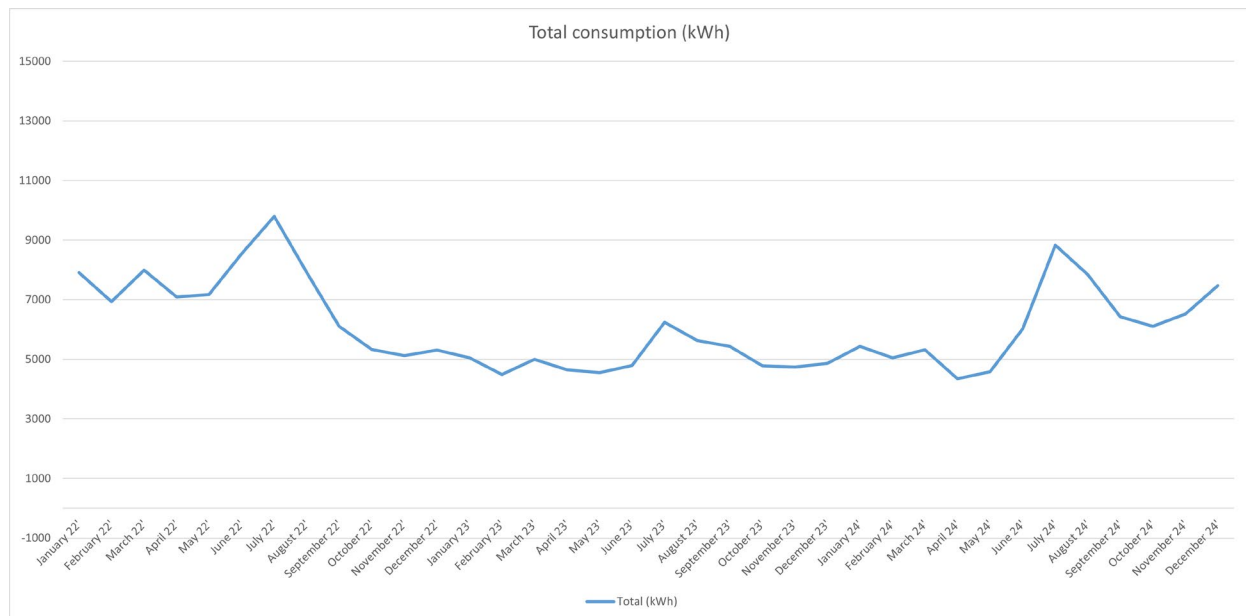


Figure 30_Electricity consumption buildings for PA activities from 2022 to 2024

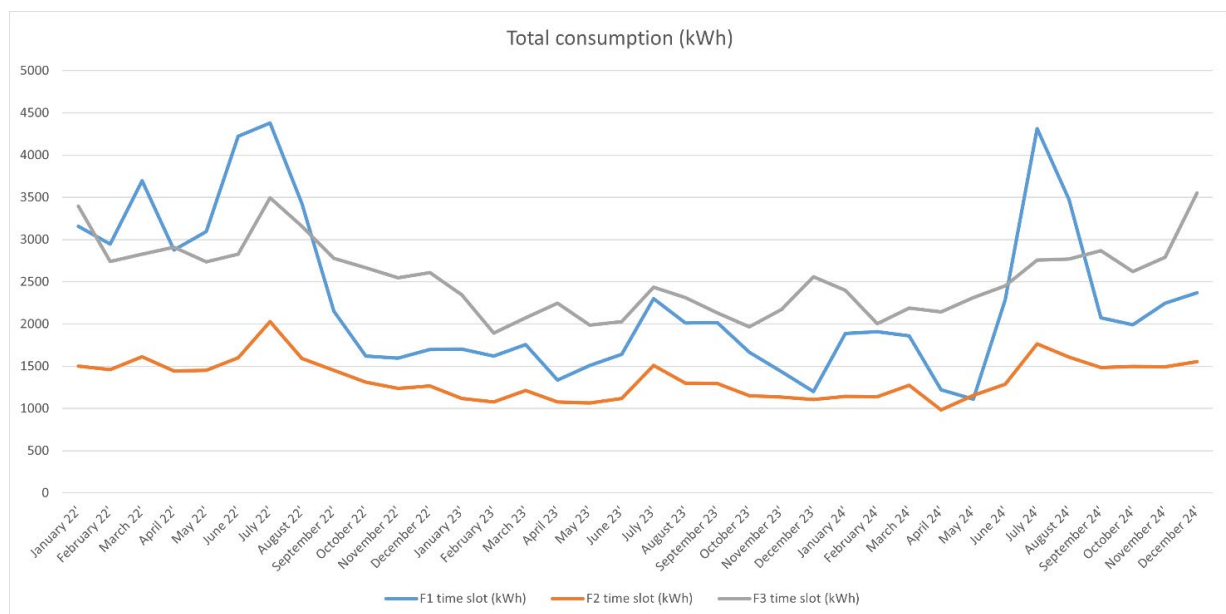


Figure 31_Electricity consumption buildings for PA activities divided by time slots from 2022 to 2024

The overall electricity consumption trend of public administration buildings shows a clear seasonal pattern, with significant peaks during the summer months (particularly July and August 2022 and 2024) and reductions in spring and autumn. The summer increase is likely due to the intensive use of air conditioning systems, especially in buildings that remain operational during this period. Comparing the years, there is an overall decrease in consumption starting from late 2022, with greater

stability and lower average levels during 2023, followed by a slight rebound in 2024. The time-slot analysis (F1, F2, and F3) highlights that F1 (daytime working hours) accounts for the largest share of consumption, consistent with the operational schedule of public offices. F3 (night and weekend hours) shows relatively high values, sometimes even exceeding F1, which may indicate constant loads or equipment left running outside working hours. F2, the intermediate slot, remains relatively stable with limited fluctuations. This pattern suggests there is room for improvement in optimising night-time and weekend energy use to reduce unnecessary waste.

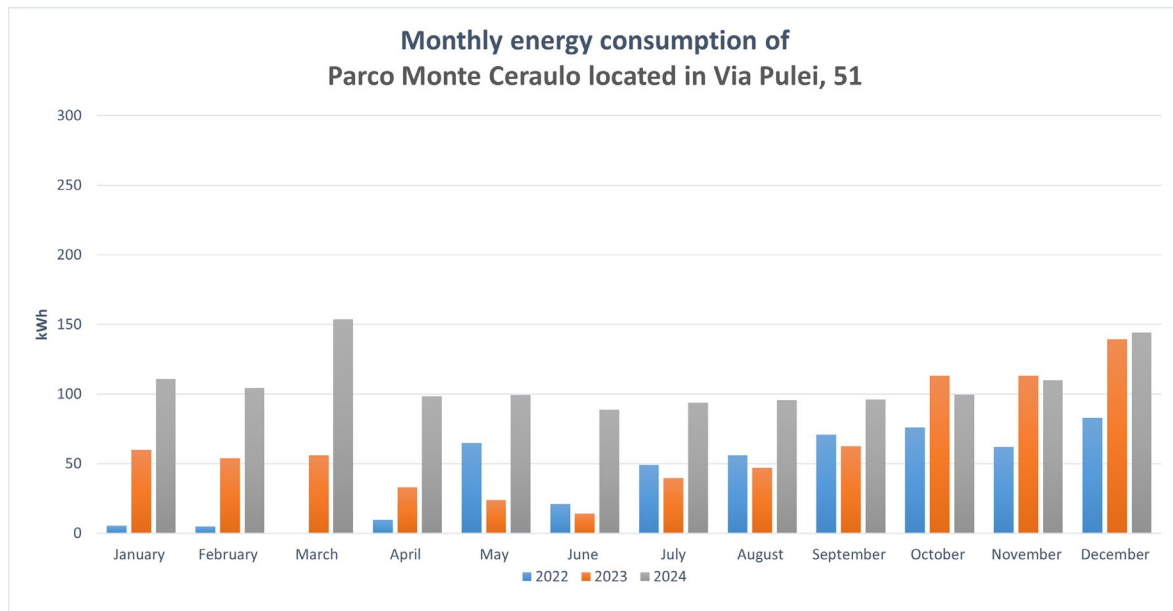


Figure 32_Electricity consumption from 2022 to 2024 of Parco Monte Ceraulo located in Via Pulei, 51

The chart for the monthly energy consumption of Parco Monte Ceraulo shows overall very low values compared to other public buildings, consistent with the nature of the facility and its mainly occasional use. However, there is a gradual increase in consumption towards the end of the year, especially in October, November, and December, particularly in 2023 and 2024. This rise may be linked to events, recreational activities, or increased lighting use due to seasonal reasons (e.g., holidays or shorter daylight hours).

Comparing the years, 2024 shows the highest consumption in most months, while 2022 records significantly lower values, likely due to reduced usage of the facility or different operational management. The monthly variability suggests that the park's use is not constant but related to specific activities, offering room for more targeted energy management, for example, through the adoption of LED lighting with motion sensors.

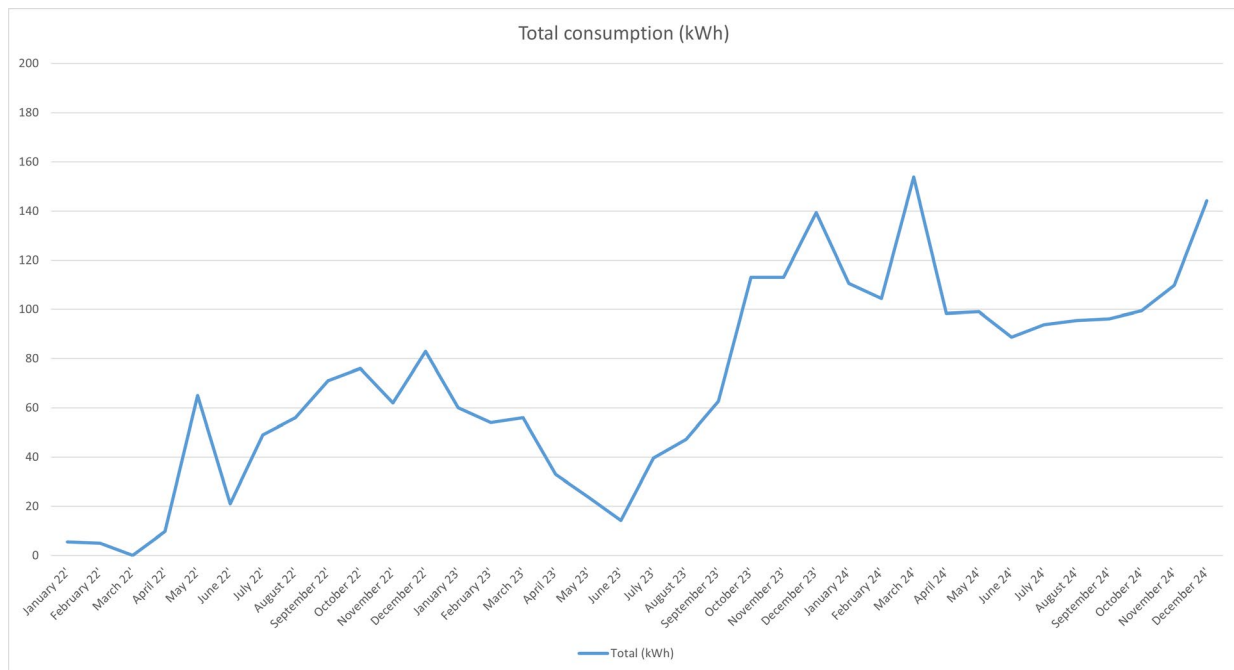


Figure 33_Electricity consumption for green areas and public parks from 2022 to 2024

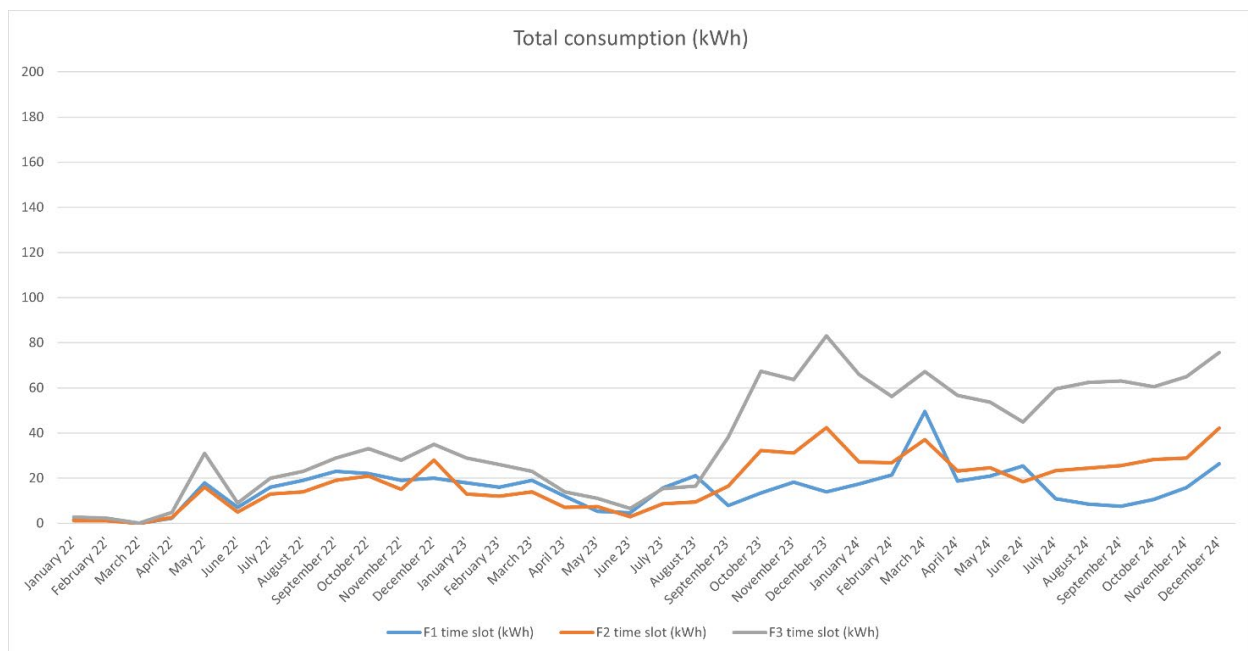


Figure 34_Electricity consumption for green areas and public parks divided by time slots from 2022 to 2024

The overall energy consumption of green areas shows very low values compared to other building categories, which is expected for outdoor spaces with limited electricity use. However, a gradual increase is noticeable from the second half of 2023, with significant peaks in March and December 2024. This growth could be linked to higher usage of the facilities (events, decorative or seasonal lighting) or upgrades to electrical installations.

The breakdown by time slots shows a consistent predominance of F3 (nighttime and weekend hours), indicating that most consumption is related to loads operating without staff presence (e.g., night-time security lighting or automatic systems). F1 and F2 remain at modest levels, consistent with limited daytime operational use. The rise in F3 during 2024 suggests an increase in operating hours or lighting intensity.

Overall, the energy management of these areas could benefit from targeted actions to reduce F3 consumption, such as high-efficiency LED lighting systems, dusk sensors, or timers to limit use during non-essential hours.

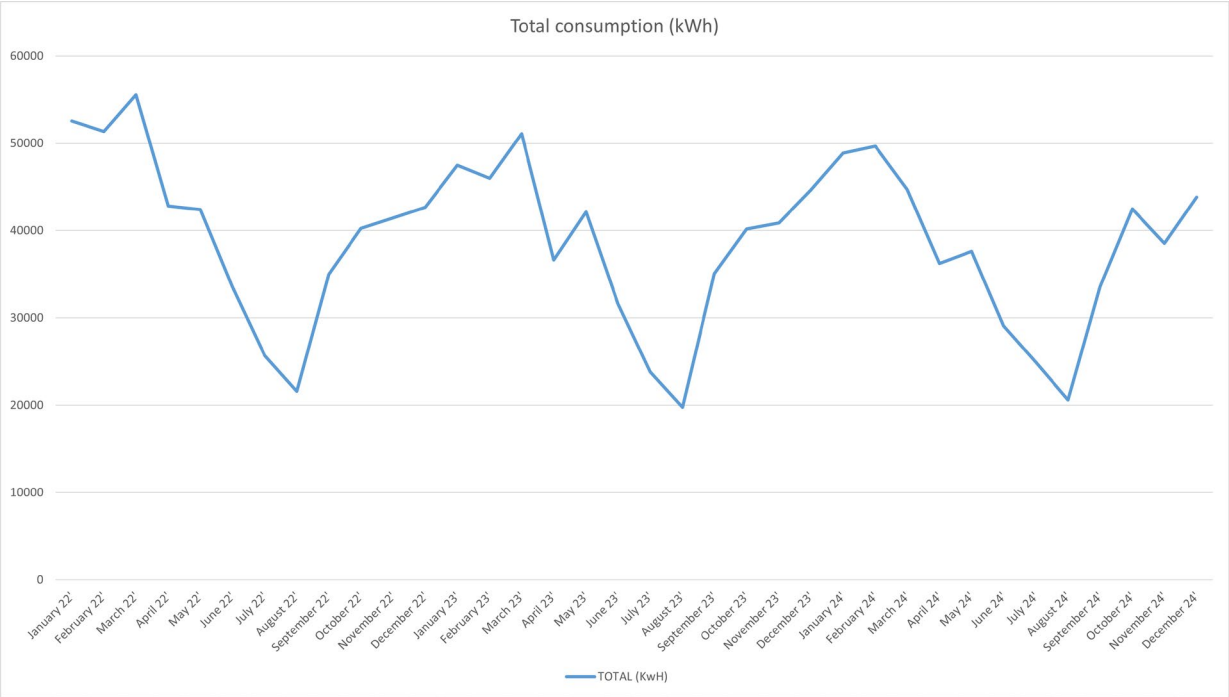


Figure 35_Electricity consumption all surveyed buildings in the Municipality of Mascalucia from 2022 to 2024

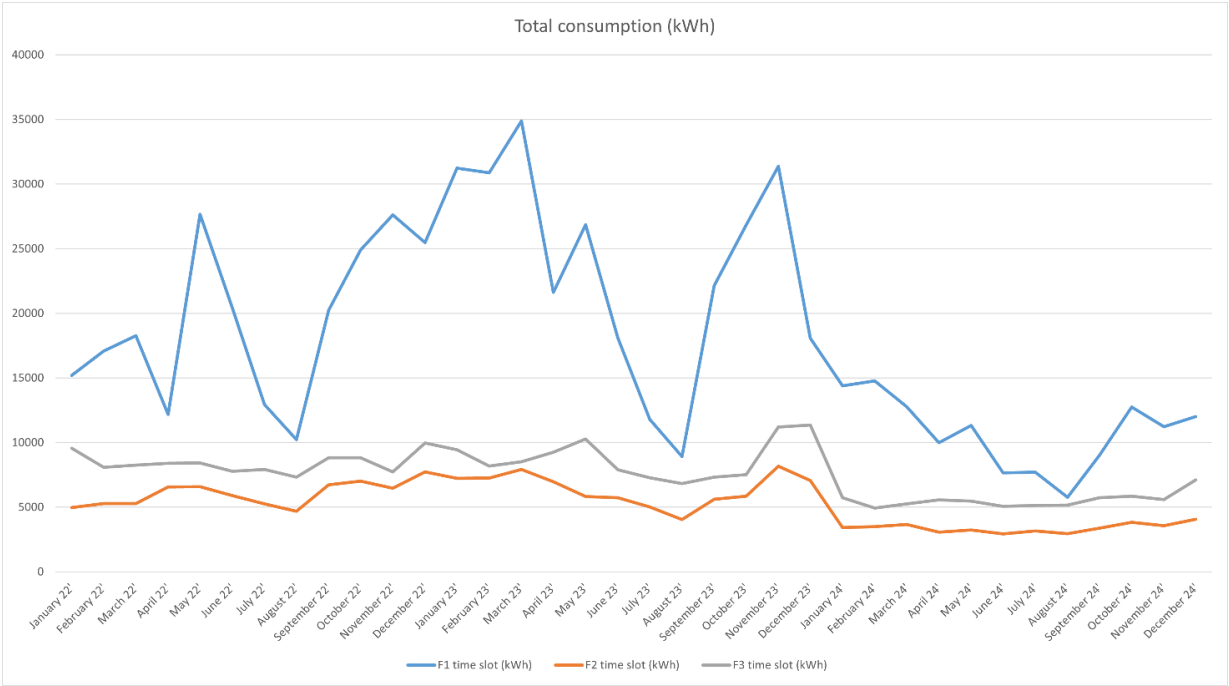


Figure 36_Electricity consumption all surveyed buildings in the Municipality of Mascalucia divided by time slots from 2022 to 2024

The charts present the overall electricity consumption trends for all analysed public administration buildings, encompassing facilities with very different functions: schools, recreational spaces

(auditorium and library/conference center), municipal offices, Civil Protection and Red Cross headquarters, and green areas. The aggregation of such varied buildings results in a non-homogeneous consumption profile, shaped by the sum of distinct energy use behaviours. Overall, a clear seasonal pattern is visible, with peaks in winter and early spring due to increased lighting demand, and significant drops during the summer, mainly linked to school closures. However, the presence of year-round operational buildings, such as offices and recreational facilities, partly mitigates these declines, maintaining a constant consumption base throughout the year. The time slot analysis shows that F1 (peak hours) accounts for the largest share of total consumption, with marked increases in certain months. F2 and F3, which are more stable and less influenced by seasonal changes, indicate that most energy-intensive activities occur during standard working hours. Some isolated spikes, especially in F1, may be related to special events, conferences, public gatherings, or maintenance activities. This distribution highlights the potential for optimizing consumption by shifting part of the load to cheaper time slots (F2 and F3) and the need to analyse different building groups separately to define targeted efficiency measures. Managing such a heterogeneous set of facilities requires tailored strategies that address the specific operational patterns and needs of each building type.

5.4 Identification of utilities

This section lists all the electrical utilities present in the analysed public buildings of the Municipality of Mascalucia. Thanks to the data collected through the direct survey of the energy-consuming elements on site, it was possible to estimate the expected consumption for each utility, considering the opening hours of the buildings. This process has the objective of calculating the energy absorbed monthly by electrical appliances, starting from their nominal power and the relative hourly usage profiles.

Given that the analysed facilities are medium-sized public buildings, lighting systems, together with air conditioning, represent the most energy-intensive utilities. They are also the elements most often left on unnecessarily, along with appliances and other devices, and even when in stand-by mode they continue to draw power. For this reason, the analysis has primarily focused on lighting points, as they offer significant opportunities for energy savings through targeted efficiency measures.

5.4.1 Lighting

This subsection provides an overview of the main types of lighting fixtures currently installed in the public buildings under analysis, together with their technical specifications. While the exact number of lighting points in each building is reported in a dedicated chapter (Cap. 5.5), the focus here is on the technical and performance characteristics of the light sources. The complete tables and technical sheets are provided in [Annex II](#) for ease of reference.

Given that most of the existing fixtures are outdated and inefficient, a relamping intervention with LED technology is considered in the following section, to assess the potential improvements in energy consumption and overall performance.

5.5 Audit of Electricity consumption

This section aims to reconstruct in detail the electrical consumption starting from the data collected during the inspection. To this end, the power absorbed by each device present in the buildings analysed was detected and, knowing the average hours of operation of the various loads, it was possible to estimate the overall consumption. In addition, an in-depth analysis was conducted to estimate the

specific consumption of each energy-intensive device, such as lighting systems, household appliances and air conditioning systems (split). This approach allows not only to understand the total consumption, but also to identify which devices contribute most to the overall energy requirement, providing a useful basis for any optimization interventions. In accordance with the recommendations of the ISO 50001 standard, an in-depth audit of all the energy-intensive elements present in the buildings under study was conducted. The analysis was carried out both through the collection of data provided by the municipal administration and through direct surveys carried out on site.

- **ICS Fava Complex located in Via dei Villini, 19:**



Figure 37_ External photo of the building surveyed_ Via dei Villini, 19

The ICS Fava primary school, located at Via dei Villini, 19, spans three floors and is set in a quiet residential area of Mascalucia, mainly characterized by single-family houses and villas. Its location, well connected to the town center, ensures easy accessibility for local families and nearby communities.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power.

The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	2	1x36	36	72
2	1	1x58	58	58
3	2	1x18	18	36
4	1	2x58	116	116
5	3	2x58 (x2) + 1x18 (x1)		250
6	2	2x36	72	72
7	5	2x36 (x3) + 1x12 (x2)		240
8	1	1x18	18	264
Hall	2	1x36 + 2x36	36	108
TOTAL GROUND FLOOR				1216 W

Figure 38_Lighting Fixtures and Power Distribution – Ground Floor of ICS Fava Complex located in Via Villini, 19

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	3	1x36	36	108
2	2	1x36	36	72
3	3	2x36	72	216
4	2	1x18	18	36
5	3	2x36	72	216
6	2	2x36	72	144
7	2	2x18 + 1x36	72	72
8	1	2x36	72	72
Hall	3	1x36	36	108
TOTAL FIRST FLOOR				936 W

Figure 39_Lighting Fixtures and Power Distribution – First Floor of ICS Fava Located in Via Villini, 19

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1				
2				

3				
4				
5	1	Coffee machine	1000	1000
6				
7	2	lim+pc	300+60	360
8				
Hall				
TOTAL GROUND FLOOR				1360 W

Figure 40_Energy-Consuming Equipment and Power Distribution – Ground Floor of ICS Fava complex located in Via Villini, 19

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR				
1	1	pc	60	60
2				
3				
4				
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7	2	pc	120	120
8				
Stairwell		pc	60	60
TOTAL FIRST FLOOR				900 W

Figure 41_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Fava complex located in Via Villini, 19

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6

Saturday	8:00/14:00	6
Sunday	Close	0

Figure 42_ Weekly Operating Schedule of ICS Fava Complex located in Via Villini, 19

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	156	130	51398
February	0	144	120	51398
March	0	162	135	51398
April	0	150	125	6478
May	0	156	135	6478
June	156	156	130	6478
July	156	156	130	6478
August	162	162	130	6478
September	156	156	130	6478
October	0	156	130	6478
November	0	156	130	6478
December	0	162	135	51398
	630	1872	1560	257146 W

Figure 43_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Fava complex located in Via Villini, 19

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-hungry elements operate under regular conditions.

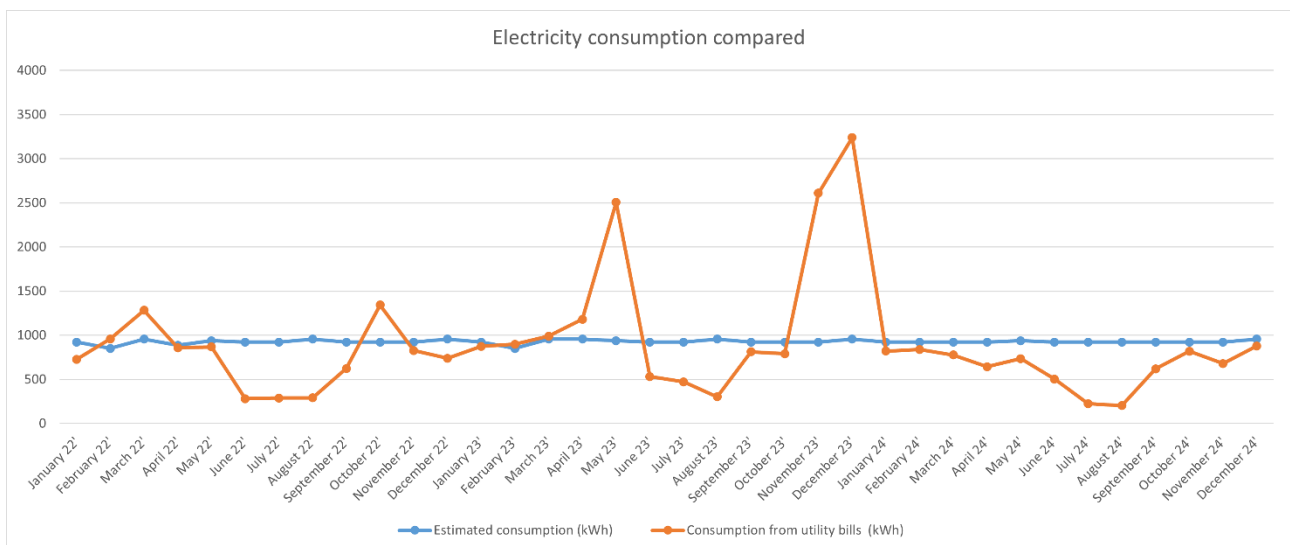


Figure 44_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Fava complex located in Via dei Villini, 19

As highlighted in the chart, the comparison between the consumption recorded on utility bills and the estimated consumption based on on-site surveys shows a reasonable level of consistency, except for May and December, where the billed consumption exhibits a significant increase. This study will provide the Municipality of Mascalucia with valuable support in investigating the causes of these consumption peaks during the school year, allowing for greater attention to these trends and the identification of effective strategies to mitigate them.

- ICS Fava complex located in Via Timparello, 53:



Figure 45_External photo of the building surveyed of ICS Fava complex located in Via Timparello, 53

The ICS Fava complex, located at Via Timparello, 53, spans three floors and accommodates a primary school as part of a comprehensive educational facility. The school is situated in a semi-central area of Mascalucia, characterized by a moderate residential fabric—mainly villas and small housing units—within easy reach of the town center and well connected by the town’s main roads.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it

possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	3	1x36	36	108
2	6	2x36	72	432
3	5	2x36	72	360
4	2	1x36	36	72
5	6	2x36	72	432
6	6	2x36	72	432
7	3	1x36	36	108
8	8	1x36	36	288
9	13	1x36 (x8) + 1x18 (x4) + 2x36 (x1)		432
10	8	1x36 (x4) + 1x18 (x4)		216
11	3	1x36	36	108
12	5	1x36 (x3) + 2 Plaf (18W)		144
13	14	2x36	72	1008
14	11	2x36	72	792
15	8	1x36 (x2) + 6 Plaf (50W)		372
16	3	1x36	36	108
17	8	1x36	36	288
18	1	1x36	36	36
19	6	2x36	72	432
20	6	2x36	72	432
21	6	2x36	72	432
22	7	2x36	72	504
23	6	2x36	72	432
24	6	2x36	72	432
25	6	2x36	72	432
26	2	2x56	112	224
Hall+Corridor	18	1x36	36	648
TOTAL GROUND FLOOR				9704 W

Figure 46_Lighting Fixtures and Power Distribution – Ground Floor of ICS Fava Complex located in Via Timparello, 53

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR (OLD ONE)				
1	18	1x36	36	648
2	3	1x36	36	108
3	3	2x36	72	216
4	4	2x36	72	288
5	4	2x36	72	288
6	3	2x36	72	216
7	2	2x36	72	144

8	3	2x36	72	216
9	4	2x36	72	288
10	4	2x36	72	288
11	3	2x36	72	216
12	3	2x36	72	216
13	8	1x36	36	188
14	11	1x36 (x4) + 2x36 (x3) + 1x18 (x4)	126	432
15	4	2x36	72	288
16	4	2x36	72	288
17	4	2x36	72	288
18	2	1x36	36	72
19	2	2x36	72	144
Stairwell	0	0	0	0
Canteen	6	2x36	72	432
TOTAL FIRST FLOOR				5264 W

Figure 47_Lighting Fixtures and Power Distribution – First Old Floor of ICS Fava Complex located in Via Timparello, 53

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR (NEW ONE)				
1	8	1x36	36	288
2	3	1x36	36	108
3	8	1x36 + 6 Plaf (50W)	86	336
4	6	2x36	72	432
5	6	2x36	72	432
6	6	2x36	72	432
7	6	2x36	72	432
8	3	2x36	72	216
9	6	2x36	72	432
10	6	2x36	72	432
11	2	1x36	36	72
Stairwell	1	2x36	72	72
Hall+corridoio	9	2x36	72	648
TOTAL FIRST FLOOR				4332 W

Figure 48_Lighting Fixtures and Power Distribution – First New Floor of ICS Fava Complex located in Via Timparello, 53

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
SECOND FLOOR				
1	8	1x36	36	288
2	3	1x36	36	108
3	8	1x36 + 6 Plaf (50W)	86	336
4	6	2x36	72	432
5	6	2x36	72	432
6	6	2x36	72	432
7	6	2x36	72	432

8	3	2x36	72	216
9	6	2x36	72	432
10	6	2x36	72	432
11	2	1x36	36	72
Stairwell	1	2x36	72	72
Hall+Corridor	9	2x36	72	648
TOTAL SECOND FLOOR				4380 W

Figure 49_Lighting Fixtures and Power Distribution – Second floor of ICS Fava Complex located in Via Timparello, 53

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1				
2	2	lim+pc	300+60	360
3	2	lim+pc	300+60	360
4				
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7				
8				
9				
10				
11				
12	2	PC	60	120
13	1	TV	600	600
14				
15				
16				
17				
18				
19	2	lim+pc	300+60	360
20	2	lim+pc	300+60	360
21	2	lim+pc	300+60	360
22	2	lim+pc	300+60	360
23	2	lim+pc	300+60	360
24	2	lim+pc	300+60	360
25	2	lim+pc	300+60	360
26	2	lim+pc	300+60	360
Hall+Corridor				
TOTAL GROUND FLOOR				9704 W

Figure 50_Energy-Consuming Equipment and Power Distribution – Ground Floor of ICS Fava complex located in Via Timparello, 53

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR (OLD ONE)				

1				
2	2	lim+pc	300+60	360
3	2	lim+pc	300+60	360
4	2	lim+pc	300+60	360
5				
6	2	PC	60	120
7				
8	2	lim+pc	300+60	360
9	2	lim+pc	300+60	360
10	2	lim+pc	300+60	360
11	2	lim+pc	300+60	360
12	2	lim+pc	300+60	360
13	33	PC	60	1980
14				
15	2	lim+pc	300+60	360
16	2	lim+pc	300+60	360
17	2	PC	60	120
18	4	PC	60	240
19	2	PC	60	120
Stairwell				
Canteen				
TOTAL FIRST FLOOR				6180 W

Figure 51_Energy-Consuming Equipment and Power Distribution – First Old Floor of ICS Fava complex located in Via Timparello, 53

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR (NEW ONE)				
1				
2				
3				
4	2	lim+pc	300+60	360
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7	2	lim+pc	300+60	360
8	2	lim+pc	300+60	360
9	2	lim+pc	300+60	360
10	2	lim+pc	300+60	360
11				
Stairwell				
Hall+Corridor				
TOTAL FIRST FLOOR				2160 W

Figure 52_Energy-Consuming Equipment and Power Distribution – First New Floor of ICS Fava complex located in Via Timparello, 53

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
SECOND FLOOR				
1				
2				
3				
4	2	lim+pc	300+60	360
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7	2	lim+pc	300+60	360
8				
9	2	lim+pc	300+60	360
10	2	lim+pc	300+60	360
11				
Hall + Entrance				
TOTAL SECOND FLOOR				2160 W

Figure 53_Energy-Consuming Equipment and Power Distribution – Second Floor of ICS Fava complex located in Via Timparello, 53

SPLIT			
Room n°	Quantity of energy-consuming elements	Partial power (W)	Total power (W)
	6	2000	12000 W

Figure 54_Quantity of Split of ICS Fava complex located in Via Timparello, 53

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 55_ Weekly Operating Schedule of ICS Fava Complex located in Via Timparello, 53

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	156	130	37060
February	0	144	120	37060
March	0	162	135	37060
April	0	150	125	37060
May	0	156	135	37060
June	156	156	130	49060
July	156	156	130	49060
August	162	162	130	49060
September	156	156	130	49060
October	0	156	130	37060
November	0	156	130	37060
December	0	162	135	37060
	630	1872	1560	492720 W

Figure 56_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Fava complex located in Via Timparello, 53

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use—in this case, a school complex. Consequently, an estimate of the expected energy consumption has been made, if all these energy-consuming elements operate under steady-state conditions.

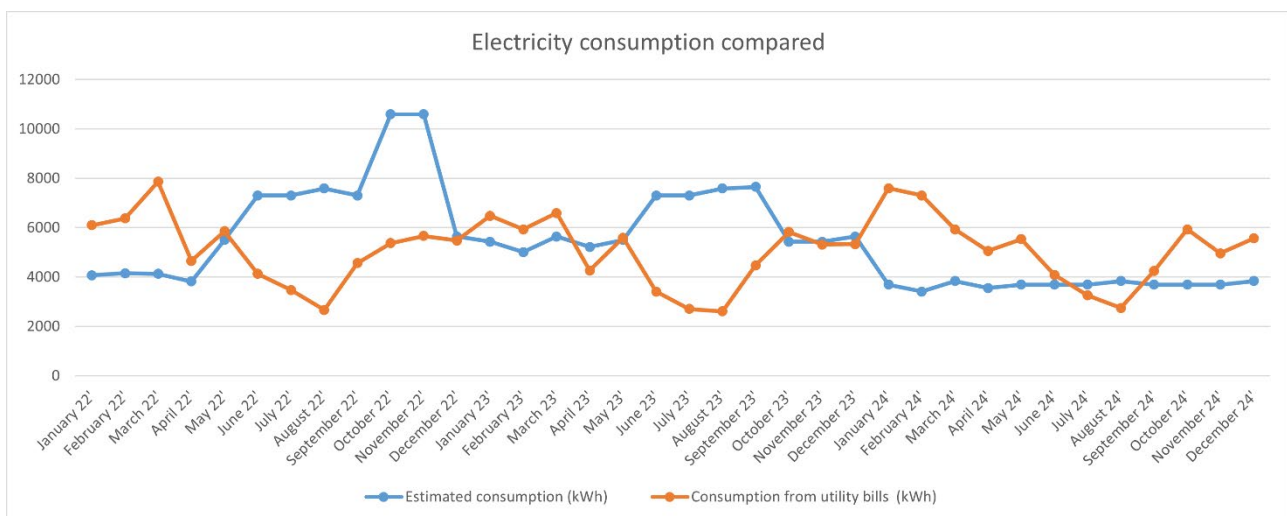


Figure 57_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Fava complex located in Via Timparello, 53

As highlighted in the chart above, a comparison was made between the energy consumption of the ICS Fava school complex, located on Via Timparello, as recorded on utility bills and the estimated consumption following the energy audit. The analysis clearly shows that, on average, the consumption recorded on the bills is significantly higher than the values calculated through the on-site survey at the school.

An exception occurs in the final months of the year, where the values align. In the early months, however, the billed consumption is noticeably higher. Conversely, during the summer period, the opposite trend is observed: the estimated consumption is higher than the recorded values, likely due to the use of air conditioning systems (split units) during the hottest months.

- **ICS Federico II Complex located in Via Massimo D’Azeglio, 14:**



Figure 58_External photo of the building surveyed of ICS Federico II complex located in Via Massimo D’Azeglio, 14

The ICS Federico II Comprehensive Institute, located at Via Massimo D’Azeglio, 14, spans three floors and includes sections for preschool, primary, and lower secondary education. It is situated in the Massannunziata district, a semi-central residential area of Mascalucia. This location is moderately developed and well connected through provincial roads and transport lines, ensuring convenient access for both local families and those from nearby municipalities.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it

possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
Hall	4	2x36	72	288
1	4	2x36	72	288
2	2	2x36	72	144
3	2	2x36	72	144
4	4	2x36	72	288
5	1	1x36	36	36
Wc 1	3	1x36	36	108
Wc 2	3	1x36	36	108
Wc 3	1	1x36	36	36
Storage room 1	1	1x36	36	36
Storage room 2	1	1x36	36	36
Corridor	1	1x36	36	36
TOTAL GROUND FLOOR				1548 W

Figure 59_Lighting Fixtures and Power Distribution – Ground Floor of ICS Federico II complex located in Via Massimo D’Azeglio, 14

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
Corridor	6	2x36	72	432
1	2	2x36	72	144
2	4	2x36	72	288
3	2	2x36	72	144
4	4	2x36	72	288
Wc 4	3	1x36	36	108
Wc 5	3	1x36	36	108
Storage room 3	1	1x18	54	54
TOTAL FIRST FLOOR				1566 W

Figure 60_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Federico II complex located in Via Massimo D’Azeglio, 14

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
SECOND FLOOR				
Corridor	2	2x36	72	144
1	2	2x36	72	144
2	4	2x36	72	288

3	2	2x36	72	144
4	4	2x36	72	288
Wc 4	3	1x36	36	108
Wc 5	3	1x36	36	108
Storage room 3	1	1x36	36	36
Storage room 4	1	1x36	36	36
Corridor 2	2	1x36	36	72
TOTAL SECOND FLOOR				1368 W

Figure 61_Energy-Consuming Equipment and Power Distribution – Second Floor of ICS Federico II complex located in Via Massimo D’Azeglio, 14

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building’s average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 62_Weekly Operating Schedule of ICS Federico II complex located in Via Massimo D’Azeglio, 14

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January		156	130	3114
February		144	120	3114
March		162	135	3114
April		150	125	3114
May		156	135	3114
June		156	130	3114
July		156	130	3114

August	There is no cooling system.	162	130	3114
September		156	130	3114
October		156	130	3114
November		156	130	3114
December		162	135	3114
	//	1872	1560	37368 W

Figure 63_Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Federico II complex located in Via Massimo D'Azeglio, 14

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use—in this case, a school complex. Consequently, an estimate of the expected energy consumption has been made, if all these energy-consuming elements operate under steady-state conditions.

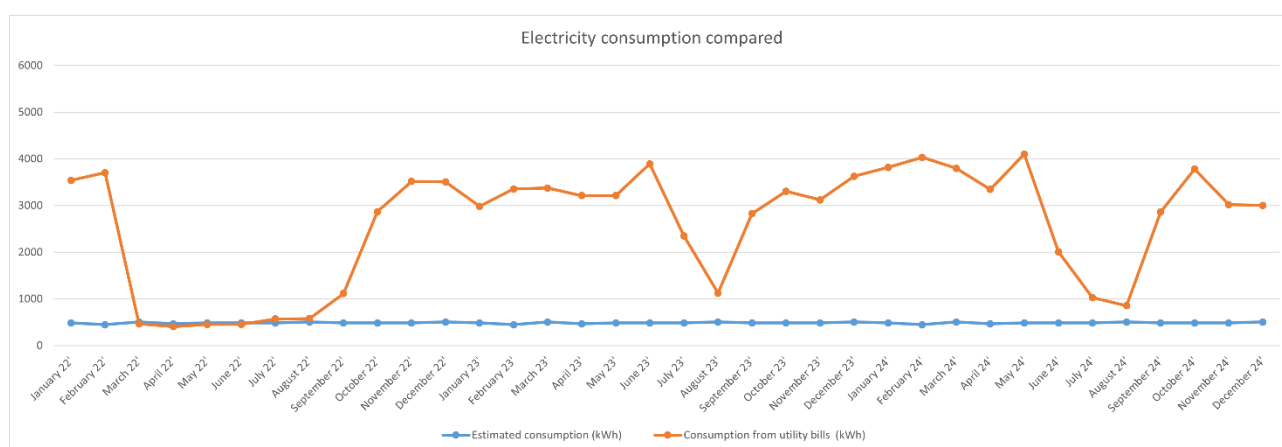


Figure 64_Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Federico II complex located in Via Massimo D'Azeglio, 14

As highlighted in the chart above, there is a sharp increase in energy consumption during the winter period. Given that this is a school complex, it is assumed that events such as performances or ceremonies may have contributed to this rise, although not to a significant extent. However, when comparing these data with the estimated consumption based on the on-site surveys, it becomes evident that even these estimates are considerably lower than the values reported on the utility bills.

- ICS Federico II Complex located in Via del Sole,2:



Figure 65_ External photo of the building surveyed of ICS Federico II complex located Via del Sole,2

The ICS Federico II Comprehensive Institute, located at Via del Sole in the Massannunziata district of Mascalucia, spans three floors and includes preschool, primary, and lower secondary school sections. The school is situated in a semi-central residential area, well-connected by main roads and easily accessible to the local community.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	11	1x36	36	396
2	6	1x36	36	216
3	4	2x36	72	288
4	5	1x36	36	180
5	10	1x18	54	540
6	11	1x36	36	396
7	5	1x36	36	180
8	4	1x36	36	144
9	2	4x18	72	144
10	1	1x18	54	54
11	1	1x18	54	54
12	1	1x36	36	36
13	5	2x36	72	360
14	6	2x36	72	432
15	6	2x36	72	432
16	4	1x18	54	216
17	3	applique	18	54
18	6	2x36	72	432
19	6	2x18	36	216
20	6	2x36	72	432
21	3	1x18	54	162
22	3	neon	18	54
23	6	2x36	72	432
24	4	2x36	72	288
25	8	applique	18	144
26	2	1x36	36	72
27	2	1x18	54	108
28	4	1x36	36	144
29	2	applique	18	36
30	2	2x36	72	144
31	2	2x36	72	144
32	13	1x36	36	468
33	6	1x36	36	216
34	5	1x36	36	180
35	2	2x36	72	144
36	11	1x58	58	638
37	7	2x58	116	812
38	2	applique	18	36
TOTAL GROUND FLOOR				9424 W

Figure 66_Lighting Fixtures and Power Distribution – Ground Floor of ICS Federico II complex located Via del Sole,2

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	14	1x36	36	504
2	6	1x36	36	216
3	14	1x36	36	504
4	4	1x18	54	216
5	4	1x36	36	144
6	5	1x36	36	180
7	6	2x36	72	432
8	5	1x18	54	270
9	3	applique	18	54
10	6	2x36	72	432
11	6	2x36	72	432
12	6	2x36	72	432
13	4	applique	18	72
14	6	2x36	72	432
15	6	2x36	72	432
16	6	2x36	72	432
17	5	1x18	54	270
18	4	applique	18	72
19	7	2x36	72	504
20	1	2x36	72	72
21	2	1x18	54	108
22	2	applique	18	36
23	3	2x36	72	216
24	9	1x36	36	324
25	18	1x36	36	648
26	4	2x36	72	288
27	1	1x36	36	36
28	2	1x18	54	108
29	7	2x58	116	812
30	2	2x58	116	232
TOTAL FIRST FLOOR				8910 W

Figure 67_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Federico II complex located Via del Sole,2

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 68_ Weekly Operating Schedule of ICS Federico II complex located Via del Sole,2

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	There is no cooling system.	156	130	18334
February		144	120	18334
March		162	135	18334
April		150	125	18334
May		156	135	18334
June		156	130	18334
July		156	130	18334
August		162	130	18334
September		156	130	18334
October		156	130	18334
November		156	130	18334
December		162	135	18334
	//	1872	1560	220008 W

Figure 69_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Federico II complex located Via del Sole,2

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use—in this case, a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

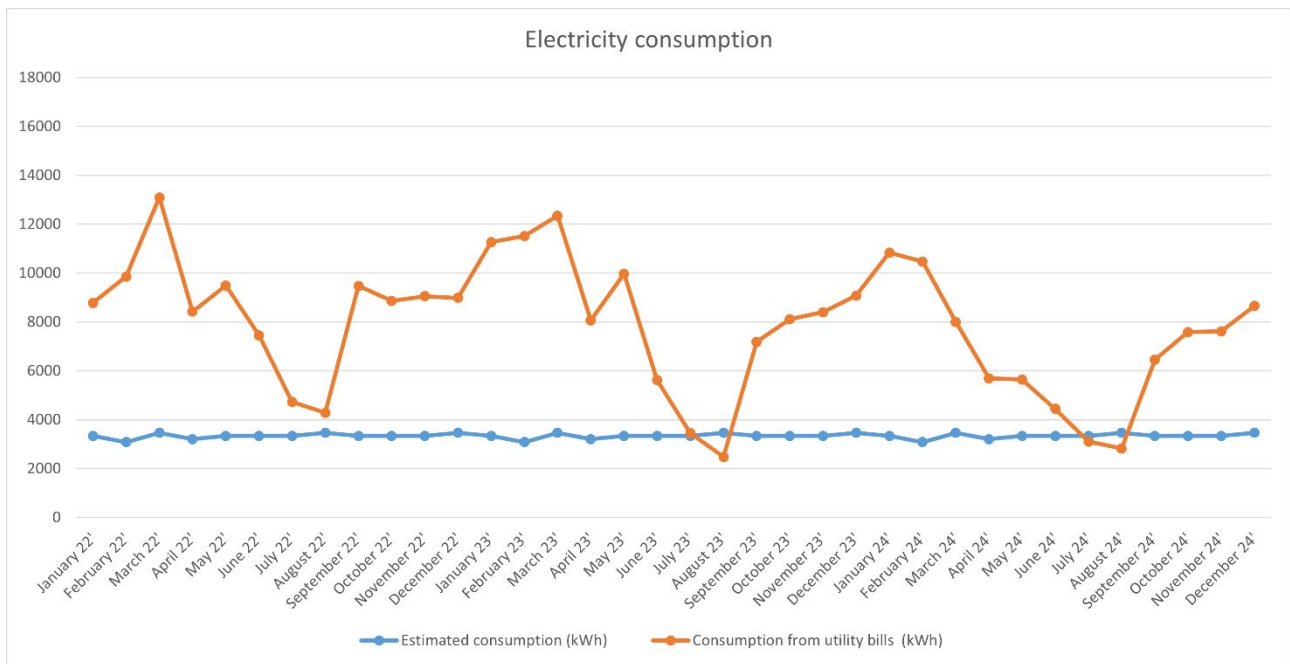


Figure 70_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Federico II complex located Via del Sole,2

As shown in the graph above, a comparison was carried out between the energy consumption data obtained from utility bills and the estimated values derived from the building's usage patterns and the results of the on-site energy audit. The estimation considered the actual operating hours of the building and the specific characteristics observed during the audit.

From the graph, it is evident that during the summer months, the estimated consumption closely aligns with the actual consumption reported in the bills. However, during the winter period, the billed energy consumption is noticeably higher than the simulated values.

This discrepancy suggests the possible presence of additional energy loads or usage patterns during the winter that were not captured or fully accounted for during the audit. Further investigation may be needed to identify these additional sources and better understand the building's energy behaviour in colder months.

- **ICS Leonardo Da Vinci Complex located in Via Roma, 217:**



Figure 71_ External photo of the building surveyed of ICS Leonardo Da Vinci complex located Via Roma, 217

The “ICS Leonardo Da Vinci” kindergarten and primary school, located at Via Roma, 217, spans three floors and houses both preschool and primary sections. The facility is situated in the northern-central residential district of Mascalucia, within a well-established area characterized by villas and the typical urban fabric of the town’s outskirts. Its position is strategically accessible: the surrounding road network is served by bus stops and pedestrian paths, offering easy access for families residing in the neighbourhood as well as those from nearby areas.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it

possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	8	2x36	72	576
2	4	2x36	72	288
3	4	2x36	72	288
4	3	36W LED	36	108
	2	1x18	18	36
5	4	2x36	72	288
6	4	2x36	72	288
7	4	2x36	72	288
8	4	2x36	72	288
9	4	2x36	72	288
10	2	1x36	36	72
	4	1x18	18	72
11	4	2x36	72	288
12	1	2x36	72	72
13	1	70W Halogen	70	70
	1	2x36	72	72
	1	1x36	36	36
TOTAL GROUND FLOOR				3418 W

Figure 72_Lighting Fixtures and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via Roma, 217

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	1	2x36	72	72
	1	70W halogen	70	70
2	7	2x36	72	504
3	4	2x36	72	288
4	4	2x36	72	288
5	4	2x36	72	288
6	4	2x36	72	288
7	4	2x36	72	288
8	2	1x36	36	72
9	4	2x36	72	288
10	2	1x36	36	72
	4	1x18	18	72
11	4	2x36	72	288
TOTAL FIRST FLOOR				2878 W

Figure 73_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via Roma, 217

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1	1	Fridge		
2	2	lim+pc	300+60	360
3				
4	2	lim+pc	300+60	360
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7	2	lim+pc	300+60	360
8	2	lim+pc	300+60	360
9				
10	2	lim+pc	300+60	360
11	2	lim+pc	300+60	360
TOTAL GROUND FLOOR				2160 W

Figure 74_Energy-Consuming Equipment and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via Roma, 217

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR				
1				
2	2	lim+pc	300+60	360
3	2	lim+pc	300+60	360
4	2	lim+pc	300+60	360
5	2	lim+pc	300+60	360
6	2	lim+pc	300+60	360
7	2	lim+pc	300+60	360
8	2	lim+pc	300+60	360
9	2	lim+pc	300+60	360
10				
11				
TOTAL FIRST FLOOR				2520 W

Figure 75_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via Roma, 217

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 76_ Weekly Operating Schedule of ICS Leonardo Da Vinci complex located Via Roma, 217

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	There is no cooling system	156	130	6566
February		144	120	6566
March		162	135	6566
April		150	125	6566
May		156	135	6566
June		156	130	6566
July		156	130	6566
August		162	130	6566
September		156	130	6566
October		156	130	6566
November		156	130	6566
December		162	135	6566
	//	1872	1560	78792 W

Figure 77_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Leonardo Da Vinci complex located Via Roma, 217

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use—in this case, a school complex. Consequently, an estimate of the expected energy consumption has been made, if all these energy-consuming elements operate under steady-state conditions.

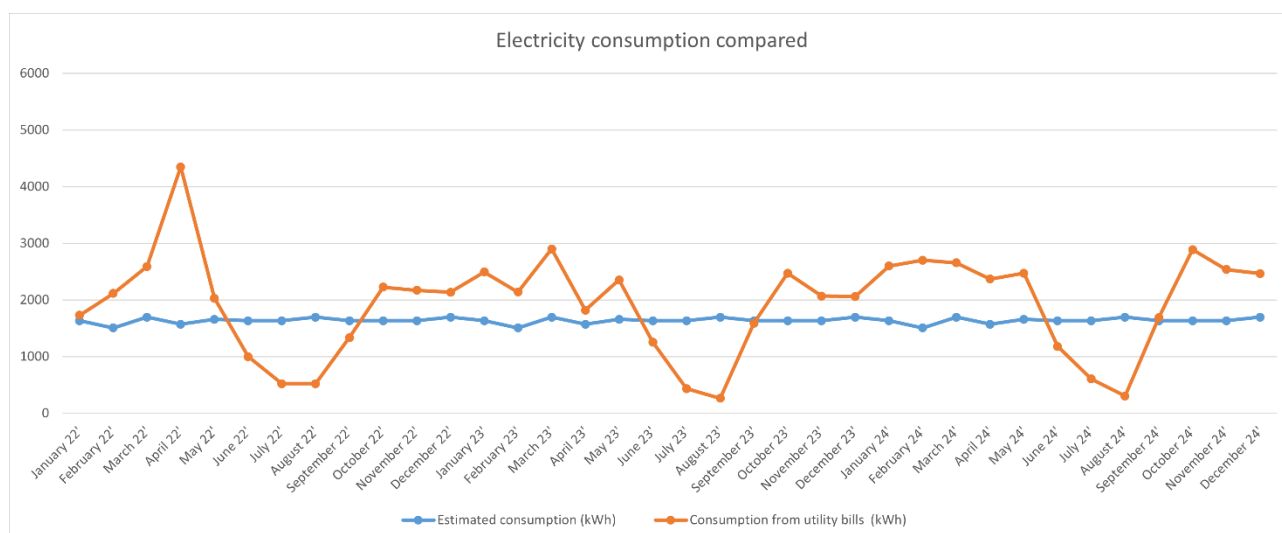


Figure 78_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Leonardo Da Vinci complex located Via Roma, 217

As highlighted in the chart above, related to the school complex located on Via Roma in the Municipality of Mascalucia, it can be observed that, when comparing the consumption recorded on the utility bills with the estimated consumption following the building survey, the former is generally always higher. An exception occurs during the summer period, when the estimated consumption is significantly higher than the values recorded on the bills. In this regard, further discussions will be held with the school staff to better understand the reasons behind this discrepancy in consumption.

- **ICS Leonardo Da Vinci Complex located in Via della Regione Siciliana, 12:**



Figure 79_ External photo of the building surveyed of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

The “ICS Leonardo Da Vinci” complex, located at Via della Regione Siciliana, 12, spans three floors and is the largest building among all those examined in this case study. It houses preschool, primary, and lower secondary school sections within a spatially larger and more complex structure compared to the other school sites. Situated in a well-established residential area of Mascalucia, the school benefits from excellent connections to main roads, making its location strategic for providing educational services across the municipality. It ensures easy access for families, supported by efficient public transportation and pedestrian infrastructure.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	14	2X58	116	1624
2	14	2X58	116	1624
3	3	1X36+1X18(X2)	54	72
4	4	2X58	116	464
5	5	1X36+1X18 (X4)	54	108
6	6	2X58	116	696
7	11	2X58+1X18+1X36(X2)	174	1110
8	4	2X58+1X18+1X36(X2)	112	206
9	4	2X58	116	464
10	4	2X58	116	464
11	4	2X58	116	464
12	5	1X36(X2)+1X18(X3)	54	126
13	6	2X58	116	696
14	4	2X58	116	464
15	4	2X58	116	464
16	4	2X58	116	464
17	6	2X58	116	696
18	8	1X18(X7)+Plaf.(x1)(80W)	98	134
19	6	2X58	116	696
20	3	2X58	116	348
21	4	2X58	116	464
22	19	2x58(x18)+1x36	152	2124
23	4	2X58	116	464
24	4	2X58	116	464
25	6	1x18(x3)+1x36+ Plaf.(x2)(80W)	134	250
26	4	2X58	116	464
27	4	2X58	116	464
28	4	2X58	116	464
29	4	2X58	116	464
30	5	1x36(x2)+1x18(x3)	54	126
31	14	2x58(x6)+1x36(x6)+1x18(x2)	170	948
32	12	12 Bulbs		
33	5	2x58(x2)+1x36(x3)	152	340
34	1	2x36	72	72
35	3	2X58	116	348
36	5	2x36	72	360
37	11	1x36(x7)1x18(x4)	54	324
38	6	2X58	116	696
39	6	2X58	116	696
40	5	2X58	116	580
41	2	2X58	116	232

42	2	2X58	116	232
43	2	2X58	116	232
44	13	2X58	116	1508
TOTAL GROUND FLOOR				23700 W

Figure 80_Lighting Fixtures and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	4	2x58	116	464
2	5	1x18 (x4)+1x36(x1)	54	108
3	4	2x58	116	464
4	4	2x58	116	464
5	6	2x58	116	696
6	4	2x58	116	464
7	3	2x58	116	348
8	12	2x58	116	1392
9	6	2x58	116	696
10	5	2x58 (x4) + 1x36 (x1)	152	500
11	6	1x36 (x2)+1x18 (x4)	54	144
12	4	2x58	116	464
13	4	2x58	116	464
14	7	2x58 (x1)+1x58 (x3)+1x18(x3)	192	344
15	5	2x58	116	580
16	5	2x58	116	580
17	5	2x58	116	580
18	8	1x36 (x2) + 1x18 (x6)	54	180
19	6	2x58	116	696
20	6	2x58	116	696
21	6	2x58	116	696
22	6	2x58	116	696
23	10	2x58 (x2)+1x58 (x2)+1x18(x3)	192	402
24	6	2x58	116	696
25	6	2x58	116	696
26	6	2x58	116	696
27	6	2x58	116	696
28	8	1x58(x2) +1x18(x6)	76	224
29	4	2x58	116	464
30	4	2x58	116	464
31	4	2x58	116	464
32	6	2x58	116	696
33	8	1x18(x6) +1x36(x2)	54	180
34	4	2x58	116	464
35	4	2x58	116	464

36	3	1x58(x1) +1x18(x2)	76	94
TOTAL FIRST FLOOR				18416 W

Figure 81_Lighting Fixtures and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

SPLIT			
Room n°	Quantity of energy-consuming elements	Partial power (W)	Total power (W)
	3	2000	8000 W

Figure 82_Quantity of Split of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1				
2				
3				
4	4	pc	60	240
5				
6	1	pc	60	60
7				
8				
9	2	lim+pc	300+60	360
10	2	lim+pc	300+60	360
11	2	lim+pc	300+60	360
12				
13				
14	2	lim+pc	300+60	360
15	2	lim+pc	300+60	360
16	2	lim+pc	300+60	360
17				
18				
19				
20				
21	2	lim+pc	300+60	360
22				
23	2	lim+pc	300+60	360
24	2	lim+pc	300+60	360
25				
26	2	lim+pc	300+60	360
27	2	lim+pc	300+60	360
28	2	lim+pc	300+60	360
29				
30				
31				
32				

33				
34				
35				
36				
37				
38	2	lim+pc	300+60	360
39	2	lim+pc	300+60	360
40	2	lim+pc	300+60	360
41				
42				
43				
44				
TOTAL GROUND FLOOR				5700 W

Figure 83_Energy-Consuming Equipment and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR				
1	3	pc	60	240
2				
3	3	pc	60	240
4	3	pc	60	240
5	1	pc	60	60
6	2	lim+pc	300+60	360
7	2	lim+pc	300+60	360
8	32	31 pc + 1 lim	300+60	2160
9	2	lim+pc	300+60	360
10	2	lim+pc	300+60	360
11				
12				
13				
14				
15	2	lim+pc	300+60	360
16	2	lim+pc	300+60	360
17	2	lim+pc	300+60	360
18				
19				
20	2	lim+pc	300+60	360
21	2	lim+pc	300+60	360
22	2	lim+pc	300+60	360
23				
24	2	lim+pc	300+60	360
25	2	lim+pc	300+60	360
26	2	lim+pc	300+60	360
27				

28				
29	2	lim+pc	300+60	360
30	2	lim+pc	300+60	360
31	2	lim+pc	300+60	360
32				
33				
34				
35				
36				
TOTAL FIRST FLOOR				8700 W

Figure 84_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 85_Weekly Operating Schedule of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	156	130	64516
February	0	144	120	64516
March	0	162	135	64516

April	0	150	125	64516
May	0	156	135	56516
June	156	156	130	56516
July	156	156	130	56516
August	162	162	130	56516
September	156	156	130	56516
October	0	156	130	56516
November	0	156	130	56516
December	0	162	135	64516
	630	1872	1560	718192 W

Figure 86_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use - in this case, a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

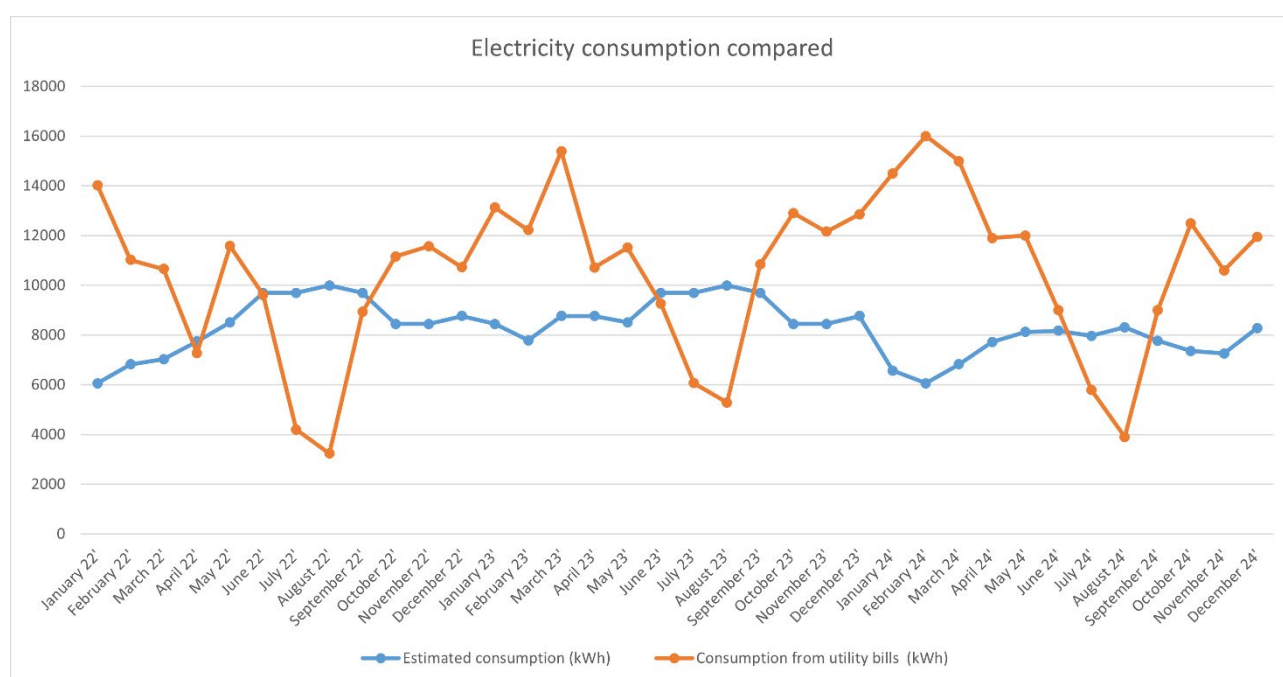


Figure 87_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Leonardo Da Vinci complex located Via della Regione Siciliana, 12

As shown in the chart above, a comparison was made between the energy consumption of the Leonardo Da Vinci school complex on Via della Regione Siciliana: the consumption recorded on the utility bills and the consumption estimated following the energy audit. It is immediately apparent that, on average, the estimated consumption is significantly lower than the values recorded on the utility bills for most of the school year, while during the summer period, the difference reduces significantly. To better understand this discrepancy, it will be necessary to investigate the situation further, including through discussions with the school's staff, to understand what happens at the school during the summer period.

- ICS Leonardo Da Vinci Complex located in Via Santa Spera, 15:



Figure 88_External photo of the building surveyed ICS Leonardo Da Vinci complex located Via Santa Spera, 15

The ICS Leonardo Da Vinci kindergarten, located at Via Santa Spera, 15, spans two floors. It is situated in a quiet residential area of Mascalucia, characterized by low-density housing such as villas and small apartment buildings. The location is easily accessible via a well-connected local road network, facilitating convenient access for families from the neighbourhood and nearby areas.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed school building, broken down by floor. For each room, data collected through on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power.

The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space. The second section refers to other electrical energy-consuming devices typically found in a school environment, such as computers, interactive whiteboards (IWBs), printers, coffee machines, and other appliances. This categorisation makes it possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	2	2x36	72	144
2	2	2x18	36	72
3	2	2x18	36	72
4	1	2x58	116	116
5	2	2x58	116	232
6	2	2x58	116	232
7	2	2x58	116	232
8	3	1x18	18	54
TOTAL GROUND FLOOR				1154 W

Figure 89_Lighting Fixtures and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	2	2x58	116	232
2	5	2x36	72	360
3	5	2x36 (x2)+1x18 (x3)	90	198
4	4	2X36 (x3) +2x58 (x1)	188	332
5	4	2x18	36	144
TOTAL FIRST FLOOR				1266 W

Figure 90_Lighting Fixtures and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1	2	lim+pc	300+60	360
2				
3				
4				
5	2	lim+pc	300+60	360

6				
7	2	lim+pc	300+60	360
8	2	lim+pc	300+60	360
TOTAL GROUND FLOOR				1440 W

Figure 91_Energy-Consuming Equipment and Power Distribution – Ground Floor of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

Room n°	Quantity of energy-consuming elements	Type energising elements	Partial power (W)	Total power (W)
FIRST FLOOR				
1	2	lim+pc	300+60	360
2	2	lim+pc	300+60	360
3				
4				
5				
TOTAL FIRST FLOOR				720 W

Figure 92_Energy-Consuming Equipment and Power Distribution – First Floor of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:00/14:00	6
Tuesday	8:00/14:00	6
Wednesday	8:00/14:00	6
Thursday	8:00/14:00	6
Friday	8:00/14:00	6
Saturday	8:00/14:00	6
Sunday	Close	0

Figure 93_Weekly Operating Schedule of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case a school complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical

Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	There is no cooling system.	156	130	4580
February		144	120	4580
March		162	135	4580
April		150	125	4580
May		156	135	4580
June		156	130	4580
July		156	130	4580
August		162	130	4580
September		156	130	4580
October		156	130	4580
November		156	130	4580
December		162	135	4580
	//	1872	1560	54960 W

Figure 94_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use -in this case, a school complex. Consequently, an estimate of the expected energy consumption was made, assuming that all these energy-consuming elements operate under steady-state conditions.

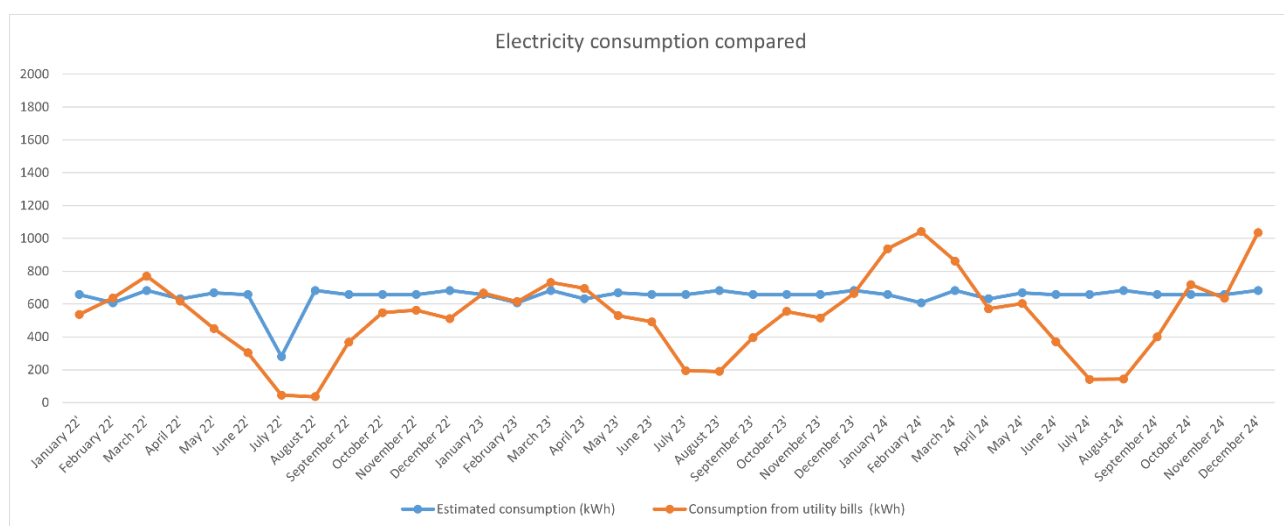


Figure 95_ Comparison between Estimated Electricity Consumption and Utility Bill Data of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

From the chart provided, related to the school complex located on Via Santa Spera in Mascalucia, it can be observed that, on average, there are no significant differences between the estimated consumption following the survey and the consumption recorded on the utility bills. The only notable discrepancy occurs during the summer period, when the school complex is evidently closed, which explains the sharp decrease in consumption.

- **Municipio located Corso San Vito,2:**



Figure 96_External photo of the building surveyed of Municipio located in Corso San Vito, 2

The Town Hall of Mascalucia, located at Corso San Vito, 2, serves as the seat of the municipal administration. The building has recently undergone renovation and, as visible in photographs, remains partly under restoration. Located at the town's core, adjacent to Piazza Leonardo da Vinci, it plays a pivotal role in both administrative operations and civic representation. Its central placement ensures excellent accessibility and strong integration into the urban fabric of Mascalucia's historic center .

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Town Hall building, broken down by floor. For each room, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the

unit power, and the calculated total power for that space. The second section refers to other electrical devices typically found in an office environment, such as computers, printers, photocopiers, telephones, coffee machines, and other small appliances. This categorisation makes it possible to separate the energy consumption contribution from lighting from that of other electrical equipment, supporting load analysis and the identification of potential energy efficiency measures.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	5	2x36	72	360
2	1	2x36	72	72
3	2	4x18	72	144
4	1	2x36	72	72
5	1	1x36	36	36
6	2	2x36	72	144
7	3	2x36	72	216
8	2	2x36	72	144
9	2	2x36	72	144
10	2	2x36	72	144
11	1	1x36	36	36
12	2	2x36	72	144
13	3	1x18	54	162
14	4	4x18	72	288
15	2	2x36	72	144
16	8	2x36	72	576
17	3	2x36	72	216
18	2	1x18	18	36
TOTAL GROUND FLOOR				3078 W

Figure 97_Lighting Fixtures and Power Distribution – Ground Floor of Municipio located in Corso San Vito, 2

Room n°	Quantity of energy-consuming elements	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
19	4	2x36	72	288
20	2	18X15W	270	540
	2	30W applique	30	60
21	1	2x36	72	72
22	2	2x36	72	144
23	2	2x36	72	144
24	2	2x36	72	144
25	2	2x36	72	144
26	1	8x40	320	320
27	1	2x36	72	72
28	2	2x36	72	144
29	1	2x36	72	72
30	1	1x36	36	36

31	2	2x36	72	144
32	3	1x18	54	162
33	2	2x18	36	72
34	2	2x36	72	144
35	2	2x36	72	144
	1	6x36	216	216
36	1	4x36	144	144
37	2	2x36	72	144
38	2	2x36	72	144
	8	1x58	58	464
19	4	2x36	72	288
20	2	18X15W	270	540
TOTAL FIRST FLOOR				3958 W

Figure 98_Lighting Fixtures and Power Distribution – First Floor of Municipio located in Corso San Vito, 2

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	9:30/12	3,5
Tuesday	9:30/12	3,5
Wednesday	9:30/12	3,5
Thursday	9:30/12 + 15:30/17	5
Friday	9:30/12	3,5
Saturday	Close	0
Sunday	Close	0

Figure 99_Weekly Operating Schedule of Municipio located in Corso San Vito, 2

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case the Municipality of Mascalucia. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it is the first year for which complete electricity consumption data were available for the municipal building.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	102	102	7036
February	0	120	120	7036

March	0	138	138	7127,155
April	0	114	114	7036
May	0	132	132	7036
June	156	126	126	7127,155
July	156	126	126	7127,155
August	162	67,5	67,5	7127,155
September	156	132	132	7127,155
October	0	126	126	7036
November	0	126	126	7036
December	0	120	120	7036
	630	1429,5	1429.5	84887,7W

Figure 100_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of ICS Leonardo Da Vinci complex located Via Santa Spera, 15

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use -in this case, a Municipal complex. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

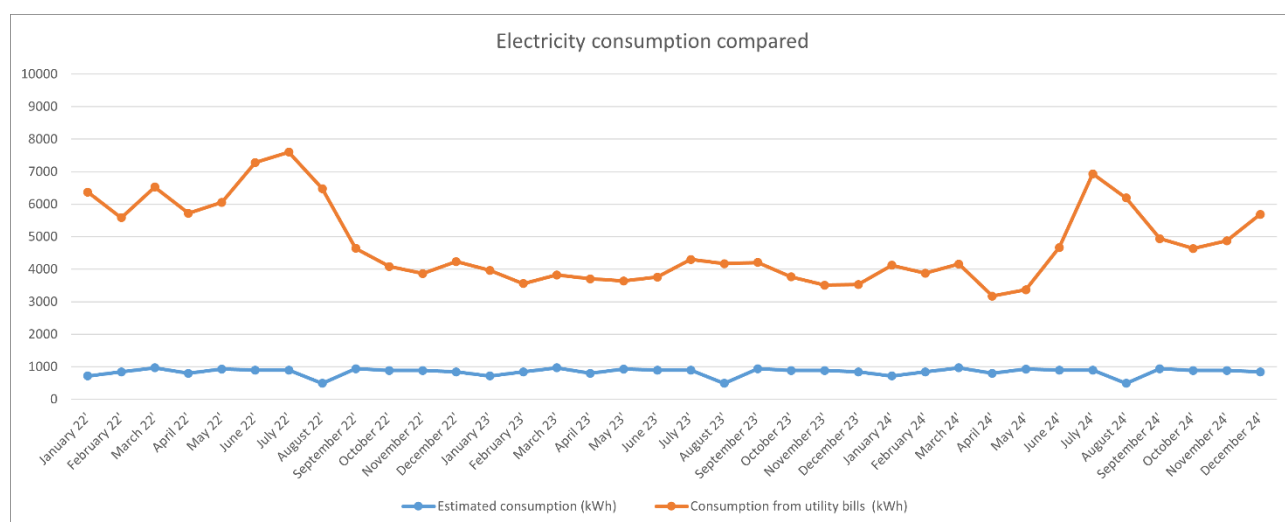


Figure 101_ Comparison between Estimated Electricity Consumption and Utility Bill Data of Municipio located in Corso San Vito, 2

The chart shows a comparison between estimated electricity consumption and actual consumption, based on utility bills, for the Mascalucia Town Hall located at Corso San Vito, 2, covering the period from January 2022 to December 2024.

- The orange line, which is higher and more irregular, represents the actual consumption from utility bills (in kWh). Significant peaks are observed in July 2022 and July 2024, followed by a general decrease starting in September 2022 and continuing into mid-2023, after which the trend stabilizes with some fluctuations.
- The blue line, lower and more stable, represents the estimated consumption based on the applied model. These values remain considerably lower than the actual recorded consumption, suggesting either an overestimation in real usage or a possible underestimation by the simulation model.

The evident gap between the two curves highlights a potential area for energy efficiency improvements in the building, as well as the need to calibrate the estimation model more accurately using parameters that better reflect the building's actual energy use.

- **Ufficio Protezione Civile located in Via Manzoni, 8:**



Figure 102_External photo of the building surveyed of Ufficio Protezione civile located in Via Manzoni, 8

The Civil Protection Office of Mascalucia, located at Via Manzoni, 8, serves as the operational hub for managing emergencies, coordinating safety measures, and supporting disaster response activities within the municipality. The building is situated in a well-connected area, allowing for rapid deployment of resources when needed. Its strategic position within the urban context ensures efficient coordination with other municipal facilities, enhancing the town's resilience and preparedness.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Civil Protection Office building, broken down by floor. For each room, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total

power. The section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	2	2x58	116	232
2	6	2x58	116	696
3	3	1x58+2x58+1x36	210	210
4	2	2x58 + Spotlight	236	236
TOTAL GROUND FLOOR				1374 W

Figure 103_Lighting Fixtures and Power Distribution – Ground Floor of Ufficio Protezione civile located in Via Manzoni, 8

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	2	2x58	116	232
2	2	2x58	116	232
3	1	Spotlight	120	120
4	1	Spotlight	120	120
5	1	2x58	116	116
6	1	2x58	116	116
Stairs	1	Spotlight	120	120
TOTAL FIRST FLOOR				1056 W

Figure 104_Lighting Fixtures and Power Distribution – First Floor of Ufficio Protezione civile located in Via Manzoni, 8

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	Variable	2
Tuesday	Variable	2
Wednesday	Variable	2
Thursday	Variable	2
Friday	Variable	2

Saturday	Variable	2
Sunday	Variable	2

Figure 105_Weekly Operating Schedule of Ufficio Protezione civile located in Via Manzoni, 8

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building, in this case the Civil Protection Office of Mascalucia. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it represents the first year for which complete electricity consumption data were available for this facility.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	62	32	285,212
February	0	56	28	254,856
March	0	62	32	285,212
April	0	60	30	273,06
May	34	62	32	557,212
June	60	60	30	753,06
July	62	62	32	781,212
August	62	62	32	781,212
September	60	60	30	753,06
October	0	62	32	285,212
November	0	60	30	273,06
December	0	62	32	285,212
	730	372	278	5567,58 W

Figure 106_Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of Ufficio Protezione civile located in Via Manzoni, 8

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use -in this case, the civil protection facility. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

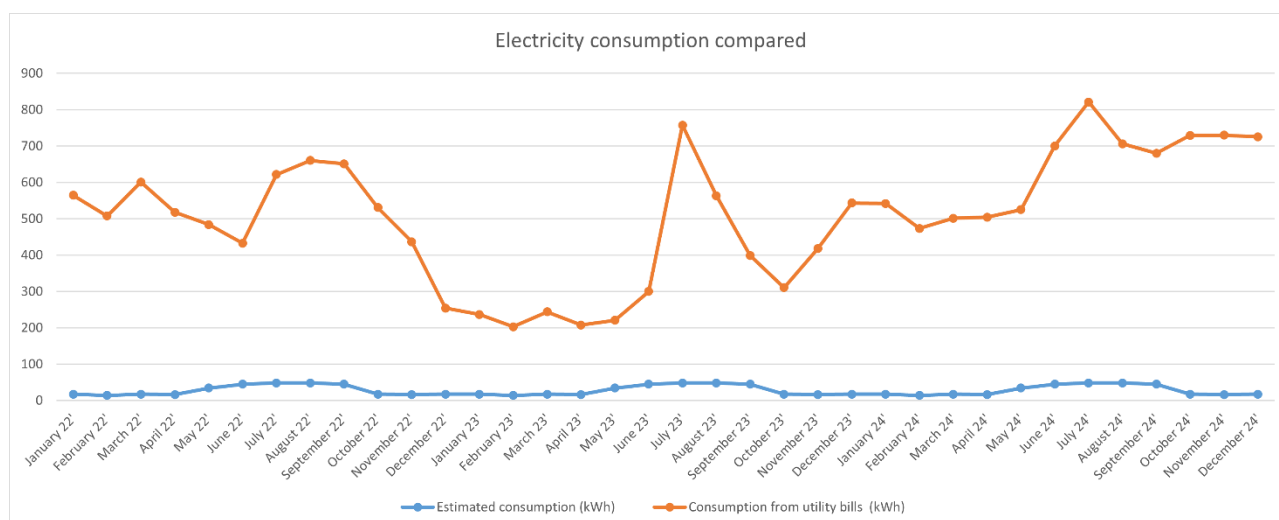


Figure 107_ Comparison between Estimated Electricity Consumption and Utility Bill Data of Ufficio Protezione civile located in Via Manzoni, 8

The chart shows a comparison between estimated electricity consumption and actual consumption from utility bills (both in kWh) for the Civil Protection Office of Mascalucia, covering the period from January 2022 to December 2024.

- The blue line represents the *estimated electricity consumption*, calculated based on an average daily usage of approximately two hours per day, as reported during an interview with office personnel. This estimated usage remains constant, with small increases during the summer months (June to August), likely due to seasonal factors such as cooling systems.
- The orange line shows the *actual electricity consumption recorded in the utility bills*, which displays significant variability. There are noticeable peaks in July 2023 and July 2024, indicating periods of particularly high energy demand. Conversely, the lowest levels of consumption are observed between December 2022 and April 2023.

Overall, the actual consumption is consistently higher than the estimated values, suggesting that real usage patterns are more intensive or irregular than the assumptions used for estimation. This discrepancy highlights the importance of continuous monitoring and possible reassessment of operating hours or energy efficiency strategies.

- **Delegazione Comunale locate del Via del Bosco, 19:**



Figure 108_External photo of the building surveyed of Delegazione Comunale located in Via del Bosco, 19

The Delegazione Comunale, located at Via del Bosco 19, is a single-storey public building situated outside the historic center of Mascalucia and surrounded by a large green area. It partially serves as a public library and partially as a large hall that, on certain occasions, is used for congresses or similar events. For this reason, based on interviews with the staff, it was found that the opening hours of part of the facility can vary significantly.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Delegazione Comunale building, broken down by floor. For each room, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total

power. The section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	4	Led	10	40
2	4	Led	10	40
3	4	Led	10	40
4	4	Led	10	40
5	6	1x36	36	216
6	2 bulbs	Bulb	80	160
TOTAL GROUND FLOOR				536 W

Figure 109_Lighting Fixtures and Power Distribution – Ground Floor of Delegazione Comunale located in Via del Bosco, 19

Room n°	Quantity of split	Type energising elements	Partial power (W)	Total power (W)
GROUND FLOOR				
1	1	Not working		0
2	1	SPLIT	2000	2000
3	1	SPLIT	2000	2000
4				0
5	1	SPLIT	2000	2000
TOTAL FIRST FLOOR				6000 W

Figure 110_Energy-Consuming Equipment and Power Distribution – Ground Floor of Delegazione Comunale located in Via del Bosco, 19

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	8:30/13:00	4,5
Tuesday	8:30/13:00	4,5
Wednesday	8:30/13:00	4,5
Thursday	8:30/13:00 - 15:30/17:30	6,5
Friday	8:30/13:00	4,5

Saturday	Close	0
Sunday	Close	0

Figure 111_Weekly Operating Schedule of Delegazione Comunale located in Via del Bosco, 19

The data entered refers to a typical year and takes into account the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building — in this case, the Delegazione Comunale of Mascalucia, which partially functions as a public library and occasionally hosts congresses or similar events. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions. The reference Typical Meteorological Year (TMY) was set to 2022, as it represents the first year for which complete electricity consumption data were available for this facility.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	0	107	There are no other appliances.	536
February	0	113,5		536
March	0	113,5		536
April	0	98		536
May	156	107		536
June	156	109		6536
July	156	102,5		6536
August	162	111,5		6536
September	156	109		6536
October	0	102,5		536
November	0	107		536
December	0	102,5		536
	786	1283	//	30432 W

Figure 112_ Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of Delegazione Comunale located in Via del Bosco, 19

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use -in this case, the Municipal delegation office. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

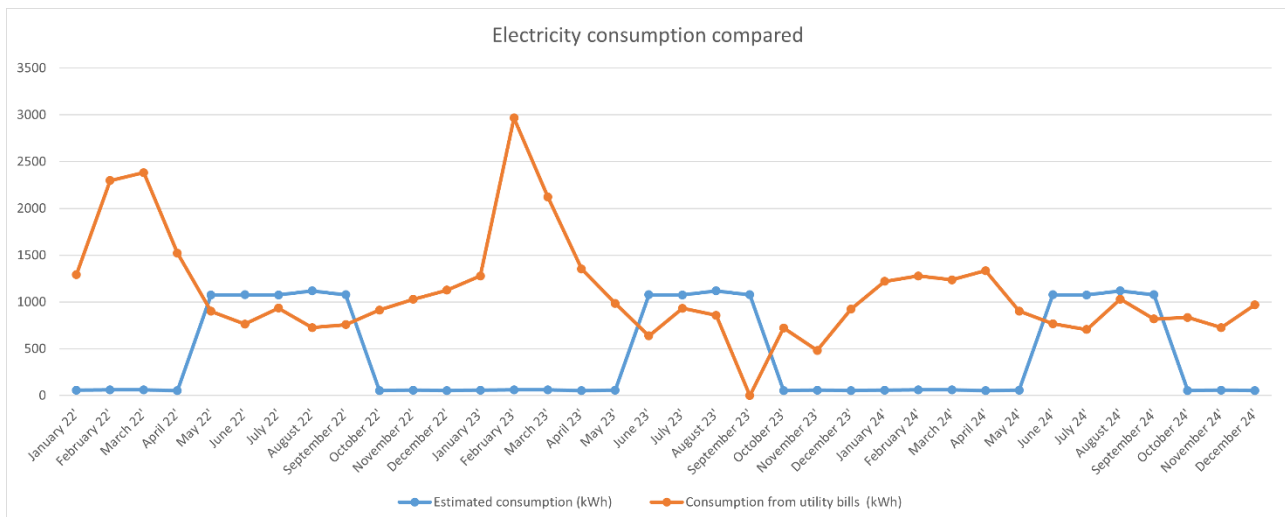


Figure 113_ Comparison between Estimated Electricity Consumption and Utility Bill Data of Delegazione Comunale located in Via del Bosco, 19

The chart shows a comparison between estimated electricity consumption and actual consumption based on utility bills (in kWh) for the Delegazione Comunale of Mascalucia, covering the period from January 2022 to December 2024.

- The blue line represents the *estimated electricity consumption*, derived from internal assessments based on the building's usage patterns. The estimates exhibit a regular, recurring trend, with distinct periods of higher consumption alternating with months showing minimal or no usage—likely corresponding to times of inactivity or closure of the facility.
- The orange line shows the *actual consumption reported in utility bills*, which fluctuates more irregularly. Notable peaks occur in March 2022 and March 2023, indicating possible intensive usage or anomalies. There is also a significant drop in October 2023, where consumption appears to be zero, suggesting either a period of non-use, meter reading issues, or billing delays.

The comparison highlights some alignment during certain months, while in others, discrepancies suggest either operational variations, measurement inconsistencies, or underestimated/overestimated usage. This analysis underscores the importance of cross-verifying estimations with real data to improve energy management accuracy and planning.

- **Croce Rossa Italiana located in Via Petrarca, 24:**



Figure 114_External photo of the building surveyed of Croce Rossa Italiana located in Via Petrarca, 24

The Croce Rossa Italiana facility, located at Via Petrarca 24, is situated slightly outside the historic center of Mascalucia and is operated by volunteers. The building is spread over three levels, one of which is below street level, and serves as a local base for various humanitarian and emergency activities. Based on interviews with the staff, it was found that the opening hours are variable. During the site survey, it was observed that most of the split air conditioning units inside the building are operational; therefore, in this study, only the number of units in working condition was reported.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Croce Rossa Italiana facility, broken down by floor. For each room, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	5	1x58	58	290
2	2	Bulbs	8	16
Stairs	3	Bulbs	8	24

4	2	1x58	58	116
TOTAL GROUND FLOOR				446 W

Figure 115_Lighting Fixtures and Power Distribution – Ground Floor of Croce Rossa Italiana located in Via Petrarca, 24

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
FIRST FLOOR				
1	1	1x58	58	58
2	4	1x58	58	232
3	1	1x58	58	58
4	2	1x58	58	116
TOTAL FIRST FLOOR				464 W

Figure 116_Lighting Fixtures and Power Distribution – First Floor of Croce Rossa Italiana located in Via Petrarca, 24

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
-1 FLOOR				
1	6	1x58	58	348
2	2	1x58	58	116
3	1	1x58	58	58
Ext.	16	Bulbs	8	128
TOTAL -1 FLOOR				650 W

Figure 117_Lighting Fixtures and Power Distribution – Underground Floor of Croce Rossa Italiana located in Via Petrarca, 24

Room n°	Quantity of luminaires	Type of energising elements	Partial power (W)	Total power (W)
TOTAL BUILDING				
1	2	Split	2000	4000
TOTAL BUILDING				4000 W

Figure 118_Energy-Consuming Equipment and Power Distribution – Ground Floor of Croce Rossa Italiana located in Via Petrarca, 24

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	09:00/14:00	5
Tuesday	09:00/14:00	5
Wednesday	09:00/14:00	5
Thursday	09:00/14:00	5
Friday	09:00/14:00	5
Saturday	Close	0
Sunday	Close	0

Figure 119_Weekly Operating Schedule of Croce Rossa Italiana located in Via Petrarca, 24

The data entered refers to a typical year and considers the operating hours of the cooling systems, lighting, and other appliances, considering the climate zone and the intended use of the building — in this case, the Croce Rossa Italiana facility of Mascalucia. Based on interviews with the staff, it was estimated that the building is open for approximately five hours per day on weekdays, with closures during weekends except in cases of emergency. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions during the identified opening hours. The reference Typical Meteorological Year (TMY) was set to 2022, as it represents the first year for which complete electricity consumption data were available for this facility.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	110	283,5	There are no other appliances.	1088
February	115	364,5		1088
March	105	364,5		1088
April	110	337,5		1088
May	110	110		1088
June	110	110		1088
July	105	105		1088
August	115	115		1088
September	110	110		1088
October	105	105		1088
November	110	110		1088
December	110	110		1088
	2225	1315	//	50720 W

Figure 120_Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of Croce Rossa Italiana located in Via Petrarca, 24

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use in this case, the Croce Rossa Italiana. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

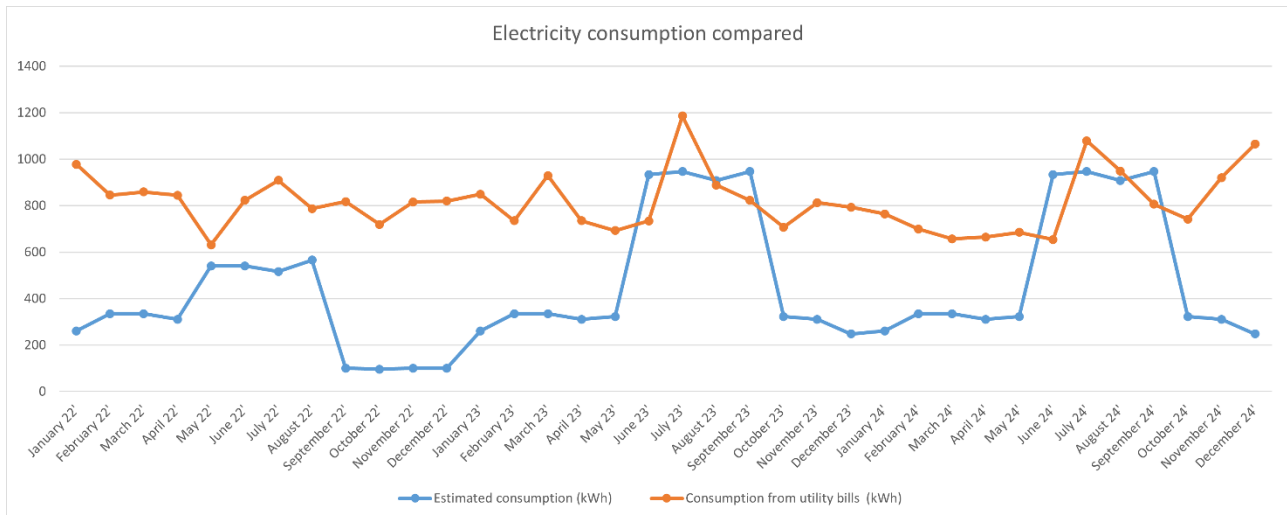


Figure 121_ Comparison between Estimated Electricity Consumption and Utility Bill Data of Croce Rossa Italiana located in Via Petrarca, 24

The graph compares estimated electricity consumption, derived from an on-site energy audit, with actual consumption based on utility bills from January 2022 to December 2024. The estimates were calculated assuming an average building occupancy of approximately 25 hours per week. The heating system consists of gas radiators, which do not contribute to the electricity consumption shown in the bills. Discrepancies between the two datasets are evident. During winter months, actual consumption exceeds estimates, despite the absence of electric heating, likely due to underestimation of lighting and plug loads. Conversely, in summer, estimated values are often higher, possibly due to overestimation of cooling use or reduced building occupancy. These findings highlight the importance of calibrating estimation models using real consumption data, especially when implementing EMs in line with ISO 50001.

- **Auditorium located in Via San Nicolò:**



Figure 122_External photo of the building surveyed of Auditorium located in Via San Nicolò

The Auditorium, located in Via San Nicolò, is housed in a former church that has been repurposed to serve as a public auditorium. Based on interviews with municipal staff, it was found that the building's opening hours are highly variable, depending on when it is requested for use, which may also vary throughout the year, with a tendency for higher occupancy during the winter months. For the purposes of this study, the opening hours published online were considered as reference. The facility is not equipped with an air conditioning system.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Auditorium building, broken down by floor. For each room, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The first section focuses on lighting fixtures, specifying the type of luminaire installed in each room, the unit power, and the calculated total power for that space.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
Hall	2	1x58	58	116
1	1	Halogen	8	8
Main Hall	14x2	Bulbs	8	224
Main Hall	4	Led	50	200
Main Hall	5	Led	50	250
2	5	1x58	58	290
TOTAL GROUND FLOOR				1088 W

Figure 123_Lighting Fixtures and Power Distribution – Ground Floor of Auditorium located in Via San Nicolò

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	7:30/21	13,5
Tuesday	7:30/21	13,5
Wednesday	7:30/21	13,5
Thursday	7:30/21	13,5
Friday	7:30/21	13,5
Saturday	7:30/21	13,5
Sunday	Close	0

Figure 124_Weekly Operating Schedule of Auditorium located in Via San Nicolò

The data entered refers to a typical year and considers the operating hours of the lighting and other appliances, considering the climate zone and the intended use of the building — in this case, the Auditorium of Mascalucia. Based on interviews with municipal staff, it was found that the opening hours vary depending on the time of year, with higher usage during certain periods, particularly in winter. For the purposes of this study, the opening hours published online were taken as reference. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions during the identified opening hours. The reference Typical Meteorological Year (TMY) was set to 2022, as it represents the first year for which complete electricity consumption data were available for this facility.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January		283,5	There are no other appliances.	1088
February		324		1088

March	There is no cooling system.	364,5		1088
April		337,5		1088
May		351		1088
June		351		1088
July		351		1088
August		283,5		1088
September		364,5		1088
October		351		1088
November		351		1088
December		270		1088
	//	1283	//	13056 W

Figure 125_Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of Auditorium located in Via San Nicolò

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use in this case, the Municipal Auditorium. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

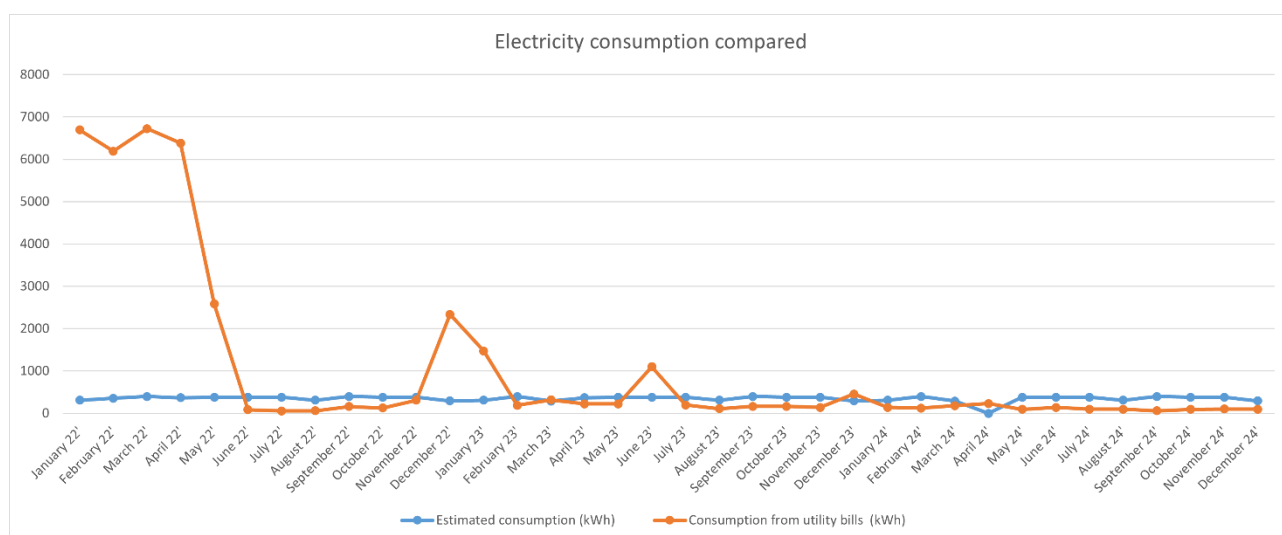


Figure 126_Comparison between Estimated Electricity Consumption and Utility Bill Data of Auditorium located in Via San Nicolò

The graph illustrates the monthly electricity consumption of the municipal Auditorium, comparing the estimated values with actual data from utility bills. In the initial part of the period under analysis (until May 2022), actual consumption was significantly higher than estimated values, suggesting either an intensive use of the facility or the presence of additional connected loads. Starting from June 2022, a sharp reduction in consumption can be observed, with values gradually aligning with the estimated trend. Occasional peaks are visible, likely corresponding to specific events or exceptional activities. From 2023 onwards, the trend becomes more stable and consistent with the estimates, indicating both regular building use and a reliable performance of the adopted estimation model.

- **Monte Ceraulo park located in Via Pulei, 51:**



Figure 127_External photo of the building surveyed of Monte Ceraulo Park located in Via Pulei, 51

The Monte Ceraulo Park, located in Via Pulei 51, is a very large natural area covering approximately 17 hectares. It features rich biodiversity, with Mediterranean scrub vegetation such as holm oaks, wild olive trees, cyclamens, and orchids, and serves as a habitat for various animal species including wild rabbits, hoopoes, goldfinches, small birds of prey, and a variety of butterflies. Within the park, there are only two small buildings for park use, one of which has been recently renovated, although both are seldom used. The area also includes some nature trails, picnic tables and benches, and a small playground for children, albeit with very simple facilities.

The following tables provide a detailed inventory of energy-consuming elements present in the analysed Monte Ceraulo Park facility, broken down by floor where applicable. For each room or building within the park, data collected during on-site surveys include the type and number of devices, their nominal power rating, and the corresponding total power. The section focuses on lighting fixtures, specifying the type of luminaire installed in each space, the unit power, and the calculated total power for that area. No other electrical energy-consuming devices were detected in this facility.

Room n°	Quantity of luminaires	Type of luminaires	Partial power (W)	Total power (W)
GROUND FLOOR				
1	4	Halogen	6	24
2	1	Halogen	6	6
3	4	Halogen	6	24
TOTAL GROUND FLOOR				54 W

Figure 128_Lighting Fixtures and Power Distribution – Ground Floor of Monte Ceraulo Park located in Via Pulei, 51

By knowing the number of electrical devices, the average power consumption, and the operating hours, an estimate of the kWh consumed per month was calculated. This estimation was obtained using the formula:

$$\text{Estimated Consumption (kWh)} = \frac{\text{Nominal Power (W)} \times \text{Operating hours}}{1000} \quad (5)$$

Through this formula, the estimated consumption of all the energy-consuming elements identified during the on-site survey was calculated.

The following table shows the building's average weekly operating hours, broken down by day, based on its opening schedule. This information was used as a reference parameter to estimate the energy consumption associated with the installed systems and equipment.

Day	Opening hours:	Tot. Hours (h.)
Monday	Close	0
Tuesday	Close	0
Wednesday	Close	0
Thursday	Close	0
Friday	Close	0
Saturday	8:00/20:00	12
Sunday	8:00/20:00	12

Figure 129_Weekly Operating Schedule of Monte Ceraulo Park located in Via Pulei, 51

The data entered refers to a typical year and considers the operating hours of the lighting and other appliances, considering the climate zone and the intended use of the facility — in this case, the Monte Ceraulo Park of Mascalucia. The park covers a large natural area and includes only two small buildings for park use, one of which has been recently renovated, although both are seldom used. Based on this limited utilization, the estimated opening hours reflect the actual operating patterns observed. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under regular conditions during the identified opening hours. The reference Typical Meteorological Year (TMY) was set to 2022, as it represents the first year for which complete electricity consumption data were available for this facility.

Month	Cooling hours (h.)	Hours lighting(h.)	Hours other appliances(h.)	Power (W)
January	There is no cooling system.	54	There are no other appliances.	130
February		48		130
March		48		130
April		72		130
May		108		130
June		86		130
July		110		130
August		96		130
September		96		130
October		120		130
November		96		130
December		102		130
	//	1036	//	1560 W

Figure 130_Monthly Operating Hours and Total Power Demand of Energy-Consuming Elements of Monte Ceraulo Park located in Via Pulei, 51

The data entered refers to a typical year and considers the operating hours of cooling systems, lighting, and other electrical appliances, considering the climate zone and the building's intended use -in this

case, the Monte Ceraulo Park. Consequently, an estimate of the expected energy consumption was made, if all these energy-consuming elements operate under steady-state conditions.

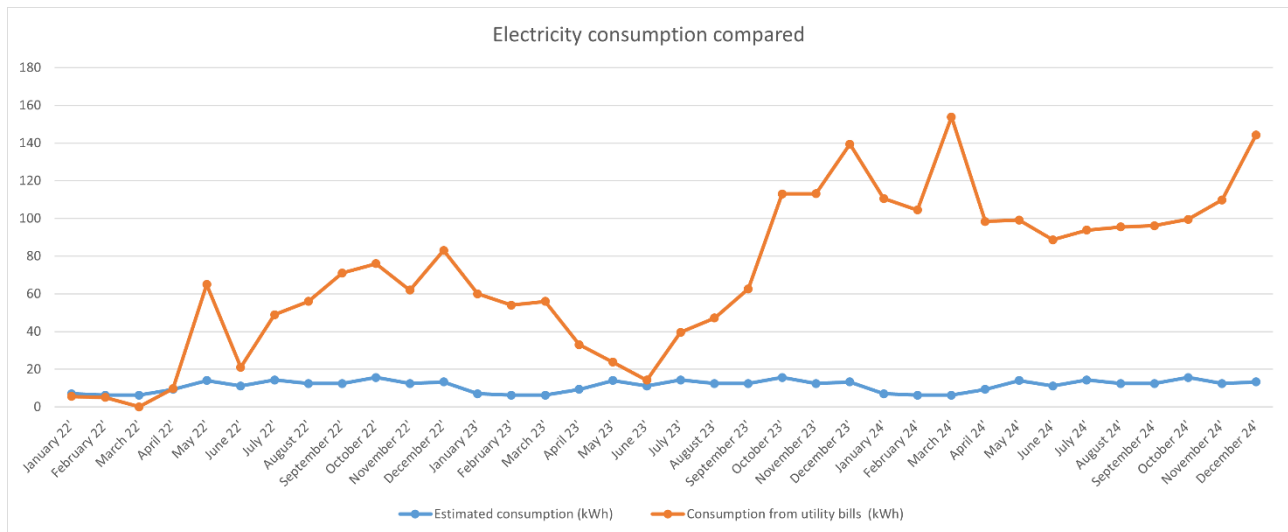


Figure 131_ Comparison between Estimated Electricity Consumption and Utility Bill Data of Monte Ceraulo Park located in Via Pulei, 51.

According to the information provided by the managers of Parco Monte Ceraulo, the facility is used exclusively on weekends and is equipped with a very limited number of lighting fixtures (nine 6 W halogen lamps, for a total installed power of just 54 W). However, the comparison between the estimated consumption and the actual monthly utility bills reveals a significant discrepancy: the recorded values consistently exceed theoretical estimates, reaching over 100 kWh in some months.

This gap suggests the presence of undeclared electrical loads, more frequent use of the facility than reported, or possible anomalies in electricity metering and billing. These findings highlight the need for further investigation to accurately identify the causes of the discrepancy and to enhance the transparency and efficiency of the facility's energy management.

5.6 Identification of improvement opportunities

The analysis of current electricity consumption, compared with the estimated theoretical values, has highlighted inefficiencies and anomalies that suggest the potential for significant improvement measures. This section proposes a set of strategies aimed at reducing energy consumption, optimizing self-production, and improving the building's energy autonomy.

Specifically, the following subsections will address:

- the estimation of photovoltaic production based on available surfaces and solar irradiance data.
- the evaluation of the building's self-consumption in relation to the expected production.
- the implementation of a relamping intervention, aimed at replacing the current lighting fixtures with more efficient technologies.

6. ANALYSIS OF DATA

6.1 Presentation of Data collected

Although all municipal buildings were analyzed, not all of them showed a significant correlation between electricity consumption and Cooling Degree Days (CDD). In most cases the regression analysis resulted in a slope $m \leq 0$, which indicates the absence of a clear relationship between cooling needs and energy use.

This outcome may be explained by several factors:

- electricity demand in some buildings is dominated by lighting rather than air conditioning;
- the influence of non-modelled variables such as occupancy patterns, operating hours, or other electrical loads;
- the impact of past energy efficiency interventions, which may have reduced the sensitivity of energy consumption to outdoor climatic conditions.

For this reason, only buildings with a positive regression slope ($m > 0$) are presented in detail, as they effectively highlight the correlation between cooling needs and electricity consumption. Among the examined buildings, this condition was met only by three cases: **Croce Rossa Italiana and the Municipal Building**. For each of these buildings, the following graphs illustrate the regression analysis results. Each figure is accompanied by a short discussion of the slope (m), the coefficient of determination (R^2), and the main deviations observed across the three years considered. These elements provide a clearer understanding of how climatic conditions influence energy use and allow to identify where cooling-related consumption plays a more relevant role.

In conclusion, although only three municipal buildings exhibited a direct correlation with CDD, these cases are particularly relevant as they reveal where cooling loads significantly affect electricity consumption. This insight supports the identification of priority areas for future efficiency measures and better energy management strategies.

- **Municipio – Corso San Vito, 2**

For the *Town Hall* building, located in Corso San Vito, 2 the CUSUM analysis is supported by tables structured according to the methodology of Fichera et al. (2020). These tables report the reference period, the relevant variable (CDD), the predicted and measured consumption values, the difference between them, and the CUSUM calculated as defined in Fichera et al. (2020). The corresponding graphical outputs are shown in the figures associated with this building.

Table 6_ CUSUM calculations for the energy performances of Building A during cooling Periods of Municipio located in Corso San Vito, 2

Month	CDD	Consumption (kWh)	Predicted	Difference	CUSUM
	<u>[-]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>
May 22'	28	6055	5465,5	589,4	589,4
June 22'	131,8	7284	6408,0	875,9	875,9
July 22'	178,8	7604	6834,7	769,2	769,2
August 22'	159,1	6477	6655,8	-178,8	-178,8
September 22'	117,6	4641	6279,0	-1638,0	-1638,0
October 22'	29,2	4081	5476,4	-1395,4	-1395,4
May 23'	4,9	3636,51	5255,7	-1619,2	-1619,2
June 23'	72,1	3757,31	5865,9	-2108,6	-2108,6
July 23'	205,9	4300,89	7080,8	-2779,9	-2779,9
August 23'	148,8	4174,34	6562,3	-2388,0	-2388,01
September 23'	102,5	4210,93	6141,9	-1931,0	-1931,0
October 23'	58	3764,83	5737,9	-1973,0	-1973,0
May 24'	17,3	3370,21	5368,3	-1998,1	-1998,1
June 24'	107,4	4672,46	6186,4	-1513,9	-1513,9
July 24'	203,8	6935,95	7061,7	-125,7	-125,7
August 24'	208	6194,51	7099,8	-905,3	-905,3
September 24'	111,2	4938,54	6220,9	-1282,4	-1282,4
October 24'	43	4636,58	5601,7	-965,1	-965,1

The analysis follows the methodology of Fichera et al. (2020), using tables that report the reference period, CDD, predicted and measured consumption, their difference, and the calculated CUSUM, with results shown in the related figures. Control charts confirm that the process is statistically under control, while the CUSUM method, as recommended by Fichera et al. (2020), provides deeper insight into deviations from the expected trend.

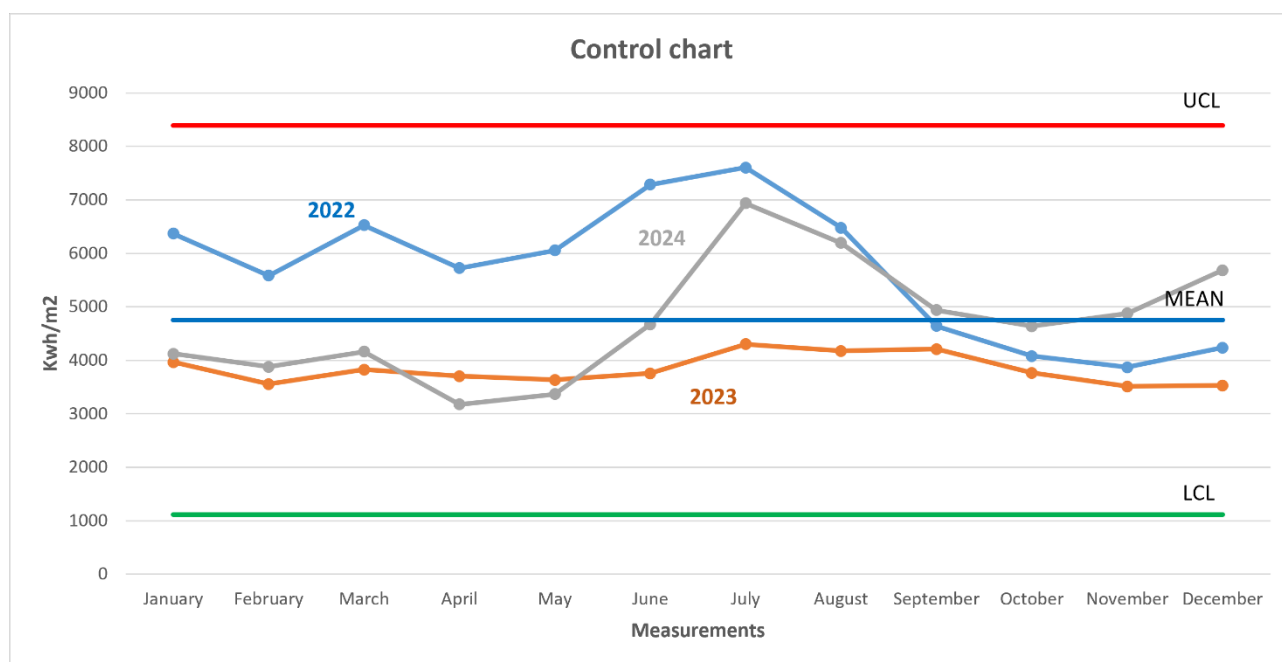


Figure 132_ Control charts for the EnPI measurements during the cooling period of Municipio located in Corso San Vito, 2

The control chart compares monthly electricity consumption for 2022, 2023, and 2024 with the reference mean and control limits (UCL and LCL), enabling the monitoring of process stability over time. All recorded values remain within the control limits, confirming that the process is statistically under control. However, notable differences are evident: 2022 consistently records the highest consumption, particularly from May to August; 2023 maintains significantly lower values throughout the year with minimal fluctuations; 2024 starts with relatively low figures, rises sharply in June and July, then drops in late summer before increasing again towards the end of the year. As highlighted by Fichera et al. (2020), these deviations from the baseline trend should be further examined through complementary analyses, such as CUSUM, to better understand their underlying causes and evaluate their impact on overall energy performance.

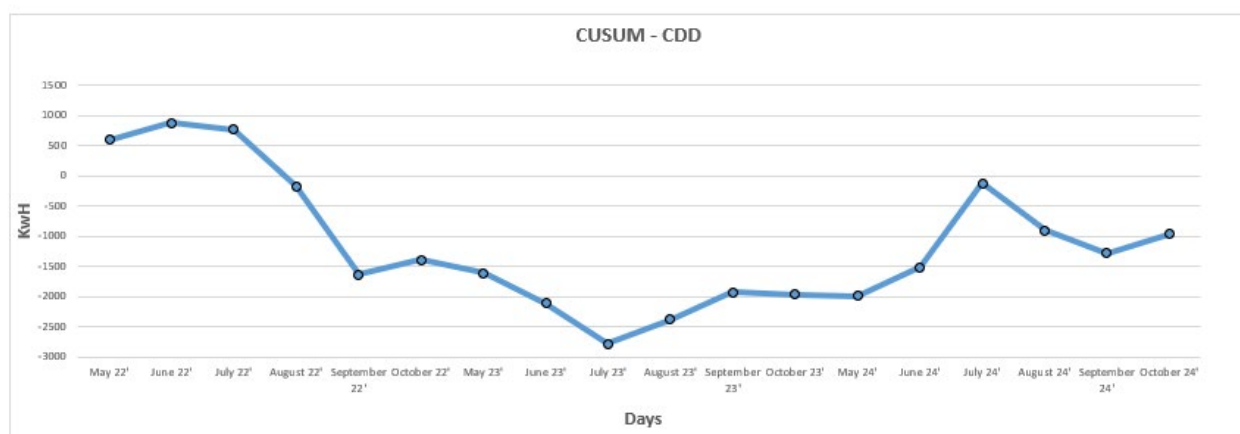


Figure 133_ CUSUM charts for the energy performances during the cooling period of Municipio located in Corso San Vito, 2

Table 6 presents the preliminary data and calculations used to generate the CUSUM chart shown in Figure 134, which analyses electricity consumption during the cooling period in relation to Cooling Degree Days (CDD) for the years 2022–2024. The chart shows cumulative deviations between measured and predicted consumption according to the reference model. From May 2022 to August 2023, a

pronounced downward trend is evident, with negative peaks approaching –2,900 kWh, indicating prolonged periods of lower-than-expected consumption. This is followed by a partial recovery from May 2024 onwards, with positive peaks in July 2024 and subsequent smaller oscillations. The analysis identifies specific intervals where performance diverged from the baseline, supporting targeted investigations into potential operational adjustments or external conditions influencing energy use.

Following the same calculation procedure as for the current scenario, Table 7 summarises the preliminary data and results for the relamping intervention, which replaces the existing lighting system with LED technology. For each month of the cooling period, the table reports the CDD, electricity consumption (kWh/m²), predicted values, the difference between measured and predicted values, and the corresponding CUSUM. Overall, smaller deviations and reduced cumulative values indicate improved energy performance, in line with the expected benefits of the intervention.

Table 7_ CUSUM calculations for the energy performances of Municipio located in Corso San Vito, 2 with Relamping

Month	CDD	Consumption (kWh)	Predicted	Difference	CUSUM
	<u>[-]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>
May 22'	28	3027,5	3161,7	-134,2	-134,2
June 22'	131,8	3642	3632,9	9,0	9,0
July 22'	178,8	3802	3846,3	-44,3	-44,3
August 22'	159,1	3238,5	3756,8	-518,3	-518,3
September 22'	117,6	2320,5	3568,4	-1247,9	-1247,9
October 22'	29,2	2040,5	3167,1	-1126,6	-1126,6
May 23'	4,9	1818,2	3056,8	-1238,5	-1238,5
June 23'	72,1	1878,6	3361,9	-1483,2	-1483,2
July 23'	205,9	2150,4	3969,3	-1818,9	-1818,9
August 23'	148,8	2087,1	3710,1	-1622,9	-1622,9
September 23'	102,5	2105,4	3499,9	-1394,4	-1394,4
October 23'	58	1882,4	3297,9	-1415,4	-1415,4
May 24'	17,3	1685,1	3113,1	-1428,0	-1428,0
June 24'	107,4	2336,2	3522,1	-1185,9	-1185,9
July 24'	203,8	3467,9	3959,8	-491,8	-491,8
August 24'	208	3097,2	3978,8	-881,6	-881,6
September 24'	111,2	2469,2	3539,4	-1070,1	-1070,1
October 24'	43	2318,2	3229,8	-911,5	-911,5

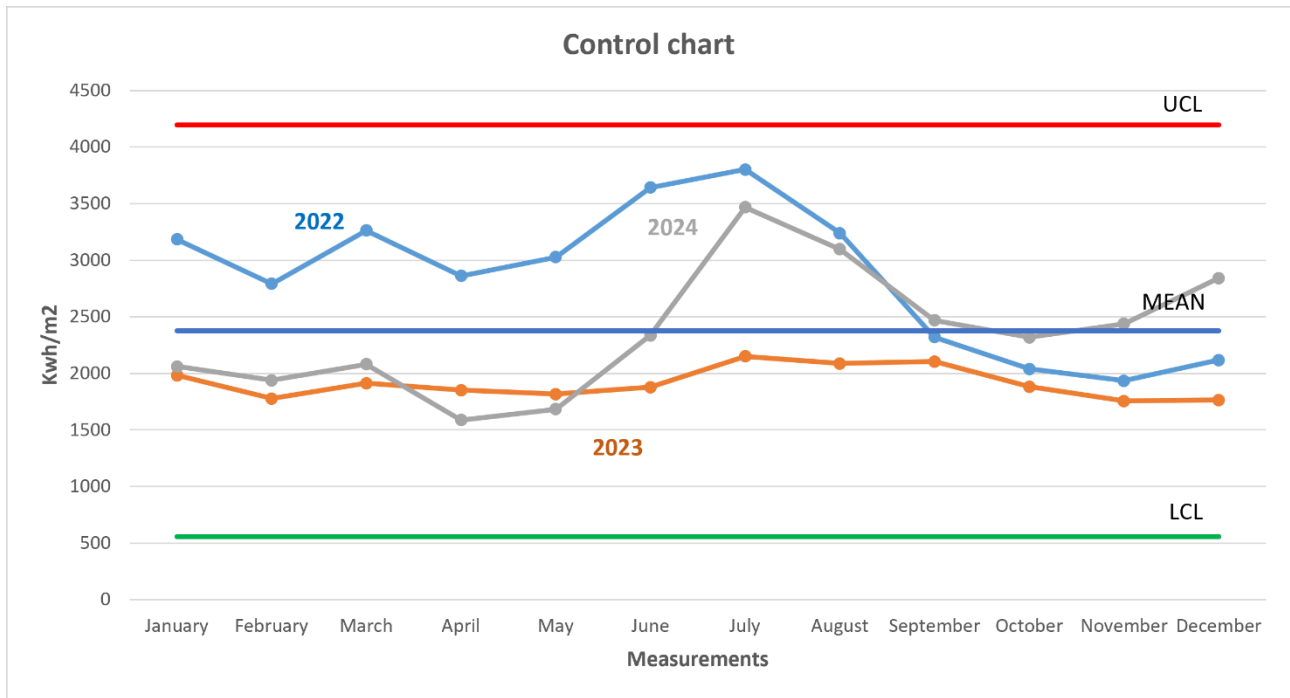


Figure 134_ Control charts for the EnPI measurements during the cooling period of Municipio located in Corso San Vito, 2 with Relamping

From the comparison between the CUSUM chart for the current scenario (Figure 134) and that for the relamping intervention scenario (Figure 136), a marked improvement in performance stability emerges. In the current scenario, fluctuations are wider, with positive peaks reaching about +1,000 kWh and negative peaks approaching -2,900 kWh, indicating significant deviations from the reference model during several months of higher cooling demand. In contrast, the post-intervention chart displays smaller oscillations, with positive peaks limited to around +500 kWh and negative peaks contained within -1,900 kWh. This reduction in the amplitude of deviations reflects a closer alignment between measured and predicted consumption, confirming that the LED replacement not only reduced lighting-related electricity use but also enhanced process stability. Furthermore, the post-intervention trend appears smoother and more regular, suggesting improved predictability and control of energy performance during the cooling period.

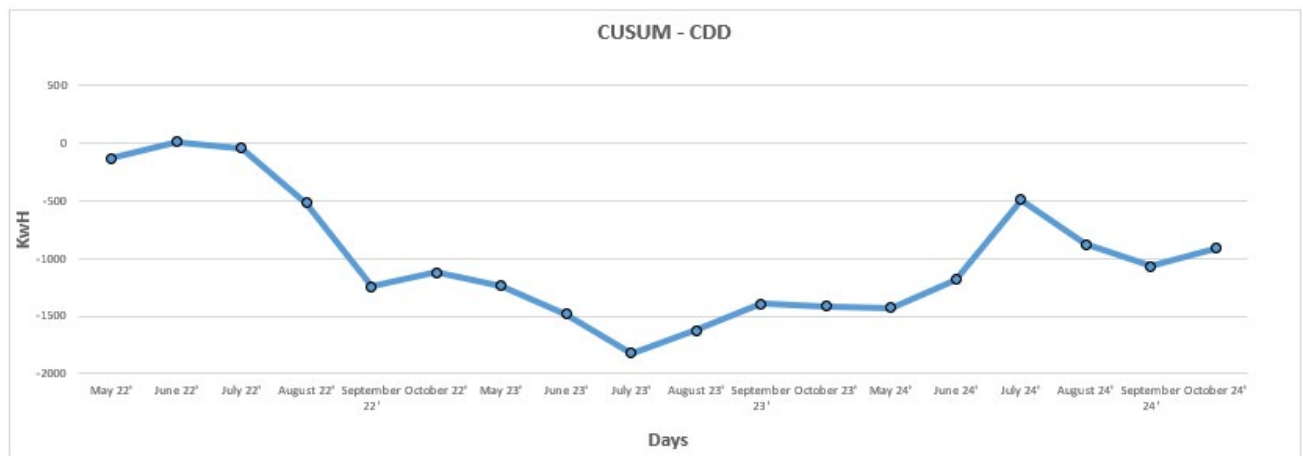


Figure 135_ CUSUM charts for the energy performances during the cooling period of Municipio located in Corso San Vito, 2 with Relamping

- **Croce Rossa Italiana – Via Petrarca, 24**

For the *Croce Rossa Italiana* building, located in Via Petrarca, 24 the CUSUM analysis is supported by tables structured according to the methodology of Fichera et al. (2020). These tables report the reference period, the relevant variable (CDD), the predicted and measured consumption values, the difference between them, and the CUSUM calculated as defined in Fichera et al. (2020). The corresponding graphical outputs are shown in the figures associated with this building.

Table 8_CUSUM calculations for the energy performances of Building A during cooling Periods of Croce Rossa Italiana located in Via Petrarca, 24

Month	CDD	Consumption (kWh)	Predicted	Difference	CUSUM
	<u>[-]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>
May 22'	28	632	819,8	-187,8	-187,8
June 22'	131,8	823	823,7	-0,7	-0,7
July 22'	178,8	909	825,5	83,4	83,4
August 22'	159,1	787	824,8	-37,8	-37,8
September 22'	117,6	818	823,2	-5,2	-5,2
October 22'	29,2	719	819,9	-100,9	-100,9
May 23'	4,9	692,8	819,0	-126,2	-126,2
June 23'	72,1	734,0	821,5	-87,4	-87,4
July 23'	205,9	1186,1	826,5	359,5	359,5
August 23'	148,8	888,1	824,4	63,7	63,7
September 23'	102,5	822,9	822,6	0,3	0,3
October 23'	58	706,8	821,0	-114,1	-114,1
May 24'	17,3	685,4	819,4	-134,0	-134,0
June 24'	107,4	653,9	822,8	-168,9	-168,9
July 24'	203,8	1079,6	826,4	253,1	253,1
August 24'	208	949,4	826,6	122,7	122,7
September 24'	111,2	806,4	823,0	-16,6	-16,6
October 24'	43	741,46	820,4	-78,9	-78,9

The analysis follows the methodology of Fichera et al. (2020), using tables that report the reference period, CDD, predicted and measured consumption, their difference, and the calculated CUSUM, with results shown in the related figures. Control charts confirm that the process is statistically under control, while the CUSUM method, as recommended by Fichera et al. (2020), provides deeper insight into deviations from the expected trend.

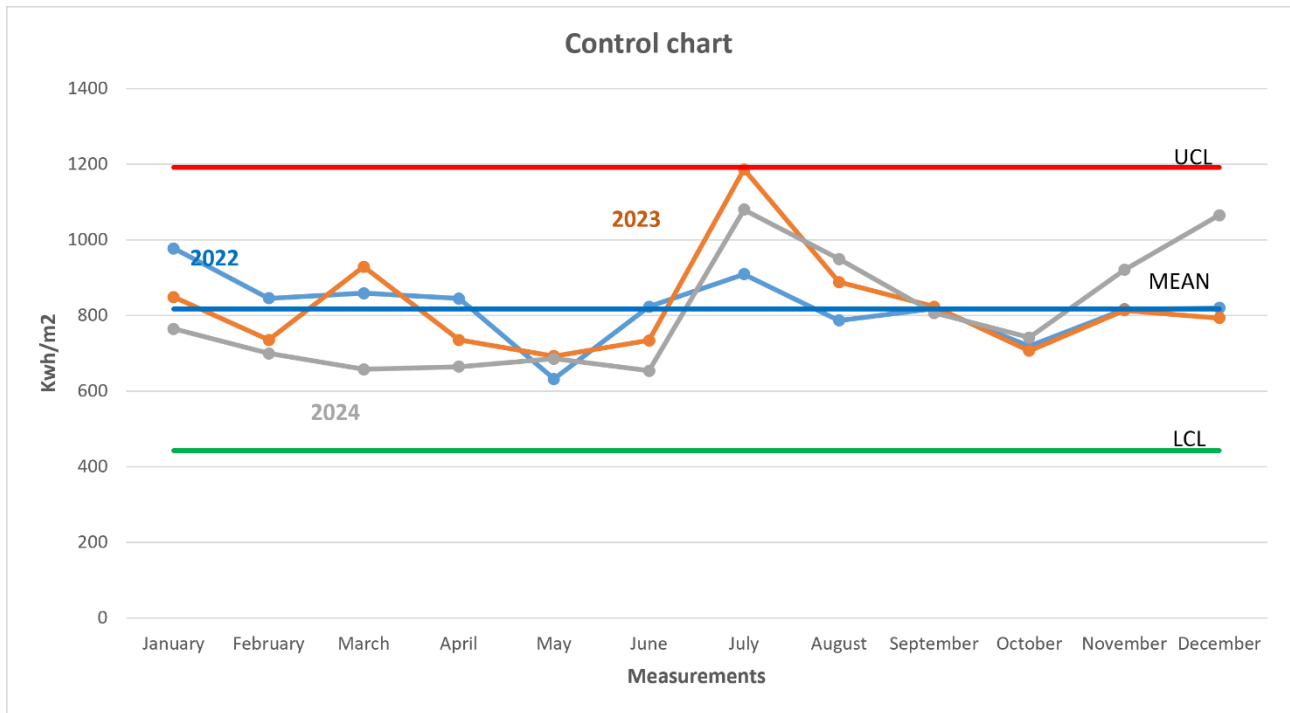


Figure 136_Control charts for the EnPI measurements during the cooling period of Croce Rossa Italiana located in Via Petrarca, 24

The control chart shows the monthly electricity consumption for 2022, 2023, and 2024, compared with the reference mean and the control limits (UCL and LCL), enabling the monitoring of process stability over time. All data points lie within the control limits, confirming that the process is statistically under control. However, some clear differences emerge between the three years: 2022 generally maintains values slightly above the mean, with limited fluctuations and a tendency towards stabilization in the second half of the year; 2023 displays greater variability, with a marked peak in July reaching values close to the UCL, followed by a gradual decline and stabilization in the last quarter; 2024 starts with lower values compared to the other years, remaining consistently below the mean until June, then progressively increases in the second half of the year, ending with the highest values in December. As noted by Fichera et al. (2020), such deviations from the baseline trend highlight the need for further investigation through complementary methods, such as CUSUM analysis, to better identify the causes and quantify their impact on overall energy performance.

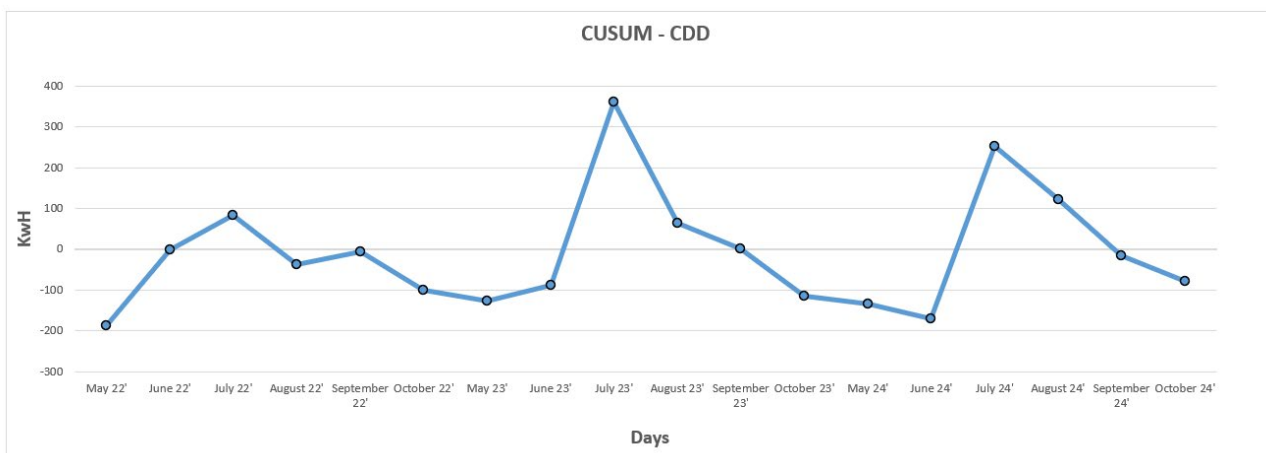


Figure 137_CUSUM charts for the energy performances during the cooling period of Croce Rossa Italiana located in Via Petrarca, 24

Table 8 presents the input data and calculations used to construct the CUSUM chart reported in Figure 138, which analyses electricity consumption during the cooling season in relation to Cooling Degree Days (CDD) for the years 2022–2024. The chart displays the cumulative deviations between measured and predicted consumption according to the reference model. In 2022, the curve starts with a slight negative deviation in May, followed by a progressive increase that culminates in July, and then gradually declines towards the autumn months. In 2023, the trend shows a sharp positive peak in July, before undergoing a marked reduction that extends into October. In 2024, the curve again rises progressively from May to July, where it reaches a pronounced peak, and subsequently decreases in the following months. These fluctuations highlight alternating phases of over- and under-consumption compared to the baseline scenario. Such evidence enables the identification of specific intervals where performance diverged from the model, supporting targeted investigations into potential operational factors or external conditions influencing energy use.

Following the same calculation procedure as for the current scenario, Table 9 summarises the preliminary data and results for the relamping intervention, which replaces the existing lighting system with LED technology. For each month of the cooling period, the table reports the CDD, electricity consumption (kWh/m²), predicted values, the difference between measured and predicted values, and the corresponding CUSUM. Overall, smaller deviations and reduced cumulative values indicate improved energy performance, in line with the expected benefits of the intervention.

Table 9_ CUSUM calculations for the energy performances of Croce Rossa Italiana located in Via Petrarca, 24 with Relamping

Month	CDD	Consumption (kWh)	Predicted	Difference	CUSUM
	<u>[-]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>	<u>[kWh/m²]</u>
May 22'	28	316	673,7	-357,7	-357,7
June 22'	131,8	411,5	424,2	-12,7	-12,7
July 22'	178,8	454,5	311,2	143,2	143,2
August 22'	159,1	393,5	358,6	34,8	34,8
September 22'	117,6	409	458,3	-49,3	-49,3
October 22'	29,2	359,5	670,9	-311,4	-311,4
May 23'	4,9	346,4	729,3	-382,9	-382,9
June 23'	72,1	367,0	567,7	-200,7	-200,7
July 23'	205,9	593,0	246,0	346,9	346,9
August 23'	148,8	444,0	383,3	60,7	60,7
September 23'	102,5	411,4	494,6	-83,1	-83,1
October 23'	58	353,4	601,6	-248,2	-248,2
May 24'	17,3	342,7	699,5	-356,7	-356,7
June 24'	107,4	326,9	482,8	-155,9	-155,9
July 24'	203,8	539,8	251,1	288,6	288,6
August 24'	208	474,7	241,0	233,6	233,6
September 24'	111,2	403,2	473,7	-70,5	-70,5
October 24'	43	370,7	637,7	-266,9	-266,9

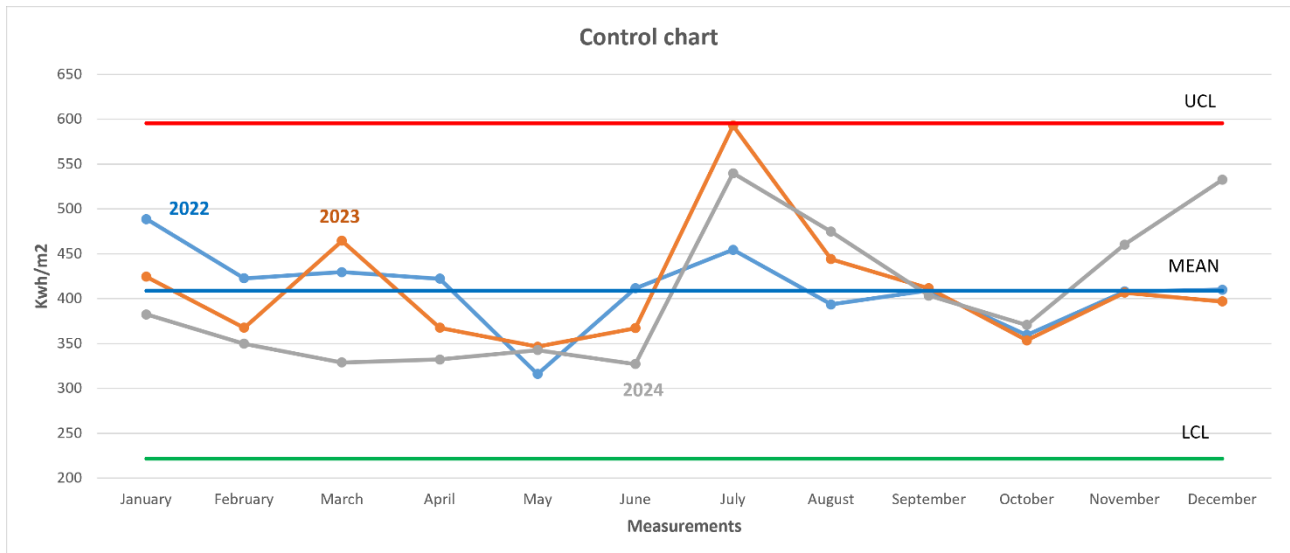


Figure 138_Control charts for the EnPI measurements during the cooling period of Croce Rossa Italiana located in Via Petrarca, 24 with Relamping

From the comparison between the CUSUM chart for the baseline scenario (Figure 138) and that for the relamping intervention scenario (Figure 140), a clear improvement in performance stability can be observed. In the baseline scenario, the curve shows wider oscillations, with positive deviations reaching about +350 kWh and negative deviations approaching -400 kWh, indicating significant divergences from the reference model during periods of higher cooling demand. In contrast, the post-intervention chart presents reduced fluctuations, with positive peaks contained within approximately +270 kWh and negative deviations limited to around -200 kWh. This reduction in the amplitude of deviations highlights a closer alignment between actual and predicted consumption, demonstrating that the LED relamping not only reduced electricity use associated with lighting but also improved process stability. Moreover, the post-intervention trend appears smoother and more consistent over time, confirming greater predictability and control of energy performance during the cooling season.

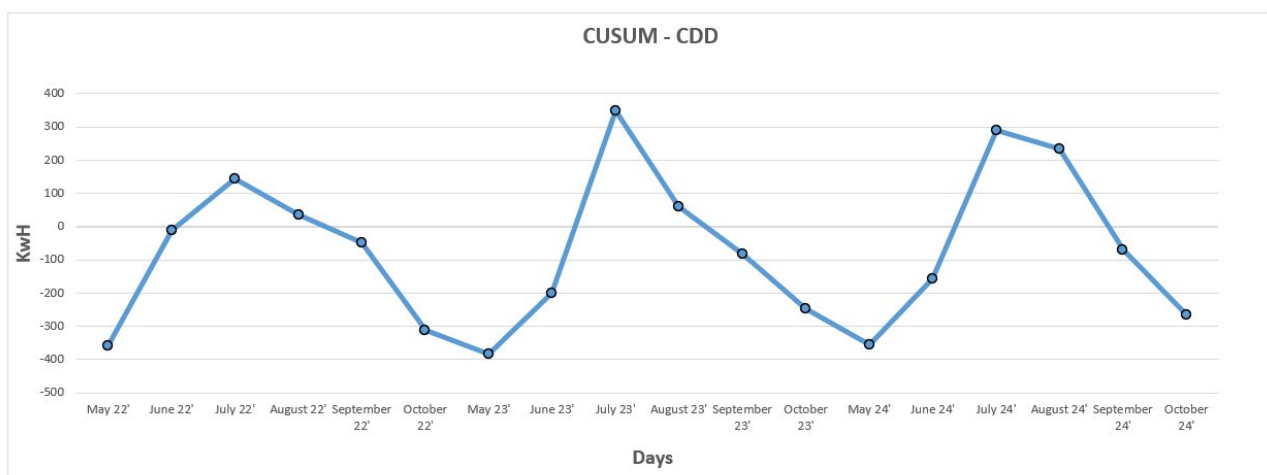


Figure 139_CUSUM charts for the energy performances during the cooling period of Croce Rossa Italiana located in Via Petrarca, 24 with Relamping

6.2 Relamping

Relamping represents the only physical intervention envisaged in this study for the public building stock of the Municipality of Mascalucia. This term refers to the replacement of existing lighting fixtures, now obsolete and characterized by low efficiency, with new high-efficiency LED lamps. The preliminary analysis showed that most municipal buildings still rely on outdated lighting systems (fluorescent, incandescent, or discharge lamps), which lead to high energy consumption, elevated maintenance costs, and a significant impact on electricity bills. Replacing them with LED technology would enable an estimated energy saving of about 50% of lighting consumption, while also ensuring better light quality, longer device lifespan, and lower maintenance costs. From an environmental perspective, reduced energy consumption translates into a corresponding reduction in CO₂ emissions associated with electricity generation, contributing to sustainability goals and compliance with ISO 50001 requirements. In this sense, relamping constitutes a strategic intervention: although it is the only one foreseen in this study, it can generate concrete, immediate, and easily measurable results, serving as a starting point for further efficiency measures.

To quantify the expected benefits, a comparative analysis of electricity consumption before and after the intervention has been prepared. The results are presented in the following tables, which compare the current situation with the post-relamping scenario for each building, highlighting energy savings, cost reductions, and decreases in CO₂ emissions.

Table 10_ Comparison of lighting consumption before and after the LED intervention

Building	Localization	Current lighting consumption (kWh/year)	Estimated post-LED consumption (kWh/year)	Energy savings (kWh/year)	Reduction (%)
Plesso ICS Fava	Via dei Villini, 19	9091,2	4545,6	4545,6	50 %
Plesso ICS Fava	Via Timparello, 53	62215,8	31107,9	31107,9	50 %
Plesso ICS Federico II	Via Massimo D'Azeglio, 14	21178,3	10589,1	10589,1	50 %
Plesso ICS Federico II	Via del Sole, 2	102494,3	51247,1	51247,1	50 %
Plesso ICS Leonardo Da Vinci	Via Roma, 217	22718,2	11359,1	11359,1	50 %
Plesso ICS Leonardo Da Vinci	Via della Regione Siciliana, 12	113992,7	56996,3	56996,3	50 %
Plesso ICS Leonardo Da Vinci	Via Santa Spera, 15	5394,2	2697,1	2697,1	50 %
Municipio	Corso San Vito, 2	68455,2	34227,6	34227,6	50 %
Ufficio Protezione civile	Via Manzoni, 8	6264,3	3132,1	3132,1	50 %
Delegazione COM	Via del Bosco, 19	14650,8	7352,4	7352,4	50 %
Croce Rossa Italiana	Via Petrarca, 24	9850,6	4925,3	4925,3	50 %
Auditorium	Via San Nicolò	31704,2	15852,1	15852,1	50 %
Parco Monte Ceraulo	Via Pulei, 51	503,4	251,7	251,7	50 %

6.3 Photovoltaic performance analysis

As part of the improvement measures foreseen within the energy management framework, a dedicated study on the integration of photovoltaic (PV) systems was carried out using the City Energy Analyst (CEA) software. CEA enabled a detailed estimation of monthly PV production for each building by integrating local climatic data (.epw files), solar radiation, and meteorological conditions with building-specific parameters such as geometry, orientation, roof inclination, and potential shading from nearby structures. To improve reliability and avoid computational overload, simulations were conducted individually for each building, ensuring accurate forecasts of solar potential. The results provide a clear representation of the expected contribution of PV systems to energy demand, highlighting their role as a concrete improvement measure. Beyond the technical estimation of renewable generation, this analysis demonstrates the potential of PV to reduce external energy dependence, lower operational costs, and decrease CO₂ emissions. In this sense, the PV study directly supports the ISO 50001 principle of continual improvement and provides municipalities with a practical pathway to enhance the efficiency and sustainability of their building stock.

6.3.1 Photovoltaic production estimation

The process of energy production through photovoltaic systems for self-consumption in public buildings, in accordance with ISO 50001, can be divided into several phases, with a focus on energy management. ISO 50001 is an international standard aimed at enabling organizations to establish and maintain an EMS that allows for continuous improvement in energy performance.

This process includes the following phases:

1. **Analysis and Identification of Opportunities** ([ISO 50001 – 4.1 e 4.2; International Organization for Standardization, 2018](#)): The first phase involves an analysis of the energy needs of public buildings; this analysis includes the assessment of energy consumption sources and the identification of various opportunities for energy efficiency.
2. **Design of the Photovoltaic System** ([ISO 50001 – 4.3; International Organization for Standardization, 2018](#)): ISO 50001 requires that the EMS considers legal and regulatory requirements, as well as the energy efficiency objectives set by the organization. Consequently, before designing the photovoltaic system, data from the PAESC/PAES should be analysed to estimate which data can also be used for the EnMS. It is essential to collect past and present energy data, such as heat and electricity consumption data for all relevant activities and assets subject to the EnMS. Additionally, it is important to identify the energy-intensive uses within the system.
3. **Implementation of the Photovoltaic System** ([ISO 50001 – 4.4; International Organization for Standardization, 2018](#)): When moving to the installation phase of the photovoltaic system, it is crucial to ensure its compliance with the requirements outlined by the standard. Monitoring measures and energy data collection can also be implemented, in line with the ISO 50001 requirements. The municipality under consideration must establish its energy baseline (EnB) based on the Energy Analysis that has been conducted and define criteria for reviewing and modifying the baseline. Additionally, energy performance indicators (EnPIs) will be defined and compared with the established baseline.
4. **Monitoring and Measurement** ([ISO 50001 – 4.4; International Organization for Standardization, 2018](#)): The standard requires continuous monitoring of energy performance. The monitoring systems must be able to collect data on energy production, consumption, and the amount fed into the grid. This can be achieved, for example, through Energy Monitoring Platforms, utilizing specialized software that collects, processes, and displays energy data, and is easily accessible to the administrative staff who will be responsible for periodic implementation. Data analysis

will also be necessary, using algorithms and analysis tools to identify trends, inefficiencies, and opportunities for energy savings.

5. **Performance Evaluation** ([ISO 50001 – 4.9; International Organization for Standardization, 2018](#)): Periodically, it will be necessary to evaluate the performance of the EMs. This evaluation will be useful to assess potential improvements and ensure that the organization is achieving the set objectives in the short to medium term, in alignment with the PAES/PAESC. Aspects related to training, communication, monitoring, maintenance, measurement, and diagnostics will also be reviewed.
6. **Continuous Improvement** ([ISO 50001 – 10; International Organization for Standardization, 2018](#)): The standard also requires continuous improvement. The organization should identify opportunities for improvement and implement corrective and preventive actions to optimize the energy efficiency of the system.

The City Energy Analyst platform has allowed for the estimation of the energy production of a hypothetical photovoltaic system placed on the roofs of each building in the case study, simulating several key factors. First, it considers the tilt and orientation of the roofs, as these parameters influence the amount of solar radiation received by the photovoltaic panels. Additionally, the software integrates historical climate data to estimate solar irradiation, which is essential for calculating energy production.

The specific characteristics of the photovoltaic panels, such as efficiency and performance, are also crucial in the calculation. Lastly, the software accounts for potential obstacles, such as surrounding buildings or shading, that may reduce the amount of energy produced. In this way, City Energy Analyst provides an accurate estimate of the annual photovoltaic energy production, supporting decisions on sustainable solutions for each building.

6.3.2 Production from photovoltaic system

To evaluate the renewable energy potential of the municipal building stock, photovoltaic (PV) electricity production was estimated for each building under study. The simulations were carried out using the CEA software, which allows monthly PV generation to be calculated based on building geometry, rooftop area, solar radiation, and climatic conditions. For each building, a dedicated simulation was performed, and the results were exported as monthly electricity production values (kWh). These data were then represented through both tables and bar charts, to provide a clear and comparable overview of seasonal production profiles. The graphical representation highlights the typical variation in PV output, with higher values in spring and summer months due to increased solar irradiance, and lower values during autumn and winter. This analysis supports the assessment of the buildings' potential for self-consumption and renewable integration, forming the basis for calculating coverage rates and evaluating the contribution of on-site PV systems to the overall energy performance of the municipal portfolio.

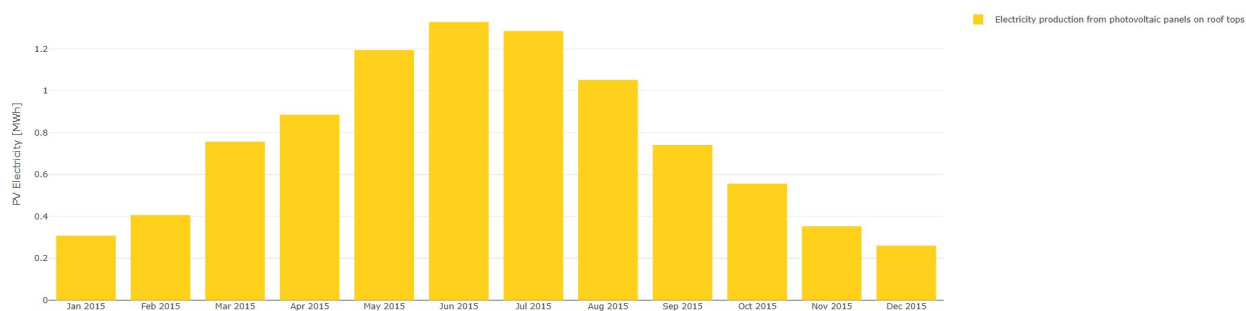


Figure 140_Monthly photovoltaic production – Plesso ICS Fava - Via dei Villini, 19

Table 11_Monthly photovoltaic electricity production – Plesso ICS Fava - Via dei Villini, 19

Electricity Production in Plesso ICS Fava – Via dei Villini, 19	
Month	Electricity production (kWh)
January	307,9
February	406,7
March	756,3
April	885,2
May	1193,8
June	1327,6
July	1284,8
August	1051,2
September	740,6
October	556,2
November	352,9
December	260,5

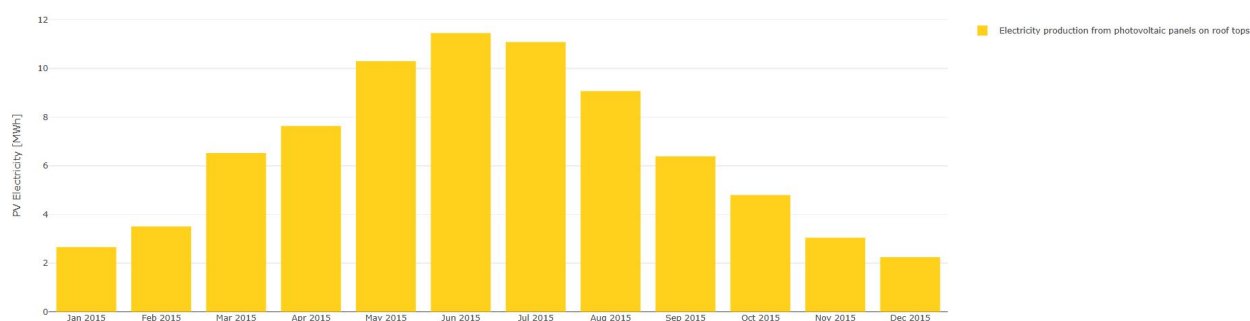


Figure 141_Monthly photovoltaic production – Plesso ICS Fava – Via Timparello,53

Table 12_Monthly photovoltaic electricity production – Plesso ICS Fava - Via Timparello,53

Electricity Production in Plesso ICS Fava – Via Timparello, 53	
Month	Electricity production (kWh)
January	2657,8
February	3509,0
March	6523,9
April	7636,3
May	10298,1

June	11451,3
July	11082,3
August	9070,1
September	6388,8
October	4798,0
November	3045,4
December	2248,5

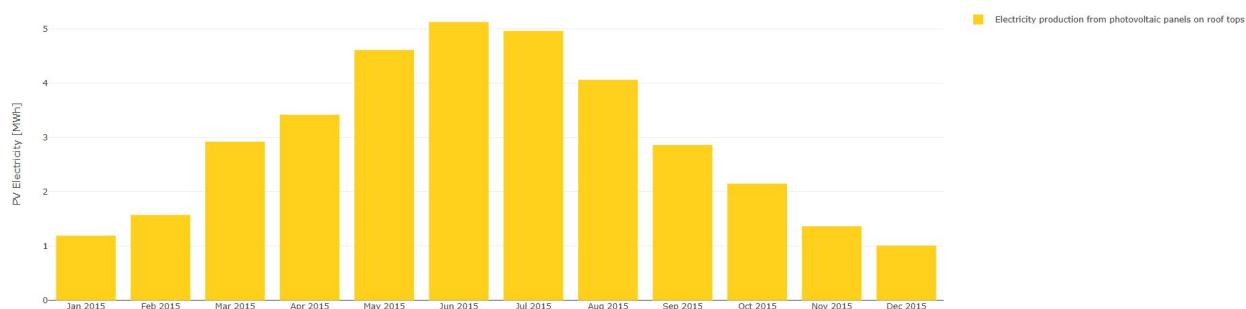


Figure 142_Monthly photovoltaic electricity production – Plesso ICS Federico II– Via M. D’Azeglio, 14

Table 13__Monthly photovoltaic electricity production – Plesso ICS Federico II– Via M. D’Azeglio, 14

Electricity Production in Plesso Federico II – Via Massimo D’Azeglio, 14	
Month	Electricity production (kWh)
January	1189,3
February	1570,1
March	2919,1
April	3416,3
May	4607,4
June	5123,0
July	4958,0
August	4058,3
September	2858,5
October	2146,8
November	1362,5
December	1006,1

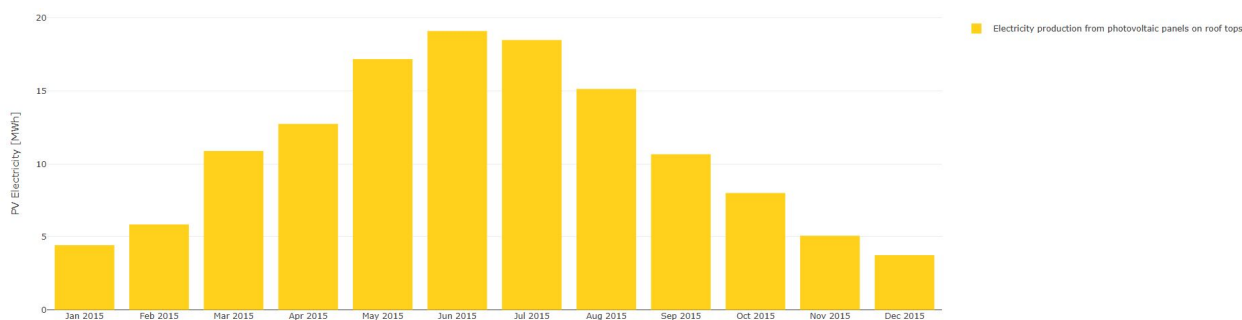


Figure 143_Monthly photovoltaic electricity production – Plesso ICS Federico II– Via del Sole, 2

Table 14_Monthly photovoltaic electricity production – Plesso ICS Federico II– Via del Sole, 2

Electricity Production in Plesso Federico II – Via del Sole, 2	
Month	Electricity production (kWh)
January	4434,1
February	5854,6
March	10887,5
April	12741,0
May	17179,6
June	19102,0
July	18486,9
August	15133,2
September	10661,6
October	8007,1
November	5080,9
December	3751,9

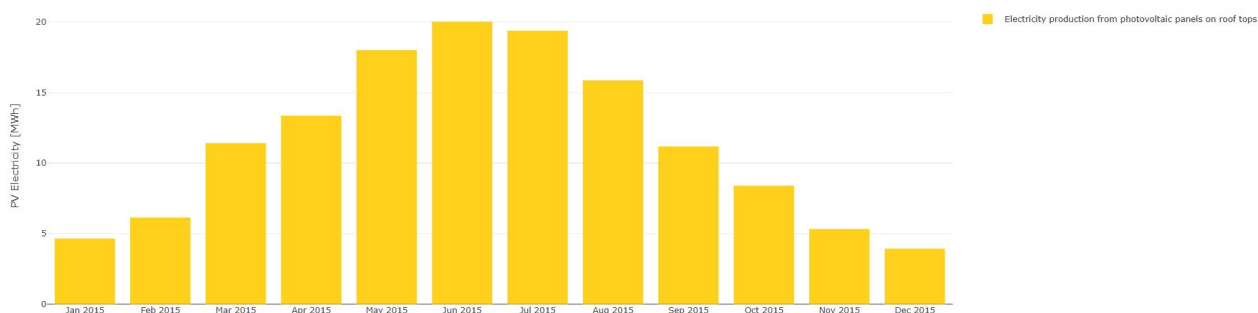


Figure 144_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via della Regione Siciliana, 12

Table 15_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via della Regione Siciliana, 12

Electricity Production in Plesso Leonardo Da Vinci – Via della Regione Siciliana, 12	
Month	Electricity production (kWh)
January	4646,1
February	6135,0
March	11408,2
April	13350,8
May	18001,1

June	20014,1
July	19370,7
August	15857,9
September	11171,8
October	8389,9
November	5323,3
December	3930,0

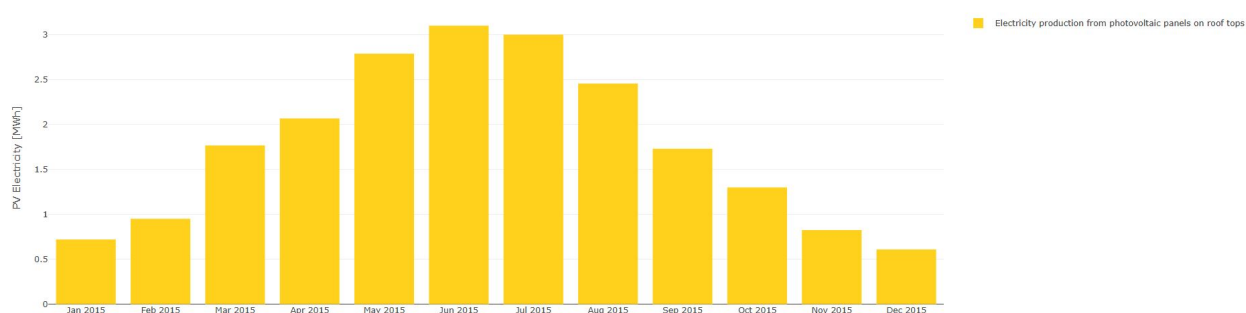


Figure 145_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via Roma, 217

Table 16_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via Roma, 217

Electricity Production in Plesso Leonardo Da Vinci – Via Roma, 217	
Month	Electricity production (kWh)
January	719,1
February	949,1
March	1764,7
April	2064,9
May	2784,4
June	3096,0
July	2724,8
August	2724,8
September	1727,8
October	1297,8
November	823,9
December	608,8

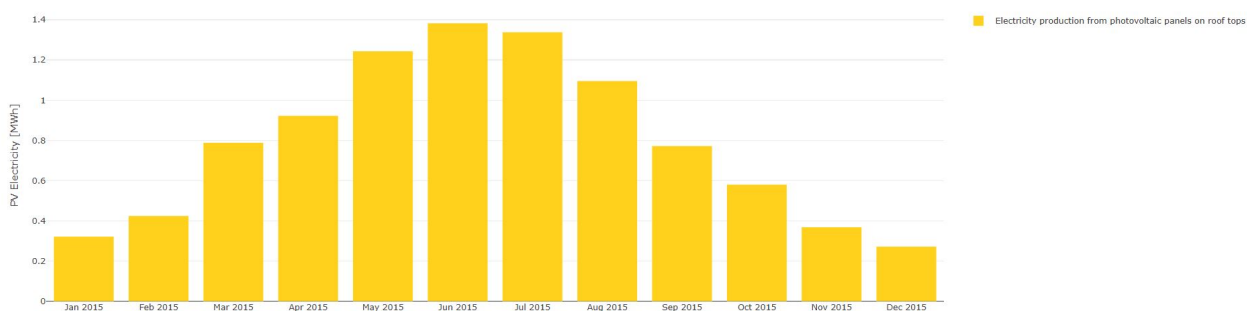


Figure 146_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via Santa Spera, 15

Table 17_Monthly photovoltaic electricity production – Plesso ICS Leonardo Da Vinci– Via Santa Spera, 15

Electricity Production in Plesso Leonardo Da Vinci – Via Santa Spera, 15	
Month	Electricity production (kWh)
January	320,9
February	432,9
March	787,9
April	922,1
May	1243,2
June	1382,3
July	1337,7
August	1095,0
September	771,5
October	579,7
November	367,8
December	271,4

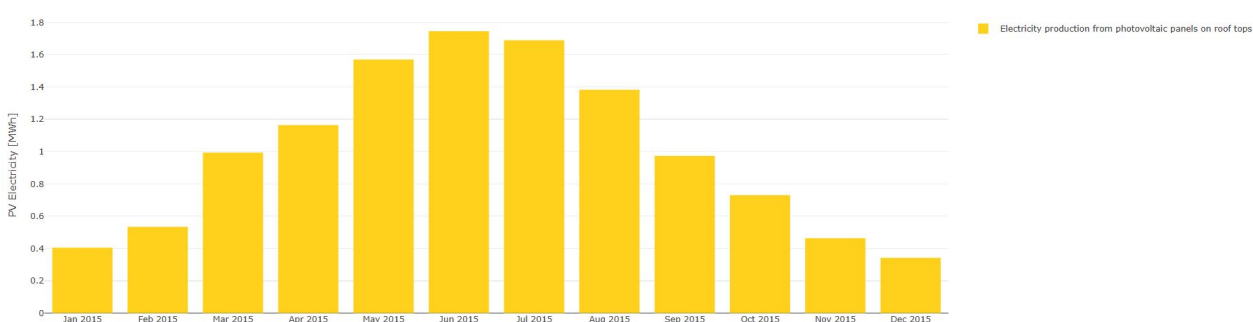


Figure 147_Monthly photovoltaic electricity production – Auditorium – Via San Nicolò

Table 18_Monthly photovoltaic electricity production – Auditorium – Via San Nicolò

Electricity Production in Auditorium – Via San Nicolò	
Month	Electricity production (kWh)
January	406,1
February	535,4
March	995,1
April	1164,0

May	1568,7
June	1744,1
July	1688,0
August	1381,8
September	974,2
October	732,1
November	465,1
December	343,71

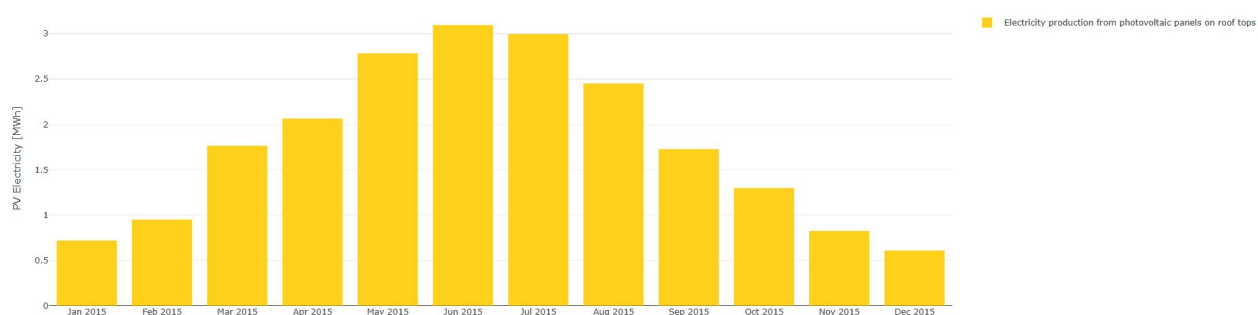


Figure 148_Monthly photovoltaic electricity production – Delegazione Comunale – Via del Bosco, 19

Table 19_Monthly photovoltaic electricity production – Delegazione Comunale – Via del Bosco, 19

Electricity Production in Delegazione Comunale – Via del bosco, 19	
Month	Electricity production (kWh)
January	806,2
February	1064,9
March	1980,2
April	2318,1
May	3126,4
June	3476,2
July	3364,7
August	2754,0
September	1939,3
October	1456
November	924,0
December	682,3

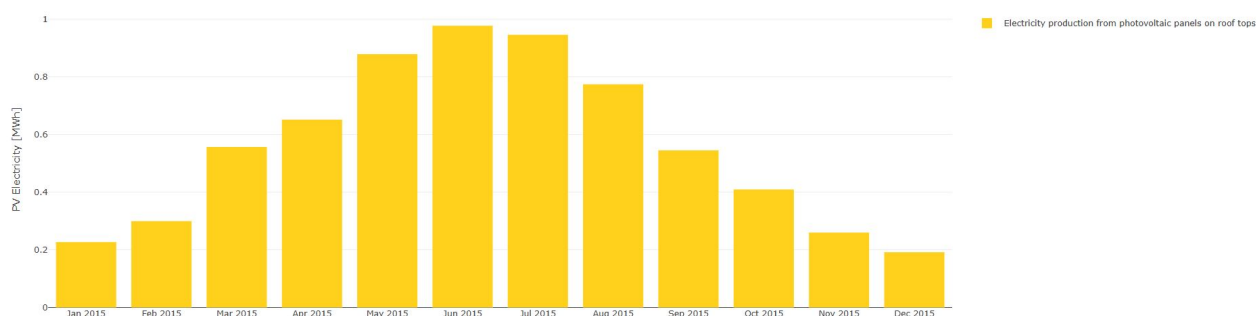


Figure 149_Monthly photovoltaic electricity production – Croce Rossa Italiana – Via Petrarca, 24

Table 20_Monthly photovoltaic electricity production – Croce Rossa Italiana – Via Petrarca, 24

Electricity Production in Croce Rossa Italiana – Via Petrarca, 24	
Month	Electricity production (kWh)
January	226,4
February	299,1
March	556,3
April	650,9
May	874,0
June	976,4
July	945,0
August	773,4
September	544,6
October	409,0
November	259,5
December	191,5

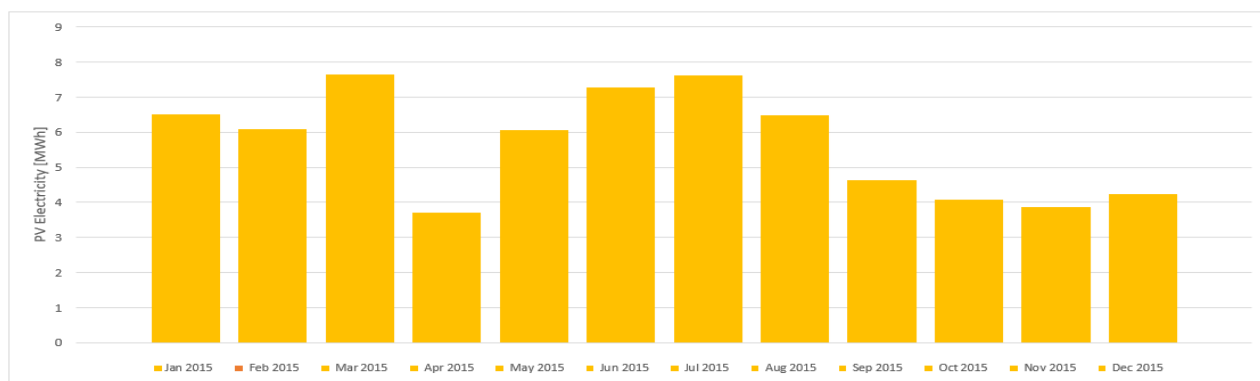


Figure 150_Monthly photovoltaic electricity production – Municipio – Corso San Vito, 2

Table 21_Monthly photovoltaic electricity production – Municipio – Corso San Vito, 2

Electricity Production in Municipio – Corso San Vito, 2	
Month	Electricity production (kWh)
January	782,4
February	1032,8
March	1920,1
April	2247,2
May	3030,4
June	3369,7
July	3261,3
August	2669,5

September	1880,3
October	1412,2
November	896,3
December	661,9

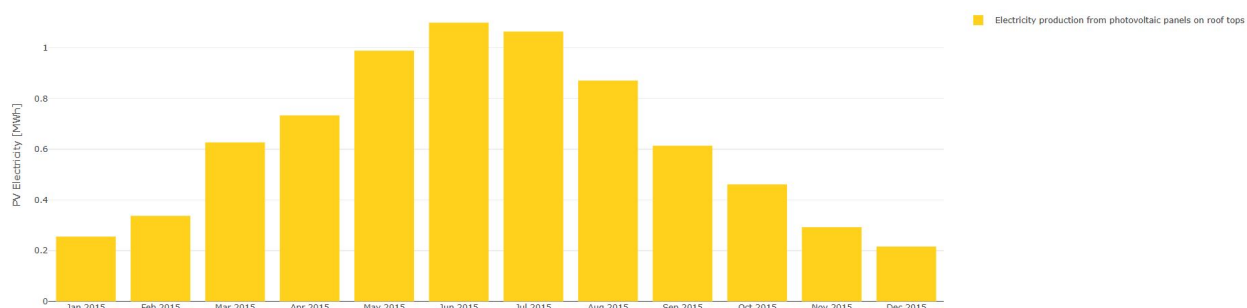


Figure 151_Monthly photovoltaic electricity production – Ufficio Protezione civile – Via Manzoni, 8

Table 22_Monthly photovoltaic electricity production – Ufficio Protezione civile – Via Manzoni, 8

Electricity Production in Ufficio protezione civile– Via Manzoni, 8	
Month	Electricity production (kWh)
January	292,5
February	337,2
March	626,9
April	733,5
May	988,8
June	1099,3
July	1064,3
August	871,0
September	613,8
October	461,3
November	292,5
December	337,2

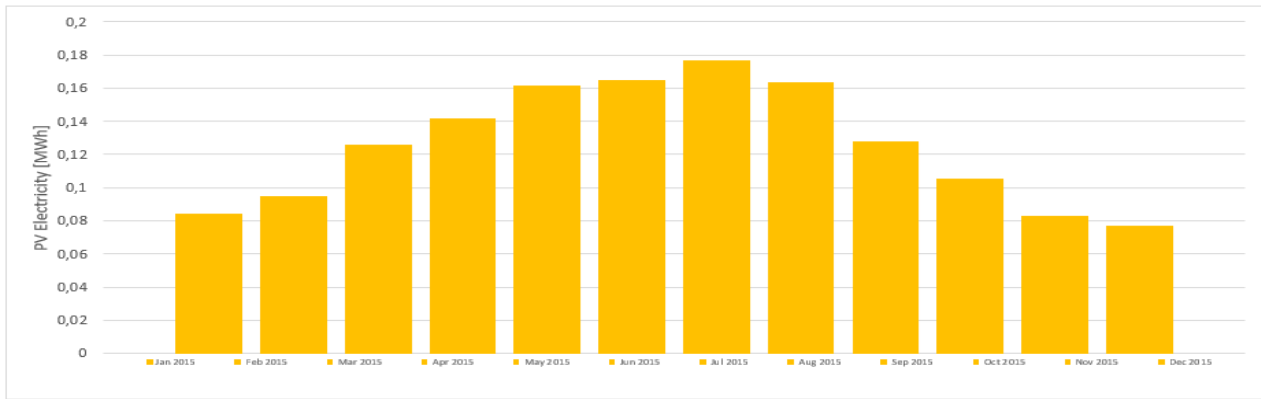


Figure 152_Monthly photovoltaic electricity production – Monte Ceraulo Park – Via Pulei, 51

Table 23_Monthly photovoltaic electricity production – Monte Ceraulo Park – Via Pulei, 51

Electricity Production in Parco Monte Ceraulo – Via Pulei, 51	
Month	Electricity production (kWh)
January	84,1
February	94,7
March	125,8
April	141,9
May	161,8
June	165,1
July	176,9
August	163,4
September	128,0
October	105,5
November	82,8
December	77,1

6.3.3 Coverage Rate Analysis

The concept of coverage rate is introduced here as a practical tool to evaluate the effectiveness of energy-saving measures in Mascalucia's public buildings. It expresses the share of electricity consumption potentially offset by interventions such as photovoltaic systems or other efficiency measures, according to the formula:

$$\text{Coverage rate (\%)} = \frac{\text{Covered portion (kWh)}}{\text{Total Consumption (kWh)}} \times 100 \quad (6)$$

This indicator makes it possible to compare the relative contribution of different buildings and to highlight which facilities benefit most from the installed technologies. The graphs presented in this chapter illustrate both cross-sectional differences among buildings and the temporal evolution of the coverage rate as new systems are installed or upgraded. In this way, the coverage rate provides insight into current performance while also serving as a reference point for future planning.

To further improve the coverage rate, strategies may include expanding renewable energy systems, prioritizing buildings with limited coverage, and promoting efficient practices among building managers.

Within the framework of ISO 50001, the coverage rate can be interpreted as an EnPI specifically tailored to municipalities. While industrial organizations often rely on production-based metrics, public

administrations require indicators that reflect the performance of their building stock. In this sense, the coverage rate provides a standardized and measurable tool for tracking the effectiveness of energy-saving measures, fully aligned with the ISO 50001 requirement of continuous performance improvement. By adopting such indicators, municipalities like Mascalucia can ensure that their energy management initiatives are both systematically monitored and progressively optimized over time.

- Plesso ICS Fava – Via dei Villini, 19**

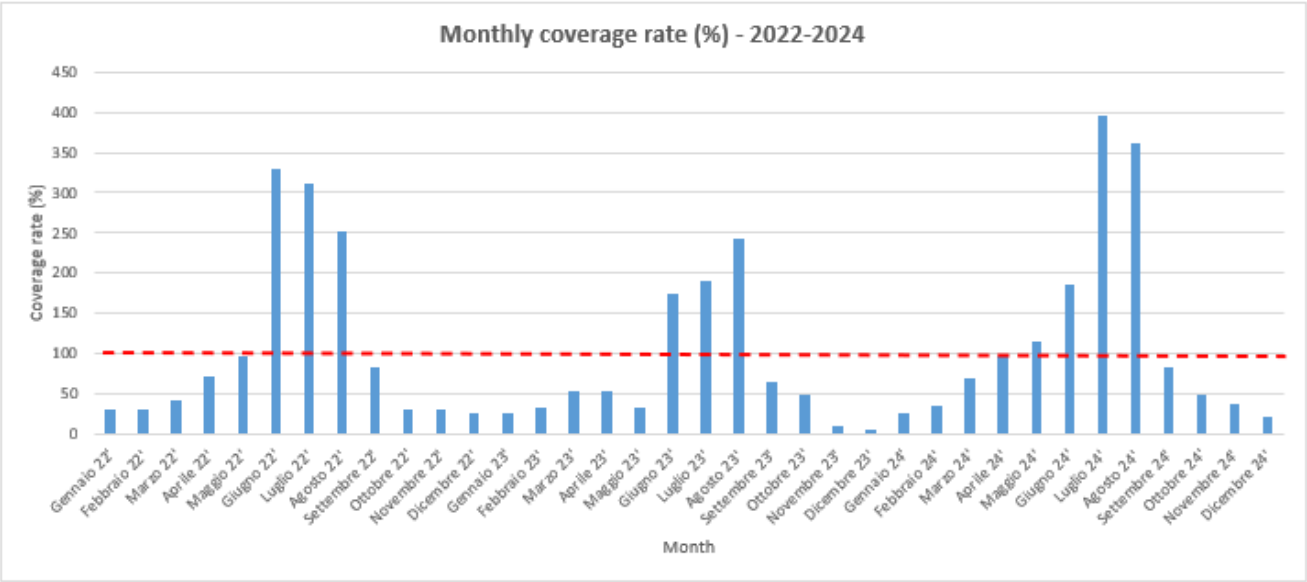


Figure 153_ Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Fava Complex located in Via dei Villini, 19.

The chart shows the monthly coverage rate (%), calculated by comparing PV production with the corresponding electricity demand, for the years 2022–2024. A value close to 100% indicates that the PV system met all the demand, whereas higher values highlight periods of surplus production. As expected, the results display a clear seasonal pattern: the coverage rate rises sharply during the summer months, while in winter it often falls well below 50%. For instance, the rate exceeded 300% in June and July 2022, and nearly reached 400% in August 2024. Considering an average monthly demand of around 300 kWh, this means that during these periods, the surplus ranged from 600 to 900 kWh. Without a storage system, however, this excess cannot be utilised locally and is therefore lost. Conversely, photovoltaics contributes much less in the winter months, sometimes approaching zero, as observed in November 2023. This strong seasonal variability highlights one of the main limitations of PV systems when used in isolation. For this reason, integrating the installation with a storage solution appears essential. This would enable the excess energy produced in summer to be stored and used later during periods of shortage, thereby improving the building’s self-sufficiency, and reducing its dependence on the grid.

- **Plesso ICS Fava – Via Timparello, 53**

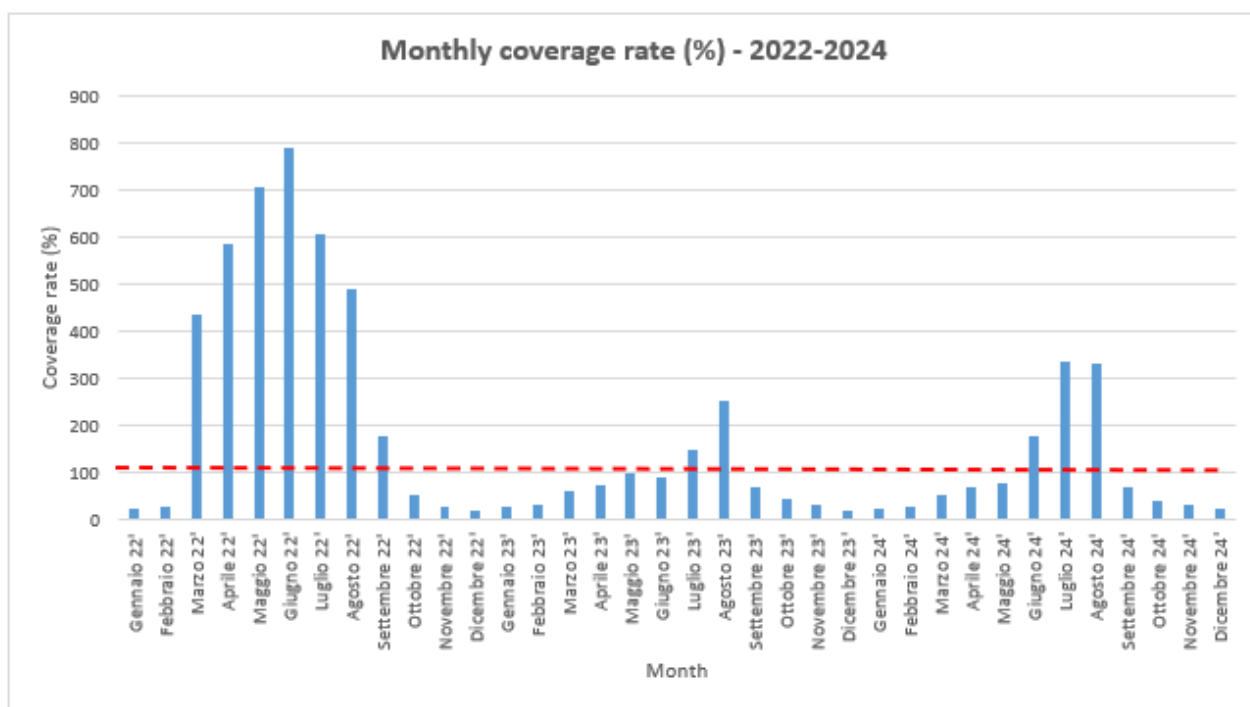


Figure 154_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Fava Complex located in Via Timparello, 53.

The chart illustrates the monthly coverage rate (%) for the years 2022–2024, considering only the contribution of PV production. The indicator expresses the share of electricity demand met by the PV system: values above 100% correspond to a surplus of generation, while values below 100% indicate the need for grid supply. A clear seasonal pattern emerges. During late spring and summer, the coverage rate rises well above demand, while in autumn and winter it drops significantly. For instance, in June and July 2023 the coverage rate exceeded 250%, peaking at nearly 300% in July. Similar surpluses were recorded in the summers of 2022 and 2024, with several months above 200%. With an average monthly demand of around 300 kWh, this means that in those periods an extra 300–600 kWh was generated each month — energy that cannot be used locally without storage. In contrast, during the winter months coverage often falls below 50%, in some cases reaching as low as 20–30%. This seasonal imbalance highlights the limits of a PV-only system and the need to complement it with storage. Integrating batteries would allow excess summer production to be stored and later used during low-generation months, increasing the building’s energy self-sufficiency and reducing dependence on the external grid.

- Plesso ICS Federico II – Via M. D’Azeglio, 14

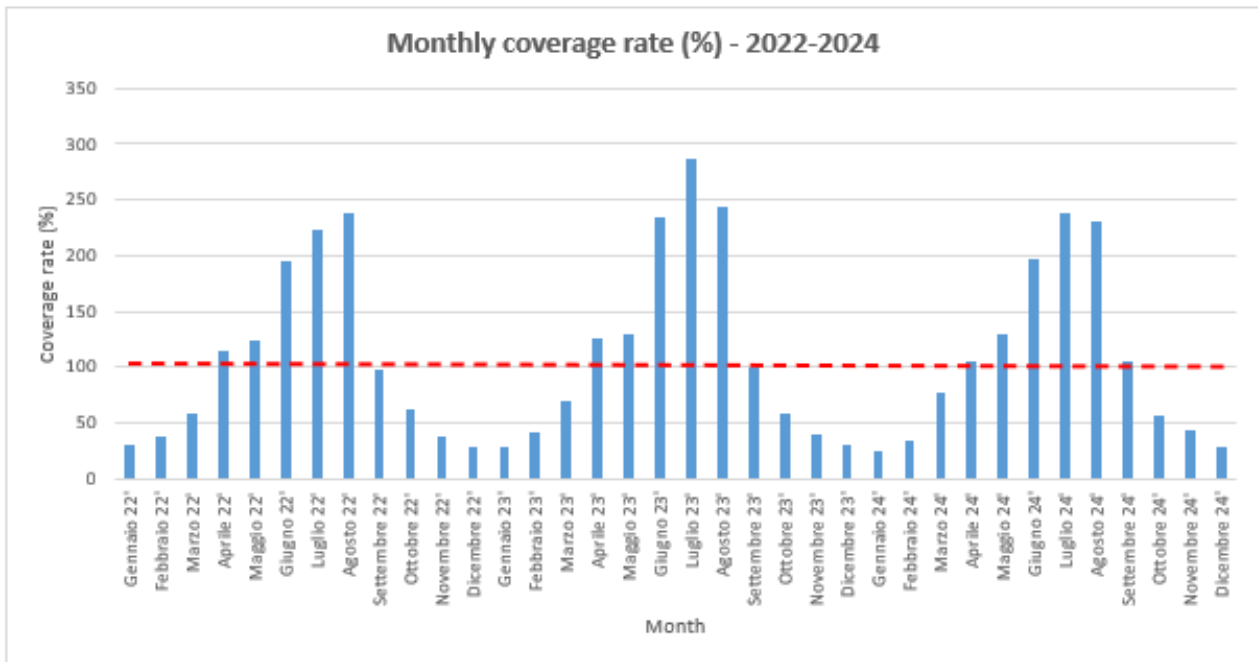


Figure 155_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Federico II Complex located in Via Massimo D’Azeglio, 14

The chart presents the monthly coverage rate (%) for the period 2022–2024, considering photovoltaic production as the sole electricity source. The indicator compares monthly PV generation with the building’s energy demand, where values above 100% represent surplus production. A marked peak in coverage can be observed in the first half of 2022, especially between March and July. In May, the rate exceeded 750%, with April and June also recording values above 600%. Taking an average monthly demand of 300 kWh, this means that in May alone the building produced over 2,200 kWh more than it required. However, this exceptional overproduction was limited to a short period. From the second half of 2022 through 2024, coverage values generally stayed around or below 100%, with only a few months — such as August 2023 and July–August 2024 — showing moderate surpluses. This contrast between very high surpluses in spring and early summer and the long stretches of underproduction in the rest of the year underlines the limits of relying only on direct consumption. Without storage, much of the excess energy cannot be used when demand is higher. For this reason, integrating a battery system would be a key step to improve self-consumption, balance seasonal variability, and reduce dependence on the grid.

- **Plesso ICS Federico II – Via del Sole, 2**

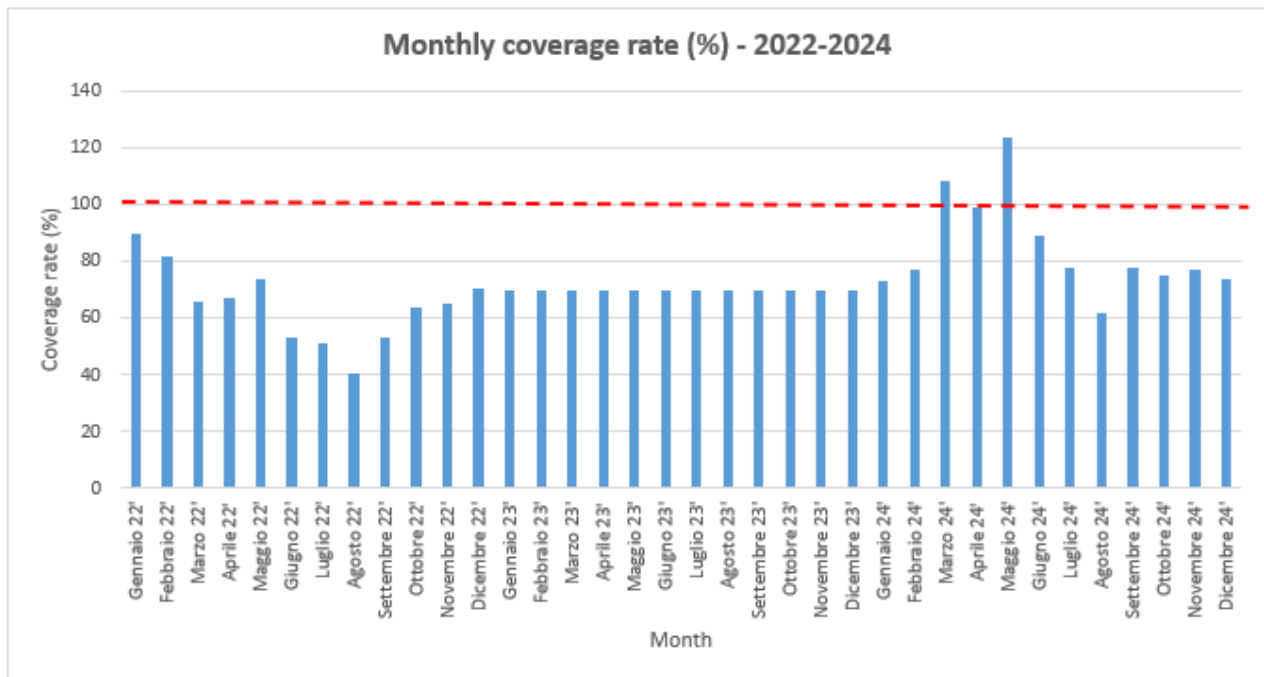


Figure 156_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Federico II Complex located in Via del Sole, 2.

The chart illustrates the monthly coverage rate between January 2022 and December 2024, considering PV production as the only electricity source. In early 2022, coverage values were below 100%, reaching about 90% in January but dropping to 40–50% during the summer. In 2023, the rate remained constant at around 70%, most likely because of modelling assumptions. By contrast, 2024 shows short periods of surplus generation, with coverage exceeding 100% in March and May (peaking at 123.6%), while in the other months values generally ranged between 61% and 88%.

These results highlight a structural limitation of self-consumption: without storage, the surplus generated in spring cannot be exploited when demand is higher. The adoption of a battery storage system would therefore be a crucial step to make better use of excess energy, increase self-sufficiency, and reduce reliance on the grid during periods of low solar production.

- **Plesso ICS L. Da Vinci – Via Roma, 217**

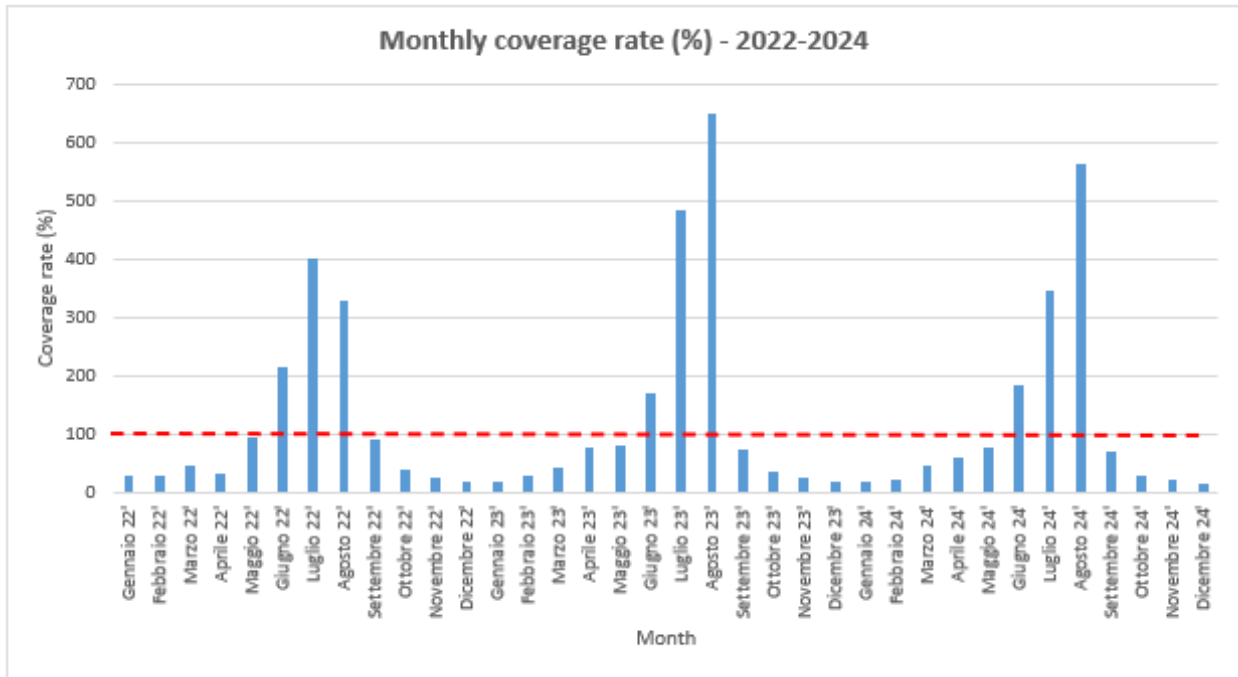


Figure 157_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Leonardo Da Vinci Complex located in Via Roma, 217.

The chart shows the monthly coverage rate (%) for the building at Via Roma 217 between 2022 and 2024, considering PV production as the only source of electricity. The coverage rate expresses the share of consumption covered by solar energy: values above 100% indicate a surplus, while those below 100% mean that additional energy from the grid is needed. The results reveal a clear seasonal trend. During late spring and summer, when solar radiation is strongest, the building produces far more than it consumes. In July 2023, for example, coverage exceeded 600%, with other peaks above 400% in June 2023 and September 2024—equivalent to more than 1,000 kWh of surplus electricity in a single month. However, without storage systems, this energy cannot be used and is effectively wasted. In contrast, during the colder months the situation is reversed: coverage rates drop well below 50%, sometimes reaching only 10–20%, particularly in December and January. This recurring imbalance underscores the building’s dependence on the grid in winter. The pattern makes it clear that adding storage, such as batteries, would allow excess solar energy generated in high-yield months to be saved and later used in periods of low production, greatly improving self-sufficiency, and reducing reliance on external supply.

- **Plesso ICS L. Da Vinci – Via della Regione Siciliana, 12**

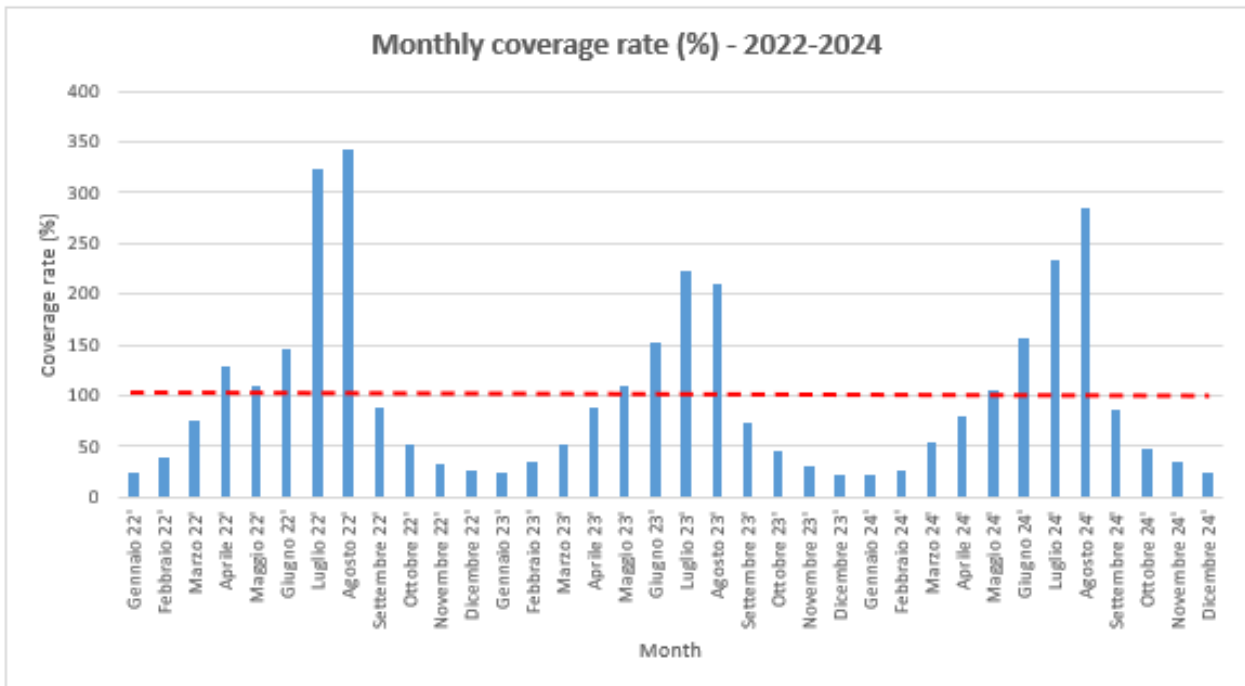


Figure 158_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Leonardo Da Vinci Complex located in Via Regione Siciliana, 12.

The chart shows the monthly coverage rate (%) for the building at Via della Regione Siciliana 12 between 2022 and 2024. The coverage rate compares the electricity generated by the PV system with the building's monthly demand: values above 100% indicate a surplus, while those below 100% mean that additional energy from the grid is required. The data highlights a clear seasonal trend. In late spring and summer, coverage rates are consistently high: in June and July 2022, values climbed to almost 340%, while in the same months of 2023 they remained above 200%. In 2024, the summer again showed strong performance, with August reaching nearly 300%. These surpluses correspond to several hundred kilowatt-hours per month that, without storage, cannot be used effectively. During autumn and winter, however, coverage rates decrease considerably. From October to February, they regularly fall below 100%, and in some months even below 50%, meaning that a large share of the building's energy needs must be supplied by the grid. This marked imbalance between seasonal surplus and deficit underlines the importance of integrating battery storage. Capturing the excess produced in sunny months and using it later would significantly increase the building's energy independence and reduce reliance on external supply.

- **Plesso ICS L. Da Vinci – Via Santa Spera, 15**

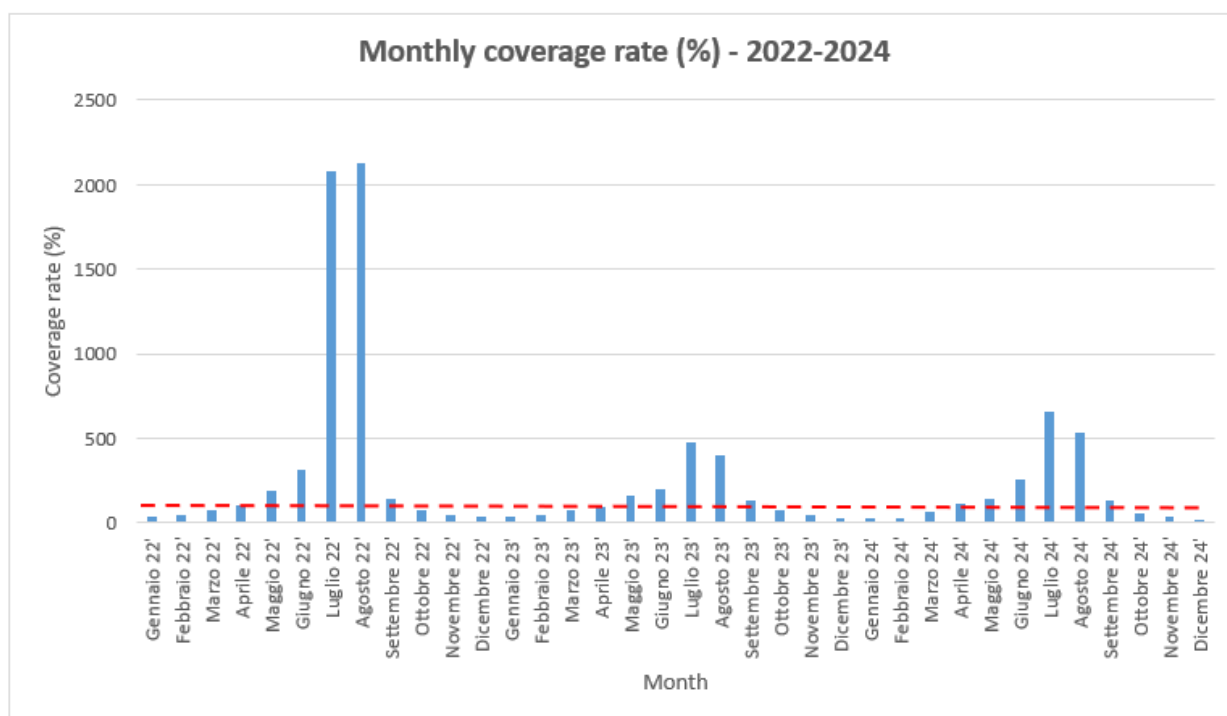


Figure 159_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of ICS Leonardo Da Vinci Complex located in Via Santa Spera, 15.

The chart illustrates the monthly coverage rate (%) for the building at Via Santa Spera between 2022 and 2024, considering only PV production. The coverage rate expresses the share of monthly consumption met by solar energy: values above 100% indicate surplus generation, while those below 100% show the need for grid electricity. The most remarkable result appears in July and August 2022, when coverage exceeded 2,000%. This indicates an extremely high production surplus—around twenty times the building’s actual demand—likely due to very low consumption combined with exceptionally high solar output. Assuming an average monthly demand of 300 kWh, this would mean a surplus of roughly 5,000–6,000 kWh, which could not be used without storage or a feed-in option. In the following years, 2023 and 2024, summer months still show very high values, with July and August reaching between 400% and 500%, though less extreme than in 2022. Outside the summer period, coverage remains much lower: in autumn and winter, especially from October to February, it often falls below 50%, meaning that most of the demand had to be met by the grid. This strong seasonal contrast highlights the limits of direct self-consumption. Adding a storage system would allow excess summer production to be saved and reused during low-yield months, improving the building’s energy independence, reducing waste, and lowering reliance on external supply.

- **Municipio – Corso San Vito, 2**

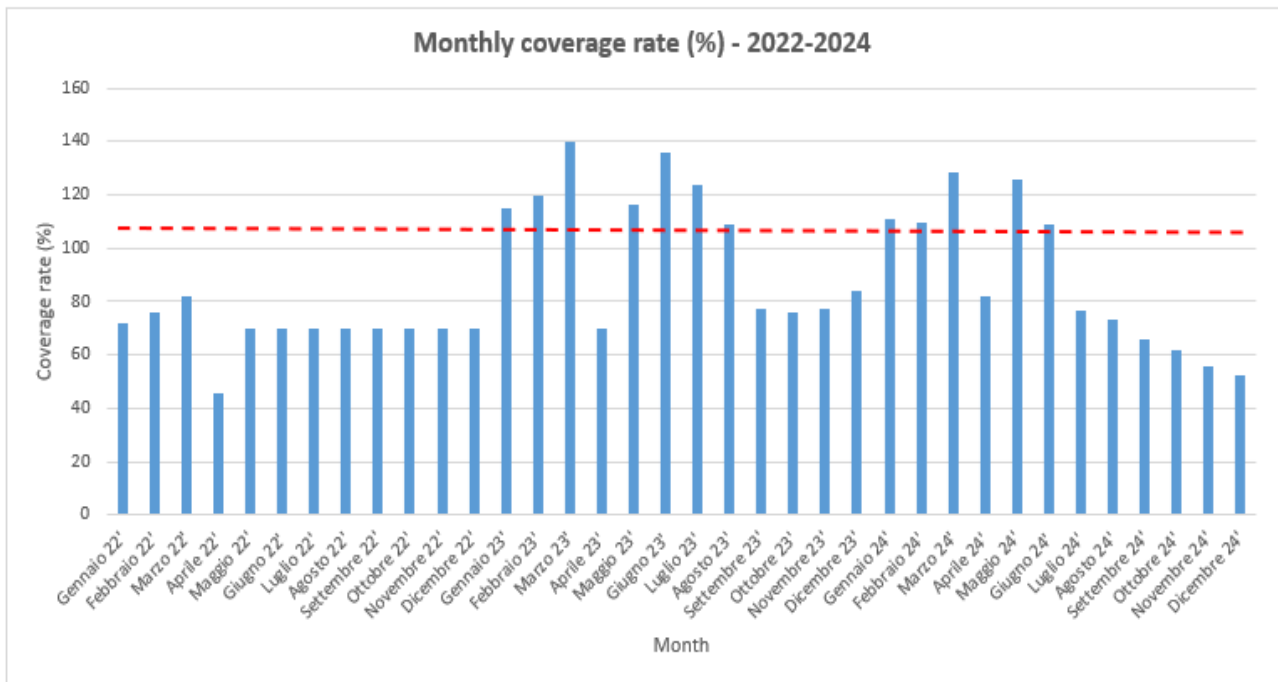


Figure 160_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Municipio located in Corso San Vito, 2.

The chart illustrates the monthly coverage rate (%) for the building at Corso San Vito over the period 2022–2024, considering only PV production. The coverage rate represents the share of electricity demand met by solar generation: values above 100% indicate surplus production, while values below 100% reflect the need to rely on the grid. The data reveal a clear seasonal pattern. In 2023, the building recorded its best results, with peaks above 140% in May and around 130% in July. Other months, such as March, April, June, and August, also exceeded 100%, showing that PV production was consistently higher than demand during spring and summer. By contrast, the colder months—from October to February—regularly show lower coverage, often below 80% and in some cases under 60%, as in February 2022 and December 2024. In 2024, March to May performed relatively well, but coverage gradually declined in the second half of the year, dropping from around 100% in August to less than 60% in December. This recurring imbalance between summer surpluses and winter deficits highlights the limits of direct self-consumption. Adding an energy storage system would make it possible to retain excess production from high-yield months and use it when solar generation is low, improving the building’s self-sufficiency and reducing dependency on the electricity grid.

- **Ufficio Protezione civile – Via Manzoni, 8**

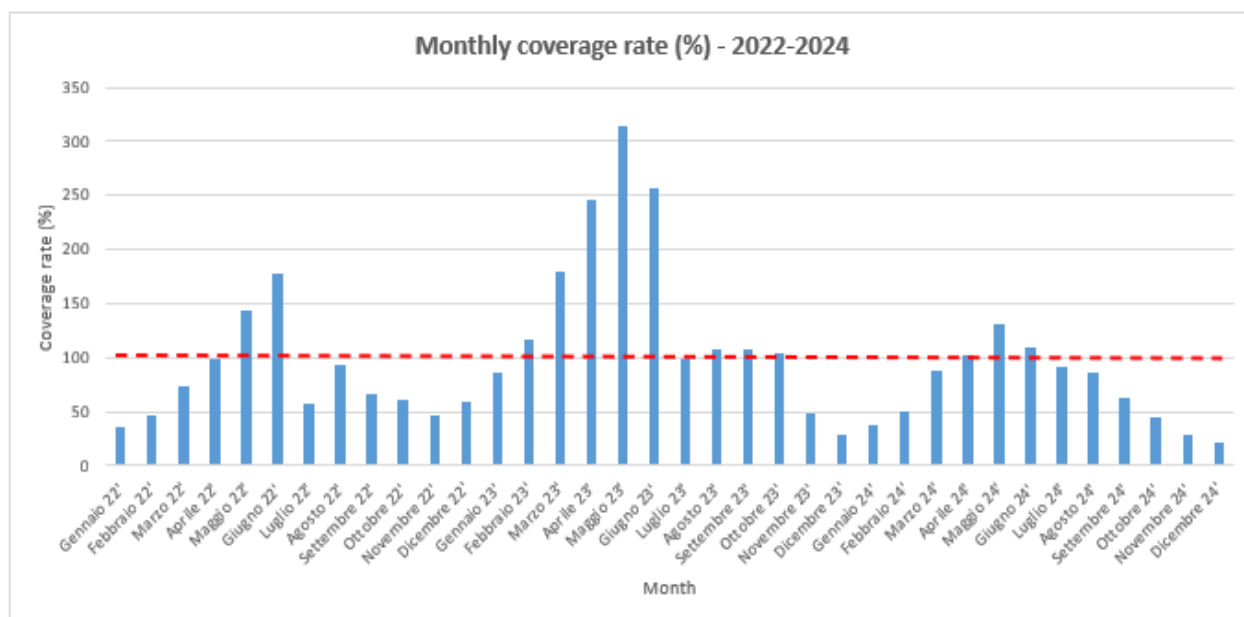


Figure 161_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Ufficio Protezione civile located in Via Manzoni, 8.

The chart illustrates the monthly coverage rate (%) for the Civil Protection Office over the period 2022–2024, based exclusively on photovoltaic (PV) production. The coverage rate shows the share of electricity demand covered by solar energy: values above 100% indicate a surplus, while values below 100% reflect the need to draw power from the grid. The data highlight a strong seasonal variability. In 2023, the building reached its best performance, with June peaking at more than 300% and April, May, and July all exceeding 200%. These results point to significant surpluses during spring and early summer, likely due to high solar generation combined with relatively low electricity demand. By contrast, the winter months—from November to February—regularly fall below 40%, in some cases close to 20%, underlining a heavy reliance on grid supply. In 2024, overall coverage is lower, with June just above 140% and a progressive decline during the second half of the year. This pronounced imbalance between summer surpluses and winter shortages emphasizes the benefits of integrating an energy storage system. Capturing excess electricity produced in high-yield months and reusing it later would enhance the building’s self-sufficiency, reduce dependence on the grid, and optimize energy use throughout the year.

- **Delegazione Comunale – Via del Bosco, 19**

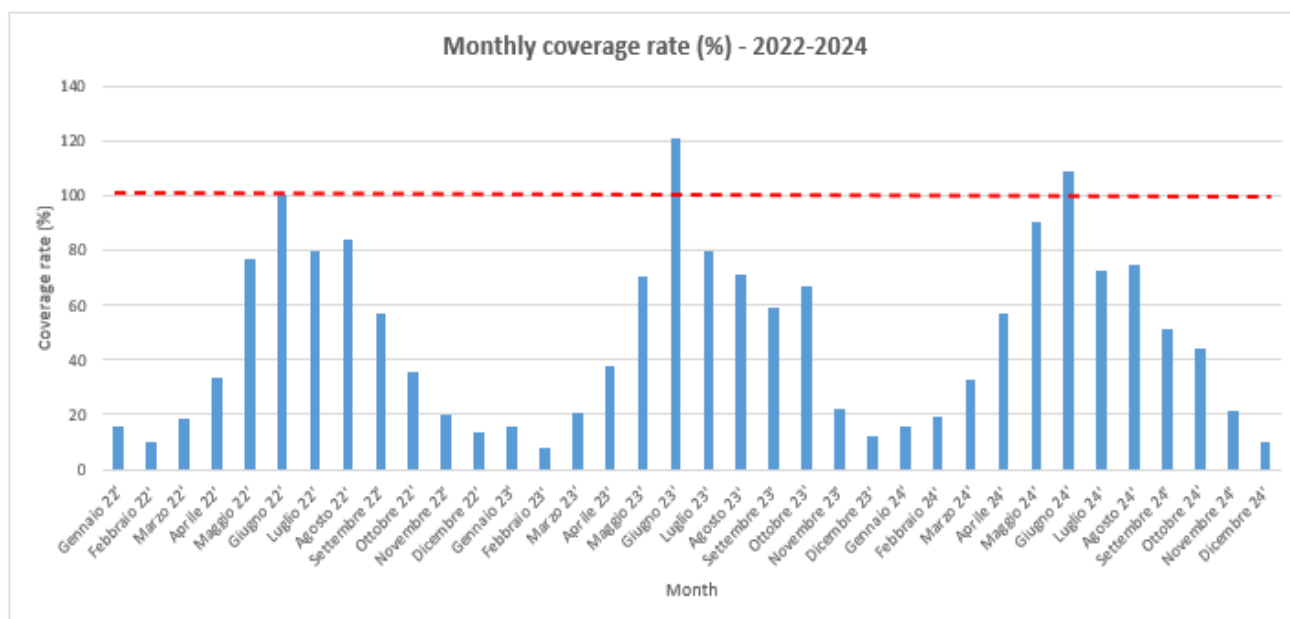


Figure 162_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Delegazione Comunale located in Via del Bosco, 19.

The chart shows the monthly coverage rate (%) for the building located at Via del Bosco 19 over the period 2022–2024, based only on photovoltaic (PV) energy production. The coverage rate indicates the share of the building’s electricity demand met by the PV system: values above 100% point to a production surplus, while values below 100% reveal the need to rely on grid electricity. The results clearly follow a seasonal pattern. In the summer months, the PV system performs particularly well, with coverage rates exceeding 120% in June 2023 and reaching around 100% in July 2024—evidence of production surpassing the building’s energy needs. In contrast, during the winter and early spring, coverage drops significantly, often below 40%, and in some cases as low as 10–20% in January and February. These figures highlight the system’s limited contribution during periods of low solar irradiance, when the building depends almost entirely on external supply. This imbalance underscores the need for energy storage. By integrating a battery system, the surplus electricity generated in the summer could be stored and reused in the winter, improving the building’s self-sufficiency, reducing waste, and lowering its dependence on the grid.

- **Croce Rossa Italiana – Via Petrarca, 24**

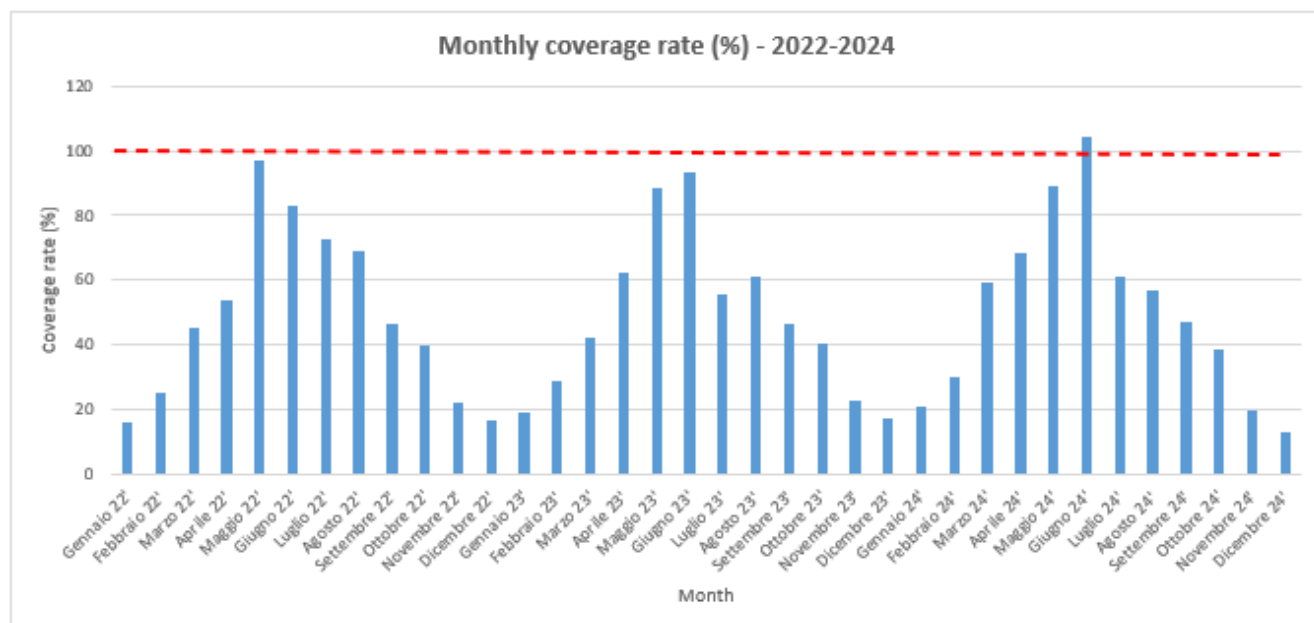


Figure 163_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Croce Rossa Italiana located in Via Petrarca, 24.

The chart shows the monthly coverage rate (%) for the building located at Via Petrarca 24 over the period 2022–2024, based only on photovoltaic (PV) production. The coverage rate expresses the share of electricity demand covered by the PV system: values above 100% indicate surplus generation, while values below 100% signal the need for grid supply. The results reveal a clear seasonal pattern. Between May and August, coverage rates are consistently higher, often above 80%. In June 2024, the building even surpassed 100%, producing more energy than it consumed, while in May 2022 and May 2024 coverage was close to full demand (about 89% and 96%). By contrast, in the winter months coverage drops sharply, with values as low as 12.6% in December 2024 and 16.2% in January 2022, reflecting the strong dependence on external electricity when solar generation is limited. This seasonality highlights the advantage of adopting storage solutions. A battery system would make it possible to capture the summer surplus and reuse it during low-generation periods, improving energy autonomy, reducing waste, and strengthening the reliability of the building’s energy supply.

- Auditorium – Via San Nicolò

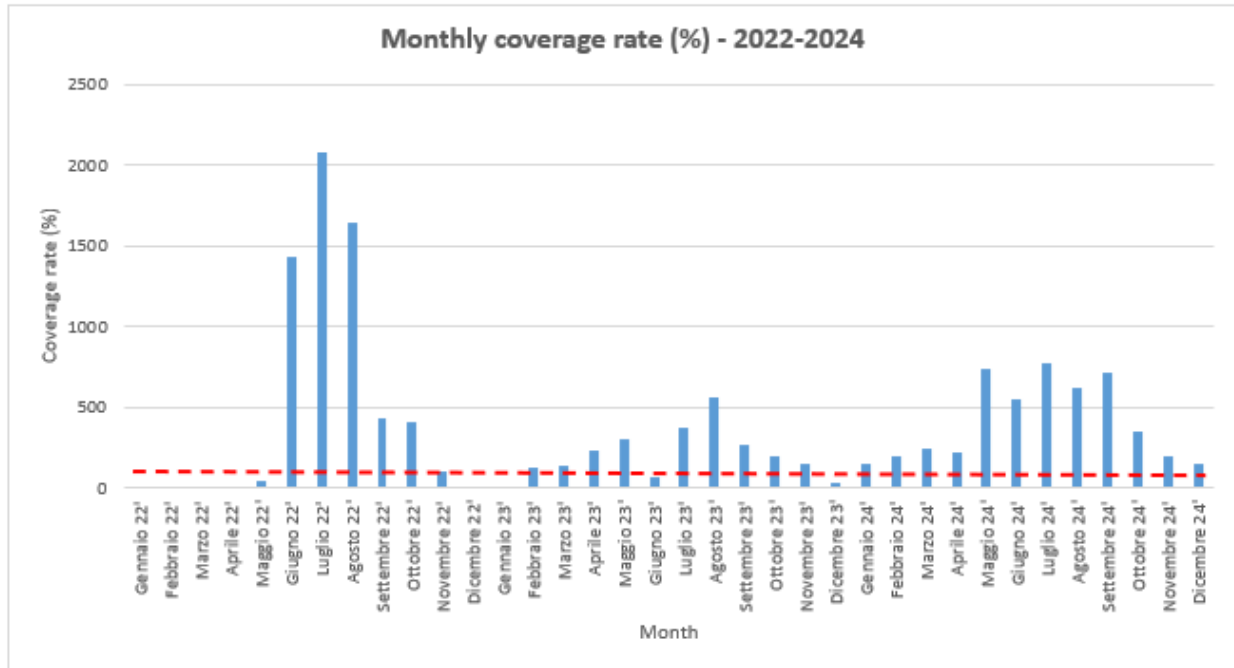


Figure 164_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Auditorium located in Via San Nicolò

The chart shows the monthly coverage rate (%) for the Auditorium building from 2022 to 2024, based only on photovoltaic (PV) production. Between May and September 2024, the system consistently outperformed demand, with coverage rates between 553% (June) and 776% (July). The peak was recorded in July 2024, when PV production was over seven times the building's consumption. In contrast, during winter 2022, coverage dropped sharply—just 4.2% in January and 6.0% in February—highlighting high reliance on the grid. Over the three years, consumption significantly decreased: from over 6,000 kWh/month in early 2022 to below 100 kWh/month in many months of 2024. This trend underscores the importance of energy storage to capture summer surpluses and improve self-sufficiency during low-production periods.

- **Parco Monte Ceraulo – Via Pulei, 51**

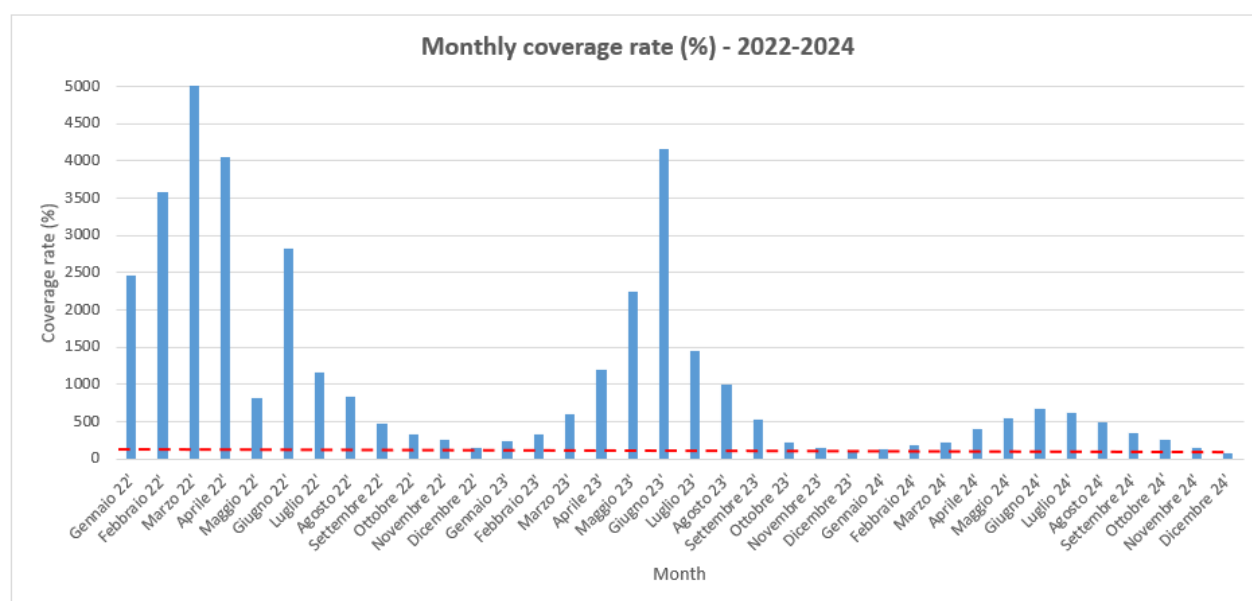


Figure 165_Trend of the Monthly Coverage Rate (%) from January 2022 to December 2024 of Parco Monte Ceraulo located in Via Pulei, 51.

The chart illustrates the monthly coverage rate (%) for Parco Monte Ceraulo over the period 2022–2024, based on PV energy production relative to electricity consumption. In this location, PV output is particularly high due to the possibility of ground-mounted panel installation, given the limited building surface area and the vast open space available. As a result, Monte Ceraulo ranks as the top-performing municipal site in Mascalucia in terms of solar energy generation. Throughout the three-year period, spring and summer months (April–September) consistently recorded coverage rates above 100%, with peaks exceeding 300% between May and July 2023—clearly indicating significant energy surplus. During the winter months (December–February), however, the coverage rate dropped noticeably, falling below 60%, with a minimum of 37% in December 2024.

These findings suggest that in similar contexts, ground-mounted PV systems can provide high levels of energy self-sufficiency. Integrating a battery storage system would allow surplus energy from high-yield months to be stored and used during low-production periods, further reducing grid dependency.

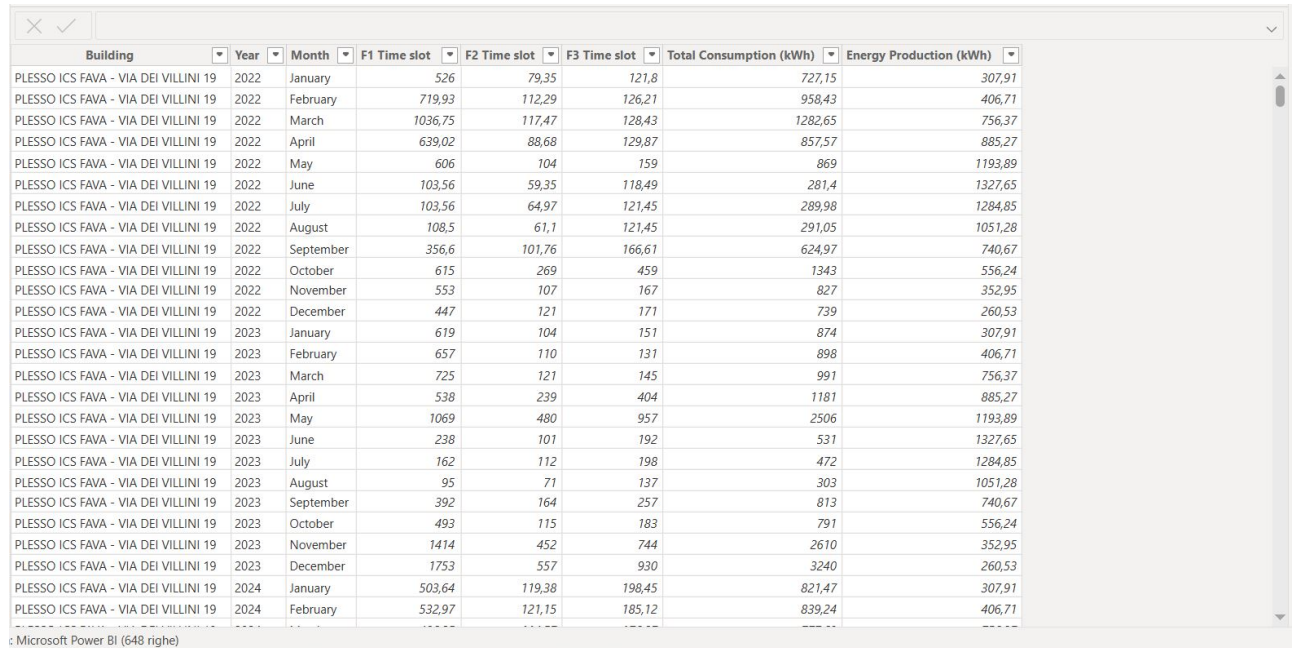
6.4 Design and Implementation of the Power BI Dashboard

Microsoft Power BI is a tool for data analysis and visualization. To analyse the energy consumption of buildings, the production of energy from PV systems, and the injection of excess energy into the grid, several steps were carried out, including:

Data collection: Thanks to the collaboration with the Municipality of Mascalucia, data related to the monthly energy consumption of 13 public buildings were provided. Using the CEA software, estimates of monthly photovoltaic energy production were made, based on the dimensions, intended use, and location of the buildings. Finally, by subtracting the consumed energy from the produced energy, an

estimate of the kWh of energy that could be injected into the grid was made. All this data was entered in table form in an Excel file, allowing it to be linked to Power BI.

Data preparation: Once the Power BI screen is opened, data will be imported from the Excel file with the .xlsx extension, followed by “data transformation.” The next step is to modify the data, if necessary, through the “query.” This means making changes to the extraction and transformation instructions applied during the data import process into the model, with the queries being defined through Power Query. (Fig.171).



Building	Year	Month	F1 Time slot	F2 Time slot	F3 Time slot	Total Consumption (kWh)	Energy Production (kWh)
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	January	526	79,35	121,8	727,15	307,91
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	February	719,93	112,29	126,21	958,43	406,71
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	March	1036,75	117,47	128,43	1282,65	756,37
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	April	639,02	88,68	129,87	857,57	885,27
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	May	606	104	159	869	1193,89
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	June	103,56	59,35	118,49	281,4	1327,65
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	July	103,56	64,97	121,45	289,98	1284,85
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	August	108,5	61,1	121,45	291,05	1051,28
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	September	356,6	101,76	166,61	624,97	740,67
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	October	615	269	459	1343	556,24
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	November	553	107	167	827	352,95
PLESSO ICS FAVA - VIA DEI VILLINI 19	2022	December	447	121	171	739	260,53
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	January	619	104	151	874	307,91
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	February	657	110	131	898	406,71
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	March	725	121	145	991	756,37
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	April	538	239	404	1181	885,27
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	May	1069	480	957	2506	1193,89
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	June	238	101	192	531	1327,65
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	July	162	112	198	472	1284,85
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	August	95	71	137	303	1051,28
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	September	392	164	257	813	740,67
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	October	493	115	183	791	556,24
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	November	1414	452	744	2610	352,95
PLESSO ICS FAVA - VIA DEI VILLINI 19	2023	December	1753	557	930	3240	260,53
PLESSO ICS FAVA - VIA DEI VILLINI 19	2024	January	503,64	119,38	198,45	821,47	307,91
PLESSO ICS FAVA - VIA DEI VILLINI 19	2024	February	532,97	121,15	185,12	839,24	406,71

Figure 166_Screenshot of the data transformation screen using Power Query

Data model creation: A data model was developed that connects and integrates various tables or datasets within the Power BI software. This model enables the analysis of the relationships between energy consumption, photovoltaic production data, and energy injection into the grid. Essentially, it allows for a deeper exploration and understanding of the relationship between these key factors in the energy domain, providing a more comprehensive and analytical view through the visualization tools offered by Power BI. This integrated approach not only provides a detailed view of energy performance but also offers valuable decision-making support to optimize energy efficiency and maximize the use of renewable resources. Moreover, the intuitive interface of Power BI allows users to easily access crucial information and effectively communicate results to stakeholders.

Report creation: The data analysis was enhanced by adding eight new sheets in Power BI, each carefully designed to provide a detailed overview of the energy data. Each sheet includes a variety of charts and a set of data filters to facilitate analysis. For example, the first sheet features a 100% stacked bar chart (Fig. 172); The 100% stacked bar chart in Microsoft Power BI is a type of visualization that allows for comparing the proportions of values relative to the whole within a set of categories. In practice, each bar represents 100% of the total, and the different sections of the bar show how the total value is divided among the specified categories. In this case, it was designed to highlight the distribution of energy consumption based on time, in relation to all 15 buildings included in the study.

Given data on energy consumption over a day and the desire to visualize how much energy is consumed by a specific energy source during different time intervals, the total consumption for each energy source

will be placed on the x-axis, while the time intervals of the day (e.g., from midnight to noon) will be placed on the y-axis. Each bar in the chart represents the distribution of consumption for a specific energy source throughout the day, showing how much of the total consumption occurs in each time interval. This type of visualization can be useful for identifying temporal trends in consumption and understanding how it varies throughout the day. The inclusion of data filters allows users to further explore the data, focusing on specific buildings or time periods. This interactive approach fosters a deeper understanding of the energy data and provides valuable insights for identifying trends and potential areas for improvement.

Analysis and monitoring: The software allows us to extract meaningful insights by providing the ability to compare energy consumption with photovoltaic production. This helps identify any discrepancies or misalignments. Additionally, it allows for the setup of alarms or notifications to monitor real-time data, ensuring that any irregularities are immediately detected. Users can receive alerts when specific conditions are met, enabling timely responses and proactive management of energy consumption and production.

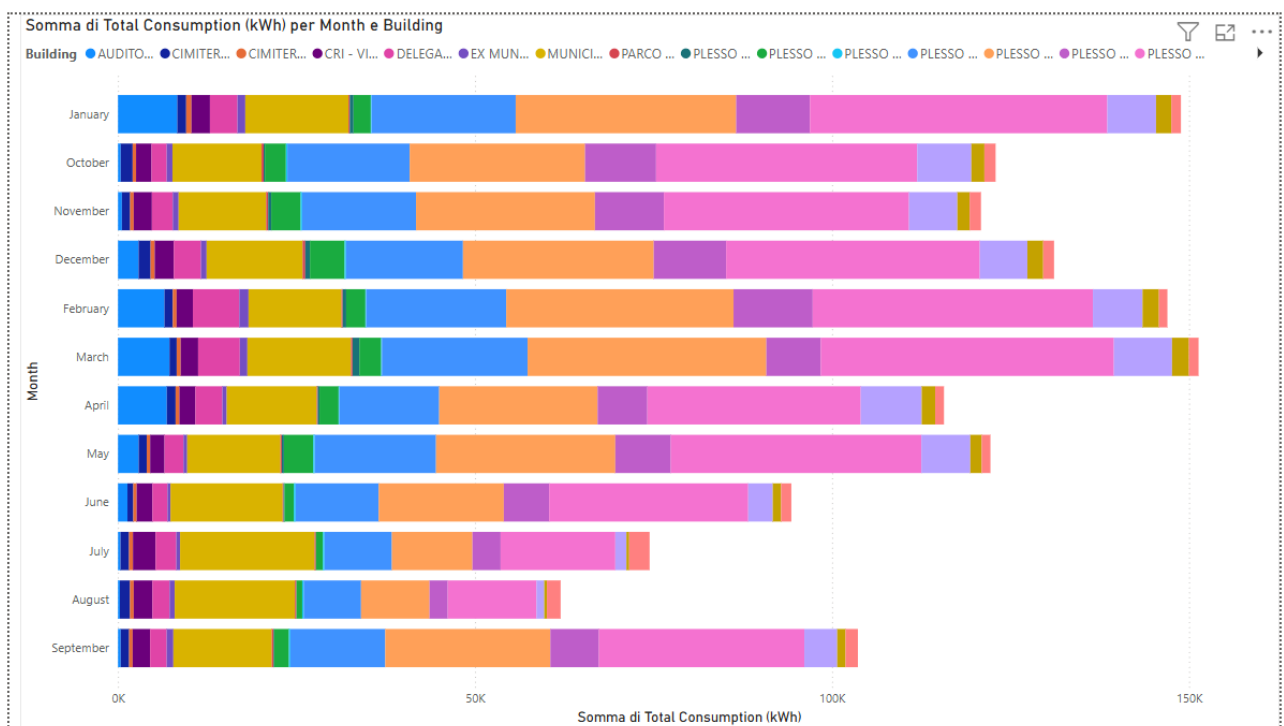


Figure 167_100% Stacked Bar Chart with the legend 'Buildings'

Thanks to the data filters (Fig. 173), it will be possible to narrow down the information to highlight from the chart, such as, for example, the energy consumption of all school buildings during the time interval from 8:00 AM to 2:00 PM, in a specific month of interest.

Year

☐ 2022
☐ 2023
☐ 2024

Month

☐ April
☐ August
☐ December
☐ February
☐ January
☐ July
☐ June
☐ March
☐ May
☐ November

Building

☐ AUDITORIUM - VIA SAN NICOLO'
☐ CIMITERO CENTRO - VIA CIMITERO
☐ CIMITERO MASSANZIATA - VIA MONPILIERI
☐ CRI - VIA PETRARCA, 24
☐ DELEGAZIONE COM - VIA DEL BOSCO 19
☐ EX MUNICIPIO - VIA ETNEA 123
☐ MUNICIPIO - CORSO SAN VITO, 2
☐ PARCO MONTE CERAULO - VIA PULEI 51
☐ PLESSO ICS FAVA - VIA AVVOCATO REINA 14
☐ PLESSO ICS FAVA - VIA DEI VILLINI 19

Figure 168_Data filter

By modifying the legend, replacing "buildings" with "year," and still using the "100% stacked bar chart" (Fig. 174), it will be possible to get an idea of how, over the course of two years, there have been changes in the overall energy consumption of the buildings. Additionally, by adjusting the data filters, users will be able to focus on specific time intervals, days, months, or buildings of interest.

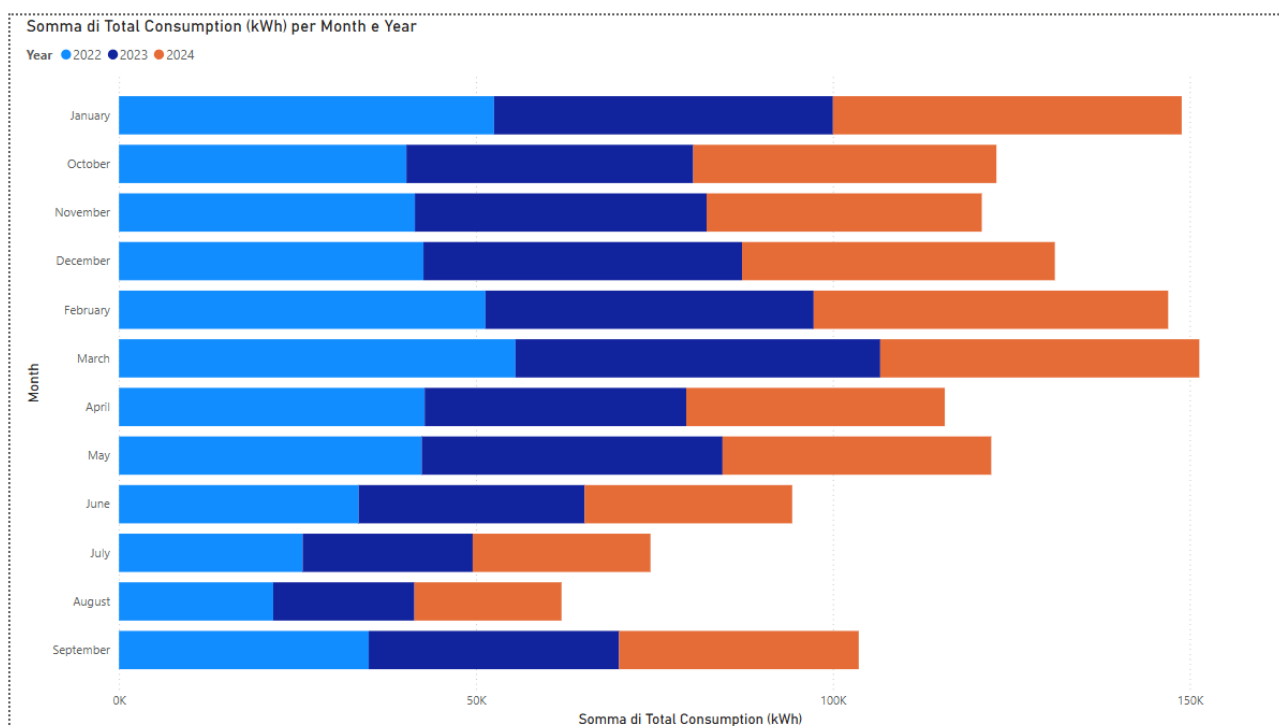


Figure 169_100% stacked bar chart with legend "Year"

Another very interesting type of chart used in the report is the stacked area chart (Fig. 175), which is useful for showing variations and changes in time categories. Each area is stacked on top of the others, making it easy to visualize how the proportions between the categories change at different time stages.

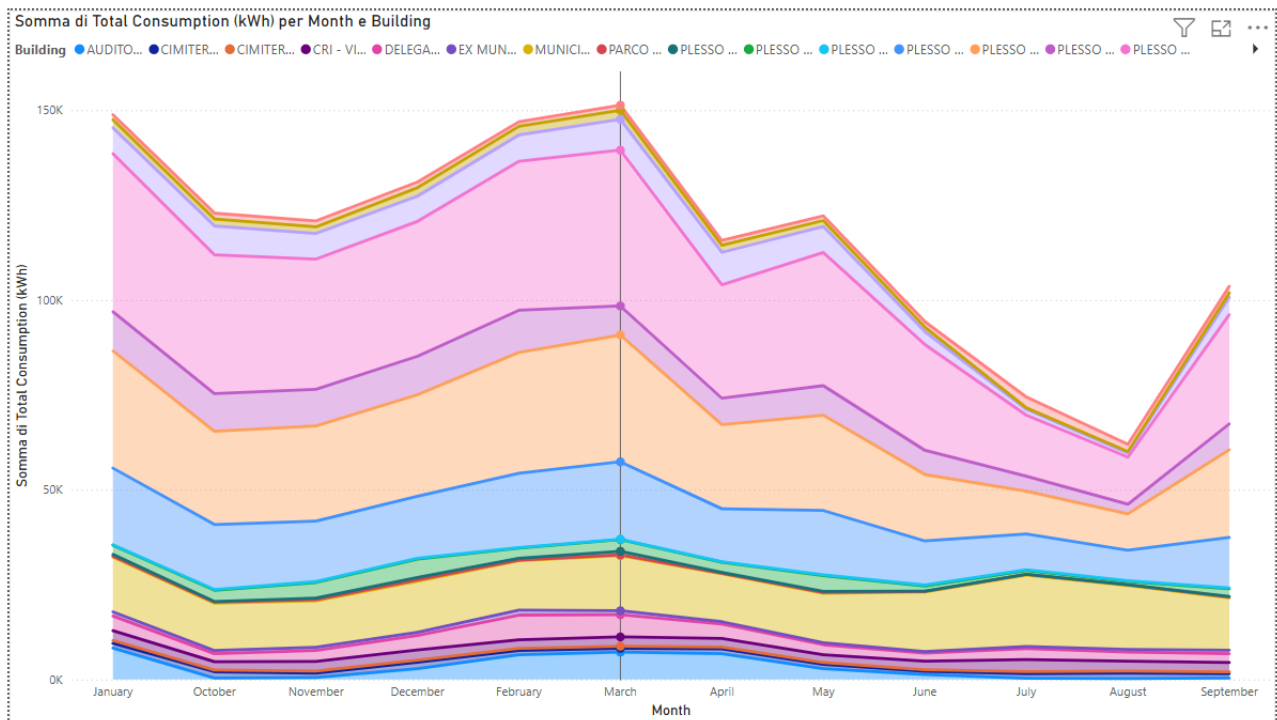


Figure 170_Stacked area chart with legend "Buildings"

In sheet 4, there are several doughnut charts (Fig. 176), which are useful for visualizing the distributions of parts of a whole, highlighting the proportion of each category relative to the total. In particular, the visualization with labels showing the percentage relative to the total is particularly useful, providing a clear view of the proportions relative to the categories.

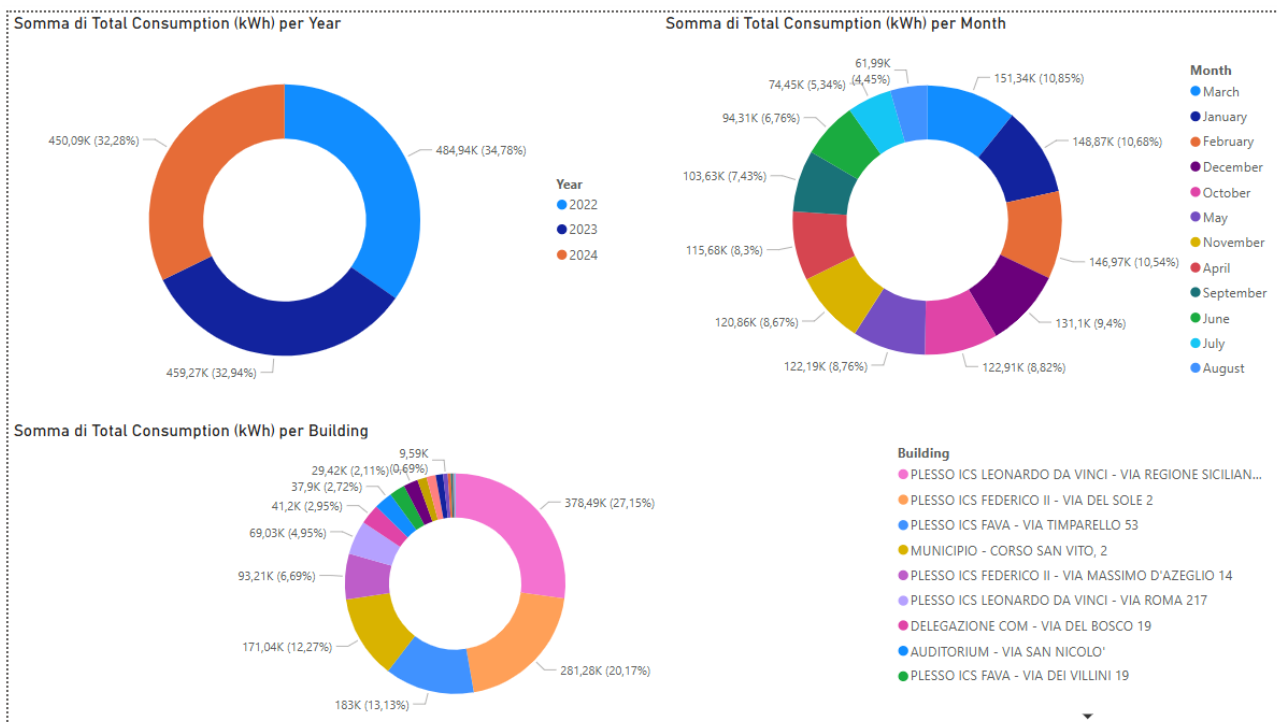


Figure 171_Doughnut chart

Another crucial point in the creation of a report is the inclusion of a KPI (Key Performance Indicator) (Fig. 177), as it is a visual element in Microsoft Power BI that represents a key metric to evaluate the success or performance of an organization, process, or specific objective. In this case, it will simplify the analysis of the average daily energy production, and with the inclusion of data filters, it will be even more useful for providing a comprehensive view of energy production from renewable sources. In sheet 8, the same indicator was used, with the dominant value being the average energy injected into the grid per day (Fig. 177).

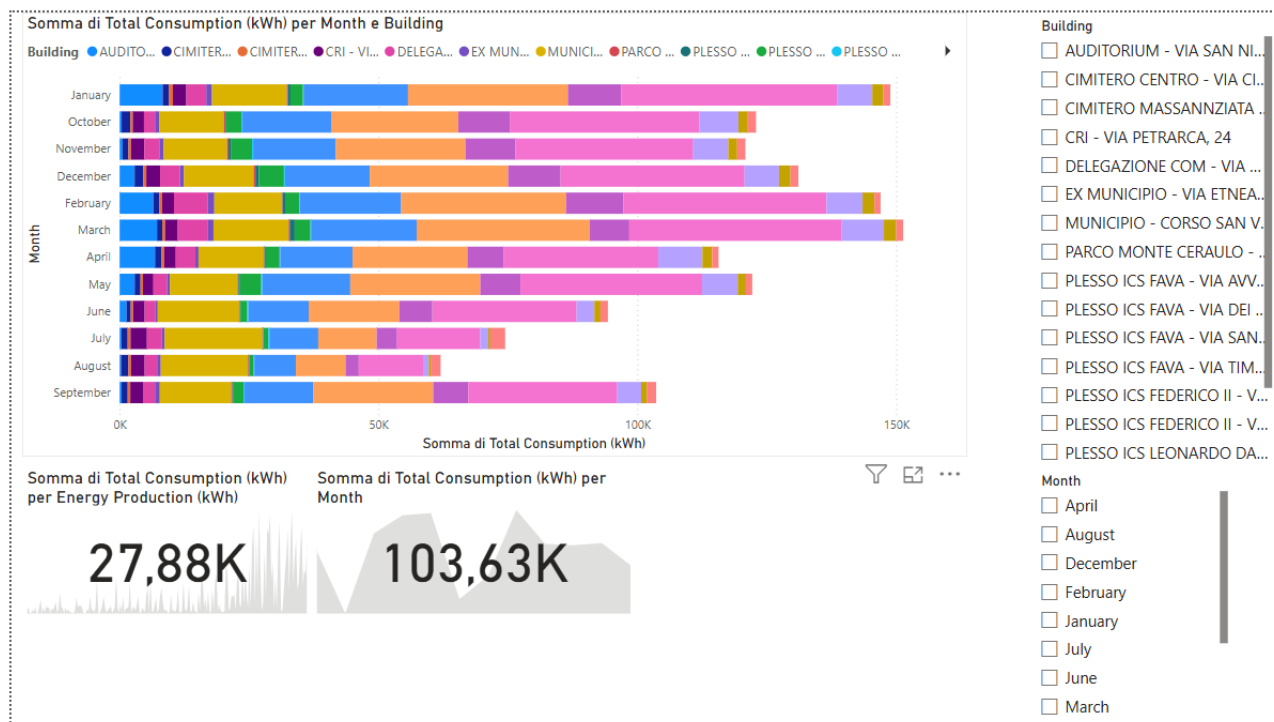


Figure 172_At the bottom of the screenshot, insert KPI (Key Performance Indicator).

The report created with Power BI provides us with the ability to easily and immediately monitor the consumption peaks of each building within the organization. Through clear and intuitively understandable visualizations, it is possible to identify the time intervals and buildings with the highest energy consumption. This enables us to focus efforts on the areas where intervention is most urgent, implementing targeted solutions to optimize consumption and reduce waste. By identifying the specific buildings and time periods with higher energy needs, we can allocate resources more effectively and efficiently. A particularly important aspect is the ability to monitor the actual energy production of photovoltaic systems. Power BI allows for real-time visualization and analysis of energy production data, enabling the assessment of photovoltaic system efficiency. This real-time capability ensures that any issues or inefficiencies in energy production can be quickly detected and addressed.

Equally crucial is the comparison between the energy produced and consumed. This analysis offers a clear and detailed view of how much additional energy can be generated beyond what is needed to power the buildings. With this awareness, it becomes possible to plan strategies to maximize the use of self-generated energy, such as selling excess energy, using it for other processes, or investing in new energy solutions. Additionally, the ability to track the performance of renewable energy sources over time enhances long-term sustainability planning. Furthermore, the ability to conduct historical comparisons and analyses helps identify trends over time, providing valuable insights for planning future actions and continuing to improve the energy sustainability of the buildings.

6.5 Visualisation of results with Power BI

- Dashboard 1

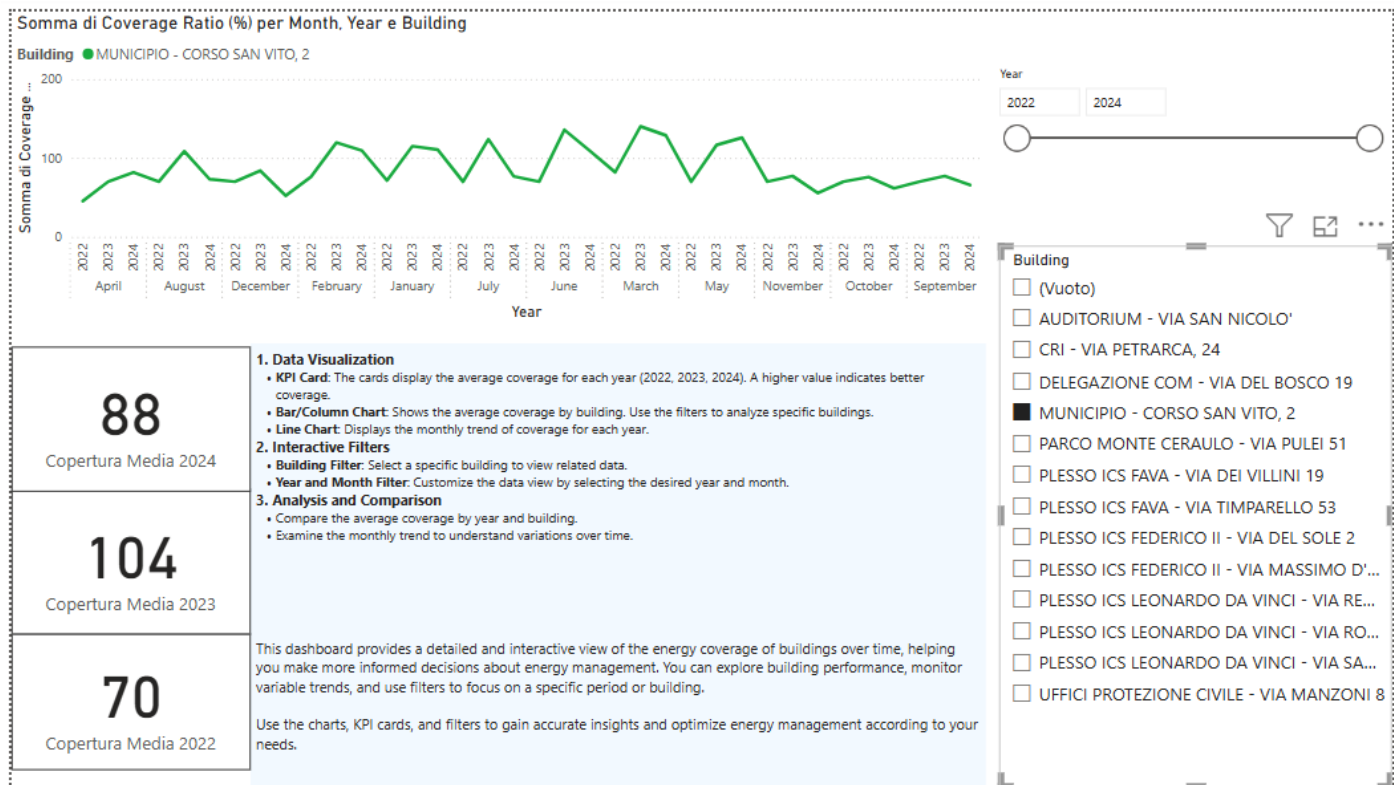


Figure 173_Dashboard 1

- Dashboard 2

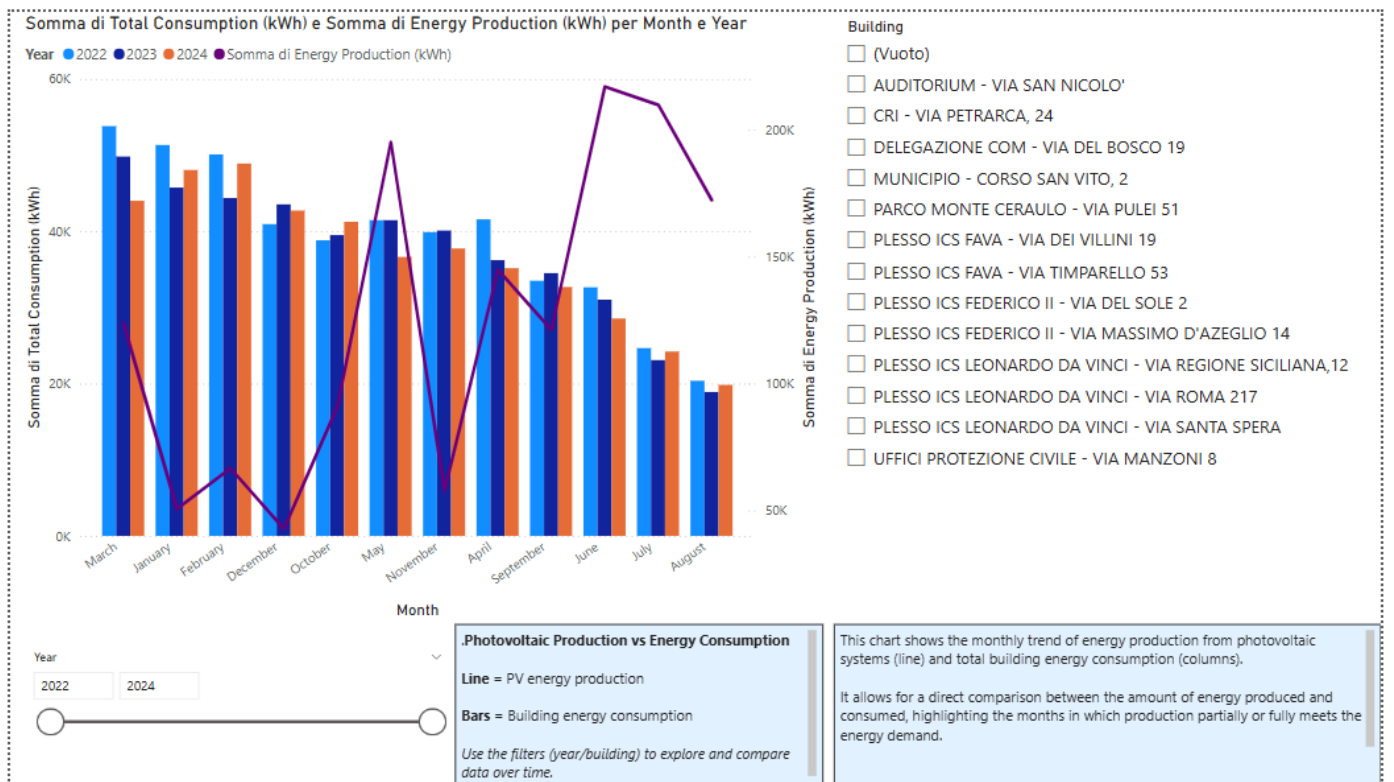


Figure 174_Dashboard 2

- Dashboard 3

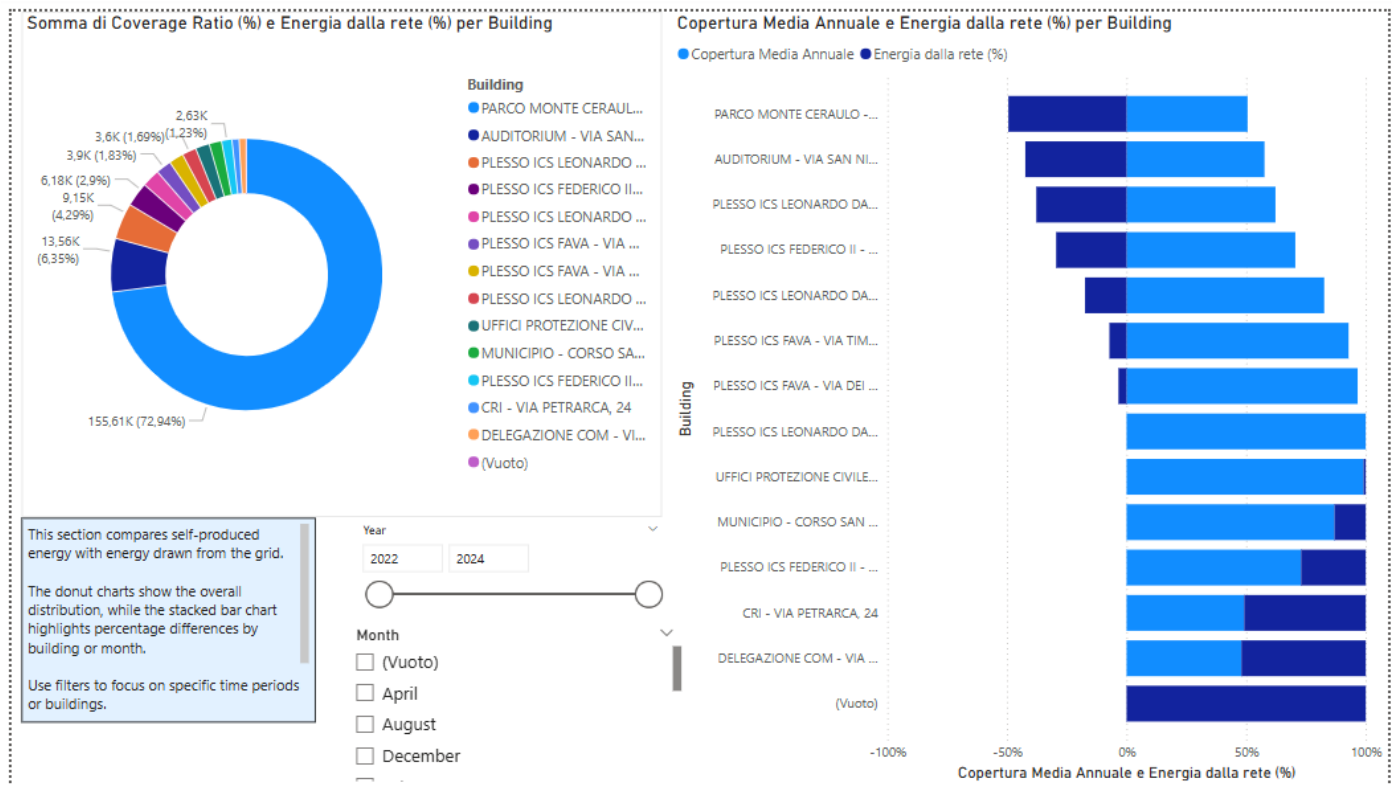


Figure 175_Dashboard 3

6.6 Comparison with Energy Baselines

In this section, the energy performance of the selected buildings is analyzed using CDD as the sole explanatory variable. The electricity consumption considered includes both air conditioning and lighting, thus providing a comprehensive representation of the buildings' overall energy demand. The analysis was conducted by comparing the measured consumption data for the three study years (2022, 2023, and 2024) with a reference model. For the definition of the baseline, the relamping model was adopted, representing a consolidated energy efficiency scenario, and serving as a benchmark for evaluating actual performance. The regression models obtained for each year were compared with the baseline to estimate the correlation between CDD and total electricity consumption. The coefficient of determination (R^2) was used as an indicator of the model's accuracy, highlighting variations in performance over time. To ensure the significance of the results, only buildings with a positive slope ($m > 0$) in the regression model were included in the analysis, since these cases indicate a meaningful relationship between CDD and electricity consumption. Buildings with zero or negative slopes were excluded, as they do not provide useful insights into the link between climatic variables and energy demand. This methodological approach makes it possible to monitor overall electricity consumption in an integrated manner, identify potential anomalies, and support the continuous improvement process required by the ISO 50001 standard.

Each graph presented in this section is accompanied by a brief explanation, aimed at clarifying the results obtained and emphasizing the most relevant aspects of the analysis.

- **Municipality of Mascalucia located in Corso San Vito, 2:**

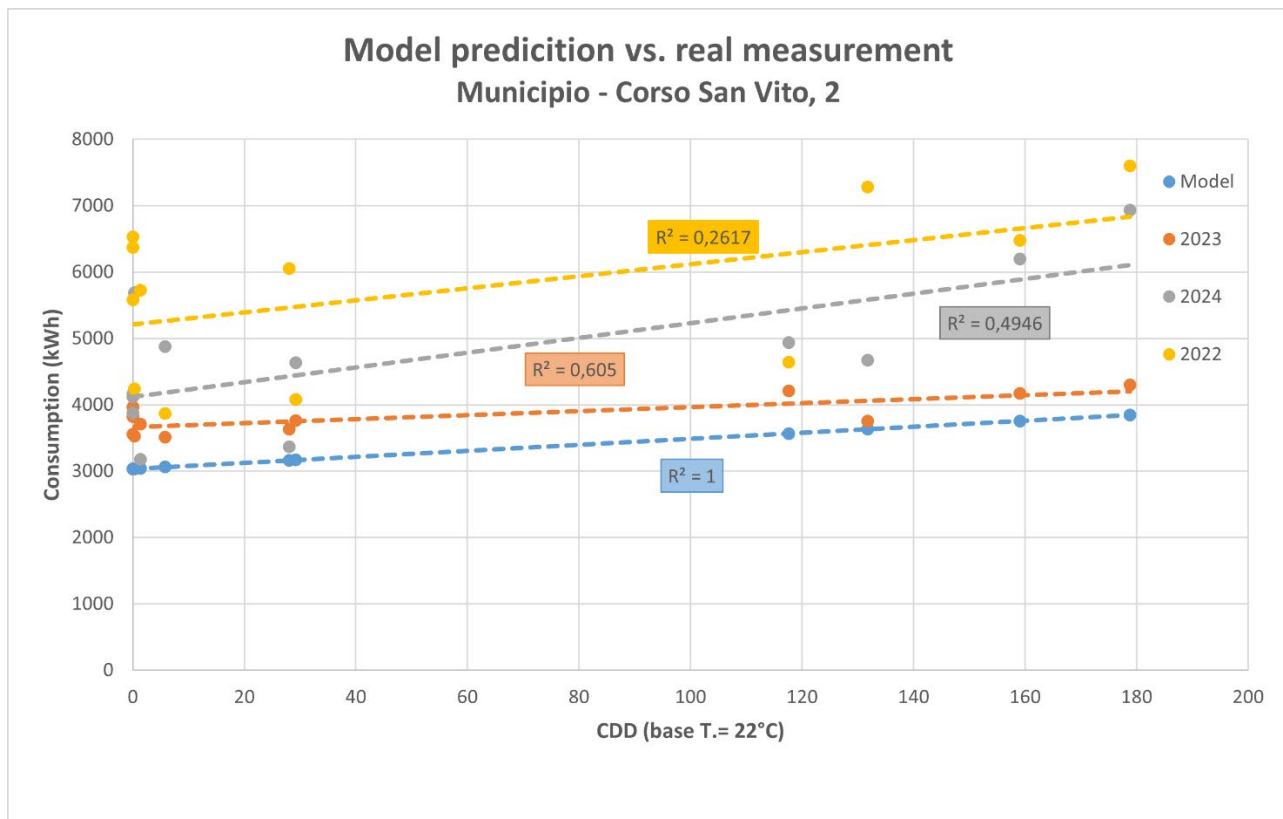


Figure 176_Measured vs. modelled electricity consumption (2022–2024) – Municipio, Corso San Vito 2.

The actual electricity consumption for the years 2022, 2023, and 2024, obtained from energy bills, was compared against a theoretical model developed under the assumption of an optimized lighting system. The theoretical model (blue line) shows a perfect correlation with the climatic variable CDD, with a coefficient of determination of $R^2 = 1$, representing an ideal scenario in which energy consumption increases linearly as cooling demand rises. In 2022, the correlation between consumption and CDD is weak ($R^2 = 0.2617$), indicating erratic energy behaviour and a poor response to external temperature variations. This suggests potential inefficiencies or uncontrolled usage patterns. In 2023, the correlation improves moderately with an R^2 of 0.605, and the regression line flattens, showing a more stable and energy-conscious trend. In 2024, however, the correlation weakens slightly ($R^2 = 0.4946$), and consumption remains high, suggesting that the energy performance gains from 2023 were not sustained or further improved.

In all three years, actual consumption values remain considerably higher than those predicted by the theoretical model. This confirms that while some efforts may have been made toward energy management, they have not yet produced a consistent or substantial impact. Overall, the fluctuating R^2 values and the consistently high consumption levels indicate that the building still has significant room for improvement in aligning its energy performance with optimal efficiency targets.

- **Croce Rossa Italiana located in Via Petrarca, 24:**

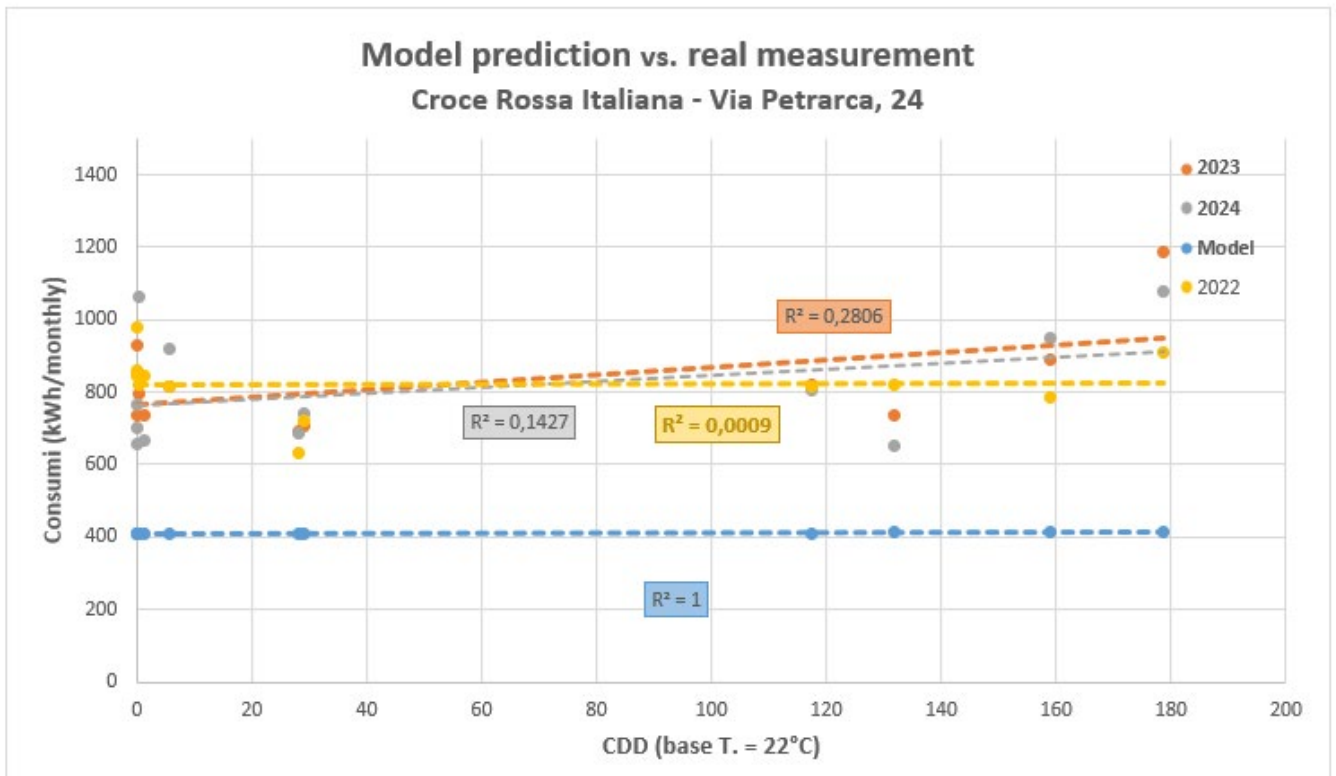


Figure 177_Measured vs. modelled electricity consumption (2022–2024) – Croce Rossa Italiana – Via Petrarca, 24

The chart compares the building's actual electricity consumption in 2022, 2023, and 2024 with a theoretical model based on an optimized lighting system. The model (blue line) represents an ideal situation where energy use rises in step with cooling demand, showing a perfect correlation with CDD ($R^2 = 1$). The real data, however, tell a different story. In 2022, the link between cooling demand and electricity consumption was almost non-existent ($R^2 = 0.0009$), meaning that usage patterns were largely independent of temperature. This suggests irregular behaviour, possibly linked to uncontrolled or inefficient operation. In 2023, the situation improved slightly, with consumption showing a weak but more visible connection to cooling demand ($R^2 = 0.2806$). By 2024, the correlation weakened again ($R^2 = 0.1427$), and consumption remained generally high and inconsistent with climatic conditions. Across all three years, actual consumption stayed well above the theoretical model, typically between 700 and 1,000 kWh per month, compared with the model's ~400 kWh. This gap shows that, while some progress may have been made, the building still consumes far more than expected under optimized conditions. Overall, the results highlight that the Croce Rossa Italiana facility has significant potential for improvement, particularly through more effective energy management to bring real performance closer to the ideal benchmark.

6.7 Performance monitoring

Energy performance monitoring was carried out monthly using a single indicator, the Coverage Rate (%), which expresses the share of electricity demand covered by photovoltaic production. This indicator makes it possible to track, over time, the effectiveness of PV installations on Mascalucia's public buildings, highlighting surpluses, deficits, and thus the degree of dependence on the electricity grid. The monthly analysis of the Coverage Rate allows seasonal variations in solar production to be observed, potential anomalies to be detected, and the benefits of the adopted energy management strategies to be monitored. Actual electricity consumption data were compared with production estimates obtained through the CEA software, which simulated monthly generation based on building geometry, surface orientation, and local solar irradiation. The outcome is a dynamic and updatable monitoring system implemented through Microsoft Power BI, where consumption, production, and Coverage Rate are displayed in Dashboard 1. This approach provides the municipal administration with a practical tool to support the continuous improvement required by ISO 50001, enabling informed decision-making and the planning of corrective or improvement actions.

To complement the graphical analysis, Table 24 summarizes the average Coverage Rate (%) calculated for each public building included in the study, over the three monitored years (2022–2024). The indicator represents the mean share of electricity demand covered by photovoltaic generation, thus allowing a direct comparison of performance among different buildings. Higher values indicate greater self-sufficiency and lower dependence on the electricity grid, while lower values highlight limited PV contribution or higher seasonal mismatches between demand and production. This synthesis facilitates the identification of buildings with significant surpluses, those with critical deficits, and provides a benchmark to support energy planning and prioritization of future improvement measures.

Table 24_Average Coverage Rate (%) of Public Buildings (2022–2024)

Building	Localization	2022 (Coverage %)	2023 (Coverage %)	2024 (Coverage %)
Plesso ICS Fava	Via dei Villini, 19	110,7	110,7	110,7
Plesso ICS Fava	Via Timparello, 53	103,9	103,9	103,9
Plesso ICS Federico II	Via Massimo D'Azeglio, 14	329,9	329,9	329,9
Plesso ICS Federico II	Via del Sole, 2	64,6	64,6	64,6
Plesso ICS Leonardo Da Vinci	Via Roma, 217	113,8	113,8	113,8
Plesso ICS Leonardo Da Vinci	Via della Regione Siciliana, 12	115,3	115,3	115,3
Plesso ICS Leonardo Da Vinci	Via Santa Spera, 15	440,7	440,7	440,7
Municipio	Corso San Vito, 2	71,9	71,9	71,9
Ufficio Protezione civile	Via Manzoni, 8	72,1	72,1	72,1
Delegazione COM	Via del Bosco, 19	45,4	48,7	49,8
Croce Rossa Italiana	Via Petrarca, 24	48,9	47,9	50,7
Auditorium	Via San Nicolò	514,6	205,2	409,7
Parco Monte Ceraulo	Via Pulei, 51	14765,8	14765,8	14765,8

From the values reported in Table 23, it emerges that the Coverage Rate varies widely across the monitored buildings, reflecting the heterogeneity of both consumption profiles and photovoltaic system sizes. Buildings such as the Auditorium and the ICS Leonardo Da Vinci – Via Santa Spera show very high average Coverage Rates, exceeding 400%, due to the combination of low consumption and relatively

large PV production. In contrast, the Delegazione Comunale and the Croce Rossa Italiana register much lower values, around 45–50%, highlighting a limited contribution of PV systems to their electricity demand. Intermediate values are observed in schools such as ICS Fava and ICS Federico II, with Coverage Rates ranging between 60% and 120%, which represent more balanced conditions between production and consumption. The extreme case of Parco Monte Ceraulo, with values exceeding 10,000%, is the result of very low consumption levels and therefore requires careful interpretation, as explained in the methodological note. Overall, the analysis confirms the uneven distribution of self-sufficiency levels among the public buildings of Mascalucia, pointing out those contexts where integration with storage systems or further efficiency measures could significantly improve the effectiveness of photovoltaic installations.

6.8 Comparison of Data

In line with the methodological framework of ISO 50001, the graphs presented for each building allow for monitoring and evaluating energy performance against the defined baseline ([ISO, 2018](#)). The comparison between estimated consumption, actual data from utility bills, and the simulated post-intervention scenario (relamping) provides a clear representation of potential energy savings and deviations from expected values. This approach meets the requirements of the standard regarding the definition of EnPIs and the establishment of reference baselines ([ISO, 2014](#); [ISO, 2018](#)), while also reflecting the scientific literature that highlights the importance of continuous monitoring and management systems for energy efficiency ([Fichera et al., 2020](#); [Dall'O' et al., 2020](#)). Furthermore, the integration of statistical control methodologies, such as Control Chart and CUSUM, is widely recognized as a useful tool for identifying anomalies, seasonal variations, and opportunities for corrective action ([Borgstein et al., 2016](#); [Fichera et al., 2020](#)). The systematic application of this analysis to each building demonstrates how data-driven monitoring can support municipalities in implementing targeted actions, validating savings, and pursuing the principle of continual improvement at the core of ISO 50001 ([ISO, 2018](#)).

- **Plesso ICS Fava - Via dei Villini, 19**

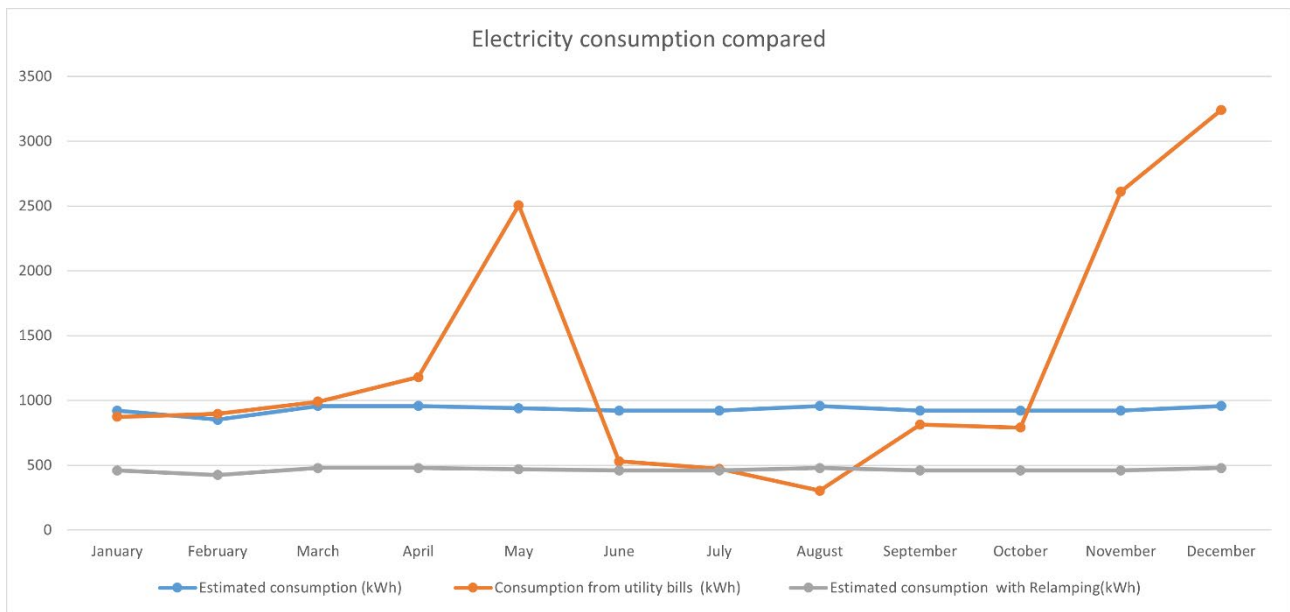


Figure 178_Comparison of actual and estimated electricity consumption with relamping scenario of ICS Fava complex located in Via dei Villini, 19

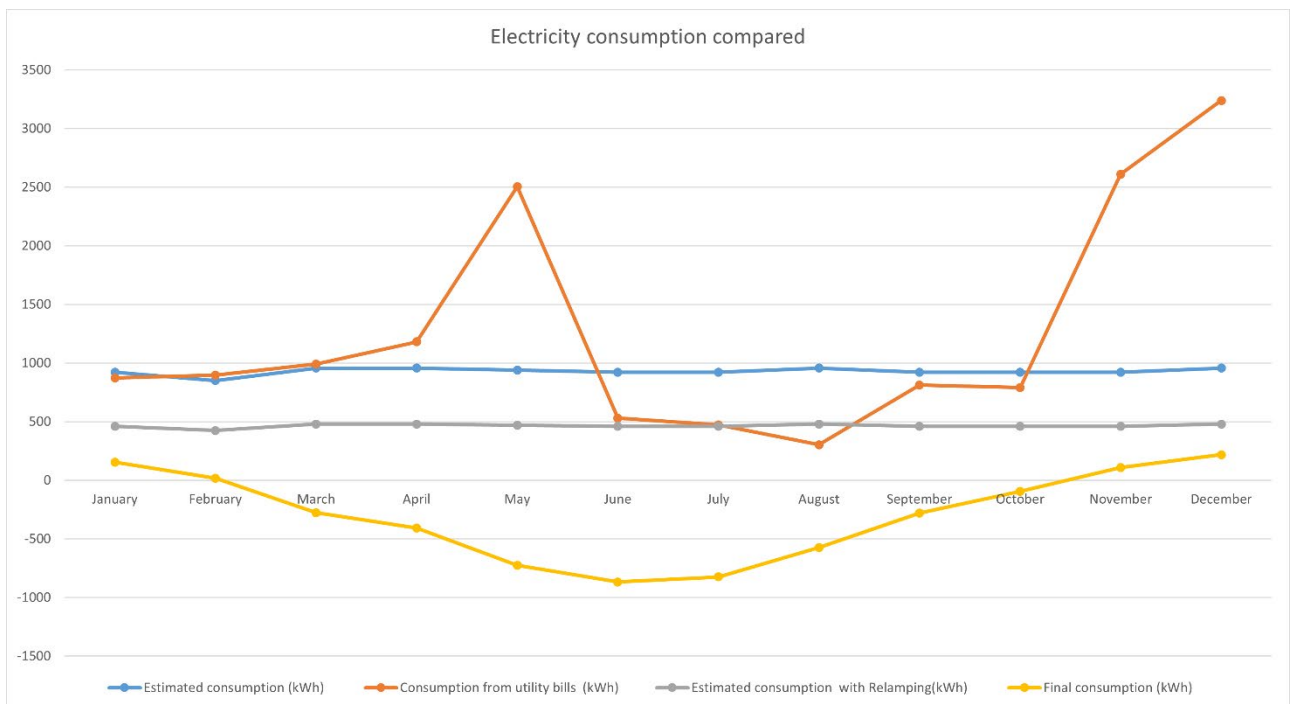


Figure 179_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Fava complex located in Via dei Villini, 19

In both charts, the actual electricity consumption (orange line) shows significant peaks in specific months—particularly May and December—standing out from an otherwise relatively stable profile. These peaks greatly exceed the estimated values, both under baseline and post-relamping conditions. The estimated consumption with relamping (grey line) remains consistently lower than the standard forecast, demonstrating the theoretical efficiency gains of the intervention. While estimated consumption trends remain regular across the months, the actual data suggests occasional anomalies or high-load events that drastically increase energy usage. This indicates that, in this specific building, the variability of real usage likely depends on exceptional operational circumstances rather than

structural inefficiencies alone. As such, while relamping offers potential savings, its real-world impact may be overshadowed by episodic spikes in demand that should be further investigated.

• **Plesso ICS Fava - Via Timparello, 53**

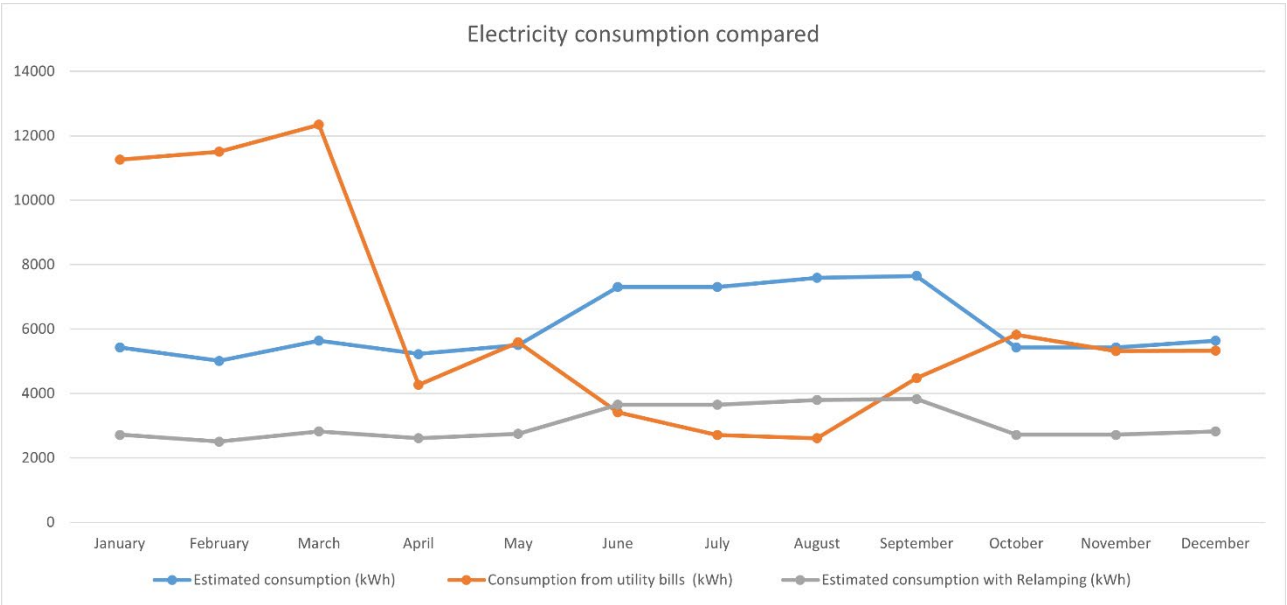


Figure 180_ Comparison of actual and estimated electricity consumption with relamping scenario of ICS Fava complex located in Via Timparello, 53

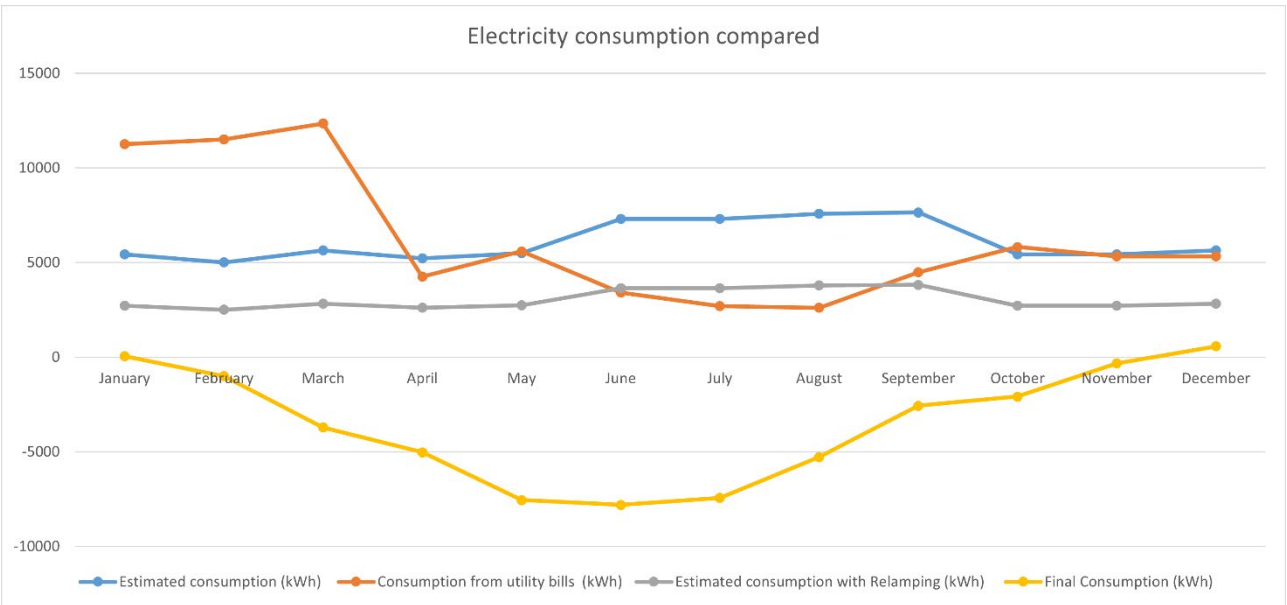


Figure 181_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Fava complex located in Via Timparello, 53

The chart suggests that the relamping intervention produced a positive effect on energy consumption, although this improvement was not immediately observable. In the initial months following the intervention, the cumulative energy savings appear limited or inconsistent, possibly due to transitional factors or delays in the full adoption of the new lighting systems. However, as time progresses, particularly from mid-2023 onward, the improvements become more evident, indicating a gradual alignment with the expected benefits of reduced consumption through more efficient lighting.

It is important to note that the achieved efficiency may be partially obscured by the influence of other variable factors, such as climatic fluctuations (e.g., extremely hot summers increasing cooling loads), variations in user behaviour, changes in building occupancy patterns, or the presence of other non-lighting electrical loads. These elements can significantly impact energy use and should be analysed separately in order to isolate and fully understand the actual impact of the relamping intervention.

- Plesso ICS Federico II – Via M. D’Azeglio, 14**

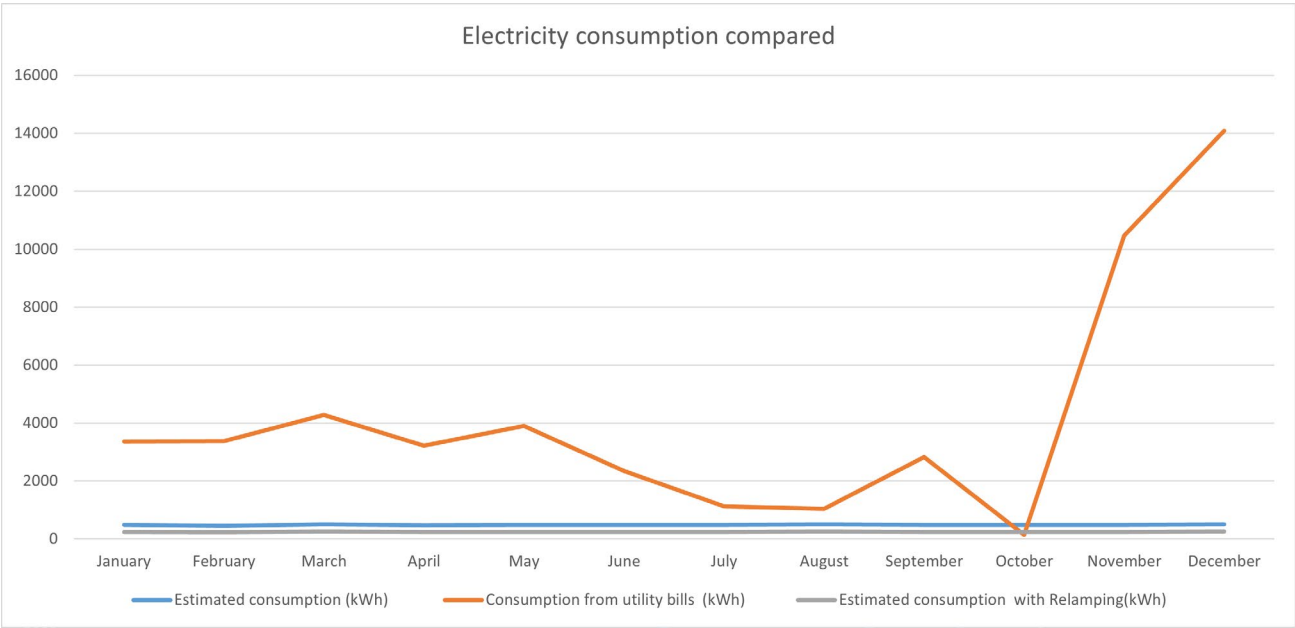


Figure 182_Comparison of actual and estimated electricity consumption with relamping scenario of ICS Federico II complex located in Via M. D’Azeglio, 14

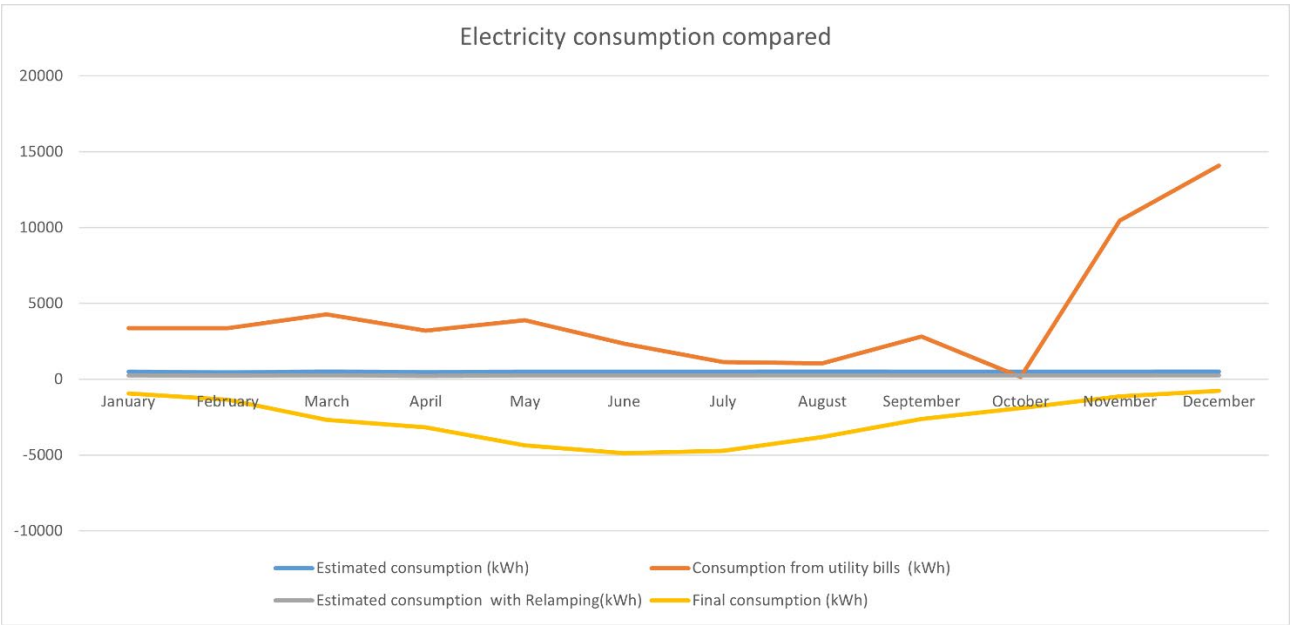


Figure 183_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Federico II complex located in Via M. D’Azeglio, 14

The chart highlights the impact of the relamping intervention and the contribution of the photovoltaic system on the building’s energy consumption. In the initial months following the relamping, the

reduction in consumption appears limited or inconsistent, likely due to transitional factors or a delayed adaptation to the new lighting systems. However, from mid-2023 onwards, the benefits become more evident, suggesting a gradual alignment with the expected energy savings from more efficient lighting. The photovoltaic production follows seasonal trends, and its contribution is reflected in the final consumption curve, which shows the net energy use after on-site generation. The gap between the estimated baseline, the post-relamping consumption, and the final consumption underlines the combined effect of both interventions. It is important to consider that other variables—such as climatic anomalies, changes in occupancy, user behaviour, and additional electrical loads—may affect consumption patterns and partially obscure the true efficiency gains. A separate analysis of these factors would be necessary to fully isolate the impact of the relamping intervention.

- Plesso ICS Federico II – Via del Sole, 2**

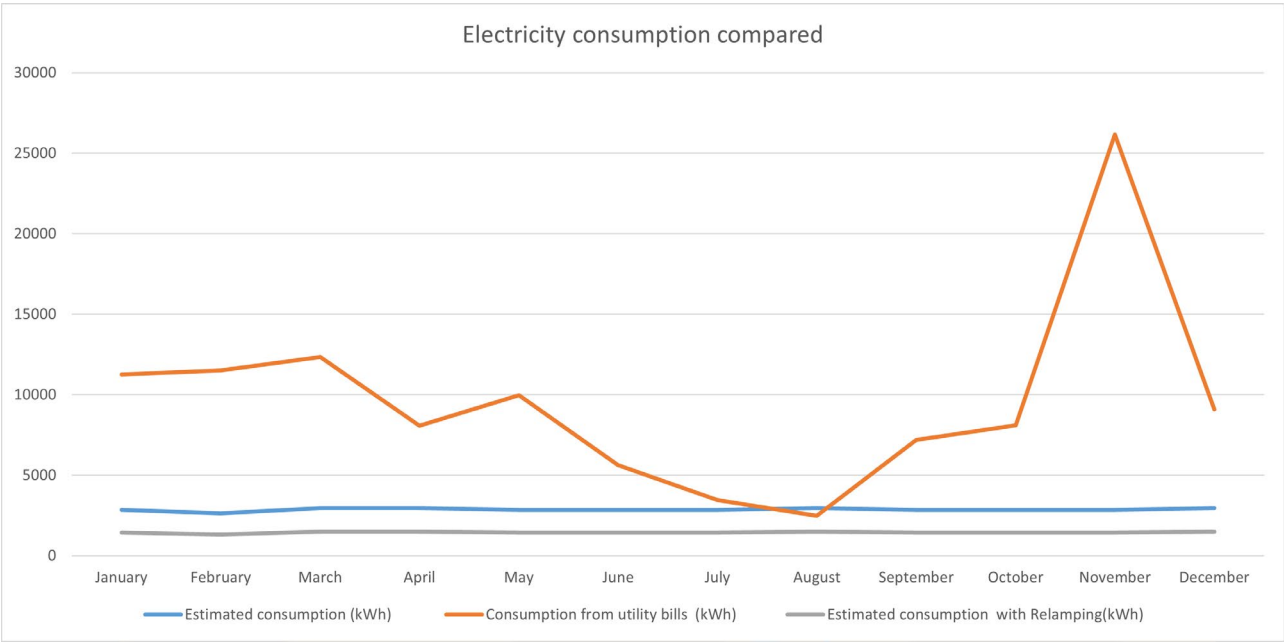


Figure 184_ Comparison of actual and estimated electricity consumption with relamping scenario of ICS Federico II complex located in Via del Sole, 2

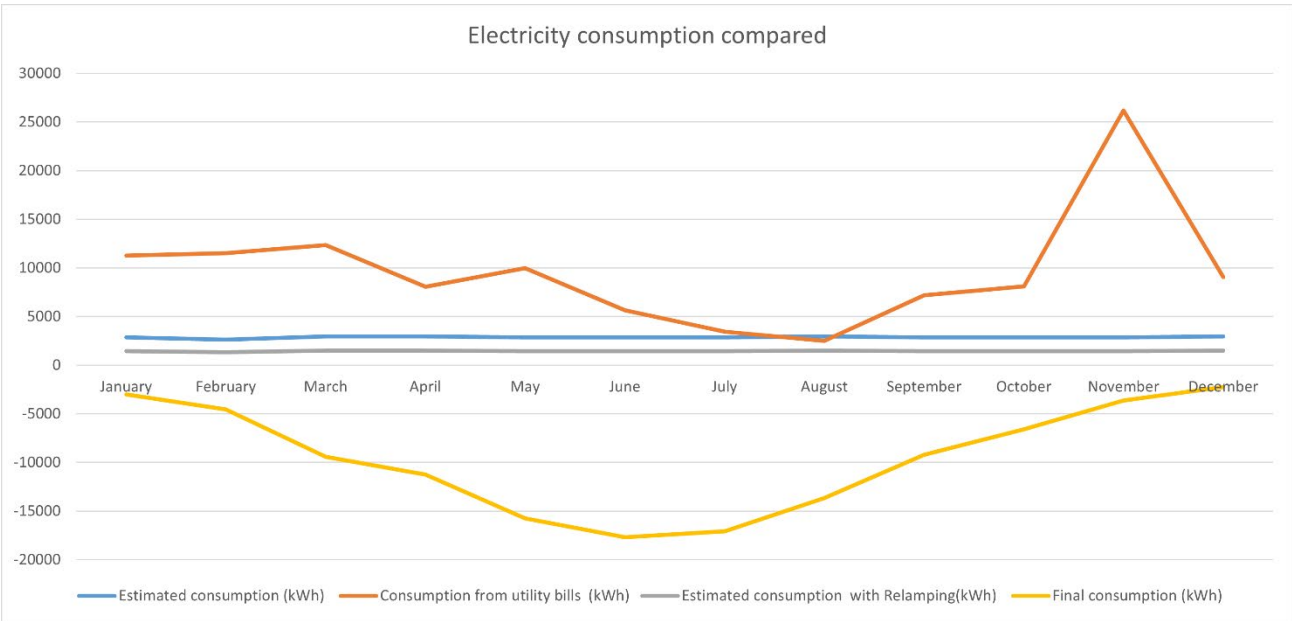


Figure 185_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Federico II complex located in Via del Sole, 2

The two charts compare actual electricity consumption with estimates under two scenarios: baseline conditions and post-relamping intervention. Estimated consumption remains relatively stable across the year in both scenarios, while real consumption (orange line) shows higher variability and significantly exceeds predictions throughout the period. The peak in November represents an exceptional increase that deviates from the general trend, possibly due to specific usage events or anomalies.

The “Final Consumption” curve in the first graph (yellow line) illustrates a substantial and cumulative gap between real and estimated values, highlighting a mismatch between forecasted and actual energy behaviour. Although the relamping intervention is associated with lower estimated values, its impact appears limited in this case, as real consumption remains consistently above expectations.

- **Plesso ICS L. Da Vinci – Via Roma, 217**

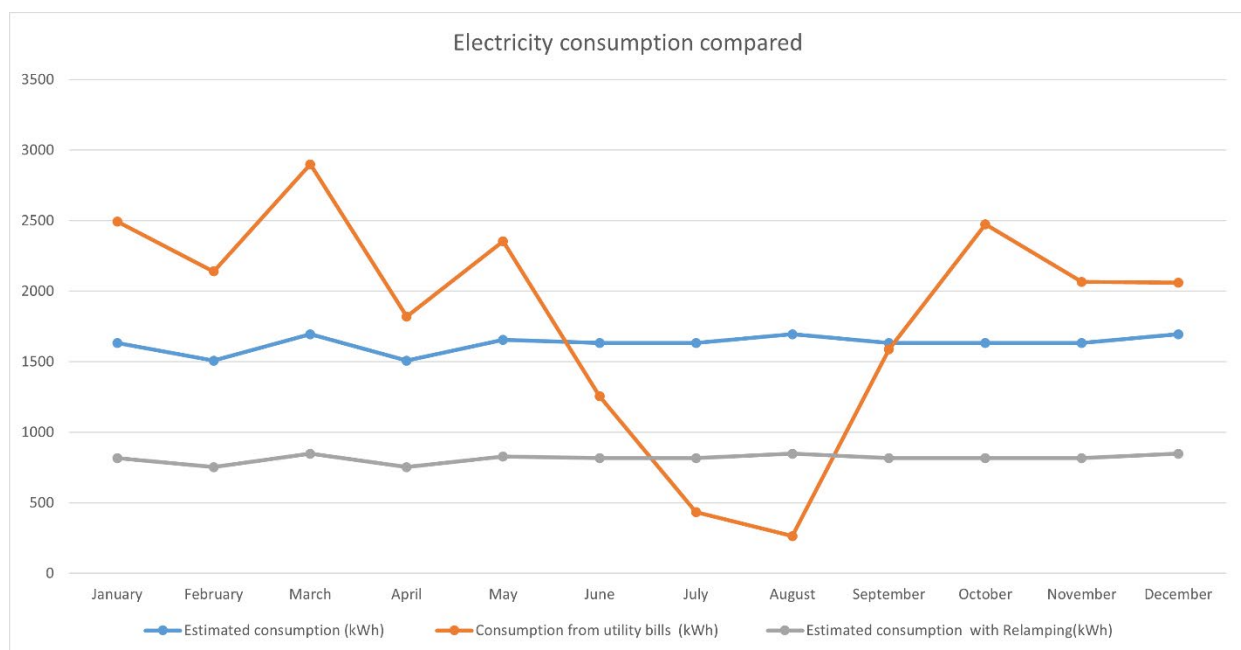


Figure 186_ Comparison of actual and estimated electricity consumption with relamping scenario of ICS Leonardo da Vinci complex located in Via Roma, 217

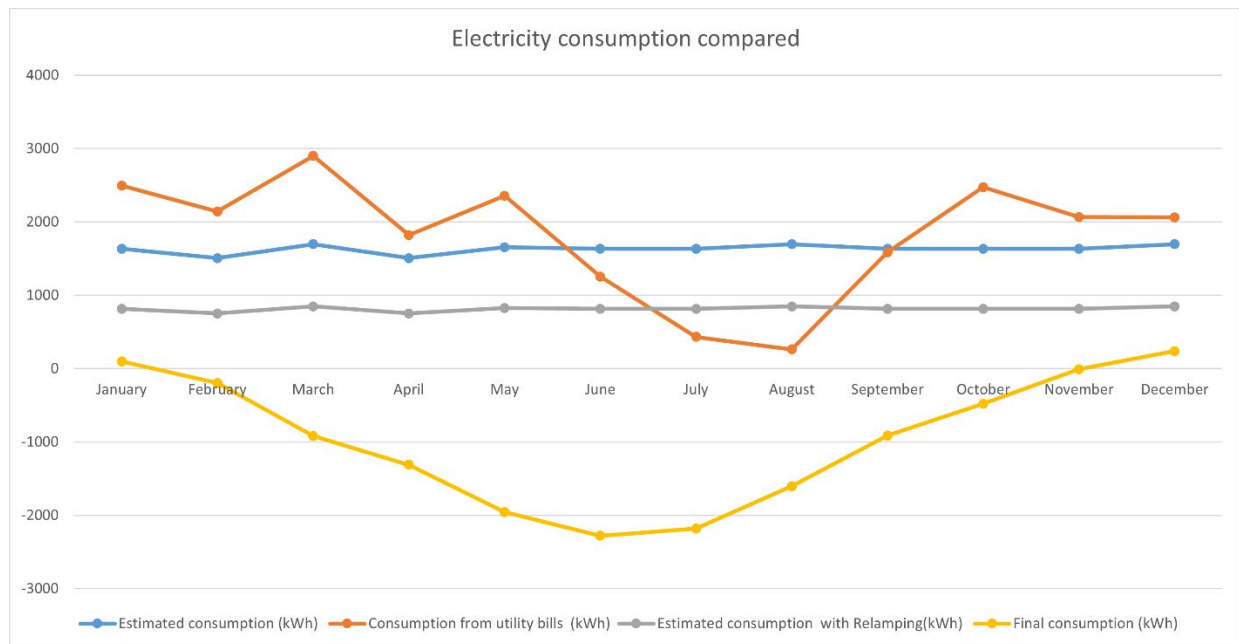


Figure 187_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Leonardo da Vinci complex located in Via Roma, 217

The first graph compares actual electricity consumption with two estimation scenarios: standard conditions and post-relamping intervention. While estimated values remain relatively stable across the months, the actual consumption (orange line) shows significant fluctuations, including a notable drop between June and August, followed by a sharp recovery. The estimated consumption with relamping remains consistently lower than the baseline estimation, confirming the theoretical benefit of the intervention.

The second graph introduces the “Final Consumption” curve (yellow line), representing the monthly difference between real and estimated values with relamping. This curve indicates a clear seasonal pattern: during the summer months, the gap between actual and estimated consumption widens substantially, suggesting unexpected operational dynamics. From September onward, however, the gap narrows progressively, pointing to a gradual stabilization of building usage and a closer alignment with the forecasted energy-saving potential.

- **Plesso ICS L. Da Vinci - Via della Regione Siciliana, 12**

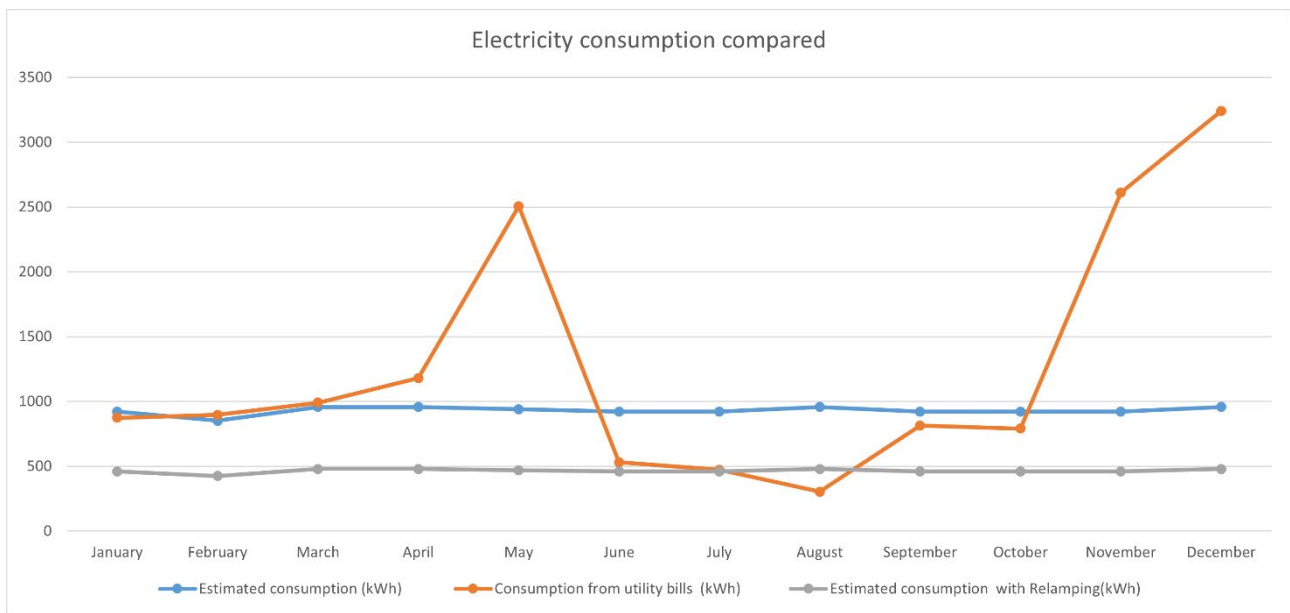


Figure 188_Comparison of actual and estimated electricity consumption with relamping scenario of ICS Leonardo da Vinci complex located in Via della Regione Siciliana, 12

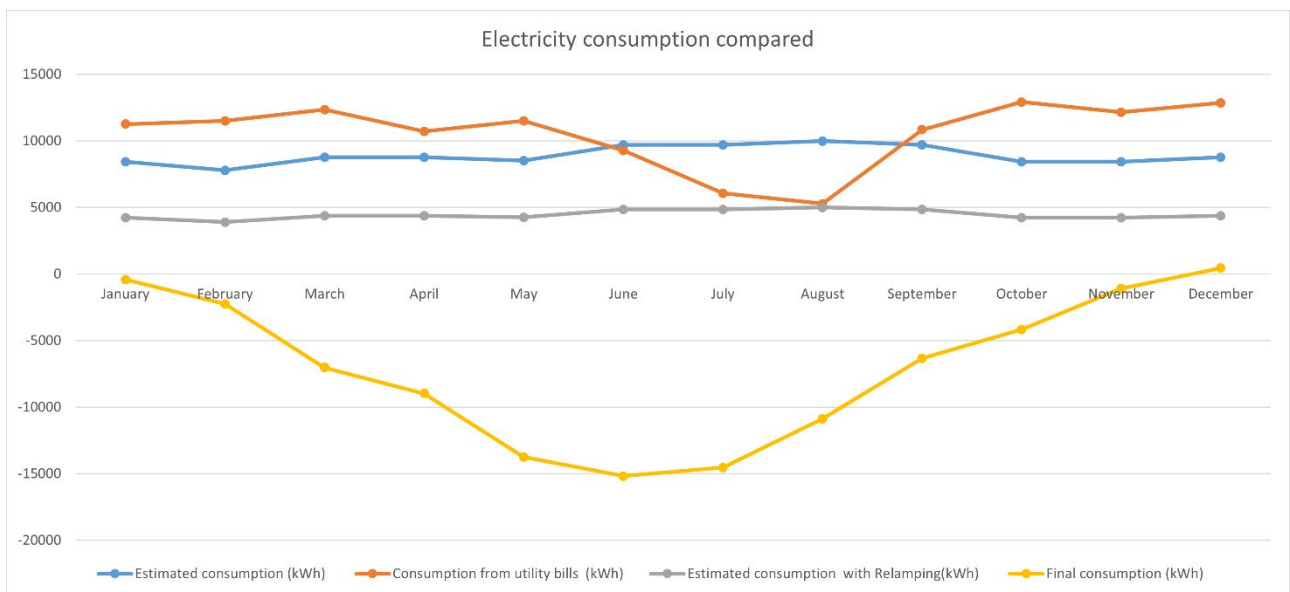


Figure 189_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Leonardo da Vinci complex located in Via della Regione Siciliana, 12

The first graph compares the actual electricity consumption (orange line) with two estimation scenarios: one without intervention and one with the relamping solution. The estimated values, particularly with relamping (grey line), are consistently lower and more stable across all months. In contrast, the real consumption exhibits considerable fluctuation, especially a marked decline in summer (July–August) followed by a strong recovery in the last quarter. In the second chart, the “Final Consumption” curve (yellow line) highlights the monthly difference between real and estimated post-relamping consumption. The curve shows a large cumulative gap, with the actual values exceeding the estimates significantly, especially from March to September. Despite the relamping intervention, the consumption pattern indicates either changes in operational conditions or inefficiencies not addressed by the intervention. A partial convergence is visible toward the end of the year, suggesting a possible trend toward stabilization.

- **Plesso ICS L. Da Vinci – Via Santa Spera, 15**

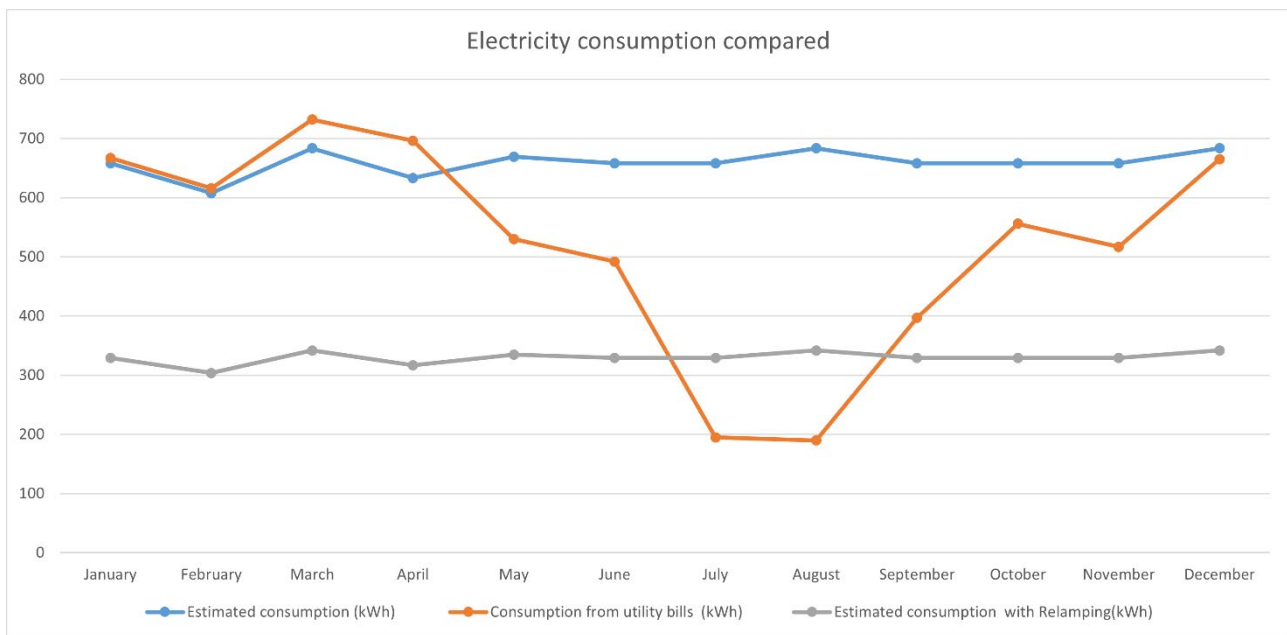


Figure 190_Comparison of actual and estimated electricity consumption with relamping scenario of ICS Leonardo da Vinci complex located in Via Santa Spera, 15

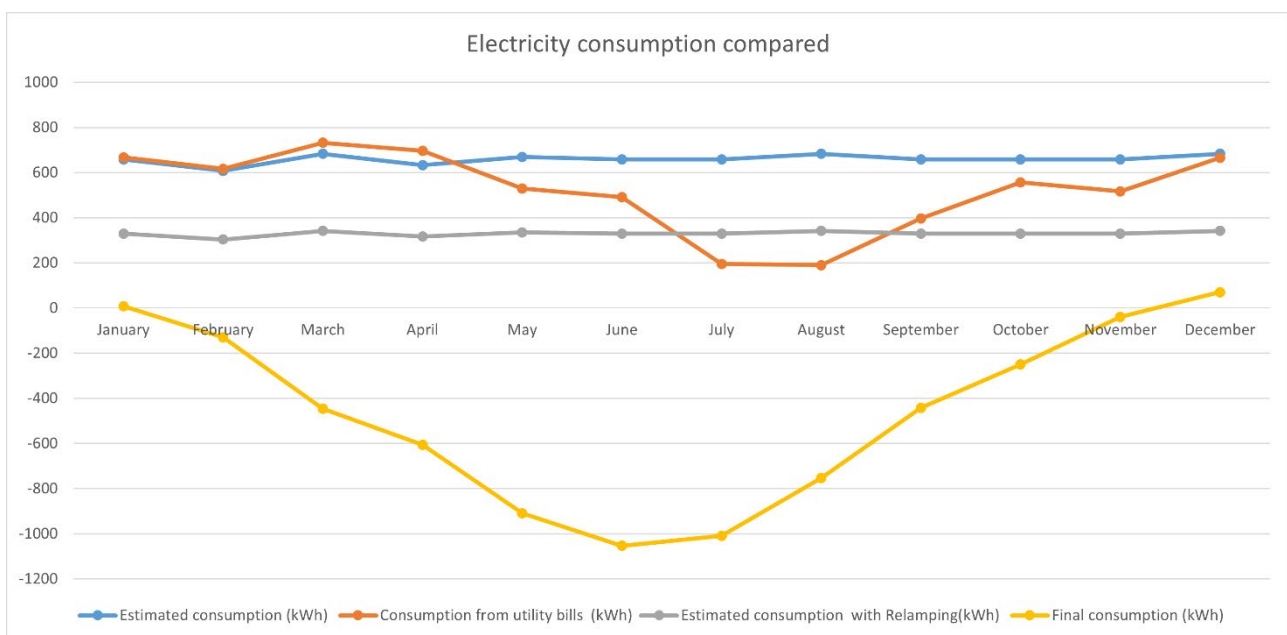


Figure 191_Electricity consumption comparison with cumulative deviation (Final consumption) of ICS Leonardo da Vinci complex located in Via Santa Spera, 15

In both graphs, the actual electricity consumption (orange line) fluctuates significantly throughout the year, with a substantial decrease during the summer months, followed by a gradual recovery in the final quarter. The estimated values remain comparatively stable across the months, with the relamping scenario (grey line) consistently predicting lower consumption. The second chart includes the “Final Consumption” curve (yellow line), which reveals the monthly deviation between real consumption and the estimated consumption after relamping. The graph shows a clear gap developing from February onwards, with the most significant divergence occurring in July and August. Although the relamping intervention indicates potential for energy savings, real data suggest that other operational factors—possibly reduced occupancy or equipment usage—play a key role in shaping actual energy demand

during the mid-year period. The trend begins to realign in the final months, suggesting a return to typical usage patterns.

• **Municipio – Corso San Vito, 2**

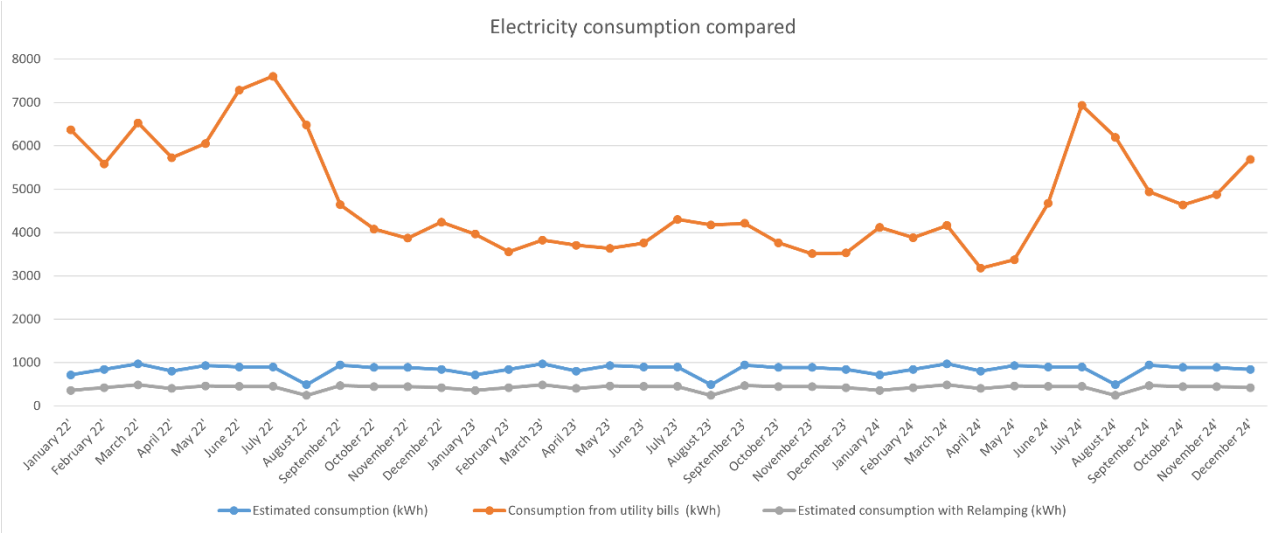


Figure 192_Comparison of actual and estimated electricity consumption with relamping scenario of Municipio located in Corso San Vito, 2

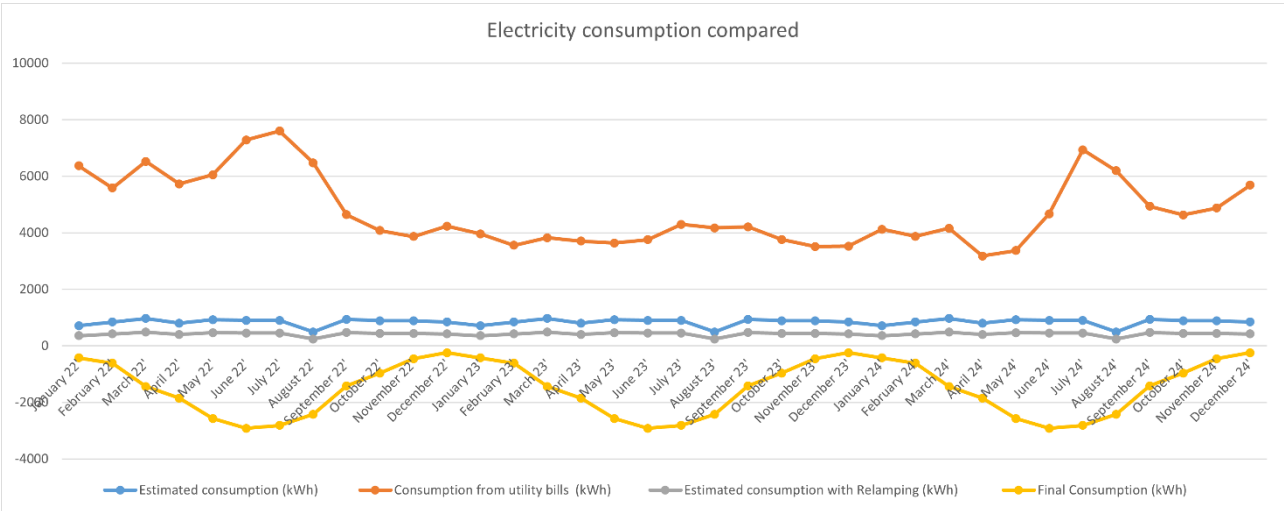


Figure 193_Electricity consumption comparison with cumulative deviation (Final consumption) of Municipio located in Corso San Vito, 2

The first graph compares the electricity consumption estimated under standard conditions and after the relamping intervention with the actual consumption data from utility bills. It shows that estimated values are consistently lower than the real consumption, with the relamping scenario leading to further reductions. The second graph introduces the "Final Consumption" line, which represents the difference between real and estimated values after the intervention. Although real consumption remains significantly higher than estimates during most of the observed period, from late 2023 onwards, a gradual reduction in this gap can be seen, indicating that the energy efficiency measures are beginning to yield tangible results over time.

- **Ufficio Protezione civile – Via Manzoni, 8**

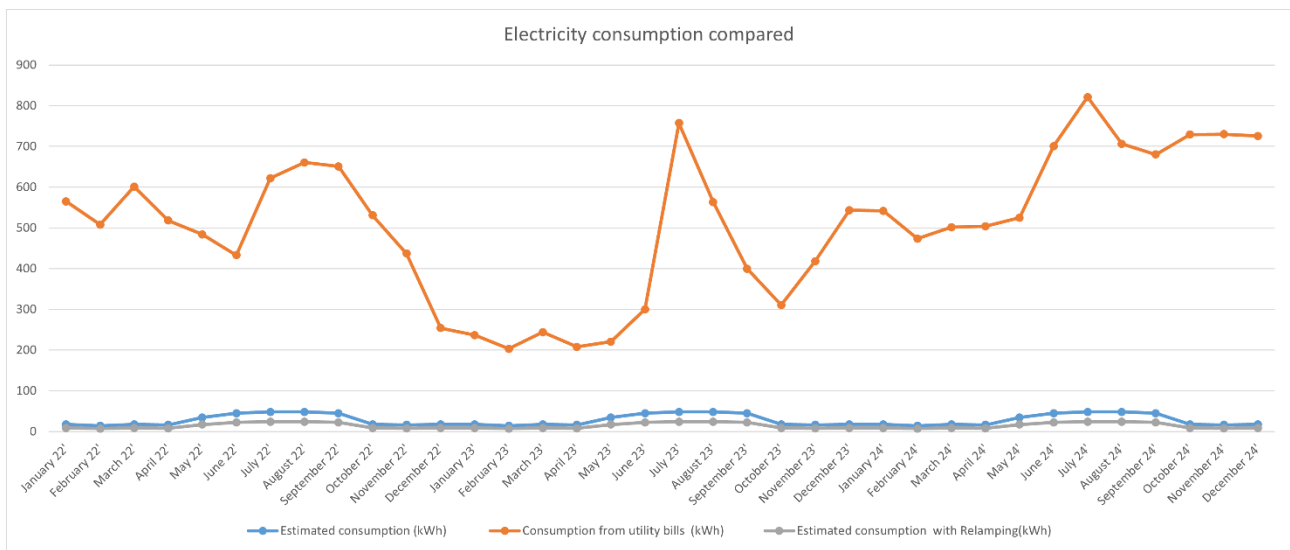


Figure 194_Comparison of actual and estimated electricity consumption with relamping scenario of Ufficio Protezione civile located in Via Manzoni, 8

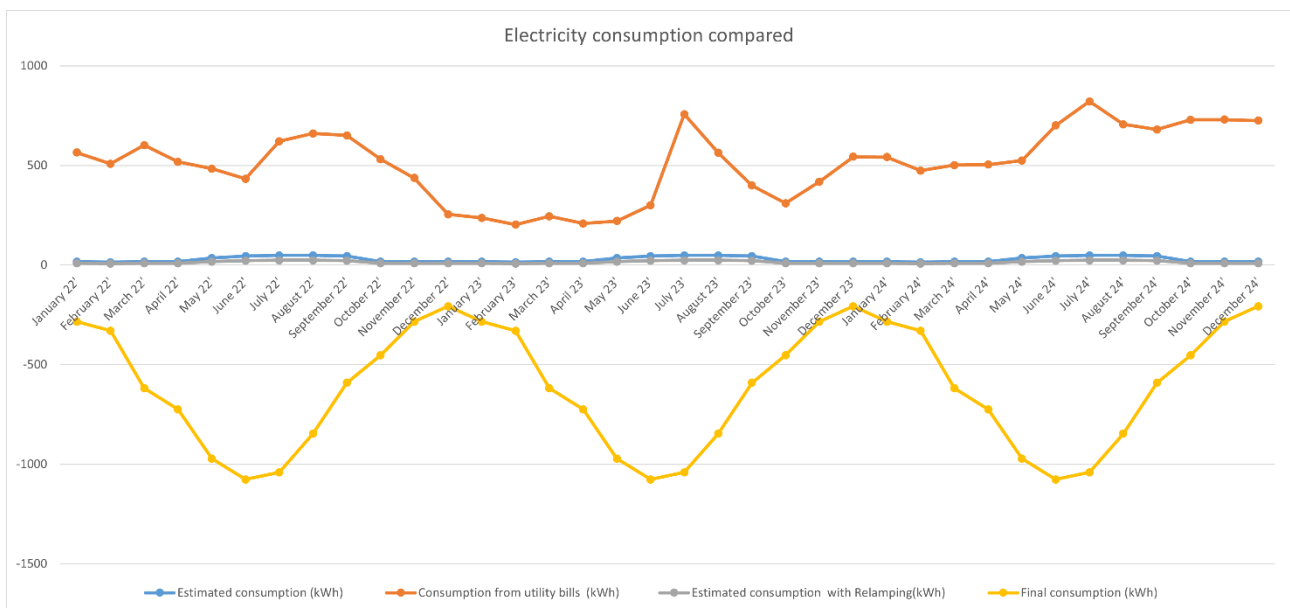


Figure 195_Electricity consumption comparison with cumulative deviation (Final consumption) of Ufficio Protezione civile located in Via Manzoni, 8

The first chart includes the actual electricity consumption from utility bills, the estimated consumption without interventions, the estimated consumption with relamping, and the final consumption (the difference between actual and estimated values). The final consumption curve (in yellow) shows a cyclical pattern of discrepancy, with real values consistently exceeding estimates, though with some periods of gradual convergence. The second chart excludes the final consumption curve and focuses on the gap between the real and estimated values (with and without relamping). It is clear that actual consumption is always higher than both estimates, but the gap narrows slightly during some months, particularly after the second half of 2023. This suggests that, while the energy-saving intervention did not fully meet expectations in terms of absolute savings, it might be contributing to a moderate reduction in consumption over time.

- **Delegazione Comunale – Via del Bosco, 19**

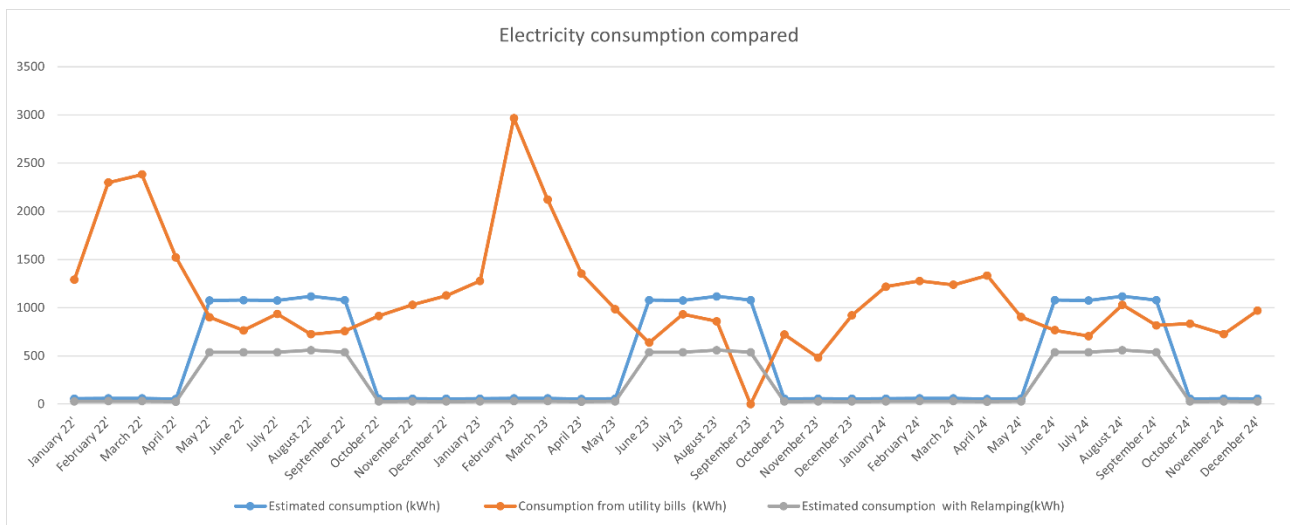


Figure 196_Comparison of actual and estimated electricity consumption with relamping scenario of Delegazione Comunale located in Via de Bosco, 19

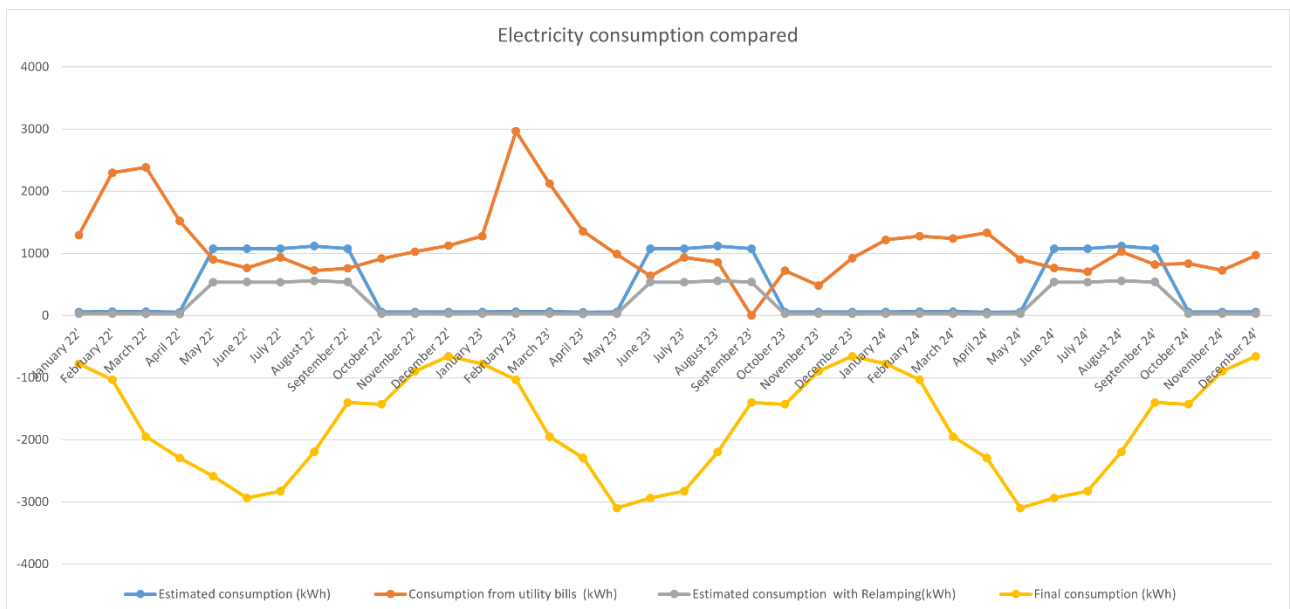


Figure 197_Electricity consumption comparison with cumulative deviation (Final consumption) of Delegazione Comunale located in Via de Bosco, 19

The first chart compares the actual electricity consumption with two estimates: one under standard conditions and one with the relamping intervention. The graph shows significant fluctuations in real consumption (orange line), particularly during certain months, while the estimated values remain more stable. Notably, there are several periods where real consumption drops to zero, suggesting possible service interruptions or metering gaps. The second chart includes the "Final Consumption" line (yellow), highlighting the difference between real and estimated post-intervention values. This line confirms the substantial gap between actual and expected consumption. In particular, during months with zero estimated consumption, the gap reaches its peak, indicating that real consumption was considerably higher than predicted, even after the relamping. This suggests either unexpected usage patterns or limitations in the estimation model's ability to capture actual building behaviour.

- **Croce Rossa Italiana – Via Petrarca, 24**

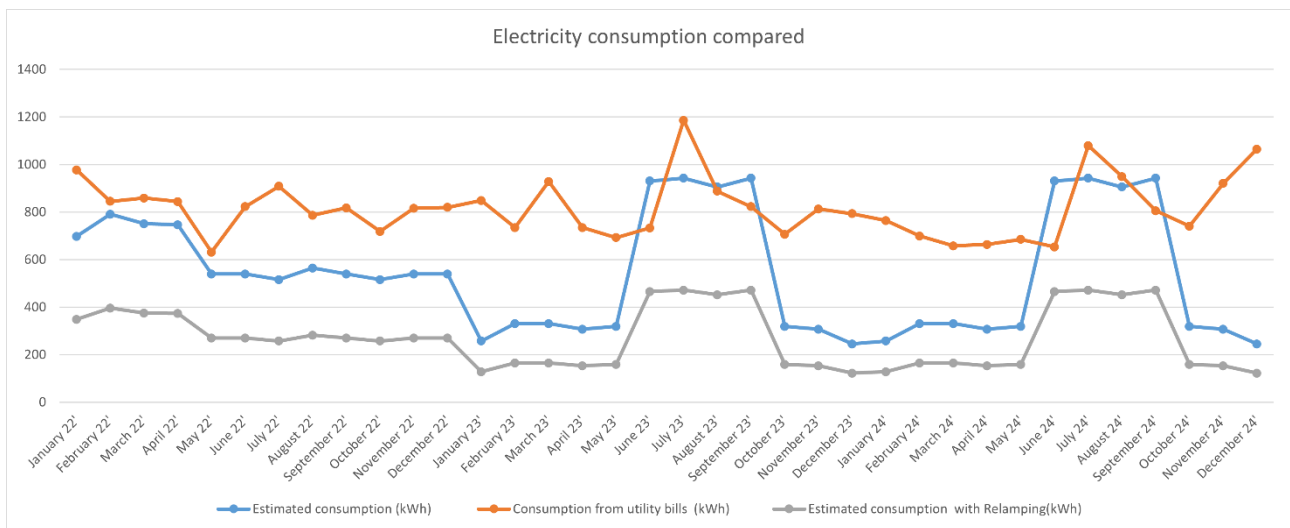


Figure 198_Comparison of actual and estimated electricity consumption with relamping scenario of Croce Rossa Italiana located in Via Petrarca, 24

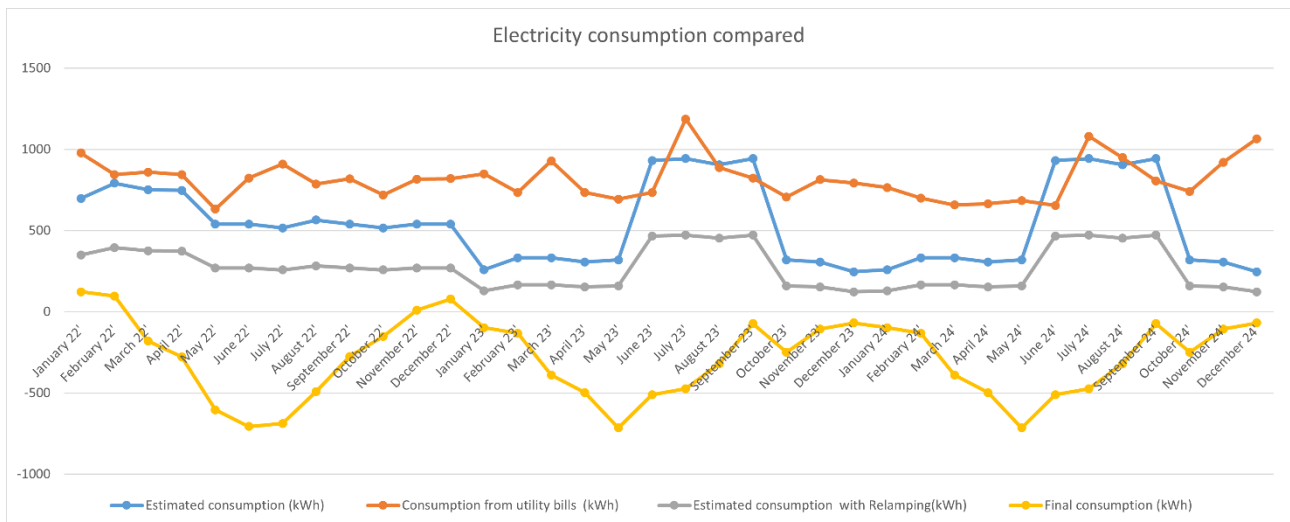


Figure 199_Electricity consumption comparison with cumulative deviation (Final consumption) of Croce Rossa Italiana located in Via Petrarca, 24

The first chart compares real electricity consumption (orange line) with two estimation scenarios: the standard estimation (blue) and the estimation after the relamping intervention (grey). The results show that real consumption consistently exceeds both estimated values, although the gap narrows slightly during some months, especially following the relamping periods. The second chart adds the “Final Consumption” curve (yellow), which represents the difference between real and estimated consumption with relamping. This line shows that, although real consumption remains higher, the difference tends to decrease in some phases, suggesting a partial improvement in efficiency. However, the fluctuations in the final consumption curve also indicate that external factors or usage patterns may still affect overall performance.

- Auditorium – Via San Nicolò

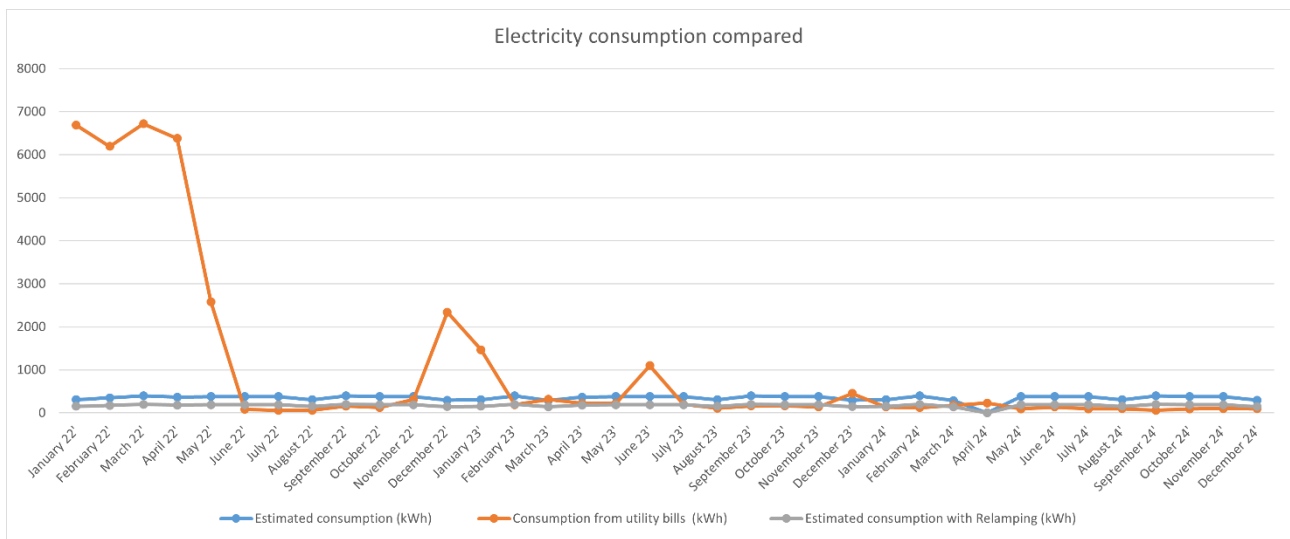


Figure 200_ Comparison of actual and estimated electricity consumption with relamping scenario of Auditorium located in Via San Nicolò

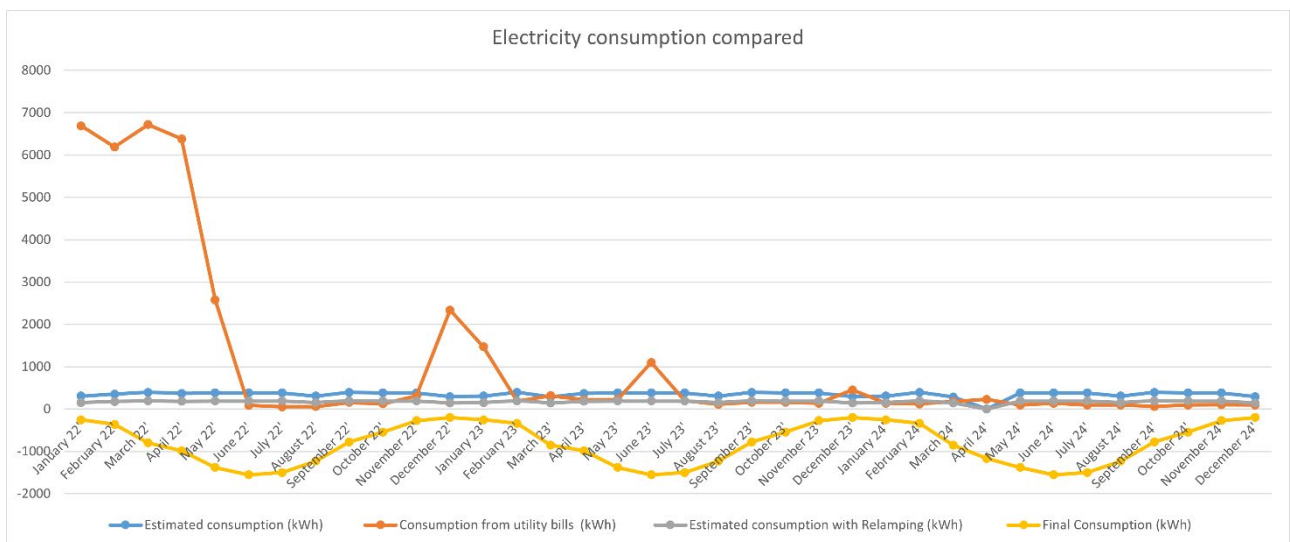


Figure 201_Electricity consumption comparison with cumulative deviation (Final consumption) of Auditorium located in Via San Nicolò

The first chart shows a steep drop in actual electricity consumption starting in mid-2022, followed by irregular peaks, while estimated values (both with and without relamping) remain stable over time. The second graph introduces the “Final Consumption” difference, which stays largely negative, indicating that real usage remained higher than predicted. However, the stable shape of the gap in the post-intervention period may reflect a certain regularization of building operation and a limited but consistent effect of the relamping.

● **Parco Monte Ceraulo – Via Pulei, 51**

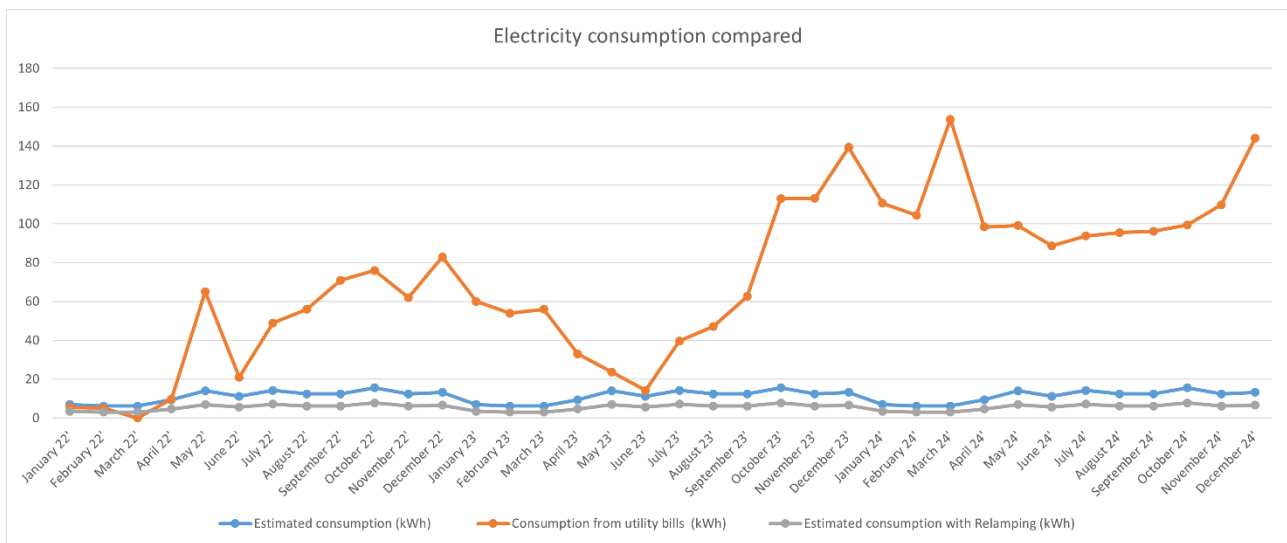


Figure 202_ Comparison of actual and estimated electricity consumption with relamping scenario of Monte Ceraulo Park located in Via Pulei, 51

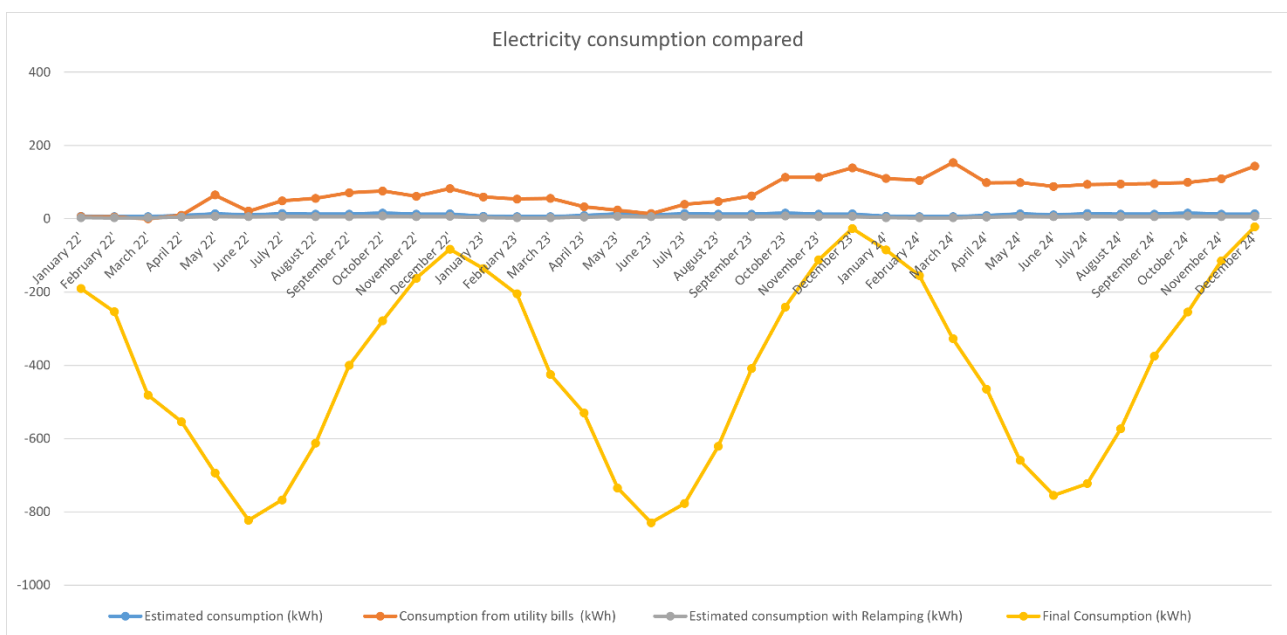


Figure 203_Electricity consumption comparison with cumulative deviation (Final consumption) of Monte Ceraulo Park located in Via Pulei, 51

The first graph presents a comparison between actual electricity consumption and estimated values, both under standard conditions and following the relamping intervention. While estimated values remain consistently low and stable, real consumption (orange line) displays considerable variability and a clear upward trend starting from mid-2023. This discrepancy becomes more evident when analysing the second chart, where the “Final Consumption” curve (yellow) shows recurring negative peaks, indicating that actual usage is significantly higher than anticipated. The regular sinusoidal pattern of the gap suggests a seasonal effect in energy demand that the model does not fully capture and highlights the limited impact of the relamping intervention in this specific context.

The comparative analysis of electricity consumption across multiple municipal and school buildings has provided a comprehensive overview of the impact of the relamping intervention. By comparing estimated consumption under standard and post-intervention conditions with actual utility data, it was possible to identify both the theoretical benefits and the real-world limitations of the energy efficiency measures implemented. In nearly all buildings, the relamping scenario resulted in consistently lower estimated consumption, confirming the potential effectiveness of the intervention in reducing baseline electricity use. However, actual consumption often exceeded both standard and post-relamping estimates, indicating the influence of external and operational factors not fully accounted for in the simulation models.

Notably, several buildings displayed seasonal or event-driven peaks in consumption that deviated significantly from estimated trends. These discrepancies underline the importance of considering user behaviour, occupancy patterns, equipment loads, and environmental variables when evaluating energy performance. In some cases, the positive impact of relamping only became evident months after implementation, suggesting that a period of adaptation or normalization may be necessary before the expected savings fully materialize. Moreover, buildings such as the ICS Federico II (Via D'Azeglio) and the Municipio (Corso San Vito) demonstrated progressive convergence between actual and estimated consumption over time, highlighting the long-term potential of such interventions when combined with consistent usage patterns or additional renewable energy sources.

Overall, while the relamping intervention has shown promise in reducing energy consumption on paper, its actual effectiveness varies significantly depending on context. This highlights the need for continuous monitoring, tailored operational strategies, and potentially integrated solutions (such as photovoltaics and smart control systems) to fully realize and sustain energy savings in public buildings.

CONCLUSION

Summary of Results

This section presents a summary of the results obtained through the application of the ISO 50001 standard for energy management, focusing primarily on key energy performance indicators and the actions taken to optimize energy consumption and savings. The application of the ISO 50001 standard has enabled the development of an EMs that allows for monitoring and improving the energy performance of buildings in the municipality of Mascalucia. The adopted methodology followed key steps, including the collection of energy consumption data, analysis of energy flows, and the definition of performance indicators. The methodology also involved evaluating potential technological solutions, such as the installation of photovoltaic systems, and developing action plans to reduce overall energy consumption. One of the main performance indicators used to assess the effectiveness of energy management was the coverage ratio, which measures the percentage of energy consumption covered by renewable energy production. This indicator highlighted how, in some buildings, photovoltaic production managed to cover more than 100% of energy consumption, especially in summer months, while during periods of low production, such as winter months, coverage rates were lower. The results showed clear seasonal variability in production and self-consumption, but also significant improvement in the energy efficiency of various buildings. To achieve these results, several activities were carried out, including the implementation of technological solutions such as the installation of photovoltaic systems on building rooftops, as well as the design and implementation of a continuous performance monitoring system using the Power BI platform. This platform allowed real-time visualization of energy consumption and production, facilitating informed decision-making for energy management and optimization.

In particular, the collected data demonstrated that the use of photovoltaic production had a positive impact on reducing energy consumption. However, to further optimize self-consumption and improve overall energy performance, it would be beneficial to implement additional solutions, such as energy storage systems (batteries). Excess energy produced during the day could be stored and used at night, thus increasing the coverage ratio, and reducing dependence on the electricity grid.

In summary, the application of the ISO 50001 standard has provided a precise evaluation of the energy performance of the buildings in Mascalucia, identifying strengths and areas for improvement. The results highlight how proper monitoring, and the adoption of appropriate technologies can lead to significant energy savings, contributing to the municipality's sustainability goals. Continuous monitoring through Power BI will provide essential support for regularly updating data and further improving energy management in the future.

Recommendations for PAs

Based on the findings from the application of ISO 50001 and the analysis of energy performance across the public buildings in Mascalucia, several strategic recommendations can be made to further enhance energy efficiency, optimize renewable energy production, and support the municipality's long-term sustainability goals. These recommendations are aimed at improving energy performance, maximizing the benefits of the installed photovoltaic systems, and ensuring the ongoing success of the EMs. Below are key recommendations for the PA:

- **Installation of energy storage systems:** Incorporating batteries to store excess energy generated by the photovoltaic systems during the day would allow the PA to use this stored energy during low production periods, reducing dependence on the grid.
- **Expansion of photovoltaic systems:** Additional installations of solar panels on underutilized rooftops, facades, or other available spaces would increase the renewable energy capacity of the PA and further reduce energy costs.
- **Optimization of energy efficiency:** Implementation of energy-saving measures, such as energy-efficient lighting, smart thermostats, and automated climate control systems, would reduce energy consumption across the public buildings.
- **Preventive maintenance:** Ensuring regular maintenance and monitoring of photovoltaic systems to guarantee their efficient functioning and prevent any loss in energy production due to faulty equipment.
- **Training and education:** Providing ongoing training programs for staff to ensure that employees are well-informed about ISO 50001 standards and best practices for energy management. This would help improve monitoring, analysis, and decision-making regarding energy performance.
- **Use of real-time data monitoring tools:** Leveraging Power BI and other data analytics platforms for continuous monitoring of energy consumption and photovoltaic energy production would enable the PA to make data-driven decisions and take corrective actions as needed.
- **Setting ambitious energy goals:** The PA should continue to set measurable energy performance targets, focusing on decarbonization and the adoption of low-carbon technologies, to align with long-term sustainability objectives.

By implementing these recommendations, the PA will further enhance its energy management practices, improve overall energy efficiency, and continue its progress toward sustainability.

Future perspectives and developments in energy management

The implementation of an EMs following ISO 50001 represents a crucial step toward improving energy performance in PA buildings. However, long-term effectiveness depends on the ability to evolve by integrating digital tools, engaging people, and aligning with broader sustainability goals. In the future, energy management will increasingly rely on smart technologies—such as IoT sensors, automation systems, and AI-driven analytics—for real-time monitoring and optimization. The use of platforms like Microsoft Power BI and City Energy Analyst can be further enhanced with predictive and data-driven features.

Another key development is the integration of renewable energy and storage systems, particularly within Renewable Energy Communities (RECs), where public buildings can support local energy resilience and cost reduction. To fully realize these benefits, municipalities will need structured governance models and digital infrastructures. Improved data management, the adoption of integrated performance indicators (KPIs), and continuous training for staff are also essential to support informed decision-making and foster a culture of sustainability. Finally, alignment with national and European funding programs—such as those under the Green Deal—will be vital to enable future energy initiatives.

In conclusion, building on the results of this study, energy management in the public sector must embrace innovation, collaboration, and long-term planning to ensure a transition toward more efficient and responsible energy use.

Annex I

The electricity bills of the buildings taken as a case study are reported below in table form.

Table 25_Electricity bill of ICS Fava Complex located in Via dei Villini, 19

Electricity Bill Plesso ICS Fava – Via dei Villini, 19				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	526	79,3	121,8	727,1
February-22	719,9	112,2	126,2	958,4
March-22	1036,7	117,4	128,4	1282,6
April-22	639,0	88,6	129,8	857,5
May-22	606	104	159	869
June-22	103,5	59,3	118,4	281,4
July-22	103,5	64,9	121,4	289,9
August-22	108,5	61,1	121,4	291,0
September-22	356,6	101,7	166,6	624,9
October-22	615	269	459	1343
November-22	553	107	167	827
December-22	447	121	171	739
January-23	619	104	151	874
February-23	657	110	131	898
March-23	725	121	145	991
April-23	538	239	404	1181
May-23	1069	480	957	2506
June-23	238	101	192	531
July-23	162	112	198	472
August-23	95	71	137	303
September-23	392	164	257	813
October-23	493	115	183	791
November-23	1414	452	744	2610
December-23	1753	557	930	3240
January-24	503,6	119,3	198,4	821,4
February-24	532,9	121,1	185,1	839,2
March-24	486,2	114,5	176,8	777,6
April-24	407,7	85,2	150,0	643,0
May-24	483,2	97,1	156,1	736,5
June-24	239,7	88,1	175,3	503,2
July-24	77,1	53,7	95,9	226,7
August-24	62,71	49,4	90,8	202,9
September-24	351,4	101,0	168,5	621,0
October-24	538,9	112,4	167,2	818,7
November-24	419,1	99,7	159,2	678,1
December-24	429,4	160,6	287,8	877,9

Table 26_Electricity bill of ICS Fava Complex located in Via Timparello, 53

Electricity Bill Plesso ICS Fava – Via Timparello, 53				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	4267,4	710,4	1123,7	6101,5
February-22	4693,0	737,8	947,2	6378,1
March-22	6021,9	820,7	1019,5	7862,2

April-22	3472,2	68,2	1110,4	4650,9
May-22	4082	717	1059	5858
June-22	2578	544	1010	4132
July-22	1938	572	963	3473
August-22	1451	434	758	2670
September-22	3137	592	838	4567
October-22	3842	623	909	5374
November-22	4188	620	860	5668
December-22	3725	770	986	5481
January-23	4864	666	951	6481
February-23	4679	583	668	5930
March-23	5163	673	763	6599
April-23	2977	494	794	4265
May-23	4213	589	789	5591
June-23	2226	472	716	3414
July-23	1484	513	709	2706
August-23	1456	443	713	2612
September-23	2905	654	923	4482
October-23	4260	624	940	5824
November-23	3946	568	808	5332
December-23	3584	702	1046	5332
January-24	5379,1	885,3	1331,4	7595,9
February-24	5340,9	819,4	1145,3	7305,7
March-24	4310,3	675,3	949,2	5934,8
April-24	3442,3	599,5	1016,2	5058,1
May-24	3955,6	600,2	979,9	5535,8
June-24	2572,3	579,2	936,1	4087,7
July-24	1804,0	538,9	911,5	3254,5
August-24	1325,5	512,3	906,7	2744,6
September-24	2707,2	608,3	932,9	4248,4
October-24	4305,4	655,4	974,4	5935,2
November-24	3499,2	576,6	885,1	4961,1
December-24	3767,7	740,1	1060,7	5568,5

Table 27_Electricity bill of Federico II Complex located in Via Massimo D'Azeglio, 14

Electricity Bill Plesso Federico II – Via Massimo D'Azeglio, 14				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	2455,9	493,2	589,1	3538,3
February-22	2695,0	537,3	472,5	3704,9
March-22	363,9	54,2	49,3	467,4
April-22	300,6	53,0	53,2	406,9
May-22	348	53	52	453
June-22	333	51	50	434
July-22	260	44	42	571
August-22	426	220	472	1118
September-22	1896	386	588	2870
October-22	2560	437	518	3515
November-22	2559	457	491	3507
December-22	2037	414	531	2982
January-23	2429	415	511	3355

February-23	2525	415	432	3372
March-23	3250	556	469	4275
April-23	2249	442	521	3212
May-23	2746	522	625	3893
June-23	1533	345	470	2348
July-23	533	217	373	1123
August-23	459	194	385	1038
September-23	1958	405	465	2828
October-23	117	16	9	142
November-23	7393	1376	1690	10459
December-23	9822	1858	2408	14088
January-24	2872,5	408,0	536,5	3817,0
February-24	3202,9	430,1	398,6	4031,7
March-24	2877,5	476,6	442,8	3797,0
April-24	2498,0	397,3	450,1	3345,5
May-24	3184,1	467,9	451,1	4103,2
June-24	1220,2	309	479,3	2008,5
July-24	457,6	197,2	374,8	1029,7
August-24	223,6	211,5	41	854,2
September-24	2035	377,7	448	2860,7
October-24	2915,9	429,7	436,6	3782,3
November-24	2213,8	379,6	427,6	3021,1
December-24	2153,1	359,2	490,1	3002,5

Table 28_Electricity bill of Federico II Complex located in Via del Sole, 2

Electricity Bill Plesso Federico II – Via del Sole, 2				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
May-22	7097.9	1069.1	1328.6	9496.1
June-22	5011.1	959.1	1483.3	7453.5
July-22	2838.9	686.9	1206.2	4732
August-22	2223.4	708.1	1357	4288.5
September-22	5707	1483	2287	9477
October-22	6003.6	1186.6	1669.3	8859.5
November-22	6727.6	1000.1	1325.3	9053
December-22	6075.7	1194.1	1715.5	8985.3
January-23	8251	1298	1713.2	11262.2
February-23	8249.1	1458.2	1802.4	11509.7
March-23	8914.1	1593.2	1837.6	12344.9
April-23	4085	1197.7	2063	8065.7
May-23	6380	1396	2195	9971
June-23	4005	776	848	5629
July-23	2186	508	754	3448
August-23	1518	362	600	2480
September-23	5558	748	876	7182
October-23	6347	767	997	8111
November-23	19696	2771	3698	26165
December-23	6222	1147	1707	9076
January-24				10829,0
February-24				10468,8
March-24				7999,3

April-24				5697,6
May-24				5644,8
June-24				4441,7
July-24				3102,2
August-24				2820,7
September-24				6461,9
October-24				7582,4
November-24				7611,0
December-24				8652,7

Table 29_Electricity bill of Leonardo Da Vinci Complex located in Via della Regione Siciliana, 12

Electricity Bill Plesso Leonardo Da Vinci – Via della Regione Siciliana, 12				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22				11333,1
February-22				12615,5
March-22				15166,9
April-22				11091,4
May-22	8898,4	1678,1	1003,5	11580
June-22	6668,6	1564,8	1378,7	9612,1
July-22	2405,9	752,4	1038,1	4196,4
August-22	1816	559,5	867,1	3242,6
September-22	6393,7	1221,6	1314	8929,3
October-22	8091,8	1691,1	1376,3	11159,2
November-22	8658,4	1650,6	1269	11578
December-22	7333,7	1781	1610	10724,7
January-23	9514,4	1969,2	1643,9	13127,5
February-23	8741,9	1897,7	1582,3	12221,9
March-23	11179,5	2346	1862,1	15387,6
April-23	7036,8	1733,2	1947,4	10717,4
May-23	8759	217	2537	11513
June-23	5638	1788	1841	9267
July-23	3233	1194	1640	6067
August-23	2493	1103	1689	5285
September-23	7415	1645	1779	10839
October-23	9035	1977	1896	12908
November-23	7909	2008	2238	12155
December-23	8166	2028	2663	12857
January-24				14674,8
February-24				16146,7
March-24				14885,8
April-24				11888,7
May-24				12094,4
June-24				9252,4
July-24				5646,1
August-24				3752,1
September-24				9226,6
October-24				12625,4
November-24				10733,8
December-24				11762,4

Table 30_Electricity bill of Leonardo Da Vinci Complex located in Via Roma, 217

Electricity Bill Plesso Leonardo Da Vinci – Via Roma, 217				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	1250,0	246,1	233,6	1729,8
February-22	1596,5	305,3	213,6	2115,4
March-22	2002,7	371,3	213,6	2587,6
April-22	1306,2	2792	250,1	4348,3
May-22	1512	276	244	2032
June-22	583	188	228	999
July-22	345	246	449	1040
August-22	929	198	206	1333
September-22	1538	368	320	2226
October-22	1595	352	223	2170
November-22	1297	381	459	2137
December-22	1767	399	327	2493
January-23	1489	335	316	2140
February-23	2082	439	379	2900
March-23	1195	284	342	1821
April-23	1679	352	323	2354
May-23	765	220	270	1255
June-23	139	105	189	433
July-23	79	63	122	264
August-23	1082	258	248	1588
September-23	1689	385	399	2473
October-23	1447	334	285	2066
November-23	1307	340	414	2061
December-23	1512	276	244	2032
January-24	1767,8	400,0	431,5	2599,4
February-24	1867,0	437,0	396,0	2700,0
March-24	1703,4	459,1	491,9	2654,5
April-24	1499,6	378,6	490,1	2368,4
May-24	1664,8	377,7	429,5	2472,1
June-24	647,6	225,0	309,0	1181,7
July-24	204,3	142,7	257,5	604,6
August-24	91,5	75,01	137,8	304,4
September-24	1109,5	257,6	319,9	1687,2
October-24	2024,7	433,4	431,2	2889,4
November-24	1636,1	449,9	450,1	2536,1
December-24	1535,4	464,3	464,3	2464,0

Table 31_Electricity bill of Leonardo Da Vinci Complex located in Via Santa Spera, 15

Electricity Bill Plesso Leonardo Da Vinci – Via Santa Spera				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	431,6	40,9	64,5	537,1
February-22	513,8	53,5	70,4	637,8
March-22	574,4	58,4	138,3	771,1
April-22	496	48,8	73,2	618,1
May-22	315	54	82	451
June-22	141	59	105	305
July-22	14	11	20	45

August-22	12	8	16	36
September-22	212	62	95	369
October-22	350	81	117	548
November-22	394	71	99	564
December-22	294	80	138	512
January-23	423	92	152	667
February-23	386	92	138	616
March-23	509	93	130	732
April-23	481	80	135	696
May-23	0	104	426	530
June-23	0	82	410	492
July-23	0	33	162	195
August-23	62	44	84	190
September-23	209	76	112	397
October-23	355	74	127	556
November-23	344	67	106	517
December-23	403	90	172	665
January-24	686,8	100,5	150,2	937,6
February-24	758,7	128,8	154,2	1041,8
March-24	612,0	111,3	139,8	863,2
April-24	365,3	80,3	125,6	571,2
May-24	373,0	92,6	138,2	603,8
June-24	175,4	75,5	119,4	370,3
July-24	48,4	34,2	60,0	142,7
August-24	44,7	35,6	63,4	143,8
September-24	198,4	74,6	126,3	399,4
October-24	442,7	107,0	169,6	719,4
November-24	389,1	92,4	154,0	635,5
December-24	585,7	151,2	298,8	1035,8

Table 32_Electricity bill of Auditorium located in Via San Nicolò

Electricity Bill Auditorium – Via San Nicolò				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	1887,1	1501,9	3303,9	6692,9
February-22	1964,1	1528,2	2700,1	6192,4
March-22	2212,1	1634,5	2875,3	6721,9
April-22	1802,6	1557,0	3020,1	6379,8
May-22	850	580	1152	2582
June-22	32	38	15	85
July-22	22	19	16	57
August-22	19	24	16	59
September-22	58	89	12	159
October-22	40	64	22	126
November-22	181	109	20	310
December-22	695	633	1011	2339
January-23	507	284	680	1471
February-23	62	86	43	191
March-23	127	122	68	317
April-23	63	95	65	223
May-23	65,0	100,9	58,2	224,2

June-23	294,1	313,3	492,3	1099,8
July-23	91,1	66,7	38,6	196,5
August-23	41,5	44,2	23,8	109,6
September-23	74,4	62,5	25,1	162,0
October-23	60,4	74,8	29,1	164,4
November-23	54,6	61,2	22,4	138,3
December-23	215,8	123,2	113,7	452,8
January-24	65,7	53,3	19,7	138,8
February-24	42,6	59,1	19,0	120,9
March-24	52,7	93,2	32,4	178,4
April-24	60,2	109,8	60,9	231,0
May-24	29,7	41,3	22,6	93,7
June-24	23,9	72,3	42,6	138,9
July-24	14,8	64,8	16,2	95,9
August-24	35,1	36,8	26,4	98,4
September-24	9,8	38,7	11,2	59,8
October-24	14,5	67,5	11,1	93,2
November-24	21,1	69,9	11,3	102,4
December-24	27,6	58,1	12,5	98,3

Table 33_Electricity bill of Delegazione Comunale located in Via del Bosco, 19

Electricity Bill Delegazione Comunale – Via del bosco, 19				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	662,1	188,3	442,6	1293,1
February-22	1341,4	330,9	626,0	2298,4
March-22	1201,1	410,6	770,8	2382,6
April-22	606,9	310,4	605,1	1522,5
May-22	324	187	390	901
June-22	230	152	383	765
July-22	265	199	471	935
August-22	185	155	385	725
September-22	198	185	375	758
October-22	257	237	421	915
November-22	393	234	402	1029
December-22	467	208	451	1126
January-23	526	202	551	1279
February-23	1547	613	807	2967
March-23	1027	502	593	2122
April-23	487	261	605	1353
May-23	566,9	147,1	272,0	986,1
June-23	306,9	107,1	223,6	637,7
July-23	340,8	184,4	407,6	932,9
August-23	233,9	181,4	442,6	858,0
September-23	288,8	148,0	286,0	722,9
October-23	226,8	84,7	169,7	481,3
November-23	354	180,4	388,7	923,2
December-23	577,0	197,3	445,6	1220
January-24	884,2	126,1	268,3	1278,7
February-24	785,0	158,6	294,0	1237,7
March-24	634,8	237,4	462,3	1334,6

April-24	330,6	161,6	411,7	903,9
May-24	324,8	121,4	320,7	767,0
June-24	280,8	124,8	299,5	705,1
July-24	529,3	151,3	348,7	1029,3
August-24	317,9	149,2	350,9	818,2
September-24	304,8	159,5	370,8	835,2
October-24	255,1	149,5	322,0	726,8
November-24	497,7	157,8	314,5	970,1
December-24	771,8	291,2	394,1	1457,2

Table 34_Electricity bill of Croce Rossa Italiana located in Via Petrarca, 24

Electricity Bill Croce Rossa Italiana – Via Petrarca, 24				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	240,2	231,2	506,1	977,5
February-22	216,3	231,5	397,5	845,3
March-22	237,4	226,9	394,7	859,1
April-22	196,1	221,9	426,4	844,5
May-22	166	186	280	632
June-22	217	225	381	823
July-22	228	266	415	909
August-22	222	204	361	787
September-22	246	236	336	818
October-22	186	209	324	719
November-22	244	227	345	816
December-22	234	225	361	820
January-23	249	217	383	849
February-23	226	214	295	735
March-23	281	269	379	929
April-23	196	191	348	735
May-23	224,6	188,7	279,4	692,8
June-23	224,7	203,2	306,1	734,0
July-23	368,2	340,0	477,8	1186,1
August-23	268,9	252,9	366,3	888,1
September-23	240,8	253	329,1	822,9
October-23	203,5	215,7	287,5	706,8
November-23	218,1	219,7	375,4	813,3
December-23	177,4	192,6	423,4	793,5
January-24	209,0	192,0	363,6	764,7
February-24	182,4	194,8	322,1	699,4
March-24	184,0	186,4	287,1	657,6
April-24	170,2	168,9	325,3	664,5
May-24	180,7	175,7	328,8	685,4
June-24	181,4	170,3	302,1	653,9
July-24	421,2	269,8	388,5	1079,6
August-24	333,1	273,9	342,2	949,4
September-24	231,9	231,4	343,0	806,4
October-24	206,5	223,8	311,0	741,4
November-24	318,1	243,2	359,3	920,7
December-24	301,6	269,5	493,9	1065,0

Table 35_Electricity bill of Municipio located in Corso San Vito, 2

Electricity Bill Municipio – Corso San Vito, 2				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	2806,3	1132,7	2429,5	6368,6
February-22	2615,7	1087,3	1882,5	5585,6
March-22	3328,8	1204,8	1993,7	6527,3
April-22	2582,6	1082,4	2059,5	5724,6
May-22	2835	1146	2074	6055
June-22	3816	1268	2200	7284
July-22	3837	1434	2333	7604
August-22	3053	1219	2205	6477
September-22	1756	1050	1835	4641
October-22	1337	964	1780	4081
November-22	1247	893	1730	3870
December-22	1392	961	1884	4237
January-23	2859	1581	2074	6514
February-23	3075	1500	1500	6075
March-23	2550	2550	2550	7650
April-23	1100	850	1800	3750
May-23	1212,3	820,8	1603,3	3636,5
June-23	1308,7	837,5	1611,0	3757,3
July-23	1545,0	994,9	1760,8	4300,8
August-23	1449,4	938,8	1786,0	4174,3
September-23	1610,8	942,9	1657,1	4210,9
October-23	1343,6	867,1	1553,2	3764,0
November-23	1107,8	812,5	1591,7	3512,1
December-23	927,13	778,2	1823,0	3528,4
January-24	1559,6	824,2	1738,3	4122,2
February-24	1633,9	820,8	1424,2	3879,0
March-24	1581,8	953,1	1627,7	4162,7
April-24	959,0	693,6	1524,4	3177,1
May-24	838,2	846,5	1685,4	3370,2
June-24	1961,7	936,5	1774,1	4672,4
July-24	3686,5	1278,1	1971,3	6935,9
August-24	3028,3	1157,7	2008,4	6194,5
September-24	1742,6	1076,9	2118,8	4938,5
October-24	1662,2	1073,5	1900,7	4636,5
November-24	1797,9	1057,0	2021,0	4876,0
December-24	1951,4	1114,7	2619,2	5685,5

Table 36_Electricity bill of Ufficio Protezione Civile located in Via Manzoni, 8

Electricity Bill Ufficio protezione civile – Via Manzoni, 8				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	111,3	135,4	317,9	564,7
February-22	113,2	140,0	254,6	507,8
March-22	130,7	180,9	289,6	601,2
April-22	97,9	139,1	281,0	518,1
May-22	94	121	269	484
June-22	188	106	139	433
July-22	316	327	639	1282

August-22	148	167	336	651
September-22	148	167	336	651
October-22	97	141	293	531
November-22	104	120	213	437
December-22	74	81	99	254
January-23	75	54	108	237
February-23	79	55	69	203
March-23	89	70	85	244
April-23	59	53	96	208
May-23	74,2	57,4	89,2	220,8
June-23	109,5	79,1	111,4	300,1
July-23	387,2	173,6	196,4	757,3
August-23	295,0	109,5	159,0	563,6
September-23	163,3	99,3	136,6	399,4
October-23	119,6	67,1	123,8	310,6
November-23	108,7	104,7	204,3	417,9
December-23	95,1	135,6	312,6	543,4
January-24	117,8	126,6	297,4	541,9
February-24	92,0	124,6	256,6	473,3
March-24	92,6	135,7	273,4	501,8
April-24	93,5	118,7	291,8	504,2
May-24	93,0	133,2	298,9	525,2
June-24	143,7	182,2	374,7	700,7
July-24	204,5	217,3	399,3	821,2
August-24	111,4	177,6	416,9	706,0
September-24	97,2	176,5	406,3	680,1
October-24	121,4	198,1	409,6	729,2
November-24	130,4	191,1	408,4	730,0
December-24	117,3	169,8	438,2	725,3

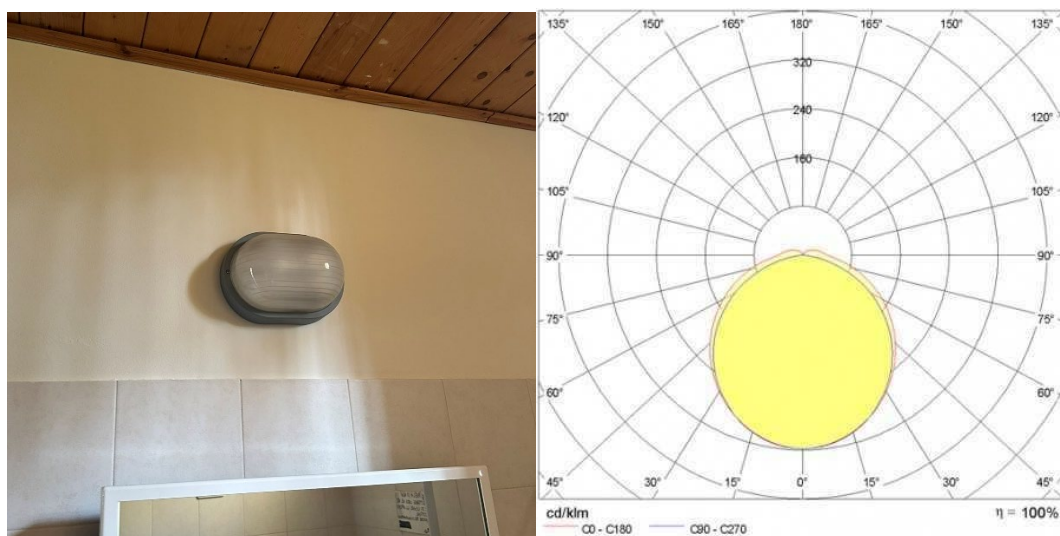
Table 37_Electricity bill of Parco Monte Ceraulo located in Via Pulei, 51

Electricity Bill Parco Monte Ceraulo – Via Pulei, 51				
Mese	F1 [kWh/month]	F2 [kWh/month]	F3 [kWh/month]	Total [kWh/month]
January-22	1,6	1,1	2,7	5,5
February-22	1,6	1,2	2,2	5,0
March-22	0	0,0	0,0	0,0
April-22	2,2	2,5	4,9	9,7
May-22	18	16	31	65
June-22	7	5	9	21
July-22	16	13	20	49
August-22	19	14	23	56
September-22	23	19	29	71
October-22	22	21	33	76
November-22	19	15	28	62
December-22	20	28	35	83
January-23	18	13	29	60
February-23	16	12	26	54
March-23	19	14	23	56
April-23	12	7	14	33
May-23	5,4	7,3	11,0	23,7

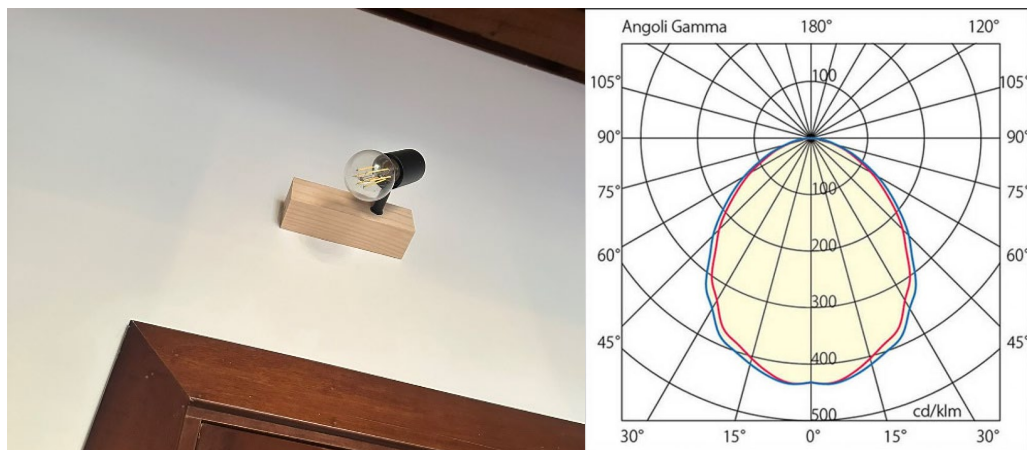
June-23	4,6	2,8	6,6	14,2
July-23	15,6	8,6	15,3	39,6
August-23	21,1	9,4	16,5	47,1
September-23	7,8	16,5	38,2	62,6
October-23	13,4	32,2	67,3	113,0
November-23	18,2	31,1	63,7	113,1
December-23	13,8	42,4	83,1	139,4
January-24	17,4	27,2	65,8	110,6
February-24	21,4	26,8	56,2	104,4
March-24	49,5	37,0	67,1	153,8
April-24	18,6	23,1	56,6	98,4
May-24	20,8	24,6	53,6	99,1
June-24	25,4	18,4	44,8	88,6
July-24	10,9	23,3	59,4	93,7
August-24	8,5	24,5	62,4	95,5
September-24	7,5	25,5	63,0	96,1
October-24	10,6	28,3	60,4	99,4
November-24	15,8	28,9	65,0	109,8
December-24	26,3	42,1	75,6	144,1

Annex II

- Interior lighting of the structure at Monte Ceraulo Park

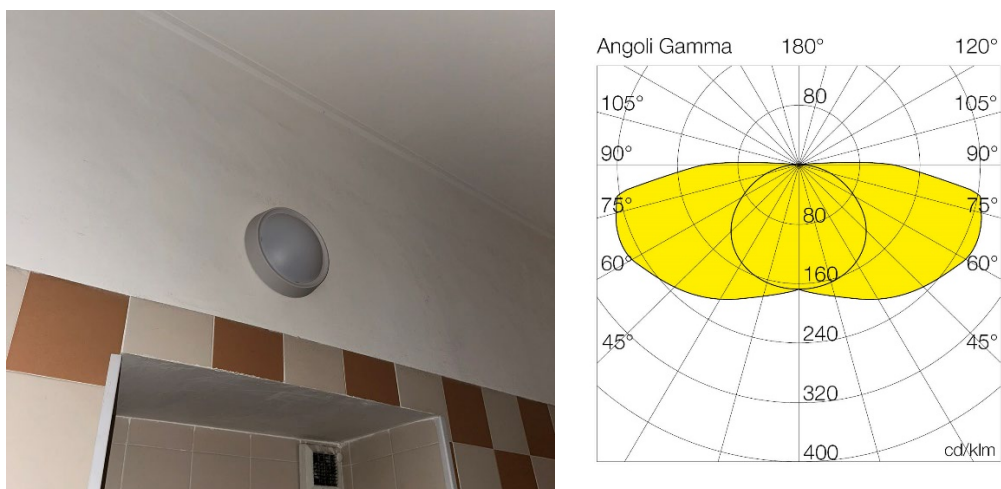


Technical features	
IP Grade	44
Material	Sheet steel
Voltage [V]	220/224 V
Rated Frequency [Hz]	50
Maximum power output [W]	10
Luminous efficiency	100 lm/W

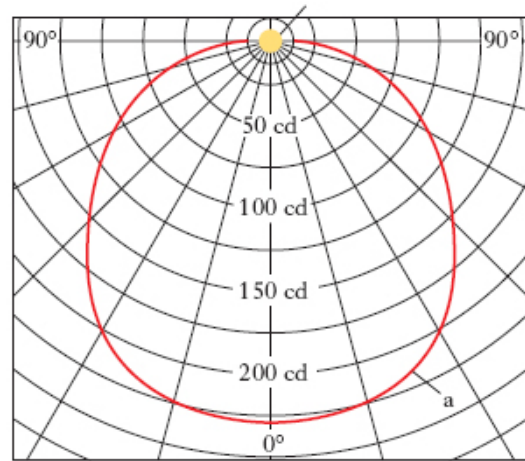


Technical features	
IP Grade	20
Material	Sheet steel
Voltage [V]	220/224 V
Rated Frequency [Hz]	50-60
Maximum power output [W]	4/10
Luminous efficiency	90/120 lm/W

- Interior lighting of the Auditorium in Via San Nicolò

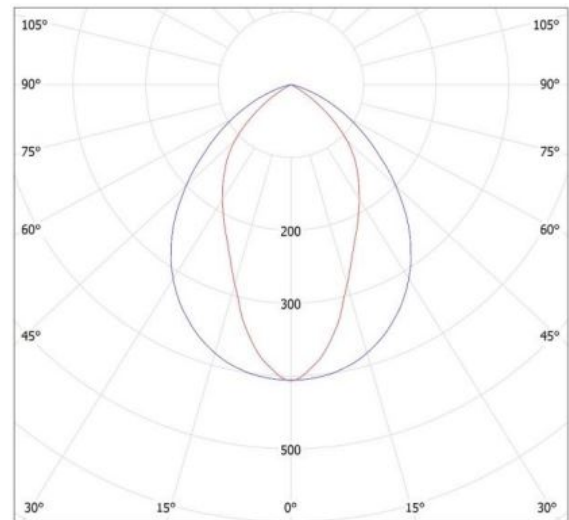


Technical features	
IP Grade	44
Material	glass
Voltage [V]	220/224 V
Rated Frequency [Hz]	50-60
Maximum power output [W]	18/24
Luminous efficiency	60/80 lm/W



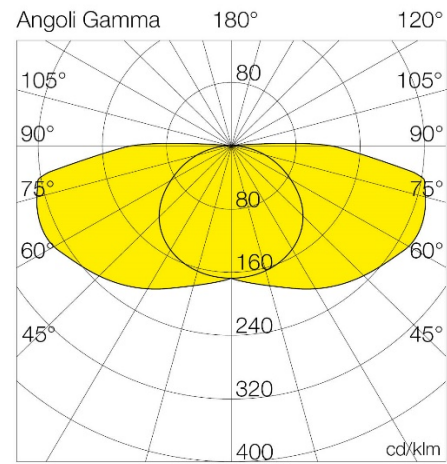
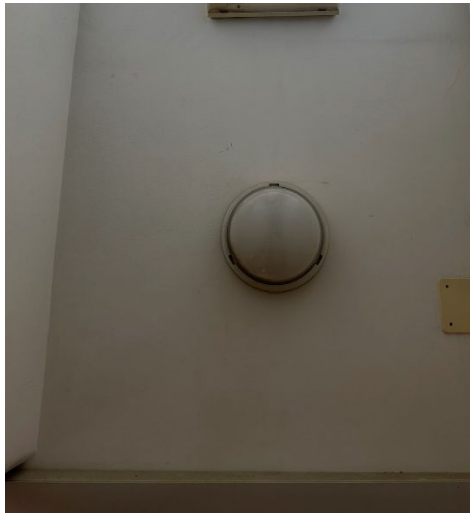
Technical features	
IP Grade	20
Material	Glass
Voltage [V]	24 V
Rated Frequency [Hz]	50
Maximum power output [W]	60
Luminous efficiency	10/15 lm/W

- **Standard lighting of all school premises**

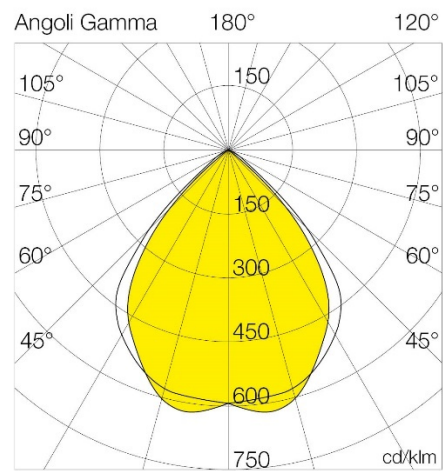
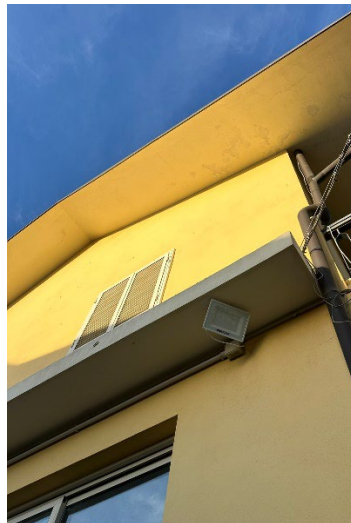


Technical features	
IP Grade	20
Material	Glass
Voltage [V]	220/224 V
Rated Frequency [Hz]	50
Maximum power output [W]	2x36
Luminous efficiency	80/85 lm/W

- Interior/exterior lighting of the Civil Defence office



Technical features	
IP Grade	44
Material	Glass
Voltage [V]	220/224 V
Rated Frequency [Hz]	50
Maximum power output [W]	60
Luminous efficiency	10/15 lm/W



Technical features	
IP Grade	65
Material	Glass
Voltage [V]	220/224 V
Rated Frequency [Hz]	60
Maximum power output [W]	20
Luminous efficiency	80/150 lm/W

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