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Energy profiling and retrofitting measures for a nursery school located in Torino

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ABSTRACT

The period of construction of the Italian building stock and the low rate of growth of new high-performance buildings from an energy point of view brings up the crucial issue of redevelopment of existing assets. In the public housing sector this issue is even more important, given that over the years has often been lacking a constant maintenance of the stable.

The case study analyzed in this thesis work is a school complex built in the Italian North-West in the second half of the 50s. The potential for improvement of the complex has been studied, evaluating different hypotheses for the reduction of electricity consumption of the entire building. To do this, in the absence of precise profiles, it was decided to study a model to obtain a daily profile, to better study the various interventions. Intervention proposals were first presented on the lighting system, and then the system situation was analyzed. For the different solutions considered was rated the primary energy requirement that would result and it was made a comparison with that of the current status. Finally, an economic analysis of the various types of intervention proposed was carried out, taking into account the investment costs, the savings that can be obtained, as well as the incentives that can be accessed.

INTRODUCTION

Energy efficiency in buildings is crucial for sustainable development, climate and resource protection and a low-risk worldwide energy system. Approximately 40% of global final energy demand and one third of the energy-related emissions are related to buildings (IEA 2008). Up to 90% of energy can be saved through energy efficiency in new buildings and in retrofits, and various co-benefits achieved at the same time. Yet, to make this happen, policy is needed to help the actors in the building value chain overcome their various barriers to harness energy efficiency and to strengthen their market-inherent incentives. The goal is to make energy efficiency as easy and attractive as possible, sometimes to make it feasible at all, and ultimately to make it the standard choice.

1.1 ENERGY EFFICIENCY OF PUBLIC BUILDINGS

In the last several years, energy efficiency ("EE") has become a capital policy for many countries around the world. It is widely recognized as the most cost-effective and readily available means of addressing numerous energy-related issues, including energy security, the social and economic impacts of high energy prices, and concerns about climate change. As a consequence, there have been many efforts to develop and deploy hardware solutions (smart meters, smart plugs, smart sensors, etc.) and sophisticated control structures to measure and control energy consumption in grids, buildings and households, and these solutions have been proved to be technologically affordable and sustainable. One of the most important problems to solve, both technically and socially, is energy consumption in public spaces and work environments. Within these environments, the building sector plays a crucial role as far as energy consumption is concerned, thus efforts and resources are used in making them more efficient. Energy waste in these areas is quite high due to several reasons. On the one hand, the implementation of technological solutions that enable efficient energy use is not spread out among old buildings or, at least, among those above a certain age. On the other hand, users' comfort level is very difficult to model because of the disparity of requirements among each user, making it difficult to deploy automatic energy management systems in buildings.

Energy efficiency ("EE") is at the cornerstone of the European energy policy and one of the main targets of the Europe 2020 Strategy for smart, sustainable and inclusive growth adopted by the European Council in June 2010. This includes the objective for a 20% reduction in primary energy consumption by 2020. As energy related emissions account for almost 80% of total EU greenhouse gas

(“GHG”) emissions, the efficient use of energy can make an important contribution to achieving a low-carbon economy and combating climate change. Buildings account for approximately 40% of final energy consumption. Investing in EE measures in buildings can yield substantial energy savings, while supporting economic growth, sustainable development and creating jobs. Greater use of energy-efficient appliances and technologies, combined with renewable energy, are cost effective ways of enhancing the security of energy supply. Despite substantial progress towards meeting the 20% reduction target, a recent European Commission ("EC") study shows that, if no additional measures are taken, the EU will meet only half of its target. In 2011, the European Commission adopted a new EE Plan, and a proposal for a new EE Directive is currently under negotiation. The latter will require public authorities to refurbish at least 3% of their building stock by floor area each year. Public and private sectors work in partnership to deliver public infrastructure projects such as roads, railways, airports, schools, hospitals and prisons. PPPs generally share the following features:

- a long-term contract between a public contracting authority and a private sector company based on the procurement of services;
- the transfer of certain project risks to the private sector;
- a focus on the specification of project outputs rather than project inputs;
- the application of private financing in most instances; and
- payments to the private sector which reflect the services delivered.

Experience over the past 30 years in the UK and North America has demonstrated that PPPs can be used to yield energy savings in the public sector; the main features of EE PPPs are similar to those of accommodation PPPs. They use Energy

Performance Contracts ("EPCs") and the private partners in these arrangements are known as Energy Service Companies ("ESCOs"). ESCOs can also be set up by public entities. There are different types of EPCs; including projects in which the private partner has the responsibility for delivering a service (i.e. providing final users with heat and/or electricity) through the construction and operation of a corresponding facility. The public entity repays the cost of the service. This Guide focuses on works to existing buildings. In an EE PPP, the "design" normally refers to the optimisation of the EE of an existing public building or a pool of buildings. The "build" phase of the project normally refers to retrofitting and the implementation of EE measures in existing buildings rather than to new constructions. EE also plays an important role in PPP accommodation projects (e.g. hospitals and schools). In this case, EE forms part of the output specification, but it is not the primary focus. The most innovative aspects of the EPC are the energy savings guarantee provided to the public partner and the payment of fees proportionate to the EE performance. This innovative approach may lead to preparation, establishment and implementation processes that are different from infrastructure PPPs. This is mainly due to the fact that the expected output (energy savings) is measured in terms of the reduction achieved. As a result, EPCs require a different approach to the management of the procurement phase. Correspondingly, an essential element will be to design the methodology for measuring and calculating the energy savings effectively at the outset, in order to properly allocate risk sharing between the various parties.

The EC and EU member states have developed policies to achieve ambitious goals in EE, promoting renewable energy and curbing GHG emissions. Public buildings represent a considerable opportunity given the estimated large potential for savings of fossil fuel-based energy. PPPs can play a key role in the development of EE through accelerating the pace of investment and mobilising private sector finance.

1.2 CHALLENGES FOR EE INVESTMENTS IN PUBLIC BUILDINGS

Four main challenges remain for the development of EE approaches in the public sector:

- **Technical challenges**: Public building owners or users often lack the technical background and expertise to understand EE methods and technologies for reducing energy consumption and/or replacing the consumption of fossil fuels with renewable energy sources. The first challenge is to ensure that public building managers are conscious that there is a gap between the level of energy consumption of the facility they are administering and the level which could be achieved if a specific energy conservation effort were to be employed and its financial value. This lack of awareness can usually be explained by the absence of methods for monitoring energy consumption and physical energy parameter regulations. A further technical challenge is to demonstrate that there are proven technologies, methods and services that can be used to substantially reduce energy consumption or substitute the energy consumed with other forms that could be less expensive and/or less polluting. ESCOs, when implementing EPCs, will install a measurement system with a twofold objective: it will help the energy manager of the building to reduce energy consumption and it will create the measurement and verification ("M&V") framework that the ESCO needs to estimate the level of savings achieved.
- **Economic challenges**: Demonstrating the cost-effectiveness of EE projects is generally problematic. EE projects have been subject to erratic variations in energy prices over the past 30 years. There is often no incentive to save when budgets are allocated on an annual basis. Similarly, if operating costs are

matched by an operating budget then, particularly, public authorities owning or renting the building will have little incentive to reduce the costs. In addition, it may be difficult to convince managers to undertake projects which might become uneconomic when energy prices decline for a limited period. Guarantees regarding the profitability of such investments are key, both from a technical (physical savings) and economic (financial savings) standpoint.

- **Budget challenges**: Public entities often encounter difficulties in raising finance for investments. They may not be able to finance their whole investment programme directly from public funding. This requires them to prioritise and, often, overlook EE investments. Additionally, the capacity of public entities to leverage debt is increasingly limited. In some cases, this may be the result of restrictions imposed by the regulatory framework or it may be due to their inability to increase the level of debt while still meeting prudent borrowing principles.
- **Legal and institutional challenges**: The introduction of EE measures or the implementation of EE investments in public buildings may also be hampered by a series of issues relating to the legal, regulatory or institutional framework.

1.3 CONTEXT

1.3.1 THE EUROPEAN LEGISLATION

The 2010 *Energy Performance of Buildings Directive* and the 2012 *Energy Efficiency Directive* are the EU's main legislative instruments promoting the improvement of the energy performance of buildings within the EU and providing a stable environment for investment decisions to be taken. As Directives, they needed to be transposed by Member States into national legislation.

The 2010 *Energy Performance of Buildings Directive* has made it possible for consumers to make informed choices that will help them save energy and money and has resulted in a positive change of trends in the energy performance of buildings. Following the introduction of energy efficiency requirements in national building codes in line with the Directive, new buildings today consume only half as much as typical buildings from the 1980s.

On 30 November 2016, as part of the *Clean Energy for All Europeans* package, the Commission proposed an update to the *Energy Performance of Buildings Directive* to help promote the use of smart technology in buildings, to streamline existing rules and accelerate building renovation. The Commission also published a new buildings database – the EU Building Stock Observatory – to track the energy performance of buildings across Europe. In order to direct investment towards the renovation of building stock, the Commission also launched the *Smart Finance for Smart Buildings* initiative, which has the potential to unlock an additional €10 billion of public and private funds for energy efficiency and renewable uptake in buildings.

On 19 June 2018 Directive (2018/844/EU) amending *the Energy Performance of Buildings Directiv*e was published. The revised provisions will enter into force on 9 July 2018. This revision introduces targeted amendments to the current Directive aimed at accelerating the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by 2050 and the mobilisation of investments. The revision also supports electromobility infrastructure deployment in buildings' car parks and introduces new provisions to enhance smart technologies and technical building systems, including automation.

1.3.2 The Italian context

As you know, art. 5 of D. LGs. 102/2014 promotes the energy upgrading of public buildings; It foresees that the Ministry of Economic Development, in agreement with the competent administrations, prepares every year, starting from 2014 and until 2020, a program for the energy upgrading of the buildings of the central Government (PREPAC) capable of achieving the energy requalification at least equal to 3% per annum of the air-conditioned useful covered surface.

For the realization of this program, the Ministry of Economic Development has proceeded to enact DM 16 September 2016 "modalities of implementation of the program of interventions for the improvement of the energy performance of the public buildings Central Administration "(PREPAC decree) governing the preparation and implementation of programs for the energy upgrading of PA Centrale44 's properties.

The central public Administrations, by 30 June of each year, prepare, also in a joint form, proposals for intervention for the energy upgrading of the buildings by the same employed, also using the Provveditorati Interregional public Works of the Ministry of Infrastructure and Transport, and transmit them, within the next fifteen days, to the Ministry of Economic Development. These proposals must be formulated on the basis of appropriate energy diagnoses or refer to energy improvement measures provided for by the Energy Performance Certificate (EPAs).

Are excluded from the Energy regeneration program:

• Real Estate with a total usable surface of less than 250 m2;

• The properties constrained according to the provisions of the Legislative Decree of 22 January 2004, no 42, to the extent that compliance with certain minimum energy performance requirements would alter their character or appearance in an unacceptable manner;

• Buildings intended for national defense purposes, with the exception of individual housing or office buildings for the armed forces and other personnel employed by the national defense authorities;

• The buildings used for places of worship and the carrying out of religious activities.

The Ministry of Economic Development in agreement with the Ministry of the Environment and the protection of the Territory and the sea, heard the Ministry of Infrastructure and Transport and in collaboration with the agency of the state, predisposes by 30 November of each Year, a program of interventions for the improvement of the energy performance of the properties of central PA. In the drafting of the program, account should also be taken of the results of the inventory, prepared in implementation of article 5 of Directive 2012/27/EU, containing information on the areas and energy consumption of buildings in Central government, the data on energy consumptions recorded in the Hyper Computer application managed by the agency of the State. For the definition of this program, identification criteria are applied between several interventions, based on the lower cost of the kWh saved, less time foreseen for the implementation of the interventions, magnitude of possible forms of co-financing, even though Borrowing through third parties.

1.4 ENERGY CONSUMPTION OF ITALIAN PUBLIC BUILDINGS

The school sector is one of the most studied, for various reasons, and its consistency is more or less ascertained in the order of 43,000 units. Taking into reference the data of the territorial division of employees, provided by CONSIP, we can deduce the following table:

	North	*Centre*	*South*
Total	17000	9500	16500
Ante 373	11400	6400	11000
Post 373	5600	3100	5500

TABLE 1: NUMBER OF UNITS

The "public directional" sector, instead, is in absolute the least known: it is known that the "contracting entities" in Italy are about 15,000 and that the totality of the "directional" buildings totally occupied by non-residential (public and private) is about 80,000 units. As mentioned in the introduction, CRESME has created for ENEA, the main results are shown below. The real estate of buildings "totally office" is 13,580 buildings, equal to a covered area of 23.4 million m^2. The articulation of public buildings by sector is shown in the following table:

	Buildings	*Surface*
Public administration	9550	16811119
Education	2025	2594456
Health	508	2285834
R&D	247	491701
Energy, gas, water utilities	129	100312
Real estate and construction	128	189469
Others	993	955683
Total	***13581***	***23428573***

TABLE 2 BUILDING AND HIS SURFACE

An evaluation carried out by CONSIP estimates the total energy costs of the nation (including automotive fuels) in about 4.5 billion euros. It is worth noting that in this case there is a consumption that is not investigated, and on which one does not intervene, and is that concerning the consumption of office equipment (computers, printers, etc.) and lifting systems. It is considered, following some analysis carried out on some buildings, that the weight of this portion of consumption can affect about one third of the total number of energy consumption of a directional building.

A parametric study on heating consumption, realized in 2007 estimates the costs of heating fuels (without VAT) in about 1.6 billion euros. This data, compared To the totality of employees occupying buildings that are linked to entities that are the subject of this study, It is worth about 1.4 billion euros (incl. VAT).

Thanks to the model developed by ENEA, it was possible to rebuild the composition of the of each type of building, the total data (total costs for thermal = 1.209 Mio €) differs by defect from the given CONSIP, since, as mentioned, in this survey are not taken in consideration all the real estate units, but only those totally destined for offices.

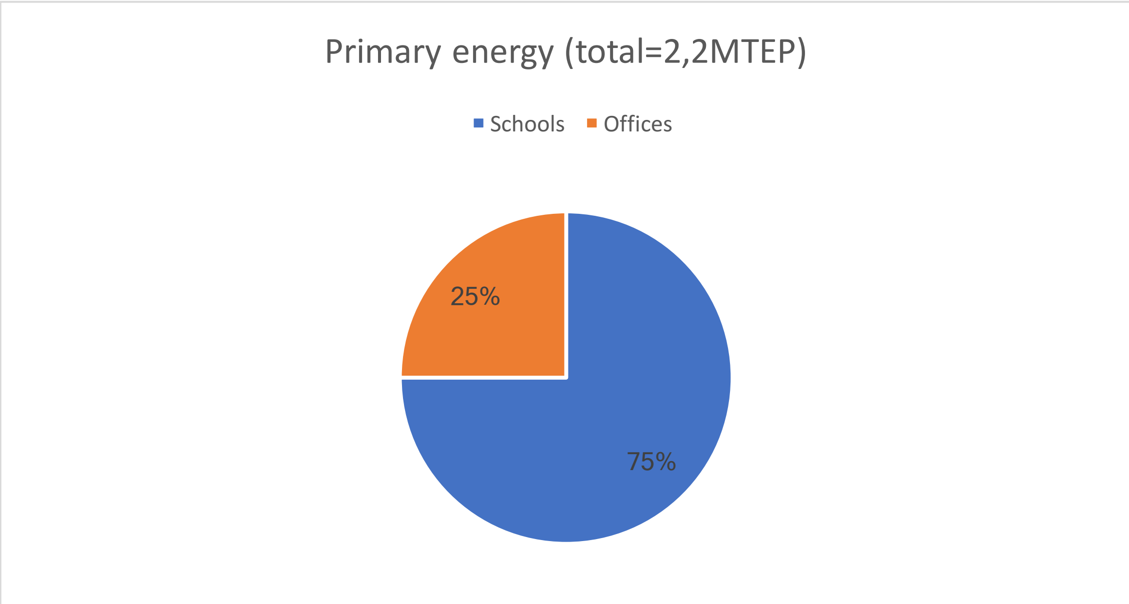


FIGURE 1 PRIMARY ENERGY

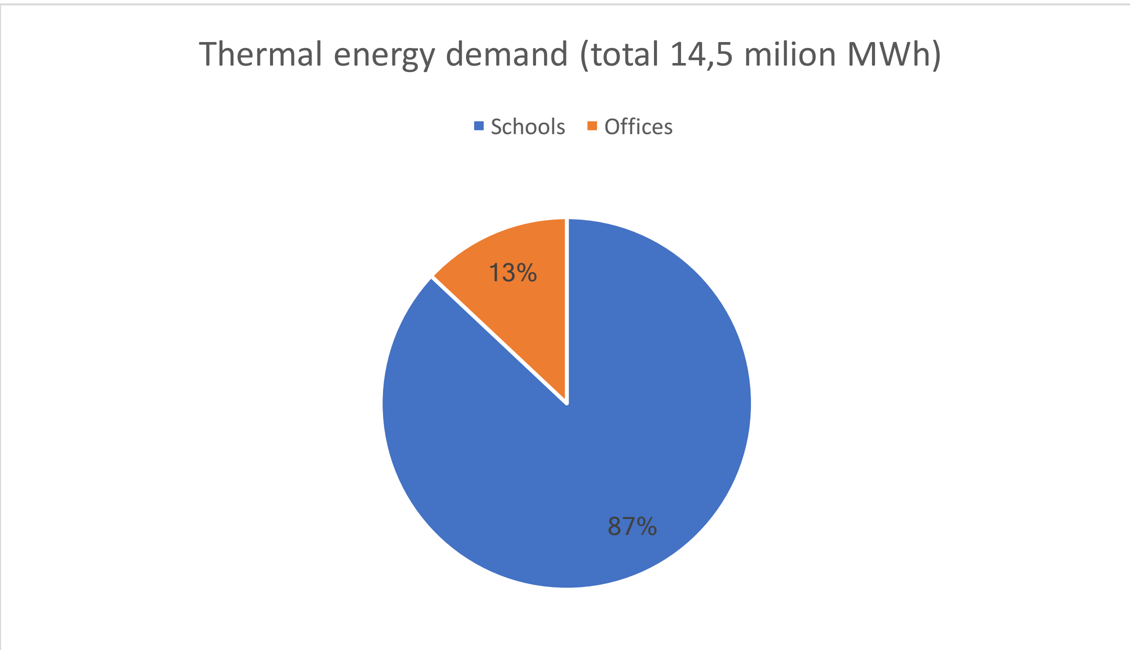


FIGURE 2: THERMAL ENERGY DEMAND

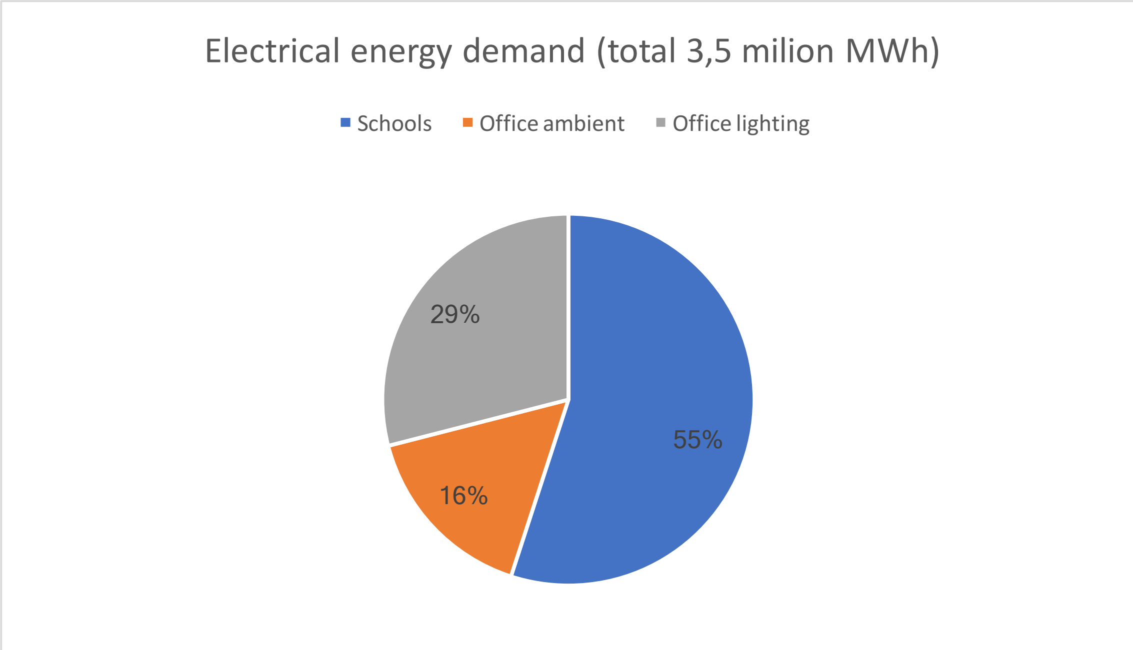


FIGURE 3: ELECTRICAL ENERGY DEMAND

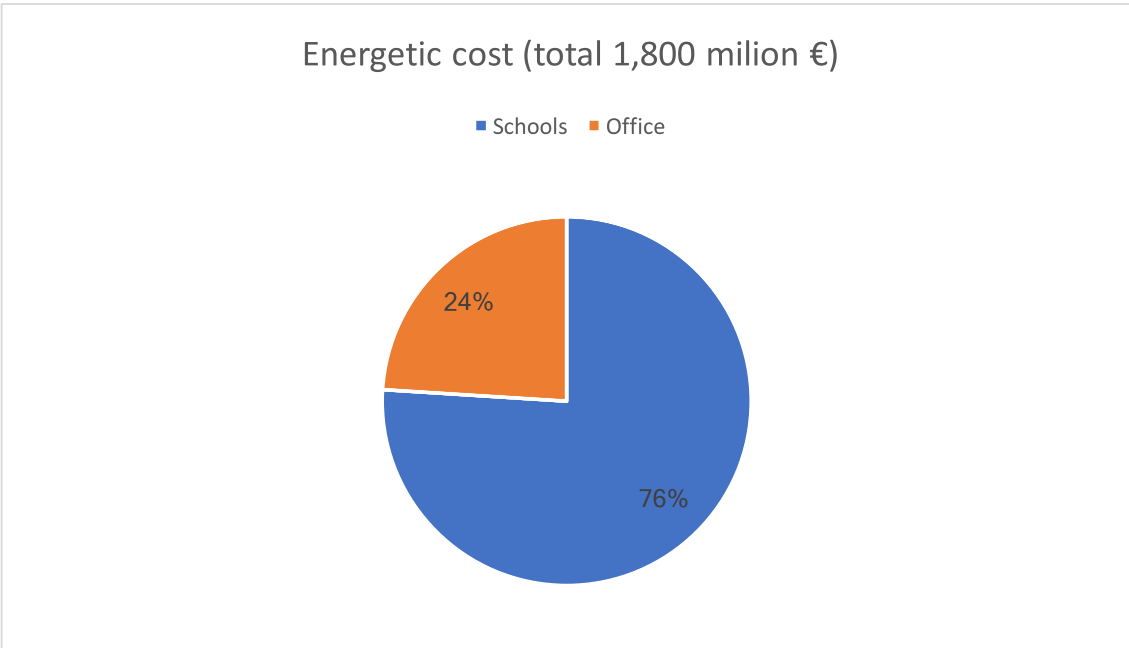


FIGURE 4:ENREGETIC COST

How can be seen from the graphs just reported, the most of energy supply of public buildings is attributable to schools. That is why my work will focus on the analysis of the reduction of energy consumption in school buildings.

1.5 SCHOOLS IN ITALY AND THEIR REDEVELOPMENT IN THE DIRECTION OF NZEB

The Italian schools are about 51,000, for an area of about 73 million of M2 and a volume of 256 million m3. The largest share of buildings (39%) has a size between 1,000 and 3,000 m2, with an average area of 1,819 m2. About 43% of the buildings are divided between three surface classes: 16% have a surface area between 751 and 1,000 m2 (average 899 m2), 14% between 501 and 750 m2 (average 631 m2) and 13% between 351 and 500 m2 (average 435 m2).

The graph of Figure 5.1 shows the construction typologies according to the climatic zone of origin, while the percentages of the different energy sources used for the winter heating of the buildings for school use are shown in Figure 1.5.

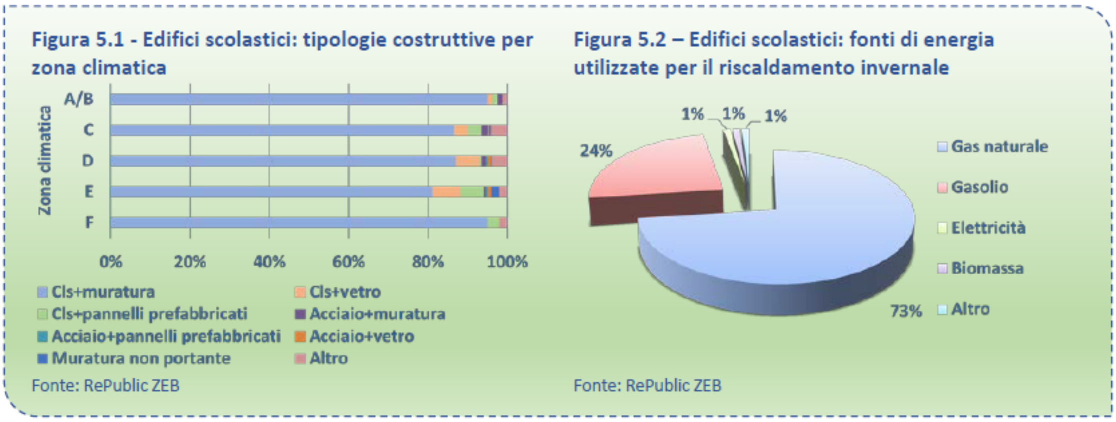


FIGURE 5: TYPE OF BUILDING

The primary energy consumption averages around 155 kWh/m2a for the air conditioning and sanitary hot water service. Thermal consumption is mainly due to the need for winter heating, with a negligible use of ACS, while the consumption of electricity is primarily due to ambient lighting and equipment related to Office and educational activities.

For buildings with an exclusive and prevalent school use, the mission structure for the school building of the Presidency of the Council of Ministers, estimates that for the approximately 41,000 school buildings surveyed and considered, the consumption of thermal energy is expected on About 9.5 TWh/A and electricity around 3.66 TWh/a. Energy regeneration interventions were carried out on about 58% of the school buildings (mission structure of the Council of Ministers) with the consequent benefits For the energy balance of the sector.

With the ministerial decree of June 26, 2015, the so-called "DM minimum Requirements", our country has defined in detail the characteristics that must have the buildings to be considered nZEB (buildings with almost zero energy) in accordance with the European Directive 2010/31/EU (EPBD) on energy performance in construction. The renovation of existing public buildings, in order to transform them into NZEB buildings, is strategic, as these buildings play an important demonstrative function. Among the public buildings, schools assume great importance from this point of view. The PANZEB46 document estimates, for the energy restructuring of existing school buildings, the potential reported in table 1.3. The overall savings achievable at 2020 is over 2,900 toe.

For newly constructed schools, however, the PANZEB forecast of surface built per year is 3.3 million of M^2. If it is assumed that 1% will be of type NZEB (33,800 m^2), corresponding to an area of about 30,500 m^2 for public schools and about 3,400 m^2 for private ones, the overall savings achievable at 2020 is over 776 toe. Table 1.4 Reports estimates for this situation.

Tabella 5.2 – PANZEB: risparmi energetici da ristrutturazioni energetiche degli edifici scolastici esistenti

EDIFICI NON RESIDENZIALI		Risparmio specifico nZEB	PUBBLICO			PRIVATO			TOTALE
			Specifiche nZEB	Specifiche nZEB cumulato 2015 - 2018	Stima Risparmi	Specifiche nZEB	Specifiche nZEB cumulato 2015 - 2020	Stima Risparmi	Stima risparmi totali al 2020
Tipologia	*Zona climatica*	*Kwh/m³ annuo*	*m³/anno*	*m²*	*tep*	*m³/anno*	*m²*	*tep*	*tep*
Scuole	A-B-C	9	23.968	95.872	321	2.663	15.979	42	362
	D	19	15.048	60.192	451	1.672	10.032	59	210
	E-F	31	37.214	148.856	1.808	4.135	24.809	234	2.043
Subtotale scuole			**76.230**	**304.920**	**2.580**	**8.470**	**50.820**	**334**	**2.914**

Fonte: PANZEB

FIGURE 6: PANZEB DOCUMENTS ESTIMATE

Tabella 5.3 – PANZEB: risparmi energetici da edifici scolastici di nuova costruzione

EDIFICI NON RESIDENZIALI		Risparmio specifico NZEB	PUBBLICO			PRIVATO			TOTALE
			Specifiche NZEB	Specifiche NZEBcumulato 2015 - 2018	Stima Risparmi	Specifiche NZEB	Specifiche NZEBcumulato 2015 - 2020	Stima Risparmi	Stima risparmi totali al 2020
Tipologia	*Zona climatica*	*Kwh/m³ annuo*	*m³ /anno*	*m²*	*tep*	*m³ /anno*	*m²*	*tep*	*tep*
Scuole	A-B-C	6	9.587	38.349	85	1.065	6.392	11	96
	D	13	6.019	24.076	120	669	4.013	16	136
	E-F	21	14.886	59.544	481	1.654	9.924	62	544
Subtotale scuole			**30.492**	**121.968**	**687**	**3.388**	**20.328**	**89**	**776**

Fonte: PANZEB

FIGURE 7: PANZEB DOCUMENTS ESTIMATE

1.6 POSSIBLE INTERVENTIONS FOR PUBLIC BUILDINGS

This operational guide is addressed to public administrators and executives As an instrument of first information on the complex matter of the Energy upgrading of buildings, in particular scholastic ones. The The issue is not intended to be exhaustive nor technically thorough, nor is it Can replace the expertise of professionals in the field, who need to be Once decided to undertake such an action. The transformation of an existing building into a high-performance structure Energy through the adoption of technologies for the improvement of energy efficiency, cannot disregard an accurate analysis of the status of the Of the building-plant system and may provide for interventions of various kinds, Example on the building envelope, interventions of retraining of electrical systems and the production and distribution systems of thermal energy, Installation of energy production plants from renewable sources, etc. The improvement of the building envelope to reduce heat dispersion in the Winter season is a priority, as it reduces the energy needs of the Primary However, this intervention requires long return time Investment and must be assessed in relation to the actual energy consumption of the building and the climatic zone of belonging. On the other hand, in some cases, limiting interventions to the mere substitution of plants involves the risk of Produce heat in an optimum way and then disperse it through the casing "Sieve". The ideal tool to solve these uncertainties is the energy diagnosis, a Procedure for the coordinated analysis of the building-plant system, which aims to Identify the actions to be carried out, define their priorities and quantify the Cost-benefit-saving opportunities for energy savings. In General, when you decide to proceed with the energy upgrading of a Building to make it highly-capable, you have to take in Consider the following key elements:

1. High energy performance casing. Greater isolation of Walls, floor slabs and roof slabs helps to Reduce heat loss in the winter season and improve comfort. Light-colored exterior walls, bia shading roofs help reduce energy loads for cooling Of the rooms in the summer season. These factors contribute to Properly sizing the air-conditioning system, thereby reducing The initial investment and management and maintenance costs in the long term.

2. Windows and daylighting. A better use of natural light helps to reduce the Use of electricity for lighting and to limit energy consumption Also for the air conditioning avoiding the heat generated by the same Devices. High-performance windows allow you to minimize Heat in the warmer months and avoid heat loss in the months most Cold.

3. Lighting and electrical systems. The LED lighting systems, body Lighter or lamp, and the management and control systems able to modulate Automatically the necessary light levels, with matched presence sensors, that automatically turn off the lights in unoccupied environments, They represent investments with very low return times and Significant and immediate energy saving.

4. Air conditioning and ventilation systems. The choice of the type and The size of the air conditioning and mechanical ventilation systems is an operation Complex because it is closely related to the elements described above and has a direct influence on the costs of exercise and maintenance. The use of Automatic systems for setting the temperature of the rooms It allows to reduce energy waste and to optimise comfort in Environments.

5. Renewable energy-powered systems. These systems can integrate the Supply of the building's electrical and thermal energy. In relation to the profiles of Consumption and the characteristics of the building it is possible to use biomass for air conditioning, photovoltaics or wind power in combination with Accumulation for safety lighting, emergency power supply and Sensitive equipment or solar thermal for the production of hot water Health.

6. Water management systems. Rainwater Collection systems capable of to allow the reuse of water for sanitary and irrigation can reduce the Supply costs up to 50%. Nchi and solar shading systems and the general assumption of interventions that generate savings Must be in any case the fulfilment of all the standards which are Structural stability and the safety of buildings as well as respect for the Of the requirements and minimum standards provided for by the Ministerial Decree of 26 June 2015 (ref. Appendix "Laws and regulations on energy efficiency").

LITERATURE REVIEW

2.1 LITERATURE REVIEW

The study of energy performance and energy management in buildings is the subject of several significant paper. In Slovenia, Butala and Novak study that in school buildings, the recommended values and the nominal heating capacity is 57% oversized, and the heat losses are 89% higher than. In Grece, Santamouris carried out energy audits on 238 schools' buildings in Greece for construction, cooling, lighting, heating and mechanical and electrical systems, in order to computed the energy-consumption indicators and the energy-saving solution. With this study it is discovere that the annual average energy consumption is 93 kWh/m^2, of which the most is consumed for space heating. The assessment of various energy-conservation techniques shows a potential for 20% overall energy conservation. In a zone of Greece Dimoudi and Kosteral assessed the energy performance, based on data, of school buildings, are evaluated in this zone for the lowest air temperature during the winter period, and the energy conservation measure are evaluated 123,31 kWh/m^2 is the annual energy consumption for all school buildings, with non-insulated buildings having a mean energy consumption of 139,16 kWh/m^2 and insulated buildings 115,38 kWh/m^2. Improving the thermal insulation a reduction of up to 13,4% is taken in the energy consumption. Another study, Theodosiou and Ordoumpozanis in Greece, on the energy efficiency thermal environment and indoor air quality in public nursery and elementary school buildings in the city of Kozani, located in the cold climatic zone of Greece. They have compute a survey both by means of measurements in the field and through questionnaires in that the main parameters affecting for investigate the overall performance of the school. The control of heating and lighting systems, the absence of proper legislative measures and, above all, the lack of interest concerning the efficiency of such buildings are the main factors in the efficiencies reported. Another piece of research, on the improving energy performance in school buildings powered by Becker whilst ensuring ventilation indoor air. A step by step process was used for this study in order to develop of the satisfaction design solutions, which cope with the EE-TC-IAQ (energy efficiency—thermal comfort—indoor air quality) Dilemma. Indication that ventilation schemes need to develop nergy-conscious building result in savings in an otherwise well-designed e of 28–30% and 17–18% respectively on the classroom orientations. On the same issue is the work of Butala which analysed school buildings in many Slovenia towns and countryside, comparing and considering both real energy consumption and indoor air quality data. The energy performance of school buildings it is the focus on the classifying and rating In Greece Santamouris studya new energy technique based on iclustering tailored for intelligent school, using energy consumption data that were collected through energy surveys performed in 320 school. In Ireland, Patxi propose a simple method in that outlines techniques for develop the energy benchmarks and rating systems starting from the data collection of first step from the building stock of primary schools. Erhorn study in 10 European countries propose a tool that assists educational building decision makers called the “Energy Concept Adviser”, in identifying and calculating the potential energy savings of new and existing buildings.

Hernandez work on the energy benchmarks outline a methodology of rating systems starting from the first step of data collection from the building stock.

Methods for rating a sample Irish school according for both calculated and measured ratings are applied, and finally the paper of the two approaches speak about and discusses the advantages and disadvantages. In London Tian and Choudhary propose probabilistic energy model for non-domestic building sectors applied to analysis of schools buildings. In Italy, Corgnati study method for the heating consumption assessment of a sample of approximately 140 buildings (120 high schools) in the Province of Turin. There are two different work interesting in support this study. The first is about the methodologies for energy retrofits on the existing buildings, in which he study the best retrofit options in a systematic approach to proper selection and identification for existing buildings.

Zeiler and Boxem theme of high energy-performance school buildings is covered. In this work the analysed one of the first designed school NZEB (Net Zero Energy Building) in the Netherlands comparing the results with the traditional schools. In this paper there a long list of pro and disadvantages taking account of the available technologies.

It is clear from the above considerations that the issue of improving the energy performance of public buildings, is a topic of current interest, and specifically school buildings. The studies discussed above have explored many important aspects of the subject. In the European legislative framework a more comprehensive approach has evolved significantly in recent years, is now required the assessment of the economic effects of the choices related to energy performance retrofit. In Italy does not exist detailed on the school building stock In the Article 7 of Law 23/96 states that MIUR (Ministry of Education, University and Research) for implementing and managing the National Register of School Construction in cooperation with local authorities, in order to ensure consistency, an appropriate situation and the functionality of the stock. Currently, however, this registry is not yet complete and helpful. The data provided by ISTAT (National Statistics Institute) estimate that the assets include a total around 43000 national school buildings, divided as follows: 49% nursery schools, 35% primary schools, 16% first level secondary schools.ANCE (Associazione Nazionale Costruttori Edili), the builders association, with the technical support of Cresme (Centro Ricerche Economiche Sociali di Mercato per l'Edilizia e il Territorio), study on the state of buildings throughout Italy from which there are a lot of information in relation to the school buildings. In this study the 64,797 school buildings are taken into account, in which 6415 were constructed before 1919, 6026 between 1919 and 1945, and 28,127 between 1945 and 1971. 62% of the them therefore more than 40 years old and often the level of maintenance is poor. The highlights of this study it is an important criticism about the school buildings: 37% of school buildings are located in areas seismic with risk zone and 9.6% in those of high risk of landslides. The security is a priority, and therefore it is strategic to promote integrated retrofit actions in order to ensure safety and energy efficiency together. At the national level, there is only one study, that evaluate the energy efficiency of the existing school and to calculate the possible actions of retrofit is the report prepared by ENEA and already mentioned.

CASE STUDY: THE SCHOOL

3.1 GEOGRAPHICAL REFERENCES

The building used to drive the evaluation analysis, as Reference Building, is the school “*Il Girasole*” a nursery and kindergarten school located in Turin, in the district called “Vanchiglia”, precisely in Via Grazia Deledda 11-13.

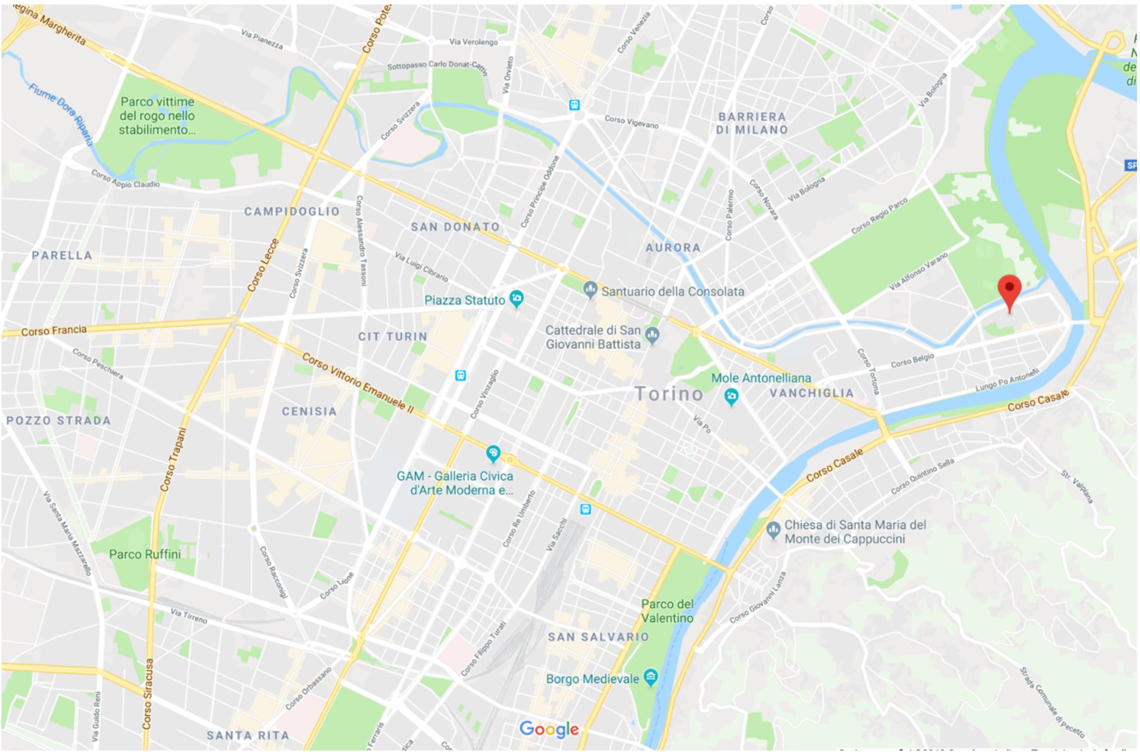


FIGURE 8: POSITION OF THE SCHOOL

As it is possible to see from the following photos, taken from Google maps, the school is composed by two building. The squared one on the right is the kindergarten and in the left with a shape like a *“L”* is the nursery school.

FIGURE 9: VISION OF THE SCHOOL FROM THE GOOGLE MAPS


FIGURE 10: NORTH-EAST SECTION OF THE KINDERGARTEN

FIGURE 11: NORTH-WESTSECTION OF THE KINDERGARTEN

The considered climatic data, as it is written before, are the one of Turin located in the climate zone E.

Degrees per Days	2617
Climatic zone	E
Location	Turin
Latitude	45° 4' 32" N
Longitude	7° 43' 16" E
Typology of building	Independent house

TABLE 3: GEOGRAPHIVAL DATA

3.2 DESCRIPTION OF SCHOOL BUILDING

In order to evaluate the existent situation and possible scenarios it is used a BIM relation. The first information is related to the occupation of the two buildings, in the kindergarten there are on average 150 students, while in the nursery school 92 children. in both building there is a canteen that makes every child a daily meal and a snack. In the nursery school is also present an internal laundry, which carries out 6 washes a day with its 2 washing machines.

The buildings were built in 1946. The building that houses the nursery mainly develops on one floor above ground and consists of a central atrium connected to the four corners, with four square-shaped buildings. The horizontal dispersing surface is therefore very extensive. in the basement there are technical rooms and a deposit, overall very small compared to the ground floor.

Inside the building there are in addition to the classrooms and offices, the kitchen where meals are prepared and the janitor accommodation, currently disabled.

The supporting structure is of the frame type in reinforced concrete and slabs in brick. The external vertical infills are of the empty-box type, consisting of a double wall in bricks or perforated blocks with external ceramic tile finish.

About the roof, the central atrium is provided with a flat roof that is presumably not insulated; the Latvian factory buildings are equipped with a covering slab bordering an unheated attic, also without insulation.

The external doors and windows are made of aluminum without thermal break, partly with single glass and partly with double glazing, with some blind sub-windows with plywood panels of about 2 cm and bins with external blinds.

The building that houses the kindergarten also develops mainly on a single floor above ground and is presented with an "L" shape.

In the basement there are the rooms dedicated to the staff (locker rooms, canteen) and the laundry, equipped with heating system. There are also service rooms and technicians (such as the thermal power plant) that are not heated, as well as an accessible bathroom.

The characteristics of the enclosure are like those of the nursery school: perimeter closing walls consisting of a double wall in bricks with ceramic tile finishing. The external doors and windows are in aluminum without thermal break with single glass, blind under-window with plywood panels of about 2 cm and boxes with external blinds.

The plexus consists of two separate buildings, but both are served by a single thermal power plant, located in the basement of the building that houses the nursery school, while in the building hosting the nursery school there is a pumping substation. the water heating system has cast iron radiators as output terminals without thermostatic valves. There are also 3 different distribution circuits that have different operating times and directed to:

- Classrooms and offices area of nursery school
- House of janitor
- Classrooms and offices area of kindergarten.

The domestic hot water production plant takes place in different ways in buildings.

In the nursery, in the kitchen there is a gas boiler with sealed chamber and forced draft, with a thermal power of 24 kw. On the other hand, there are three 1500 w electric boilers and one 1200 W electric boilers in the school bathrooms, and one 1500 W boiler in the custodian's quarters.

In the nursery, hot water is centralized and produced by a combined system with the heating system. On the semi-level floor there is a laundry room, where there are 2 electric power washing machines equal to 10.5 KW, each carrying out 3 washes a day.

The electrical system consists of an average of 4 fluorescent tube lamps for each room of the two buildings, for a total of approximately 440 W per classroom. Regarding the electrical devices inside the school complex, there are two refrigerators with a power of 400 W, one in each kitchen, two stereos and four TVs.

ELECTRIC PROFILE

This section describes the methods used to create the daily school's electrical profile. In order to carry out an energy efficiency analysis of a building, one must know what the electric and thermal consumption of the building is being present. In the report built using the software of Turin Polytechnic, only the bill data was necessary to reconstruct the electrical profile of the buildings.

4.1 ELECTRIC ANALYSIS

The starting data for this analysis, as already mentioned, are the bill data, referring to the year 2015 and 2016. The following table shows the values

Kindergarten	***2015***	***2016***
January	1080	3952
February	2785	3952
March	1120	2503
April	3952	2770
May	2291	1582
June	2192	1028
July	1397	3952
August	3952	3952
September	780	3952
October	3952	2657
November	3952	2455
December	3952	1877

TABLE 4: ELECTRICAL VALUE KINDERGARTEN

Nursery school	***2015***	***2016***

January	2801	1728
February	1849	1588
March	2328	1669
April	2328	1155
May	1505	1152
June	1429	749
July	906	2328
August	2328	2328
September	2328	2328
October	2328	1540
November	2328	1475
December	2328	1128

TABLE 5 ELECTRIC VALUE NURSERY SCHOOL

Total	***2015***	***2016***
January	3881	5680
February	*4634*	*5540*
March	3448	4172
April	*6280*	*3925*
May	3796	2734
June	*3621*	*1777*
July	2303	6280
August	*6280*	*6280*
September	3108	6280
October	*6280*	*4197*
November	6280	3930
December	*6280*	*3005*

TABLE 6: TOTAL ELECTRIC PROFILE

As can be seen by scrolling through the values, for some months the value remains unchanged, furthermore it can be noted that the values of the summer months of 2016 are higher than the winter values, even though the building is closed. Initially all the values were used, but in a second part some were rejected because they were considered unreliable. With this purpose, different approaches were used, to be precise four. Evaluated for their accuracy.

The 4 methods are:

- Load Profile Generator
- *Normativa ISO_DIS_18523*
- Method A
- Method B

In the following paragraphs the hypotheses underlying the different metrics will be described.

4.2 LOAD PROFILE GENERATOR

The Load Profile Generator (LPG) is a tool for creating load profile for the energy and water consumption in households. These profiles are meant to be used in other simulation as foundation for the analysis, for example, of optimal battery sizes, fuel cell sizes or demand side management systems.

This tool was created to help with research into new energy technologies, low voltage energy grids and energy storages. This model says that every person has desires, which that person will try to full. They decide on which activity to choose based on what would give them the maximum improvement in wellbeing at that moment.

The LPG provides a user interface to help the user put together a list of desires and an environment that enables the simulated people to full those desires. Such an environment is either a household or a house. A household contains locations, which contain devices which for possible actions (called affordances in psychology) to people.

The LPG contains a large number of predefined persons, devices and households, but it's not possible to cover every case. One important thing to consider when using the LPG is that the goal is not to create some mythic “average" household, but to create a large number of different, realistic individual cases.

The LPG tries to help with this problem by providing load profile for several simple cases and providing the tools for the user to create any kind of household that they might imagine.

Because during the development of the LPG a lot of different elements were added, it is helpful to organize them a bit. One approach is organizing by development area as shown in figure 4.1.

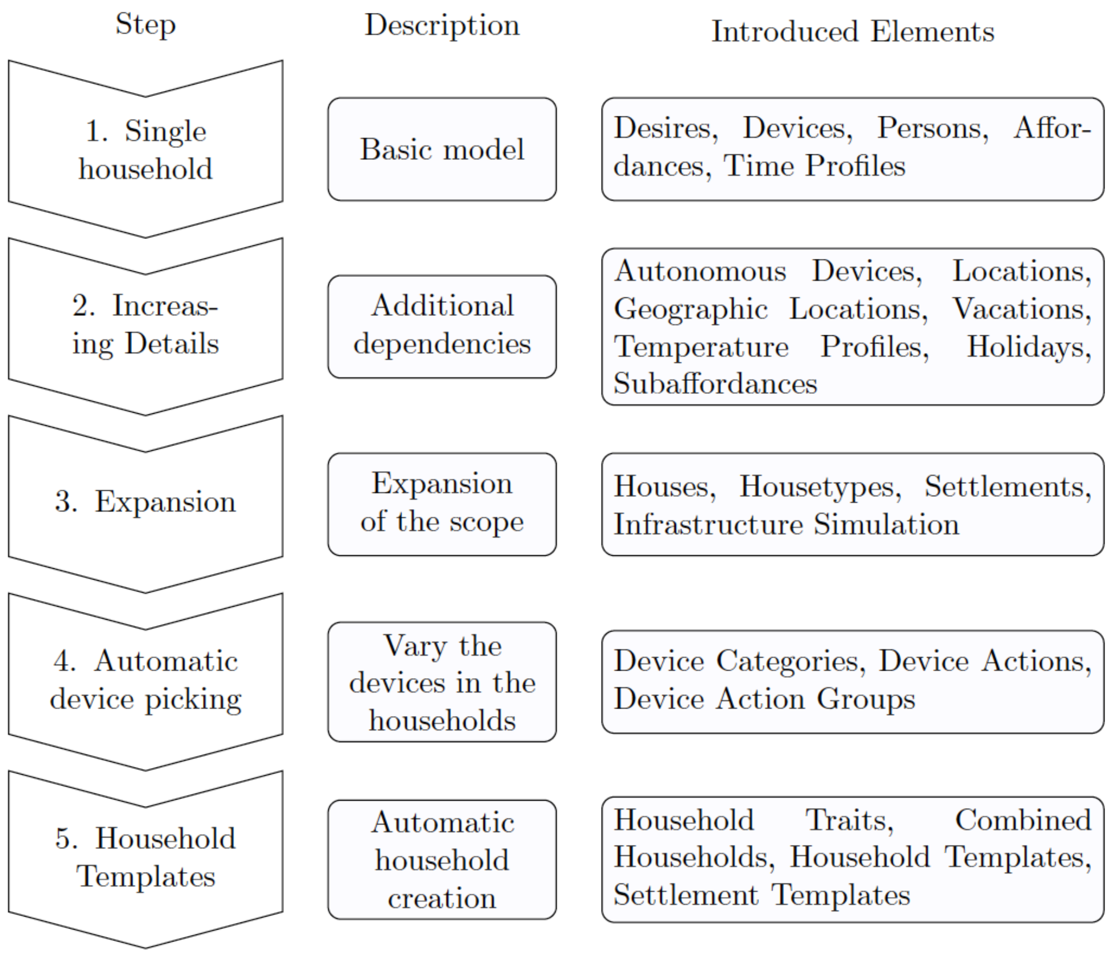


FIGURE 13: APPROACH SCHEME

Due to the nature of the software, the environment in which it works is a house, but in our case the building is a school, so we had to reason the other way around. it was assumed to include people who were at home when in fact they should work and consider them to work when I was sick, on vacation or at the weekend. Even regarding the apparatus, we had to reason this way. Electrical profiles were created that worked during the day, and switched off during the night, so that the electrical profile was the one desired. Later, the thought process will be better explained.

As already mentioned, in order to implement this tool, it was necessary to create the profiles of the different people, the different area and the devices of the school. To do this, the profiles of the teachers, canteen cooks and the pupils were created, in the different age groups. Once this step was made, the electrical devices inside the school were inserted, and the users, of the aforesaid devices, were defined. In the figure below, there are the details provides for individuals, in the first it is possible to identify one student, in the second one teacher.

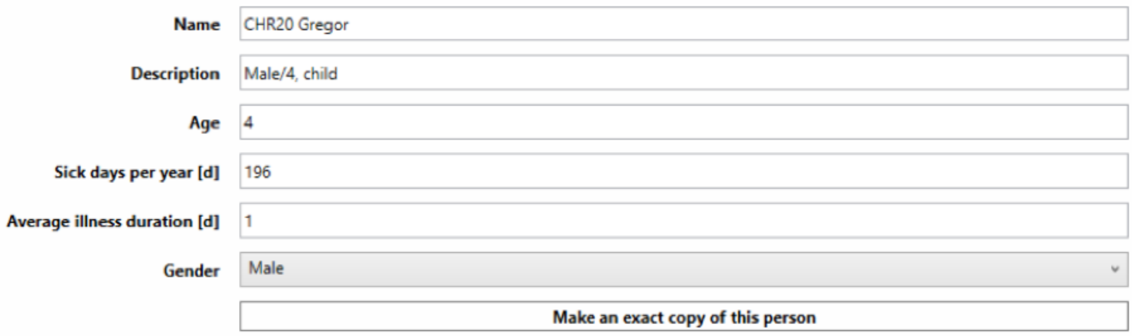


FIGURE 14: STUDENT SETTING FOR LPG

The information required to identify the person's profile was 6: name, description, age, sick days, mean days of illness and gender. As you can see, the days of illness of the teacher are equal to 163, this because the software reasons as if the school was a house, so for us the days of illness actually correspond to the days when the teacher works.

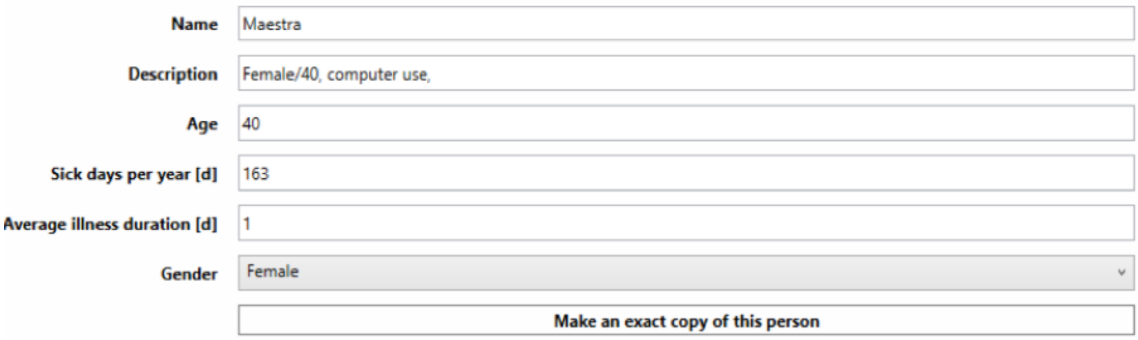


FIGURE 15: TEACHER SETTING FOR LPG

As far as the appliances are concerned, the information requested was the different types of appliance, the average hours of use within the day and the time slots in which they are usually used. It was also inserted which profile of person could use it. Obviously, the students have not been assigned the use of any device. With this information, the output of the LPG software of a classical school weekday was as follows (Figure 4.4).

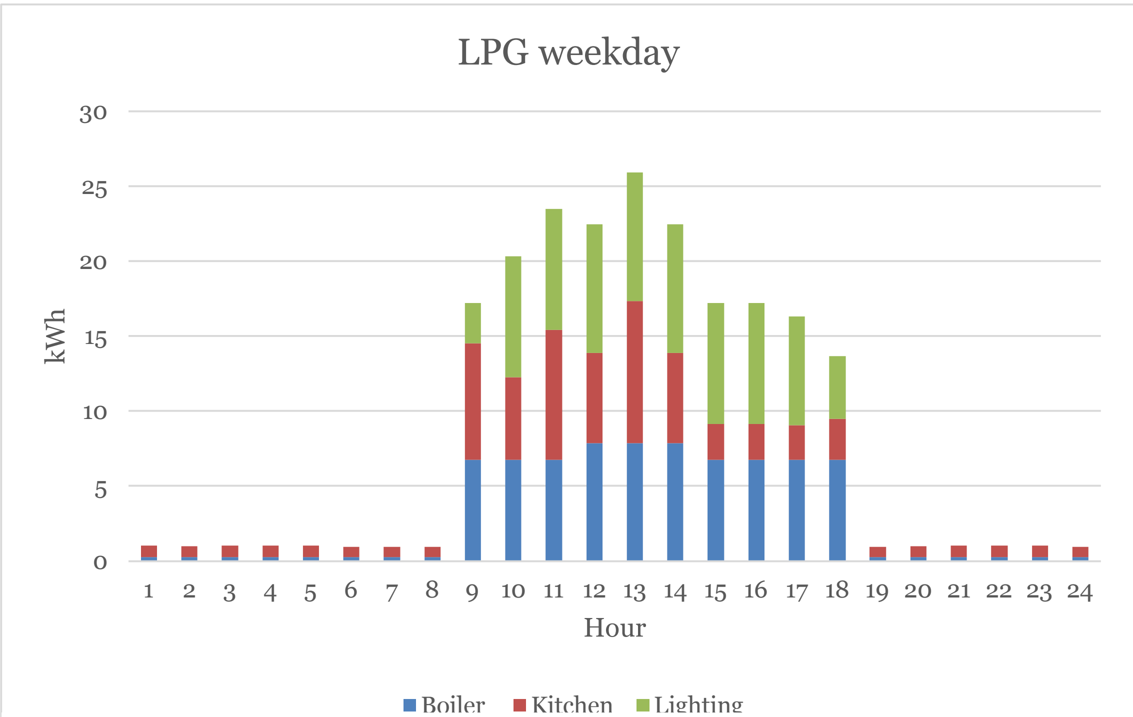


FIGURE 16: WEEKDAY PROFILE

From the profile you can see that the hours with the maximum demand for electricity are the central ones of the day. Precisely the peak power required is from 11 to 14, which corresponds to the use of the kitchen and its appliances such as ovens, dishwashers and washing machines. At the other school opening hours, from 8 to 19 the request is almost the same. So, it can be mainly attributed to lighting equipment, computers and televisions. It is also possible to see that in the hour when the school is closed, the request of electricity is not zero, this is because all the appliance needs a stand-by powers.

A profile was also created for the school holidays (figure 4.5), which shows how the required load of electricity is about the same. In fact, during the days when the school is closed, only the stand-by powers make up the load. Observing which components require the most power, it has been noted that the boilers require approximately 32% of the total stand-by power. The rest is to be charged with all other equipment, such as refrigerators, washing machines and dishwashers.

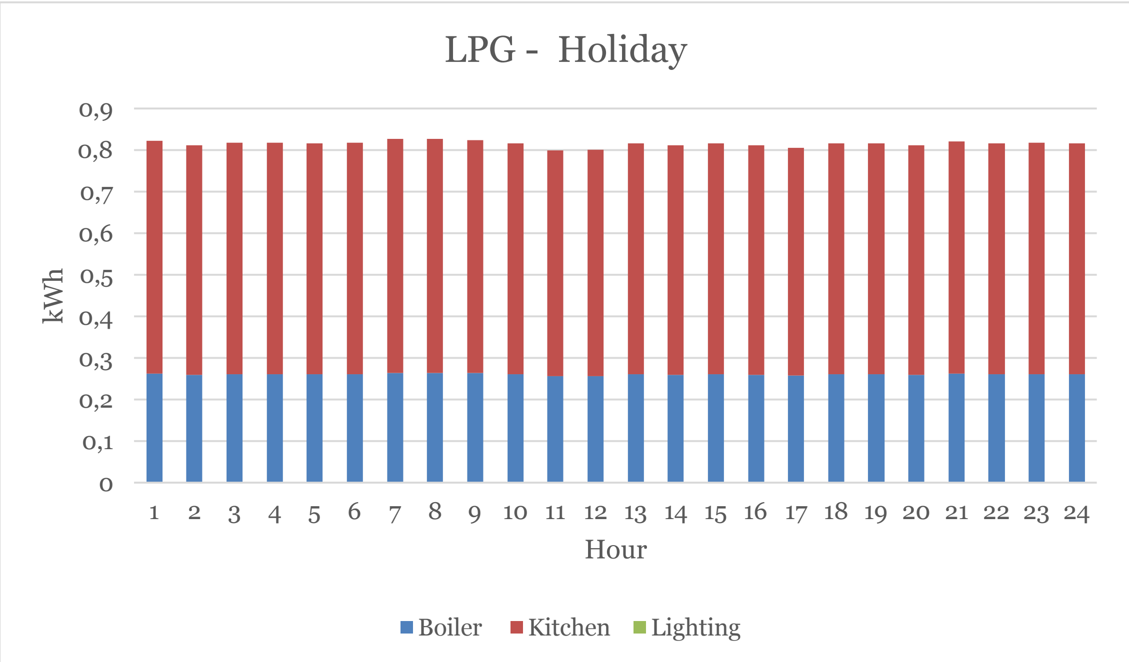


FIGURE 17: HOLYDAY PROFILE

The table below shows the electricity demand values for the single day, weekdays and holidays.

	kWh
Weekdays	210
Holiday	20

TABLE 7: DAILY CONSUMPTION

4.3 Legislation ISO_DIS_18523

This standard specifies the formats to present schedule and condition of building, zone and space usage, which shall be referred as input data of energy calculations for non-residential buildings.

The schedule and condition include schedules of occupancy, operation of technical building systems, ventilation rate, hot water usage and internal heat gains due to occupancy, lighting and equipment.

This standard also gives categories of building, zone and space according to differentiating schedule and condition. Depending on necessary minuteness of the energy calculation, different levels of schedule and condition from the view point of time and space averaging are specified. The values and categories for the schedule and condition are included informatively.

It should be noted that the schedule and condition in this international standard is basically different from assumptions in order to determine the size of technical building systems in the process of design, where possible largest values should be assumed. Instead, most usual and average values, which are assumed for the building energy calculation, are dealt with in this standard.

The daily electric profile is representing in the following graph, As for the LPG software, two types of load were produced, one for the holiday and one for the weekday.

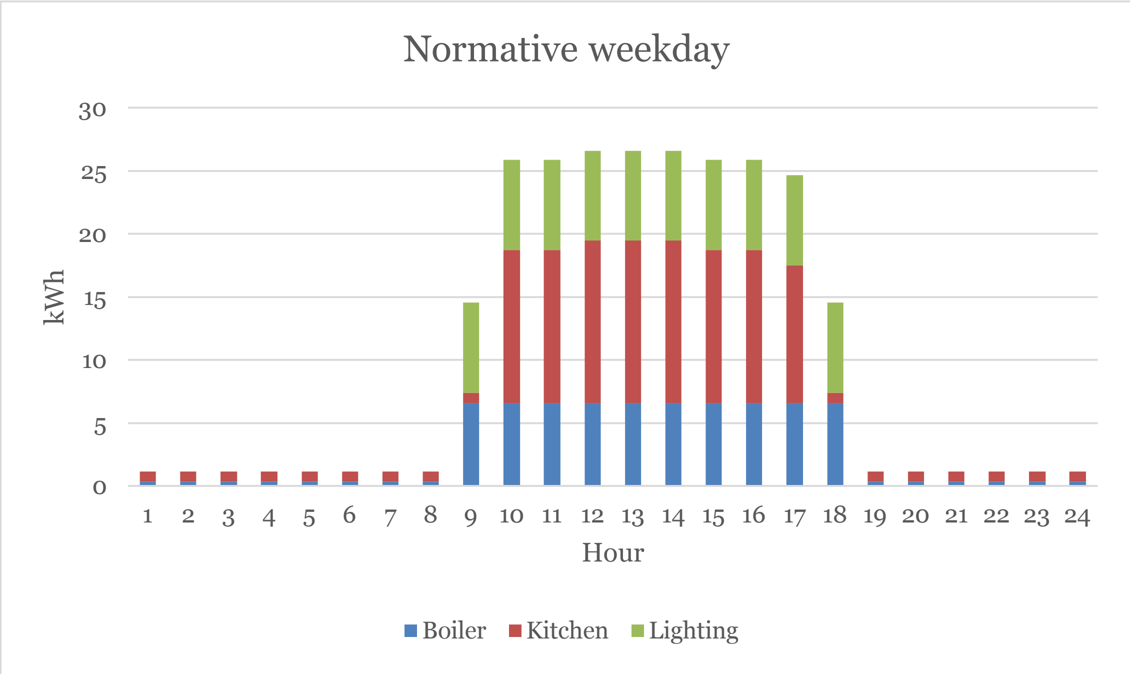


FIGURE 18: WEEKDAY PROFILE

As it is possible to see the pick of demand, is on the three hour, between 12-14 this is because the kitchen is on use in the hour of paste, and increment the value of the hot water, produced by the boiler.

The hour 18 have a decrement caused by the less use of office and the exit student of the nursey school.

It is also calculated the daily electrical for a holiday, the graph below show the profile.

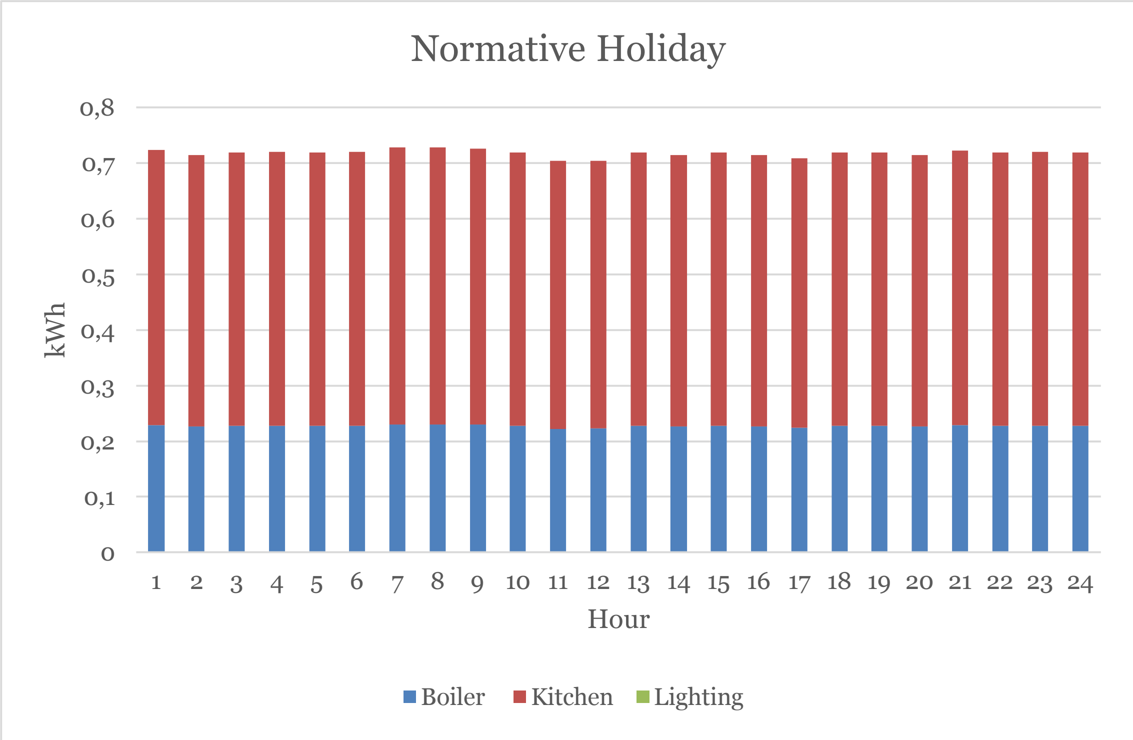


FIGURE 19: HOLIDAY PROFILE

The table below shows the electricity demand values for the single day, weekdays and holidays.

Period	***kWh***
Weekdays	253
Holiday	17

TABLE 8: DAILY CONSUMED VALUE

4.4 METHOD A

The method A, called in this way for ease is a change of the *Normativa ISO_DIS_18523* as already described above the legislation aims to define in addition to the minimum requirements also the hours and days of use of the facilities.

With this variation the requirements are kept together with the operating hours but instead the actual days of use of the structures are used.

These data have been extrapolated from the school calendar by the municipality of Turin and the Piedmont region. The table below shows the weekdays and public holidays for each month considered.

Month	***Workdays***	***Holiday***
Jan -15	19	12
Feb -15	19	9
Mar -15	22	9
Apr -15	21	9
May -15	19	12
Jun -15	10	20
Jul -15	0	31
Aug -15	0	31
Sep -15	13	18
Oct -15	22	9
Nov -15	21	9
Dic -15	14	17

TABLE 9: TORINO SCHOOL CALENDAR FOR 2015

Month	*Workdays*	*Holiday*
Jan -16	17	14
Feb -16	19	9
Mar -16	19	11
Apr -16	20	11
May -16	22	11
Jun -16	21	9
Jul -16	0	31
Aug -16	0	31
Sep -16	15	15
Oct -16	20	11
Nov -16	18	12
Dec -16	14	17

TABLE 10: TORINO SCHOOL CALENDAR FOR 2016

With this change, the daily electric profile of the building remains unchanged compared to that of the legislation, because the hours of daily use and the power loads considered remain unchanged. what changes instead is the current profile of the whole month.

For this reason, in the following figures (Fig 4.3;4.4;4.5) it is shown the profiles for three random months, February and September 2015 and May 2016.

For February, the demand of electricity remains the same, as the number of weekdays/holidays remains unchanged between Turin school regulations and calendar.

For September 2015 the number of weekday in the normative is higher than in the school calendar, so the amount of demand decreases with the method A. it became from 4990 kWh to 3595 kWh.

What happens in May 2016 is the exact opposite, the load increases as the number of working days increases. Go from 5007 kWh to 5748 kWh.

4.5 METHOD B

To try to improve still in the estimation of the electric profile, to get closer to the consumption of bills it was decided to use a new method, called B.

Method B is an evolution of method A and consequently of regulation, it uses:

- Regulatory requirements
- Real Days of the structure
- Real operating hours of the structure

In the Tab 11 are shown the operating hour of the two buildings,

	From	*To*
Kindergarten	8	18
Nursery School	8	17

Table 11 Operating hour of the structure

In the following figure is shown the workdays electrical profile.

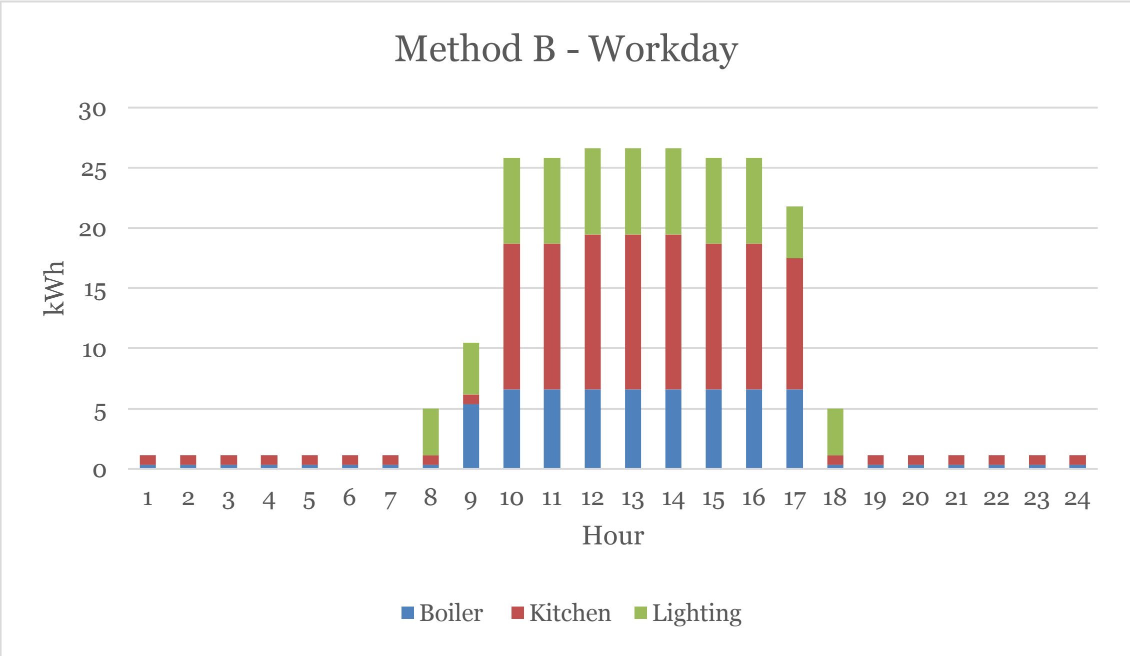


FIGURE 20 WEEKDAY PROFILE

With this methodology, the daily electrical profile of the building changes with respect to the normative profile, but it is not present a big change. Daily consumption goes from 253 [kWh] to 240 [kWh] on weekdays, this decrease is due to the reduction of the school timetable. The decrementing it is visible at 17, 18 and 19 where there is a reduction in demand.

Regarding the profile on holidays, the difference between legislation and method B does not exist, because being always closed there is no time difference.

4.6 COMPARISON AMONG METHOD

The following paragraph aims to examine the methodology, among the 4, that is closest to the measured electrical profile of the school.

The evaluation was carried out monthly to be able to compare them with the data in possession. To better compare the results, it was decided to calculate a percentage error of the various methods. The errors of each method are calculated for every month. In some months as: June, July, August 2015 the percentage error is very high for any methodology. As already written above, however, we need to understand how much the measured data are reliable. In other words, the electrical load of the summer months is very high even though the school complex is almost always closed.

Starting from this analysis, a few months were no longer considered for the rest of the study.

Going then to see what are the most information that give us these results the methodology that a lower average error has is the methodology B. Which has a mean error of 21% that, however, cleansed the months not very reliable is reduced to 5 %. In the following table are present the value of error for each methodology.

	LPG	*Normative*	*Method A*	*Method B*
Error	15,83%	37,70%	9,95%	4,85%

TABLE 12: ERROR VALUE

It is possible to see that the worst one method is the normative, but it is justifiable, considering the fact that it does not use the days of real use of the structures.

In the two graphs below, the methodologies were compared with each other and with respect to the value measured for two random months.

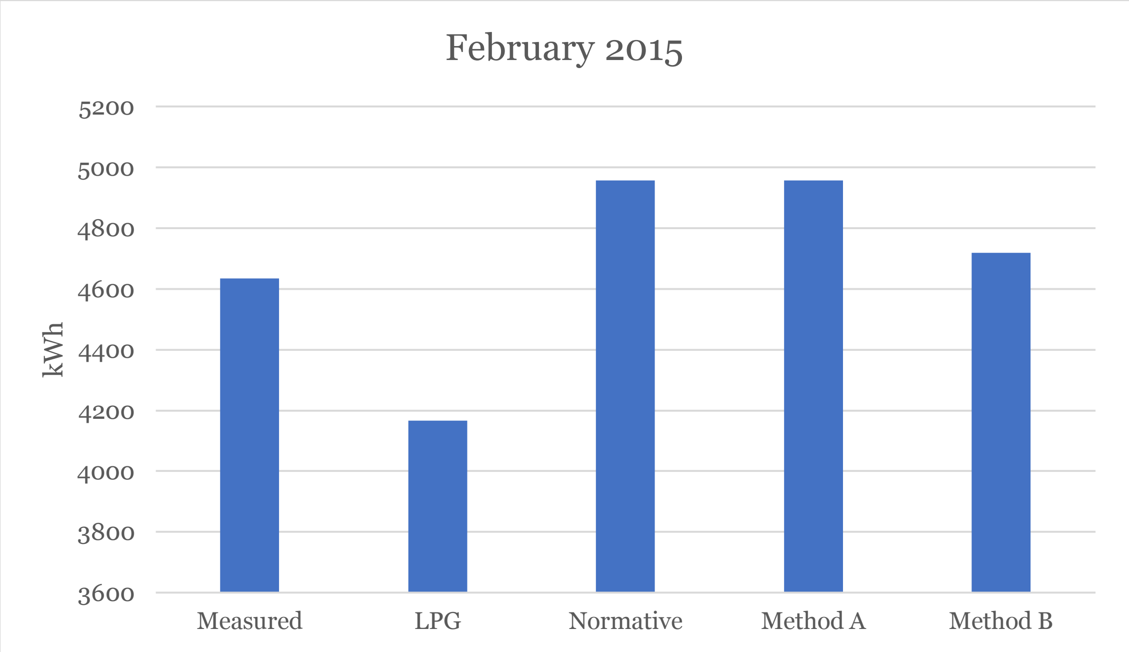


FIGURE 21: MONTHLY CONSUME IN FEBRUARY

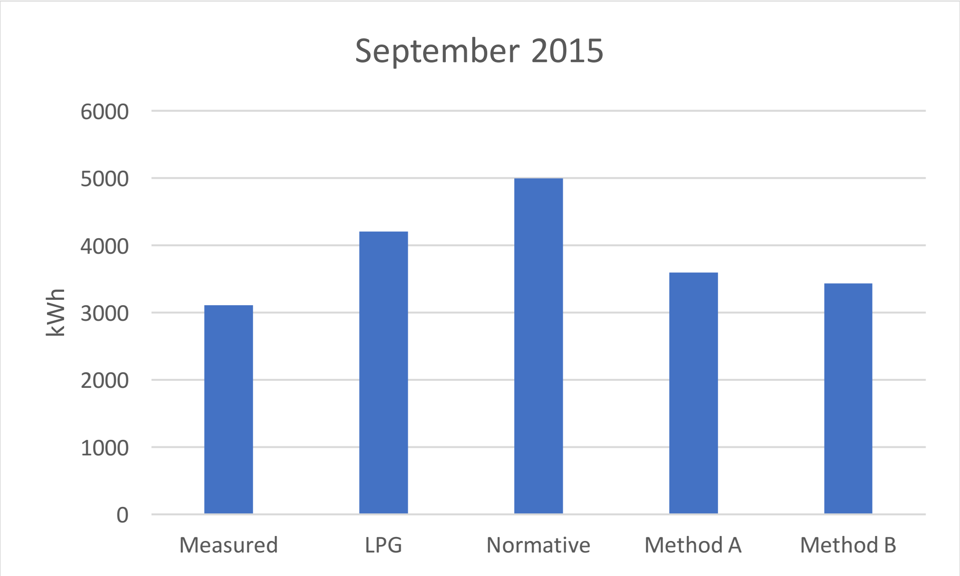


FIGURE 22: MONTHLY CONSUME IN SEPTEMBER

In particular, the months in question are February and September 2015. You can see how for February the value found through the methodology B is almost the same as the one measured, also the methodology A and the law behave well, having only an error of 6%. Discourse different for September in which the methodology B is 10% wrong, the A method is 16%, the regulation has a 60% error while the LPG software is 37%.

RETROFIT MEASURE

In the following section of the work the main interventions aimed at reducing the energy needs of the school complex are exposed. It was decided to delve more deeply into the electrical part of the needs.

5.1 ANALYSIS OF ELECTRICAL CONSUMPTION

Starting from the load profile reconstructed using the methods described above, the electrical consumption of the entire school complex was analyzed to evaluate the possibility of installing a photovoltaic system on the roof. Analyzing the electricity consumption of the school we understand that the sources of greatest consumption are lighting, boilers and appliances in the kitchens. For this reason, the analysis of retrofit measures will mainly focus on replacing old luminaires and replacing heat pumps with heat pumps. For this purpose, it was considered to install the heat storage pump.

Therefore, different types of electrical consumption were considered:

- lighting and appliances
- heat pump for water production
- heat generation and distribution systems.

In the following paragraphs, the individual consumption profiles considered are described in more detail. Finally, the installation of the photovoltaic system and the results obtained are analyzed.

5.2 LIGHTING AND APPLIANCES

As far as the lighting and domestic appliance profiles are concerned, the graphs shown below have been calculated starting from the B method described above, purifying it of all the elements that are not precisely those considered by us.

The possibility of replacing all the lighting systems of the school complex has therefore been hypothesized. at the present state of the building there were 4 fluorescent tube fixtures in each class, each of the power of 110 W. In order to choose the replacement lamps, the UNI-EN-12464-1 technical regulation was examined, in which the necessary structure is present on the work plan of the occupants of a school building, which is equal to 500 lm for the desks in the classrooms, and in the offices, while in the corridors, in the atrium and in the bathroom, it is 100 lm.

From this point of view, the devices that kept the requirements of the regulation had the lowest consumption were analysed. It was decided to use two different types of luminaires, both LED type. The first one, used inside the classes, offices and kitchens has a power of 47 W, while that in the corridors 32 W. This decrease is precisely given by the lower flow of light that must satisfy. In this lighting studio, it was decided to keep the number of luminaires unchanged, both in the classrooms and in the corridors.

The physical, electrical and optical characteristics of the selected devices are shown in the following tables.

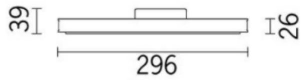
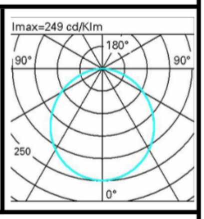
NOME	FOTOGRAFIE	
NOME: Iplan **PRODUTTORE: Iguzzini**		
Caratterisitche sorgente	Caratteristiche apparecchio	
Tipologia: LED Potenza: 47 W Flusso Luminoso: 4270 Lm TCC: 4000 K Ra: 80 Durata: 5000h	IP:20 Classe di protezione: 1 Rendimento: 70%	
Efficienza luminosa del sistema lampada + apparecchio: 90,9 lm/W		

FIGURE 23: CLASSROOM LAMP

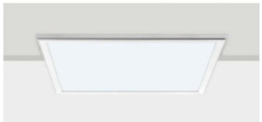
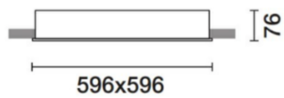
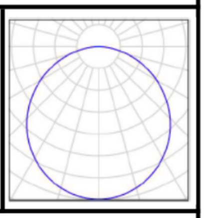
NOME	FOTOGRAFIE	
NOME: Wide **PRODUTTORE: Iguzzini**		
Caratterisitche sorgente	Caratteristiche apparecchio	
Tipologia: LED Potenza: 32,4 W Flusso Luminoso: 3519Lm TCC: 4000 K Ra: 80 Durata: 5000h	IP:20 Classe di protezione: 1 Rendimento: 55%	
Efficienza luminosa del sistema lampada + apparecchio: 108,6 lm/W		

FIGURE 24: CORRIDOR LAMP

It was therefore decided to analyze the decrease in electricity consumption with this substitution. In the first figure (Fig 25) it is possible to observe how the electric demand profile changes during the day. It can be seen that in the first two hours and in the last two hours the reduction is greater because only the lights of the corridors, being the classes already closed, are still on, and as mentioned previously the power of the lamps placed in the corridors are less than to those in the classrooms.

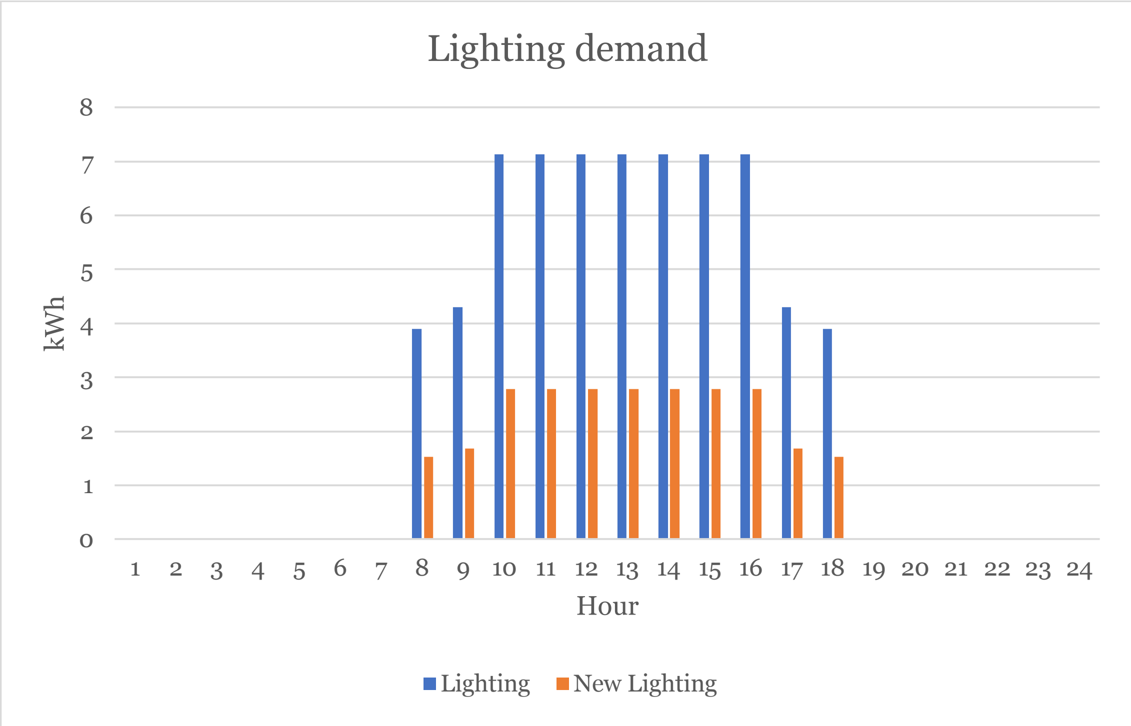


FIGURE 25: LIGHTING DEMAND

In the figure (fig 28) below, on the other hand, the power required by the new lamps was calculated, compared to the pre-existing ones. Electricity demand goes from 66 kWh per day to 26 kWh. With a daily percentage reduction of 61%.

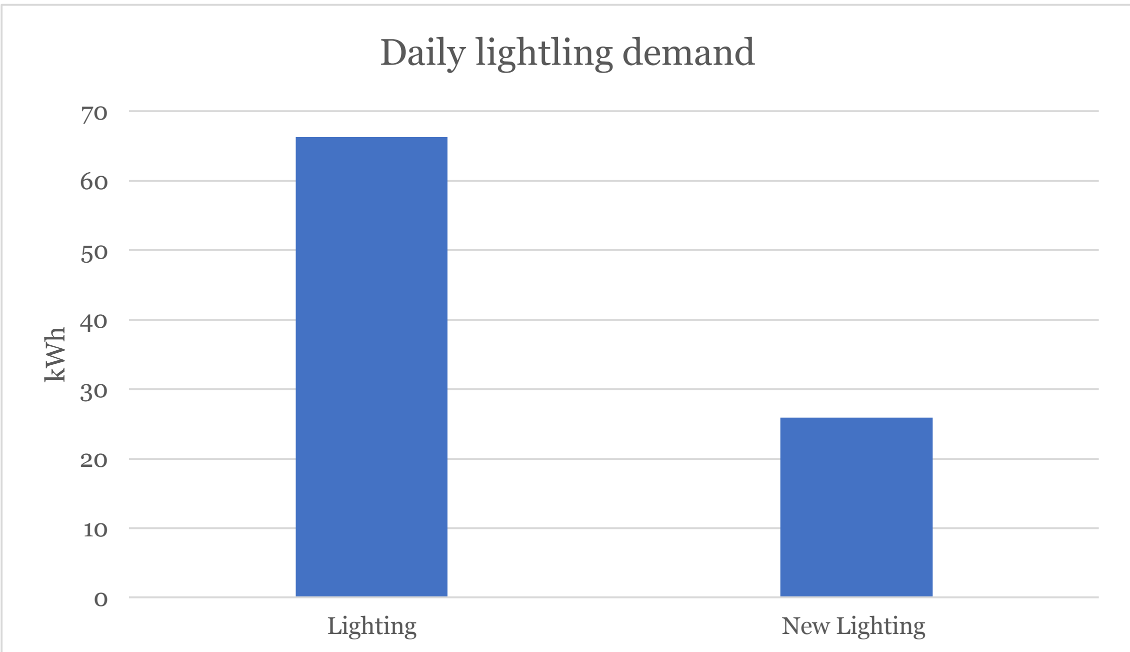


FIGURE 26: DAILY LIGHTING DEMAND

It has still been calculated how the total electric demand of the entire school changes with this intervention. in the histograms below it is possible to see in two random months how the electric demand varies.

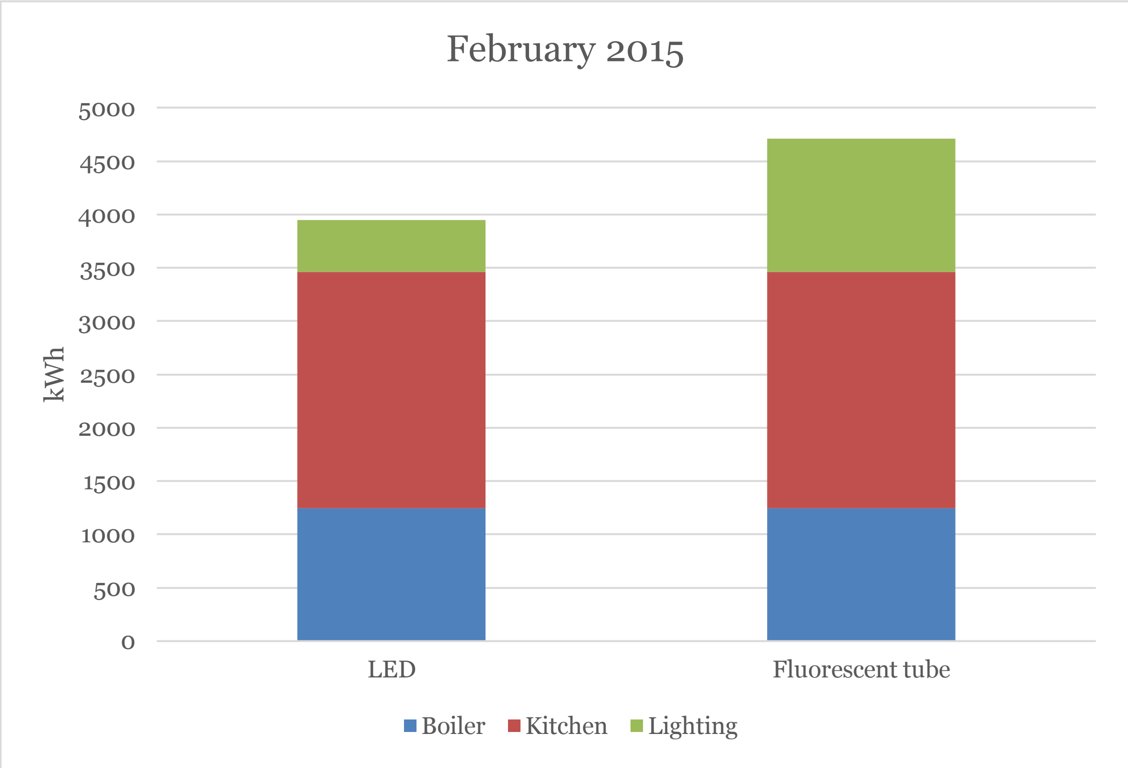


FIGURE 27: MONTHLY ELETRIC COSUME IN FEBRUARY

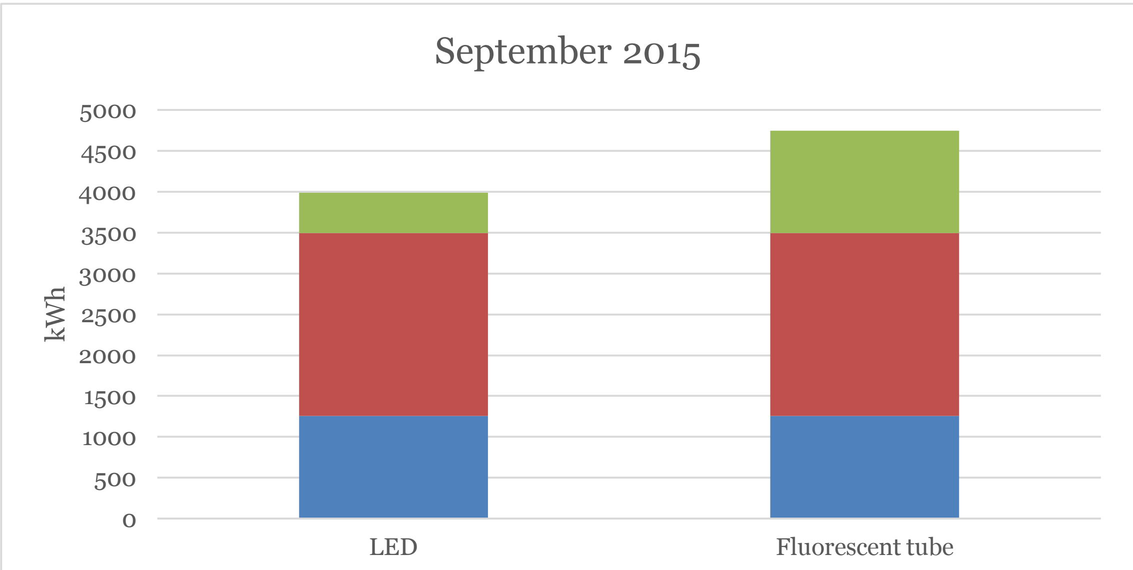


FIGURE 28: MONTHLY ELECTRIC CONSUME IN SEPTEMBER

In the two graphs it is possible to see how only the part related to the lighting has decreased. For both months the replacement of the lighting system by LED fluorescent tubes led to a decrease in total electricity demand of 17%.

5.3 PHOTOVOLTAIC SYSTEM

The installation of a photovoltaic system on the roof of the school complex under study was hypothesised.

The first topic examined was the place to mount the photovoltaic panels. We started from the possibility of inserting them only on the slopes of the roof, up to that of finding free spaces in the immediate vicinity of the structure. Unfortunately, the space available around the school did not allow any panel to be placed in any other location other than on the roof.

From this theme it was decided to start with the feasibility study of the insertion of solar panels on all the layers of the roof of the two buildings. For how the buildings are positioned, however, some flaps were immediately eliminated from the studio because they are in the shade for a long time during the day. Therefore in the following picture it is possible to examine which are the parts of the roof considered in the study.

FIGURE 29: PART OF ROOF UNDER INVESTIGATE

The second theme considered was the choice of the best photovoltaic panel to be placed on the roof. Therefore, different types of panel were examined, and the characteristics were analyzed in such a way that it was the best in relation to the function, the position in which they are located, understood as a climatic band and their performance.

Then the choice then fell on a polycrystalline silicon module, 156.5 mm x 156.5 mm, characterized by 60 cells in series were considered (Fig. 5.3) for a total of 1,46 m^2. The front glass is 3 mm, tempered and anti-reflective to increase the absorption of light. The frame is in anodized aluminum alloy. The main technical characteristics of the photovoltaic module are summarized in Tab. 5.3 and Tab. 5.4.

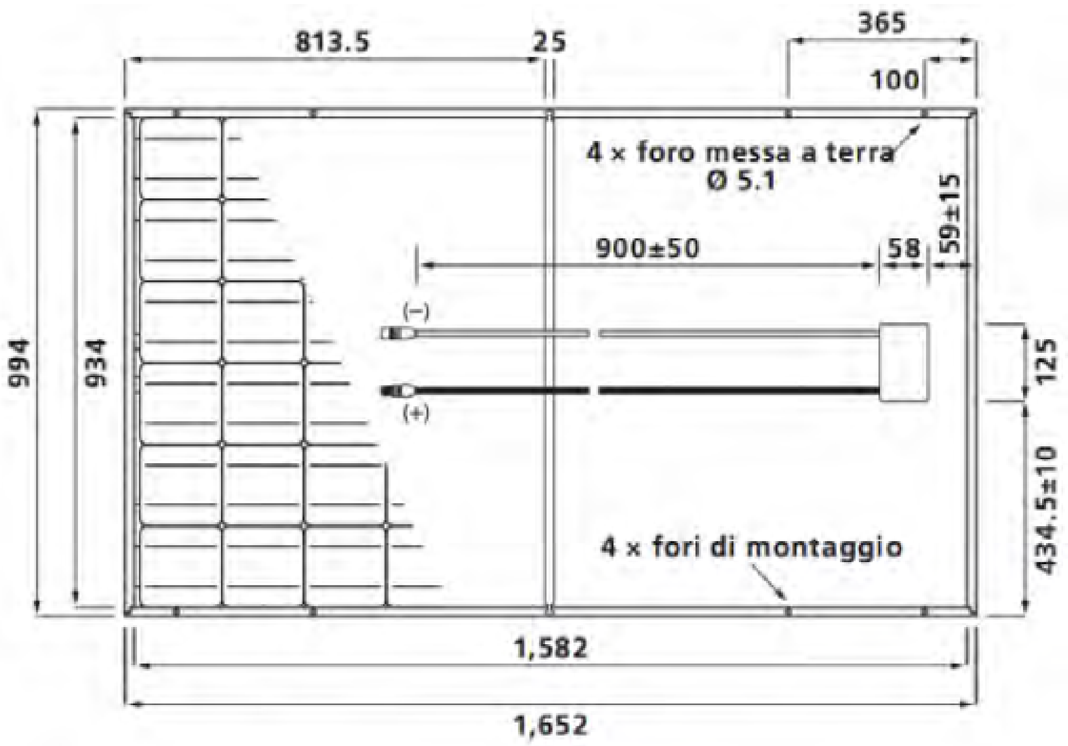


FIGURE 30: MEASURE OF PANEL

5.3.1 POLYSUN COMPUTATION

The study for the panel surface, maximum power and position was performed using the *Polysun* software.

The software needs the building coordinates and the climate range as basic information. Furthermore, you have to decide, which are the necessary inclinations of the panel and the orientation. As already mentioned above, the roof pitches chosen are those with orientation towards South-East and South-West, precisely given by the position of the building with respect to the cardinal points.

Regarding the inclination of the panel, it was decided to take as 7 possible intervals those from 23° to 68° degrees, precisely (23°; 30,5°; 38°; 45,5°; 53°, 60,5°; 68°). it was decided to take these values, first of all to limit the simulations of the software second because 23 ° turns out to be the slope of the roof and 68 °

an angle so that beyond this inclination hardly at the latitude of Turin we can produce electricity.

To understand the ideal inclination of the panels, simulations were made when the angle β was changed, but with a surface of 100 m and a power of 20 kW. The results of these simulations can be seen in the following table.

β[°]	**23**	**30,5**	**38**	**45,5**	**53**	**60,5**	**68**
kWh	16767	17000	16942	16651	16068	15224	14205

FIGURE 31: PV PANEL PRODUCTION

As it is possible to see, the angle that maximizes the annual production of electricity is around 30° from the horizontal. Therefore it will be necessary to create special supports that increase the inclination of the pitch from 23° to 30°.

Once the optimal inclination β has been found, three possible scenarios of size of the photovoltaic system were analyzed, the three possible scenarios were:

- orientation on South-East
- orientation on South-West
- 50% on the South-East, 50% on the South-West

And three cases of installed plant power were also considered:

- 15 kW
- 20 kW
- 25 kW

A dynamic simulation was then made with Polysun software to derive the producibility of the plant for each of the cases considered. The results obtained are shown below. Fig. 5.4 compares the energy produced according to the installed power (25 kW, 20 kW and 15 kW) for the three hypothesis of placing the system on the roof pitch.

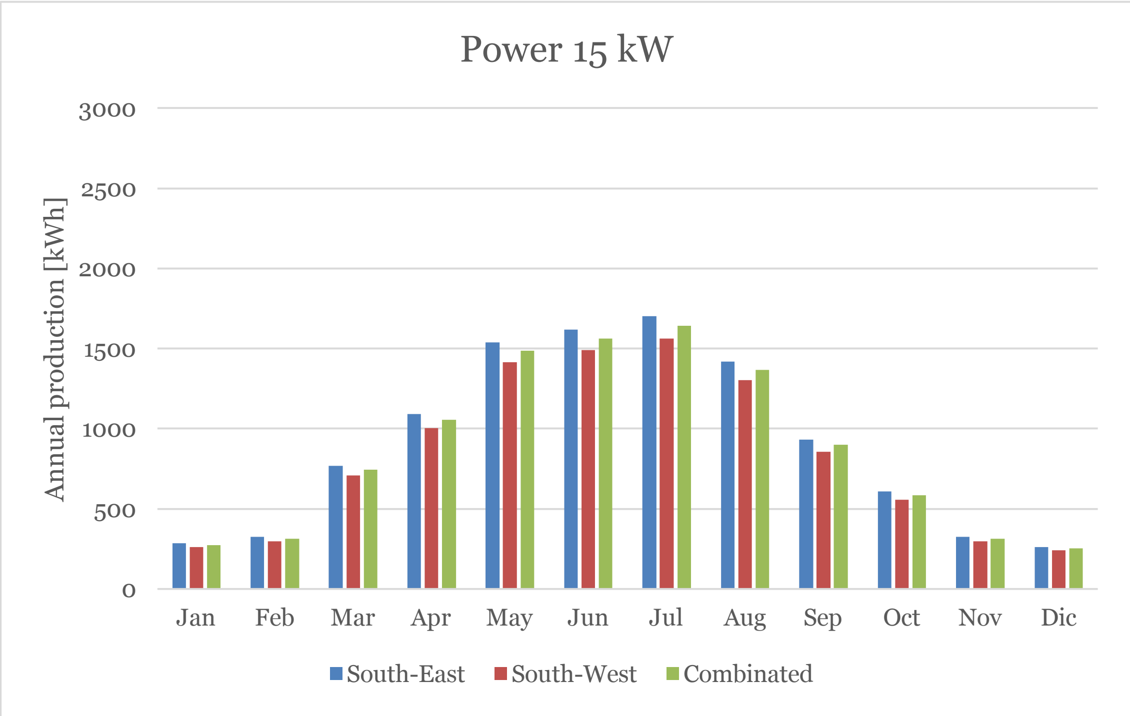


FIGURE 32: MONTHLY PROFILE FOR A POWER OF 15 KW

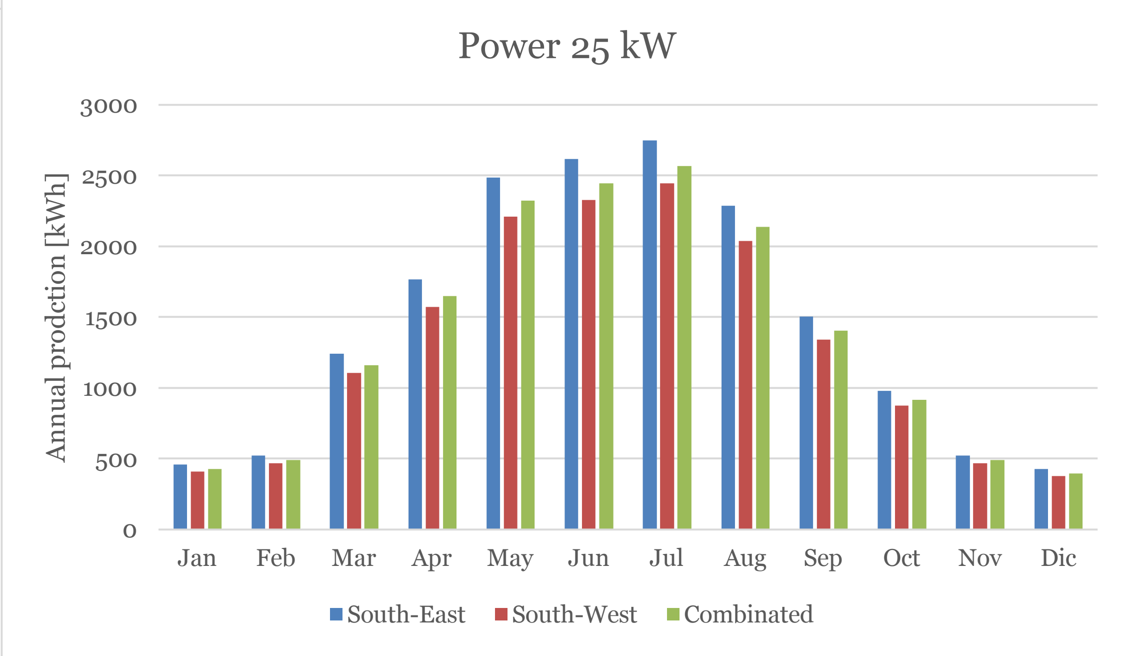


FIGURE 34: MONTHLY PROFILE FOR A POWER OF 25 KW

As you could imagine the production chart has a bell curve, and is strongly influenced by the different seasonality, the change in temperature and solar radiation.

The most important information that comes out of these simulations, however, is that the position that maximizes the production of electricity is that facing south-east. Regardless of the installed peak power. In particular, for the entire year, by positioning the photovoltaic system in this position, there is an increase of 11% with respect to the orientation to the south-west and of 7 % with respect to the combined solution.

Considering the best orientation, the required electricity decrease was calculated. The tables below show the monthly production values for 2 typical months, one winter and one summer. In order to take into account, the different seasonality.

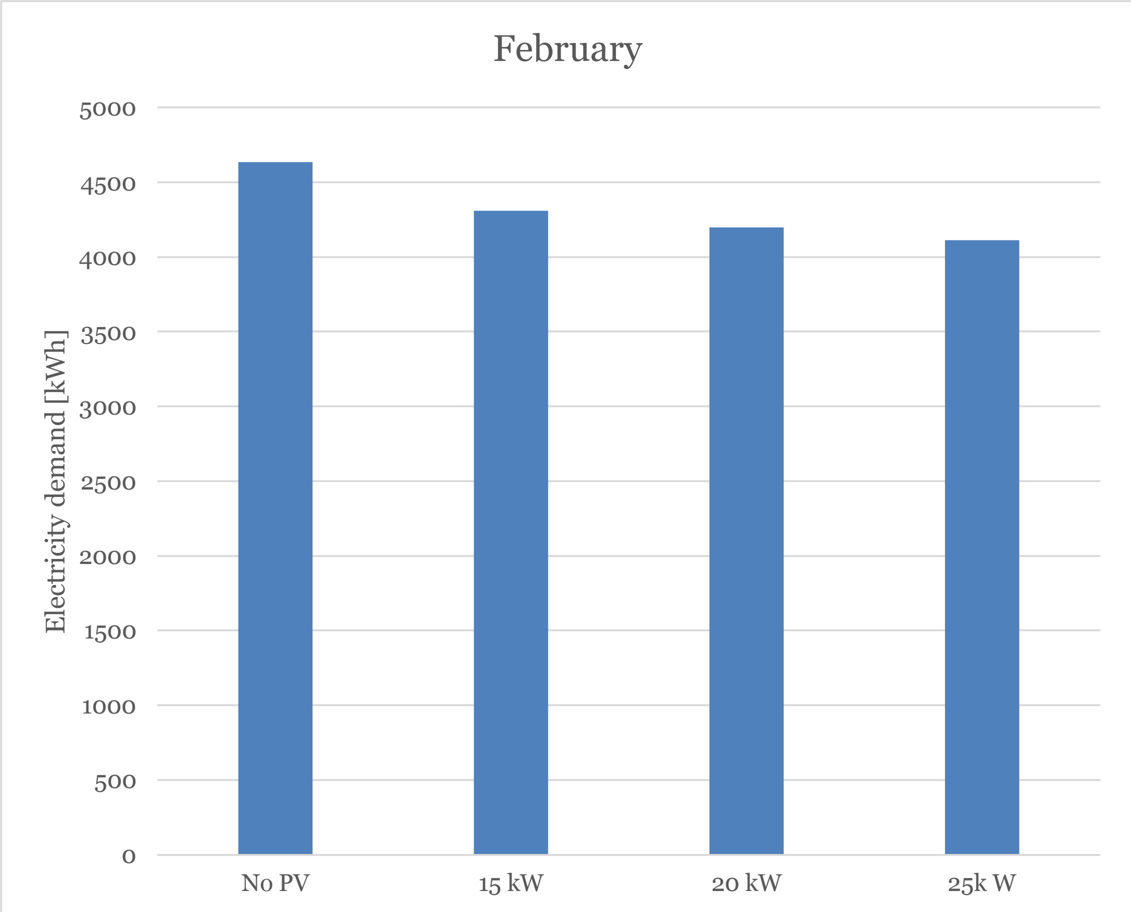


Figure 35: Electricity demand with PV plant in February

For the month of February, the decrease in electricity demand is not so substantial, there is a reduction that goes from 7% to 12% with the increase in peak power. This variation is justifiable because in February the electricity demand from the school is very high, while photovoltaic production is low.

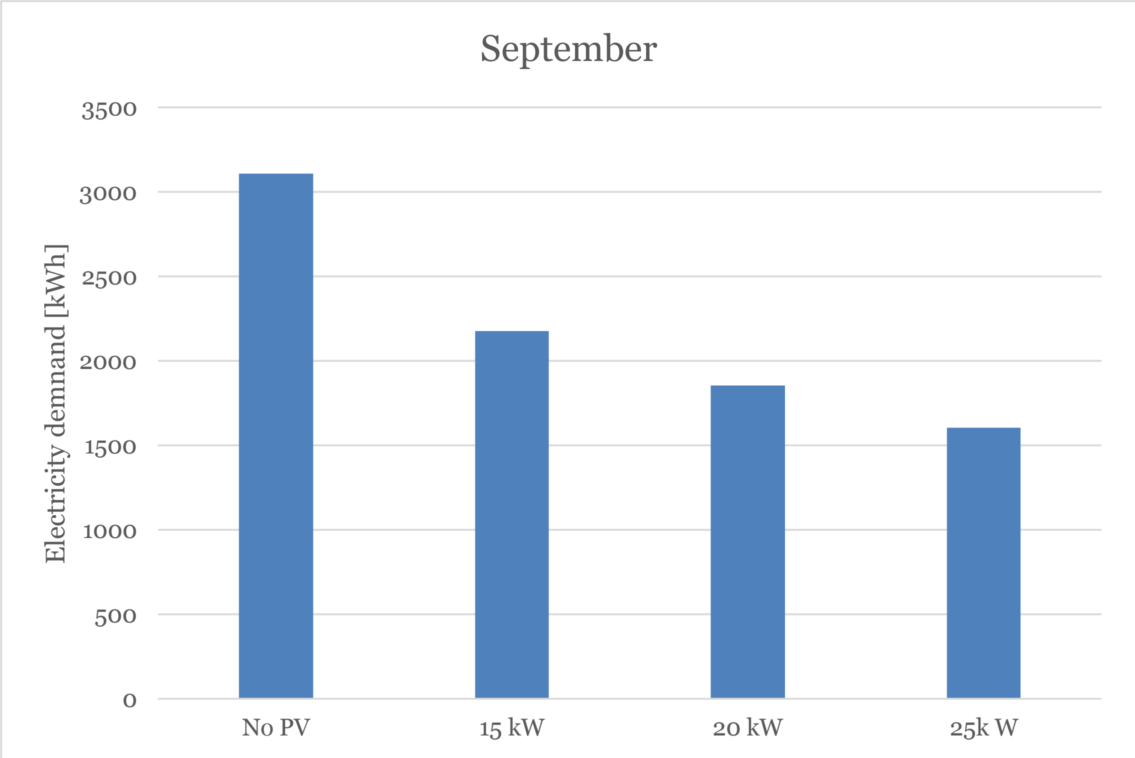


Figure 36: Electricity demand with PV plant in September

As for the month of September the speech is completely different, the electricity demand with the installation of the solar panels varies considerably. This high decrease is justified by the fact that September is one of the months with the largest electricity production, and that the month in question does not have a very high demand. Against this, the electricity demand decreases by 30% with a peak power of 15 kW, up to a decrease of 49% with a power of 25 kW.

ECONOMIC ANALYSIS

The economic analysis carried out for the case in question analyzes three main aspects:

- the costs of the operation;
- savings in bills;
- the incentives that can be accessed.

6.1 INVESTEMENT COST

The cost of individual interventions has been obtained from various sources. First, the principles of the Piemonte region were viewed.

As indicated in the price list of the Piemonte region, "the prices shown [...] are obtained by analysis obtained from the composition of elementary resources (labour and materials), freight and semi-finished products (mortar and concrete mixes) and include use of scaffolding, scaffolding or ladders [...]. Furthermore, all the equipment that the company specialized in carrying out the work activity must necessarily have in its own yard organization is considered included in the prices. The entries relating to the completed works include [...] the supply and installation of the item described and any necessary assembly accessories. The cost of labor in the construction sector is an average calculated on the basis of surveys carried out at the trade associations [...]. The cost of the workforce of the plant engineering sector is recorded at ASSISTAL - National Association of Plant Builders and refers to both the electrical and mechanical sectors. The costs of the materials are a measured average of the price lists provided by the major manufacturers [...]. The prices, therefore, are informative and average for supplies and works of a certain consistency ".

The prices shown in these documents were then compared to the price lists made available by various specialized companies to verify that they were consistent with the current market. As regards heating and domestic hot water production plants and the photovoltaic system, the price lists do not report prices referring to the powers considered. They have therefore been derived from the comparison of the price lists of different specialized firms in order to obtain the most consistent values possible with the current market status.

The table below shows the costs related to the various interventions: for each type of intervention unit prices and total expenditure, including IVA, have been reported.

	€
PV plant 15 kW	27000
PV plant 20 kW	36500
PV plant 25 kW	46000

TABLE 13: COST OF INVESTEMENT FOR PV

	€
LED lamps	8800

TABLE 14: COST OF INVESTEMENT FOR LAMP

Regarding the calculation of the replacement of luminaires, it was considered beyond the cost of the appliance itself and even the implementation of each of them, this cost is equal to € 120, with a total of 74 devices in the entire school complex.

6.2 SAVINGS IN BILL

To calculate the savings achievable in the bill were considered different rates for electricity. In fact, the price of electricity varies according to consumption and the size of the meter. An average electricity price of 0.051 €/kWh was considered, in which there are not all taxes related to the use of transmission facilities and fixed costs. Furthermore, a monoraria tariff pricing was considered. in fact, considering a rate with several price ranges for the school makes little sense, being always closed at weekends and at times when electricity is cheaper.

The size of the counter has remained unchanged in the various cases examined, as a reduction could have given rise to network problems during winter.

6.3 INCENTIVES

Only one type of incentives was considered: as reported on the site of the *Gestore dei Servizi Energetici (GSE)* is the "Certificati Bianchi", also known as "titoli di efficienza energetica" a sort of energy efficiency certificates , are negotiable securities that certify the achievement of energy savings in the final uses of energy through interventions and projects of increase of energy efficiency ", while the" DM 12/28/12, the cd Decree "Thermal Account", [...] implements the support scheme [...] to encourage small-scale measures to increase energy efficiency and produce heat from renewable sources ".

There are three methods for evaluating savings:

- standard: the evaluation is carried out on the basis of technical data sheets in which the savings associated with the specific intervention are determined exclusively according to the number of physical reference units (UFR) involved in the intervention;
- analytical: the assessment is made on the basis of technical data sheets in which the savings are determined through a specific algorithm powered by a few parameters characterizing the operating status and energy absorption of the equipment object of the intervention and measured at least once a year;
- in the final balance: since no technical data sheet is prepared, the savings are calculated through a complete monitoring plan.

For the case in question, the standard method was considered, in particular, the reference technical sheet is the 7T "use of photovoltaic plants with electrical power below 25 kW".

6.4 RETURN OF INVESTMENT

Taking into account the costs of the operation, the savings in the bill and any perceivable incentives, the time of return on investments was assessed. The calculation was carried out considering 2.5% inflation and a 7% interest rate. For each intervention it was also considered that the entire investment is made during the first year.

The following intervention hypotheses were therefore considered:

- replacement of the electrical system
- installation of a 15-kw photovoltaic system
- installation of a 20-kw photovoltaic system
- installation of a 25-kw photovoltaic system

Initially each intervention was analysed by itself, then calculating what was the peak power with the return period of the minor investment was analysed together both the replacement of lighting systems and the installation of the photovoltaic system.

For each hypothesis of installation of PV system, the return times were compared in the following cases:

- with incentive
- without incentive

The net present value was calculated at 25 years from the investment itself and the profitability index always at 25 years.

For what concerns the cost of the intervention, please refer to the previous paragraph.

For the case with a photovoltaic system, an on-site exchange contract was considered. the contribution for the exchange on site Cs was calculated using the following formula (Annex A to resolution 570/2012/R/efr):

$$Cs = \min[Oe; Cei] + CUsf * Es$$

Where *Oe* is the part of conventional energy of the annual charge incurred for the purchase of electricity expressed in €, that is the valuation of the electricity produced annually and fed into the grid by the plant expressed in €, *CUsf* is the consideration annual flat-rate exchange unit expressed in $c€/kWh$; Es is electricity annually exchanged with the network expressed in kWh.

For the portion of electricity consumed by the grid, starting from the tariff, the average energy price was calculated for that band of consumption: which was equal to 0,027euro/kWh.

First, the net present value was calculated after 25 years which is equal to €200, and a profitability index of 0.03. This value if positive in the year of calculation means that the investment has a pension in the pre-established time. Therefore, the investment makes sense to carry it out.

Starting from this result, it was decided to analyze what was the size of the photovoltaic plant with the major NPV after 25 and consequently the one with the payback time (PBT) minor.

The following graphics show the values of the NPV for each dimension of the PV plant, reported year after year.

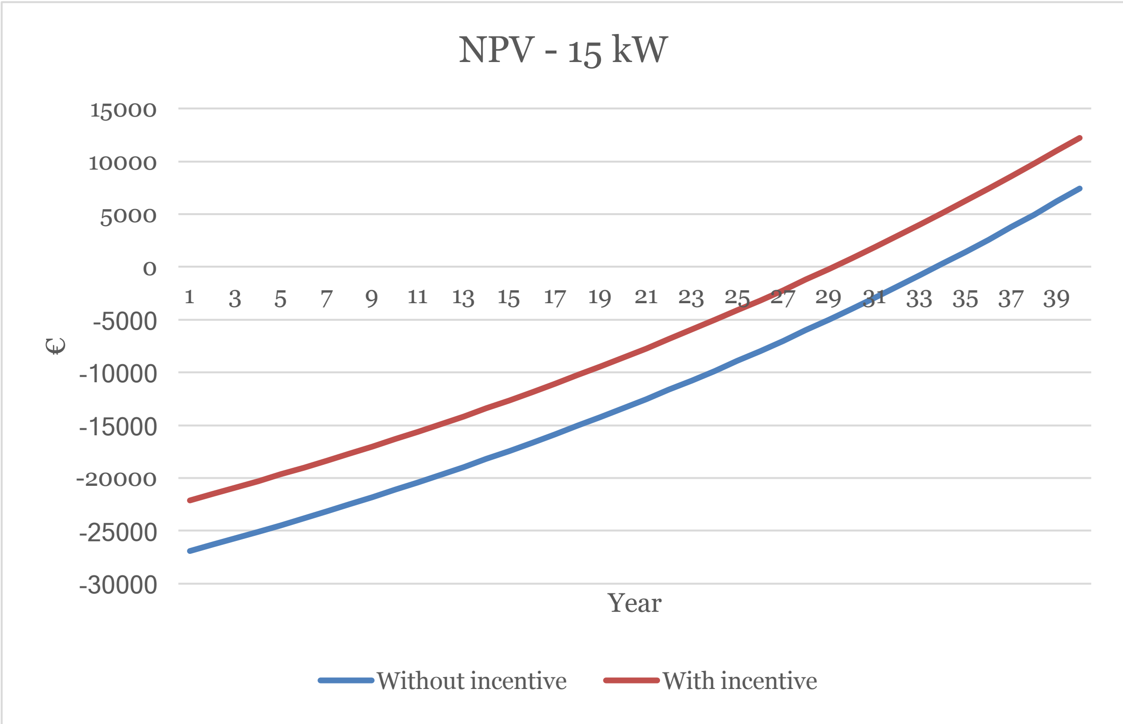


FIGURE 37: NPV FOR 15 KW POWER

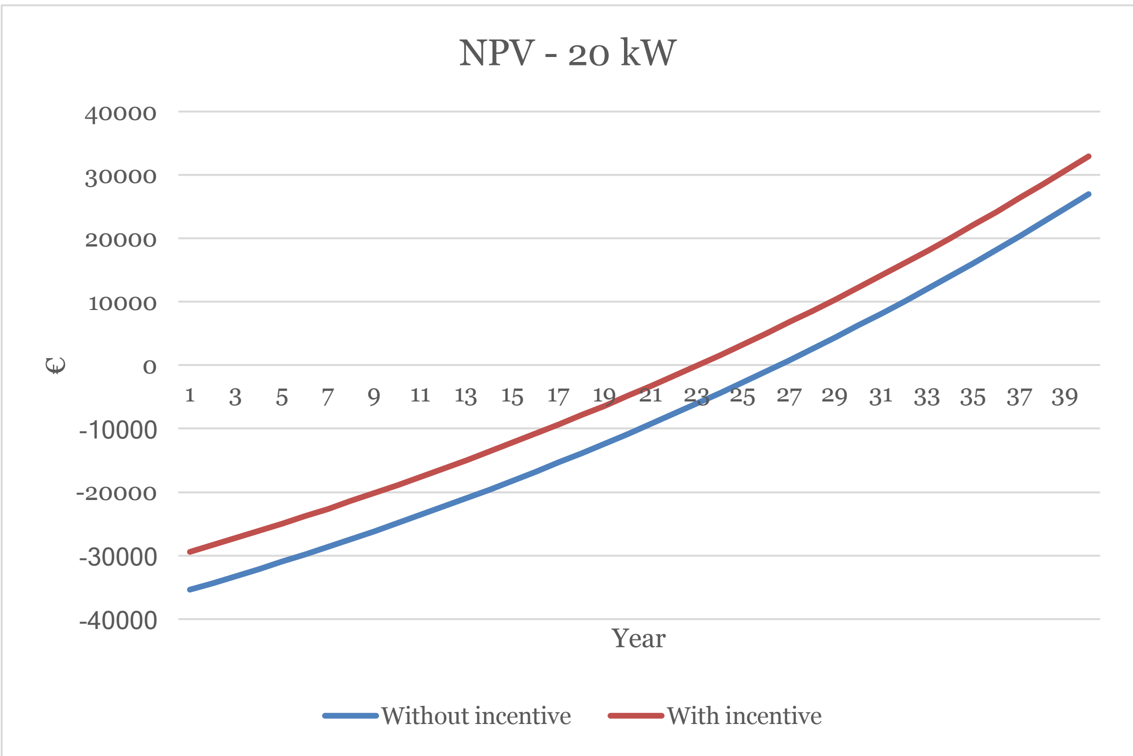


FIGURE 38: NPV FOR 20 KW POWER

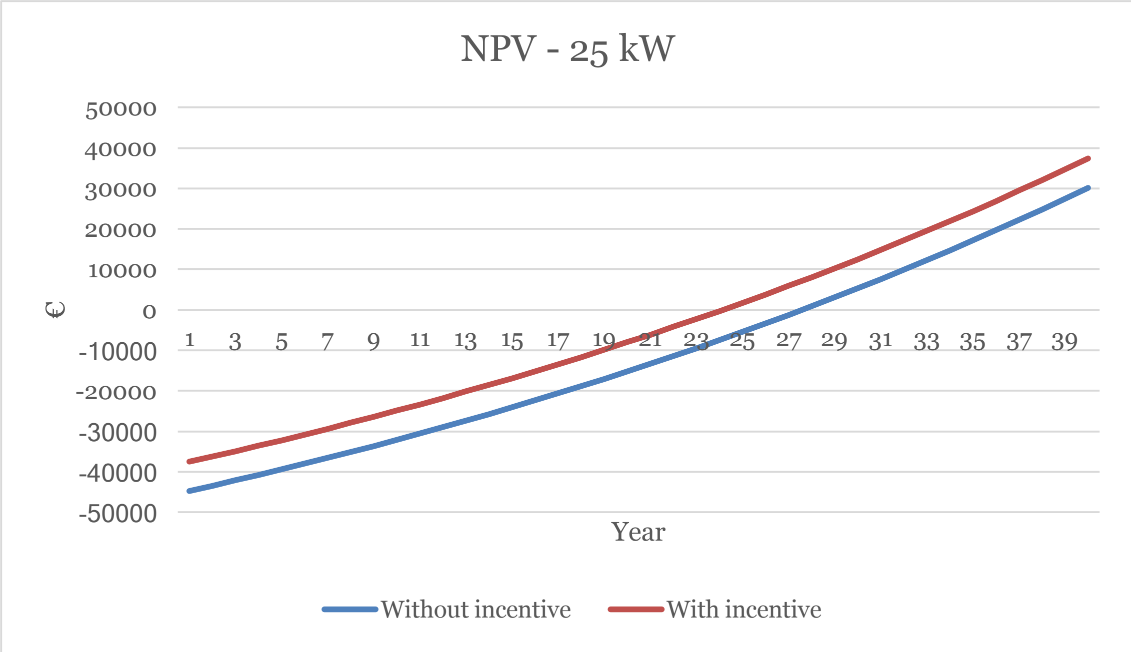


FIGURE 39: NPV FOR 25 KW POWER

For ease of observation the table below shows the value of the NPV calculated at 25 years.

kW	*Without incentive* *[€]*	*With incentive* *[€]*
15	-8913	-4113
20	-2705	3295
25	-5446	1754

FIGURE 40: NPV FOR DIFFERENT PERIOD

What we can deduce is that for any size of the plant if there were no incentives, after 25 years would not have yet returned investment. With the incentives, the size of the plant with the higher NPV is 20 KW.

This conclusion is further supported by the calculation of PBT

The three graphs just examined show how regardless of the size of the plant the Pay-back time without incentive turns out to be greater than that without incentives this difference is about 3 years for all sizes.

The table below shows the return time of the investment for each possible scenario.

kW	*Without incentive* *[year]*	*With incentive* *[year]*
15	34	30
20	27	24
25	28	25

TABLE 15: PBT FOR DIFFERENT SIZE

The values just examined show how regardless of the size of the plant the Pay-back time without incentive is greater than that without incentives this difference is about 3 years for all sizes.

It was also calculate the profitability index for each size, the results obtained are shown in the table below:

kw	***Without incentive***	***With incentive***
15	-0,32	-0,15
20	-0,07	0,09
25	-0,12	0,04

TABLE 16: PROFITABILITY INDEX

This figure even more supports the fact that in economic terms the best size of the plant is that of 20 kW.

Downstream of this analysis, was carried out, with the same methodology, the case in which you install both the luminaires and the installation of the photovoltaic system. For this analysis it was decided to consider only the photovoltaic system from 20 KW. The table below shows the values of NPV, PBT, and IP.

The results obtained show how, the combination of the two interventions increases the NPV and consequently reduces the PBT. Although the replacement of the light fixtures is not stimulated, NPV is positive for both incentive scenarios.

CONCLUSION

The energy requalification of the existing building heritage is a crucial issue if one thinks of the years of the Italian building stock and the low growth rate of new high-performance buildings.

The energetic analysis carried out on the public building building object of the present thesis work has revealed high net heating energy demand values, compatible with the building's construction time, to which they achieve considerable potential for improvement. Given the poor electrical performance, in the first part of the thesis the following interventions were analyzed: replacement of the lighting system, installation of a photovoltaic system and feasibility study to insert a battery. Among the proposed interventions the one that involves a greater reduction of the net electricity requirement, equal to 34%, is the substitution of the lighting systems. The interventions analyzed as a whole guarantee a reduction in primary energy requirements compared to the actual situation. The possibility of installing a 20 kW photovoltaic system on the roof pitch has therefore been analyzed. The building's electricity consumption profile was constructed, taking into account the heat pump for heating, the heat pump water heaters and the electrical consumption of the various types of apartments. The resulting self-consumption rate is equal to 60% and guarantees 24% coverage of the electricity requirement of the plexus. The installation of a plant with a capacity of more than 20 kW is not justified by consumption.

As the last step of the work, the economic aspect of the hypothesized interventions was analyzed. First of all, an estimate was made of the expenditure that would be incurred for heating in the various hypotheses.

The complete redevelopment of the building has, with the incentives, return times all in all reasonable. The discourse is different when jointly intervening also on the plant engineering part: the return time is, depending on the solution and the chosen incentive form, from about 9 to 12 years, which includes in the initial investment. It can therefore be concluded that for the building in question the retrofit operation of the replacement of luminaires among the solutions analyzed, the one that combines the best results in terms of reducing the electrical requirements with the shortest time of return on investment.

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