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Light and heavy energy refurbishments of Mediterranean offices. Part I: energy audit of an institutional building on the Naples coast

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Abstract

The public hand has a demonstrative role in matter of energy efficiency of owned or occupied buildings. Here, the energy audit of a high-rise university building is proposed. The methodology adopts the Cost-Optimal approach, as imposed by the European guidelines (EU Directive 2010/31/EU), based on feasibility studies performed with transient energy simulations. In particular, in situ surveys (infrared thermography and measurements of U-values) have been used for building, as detailed as possible, the building model for the numerical study. The analysis evidenced high-energy demands, mainly for the space heating and cooling. A second study discusses a cost-effective energy retrofit.

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Keywords: Energy efficiency in buildings; Building energy simulation; Energy retrofit.

1. Introduction: where the policies in matter of energy efficiency are going?

The last years, in Europe and, really, at world level, have been characterized by an increasing feeling for a sustainable future, by involving all human activities impacting on the energy usage, greenhouse pollution, global warming, urban heat islands effects (UHI). With the reference to the main documents enacted at World level, the

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most recent one is, of course, the Agreement of Paris, shared at the end of the 2015 United Nations Climate Change Conference [1], the so-called COP21, hosted in France in December 2015. More than 195 countries defined the end of 'Fossil Fuels Era'. Without being too optimistic or sceptic, for sure this is the first agreement that set a "threshold of salvation", by fixing the average temperature increase, compared to pre-industrial levels, at a limit value of 1.5 °C. Moreover, the agreement identified funding measures, a path that includes balance between emissions of greenhouse gases and storage of these, periodical revisions of targets, mandatory Intended Nationally Determined Contributions (INDCs) required to all Nations.

Two main documents, enacted in the last years, already have had a significant impacts: the Directives 2010/31/EU [2] and the 2012/27/EU [3]. The Directive 2010/31/EC "Directive of the European Parliament and of the Council of 19 may 2010 on the energy performance of buildings" moved the targets of the previous version (Directive Energy Performance of Buildings, EPBD [4]) toward more ambitious targets, for instance by establishing that, by 31 December 2020, all new buildings should demand nearly zero-energy. Moreover, the demonstrative role of public buildings and, in general, of the public hand, is strongly affirmed so that also the target nearly zero-energy buildings is anticipated, at January 2019, for all buildings occupied and/or owned by public authorities. On the other hand, given the very low turn-over rate of buildings (i.e., it is quite well known that, in Europe, it ranges between 1-3%/yearly depending on the single country), each policy that does not consider the renovation of the existing building stock cannot be effective in the short and medium periods. About it, also the Directive 2012/27/EU [3] is very explicit, by establishing that Member States have to set "a long-term strategy for mobilizing investment in the renovation of the national stock of residential and commercial buildings, both public and private".

The same Directive strongly underlined the necessity of cost-effective approaches to renovations. Moreover, at the at. 5, it is affirmed that "each Member State shall ensure that, as from 1 January 2014, 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements". According to these international guidelines, all Member States shall upgrade their own legislations. For instance, in Germany there were the several versions of EnEV, "Energieeinsparverordnung" (i.e., Energy Saving Ordinance) and the present one into force is the EnEV 2014 [5]. In Italy, after the first documents for receiving the EPBD 2002/91/EU, among which Legislative Decrees 192/2005 [6], 311/2006 [7], the Presidential Decree 59/2009 [8] and the Ministerial Decree 26.06.2009 [9], at today new regulations have been enacted. These receive EPBD Recast and are the Law 90/2013 [10] and the three Ministerial Decrees of the 26 June 2015. The cited documents receive and transpose into the Italian regulation body the principles of the Directive 2010/31/EC and of the Delegated Regulation 244/2012 [11]. All told, both concepts of cost-optimality and nearly zero energy buildings have been defined and established, respectively as present strategy and future target.

The cost-optimal methodology proposed by the Directive 2010/31/EU [2] is summarized in equation (1). Any occurrence and expenditure along the building life (20 years for buildings of tertiary sectors, 30 year residential buildings) is considered, also by considering the variable value of the money over the time [12].

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) \right) - V_{f,\tau}(j) \right] \tag{1}$$

The terms of equation (1) are:

$C_g(\tau)$	global cost, referred to the present year τ_0
T	the calculation period, and thus the building lifespan
C_I	initial cost for the investigated energy efficiency measures or set of these (j)
$C_{a,i}(j)$	annual costs (operational, maintenance and replacement) during the year "i" for energy efficiency measure or for a set of measures "j"
$R_d(i)$	annual discount factor, for transposing a cash flow of a given point in time to its equivalent at the starting point
$V_{f,\tau}(j)$	residual value of measure or set of measures "j" at the end of the calculation period (discounted to the present year τ_0).

Really, here the cost-optimal method will be applied at the scale of single building, even if the approach of EU Directives and regulations is more general, and thus prescribes the application of this methodology for reference buildings, such as specified in the EU Cost-Optimality Commission Delegated Regulation [11]. The cited regulation would identify, for particular building categories, the energy performance level that is the most suitable for achieving the lower global cost for investments, operations and maintenance. The whole procedure is based on the application of six consecutive steps, and it is fully described in other studies [13, 14].

Starting from the consideration that an effective policy for reducing the impact of the building sector on the energy balance of European countries is necessary and by taking into account also environmental issues, the role played by existing edifices cannot be neglected, so that approaches aimed at reducing their impacts are needed. About it, in Italy as well as all around Europe, in the last years, the energy refurbishments of the building stock already have been strongly supported. In details, starting from the 2007 [15], the energy retrofit (i.e., new thermal insulation, new energy-effective windows, condensing boilers, high-efficient heat pumps, solar system for hot water productions, heat pump water boilers, energy conversion from renewables) has been largely financed for private buildings. Other funding measures, specific for public buildings, are provided by the so-called “Thermal Account” (Decree 28/12/2012 [16]).

From the brief description above reported, it is quite evident that that several legislative measures have been enacted, in the last years, for promoting the Italian, European and World targets in matter of energy efficiency of buildings. In particular, specific measures have been promoted for improving:

a) the building thermal envelope,
b) the active energy systems such as HVAC equipment or lamps or appliances,
c) energy conversion, on-site, from renewable energy sources.

This great effort is already producing evaluable results, even if feasible and optimized projects are always necessary for successful and fully-sustainable energy refurbishments of buildings. In other words, even if guidelines can be found for typological buildings and/or homogenous construction periods and technologies, however a specific verification has to be tested at the scale of single edifice. An example is shown in the following sub-sections. In particular, in Europe, there is a significant number of buildings quite poor for what concerns the energy demands, mainly built after the economic development and urban expansions happened after the end of the second World war, characterized by the load bearing structures in reinforced concrete and walls, ceiling and roof not provided with thermal insulation. The ISTAT (Italian National Institute for Statistics) revealed that in Italy there are around 13,000,000 of edifices, about 27,000,000 of dwellings, and, among these, a big part (more than 50%) has been built between the 1940 and the 1980 [17]. In particular, a) 14.8% of the Italian stock has been built between 1946 and 1961, b) 17.5% between 1962 and 1971, c) 17.7% between 1972 and 1981. In this paper, we will focus on an example of the 35% of buildings, very poor, built in the period 1960-1980. These are the years of lightweight buildings, not provided with enough thicknesses of walls nor insulating layers.

It is well known that the first regulation in matter of energy efficiency of buildings have been enacted, in Europe, after the Kippur War (1973), so that easily it can be understood that the aforementioned time interval, is characterized by very poor energy performance. Indeed, before the 1946, it was common the use of masonry with high thickness, and thus satisfactory thermal resistance were achieved by means of the big walls. After the first energy regulations, the use of thermal insulation was mandatory. Finally, the main problem concerns just these buildings where the reinforced concrete was largely used, without insulation, because the technology was suitable for fast building process, lightweight and suitable for multistory edifices, and these peculiarities allowed to answer to the great demand of dwellings and offices. Conversely, the energy performances of this construction technology are inadequate, because of the lack of insulation, very critical thermal bridges, poor attention to the indoor overheating. Finally, these buildings are, presently, very energy-intensive and require the highest share of energy. It is important to underline that each project has to be specified for the single building and it is enough just an example to understand it: the ‘sick syndrome building’, a negative phenomenon caused by the air-tightness imposed for existing edifices, through the adoption of hermetic windows in buildings not efficient for what concerns the natural ventilation. It is a typical example of a wrong energy refurbishment, that, probably, causes performances worse than the previous ones. With reference to both conservation of energy and installation of systems and equipment for energy efficiency, this paper proposes the cost-optimal refurbishment of one building of the University of Naples

Federico II. Indeed, it is just one of the poor-efficient buildings previously cited and, moreover, it is also owned by a public Institution, that, as seen in [2, 3] should have a demonstrative role in retrofitting its own edifices, particularly if not efficient under the 'energy' and 'environmental' points of view. On the other hand, this is a public Institution, so that it should be exemplar also in the use of public money. Finally, all these issues were solved with a refurbishing process following the principles of the cost-optimality.

2. Office buildings: Motivation for a new study

The aim of this study is a reliable energy audit of a present building, for a consequent energy refurbishment concerning the thermal envelope, heating/cooling and lighting systems, integration of energy demand by means of on-site conversion from renewables. Building Energy Performance Simulations (BEPS) have been carried out by the use of EnergyPlus 7.2.0 [18]. All available data, and thus documental information and in-situ investigations, have been used for the model definition, and thus the building use, the thermal-physical characteristics of the envelope such as above described, occupancy, load profiles and use of the HVAC.

The main motivation of this study is just the proposition of a repeatable methodology, starting from adequate literature studies, definition of a set of analyses for understanding the actual energy performance of buildings, selection of common and innovative technologies for improving the energy efficiency, and thus for reducing the actual energy demands. Every energy conservation measure will be analyzed also according to economic indexes, as well as for what concerns the impacts on general livability of the buildings, and thus also the alteration of daylight. This is, for instance, the case of control strategies for windows' shadings. By means of consolidated indicators of profitability, as well as by adoption of the method of the cost-optimality, every single action is deeply investigated, and the best ones will be cumulated in a last simulation, in order to take into consideration also the so called "super-position principle". All studies will be performed by means of the most accredited program for the transient energy simulations, according to 'tailored' energy ratings, in order to have outcomes as reliable as possible.

3. Description of the case-study: Location, building and use

The investigated building is located in the southern part of the Italian peninsula, where the weather conditions are quite moderate, as typical for Mediterranean areas. In detail, summers are warm and the winter season is not very cold, with few days of air temperatures slightly above the 0°C and few hours under this level. According to the Köppen-Geiger classification [19], the city is located in Csa class. Naples lies just on the Tyrrenian coast, and the climate is strongly influenced by that position, with an annual average temperature of 15.8 °C (27 °c and 10.5°C, respectively in the hottest and colder months, and thus July and January). The annual rainfall is 900 mm. The month characterized by the higher rainfall is November, and, conversely, the driest season is the summer, with a low peak of rain in July. The rated external temperatures conditions, for the calculation of heating and cooling loads at the peak, are 2°C and 32°C respectively. With reference to the investigated building, the public hand, and thus the University of Naples Federico II, owned it. The University is the oldest School in the World to be founded by a head of State (the king Federico II), during the 1224. This is the biggest Athenaeum of South Italy, with four schools, 26 Departments, a staff of more than 5,000 persons. Of course, also the owned buildings are many, by including a Castle, several historical buildings, a campus with many edifices. On the boardwalk, together with many buildings of the humanistic Faculties, there is also a modern building used for the Office of Professors and Researchers (Human Resources). This is the building investigated in this paper and, as shown in figure 1, it is located just in the Historical city, and it is surrounded by other University architectures.

The building here investigated is the one on the right hand of Figure 1. This is the office for assistance and administration of the teaching staff, and thus professors and researchers of the University. The edifice, known as Palazzo ex-ISVEIMER or, simply, 'Palazzo degli Uffici', has been built between the 1971 and 1975, according to the design of the architect Luigi Moretti. The building has the shape established by Luigi Cosenza for all new buildings of 'Via Nuova Marina'. He was the famous engineer that, in the middle of XX century, designed many of the most beautiful architectures of the Italian rational style (Figure 2). According to the tradition, the lines of his architecture were so light and close to nature that, on the day when the glazed facades were mounted at the Olivetti headquarters of Pozzuoli, many birds died as results of impacts against buildings. Indeed, they confused the pillars with natural elements of the forest. Luigi Cosenza was the one that established, in the urban planning of the waterfront, all high-rise buildings of the same height with larger basements (i.e., the first two floors). Finally, this is the shape of Palazzo ex-ISVEIMER (figure 3). In particular, the building occupies a square block, defined by via De Gasperi, via Chiavettieri and via Giulio Cesare Cortese, while on the fourth side, there is an almost adjacent building, just separated by a very small road. The main front of the building has a projecting roof (figure 4, left side), made in reinforced concrete that defines a porch on the sides facing on Via Cortese and via De Gasperi. The main building has an elongated shape, along the South-East direction. The surrounding buildings, with the exception of the one on the backside, are quite distant, so that no significant shadows are verified. In total, the building has nine storeys above the ground. The total conditioned area is 7,153 m^2, with an overall height of 33 m, a single floor area of the tower is around 700 m^2. The net conditioned volume is equal to 25,034 m^3. For what concerns other dimensions and geometrical peculiarities, as well as a description of the heating, cooling and main active energy systems, further information are reported in Table 1.

Fig.1. University Buildings in the Historical center of Naples and, on extreme right, the case-study here investigated.

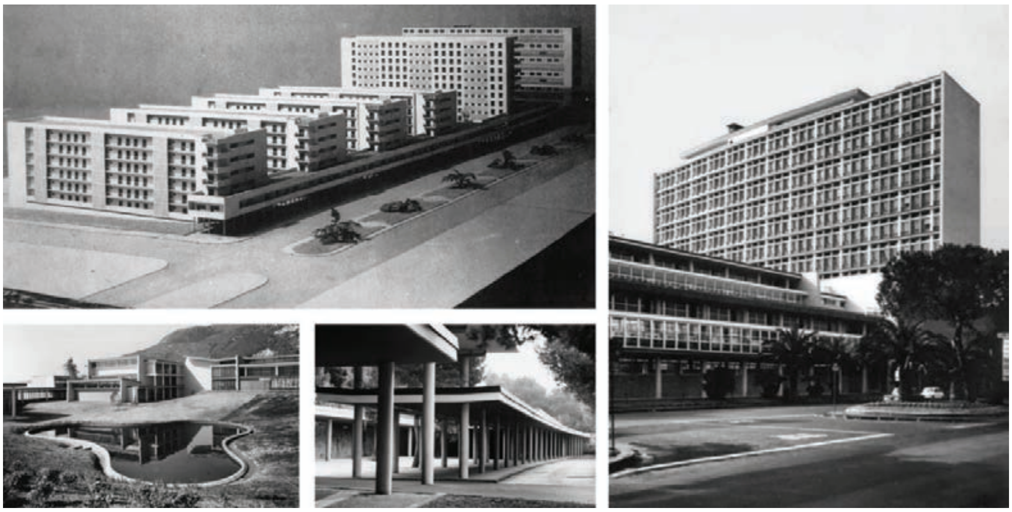

Fig. 2. Architectures of Luigi Cosenza in Naples.

The building was designed and finished before the emanation of the first Italian law in matter of energy efficiency of the building sector, dated 1976. Therefore, even if a minimal attention to the thermal insulation however was applied, mandatory regulations were not into force at the construction time. The description of components follow:

- The external walls of the building have a composite structure. Indeed, the structural frame is in reinforced concrete, with pillars and beams, while the walls are made in prefabricated panels, in which also the windows are included, made in sandwich metallic panels, with layers of concrete-asbestos, and interposed thermal insulation. The overall thermal transmittance is 0.58 W/m^{2}K.
- The horizontal structures (i.e., ceiling, basement and floors) have, as usual for that period, beams, cross joists in reinforced concrete and interposed hollow blocks. The overall U_{values} are 1.57 W/m^{2}K for the roof, 1.13 W/m^{2}K for the slab on the ground, characterized by a higher thermal resistance because of the insulation system from the ground.
- The windows have metallic frame, without thermal breaks, with a double layer of glass and an air gap air-filled (3/6/3). The overall U_W (i.e., the average weighted value by taking into account glazed part and frame) is around 3.03 W/m^{2}K, with a SHGC equal to 0.70.
-

Fig. 3. Images of the buildings, from via de Gasperi (waterfront) (left side) and aerial view (right side).

Table 1. Main building characteristics.

MAIN BUILDINGS' DIMENSIONS AND GEOMETRY					
Total building Area	7,153 m^2	Length (N-S direction)	18.5 m	Gross Volume	25,034 m^3
Maximum Height	33.00 m	Length (N-S direction)	38.0 m	Roof Area of the tower	700 m^2
BUILDING ENVELOPE					
$U_{EXTERIOR\ WALLS}$	0.58 W/m^{2}K	$U_{UPPER\ ROOF}$	1.57 W/m^{2}K	Windows SHGC	0.70
$U_{GROUND\ FLOOR}$	1.13 W/m^{2}K	$U_{WINDOWS}$	3.03 W/m^{2}K	Infiltration flow Rate	0.75 ACH
HEAT TRANSFER AREA OF EXTERNAL WALLS, ROOF AND FENESTRATION FOR THE EXAMINED BUILDING					
	Total	North from 315° to 45°	East from 45° to 135°	South from 135° to 225°	West from 225° to 315°
Gross area of vertical walls	4109.70	1220.15	833.54	1225.06	830.95
Window opening area	1657.09	447.72	341.54	523.30	344.53
Window-to-wall ratio	40.32	36.69	40.97	42.72	41.46

MIXED AIR/WATER SYSTEM, WITH FAN COILS AND DEDICATED OUTDOOR AIR HANDLING UNIT	
HVAC Typology (Office)	All water systems, with in-room fan-coils
HVAC Typology (Mensa and Conference Hall)	Mixed air/water System, with fan coils and Dedicated Outdoor Air Handling Unit
Ventilation Air	No (only Mensa and Conference Room at the basement block)
Sensible Load control	Yes, for single zone
Latent Load Control	No (only Mensa and Conference Room at the basement block)
Fan and Pumps parameters	Efficiency 0.7 and 0.9, respectively
Hydronic Units	Two pipe fan-coils, located in each room - Cumulative Maximum Air flow rate: 5.6 m^3/s (i.e., recirculation air)
Boilers (two, traditional technology)	Nominal Capacity: 1,600 kW, Nominal η: 0.80
Chiller (Water cooled, centrifugal compressor)	Nominal Capacity: 1,300 kW, Nominal EER 6.0 $Wh_{THERMAL}/Wh_{ELECTRIC}$

The building is equipped with a hydronic system (in-room fan coils), for the space heating and cooling. At the basement (first and second floor), there are also two air handling units for ventilating the conference room and the 'Mensa'. These are the only indoor spaces equipped with the mechanical ventilation and where also the relative humidity is managed. For what concerns the production of hot and chilled water, respectively gas water boilers and a water-to-water chiller are installed. The combustion system consists into two gas boilers, with a global capacity of 1,600 $kW_{THERMAL}$. The two centrifugal chillers have an overall capacity of 1,300 $kW_{THERMAL}$ and these are provided with four cooling towers located on the building roof, as visible in figure 3, right side.

4. Building energy audit: In-situ investigations

The target of the energy audit was to identify the building's energy performance, in order to evaluate opportunities for energy savings, through an investigation of the current equipment, operations, building energy use. In this case, in-situ investigations combined infrared thermography and heat flux measures. The building thermography has allowed the identification of major heat losses, missing or damaged thermal insulation in walls and roofs, air leakages. As reported in figure 4 (January 2014), the thermal analysis reveals significant air-infiltrations from windows, absence of relevant thermal bridges and weakness of the large glazed area of the stair block.

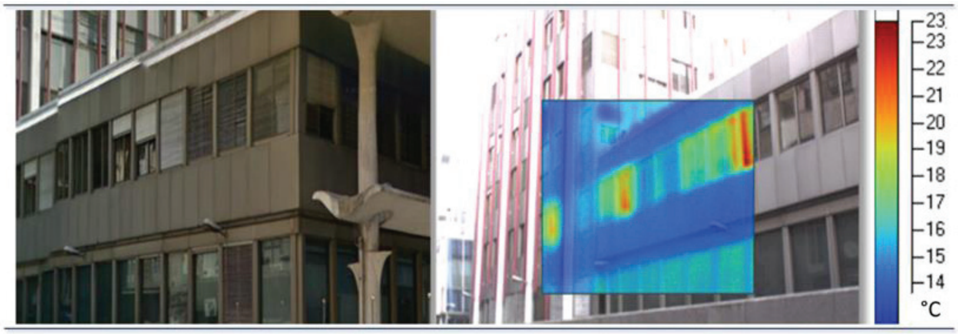

Fig.4. Infrared thermography of the building envelope.

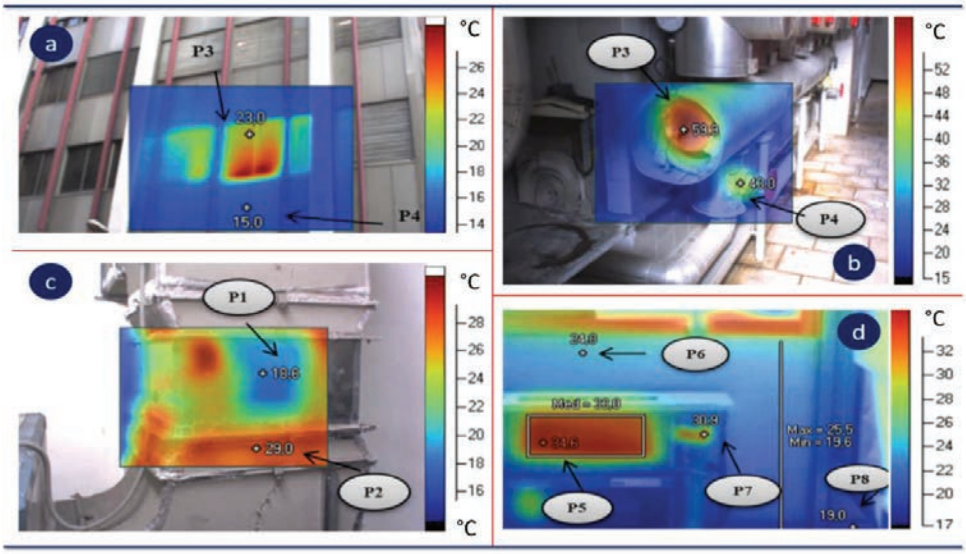

Fig. 5. (a) Infrared thermography of windows, (b) gas boiler, (c) ducts and pipes, (d) fan coils.

As evidenced in Fig.5a, the windows have the highest external surface temperature compared to the other structural components and this is due to the higher thermal transmittance; a reliable average thermal transmittance of the window is about 3.03 W/(m^2K). The infrared inspection around the windows' frame has evidenced also relevant air leakages and infiltrations. The poor airtightness, especially in the lower part of the window, increases both heating and cooling loads and, mainly during the winter, it is the main cause of thermal discomfort for the occupants. This aspect will be taken into account in the refurbishment process. By assuming the internal and external conductances equal to 7.7 W/m^2K and 25 W/m^2K respectively, the evaluated overall thermal transmittance is equal to 0.58 W/(m^2K). Also a simple investigation of the technical systems has been done: in particular a IR thermography of gas boilers (fig.5b) and fan coils (fig.5d) has been performed. The thermography evidences a correct functioning of the system but significant heat losses through channels, ducts and pipes of the space heating system (gas boiler, fig.5c).

5. Methodology: tailored energy simulations and building energy audit

5.1 Kind of energy ratings of buildings

The achieved data, in terms of envelope thermo-physics and geometry, have been used for the energy modeling of the building, under transient conditions. Several zones – with reference to the use, installed equipment, occupancy, lighting rate, set points for temperature and relative humidity - have been defined. The building model has been defined by using EnergyPlus, with the graphical definition of the geometry, dimensions and positions of the thermal envelope assigned by means of DesignBuilder. Weather data ASHRAE IWEC for Naples have been used. Transient energy simulations have been used by the authors of this paper frequently, also by coupling that programs with new algorithms for solving thermal bridges, or for evaluating spatial distribution of thermal parameters by means of CFD codes, in [20] and [21, 22], respectively. For reducing both simulation time and required computational power for the energy calculations, the building has been divided in a certain number of homogeneous and contiguous rooms. The grouping has been carried out carefully, by considering uses of spaces, exposures and sources of gains and losses. Beyond a number of person (i.e., occupancy rate), variable depending on the kind of use of the specific room, also the metabolic rate has been diversified, depending on the typical hosted function. As known (ISO 13790 [23] and CEN 15603 [24]), energy ratings of building can be "Asset", "Design" or "Tailored", depending on various levels of detail; of course, a well-representative model of the real building is the necessary base from which starting for investigation concerning potential energy refurbishments. In this study the Tailored Rating has been applied: the boundary conditions are specified with reference to the single building just investigated. Indeed, the required outcome is not a standard energy performance, but a reliable building energy behavior, in order to identify criticalities and to program optimization, validation, opportunity of renovations, feasibility of adoption of energy efficiency measures.

In this regard, the transient energy simulation is much more suitable and precise compared to methods based on steady state heat transfer algorithms. Briefly, the inertial effect of mass, specific heat and insulation are taken into consideration, so that important phenomena, such as the time lag effect, the attenuation of the heat wave, the start-up of the active energy systems and, analogously the time constant of the building, can be exhaustively contemplated.

In particular, different algorithms for the resolution of the heat transfer and various time steps for the running of the simulations have been considered. More in detail, EnergyPlus can solve the transient heat transfer through the building according to several methodologies: Conduction Transfer Function algorithms (CTF), Conduction Finite Differences algorithms (ConFD), Combined Heat And Moisture Finite Element algorithms (HAMT).

The CTF method relates the heat flux through the envelope element to the current and previous internal and external temperatures and to the previous values of heat flows. The methodology is very powerful and fast, because the nodal temperatures are not calculated, so that the method does not require the discretization of the walls in several nodes.

Conversely, Finite Differences (ConFD) provide completely the spatial heat transfer through the building surfaces, by identifying the temperatures at each node of the thermal envelope, so that the thermal field is completely determined. Compared to CTF, the required calculation power is higher, as well as the simulation time.

The last one, and thus the "Combined heat and moisture finite Element algorithm", solves one-dimensional heat flows through the building components by considering contemporarily vapor and heat transfers. Transportation and storage of moisture and thermal energy are solved simultaneously. It allows identification of, for instance, risks of mold and interstitial condensations. The method should be applied only for particular studies.

5.2 The Energy audit of the case-study building

The described methods are characterized, as said, by very different computational times. Moreover, also the "Number of time-steps per hour" (representing the time interval between consecutive energy balances) strongly affects simulation time and reliability. For this reason, a sensitive analyses at the boundary conditions has been performed, in order to ensure the maximum precision, combined with the minimum simulation time.

The following tests have been performed, with reference to the base building and HVAC system:

- Conduction Transfer Function with 2 time-steps/hour
- Conduction Transfer Function with 6 time-steps/hour
- Conduction Transfer Function with 15 time-steps/hour
- Conduction Transfer Function with 30 time-steps/hour
- Conduction Transfer Function with 60 time-steps/hour
- Conduction Finite Difference with 60 time-steps/hour

With reference to the required computational time, the values are quite different (line in Figure 6) and these concern the use of a personal computer characterized by the following characteristics: Intel Core i7 1.73 GHz, 64 bit, Ram: 6 GB, Operating System Windows 7 Home Premium. In figure 7, moreover, with reference to overall primary energy demand, the annual errors compared to the most accurate method have been reported. Indeed, this is the unique possible calibration, being not available measured energy demands from energy billings.

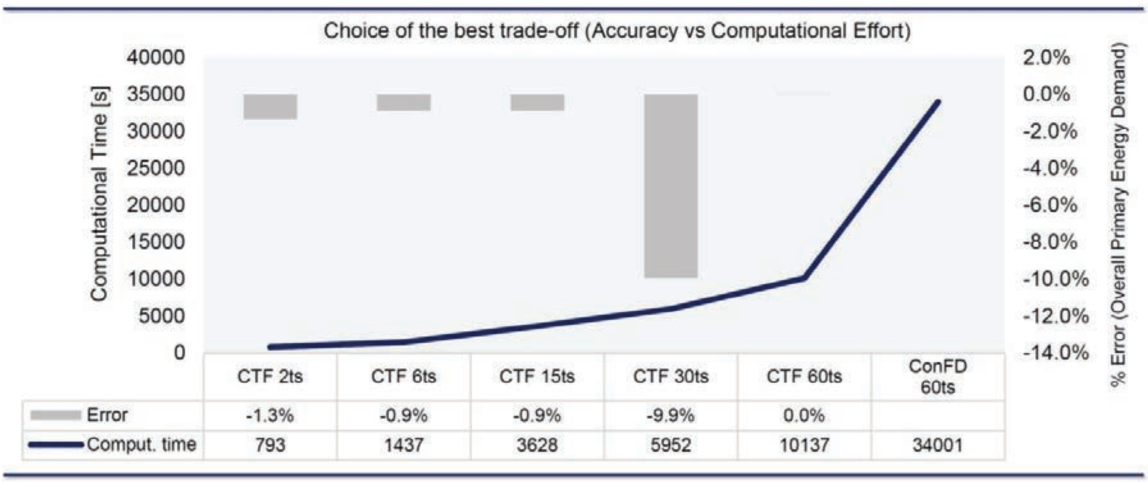

Fig. 6. Sensitive analysis to the time steps and choice of the best trade off.

It is quite evident that Conduction Transfer Functions with 6 time steps are completely reliable, with an average error, in the calculation of primary energy required for the annual air-conditioning, lower than 0.9% compared to the Finite Difference methods and the computational time is around 23 times lower (1,437 seconds vs. 34,001 seconds). Therefore, in the following studies, CTFs at 6 time-steps have been adopted.

The present energy demands are shown in figure 7. In the reference state, the building primary energy demand, for the space heating is equal to 33.1 kWh/m^2, while for the space cooling is 45.7 kWh/m^2. Moreover, the energy demand for lighting is 21,930 kWh electric, and it corresponds to about 6.67 $kWh_{PRIMARY}/m^2$, by taking into account the efficiency of the Italian power system, established equal to 0.46 $kWh_{ELECTRIC}/kWh_{PRIMARY}$. Globally, according to the LCA coefficient suggested by the Covenant of Mayors [25] (Natural Gas: 0.237 ton $CO_{2\text{-equiv}}/MWh_{GAS}$, electric energy 0.708 ton $CO_{2\text{-equiv}}$ /MWh_{EL}), the overall CO_2 equivalent emissions for the building operations are 237 tons per year, and the 71% (169.4 tons/year) of these is due to the heating and cooling service.

By considering that the building is used only during the diurnal hours, five days per week, and that there are significant holiday periods, the energy demands above reported are quite high, far from an energy-efficient building. Moreover, the presence of asbestos requires, sooner or later (it depends from the conservation state and the exposure), a removal of such material.

For what concerns the energy costs, the following values have been calculated:

- Annual expenditure for the space heating service: 37,565 €;
- Annual expenditure for the space heating service: 35,193 €;
- Annual expenditure for the global building use: 81,571 € (i.e., 1,140 €/100 m^2).

Please note the aforementioned values derive from a simulation calibrated as reliable as possible in the input data. Indeed, as said, no billings are available. In the second part of the paper, after the introduction on recent and authoritative studies in matter of energy refurbishment of office buildings, proper methods for cost-optimal investigations of effective building rehabilitation will be discussed, also by taking into account the economic profitability.

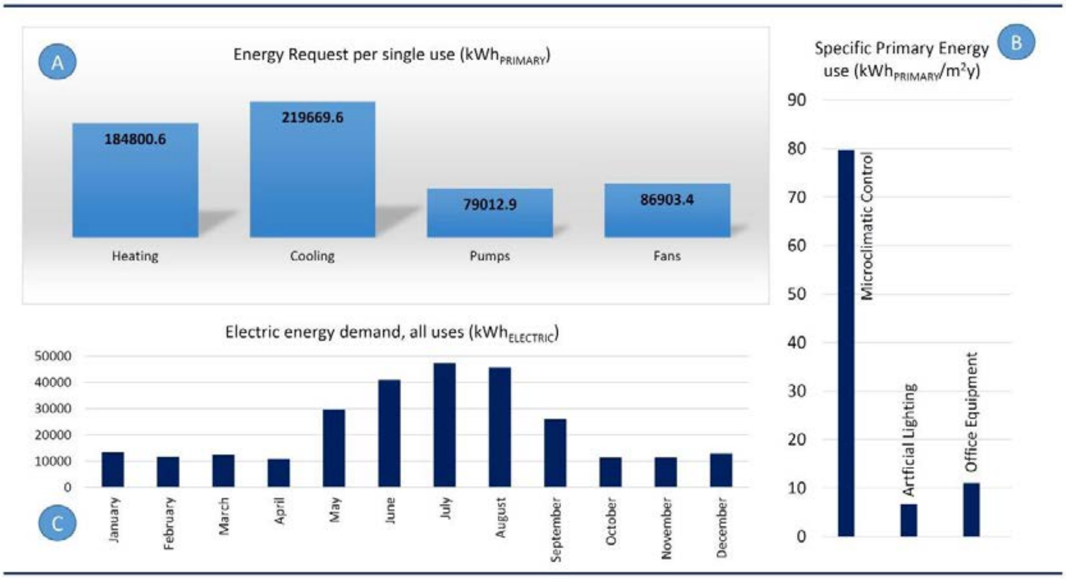

Fig. 7. Summary energy demands of the building, with reference to all single annual energy uses (A), specific requests for macro-functions (B), annual electric demands on monthly basis (C).

6. Conclusion

The paper has proposed an overview of new policies for improving the buildings' quality, according to new targets of energy efficiency, demonstrative role of the public hand, effective goals in terms of reduction of energy requests and related pollution of the existing building stock. In particular, a case-study building, and thus a modern high-rise building owned by the University of Napoli Federico II was investigated. Tailored in-situ surveys, inspections, non-invasive investigations have been performed in order to model the building by means of a transient energy code. The used program solves energy balances by taking into account dynamic effects, and it requires proper definition of the model, in terms of input data, for having reliable outcomes. Being not available measured energy demands, for an 'a posteriori' calibration, the energy simulations have been performed by applying various different algorithms and diversified time steps, in order to verify the consistency and choose the best trade-off between computational time and accuracy.

The calculated energy demands, as well as the first investigations, revealed that the building is far from being effective, characterized by high energy costs, emissions and demands. In a second part of the study, a profitable energy renovation will be proposed, by means of the approach of the cost-optimality, capable to join energy savings and profitability of the investments.

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