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Energy Retrofit. A Case Study—Santi Romano Dormitory on the Palermo University

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Abstract: Electrical and thermal consumption related to buildings, whether civil, commercial, public, or of any other kind, is very much in focus today. With today's targets for energy savings, reduction of consumption, and environmental impact, it is necessary to carry out energy retrofits to modernize installations and their management. The realization of an effective improvement requires a careful analysis of the case study because each category of building has different requirements such as different load profiles and different installations and needs. This was carried out by studying the electrical and thermal load profiles. A good initial energy audit can provide the retrofit solutions capable of achieving the reduction of energy consumption and the emission of climate-changing gases into the atmosphere. A case study, carried out by the Department of Engineering of Palermo, showed how it is possible to perform an energy retrofit to modernize the energy system of the student dormitory at the University of Palermo. The paper presented a study carried out by programming a series of interlinked calculations in Microsoft Excel. In order to quantify the energy savings of the structure under examination, it is necessary to enter some input data, thanks to which all the formulas implemented in the calculation software were automatically completed. The programming of the calculations makes it possible to carry out an energy retrofit with interventions on the building envelope and the installations. The desire to program an automated calculation by modifying only the input data is intended to replicate a study on other buildings with the same peculiarities. In this way, it is possible to verify which retrofit hypotheses would be useful to upgrade old public administration buildings. In the analyzed case study, 65% of electrical energy and 33% of thermal energy could be saved by replacing generation systems, installing a co-generator, replacing windows, and replacing lamps with LED ones.

Keywords: energy audit; building energy saving; energy load profile; energy retrofit; LED technology; cogeneration

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1. Introduction

The problems related to the energy supply have taken on an increasingly important role in the political and economic management of countries in recent years [1]. Building energy consumption is an important issue that the entire world focuses on [2], because both residential and commercial building consumption represents 40% of the total primary energy consumption [3,4]. European research data state that it is estimated that the energy consumption of the public buildings accounts for approximately the 10% of the total annual energy of the EU countries [4,5]. The study of the energy consumption of public buildings is very important due to the large number of facilities owned by institutions. If they were all improved from an energy point of view, there would be considerable savings in emissions, primary energy, and money. This article could be used as a sample to be replicated in many public buildings. The possibility of replicating this approach on other public buildings can be very convenient.

Many studies are carried out in order to make public and private buildings more efficient. Mehdi Tavakolan et al., with MATLAB® and an energy simulator, Energy plus, studied how to minimize the primary energy consumption of a single house [6]. They determined that the insulation of the wall and the replacement of windows are very affordable. The replacement of thermal and cooling plants are moderately affordable and the installation of photovoltaic panels is very affordable [6].

Yujie Lu et al. studied how to improve the energy efficiency in institutional buildings in a tropical climate with different improvement measures such as: optimal management of the set point temperatures of the systems, control of lighting, replacement of chillers with new-generation ones, and replacement of emission terminals with more efficient fan-coils [7].

Qing Li et al. carried out a school building retrofit in Wuhan, China [8]. By using a multi-objective optimization model, they determined that the most sensitive elements of a structure are the external walls, the roof, the heat transmission through the windows, and the window to wall ratio [8].

Zhenjun Ma et al. listed firstly the phases to carry out an energy retrofit, then several interventions such as: installation and/or replacement with renewable energy sources, and thermal improvements of the building envelope [9].

In the same way, N. SoledadIbañez Iralde et al. suggested that old buildings need a renovation. They distinguished between passive interventions (on the envelope) and active interventions (on systems). Their important consideration is that the retrofit must be studied on a case-by-case basis according to the structure being studied and its boundary conditions [10].

Saleh Seyedzadeh et al. performed a prediction model capable of quickly carrying out retrofit solutions for non-domestic buildings. Their multi-objective model was capable of carrying out an energy performance prediction to accelerate the calculation of the energy retrofit [11].

Li X. and Yao R. performed a hybrid approach based on algorithm solving regression problems. This model carried out heating and cooling loads prediction. In this way, it is possible to evaluate the different retrofit solutions [12].

Dengyun Wang et al. focused on energy saving in hotel buildings. They proposed the intelligent control of HVAC systems, the replacement of old thermal boilers, the replacing of inefficient lighting systems, and other interventions in the kitchens. The energy reduction with LED systems was around 70% and with the boiler replacement was around 25%. The control of HVAC system reduced the consumption by only 2% [13].

In a country like Italy, characterized by limited energy resources, savings must be considered as the most important source of energy. In fact, the current methods of energy production and use sometimes appear highly inadequate for our systems. Within the complex Italian energy scenario, consumption in the sector of residential and similar buildings deserves particular interest [14]. Trying to minimize energy consumption in this sector, with the same guaranteed services, is an excellent way in order to improve the Italian energy situation [15]. The current political administration is putting a lot of emphasis on this. In fact, it has provided many incentives and eco-bonuses encouraging the population to renovate their homes in order to reduce their energy consumption. It is important to optimize the energy consumption in every kind of building, from civil homes to hotels to school buildings [16]. In aid of state incentives, it is necessary to clarify the guidelines for good energy efficiency. In fact, one of the most important activities is the study of the load profiles of the analyzed structure [17,18].

This article focused on this topic with an energy audit and energy saving in the "Santi Romano" building. This structure is the public building that the "ERSU—Regional Agency for the Right to University Studies" uses as an office and as student accommodations at the University of Palermo.

2. Energy Modernization of the Campus

The University of Palermo is divided into many buildings dislocated in different neighborhoods of the city of Palermo. Most university activities are carried out on the campus located in "Viale delle Scienze". Here, there are several departments, classrooms, libraries, conference rooms, laboratories, and a building called "Santi Romano", which is used partly as administrative offices, partly as dormitories for off-site students, and, adjacent to it is a canteen. Figure 1 shows how the campus is divided. The Santi Romano buildings are 1–2.

Figure 1. Campus of University of Palermo.

Over the years, the administration of the university has devoted time and money to the technical management of the campus. As shown in the Figure 1, there is a significant garden area with gardeners who maintain it all year round. Instead, from an energy point of view, the infrastructure of the campus has been renewed over the years. The campus was established in the 1960s and, therefore, energy management had to be modernized. One of the first actions was the installation of photovoltaic plants over the roofs of some buildings, and photovoltaic shelters were recently installed in a car park near the main entrance of the campus.

An important retrofit has been carried out to reduce the energy consumption of the lighting system of the campus streets [19]. The aim of this project was to replace the old luminaires with new ones based on LED technology. This is a very important modernization because the power installed and absorbed from the new lighting system was decreased by approximately 70%. The LED lighting guarantees several advantages like: reduction of the cost of maintenance, long life of the lighting body, excellent lighting performance, and reduction of environmental impact because the system reducing energy consumption could reduce CO_2 emissions [20]. To improve the efficiency of the LED lighting, it is possible to adopt a control strategy based on dimmer control. This technology modulates the luminous flux of the lighting body manually or automatically according to the intensity of natural light.

The last innovation reported in the campus is the installation of a solar device that exploits the solar radiation, concentrating it with a parabolic collector to a thermal Stirling engine; this technology is called a dish-Stirling system [21]. This is a pilot plant (see Figure A1) installed near building 9 of the campus.

The system is composed by several mirrors installed to create a parabolic device that reflects the solar radiation into the focal point where the Stirling engine is installed. To maximize the energy production, a tracking system of the path of the sun is necessary.

Part of the thermal energy that hits the engine is converted into mechanical energy and then converted into electrical energy by an alternator. The electrical power of the system is equal to 32 kW with a solar radiation of 960 W/m^2, and the energy produced is fed into the electrical grid [21]. This article was based on a similar aim; in fact, it focused on the energy retrofit carried out to modernize the energy production of the Santi Romano building. This preliminary study discerned the technical characteristics of the structure like wall stratigraphy, kind of windows, kind of body lighting installed, and the age of air conditioning and heating machines. Then, the load profile of the structure was evaluated; in this way, it is possible to carry out solutions to reduce the energy consumption. Finally, the best solutions were listed.

3. Case study

3.1. Research Methodology

The aim of the study was to perform and to modernize a student dormitory at the University of Palermo. The research team focused on some important steps to carry out solutions that reduce the energy consumption. The first activity carried out was an audit, i.e., an inspection of the facility in order to obtain data such as: the dimensions of the halls, the technical characteristics of the walls, windows, and ceilings, the type of lighting installed, the characteristics of the heating and electrical plant, the characteristics of the air conditioning machines, and the type of heating system. Subsequently, the energy loads associated with the facility's utilities were estimated. Considering that a part of the building is used as offices, whereas the other part is a dormitory, different load profiles were evaluated. For this reason, electrical and thermal energy consumption were estimated based on the equipment present during the inspection. In this phase, the winter heat losses and summer loads were calculated to size the new machines to be proposed for replacing the old ones. Finally, the proposed retrofits were listed in order to reduce consumption and improve the efficiency of all installations. Figure 2 shows the procedure of the research methodology.

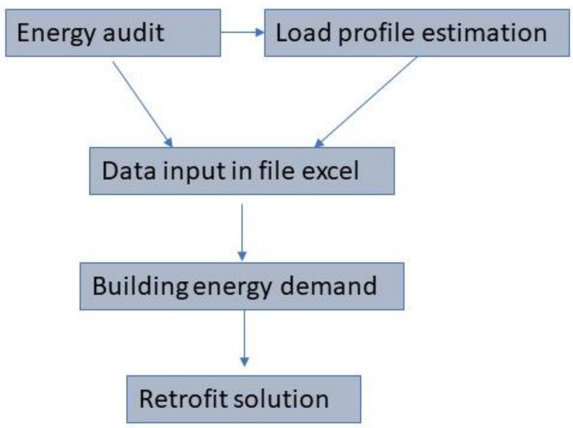

Figure 2. Block diagram of the research methodology.

The following chapter lists the technical characteristics of the building envelope, the thermal and electrical generation systems, and the type of luminaires carried out by the energy audit.

3.1.1. Energy Audit

- Building technical description

ERSU is the Regional Agency for the Right to University Studies. Every year it awards about 3000 scholarships and 750 beds for the students of Palermo University. The number of accommodations corresponding to Santi Romano is 350. The other 400 are divided among other structures around Palermo. The building (see Figure A2) has a total length of about 120 m and can be ideally divided into two parallel and staggered pavilions, which are interconnected at their ends by a section of construction perpendicular to them.

The first pavilion, which is the tallest, has nine vertical floors above the ground, the first three of which are offices, while the next six are accommodations for off-site students and a basement floor housing the building's heating, electricity, and water supply system. The second pavilion has seven floors above ground and a basement. The basement and first floor host the university canteen, while the second to seventh floors are used as accommodations. The building envelope is made of a reinforced concrete pillar and beam structure with walls made of tuff ashlars, brick partitions, and a flat roof. There are several models of window components in the structure, which differ in size and shape. In any case, the type is always the same: a single thermal break window with double glazing and an air space. However, the windows are equipped with a roller shutter system.

- Air-conditioning system features

The air-conditioning system consists of a three-phase (400 V) water-source heat pump (Blue Box model ZETA/HP/ST/NL 393) with a thermal capacity of 83.9 kW. It is installed on the roof of the 2nd floor. The cold/hot fluid produced by the heat pump is piped to the fan-coils located in the offices. Each fan-coil is locally controlled with an on-board temperature controller.

- Thermal features

In the basement of the building, there is a central heating plant. It consists of two identical gas boilers, each one with a maximum output of 707 kW, made by Baltur and purchased in 1996. These boilers generally work alternately to produce domestic hot water only, while when it is necessary to produce thermal power for space heating as well, they both work in parallel. The heat carrier fluid, which passes through the primary circuit, is water. The power generation is controlled by a system that uses thermostats to measure the temperature of the fluid in the primary circuit at the outlet of the heat exchanger. When the water temperature reaches approximately 65 °C, a valve is activated modulating the amount of gas reaching the firebox and decreasing the heat output produced by the boiler. If the lower limit of heat output produced by the boiler is reached, the valve closes completely, and the firebox shuts down. The heating terminals in the dormitory are radiant plates, whereas heat pumps are installed in the office.

- Electrical features

In the basement of the building, in addition to the heating plant, there is also the electric power plant. ERSU has a supply contract of 243 kW, supplied in three phases (400 V). Most of the electricity consumed by the facility is purchased from external providers and a small part is self-produced through the photovoltaic system, which is installed on the roof of the facility. The photovoltaic system consists of 144 modules of 140 W each, assembled into six strings of 24 modules each. To optimize the energy production, the modules are oriented to south with a tilt angle of 30°. This photovoltaic plant produces approximately 20,000 kWh per year. All the lighting in the building, in both the offices and dormitories, is still provided by fluorescent tubes and halogen lights.

3.1.2. Load Profiles

It is necessary to carry out two different load profiles, because the Santi Romano comprises offices and dormitories. For this reason, the research team studied these two profiles. In the dormitories, it was estimated that the students occupy the rooms from 6 a.m. to 9 a.m. and from 4 p.m. onward. The heating system, instead, works from 6 a.m. to 9 a.m. and from 4 p.m. to 11 p.m. In Italy, there is a law regulating the periods when heating systems are switched on, dividing the country into climate zones. Palermo is in climate band B; therefore, heating is guaranteed from 1 December until 31 March [14].

The same approach was used to draw up office profiles. Here, the occupation and heating profiles are the same, considering a working time from 8 a.m. to 2 p.m.

The profiles related to the air conditioning of offices could be considered the same as the heating, but the dormitory is not served by any air conditioning system. The lighting system load profile is simply in the office because it works from 8 a.m. to 2 p.m.; instead, in the dormitory, the light in corridor is the only one controlled with timers. For this reason, an annual operation of about 2500 h was estimated for the whole dormitory.

3.1.3. Load Estimation

The theory behind the load calculation is explained in this section. To estimate the winter thermal load, summer conditioning load, and lighting load, an Excel file was implemented by the research teams. This automatized calculation tool is an Excel sheet based on current standards, and it is very simple to use. With limited input data, it was possible to produce the three outputs listed above. The winter and summer loads were carried out by the methodology of degree days; in fact, with these input data, the loads were calculated.

Equations (1) and (2) show how it is possible to estimate winter and thermal loads. It was replicated for all surfaces of the facility, which were then added together. The calculation must be carried out in both summer and winter. For the calculation, the degree days correspondent to an indoor temperature set to 20 °C in winter and 22 °C in summer were used [22].

$$WL = \sum\left[(S_{wall,i} * U_{wall,i}) + \left(S_{window,j} * U_{window,j}\right)\right] * DD_{20} * \frac{24}{1000}[\text{kWh/y}] \quad (1)$$

$$SL = \sum\left[(S_{wall,i} * U_{wall,i}) + \left(S_{window,j} * U_{window,j}\right)\right] * DD_{22} * \frac{24}{1000}[\text{kWh/y}] \quad (2)$$

The terms used are:

WL: winter loads
SL: summer loads
S: surface in [m^2] of the *i*-th wall or *j*-th window
U: thermal transmittance in [W/m^2K] of the *i*-th wall or *j*-th window
DD_{20}: degree day in winter condition [K day/year]
DD_{22}: degree day in summer condition [K day/year]
24/1000: conversion in [kWh/year]

The main inputs are: data radiation of the site [23], degree days of the site [22], opaque and transparent surfaces divided by exposures, overall transmittance of opaque and transparent components, type of thermal regulation [24], type of thermal generator (gas, gasoline, or condensation), and type of electrical chiller (with COP). With all these inputs the file Excel was automatized to calculate the pre-retrofit consumption. The same calculations were carried out to calculate the post-intervention consumption. It is sufficient to enter the new transmittance values and performance coefficients of the generating machines. In this way, the difference of consumptions is reported instantly.

In the same way, it is possible to calculate the consumption of lighting pre and post retrofit. The input data are: illuminance density [25], system operating hours per year, and luminaire consumption. Equation (3) shows how the lighting load was calculated.

$$LL = \frac{P_{light} * S_{floor}}{1000}\ [\text{kW}] \quad (3)$$

The terms used are:

LL: lighting load
P_{light}: power density of lights [W/m^2]
S_{floor}: Surface of the floor [m^2]
1000: conversion in kW.

The amount of domestic hot water was carried out by the gas consumption in the summer months. The resume of the loads carried out at the end of energy audit are shown in Table 1.

Table 1. Thermal and electrical loads of Santi Romano.

Thermal and Electrical Loads		
Thermal losses through the building envelope	11,250,000	(kWht/y)
Domestic hot water	363,000	(kWht/y)
Summer heat load	594,530	(kWhe/y)
Lighting load	210,000	(kWhe/y)

3.1.4. Energy Saving Measures

In this section, all the energy saving measures proposed by the research team are listed. They include: replacement of windows and installation of screening film, replacement of old boilers and chillers with more efficient machines, replacement of lighting with LED lamps, and installation of a cogeneration plant.

- The first solution focuses on the windows. It is important to reduce the heat losses through the windows. For this reason, it was proposed to replace the windows with a thermal transmittance lower than 2 W/m^2K. In addition, it was proposed to cover some of the windows with a sunscreen film. The structure has no shading, which means that the sun's rays penetrate through the windows, specifically those facing south, south-east, and south-west. The energy saving was estimated in the same way as shown in Equations (1) and (2) with the replacement of the old transmittance with new one.
- The second solution focuses on the generation system. It was proposed to replace boilers with modern condensing boilers. The old boilers are characterized by a combustion performance approximately of 85% with very dangerous emission. Due to these reasons, the replacement of them reduces the consumption because the new machines have a combustion performance of 93%, and then cuts the emission of greenhouse gases and NOx. The existing boilers are very old, and their replacement is almost necessary [26]. The energy saving connected to the old boiler replacement was calculated by the difference between the energy, required in the pre-retrofit situation, produced with conventional boilers and the energy, required after the retrofit, versus that produced with condensing boilers. This is shown in Equation (4).

$$ES = \frac{WL\,1}{\in_{reg,1} * \in_{dist,1} * \in_{term,1} * n_{boiler,1}} - \frac{WL\,2}{\in_{reg,2} * \in_{dist,2} * \in_{term,2} * n_{boiler,2}}\ [\text{kWh/y}]. \quad (4)$$

The terms used are:

TES: thermal energy saving (kWh/year)
WL 1: winter loads ante retrofit (kWh/year)
WL 2: winter loads post retrofit (kWh/year)
ε_{reg}: efficiency of the regulation system
ε_{dist}: efficiency of the distribution system
ε_{term}: efficiency of the terminal
η_{boiler}: efficiency of the boiler
Subscript 1 refers to the ante situation d subscript 2 refers to the post-retrofit situation.

- For the same reason as replacing the old boilers, it was proposed to replace the old heat pump chiller. This renovation increases the COP of chiller unit from the 2.5 of the existing machine to the 3.9 of the new one. Consequently, this intervention significantly reduces the energy consumption because the machine is more efficient than the old one [27]. This also involves savings in terms of emissions into the atmosphere. The electrical energy saving (EES) was calculated in the same way as for the replacement of boiler, i.e., with the difference of efficiency, because the COP ante and post retrofit must be considered. This is shown in Equation (5).

$$EES = \frac{Summer\ loads\ 1}{\in_{reg,1} * \in_{dist,1} * \in_{term,1} * COP_1} - \frac{Summer\ loads\ 2}{\in_{reg,2} * \in_{dist,2} * \in_{term,2} * COP_2}\ [\mathrm{kWh/y}] \quad (5)$$

- One of the most effective energy-saving measures is the replacement of fluorescent and halogen luminaires with LEDs [28,29]. The replacement of all the luminaires was proposed based on the requirements of standard UNI EN 12464-1. In fact, it has been estimated that with the new LED luminaires, which provide 300 lux of illuminance [25], the total installed power is practically halved. In this way, the consumption of electrical energy will be very low. To calculate the electrical energy saving (EES), in this case of the energy consumed with LED lamps, it must be subtracted from that calculated in Equation (3). Equation (6) shows how the electrical saving is calculated. Subscript 1 refers to the ante situation and subscript 2 refers to the post-retrofit situation. The power density decreased from 6 (W/m^2) to 3 (W/m^2). The lighting system was estimated to work about 5000 h per year.

$$EES = \left(\frac{P_{light,1} * S_{floor}}{1000} - \frac{P_{light,2} * S_{floor}}{1000} \right) * 5000\ [\mathrm{kWh/y}] \quad (6)$$

- The ultimate proposal concerned the designing of a cogeneration power plant. Cogeneration attempts to usefully recover a part of the heat produced by the thermal engine, which must then necessarily be discharged to the environment.

The decision to propose the installation of an internal combustion engine as a cogeneration system stemmed from the fact that it is well suited to the production of small quantities of energy and has great flexibility and reliability. Internal combustion engines used for cogeneration are generally powered by natural gas. This fuel reduces polluting gas emissions and helps to increase the service life of the engine with a significant reduction in maintenance costs [30]. It is important to size the cogeneration plant on a thermal basis to ensure that a large part of the heating load is covered. It was analyzed that in the winter months, a large amount of thermal energy is required and in the other months, the two amounts of energy (thermal and electrical) are of the same order of magnitude. Of course, if the energy produced by the system is not sufficient to cover all needs, then part of it is produced in the boiler (thermal energy) or purchased from the grid (electricity). For this reason, it was estimated that, if all work were carried out at the same time, the back-up power from the boiler would be reduced by a large percentage. It was estimated to be reduced by 25%.

To dimension the system, the trends of the required thermal load were used, both in winter and in summer. Based on the consumption, a profile was reconstructed which represents the cumulative thermal demand curve, shown in Figure 3 (left). This allows us to make a forecast of when the plant will work during the year at full load. From this curve, it is possible to obtain the trend of the Energy Supplied at Full Load (see Figure 3, right). This graph reveals the best size for the system in order to maximize the operative hours in which the machine works at full load and consequently the amount of energy produced [30].

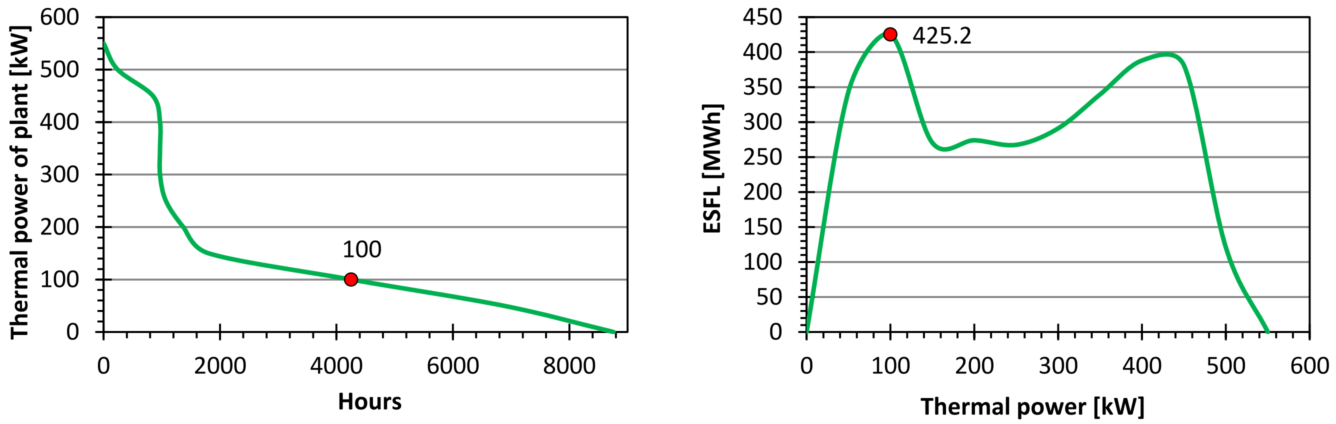

Figure 3. Cumulative thermal demand curve (**left**) and the Energy Supplied at Full Load (ESFL) curve (**right**).

The optimal size chosen for the cogeneration plant, capable of covering part of the thermal power required by the utility with high efficiency during his work, was 100 kWt. This corresponds to a number of operating hours of 4250 h/year. The assumed efficiency of this cogeneration plant is ηtot = 0.78, of which the electrical efficiency is ηel = 0.33 and the thermal efficiency is ηt = 0.45. Consequently, the power that the prime mover must have is 220 kW.

Equations (7) and (8) show how the electrical and thermal energy saving were calculated.

$$EES = 220 * 4100 * 0.33 = 297660 \ [\text{kWh/y}] \tag{7}$$

$$TES = 220 * 4100 * 0.45 = 405900 \ [\text{kWh/y}] \tag{8}$$

3.1.5. Results and Discussion

The proposed retrofit solutions were examined above. Now, it possible to discuss the results of calculations. The Excel file allows the quick assessment of all the interventions listed above. In this way, the comparison between them is simply examined in the last sheet, where a table shows the values connected to the energy saving. All retrofit solutions have the aim to reduce the electrical or thermal consumption of the structure. It is important to underline that the solutions do not guarantee both thermal and electrical energy reduction. The values are shown in Table 2, where it is possible to distinguish for each intervention which energy carrier was saved on.

Table 2. Thermal and electrical energy saving.

Proposed Retrofit Solutions	Electrical Energy Saving (kWhe/y)	Thermal Energy Saving (kWht/y)
Window replacement	4733	29,914
Sunscreen film	27,661	/*
Boilers replace **	/*	46,857
Chiller replacement	81,623	/*
Relamping	102,800	/*
Cogeneration plant	297,660	405,900
Total	514,477	482,671

* No saving guaranteed from the proposed intervention. ** In this case, the boiler substitution is considered with respect to 75% of the power installed before retrofit.

Table 2 shows that the most effective solutions in terms of energy saving are the replacement of lamps and the installation of cogeneration plant.

The technical feasibility of these interventions is not the same for everyone. This operational phase should not be neglected, since during the works it will be necessary to maintain service to the students who will have to continue their studies. Installing shading films is certainly the easiest solution, followed by replacing windows. In this case, the complicated aspect is transport from the ground floor to the upper floors. The replacement of generators can be classified as moderately complicated, since their weight requires the use of cranes to position them. Finally, the most complicated approach is the installation of a cogeneration system since another technical room would have to be created in which to install both the generator, the heat exchangers, and pumping units. In addition, the necessary piping would have to be built to connect the machine to the existing network. Considering the electrical production of the photovoltaic plant installed on the roof, as described in Section 3.1.1, the electrical consumption decreased from approximately 800,000 kWh/y to approximately 285,523 kWh/y. This means that the consumption was reduced by 65%.

The reduction of thermal energy consumption depends largely on the cogeneration plant. The consumption decreased from 1,488,000 kWh/y to 1,005,329 kWh/y. This means that the consumption was reduced by 33%. These two calculations are shown in Table 3.

Table 3. Summary of the energy saving.

	Electrical Consumption (kWhe/y)	Thermal Consumption (kWht/y)
Ante-retrofit	800,000	1,488,000
Post-retrofit	285,523	1,005,329
Saving	514,477 (65%)	482,671 (33%)

These two values of saving, shown in Table 3, depend on several interventions. It is necessary to mix improvement measures based on the building envelope and plants in order to achieve an importance reduction in energy consumption. The energy retrofit solutions proposed in this study were based on the best available technology present on the market. In this way, the elevated performance of all proposed components is guaranteed, from the windows to cogeneration plant. One of the advantages of this Excel file approach is the easy modification of the input data of the technical features of the solutions proposed such as chiller COP, window thermal transmittance, boiler efficiency, etc. The replicability of the study on other buildings is also possible if the standards were updated.

4. Conclusions

This paper assessed the high energy consumption of public buildings if they are not renovated. This aspect translates into emissions that need to be reduced. To solve this problem, it is necessary that the administrations find solutions. The case of Santi Romano, at the University of Palermo, showed that it is possible to significantly reduce energy consumption. The results showed that they can be reduced by 50% or more. The energy saving calculated is based on the same service guaranteed to the occupants of the structure.

The research team also focused on an aspect that could be implemented in the future. In the dormitory, there is no cooling plant, which is necessary during the summer months. In these months, the average temperature of Palermo is also high during the night, and thus students can only use portable fans. Obviously, the implementation of the air conditioning in entire dormitory is an invasive and expensive intervention, but would improve the service provided to students.

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Appendix A

Figure A1. Dish-Stirling installed in the campus of University of Palermo.

Figure A2. Santi Romano Building.

References

1. Luomi, M.; Abdullah, K.; Studies, P. Where Are the Leaders? In Proceedings of the Dr Mari Luomi * Analysis of the COP 25 Climate Change Conference, Madrid, Spain, 2–13 December 2019.
2. Cole, L.B. Green building literacy: A framework for advancing green building education. *Int. J. STEM Educ.* **2019**, *6*, 18. [CrossRef]
3. Staudt, P.; Ludwig, N.; Huber, J.; Hagenmeyer, V.; Weinhardt, C. SCiBER: A new public data set of municipal building consumption. In Proceedings of the e-Energy Ninth International Conference on Future Energy Systems, Karlsruhe, Germany, 12–15 June 2018; pp. 618–621. [CrossRef]

4. European Commision. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union. 2010, pp. 13–35. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010L0031 (accessed on 1 November 2021).
5. Miletić, M.; Krstić-Furundzić, A. *Energy Refurbishment of a Public Building in Belgrade*; University of Belgrade: Belgrade, Serbia, 2018; p. 10.
6. Tavakolan, M.; Mostafazadeh, F.; Jalilzadeh, S.; Safari, A.; Mirzaei, K. A simulation-based multi-objective optimization framework for economic analysis of building energy retrofit: A case study in Iran. *J. Build. Eng.* **2021**, 103485. [CrossRef]
7. Lu, Y.; Li, P.; Lee, Y.P.; Song, X. An integrated decision-making framework for existing building retrofits based on energy simulation and cost-benefit analysis. *J. Build. Eng.* **2021**, *43*, 103200. [CrossRef]
8. Li, Q.; Zhang, L.; Zhang, L.; Wu, X. Optimizing energy efficiency and thermal comfort in building green retrofit. *Energy* **2021**, *237*. [CrossRef]
9. Ma, Z.; Cooper, P.; Daly, D.; Ledo, L. Existing building retrofits: Methodology and state-of-the-art. *Energy Build.* **2012**, *55*, 889–902. [CrossRef]
10. Ibañez Iralde, N.S.; Pascual, J.; Salom, J. Energy retrofit of residential building clusters. A literature review of crossover recommended measures, policies instruments and allocated funds in Spain. *Energy Build.* **2021**, *252*. [CrossRef]
11. Seyedzadeh, S.; Pour Rahimian, F.; Oliver, S.; Rodriguez, S.; Glesk, I. Machine learning modelling for predicting non-domestic buildings energy performance: A model to support deep energy retrofit decision-making. *Appl. Energy* **2020**, *279*, 115908. [CrossRef]
12. Li, X.; Yao, R. Modelling heating and cooling energy demand for building stock using a hybrid approach. *Energy Build.* **2021**, *235*, 110740. [CrossRef]
13. Wang, D.; Meng, J.; Zhang, T. Post-evaluation on energy saving reconstruction for hotel buildings, a case study in Jiangsu, China. *Energy Build.* **2021**, *251*, 111316. [CrossRef]
14. Presidente della Repubblica Italiana D.P.R. 26 agosto 1993, n. 412. Regolamento Recante norme per la Progettazione, l'installazione, l'esercizio e la Manutenzione degli impianti termici degli edifici ai fini del Contenimento dei Consumi di Energia, in attuazione dell'art. 4, comma 4, della L. 1993. Available online: https://www.gazzettaufficiale.it/eli/id/1993/10/14/093G0451/sg (accessed on 1 November 2021).
15. Braccio, G.; Sharma, V.K. Important Aspects of Green Energy in Italy. 2016. Available online: https://www.researchgate.net/publication/305140317 (accessed on 1 November 2021).
16. Ruparathna, R.; Hewage, K.; Sadiq, R. Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. *Renew. Sustain. Energy Rev.* **2016**, *53*, 1032–1045. [CrossRef]
17. Delmastro, C.; Mutani, G.; Perassi, S. In use monitoring of public buildings. Case study in North Italy. *Int. J. Heat Technol.* **2016**, *34*, S266–S276. [CrossRef]
18. Menezes, A.C.; Cripps, A.; Bouchlaghem, D.; Buswell, R. Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. *Appl. Energy* **2012**, *97*, 355–364. [CrossRef]
19. Beccali, M.; Bonomolo, M.; Lo Brano, V.; Ciulla, G.; Di Dio, V.; Massaro, F.; Favuzza, S. Energy saving and user satisfaction for a new advanced public lighting system. *Energy Convers. Manag.* **2019**, *195*, 943–957. [CrossRef]
20. Campisi, D.; Gitto, S.; Morea, D. Economic feasibility of energy efficiency improvements in street lighting systems in Rome. *J. Clean. Prod.* **2018**, *175*, 190–198. [CrossRef]
21. Buscemi, A.; Lo Brano, V.; Chiaruzzi, C.; Ciulla, G.; Kalogeri, C. A validated energy model of a solar dish-Stirling system considering the cleanliness of mirrors. *Appl. Energy* **2020**, *260*, 114378. [CrossRef]
22. UNI 10349-3: 2016. *Heating and Cooling of Building-Climate Data—Part 3: Accumulated Temperature Differences (Degree-Days) and Other Indices*; Italian Organization for Standardization (UNI): Milano, Italy, 2016.
23. UNI 10349-1: 2016. *Heating and Cooling of Building-Climate Data—Part 1: Monthly Means for Evaluation of Energy Need for Space Heating and Cooling and Methods for Splitting Global Solar Irradiance into the Direct and Diffuse Parts and for Calculate the Solar Irradiance on Tilted Planes*; Italian Organization for Standardization (UNI): Milano, Italy, 2016.
24. UNI/TS 11300-2: 2019. *Energy Performance of Buildings—Part 2: Evaluation of Primary Energy Need and of System Efficiencies for Space Heating, Domestic Hot Water Production, Ventilation and Lighting for Non-Residential Buildings*; Italian Organization for Standardization (UNI): Milano, Italy, 2019.
25. UNI EN 12464-1: 2011. *Light and Lighting—Lighting of Workplaces—Part 1: Indoor Work Places*; Italian Organization for Standardization (UNI): Milano, Italy, 2011.
26. Bălănescu, D.T.; Homutescu, V.M. Study on condensing boiler technology potential accounting various fuels. *Procedia Manuf.* **2019**, *32*, 504–512. [CrossRef]
27. Namirian, Z. *Report on HVAC Design of a Building*; University of Mumbai: Mumbai, India, 2021.
28. Raimondi, F.M.; Curto, D.; Frazitta, V.; Milone, D. Energy savings for indoor lighting in a shopping mall: A case of study. In Proceedings of the 2018 Thirteenth International Conference on Ecological Vehicles and Renewable Energies (EVER), Monte Carlo, Monaco, 10–12 April 2018; pp. 1–6.

29. Curto, D.; Milone, D. Improvement of Energy Efficiency for Indoor Lighting in a Big Shopping Center. In Proceedings of the 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Palermo, Italy, 12–15 June 2018; pp. 1–6.
30. Catrini, P.; Curto, D.; Franzitta, V.; Cardona, F. Improving energy efficiency of commercial buildings by Combined Heat Cooling and Power plants. *Sustain. Cities Soc.* **2020**, *60*, 102157. [CrossRef]