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Transforming a Historic Public Office Building in the Centre of Rome into nZEB: Limits and Potentials

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Abstract: According to the last census of 2019, about two million Italian buildings are more than 100 years old. Building energy retrofitting involves a diverse mix of influencing factors, depending on history, intended use, and construction techniques. This paper aims to assess the energy needs of a historic building by evaluating the variability of climatic conditions and internal loads, as well as the thermal capacity of the building envelope. The energy analysis was conducted using dynamic simulation systems (TRNSYS). The purpose of the study is to provide an analysis of the current energy conditions of the building to identify the main critical issues and suggest the most suitable interventions to be implemented. All the transformations were conducted to meet the nZEB requirements and evaluate technical and economic feasibility, compatibility with architectural and landscape constraints, and large-scale replicability. Specifically, to reach the proposed targets, a 36 kWp PV system was implemented for an area of 210 m^2, in addition to the Air Handling Unit (AHU) already present. The profit index is above the unit, and it yields a time range between three and four years. Therefore, fully respecting the energy performance parameters required by the Italian legislation, the study demonstrated the unattainability of the nZEB class for a listed building.

Keywords: nZEB; historical buildings; TRNSYS; buildings retrofitting; buildings office; economic feasibility

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1. Introduction

The energy efficiency of public buildings in Italy is often a matter of joint solutions to energy issues and the preservation of historical buildings. Maintaining the protection of the architectural heritage and landscape of historical Italian cities while upgrading their energy efficiency status almost always involves complex planning and delicate execution. In public housing, where current intended uses are not those for which buildings were originally designed, it is necessary to extensively alter the building envelope and the technical building system (TBS). The energy efficiency measures (EEMs) for energy retrofitting of historic buildings in cold and hot climates impact the TBS but especially the opaque envelope [1,2]. A list reference was developed by ANSI/ASHRAE Standard 100-2006 as a guide to address commercial and residential occupancies, though much of the content pertains primarily to commercial and institutional buildings [3]. Insulation interventions on the external envelopes of historical buildings that allow improving the transmittance and the consequent dispersions are often impractical due to the protection constraints of the architectural and landscape heritage. The impact of the thermophysical performance of envelopes on the global energy consumption is estimated to be 40–50% [4]. The aims of the construction sector decarbonisation policies can only be achieved by accounting for the impact of the design solutions on public buildings, including those which fall within the historical and architectural heritage [5]. For public buildings, the near-zero energy buildings (nZEB) requirements are not easy to achieve, especially in a restricted area such as the territory of Rome.

Italian public buildings are estimated to be at more than 65,000 units, and approximately 60% consist of buildings constructed prior to the first Italian energy-saving legislation [6]. About 2700 public administration buildings are particularly energy intensive, absorbing 1.2 TWh/year, with a cost of 177 million euros. The energy consumption of historical buildings in the EU is currently estimated at more than 250 kWh/m^2/year [7,8]. The TBS solution is somewhat "outdated"; from 2014, the most used fuel appears to be methane (62%), but diesel is still widely used (22%). Only 34% of the buildings are equipped with a temperature control system for each room, and air-conditioning system is available in only 46% of the buildings.

The European Directive 27/2012 on energy efficiency, implemented in Italy by Legislative Decree 102/2014, found that from 2014 to 2020, at least 3% per year of the indoor floor area of the air-conditioned buildings of Central Public Administration should be renovated, as required by the Energy Redevelopment Program of the Central Public Administration [9]. These buildings, mainly in the historic city centres, were built with traditional and local construction techniques and many have bearing structures of bricks or local stones (tuffs) and mixed iron and brick slabs. In some areas of Rome's historic city centre, there are still slabs in wooden structures. If not replaced as obsolete or retrofitted as part of the redevelopment of the transparent envelope, these buildings have wooden or iron frames and single glass.

The purpose of this paper is to highlight the limitations facing the transformation of a Listed Public Building (LPB) into offices of the nZEB standards while taking into account the interventions on TBS. The unattainability of the Italian legal requirements for nZEB is investigated in light of the latest published research. The analysis of the interactions between the three categories LPB, nZEB, and TBS, using the Banco Napoli building as a case study, points to the potential for improvement in the energy efficiency of Italy's public building of high architectural and cultural value.

The highest energy consumption is found in the residential sector [10]; it is responsible for around 40% of the global primary energy demand [4,11–13], and therefore, it provides an opportunity for saving a significant amount of energy. On this premise, the European energy policy aims to improve energy redevelopment schemes applied to buildings [14].

Mancini et al. [15] suggest that new buildings, as well as historical ones, will have to combine energy-saving requirements with those of comfort both in terms of indoor air quality and thermal comfort. Lo Basso et al. [16], concerning the energy balance of the nZEB, consider the overall sustainability of the urban areas in which they are located to contain the effects of climate change on energy consumption. Nastasi et al. [17] propose solutions to avoid further soil consumption following the installation of new plants powered by renewable energy sources (RES) at the service of nZEB. Mancini et al. [18] consider the effects on electrification and flexibility in nZEB development. The nZEB construction and the transformation of the existing heritage-status buildings are studied by De Santoli et al. [19]. Improvements in the passive performance of the building envelope and the efficiency of the energy systems and the introduction of renewable energy sources in the energy balance of buildings were investigated by Astiaso Garcia et al. [10] and Pennacchia et al. [20].

By 2021, all new buildings, as well as buildings subjected to substantial renovations, will have to meet nearly zero energy needs. The anticipated deadline for new public buildings, including schools, has been 2019 [11,21]. The term near-zero energy buildings (nZEB) is generally intended to indicate a category of buildings with a very high energy performance, characterised by a very low (almost zero) annual energy consumption, almost entirely covered by on-site renewable sources [22–24].

The characteristics of near-zero energy buildings in Italy are established by the Ministerial Decree of 26 June 2015 of the Ministry of Economic Development, "Minimum requirements for buildings" [25]. The construction of nZEB, as reported by Nucara et al. [26], and the transformation of the existing heritage will be carried out through improvements in the passive performance of the building envelope, the TBS efficiency, and the introduction of renewable energy sources for balancing of the buildings energy efficiency, as reported by Rosa et al. [18].

Since buildings are usually connected to external energy supply networks (gas, electricity) and due to the discontinuous nature of renewable sources [27], the nearly zero value concerns the balance between withdrawn energy and self-produced energy, consumed directly or fed into the national grid [28]. That is why city planning becomes crucial for the production and consumption of energy [29].

The challenge is to apply an appropriate retrofitting to historical buildings which, in Central Italy and in particular in climate zone D, as defined by the Italian legislation [30], are subject to strict regulations on renovations [31–34], to generate a significant impact in an area of such great artistic and architectural value as the historical centre of Rome [35,36]. Where installed, the HVAC system is the first component to be refurbished [37] or to be upgraded by innovative technologies [37] or to extreme conditions [38].

Many authors have approached the study of historic buildings and their possible efficiency in the scientific community. Ascione et al. [39] suggest a multicriteria approach for energy efficiency of historical buildings, proposing methodologies for performance analysis, combining different experimental and numerical studies, and applying such methodologies to a historical building in the province of Benevento. Giombini et al. [40] addressed a case study for a historical building in the city of Perugia, indicating a methodology for the analysis of this type of building. This methodology can be useful to address the energy efficiency status of historical buildings. De Bernardis et al. propose a methodology to guide the recovery design, using a "case by case" approach to identify the best intervention method for each context.

Galatioto et al. [41], Martinez-Molina et al. [42], and Webb [5] suggest a state-of-the-art methodology to analyse the possibility of efficiency in historic buildings. In these works, various types of buildings are studied and classified by purposes of use. Ma et al. and other researchers [33,43,44] proposed a systematic approach to selecting and identifying the best retrofit possibilities for existing buildings, providing methodologies and promoting energy conservation and sustainability. This approach requires research to create dedicated databases for benchmarking performance. Jafari et al. [45] proposed a decision-making framework to calculate the economic benefits of energy retrofitting and determine the optimum energy retrofitting strategy.

The impact of the energy improvement measures on historical buildings is studied by Grytli et al. [46], who presented an integrated analysis method that examined different impacts from various energy efficiency measures on a model building. Many other authors have focused on integrating renewable and nonrenewable energy systems in retrofitting historical buildings [47–49]. Few studies tested innovative on-site technologies such as storage devices [50], while the largest scale of planning interventions has been the master planning of entire districts [51]. Careful analysis of noneconomic barriers is fundamental for the feasibility of any intervention [52,53].

Becchio [53] evaluated the economic component for the nZEB design and noted that it is fundamental to consider both the energy and the economic perspective. In the application phase of the study, the work by Ciampi et al. [54] is a valuable reference since the performance and consequent retrofit actions are simulated on an existing historical public building using the TRNSYS simulation software. Meanwhile, De Santoli et al. used a MATLAB/Simulink tool to design the refurbishment scenarios [55] and evaluate the performance of innovative technologies [56]. Synergies among the simulation software are expected to cover all the energy aspects, as reported in Groppi et al. [57].

The study of historical buildings, the possible efficiency improvements, and the achievement of the nZEB class find support in Dalla Mora et al. [58] and Sauchelli et al. [59]. The authors offer specific case studies of the energy efficiency improvements on historic buildings to meet the nZEB requirements and the Italian legislative regulations. Mauri [60] hypothesised different retrofit scenarios to achieve the nZEB objective with the simulation on a historical building in the province of Agrigento. The author conducted a cost analysis to achieve optimal economic solutions and energy savings. The study can contribute to the development of specific policies and the adoption of suitable measures to facilitate optimal design choices for the energy improvement of historical buildings.

A number of studies addressing the transformation of public buildings into nZEB have been carried out, while the interest in buildings bound for use as energy-intensive offices is scarce. This observation also derives from the work of the authors of this study, who have, for years, carried out research on the topic of energy efficiency of the historic building stock [32,47,61–68].

The present paper highlights technical and economic limitations in transforming a listed public building into nZEB. The object is to evaluate the limitations of energy retrofitting aimed at achieving the nZEB objectives based on the Italian regulatory restrictions, focusing on historic office buildings in areas with landscape and architectural constraints. More specifically, the objective is to show that, based on the regulatory requirements of the Ministerial Minimum Decree, it is impossible to carry out external insulation interventions, even on the building's opaque envelope, together with the energy retrofitting of the TBS, resulting in the unattainability of the nZEB status. Dynamic numerical analyses were set up and performed using TRNSYS software based on the data obtained from an energy analysis conducted on the building envelope and energy systems. In Materials and Methods, the characteristics of the case study are illustrated. Section 3.1 describes the numerical model implemented in TRNSYS to evaluate the reachability of the nZEB objectives described in Section 2.3. In Section 4, the results obtained by comparing the outcomes of efficiency improvements in a proposed case study of BancoNapoli are reported. Section 5 contains the diagram of the impacts of the transformations on the Banco Napoli, highlighting the limits and the potentials for its transformation into nZEB.

2. Case Study

Existing regulatory constraints in the municipality of Rome for building redevelopment activities can be classified into two main categories: architectural and landscape. "Cultural assets" and their respective architectural constraints are the assets protected under Part II of the Cultural Heritage Code (Legislative Decree no. 42/2004) [69] and can be individual buildings, small groups of buildings, historic villas, and others. They are assets protected because their history, their forms, or their materials are a testimony of Italian culture, history, and art.

The historic centre of the city of Rome, included in the perimeter of the Aurelian walls, is classified as UNESCO heritage. The constraints of this qualification overlap those present in the Municipality of Rome (RMP). The protection of the buildings in this area falls under the Superintendence of Rome Capital which imposes restrictions on the interventions that can be carried out on the external envelope of the buildings, especially on the opaque components, while for transparent components, there is only the obligation of frames that respect the forms and materials of the existing ones. This allows them to be replaced with the latest generation high-performance window fixtures.

Whenever an intervention of protected assets is carried out, the operations belong to the field of restoration, and the priority aims are those of conservation and transmission as investigated in Jafari et al. [45] and Grytli et al. [46].

The use of historic/listed buildings intended for public use repeats in all its particularity the issue of energy efficiency as a protection tool, not a single regeneration process in contrast with the conservation requirements. The surveys and analyses conducted during the audit were aimed at optimizing consumption related to air-conditioning systems. Therefore, they analyzed the uses and consumption related to air-conditioning systems to evaluate the possibility of reaching the nZEB building targets set by Italian legislation, analyzing the building focusing on the energy generation systems. However, being an asset of considerable historical interest and subject to various types of constraints, the interventions on energy systems of the entire building—with priority to HVAC systems—must be planned in a strategic vision, focusing on the high quality of the building complex, and ensuring maximum efficiency for energy consumption.

The building object of study, "Banco Napoli", belongs to the patrimony of the Italian House of Parliament and is in the historic centre of Rome at an altitude of 20 m above sea level, at a north latitude of 41°53′ and an east longitude of 12°28′. The building is part of the historical city and has a medieval origin, as defined by the technical standards of the RMP. These are specific morphologies of implantation of the "Fabrics of medieval origin" of the Historical City (Figure 1a,b). The technical standards indicate that attention must be paid to the presence and conservation of the remains of ancient buildings, as stated at the beginning of this section.

(**a**) (**b**)

Figure 1. (**a**) Rome historic centre and case study building detail; (**b**) building view.

In the city of Rome, 35% of the buildings are characterised as historic by age and building techniques and therefore subject to urban planning constraints included in the RMP and QC (quality chart).It is, therefore, necessary to guarantee the preservation of the walls and wall textures that testify to the stratification process over time. The transformation of the TBS of the Banco Napoli building took place over many years with partial interventions on specific areas such as floors or for intended use such as offices or toilets only.

The characteristics of the envelope and TBS of the "Banco Napoli" building are shown below. The raw data collected and classified in this section have been reprocessed and transcribed in Section 3.1 in specific "Types" subsequently implemented in TRNSYS.

2.1. Building Envelope

The current building consists of the union of two building blocks, called A and B-C-D, as shown in Figure 2 below:

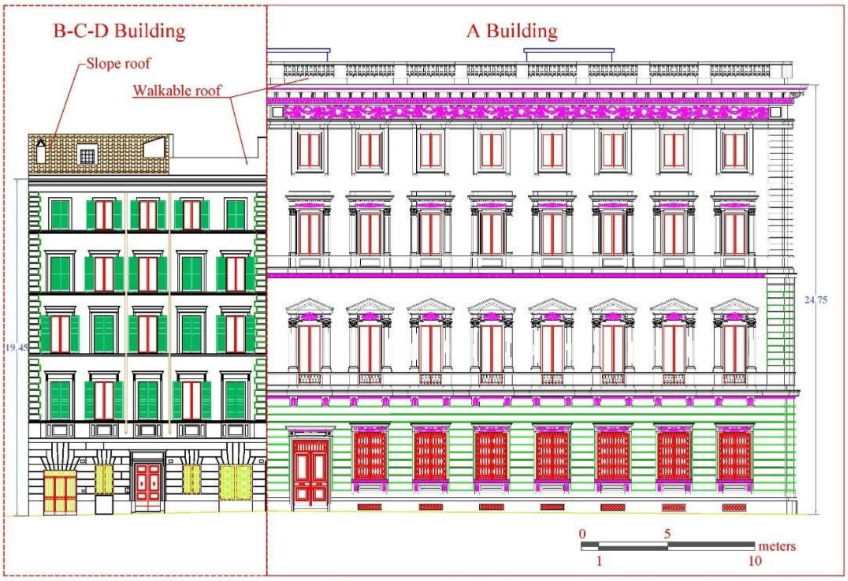

Figure 2. Building overview.

The rooftop type is not thermally insulated and is differentiated into two types: walkable with flooring and nonwalkable (see Figure 2). Regarding the thermal characteristics, a type of vertical wall was identified as made of uninsulated solid masonry with a thickness ranging from 130 cm to 80 cm. The transmittance of the perimeter walls has been assumed to be equal to the average value calculated based on the greater thicknesses on the ground floor and lesser on the top floor, equal to 1.15 W/m^{2}K.

Regarding the external façade, the building is typical of the late nineteenth-century housing in Rome's city centre. A type of floor was identified, and the transmittance is equal to 1.34 W/m^{2}K, extending for a total surface area of approximately 1007 m^2. The thermal transmittance is 1.51 W/m^{2}K. These data were deducted from the audit process, and a check-in reference to the technical report UNI/TR 11552:2014 provides the main thermophysical parameters (thermal transmittance, heat capacity per unit area, and periodic thermal transmittance) of the most used casing opaque components in existing buildings.

The supporting structure is made of bricks with mixed slabs, iron, and bricks. It consists of a basement and four floors above ground. It has total gross and net areas of 6676 m^2 and 4673 m^{2,} respectively, corresponding to a gross volume of 25,195 m^3 and a net volume of 17,636 m^3.

The load-bearing masonry made of solid bricks has a thickness of 130 cm on the first and second floor, up to 80 cm on the last floor. The internal partitions are made of solid brick for the load-bearing partitions and 10 cm perforated bricks.

The glazed surfaces consist of windows with double-glazed wooden frames and Roman blinds, also in wood.

All the windows of the Banco Napoli building have been redeveloped to improve their energy performance by reducing dispersion.

The windows are made of double glass 4–12–4 wooden frames with thermal break. From an analysis of the transmittance characteristics of the windows, the simple window type has a thermal transmittance of 3.74 W/m^{2}K. All classical window surfaces have solar shutters consisting of Roman blinds. The total area of the glazed elements is 450 m^2.

2.2. Technical Building Systems

The systems that have undergone significant transformations are HVAC and electricity distribution systems. Given the intended use of offices, HVAC systems upgrades are the most widespread and invasive components of the building. The external surfaces of the terraces have been almost entirely occupied, were authorized by the Superintendency offices, with Rooftop HVAC machines.

An energy audit was conducted to determine and classify HVAC by type, power, and areas served. The layouts have been classified into five macro components and the data processed to be able to insert them into the TRNSYS type components:

- Heating systems (thermal and cooling);
- Distribution (heat transfer fluid);
- Settings (Heating systems and terminal units);
- Emission (terminals units);
- Water storage (if any).

The generation plant consists of traditional methane-fueled boilers, electric refrigeration units and 4 Air Handling Units, all located on the terrace of the building.

The air-conditioning of spaces is constituted by primary air systems, fresh air, and fan coil in offices, while in the corridors, toilets, and some common areas, high-temperature radiators are present.

The building's air-conditioned rooms are kept at a uniform temperature through several air-conditioning systems and various centralized and noncentralized technologies: centralized Air Handling Unit (AHU) or Variant Refrigerant Fluid (VRF). The building has been divided into four thermal zones, the AHU BANK (Naples bank building), AHU A, AHU B, and AHU Int, each served by a specific air-conditioning system. The thermal energy generation system consists of four nominal 263 kW methane boilers that provide

DHW and heat the radiator circuit. The fan coil systems and the AHU batteries are powered by two heat pumps and three VRF.

Regarding electricity loads, there are three primary thermal generation systems: two heat pumps that supply the fan coils, the AHU BANK (Naples bank building), the AHU A and the AHU B; four natural gas boilers for the radiator circuit; three Variant Refrigerant Fluid (VRF) with multiple expansion for the AHU in the basement and the air-conditioning of the first floor.

The heating system was built using traditional gas boilers placed on the roofing level of the building, which also produces Domestic Hot Water (DHW) with the integration of solar panels.

There are four traditional boilers (Bongiovanni Bongas 2/14 type) with a capacity of 263.3 kW each, supplied by gas with an efficiency of 90.2%.

The thermal power plant is always in operation as it must guarantee coverage of the demand for DHW production. DHW production is integrated by a system of 13 solar collectors placed on the roof of the building. The total area of the collectors is 26 $m^{2,}$ with a total production of about 4000 kWh per year.

DHW production is centralized in the basement of building A. There are three pumps with a capacity of 250 L/m and a power of 3 HP each. Accumulation is guaranteed by three tanks of 1500 L each.

Inside the building, there are several types of user terminals: the four-pipe fan-coil, radiators, and split units connected to outdoor multiunits serving some offices.

The user terminals, fan-coils, and radiators do not have thermoregulation systems. In particular, the fan-coils have only a manual on/off regulation system, while the radiators do not have a thermostatic valve.

The rooms are heated, as reported in Table 1.

Table 1. Operating hours of heating systems.

Winter/Summer	**Conditioning**			**Heating**		
	Mon–Fri	Sat	Sun	Mon–Fri	Sat	Sun
Building A	8–19	Off	Off	7–13 16–19	7–13	Off
Building B-C-D				7–13 16–22	7–13 16–22	7–13 16–22

In the various buildings, there are three different Air Handling Units (AHU) in addition to one located in the underground rooms, whose characteristics are shown in Table 2.

Table 2. AHU position and characteristics.

AHU Position	**Technical Characteristics**
AHU Bank	Brand: Atisa 17,500 m^3/h
AHU Int/Basement	Brand: Atisa 6000 m^3/h
AHU A	Brand: Atisa 12,500 m^3/h
AHU B	Brand: Atisa 6000 m^3/h

Two heat pumps for the thermal power generation system provide refrigeration with a cooling capacity of 362 kW and a compressor power input of 113 kW and EER of 2.7 each. The thermoregulation of the central unit operates through a single centralized reading from the various circuits served. As a result of the decrease in the return temperature, the refrigeration load delivered by the group will decrease. The distribution subsystem is mainly made up of concealed pipes or interspaces, while the emission has four-pipe fan-coil terminals and metal radiators.

2.3. Lighting Systems and Electric Equipments

To determine the loads due to lighting, the installed power density value (W/m^2) was multiplied by the surface area. A strategy for controlling the ignition of the lighting system within the thermal zone was selected through TRNSYS. For the Banco di Napoli building, the following reference values have been set according to UNI EN 12464-1 Standard: (a) Power density for lighting: 10 W/m^2; (b) Power density for electronic equipment: 3.2 W/m^2.

The building managers have already made interventions to improve efficiency with LED lighting systems only in the offices of the building, with presence sensors and elevators with inverter motors and centralized controls of consumption. In corridors and other spaces, fluorescent lamps are installed.

3. Materials and Methods

The present energy analysis identifies and defines the main technological, air-conditioning, and electrical systems and the thermal zones served by them: each area has been characterized by surface and volume concerning the number of floors in the buildings.

According to a stringent redevelopment constraint, nothing can be altered on the outside of the building to reduce winter heat losses due to the protection regulations of the Italian directives regarding the building analyzed. The solutions were evaluated with consumption dynamics simulations to achieve the aims of the nZEB Italian legislation, acting on the climate systems and maximum energy production from photovoltaic systems installed on the available roof space. Finally, an economic analysis of the interventions is proposed to assess an acceptable economic return.

3.1. Numerical Model

In the following section, the simulation model used to carry out the energy audit for the Banco Napoli building will be presented. The energetic diagnosis is carried out through a dynamic simulation that foresees the use of the TRNSYS software [70].

The TRNSYS is used for dynamic simulations of established phenomena to validate, in this specific application, a new energy management concept, which can range from the evaluation of the behaviour of a DHW production system from solar collectors to the dynamic analysis of the behavior of a “multizone” building. The software gives the user the possibility to easily develop customized components using the most common programming languages (C, C++, PASCAL, FORTRAN, etc.).

The implemented building model needs inputs that provide information regarding the climatic data of the geographical area to which the building belongs and the characteristics of the building’s air-conditioning system. The climate data used are provided directly by the software, which contains a library with the climate information of various sites worldwide coming from the Meteonorm database and information on over 1000 sites in 150 different countries. The climate data included in the model relate to Ciampino (the year 2018), as it represents the location (among the available) geographically closest to the Banco Napoli headquarters.

The model was built following the directives imposed by the UNI/-ISO 52016-1 and UNI-ISO 52017-1 standard [71] “Energy performance of buildings—Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads—Part 1: Calculation procedures”. The legislation defines a building as “consisting of one or more buildings (building envelopes) or portions of a building, air-conditioned through a single generation system”.

The model was calibrated and validated with actual consumption, both for the gas part and for the electricity part. The calibration of the model is presented in Annex A to make the manuscript more readable.

This was followed by identifying the thermal zones to be analyzed during the study. The distribution of the various floors in thermal zones has always been carried out following the directives imposed by the UNI/TS 11300-1 standard that dictates the conditions for the subdivision of the building into sub-areas called "Thermal Zones": "each part of the building, air-conditioned at a certain temperature with the same regulation mode, constitutes a thermal zone". Adhering to this definition, it was possible to divide the whole building into 63 thermal zones.

The breakdown of the building is shown in Figures 3–7, where the spaces for office use (blue), hallways and stairs (yellow), and toilets (green) are highlighted:

Once the distribution of the building was defined, each thermal zone was characterized by determining the indispensable properties for calculating the thermal regime inside the building, such as dimensions of the thermal zone, the definition of walls bordering with other thermal zones or with the external environment, thermal characteristics of opaque and transparent surfaces, the definition of thermal loads inside the thermal zone, hourly frequency of air changes [34], characteristics of the heating system, characteristics of the cooling system, characteristics of the ventilation system, and characteristics of hygrometric air.

Transmittance values of the building envelope were extracted by UNI/TR 11552:2014 Opaque envelope components of buildings—Thermophysical parameters [72]. Table 3 shows the transmittance values of the external envelope.

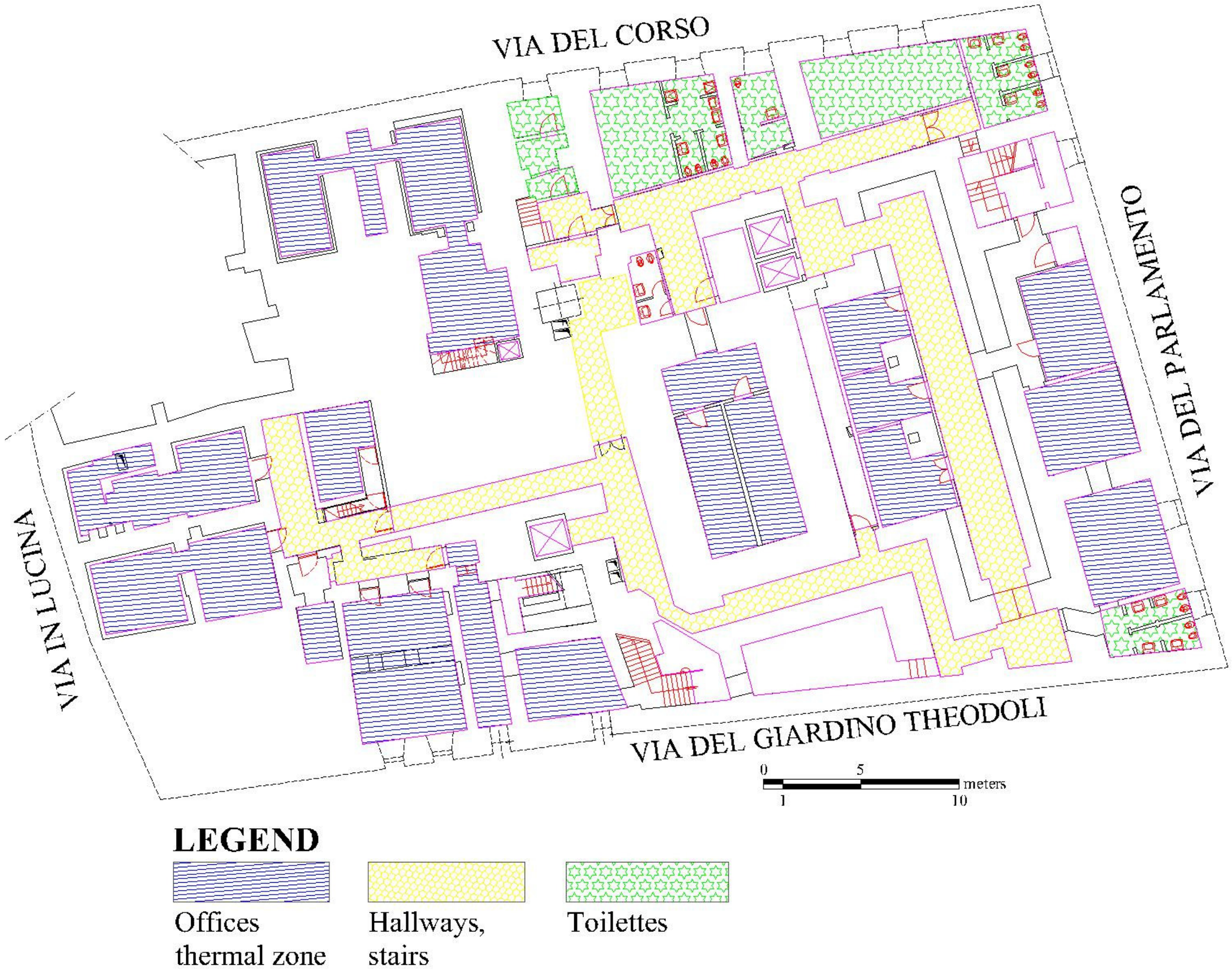

Figure 3. Designated uses on the Int/basement floor.

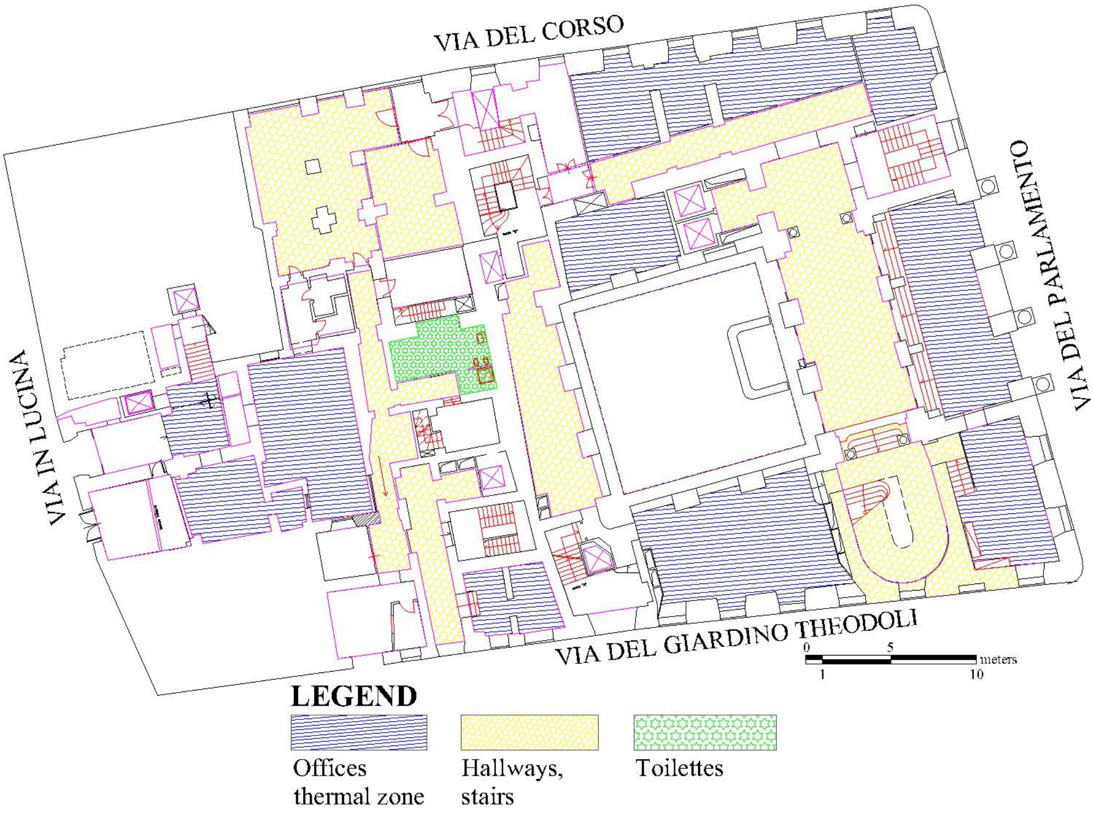

Figure 4. Designated uses on the ground floor.

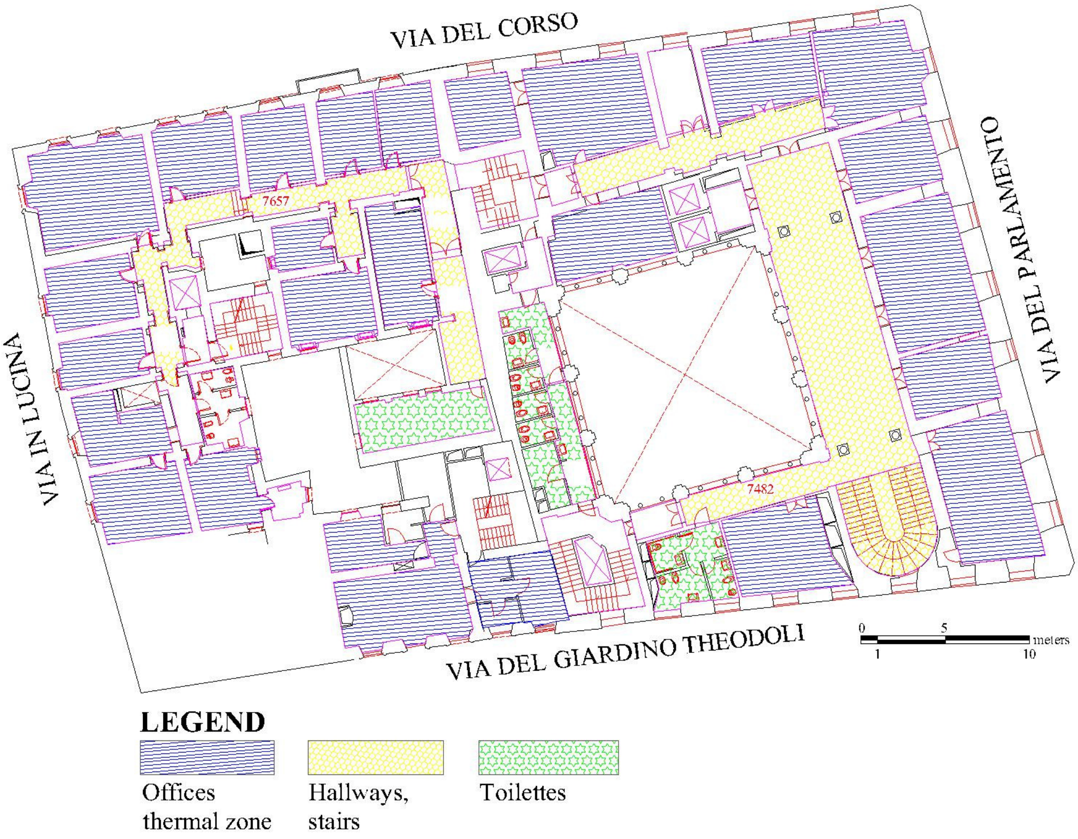

Figure 5. Designated uses on the first floor.

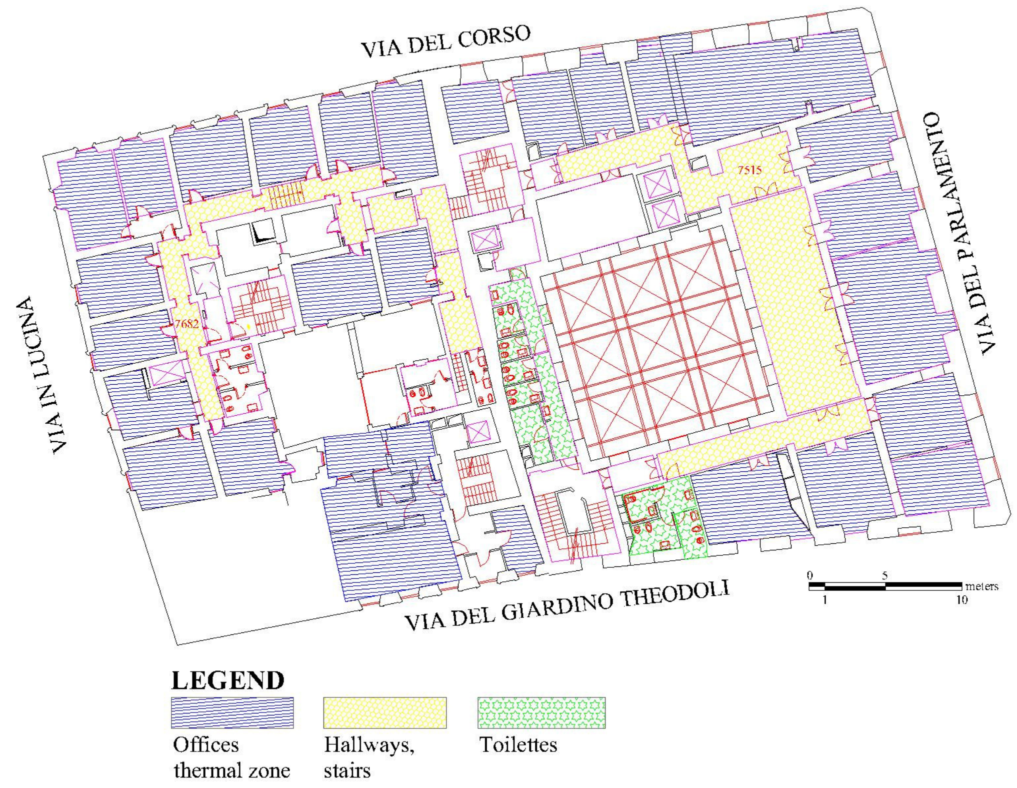

Figure 6. Designated uses on the second floor.

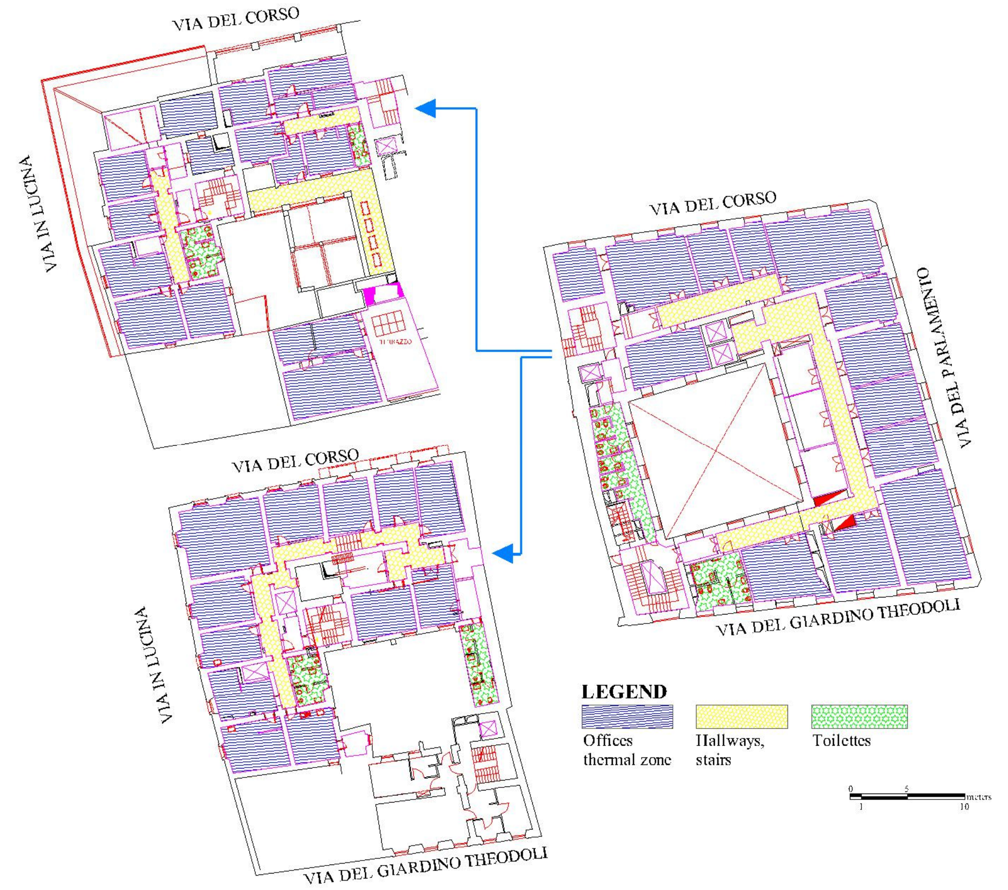

Figure 7. Designated uses on the third floor.

Table 3. Transmittance value of the building envelope.

Type	Transmittance (W/m^{2}K)
Vertical opaque areas	1.15
Inter-floor slab	1.34
Covering slab	1.51
Slab-on-grade floor	1.08
Windows	3.74

The thermal loads for the Banco Napoli building (occupants, lighting equipment) were set using the following values taken from the literature (Fasano et al., ENEA) [70,71] as shown in Table 4.

Table 4. Thermal loads form.

	Power Density
People	150 W/people
Illumination	10 W/m^2
Electronic devices	3.2 W/m^2

To determine the loads due to lighting, the value of installed power density (W/m^2) was multiplied according to the extension of the surface. The software was selected to control the lighting system ignition within the thermal zone. At present, there is an absence of control systems and centralized lighting system management in the Banco Napoli building. For this reason, manual switching was chosen. Currently, lighting is essentially supplied by LED in offices and fluorescent lamps in corridors and other spaces, dissipating about 25% of the absorbed energy by radiation towards the surrounding surfaces. The remaining 50% is dissipated by conduction and by convection. In addition to the lighting thermal loads, other thermal loads deriving from electrical equipment such as computers, printers, coffee dispensers, and elevators were implemented. For each of these, the operating time and the heat output generated based on the occupancy has been defined.

Table 5 are reported the data inserted in TRNSYS Building Model.

Table 5. TRNSYS input model.

Input
Heating set-point temperature: 19 °C
Relative humidity percentage indoor before humidification: 38%
Cooling set-point temperature: 26 °C
Relative humidity percentage indoor before dehumidification: 52%
External air temperature: variable according to outdoor simulation period
Incident solar radiation each cardinal axis varies according to the simulation period

For each thermal zone, it is possible to set the window opening frequency. The average value of fresh air flow rate inside the single room was set to 11 m^3/h according to current legislation [72].

The action carried out by the four AHUs present in the building were implemented by setting the air flows introduced into the environment considering the characteristics of Table 2. The airflow rate is assumed to be constant during operation as currently, the system is not equipped with flow regulation systems. Two separate airflow inputs have been implemented according to the type of distribution organ present inside the environment: delivery hoses AHU = 250 (m^3/h) and diffusers = 150 (m^3/h).

3.2. nZEB Targets

The energy performance of a building is determined considering all energy services (heating, cooling, ventilation, DHW, artificial lighting, and the transport of people or things, the latter limited to nonresidential buildings). The calculation of the energy performance can be carried out with different algorithms and methodologies, depending on the available data and the required accuracy. It seems clear that as the complexity of the algorithm increases, the approximation of the results improves. The current legislation (Decree of the Ministry of Economic Development 26 June 2015) [73] provides a methodology for the calculation of the energy performance in buildings, including the use of renewable sources in compliance with national technical standards following the development of EN standards to support Directive 2010/31/EU [22]. In most cases, the calculation of the energy requirement is performed to achieve a standardized assessment of the needs and a certified classification of the building from an energy consumption point of view. It is, therefore, important that the calculation procedures not only have a recognized scientific validity but also meet the regulatory requirements of the sector.

For research purposes of reaching more precise assessments of energy needs, according to the current occupation of the building, it is possible to use more sophisticated simulation methods that provide dynamic modelling.

The regulatory obligations compare the building to a "reference" building, identical in geometry, orientation, territorial location, intended use, and surrounding situation, with different thermal characteristics and pre-established energy parameters. The reference building is therefore considered to be equipped with the same energy production facilities as the actual building, assigning a reference average efficiency for both the utilization subsystems of the reference building and the generation subsystems. Furthermore, the reference building is considered equipped with generation systems for winter heating energy services, summer air-conditioning, and DHW production of the same type as those present in the actual building.

The set of buildings Banco Napoli has a gross area of 6676 m^2 and a gross volume of 25,195 m^3 with a form factor S/V equal to 2.6. The parameters to be respected for the case study were therefore obtained from a table [32] or determined by the calculations of the reference building, modelled with the mandatory limit values as of 1 January 2019 for public buildings. These parameters are summarized in Table 6 below.

Table 6. Threshold limit value.

Parameter		u.m.	Requirements
$\mathbf{H'_T}$	Average overall heat transfer coefficient for transmission per unit of surface dispersant	(W/m^{2}K)	$\leq$0.53
$\mathbf{A_{sol.est}/A_{sup\ utile}}$	Summer equivalent solar area per unit of useful surface	(-)	$\leq$0.040
η_H	Seasonal average efficiency for domestic hot water production	(%)	$\geq$81%
$\mathbf{Ep_H}$	Specific primary energy index for winter heating. (1)	(kWh/m^2)	$\leq$80.35
$\mathbf{Ep_{H.nd}}$	Useful thermal performance index for winter heating	(kWh/m^2)	$\leq$99.19
η_w	Seasonal average efficiency for domestic hot water production	(%)	$\geq$81%
$\mathbf{Ep_w}$	Specific primary energy index for hot water supply. (1)	(kWh/m^2)	$\leq$18.45
$\mathbf{Ep_{w.nd}}$	Useful thermal performance index for hot water supply.	(kWh/m^2)	$\leq$26.35
η_c	Seasonal average efficiency for air cooling systems (including the possible humidity control)	(%)	$\geq$81%
$\mathbf{Ep_c}$	Specific primary energy for summer cooling (including the possible humidity control). (1)	(kWh/m^2)	$\leq$45.22
$\mathbf{Ep_{c.nd}}$	Useful thermal performance index for summer cooling	(kWh/m^2)	$\leq$52.77
$\mathbf{Ep_t}$	Energy performance index of the service for the transport of people and things (lift systems and escalators). (2)	(kWh/m^2)	$\leq$15.46
$\mathbf{Ep_v}$	Energy performance index for ventilation. (1).	(kWh/m^2)	$\leq$22.47
$\mathbf{Ep_L}$	Energy performance index of the service for lighting. (2)	(kWh/m^2)	$\leq$21.15
$\mathbf{Ep_{gl}}$	Index overall energy performance of the building. (1)	(kWh/m^2)	$\leq$165.17
$\mathbf{P_{el.ren}}$	Photovoltaic power plant	(kW)	$\geq$35.20
$\mathbf{CFE_{ren.DHW+CLIM}}$	Requirements for DWH and air-conditioning due to renewable sources	(%)	$\geq$55
$\mathbf{CFE_{ren.DHW}}$	Requirements for DWH due to renewable sources	(%)	$\geq$55

(1) It is expressed in nonrenewable primary energy ("nren" index) or total ("tot" index). (2) This index is not calculated for category E.1 (residential buildings), except for colleges, convents, dormitories, barracks, as well as for category E.1.

The analyzed building represents a common type of building of historical importance, as defined above, on which it is impossible to intervene on the outer shells and living space, focusing all the performance improvement on technological systems only. Furthermore, the Minimum Requirements Decree imposes the highest percentage of energy requirement coverage with renewable sources on near-zero energy buildings. However, it is noted that this coverage relates exclusively to the heating, cooling and production needs of DHW, while the contribution due to lighting is wholly neglected, although it affects the overall value of global energy performance. Other energy services are also neglected, such as ventilation and transport of things or people.

4. Results

This section displays the results related to the dynamic simulations of the actual state of the building under examination and subsequent retrofit interventions. Attention is focused on calculating the parameters that contribute to the building being defined as nZEB.

The proposed feasibility intervention will demonstrate its suitability by addressing an economic analysis covering the time period of 20 years.

4.1. Analysis of the State of the Dynamic Simulations

The following illustrates the results obtained from the dynamic simulations carried out in TRNSYS relating to the current state of the Banco Napoli building-TBS system. The study was conducted by analyzing the consumption resulting from the conditioning of the interior spaces, as shown in Figures 3–7, highlighting the distribution of electricity consumption and for cooling and heating between the various thermal zones. The results obtained were then compared with the consumption recorded by the energy audit. As previously illustrated, the air-conditioning system is a “primary air” system mixed with four-pipe fan coils placed in each room, except for services. Figures 8 and 9 show the hourly thermal energy supplied to the building by fan coils during heating and cooling mode. The HVAC maintenance is managed by a facility management company that receives directly from the Administration of the House of Parliament an indication of when to turn off the boilers and turn on the refrigeration groups to make the reversal of the system. Seasonal transients and conditioning of some areas that require special climatic conditions managed by some local autonomous air-conditioning systems were not considered in the simulation as they had a negligible impact on the final consumption. From the graphs in Figures 8 and 9 (Hours of operation on the abscissa and kWh for the energy generated on the ordinate), it is possible to notice that the duration of the heating period is higher than that of the cooling, but on the other hand, the peak of cooling power (about 280 kW) is well above the peak of thermal power (about 190 kW).

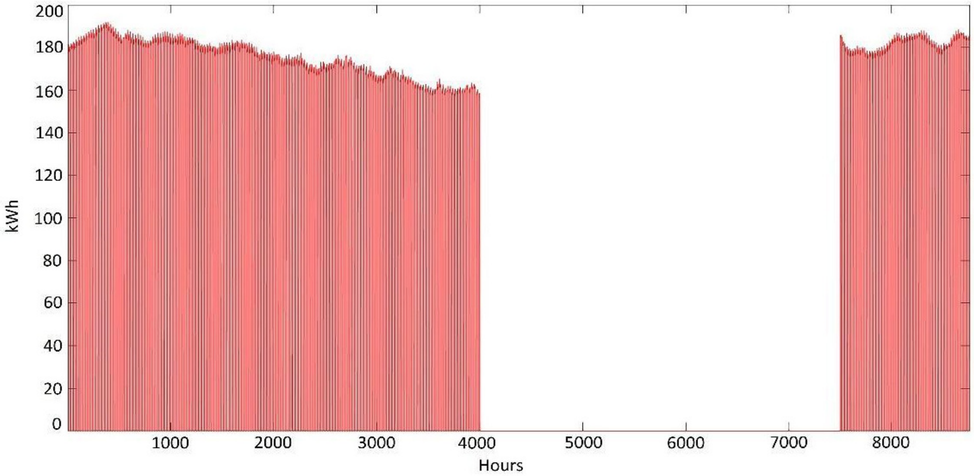

Figure 8. Fan coils hourly thermal energy trend.

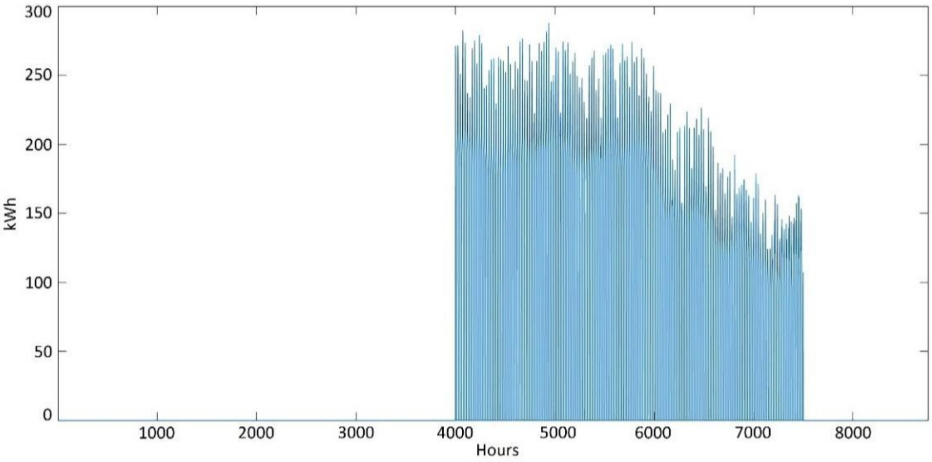

Figure 9. Fan coil hourly cooling energy trend.

The trends obtained in Figures 8 and 9 reflect the consumption obtained in most common office buildings types. It can be clearly seen that the cooling trend decreases after the first half. This corresponds to the period of vacation from work that generally takes place in Italy. The AHUs are left on, but they work at their lowest power. On the other hand, the heating period has an approximately constant trend over time. In the spring season, the plant still works at high speed despite the higher outside temperatures. This is due to the large volume of the building and, therefore, the longer time to heat it than in a standard building.

Figures 10 and 11 show the cooling energy and hourly thermal performances provided by the four AHUs present in the building if all AHUs process their nominal capacity.

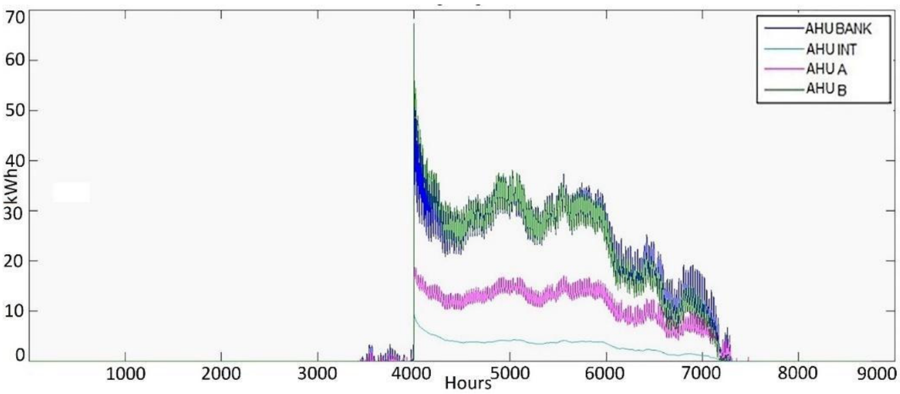

Figure 10. AHU hourly Cooling energy consumptions.

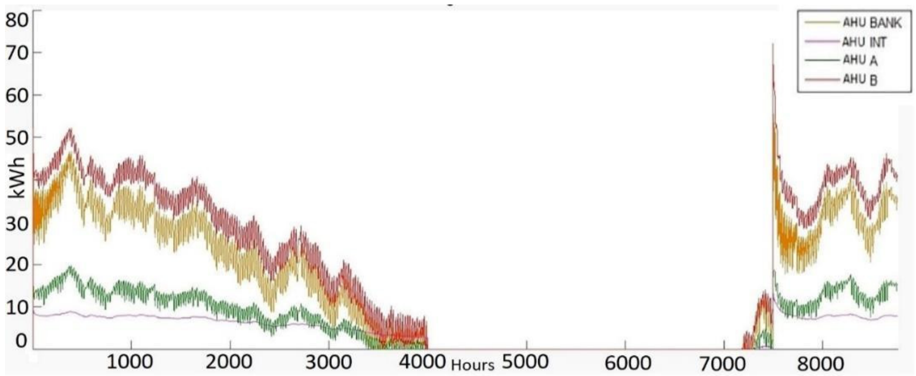

Figure 11. AHU hourly thermal energy consumptions.

It is evident that the AHU Bank provides a quantity of thermal energy in heating and cooling, similar to the AHU B, despite a higher nominal airflow. Thus, the AHU B can easily supply the average needs of the entire structure, but to meet the peak demand, the other AHUs are also used. It is interesting to note the behaviour of the AHU INT; this machine must adopt the minimum variations of the temperature inside the room it serves. Being designed to meet the needs of the basement, considering that the temperature trend of this environment is minimally affected by changes in the external temperature, its operation is not adaptive but almost constant.

The values showing the average energy performance (calculated over a year), the hourly maximum for the AHU and the fan coils are shown in Table 7.

Table 7. Supply hourly thermal/cooling energy values.

Plant	kWh$_{avg}$/Heating Hour	kWh$_{max}$/Heating Hour	kWh$_{avg}$/Cooling Hour	KWh$_{max}$/Cooling Hour
FAN COILS	52.87	191.87	37.16	287.51
AHU BANK	14.51	59.75	9.09	62.57
AHU B	18.44	72.07	8.88	67.32
AHU A	6.08	19.69	4.16	22.03
AHU INT/Basement	3.98	13.79	1.18	10.89

Once the time thermal profile of the building was defined, it was possible to obtain the annual thermal and cooling energy. Table 8 and Figure 12 show the values of annual thermal and cooling energy divided according to the distribution apparatus. All data are derived from the House of Parliament monitoring data centre.

Table 8. nZEB parameters of the current state.

Parameters		u.m.	Requirements	Current State Data
$\mathbf{H'_T}$	Average overall heat transfer coefficient for transmission per unit of surface dispersant	(W/m^{2}K)	≤0.53	0.78
$\mathbf{A_{sol.est}/A_{sup\ utile}}$	Summer equivalent solar area per unit of useful surface	(-)	≤0.040	0.035
$\boldsymbol{\eta_H}$	Seasonal average efficiency for domestic hot water production	(%)	≥81%	85%
$\mathbf{Ep_H}$	Specific primary energy index for winter heating. (1)	(kWh/m^2)	≤80.35	79.10
$\mathbf{Ep_{H.nd}}$	Useful thermal performance index for winter heating	(kWh/m^2)	≤99.19	93.06
$\boldsymbol{\eta_w}$	Seasonal average efficiency for domestic hot water production	(%)	≥81%	85%
$\mathbf{Ep_w}$	Specific primary energy index for hot water supply. (1)	(kWh/m^2)	≤18.45	17.65
$\mathbf{Ep_{w.nd}}$	Useful thermal performance index for hot water supply.	(kWh/m^2)	≤26.35	24.85
$\boldsymbol{\eta_c}$	Seasonal average efficiency for air cooling systems (including the possible humidity control)	(%)	≥81%	85%
$\mathbf{Ep_c}$	Specific primary energy for summer cooling (including the possible humidity control). (1)	(kWh/m^2)	≤45.22	43.24
$\mathbf{Ep_{c.nd}}$	Useful thermal performance index for summer cooling	(kWh/m^2)	≤52.77	52.34
$\mathbf{Ep_t}$	Energy performance index of the service for the transport of people and things (lift systems and escalators). (2)	(kWh/m^2)	≤5.46	3.58
$\mathbf{Ep_v}$	Energy performance index for ventilation. (1).	(kWh/m^2)	≤22.47	17.45
$\mathbf{Ep_L}$	Energy performance index of the service for lighting. (2)	(kWh/m^2)	≤21.15	18.65
$\mathbf{Ep_{gl}}$	Index overall energy performance of the building. (1)	(kWh/m^2)	≤171.95	168.64
$\mathbf{P_{el.ren}}$	Photovoltaic power plant	(kW)	≥35.20	0
$\mathbf{CFE_{ren.DHW+CLIM}}$	Requirements for DWH and air-conditioning due to renewable sources	(%)	≥55	71%
$\mathbf{CFE_{ren.DHW}}$	Requirements for DWH due to renewable sources	(%)	≥55	60%

(1) It is expressed in nonrenewable primary energy ("nren" index) or total ("tot" index). (2) This index is not calculated for category E.1 (residential buildings), except for colleges, convents, dormitories, barracks, as well as for category E.1.

The winter thermal loads are quite different from the summer season regarding the total consumption of the building (Figure 12). A total thermal energy requirement of around 1140 MWh/year is observed, compared to a cooling energy requirement of about 530 MWh/year.

The winter thermal load is therefore double the summer one. This result reflects the trends seen in Figures 10 and 11, where, as mentioned above, in the end part of the summer period, there is a decrease in the thermal load due to the nonoccupation of the building.

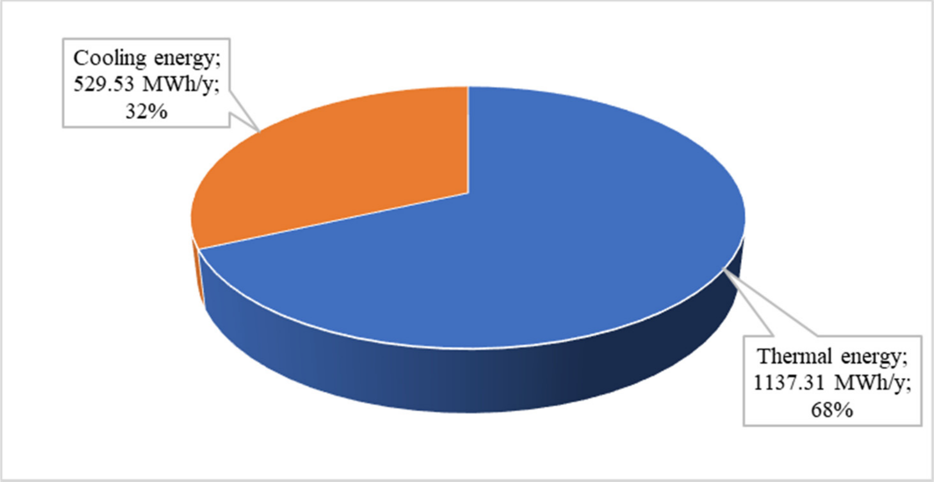

Figure 12. Distributed thermal and cooling energy.

The main part of the energy is supplied to fan coils and radiators (67% for heating and 61% for cooling), and only 35% is absorbed by AHUs as reported in Figure 13.

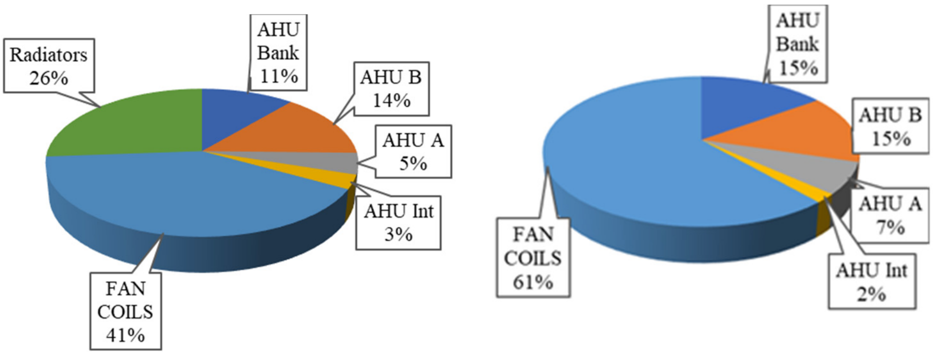

Figure 13. Energy distribution: heating (on the **left**) and cooling (on the **right**).

It is interesting to note that the radiators cover almost the same percentage of all the AHUs together during the winter period. During the summer period, the portion relating to the AHUs always remains the same, and the fan coils cover the portion of energy that was due to the radiators during the winter.

Figure 14 shows the annual demand for electricity from the distribution network, with a breakdown between the two generation systems and the electrical consumption of the VRF and the two heat pumps. The correspondent hourly electric power demand is shown in Figures 15 and 16.

The trend observable in Figures 15 and 16 reflects all the above considerations. The electricity consumption, first at maximum during the coldest period, decreases until it reaches a minimum before the summer period. From here, we notice another peak due to the cooling phase. The electricity consumption does not remain constant during this period but decreases until it reaches a minimum due to the nonoccupation of the building already mentioned above. With the start of the winter period, there is another peak in consumption again.

Table 8 shows the parameters for calculating nZEB requirements referred to the current state. The unmet parameters are in bold.

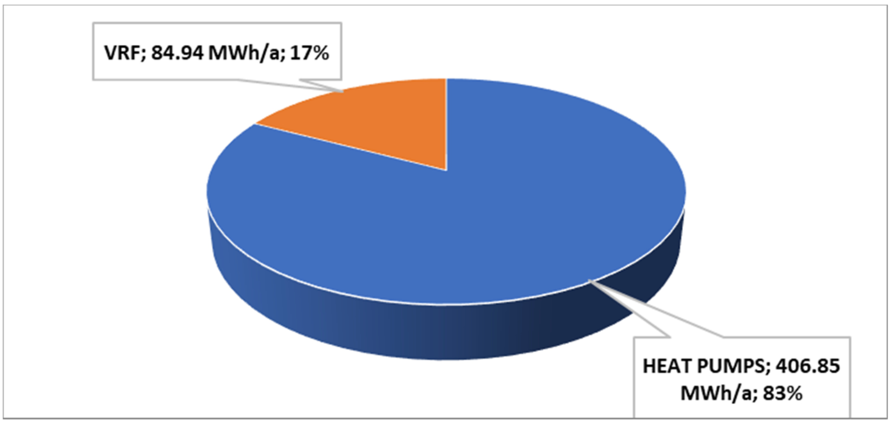

Figure 14. Electric power yearly consumption.

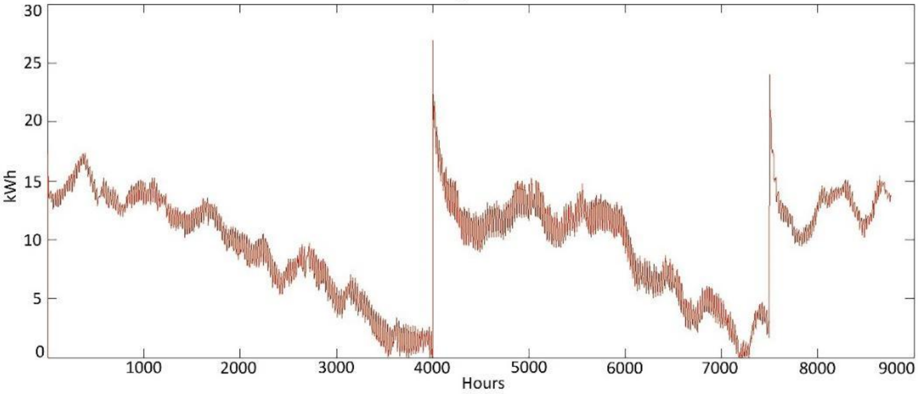

Figure 15. Hourly absorbed electric power VRF.

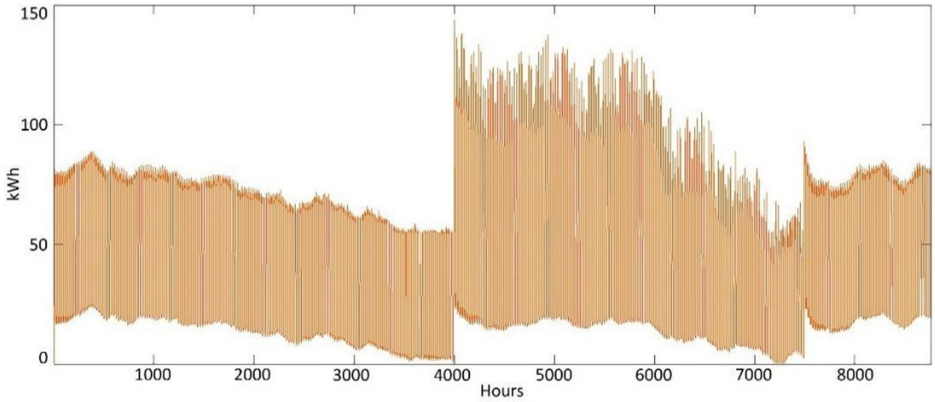

Figure 16. Hourly absorbed electric power heats pumps.

The table above shows how currently, the building does not fit with some of the parameter ranges to be classified as nZEB. The energy performance indexes for the individual energy services in the building are below the threshold values established following the study of the reference building, as reported in the UNI TS 11,300 standard [74]. The presence of heat pumps and VRF grants thermal energy (for DHW and DHW with heating and cooling) from renewable sources above standard thresholds.

As a listed building, it is impossible to consider any kind of intervention that includes an external opaque envelope. That is why it is difficult to reach the threshold value of 0.53 of the H'_T building's global thermal exchange parameters.

The two parameters not respected in the verification concern the performance of the external envelope H'T and Pel Ren.

To achieve the legal requirements on Italian nZEB buildings, an energy efficiency intervention is proposed by installing a photovoltaic system as described in the following Section 4.2.

4.2. Retrofit Efficiency Analysis

The Italian legislation requires the use of a significant increase of energy coming from renewable sources (26 June 2015, "minimum decree" transposition of Directive 2010/31/EU). The proposed intervention aims to reach the threshold value to produce electric power, which in the case study consists of a value of 35.20 kWp, from renewable sources. To reach the goal, it is necessary to install a 36 kWp photovoltaic system according to the available surface of the building roof (about 210 m^2). The intervention, therefore, proposes the installation of about 110 photovoltaic modules of 325 Wp south-east oriented at 45° angle. All the energy produced is supplied to the electricity users of the Banco Napoli set buildings The chart shows the characteristics of the suggested intervention and the relative costs of supply and installation, assuming the cost of a single PV module of €315.56 and the installation cost equal to 20% of the supply cost [75] as reported in Table 9.

Table 9. Photovoltaic system characteristics.

Monocrystalline module power	(Wp)	325
Module efficiency	(%)	20
Modules number	(-)	110
Total power plant	(kWp)	35.75
Inverter number	(-)	1
Auxiliaries efficiency	(%)	85
Electric power consumption preintervention	(MWh/year)	876
Electric power consumption postintervention	(MWh/year)	832
Energy saving	(kWh/year)	43,900
PV total cost	(€)	11,281
Inverter cost	(€)	6000
Additional costs: parallel switchboard, conduits, connections, etc.	(€)	2000
Total supply costs	(€)	19,281
Cost of labour	(€)	3800
Investment	(€)	24,001

An energy analysis of the proposed intervention was conducted. Figure 17 shows energy production during each month of the year.

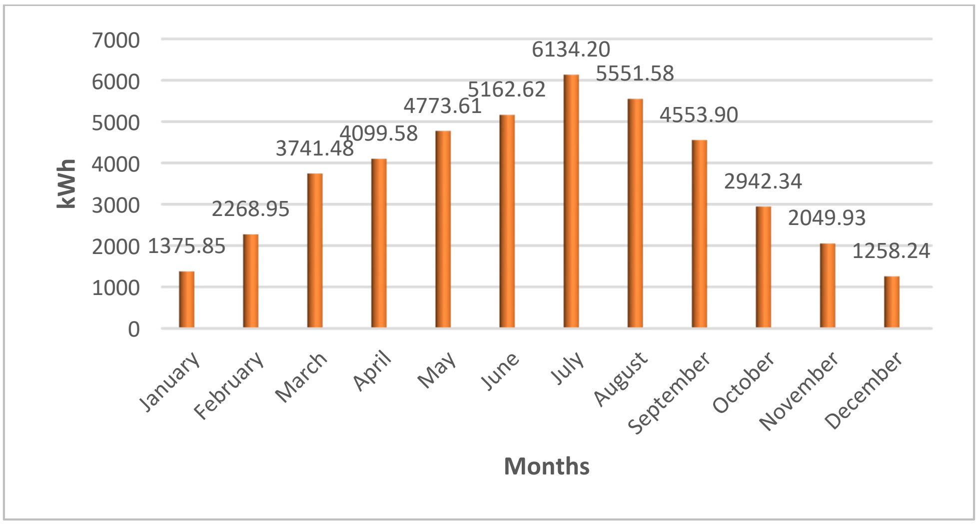

Figure 17. Monthly photovoltaic production.

The annual energy production is about 43.9 MWh. Therefore, by determining the annual production of the proposed PV plant, the economic feasibility of the intervention was analyzed, estimating an intervention lifespan of 20 years, considering an electricity fee of 0.18 €/kWh.

The present net value (NPV) was calculated as a function of different values of the interest rate (i), and for easier reading, the results were merged into a single graph. The following figure shows the NPV according to different values of the interest rate (i) between 0 and 10% and the relative recovery periods of the initial investment as represented in Figure 18.

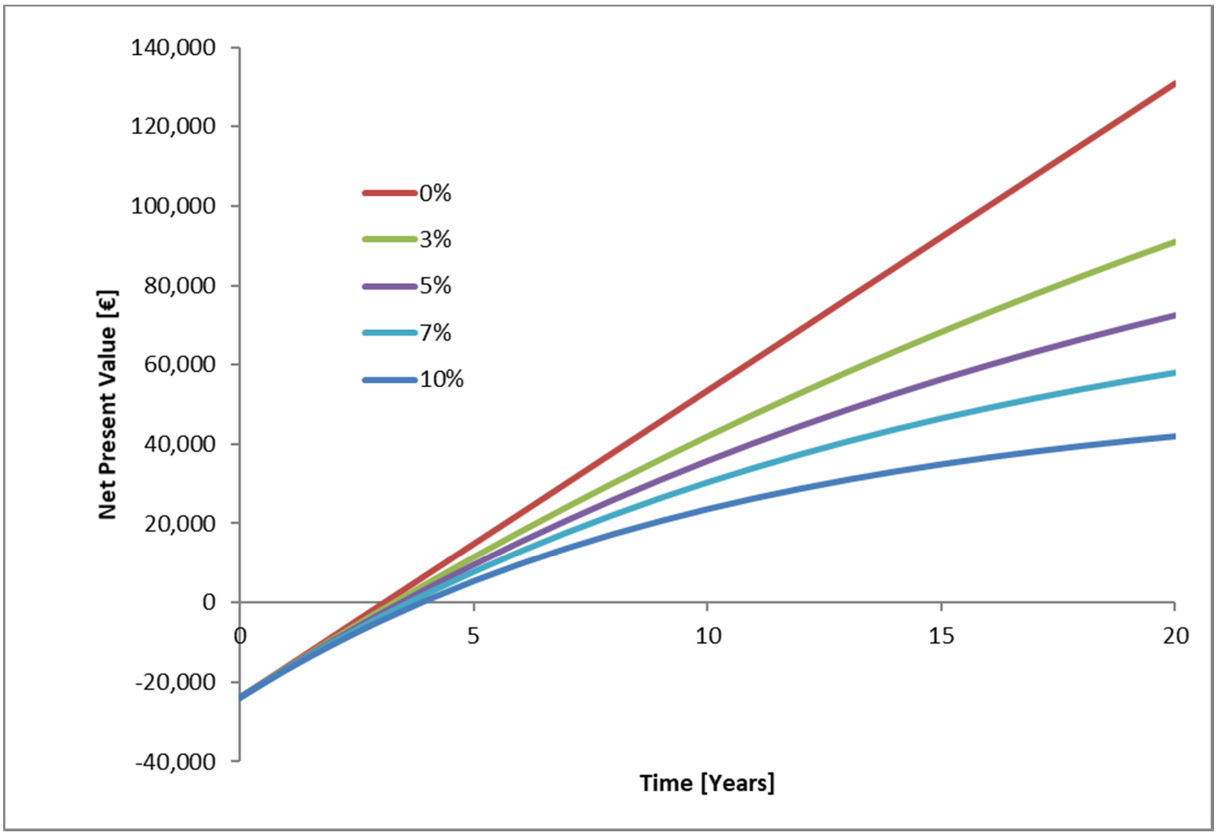

Figure 18. The net present value at fixed rate variation according to with 2020 Regione Lazio price list.

Yields of investments, the NPV and the profit rate based on the interest rate (Profitability Index PI) are shown in Table 10.

Table 10. Economic indicators intervention.

i (%)	In (Years)	NPV (€)	PI (€/€)
0	3	130,791.00	5.44
3	3	91,142.66	3.79
5	3	72,448.51	3.02
7	3	57,988.67	2.42
10	4	41,885.98	1.74

According to the economic analysis, the proposed intervention is economically advantageous, generating a positive NPV. The profit index is always above the unit, and it yields time a range between 3 and 4 years, depending on the interest rate.

In conclusion, this will reduce the network absorbed electric energy consumption by almost 10%. The proposed intervention exceeds the self-production threshold from renewable sources but does not allow, on its own, to reach all the parameters for the classification of the building as nZEB. Therefore, the values of the NZEB parameters of the solution with photovoltaics were calculated to verify the achievement of the expected requirements. These results are shown in Table 11.

Table 11. Italian standard parameters nZEB post retrofit efficiency with 36 kW PV system.

Parameters		**u.m.**	**Requirements**	**Post Retrofit Data**
$\mathbf{H'_T}$	Average overall heat transfer coefficient for transmission per unit of surface dispersant	(W/m^2K)	≤ 0.53	0.78
$\mathbf{A_{sol.est}/A_{sup\ utile}}$	Summer equivalent solar area per unit of useful surface	(-)	≤ 0.040	0.035
η_H	Seasonal average efficiency for domestic hot water production	(%)	$\geq 81\%$	85%
$\mathbf{Ep_H}$	Specific primary energy index for winter heating. (1)	(kWh/m^2)	≤ 80.35	79.10
$\mathbf{Ep_{H.nd}}$	Useful thermal performance index for winter heating	(kWh/m^2)	≤ 99.19	93.06
η_w	Seasonal average efficiency for domestic hot water production	(%)	$\geq 81\%$	85%
$\mathbf{Ep_w}$	Specific primary energy index for hot water supply. (1)	(kWh/m^2)	≤ 18.45	17.65
$\mathbf{Ep_{w.nd}}$	Useful thermal performance index for hot water supply.	(kWh/m^2)	≤ 26.35	24.85
η_c	Seasonal average efficiency for air cooling systems (including the possible humidity control)	(%)	$\geq 81\%$	85%
$\mathbf{Ep_c}$	Specific primary energy for summer cooling (including the possible humidity control). (1)	(kWh/m^2)	≤ 45.22	43.24
$\mathbf{Ep_{c.nd}}$	Useful thermal performance index for summer cooling	(kWh/m^2)	≤ 52.77	52.34
$\mathbf{Ep_t}$	Energy performance index of the service for the transport of people and things (lift systems and escalators). (2)	(kWh/m^2)	≤ 5.46	3.58
$\mathbf{Ep_v}$	Energy performance index for ventilation. (1).	(kWh/m^2)	≤ 22.47	17.45
$\mathbf{Ep_L}$	Energy performance index of the service for lighting. (2)	(kWh/m^2)	≤ 21.15	18.65
$\mathbf{Ep_{gl}}$	Index overall energy performance of the building. (1)	(kWh/m^2)	≤ 171.95	168.64
$\mathbf{P_{el.ren}}$	Photovoltaic power plant	(kW)	≥ 35.20	36
$\mathbf{CFE_{ren.DHW+CLIM}}$	Requirements for DWH and air-conditioning due to renewable sources	(%)	≥ 55	71%
$\mathbf{CFE_{ren.DHW}}$	Requirements for DWH due to renewable sources	(%)	≥ 55	60%

(1) It is expressed in nonrenewable primary energy ("nren" index) or total ("tot" index). (2) This index is not calculated for category E.1 (residential buildings), except for colleges, convents, dormitories, barracks, as well as for category E.1.

The data in Table 11 show that, even with an energy efficiency intervention with a new 36 kWp photovoltaic system with power exceeding the legal threshold, the nZEB requirements for the Italian legislation are not met as the H'_T parameter is in any case not respected.

5. Discussion

The primary purpose of this paper was to evaluate the transformation of an office LPB into an nZEB in the historic centre of Rome and to highlight its limits and potential. The design and construction path indicated by the European and Italian regulations on restricted buildings, as in the case study presented, does not always allow to reach the regulatory requirements. Installing a photovoltaic system with a higher rated power than the minimum required on the building roof would eventually reach the minimum value of self-produced electric power from the building and respect the established criteria.

Despite this intervention, it is not possible to fit all the nZEB parameters due to the impossibility of acting on the external vertical opaque structure and, therefore, on the parameter H'_T, which is, however, fulfilled for the limit value established for the reference building.

To overcome the problem in some rooms, internal insulation of walls and ceilings has been created using a 10 cm thick natural insulation, completed by a 2 cm finish of interior plaster. This solution, which would have made it possible to satisfy the HT requirement fully, was practically impossible to achieve as it involves a series of logistical and functional problems. The main problem is making the rooms unusable for the occupants for at least 15 days due to the insulating interventions. Moreover, a construction site area inside a functioning building involves a series of delays in the technical works and disturbance to the activities of the employees. Finally, the internal insulation of all the perimeter walls would lead to a reduction from 2% to 5% of the floor area of the building, with evident negative repercussions from the functional and economic point of view.

The results show that, for listed buildings, if the H'_T parameter is not considered, all the parameters to achieve nZEB status can be obtained by applying adequate efficiency measures.

A graphical summary of what has been discussed in this work is the impact diagram in Figure 19.

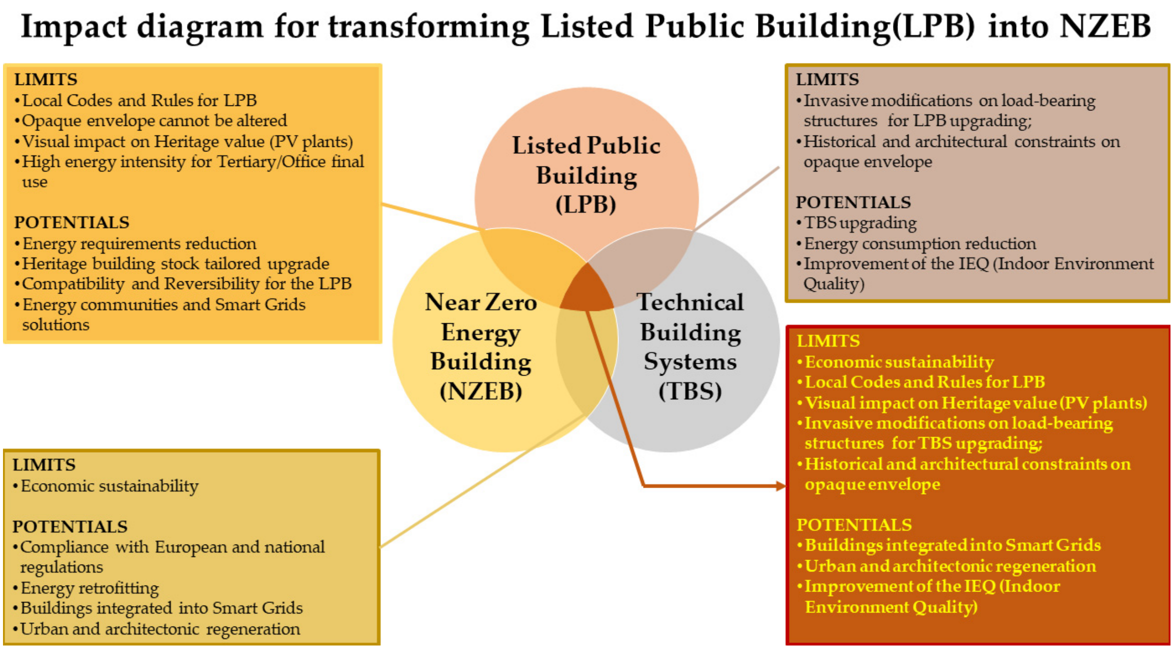

Figure 19. Impact diagram of limits and potentials on transforming LPB in nZEB.

With a logic of overlap of the effects with pairwise comparisons of the three categories (LPB, NZEB, TBS), the significant impacts on a historic building such as that of the case study have been highlighted, from the point of view of the limits and potential for a transformation in NZEB.

6. Conclusions

In this paper, the limits have been highlighted in the transformation of a Listed Public Building to an office destination in nZEB, taking into account the interventions on TBS.

Based on the data obtained from an energy analysis conducted both on the building envelope and energy systems, dynamic numerical analyses were set up and performed using TRNSYS software

This highlighted the potential for improvement through the case study by analysing and presenting the interactions between the three categories LPB-nZEB and TBS.

The Banco Napoli has a building envelope that does not lend itself energetically. Although it should be necessary to carry out the redevelopment of the enclosure to reach the parameters for the nZEB definition, this intervention is not possible because of the architectural and cultural value of the external walls.

Through the suggested intervention of installing a 36 kWp PV plant (higher than the required limit value), integrated with the generation of thermal energy through the existing

VRV systems, the requirements of consumption of thermal energy from renewable sources and consumption electricity from renewable sources are met.

The proposed intervention allows to exceed the self-production threshold from renewable sources but does not allow, on its own, to reach all the parameters for the classification of the building as nZEB. Therefore, it is not possible to reach the nZEB class even if all the parameters shown in Table 7 have been respected.

Hence, the only possible interventions for achieving the nZEB class consists of installing new fixtures with transmittance values in compliance with the new limits established by legislation. Such interventions would attain the energy parameters related to the thermal energy needs for heating but are not compatible with the constraint imposed on the historic building.

The unattainability of the nZEB class for historic buildings is further emphasized by the case of the building chosen in this paper since Banco Napoli has an excellent degree of efficiency not easy to improve.

The cost–benefit analysis showed the suggested intervention as economically advantageous in generating a positive NPV. The profit index is always above the unit, and the returns range between three and four years, depending on the interest rate. The analysis also shows an innovative approach that can guarantee the safeguarding and protection of historic buildings with high energy consumption, such as those intended for offices, is the energy communities model [76,77]. The aggregation of utilities, for example, entire buildings, within an energy community allows for the management of overall incoming and outgoing flows with the availability of energy from renewable sources also produced externally. The balance between imported and exported energy is assessed on the perimeter of the entire energy community or cell [78]. Indeed, what is presented in this paper represents the first phase of ongoing research that will be extended from the single building to cells/energy communities in historical urban contexts. This approach can reduce the impacts on architectural and landscape sensitive historical contexts and buildings.

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