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Climate Change and Building Renovation: Effects on Energy Consumption and Internal Comfort in a Social Housing Building in Northern Italy

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Abstract: Climate change is becoming a crucial factor to consider within human activities and the building sector is particularly influenced by aspects of internal comfort and energy. In Italy, great attention has been paid to the energy refurbishment of buildings. However, such interventions are mostly focused on reducing heating energy consumption, thus neglecting summer season performance. Moreover, climate change is barely considered during the design phase. This issue is addressed in this work which analyzes some of the most common refurbishment interventions applied to a social housing building in Trieste, while also considering internal comfort during the summer season. A dynamic analysis of the building-plant system is carried out using EnergyPlus. Fanger, UTCI and the adaptive comfort models were used to represent internal health, while three TRY data sets were generated using two GCM–RCM projections to evaluate the influence of climate change. The results show that both building insulation and climatic change affect heating consumption reaching a 70% reduction. However, building insulation does not greatly affect internal comfort, although different models show different behavior to protect against external temperatures. On the contrary, climatic change influences the percentage of hours of discomfort, with a 20% increase for all of the models. The final consideration is that people's internal health should always be considered when carrying out refurbishment activities.

Keywords: climatic data; consumption reduction; indoor health; numerical simulation; health models

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1. Introduction

Climate change is now a determining factor in many sectors of human life such as agriculture, health, and obviously construction. The increasing trend of temperatures has now been widely confirmed in many studies as reported in the 2021 Sixth Assessment Report of the IPCC [1]. Many authors have concentrated their research on the effects of global warming on the energy performance of buildings, demonstrating how it has now become crucial to consider climate evolution to develop mitigation and adaptation policies [2].

Equally important has become the evaluation of the comfort perceived by people inside the buildings. In fact, one of the major challenges that the building sector shall face in the coming decades will be to guarantee the strong resilience of buildings to protect against extreme phenomena such as heat waves, trying to minimize the phenomena of the internal overheating of buildings [3]. In this sense, the use of instrumentation dedicated to the automatic detection of climatic and physiological parameters inside buildings can be a useful tool for the protection and safeguarding of the most fragile categories, creating the possibility of automatically activating alarm systems and health care for these categories in the event of exceeding pre-established comfort limit values [4]. On the other hand, it is more and more important to preview the internal health environment in buildings in order to support policies and decision makers to orient investments and efforts toward building refurbishment. Due to these factors, the effects of climate change on the construction sector should be carefully analyzed taking into account the effects on building energy consumption and on the health conditions of inhabitants.

The main action for tackling the problem of energy consumption reduction for building climatization is to carry on refurbishment activities in existing buildings. However, due to the climatic change, the summer behavior of buildings is starting to assume great importance, which for a long time has been neglected in the design of refurbishing strategies focused more on the aspects of energy savings during the heating season. As an example, Corrado in [5] analyzing the building stock of Piedimont Region neglected space cooling because it was considered to be of scarce influence in the residential sector. Again, Hummel [6] presented a cost analysis of measures to reduce heating energy consumption without taking into account the effects on space cooling, but signaling its importance because of climatic change. Qiu et al. [7], instead, declared that cooling loads should be considered for conditioned buildings. Ozarisoy [8] analyzed passive cooling retrofit design strategies to improve occupants' thermal comfort and reduce the overheating risk in social housing in Cyprus, six different passive-cooling design strategies were applied, leading to up to 81% of cooling consumption reduction. Climatic change is an additional factor to take into account in building refurbishment. Andric et al. [9] carried on a review of the literature regarding the effects of climate change and the built environment, drawing attention to passive measures such as building fabric insulation, the installation of energy-efficient glazing and solar shading devices to reduce cooling loads. Climate change affects also the production of energy from renewable energy sources. In southern Italy, De Masi et al. [10] found an increase in electricity production frm PV systems using future weather data, but they also found a greater increse in cooling energy demand. However, climatic change has an effect also on the internal conditions in buildings. Vellei et al. [11] considered the effect on internal health condition in renovated social houses studying the occurrence of overheating risks, whereas Attia [12] analyzed cooling strategies to overcome the overheating problem due to heat waves developing a framework to be used by building designers, authorities and developers for designing resilient buildings. Khan et al. [13] emphasized the need to maintain indoor thermal comfort during extreme heat conditions, also in the absence of any mechanical ventilation, to manage the climate change impact. Haddad [14] considered the indoor temperatures in social housing buildings properties in New South Wales, Australia, where high summer temperatures were found well above the temperature standards for comfort and health purposes.

This research considers all the aspects previously highlighted by analyzing the performance of a residential building in the coastal city of Trieste in northeastern Italy. The analysis was conducted in terms of heating energy savings and summer comfort, considering the current state of the building and the effect of refurbishment interventions using present and future climatic data. The use of future climatic data was considered in order to include the effect of climatic change, since it can affect energy consumption as well as the internal health conditions of buildings. Furthermore, in order to assess the internal health conditions three different models have been used, highlighting the different results that can be obtained and how they can identify the effect, in occupied internal spaces, of rising external temperatures.

Two aspects were considered when selecting the building. First, the construction is typical for the city of Trieste, with a large share of constructions built before the early years of the twentieth century; however, similar constructions are widespread in Italy [15]. Second, since the building is a social housing construction it could be considered that the residents could be fragile people and the most affected by high temperatures during extreme conditions, especially the elderly and children, are particularly vulnerable as stated by Daly and others [16], and for this more affected by climatic change. Furthermore, it is common that the public administrations engaged in climate adaptation and mitigation policies focus a large part of their efforts on the renovation of public building stock [17]. The renovation strategy considered both external and internal insulation systems, since the former is more practical, but sometimes cannot be used in old buildings where the interventions can be limited by laws or architectural heritage regulations. In this case, internal insulation is the only viable alternative [18,19] as suggested also in national guidelines for the refurbishment of historical buildings [20,21].

2. Modeling the Current and Future Climate

Present and future climatic conditions were considered in this research. Regarding the former, the data collected by the meteorological station of the Molo Fratelli Bandiera in Trieste during the period of 1995–2019 were used, by applying the ISO 15927-4:2005 standard [22], and a Test Reference Year (TRY) was created to represent the analyzed period.

The future behavior of the climate was considered through the application of GCM-RCM models, obtained from the "Cognitive study of climate change and some of its impacts in Friuli Venezia Giulia" drawn up by the Regional Agency for Environmental Prevention and Protection of the Friuli-Venezia Giulia [23]. This document identified, within the many coupled global-regional models available on the CORDEX platform, the most indicative ones for the regional territory.

The climatic data obtained, which provide projections up to 2100, were further treated with a statistical correction concerning the data collected by applying the Quantile Mapping method [24] to try to minimize the error that is generated above all in long-term scenarios. The correction took place in two steps, as shown in Figure 1. A common period between models and measurements is used to calibrate the correction and evaluate its effects; then, future model data is modified accordingly. The correction was calibrated using the period of 1995–2005 and tested from 2006 to 2019. The operation was performed on the temperature, relative humidity and atmospheric pressure data, obtaining in all cases a reduction of the mean squared error calculated in the control period. Table 1 shows the mean squared errors between models and measurements relating to the temperature, mean daily Tas, minimum Tasmin and maximum Tasmax, before and after correction.

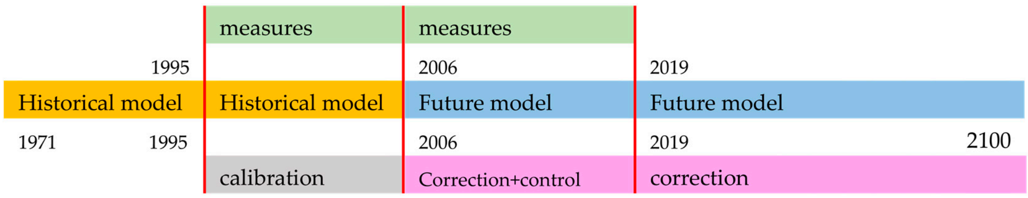

Figure 1. Subdivision of periods for the correction and verification of climate models.

Table 1. RMS error of five climate models, original (m) and corrected (q).

Model	Tasmin		Tas		Tasmax	
	RMS_m	RMS_q	RMS_m	RMS_q	RMS_m	RMS_q
MPI-ESM-LR_REMO2009	2.56	2.06	2.35	2.09	2.31	2.2
HadGEM2-ES_RACMO22E	4.03	2.08	2.93	2.12	2.36	2.24
EC-EARTH_CCLM4-8-17	2.56	2.07	2.35	2.07	2.31	2.13
EC-EARTH_RACMO22E	6.00	2.03	4.63	2.02	3.58	2.08
EC-EARTH_RCA4	5.66	1.98	4.51	1.96	3.4	2.02

The calibrated models relate to the IPCC RCP8.5 scenario that represents a situation in which climate mitigation measures on a global scale have not yet been considered. The future climate data for the simulations were obtained by applying a morphing procedure to the TRY file [25] and are representative of the period of 2021–2035, thus considering a climate evolution in the immediate future. Table 2 reports the heating and cooling degree days (DD) for Trieste for current and future climates using a base temperature equal to 20 °C for both heating and cooling. It can be seen that for all the climate models, an increase in temperature is expected, with a reduction in the heating DD but with an increase in the cooling DD with respect to the historical data.

Table 2. Global-regional models for Friuli-Venezia Giulia Region with HDD and CDD and TRY used for the simulations.

Model	TRY	HDD	CDD
Historical	C0	2031	532
MPI-ESM-LR_REMO2009	C1	1985	619
HadGEM2-ES_RACMO22E	C2	1703	690
EC-EARTH_CCLM4-8-17		1944	657
EC-EARTH_RACMO22E		1826	655
EC-EARTH_RCA4		1965	671

Among the future situations, the one deriving from the MPI-ESM-LR_REMO2009 model presents the smallest increase in temperature with respect to the current situation, while the one deriving from the HadGEM2-ES RACMO22E model presents the largest one. These two models, named C1 and C2, respectively, were selected for the execution of dynamic simulations with future climates, along with the historical one, C0. This choice allows us to analyze the two extreme situations among all the models considered.

3. Description of the Building and Redevelopment Interventions

The case study is a building of the first decades of the 20th century in Trieste, made up of four blocks with a ground floor and three upper floors.

The original building features a massive structure without any insulation. The outer walls are composed of two layers of solid bricks 25 cm thick each. The floor of the ground level, the roof and the ceiling of the top floor have concrete structures whose thickness varies from 15 to 22 cm. The windows consist of single glass and wooden frames. The floors on the ground level and the ceilings on the top floor overlook unheated rooms. The main features of the building were already described in a previous work [26].

The system serving the complex is made up of traditional natural gas boilers with radiators as heaters. No cooling system is present for summer periods, as is usual for such type of building.

The refurbishment of the building consisted in an improvement of the building fabric by insulating the ceilings of the top floor, roof and floors of the ground floor by adding a layer of 8 cm of insulation material and the replacement of the existing windows with double-glazed ones with an Argon and PVC frame. Thermal transmittance of vertical opaque surfaces was improved by the addition of insulating layers with thicknesses of 8, 10 or 12 cm; the layers were considered on the internal or external side of exterior walls, resulting in six redevelopment interventions, as presented in Table 3. The economic perspective of the interventions goes beyond the scope of this work; however, in a previous paper [26] the problem was carefully treated for the same interventions. Similar retrofit measures were adopted by Ciulla [15] and are in compliance with the national guideline on energy efficiency in historic buildings [20]. Table 4 shows the conductance values, before and after the intervention, of the opaque components along with the transmittance and solar heat gain coefficient of the windows. The conductance of the ceiling in the actual state appears to be particularly high, deriving from a construction method with thin layers, widely used in constructions built at the beginning of the 20th century. The values are in line with national regulations [27]; only the external insulation with the lower insulation thickness has a value higher than the national limits; nevertheless the solution was analyzed in order to assess the performance of the intervention with a future warmer climate.

Table 3. Cases with different insulation thicknesses.

Case	Thickness [cm]	Wall Surface
No_Ins	-	-
EXT_8	8	External
EXT_10	10	External
EXT_12	12	External
INT_8	8	Internal
INT_10	10	Internal
INT_12	12	Internal

Table 4. Thermal characteristics of the elements of the envelope in its current state and after the redevelopment.

Element	C_{No_Ins} [W/(m^2 K)]		$C_{[INT,EXT]}$ [W/(m^2 K)]	
			Max	Min
Wall	1.55		0.341	0.246
Ceiling	14.71		0.345	
Roof	5.88		0.407	
Floor	2.89		0.380	
	U_{g,No_Ins} [W/(m^2 K)]	$SHGC_{No\_Ins}$ [-]	$U_{g,[INT,EXT]}$ [W/(m^2 K)]	$SHGC_{[INT,EXT]}$ [-]
Window	5.70	0.870	1.20	0.425

Modeling of the Building-Plant System

The building was modeled using DesignBuilder version 7.02.004 and EnergyPlus version 9.4 software. Each apartment is a single thermal zone, maintaining the partitions between the different apartments and between the apartments and the common spaces; however, the internal partitions were inserted as equivalent masses, and Figure 2 presents the floor subdivision with the different type of apartments modelled. Figure 3 shows an overview of the model along with the surrounding buildings added in order to take into account the shading effect especially during the summer period.

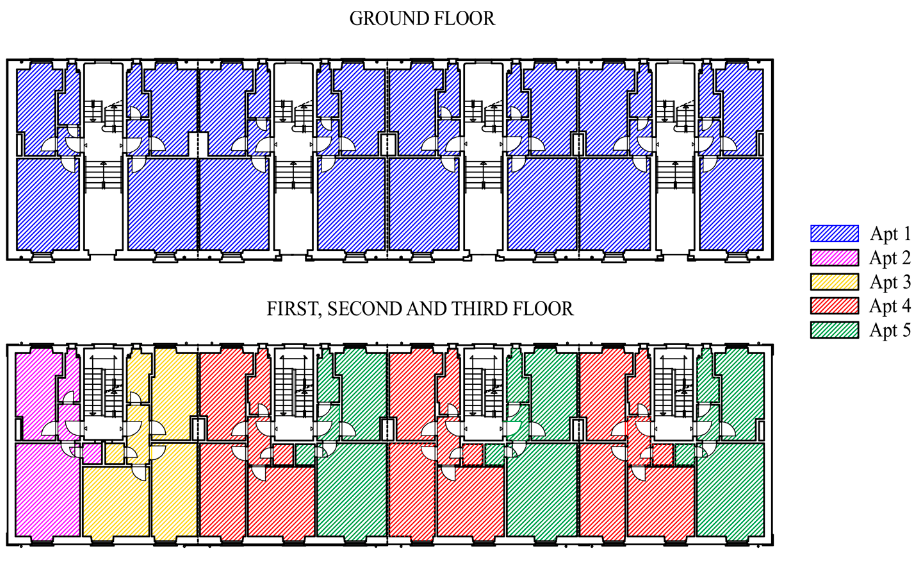

Figure 2. Floor plans with different type of simulated apartments.

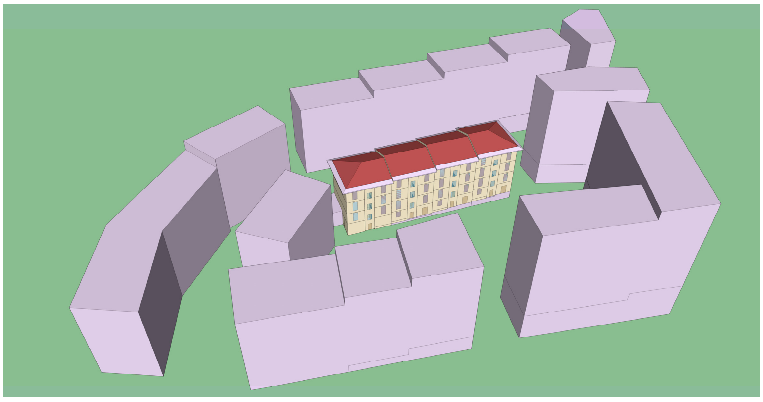

Figure 3. Building model with surrounding buildings for shading analysis.

The internal loads were modeled according to ISO 13790:2008 [28]. Air infiltrations were considered in a simplified way during the winter season by imposing an air exchange rate equal to 0.5 ACH for each apartment. During the summer season, on the other hand, a variable air flow was modeled to represent the opening of the windows by the user [26] to mitigate the inner temperatures and the ventilation is active only when the external temperature is lower than the internal one.

In order to reduce the solar heat gains, windows shutter closing during the summer season was also applied. This was considered during the months from May to September if the total solar radiation incident on the windows exceeded the threshold of 200 W/m^2, following what was reported by Tzempelikos and Shen [29]. The approach is quite simple; however, it is common in social house buildings, which often lack cooling systems or other more advanced solar shading systems such as awnings or external blinds.

During the winter the heating set-point was set to 20 °C from 7 a.m. to 2 p.m. and from 4 p.m. to 11 p.m., with a setback temperature of 18 °C for the remaining hours. Common and circulation spaces were considered unheated. Domestic hot water was not included in the simulation; therefore, the energy consumption considers the heating system only.

4. Interior Comfort Modeling

To evaluate how the interior environment of the building variates with climate change and refurbishment interventions, three comfort models were tested: Fanger, the adaptive model of EN 16798-1, and the Universal Thermal Climate Index or UTCI.

For the Fanger model [30] the mathematical model considers the variables relating to the activity, the type of clothing, and the environmental variables such as temperature, speed and relative humidity of the internal air and mean radiant temperature. The evaluation was carried out using the PMV (predicted mean vote), which expresses the thermal sensations on a 7-point scale, from a minimum of −3 (feeling very cold) to a maximum of +3 (sensation very hot).

The EN 16798-1 adaptive model [31] is applicable to buildings without cooling systems and identifies recommended indoor operative temperatures depending on the external one. This alternative method applies where thermal conditions are regulated through the opening and closing of windows. This method evaluates the acceptability of the internal conditions starting from the exponentially weighted running mean of the daily mean external air temperature and the internal operating temperature. The model defines three categories of comfort depending on the level of expectation. This research analyzed the behavior of the building in relation to Category II, intended for a normal level of expectation.

The UTCI, Universal Thermal Climate Index, comfort model was developed by COST (Cooperation in Science and Technical Development) [32]. The UTCI combines several key factors associated with thermal comfort (temperature, humidity, solar radiation, and wind speed) to determine an equivalent temperature, the UTCI, defined as the air temperature of a reference condition which causes the same heat stress obtained in the actual conditions [33]. The calculation is based on the multi-node thermoregulation model 'Fiala' [34] which divides the human organism into an active control system, given by all the reactions of the central nervous system (vasodilation, vasoconstriction, sweat production, etc.), and a passive controlled system, given by the modeling of the average physical characteristics of a person. The obtained value of UTCI allows the use of a rating scale with ten levels that varies from a minimum of −40, feeling of extreme cold, to a maximum of +46, feeling of extreme heat. UTCI was compared with different heat stress indices [35–37] showing a good correlation. Despite the model being developed for outdoor environments, it has been successfully employed in indoor environments, too [36,38].

5. Simulations and Results

The effect of climate and refurbishment activities on internal health conditions has been computed as the ratio of not-met hours over a total number of hours. This allows a direct comparison between health models that consider different parameters, once the limits are defined to consider if the environment is acceptable or not.

For each configuration of the refurbishment intervention along with the starting situation, EnergyPlus simulations provided the primary energy consumption for heating and the values of health parameters on an hourly basis. To compute the primary energy consumption, the Italian values of the nonrenewable primary energy factors were used: 1.05 for natural gas and 2.42 for electricity. EnergyPlus outputs provided the PMV index for the Fanger model and for the EN 16798 model the compliance with the limits of the Category II. The UTCI comfort model is not present in EnergyPlus therefore a post-processing phase was necessary, all the data for the model were extracted and the comfort index was calculated.

The performance of the different configurations, subjected to the three different climatic sets, in terms of primary energy for heating and comfort during the summer period, was then evaluated. With regard to the three comfort models used, the performance was evaluated by analyzing the percentage of hours in which, during the period of May–September, users perceive a situation of discomfort, i.e., situations for which the indices used in the simulations exceed the thresholds limits.

For the PMV of the Fanger model and the UTCI model, values of +1 and +26, respectively, were selected which represent, in the respective models, a situation in which users are subjected to moderate thermal stress. For the EN 16798 model, the considered parameter is the verification of the conditions due to satisfy the Category II of comfort, from EnergyPlus which provides directly the values of the EN 15251 [39] model, but with a method and values corresponding to the ones of the more recent EN 16798-1 standard.

Table 5 reports the results of all the simulations performed in terms of the percentage of hours of discomfort with the Fanger (PMV), UTCI (UTCI), and EN16798 (EN) models along with the primary energy consumption for heating (PE). Figure 4 presents the results in graphical form for the internal insulation cases since the one for external insulation is very similar. The figure reports the percentage of hours of discomfort in the upper part and the primary energy consumption percentage reduction with respect to the No_Ins case (ΔPE) in the lower part. The results are distinguished according to the climatic set used: C0, C1 and C2.

Table 5. Results for the simulated cases, percentage of dissatisfaction hours with different health models and primary energy consumption of the building with different climate data.

	C0				C1				C2			
ID	**PMV [%]**	**EN [%]**	**UTCI [%]**	**PE [MWh]**	**PMV [%]**	**EN [%]**	**UTCI [%]**	**PE [MWh]**	**PMV [%]**	**EN [%]**	**UTCI [%]**	**PE [MWh]**
No_Ins	54.21	5.49	42.72	111.56	57.8	9.37	47.39	106.72	64.64	5.85	50.61	91.37
EXT_8	53.75	4.94	41.13	34.31	56.75	7.57	45.68	32.71	65.08	5.58	49.23	27.38
EXT_10	53.85	4.7	41.07	32.34	56.75	7.21	45.72	30.81	65.13	5.54	49.21	25.75
EXT_12	53.82	4.48	41.08	30.84	56.8	6.91	45.68	29.28	65.22	5.48	49.2	24.49
INT_8	54.6	2.41	41.49	34.57	57.31	3.76	46.08	33.00	65.6	4.4	49.51	27.71
INT_10	54.77	2.18	41.49	32.60	57.33	3.22	46.07	31.12	65.7	4.37	49.5	26.07
INT_12	54.98	2.04	41.52	31.20	57.48	2.91	46.03	29.76	65.77	4.33	49.47	24.87

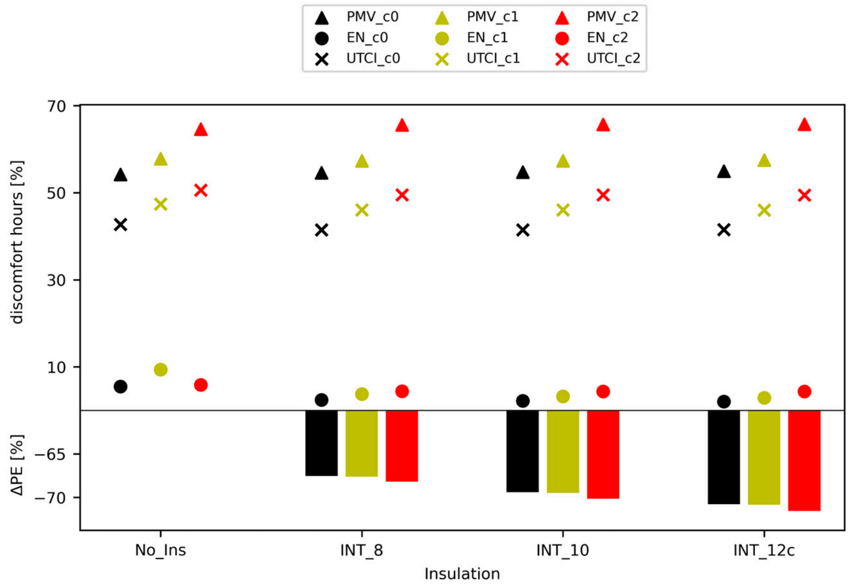

Figure 4. Energy and health results for internal insulation refurbishment. In the upper part the percentage of hours of discomfort for the three comfort models, in the bottom the percentage of reduction of primary energy with respect to the No_Ins case. Black results for C0 climate, yellow for C1 and red for C2.

The energy performance of all the solutions is excellent, with energy savings between 67% and 72% and, predictably, the application of greater thicknesses of insulation to the walls could lead to greater savings for all the climate sets considered. In addition to this, it is interesting to note how the obtainable savings are greater in the case of warmer climates C1 and C2. The results are in line with the ones of Andric [9] who found a reduction in heat demand up to 57% by applying thermal insulation to residential buildings. The energy reduction rates are also in line with similar renovation examples, such as the ones presented by Fantozzi [40] and Magrini et al. [41] that found primary energy reduction for heating up to 87%, but replacing the boiler with a heat pump.

Inspecting Table 5 and Figure 4, it is worth noting the great difference between the values obtained using the three models. The Fanger model always reports the worst performances, with a high value of hours with unmet health conditions. The EN 16798 model is the one with lower hours of discomfort, while the UTCI always positions itself on intermediate values. These differences are mainly attributable to the different approaches of the various methods, which consider distinct parameters in the assessment of environmental comfort. Another interesting aspect is the discordant behavior that the EN 16798 model demonstrates with respect to the other two. While the UTCI and Fanger models display a monotonic behavior, i.e., the percentage of discomfort hours constantly increases with higher external temperatures, the EN 16798 shows an erratic behavior. For example, the No_Ins case shows an increase in non-comfort hours with climate C1 followed by a decrease with the hotter environment C2. This behavior is due to the independence of the limit values of the UTCI and Fanger models with respect to the external temperature, while for the EN 16798 model, the limit values increase with the external temperature. The behavior is depicted in Figure 5 using boxplots of operative temperature against running external temperature; it can be seen that the former increases with the latter. This does not happen for the others two models where the limits in terms of PMV or UTCI are independent from the external temperatures. As can be seen in Figure 5, when the external temperature increases, the internal one increases, too, and so the large part of values remains inside the Category II limits. The situation is different for the Fanger and UTCI models reported in Figures 6 and 7, respectively, with the higher external temperatures of the PMV and UTCI values increasing and reaching values higher than the limit of PMV = 1 and UTCI = 26, respectively, generating a large number of hours with unsatisfied conditions. The situation worsens with future climates with values reaching and easily overcoming the PMV = 2 limit for the Fanger model and UTCI = 32 for the UTCI approach.

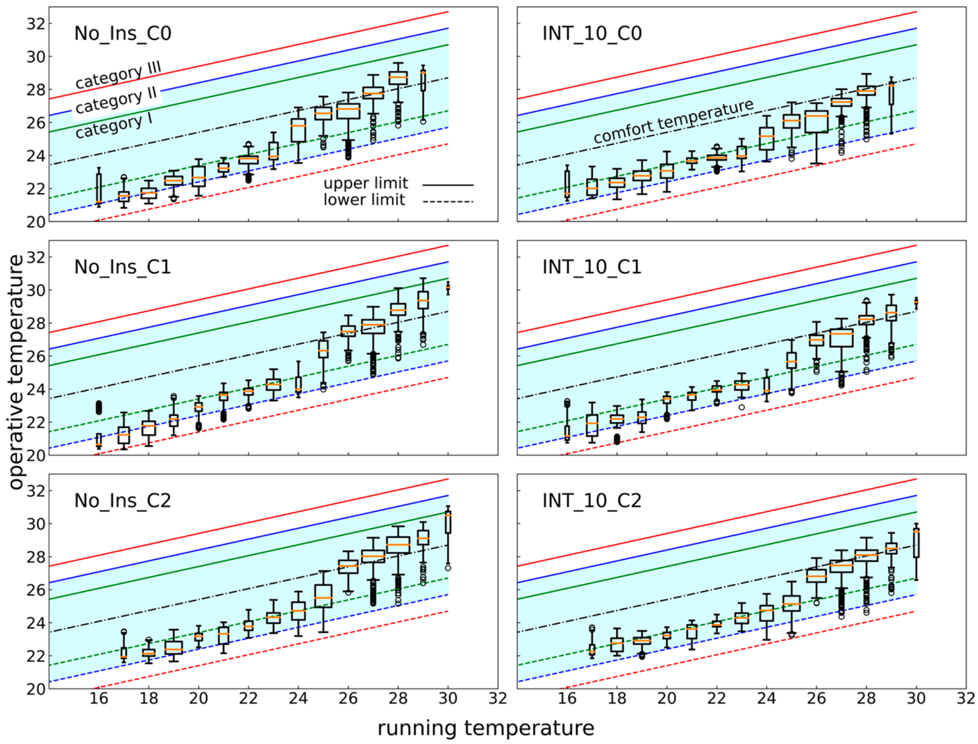

Figure 5. Boxplot of operative temperature distribution for each running external temperature for the EN16798 model for No_Ins and INT10 cases. Green lines identify the upper and lower limits of Category I, blue lines of Category II and red lines of Category III, black dash-dot line represents the comfort temperature. The shaded area represents the Category II situation identified as healthy condition.

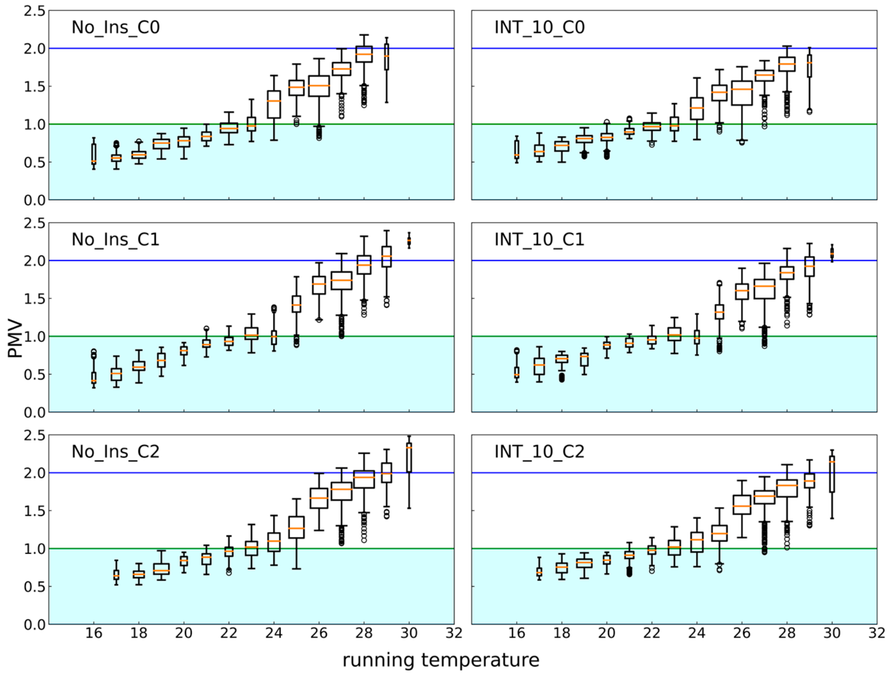

Figure 6. Boxplot of PMV distribution for each running external temperature for the Fanger model for No_Ins and INT10 cases. Green and blue lines identify the PMV = 1 and PMV = 2 limits respectively. The shaded area represents the healthy condition with PMV < 1.

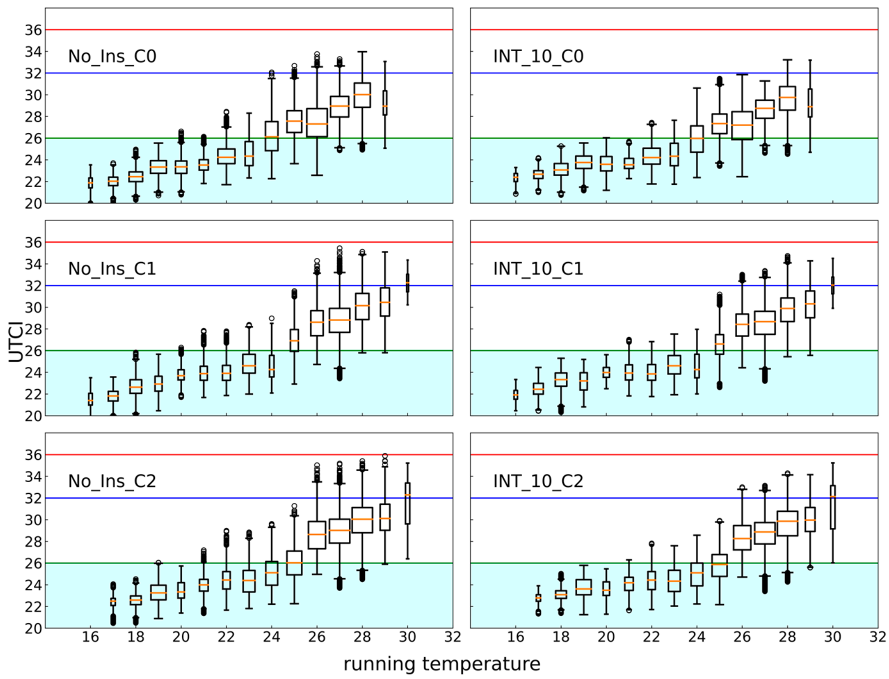

Figure 7. Boxplot of UTCI distribution for each running external temperature for the UTCI model for No_Ins and INT10 cases. Green, blue and red lines identify the 26, 32 and 36 UTCI limit values respectively. The shaded area represents the healthy condition with UTCI < 26.

6. Discussion

The results show that the climatic change, as expected, leads to a decrease in primary energy consumption for heating. However, for buildings that are not climatized, an additional problem is represented by the health risk for people inside the buildings, which should always be taken into account with proper indices. The present work showed also that the application of different health models can greatly affect the outcomes. While the UTCI and Fanger models highlight the risk for people, the adaptive EN 16798 model demonstrated to be insensitive to the increased external temperatures. Therefore, its applicability to resident people, especially the ones who are more fragile, such as the elderly, is questionable and further research is required. Furthermore, this model considers the adaptation of people to external temperatures and disregards the effect of humidity; therefore, it is more suitable to describe the effects on people that spend a large part of the time in the open air and can adapt to external conditions. On the other hand, PMV and UTCI methods could be considered better suited for analyzing the effects on people that spend the major part of their hours inside buildings and that can also be affected by high humidity levels, such as elder or more fragile people. An additional issue is due to the limits of the adopted model: the adaptive EN 16798 could be used with external running temperatures below 30 °C, as the results show that some of the reported outputs are close this value and this should be considered if the model is applied in the presence of extreme situations such as heat waves. A further outcome of the simulations reveled that, although the refurbishment interventions lead to a strong reduction of heating energy, they do not greatly influence the health inside buildings, leading to only a slight reduction of hours of discomfort if compared with the original building. This result is not surprising since the model considered the closure of window shutters in case of high external radiation; therefore, the environment is greatly affected by natural ventilation. On the other hand, climate change inevitably worsens the health problem with a general increase in hours of discomfort with a warmer future climate than the current one. This effect is of particular interest in case of extreme events such as heat waves that can cause higher internal temperatures. The problem is not of an easy solution since alternative approaches must be identified to reduce the problem or at least to monitor the most critical situations in case of extreme events such as heat waves. The straightforward solution could be the installation of cooling systems, but also alternative approaches could be considered; for example, the use of fans [42,43] can lead to a marginal benefit, but without affecting too much of the energy consumption. The results suggest that further research should be carried out to study the effect in case of extreme events such as heat waves, and also to study the behavior of the building using extreme reference years. One of the limitations of this work is that the external temperatures were obtained by applying mean values of historical weather data to generate the TRY using the ISO 15927-4:2005 standard; however, other approaches consider extreme historical data [44] that could be more appropriate to highlight the internal conditions in extreme conditions.

7. Conclusions

Climate change affects the energy consumption of buildings, but above all the building's internal well-being. In this work, the effect of different refurbishment solutions on the energy performance of heating and on summer comfort of a public housing building was analyzed considering the current and future climate. The building is a social house from the beginning of the 20th century, refurbished by applying insulation layers to the horizontal surfaces and replacing the windows with more performant ones, added to six different insulation strategies for vertical surfaces obtained by changing the insulation thickness and the installation, internal or external on the vertical walls. The results showed that, thanks to the improvement of the building fabric, the primary energy for heating could be cut by up to 70%. For the current weather situation, a reference climatic year was generated, while projections from climate models were used to generate reference years for the immediate future. The results of the projections showed how the climate could evolve towards higher temperatures in each considered case. Through hourly dynamic simulation, both energy consumption for heating and internal comfort conditions were evaluated using three different health models: Fanger, UTCI and adaptive EN 16798. The results of the three models proved to be insensitive to building renovation, but strongly influenced by climate change. The evolution towards higher external temperatures in the near future entails a substantial decrease in energy needs for heating, but worsens internal living conditions during the summer season. However, the application of the health models led to conflicting results: while the Fanger and UTCI models showed an increase in hours of discomfort with increasing outdoor temperatures, the adaptive model did not confirm this trend as the limit values for comfort increase with the external temperature. It is believed that the aspects of the internal conditions will have to be increasingly considered during the design phases of the interventions, also with the introduction of possible mitigation strategies, both active and passive, in order to improve the comfort conditions of the residents. This last point suggests that renovation activities, usually driven by the need to reduce energy consumption for heating, should be improved to take care of the outcomes during the summer period.

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