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ARCHITECTURE FOR THE SUSTAINABILITY DESIGN

The Impact of Building Variables on the Heating and Cooling Energy Consumptions. The Case Study of Turin.

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ABSTRACT

Nowadays In metropolitan settings, the utilization of energy in buildings is one of the fundamental drivers of ozone depleting substance discharges. In fact, the atmosphere and the ambient air quality of urban communities that have a warm equilibrium relying upon the Thermal utilizations of structures cause an expansion of two main phenomena in metropolitan areas: urban heat island mitigation and climate change. The aim of this work is to showcase how different building variables and urban parameters can impact the residential building's Energy heating and cooling Consumptions. In fact, buildings energy-related variables, are urgent viewpoints to improve the power execution of structures in smaller urban scales, especially in futural designed building constructions. In fact, this thesis examines four neighborhoods in the city of Turin [Italy]: Arquata, Crocetta, Sacchi, and Olympic Village each characterized by different metropolitan morphologies and urban fabrics. Six different building variables: infiltration rate, glazing ratio and windows, walls, roofs, and floor U-values, on specifically chosen buildings, following several periods of constructions: Before 1919, 1919-1945, 1961-1970, and 2001-2005. The challenge of this work is to introduce four distinctive energy-use models using the Engineering Tool CitySim Pro software, to contrast their attributes and establish the best highlights of an "ideal" model to break down and showcase the most effective energy arrangements and best energy approaches for future built cities or neighborhoods by using a sensitivity and a comparative analysis approach. The results of this examination show an immediate connection between the energy consumption of these residential structures and the six main Analyzed variables at building and neighborhood scale. Adding to that, from these building simulated models, it has been discovered that when the studied building variables ranges increased, the structures tend to consume more yearly energy demands. in this case study, several ideal ranges were found for each studied variable: 0.2 h^{-1} for the infiltration rate, 0.2 for the window to wall ratio, 2.15 W/(m^2. K) for the windows' U-value, 0.67 W/(m^2. K) for the walls' U-value, 0.53 W/(m^2. K) for the roof's U-value, and finally 1.16 for the floor's U-value. This sensitivity analysis approach can help in understand how different building's Energy-based variables can impact the residential structures heating and cooling yearly energy utilization differently according to the building's period of construction. The results of this study can be used as tool to support the futural built constructions, at the earliest possible design phase of the building in order the optimize the structure's energy consumptions.

INDEX

LIST OF TABLES:

1-INTRODUCTION

Urbanization is to a great extent affected by the shifting of individuals from rustic networks to existing metropolitan habitats because of better urban transportation systems, social and financial turn of events, way of life, or a blend of these factors. As per the United Nations (UN), 66% of the worldwide general population will dwell in metropolitan communities by 2050, while 86% of them are expected to be developed in metropolitan regions as opposed to rural ones (Pradhan, Al-Ghamdi and Mackey, 2018). This is the main reason why these grouping of populace triggers enormous changes of metropolitan and rural scenes with related ecological effects, which include metropolitan warmth island impact and raise in energy interest. In fact, according to Rehan, 2014 the heat island mitigation phenomena are mainly caused by the expansion in the quantity of structures, as well as in the measure of high warm mass and low albedo materials, such as concrete, related to the deficiency of vegetative land cover and the expansion in unnatural heat yields. The warmth island impact concerns higher temperatures in focal metropolitan regions when contrasted with rural territories and is considered as the most recorded wonder of climatic change, causing a significant expansion in metropolitan temperatures (Kolokotsa, Santamouris, and Zerefos, 2013). As stated by the European commission, 2016, buildings are held accountable for 40% of energy utilization and 36% of CO_2 outflows in Europe. Adding to that, urban areas are responsible for 75% of GHG {Green House Gas} discharges, mainly caused by the structures and transportation systems that are the fundamental patrons of this phenomenon (UNEP 2018). In this edge, the Buildings energy proficiency is an undeniably significant case for natural manageability in order to achieve a more sustainable and energy efficient environment in urban regions. In Italy and in most European nations, energy approaches are centered around two earlier activities to diminish energy utilization and GHG discharges: an increase in energy productivity and the excessive use of accessible sustainably powered sources (Mutani and Todeschi, 2020). To accomplish energy efficiency in metropolitan settings, various arrangements might be embraced, for example: The circulation of warmth through District Heating Network, the use of construction coverings and metropolitan spaces to create energy from inexhaustible sources, and a mixture of different types of users with a distinctive everyday energy load in similar territories. The restricted accessibility of sustainable powered sources in metropolitan settings stimulates the requirement for a blend of these arrangements, with procedures to diminish, oversee and screen energy employments in designated neighborhoods (Mutani and Todeschi, 2020).

1.1-RESEARCH GAP AND BACKGROUND

In European nations, practically half of the last energy utilization is applied for space warming and cooling, and therefore 80% of this energy consumption is dedicated for built structures. Hence, the streamlining of building effectiveness is one of the objectives to advance the low-carbon emission and strongly improve the development of urban areas (Mutani, Todeschi and Beltramino, 2020).

The energy exploitation of Buildings is identified with the nearby atmosphere conditions and the metropolitan morphology. These models need to take into consideration the urban setting of each neighborhood, focusing mainly on developed zones and very dense areas (Boghetti et al. 2019). However, there are numerous factors used to evaluate the relationship between the urban shape and their environmental implementation. In fact, according to Stromann-Andersen and Sattrup, 2011, the main parameters that will help us analyze the energy performance of an urban setting are: the existence of vegetation, the albedo, the canyon effect, the gap in between structures, the urban fabric concentration, the constructed surfaces along with the materials and urban pattern used. In addition, examinations on sun-based accessibility in the metropolitan climate are exceptionally unpredictable. However, late advancement has been made due to the development of 3D metropolitan model of urban communities. In fact, by planning and designing the urban areas according to their exposure, sun-oriented energy can be used both passively for warming and day lighting and effectively for electrical powering and water heating production (Sanaieian et al. 2014).

1.2-RESEARCH OBJECTIVES

The work introduced examines the connection between urban shape and its energy execution with suggestions for sun-oriented accessibility in metropolitan regions, to enhance sun-based gains and controlling sunlight-based energy as inexhaustible asset for neighborhood in densely developed areas. An adaptable technique to investigate metropolitan morphology utilizing a few boundaries, for example, the building concentration, to mimic the energy utilization at neighborhood scale. This investigation was completed in four chosen areas located in the city of Turin, Italy. This study will be founded on the production of the four neighborhood's 3D models characterized by different urban densities and various periods of construction: Sacchi {before 1919}, Crocetta {1919-1945}, Arquata {1961-1970}, and Olympic Village neighborhood {2001-2005}. These energy models were inserted in the CitySim Pro software along with building and urban scale input data, in order to retrieve several simulation values regarding the hourly Cooling and Heating Demands of the residential buildings per year. In fact, the buildings variables analyzed are: Building's Surface to Volume ratio {S/V}, Building's opening properties, Building's Orientation {BO}, infiltration rate, glazing ratio, and thermal transmittances of windows, wall roofs and floors. Urban parameters such as building coverage ratio, canyon effect, building density and Main Street Orientation, also played an important role in analyzing the impact of these factors on the heating and cooling energy consumption of the four different neighborhoods. Moreover, this work will showcase which of these parameters and urban boundaries has the most influential impact on the structure's warming and cooling energy-use, considering the buildings' periods of constructions. The aftereffects of this examination give new experiences into the recognition of the ideal Input data ranges regarding each urban and building variables to have the lowest possible energy utilization with high sun-based energy efficiency that will effectively impact the building's heating consumption.

2- LITERATURE REVIEW

2.1- ANALYSIS METHODS FOR URBAN MODELS

Several analysis methods have been developed throughout the years to specify rules and methods to investigate in the clearest way possible the complex results, input data and simulations retrieved from a specific urban study and therefore the Urban model. In fact, in 1991 Morris.M.D. proposed a viable screening affectability measure (sensitivity analysis approach) to distinguish a couple of significant elements in models with numerous variables. The technique depends on processing for each information or input data various steady ratios, to have precise fundamental impacts, that are later averaged to survey the significance of these collected data in relation to the results obtained. The technique depends on determining for each input various steady proportions, known as Elementary Effects (EE), from which essential insights are processed to deduce sensitivity records. The controlling way of thinking of the first EE strategy (Morris,1991) is to figure out which information variables might be considered to have impacts which are irrelevant or can be neglected, straight and added substance, or on the other hand non-straight or engaged with collaborations with different components. For each info, two affectability measures are processed: u, which evaluates the general impact of the factor on the yield, and o, which determines the factor's with higher request impacts, for example non-direct and additional variables because of their collaborations with different components. The test plan is made of independently randomized tests. Every model's input data Xi is accepted to shift across p chosen levels in the space of the related information to the factors. Observing a standard practice in affectability examination, factors are thought to be consistently dispersed in between 0 to 1 and afterward changed from the unit associated to it, to their genuine dispersions. Morris's method, depends on the development of r directions in the space of the chosen input data analyzed, commonly somewhere ranging between 10 and 50. The configuration depends on the production of an arbitrary beginning stage for every direction and afterward finishing it by moving one factor at a time in an irregular request. However, this methodology could prompt a non-ideal result of the data's space, particularly for models with countless variable factors. This is when, Campolongo.F, Cariboni.J and Saltelli.A (2006), tried to improve Morris's sensitivity analysis method by a superior filtering of the input data's area without expanding the quantity of model executions required. In fact, they investigated the performance of KIM, a model of the tropospheric science. The results of this model show that the best way to apply different based strategies is to gather factors into subsets. Beginning from the results of the screening, they assembled the factors into two subsets, the first containing the most un-compelling elements and the second one including the residual components. To recognize these most un-persuasive elements, they processed for each yield several variables as per the amount of their scores. This procedure delivers a solitary positioning beginning from numerous outputs, along with the gathering of components into two separate sets. The change-based investigation completely affirms the results obtained in the EE methodology, since for all the yields, the primary gathering of variables represents under 1% of the complete fluctuation. This authenticates the wellness of Morris's sensitivity analysis strategy used as a screening strategy in models with several yields and numerous input data components.

Various methodologies have been proposed for demonstrating metropolitan structure energy use in the previous years. In their paper, Li.W, Zhou.Y, Cetin.K et al. (2017), depict the essential work process of Top-down and Bottom-up approaches and their applications in modeling metropolitan scale structure and their energy use. In fact, according to the authors, the top-down and bottom-up analysis methods, face both some advantages along with several limitations. The Top-down methodology regularly utilizes energy economy connections, along these lines being equipped for demonstrating energy use under different financial situations. It likewise takes into consideration both socio-segment and market monetary factors. Furthermore, the top-down procedures commonly utilize moderately direct techniques for usage by depending on a restricted arrangement of input data, for example, amassed financial information. As the accentuation is given to the energetical and economic cooperation, detailed data about the kinds of energy consumption through advances used in the chosen buildings and their definite energy utilization information are typically not needed. Because of its effortlessness, this method, have been broadly utilized for assessing metropolitan energy utilization. Adding to that, according to Li.W, Zhou.Y, Cetin.K et al. (2017), The bottom-up methodologies, embodies the energy utilization dependent on itemized input data chosen in the analysis procedure. These data can be arranged into two sorts: numerical against science-based strategies. This approach generally takes building energy consumption esteems from test structures to investigate the connection amongst end-utilizes and complete energy utilization. The numerical technique is very related to the top-down methodology in wording of its capacity of joining financial components. Nonetheless, the technique utilizes more definite and regularly disaggregated information, which often speak to energy utilization information for specific structures. On the other hand, the science-based strategy, reenacts energy utilization dependent on the actual physical qualities of some specifically chosen buildings, for example, in relation to the building's shape or other features such as: heating and cooling consumptions, ventilation, building's covering façade materials and components as well as the users attributes. The bottom-up measurable technique recreates metropolitan structure energy utilize dependent on long period recorded information including their energy demand. Urban parameters are conceivably the main factors that influence the building's energy consumption and a critical measure to assess the area of the urban site.

In this thesis, both the sensitivity analysis approach presented by Morris in 1991 and the bottom-up methodology were applied to the urban energy models studied in the city of Turin. In fact, several physically and geometrically based data were taken into consideration and well as different variables such as: infiltration rate, glazing ratio, building's opaque and transparent envelopes in relation to their thermal transmittance and the structure's surface to volume ratio. Each of these input data, were based on statistical and historical information regarding specific information on individual buildings following their date of construction. These variables were separated or categorized according to different ranges helping in sensitively analyzing the impact of the changed chosen values on the yearly energetical utilization of the building. The simulated results, were compared, allowing the evaluation of the most influential and best ranged variable in accordance with the heating and cooling demands obtained.

2.2- COMPUTER BASED ANALYSIS AND TOOLS

Computer helped research instruments profoundly affected the field of metropolitan morphological exploration. More intricate calculations could be investigated, and geometrical shapes could be rehashed instantly for several buildings to extend the examination to smaller and more local scales. In 1996, Baker.N and Steemers.K, introduced a research tool previously utilized by geographers to overlap three dimensional geographical highlights on top of two-dimensional drawings, delivering something very similar to a 3D configuration and permitting the robotization of the already existing technique {LT-method}. At the degree of the individual structure, the authors, directed an exhaustive classification of "nondomestic building stock" with the essential point of making a data set of building structure to be utilized for energy investigation. From a study of 3350 structures in four neighborhoods, arrangement standards centered on structures' outer façade or envelope, recognized to be profoundly critical in the energy request computations of the buildings. In fact, Baker.N et al. (1996), present "LT 3.0 i" a tool for South-European cities which incorporates a strategy to assess the impact of shading elements on the building's envelope on the cooling demands and on the artificial electrical lighting. Several energy flows were taken in consideration in the analyzed LT model these authors preformed: heating and cooling demands, lighting powered energy, solar gains, ventilation heat loss and gain as well as the conductions through the transparent and the opaque envelopes of the designated buildings (fig.1.).

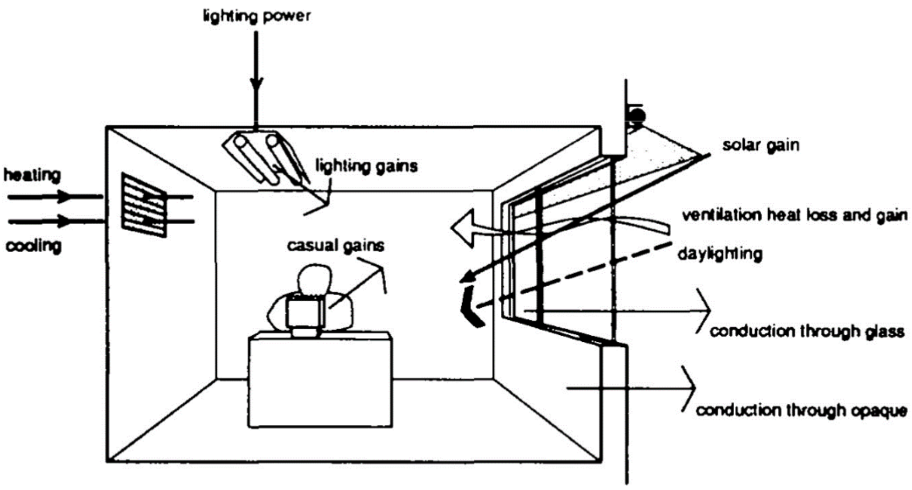


Fig.1. Energy flows in the LT Model (Baker.N and Steemers.K, 1996).

The results of the LT model reflected the serious requirement for shading elements to be ordered along this specific manner: that is a specific time period incorporated between the proportion of the sun based concealing devices and the daylight, solar gain diffusion period.

Mathematical demonstrating devices for researching at a district or neighborhood scale were additionally sharpened by Ratti.C, Bakerb.N and Steemers.K, in 2004. In fact, additional urban factors were analyzed to explore the impact of the urban texture on the yearly energy demands of a building based on a Digital Elevation Models analysis {DEM} combined with the LT method developed by Baker and Steemers in 1996. The added urban variables in this study they conducted consists of the building's Surface to Volume Ratios, building's orientation, the Sky View Factor, the passive and non-passive zones of the buildings and the Main Street Orientation {MOS} that identifies the value of the street's orientation. In fact, when MOS is equivalent to 1, it indicates that the street orientation is East-West with a maximum solar gain due to the similar sun orientation. When MOS is equal to 0, this value implies a North-South street orientation and therefore minimal solar gain.

In this work, several Main Street Orientations were studied to analyze the best orientation in regards of the lowest Energy consumption. It has been found that the proportion of detached to non-passive zones of the building was demonstrated to be a superior pointer, by burning-through roughly twice as much energy as passive zones. However, this finding generally pertinent to non-residential structures given that non-passive zones are generally absent in private buildings. Even though this had the impact of debilitating the connection between energy utilization and urban shape, fluctuations as extensive as 10% were yet seen because of morphology contrasts amongst two mainly observed cities: Berlin and Toulouse. Despite that, a huge potential in energy reduction and advocated future work towards improving metropolitan morphology for decreased energy interest were observed in this work.

More recent Computer tools were later developed to facilitate the calculations and simulations of the energy consumptions of different urban zones regarding their energy models such as: GIS software, Energy Plus as well as CitySim software. In 2015, Delmastro.C, Mutani.G et al. analyzed the relation between urban shape and energy heating demands using both tools GIS and CitySim Pro. The Geographical Information System {GIS} can identify and calculate several building and urban variables. In fact, using the ArcGIS software, different urban parameters can be computed such as: the Building Coverage Ratio {BCR} expressed in (m^2 / m^2), That is the ratio of the buildings area over the site area. In other words, the gross built area of the neighborhood over the census parcel area of the chosen district or urban zone. The BCR ratio can have a minimum value of 0 where the plot is totally empty, and a maximum value of 1 where the urban zone or neighborhood is fully covered with buildings. Therefore, the higher the value of this ratio, the higher the Gross built area and the lower the open spaces and green areas which determines the studied built area in relation to the total urban area. Adding to that, this study analyzed as well, the Main orientation of the Streets {MOS}, the Building's Density, the Height to Width Ratio determining the distances in between the building and its surrounding, the building's Solar Exposure taking into consideration the surrounding average height of the built zone and the Albedo indicating the reflection power of a certain surface. In fact, the Sky to view Factor {SVF}, is the ratio between the building's height and the average height of the surrounding buildings {H/H*avg*} expressed in (m/m). This variable is used to calculate the building's solar exposure and therefore its heat gain and its impact on the yearly heating and cooling demand. Adding to that, different building variables can be assigned to the three-dimensional configurations using the ArcGIS software such as: the buildings different period of constructions allowing the identification of the materials and composites used along with their respective thermal transmittance, resistance and infiltration rates, the building's net heated volumes along with its usable area, the Surface to Volume Ratio identifying the building's typological characteristics and the building's orientation reflecting the daily heat gain through the solar radiation. These variables are crucial to investigate to understand the relation between these cited parameters and the energy consumption. In order to simulate and analyze various metropolitan arrangements, the engineering software CitySim Pro, that is a metropolitan performing simulator, engine comes into place. In 2013, Dr. Jerome Kämpf, developed this engineering tool, allowing the recreation and the improvement of the supportability of metropolitan settlements in the most sustainable possible manner. CitySim is mainly based on different inserted input data regarding one or several selected buildings placed in the studied urban three-dimensional context as well as the climatic properties of a selected city. The added information will allow the simulation of the urban zone in the most accurate way. These input variables mainly consist of: building's infiltration rate, Indoor minimum and maximum Temperatures, shading devices, building's composite and materials along with their individual characteristics, Opening properties composed of the Glazing Ratio located on the building's facades and their respective thermal transmittance {U-Value} and finally the building occupant's profile, number and density (Mutani.G, Coccolo.S, Kampf.J and Bilardo.M, 2018). These incorporated input data and climatic specification, will allow the software to simulate hourly based results related to the urban model, dissecting the yearly Heating and Cooling demands of each building in {Wh}. These outcomes will permit the identification of the ideal energy based needs to reach the most suitable internal temperature as well as exploring the impact of the added data on the results of the simulated building or neighborhood.

2.3- BUILDING AND URBAN PARAMETERS IN RELATION TO THE ENERGY CONSUMPTION

Throughout the years, with the undeniable impact of the greenhouse gas emissions on the environment, several scientists and researchers investigated how different structural or metropolitan variables can impact the energy consumption of different urban, building and city scales. In fact, in 1972, Martin.L. and March.L., examined the connections between various factors: building coverage ratio, building's altitude, building profundity, and building's density to comprehend the identical degrees of daylight. After that, Steadman.P (1979) was amongst the first scientist to hypothesize the energy ramifications of big scope metropolitan zones. His discoveries, demonstrated that high-thickness urban areas developed along a straight and organized infrastructure, would be more beneficial than a centrally unified thick urban development. According to Steadman, this point, will help in the expression of solar gains, natural sun lighting exposures, air circulation, and nearby food creation were viewed as the advantages of this sort of metropolitan impression. These early discoveries conducted by Martin and March (1972), and Steadman (1979) framed the reason for some future examinations on the impacts of urban morphology and building variables on the energy consumption according to different scales.

In 2011 Strømann-Andersen.J and Sattrup.P.A., examined how a far-reaching set-up of atmosphere-based analysis and daylight reproductions, can impact the energy assets of a building especially in highly dense urban zones. The study was based on different observed factors considering a typical three-dimensional representation of metropolitan pattern and urban canyon proportions in the city of Copenhagen. In fact, the canyon effect, reflects the height to Width ratio {H/W} expressed in (m/m). This ratio represents the building's height over the width of the street (gap in between the buildings). The neighborhood's building density plays a major role in the variation of the canyon effect. Several urban parameters were taken into matter during this research such as: Hight to width ratios, daylight environmental situations, annual illuminance as well as the user's pattern. The results showed a big correlation between urban density and yearly solar gains. Indeed, the urban canyon's shape, undeniably affects the structure's energy utilization, in the scope of up to +30% for non-residential buildings vs 19% for residential ones. In addition to that, Sanaieian.H, Tenpierik.M et al., 2014, focused on the same topic by analyzing the impact of these street canyons not only on the building's energy consumption but also on the solar access and natural ventilation of the outdoor environment. The obtained outcomes, demonstrated that, a winder street canyon with a height-to-width ratio equal to 9.7 meters compared to a smaller one with a ratio equal to 0.6, had a colder temperature during the day versus shallower streets. Therefore, during the summer season, streets with a bigger H/W ratio, had a cooler outdoor temperature than in wintertime. Based on the previous researches and studies related to canyon typologies, Huang.K.T, and Li.Y.J, (2017), investigated the impact of this ratio by adding two new variables: building's orientation as well as the surrounding green areas in the city of Taipei. According to their observations, Li and Huang concluded that: The highest cooling energy utilization of structures with a North-South Street orientation, use approximately 16.9% more energy compared to street with South-West/North-East orientations roads. While buildings with a shallow canyon ratio, burn-through 37.13% more energy than those with bigger distances in between the buildings. Adding to that, both researchers demonstrated when streets are smaller, the surrounding green areas and trees can have a much higher impact on the cooling consumption compared to wider streets.

Other than the urban canyon effect, different urban and building parameters were studied by several researchers. In fact, in 2014, Rehan.R.M., analyzed how the characteristics of the coolest city in the world (Stuttgart) are composed at an urban scale and examines a useful method on cool metropolitan zones to apply it in the city of Cairo, Egypt. Rehan considered various factors: Surface's colors and materials, Albedo indicating the reflecting strength of a certain material, metropolitan greening as well as ventilation rates. The author discovered that to minimize the Urban Heat Island Mitigation phenomena, different techniques should be applied: Green halls, energy-effective constructions to higher in the most efficient way possible the metropolitan natural environmental and outdoor quality, and finally the utilization of cooler materials for example concrete instead of brick. Rode P. et al., (2014), combined both urban and building scale in their study. Their aim was to Investigate sun powered gains and building's envelope energy misfortunes to evaluate the heating energy consumption, as well as the impact of the glazing ratio, the material's thermal transmittances and climatic data on the energy demand. In 2015, Delmastro et al., mainly studied the building's period of construction and its relation to the energy utilization. In fact, a structure's-built time, can help us identify different characteristics and specification such as: shape, materials and composite, infiltration rate, typology, thermal transmittances, district's density, etc. The conducted exploration showed that mostly buildings with an older construction period, consumed more energy compared to newly built neighborhoods and therefore buildings. Adding to that, Carozza M., Mutani G., et al. (2017) created a hybrid energy-use model in the city of Turin to explore the effect of various urban parameters on the energetical consumption. It has been found that the ideal Building Coverage Ratio {BCR} to achieve the lowest warming interest, is 0.3 while the optimal Heigh to Width ratio {H/W} is estimated to be around 0.9, where the street width is roughly equivalent to the structure's height. In 2019, Boghetti R., Fantozzi F., et al., found a relation between street canyons and the Sky View Factor {SVF}. In fact, according to their study, when the Height to Width ratio decreases, the SVF factor decreases and thus the energy consumption increases simultaneously and when SVF is characterized by a higher value along with an optimal MOS {Main Street Orientation East-West}, the energy demand is considerably lower in comparison to an unfavorable positioning. To sum up, according to several past studies and research, it has been found that urban and building variables have an undeniable impact on the yearly energy consumption.

AUTHOR	TITLE	DATE	LOCATION	SCALE	THE AIM OF THE STUDY	ANALYSED FACTORS	RESULTS	OTHERS
Martin.L. and March.L.	Urban Space and Structures	1972	———	Building	The aim was to examine the connections between various building factors: in order to comprehend in a clear way its connection to the the identical degrees of daylight.	Building coverage ratio, building's altitude, building profundity, and building's density to comprehend the identical degrees of daylight	The results of this study, showed how three generic built forms—freestanding 'pavilions', parallel 'streets', and inward-looking 'courts'—make use of land in distinctively different ways, again measuring their density .	———
Steadman.P	Energy and patterns of land use	1979	———	Urban	Was amongst the first scientist to aim for a hypothesize regardin the energy ramifications of big scope metropolitan zones.	The Urban solar gains, natural sun lighting exposures in accordance to the surroundings, air circulation, and nearby food creation	His discoveries, demonstrated that high-thickness urban areas developed along a straight and organized infrastructure, would be more beneficial than a centrally unified thick urban development.	This study, framed the reason or the base for some future examinations regarding this field
Morris, M.D.	Factorial sampling plans for preliminary computational experiments	1991	———	Building	Propose a viable screening affectability measure (sensitivity analysis approach) to distinguish a couple of significant elements in models with numerous variables.	The technique depends on processing for each information or input data various steady ratios, to have precise fundamental impacts, later averaged	Results of this methodology, could prompt a non-ideal outcomes of the data's space, nad input data inserted following several ranges particularly for models with countless variable factors.	Factors are thought to be consistently dispersed in between 0 to 1
Nick Baker and Koen Steemers	LT Method 3 . 0 - A strategic energy-design tool for Southern Europe.	1996	Southern Europe	Building	Introducing LT 3.0 i a version for S-Europe which includes a procedure to evaluate the affect of shading devices on cooling loads and on lighting.	Building, services and occupants.Plan, section, facade design,orientation, position on the site in relation to surroundings.	Urgent need for shading devices to be classified in this way integrated ratio of solar shading to critical daylight transmission.A comparative viewpoint they can help to optimise design.	The LT Method is an energy-design tool. Parameters available early in the design development.
Carlo Rattia, Nick Bakerb, Koen Steemers	Energy consumption and urban texture.	2004	Central London, Toulouse, Berlin	Urban	This paper explores the effects of urban texture on building energy consumption based on the analysis (DEMs) coupled with an LT model.	-Built volume+ Surface -Surface to volume ratios -Passive and non-passive zones,orientation of facade,urban horizon angle,obstruction skyview.	The results show the importancenof the distinction in passive and non-passive zones. Parts of buildings within 6 m of a facade present a reduction of 50% in energy consumption compared with non-passive ones.	-DEMs: digital elevation models. -LT model: evaluates the solar gain and applies a utilisation factor.
Campolongo.F, Cariboni.J, and Saltelli.A.	An effective screening design for sensitivity analysis of large models	2006	———	Chemical Model	Improving Morris's sensitivity analysis method by a superior filtering of the input data's area without expanding the quantity of model executions required.	The performance of KIM, a model of the tropospheric science by applying different based strategies by gathering factors into subsets.	The change-based investigation completely affirms the results obtained in the EE methodology, since for all the yields, the primary gathering of variables represents under 1% of the complete fluctuation.	This study, Authenticates the wellness of Morris's sensitivity analysis strategy

AUTHOR	TITLE	DATE	LOCATION	SCALE	THE AIM OF THE STUDY	ANALYSED FACTORS	RESULTS	OTHERS
J. Strømann-Andersen and P.A. Sattrup	The urban canyon and building energy use: Urban density versus daylight and passive solar gains	2011	Copenhagen	Urban	Analyzing how H/W ratios of urban canyons affect building energy use for lighting, heating and cooling and the impact of H/W ratio on the energy use vs unobstructed solar access.	Urban canyon and urban density. Daylight enviro-ment,Building and user pattern and annual illuminance/Urban density vs Solar gain and AL.	The geometry of urban canyons has a relative impact on total energy consump-tion, compared to unobstructed sites, in the range of up to +30% for offices and +19% for housing, thus urban geometry is a key factor in energy use in buildings.	-AL: Artificial Light -ECOTECT:For solar radiation calculations -DAYSIM: simulations of outdoor/indoor illuminance daylight.
D. Kolokotsa, M. Santamouris, S.C. Zerefos	Green and cool roofs' urban heat island mitigation potential in European climates for office buildings under free floating conditions.	2013	Chania, Greece, lodon, Rome	Building Roofs	Analysing the potential of green and cool roofs by performing a comparative Study using Energy Plus to analyse the sensible and latent heat flux released to the atmosphere for roofs.	Climatic, optical, thermal and hydrological conditions.	A cautious plan considering the particular presentation of green and cool rooftops yet additionally other factors like the maturing of cool materials, the green rooftops' as well as climatic varieties should be considered in order to maximize the mitigation phenomena.	Sensible heat flux {heat absorption / reflectiveness}: W/m²
Reeman Mohammed Rehan	Cool city as a sustainable example of heat island management case study of the coolest city in the world.	2014	Stuttgart, Germany Cairo, Egypt	Urban	Dissecting how the idea of the coolest city (Stuttgart) is created and investigates a functional methodology toward cool urban areas and applying it in the city of Cairo.	-Surfaces colour and material. -Albedo -Urban greening -Ventilation -Enviro-management	To lessen the UHI, techniques of the cool city should be applied such as: green corridors, energy-efficient structures and thus higher the urban ecological quality. The use of reflective materialscan reduce the ambient temperature of the city.	Heat absorption depends on the color and the materials used in pavement. -Concrete is cool -Brick is Hot
H. Sanaieian, M. Tenpierik, K. van den Linden, F. Mehdizadeh Seraj, S.M. Mofidi Shemrani	Review of the impact of urban block form on thermal performance, solar access and ventilation	2014	Iran, Sweden and different continents	Urban	Analyzing how the forms and the positions of urban blocks not only influence the micro-climate but also the energy performance of each block based on existing methods and techniques.	-Thermal behaviour inside and outside the building. -Solar access inside and outside the building. -Indoor and outdoor natural ventilation.	A deep canyon (H/W of 9.7) to a shallower one (H/W of 0.6), showed that during the day the deep was colder than the shallow. Thus in summer the deeper one had a cooler temp than in winter/Sunlight decreased by 10–75% if the urban blocks were surrounded by other buildings.	-LT method develope-by Baker and Steem-ers:predicts building energy consumption by modifying the effects of lighting and thermal (LT).
P Rode, C Keim, G Robazza, P Viejo, J Schofield	Cities and energy: urban morphology and residential heat-energy demand	2014	London, Paris, Berlin, Istanbul	Urban + Building	Analyse solar gains and buildin surface energy losses to estimate heat-energy demand The effect U-values and glazing ratios and climat effects	Building type,number of floors;plot shape and prop;alignments; street pattern;street width; building density;coverage ratio.	Morphologies with FAR under 0.5)display a heat-energy demand of at least 100 to 200 kWh/m2/a. At the same time, efficiency levels of less than 50 kWh/m2/a are common only above FAR 4 ex tall buildings.	-FAR: Floor Area Ratio
C. Delmastro, G. Mutani, M. Pastorelli and G. Vicentini	Urban morphology and energy consumption in Italian residential buildings.	2015	Districts 1,3 and 4 in Turin, Italy	Urban	Finding a preliminary correlation between urban form and space heating energy consumption, using GIS and CitySim Tools.	Period of construction, shape factor, typology, occupants behavior, orient.Climate,canyon and the heat island effect.	The worst result is represented by low density districts with an unfavorable solar exposure.Very high density urban contexts have an average energy consumption with a certain difference depending on their orientation.	Building Orientation (BO) is equal to 0 for(North-South) and is equal to 1 for (East-West).

AUTHOR	TITLE	DATE	LOCATION	SCALE	THE AIM OF THE STUDY	ANALYSED FACTORS	RESULTS	OTHERS
Mutani.G ; Gamba.A and Maio.S.	Space heating energy consumption and urban form. The Case Study of Residential Buildings In Turin (Italy).	2016	Turin, Italy	Urban	The aim of this study is to understand how the urban form of the city can influence the buildings' energy consumptions for space heating.Using ArcGIS (ESRI) and CitySim Pro.	Building coverage ratio (BCR), aspect ratio (H/W), and main orientation of streets (MOS).The Urban Morphology factor (UM) and The Solar factor (S).	An optimum range of GUMS between 0.3 to 0.45 can be defined ensuring lower heating energy consumptions both in the case of optimal and not optimal SF.Higher Solar factor means more solar heat gains and energy savings.With low or high UM or BD heating energy increases.	Global Urban Morphology and Solar factor (GUMS) calculated by the product of the urban morphology UM and the solar factor S.
Carozza.M, Mutani.G, Coccolo.S and Kaempf.J	Introducing a hybrid energy-use model at the urban scale: the case study of Turin (IT).	2017	Turin, Italy	Urban	Analyse how the urban form, the solar exposure of buildings, the outdoor spaces and the material characteristics of urban surfaces impact on the energy performance of buildings. Using CitySim Pro.	Building Coverage Ratio, Aspect ratio, Main Orientation of the Streets, Solar factor and albedo.Building density ,the urban canyon and solar exposure.	The optimum BCR to reach lower heating demand, is 0.3{the built area is the 30% of the total site area}.The optimal H/W values is 0.9{the road width is approximately equal to the buildings height}.The best orientation of the streets is West East buildings energy efficiency is optimal.	Very dark surfaces (low values of Albedo) absorb more solar radiation with a rise in outside air temperature.reduction of heat losses.
Li.W, Zhou.Y, Cetin.K, Eom.J, Wang.Y, Chen.G, and Zhang.X.	Modeling urban building energy use: A review of modeling approaches and procedures	2017	US, Norway, Denmark, U.K, China, Japan, Canada	Building	A survey of the classifications of energy models for urban buildings and depicts the fundamental work process of scienc based, bottom-up models and their applications in building energy use.	- Top-down models: statistical analysis -Bottom-up models: Statistical analysis and physics based models with limitalitions and advantages (approaches)	-Top-down approach:statistical methods are used to analyze building energy use based on market, economic and socio-demographic data. -Bottom-up approach:detailed predictions of end-use and whole-building energy consumption. Adresses individual buildings	the top-down approaches are also incapable of representing the impact of new construction on existing buildings (not the most ideal)
Michael Mitterboeck, Azra Korjenic	Analysis for improving the passive cooling of building's surroundings through the creation of green spaces in the urban built-up area.	2017	Vienna, accurately the Karlsplatz	Parks and courtyards	The goal of this study was to inquire whether it makes a diffrence if an urban place is planted or not, by performing mesurments for outdoor temperature.	Analysing Karlsgarten and Karlsplatz to quantitatively evaluate the impact of green space, by considering The air temperature	Comparative results with the first one surrounded by greenery and the second with asphalt and concrete in Karlsgarten and Karlsplatz. These results show that improvement can be made in large urban areas through planting.	UHI urban heat island reflecting high ground-level air temperatures in urban areas.
Huang.K.T, and Li.Y.J	Impact of street canyon typology on building's peak cooling energy demand: A parametric analysis using orthogonal experiment	2017	Taipei	Urban	Investigate how street canyon typology and road greening impact the peak cooling power utilization of structures during the hottest climate conditions	-Height over Width ratio {Street Canyons} -the building's orientation -Surrounding green areas	The peak cooling energy consumption of buildings of N-S oriented streets consume 16.9% more energy than SW-NE streets, while buildings in street canyons whose H/W = 0.5 consume 37.13% more energy than those in street canyons H/W = 2.0.	The smaller the street, the more the green areas can impact cooling consumption.
Snigdhendubala Pradhan, Sami G. Al-Ghamdi, Hamish R. Mackey	Greywater recycling in buildings using living walls and green roofs: A review of the applicability and challenges.	2018	Doha, Qatar	Building walls	Analyzing if integrated greywater treatment in buildings provides plants not only with water but other required nutrients and organics. And to revealing benefits and potential pitfalls of this technology.	-Type of living wall: if Hydroponic green wall system or Substrate based system. -Types of green roof: if Extensive, Intensive or Hybrid green roof.	The use of hybrid material will help us in obtaining suitable characteristics of porosity,and physical/chemical interactions with pollutants. Coarse media are effective for the removal of 75% of organic pollutants , avoiding clogging issues. Greywater treatment using green walls hepls with water recycling and urban cooling.	Coarse media such as vermiculite, perlite, and sand.

AUTHOR	TITLE	DATE	LOCATION	SCALE	THE AIM OF THE STUDY	ANALYSED FACTORS	RESULTS	OTHERS
Boghetti, R.; Fantozzi, F.; Kämpf, J.H.; Mutani, G.; Salvadori, G.; Todeschi, V.	Building Energy Models with Morphological Urban-Scale Parameters: A Case Study in Turin.	2019	Turin, Italy	Urban	Analizing if the urban context strongly influences the energy performance of buildings located in highbuilt-up areas using Scikit-learn for the model creation and GIS tool.	- height-to-width H/W -Solar exposition -sky view factor (SVF) -Climate and microclimate and the hourly energy consumption	with high values of SVF and good orientation, energy consumption is lower than in unfavourable conditions. The shape of building is fundamental in its heat exchange.H/ W decreases, the SVF increases thus consumption also increases.	ISO 52016-1:2017 ISO 52017-1:2017 standards data at neighborhood scale and morphological urban para
Guglielmina Mutani, Valeria Todeschi and Simone Beltramino.	Energy Consumption Models at Urban Scale to Measure Energy Resilience.	2020	Turin, Italy	Urban	Improve the energy resilience of neighborhoods and cities using an urban-scale model throught GIS tool, and analyzing the impact of climate change or other scenarios on energy consumption.	-Presence of greenery -The Albedo -The Canyon effect -Climate/Solar expo -Building temperatures -Energy management/ Hourly District Heating.	Percentage of daily consumption: 10% to 16% for the 1919–1945 period, from 9% to 15% for 1945–1960, from 8% to 12% for 1961–1970,and from 8% to 11% for 1971–1980. Buildings that consume less have a higher peak at the same outdoor temperature.	-Albedo: the proportion of light or radiation that is reflected by a surface -Street Canyon: Narrow street with skyscrappers H/W.
Guglielmina Mutani and Valeria Todeschi	The Effects of Green Roofs on Outdoor Thermal Comfort, Urban Heat Island Mitigation and Energy Savings.	2020	Turin, Italy	Urban	Investigation on the use of green roofs as a strategy to reduce the urban heat island effect and to improve the thermal comfort of indoor and outdoor environments.	Characteristics of building,presence of empty spaces, and identification of critical areas, in which the thermal comfort conditions are poor with low vegetation.	With an increase of 0.1 of NDVI in the most critical areas, there would be a 15% increase in green, a decrease in LST of 2.7 ◦C (with lower air temperatures), and an energy saving of approximately 14 GWh/year with a reduction in GHG emissions.	-Critical areas (with low thermal comfort conditions and a high UHI effect). -NDVI: Normalized difference vegetation
Guglielmina Mutani and Valeria Todeschi	Low-Carbon Strategies for Resilient Cities: A Place-Based Evaluation of Solar Technologies and Green Roofs Potential in Urban Context.	2020	Pozzo Strada, Turin, Italy	Urban	Examines the roofs' potential in a densely built-up context, analyzing the effects of smart green technologies on energy savings and thermal comfort conditions at district scale. Using ArcGIS 10.7.	Photovoltaic (PV) panels, solar thermal (ST) collectors and green-roofs technologies.Roofs analysis and the Solar energy potential.	50% of the annual domestic hot water consumption must be covered by the ST production.The installed electric power (in kW) must be greater than or equal to P, where P is (1/50)·S and S is the footprint area of the building (m2).With green roofs, the roof albedo criterion is respected due to passive summer air conditioning tech.	-RES: Renewable energy sources -DHW: Domestic Hot Water.
Guglielmina Mutani and Valeria Todeschi	Building energy modeling at neighborhood scale.	2020	Turin, Italy	Urban	To estimate the monthly energy use of the residential buildings, which also considers the urban context. And investigate how the urban form can influence energy consumptions using GIS and CitySim softwares.	-S/V ration, climate and urban morphology such as SO and SVF/MOS. -H: Buildings space heating. - H + DHW: Domestic hot water consumption.	High SVF, H/Havg, and MOS values, the energy consumption values were about 10% lower than the unfavorable condition values. If high BCR with low Albedo and vegetation, have a higher monthly temperature of 1.5 °C (according to the simulation results).	-SO: Street Orientation -DH: Data provided by the Iren DH company for each mesh.

3- CASE STUDY

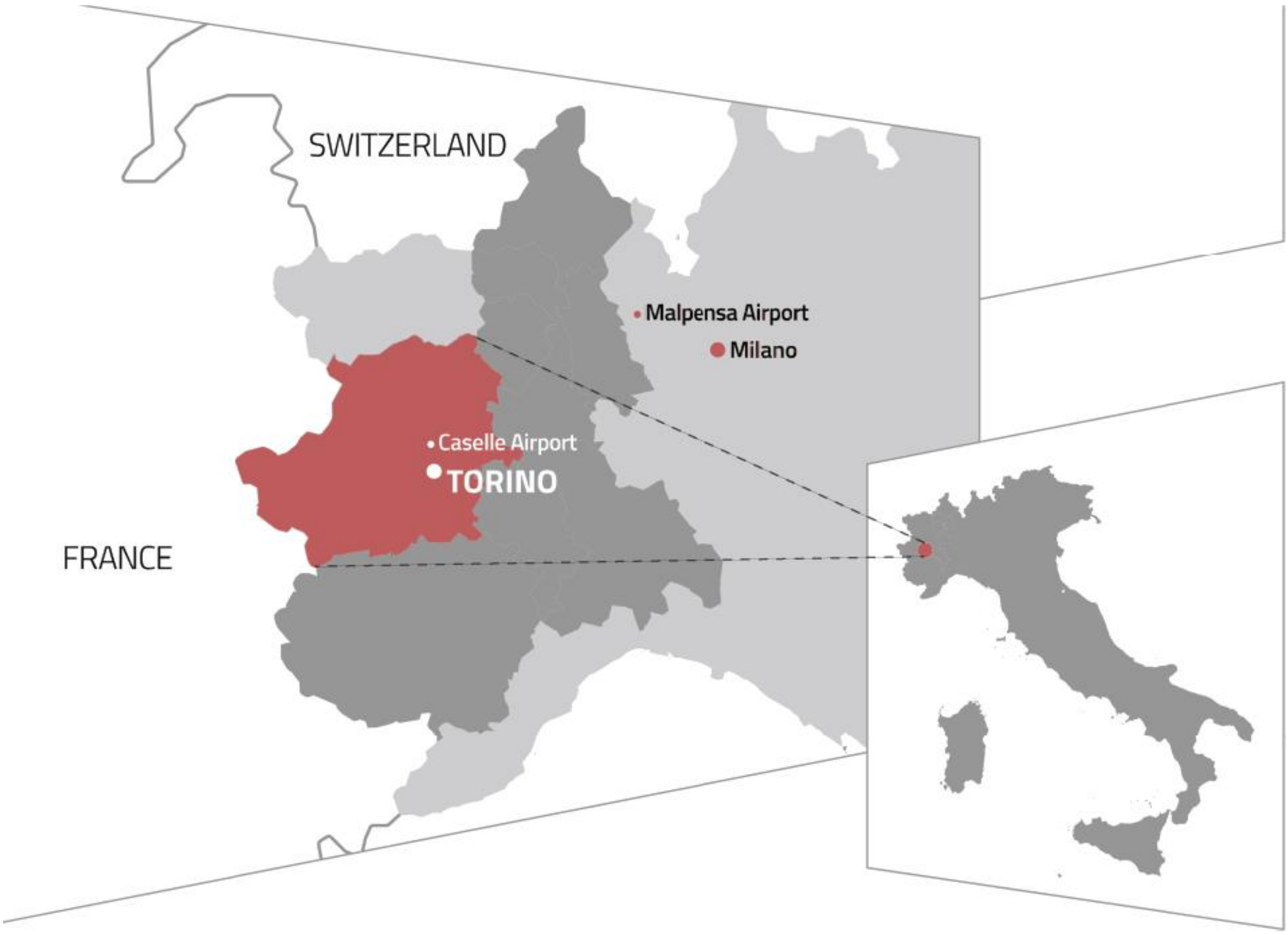


Fig. 2. Location of the city of Turin in relation to Italy

Turin is a city situated in the northwestern piece of italy (Fig. 2). This city is a significant business and social focus in northern Italy. It is the capital city of Piedmont and of the Metropolitan City of Turin and was the primary Italian capital from 1861 to 1865. The city is predominantly located on the west side of the Po River, encircled by the western Alpine curve and Superga Hill and located beneath its Susa Valley. The number of inhabitants in the city legitimate is 866,425 (31 August 2020) while the number of inhabitants in the metropolitan territory is assessed by Eurostat to be 1.7 million occupants. The Turin metropolitan zone is assessed by the OECD to have a populace of 2.2 million. The city's weather includes a European-Atlantic atmosphere, as does a large portion of northern Italy. Winters are decently cold and dry; however, summers are mellow in the slopes and very blistering in the fields. Throughout the colder time of year and fall months banks of mist, which are in some cases extremely thick, structure in the fields however infrequently on the city considering its area located towards the finish of the Susa Valley. Its situation on the east side of the Alps makes the climate drier than on the west side mainly due to the föhn wind impact. In fact, according to the Italian standards, the city of turin has a mainland temperature atmosphere with 2648 at 20°C warming degrees day. The warming period for the city of Turin is from October fifteenth to April fifteenth and covers a time of 183 days; In fact, in turin there are around 60 000 warmed structures, of which 75 percent are private condos and 80% of them were constructed before 1970 (Mutani and Todeschi, 2020). In this study, four Homogeneous zones in Turin were selected to analyze the heating and cooling demand of each neighborhood at urban and building scales (Fig. 3.). The four areas chosen are: Arquata neighborhood (highlighted in orange), Olympic Village neighborhood (highlighted in red), Crocetta neighborhood (highlighted in blue) and Sacchi neighborhood (highlighted in purple). These specific zones in Turin were chosen according to some specific traits:

- Different neighborhoods served by the area warming organization, to have the deliberate hourly warming utilization and considerable Cooling Demand of Residential structures given by the District Heating corporation in the city of Turin.
- Regions portrayed by a homogeneous metropolitan texture, Residential buildings and by measurements of roughly areas of 400 by 400 meters.
- Different zones portrayed by various periods of constructions considerably between 1919 and 2005 (specifically residential buildings).

The four chosen neighborhoods are constructure in different periods in fact, Arquata and Crocetta are two zones characterized by residential buildings constructed between 1919 until 1970s; Were as both Olympic village and Arquata are characterized by a more recent construction period in between 1970 and 2005. This difference in construction period in between the four analyzed zones, will help us understand better the main differences in energy consumptions in relation to the age of the building by considering several structural and urban parameters over the different periods of constructions of residential buildings.

One of the other important factors taken into account in choosing these four neighborhoods, has been the Building Coverage Ratio (BCR) characterized by the relation between the built area and the total census area of the analyzed zones. This ratio will help us understand the built density of these neighborhoods at an urban and city scale.

Fig. 3. Map of the city of Turin: Location of the four studied neighborhoods.

Crocetta Neighberhood

Arquata Neighberhood

Sacchi Neighberhood

Olympic Village Neighberhood

The city of Turin is characterized by 3 700 census parcels. The relation between the Building Coverage Ratio and Census Parcel is described in Table I while the BCR of the four chosen neighborhoods is described in Fig. 4 (Mutani, Carozza, Todeschi and Roland, 2020).

Table. I. Building Coverage Ratio: Different Classes in relation to Census Parcel repartition.

Urban Parameters		Class 1	Class 2	Class 3	Class 4
BCR		BCR ≤ 0.18	0.18 < BCR ≤ 0.34	0.34 < BCR ≤ 0.49	BCR > 0.49
	Census Parcel	687	1115	1405	529
	%	18	30	38	14

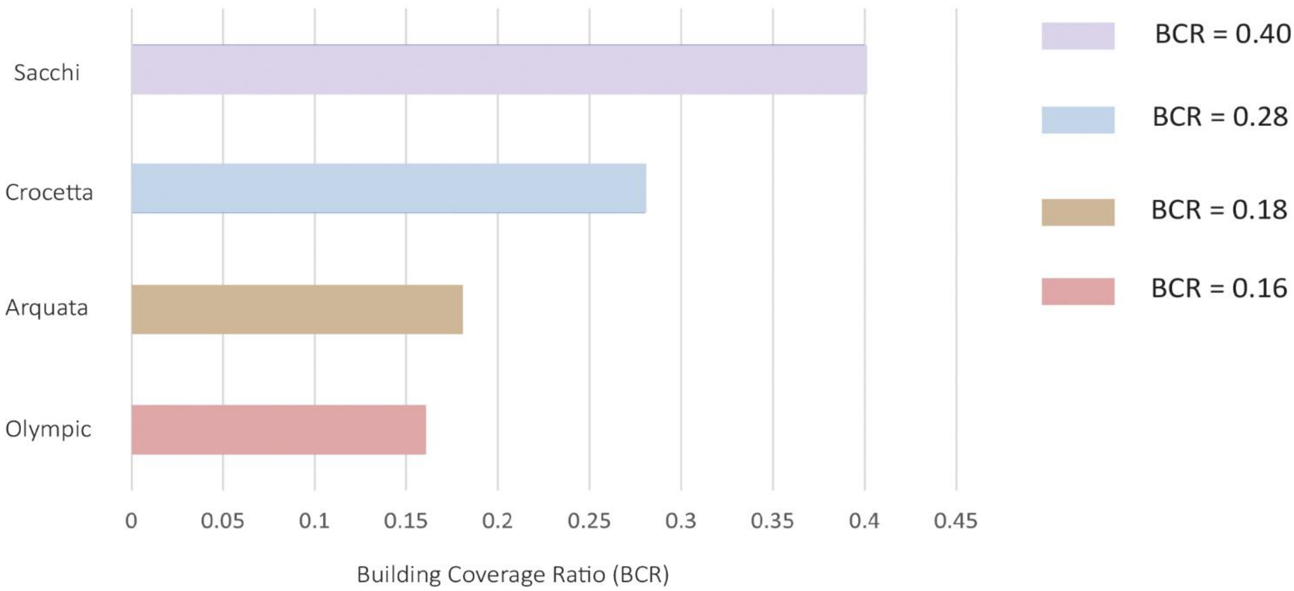


Fig. 4. Building Coverage Ratio (m^2/m^2) of the four selected neighborhoods

- In fact, for what concerns the BCR, around 70% of the enumeration bundles in the city of Turin varies from 0.19 to 0.49. However, the recently built areas such as: Arquata with a BCR equal to 0.18 and Olympic Village neighborhood with a BCR value equal to 0.16, are described by Building Coverage Ratios below the normal estimations of the city. This shows that contemporary built areas, favors a less thick metropolitan texture portrayed by more open spaces and green areas. However, older constructed zones such as: Sacchi with a BCR value equal to 0.4 and Crocetta Neighborhood with a BCR equal to 0.28, are characterized by a Building Coverage Ratio close to the average BCR of the city of Turin. These numbers, show clearly that the older constructed urban zones, have a much higher urban density compared to newer construction, and therefore fewer open spaces and green public areas. Adding to that, the other urban parameter taken into consideration while selecting the four districts, is the urban built density, that represents the proportion between the overall volume of the buildings and the census parcel zone, the greater the amount, the denser the metropolitan framework. In fact, sacchi neighborhood is characterized by the highest built density of approximately 7.22, after it comes crocetta with a value equal to 5.86, while the least dense urban context is in Arquata with a building density equivalent to 3.56 represented in Fig. 5.. The last urban variable taken into account, is the canyon effect, which reflects the height to Width ratio {H/W} expressed in (m/m). This ratio represents the building's height over the width of the street (gap in between the buildings). The neighborhood's building density plays a major role in the variation of the canyon effect. Sacchi and Crocetta neighborhoods, that are characterized by the oldest periods of constructions ranging from before 1919 until 1945, have the highest height to width ratios equivalent to 0.6 and 0.52. while the newly built urban zones (in this case, Arquata and Olympic Village neighborhoods), have a much lower ratio with respective values equal to 0.27 and 0.34. This shows that these districts are portrayed by more open spaces and bigger distances in between the buildings, allowing the better air circulation among the built residential structures during the summer and the winter seasons (Fig. 6.).

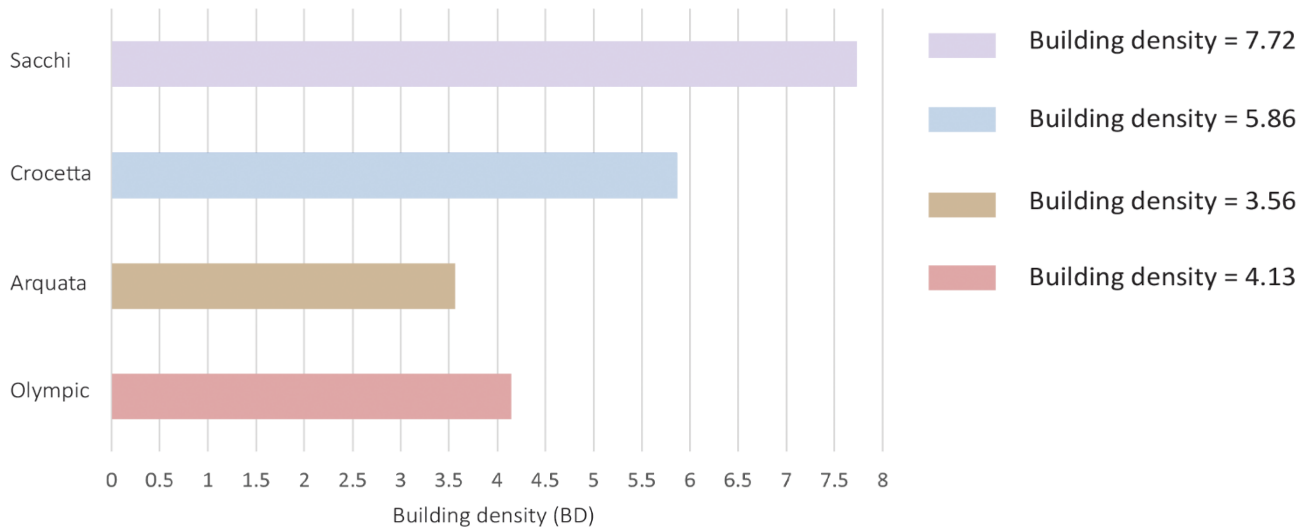


Fig. 5. Building density (m^3/m^2) of the four selected neighborhoods

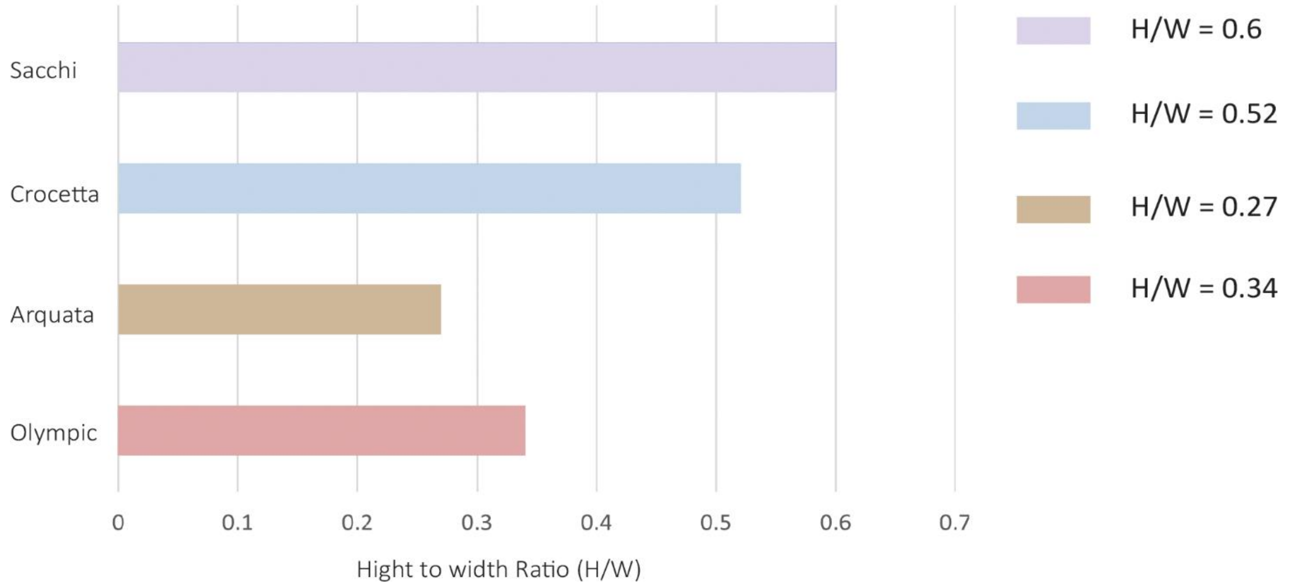


Fig. 6. Height to Width ratio (m/m) of the four selected neighborhoods

Fig. 7. Until Fig. 10. Show in a detailed manner the construction periods, the 3D models, and the land use of the four analyzed neighborhoods in the city of Turin. In fact, all these areas, do not have any private green areas. However, Olympic village and Arquata have the highest public green areas compared to the other two neighborhoods, while Crocetta and Sacchi are characterized by a much higher public asphalted surface. In Crocetta and Sachhi, most of the residential buildings were constructed before 1960. Crocetta neighborhood is categorized by 80% of structures constructed before 1945 compared to 75% for Sacchi and only 15% of residential building were built between 1946 and 1980 for both neighborhoods. Regarding Arquata neighborhood, all the buildings when executed between 1961 and 1970. While Olympic Village features newly built structure, with 80 % of residential buildings constructed after 2000 and only 20 % of them built among 1980 and 1990. Both Crocetta and Sacchi are characterize by a very high gross built area: 82 100 m^2 for the first neighborhood, and 99 400 m^2 for the second one. While both more recently built areas Arquata and Olympic Village have a much lower gross built area with 22 300 m^2 and 52 100 m^2. Sacchi neighborhood has the most population density with 4 271 inhabitants. After that comes Crocetta with 3 703 inhabitants, followed by Olympic Village with 2 803 inhabitants and Arquata with 1 756.

According to that, we can conclude that older built neighborhoods, have a higher Building Coverage Ratio with very high gross built areas compared to newly constructure urban areas, Less public green areas, and a much higher public asphalted surface. Adding to that, the newer urban neighborhoods in this case, Arquata and Olympic Village are characterized by a lower population density compared to older areas such as Crocetta and Sacchi.

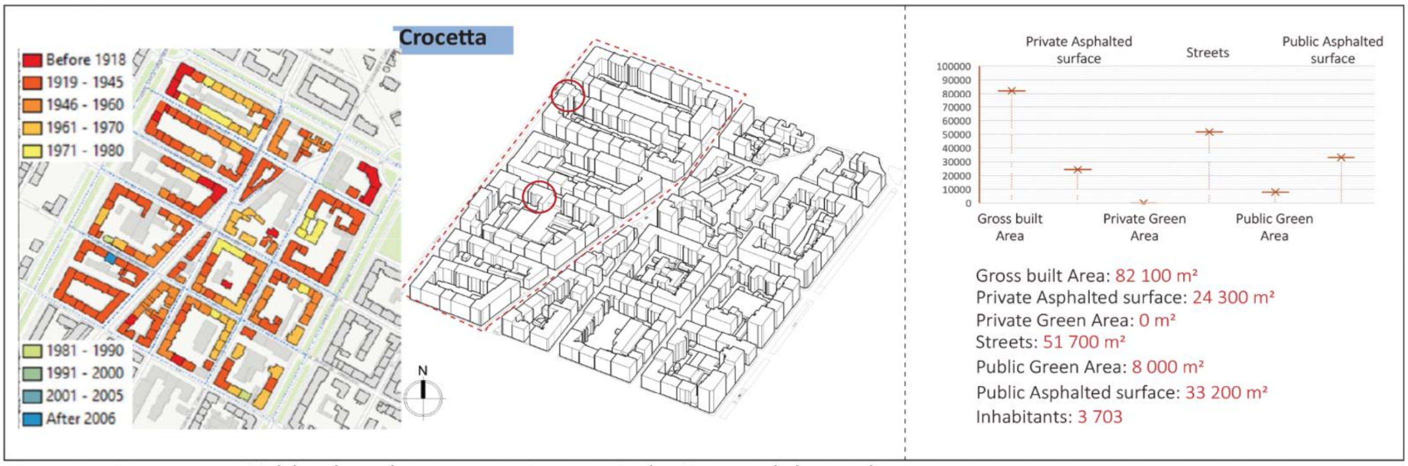


Fig. 7. Crocetta Neighborhood: Construction Periods, 3D Model, Land Use.

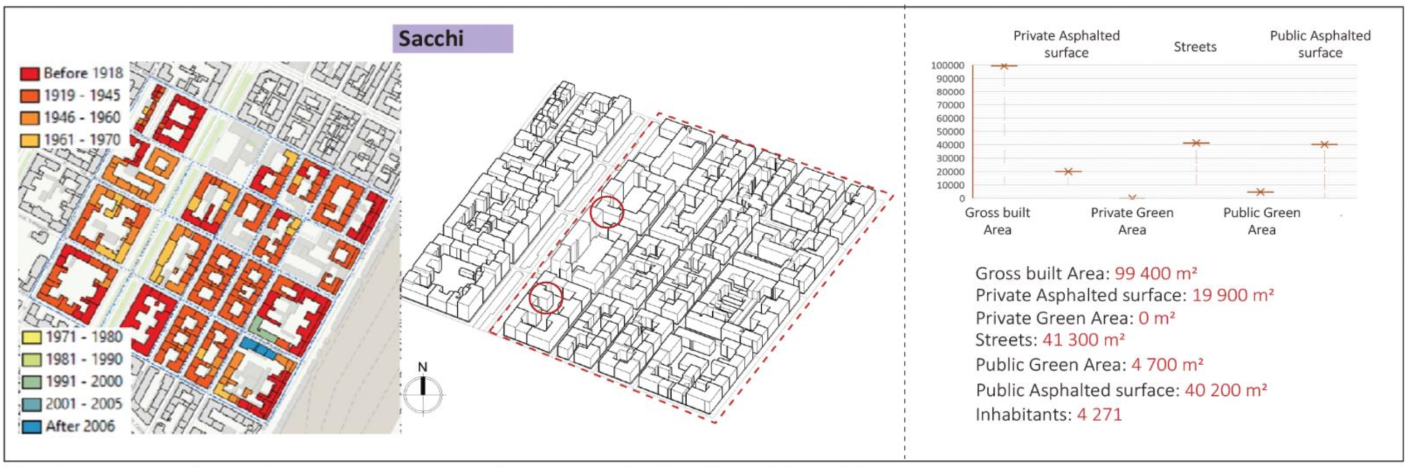


Fig. 8. Sacchi Neighberhood: Construction Periods, 3D Model, Land Use.

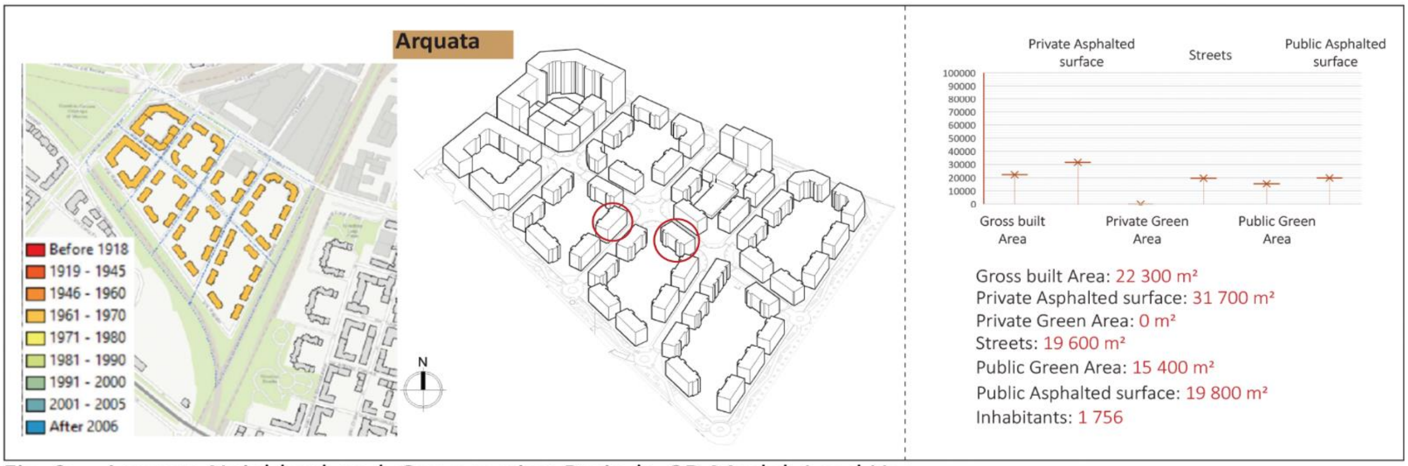


Fig. 9. Arquata Neighborhood: Construction Periods, 3D Model, Land Use.

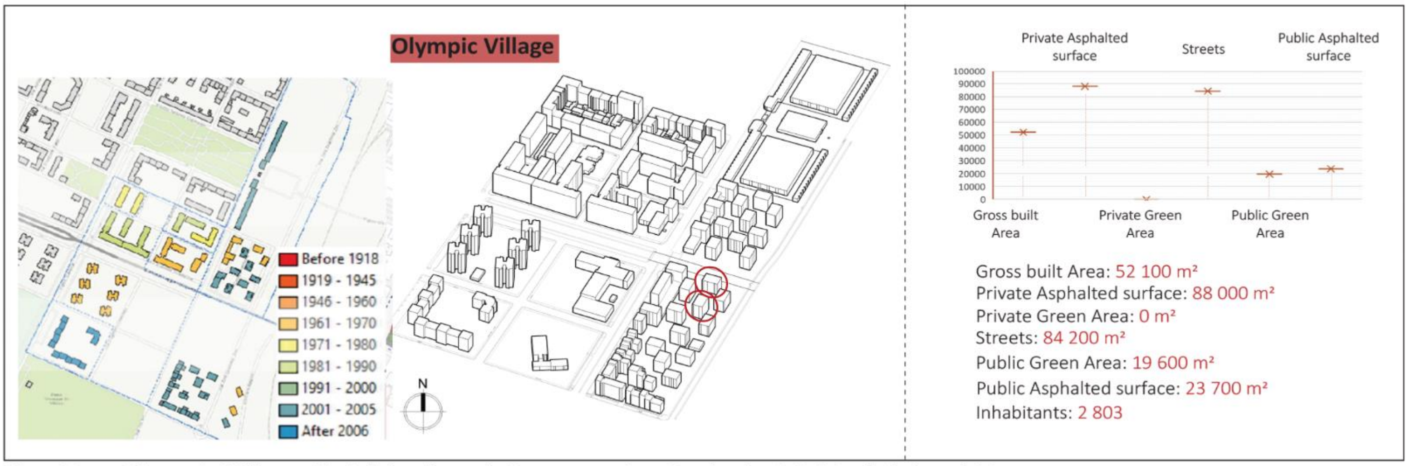


Fig. 10. Olympic Village Neighborhood: Construction Periods, 3D Model, Land Use.

4- METHODOLOGY

The purpose of this study is to analyze the impact of several building and urban variables on the heating and cooling consumption of residential buildings taking into account their date of construction. In fact, both the heating and cooling demands of a building, depend mainly on the building's characteristics as well as the context surrounding this specific structure along with the climatic changes over a year:

$$\left.\frac{kWh}{m^2}\right|_{measured} = \left.\frac{kWh}{m^2}\right|_{building} + \left.\frac{kWh}{m^2}\right|_{context}.$$

In this Thesis, a sensitivity analysis is conducted, by comparing results of energy demands: of different buildings characterized by various periods of construction in between 1919 until 2005. The Energy results, are retrieved from the energy simulation of four urban models, using the engineering software CitySim. In fact, this study will mainly be focused on residential buildings in specifically chosen neighborhoods in the city of Turin: Arquata, Olympic Village, Crocetta and Sacchi.

Fig. 9. Describes in details the methodology followed in this work. In fact, three input data were inserted in the energy models of the four chosen urban areas: Building scale data, Climatic data, and finally urban data. Each of these inputs, were composed of several variables and parameters. For the building scale the variable analyzed are: Building's density, shape, Period of construction (indicating the building's infiltration rate, thermal capacity, the characteristics of the transparent and opaque envelope regarding the materials used with their insulation value), Building's Surface to Volume ratio (ranging between: 0.30, 0.37, 0.39, 0.45, 0.55), building's orientation, infiltration rate (ranging between: 0.2, 0.4 and 0.6), Glazing Ratio (ranging between: 0.2, 0.4 and 0.6), and thermal transmittances of windows, walls, roof and floor expressed in W/(m^2.K). Adding to that, the Building Coverage Ratio that is expressed in (m^2 / m^2) this factor can have a minimum value of 0 where the plot is totally empty, and a maximum value of 1 where the urban zone or neighborhood is fully covered with buildings, in this case study, the {BCR} of the four neighborhoods ranges between: 0.16, 0.18, 0.28 and 0.40, The Main Street Orientation, the Canyon effect and the building density, are the main composites of the Urban scale data considered in order to understand the impact of these different parameters on the yearly heating and cooling energy consumptions. After that, both the buildings scale data and the climate data were inserted to the energy model using

CitySim software in relation to the construction period of the selected residential buildings. This is when, the Energy Simulation regarding each building were retrieved in Excel sheets figuring the yearly, hourly energy heating and cooling demand is calculated and analyzed.

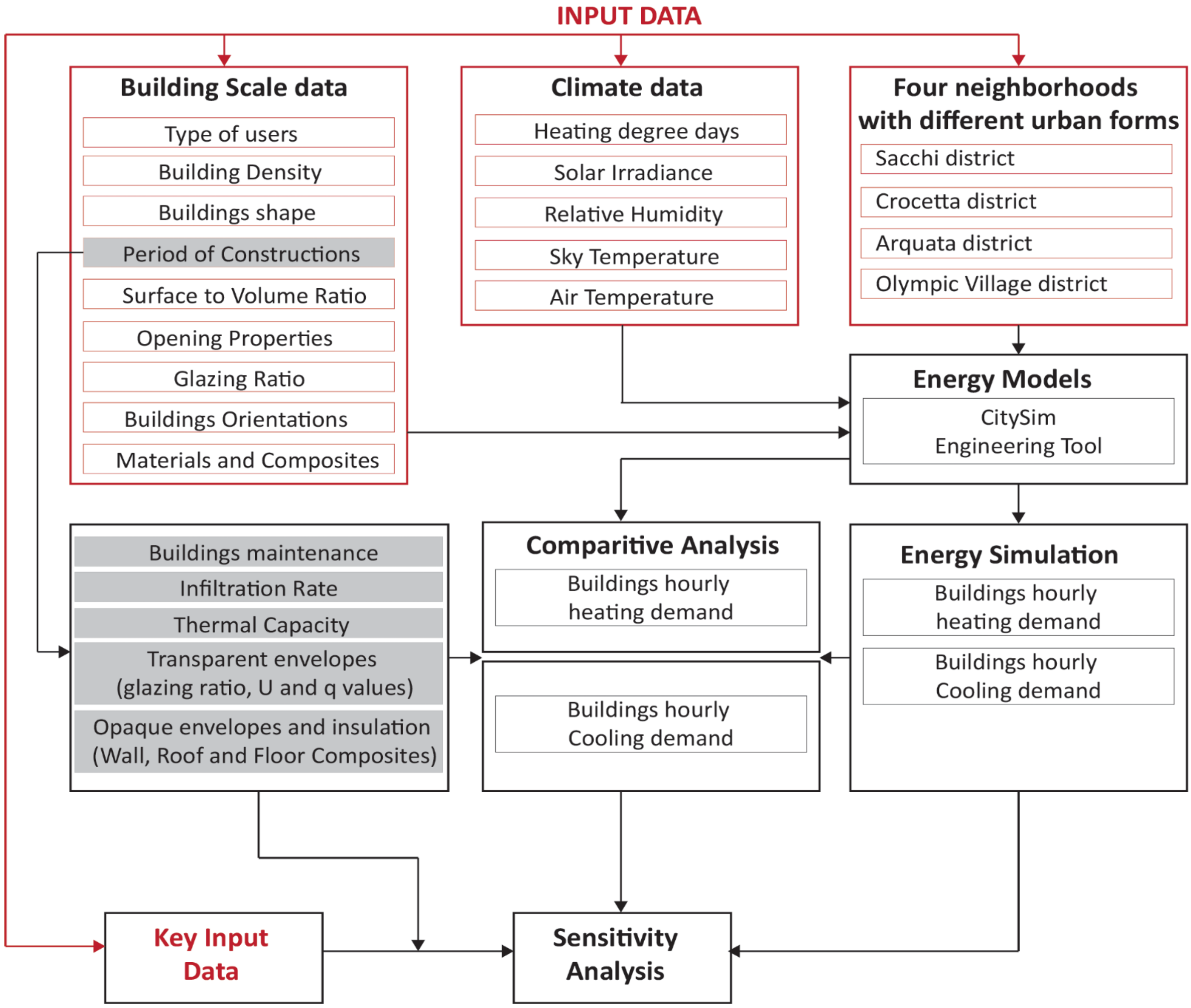


Fig. 9. Flowchart of the Methodology applied in this study: Input data (Buildings data, Climatic data, and Urban data), Energy models data, Energy Simulation with a sensitivity analysis of the results of buildings and neighborhoods located in the city of Turin.

Finally, the simulated data were compared and observed, by sensitively analyzing the results in relation to buildings variables, Urban Parameters, and climatic data. The aim of this work is to analyze the impact of these different factors on the average yearly energy consumption of the building and how the built period of the building can influence its energy demand.

4.1- INPUT DATA

In this study, the input data collected or calculated was a crucial step in order to analyze several simulated buildings in relation to their energy consumption in the most accurate possible manner. In fact, Table. II. Shows the main input data used in this work with their related sources and used tools. The following table was divided into three different analyzed scales: Building scale data, Urban scale data and finally City scale data.

Table. II. Building, Urban and city scale Input data used with their sources and the used tools.

	Input data	Source	Tools
Building Scale	Type of users and geometrical shape	Geoportale-Cadastral map	3D Model
	Period of Construction	Geoportale-Cadastral map	-
	Infiltration Rate	norm SIA 380/1:2009	-
	Opening Properties	UNI/TS 11300-1	-
	Materials and Composites	UNI/TR 11552	-
	Surface to Volume Ratio	Geoportale-Cadastral map	3D Model
	Buildings Orientations	Geoportale-Cadastral map	2D Model
City Scale	Climate data	meteonorm.com	meteonorm Software

Building data implies several factors: the type of users retrieved from the Cadastral map of the city of Turin as well as the 2D drawings that allowed the creation of the 3D models and therefore to determine the geometrical shape of the analyzed residential buildings as well as their Surface to Volume ratio. Adding to that, the period of construction allowed us to assign: the buildings Glazing ratio along with its thermal transmittance, as well as its ventilation rate, and finally the materials thickness, density and thermal transmittance of the walls, roofs, and floors composites. In fact, the four main periods of construction were analyzed in this study: residential structure built before 1919, between 1919-1945, 1961-1970 and finally the most recent one that is represented in Olympic village neighborhood constructed between 2001 and 2005. Concerning the input data inserted at an urban scale, most of the factors were retrieved from Geoportal and therefore from the Cadastral map of the city of Turin. In fact, both the Building Coverage Ratio and the Main street Orientation were deducted from the 2D drawings of the four analyzed neighborhoods. The calculation of the Height/Width factor was based on the drawn 3D models, while the sky View Factor followed the simulation results using the Engineering Tool {CitySim Pro}.

4.2- ANALYZED BUILDING VARIABLES

Five building variables were analyzed in this work. In fact, a comparative approach was performed in order to observe the impact of these variables on the Energy Heating and Cooling demand and how this energy consumption can be minimized in relation to different factors. The simulation regarding the building variables, was executed on several chosen buildings that are characterized by different periods of construction. This approach will help in understanding the relation between the Energy consumption and the age of the building. The analyzed building variables are:

- Buildings Surface to Volume Ratio (S/V) expressed in {m^2 / m^3}. This ratio is the proportion between the heat lost surface and the gross warmed Volume of a structure. It demonstrates how compact the building is, and therefore recognizing the building's typology. The more prominent the surface territory, the more noteworthy the potential warmth gain or loss is reflected. Therefore, a smaller S/V proportion suggests lower heat gain and loss and thusly a more compact building. Building's Surface is the sum of areas of outer appearances or building's envelope taking into consideration the areas of the walls and roofs.

- Building Orientation {BO} this variable, indicates the building's Solar exposure affecting its Energy consumption during summer and winter seasons. Several buildings with different orientations were analyzed by comparing their cooling and heating demands. The examined orientations are: E-W {90 °}, N-S {0 °), NE-SW {45 °- 22 °} and SE-NW {135 °- 122 °} illustrated in Fig .11. in fact, this factor, mainly plays an important role on the impact of the yearly heating and cooling energy consumptions, in regard to the sun's orientation that is from the East to the West. However, during the winter season, the angle of exposure is tighter compared the summer period (Fig. 12.).

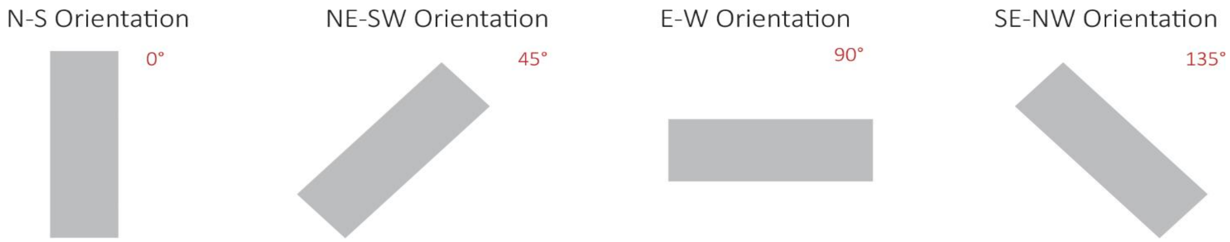


Fig .11. Illustrations of the building's orientations of {N-S}, {NE-SW}, {E-W}, and {SE-NW}, with their respective degrees.

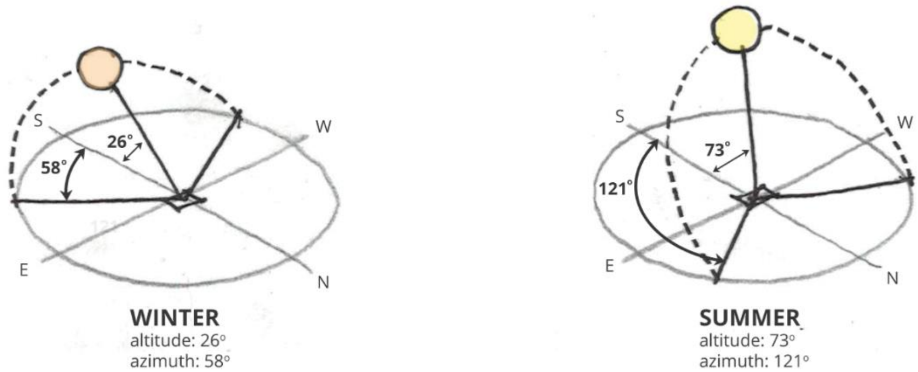


Fig .12. Illustrations of the sun's orientations during summer and winter with their respective degrees of altitude and azimuth.

- Building's infiltration rate expressed in (h^{-1}) is the unintentional or coincidental presentation of outdoor air into a building, ordinarily through cracks in the structure envelope and through utilization of entryways such as doors. The higher the infiltration rate, the more outdoor air is penetrating inside the building and therefore affecting the building's internal temperature. In this analysis, three main infiltration rate ranges were examined: 0.2, 0.4 and 0.6.

- Glazing ratio also known as Window to Wall Ratio, is the proportion of the transparent envelope in relation to the façade's surface. The smaller the glazing ratio, the smaller the proportion of the window compared to the wall. In this analysis, three main ratios were studied: 0.2, 0.4 and 0.6. These different ranges will help in the understanding of the impact of the glazing ratio on the yearly heating and cooling demands of the residential buildings following several periods of constructions.

- Windows thermal transmittances expressed in W/(m^2.K), retrieved from UNI/TS 11300-1 according to building's construction period. The U-value of the opening properties were analyzed as well. The lower the U-value the more the window is insolated. In fact, older constructions are generally characterized by a higher windows U-value shown in Table. III.. In this study, three ranges were analyzed: 2.15, 4.40 and 4.90.

Table. III. Building's U-values in relation to its period of construction: data according to (Mutani G., and Todeschi V., 2020).

Period of Construction	before 1918	1919-1945	1946-1960	1961-1970	1971-1980	1981-1990	1991-2005
$U_{windows}$ W/m²/K	4.85	4.75	4.40	4.90	4.57	3.80	2.15

- Building's Materials and composites retrieved from UNI/TR 11552 that varies according to the building's construction period. In this variable, walls, roofs, and floors composites were taken into consideration by specifying their thermal transmittance, resistance, materials densities as well as their thermal capacity. Concerning the U-values of walls, three main thermal transmittances were analyzed: 0.67, 0.9 and 1.10. for the roof composites the studied ranges are: 0.53, 1.27 and 1.60. and finally, two different floor materials were compared: SOL03 characterizing buildings constructed from 1919 until 1960 and SOL04 for more recently built structures.

Table. IV. This table, shows the chosen analyzed neighborhoods in relation to different building variables.

	Building Variables							
Case Study	S/V	Building's orientation	Infiltration Rate	Glazing Ratio	U-value Window	U-value wall	U-value Roof	U-value Floor
Crocetta neighberhood	✓	✓	✓	✓	✓	✓	✓	✓
Sacchi neighberhood	✓	✓	✓	✓	✓	✓	✓	✓
Arquata neighberhood	✓	✓	✓	✓	✓	✓	✓	✓
Olympic neighberhood	✓	✓	✓	✓	✓	✓	✓	✓

Table. III. Shows the analyzed neighborhoods for each chosen variable at a building scale in relation to their Energy consumption. In fact, for the Surface to Volume ratio, all four neighborhoods were analyzed in order to understand the relation between this specific ratio, the building's construction period and the Energy demand. For the opening properties, Arquata and Olympic Village were studied due to the abondance of identically shaped buildings with different building orientations and therefore various solar exposures. Adding to that, for the materials and composites variables, both Sacchi and Olympic Village neighborhoods where analyzed. In fact, both of these urban zones are characterized by buildings constructed between 1919 and 2005, which allowed the examination of different walls, roofs and floors materials and their impact on the Energy Heating and Cooling consumption of the building.

4.3- SENSITIVITY ANALYSIS

A sensitivity analysis was performed in this work, by comparing several input data at different neighborhood scale parameters following specific ranges for each building variable. Table. V. represents the diverse ranges taken into consideration for each input data along with their respective units: Surface to Volume ratio {S/V} (ranging between 0.3, 0.37, 0.39, 0.45 and 0.55 m^2/m^3), two building's orientations equivalent to 45 {NE-SW} and 135 degrees {NW-SE}, building infiltration rate (ranging between 0.2, 0.4 and 0.6 h^{-1}), Glazing ratio (ranging between 0.2, 0.4 and 0.6), Windows thermal transmittances (with U-value ranging between 2.15, 4.40 and 4.90 $W/(m^2.K)$), wall thermal transmittances (with U-value ranging between 0.67, 0.90 and 1.10 $W/(m^2.K)$), Roof thermal transmittances (with U-value ranging between 0.53, 1.27 and 1.60 $W/(m^2.K)$), and finally floor thermal transmittances (with U-value ranging between 1.16 and 1.25 $W/(m^2.K)$). These different values were examined in relation to the cited building variables by comparing and analyzing how these ranges can impact the yearly heating and cooling energy consumptions of residential structures, following different periods of constructions in Sacchi, Crocetta, Arquata and Olympic Village neighborhoods. Urban factors were also taken into account following the four studied districts. In fact, the building coverage ratio ranged between 0.16, 0.18, 0.28 and 0.4. while the building density were equivalent to: 3.56, 4.13, 5.86 and 7.72. and finally, the canyon effect that represents the Height to Width ratio {H/W}, ranging between 0.27, 0.34, 0.52 and 0.60 (Table. V.).

Table. V. This table, shows the Input data in relation to their respective studied ranges, applied is the sensitivity analysis.

Scale	Input data	Unit	Ranges
Building Variables	Surface to Volume Ratio	m^2/m^3	0.3 - 0.37 - 0.39 - 0.45 - 0.55
	Building Orientation	°	45 - 135
	Building Infiltration Rate	h^{-1}	0.2 - 0.4 - 0.6
	Glazing Ratio	——	0.2 - 0.4 - 0.6
	Thermal Transmittances of Window	$W/(m^2.K)$	2.15 - 4.40 - 4.90
	Thermal Transmittances of Wall	$W/(m^2.K)$	0.67 - 0.9 - 1.10
	Thermal Transmittances of Roof	$W/(m^2.K)$	0.53 - 1.27 - 1.60
	Thermal Transmittances of Floor	$W/(m^2.K)$	1.16 - 1.25
Urban Variables	Building Coverage Ratio	m^2/m^2	0.16 - 0.18 - 0.28 - 0.40
	Building Density	m^3/m^2	3.56 - 4.13 - 5.86 - 7.72
	Height to Width Ratio {H/W}	m/m	0.27 - 0.34 - 0.52 - 0.60

For the building variables, the different ranges of the designated input data were inserted into the Engineering Software CitySim Pro. The results of these changed simulations, where analyzed in a comparative way on selected buildings retrieved from the four chosen neighborhoods. The sensitivity analysis of these Simulations was investigated and compared in order to understand the impact of these variables along with their different ranges of the average yearly Heating and Cooling consumptions of residential buildings. Adding to that, Table. VI. embodies all the studied buildings used for the sensitivity analysis characterized mainly by two opposite orientations and approximately similar Surface to Volume ratios: NE-SW and NW-SE. the chosen residential buildings are: S27 and S22 in Sacchi district characterized by the oldest period of construction (before 1919), C110 and C189 in Crocetta neighborhood with a built cycle ranging from 1919 until 1945, A1 and A9 in Arquata zone with a more recent period of construction (1961-1970), and finally O11 and O8 in Olympic village neighborhood with the most recent structures (2001-2005).

Adding to that, each analyzed urban zone, is illustrated by different urban parameters. The oldest district (Sacchi) with the most abundant residential buildings constructed before 1919, has a building Coverage ratio equal to 0.4, with a building density of 7.72 and a Height to Width ratio equivalent to 0.6. In Crocetta (1919-1945), is characterized by: a BCR equal to 0.28, building density of 5.86 and a canyon effect of 0.52. adding to that, even though Arquata has an older construction period compared to Olympic Village, it has a lower building density and Height to Width ratio respectively equal to 3.56 and 0.27. Finally, Olympic Village neighborhoods, that is the most recently built studied urban zone (2001-2005), shows to have the lowest Building Coverage Ratio (BCR equal to 0.16), a building density of 4.13 and a canyon effect {H/W} equivalent to 0.3 (Table. VI).

These results show that Sacchi neighborhood has the densest urban fabric while Arquata has the lowest built amount of construction in relation to its studied census parcel. More recently constructed metropolitan zones, are characterized by bigger open spaces and therefore more spaces in between the built structures, allowing the circulation of natural ventilation.

In fact, these comparative simulated outcomes can help in the identification of the most ideal range of the analyzed input data allowing the recognition of the most energy efficient scenario regarding the studied buildings.

Table. VI. This table, shows the Input data at four different neighborhood scales, in relation to their respective Studied buildings along with their periods of construction.

			NEIGHBERHOOD SCALE DATA			
District	**Buildings ID**	**Period of construction**	**Main orientation of the street**	**Building density {m³/m²}**	**Building coverage ratio {m²/m²}**	**Height to Width Ratio {m/m}**
Sacchi	S27	before 1919	0.8	7.72	0.4	0.6
	S22	before 1919	1.2	7.72	0.4	0.6
Crocetta	C110	1919-1945	0.8	5.86	0.28	0.52
	C189	1919-1945	1.2	5.86	0.28	0.52
Arquata	A1	1961-1970	0.8	3.56	0.18	0.27
	A9	1961-1970	1.2	3.56	0.18	0.27
Olympic Village	O11	2001-2005	0.8	4.13	0.16	0.34
	O8	2001-2005	1.2	4.13	0.16	0.34

5- RESULTS

The conducted results of this thesis were observed on a macro and micro scales. In fact, different building variables according to several urban scale data, were studied and examined to understand their impact on the energy consumption of residential buildings in four chosen homogeneous zones or neighborhoods in the city of Turin Italy. Five factors for both scales were analyzed taking into consideration the period of construction as well as the urban pattern's density affecting the built structure's surroundings such as open spaces or gaps in between the buildings as well as their solar exposure. In fact, Crocetta and Sacchi districts, are characterized by a dense urban fabric with limited outdoor areas and construction periods ranging between 1919 and 1980s. whereas the other two zone: Arquata and Olympic Village, illustrate a much recent urban configuration with more gaps in between structures and therefore more outdoor spaces and green areas. Each district is studied separately by inserting different ranges of building variable on two chosen residential structure characterized by opposite orientations and approximately similar Surface to Volume values. Different heating and cooling Energy consumption results were analyzed separately in order to understand the impact of the inserted input data with several ranges on the yearly energy utilization. The results of the energy simulations related to the chosen residential buildings, was conducted using the engineering Software CitySim pro, by changing the values of the studied building variables: Infiltration rate (ranges equivalent to 0.2, 0.4 and 0.6 h^{-1}), Glazing ratio (ranges equivalent to 0.2, 0.4 and 0.6), Thermal transmittances of walls (ranges equivalent to 2.15, 4.40 and 4.90 $W/(m^2.k)$), Thermal transmittances of roof (ranges equivalent to 0.53, 1.27 and 1.60$W/(m^2.k)$), and finally, Thermal transmittances of floor (equivalent to 1.16 and 1.25 $W/(m^2.k)$).

This examination will help in the comparative and sensitivity analysis conducted, to understand the impact of the different input data studied on the yearly energy consumption of Residential buildings in these four cited neighborhoods and understand which of these parameters had the most impact of the structure according to different periods of construction.

In fact, Fig. 13., illustrates the two studied buildings for each of the four neighborhoods: Sacchi, Crocetta, Arquata and Olympic Village. In Sacchi district, building IDs of S27 and S22 were studied constructed before 1919, in Crocetta C110 and C189 characterized by a built period between 1919 and 1945, in Arquata residential structures A1 and A9 were analyzed with a more recent construction date (1961-1970), and finally O11 and O8 in Olympic Village with the newest constructed structures (2001-2005). Each two chosen buildings for the different urban zones, are characterized by respective opposite orientations of {NE-SW} and {NW-SE}.

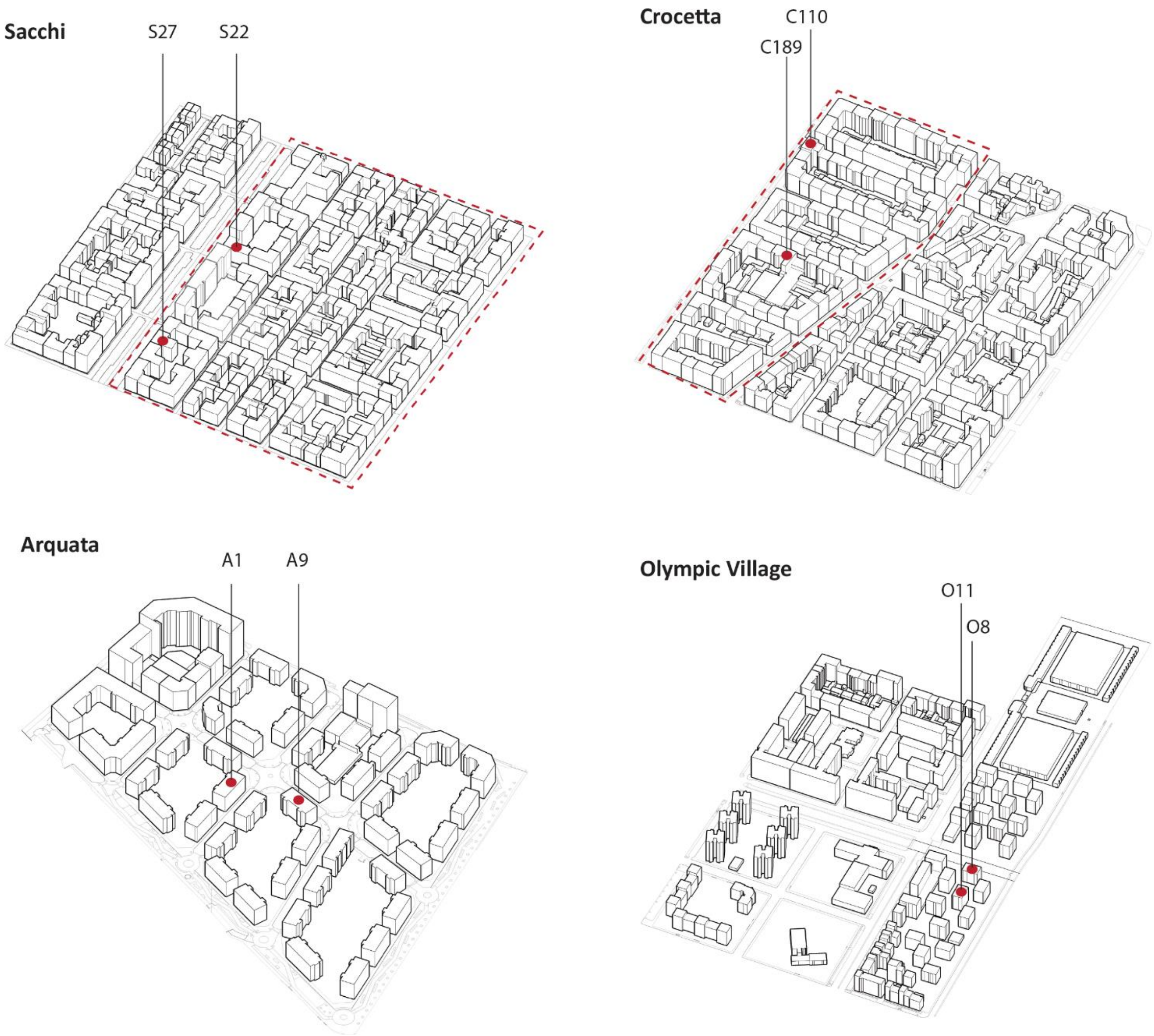


Fig. 13. Three dimensional representations of the four analyzed neighborhoods: Sacchi, Crocetta, Arquata and Olympic Village, indicating the two studied buildings for each district.

5.1-- Sacchi district: Impact of energy-related building variables

Sacchi neighborhood, is located in the city of Turin, Italy. This urban zone is characterized by a big number of buildings constructed before 1919. In fact, it has the highest Building coverage ratio (0.4), that reflects the gross built area of the neighborhood over the census parcel area, with a building density equivalent to 7.72 m^3/m^2, that represents the proportion between the overall volume of the buildings and the census parcel zone. And a Height to Width urban ratio of 0.6 m/m. Two buildings were analyzed (S27 and S22), were their respective heating and cooling demands were compared and analyzed following different ranges of urban variable inserted in the engineering software CitySim Pro. The analyzed residential building parameters are: Infiltration rate (ranges equivalent to 0.2, 0.4 and 0.6 h^{-1}), Glazing ratio (ranges equivalent to 0.2, 0.4 and 0.6), Thermal transmittances of walls (ranges equivalent to 2.15, 4.40 and 4.90 W/(m^2.k)), Thermal transmittances of roof (ranges equivalent to 0.53, 1.27 and 1.60W/(m^2.k)), and finally, Thermal transmittances of floor (equivalent to 1.16 and 1.25 W/(m^2.k)). In fact, for each variable, results were separated into monthly heating and cooling energy data, Hourly results for three heating and cooling season (5th of February, 7th of November, 15th of December, 5th of June, 7th of July and finally 15th of August), as well as the hourly heating and cooling Energy consumptions over the course of one year (equivalent to 8761 hours).

5.1.1- Building's Surface to Volume ratio

In fact, the Surface to Volume {S/V} proportion is a ratio indicating the compactness of a certain structure or building. It is frequently communicated as the 'heat misfortune structure factor', which is the proportion the building's envelope area (walls, roofs, terraces…etc.) to the treated floor area of the designated structure. This ratio will help in the identification of the building's typology, weather it is a small condominium house or a tower for example. In this case, building S27 has a S/V ratio equal to 0.39 while S22 has a bigger value of 0.45. the two structures are characterized by opposite orientations of {NE-SW} and {NW-SE} respectively. S27 is characterized by a bigger heated Volume (7810 m^3), compared to S22 (6857 m^3) shown in Table. VII.. Building S27 has an energy heating consumption equal to 25.55 kWh/m^3/y, with a cooling demand of -4.14 kWh/m^3/y. However, S22 is characterized by a lower energy utilization with 23.51 kWh/m^3/y warmth consumption, and -3.43 kWh/m^3/y for its yearly cooling consumption (Fig. 14).

Table. VII. This table, shows the heated volume, building orientation, Surface to Volume ratio and Energy heating and cooling of buildings S27 and S22.

Building ID	Heated Volume	Building orientation	S/V	Energy heating Consumption (kWh/m³/y)	Energy cooling Consumption (kWh/m³/y)
S27	7810	NE-SW	0.39	25.55	-4.14
S22	6857	NW-SE	0.45	23.51	-3.43

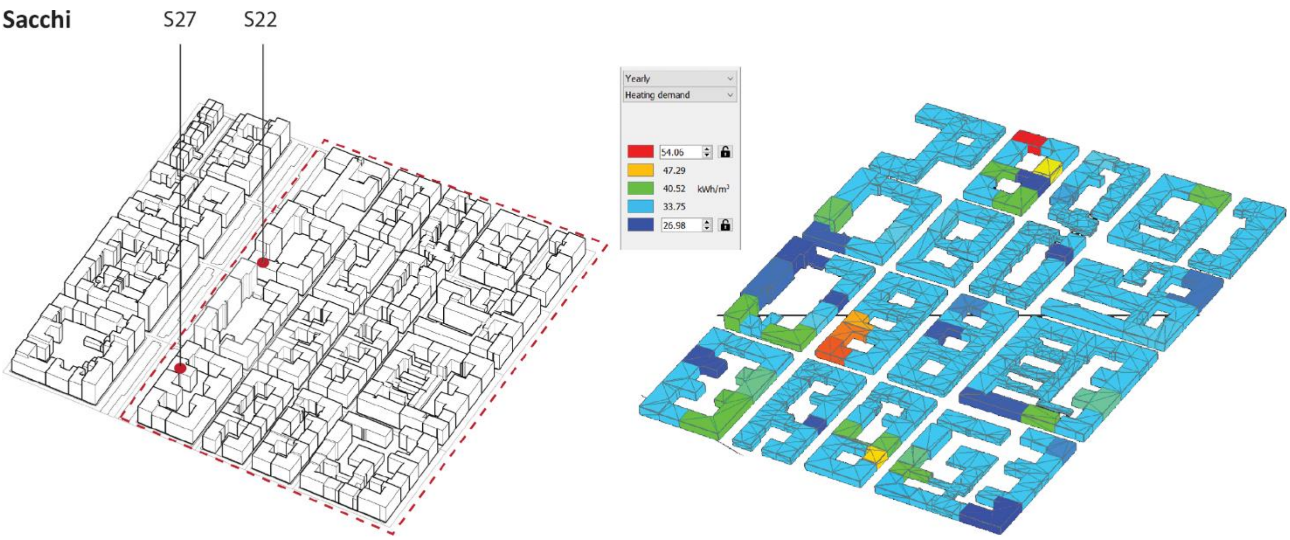


Fig. 14. Three-dimensional representation of Sacchi neighborhood indicating the two analyzed buildings. And Yearly Heating demand of Sacchi district calculated by CitySim Pro.

5.1.2- Building's infiltration rate (h^{-1})

Infiltration is the unintentional or coincidental presentation of outdoor air into a building, ordinarily through cracks in the structure envelope and through utilization of entryways such as doors. The higher the infiltration rate, the more outdoor air is penetrating inside the building and therefore affecting the building's internal temperature. In this analysis, three different infiltration rates were studied: 0.2 h^{-1} (indicated in green), 0.4 h^{-1} (indicated in blue), and 0.6 h^{-1} (indicated in orange), in order to compare and analyse the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (S27 and S22). The first warmth Energy utilization results are shown in Fig. 15. In fact, the monthly heating demand of both structures S27 and S22, increased when the infiltration rate was higher, mainly due to the penetration of the cold

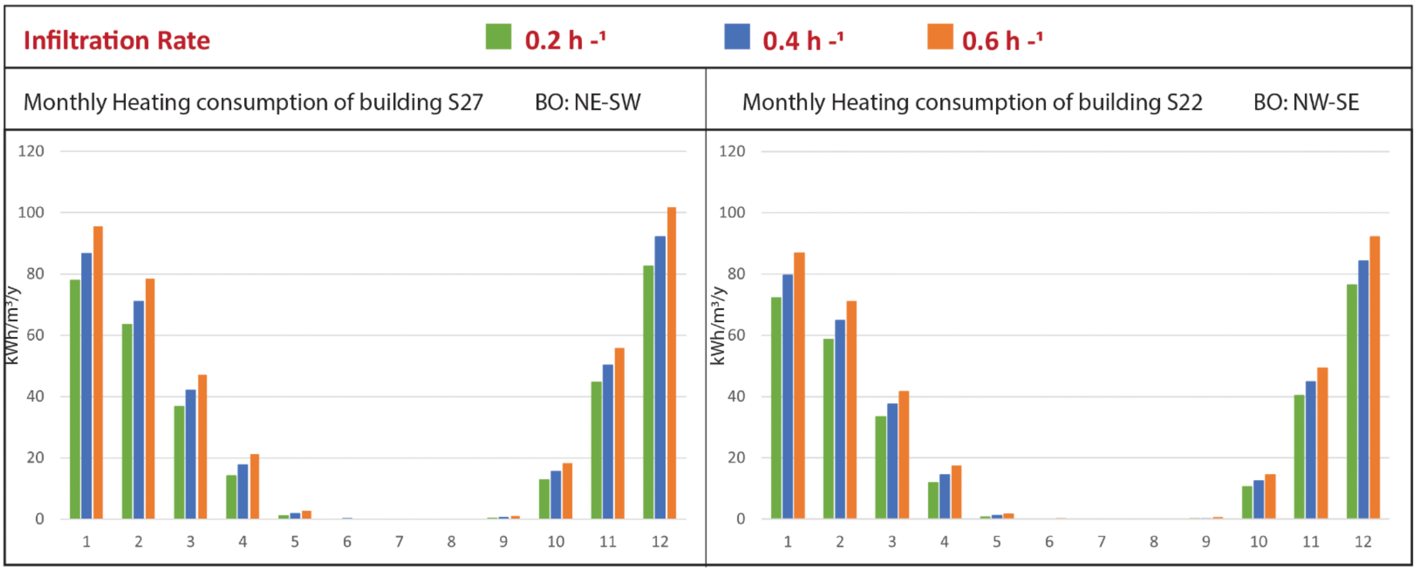


Fig. 15. **Monthly heating consumption of buildings S27 and S22 according to three infiltration rates.**

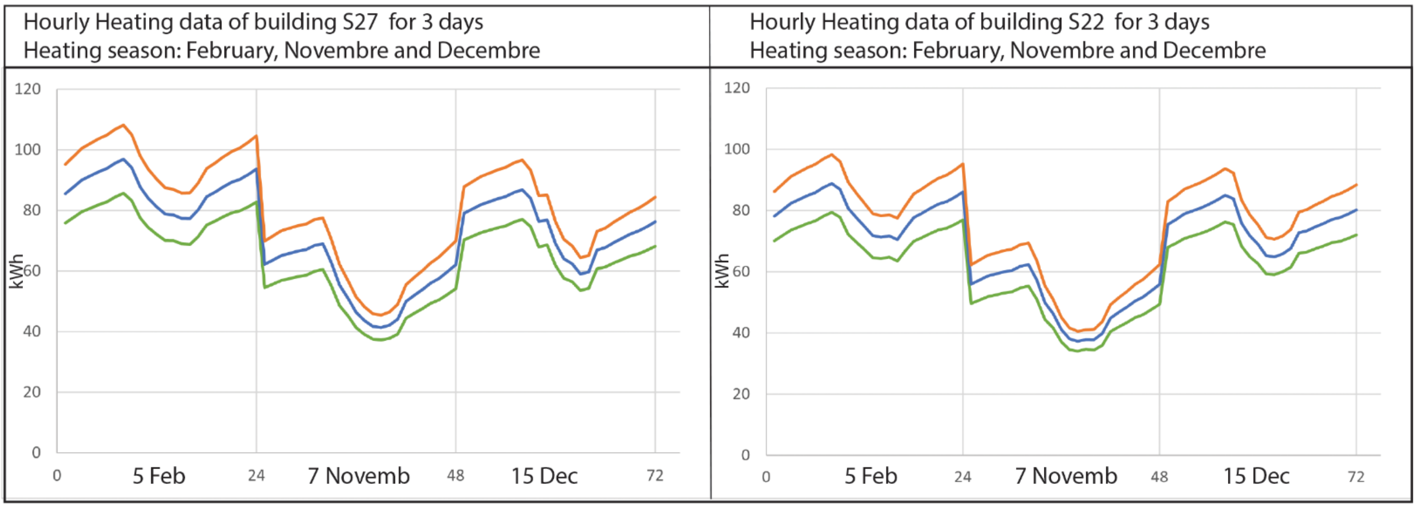


Fig. 16. **Hourly heating consumption of buildings S27 and S22 according to three infiltration rates during three days.**

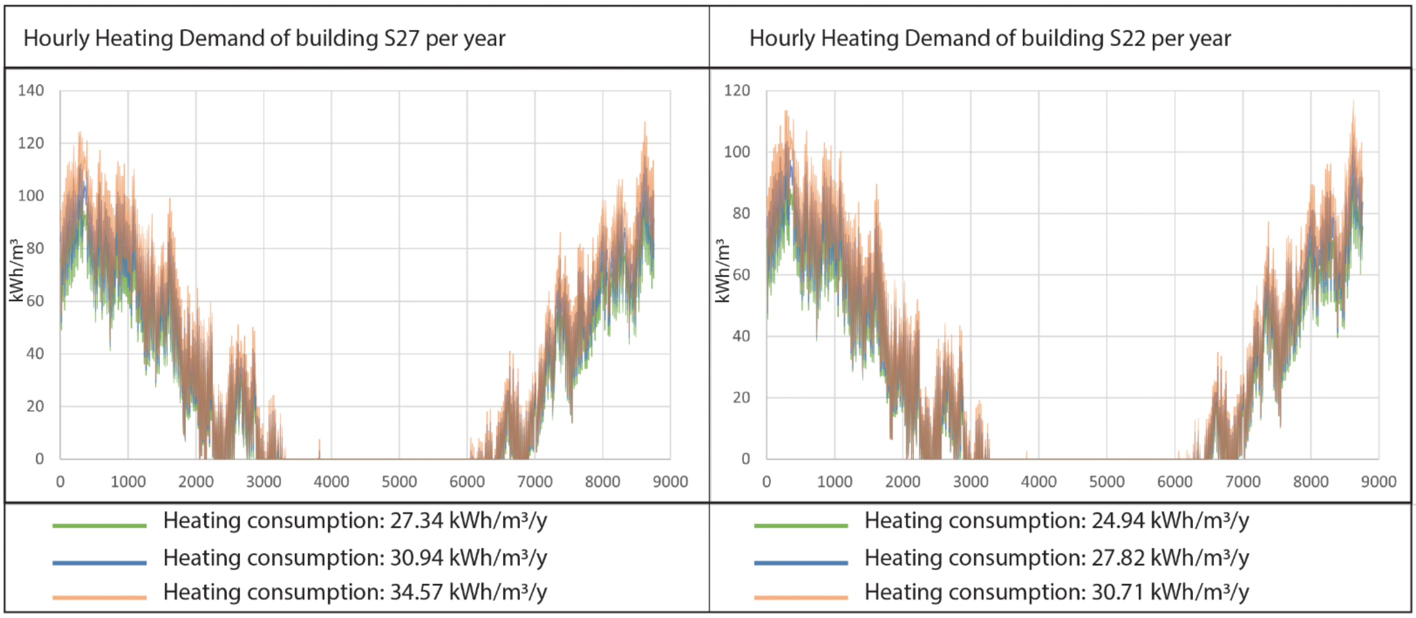


Fig. 17. **Hourly heating consumption of buildings S27 and S22 according to three infiltration rates during a year.**

outdoor air inside of the building. Adding to that, Fig. 16., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, infiltration rate equal to 0.6 h^{-1}, had constantly the highest warmth utilization, while the lowest rate (0.2 h^{-1}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with the highest infiltration rate of 0.6 h^{-1} (represented in orange), compared to rates equivalent to 0.4 h^{-1} (represented in green), and 0.2 h^{-1} (represented in blue) (Fig. 17.).

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18., reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 kWh/m^3/y and -3.43 kWh/m^3/y respectively. In fact, the first deducted monthly results represented in Fig. 19., show that, when the infiltration rate of the building increased, on the opposite of the heating consumption, the cooling Energy demand decreased for both the structures S27 and S22. Adding to that, the residential building characterized by a {NW-SE} orientation, had a

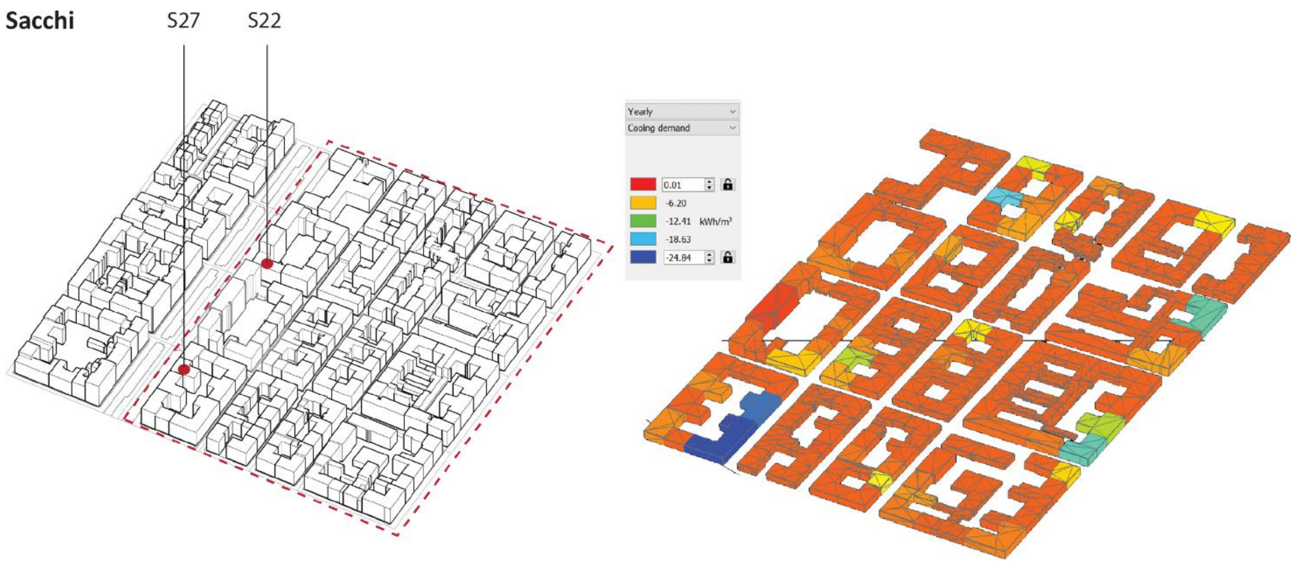


Fig. 18. Three-dimensional representation of Sacchi neighborhood indicating the two analyzed buildings. And Yearly Cooling demand of Sacchi district calculated by CitySim Pro.

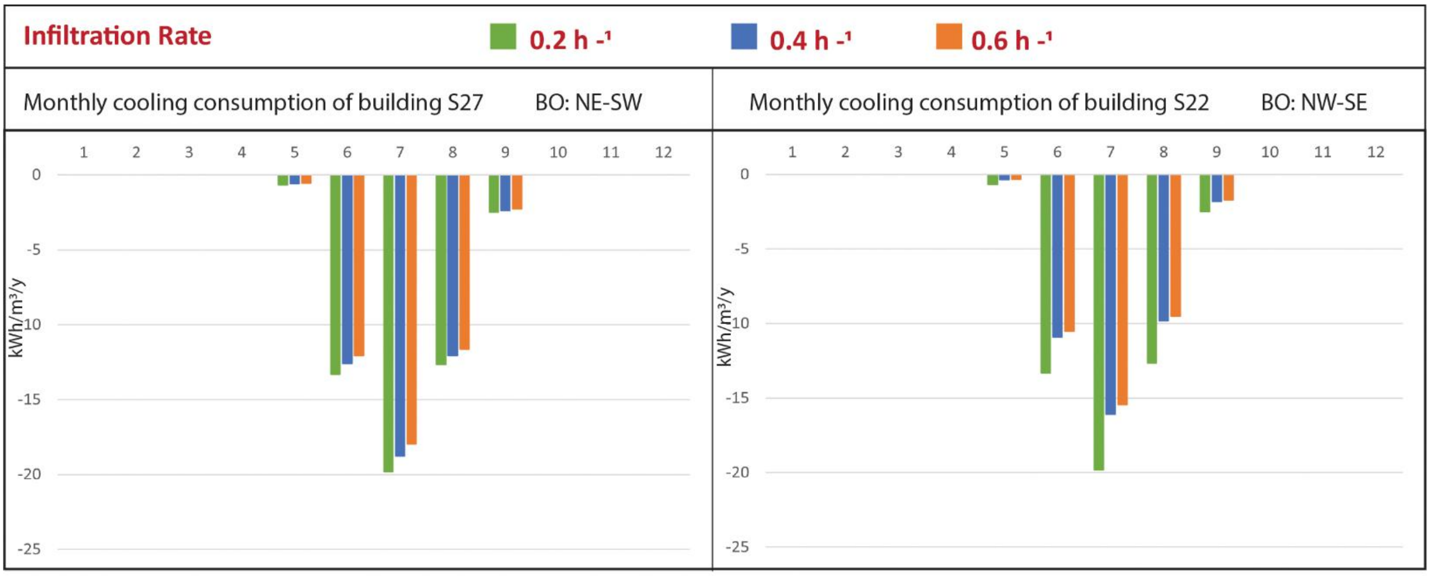


Fig. 19. Monthly cooling consumption of buildings S27 and S22 according to three infiltration rates.

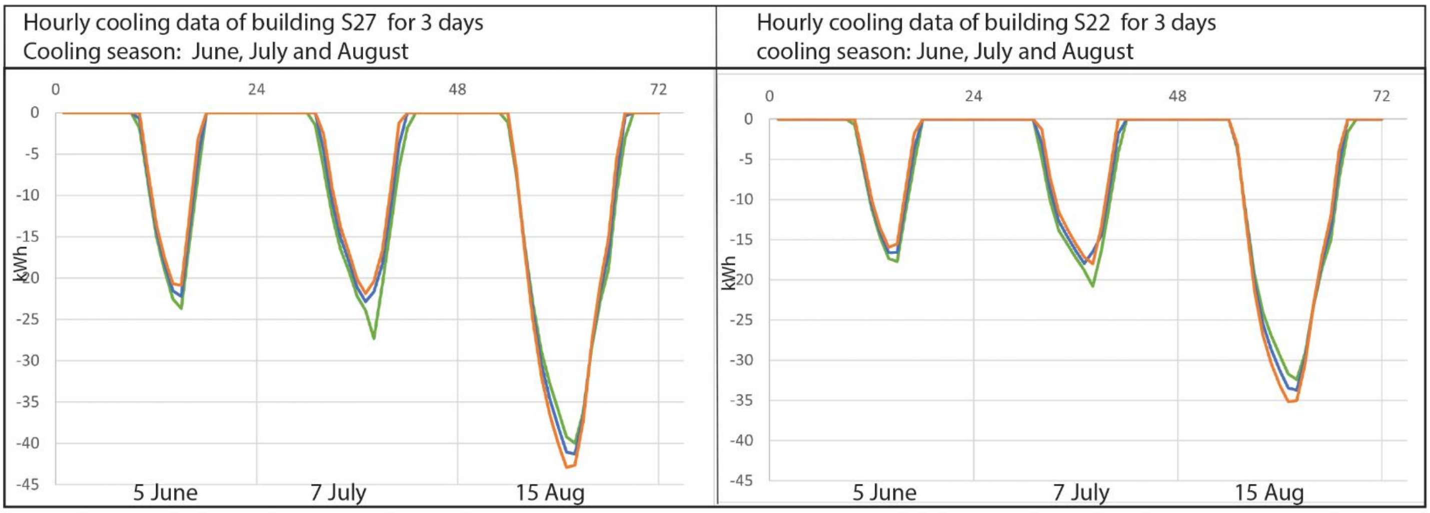


Fig. 20. Hourly cooling consumption of buildings S27 and S22 according to three infiltration rates during three days.

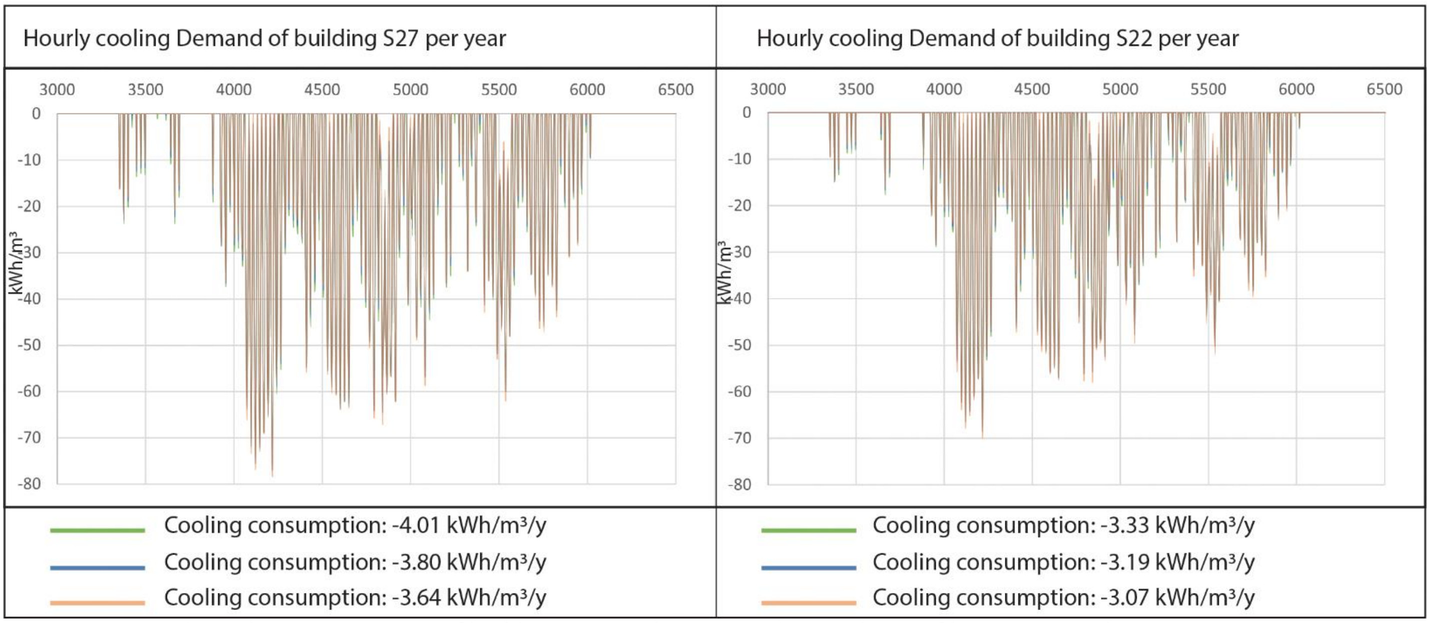


Fig. 21. Hourly cooling consumption of buildings S27 and S22 according to three infiltration rates during a year.

much higher energy impact with an infiltration rate equal to 0.2 h^{-1} (represented in green), compared to higher rates (0.4 and 0.6 h^{-1}), while the structure with a {NE-SW} building orientation was less impacted by this rate, by approximately keeping the same percentage of energy changed for the three different ranges. Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 20.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with an infiltration rate equal to 0.6 h^{-1}, the energy consumption was higher compared to rates equal to 0.2 and 0.4, even though the yearly energy cooling consumption of this range was the lowest with -3.64 kWh/m^3/y for S27 and -3.07 kWh/m^3/y for S22 (Fig. 21). However, during the months June and July, the lowest infiltration rate (0.2 h^{-1}) had the highest Energy cooling utilization.

Table. VIII. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on infiltration rates equal to 0.2, 0.4 and 0.6 h^{-1}.

Infiltration Rate h^{-1}	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
0.2	27.34	-4.01	24.94	-3.33
0.4	30.94	-3.80	27.82	-3.19
0.6	34.57	-3.64	30.71	-3.07

Table. VIII. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on three changed infiltration rates equivalent to 0.2, 0.4 and 0.6 h^{-1}. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 26% in its highest value (with infiltration rate equal to 0.6) in regard to its lowest consumption of 27.34 kWh/m^3/y (with an infiltration rate equal to 0.2). while S22 with a (NW-SE) had a lower warmth energy impact with 23% between the lowest and highest reached value. Fig. 22., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that when the infiltration rate increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings with a NE-SW orientation, have a higher Energy consumption impact, in comparison to structures with NW-SE orientations.

Heating consumption *Cooling consumption*

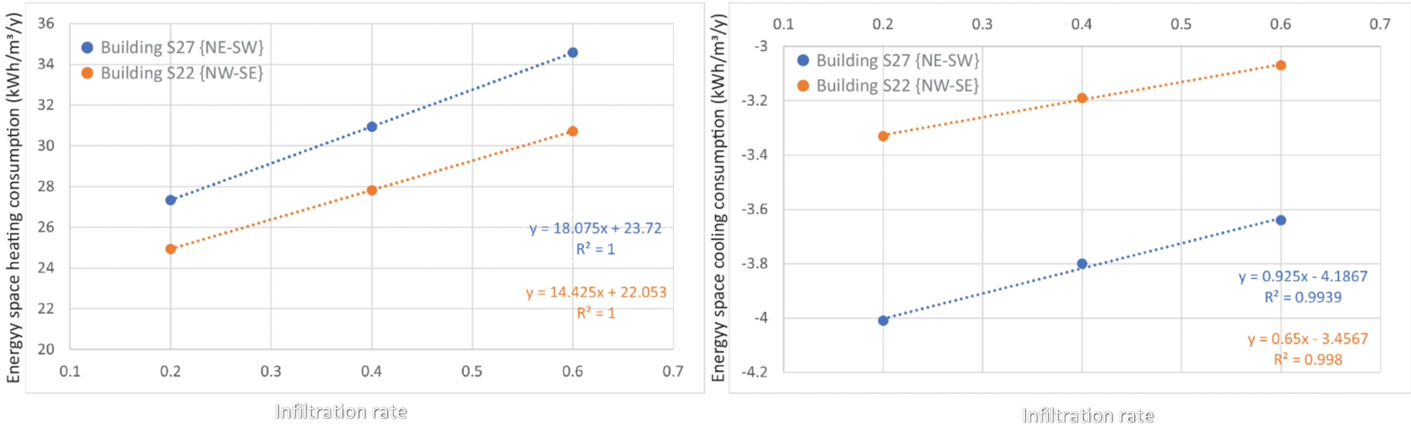


Fig. 22. Energy space heating and cooling demands of buildings S27 and S22 depending on the infiltration rate.

5.1.3- Building's Glazing ratio

Glazing ratio also known as Window to Wall Ratio, is the proportion of the transparent envelope in relation to the façade's surface. The smaller the glazing ratio, the smaller the proportion of the window compared to the wall. In this analysis, three main ratios were studied: 0.2, 0.4 and 0.6. These different ranges will help in the understanding of the impact of the glazing ratio on the yearly heating and cooling demands of the residential buildings. In this analysis, three different Glazing ratio values were studied: 0.2 (indicated in green), 0.4 (indicated in blue), and 0.6 (indicated in orange), in order to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (S27 and S22). The first warmth Energy utilization results are shown in Fig. 23. In fact, the monthly heating demand of both structures S27 and S22, increased when the Glazing ratio value was higher (where the structure consumed more heating energy with a glazing ratio equal to 0.6, compared to a smaller window to wall ratio of 0.2). Adding to that, Fig. 24., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, with a glazing ratio equivalent to 0.6, had constantly the highest warmth utilization, while the lowest ratio (equal to 0.2), consumed the least heating demand. Adding to that, the 5th of February showed the most

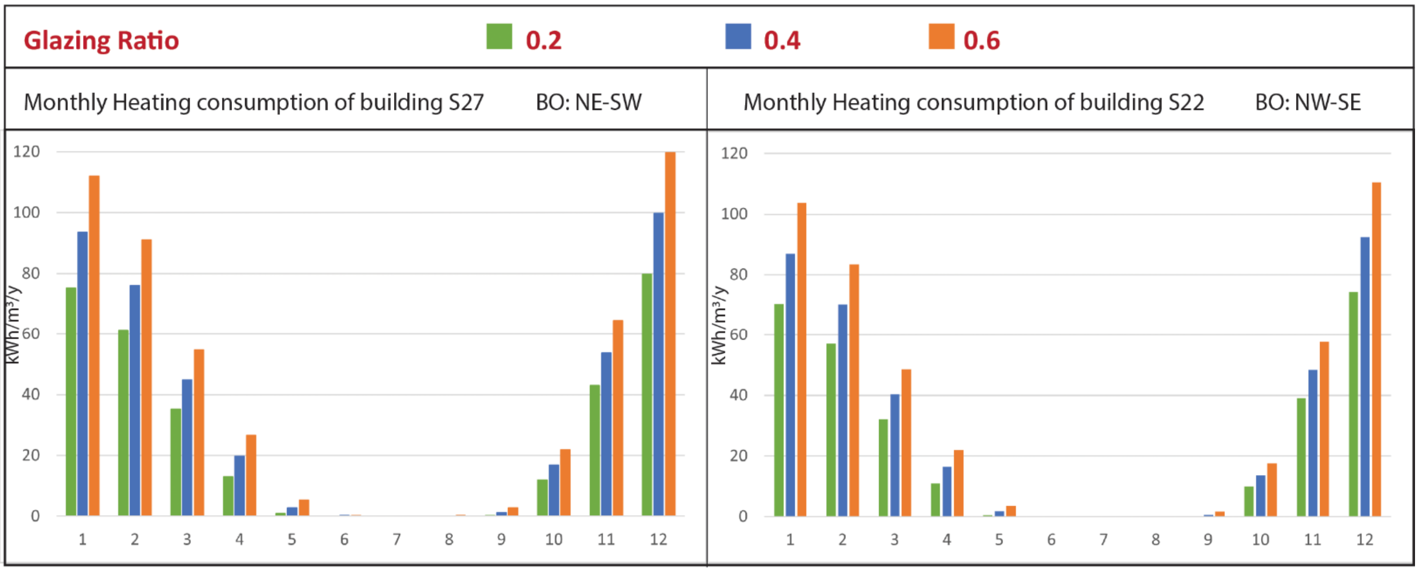


Fig. 23. Monthly heating consumption of buildings S27 and S22 according to three Glazing ratio values.

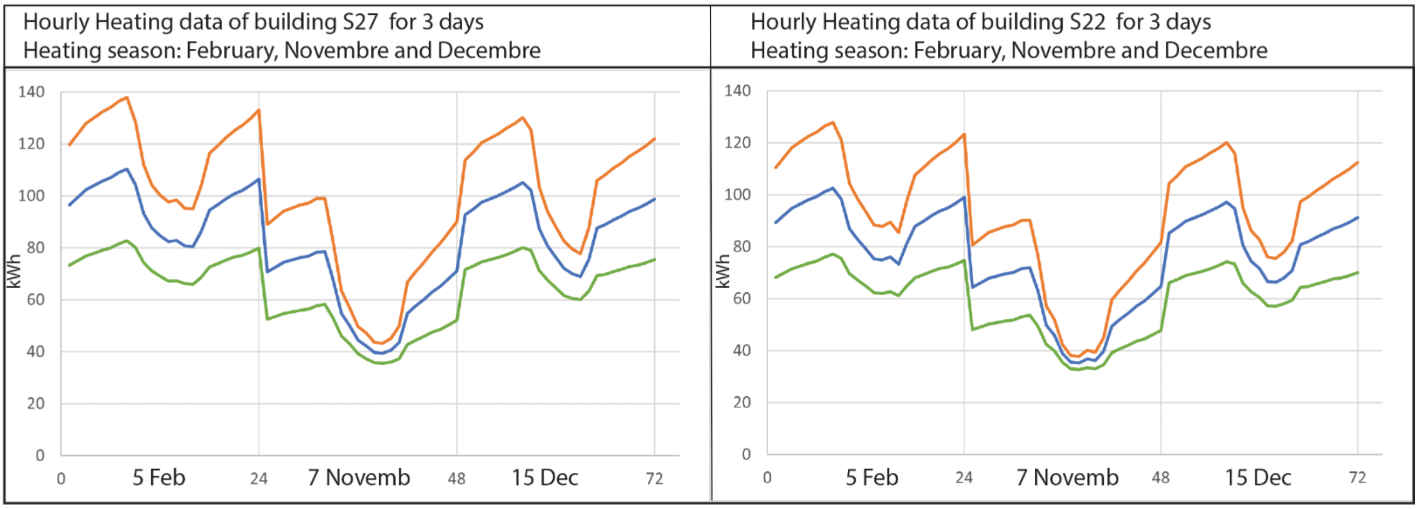


Fig. 24. Hourly heating consumption of buildings S27 and S22 according to three Glazing ratio value during three days.

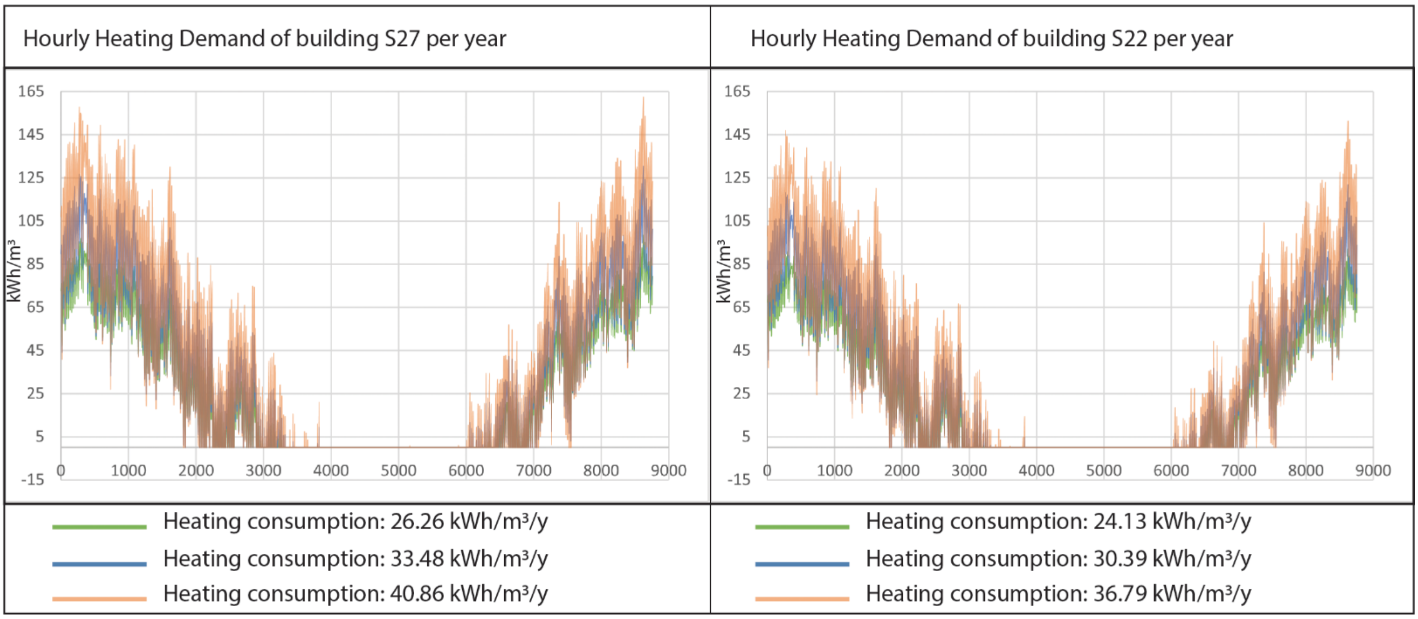


Fig. 25. Hourly heating consumption of buildings S27 and S22 according to three Glazing ratio values during a year.

energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with the highest Window to Wall ratio of 0.6 (represented in orange), compared to ratios equivalent to 0.4 (represented in green), and 0.2 (represented in blue), shown in Fig. 25.

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18. (previously analyzed), reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 $kWh/m^3/y$ and -3.43 $kWh/m^3/y$ respectively. In fact, the first deducted monthly results represented in Fig. 26., show that, when the Glazing ratio of the building increased, similarly to the heating consumption (previously analyzed), the cooling Energy demand increases as well for both structures S27 and S22. Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 27.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for both analyzed residential buildings (S27 and S22), during the whole yearly cooling season, Structure with the highest window to wall ratio (equal to 0.6) constantly had the highest cooling Energy consumption (represented in orange), followed by the simulated results of ratio equivalent to 0.4 (represented in blue), and finally the lowest hourly and yearly cooling Energy utilization is represented by the lowest studied glazing ratio, that is equal to 0.2 (represented in green) in accordance to Fig. 28.

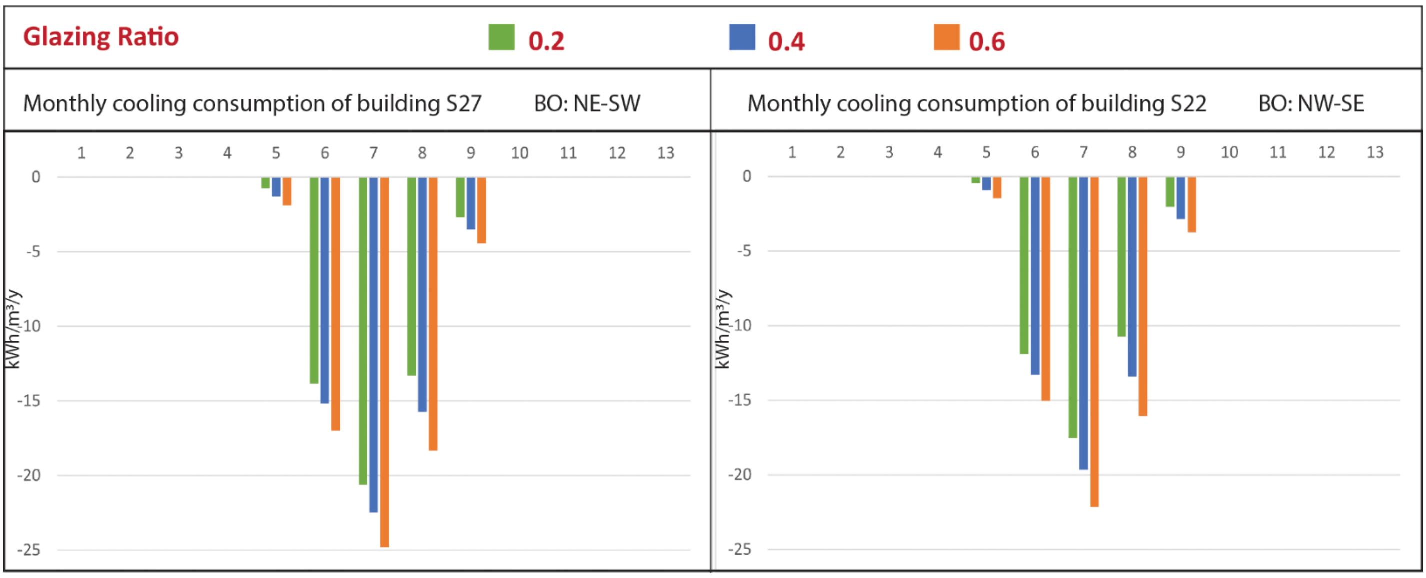


Fig. 26. Monthly cooling consumption of buildings S27 and S22 according to three Glazing ratio values.

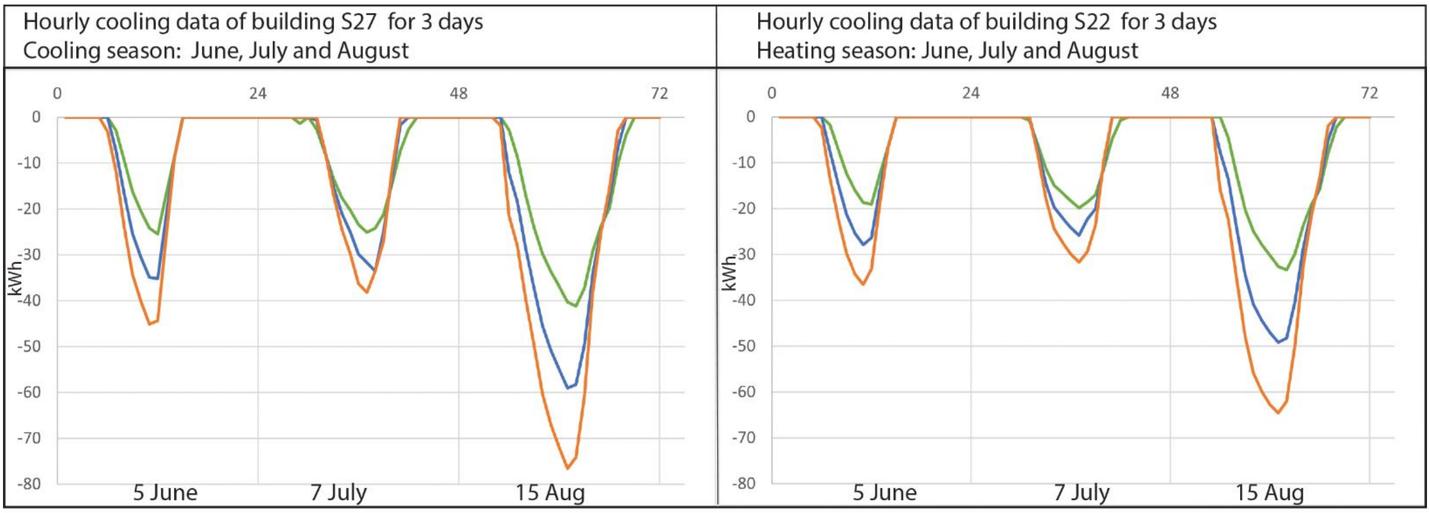


Fig. 27. Hourly cooling consumption of buildings S27 and S22 according to three Glazing ratio value during three days.

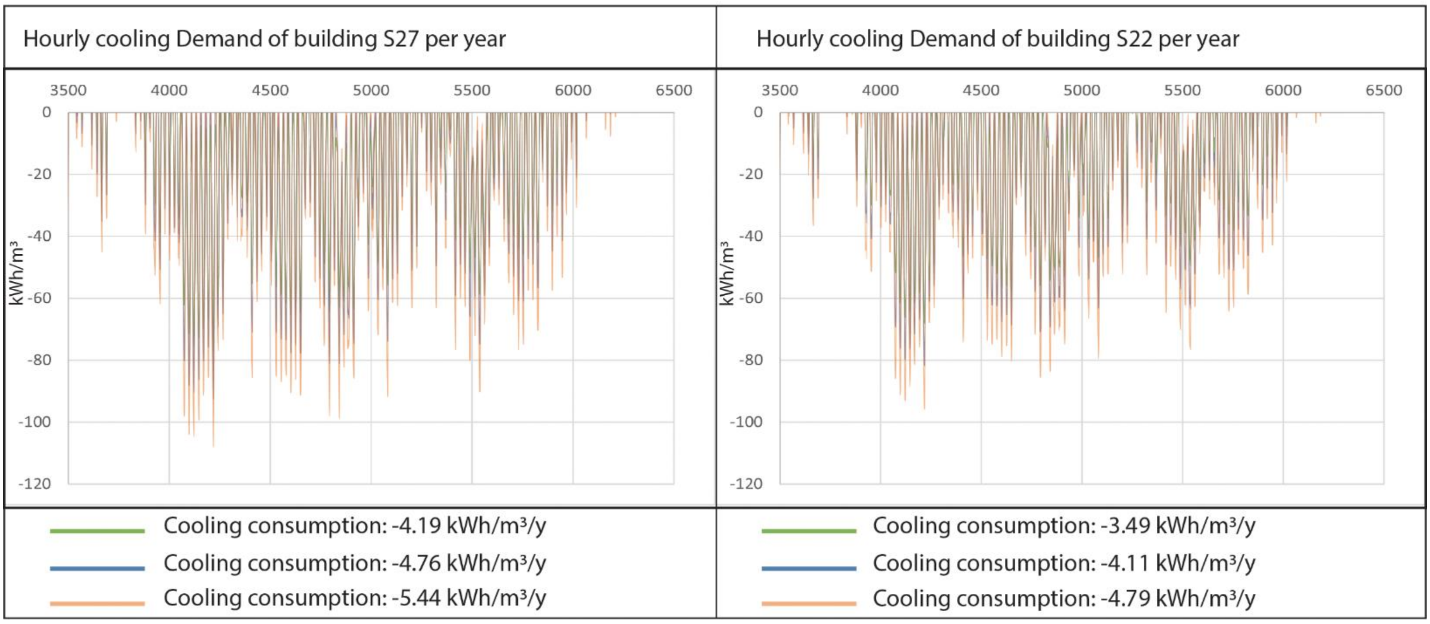


Fig. 28. Hourly cooling consumption of buildings S27 and S22 according to three Glazing ratio values during a year.

Table. IX. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on three changed Window to Wall ratios equivalent to 0.2, 0.4 and 0.6. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 55% in its highest value (with a glazing ratio equal to 0.6) in regard to its lowest consumption of 26.26 kWh/m^3/y (with a glazing ratio equal to 0.2). while S22 with a (NW-SE) had a lower warmth energy impact with 52% between the lowest (24.13 kWh/m^3/y) and highest reached value (36.79 kWh/m^3/y). Fig. 29., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} and building S22 characterized by a {NW-SE} orientation, had approximately the same amount of impact of the cooling energy consumption, with a similarly linear equational value (presented in blue for building S27 and in orange for building S22). Therefore, we can conclude that when the glazing ratio of the building increases, the energy heating, and cooling demands of the structures, increases as well simultaneously. Adding to that, buildings with a NE-SW orientation, have a higher heating Energy consumption impact, in comparison to structures with NW-SE orientations. While the impact on the cooling demand is approximately the same for both buildings' orientations.

Table. IX. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on Glazing ratios equal to 0.2, 0.4 and 0.6.

Glazing Ratio	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
0.2	26.26	-4.19	24.13	-3.49
0.4	33.48	-4.76	30.39	-4.11
0.6	40.86	-5.44	36.79	-4.79

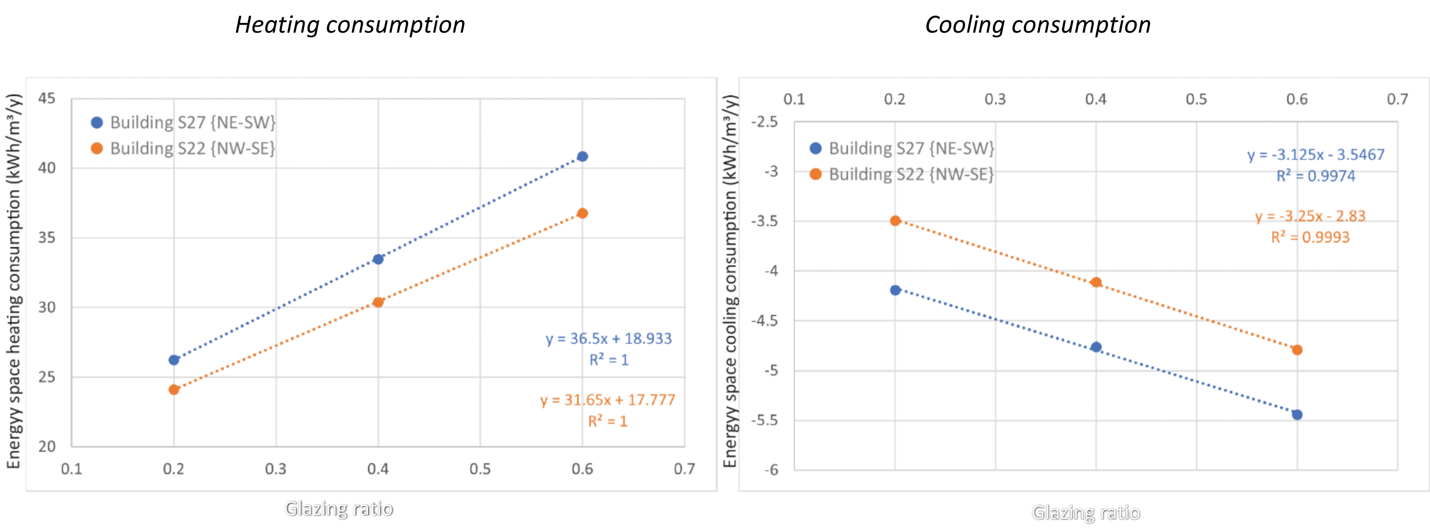


Fig. 29. Energy space heating and cooling demands of buildings S27 and S22 depending on the building's glazing ratio.

5.1.4- Thermal properties of building envelope

The thermal propertied of a building, are subdivided in this analysis into four main categories: Thermal transmittance of the opaque envelope of the building (Windows U-value), and thermal transmittances of walls, roof, and floor in regard to the building composites and materials. In fact, the opening properties' U-values, are retrieved from UNI/TS 11300-1 according to building's periods of construction. The lower the U-value the more the window is insulated from the outdoor factors of the building. In this variable, three main values were analyzed: 2.15, 4.40 and 4.90 expressed in {W/m^2. K}. Adding to that, Building's Materials and composites retrieved from UNI/TR 11552 varying according to the building's-built period. In this variable, walls, roofs, and floors composites were taken into consideration by specifying their thermal transmittance, resistance, materials densities as well as their thermal capacity. Ranges of 0.67, 0.9 and 1.10 {W/m^2. K} were examined for the walls' U-values, while for the roof composites, values varied between 0.53, 1.27 and 1.60{W/m^2. K}. and finally, the last studied building variable is the floor's composites and materials with values equivalent to 1.16 {W/m^2. K} for construction periods ranging between 1919 and 1960, and 1.25 {W/m^2. K} for residential structure building between 1961 and 2005.

5.1.4.1- Window's U-value ($U_{windows}$, W/m^2/K)

In fact, the building's windows U-values, are assigned to each residential building, according to its respective period of construction. The lower the U-value the more the window is insulated from the outdoor factors. Table. III. (previously shown), indicates that structures that are characterized by older construction dates, have a higher window U-value compared to more recently built structures with values ranging between 2.15 and 0.9, (according to Mutani G., and Todeschi V., 2020). In this analysis, three different windows thermal transmittances were studied: 2.15 {W/m^2. K} (indicated in green), 4.40 {W/m^2. K} (indicated in blue), and 4.90{W/m^2. K} (indicated in orange), in order to sensitively compare and analyze the impact of this changed variable on the heating and cooling consumption of the two chosen residential buildings (S27 and S22) in Sacchi neighborhood that are characterized with a construction period before 1919. The first warmth Energy utilization results are shown in Fig. 30. In fact, the monthly heating demand of both structures S27 and S22, increased when the windows' U-value was higher, mainly due to the penetration of the cold outdoor air inside

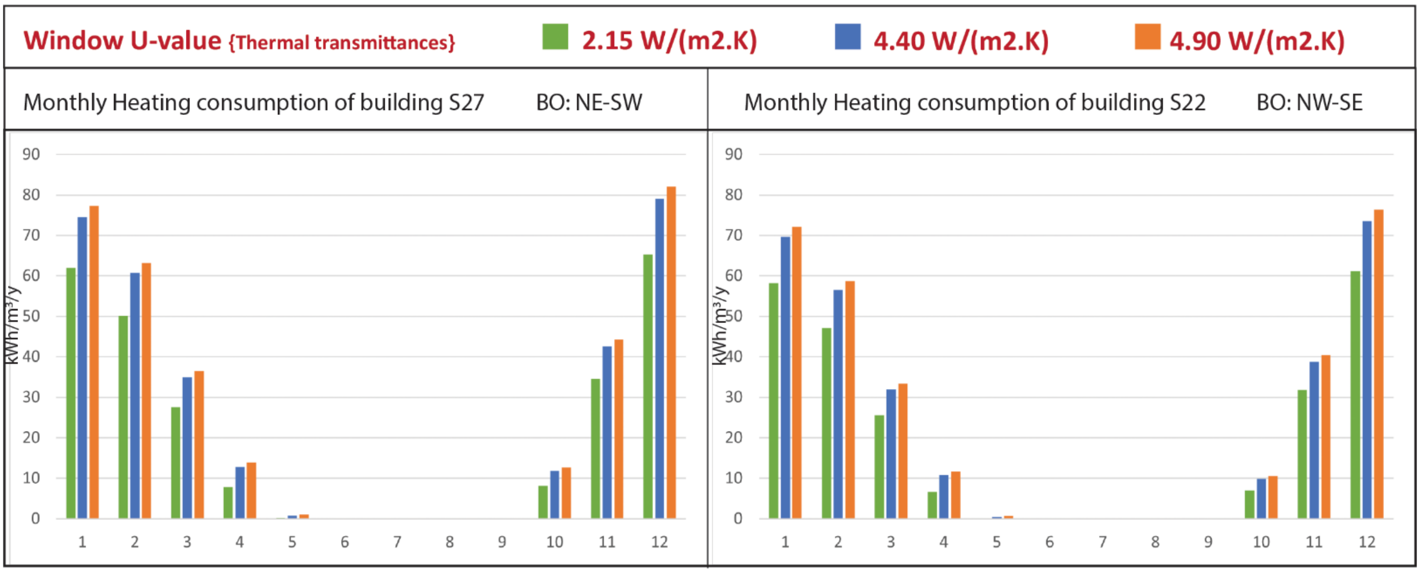


Fig. 30. **Monthly heating consumption of buildings S27 and S22 according to three Window U-values.**

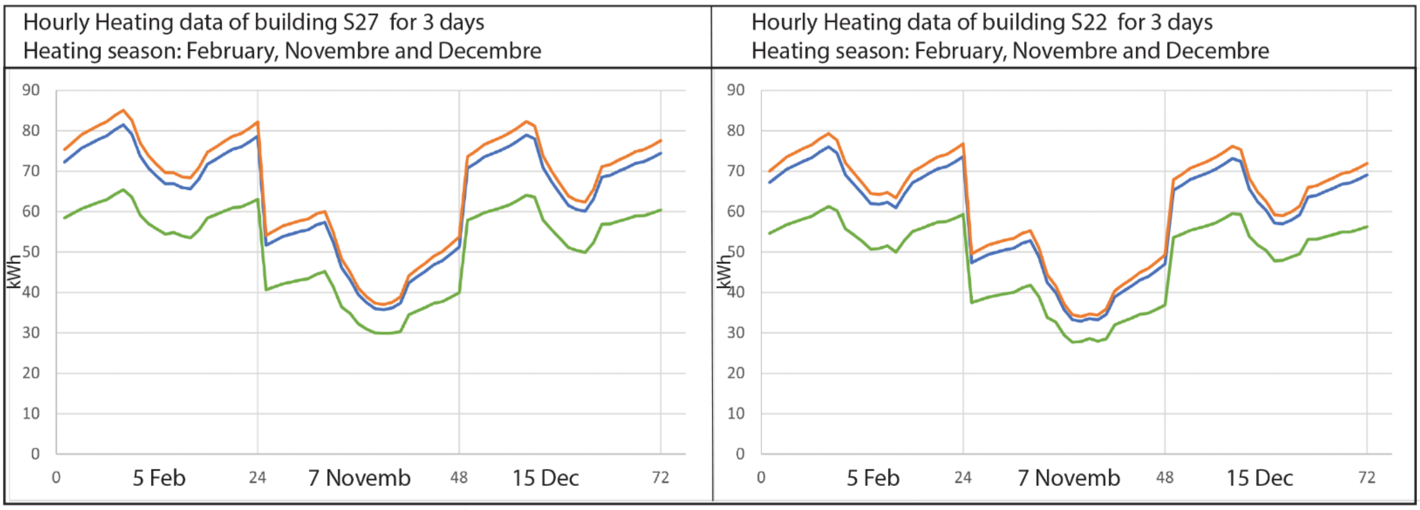


Fig. 31. **Hourly heating consumption of buildings S27 and S22 according to three Window U-values during three days.**

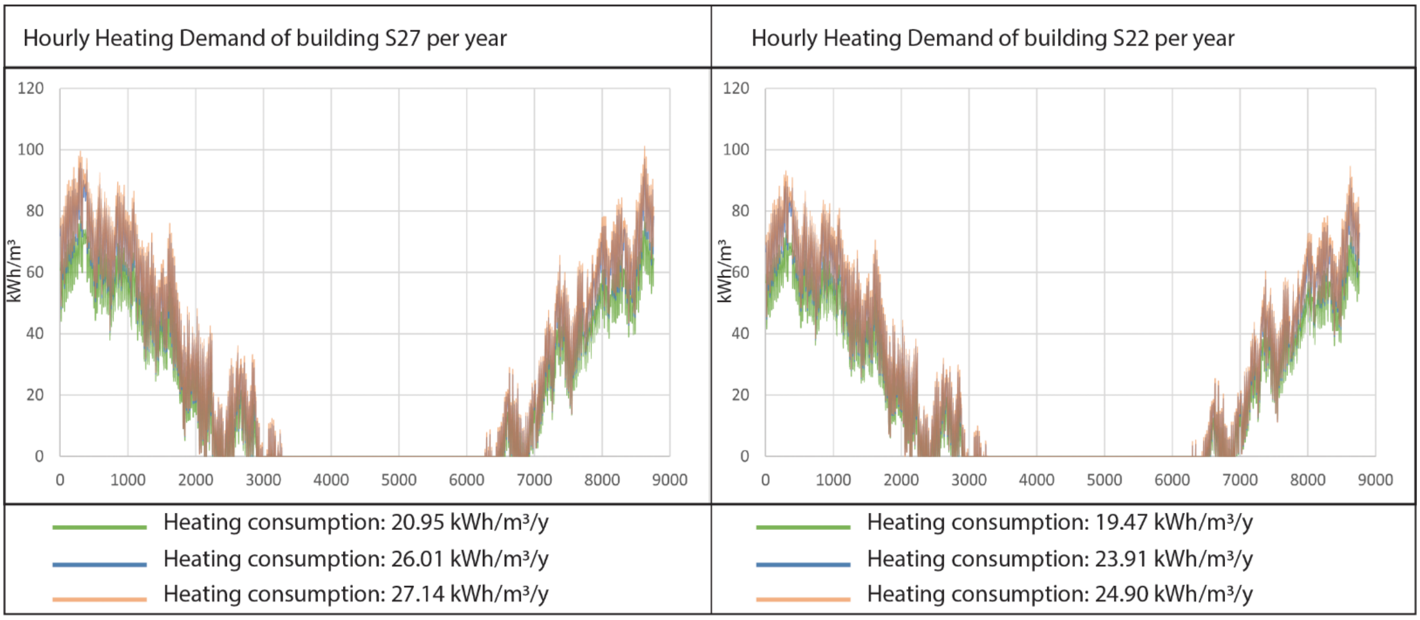


Fig. 32. **Hourly heating consumption of buildings S27 and S22 according to three Window U-values during a year.**

of the building during the heating season, because of the lower window insulation. Adding to that, Fig. 31., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the opaque envelope's thermal transmittance that is equal to 4.90 {W/m^2. K}, had constantly the highest warmth utilization, while the lowest window's U-value (2.15 {W/m^2. K}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with the highest window U-value equivalent to 4.90 {W/m^2. K} (represented in orange), compared to lower values of 4.40 {W/m^2. K} (represented in green), and 2.15 {W/m^2. K} (represented in blue) (Fig. 32.).

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18. (previously analyzed), reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 kWh/m^3/y and -3.43 kWh/m^3/y respectively. In fact, the first deducted monthly results represented in Fig. 33., show that, when the window's U-value of the building increased, on the opposite of the heating consumption results (previously discussed), the cooling Energy demand decreased for both buildings S27 and S22. Adding to that, an hourly Energy

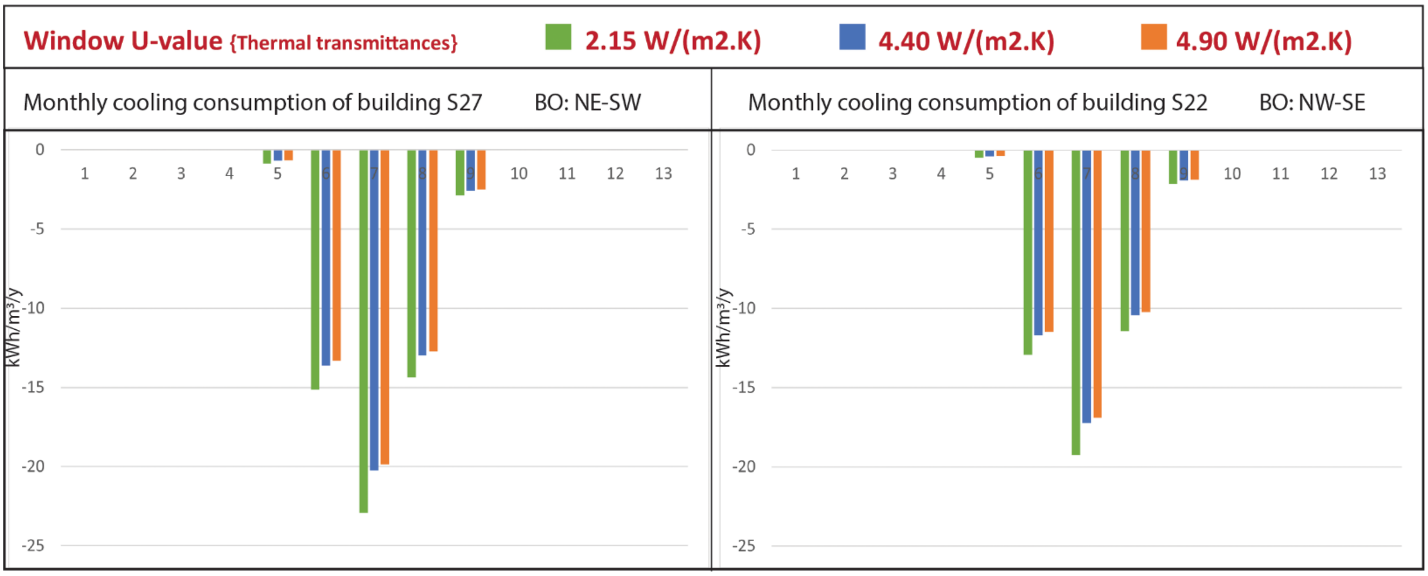


Fig. 33. Monthly cooling consumption of buildings S27 and S22 according to three Window U-values.

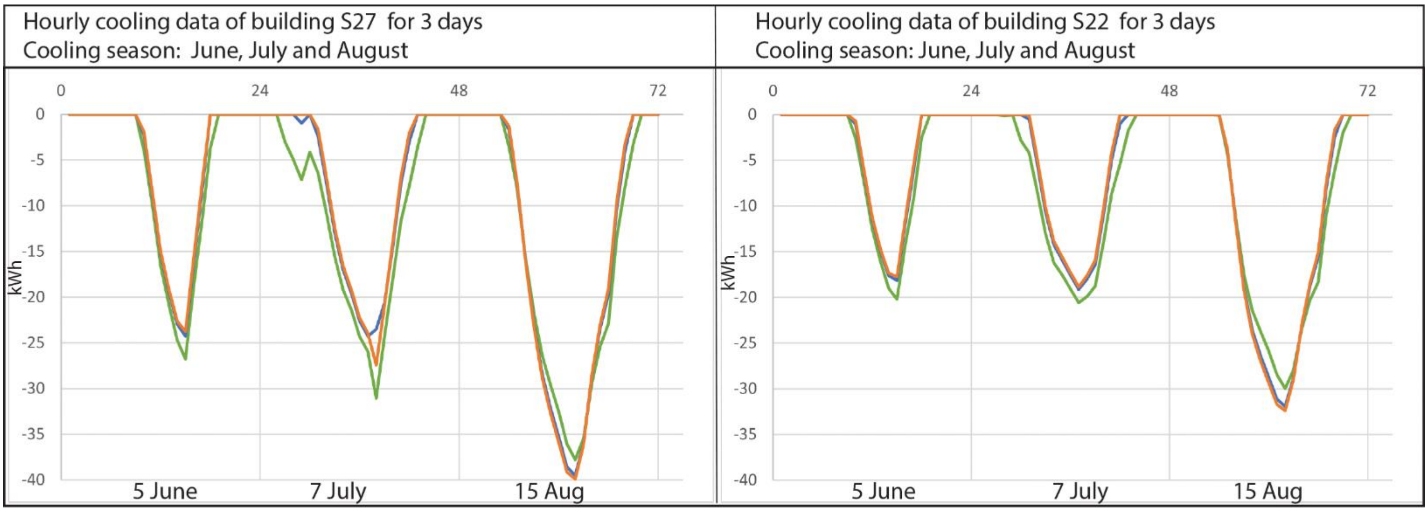


Fig. 34. Hourly cooling consumption of buildings S27 and S22 according to three Window U-values during three days.

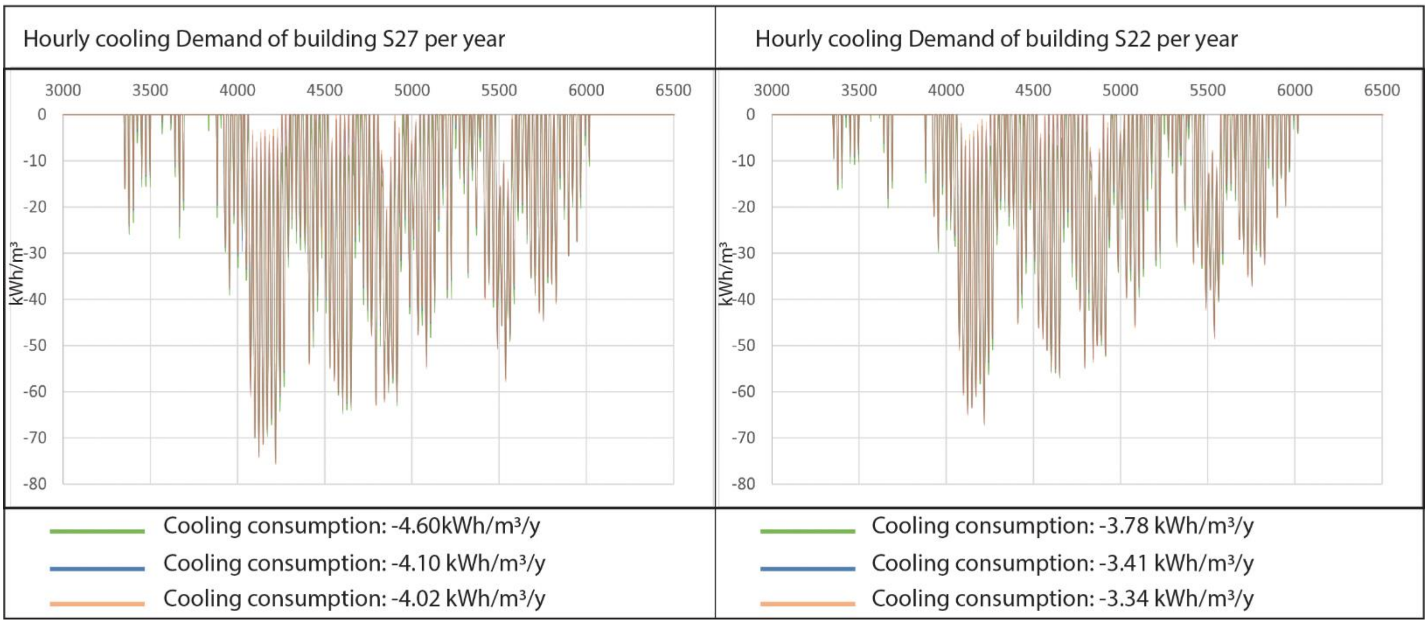


Fig. 35. Hourly cooling consumption of buildings S27 and S22 according to three Window U-values during a year.

was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 34.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with a window U-value equivalent to 4.90 {W/m^2. K} represented in orange, the energy consumption was higher compared to values equal to 4.40 and 2.15 {W/m^2. K}, even though the yearly energy cooling consumption of this range was the lowest with -4.06 kWh/m^3/y for S27 and -3.34 kWh/m^3/y for S22 (Fig. 35). However, during the months June and July, the lowest thermal transmittance of the opaque envelope (2.15 {W/m^2. K}) had the highest Energy cooling utilization during the months of June and July for both buildings S27 and S22.

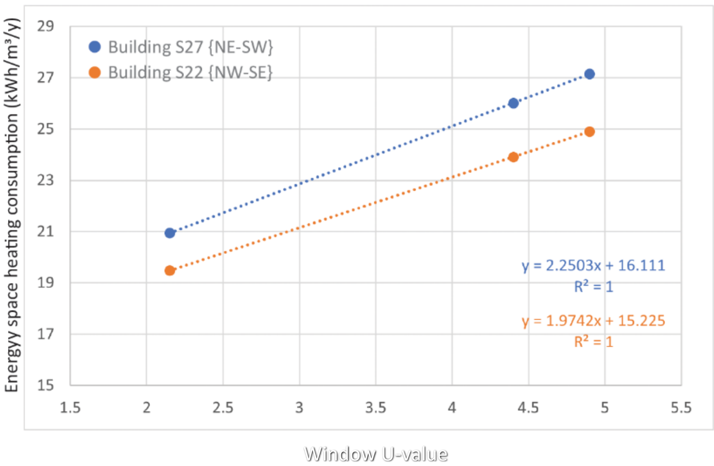
Table. X. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on window U-values equal to 2.15, 4.40, and 4.90 W/m^2. K.

Window U-value W/(m2.K)	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
2.15	20.95	-4.60	19.47	-3.78
4.40	26.01	-4.10	23.91	-3.41
4.90	27.14	-4.02	24.90	-3.34

Table. X. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on three changed window's thermal transmittances values equivalent to 2.14, 4.40 and 4.90 {W/m^2. K}. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 29% in its highest value (with a window U-value equal to 4.90 {W/m^2. K}), in regard to its lowest consumption of 20.95 kWh/m^3/y (with a window U-value equal to 2.15 {W/m^2. K}), while S22 with a (NW-SE) had a lower warmth energy impact with 27% between the lowest and highest reached value respectively equal to 19.74 kWh/m^3/y and 24.90 kWh/m^3/y. Fig. 36., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that when the window's U-value increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings with a NE-SW orientation, have a higher Energy consumption impact, in comparison to structures with NW-SE orientations.

Heating consumption

Cooling consumption



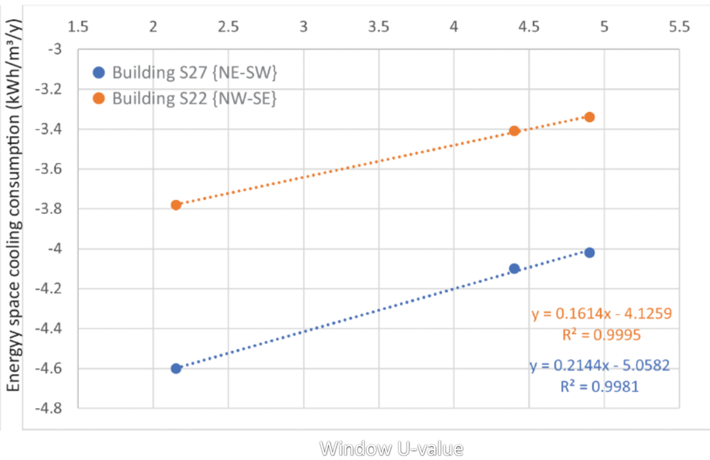


Fig. 36. Energy space heating and cooling demands of buildings S27 and S22 depending on the building's Window's U-value.

5.1.4.2- Wall’s U-value (U_{wall}, W/m²/K)

Building’s Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building’s construction period. In fact, the lower the wall’s U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.10, 0.9 and 0.67 expressed in {W/m^2. K}. Table. XI. Shows the three examined walls composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.10 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a wall code of MLP02. The second studied value is 0.9 {W/m^2. K}, with a wall code of MLP03 (constructed between 1961 and 1970). And the most recent wall composite is MPF03 (1990-2005), with a thermal transmittance value equivalent to 0.67 {W/m^2. K}. these different ranges were inserted in the engineering software CitySim Pro, where simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (S27 and S22) in Sacchi neighborhood characterized by a period of construction before 1919.

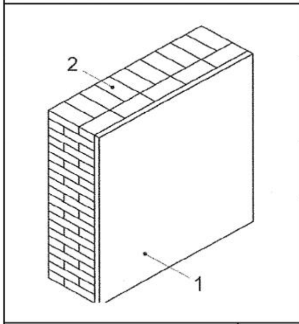
Table. XI. Walls codes along with their respective U-values.

1919-1945		
	Code	U-value [W/(m²K)]
Wall	MLP02	1.10
1961-1970		
	Code	U-value [W/(m²K)]
Wall	MLP03	0.9
1990-2005		
	Code	U-value [W/(m²K)]
Wall	MPF03	0.67

Table. XII. to. XIV., shows the three walls composites: MLP02, MLPO3 and MPF03 retrieved from UNI/TR 11552, the Italian residential buildings standard. These table, shows the material’s different composite’s thickness, conductivity, and density as well as their respective thermal transmittances expressed in {W/m^2. K}. According to this collected information, the input data of each wall composite was inserted the xml. Sheet of the engineering software CitySim Pro allowing the change of the selected buildings walls materials in order to examine their impact on the heating and cooling energy consumptions by comparing the results.

Table. XII. Wall MLP02 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Wall Composite: MLP02					1919-1945
MLP02 - Brick masonry wall					
Layer	d [cm]	ρ [kg/m³]	c [J/kgK]	λ [W/mK]	R [m²K/W]
1 Internal plaster	1.5	1400	1000	0.70	-
2 Full brick	12-64	1800	1000	0.72	-



Thickness in cm	U [W/(m²K)]]	κ [kJ/(m²K)]	Y_{ie} [W/(m²K)]
1.5 – 12	2.79	63.3	2.000
1.5 – 25	1.86	70.0	0.576
1.5 – 38	1.39	64.1	0.167
1.5 – 51	1.11	62.2	0.048
1.5 – 64	0.93	62.3	0.014

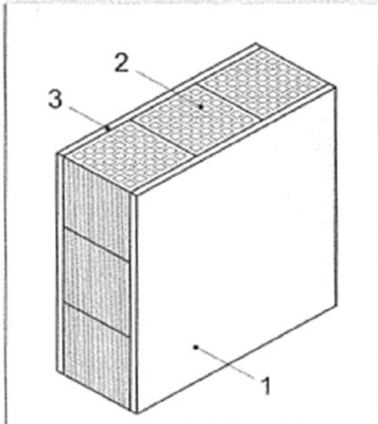
MLP02 – brick masonry wall			
Layer	Thickness (d) [m]	Conductivity (λ) [W/mK]	Thermal resistance (R) [m²K/W]
Internal surface resistance	-	-	0.13
Internal plaster	0.015	0.7	0.02
Brick layer	0.5	0.72	0.69
External plaster	0.02	0.9	0.02
External surface resistance	-	-	0.04

U-value [W/(m²K)]	1.10

```
<Composite id="1" name="MLP02" category="Wall">
    <Layer Thickness="0.0200" Conductivity="0.9000" Cp="1000" Density="1800" nre="0" gwp="0" ubp="0"/>
    <Layer Thickness="0.5000" Conductivity="0.7200" Cp="1000" Density="1000" nre="0" gwp="0" ubp="0"/>
    <Layer Thickness="0.0150" Conductivity="0.7000" Cp="1000" Density="1400" nre="0" gwp="0" ubp="0"/>
```

Table. XIII. Wall MLP03 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Wall Composite: MLP03					1919-1945
MLP03 - Semi-solid brick masonry					
Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Intonaco interno	2	1400	1000	0,700	-
2 Blocchi in laterizio	25 30	1000	1000	-	0,625[a)] 0,890[a)]
3 Intonaco esterno	2	1800	1000	0,900	-



Descrizione (spessori in cm)	U [W/(m² K)]	κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
2 - 30 - 2	0,90	53,7	0,197

a) Resistenza termica ricavata secondo la norma UNI 10355.

```
</Composite>
<Composite id="4" name="MLP03" category="Wall">
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    <Layer Thickness="0.3000" Conductivity="2.9667" Cp="1000" Density="1000" />
    <Layer Thickness="0.0200" Conductivity="0.7000" Cp="1000" Density="1400" />
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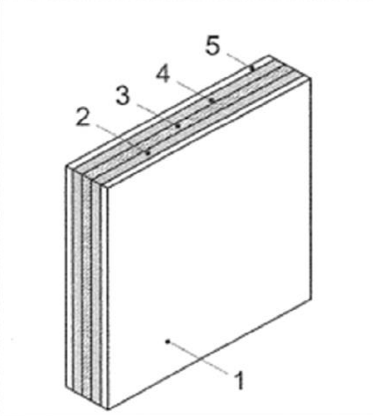
Table. XIV. Wall MPF03 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Wall Composite: MPF03 — 1990-2005

MPF03 - Parete prefabbricata in calcestruzzo isolato, esempio 1 – [2]



Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Intonaco interno	1	1400	1000	0,700	-
2 Pannello in calcestruzzo	1	1400	1000	0,580	-
3 Pannello isolante in fibra di vetro	3	30	670	0,040	-
4 Pannello in calcestruzzo	5-30	1400	1000	0,580	-
5 Intonaco esterno	2	1800	1000	0,900	-

Descrizione (spessori in cm)	U [W/(m² K)]	κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
1 - 1 - 3 - 30 - 2	0,67	28,6	0,082

```
</Composite>
<Composite id="40" name="MPF03" category="Wall">
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    <Layer Thickness="0.3000" Conductivity="0.5800" Cp="1000" Density="1400" />
    <Layer Thickness="0.0300" Conductivity="0.0400" Cp="670" Density="30" />
    <Layer Thickness="0.0100" Conductivity="0.5800" Cp="1000" Density="1400" />
    <Layer Thickness="0.0100" Conductivity="0.7000" Cp="1000" Density="1400" />
```

In fact, the first heating Energy utilization results are shown in Fig. 37. The monthly warmth demand of both structures S27 and S22 had the highest energy utilization with a wall U-value equivalent to 0.9 {W/m^2. K} (indicated in blue), and the lowest one represented with the most recent wall composite MPF03 with a thermal transmittance of 0.67 {W/m^2. K}. We can visualize a huge gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 38., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the wall's thermal transmittance that is equal to 0.9 {W/m^2. K} (MLP03), had constantly the highest warmth utilization, while the lowest wall's U-value (0.67 {W/m^2. K}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with a window U-value equivalent to 0.9 {W/m^2. K} (represented in blue, MLP03), compared to values of

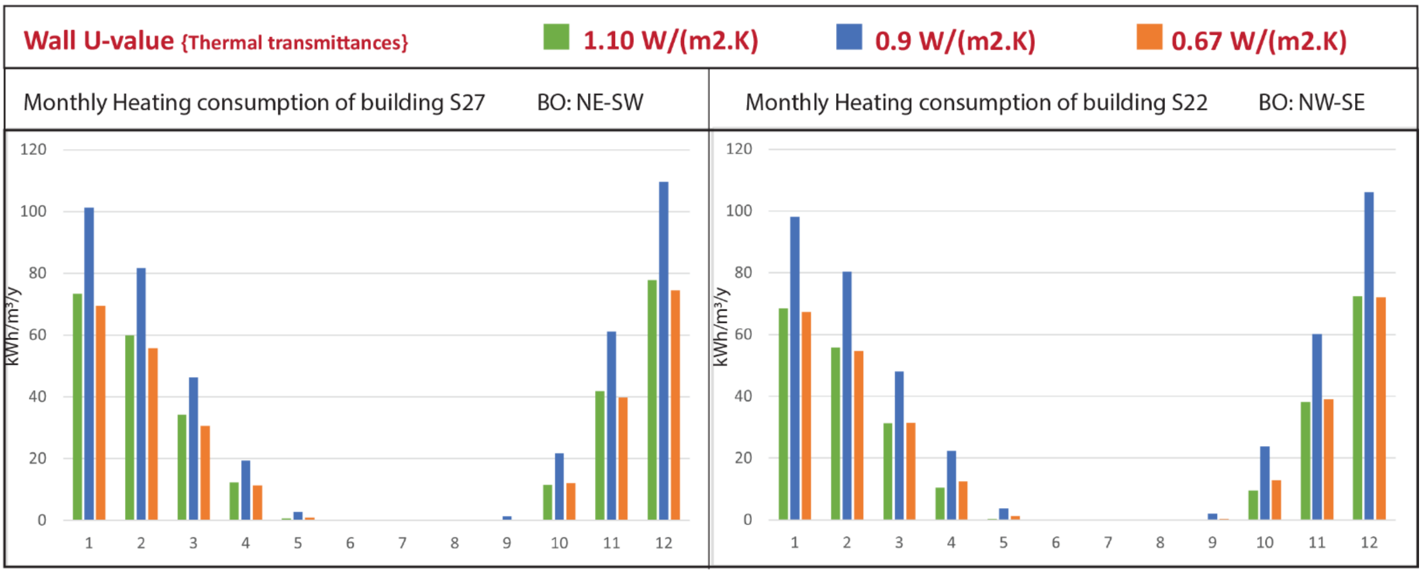


Fig. 37. Monthly heating consumption of buildings S27 and S22 according to three walls U-values.

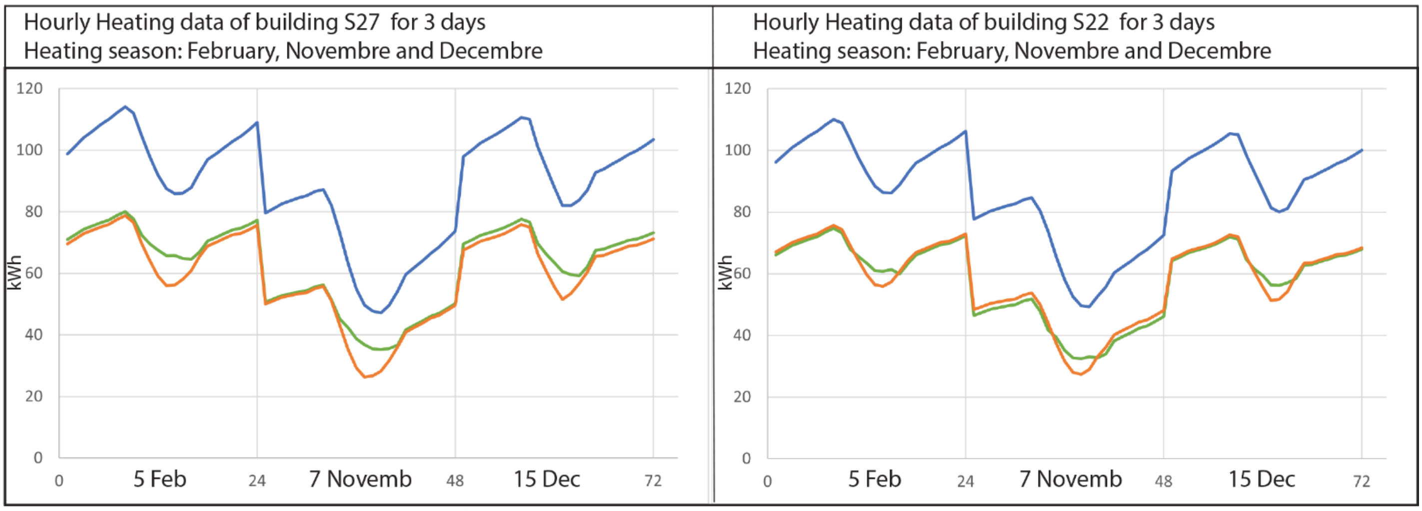


Fig. 38. Hourly heating consumption of buildings S27 and S22 according to three Walls U-values during three days.

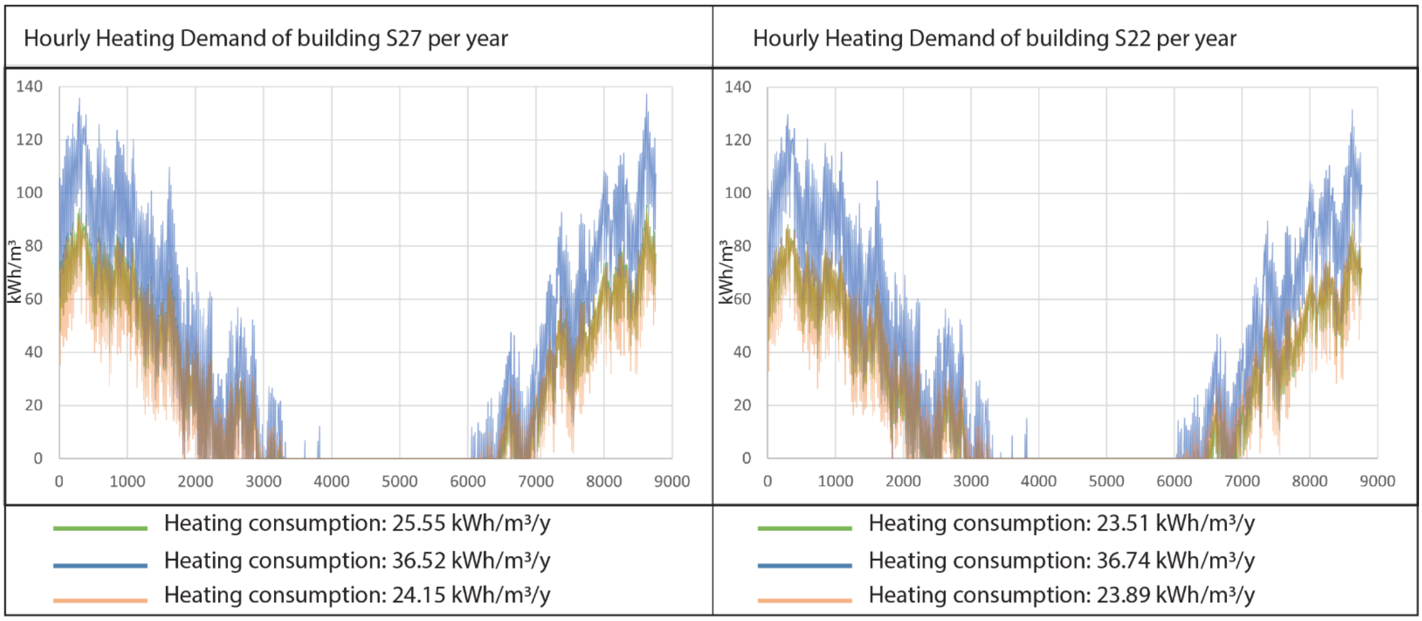


Fig. 39. Hourly heating consumption of buildings S27 and S22 according to three Walls U-values during a year.

1.10 {W/m^2. K} (represented in green, MLP03), and 0.67 {W/m^2. K} (represented in blue, MPF03) (Fig. 39.).

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18. (previously analyzed), reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 kWh/m^3/y and -3.43 kWh/m^3/y respectively. In fact, the first deducted monthly results represented in Fig. 40., show that, when the wall's thermal transmittance of the building was equal to 0.9 {W/m^2. K} (MLP03), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures S27 and S22 were the highest compared to the two other wall composites (MLP02 and MPF03). However, the most recent wall configuration, MPF03, with a U-value equivalent to 0.67 {W/m^2. K} (represented in orange), consumed more cooling energy compared to the oldest wall code, MLP02 (1919-1945), represented on the graph in green. Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5^{th} of June, 7^{th} of July and 15^{th} of August (Fig. 41.). Results show that, for both buildings, the highest Energy Utilization was on the 15^{th} of August, while the lowest one is represented on the 7^{th} of July. In fact, for building S27 characterized by a NE-SW orientation, during the whole yearly cooling season, the structure with the wall's thermal transmittance equal to 0.9 {W/m^2. K} (MLP03), constantly had the highest cooling Energy consumption (represented in blue), followed by the simulated results wall MPF03 (represented in blue), and finally the lowest hourly and yearly cooling Energy utilization is represented by the highest wall U-value, that is equal to 1.10 (wall composite MLP02: represented in green) in accordance with Fig. 42. However, for building S22 with an orientation of NW-SE, wall composite MPF03, consumed the highest cooling Energy during months with a lower outdoor temperature during the cooling season (Month of July for example, represented in orange in Fig. 41.), even though it yearly energy consumption was lower compared to the wall composite MLP03 with respective values equivalent to -6.04 {kWh/m^3/y} (represented in orange), and -6.14 {kWh/m^3/y} (represented in blue).

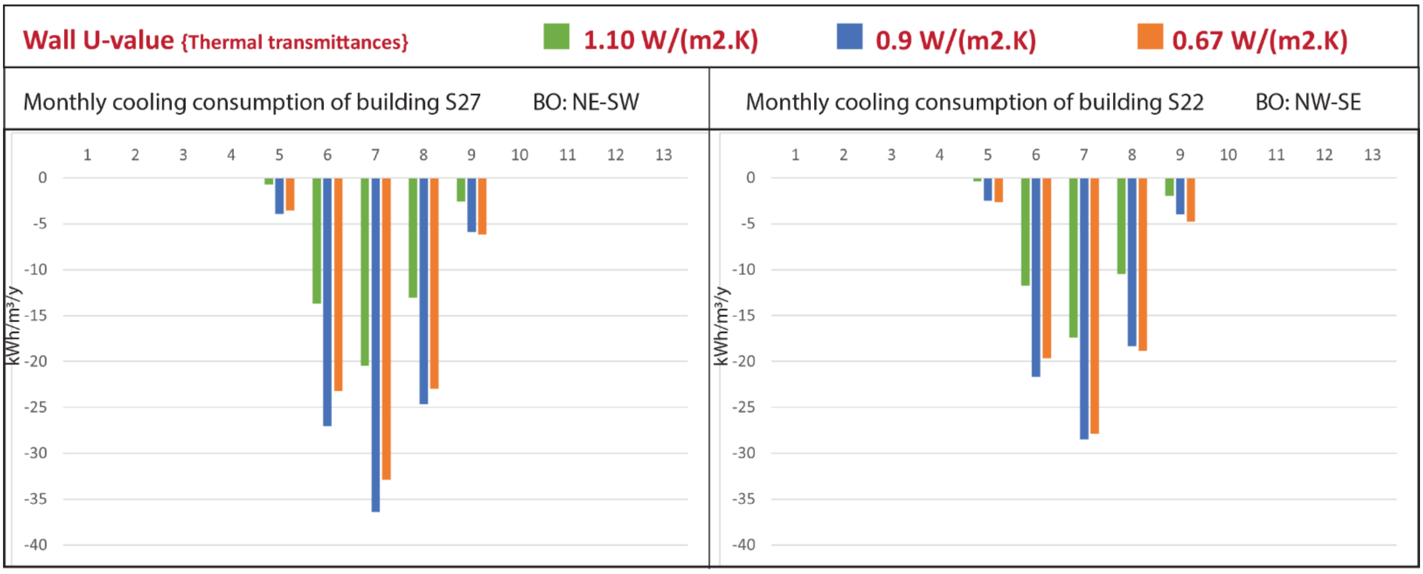


Fig. 40. Monthly cooling consumption of buildings S27 and S22 according to three Walls U-values.

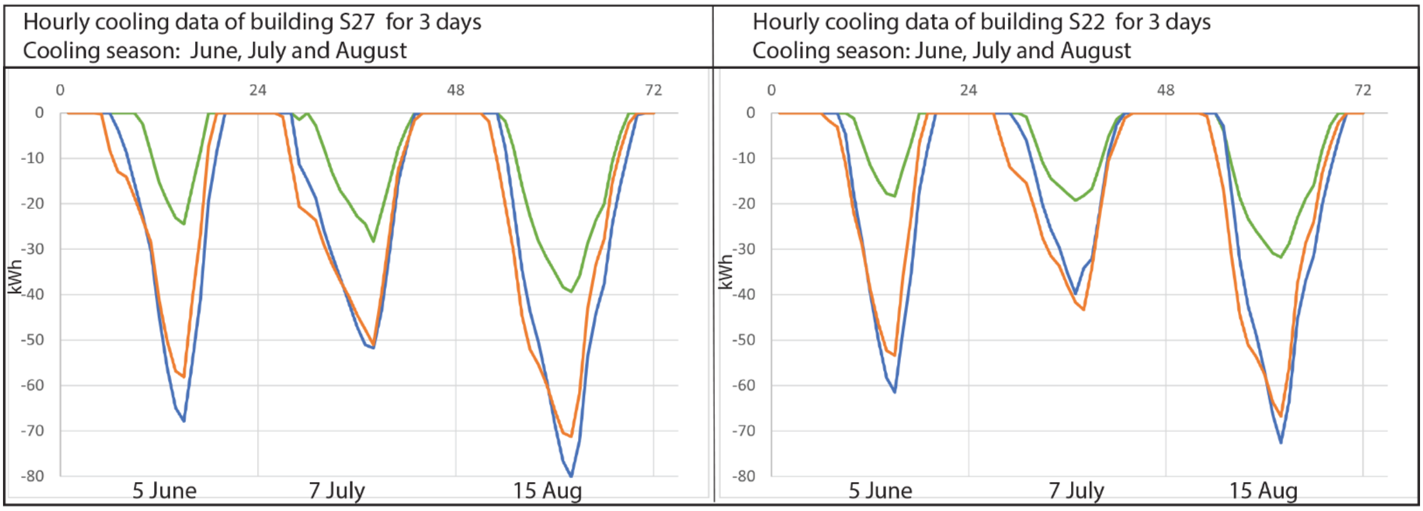


Fig. 41. Hourly cooling consumption of buildings S27 and S22 according to three Walls U-values during three days.

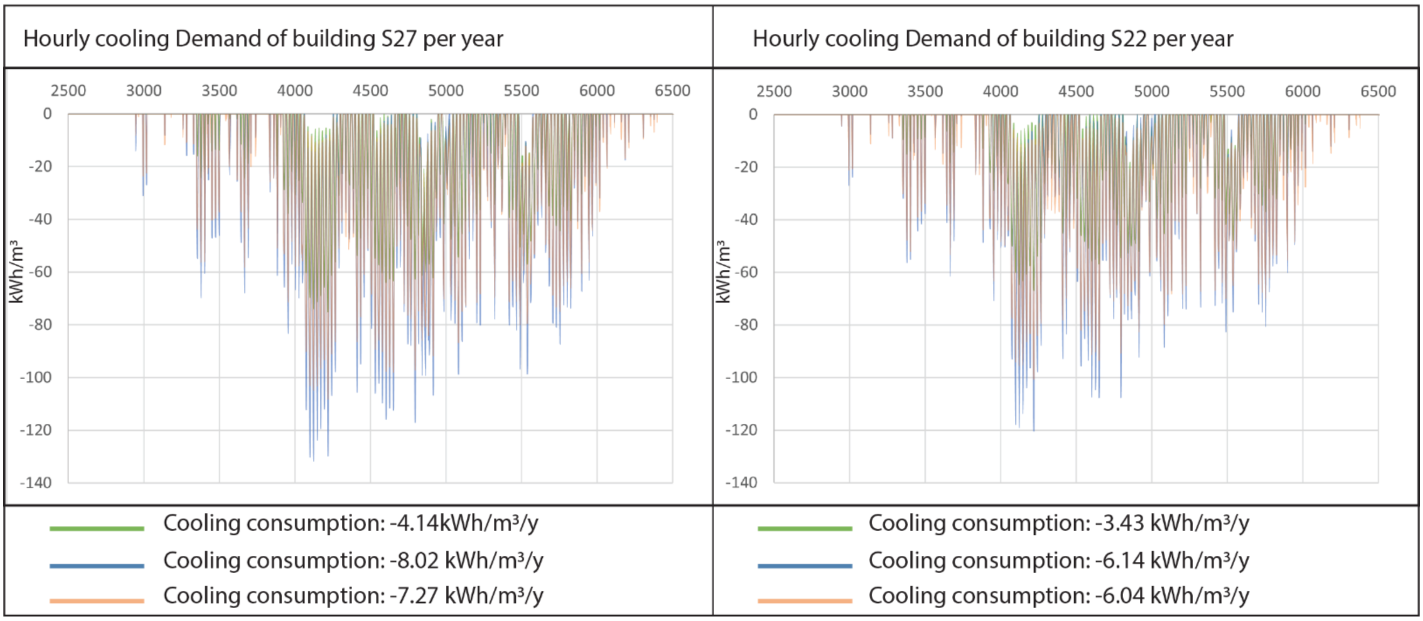


Fig. 42. Hourly cooling consumption of buildings S27 and S22 according to three Walls U-values during a year.

Table. XV. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on walls U-values equal to 1.10, 0.9, and 0.67 W/m². K.

Wall U-value W/(m2.K)	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
1.10	25.55	-4.14	23.51	-3.43
0.9	36.52	-8.02	36.47	-6.14
0.67	24.15	-7.27	23.89	-6.04

Table. XV. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on three changed walls thermal transmittances values equivalent to 1.10, 0.9, and 0.67 W/m². K. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 51%, with a wall U-value equal to 0.9 {W/m². K}, in regard to its lowest consumption of 24.15 kWh/m³/y (with a wall U-value equal to 0.67 {W/m². K}). while S22 with a (NW-SE) had a approximately the same warmth energy impact with 52% between the lowest and highest reached value respectively equal to 23.89 kWh/m³/y and 36.47 kWh/m³/y. Fig. 43., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that MPF03 walls composites consumed the least heating energy demand, while the oldest composite MLPO2 has the lowest cooling energy consumption. MLP03 showed the highest energy consumption for both heating and cooling seasons. Adding to that, buildings with a NE-SW orientation, have a higher Energy consumption impact, in comparison to structures with NW-SE orientations.

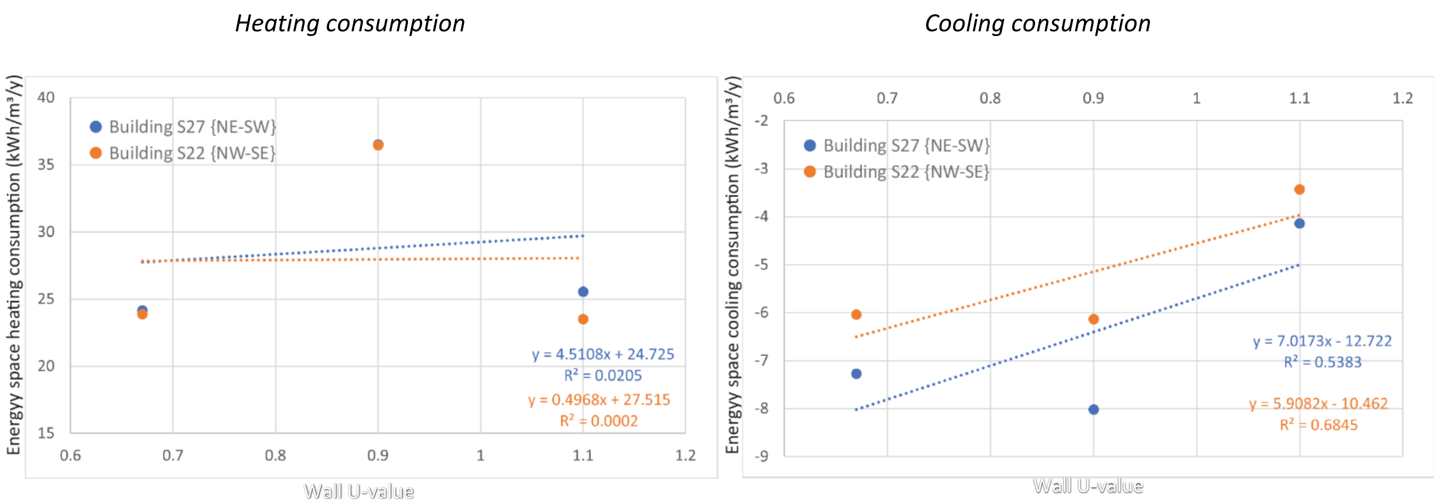


Fig. 43. Energy space heating and cooling demands of buildings S27 and S22 depending on the building's walls U-value.

5.1.4.3- Roof's U-value (U_{roof}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the roof's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.60, 1.27 and 0.53 expressed in {W/m^2. K}. Table. XVI. Shows the three examined roof composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.60 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a roof code of COP01. The second studied value is 1.27 {W/m^2. K}, with a roof code of COP04 (constructed between 1961 and 1970). And the most recent roof composite is COP03 (1990-2005), with the lowest thermal transmittance value equivalent to 0.53 {W/m^2. K}. These different ranges, were inserted in the engineering software CitySim Pro, were simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (S27 and S22) in Sacchi neighborhood characterized by a period of construction before 1919.

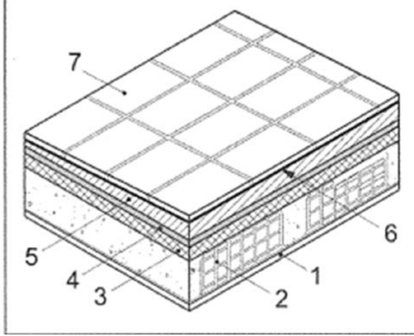
Table. XVI. Roofs codes along with their respective U-values

1919-1945		
	Code	U-value [W/(m²K)]
Roof	COP01	1.60
1961-1970		
	Code	U-value [W/(m²K)]
Roof	COP04	1.27
1990-2005		
	Code	U-value [W/(m²K)]
Roof	COP03	0.53

Tables. XVII. And . XVIII., show the three roofs composites: COP01, COPO4 and COP03 retrieved from UNI/TR 11552, the Italian residential buildings standard. These tables show the material's different composite's thickness, conductivity, and density as well as their respective thermal transmittances expressed in {W/m^2. K}. According to this collected information, the input data of each roof composite was inserted the xml. Sheet of the engineering software CitySim Pro allowing the change of the selected buildings walls materials in order to examine their impact on the heating and cooling energy consumptions by comparing the results.

Table. XVII. Roof COP04 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Roof Composite: COP04	1919-1945
COP04 - Copertura piana praticabile, esempio 2- [3]	



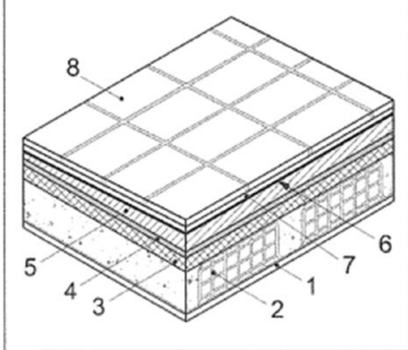
Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Intonaco interno	2	1400	1000	0,700	-
2 Soletta (blocchi di laterizio+travetti in calcestruzzo)	16-24	900	1000	-	0,330-0,370 a)
3Calcestruzzo armato	4	2400	1000		
4 Malta di cemento	2	2000	1000		
5 Massetto in calcestruzzo ordinario	2-12	2000	1000	1,060	-
6 Membrana impermeabilizzante bituminosa	1	1200	1000	0,170	-
7 Pavimentazione esterna - klinker	3	1500	1000	0,700	-

Descrizione (spessori in cm)	U [W/(m² K)]			κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
2 - 24 - 4 - 2 - 12 - 1 - 3	1,33	1,21	1,28		
a) Resistenza termica ricavata secondo la norma UNI 10355.					

```
</Composite>
<Composite id="12" name="COP04" category="Roof">
    <Layer Thickness="0.0300" Conductivity="0.7000" Cp="1000" Density="1500" />
    <Layer Thickness="0.0100" Conductivity="0.1700" Cp="1000" Density="1200" />
    <Layer Thickness="0.1200" Conductivity="1.0600" Cp="1000" Density="2000" />
    <Layer Thickness="0.0200" Conductivity="16.500" Cp="1000" Density="2000" />
    <Layer Thickness="0.0400" Conductivity="8.2500" Cp="1000" Density="2400" />
    <Layer Thickness="0.2400" Conductivity="1.3750" Cp="1000" Density="900" />
    <Layer Thickness="0.0200" Conductivity="0.7000" Cp="1000" Density="1400" />
```

Table. XVIII. Roof COP03 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Roof Composite: COP03	1990-2005
COP03 – Copertura piana praticabile, esempio 1- [3]	



Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Intonaco interno	2	1400	1000	0,700	-
2 Soletta (blocchi di laterizio+travetti in calcestruzzo)	16 24	900	1000	-	0,330-0,370 a)
3 Calcestruzzo armato	4	2400	1000		
4 Malta di cemento	2	2000	1000		
5 Massetto in calcestruzzo ordinario	2-12	2000	1000	1,060	-
6 Membrana impermeabilizzante bituminosa	1	1200	1000	0,170	-
7 Pannello isolante in polistirolo	2-5	30	1220	0,045	-
8 Pavimentazione esterna – klinker	3	1500	1000	0,700	-

Descrizione (spessori in cm)	U [W/(m² K)]			κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
	Fl.ascendente	Fl.discendente	Fl.orizzontale		
2 – 24 – 4 – 2 – 12 – 1 -5 – 3	0,54	0,52	0,53		
a) Resistenza termica ricavata secondo la norma UNI 10355.					

```
</Composite>
<Composite id="120" name="COP03" category="Roof">
    <Layer Thickness="0.0300" Conductivity="0.7000" Cp="1000" Density="1500" />
    <Layer Thickness="0.0500" Conductivity="0.0450" Cp="1220" Density="30" />
    <Layer Thickness="0.0100" Conductivity="0.1700" Cp="1000" Density="1200" />
    <Layer Thickness="0.1200" Conductivity="1.0600" Cp="1000" Density="2000" />
    <Layer Thickness="0.0200" Conductivity="16.500" Cp="1000" Density="2000" />
    <Layer Thickness="0.0400" Conductivity="8.2500" Cp="1000" Density="2400" />
    <Layer Thickness="0.2400" Conductivity="1.375" Cp="1000" Density="900" />
    <Layer Thickness="0.0200" Conductivity="0.7000" Cp="1000" Density="1400" />
```

In fact, the first heating Energy utilization results are shown in Fig. 44. The monthly warmth demand of both structures S27 and S22 had the highest energy utilization with a roof U-value equivalent to 1.27 {W/m^2. K} (indicated in blue), and the lowest one represented with the oldest roof composite COP03 with a thermal transmittance of 1.60 {W/m^2. K}. We can visualize a big gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 45., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the roof's thermal transmittance that is equal to 1.27 {W/m^2. K} (COP04), had constantly the highest warmth utilization. However, for the residential structure S27 characterized by a NE-SW orientation, roof composite COP03 consumed the least heating demand, while for the building S22 with a NW-SE orientation, during the three analyzed days, roof composite with the highest U-value had the lowest warmth Energy consumption (Fig. 45.). As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with a wall U-value equivalent to 1.27 {W/m^2. K} (represented in blue, COP04, according to Fig.46.

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18. (previously analyzed), reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 kWh/m^3/y and -3.43 kWh/m^3/y respectively. In fact, the first monthly

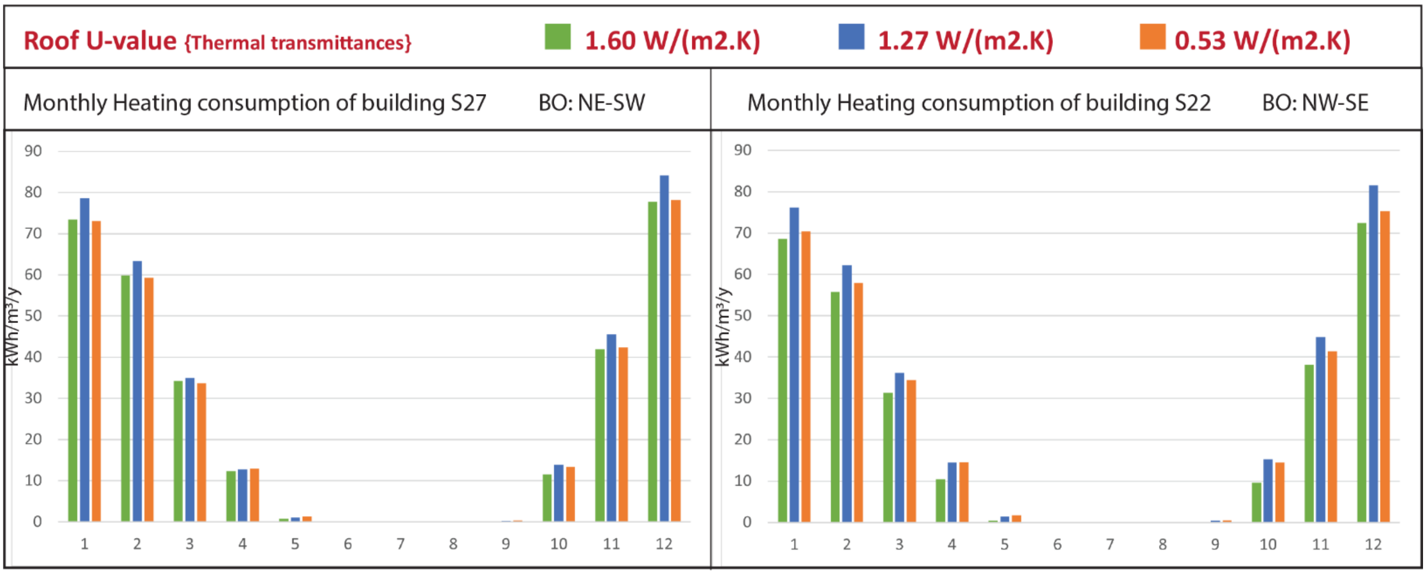


Fig. 44. Monthly heating consumption of buildings S27 and S22 according to three roof U-values.

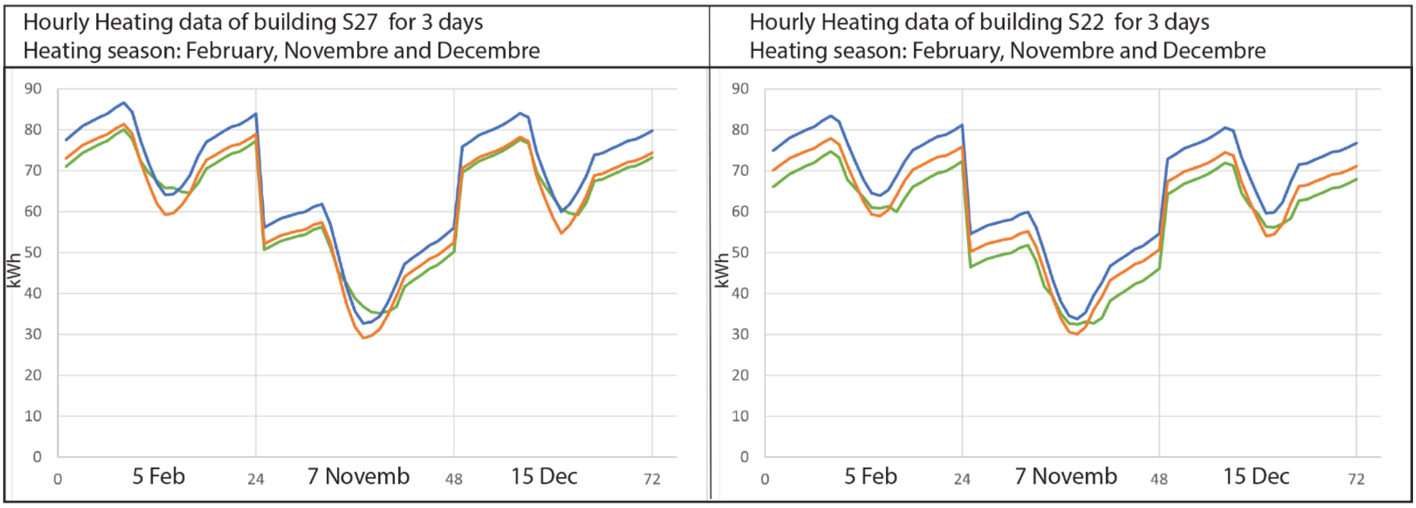


Fig. 45. **Hourly heating consumption of buildings S27 and S22 according to three roof U-values during three days.**

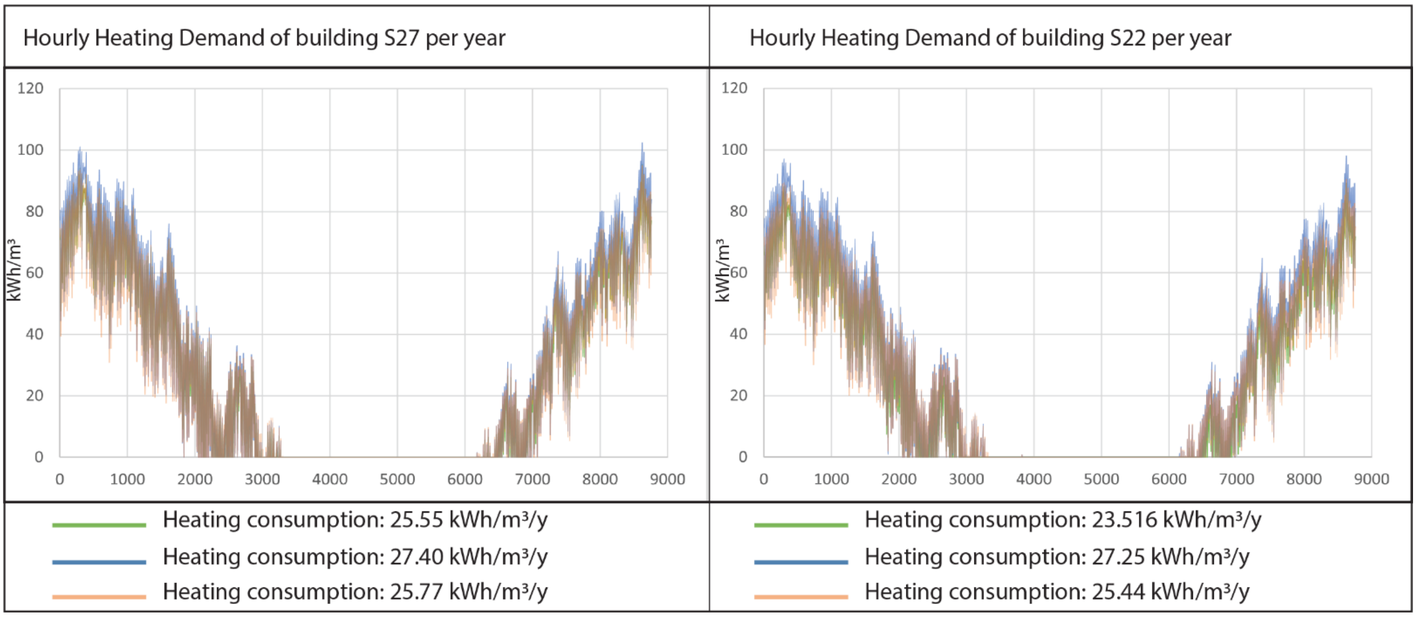


Fig. 46. **Hourly heating consumption of buildings S27 and S22 according to three roof U-values during a year.**

results represented in Fig. 47., show that, when the roof's thermal transmittance of the building was equal to 1.27 {W/m^2. K} (COP04), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures S27 and S22 were the highest compared to the two other roof composites (COP01 and COP04). However, the most recent roof configuration, COP03, with a U-value equivalent to 0.53 {W/m^2. K} (represented in orange), consumed more cooling energy compared to the oldest roof code, COP01 (1919-1945), represented on the graph in green. Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 48.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building S27 characterized by a NE-SW orientation, and S22 with a NW-SE orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the roof thermal transmittance equal to 1.27 {W/m^2. K} (COP04), constantly had the highest cooling Energy consumption (represented in blue), followed by the simulated results of roof COP03 (represented in orange), and finally the lowest hourly and yearly cooling Energy utilization is represented by the highest wall U-value, that is equal to 1.60 (wall composite COP01: represented in green and characterized by the oldest period of construction {1919-1945}) in accordance with Fig. 49.

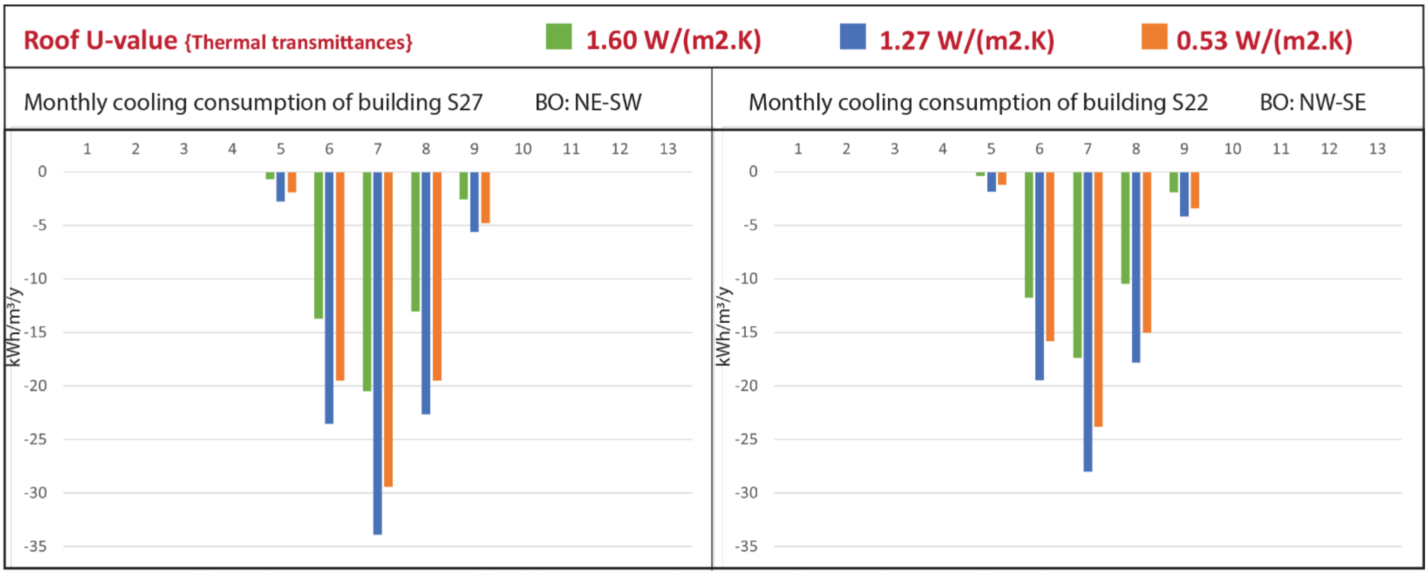


Fig. 47. **Monthly cooling consumption of buildings S27 and S22 according to three Roof U-values.**

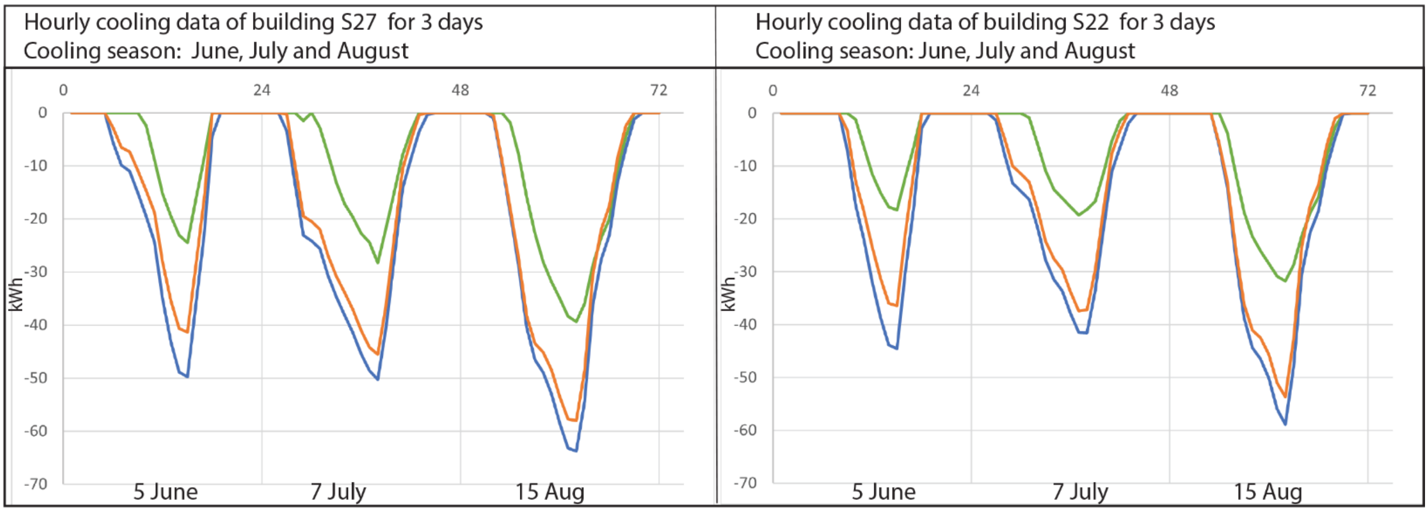


Fig. 48. **Hourly cooling consumption of buildings S27 and S22 according to three roof U-values during three days.**

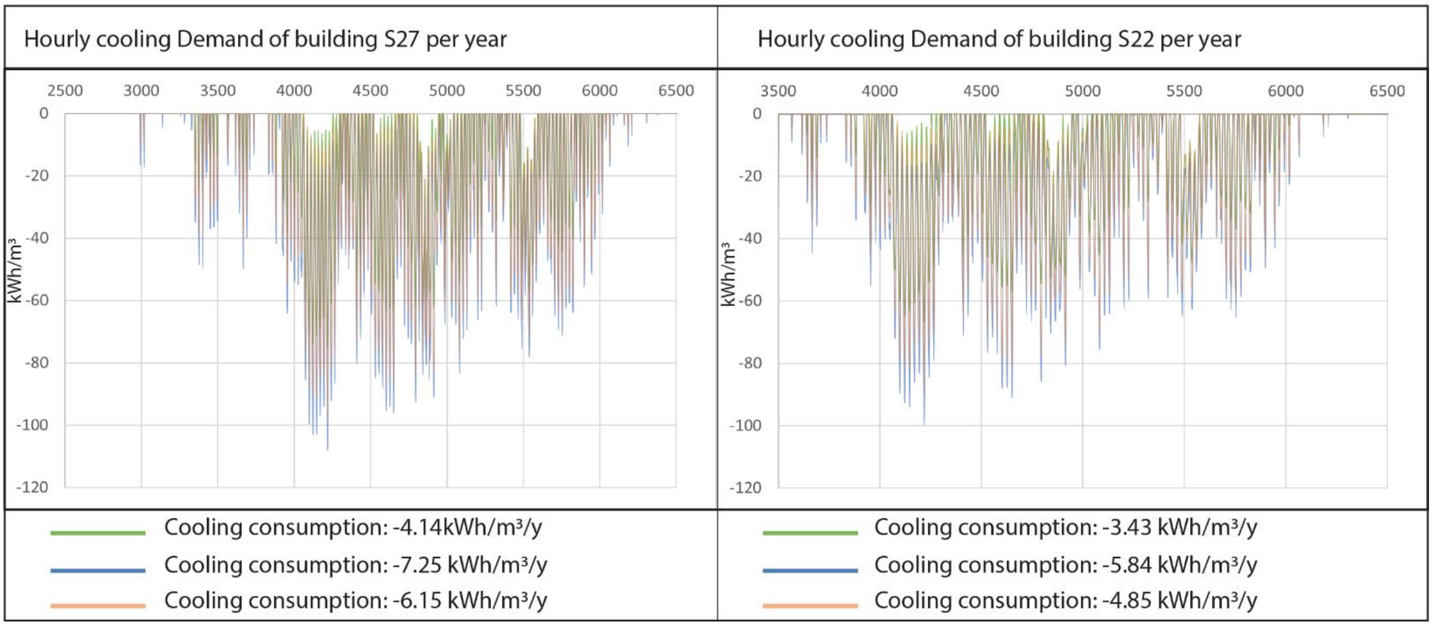


Fig. 49. Hourly cooling consumption of buildings S27 and S22 according to three roof U-values during three days.

Table. XIX. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on roof U-values equal to 1.60, 1.27, and 0.53 W/m^2. K.

Roof U-value W/(m2.K)	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
1.60	25.55	-4.14	23.51	-3.43
1.27	27.40	-7.25	27.25	-5.84
0.53	25.77	-6.15	25.44	-4.85

Table. XIX. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on three changed roof thermal transmittances values equivalent to 1.60 {1919-1945}, 1.27 {1961-1970}, and 0.53 W/m^2. K with residential buildings constructed with the most recent period ranging between 2001 and 2005. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 7%, with a roof U-value equal to 1.27 {W/m^2. K}, in regard to its lowest consumption of 25.55 kWh/m^3/y (with the oldest roof composite with a U-value equal to 1.60 {W/m^2. K}). while S22 with a (NW-SE) had a higher energy, impact compared to S27, with 16% between the lowest and highest reached value respectively equal to 23.51 kWh/m^3/y and 27.25 kWh/m^3/y. Fig. 50., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that COP04 roof composite consumed the highest heating and cooling energy demand, while the oldest composite COP01, had the lowest yearly energy Utilization. Adding to that, buildings with a NE-SW orientation, have a higher cooling Energy consumption impact, in comparison to structures with NW-SE orientations. While S22 {NW-SE} was more impacted regarding the heating demand in comparison to S27 {NE-SW}.

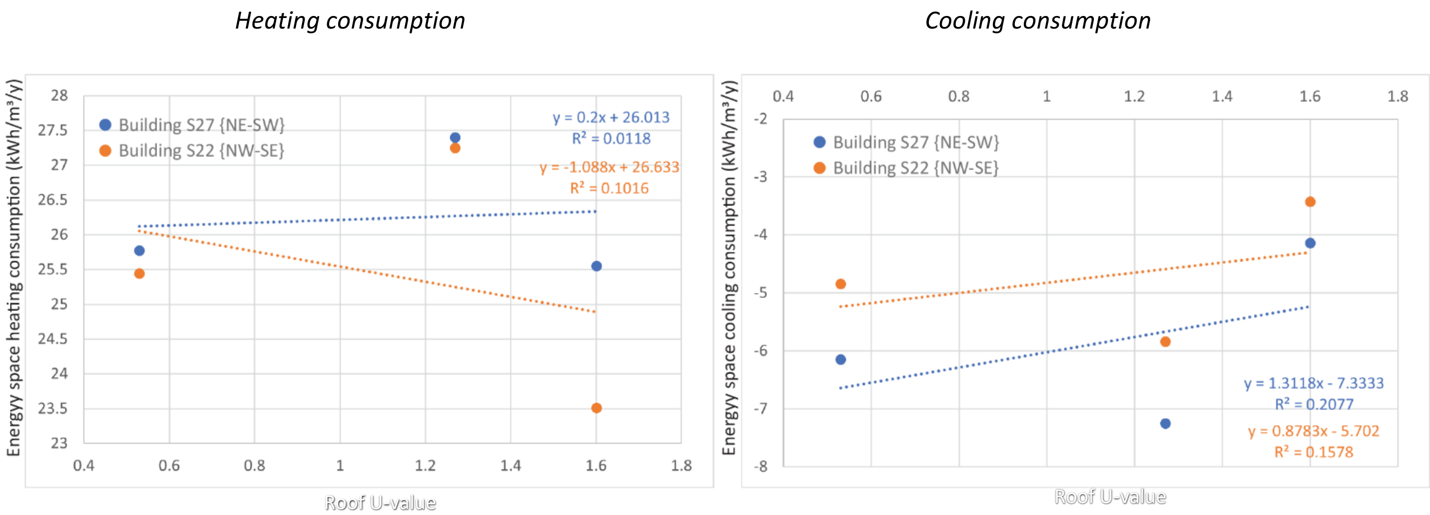


Fig. 50. Energy space heating and cooling demands of buildings S27 and S22 depending on the building's roof U-value.

5.1.4.4- Floor's U-value (U_{floor}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with floor U-values varying according to the building's construction period. In fact, the lower the floor's U-value the more the building is insulated from the ground factors. In this variable, two main values were analyzed: 1.16, and 1.25 expressed in {W/m^2. K}. Table. XX. Shows the two examined floor composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.25 {W/m^2. K} characterized by the newest built period ranging between 1961 and 2005 with a floor code of SOL04. The second studied value is 1.16 {W/m^2. K}, with a floor code of SOL03 (characterized by a constructed period varying between 1919 and 1960). These different ranges were inserted in the engineering software CitySim Pro, where simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (S27 and S22) in Sacchi neighborhood characterized by a period of construction before 1919.

Table. XX. Floor codes along with their respective U-values

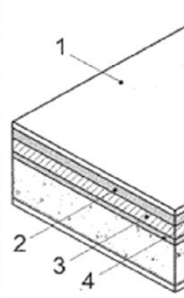
1919-1960		
	Code	U-value [W/(m²K)]
Floor	SOL03	1.16
1961-2005		
	Code	U-value [W/(m²K)]
Floor	SOL04	1.25

Tables. XXI. And . XXII., show the two floor composites: SOL03 and SOL04 retrieved from UNI/TR 11552, the Italian residential buildings standard. These tables show the material's different composite's thickness, conductivity, and density as well as their respective thermal transmittances expressed in {W/m^2. K}. According to this collected information, the input data of each roof composite was inserted the xml. Sheet of the engineering software CitySim Pro allowing the change of the selected buildings walls materials in order to examine their impact on the heating and cooling energy consumptions by comparing the results.

In fact, the first heating Energy utilization results are shown in Fig. 51. The monthly warmth demand of both structures S27 and S22 had the highest energy utilization with a floor U-value equivalent to 1.25 {W/m^2. K} (indicated in orange), and the lowest one represented with the oldest floor composite SOL04 with a thermal transmittance of 1.16 {W/m^2. K}. We can visualize a big gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 52., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the floor's thermal transmittance that is equal to 1.25 {W/m^2. K} (SOL04), had constantly the highest warmth utilization. While SOL04 that is characterized by the most recent period of construction {1961-2005}, consumed more heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours)

Table. XXI. Floor SOL03 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Floor Composite: SOL03	1919-1960
SOL03 - Solaio in laterocemento - blocchi collaboranti, esempio 2- [3]	



Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Pavimentazione interna - gres	1,5	1700	1000	1,470	-
2 Malta di cemento	2	2000	1000	1,400	-
3 Massetto in calcestruzzo ordinario	2 6 12	1500 1700 1900	1000	1,060	-
4 Malta di cemento	2	2000	1000	-	0,300 - 0,350 [a)]
5 Soletta (blocchi in laterizio+travetti in calcestruzzo)	16-24	900	1000		
6 Intonaco esterno	2	1800	1000	0,900	-

Descrizione (spessori in cm)	U [W/(m² K)]			κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
	Fl.ascendente	Fl.discendente	Fl.orizzontale		
1,5 - 2 - 6 – (2 +24)- 2	1,69	1,51	1,60		
NOTA 1 A titolo esemplificativo si ipotizza una pavimentazione in gres ceramico.					
a) Resistenza termica ricavata secondo la norma UNI 10355.					

```
</Composite>
<Composite id="502" name="SOL03" category="Floor">
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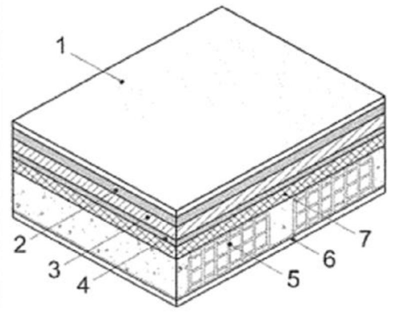
    <Layer Thickness="0.2000" Conductivity="0.5714" Cp="1000" Density="2000" />
    <Layer Thickness="0.0600" Conductivity="1.0600" Cp="1000" Density="1700" />
    <Layer Thickness="0.0200" Conductivity="1.4000" Cp="1000" Density="2000" />
    <Layer Thickness="0.0150" Conductivity="1.4700" Cp="1000" Density="1700" />
```

Table. XXII. Floor SOL04 composites and materials input data along with the inserted input data in the xml. Sheet of CitySim software.

Floor Composite: SOL03	1961-2005
SOL04 - Solaio in laterocemento – blocchi non collaboranti, esempio 1- [3]	



Strato	d [cm]	ρ [kg/m³]	c [J/(kg K)]	λ [W/m K]	R [m²K/W]
1 Pavimentazione interna - gres	1,5	1700	1000	1,470	-
2 Malta di cemento	2	2000	1000	1,400	-
3 Massetto in calcestruzzo alleggerito	2 6 12	400 900 1400	1000	0,580	-
4 Malta di cemento	2	2000	1000	-	0,330-0,370 [a)]
5 Calcestruzzo armato	4	2400	1000		
6 Soletta (blocchi di laterizio+travetti in calcestruzzo)	16-24	900	1000		
7 Intonaco esterno	2	1800	1000	0,900	-

Descrizione (spessori in cm)	U [W/(m² K)]			κ_i [kJ/(m² K)]	Y_{ie} [W/(m²K)]
	Fl.ascendente	Fl.discendente	Fl.orizzontale		
1,5 - 2 -12 – (2 + 4 + 24) - 2	1,31	1,20	1,26		
NOTA 1 A titolo esemplificativo si ipotizza una pavimentazione in gres ceramico.					
a) Resistenza termica ricavata secondo la norma UNI 10355.					

```
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    <Layer Thickness="0.0400" Conductivity="8.2500" Cp="1000" Density="2400" />
    <Layer Thickness="0.0200" Conductivity="16.500" Cp="1000" Density="2000" />
    <Layer Thickness="0.1200" Conductivity="0.5800" Cp="1000" Density="1400" />
    <Layer Thickness="0.0200" Conductivity="1.4000" Cp="1000" Density="2000" />
    <Layer Thickness="0.0150" Conductivity="1.4700" Cp="1000" Density="1700" />
```

Floor U-value {Thermal transmittances} 1.16 W/(m2.K) 1.25 W/(m2.K)

Monthly Heating consumption of building S27 BO: NE-SW	Monthly Heating consumption of building S22 BO: NW-SE

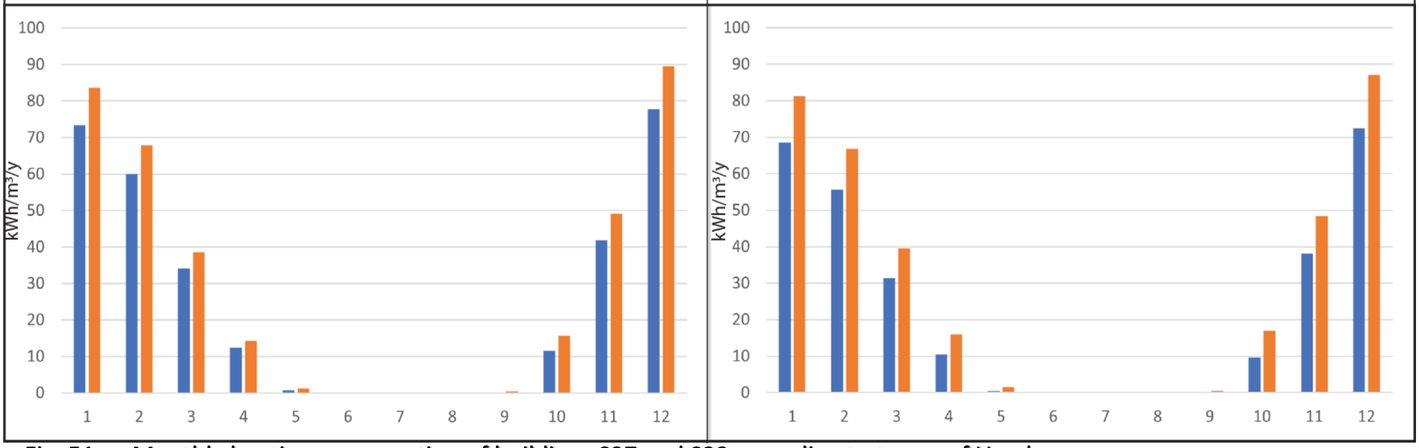


Fig. 51. Monthly heating consumption of buildings S27 and S22 according to two roof U-values.

Hourly Heating data of building S27 for 3 days Heating season: February, Novembre and Decembre	Hourly Heating data of building S22 for 3 days Heating season: February, Novembre and Decembre

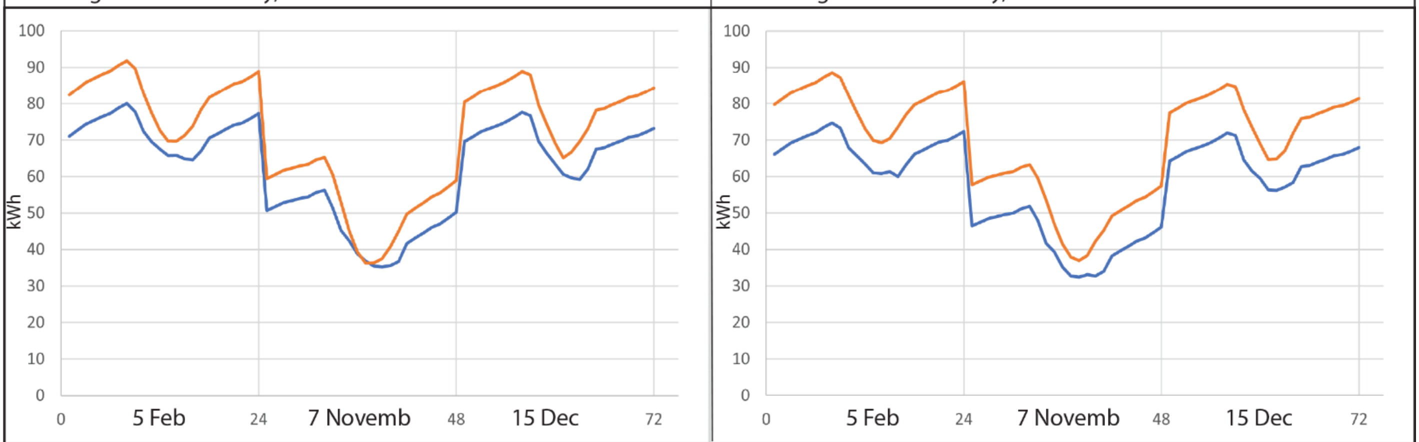
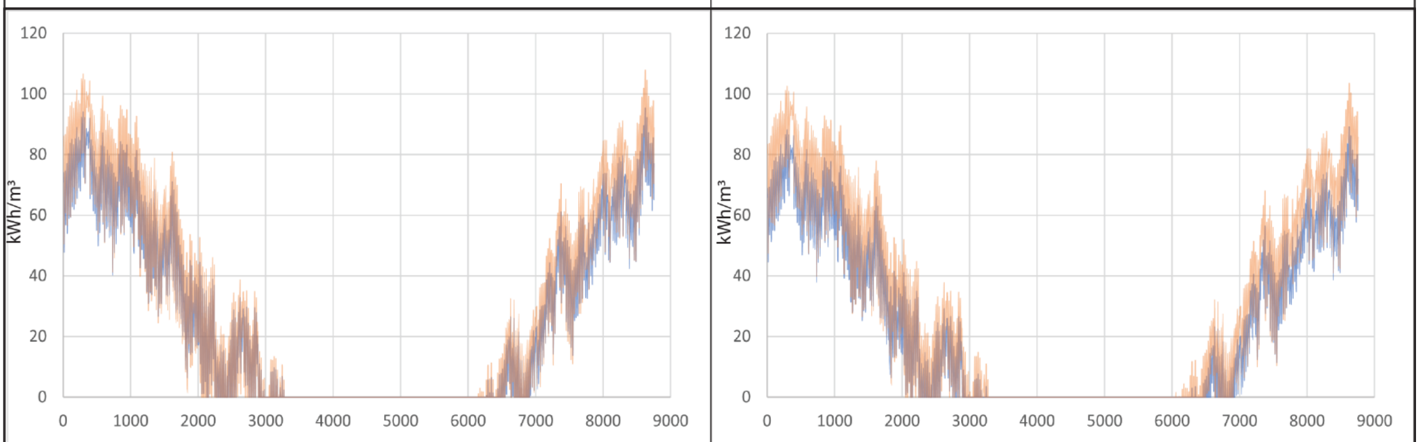


Fig. 52. Hourly heating consumption of buildings S27 and S22 according to two roof U-values during three days.

Hourly Heating Demand of building S27 per year	Hourly Heating Demand of building S22 per year



S27	S22
Heating consumption: 25.55 kWh/m³/y	Heating consumption: 23.51 kWh/m³/y
Heating consumption: 29.55 kWh/m³/y	Heating consumption: 29.35 kWh/m³/y

Fig. 53. Hourly heating consumption of buildings S27 and S22 according to two roof U-values during a year.

buildings S27 and S22, both regularly consumed more heating Energy with a floor U-value equivalent to 1.25 {W/m^2. K} (represented in orange, SOL04) in accordance with the hourly results shown in Fig.53.

Adding to that, the cooling Energy consumptions of building S27 and S22 were analyzed as well. In fact, Fig. 18. (previously analyzed), reflects the yearly Cooling demand of Sacchi neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure S27 consumed more cooling energy compared to S22 with equivalent values of -4.14 kWh/m^3/y and -3.43 kWh/m^3/y respectively. In fact, the first monthly results represented in Fig. 54., show that, when the roof's thermal transmittance of the building was equal to 1.25 {W/m^2. K} (SOL04 represented in orange), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures S27 and S22 were the highest compared to the other roof composite (SOL03, represented in blue). Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 55.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building S27 characterized by a NE-SW orientation, and S22 with a NW-SE orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the floor thermal transmittance equal to 1.25 {W/m^2. K}, constantly had the highest cooling Energy demand,

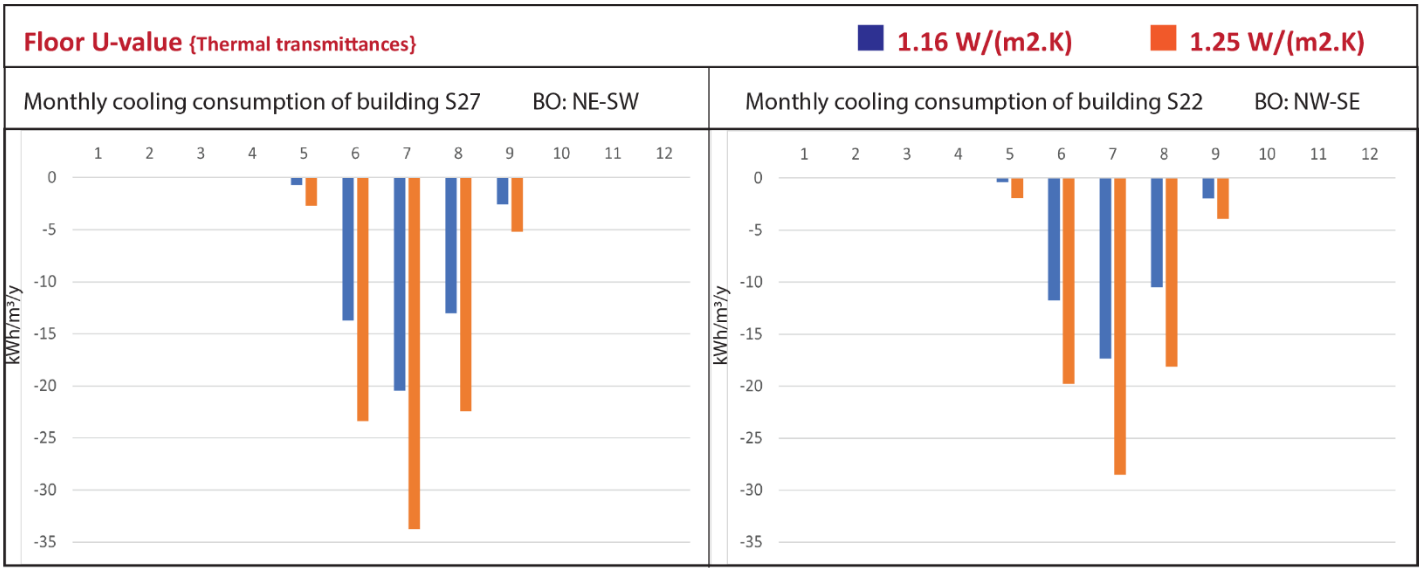


Fig. 54. Monthly cooling consumption of buildings S27 and S22 according to two floor U-values.

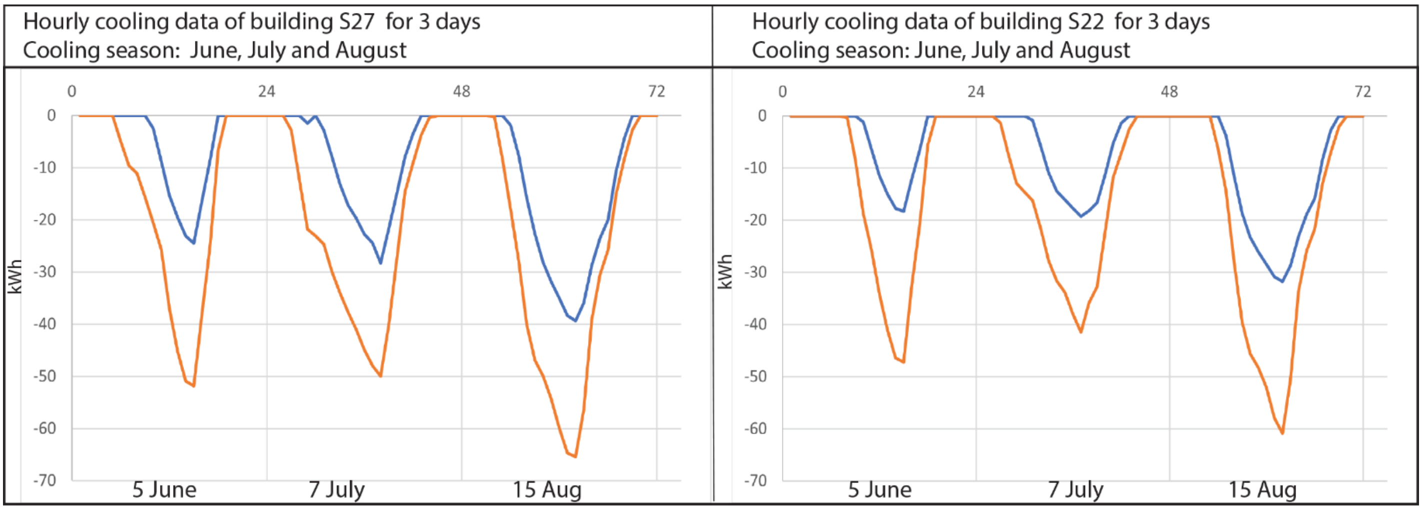


Fig. 55. Hourly cooling consumption of buildings S27 and S22 according to two floor U-values during three days.

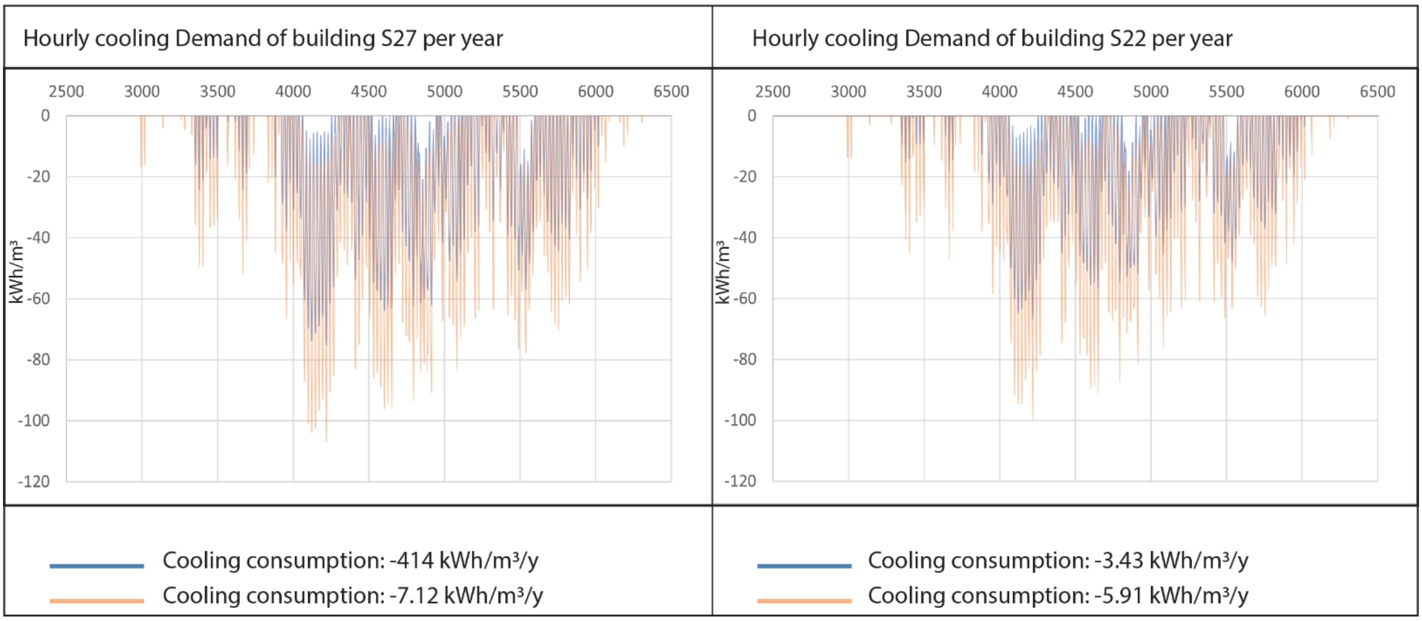


Fig. 56. Hourly cooling consumption of buildings S27 and S22 according to two floor U-values during a year.

(represented in orange), compared to the floor material SOL03 that is characterized by an older period of construction (represented in blue), in accordance with the cooing simulated energy results shown in Fig. 56.

Table. XXIII. Buildings S27 and S22 Heating and Cooling Energy consumptions depending on floor U-values equal to 1.16, and 1.25 W/m². K.

Floor U-value W/(m2.K)	Building S27 Heating Consumption (kWh/m³/y)	Building S27 Cooling Consumption (kWh/m³/y)	Building S22 Heating Consumption (kWh/m³/y)	Building S22 Cooling Consumption (kWh/m³/y)
1.16	25.55	-4.14	23.51	-3.43
1.25	29.55	-7.12	29.35	-5.91

Table. XXIII. Shows the variations in the heating and cooling energy consumptions of buildings S27 and S22 depending on two changed floor thermal transmittances values equivalent to 1.16 {1919-196}, and 1.25 {1961-2005}, expressed in {W/m^2. K}. In fact, S27 characterized by a {NE-SW} building orientation, had an increase of 15%, with a floor U-value equal to 1.16 {W/m^2. K}, in regard to its lowest consumption of 25.55 kWh/m^3/y. while S22 with a (NW-SE) had a higher energy, impact compared to S27, with 25% between the lowest and highest reached value respectively equal to 23.51 kWh/m^3/y and 29.35 kWh/m^3/y. Fig. 57., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of S27 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that SOL04 floor composite consumed the highest heating and cooling energy demand, while the oldest composite SOL03, had the lowest yearly energy Utilization. Adding to that, buildings with a NE-SW orientation, have a higher cooling Energy consumption impact, in comparison to structures with NW-SE orientations. While S22 {NW-SE} was more impacted regarding the heating demand in comparison to S27 {NE-SW}.

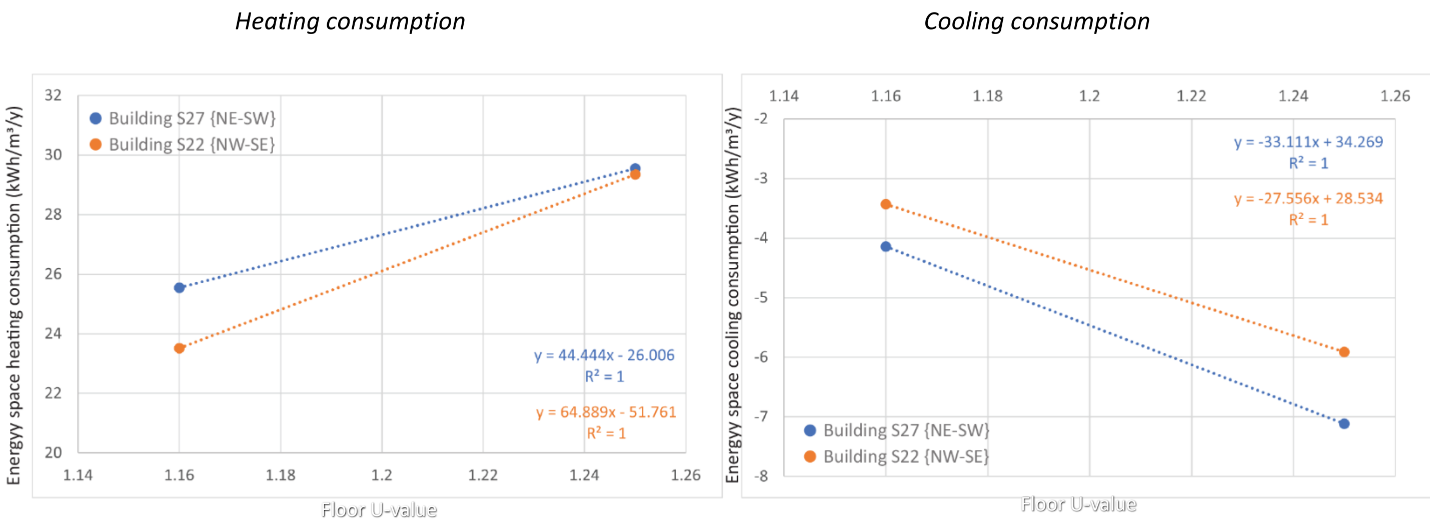


Fig. 57. Energy space heating and cooling demands of buildings S27 and S22 depending on the building's floor U-value.

5.2- Crocetta district: Impact of energy-related building variables

Crocetta neighborhood, is located in the city of Turin, Italy. This urban zone is characterized by a big number of buildings constructed between 1919 and 1945. In fact, it has a moderate Building coverage ratio equivalent to 0.28, that reflects the gross built area of the neighborhood over the census parcel area, with a building density equivalent to 5.86 m^3/m^2, that represents the proportion between the overall volume of the buildings and the census parcel zone. And a Height to Width urban ratio of 0.52 m/m. Two buildings were analyzed (C110 and C189), where their respective heating and cooling demands were compared and analyzed following different ranges of urban variable inserted in the engineering software CitySim Pro. The analyzed residential building parameters are: Infiltration rate (ranges equivalent to 0.2, 0.4 and 0.6 $h\text{-}^1$), Glazing ratio (ranges equivalent to 0.2, 0.4 and 0.6), Thermal transmittances of walls (ranges equivalent to 2.15, 4.40 and 4.90 $W/(m^2.k)$), Thermal transmittances of roof (ranges equivalent to 0.53, 1.27 and 1.60$W/(m^2.k)$), and finally, Thermal transmittances of floor (equivalent to 1.16 and 1.25 $W/(m^2.k)$). In fact, for each variable, results were separated into monthly heating and cooling energy data, Hourly results for three heating and cooling season (5th of February, 7th of November, 15th of December, 5th of June, 7th of July and finally 15th of August), as well as the hourly heating and cooling Energy consumptions over the course of one year (equivalent to 8761 hours).

5.2.1- Building's Surface to Volume ratio

In fact, the Surface to Volume {S/V} proportion is a ratio indicating the compactness of a certain structure or building. It is frequently communicated as the 'heat misfortune structure factor', which is the proportion the building's envelope area (walls, roofs, terraces…etc.) to the treated floor area of the designated structure. This ratio will help in the identification of the building's typology, weather it is a small condominium house or a tower for example. In this case, building C110 has a S/V ratio equal to 0.37 while C189 has a bigger value of 0.55. the two structures are characterized by opposite orientations of {NE-SW} and {NW-SE} respectively. C110 is characterized by a bigger heated Volume (5735 m^3), compared to C189 (4753 m^3) shown in Table. XXIV. Building C110 has an energy heating consumption equal to 15.70 $kWh/m^3/y$, with a cooling demand of -2.52 $kWh/m^3/y$.

However, C189, is characterized by a higher energy utilization with 16.14 kWh/m^3/y in warmth consumption, and -2.85 kWh/m^3/y for its yearly cooling consumption (Fig. 58).

Table. XXIV. This table, shows the heated volume, building orientation, Surface to Volume ratio and Energy heating and cooling of buildings C110 and C189.

Building ID	Heated Volume	Building orientation	S/V	Energy heating Consumption (kWh/m³/y)	Energy cooling Consumption (kWh/m³/y)
C110	5735	NE-SW	0.37	15.70	-2.52
C189	4753	NW-SE	0.55	16.14	-2.85

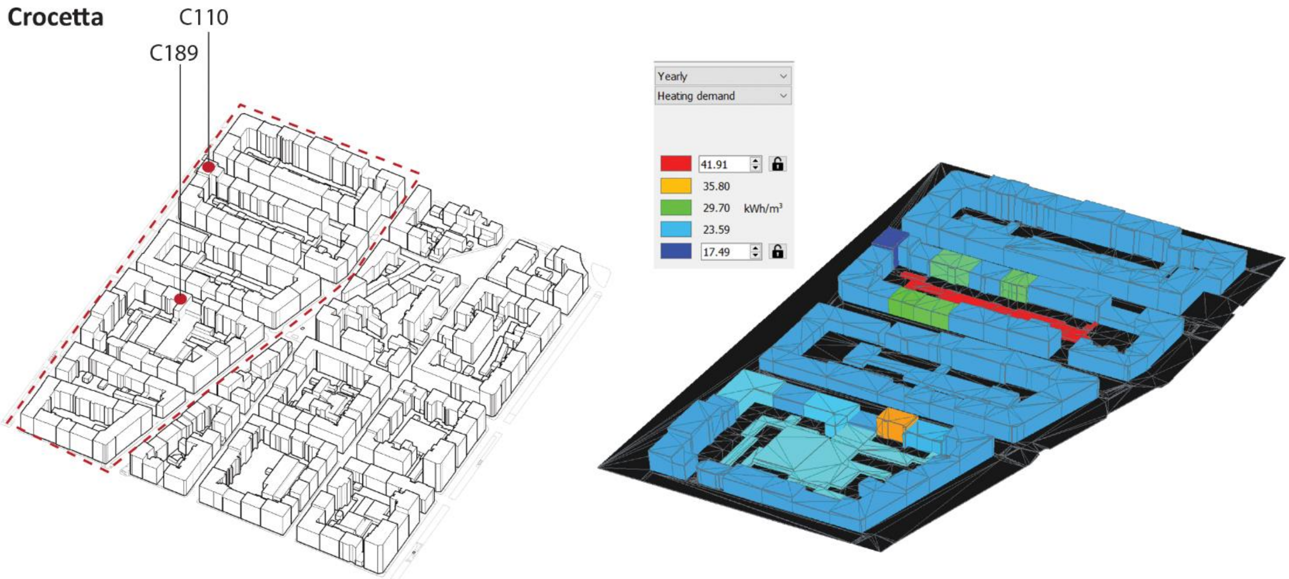


Fig. 58. Three-dimensional representation of Crocetta neighborhood indicating the two analyzed buildings. And Yearly Heating demand of Crocetta district calculated by CitySim Pro.

5.2.2- Building's infiltration rate (h^{-1})

Infiltration is the unintentional or coincidental presentation of outdoor air into a building, ordinarily through cracks in the structure envelope and through utilization of entryways such as doors. The higher the infiltration rate, the more outdoor air is penetrating inside the building and therefore affecting the building's internal temperature. In this analysis, three different infiltration rates were studied: 0.2 h^{-1} (indicated in green), 0.4 h^{-1} (indicated in blue), and 0.6 h^{-1} (indicated in orange), in order to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (C110 and C189). The first warmth Energy utilization results are shown in Fig. 59. In fact, the monthly heating demand of both structures C110 and C189, increased when the infiltration rate was higher, mainly due to the penetration of the cold outdoor air inside of the building. Adding to that, Fig. 60., represents the hourly heating data of buildings S27 and S22 in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December.

The graphs show that for the two selected residential structures, infiltration rate equal to 0.6 h^{-1}, had constantly the highest warmth utilization, while the lowest rate (0.2 h^{-1}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November (mainly due to a higher outdoor air temperature in this month), it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with the highest infiltration rate of 0.6 h^{-1} (represented in orange), compared to rates equivalent to 0.4 h^{-1} (represented in green), and 0.2 h^{-1} (represented in blue) (Fig. 61.).

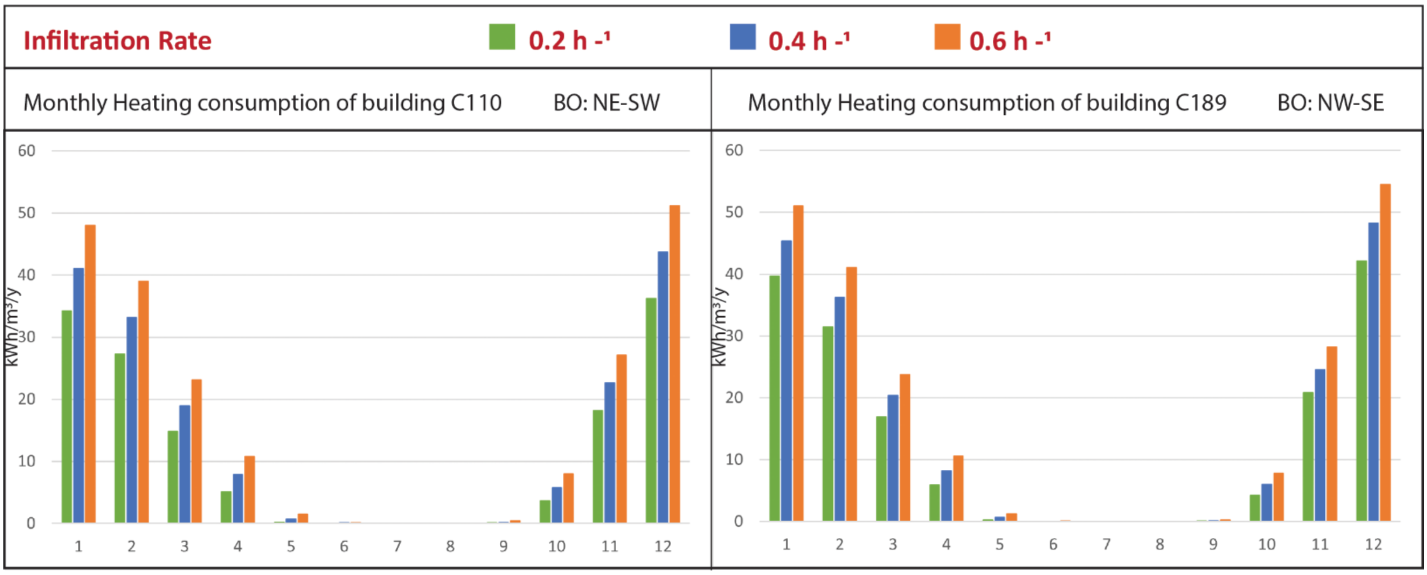


Fig. 59. Monthly heating consumption of buildings C110 and C189 according to three infiltration rates.

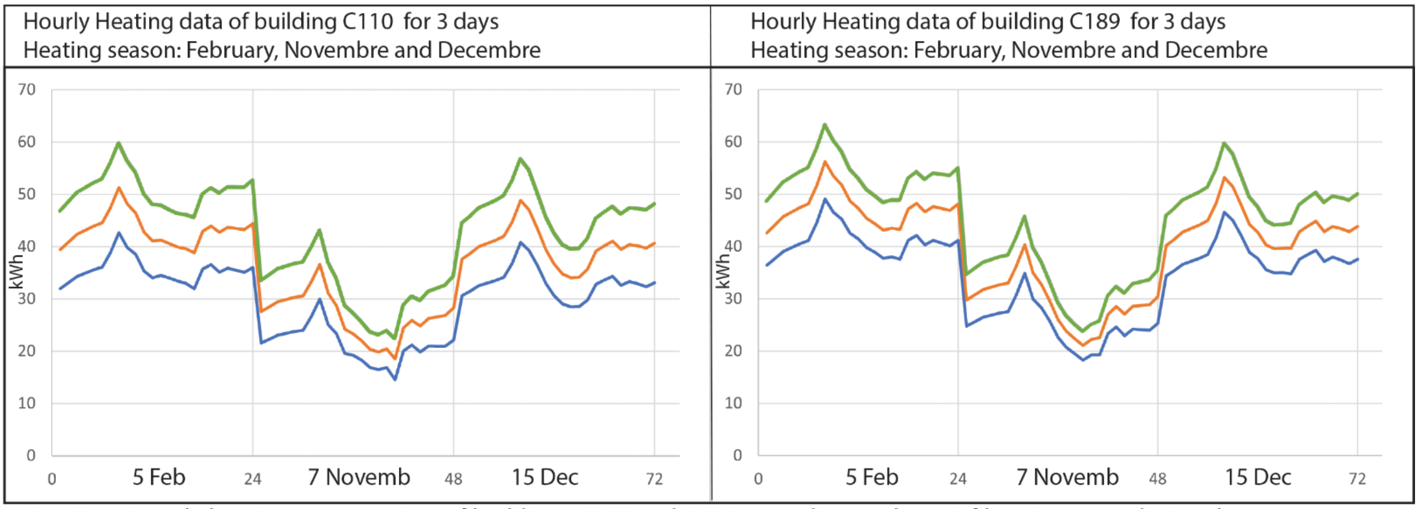


Fig. 60. Hourly heating consumption of buildings C110 and C189 according to three infiltration rates during three

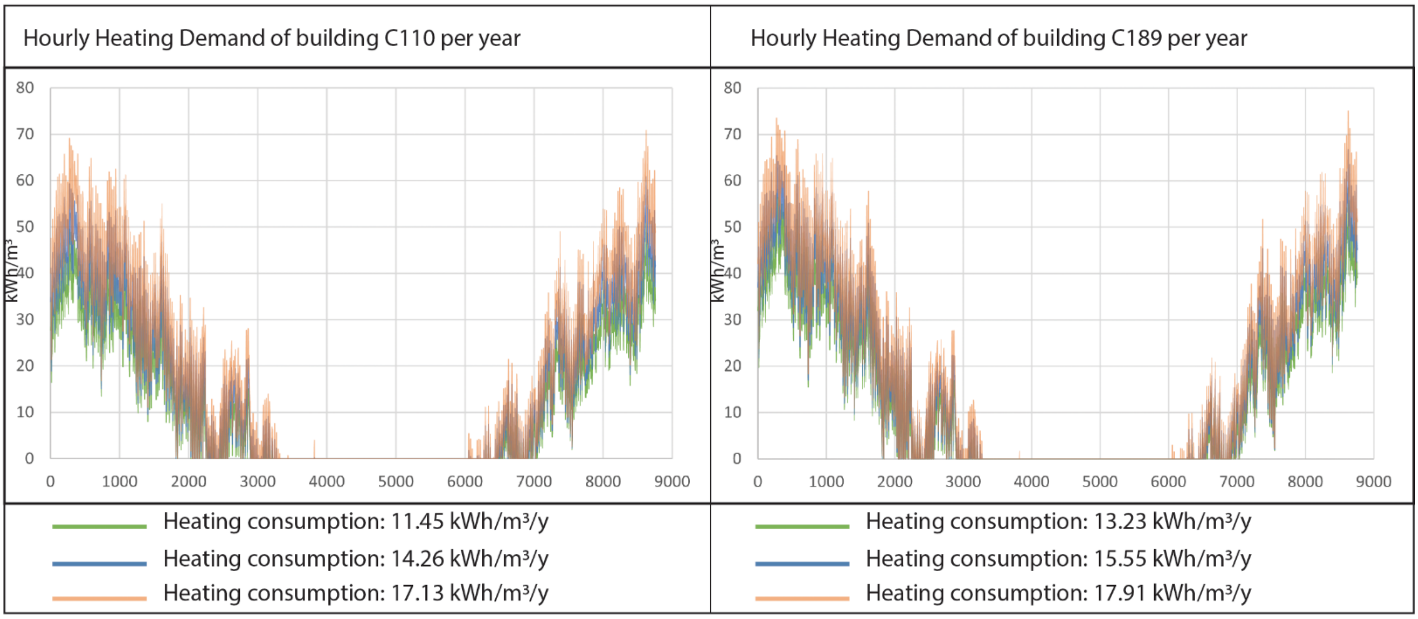


Fig. 61. Hourly heating consumption of buildings C110 and C189 according to three infiltration rates during a year.

Adding to that, the cooling Energy consumptions of buildings C110 and C189, were analyzed as well. In fact, Fig. 62., reflects the yearly Cooling demand of Crocetta neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure C189 consumed more cooling energy compared to C110 with equivalent values of -2.85 $kWh/m^3/y$ and -2.52 $kWh/m^3/y$ respectively. In fact, the first deducted monthly results represented in Fig. 63., show that, when the infiltration rate of the building increased, on the opposite of the heating consumption, the cooling Energy demand decreased for both the structures C110 and C189.

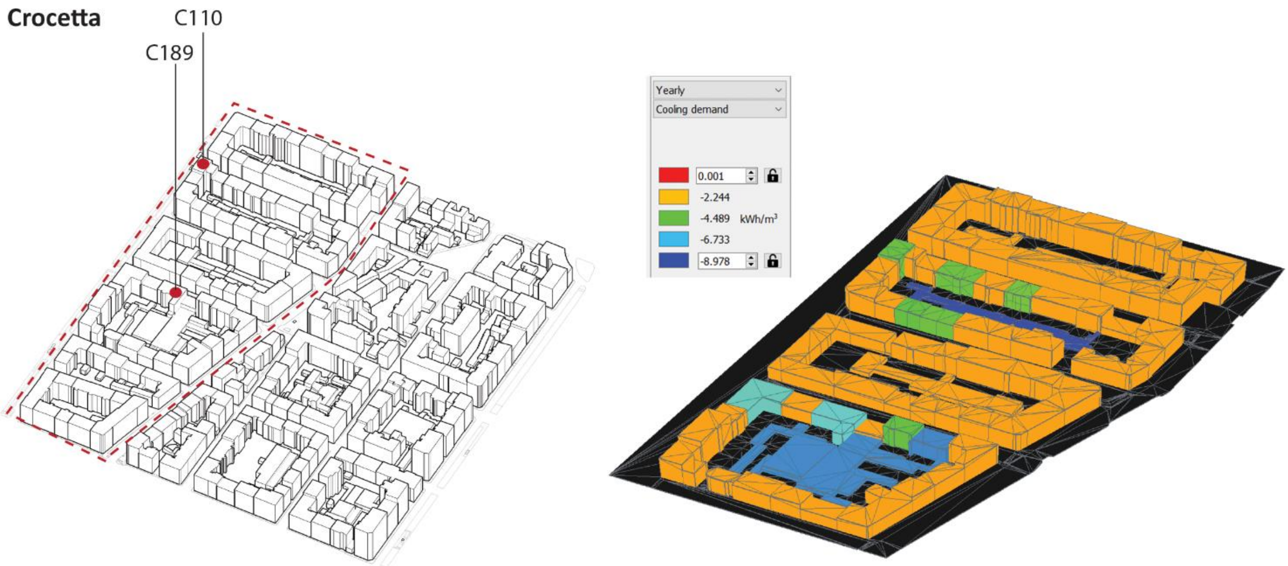


Fig. 62. Three-dimensional representation of Crocetta neighborhood indicating the two analyzed buildings. And Yearly cooling demand of Crocetta district calculated by CitySim Pro.

Adding to that, an hourly Energy data was conducted for C110 and C189, for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 64.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with an infiltration rate equal to 0.6 h^{-1}, the energy consumption was higher compared to rates equal to 0.2 and 0.4, even though the yearly energy cooling consumption of this range was the lowest with -2.43 kWh/m^3/y for C110 and -2.73 kWh/m^3/y for C189 (Fig. 21). However, during the months June and July, the lowest infiltration rate (0.2 h^{-1}) had the highest Energy cooling utilization.

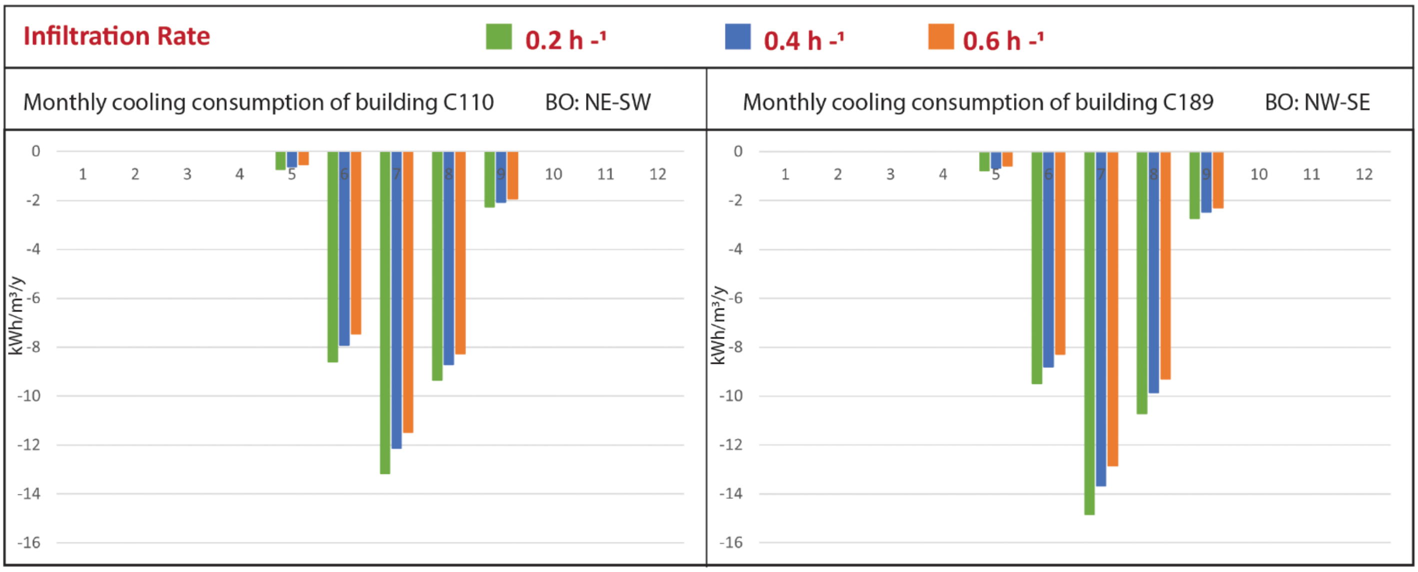


Fig. 63. Monthly cooling consumption of buildings C110 and C189 according to three infiltration rates.

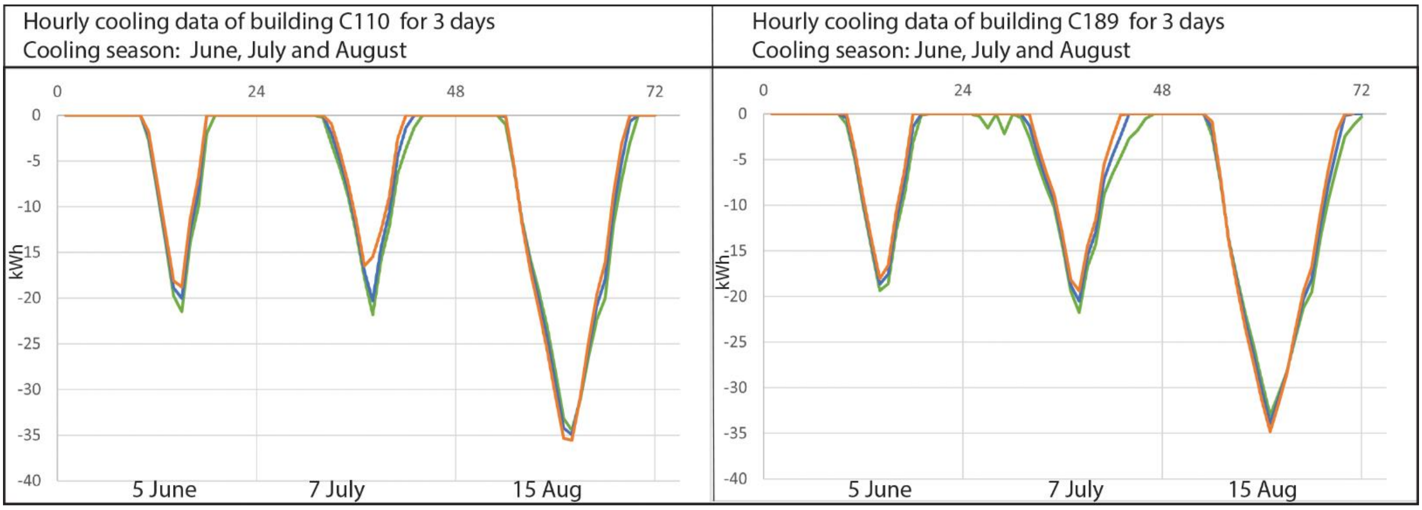


Fig. 64. Hourly cooling consumption of buildings C110 and C189 according to three infiltration rates during three days.

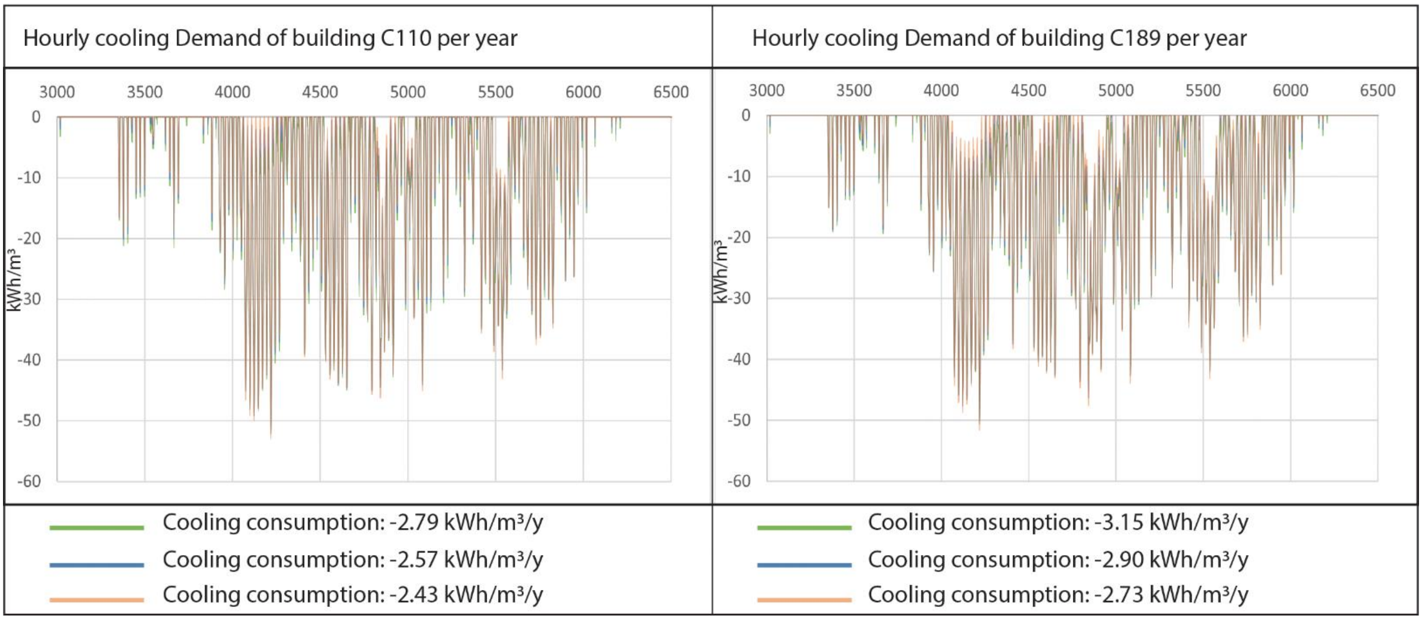


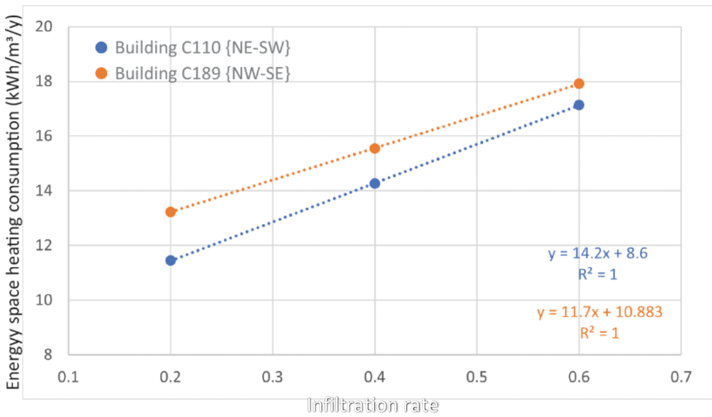
Fig. 65. Hourly cooling consumption of buildings C110 and C189 according to three infiltration rates during a year.

Table. XXV. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on infiltration rates equal to 0.2, 0.4 and 0.6 h^{-1}.

Infiltration Rate h^{-1}	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
0.2	11.45	-2.79	13.23	-3.15
0.4	14.26	-2.57	15.55	-2.90
0.6	17.13	-2.43	17.91	-2.73

Table. XXV. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189 depending on three changed infiltration rates equivalent to 0.2, 0.4 and 0.6 h^{-1}. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 54% in its highest value (with infiltration rate equal to 0.6) in regard to its lowest consumption of 11.45 kWh/m^3/y (with an infiltration rate equal to 0.2). while C189 with a (NW-SE) had a lower warmth energy impact with 35% between the lowest and highest reached value. Fig. 66., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C110 {NE-SW} was less impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in orange). Therefore, we can conclude that when the infiltration rate increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings with a NE-SW orientation, have a higher Energy consumption impact, in comparison to structures with NW-SE orientations.

Heating consumption



Cooling consumption

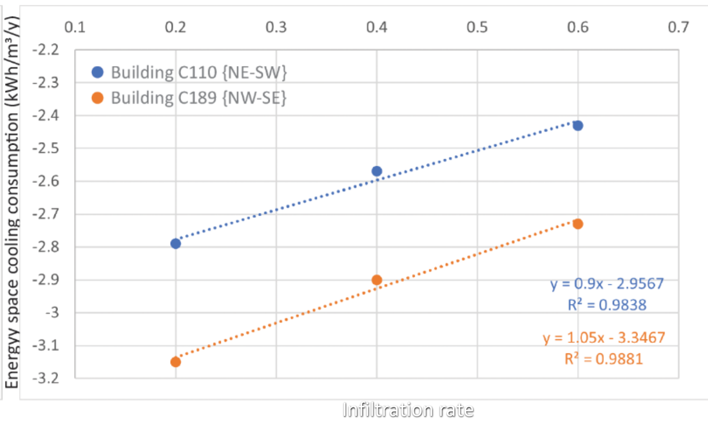


Fig. 66. Energy space heating and cooling demands of buildings C110 and C189 depending on the infiltration rate.

5.2.3- Building's Glazing ratio

Glazing ratio also known as Window to Wall Ratio, is the proportion of the transparent envelope in relation to the façade's surface. The smaller the glazing ratio, the smaller the proportion of the window compared to the wall. In this analysis, three main ratios were studied: 0.2, 0.4 and 0.6. These different ranges will help in the understanding of the impact of the glazing ratio on the yearly heating and cooling demands of the residential buildings. In this analysis, three different Glazing ratio values were studied: 0.2 (indicated in green), 0.4 (indicated in blue), and 0.6 (indicated in orange), in order to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (C110 and 189). The first warmth Energy utilization results are shown in Fig. 67. In fact, the monthly heating demand of both structures C110 and C189, increased when the Glazing ratio value was higher (where the structure consumed more heating energy with a glazing ratio equal to 0.6, compared to a smaller window to wall ratio of 0.2). Adding to that, Fig. 68., represents the hourly heating data of buildings C110 and C189, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, with a glazing ratio equivalent to 0.6 (represented in orange), had constantly the highest warmth utilization, while the lowest ratio (equal to 0.2, represented in green), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings C110 and C189, both regularly consumed more heating Energy with the highest Window to Wall ratio of 0.6 (represented in orange), compared to smaller ratios equivalent to 0.4 (represented in blue), and 0.2 (represented in green), shown in Fig. 69.

Adding to that, the cooling Energy consumptions of building C110 and C189 were analyzed as well. In fact, Fig. 62. (previously analyzed), reflects the yearly Cooling demand of Crocetta neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As

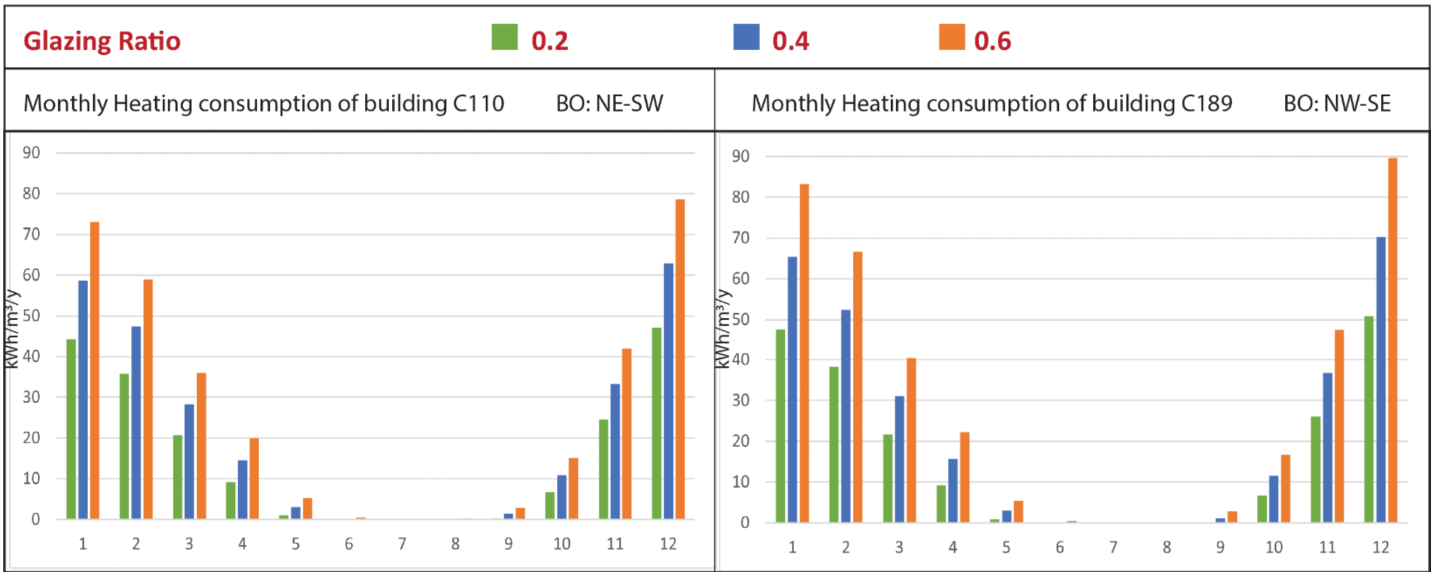


Fig. 67. Monthly heating consumption of buildings C110 and C189 according to three Glazing ratio values.

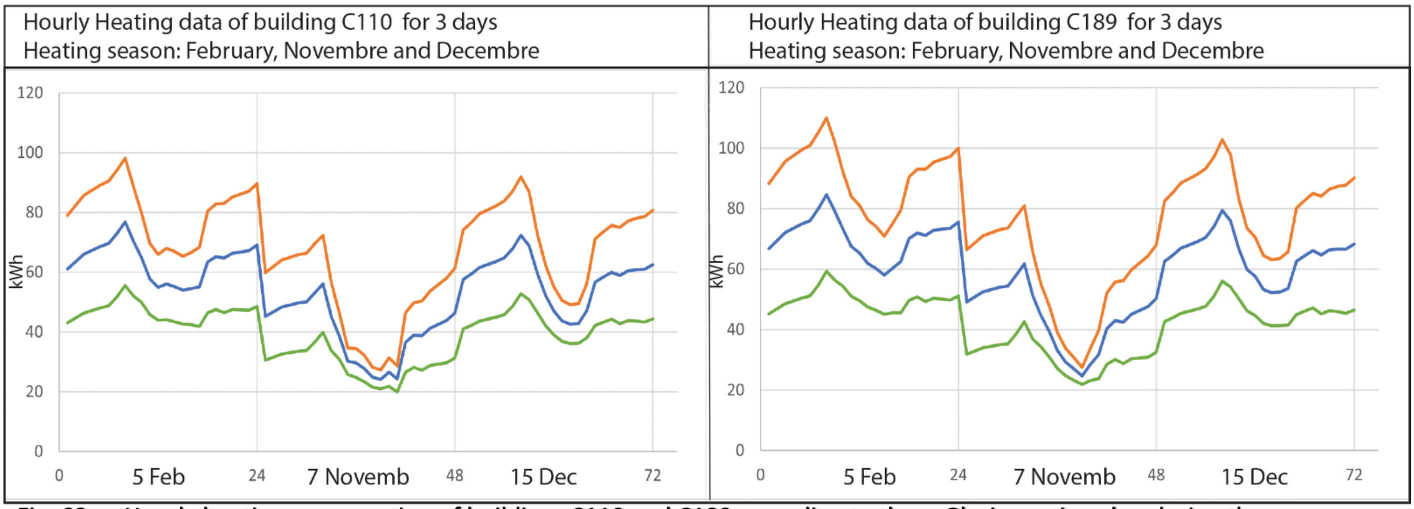


Fig. 68. **Hourly heating consumption of buildings C110 and C189 according to three Glazing ratio value during three**

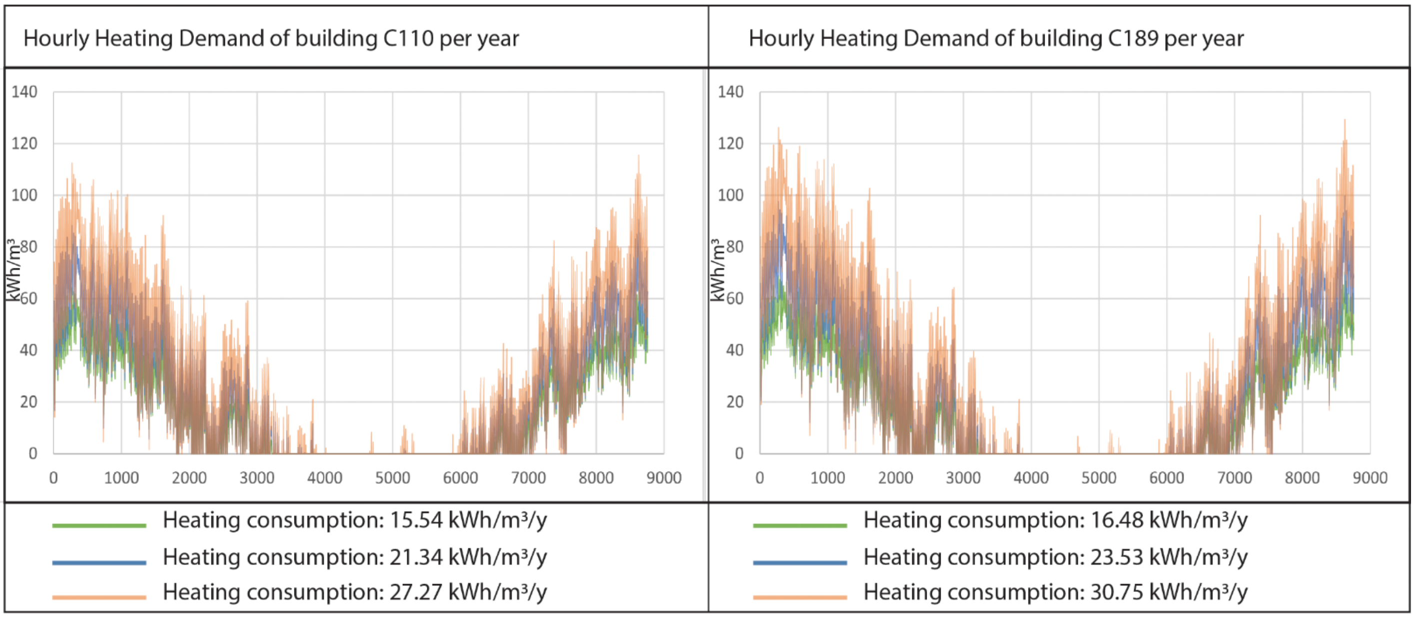


Fig. 69. **Hourly heating consumption of buildings C110 and C189 according to three Glazing ratio values during a year.**

mentioned before, the residential structure C189 consumed more cooling energy compared to C110 with equivalent values of -2.85 kWh/m^3/y and -2.52 kWh/m^3/y respectively. In fact, the first deducted monthly results represented in Fig. 70., show that, when the Glazing ratio of the building increased, similarly to the heating consumption (previously analyzed), the cooling Energy demand increases as well for both structures C110 and C189. Adding to that, an hourly Energy data was conducted for these residential buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 71.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for both structures, during the whole yearly cooling season, the highest window to wall ratio (equal to 0.6) constantly had the highest cooling Energy consumption (represented in orange), followed by the

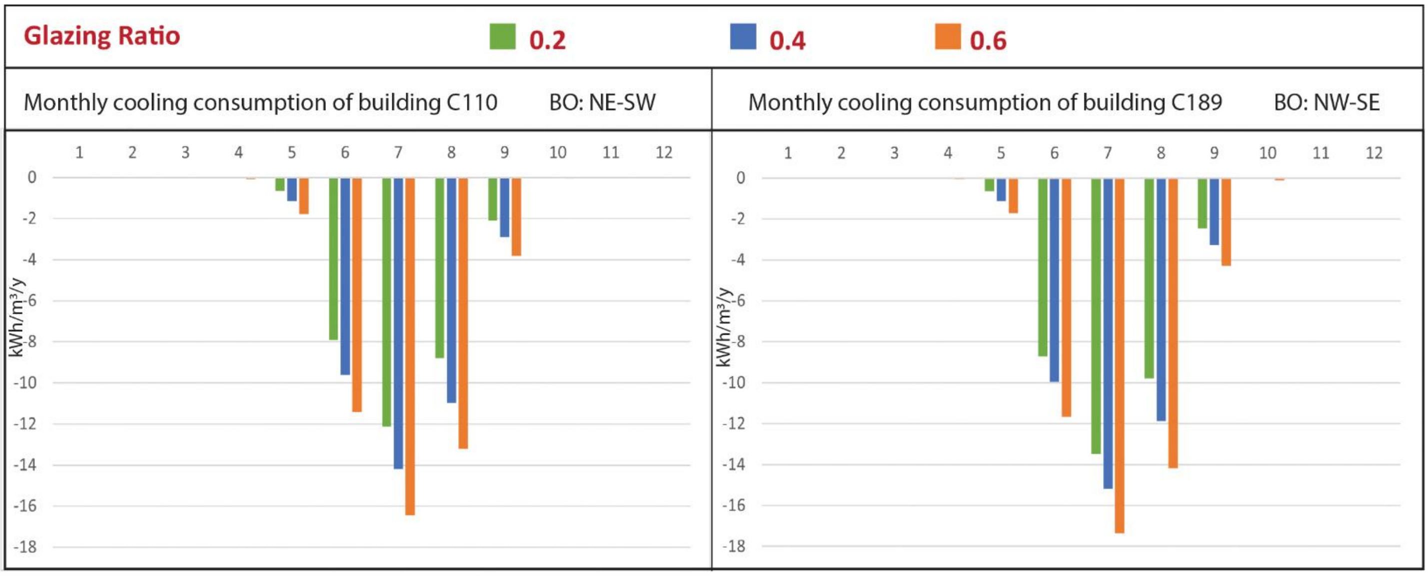


Fig. 70. Monthly cooling consumption of buildings C110 and C189 according to three Glazing ratio values.

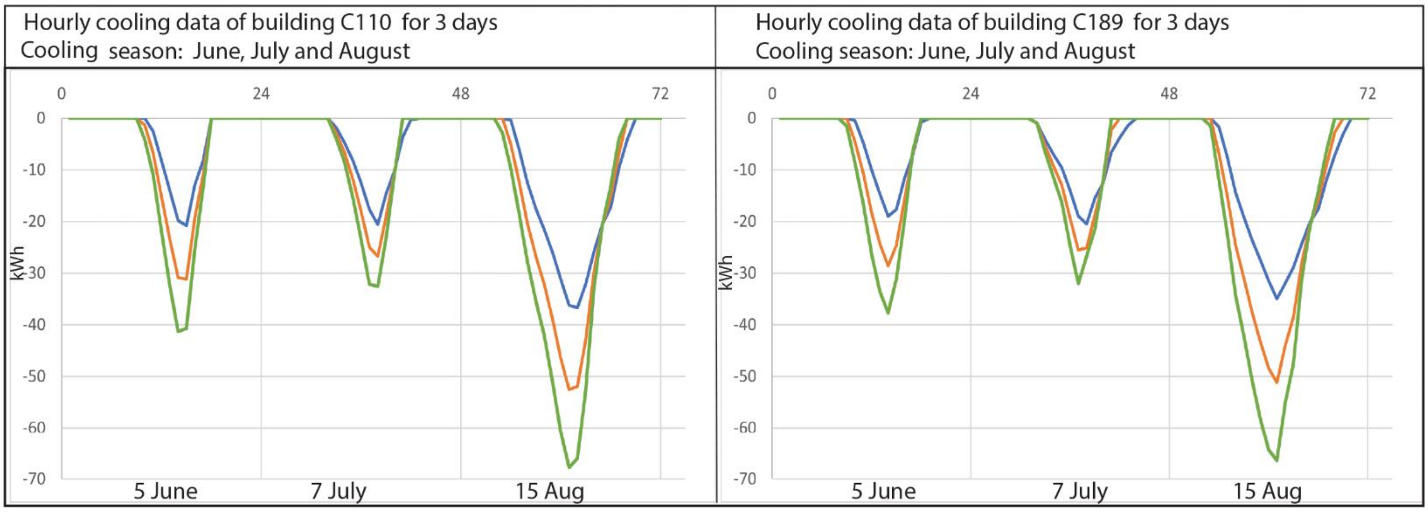


Fig. 71. Hourly cooling consumption of buildings C110 and C189 according to three Glazing ratio during three days.

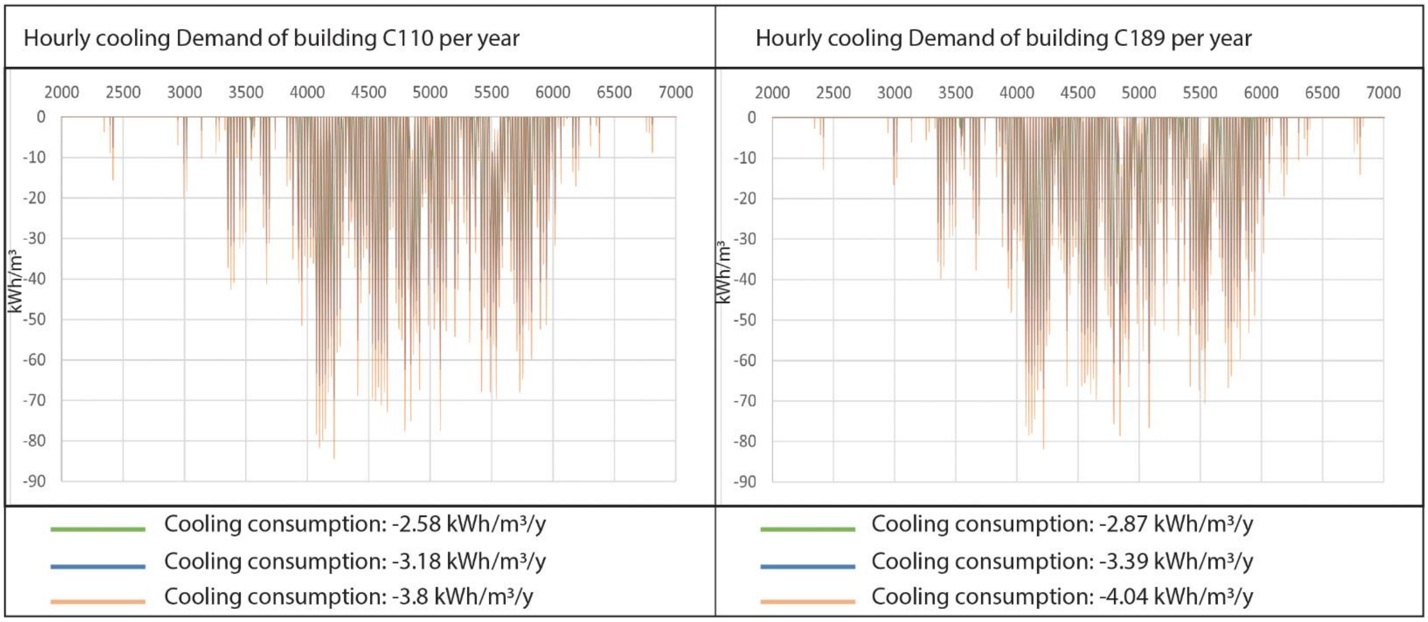


Fig. 72. Hourly cooling consumption of buildings C110 and C189 according to three Glazing ratio values during a year.

simulated results of ratio equivalent to 0.4 (represented in blue), and finally the lowest hourly and yearly cooling Energy utilization is represented by the lowest studied glazing ratio, that is equal to 0.2 (represented in green) in accordance with Fig. 72.

Table. XXVI. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on Glazing ratios equal to 0.2, 0.4 and 0.6.

Glazing Ratio	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
0.2	15.54	-2.58	16.48	-2.87
0.4	21.34	-3.18	23.53	-3.39
0.6	27.27	-3.80	30.75	-4.04

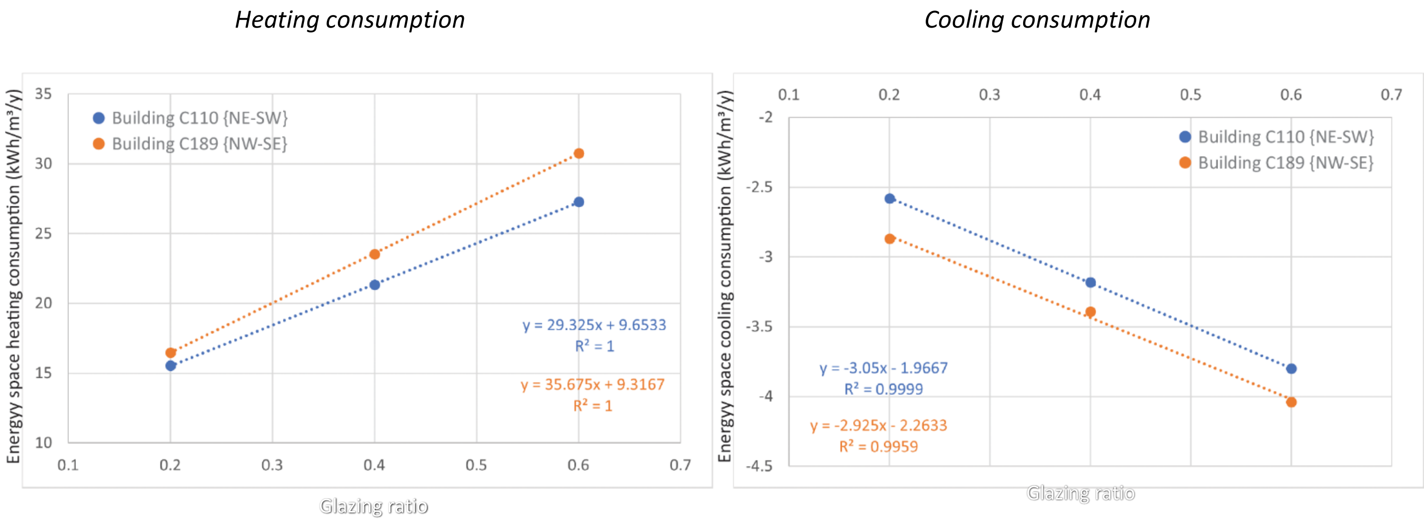


Fig. 73. Energy space heating and cooling demands of buildings C110 and C189 depending on the Glazing ratio

Table. XXI. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189, depending on three changed Window to Wall ratios equivalent to 0.2, 0.4 and 0.6. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 75% in its highest value (with a glazing ratio equal to 0.6) in regard to its lowest consumption of 15.54 kWh/m^3/y (with a glazing ratio equal to 0.2). while C189 with a (NW-SE) had a higher warmth energy impact with 86% between the lowest (16.48 kWh/m^3/y) and highest reached value (30.75 kWh/m^3/y). Fig. 73., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C110 {NE-SW} and building C189 characterized by a {NW-SE} orientation, had approximately the same amount of impact of the cooling energy consumption, with a similarly linear equational value (presented in blue for building C110, and in orange for building C189).

Therefore, we can conclude that when the glazing ratio of the building increases, the energy heating, and cooling demands of the structures, increases as well simultaneously. Adding to that, buildings with a NW-SE orientation, have a higher heating Energy consumption impact, in comparison to structures with NE-SW orientations. While the impact on the cooling demand is approximately the same for both buildings' orientations.

5.2.4- Thermal properties of building envelope

The thermal propertied of a building, are subdivided in this analysis into four main categories: Thermal transmittance of the opaque envelope of the building (Windows U-value), and thermal transmittances of walls, roof, and floor in regard to the building composites and materials. In fact, the opening properties' U-values, are retrieved from UNI/TS 11300-1 according to building's periods of construction. The lower the U-value the more the window is insulated from the outdoor factors of the building. In this variable, three main values were analyzed: 2.15, 4.40 and 4.90 expressed in {W/m^2. K}. Adding to that, Building's Materials and composites retrieved from UNI/TR 11552 varying according to the building's-built period. In this variable, walls, roofs, and floors composites were taken into consideration by specifying their thermal transmittance, resistance, materials densities as well as their thermal capacity. Ranges of 0.67, 0.9 and 1.10 {W/m^2. K} were examined for the walls' U-values, while for the roof composites, values varied between 0.53, 1.27 and 1.60{W/m^2. K}. and finally, the last studied building variable is the floor's composites and materials with values equivalent to 1.16 {W/m^2. K} for construction periods ranging between 1919 and 1960, and 1.25 {W/m^2. K} for residential structure building between 1961 and 2005.

5.2.4.1- Window's U-value ($U_{windows}$, $W/m^2/K$)

In fact, the building's windows U-values, are assigned to each residential building, according to its respective period of construction. The lower the U-value the more the window is insulated from the outdoor factors. Table. III. (previously shown), indicates that structures that are characterized by older construction dates, have a higher window U-value compared to more recently built structures with values ranging between 2.15 and 0.9, (according to Mutani G., and Todeschi V., 2020). In this analysis, three different windows thermal transmittances were studied: 2.15 {W/m^2. K} (indicated in green), 4.40 {W/m^2. K} (indicated in blue), and 4.90{W/m^2. K} (indicated in orange), in order to sensitively compare and analyze the impact of this changed variable on the heating and cooling consumption of the two chosen residential buildings (C110 and C189) in Crocetta neighborhood that are characterized with a construction period between 1919 and 1945. The first warmth Energy utilization results are shown in Fig. 74. In fact, the monthly heating demand of both structures C110 and C189, increased when the windows' U-value was higher, mainly due to the penetration of the cold outdoor air inside of the building during the heating season, because of the lower window insulation. Adding to that, Fig. 75., represents the hourly heating data of buildings S27 and S22 regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the opaque envelope's thermal transmittance that is equal to 4.90 {W/m^2. K}, represented in orange, had constantly the highest warmth utilization, while the lowest window's U-value (2.15 {W/m^2. K}), represented in green, consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings S27 and S22, both regularly consumed more heating Energy with the highest window U-value equivalent to 4.90 {W/m^2. K} (represented in orange), compared to lower values of 4.40 {W/m^2. K} (represented in blue), and 2.15 {W/m^2. K} (represented in green) (Fig. 76.).

Adding to that, the cooling Energy consumptions of building C110 and C189 were analyzed as well. In fact, Fig. 62. (previously analyzed), reflects the yearly Cooling demand of Crocetta neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. As mentioned before, the residential structure C189 consumed more cooling energy compared to C110 with equivalent values of -2.85 kWh/m^3/y and -2.52 kWh/m^3/y respectively. In fact, the first deducted monthly results represented in Fig. 77., show that, when the window's U-value of the building increased, on the opposite of the heating consumption results (previously discussed), the cooling Energy demand decreased for both buildings C110 and C189. Adding to that, an hourly

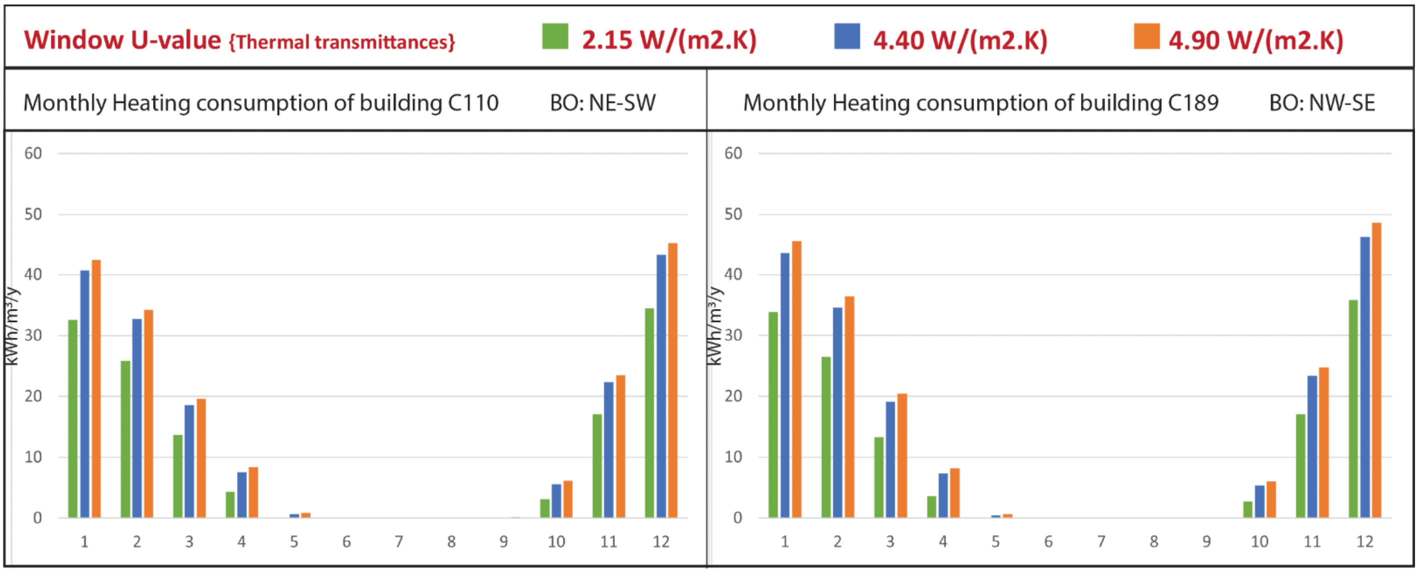


Fig. 74. **Monthly heating consumption of buildings C110 and C189 according to three windows U-values.**

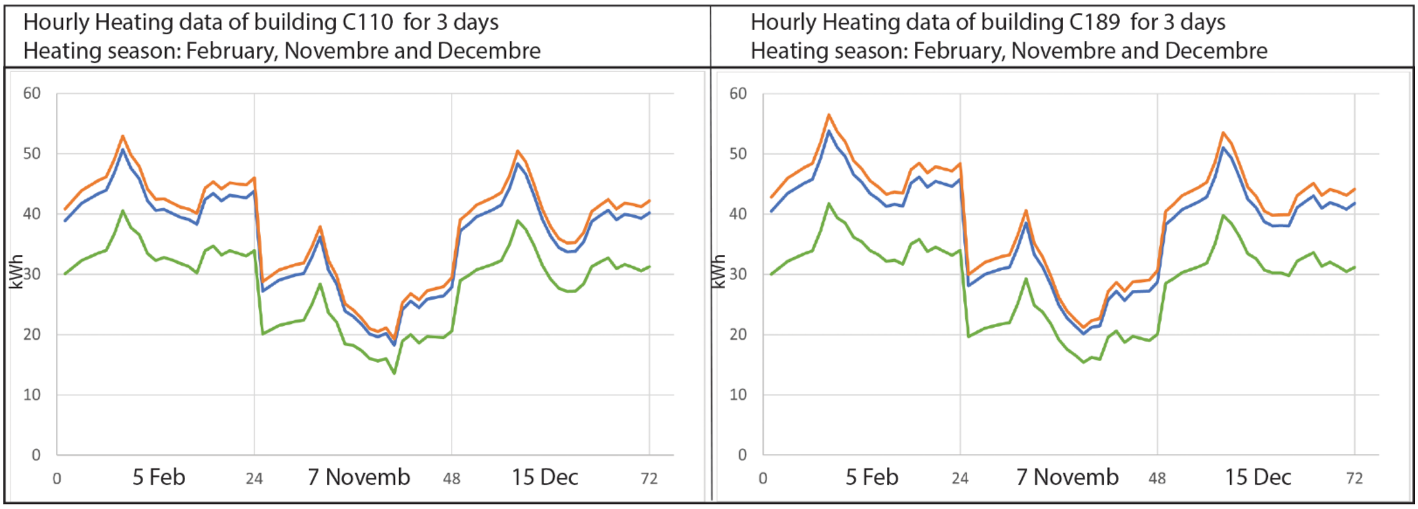


Fig. 75. **Hourly heating consumption of buildings C110 and C189 according to three windows U-values during three**

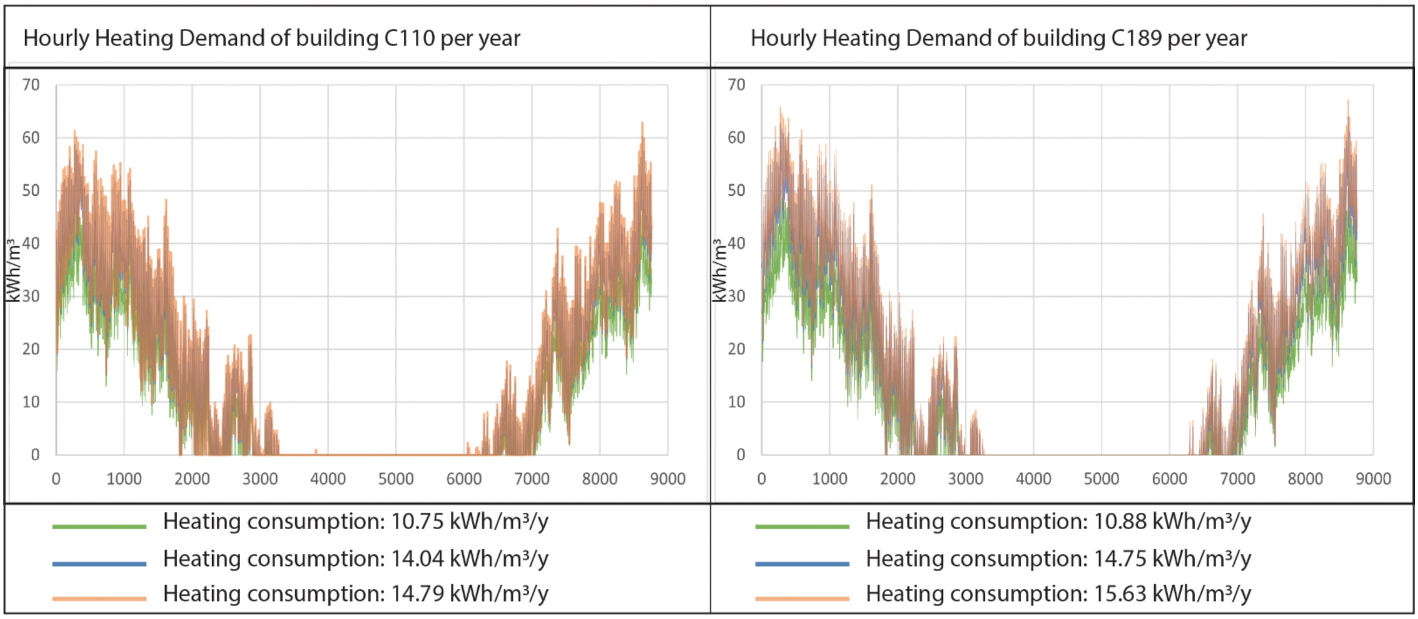


Fig. 76. **Hourly heating consumption of buildings C110 and C189 according to three windows U-values during a year.**

Energy consumption was conducted for C110 and C189 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 78.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with a window U-value equivalent to 4.90 {W/m^2. K} represented in orange, the energy consumption was higher compared to values equal to 4.40 and 2.15 {W/m^2. K}, even though the yearly energy cooling consumption of this range was the lowest with -2.60 kWh/m^3/y for C110 and -2.96 kWh/m^3/y for C189 (Fig. 79). However, during the months June and July, the lowest thermal transmittance of the opaque envelope (2.15 {W/m^2. K}) had the highest Energy cooling utilization during the months of June and July for both buildings C110 and C189.

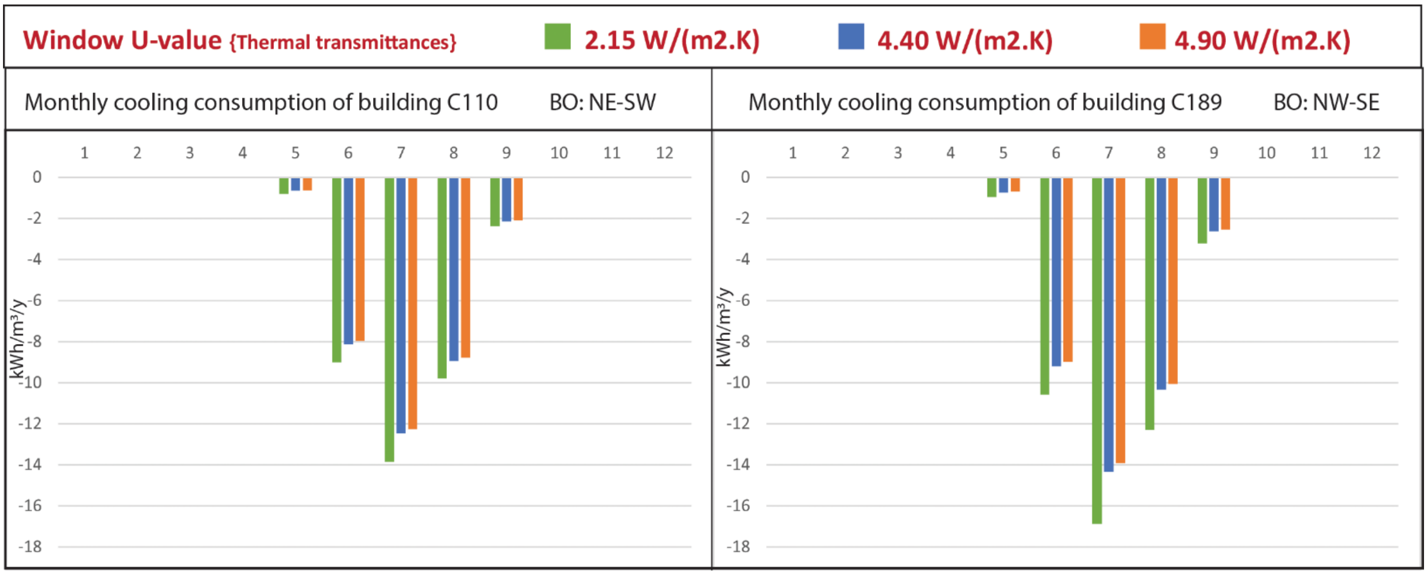


Fig. 77. Monthly cooling consumption of buildings C110 and C189 according to three windows U-values.

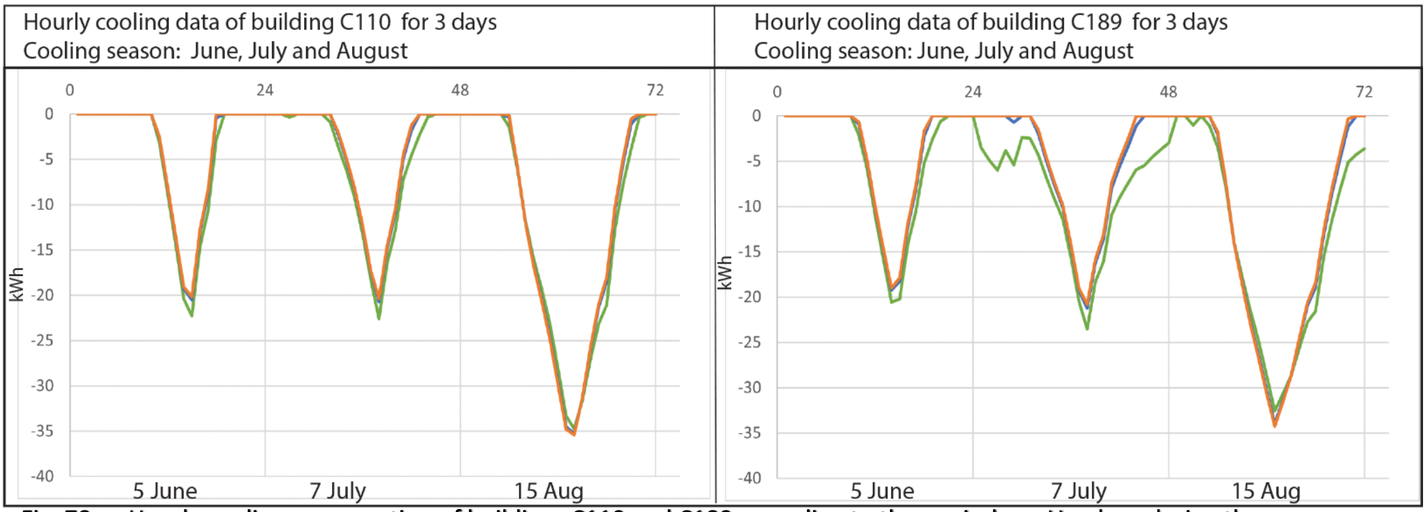


Fig. 78. Hourly cooling consumption of buildings C110 and C189 according to three windows U-values during three

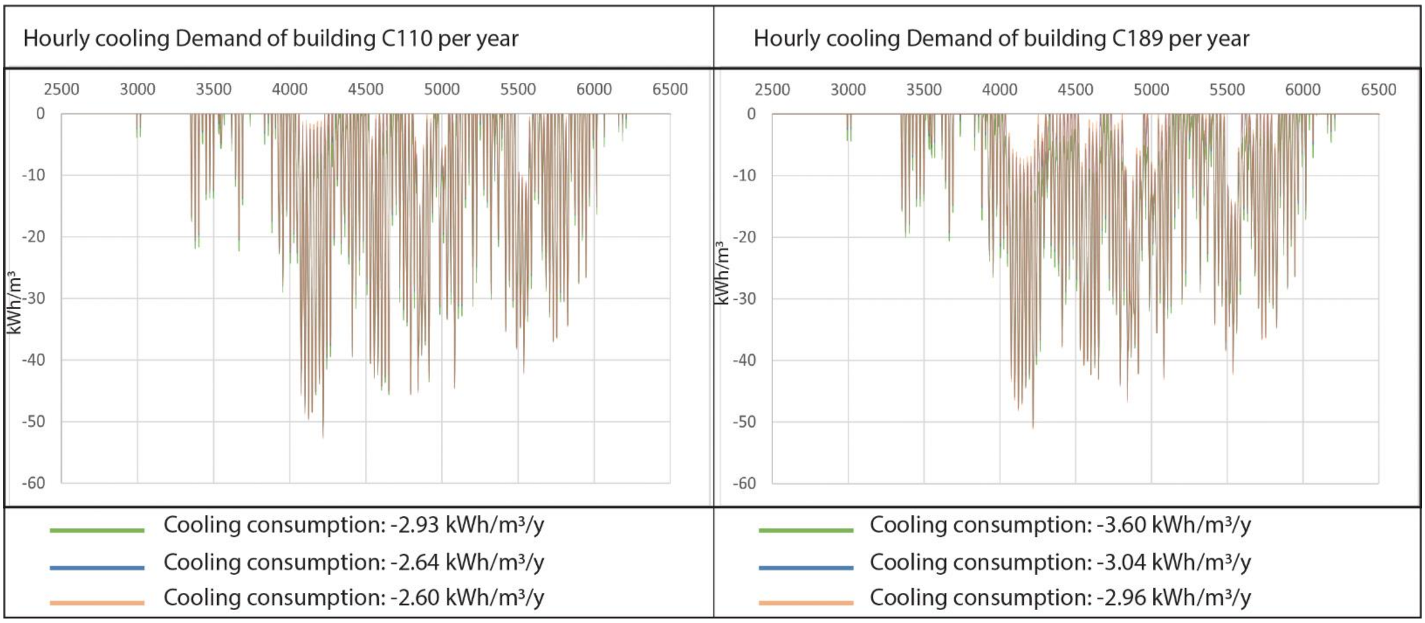


Fig. 79. Hourly cooling consumption of buildings C110 and C189 according to three windows U-values during a year.

Table. XXVII. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on window U-values equal to 2.15, 4.40, and 4.90 W/m^2. K.

Window U-value W/(m2.K)	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
2.15	10.75	-2.93	10.88	-3.60
4.40	14.04	-2.64	14.75	-3.04
4.90	14.79	-2.60	15.63	-2.96

Table. XXVII. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189, depending on three changed window's thermal transmittances values equivalent to 2.14, 4.40 and 4.90 {W/m^2.K}. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 37% in its highest value (with a window U-value equal to 4.90 {W/m^2. K}), regarding its lowest consumption of 10.75 kWh/m^3/y (with a window U-value equal to 2.15 {W/m^2. K}), while C189 with a (NW-SE) had a higher warmth energy impact with 43% between the lowest and highest reached value respectively equal to 10.88 kWh/m^3/y and 15.63 kWh/m^3/y. Fig. 80., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C189 {NW-SE} was more impacted compared to a building orientation of {NE-SW}, with a higher linear equational value (presented in blue). Therefore, we can conclude that when the window's U-value increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings characterized by a NW-SE orientation, had a higher impact in the heating and cooling consumptions depending on the window's U-values.

Heating consumption *Cooling consumption*

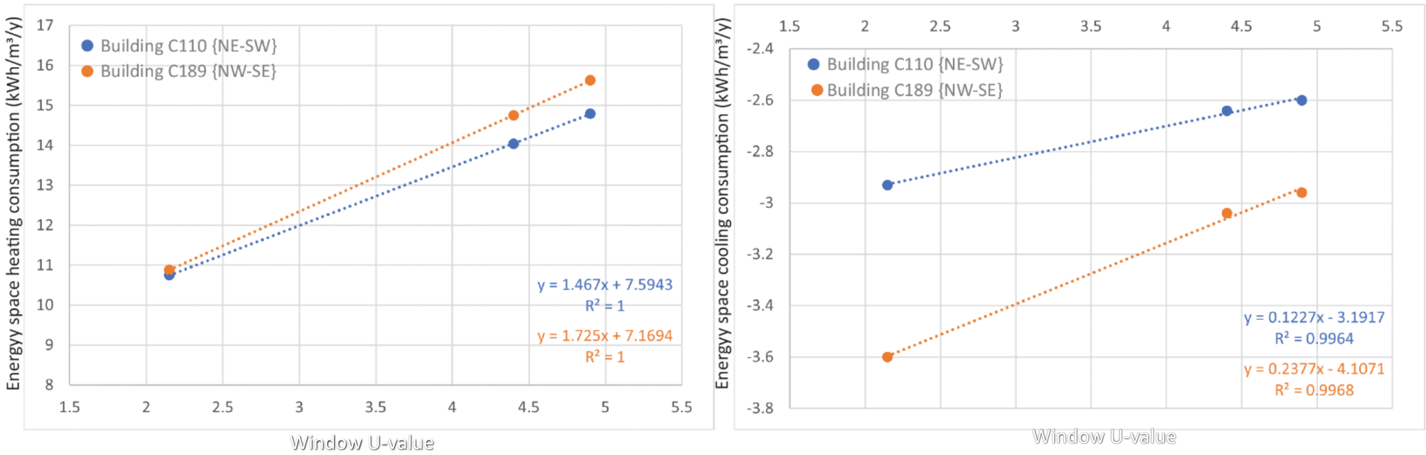


Fig. 80. Energy space heating and cooling demands of buildings C110 and C189 depending on Windows U-values.

5.2.4.2- Wall's U-value (U_{wall}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the wall's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.10, 0.9 and 0.67 expressed in {W/m^2. K}. Table. XI. (previously shown) reflects the three examined walls composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.10 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a wall code of MLP02. The second studied value is 0.9 {W/m^2. K}, with a wall code of MLP03 (constructed between 1961 and 1970). And the most recent wall composite is MPF03 (1990-2005), with a thermal transmittance value equivalent to 0.67 {W/m^2. K}. According to the detailed information about each wall composite, the input data of each material, was inserted the xml. Sheet of the engineering software CitySim Pro allowing the change of the selected buildings walls input data to examine their impact on the heating and cooling energy consumptions by comparing the results. Simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (C110 and C189) in Crocetta neighborhood characterized by a period of construction between 1919 and 1945.

Table. XI. Walls codes along with their respective U-values.

1919-1945		
	Code	U-value [W/(m²K)]
Wall	MLP02	1.10
1961-1970		
	Code	U-value [W/(m²K)]
Wall	MLP03	0.9
1990-2005		
	Code	U-value [W/(m²K)]
Wall	MPF03	0.67

In fact, the first heating Energy utilization results are shown in Fig. 81. The monthly warmth demand of both structures C110 and C189, had the highest energy utilization with a wall U-value equivalent to 0.9 {W/m^2. K} (indicated in blue), and the lowest one represented with the most recent wall composite MPF03 with a thermal transmittance of 0.67 {W/m^2. K}. We can visualize a huge gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 82., represents the hourly heating data of buildings C110 and C189, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the wall's thermal transmittance that is equal to 0.9 {W/m^2. K} (MLP03), had constantly the highest warmth utilization, while the lowest wall's U-value (0.67 {W/m^2. K}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings C110 and C189, both regularly consumed more heating Energy with a wall U-value equivalent to 0.9 {W/m^2. K} (represented in blue, MLP03), compared to values of 1.10 {W/m^2. K} (represented in green, MLP03), and 0.67 {W/m^2. K} (represented in orange, MPF03) (Fig. 83.).

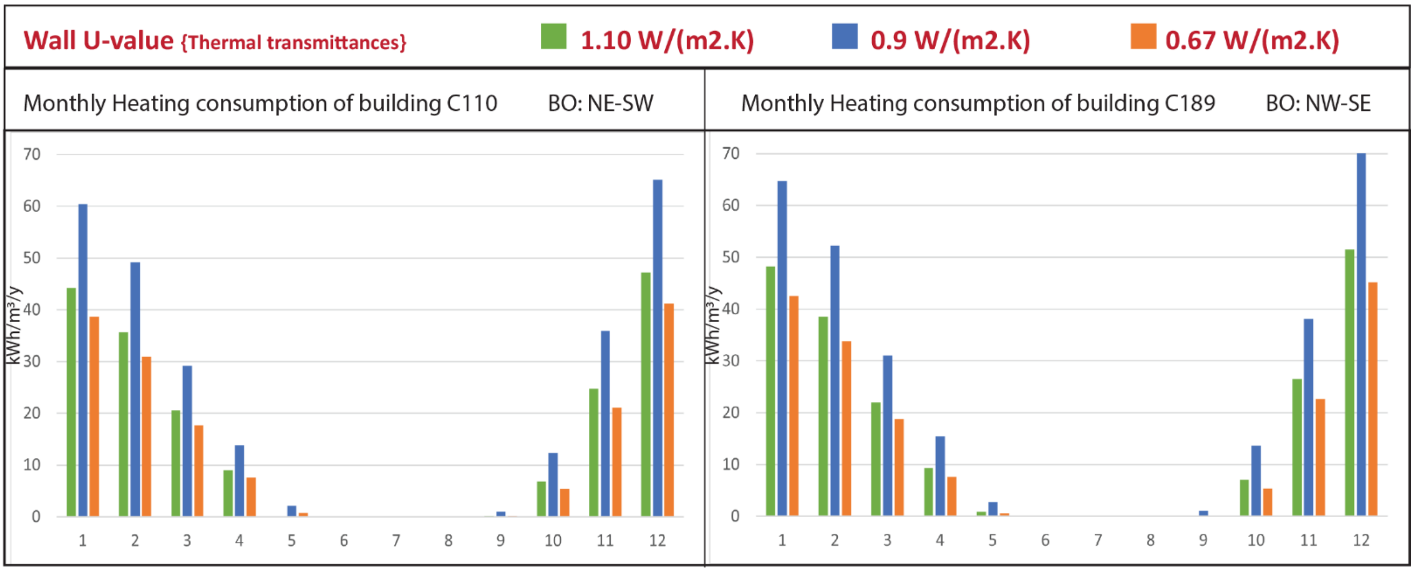


Fig. 81. Monthly heating consumption of buildings C110 and C189 according to three walls U-values.

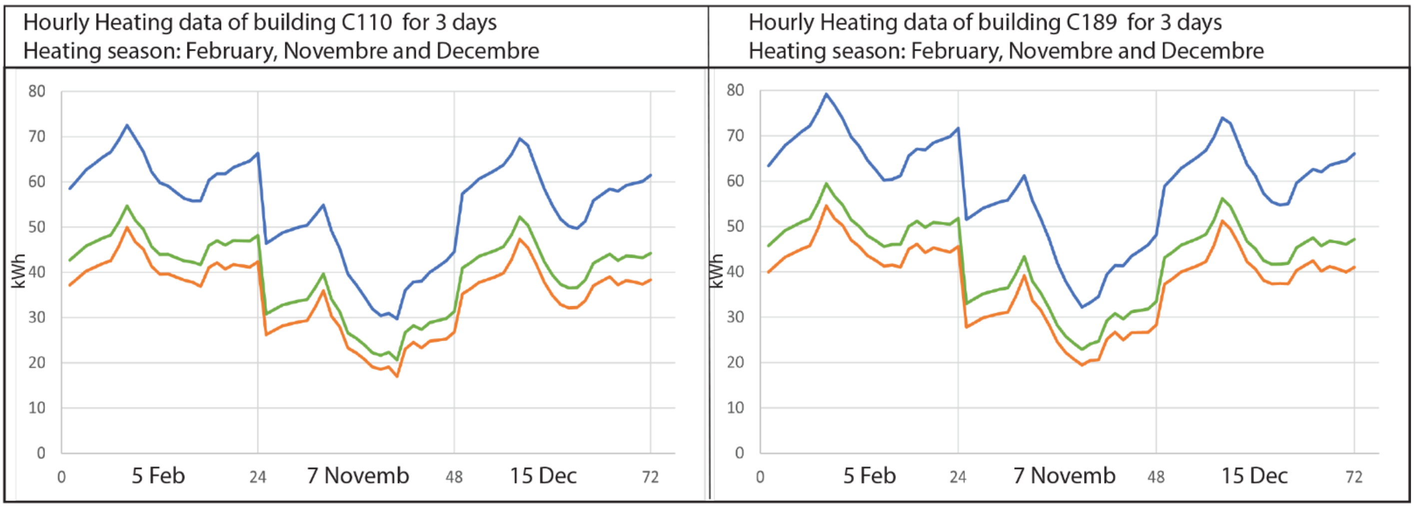


Fig. 82. Hourly heating consumption of buildings C110 and C189 according to three Walls U-values during three days.

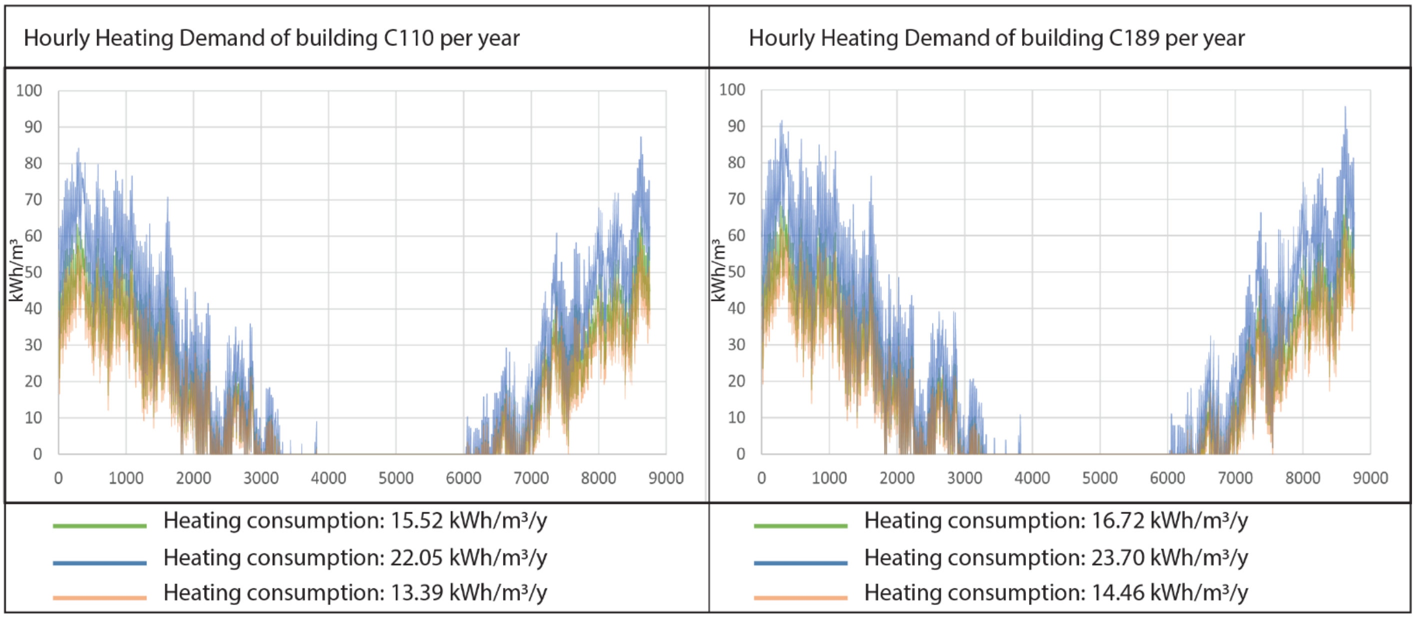


Fig. 83. Hourly heating consumption of buildings C110 and C189 according to three Walls U-values during a year.

Adding to that, the first deducted monthly results represented in Fig. 84., show that, when the wall's thermal transmittance of the building was equal to 0.9 {W/m^2. K} (MLP03), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures S27 and S22 were the highest compared to the two other wall composites (MLP02 and MPF03). However, the most recent wall configuration, MPF03, with a U-value equivalent to 0.67 {W/m^2. K} (represented in orange), consumed more cooling energy compared to the oldest wall code, MLP02 (1919-1945), represented on the graph in green. Adding to that, an hourly Energy data was conducted for S27 and S22 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 85.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building C110 characterized by a NE-SW orientation, during the whole yearly cooling season, the structure with the wall's thermal transmittance equal to 0.9 {W/m^2. K} (MLP03), constantly had the highest cooling Energy consumption (represented in blue), followed by the simulated results wall MPF03 (represented in blue), and finally the lowest hourly and yearly cooling Energy utilization is represented by the highest window U-value, that is equal to 1.10 (wall composite MLP02: represented in green) in accordance with Fig. 85. However, for building C189, with an orientation of NW-SE, wall composite MPF03, consumed the highest cooling Energy during months with a lower outdoor temperature during the cooling season (Month of July for example, represented in orange), even though its yearly energy consumption was lower compared to the wall composite MLP03 with respective values equivalent to -3 {kWh/m^3/y} (represented in orange), and -3.18 {kWh/m^3/y} (represented in blue).

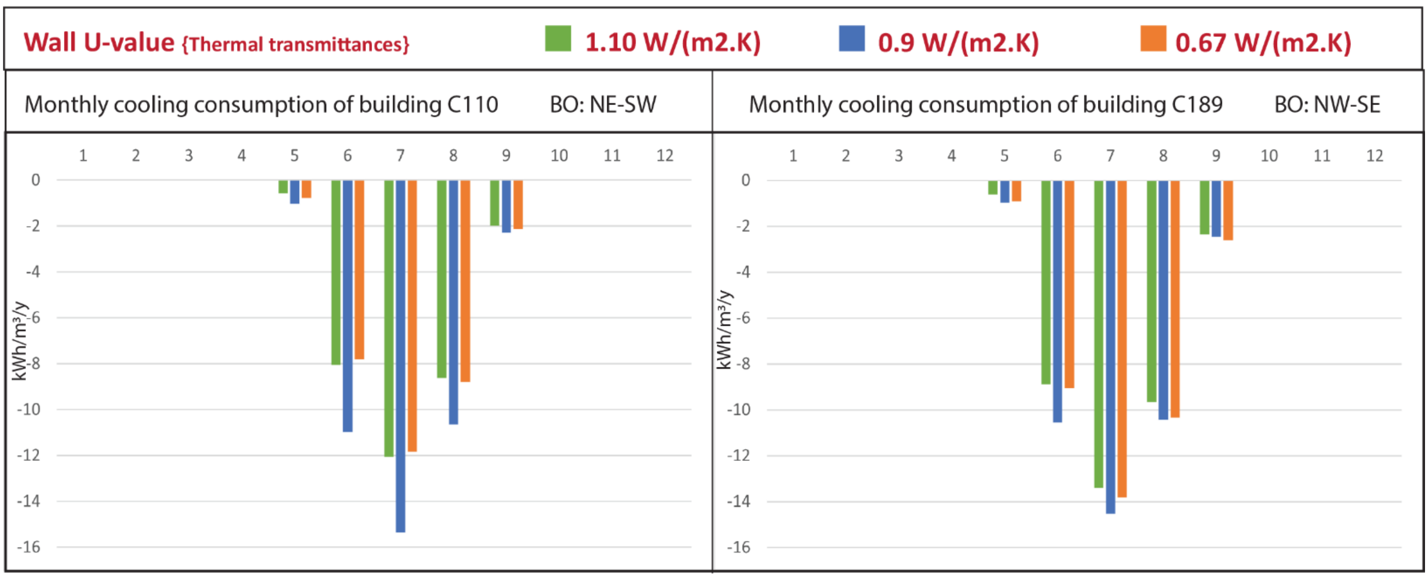


Fig. 84. Monthly cooling consumption of buildings C110 and C189 according to three walls U-values.

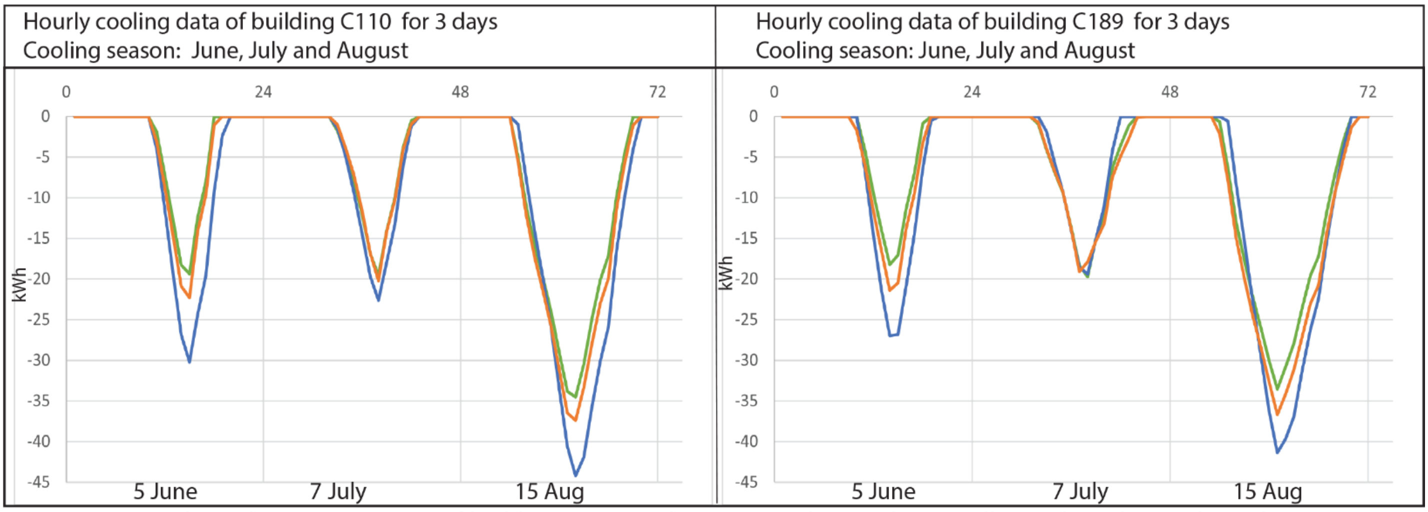


Fig. 85. Hourly cooling consumption of buildings C110 and C189 according to three Walls U-values during three days.

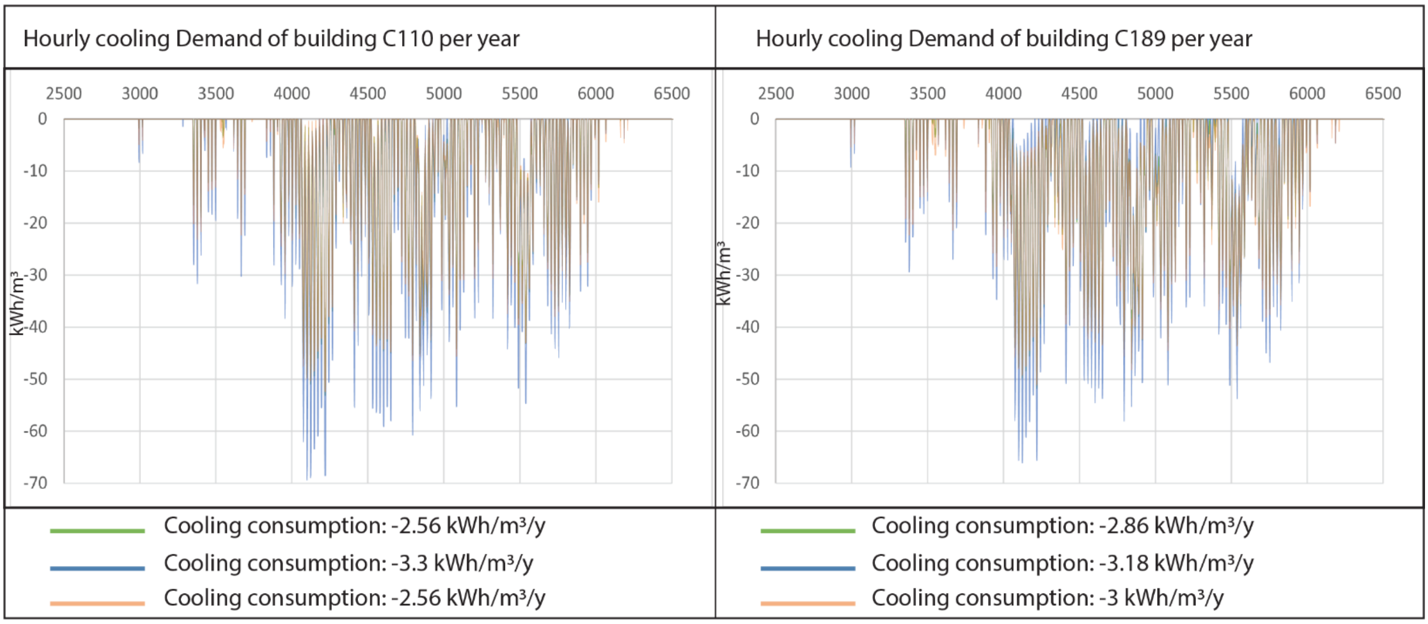


Fig. 86. Hourly cooling consumption of buildings C110 and C189 according to three Walls U-values during a year.

Table. XXVIII. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on walls U-values equal to 1.10, 0.9, and 0.67 W/m^2. K.

Wall U-value W/(m2.K)	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
1.10	15.52	-2.56	16.72	-2.86
0.9	22.05	-3.30	23.70	-3.18
0.67	13.39	-2.56	14.46	-3

Table. XXVIII. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189, depending on three changed walls thermal transmittances values equivalent to 1.10, 0.9, and 0.67 W/m². K. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 64%, with a wall U-value equal to 0.9 {W/m². K}, in regard to its lowest consumption of 13.39 kWh/m³/y (with a wall U-value equal to 0.67 {W/m². K}). while C189, with a (NW-SE) had approximately the same warmth energy impact with 63% between the lowest and highest reached value respectively equal to 14.46 kWh/m³/y and 23.70 kWh/m³/y. Fig. 87., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C110 {NE-SW} was less impacted compared to a building orientation of {NW-SE}, with a lower linear equational value (presented in blue). Therefore, we can conclude that MPF03 walls composites consumed the least heating energy demand, while the oldest composite MLPO2 has the lowest cooling energy consumption. MLP03 showed the highest energy consumption for both heating and cooling seasons.

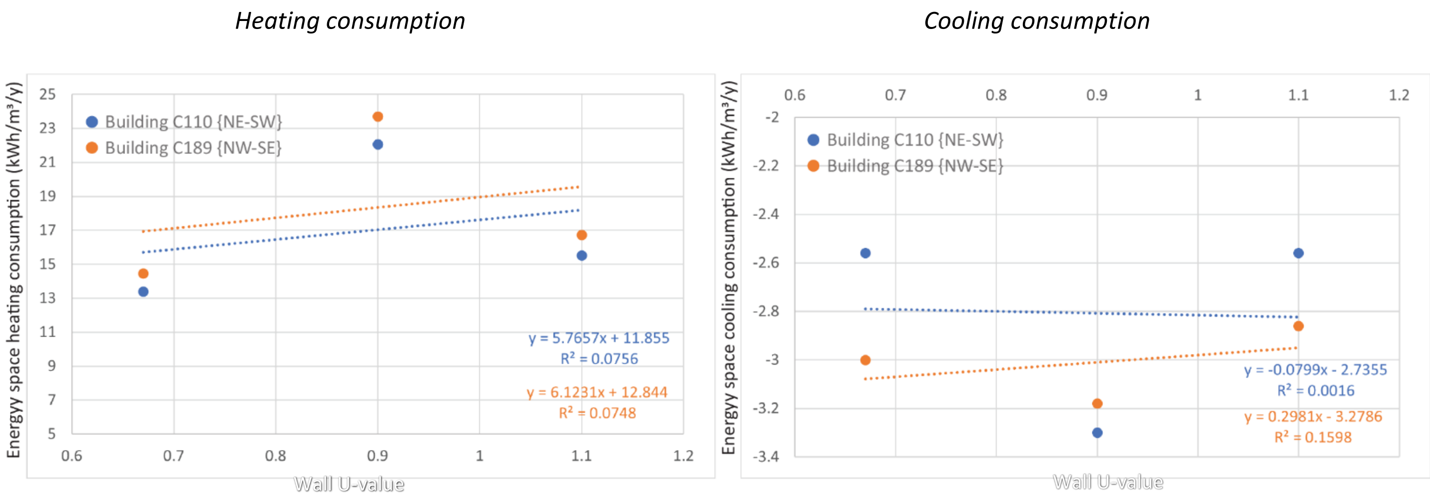


Fig. 87. Energy space heating and cooling demands of buildings C110 and C189 depending on the walls U-values.

5.2.4.3- Roof's U-value (U_{roof}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the roof's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.60, 1.27 and 0.53 expressed in {W/m². K}. Table. XVI. (previously shown), reflects the three examined roof composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.60 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a roof code of COP01. The second studied value is 1.27 {W/m^2. K}, with a roof code of COP04 (constructed between 1961 and 1970). And the most recent roof composite is COP03 (1990-2005), with the lowest thermal transmittance value equivalent to 0.53 {W/m^2. K}. These different ranges, were inserted in the engineering software CitySim Pro, were simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (C110 and C189) in Crocetta neighborhood characterized by a period of construction ranging between 1919 and 1945.

Table. XVI. Roofs codes along with their respective U-values

1919-1945		
	Code	U-value [W/(m²K)]
Roof	COP01	1.60
1961-1970		
	Code	U-value [W/(m²K)]
Roof	COP04	1.27
1990-2005		
	Code	U-value [W/(m²K)]
Roof	COP03	0.53

In fact, the first heating Energy utilization results are shown in Fig. 88. The monthly warmth demand of both structures C110 and C189, had the highest energy utilization with a roof U-value equivalent to 1.27 {W/m^2. K} (indicated in blue), and the lowest one represented with the newest roof composite COP03 with a thermal transmittance of 0.53 {W/m^2. K} (indicated in orange). Adding to that, Fig. 89., represents the hourly heating data of buildings C110 and C189, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the roof's thermal transmittance that is equal to 1.27 {W/m^2. K} (COP04), had constantly the highest warmth utilization. However, for the residential structure C110 characterized by a NE-SW orientation, and building C189 with a NW-SE orientation, the newest roof composite {COP03} consumed the least heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings C110

Roof U-value {Thermal transmittances} 1.60 W/(m2.K) 1.27 W/(m2.K) 0.53 W/(m2.K)

Monthly Heating consumption of building C110 BO: NE-SW	Monthly Heating consumption of building C189 BO: NW-SE

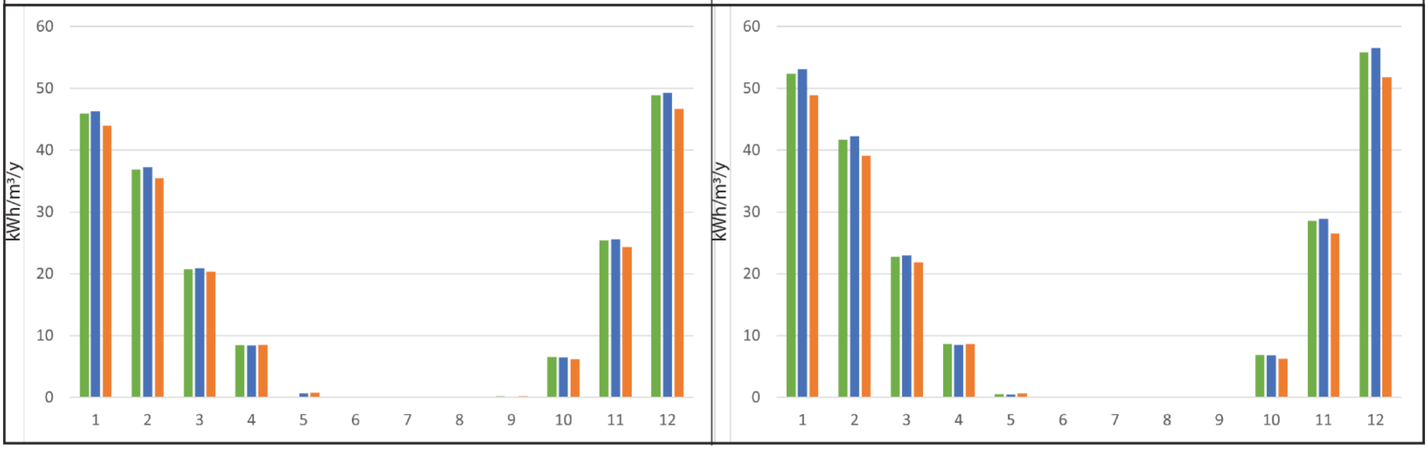


Fig. 88. Monthly heating consumption of buildings C110 and C189 according to three Roof U-values.

Hourly Heating data of building C110 for 3 days Heating season: February, Novembre and Decembre	Hourly Heating data of building C189 for 3 days Heating season: February, Novembre and Decembre

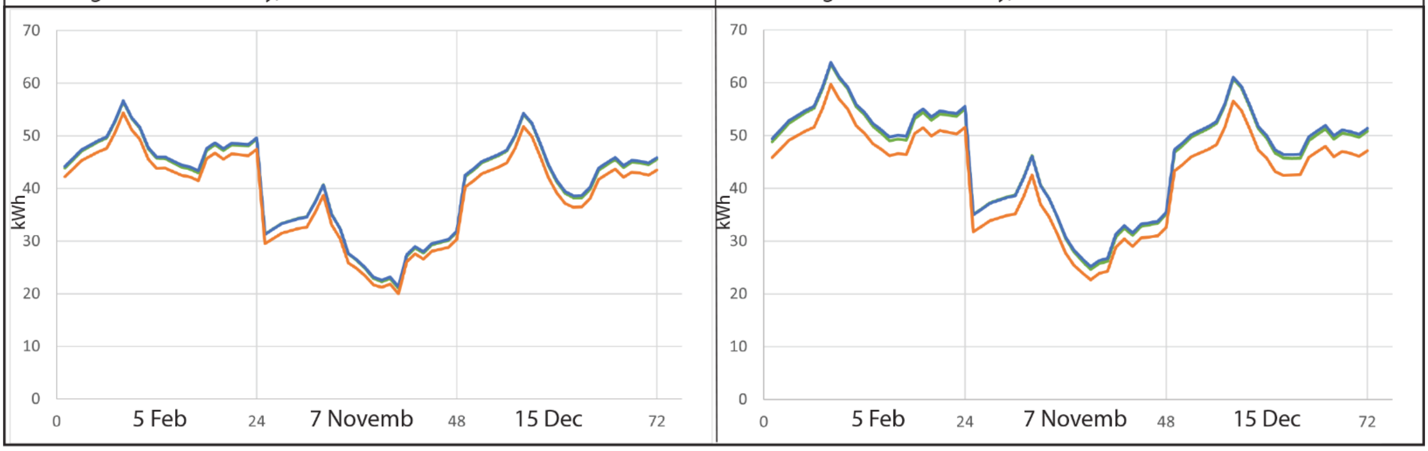
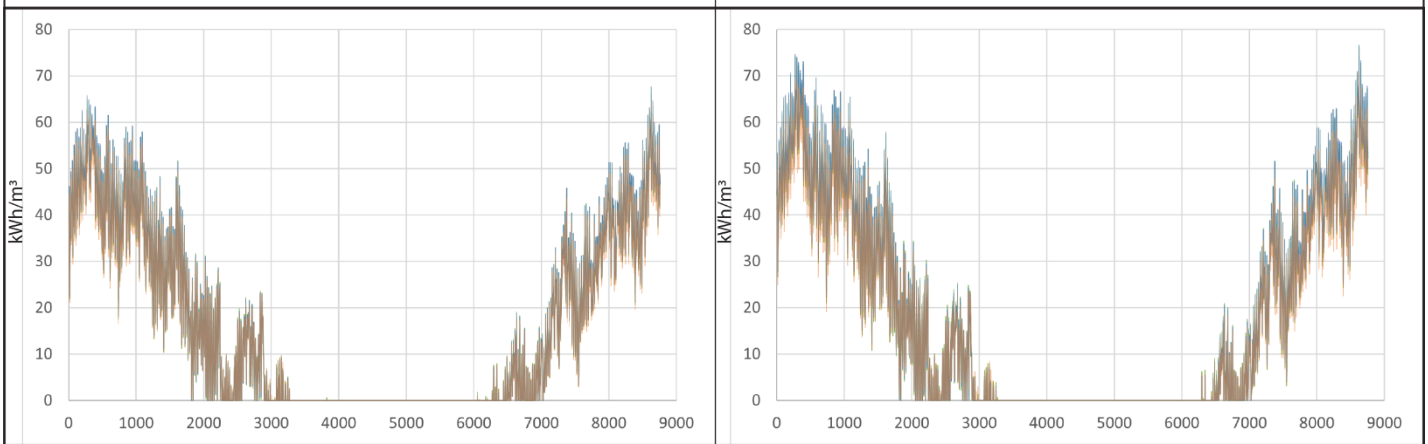


Fig. 89. Hourly heating consumption of buildings C110 and C189 according to three Roof U-values during three days.

Hourly Heating Demand of building C110 per year	Hourly Heating Demand of building C189 per year



C110	C189
Heating consumption: 15.89 kWh/m³/y	Heating consumption: 17.82 kWh/m³/y
Heating consumption: 15.98 kWh/m³/y	Heating consumption: 17.99 kWh/m³/y
Heating consumption: 15.28 kWh/m³/y	Heating consumption: 16.70 kWh/m³/y

Fig. 90. Hourly heating consumption of buildings C110 and C189 according to three Roof U-values during a year.

and C189, both regularly consumed more heating Energy with a wall U-value equivalent to 1.27 {W/m^2. K} (represented in blue, COP04, according to Fig.90.).

Adding to that, the cooling Energy consumptions of building C110 and C189 were analyzed as well. In fact, the first monthly results represented in Fig. 91., show that, when the roof's thermal transmittance of the building was equal to 1.27 {W/m^2. K} (COP04), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures C110 and C189 were the highest compared to the two other roof composites (COP01 and COP04). However, the most recent roof configuration, COP03, with a U-value equivalent to 0.53 {W/m^2. K} (represented in orange), consumed the least cooling energy compared to the oldest roofs' composites. Adding to that, an hourly Energy data was conducted for both analyzed buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 92.). Results show that, for both constructions, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building C110 characterized by a NE-SW orientation, and C189 with a NW-SE orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the roof thermal transmittance equal to 1.27 {W/m^2. K} (COP04), constantly had the highest cooling Energy consumption (represented in blue), while the lowest hourly and yearly cooling Energy utilization is represented by the lowest wall U-value, that is equal to 0.53 (wall composite COP03: represented in orange and characterized by the newest period of construction {2001-2005} in accordance with Fig. 93.

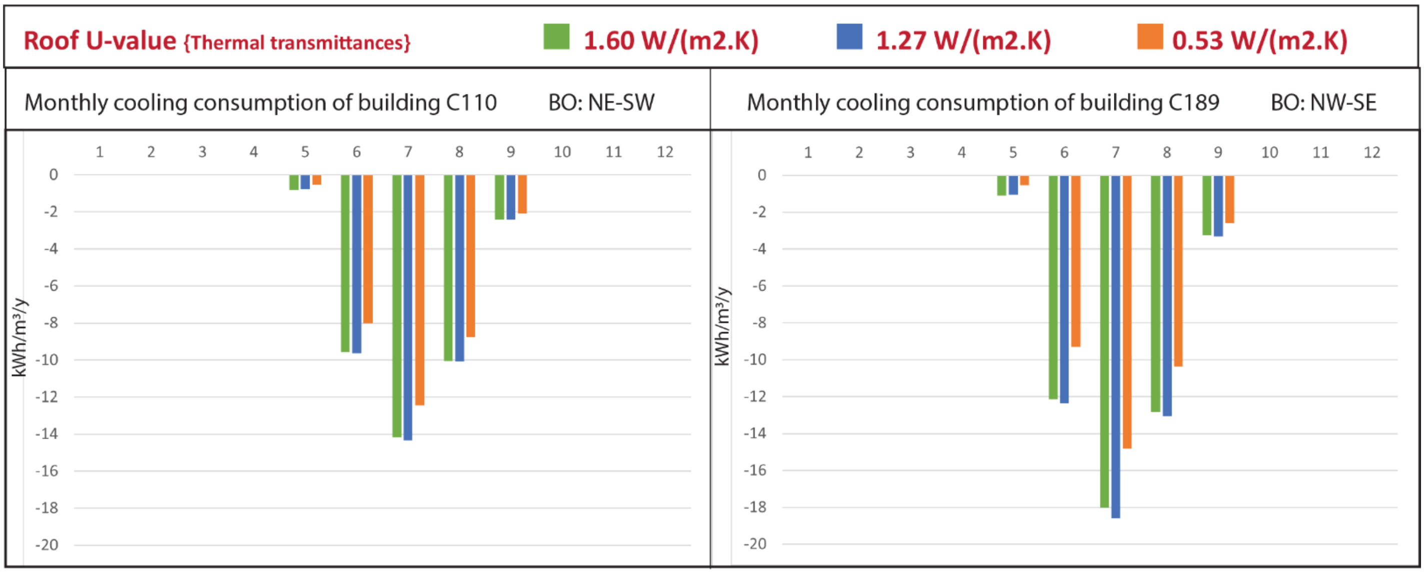


Fig. 91. Monthly cooling consumption of buildings C110 and C189 according to three Roof U-values.

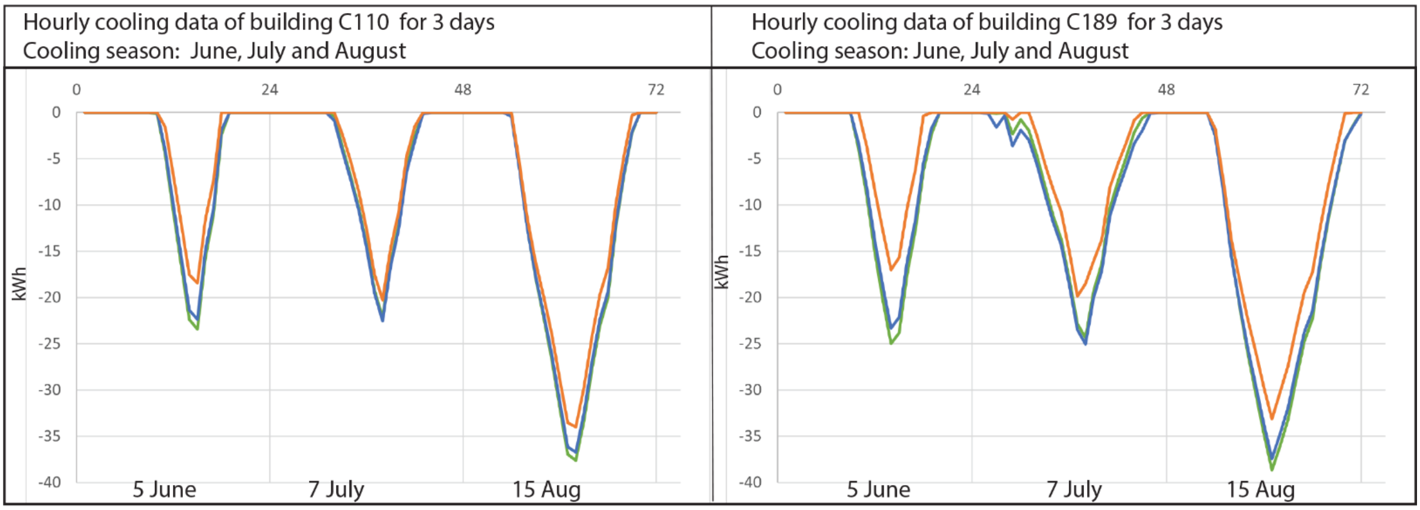


Fig. 92. Hourly cooling consumption of buildings C110 and C189 according to three Roof U-values during three days.

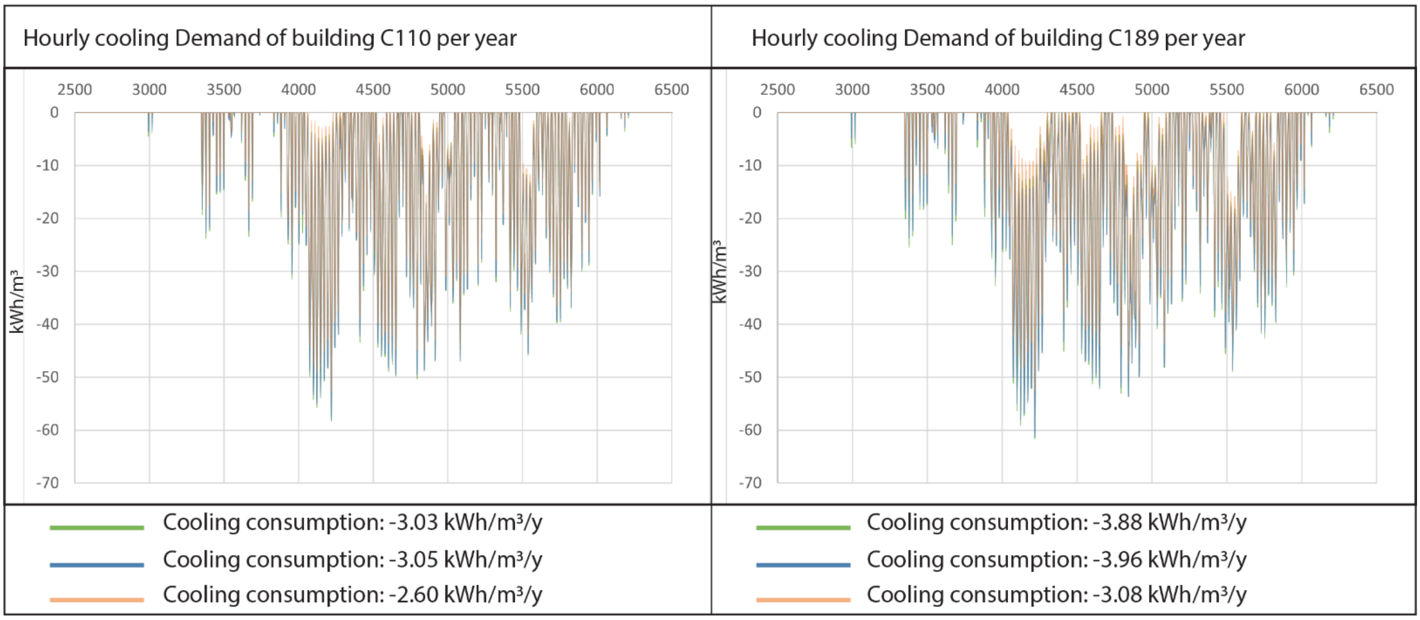


Fig. 93. Hourly cooling consumption of buildings C110 and C189 according to three Roof U-values during a year.

Table. XXIX. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on roof U-values equal to 1.60, 1.27, and 0.53 W/m^2. K.

Roof U-value W/(m2.K)	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
1.60	15.89	-3.03	17.82	-3.88
1.27	15.98	-3.05	17.99	-3.96
0.53	15.28	-2.60	16.70	-3.08

Table. XXIX. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189, depending on three changed roof thermal transmittances values equivalent to 1.60

{1919-1945}, 1.27 {1961-1970}, and 0.53 W/m^2.K, with residential buildings constructed with the most recent period ranging between 2001 and 2005. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 5%, with a roof U-value equal to 1.27 {W/m^2. K}, regarding its lowest consumption of 15.28 kWh/m^3/y (with the newest roof composite with a U-value equal to 0.53 {W/m^2. K}). while C189, with a (NW-SE) had a higher energy, impact compared to C110, with 7% between the lowest and highest reached value respectively equal to 16.70 kWh/m^3/y and 17.99 kWh/m^3/y. Fig. 94., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C110 {NE-SW} was less impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that COP04 roof composite consumed the highest heating and cooling energy demand, while the newest roof composite COP03, had the lowest yearly energy Utilization.

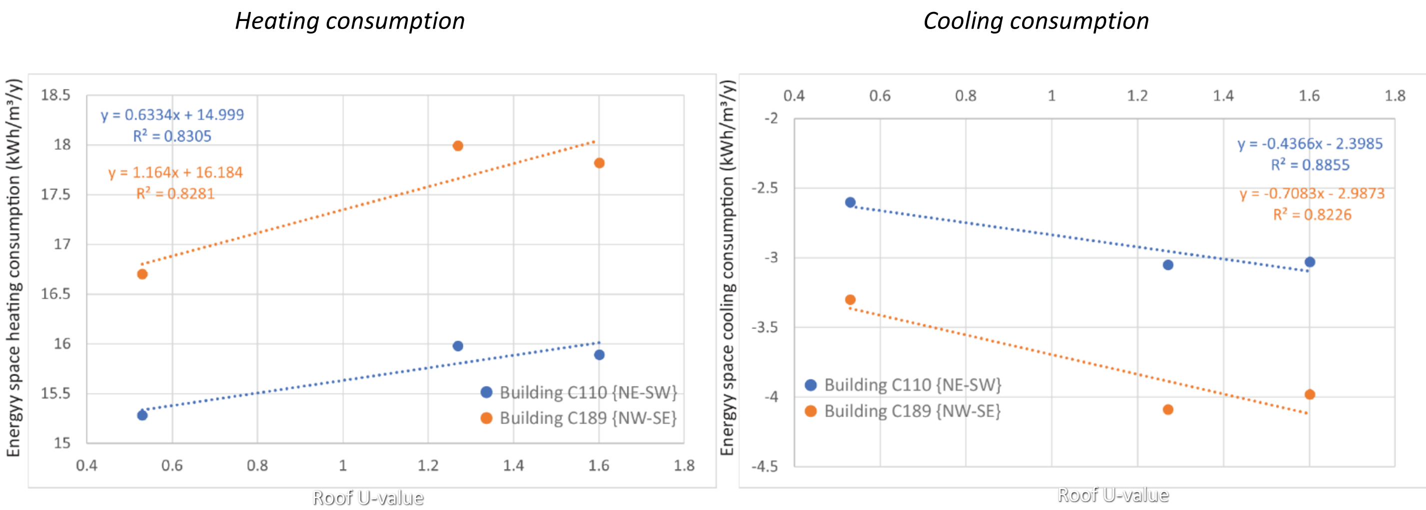


Fig. 94. Energy space heating and cooling demands of buildings C110 and C189 depending on roof U-values.

5.2.4.4- Floor's U-value (U_{floor}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with floor U-values varying according to the building's construction period. In fact, the lower the floor's U-value the more the building is insulated from the ground factors. In this variable, two main values were analyzed: 1.16, and 1.25 expressed in {W/m^2. K}. Table. XX. (previously shown), represents the two examined floor composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.25 {W/m^2. K} characterized by the newest built period ranging between 1961 and 2005 with a floor code of SOL04. The second studied value is 1.16 {W/m^2. K}, with a floor code of SOL03 (characterized by a constructed period varying between 1919 and 1960). These different ranges were inserted in the engineering software CitySim Pro, where simulated results were compared and analyzed to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (C110 and C189) in Crocetta neighborhood characterized by a period of construction ranging between 1919 and 1945.

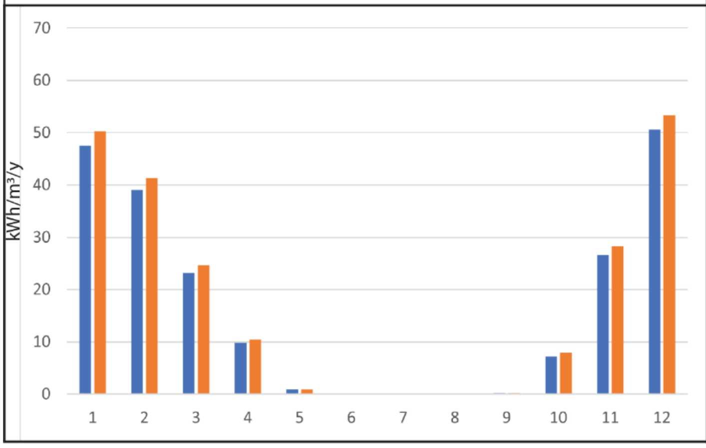
Table. XX. Floor codes along with their respective U-values

1919-1960		
	Code	U-value [W/(m²K)]
Floor	SOL03	1.16
1961-2005		
	Code	U-value [W/(m²K)]
Floor	SOL04	1.25

In fact, the first heating Energy utilization results are shown in Fig. 95. The monthly warmth demand of both structures C110 and C189, had the highest energy utilization with a floor U-value equivalent to 1.25 {W/m^2. K} (indicated in orange), and the lowest one represented with the oldest floor composite SOL04 with a thermal transmittance of 1.16 {W/m^2. K}. We can visualize a big gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 96., represents the hourly heating data of buildings C110 and C189, regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the floor's thermal transmittance that is equal to 1.25 {W/m^2. K} (SOL04), had constantly the highest warmth utilization. While SOL04 that is characterized by the most recent period of construction {1961-2005}, consumed more heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours) buildings S27 and S22, both regularly consumed more heating Energy with a floor U-value equivalent to 1.25 {W/m^2. K} (represented in orange, SOL04) in accordance with the hourly results shown in Fig.97.

Floor U-value {Thermal transmittances}   1.16 W/(m2.K)   1.25 W/(m2.K)

Monthly Heating consumption of building C110   BO: NE-SW



Monthly Heating consumption of building C189   BO: NW-SE

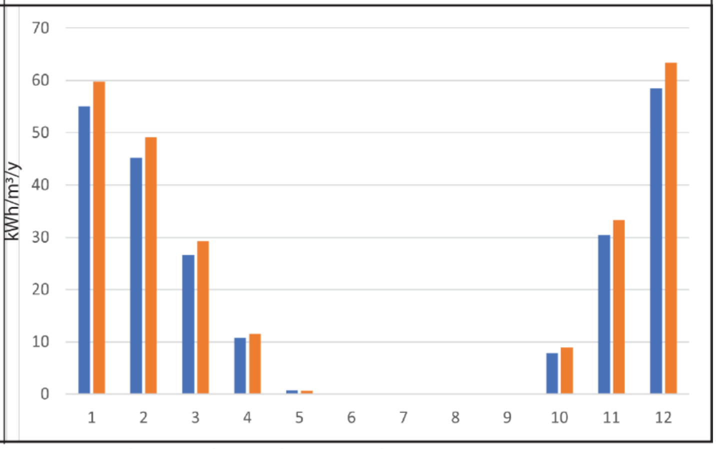
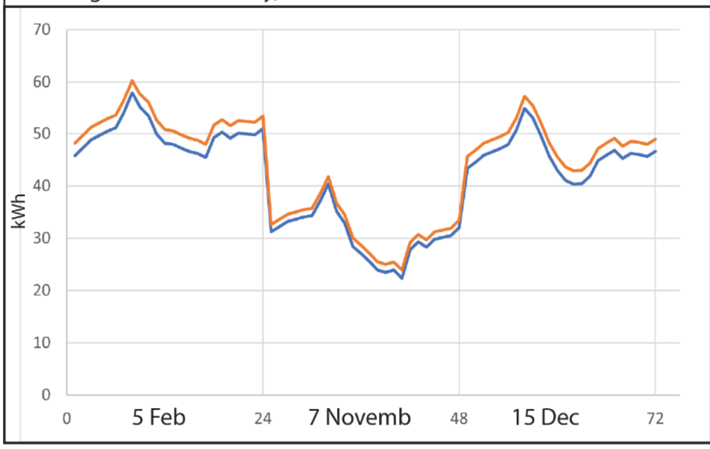


Fig. 95. Monthly heating consumption of buildings C110 and C189 according to three Floor U-values.

Hourly Heating data of building C110 for 3 days
Heating season: February, Novembre and Decembre



Hourly Heating data of building C189 for 3 days
Heating season: February, Novembre and Decembre

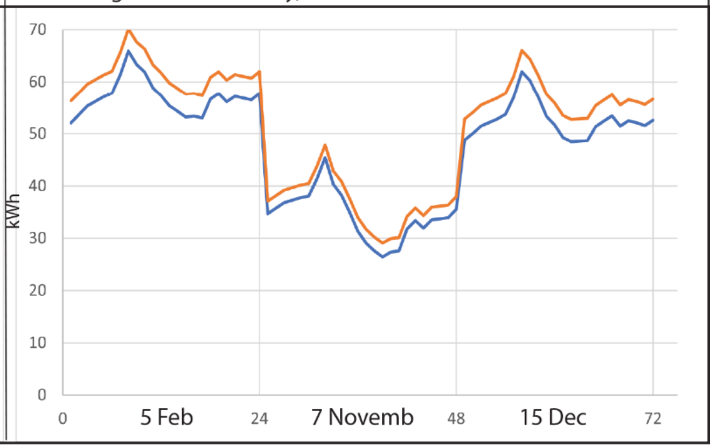
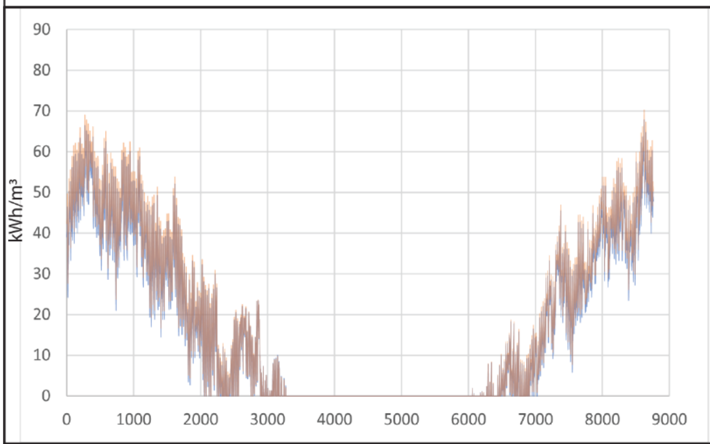
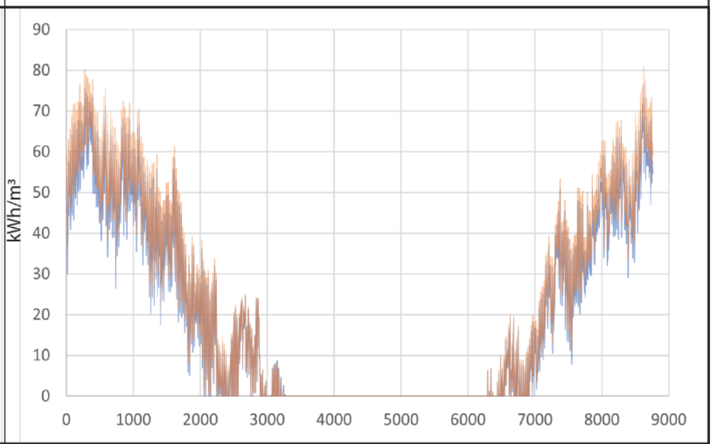


Fig. 96. Hourly heating consumption of buildings C110 and C189 according to three Floor U-values during three days.

Hourly Heating Demand of building C110 per year



Hourly Heating Demand of building C189 per year



Heating consumption: 16.82 kWh/m³/y
Heating consumption: 17.82 kWh/m³/y

Heating consumption: 19.27 kWh/m³/y
Heating consumption: 20.98 kWh/m³/y

Fig. 97. Hourly heating consumption of buildings C110 and C189 according to three Floor U-values during a year.

Adding to that, the cooling Energy consumptions of buildings C110 and C189 were analyzed as well. In fact, the first monthly results represented in Fig. 98., show that, when the roof's thermal transmittance of the building was equal to 1.25 {W/m^2. K} (SOL04 represented in orange), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures were the highest compared to the other roof composite (SOL03, represented in blue). Adding to that, an hourly Energy data was conducted C110 and C189, for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 99.). Results show that, for both analyzed residential buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building C110 characterized by a {NE-SW} orientation, and C189 with a {NW-SE} orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the most recent floor composite (1961-2005), characterized by a thermal transmittance equal to 1.25 {W/m^2. K}, (represented in orange), constantly had the highest cooling Energy demand.

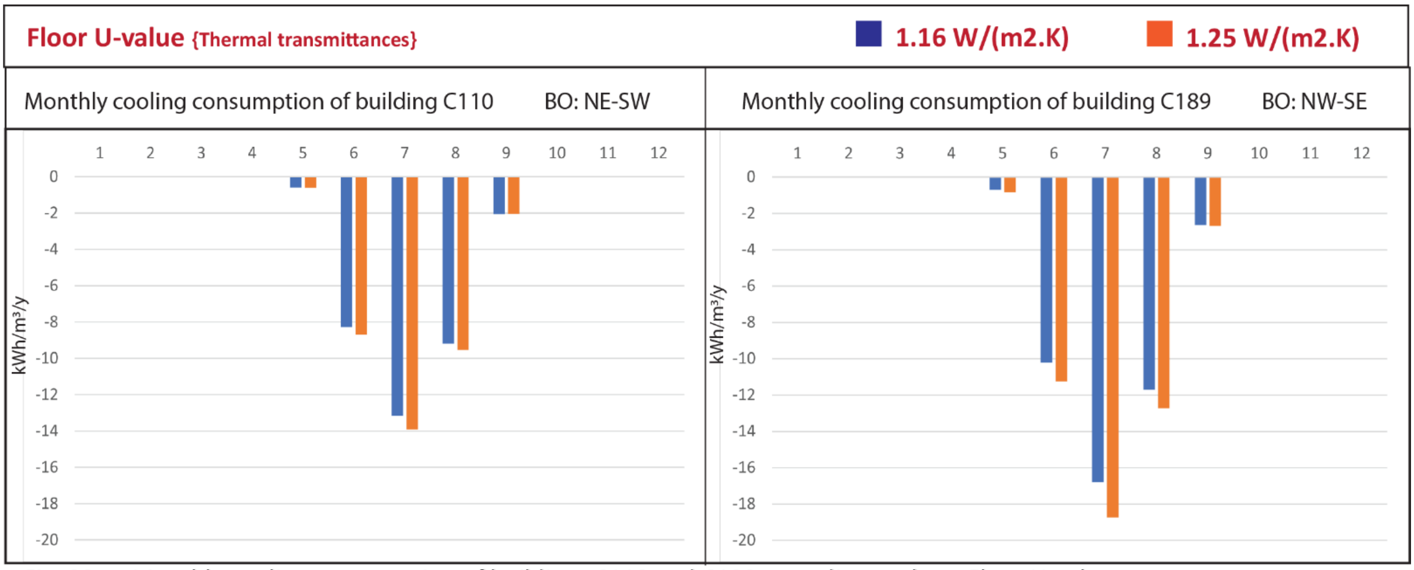


Fig. 98. Monthly cooling consumption of buildings C110 and C189 according to three Floor U-values.

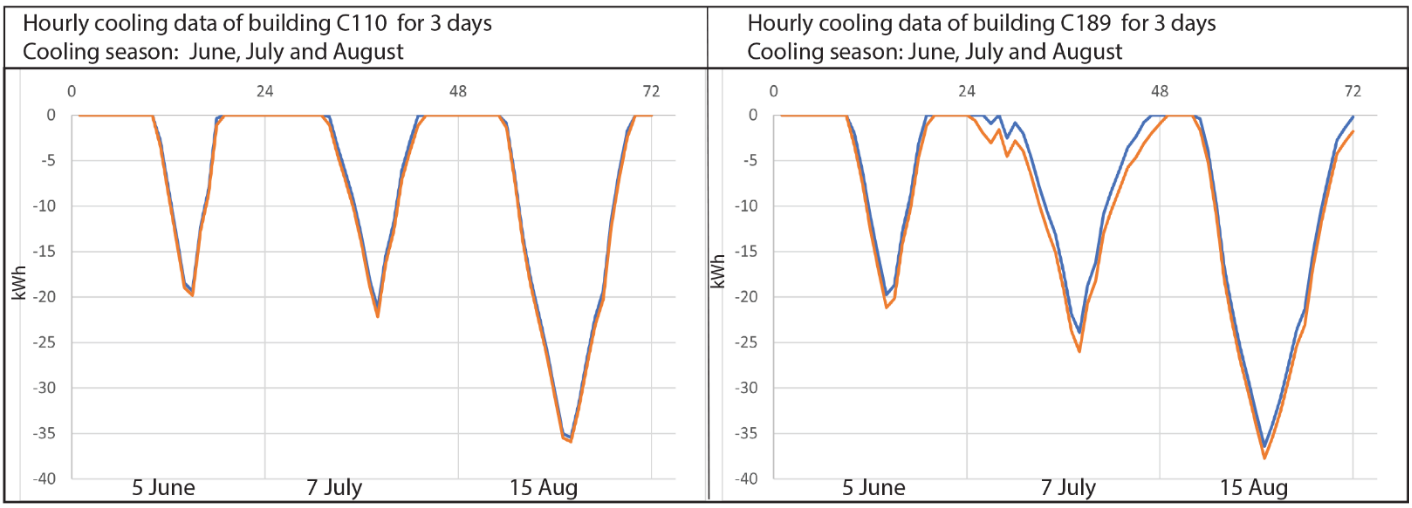


Fig. 99. Hourly cooling consumption of buildings C110 and C189 according to three Floor U-values during three days.

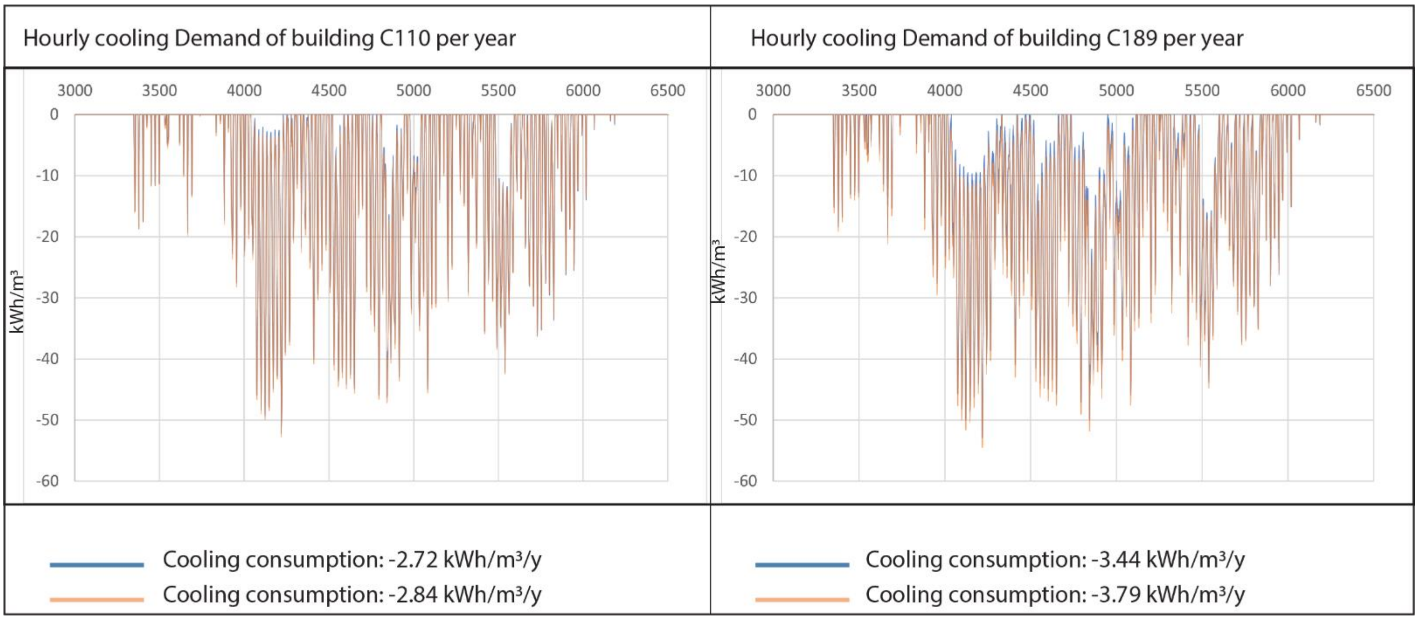


Fig. 100. Hourly cooling consumption of buildings C110 and C189 according to three Floor U-values during a year.

Table. XXVIII. Buildings C110 and C189 Heating and Cooling Energy consumptions depending on floor U-values equal to 1.16, and 1.25 W/m^2. K.

Floor U-value W/(m2.K)	Building C110 Heating Consumption (kWh/m³/y)	Building C110 Cooling Consumption (kWh/m³/y)	Building C189 Heating Consumption (kWh/m³/y)	Building C189 Cooling Consumption (kWh/m³/y)
1.16	16.82	-2.72	19.27	-3.44
1.25	17.82	-2.84	20.98	-3.79

Table. XXVIII. Shows the variations in the heating and cooling energy consumptions of buildings C110 and C189, depending on two changed floor thermal transmittances values equivalent to 1.16 {1919-196}, and 1.25 {1961-2005}, expressed in {W/m^2. K}. In fact, C110 characterized by a {NE-SW} building orientation, had an increase of 6%, with a floor U-value equal to 1.16 {W/m^2. K}, in regard to its lowest consumption of 16.82 kWh/m^3/y. while C189, with a (NW-SE) building orientation, had a higher energy, impact compared to C110, with 9% between the lowest and highest reached value respectively equal to 19.27 kWh/m^3/y and 20.98 kWh/m^3/y. Fig. 101., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of C110 {NE-SW} was less impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that SOL04 floor composite consumed the highest heating and cooling energy demand, while the oldest composite SOL03, had the lowest yearly energy Utilization. Adding to that, buildings with a NW-SE orientation, have a higher cooling and heating Energy consumption impact, in comparison to structures with NW-SE orientations.

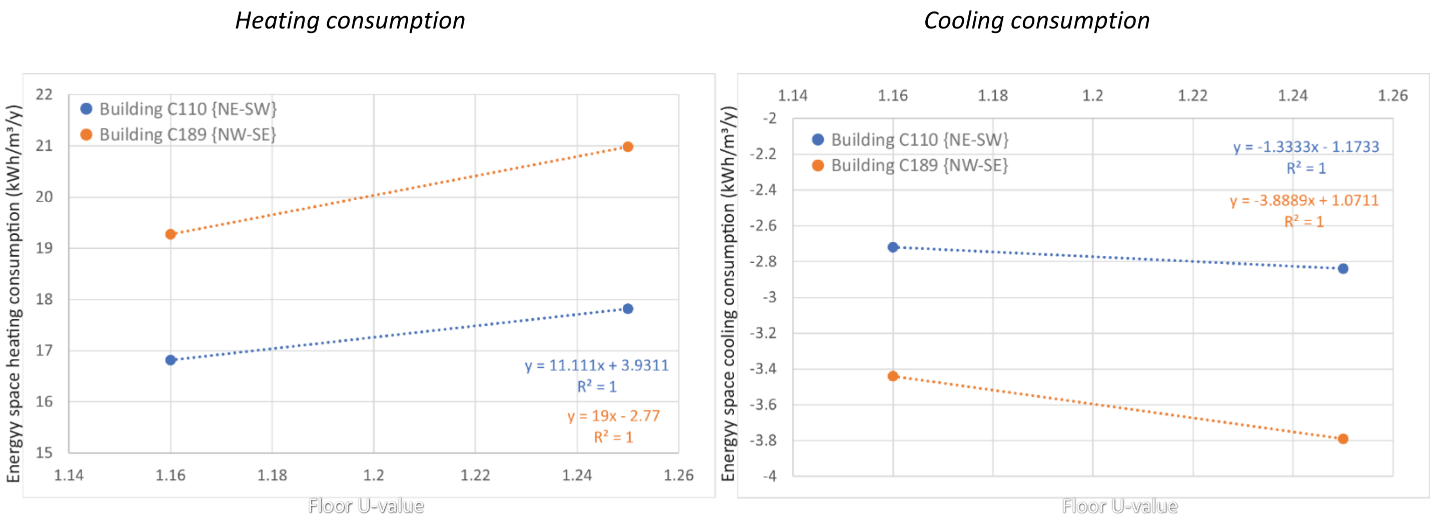


Fig. 101. Energy space heating and cooling demands of buildings C110 and C189 depending on floor U-values.

5.3- Arquata district: Impact of energy-related building variables

Arquata neighborhood, is located in the city of Turin, Italy. This urban zone is characterized by buildings constructed between 1961 and 1970. In fact, it has one of the lowest Building coverage ratio equal to 0.18, that reflects the gross built area of the neighborhood over the census parcel area, with a building density equivalent to 3.56 m^3/m^2, that represents the proportion between the overall volume of the buildings and the census parcel zone. And a Height to Width urban ratio of 0.27 m/m. Two buildings were analyzed (A1 and A9), where their respective heating and cooling demands were compared and analyzed following different ranges of urban variable inserted in the engineering software CitySim Pro. The analyzed residential building parameters are: Infiltration rate (ranges equivalent to 0.2, 0.4 and 0.6 h^{-1}), Glazing ratio (ranges equivalent to 0.2, 0.4 and 0.6), Thermal transmittances of walls (ranges equivalent to 2.15, 4.40 and 4.90 $W/(m^2.k)$), Thermal transmittances of roof (ranges equivalent to 0.53, 1.27 and 1.60$W/(m^2.k)$), and finally, Thermal transmittances of floor (equivalent to 1.16 and 1.25 $W/(m^2.k)$). In fact, for each variable, results were separated into monthly heating and cooling energy data, Hourly results for three heating and cooling seasons (5th of February, 7th of November, 15th of December, 5th of June, 7th of July and finally 15th of August), as well as the hourly heating and cooling Energy consumptions over the course of one year (equivalent to 8761 hours).

5.3.1- Building's Surface to Volume ratio

In fact, the Surface to Volume {S/V} proportion is a ratio indicating the compactness of a certain structure or building. It is frequently communicated as the 'heat misfortune structure factor', which is the proportion the building's envelope area (walls, roofs, terraces…etc.) to the treated floor area of the designated structure. This ratio will help in the identification of the building's typology, weather it is a small condominium house or a tower for example. In this case, buildings A1 and A9 have the same Surface to Volume ratio that is equal to 0.45. the two structures are characterized by opposite orientations of {NE-SW} and {NW-SE} respectively. A9 is characterized by a bigger heated Volume (2610 m^3), compared to A1 (2435 m^3) shown in Table. XXIX. Building A1 has an energy heating consumption equal to 18.90 $kWh/m^3/y$, with a cooling demand of -5.26 $kWh/m^3/y$.

However, A9, is characterized by a higher energy utilization with 19.12 kWh/m^3/y in warmth consumption, and -5.27 kWh/m^3/y for its yearly cooling consumption (Fig. 102).

Table. XXIX. This table, shows the heated volume, building orientation, Surface to Volume ratio and Energy heating and cooling of buildings A1 and A9.

Building ID	Heated Volume	Building orientation	S/V	Energy heating Consumption (kWh/m^3/y)	Energy cooling Consumption (kWh/m^3/y)
A1	2435	NE-SW	0.45	18.90	-5.26
A9	2610	NW-SE	0.45	19.12	-5.27

Arquata

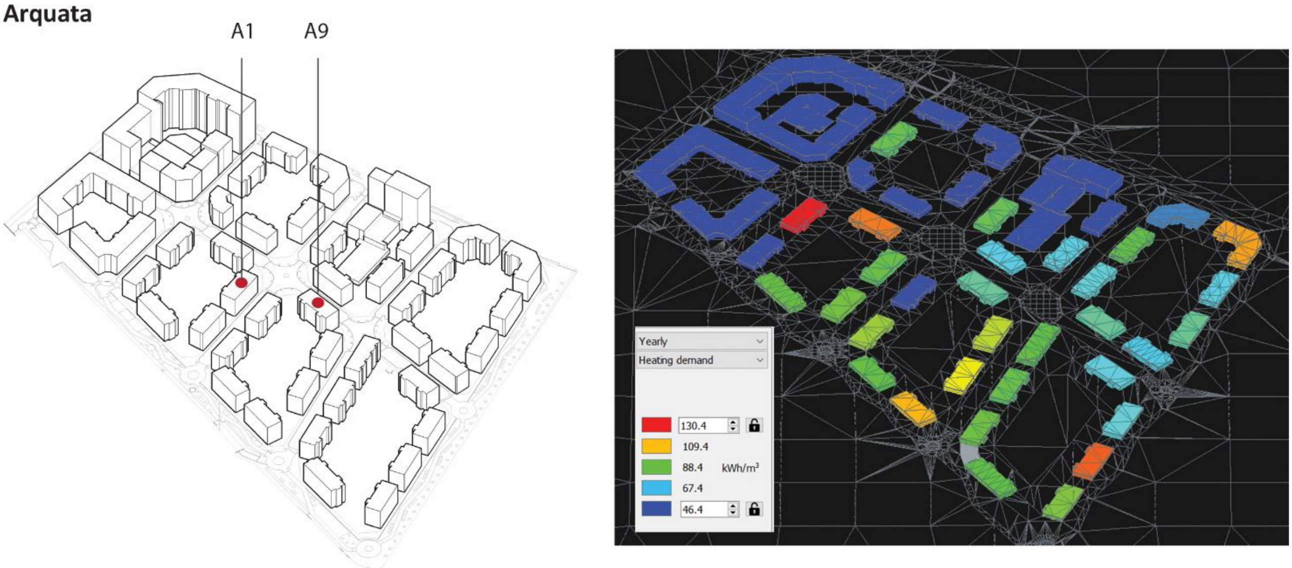


Fig. 102. Three-dimensional representation of Arquata neighborhood indicating the two analyzed buildings. And Yearly Heating demand of Arquata district calculated by CitySim Pro.

5.3.2- Building's infiltration rate (h^{-1})

Infiltration is the unintentional or coincidental presentation of outdoor air into a building, ordinarily through cracks in the structure envelope and through utilization of entryways such as doors. The higher the infiltration rate, the more outdoor air is penetrating inside the building and therefore affecting the building's internal temperature. In this analysis, three different infiltration rates were studied: 0.2 h^{-1} (indicated in green), 0.4 h^{-1} (indicated in blue), and 0.6 h^{-1} (indicated in orange), in order to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (A1 and A9). The first warmth Energy utilization results are shown in Fig. 103. In fact, the monthly heating demand of both structures A1 and A9, increased when the infiltration rate was higher, mainly due to the penetration of the cold outdoor air inside of the building. Adding to that, Fig. 104., represents the hourly heating data of buildings A1 and A9, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, infiltration rate equal to 0.6 h^{-1}, had constantly the highest warmth utilization, while the lowest rate (0.2 h^{-1}), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November (mainly due to a higher outdoor air temperature in this month), it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings A1 and A9, both regularly consumed more heating Energy with the highest infiltration rate of 0.6 h^{1}

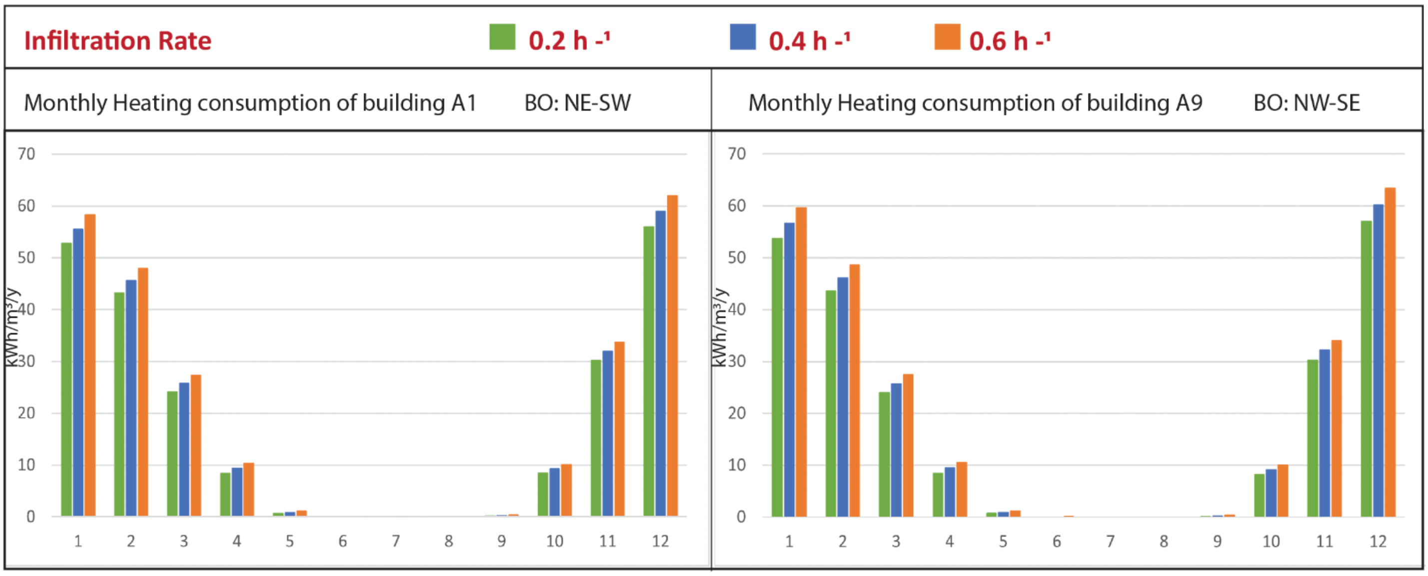


Fig. 103. Monthly heating consumption of buildings A1 and A9 according to three infiltration rates.

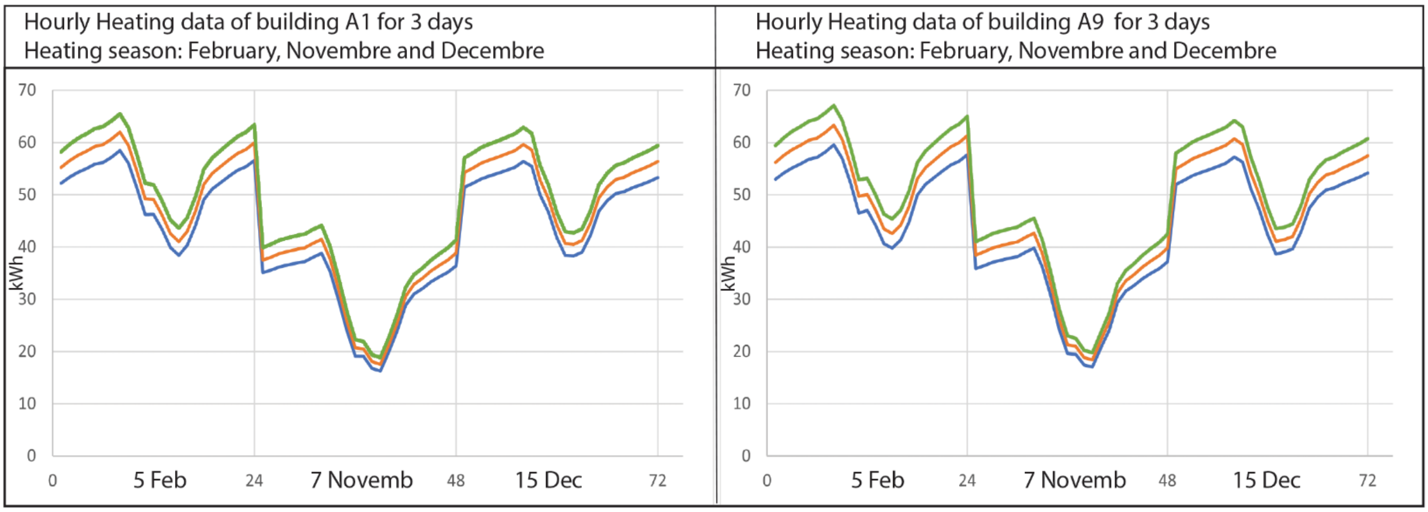


Fig. 104. Hourly heating consumption of buildings A1 and A9 according to three infiltration rates during three days.

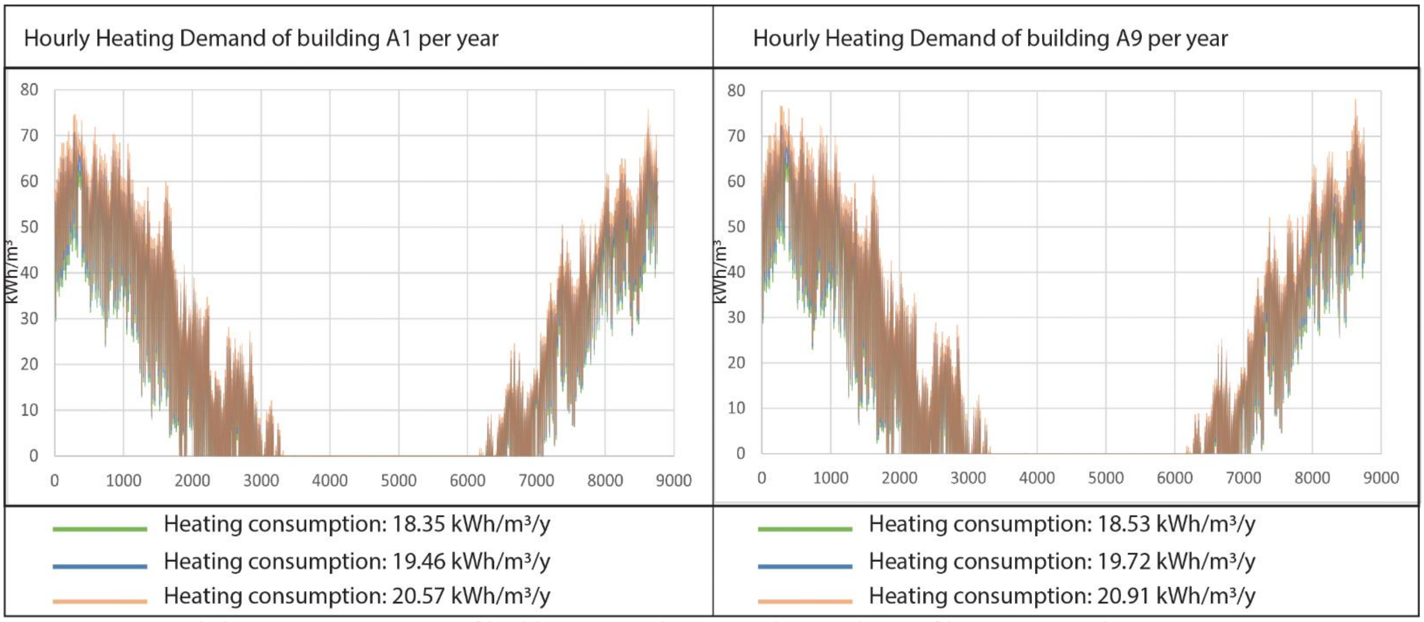


Fig. 105. Hourly heating consumption of buildings A1 and A9 according to three infiltration rates during a year.

represented in orange), compared to rates equivalent to 0.4 h^{-1} (represented in green), and 0.2 h^{-1} (represented in blue) (Fig. 105.).

Adding to that, the cooling Energy consumptions of buildings A1 and A9, were analyzed as well. In fact, Fig. 106., reflects the yearly Cooling demand of Arquata neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. In fact, the first deducted monthly results represented in Fig. 107., show that, when the infiltration rate of the building increased, on the opposite of the heating consumption, the cooling Energy demand decreased for

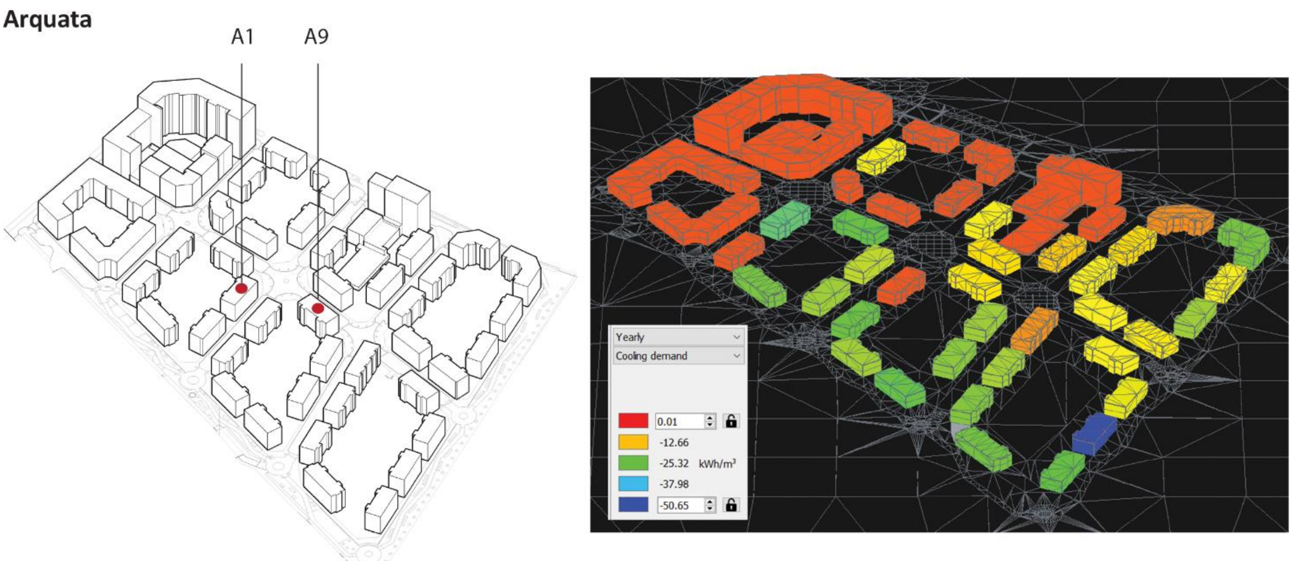


Fig. 106. Three-dimensional representation of Arquata neighborhood indicating the two analyzed buildings. And Yearly cooling demand of Arquata district calculated by CitySim Pro.

both analyzed residential structures. Adding to that, an hourly Energy data was conducted for A1 and A9, for three days during the cooling season: 5^{th} of June, 7^{th} of July and 15^{th} of August (Fig. 108.). Results show that, for both buildings, the highest Energy Utilization was on the 15^{th} of August, while the lowest one is represented on the 5^{th} of June. In fact, in August, for both residential structures, with an infiltration rate equal to 0.6 h^{-1} (represented in orange), the energy consumption was higher compared to rates equal to 0.2 and 0.4, even though the yearly energy cooling consumption of this range was the lowest with -4.99 kWh/m^3/y for building A1, and -5 kWh/m^3/y for A9 (Fig. 109). However, during the months June and July, the lowest infiltration rate (0.2 h^{-1}) had the highest Energy cooling utilization (represented in green).

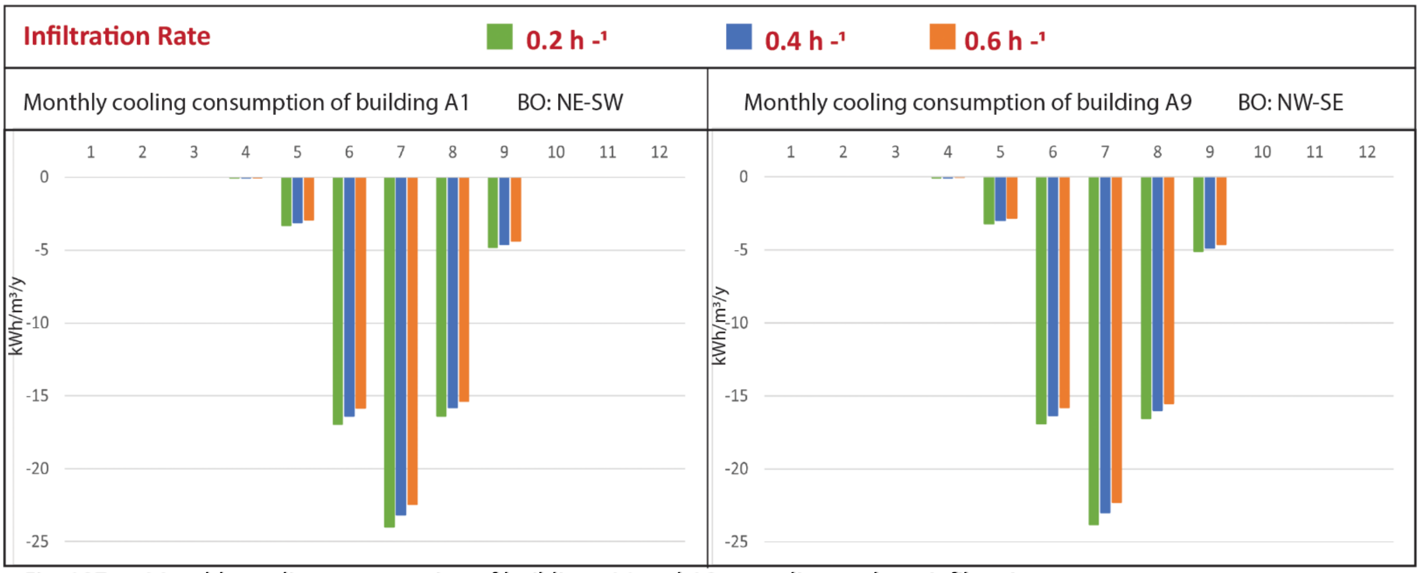


Fig. 107. Monthly cooling consumption of buildings A1 and A9 according to three infiltration rates.

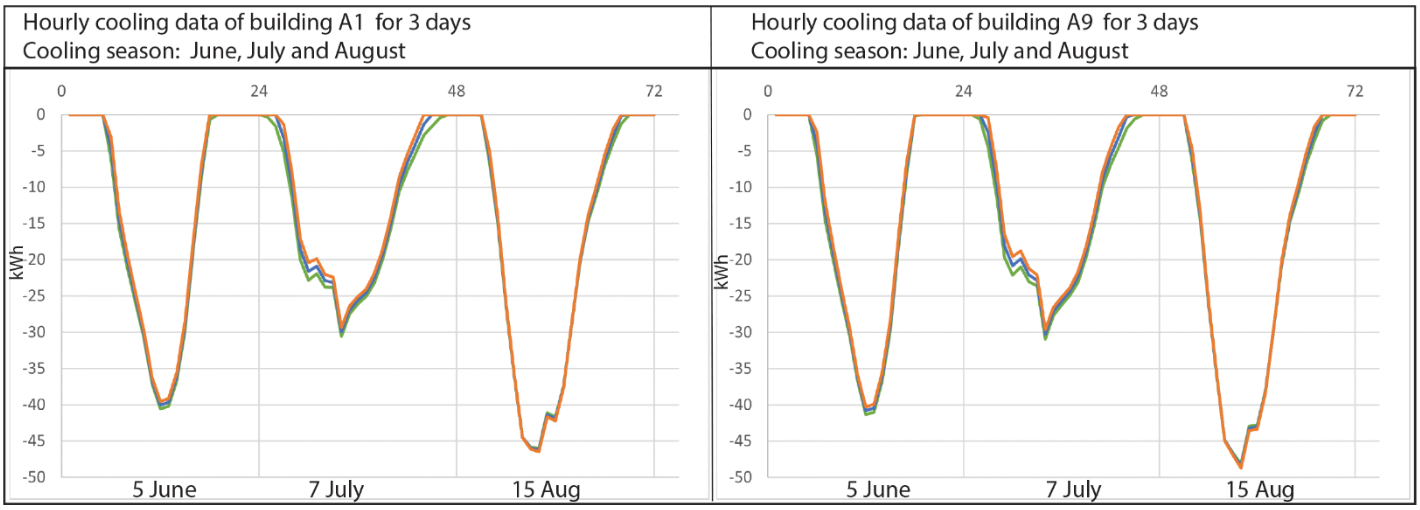


Fig. 108. Hourly cooling consumption of buildings A1 and A9 according to three infiltration rates during three days.

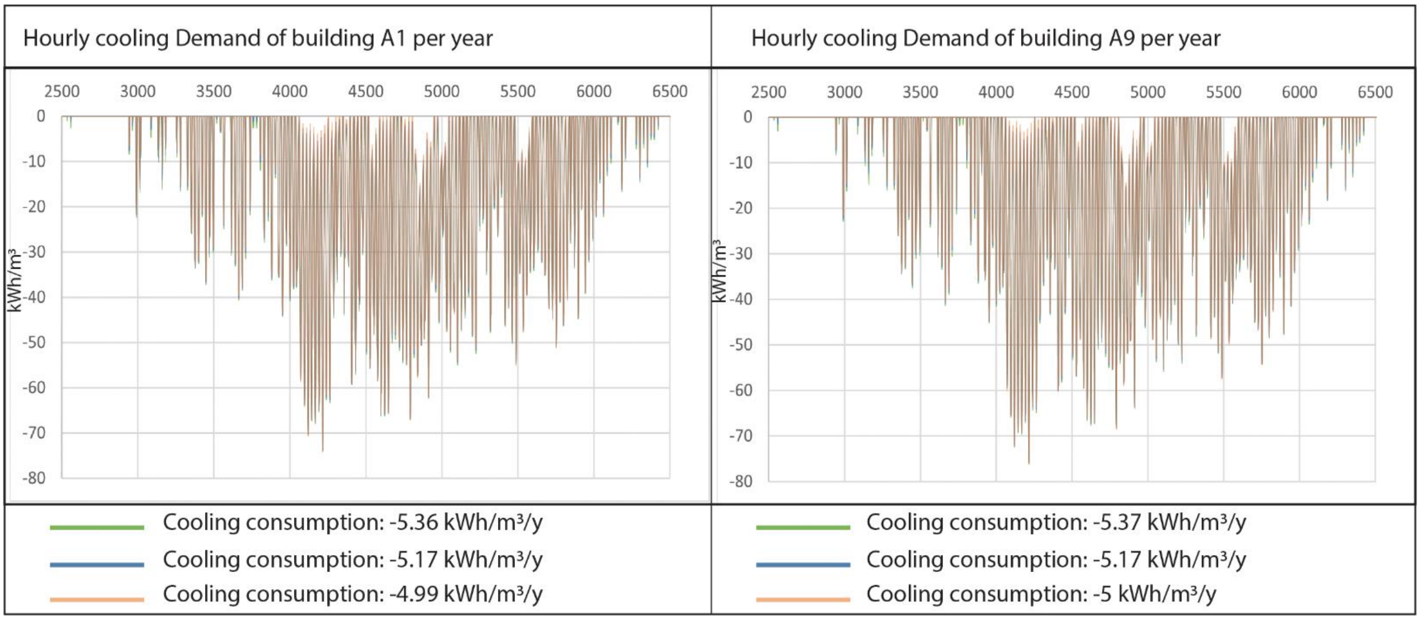


Fig. 109. Hourly cooling consumption of buildings A1 and A9 according to three infiltration rates during a year.

Table. XXX. Buildings A1 and A9 Heating and Cooling Energy consumptions depending on infiltration rates equal to 0.2, 0.4 and 0.6 h^{-1}.

Infiltration Rate h^{-1}	Building A1 Heating Consumption (kWh/m³/y)	Building A1 Cooling Consumption (kWh/m³/y)	Building A9 Heating Consumption (kWh/m³/y)	Building A9 Cooling Consumption (kWh/m³/y)
0.2	18.35	-5.36	18.53	-5.37
0.4	19.46	-5.17	19.72	-5.17
0.6	20.57	-4.99	20.91	-5

Table. XXX. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9 depending on three changed infiltration rates equivalent to 0.2, 0.4 and 0.6 h^{-1}. In fact, A1 characterized by a {NE-SW} building orientation, had an increase of 11% in its highest value (with infiltration rate equal to 0.6) in regard to its lowest consumption of 18.35 kWh/m³/y (with an infiltration rate equal to 0.2). while A9 with a (NW-SE) had a higher warmth energy impact with 13% between the lowest and highest reached value. Fig. 110., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of A1 {NE-SW} and A9 with a building orientation of {NW-SE}, had approximately the same amount of impact on the energy cooling consumption according to their respective linear equational values. Therefore, we can conclude that when the infiltration rate increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings with a NW-SE orientation, have a higher Energy consumption impact, in comparison to structures with NE-SE orientations.

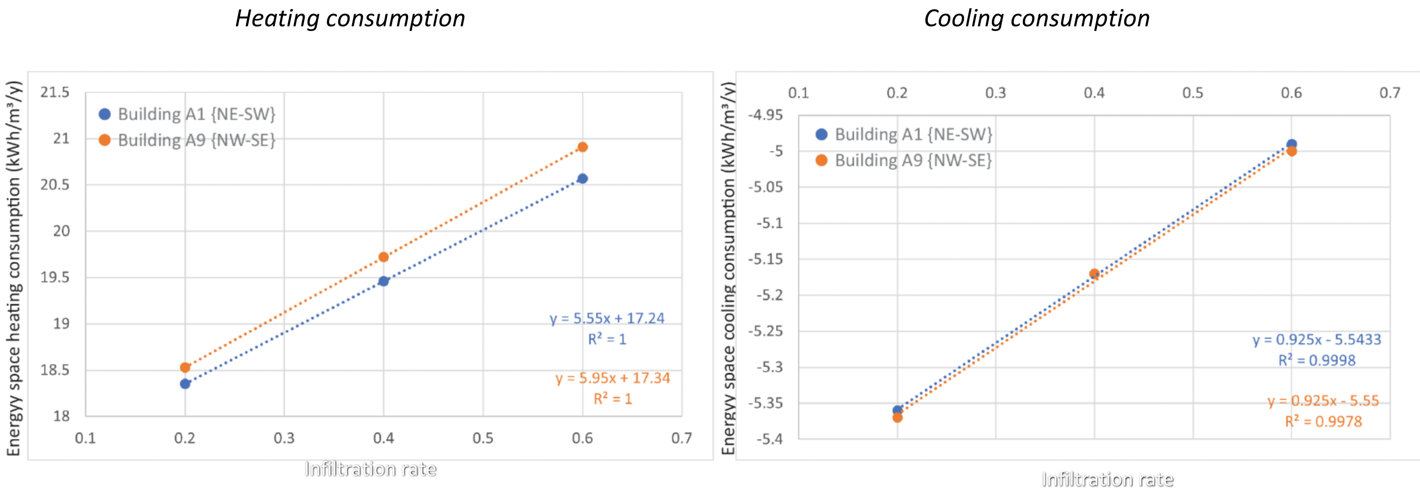


Fig. 110. Energy space heating and cooling demands of buildings A1 and A9 depending on the infiltration rate.

5.3.3- Building's Glazing ratio

Glazing ratio also known as Window to Wall Ratio, is the proportion of the transparent envelope in relation to the façade's surface. The smaller the glazing ratio, the smaller the proportion of the window compared to the wall. In this analysis, three main ratios were studied: 0.2, 0.4 and 0.6. These different ranges will help in the understanding of the impact of the glazing ratio on the yearly heating and cooling demands of the residential buildings. In this analysis, three different Glazing ratio values were studied: 0.2 (indicated in green), 0.4 (indicated in blue), and 0.6 (indicated in orange), to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (A1 and A9). The first warmth Energy utilization results are shown in Fig. 111. In fact, the monthly heating demand of both structures, increased when the Glazing ratio value was higher (where the structure consumed more heating energy with a glazing ratio equal to 0.6, compared to a smaller window to wall ratio of 0.2). Adding to that, Fig. 112., represents the hourly heating data of buildings A1 and A9, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that, with a glazing ratio equivalent to 0.6 (represented in orange), had constantly the highest

Glazing Ratio 0.2 0.4 0.6

Monthly Heating consumption of building A1 BO: NE-SW	Monthly Heating consumption of building A9 BO: NW-SE

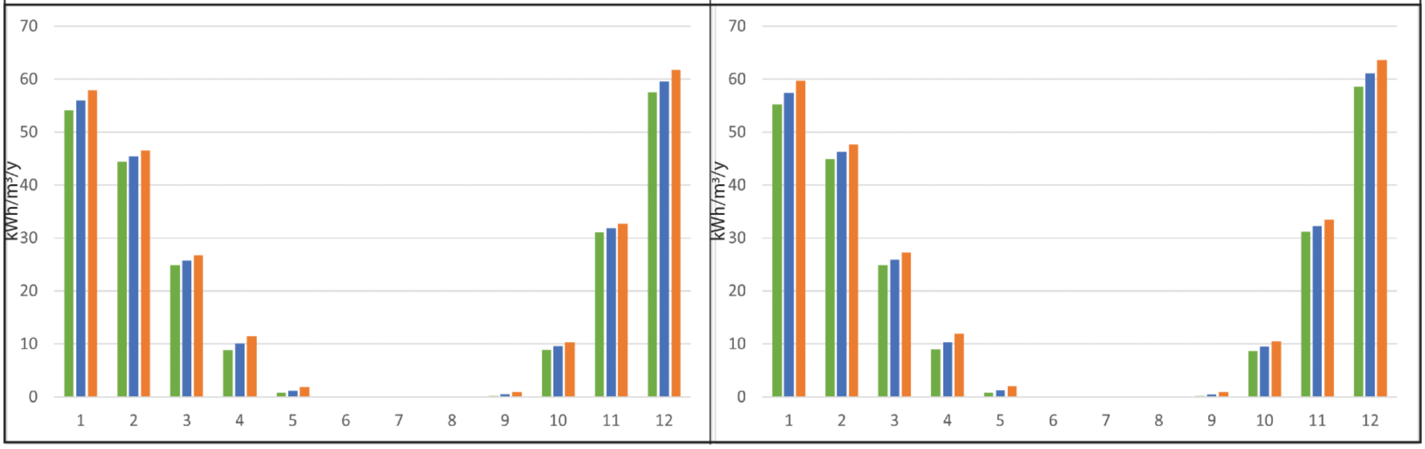


Fig. 111. **Monthly heating consumption of buildings A1 and A9 according to three Glazing ratios.**

Hourly Heating data of building A1 for 3 days Heating season: February, Novembre and Decembre	Hourly Heating data of building A9 for 3 days Heating season: February, Novembre and Decembre

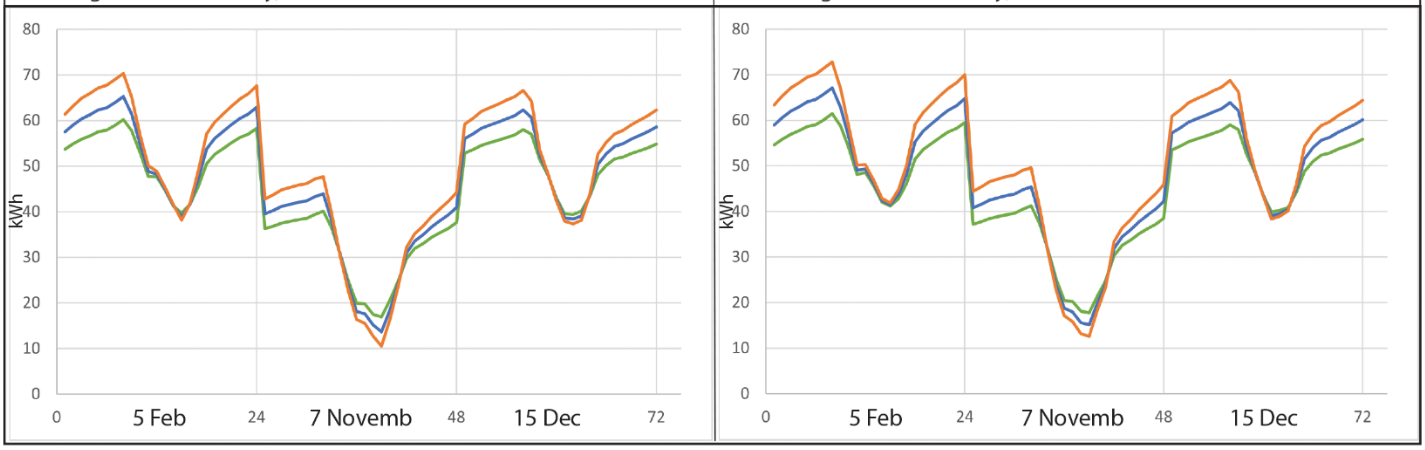
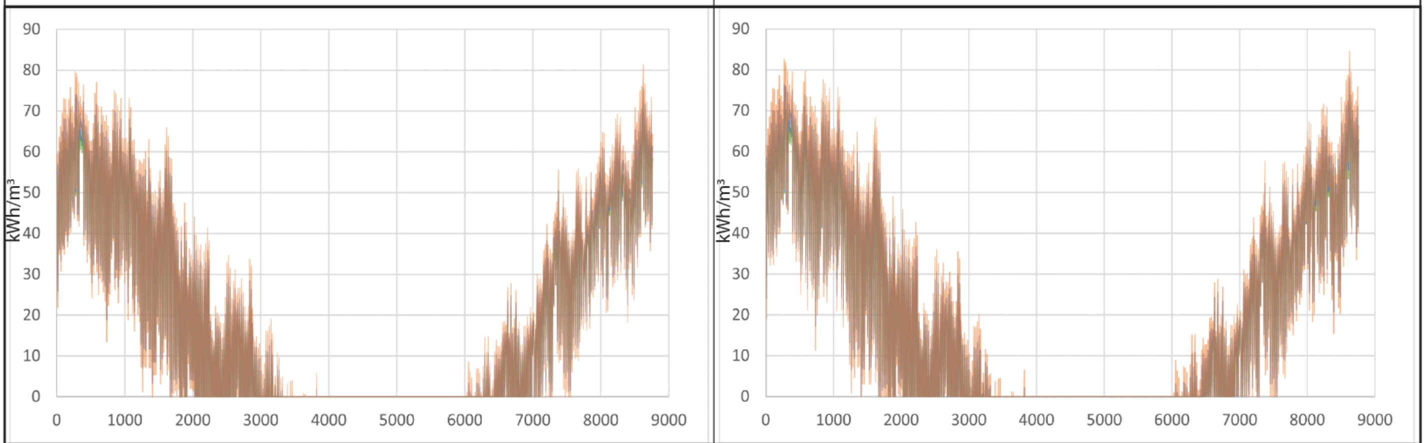


Fig. 112. **Hourly heating consumption of buildings A1 and A9 according to three Glazing ratios during three days.**

Hourly Heating Demand of building A1 per year	Hourly Heating Demand of building A9 per year



Building A1	Building A9
Heating consumption: 18.90 kWh/m³/y	Heating consumption: 19.12 kWh/m³/y
Heating consumption: 19.66 kWh/m³/y	Heating consumption: 20.04 kWh/m³/y
Heating consumption: 20.52 kWh/m³/y	Heating consumption: 21.06 kWh/m³/y

Fig. 113. **Hourly heating consumption of buildings A1 and A9 according to three Glazing ratios during a year.**

warmth utilization, during February and December, while the lowest ratio (equal to 0.2, represented in green), consumed the least heating demand. However, the results were completely opposite in the month of November for both residential buildings, where: the glazing ratio equal to 0.6 had the lowest consumption, while the highest achieved energy utilization was represented with a Window to wall ratio of 0.2 (represented in green). As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings A1 and A9, both regularly consumed more heating Energy with the highest Window to Wall ratio of 0.6 (represented in orange), compared to smaller ratios equivalent to 0.4 (represented in blue), and 0.2 (represented in green), in accordance with Fig. 113.

Adding to that, the cooling Energy consumptions of building A1 and A9, were analyzed as well. In fact, the first deducted monthly results represented in Fig. 114., show that, when the Glazing ratio of the building increased, similarly to the heating consumption (previously analyzed), the cooling Energy demand increases as well for both structures A1 and A9. Adding to that, an hourly Energy data was conducted for these residential buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 115.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for both structures, during the whole yearly cooling season, the highest window to wall ratio (equal to 0.6) constantly had the highest cooling Energy consumption (represented in orange), followed by the simulated results of ratio equivalent to 0.4 (represented in blue), and finally the lowest hourly and yearly cooling Energy utilization is represented by the lowest studied glazing ratio, that is equal to 0.2 (represented in green) in accordance with Fig. 116.

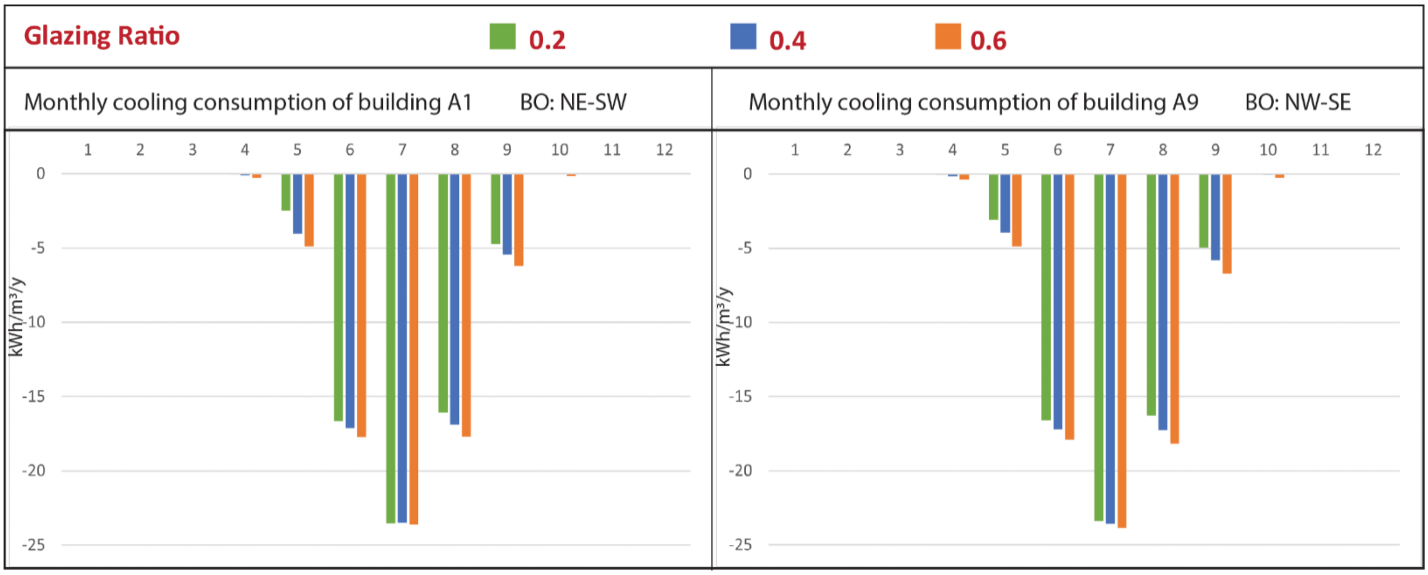


Fig. 114. Monthly cooling consumption of buildings A1 and A9 according to three Glazing ratios.

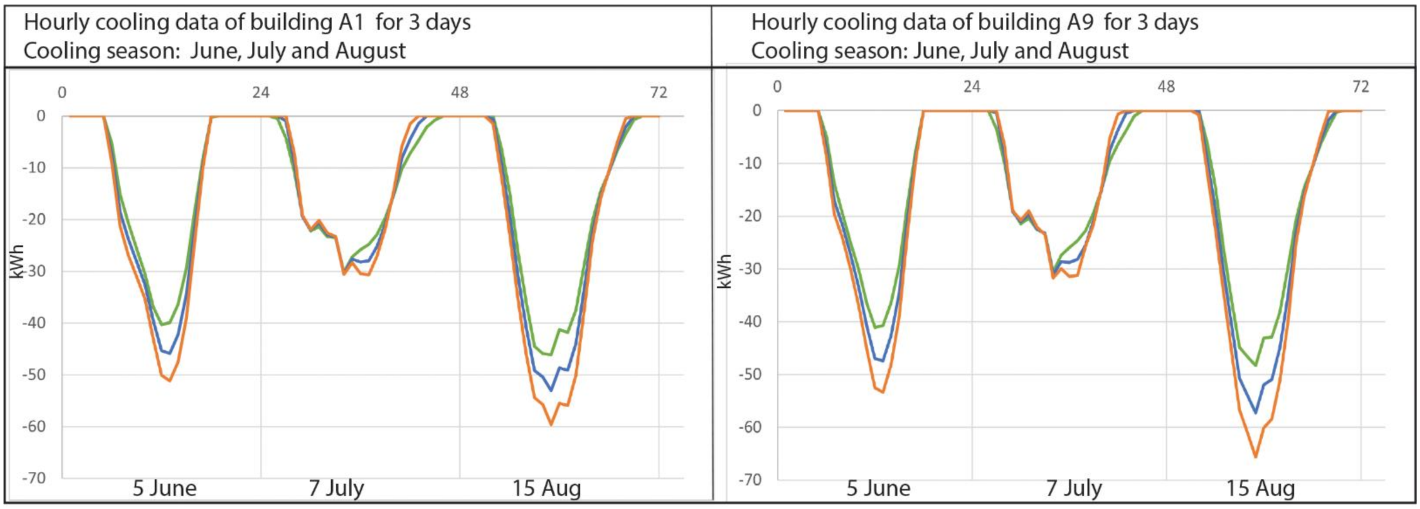


Fig. 115. Hourly cooling consumption of buildings A1 and A9 according to three Glazing ratios during three days.

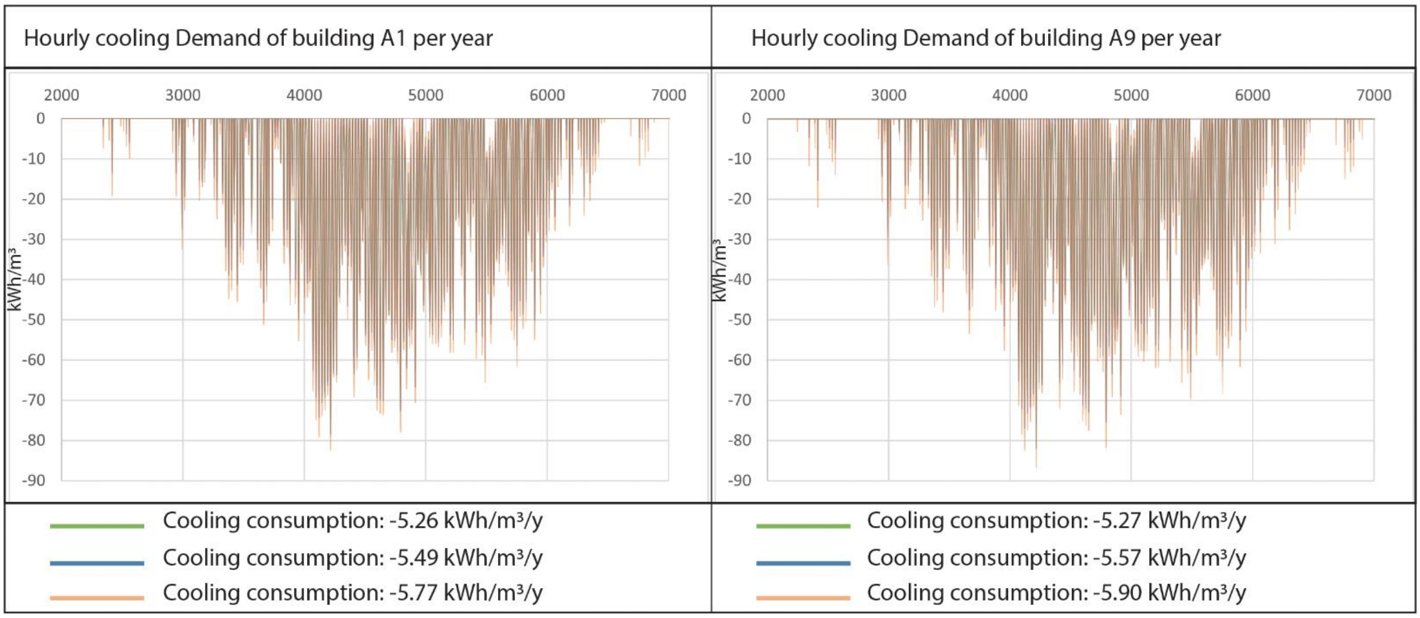


Fig. 116. Hourly cooling consumption of buildings A1 and A9 according to three Glazing ratios during a year.

Table. XXXI. Buildings A1 and A9 Heating and Cooling Energy consumptions depending on Glazing ratios equal to 0.2, 0.4 and 0.6.

Glazing Ratio	Building A1 Heating Consumption (kWh/m³/y)	Building A1 Cooling Consumption (kWh/m³/y)	Building A9 Heating Consumption (kWh/m³/y)	Building A9 Cooling Consumption (kWh/m³/y)
0.2	18.90	-5.26	19.12	-5.27
0.4	19.66	-5.49	20.04	-5.57
0.6	20.52	-5.77	21.06	-5.90

Table. XXXI. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9, depending on three changed Window to Wall ratios equivalent to 0.2, 0.4 and 0.6. In fact, A1 characterized by a {NE-SW} building orientation, had an increase of 8% in its highest value (with a glazing ratio equal to 0.6) regarding its lowest consumption of 18.90 kWh/m^3/y (with a glazing ratio equal to 0.2). while A9 with a (NW-SE) had a higher warmth energy impact with 10% between the lowest (19.12 kWh/m^3/y) and highest reached value (21.06 kWh/m^3/y). Fig. 117., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of A1 {NE-SW} had a lower impact regarding the glazing ratio changes, compared to building A9 characterized by a {NW-SE} orientation. Therefore, we can conclude that when the glazing ratio of the building increases, the energy heating, and cooling demands of the structures, increases as well simultaneously. Adding to that, buildings with a NW-SE orientation, have a higher Energy consumption impact, in comparison to structures with NE-SE orientations.

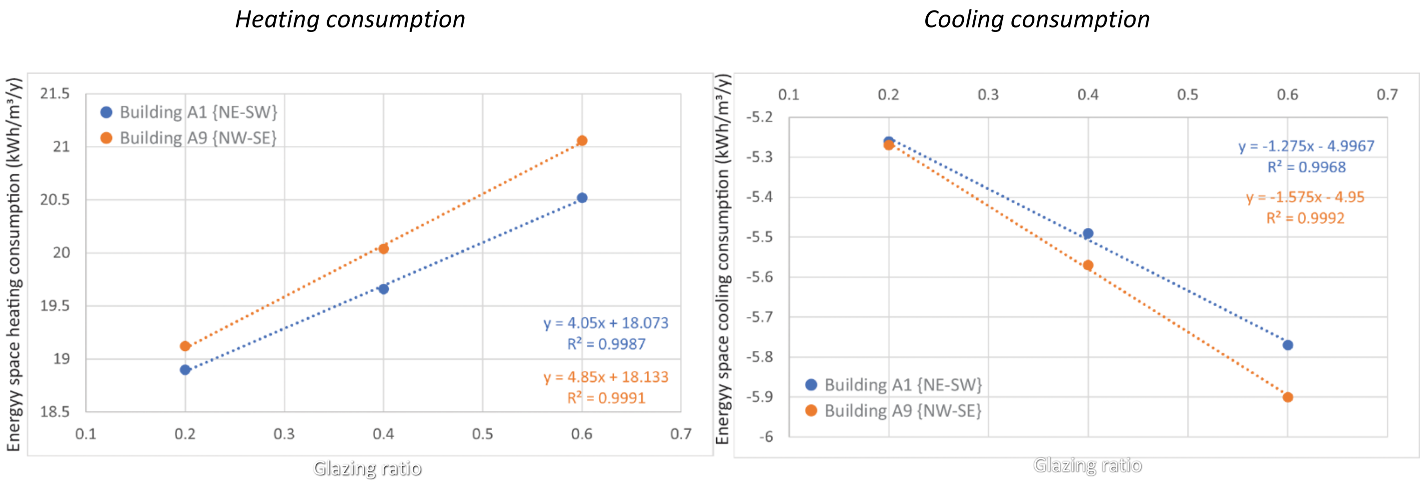


Fig. 117. Energy space heating and cooling demands of buildings A1 and A9 depending on the infiltration rate.

5.3.4- Thermal properties of building envelope

The thermal propertied of a building, are subdivided in this analysis into four main categories: Thermal transmittance of the opaque envelope of the building (Windows U-value), and thermal transmittances of walls, roof, and floor in regard to the building composites and materials. In fact, the opening properties' U-values, are retrieved from UNI/TS 11300-1 according to building's periods of construction. The lower the U-value the more the window is insulated from the outdoor factors of the building. In this variable, three main values were analyzed: 2.15, 4.40 and 4.90 expressed in {W/m^2. K}. Adding to that, Building's Materials and composites retrieved from UNI/TR 11552 varying according to the building's-built period. In this variable, walls, roofs, and floors composites were taken into consideration by specifying their thermal transmittance, resistance, materials densities as well as their thermal capacity. Ranges of 0.67, 0.9 and 1.10 {W/m^2. K} were examined for the walls' U-values, while for the roof composites, values varied between 0.53, 1.27 and 1.60{W/m^2. K}. and finally, the last studied building variable is the floor's composites and materials with values equivalent to 1.16 {W/m^2. K} for construction periods ranging between 1919 and 1960, and 1.25 {W/m^2. K} for residential structure building between 1961 and 2005.

5.3.4.1- Window's U-value ($U_{windows}$, W/m²/K)

In fact, the building's windows U-values, are assigned to each residential building, according to its respective period of construction. The lower the U-value the more the window is insulated from the outdoor factors. In this analysis, three different windows thermal transmittances were studied: 2.15 {W/m^2. K} (indicated in green), 4.40 {W/m^2. K} (indicated in blue), and 4.90{W/m^2. K} (indicated in orange), to sensitively compare and analyze the impact of this changed variable on the heating and cooling consumption of the two chosen residential buildings (A1 and A9) in Arquata neighborhood that are characterized with a construction period between 1961 and 1970. The first warmth Energy utilization results are shown in Fig. 118. In fact, the monthly heating demand of both analyzed, increased when the windows' U-value was higher, mainly due to the penetration of the cold outdoor air inside of the building during the heating season, because of the lower window insulation. Adding to that, Fig. 119., represents the hourly heating data of buildings A1 and A9 regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the opaque envelope's thermal transmittance that is equal to 4.90 {W/m^2. K}, represented in orange, had constantly the highest warmth utilization, while the lowest window's U-value (2.15 {W/m^2. K}), represented in green, consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), both structures, regularly consumed more heating Energy with the highest window U-value

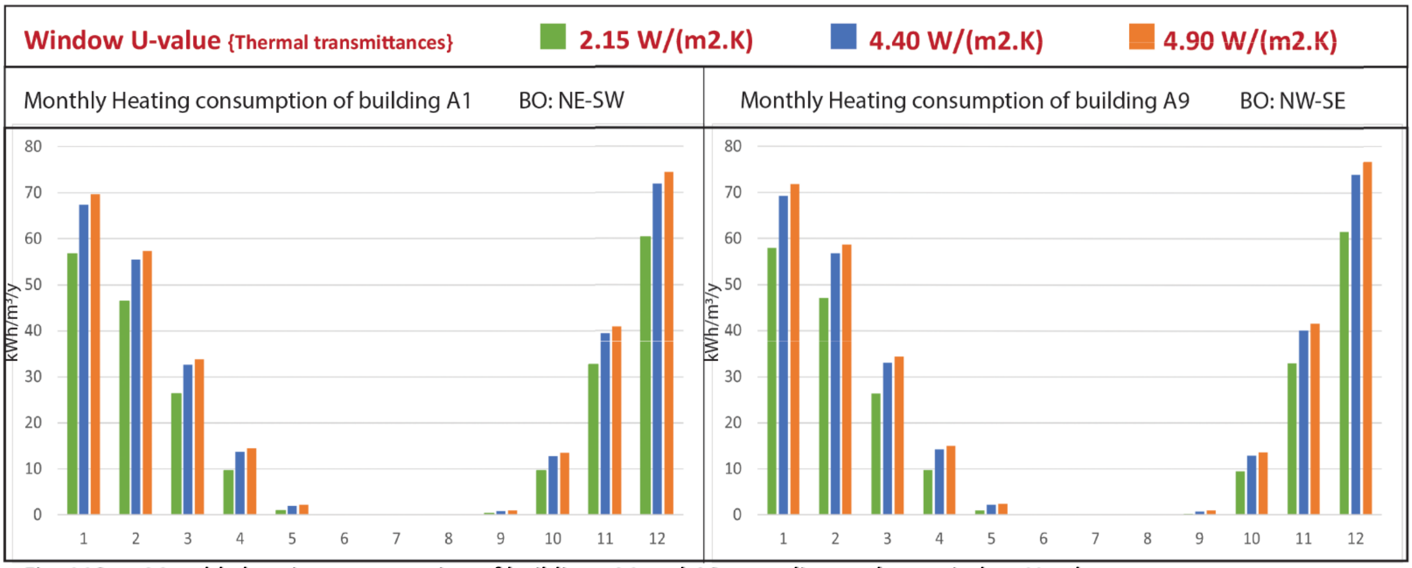


Fig. 118. Monthly heating consumption of buildings A1 and A9 according to three window U-values.

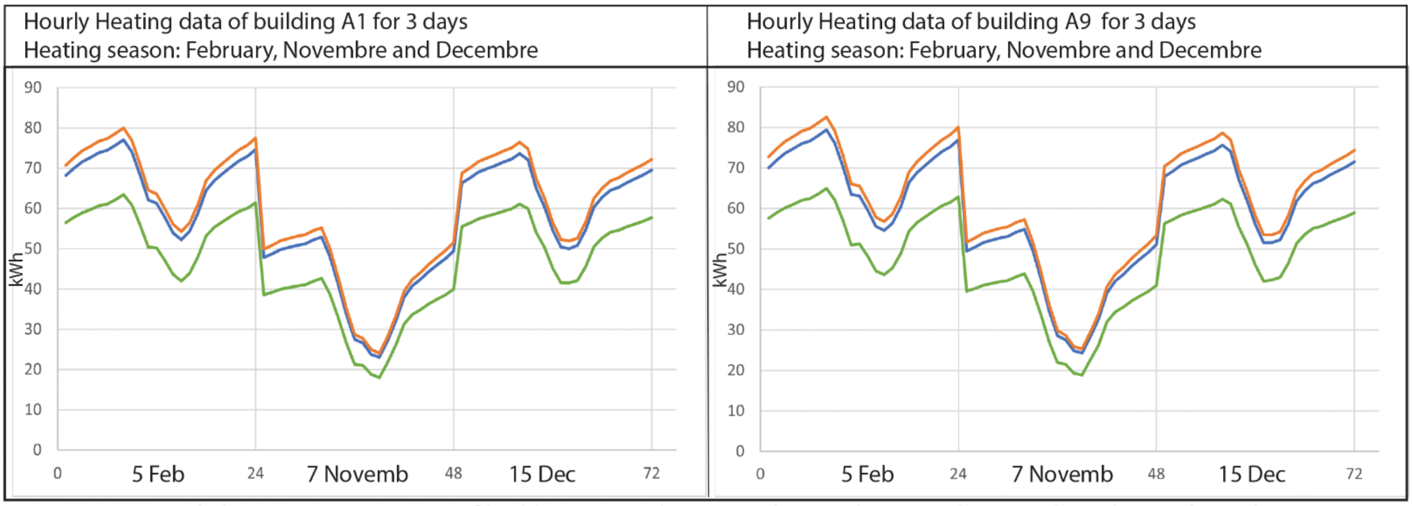


Fig. 119. Hourly heating consumption of buildings A1 and A9 according to three window U-values during three days.

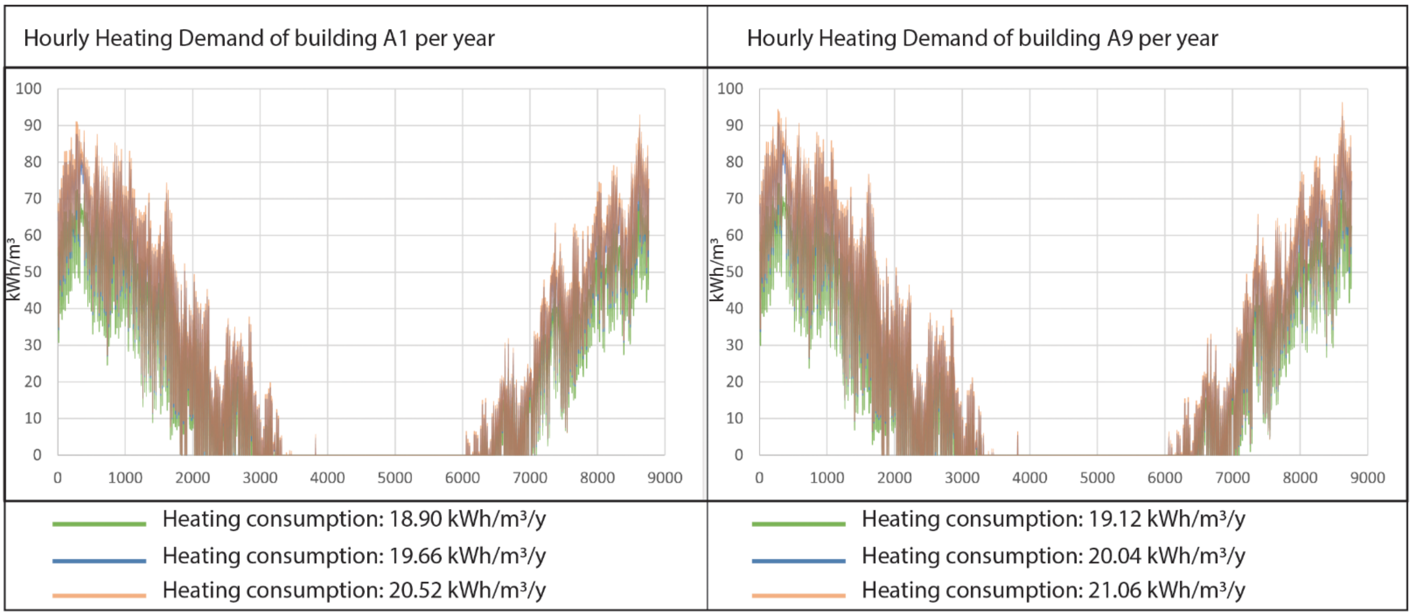


Fig. 120. Hourly heating consumption of buildings A1 and A9 according to three window U-values during a year.

equivalent to 4.90 {W/m². K} (represented in orange), compared to lower values of 4.40 {W/m². K} (represented in blue), and 2.15 {W/m². K} (represented in green) (Fig. 120.).

Adding to that, the cooling Energy consumptions of building A1 and A9, were analyzed as well. In fact, the first deducted monthly results represented in Fig. 121., show that, when the window's U-value of the building increased, on the opposite of the heating consumption results (previously discussed), the cooling Energy demand decreased for structures. Adding to that, an hourly Energy consumption was conducted for A1 and A9 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 122.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with a window U-value equivalent to 4.90 {W/m². K} represented in orange, the energy consumption was higher compared to values equal to 4.40 and

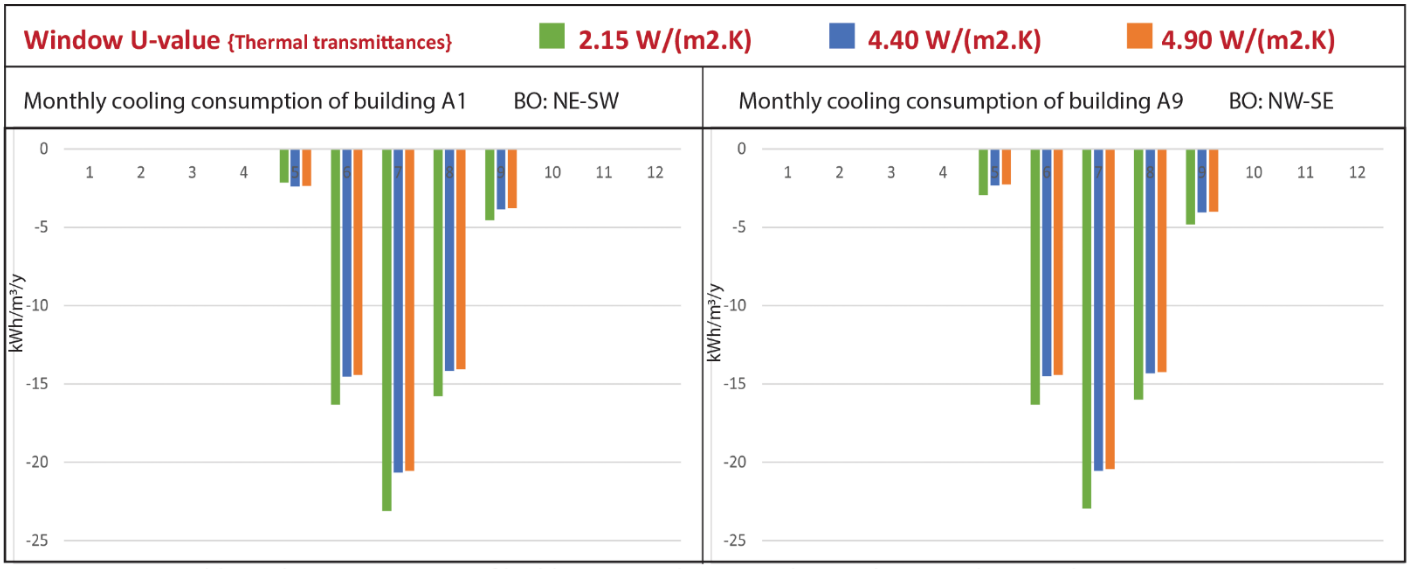


Fig. 121. **Monthly cooling consumption of buildings A1 and A9 according to three window U-values.**

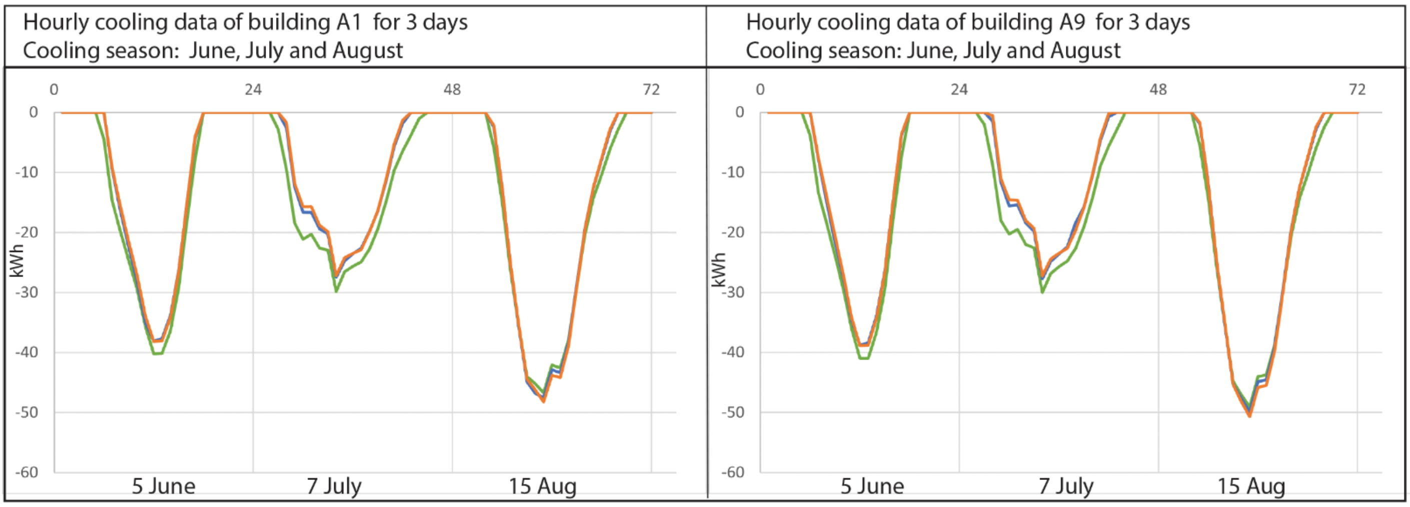


Fig. 122. **Hourly cooling consumption of buildings A1 and A9 according to three window U-values during three days.**

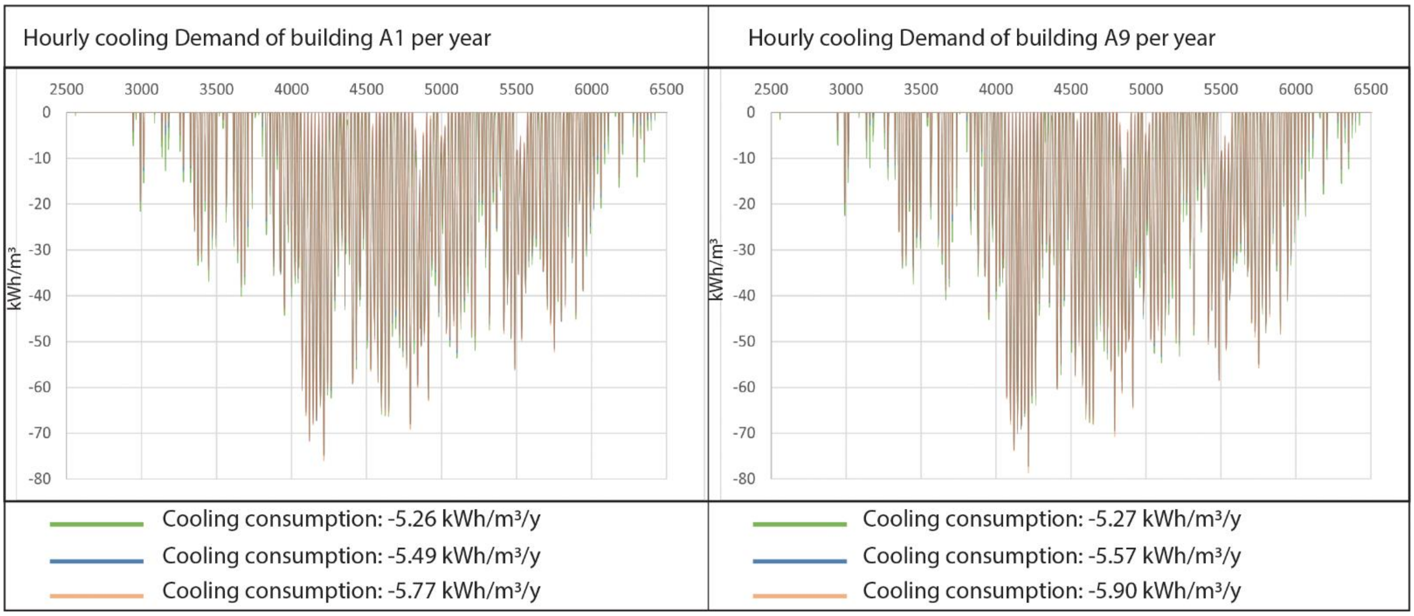


Fig. 123. Hourly cooling consumption of buildings A1 and A9 according to three window U-values during a year.

2.15 {W/m^2. K}, even though the yearly energy cooling consumption of this range was the lowest with -4.52 kWh/m^3/y for A1 and -4.54 kWh/m^3/y for A9 (Fig. 123). However, during the months June and July, the lowest thermal transmittance of the opaque envelope (2.15 {W/m^2. K}) had the highest Energy cooling utilization during the months of June and July for both buildings A1 and A9.

Table. XXXII. Buildings A1 and A9 Heating and Cooling Energy consumptions depending on window U-values equal to 2.15, 4.40, and 4.90 W/m^2. K.

Window U-value W/(m2.K)	Building A1 Heating Consumption (kWh/m³/y)	Building A1 Cooling Consumption (kWh/m³/y)	Building A9 Heating Consumption (kWh/m³/y)	Building A9 Cooling Consumption (kWh/m³/y)
2.15	19.86	-5.15	20.18	-5.17
4.40	24.28	-4.56	24.85	-4.57
4.90	25.18	-4.52	25.82	-4.54

Table. XXXII. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9, depending on three changed window's thermal transmittances values equivalent to 2.14, 4.40 and 4.90 {W/m^2.K}. In fact, A1 characterized by a {NE-SW} building orientation, had an increase of 26% in its highest value (with a window U-value equal to 4.90 {W/m^2. K}), regarding its lowest consumption of 19.86 kWh/m^3/y (with a window U-value equal to 2.15 {W/m^2. K}), while A9 with a (NW-SE) had a higher warmth energy impact with 28% between the lowest and highest reached value respectively equal to 20.18 kWh/m^3/y and 25.82 kWh/m^3/y. Fig. 124., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of A1 {NE-SW} and A9 with a building orientation of {NW-SE}, had approximately the same amount of impact on the energy cooling consumption according to their respective linear equational values. Therefore, we can conclude that when the window's U-value increased, the energy heating demand is higher, while the energy cooling consumption is lower. Adding to that, buildings with a NW-SE orientation, have a higher Energy consumption impact, in comparison to structures with NE-SW orientations.

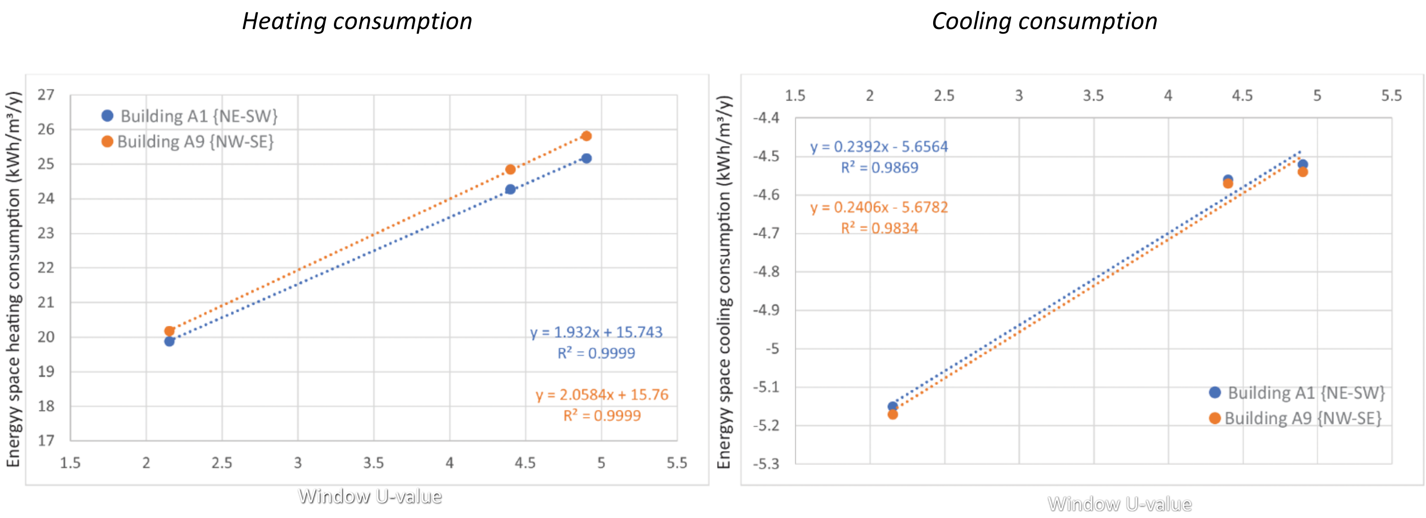


Fig. 124. Energy space heating and cooling demands of buildings A1 and A9 depending on window U-values.

5.3.4.2- Wall's U-value (U_{wall}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the wall's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.10, 0.9 and 0.67 expressed in {W/m^2. K}. Table. XI. (previously shown) reflects the three examined walls composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.10 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a wall code of MLP02. The second studied value is 0.9 {W/m^2. K}, with a wall code of MLP03 (constructed between 1961 and 1970). And the most recent wall composite is MPF03 (1990-2005), with a thermal transmittance value equivalent to 0.67 {W/m^2. K}. According to the detailed information about each wall composite, the input data of each material, was inserted the xml. Sheet of the engineering software CitySim Pro allowing the change of the selected buildings walls input data to examine their impact on the heating and cooling energy consumptions by comparing the results. Simulated results were compared and analyzed in order to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (A1 and A9) in Arquata neighborhood characterized by a period of construction between 1961 and 1970.

In fact, the first heating Energy utilization results are shown in Fig. 125. The monthly warmth demand of both structures A1 and A9, had the highest energy utilization with a wall U-value equivalent to 0.9 {W/m^2. K} (indicated in blue), and the lowest one represented with the most recent wall composite MPF03 with a thermal transmittance of 0.67 {W/m^2. K}. We can visualize a huge gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 126., represents the hourly heating data of the two analyzed residential buildings, in regard to three chosen days during the heating season: 5^{th} of February, 7^{th} of November and the 15^{th} of December. The graphs show that for the two selected residential structures, the wall's thermal transmittance that is equal to 0.9 {W/m^2. K} (MLP03, represented in blue), had constantly the highest warmth utilization, while the lowest wall's U-value (0.67 {W/m^2. K}, represented in orange), consumed the least heating demand. Adding to that, the 5^{th} of February showed the most energy need, however, on the 7^{th} of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings A9 and A1, both regularly consumed more heating Energy with a wall U-value equivalent to 0.9 {W/m^2. K} (represented in blue, MLP03), compared to values of 1.10 {W/m^2. K} (represented in green, MLP03), and 0.67 {W/m^2. K} (represented in orange, MPF03) (Fig. 127.).

Adding to that, the first deducted monthly results represented in Fig. 128., show that, when the wall's thermal transmittance of the building was equal to 0.9 {W/m^2. K} (MLP03), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures A1 and A9 were the highest compared to the two other wall composites (MLP02 and MPF03). However, the most recent wall configuration, MPF03, with a U-value equivalent to 0.67 {W/m^2. K} (represented in orange), consumed more cooling energy compared to the oldest wall code, MLP02

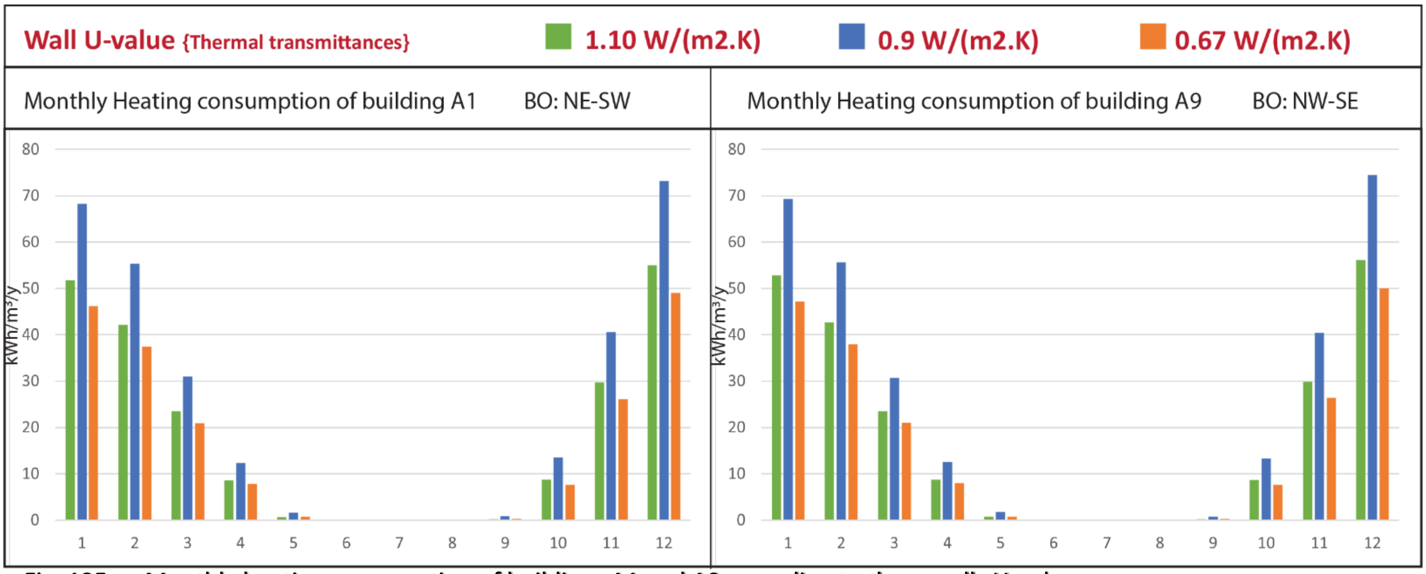


Fig. 125. **Monthly heating consumption of buildings A1 and A9 according to three walls U-values.**

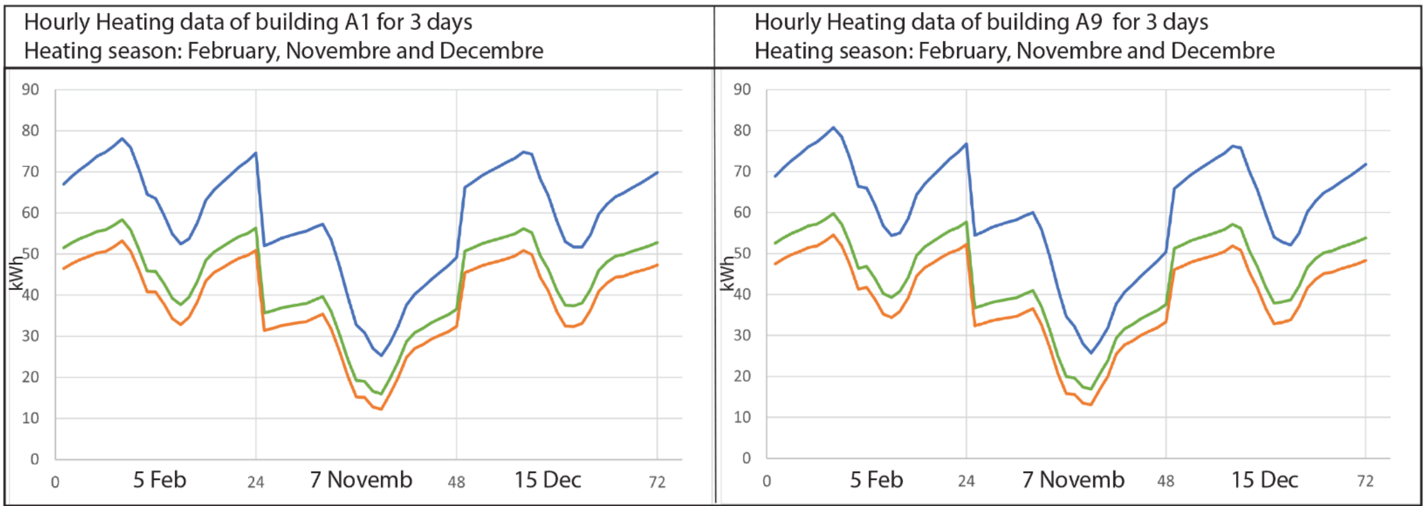


Fig. 126. **Hourly heating consumption of buildings A1 and A9 according to three walls U-values during three days.**

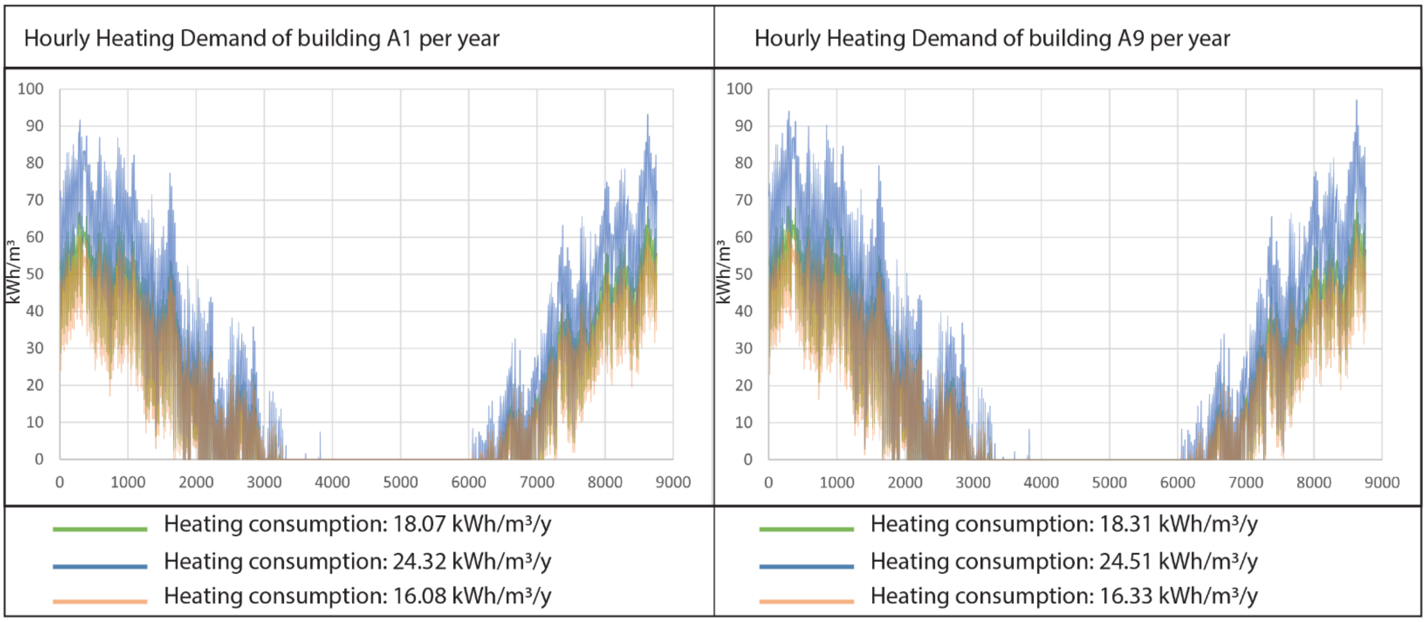


Fig. 127. **Hourly heating consumption of buildings A1 and A9 according to three walls U-values during a year.**

(1919-1945), represented on the graph in green. Adding to that, an hourly Energy data was conducted for A1 and A9 for three days during the cooling season: 5^{th} of June, 7^{th} of July and 15^{th} of August (Fig. 130.). Results show that, for both buildings, the highest Energy Utilization was on the 15^{th} of August, while the lowest one is represented on the 7^{th} of July. In fact, for both analyzed residential structures, during the whole yearly cooling season, the buildings with the wall's thermal transmittance equal to 0.9 {W/m^2. K} (MLP03), constantly had the highest cooling Energy consumption (represented in blue).

Table. XXXII. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9, depending on three changed walls thermal transmittances values equivalent to 1.10, 0.9, and 0.67 W/m^2. K. In fact, A1, characterized by a {NE-SW} building orientation, had an increase of 51%, with a wall U-value equal to 0.9 {W/m^2. K}, in regard to its lowest heating energy Consumption

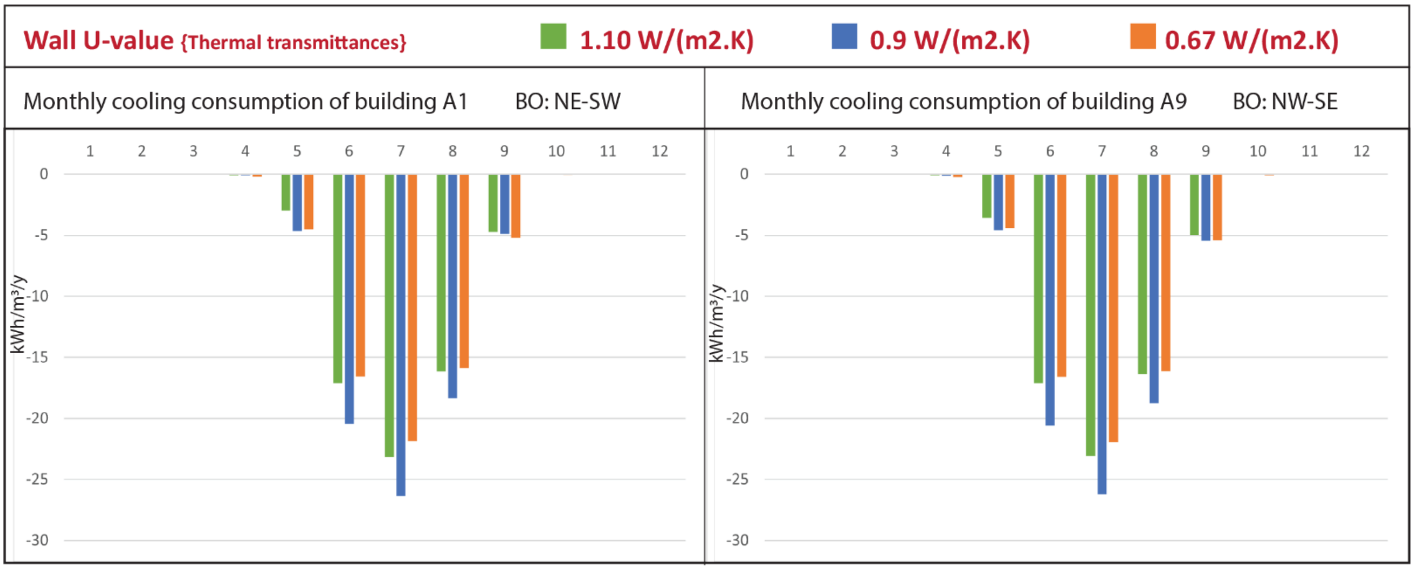


Fig. 128. Monthly cooling consumption of buildings A1 and A9 according to three walls U-values.

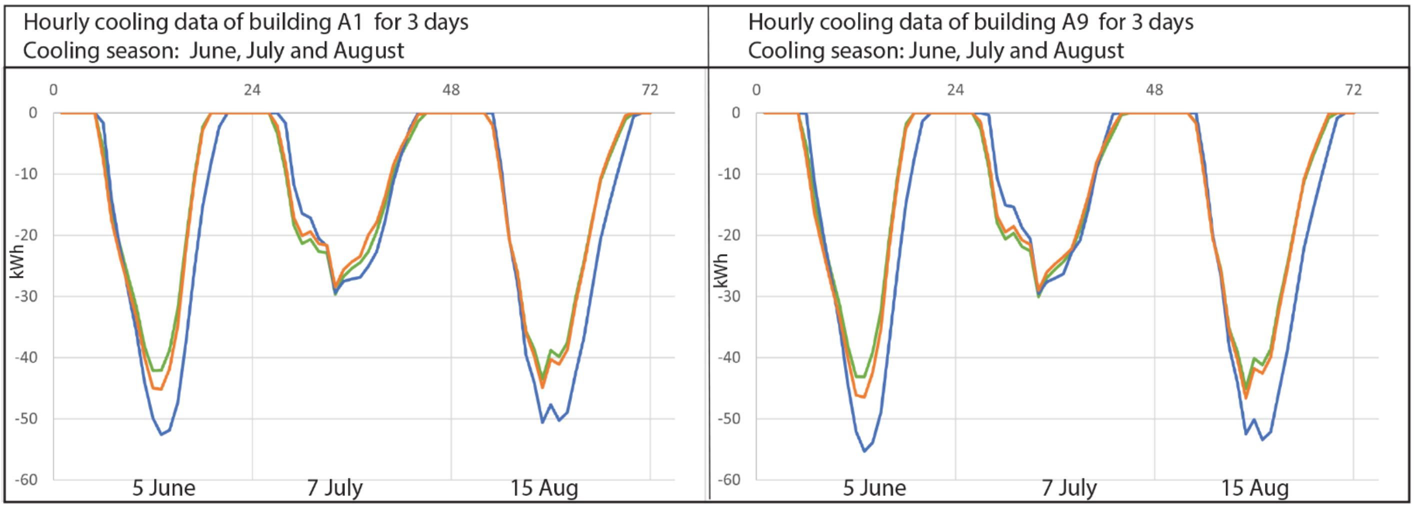


Fig. 129. Hourly cooling consumption of buildings A1 and A9 according to three walls U-values during three days.

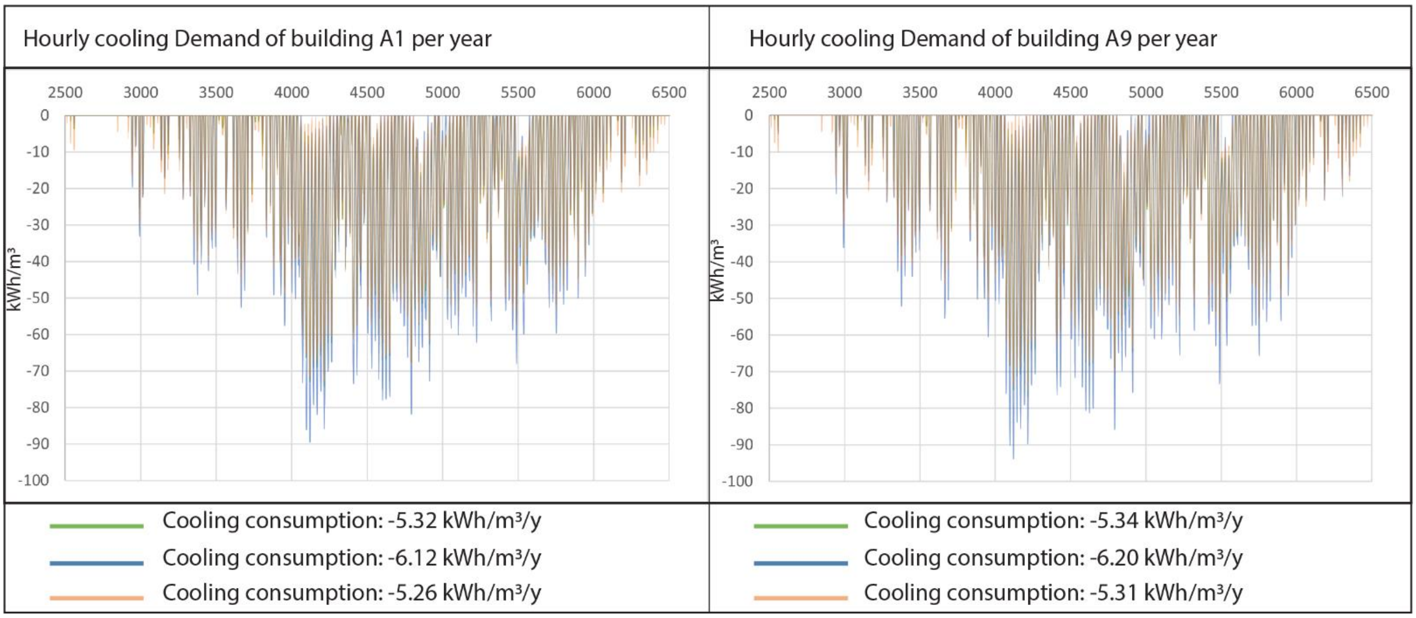


Fig. 130. Hourly cooling consumption of buildings A1 and A9 according to three walls U-values during a year.

of 16.08 kWh/m^3/y (with a wall U-value equal to 0.67 {W/m^2. K}). while A9, with a (NW-SE) had approximately the same warmth energy impact with 50% between the lowest and highest reached value respectively equal to 16.33 kWh/m^3/y and 24.51 kWh/m^3/y. Fig. 131., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of A1 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that the most recently used walls composite (MPF03, 2001-2005), consumed the least yearly energy demand, while composite MLP03 showed the highest one for both heating and cooling energy utilization during both seasons.

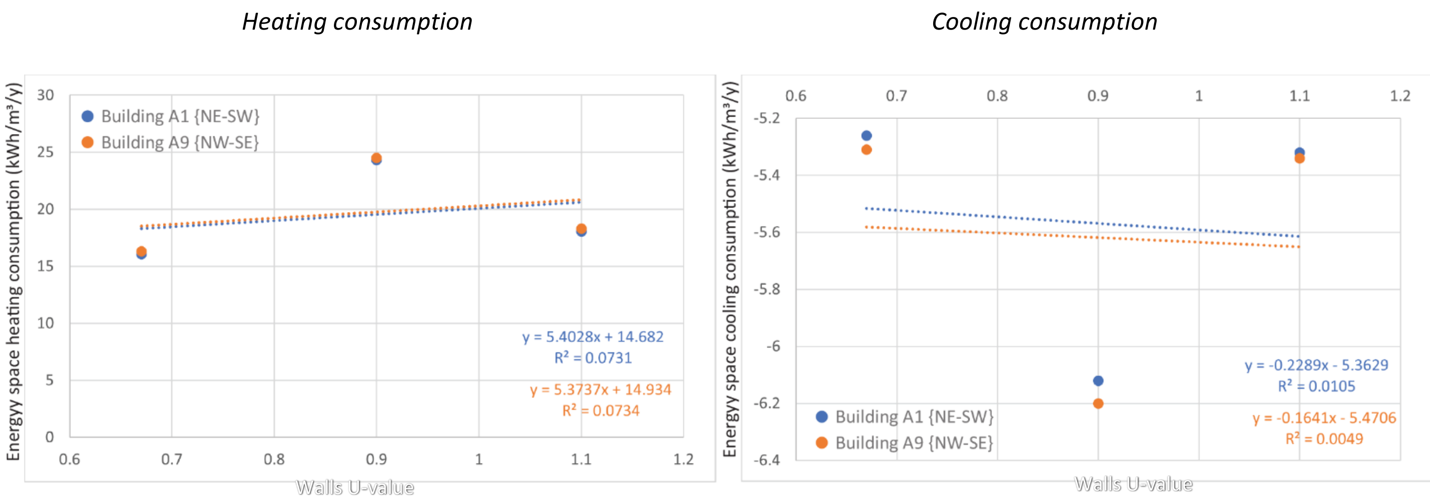


Fig. 131. Energy space heating and cooling demands of buildings A1 and A9 depending on walls U-values.

5.3.4.3- Roof's U-value (U_{roof}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the roof's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.60, 1.27 and 0.53 expressed in {W/m^2. K}. Table. XVI. (previously shown), reflects the three examined roof composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.60 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a roof code of COP01. The second studied value is 1.27 {W/m^2. K}, with a roof code of COP04 (constructed between 1961 and 1970). And the most recent roof composite is COP03 (1990-2005), with the lowest thermal transmittance value equivalent to 0.53 {W/m^2. K}. These different ranges, were inserted in the engineering software CitySim Pro, were simulated results were compared and analyzed to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (A1 and A9) in Arquata neighborhood characterized by a period of construction ranging between 1961 and 1970.

In fact, the first heating Energy utilization results are shown in Fig. 132. The monthly warmth demand of both structures A1 and A9, had the highest energy utilization with a roof U-value equivalent to 1.27 {W/m^2. K} (indicated in blue), and the lowest one represented with the newest roof composite COP03 with a thermal transmittance of 0.53 {W/m^2. K} (indicated in orange). Adding to that, Fig. 133., represents the hourly heating data of the two analyzed residential buildings, regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for buildings A1 and A9, the roof's thermal transmittance that is equal to 1.27 {W/m^2. K} (COP04), had constantly the highest warmth utilization. While, for the residential structure A1 characterized by a NE-SW orientation, and building A9, with a NW-SE orientation, the newest roof composite {COP03} consumed the least heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings A1 and A9, both regularly consumed more heating Energy with a wall U-value equivalent to 1.27 {W/m^2. K} (represented in blue, COP04, according to Fig.134.).

Roof U-value {Thermal transmittances} 1.60 W/(m2.K) 1.27 W/(m2.K) 0.53 W/(m2.K)

Monthly Heating consumption of building A1 BO: NE-SW

Monthly Heating consumption of building A9 BO: NW-SE

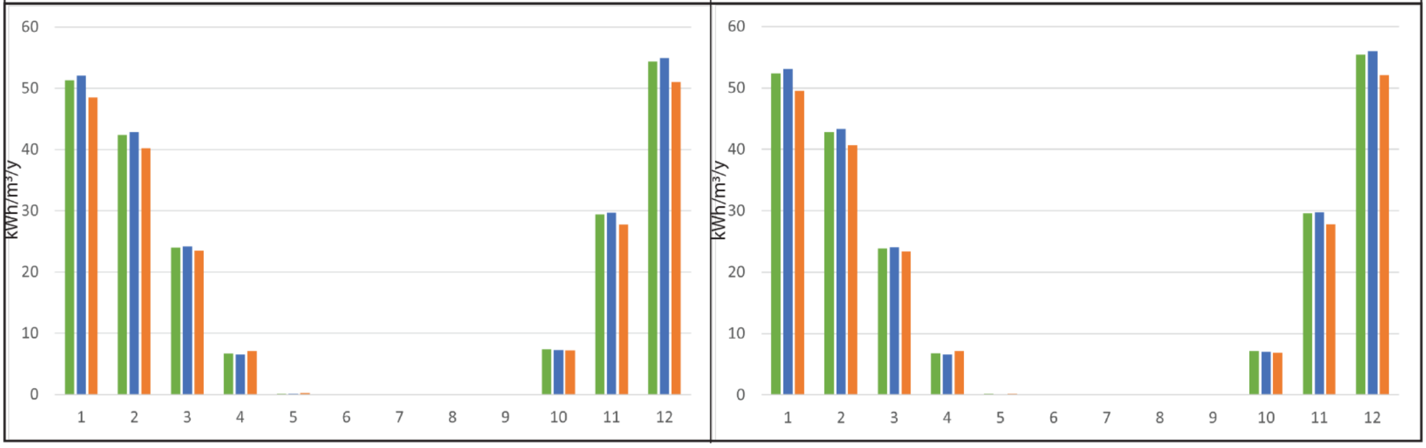


Fig. 132. **Monthly heating consumption of buildings A1 and A9 according to three roof U-values.**

Hourly Heating data of building A1 for 3 days
Heating season: February, Novembre and Decembre

Hourly Heating data of building A9 for 3 days
Heating season: February, Novembre and Decembre

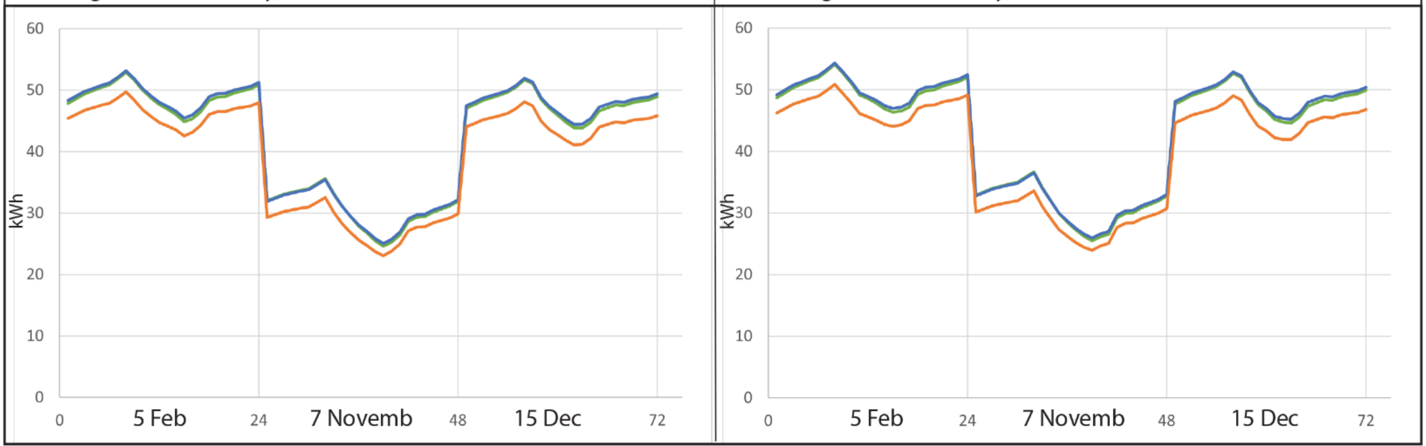
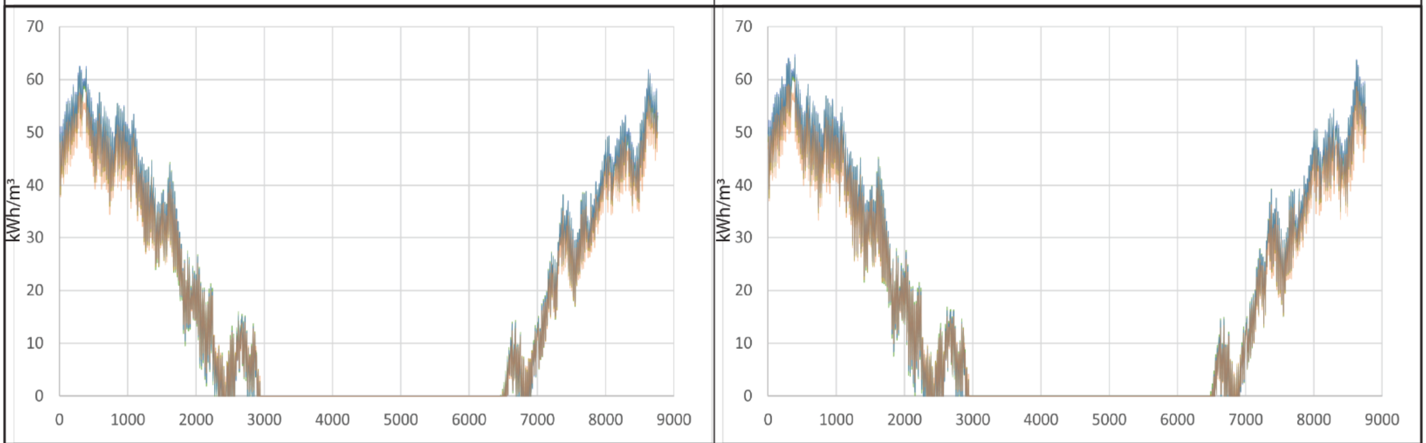


Fig. 133. **Hourly heating consumption of buildings A1 and A9 according to three roof U-values during three days.**

Hourly Heating Demand of building A1 per year

Hourly Heating Demand of building A9 per year



Building A1:
- Heating consumption: 17.68 kWh/m³/y
- Heating consumption: 17.84 kWh/m³/y
- Heating consumption: 16.84 kWh/m³/y

Building A9:
- Heating consumption: 17.88 kWh/m³/y
- Heating consumption: 18.04 kWh/m³/y
- Heating consumption: 17.02 kWh/m³/y

Fig. 134. **Hourly heating consumption of buildings A1 and A9 according to three roof U-values during a year.**

Adding to that, the cooling Energy consumptions of building A1 and A9 were analyzed as well. In fact, the first monthly results represented in Fig. 135., show that, when the roof's thermal transmittance of the building was equal to 1.27 {W/m². K} (COP04), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures had the highest simulated results, compared to the two other roof composites (COP01 and COP04). while the most recent roof configuration, COP03, with a U-value equivalent to 0.53 {W/m². K} (represented in orange), consumed the least cooling energy compared to the oldest roofs' composites. Adding to that, an hourly Energy data was conducted for both analyzed buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 136.). Results show that, for both constructions, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building A1 characterized by a NE-SW orientation, and A9 with a NW-SE orientation, during the whole yearly cooling season (equivalent

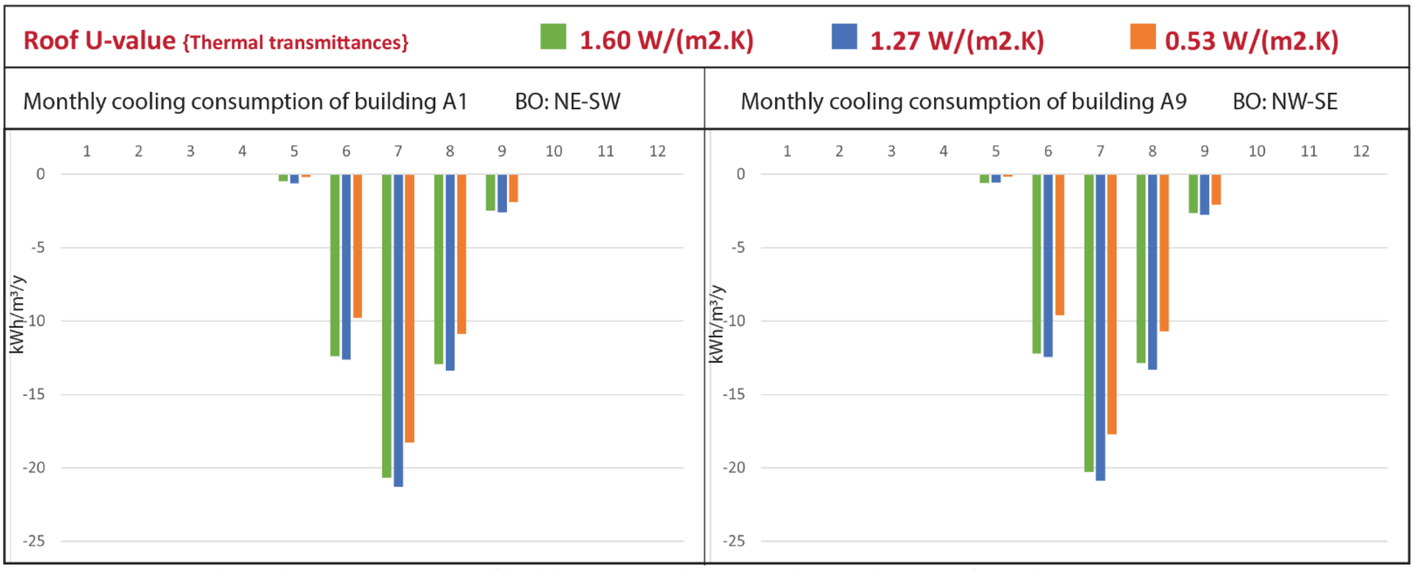


Fig. 135. **Monthly cooling consumption of buildings A1 and A9 according to three roof U-values.**

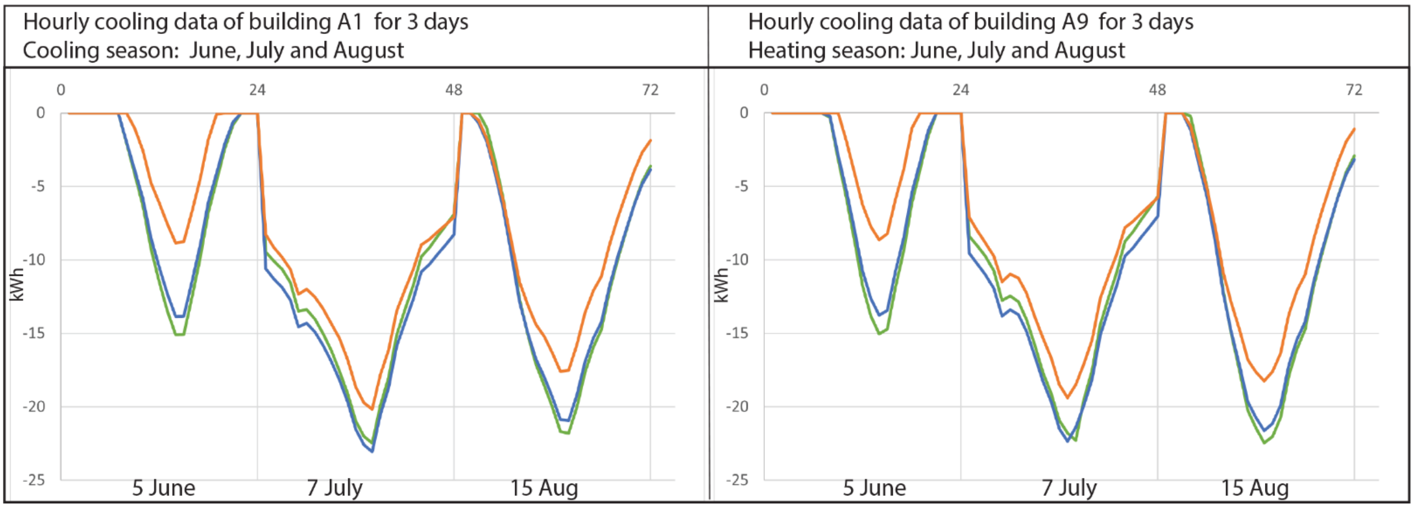


Fig. 136. **Hourly cooling consumption of buildings A1 and A9 according to three roof U-values during three days.**

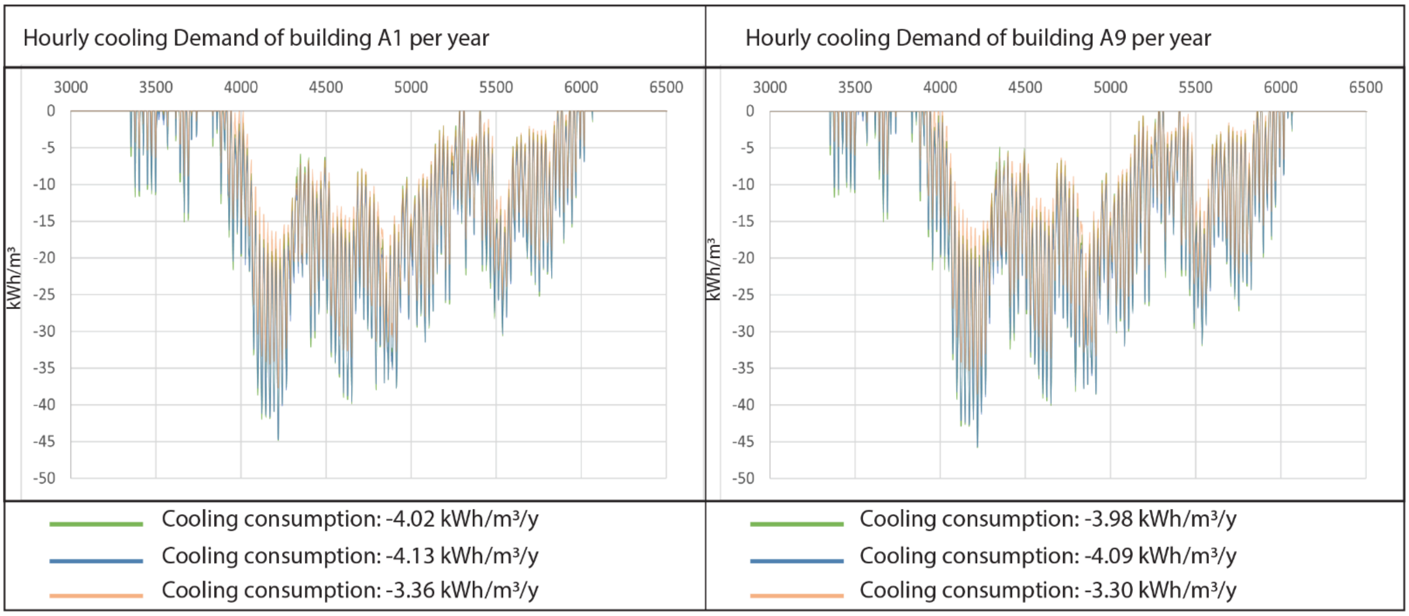


Fig. 137. Hourly cooling consumption of buildings A1 and A9 according to three roof U-values during a year.

to 8761 simulated hours), both structures with the roof thermal transmittance equal to 1.27 {W/m^2. K} (COP04), constantly had the highest cooling Energy consumption (represented in blue, Fig. 137).

Table. XXXIII. Buildings A1 and A9 Heating and Cooling Energy consumptions depending on roof U-values equal to 1.60, 1.27, and 0.53 W/m^2. K.

Roof U-value W/(m2.K)	Building A1 Heating Consumption (kWh/m³/y)	Building A1 Cooling Consumption (kWh/m³/y)	Building A9 Heating Consumption (kWh/m³/y)	Building A9 Cooling Consumption (kWh/m³/y)
1.60	17.68	-4.02	17.88	-3.98
1.27	17.84	-4.13	18.04	-4.09
0.53	16.84	-3.36	17.02	-3.30

Table. XXXIII. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9, depending on three changed roof thermal transmittances values equivalent to 1.60 {1919-1945}, 1.27 {1961-1970}, and 0.53 W/m^2.K, with residential buildings constructed with the most recent period ranging between 2001 and 2005. In fact, A1 characterized by a {NE-SW} building orientation, had an increase of 6%, with a roof U-value equal to 1.27 {W/m^2. K}, regarding its lowest consumption of 16.84 kWh/m^3/y (with the newest roof composite with a U-value equal to 0.53 {W/m^2. K}). while A9, with a (NW-SE) had the same energy, impact compared to A1, with 6% between the lowest and highest reached value respectively equal to 17.02 kWh/m^3/y and 18.04 kWh/m^3/y. Fig. 138., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of A1 {NE-SW} , and A9 {NW-SE}, had approximately the same consumption impact, with similar linear equational values . Therefore, we can conclude that COP04 roof composite consumed the highest heating and cooling energy demand, while the newest roof composite COP03, had the lowest yearly energy Utilization.

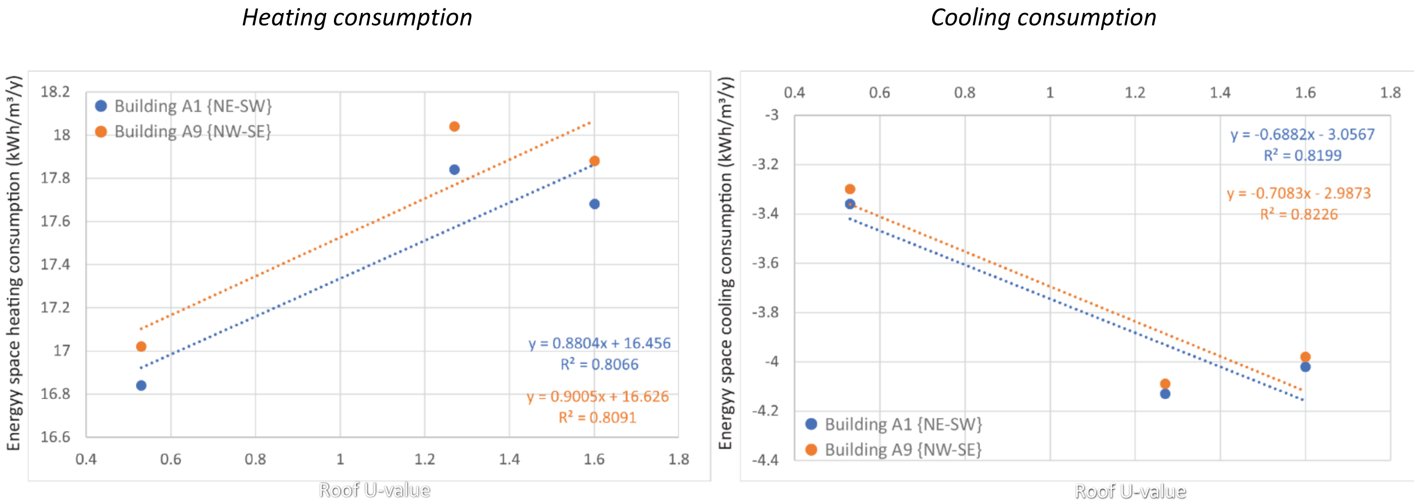


Fig. 138. Energy space heating and cooling demands of buildings A1 and A9 depending on roof U-values.

5.3.4.4- Floor's U-value (U_{floor}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with floor U-values varying according to the building's construction period. In fact, the lower the floor's U-value the more the building is insulated from the ground factors. In this variable, two main values were analyzed: 1.16, and 1.25 expressed in {W/m^2. K}. Table. XX. (previously shown), represents the two examined floor composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.25 {W/m^2. K} characterized by the newest built period ranging between 1961 and 2005 with a floor code of SOL04. The second studied value is 1.16 {W/m^2. K}, with a floor code of SOL03 (characterized by a constructed period varying between 1919 and 1960). These different ranges were inserted in the engineering software CitySim Pro, where simulated results were compared and analyzed to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (A1 and A9) in Arquata neighborhood characterized by a period of construction ranging between 1961 and 1970.

Floor U-value {Thermal transmittances} 1.16 W/(m2.K) 1.25 W/(m2.K)

Monthly Heating consumption of building A1 BO: NE-SW	Monthly Heating consumption of building A9 BO: NW-SE

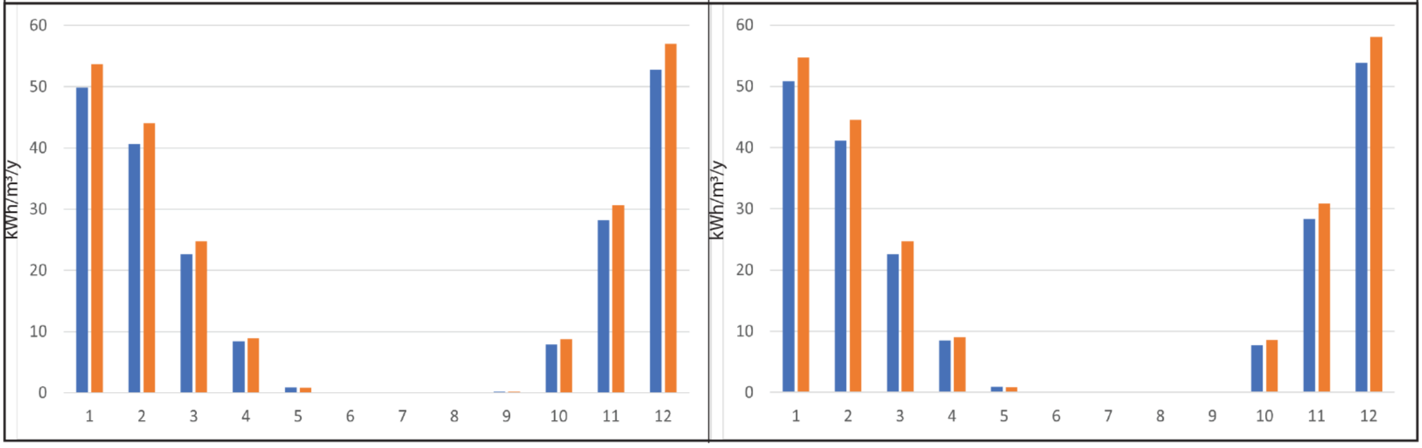


Fig. 139. Monthly heating consumption of buildings A1 and A9 according to two Floor U-values.

Hourly Heating data of building A1 for 3 days Heating season: February, Novembre and Decembre	Hourly Heating data of building A9 for 3 days Heating season: February, Novembre and Decembre

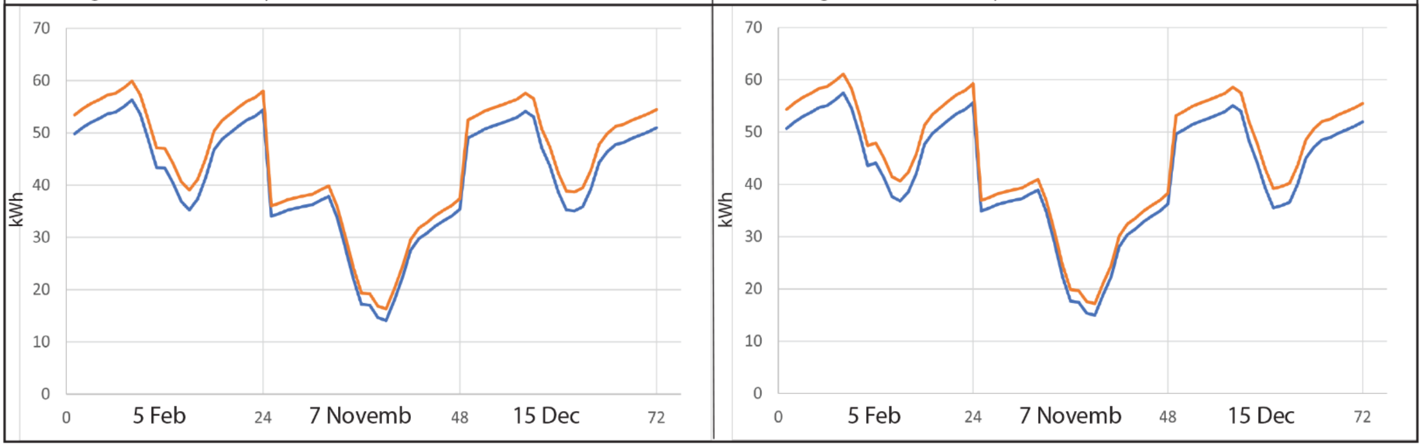
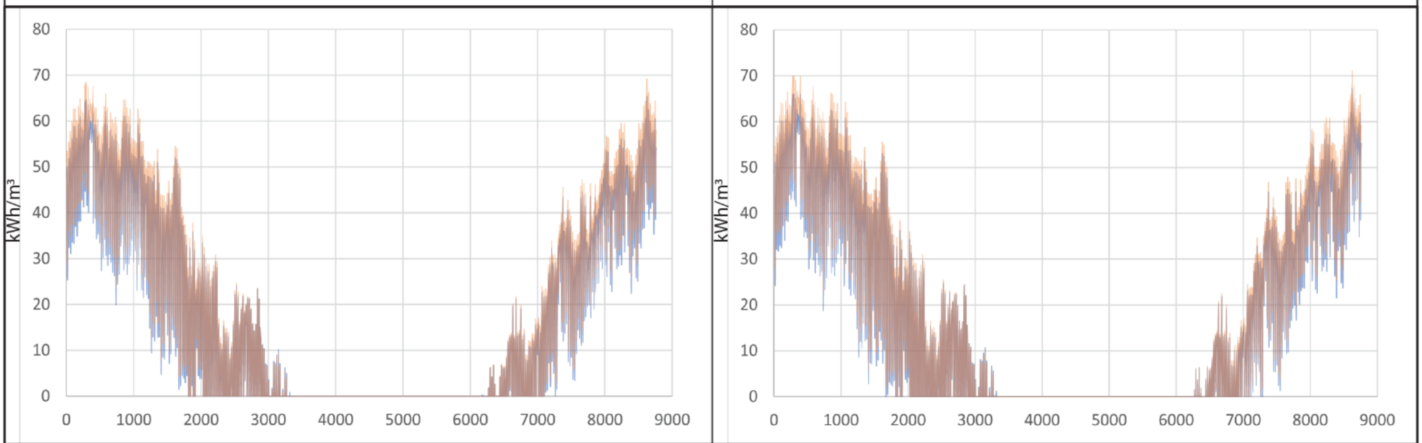


Fig. 140. Hourly heating consumption of buildings A1 and A9 according to two Floor U-values during three days.

Hourly Heating Demand of building A1 per year	Hourly Heating Demand of building A9 per year



Building A1	Building A9
Heating consumption: 17.35 kWh/m³/y	Heating consumption: 17.55 kWh/m³/y
Heating consumption: 18.75 kWh/m³/y	Heating consumption: 18.97 kWh/m³/y

Fig. 141. Hourly heating consumption of buildings A1 and A9 according to two Floor U-values during a year.

In fact, the first heating Energy utilization results are shown in Fig. 139. The monthly warmth demand of both structures A1 and A9, had the highest energy utilization with a floor U-value equivalent to 1.25 {W/m^2. K} (indicated in orange), and the lowest one represented with the oldest floor composite SOL04 with a thermal transmittance of 1.16 {W/m^2. K}. We can visualize a small gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 140., represents the hourly heating data of buildings A1 and A9, regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the floor's thermal transmittance that is equal to 1.25 {W/m^2. K} (SOL04), had constantly the highest warmth utilization. While SOL04 that is characterized by the most recent period of construction {1961-2005}, consumed more heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours) buildings A1 and A2, both regularly consumed more heating Energy with a floor U-value equivalent to 1.25 {W/m^2. K} (represented in orange, SOL04) in accordance with the hourly results shown in Fig. 141.

Adding to that, the cooling Energy consumptions of buildings A1 and A9 were analyzed as well. In fact, the first monthly results represented in Fig. 142., show that, when the roof's thermal transmittance of the building was equal to 1.25 {W/m^2. K} (SOL04 represented in orange), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures were the highest compared to the other roof composite (SOL03, represented in blue). Adding to that, an hourly Energy data was conducted A1 and A9, for three days during the cooling

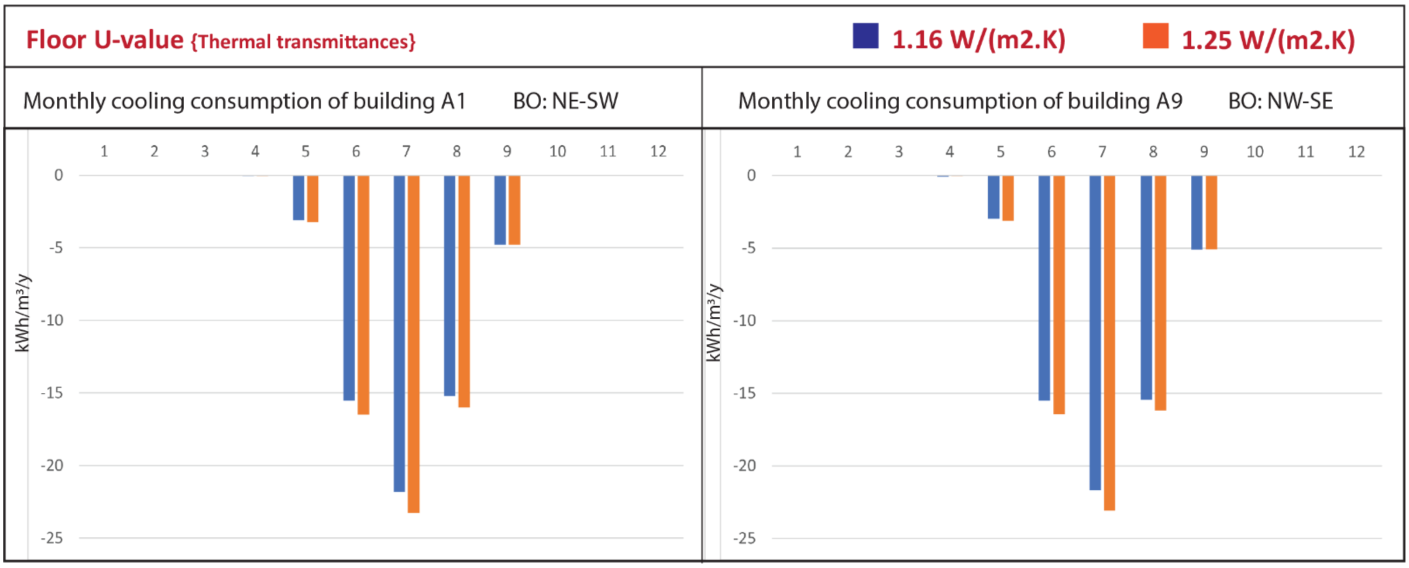


Fig. 142. Monthly cooling consumption of buildings A1 and A9 according to three floor U-values.

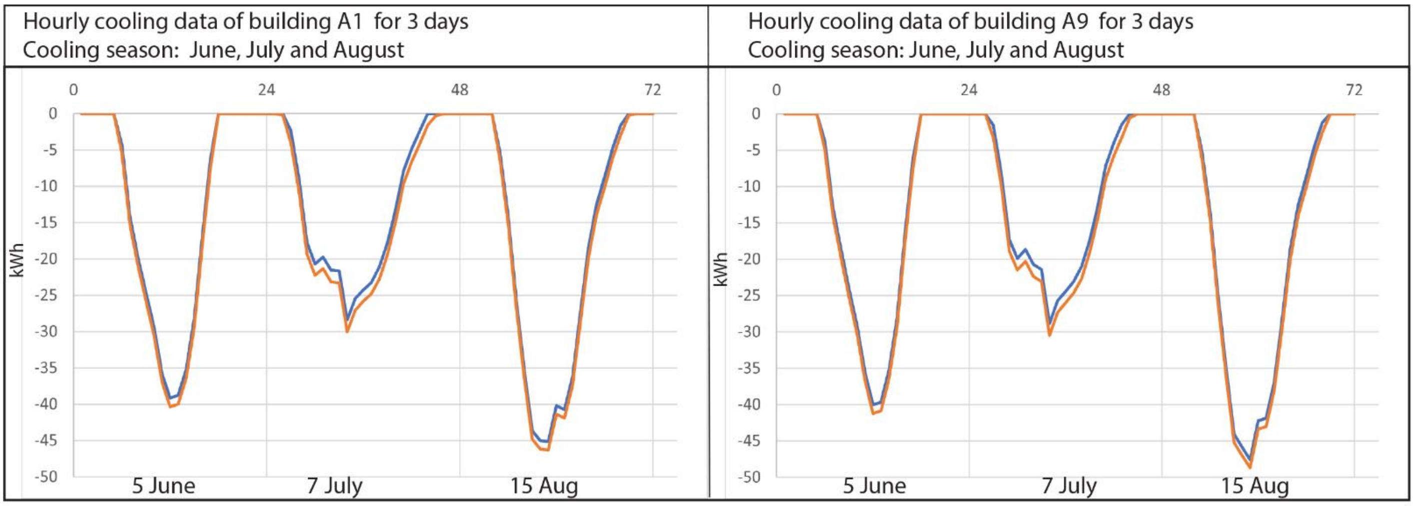


Fig. 143. Hourly cooling consumption of buildings A1 and A9 according to three floor U-values during three days.

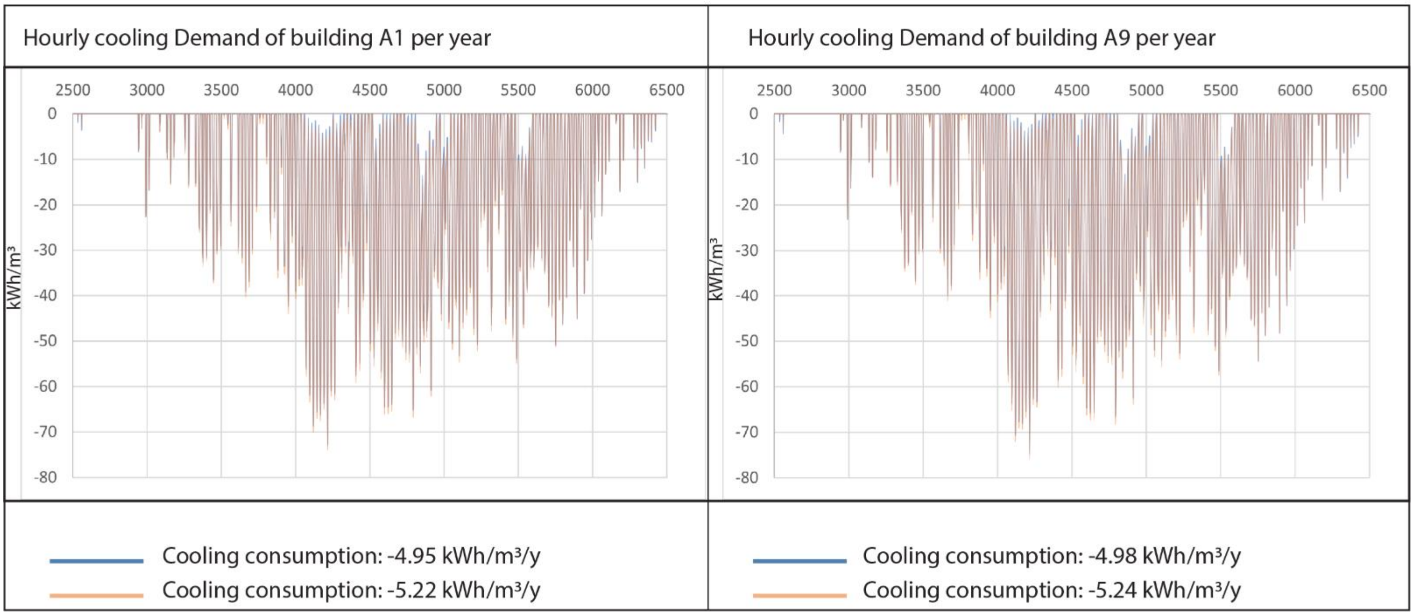


Fig. 144. Hourly cooling consumption of buildings A1 and A9 according to three floor U-values during a year.

season: 5th of June, 7th of July and 15th of August (Fig. 99.). Results show that, for both analyzed residential buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building A1 characterized by a {NE-SW} orientation, and A9 with a {NW-SE} orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the most recent floor composite (1961-2005), characterized by a thermal transmittance equal to 1.25 {W/m^2. K}, (represented in orange), constantly had the highest cooling Energy demand.

Table. XXXIV. Shows the variations in the heating and cooling energy consumptions of buildings A1 and A9, depending on two changed floor thermal transmittances values equivalent to 1.16 {1919-196}, and 1.25 {1961-2005}, expressed in {W/m^2. K}. In fact, A1 characterized by a {NE-SW} building

Table. XXXIV. Buildings A1 and A9 Heating and Cooling Energy consumptions depending on floor U-values equal to 1.16, and 1.25 W/m². K.

Floor U-value W/(m2.K)	Building A1 Heating Consumption (kWh/m³/y)	Building A1 Cooling Consumption (kWh/m³/y)	Building A9 Heating Consumption (kWh/m³/y)	Building A9 Cooling Consumption (kWh/m³/y)
1.16	17.35	-4.95	17.55	-4.98
1.25	18.75	-5.22	18.97	-5.24

orientation had an increase of 8%, with a floor U-value equal to 1.16 {W/m². K}, in regard to its lowest consumption of 17.35 kWh/m³/y. while A9, with a (NW-SE) building orientation, had the same amount of impact compared to A1, with 8% between the lowest and highest reached value respectively equal to 17.55 kWh/m³/y and 18.97 kWh/m³/y. Fig. 145., shows the Energy space heating and cooling utilizations of both buildings. Therefore, we can conclude that SOL04 floor composite consumed the highest heating and cooling energy demand, while the oldest composite SOL03, had the lowest yearly energy Utilization.

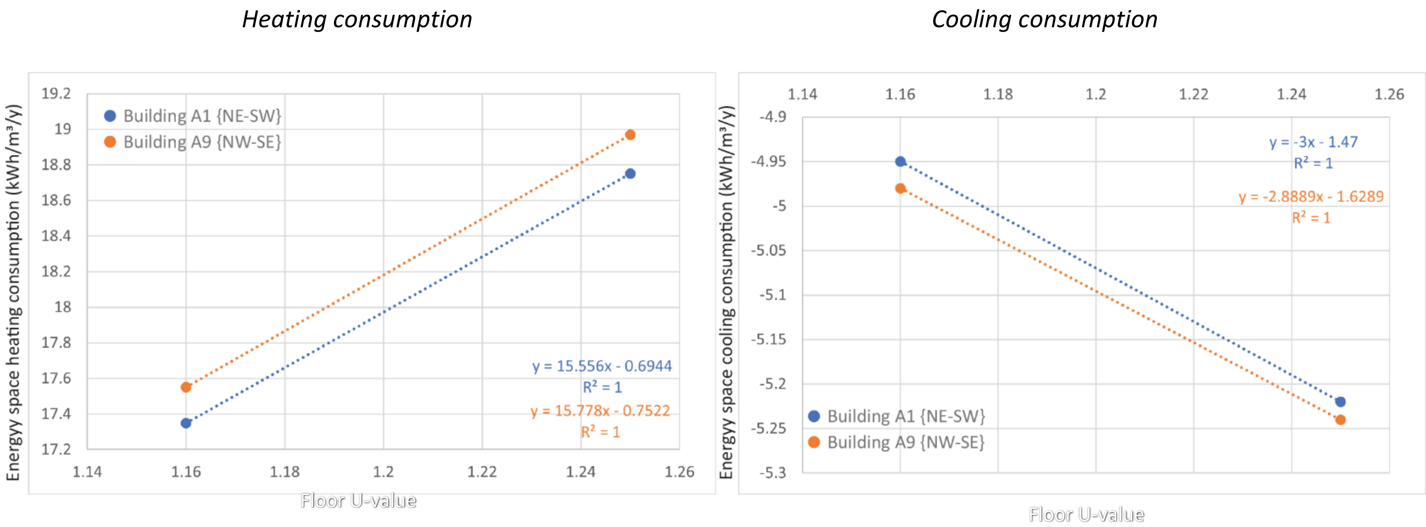


Fig. 145. Energy space heating and cooling demands of buildings A1 and A9 depending on roof U-values.

5.4- Olympic Village district: Impact of energy-related building variables

Olympic Village neighborhood is located in the city of Turin, Italy. This urban zone is characterized by buildings constructed between 2001 and 2005. In fact, it has the lowest Building coverage ratio equal to 0.16, that reflects the gross built area of the neighborhood over the census parcel area, with a building density equivalent to 4.13 m^3/m^2, that represents the proportion between the overall volume of the buildings and the census parcel zone. And a Height to Width urban ratio of 0.34 m/m. Two buildings were analyzed (O11 and O8), where their respective heating and cooling demands were compared and analyzed following different ranges of urban variable inserted in the engineering software CitySim Pro. The analyzed residential building parameters are: Infiltration rate (ranges equivalent to 0.2, 0.4 and 0.6 h^{-1}), Glazing ratio (ranges equivalent to 0.2, 0.4 and 0.6), Thermal transmittances of walls (ranges equivalent to 2.15, 4.40 and 4.90 W/(m^2.k)), Thermal transmittances of roof (ranges equivalent to 0.53, 1.27 and 1.60W/(m^2.k)), and finally, Thermal transmittances of floor (equivalent to 1.16 and 1.25 W/(m^2.k)). In fact, for each variable, results were separated into monthly heating and cooling energy data, Hourly results for three heating and cooling seasons (5th of February, 7th of November, 15th of December, 5th of June, 7th of July and finally 15th of August), as well as the hourly heating and cooling Energy consumptions over the course of one year (equivalent to 8761 hours).

5.4.1- Building's Surface to Volume ratio

In fact, the Surface to Volume {S/V} proportion is a ratio indicating the compactness of a certain structure or building. It is frequently communicated as the 'heat misfortune structure factor', which is the proportion the building's envelope area (walls, roofs, terraces…etc.) to the treated floor area of the designated structure. This ratio will help in the identification of the building's typology, weather it is a small condominium house or a tower for example. In this case, buildings O11 and O8 have the same Surface to Volume ratio that is equal to 0.30. the two structures are characterized by opposite orientations of {NE-SW} and {NW-SE} respectively. O11 is characterized by a bigger heated Volume (6164 m^3), compared to O8 (5496 m^3) shown in Table. XXXV. Building O11 has an energy heating consumption equal to 16.62 $kWh/m^3/y$, with a cooling demand of -19.95 $kWh/m^3/y$.

However, O8, is characterized by a lower energy utilization with 12.23 kWh/m^3/y in warmth consumption, and -22.58 kWh/m^3/y for its yearly cooling consumption (Fig. 146).

Table. XXXV. This table, shows the heated volume, building orientation, Surface to Volume ratio and Energy heating and cooling of buildings O11 and O8.

Building ID	Heated Volume	Building orientation	S/V	Energy heating Consumption (kWh/m³/y)	Energy cooling Consumption (kWh/m³/y)
O11	6164	NE-SW	0.30	16.62	-19.95
O8	5496	NW-SE	0.30	12.23	-22.58

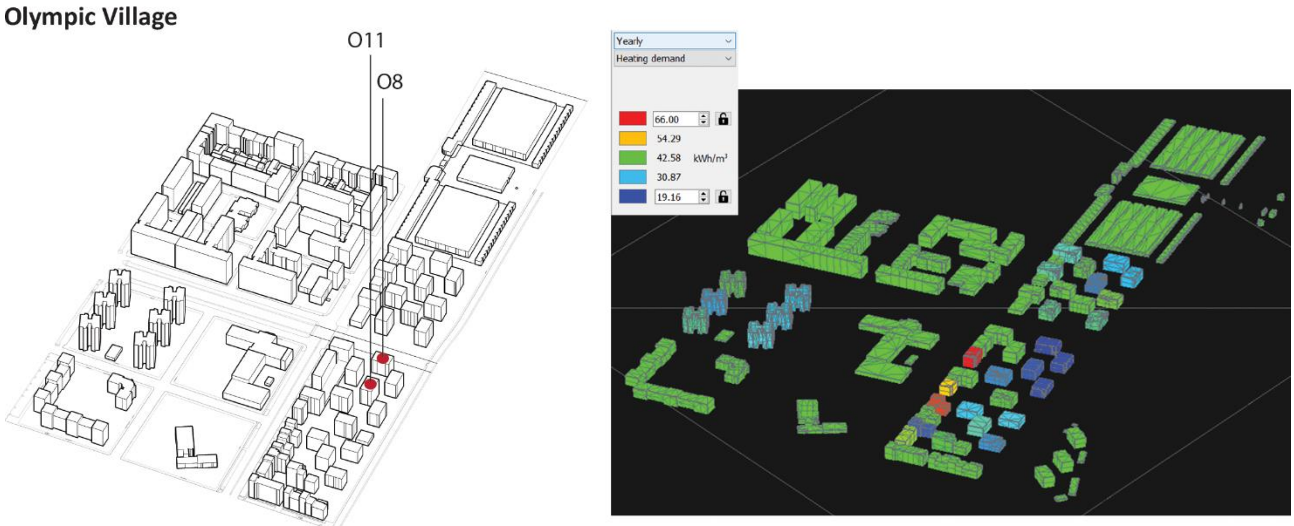


Fig. 146. Three-dimensional representation of Olympic Village neighborhood indicating the two analyzed buildings. And Yearly Heating demand of this district calculated by CitySim Pro.

5.4.2- Building's infiltration rate (h^{-1})

Infiltration is the unintentional or coincidental presentation of outdoor air into a building, ordinarily through cracks in the structure envelope and through utilization of entryways such as doors. The higher the infiltration rate, the more outdoor air is penetrating inside the building and therefore affecting the building's internal temperature. In this analysis, three different infiltration rates were studied: 0.2 h^{-1} (indicated in green), 0.4 h^{-1} (indicated in blue), and 0.6 h^{-1} (indicated in orange), to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (O11 and O9). The first warmth Energy utilization results are

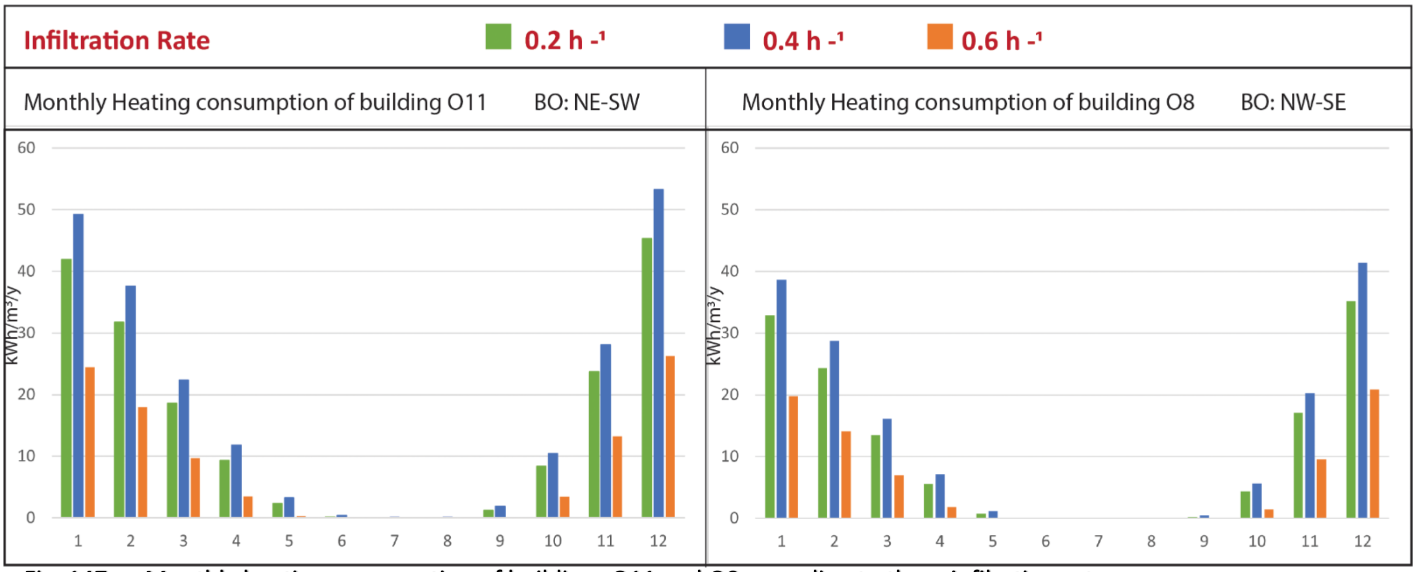


Fig. 147. Monthly heating consumption of buildings O11 and O8 according to three infilration rates.

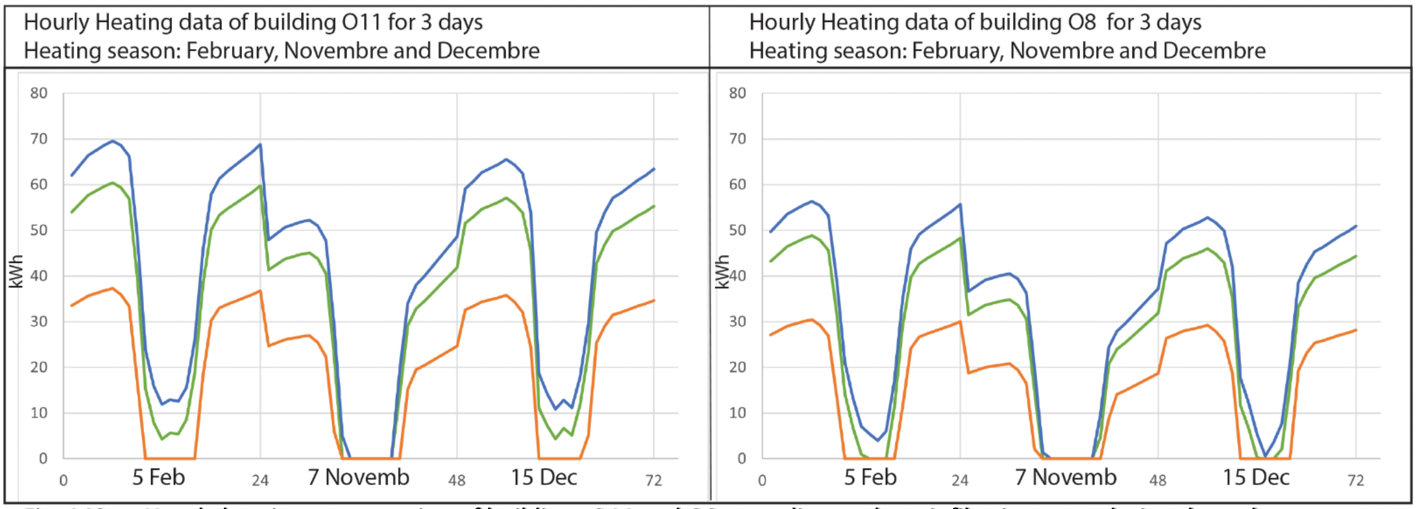


Fig. 148. Hourly heating consumption of buildings O11 and O8 according to three infilration rates during three days.

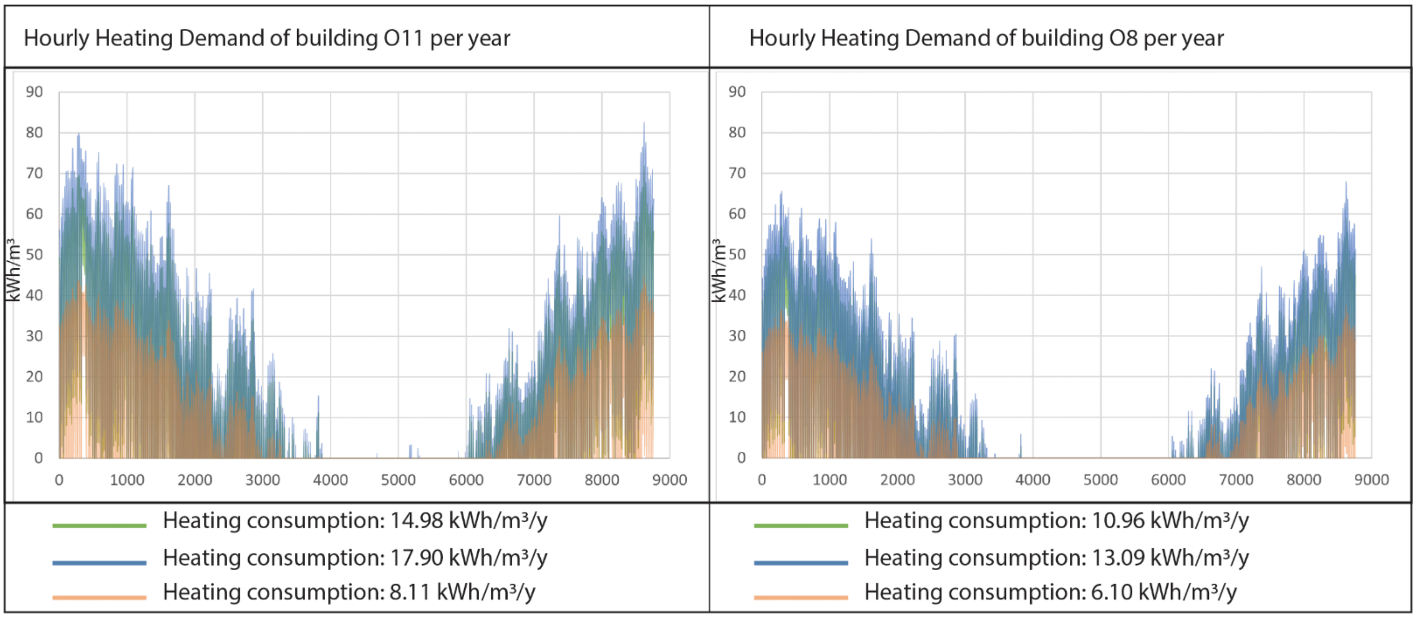


Fig. 149. Hourly heating consumption of buildings O11 and O8 according to three infilration rates during a year.

shown in Fig. 147. In fact, the monthly heating demand of both structures O11 and O8, increased when the infiltration rate changed from 0.2 to 0.4, mainly due to the penetration of the cold outdoor air inside of the building. With the highest rate (0.6 h^{-1}) both building's cooling consumption decreased remarkably. Adding to that, Fig. 148., represents the hourly heating data of buildings O11 and O8, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, infiltration rate equal to 0.6 h^{-1}, had constantly the lowest warmth utilization, while the rate that is equal to (0.4 h^{-1}), consumed the most heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November (mainly due to a higher outdoor air temperature in this month), it was considerably lower compared to the other analyzed days.

Adding to that, the cooling Energy consumptions of buildings O11 and O8, were analyzed as well. In fact, Fig. 150., reflects the yearly Cooling demand of Olympic Village neighborhood expressed in kWh/m^3 calculated by the engineering software CitySim pro during its normal state. In fact, the first deducted monthly results represented in Fig. 151., show that, when the infiltration rate of the building increased, on the opposite of the heating consumption, the cooling Energy demand

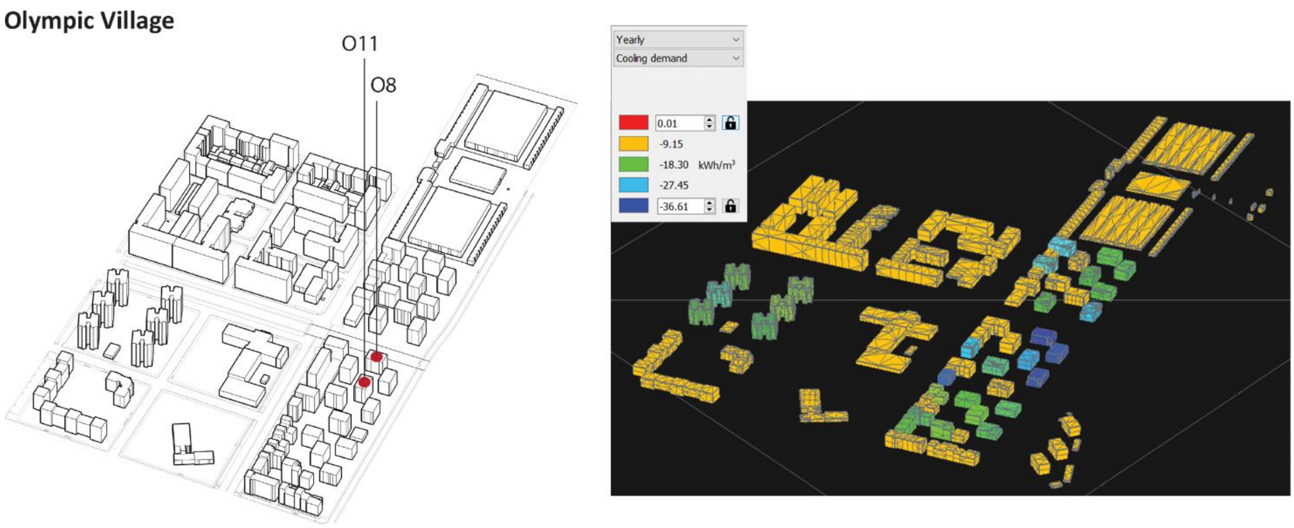


Fig. 150. Three-dimensional representation of Olympic Village neighborhood indicating the two analyzed buildings. And Yearly Cooling demand of this district calculated by CitySim Pro.

decreased for infiltration rates equal to 0.2 and 0.4 and increased with the highest rate 0.6. Adding to that, an hourly Energy data was conducted for O11 and O8, for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 152.). Results show that, for both buildings,

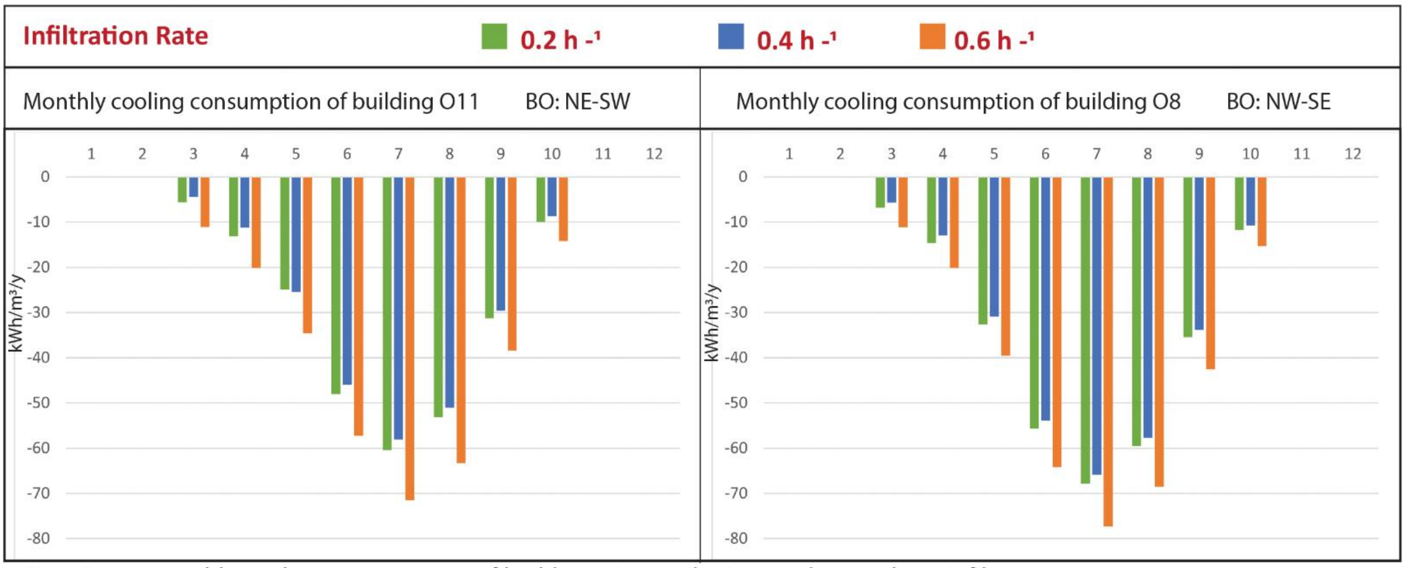


Fig. 151. Monthly cooling consumption of buildings O11 and O8 according to three infilration rates.

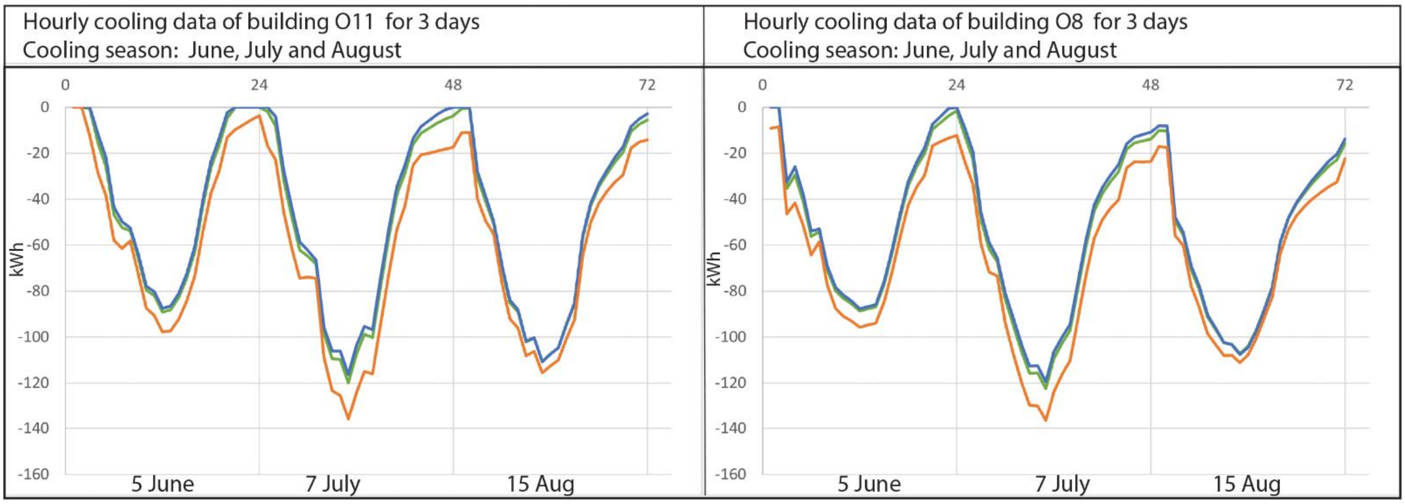


Fig. 152. Hourly cooling consumption of buildings O11 and O8 according to three infilration rates during three days.

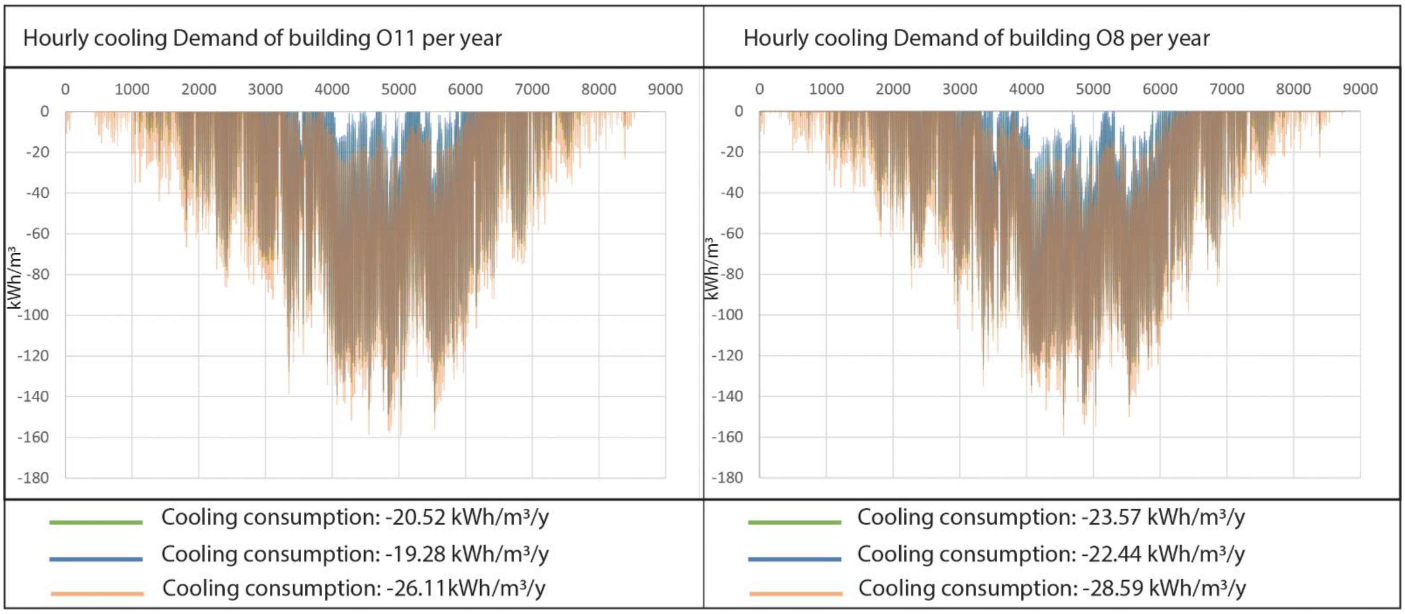


Fig. 153. Hourly cooling consumption of buildings O11 and O8 according to three infilration rates during a year.

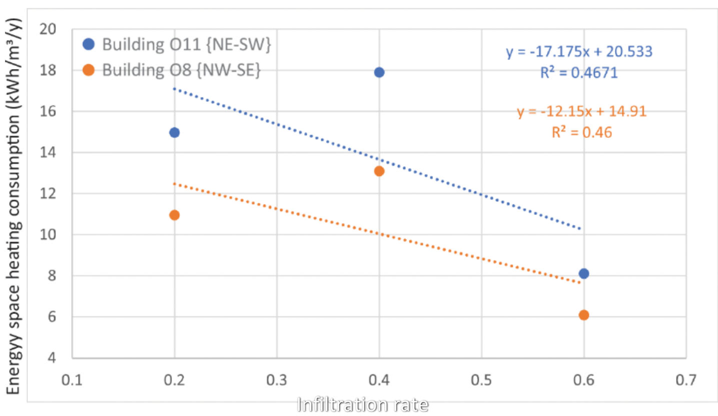
the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, for the two selected residential structures, with an infiltration rate equal to 0.6 h^{-1}, the buildings had constantly the highest cooling energy utilization, while the rate that is equal to (0.4 h^{-1}), consumed the least energy during the cooling season.

Table. XXXVI. Buildings O11 and O8 Heating and Cooling Energy consumptions depending on infiltration rates equal to 0.2, 0.4 and 0.6 h^{-1}.

Infiltration Rate h^{-1}	Building O11 Heating Consumption (kWh/m³/y)	Building O11 Cooling Consumption (kWh/m³/y)	Building O8 Heating Consumption (kWh/m³/y)	Building O8 Cooling Consumption (kWh/m³/y)
0.2	14.98	-20.52	10.96	-23.57
0.4	17.90	-19.28	13.09	-22.44
0.6	8.11	-26.11	6.10	-28.59

Table. XXXVI. Shows the variations in the heating and cooling energy consumptions of buildings O11 and O8 depending on three changed infiltration rates equivalent to 0.2, 0.4 and 0.6 h^{-1}. In fact, O11 characterized by a {NE-SW} building orientation, had an increase of 120% in its highest value (with infiltration rate equal to 0.4) in regard to its lowest consumption of 8.11 kWh/m³/y (with an infiltration rate equal to 0.6). while O8 with a (NW-SE) had a lower warmth energy impact with 114% between the lowest and highest reached value. Fig. 154., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of O11 {NE-SW} had a higher Energy cooling impact compared to O8 with a building orientation of {NW-SE}.

Heating consumption



Cooling consumption

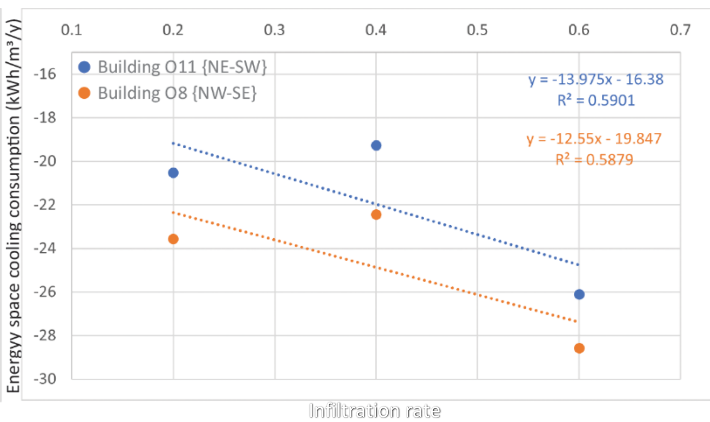


Fig. 154. Energy space heating and cooling demands of buildings O11 and O8 depending on the infiltration rate.

5.4.3- Building’s Glazing ratio

Glazing ratio also known as Window to Wall Ratio, is the proportion of the transparent envelope in relation to the façade’s surface. The smaller the glazing ratio, the smaller the proportion of the window compared to the wall. In this analysis, three main ratios were studied: 0.2, 0.4 and 0.6. These different ranges will help in the understanding of the impact of the glazing ratio on the yearly heating and cooling demands of the residential buildings. In this analysis, three different Glazing ratio values were studied: 0.2 (indicated in green), 0.4 (indicated in blue), and 0.6 (indicated in orange), to compare and analyze the impact of this changed variable of the heating and cooling consumption of the two chosen residential buildings (O11 and O8). The first warmth Energy utilization results are shown in Fig. 155. In fact, the monthly heating demand of both structures, increased when the Glazing ratio value was higher (where the structure consumed more heating energy with a glazing ratio equal to 0.6, compared to a smaller window to wall ratio of 0.2). Adding to that, Fig. 156., represents the hourly heating data of buildings O11 and O8, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that, with a glazing ratio equivalent to 0.6 (represented in orange), had constantly the highest warmth utilization, during February and December, while the lowest ratio (equal to 0.2, represented in green), consumed the least heating demand.

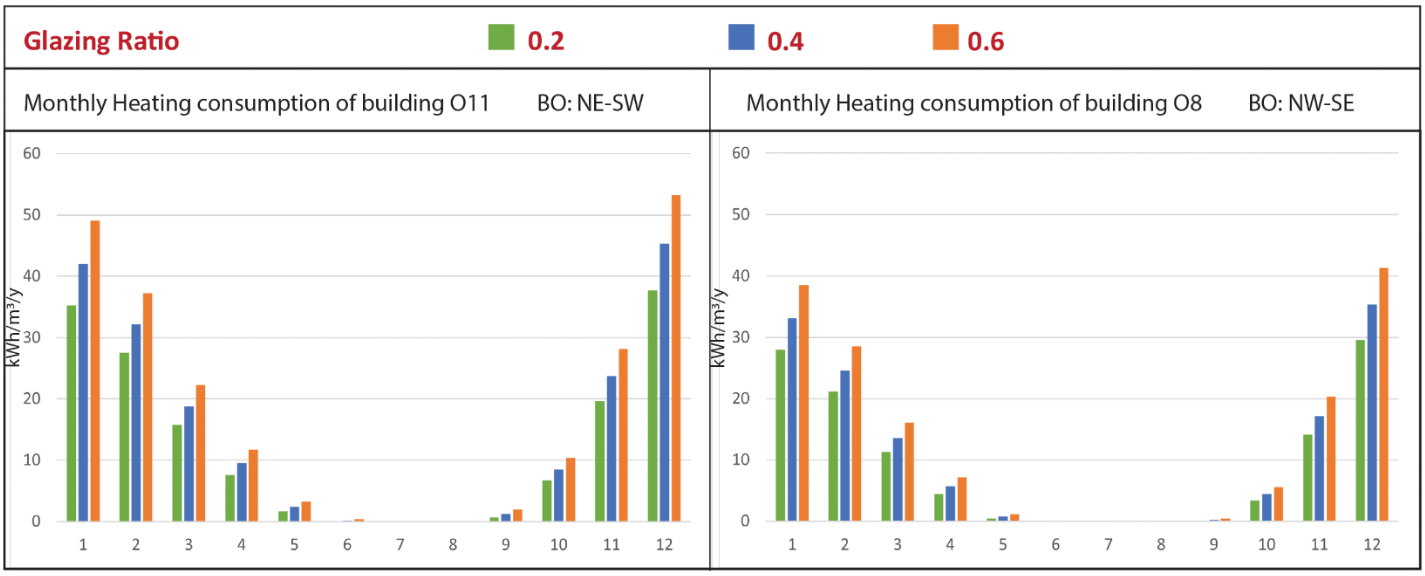


Fig. 155. **Monthly heating consumption of buildings O11 and O8 according to three Glazing ratios.**

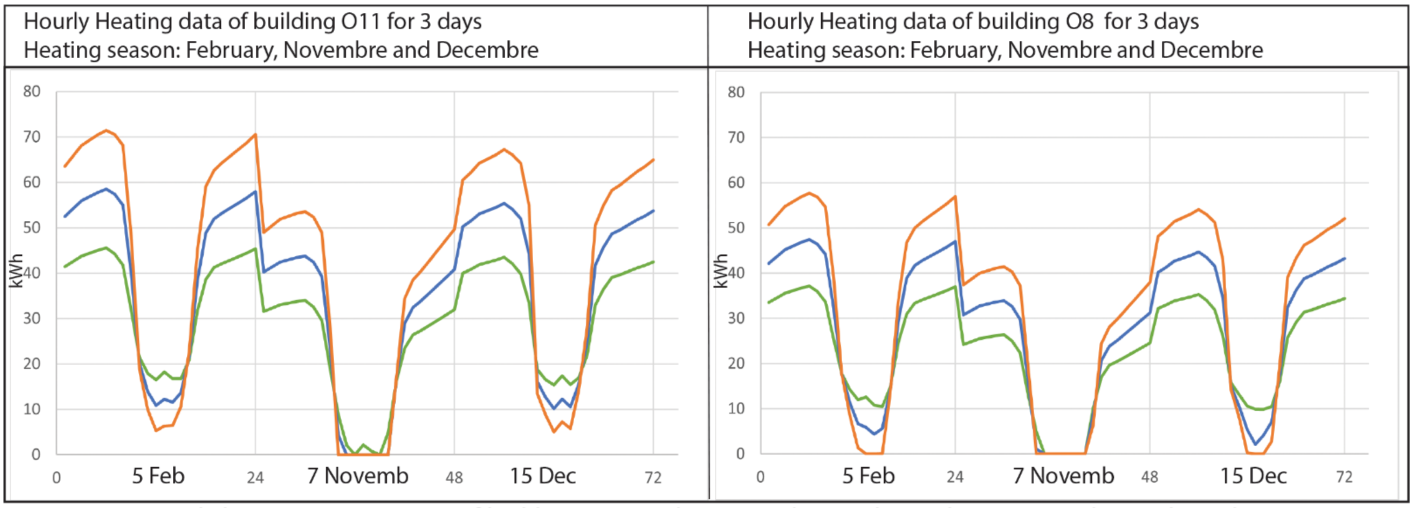


Fig. 156. **Hourly heating consumption of buildings O11 and O8 according to three Glazing ratios during three days.**

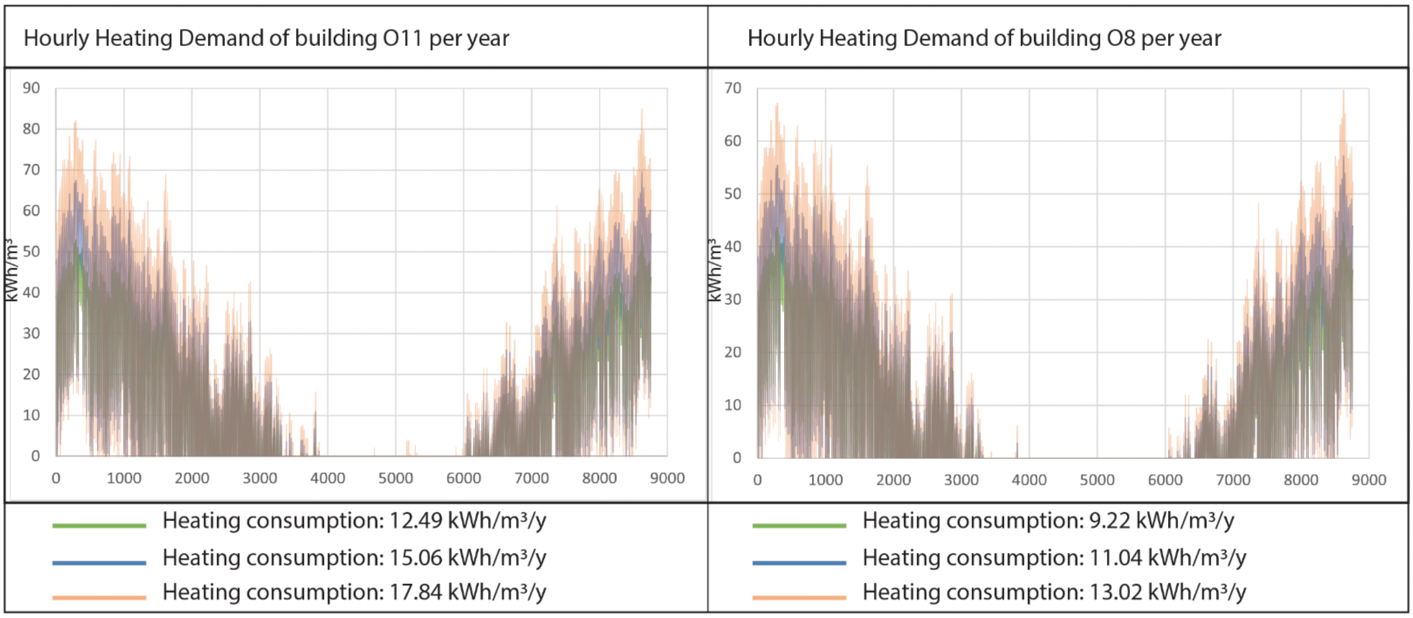


Fig. 157. **Hourly heating consumption of buildings O11 and O8 according to three Glazing ratios during a year.**

Adding to that, the cooling Energy consumptions of building O11 and O9, were analyzed as well. In fact, the first deducted monthly results represented in Fig. 158., show that, when the Glazing ratio of the building increased, similarly to the heating consumption (previously analyzed), the cooling Energy demand increases as well for both structures. Adding to that, an hourly Energy data was conducted for these residential buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 158.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for both structures, during the whole yearly cooling season, the highest window to wall ratio (equal to 0.6) constantly had the highest cooling Energy consumption (represented in orange), while the

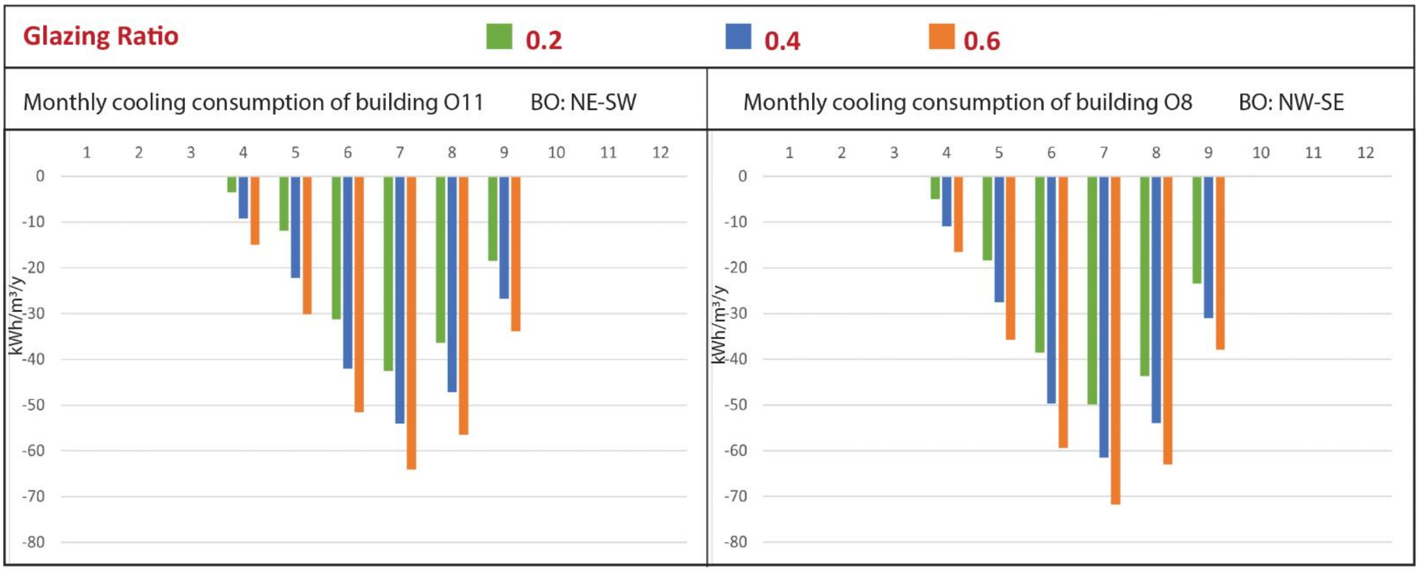


Fig. 158. Monthly cooling consumption of buildings O11 and O8 according to three Glazing ratios.

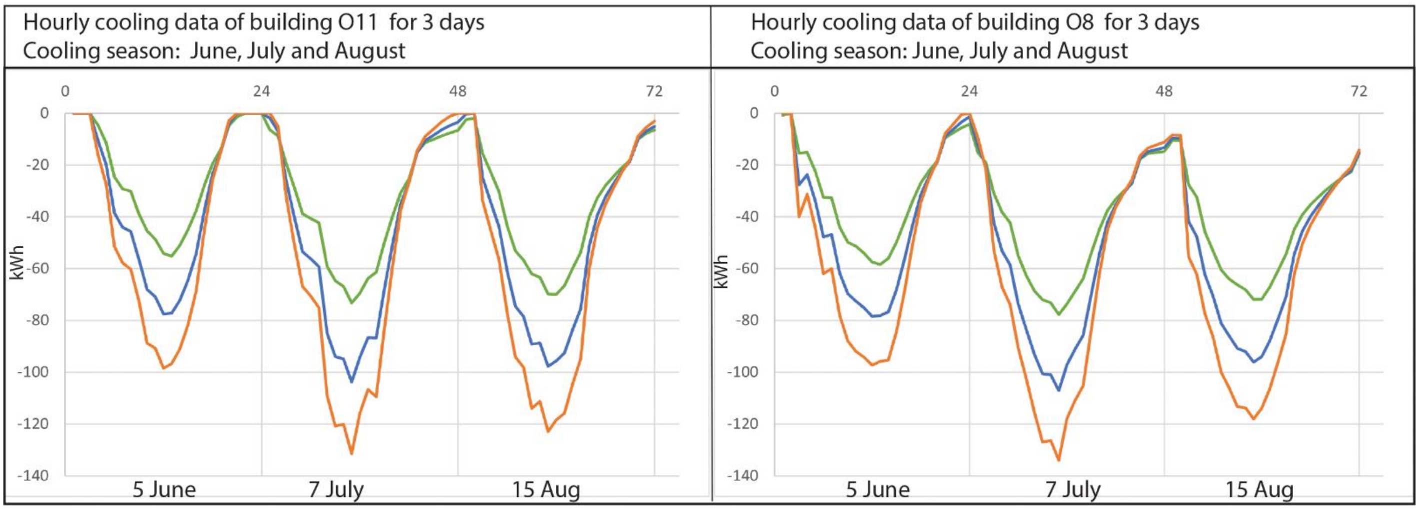


Fig. 159. Hourly cooling consumption of buildings O11 and O8 according to three Glazing ratios during three days.

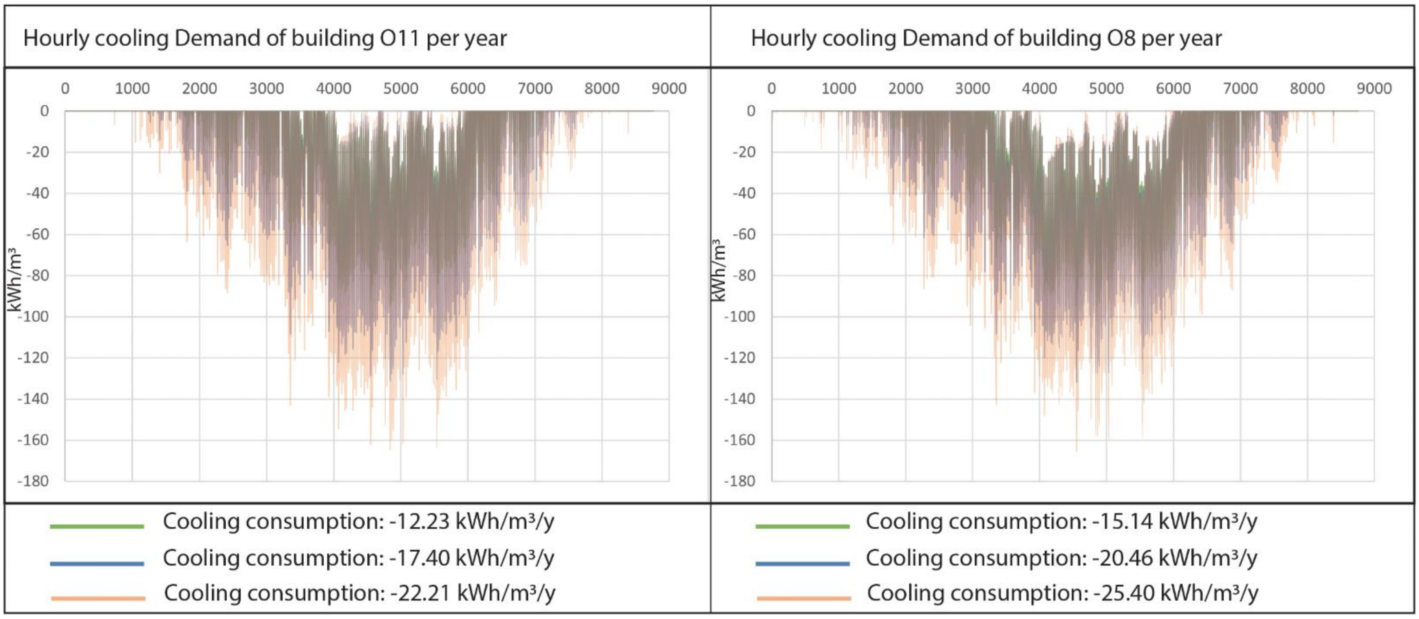


Fig. 160. Hourly cooling consumption of buildings O11 and O8 according to three Glazing ratios during a year.

lowest yearly cooling Energy utilization is represented a glazing ratio, that is equal to 0.2 (represented in green) in accordance with Fig. 160.

Table. XXXVII. Buildings O11 and O8 Heating and Cooling Energy consumptions depending on Glazing ratios equal to 0.2, 0.4 and 0.6.

Glazing Ratio	Building O11 Heating Consumption (kWh/m³/y)	Building O11 Cooling Consumption (kWh/m³/y)	Building O8 Heating Consumption (kWh/m³/y)	Building O8 Cooling Consumption (kWh/m³/y)
0.2	12.49	-12.23	9.22	-15.14
0.4	15.06	-17.40	11.04	-20.46
0.6	17.84	-22.21	13.02	-25.40

Table. XXXVII. Shows the variations in the heating and cooling energy consumptions of buildings O11 and O8, depending on three changed Window to Wall ratios equivalent to 0.2, 0.4 and 0.6. In fact, O11 characterized by a {NE-SW} building orientation, had an increase of 43% in its highest value (with a glazing ratio equal to 0.6) in regard to its lowest consumption of 12.49 kWh/m^3/y (with a glazing ratio equal to 0.2). while O8 with a (NW-SE) had a lower warmth energy impact with 41% between the lowest (9.22 kWh/m^3/y) and highest reached value (13.02 kWh/m^3/y). Fig. 161., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of O11 {NE-SW} and building O9, characterized by a {NW-SE} orientation, had approximately the same amount of impact of the cooling energy consumption, with a similarly linear equational value (presented in blue for building O11, and in orange for building O8).

Therefore, we can conclude that when the glazing ratio of the building increases, the energy heating, and cooling demands of the structures, increases as well simultaneously. Adding to that, buildings with a NW-SE orientation, have a higher heating Energy consumption impact, in comparison to structures with NE-SW orientations.

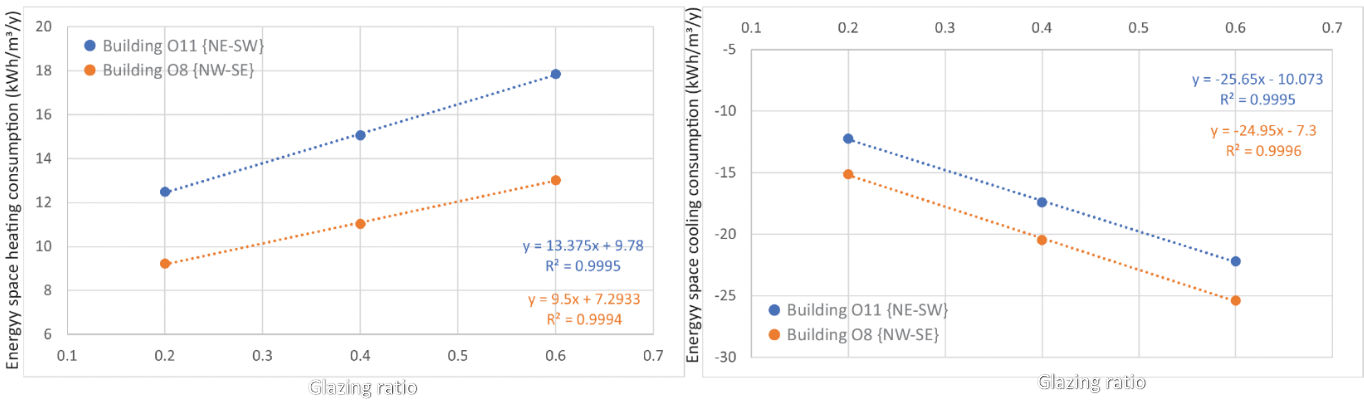


Fig. 161. Energy space heating and cooling demands of buildings O11 and O8 depending on Glazing ratio.

5.4.4- Thermal properties of building envelope

The thermal propertied of a building, are subdivided in this analysis into four main categories: Thermal transmittance of the opaque envelope of the building (Windows U-value), and thermal transmittances of walls, roof, and floor in regard to the building composites and materials. In fact, the opening properties' U-values, are retrieved from UNI/TS 11300-1 according to building's periods of construction. The lower the U-value the more the window is insulated from the outdoor factors of the building. In this variable, three main values were analyzed: 2.15, 4.40 and 4.90 expressed in {W/m^2. K}. Adding to that, Building's Materials and composites retrieved from UNI/TR 11552 varying according to the building's-built period. In this variable, walls, roofs, and floors composites were taken into consideration by specifying their thermal transmittance, resistance, materials densities as well as their thermal capacity. Ranges of 0.67, 0.9 and 1.10 {W/m^2. K} were examined for the walls' U-values, while for the roof composites, values varied between 0.53, 1.27 and 1.60{W/m^2. K}. and finally, the last studied building variable is the floor's composites and materials with values equivalent to 1.16 {W/m^2. K} for construction periods ranging between 1919 and 1960, and 1.25 {W/m^2. K} for residential structure building between 1961 and 2005.

5.4.4.1- Window's U-value ($U_{windows}$, $W/m^2/K$)

In fact, the building's windows U-values, are assigned to each residential building, according to its respective period of construction. The lower the U-value the more the window is insulated from the outdoor factors. In this analysis, three different windows thermal transmittances were studied: 2.15 {W/m^2. K} (indicated in green), 4.40 {W/m^2. K} (indicated in blue), and 4.90{W/m^2. K} (indicated in orange), to sensitively compare and analyze the impact of this changed variable on the heating and cooling consumption of the two chosen residential buildings (O11 and O8) in Olympic Village neighborhood that are characterized with a construction period between 2001 and 2005. The first warmth Energy utilization results are shown in Fig. 162. In fact, the monthly heating demand of both analyzed, increased when the windows' U-value was higher, mainly due to the penetration of the cold outdoor air inside of the building during the heating season, because of the lower window insulation. Adding to that, Fig. 163., represents the hourly heating data of buildings O11 and O8 regarding three chosen days during the heating season: 5th of February, 7th of November and the

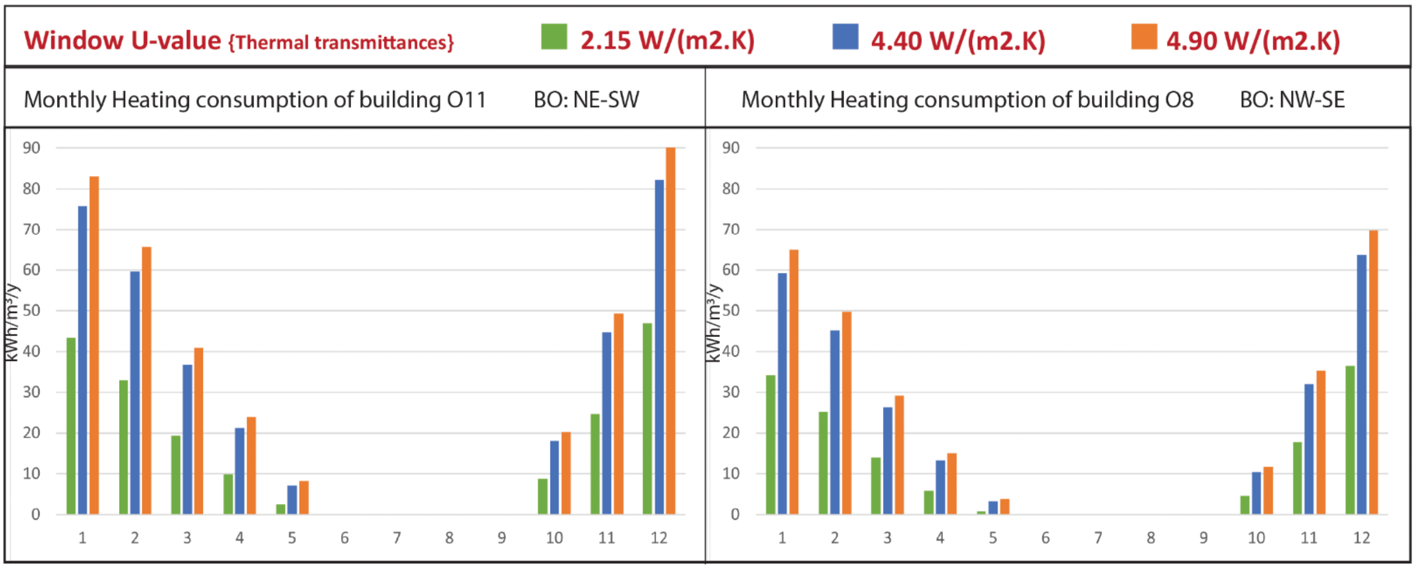


Fig. 162. **Monthly heating consumption of buildings O11 and O8 according to three window U-values.**

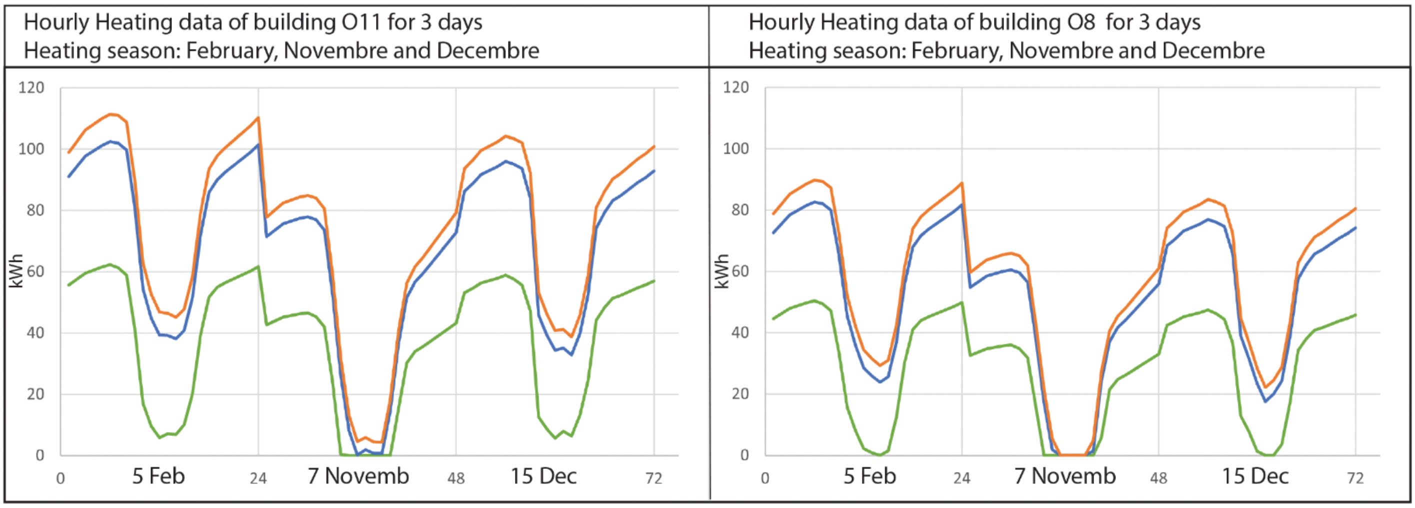


Fig. 163. **Hourly heating consumption of buildings O11 and O8 according to three window U-values during three days.**

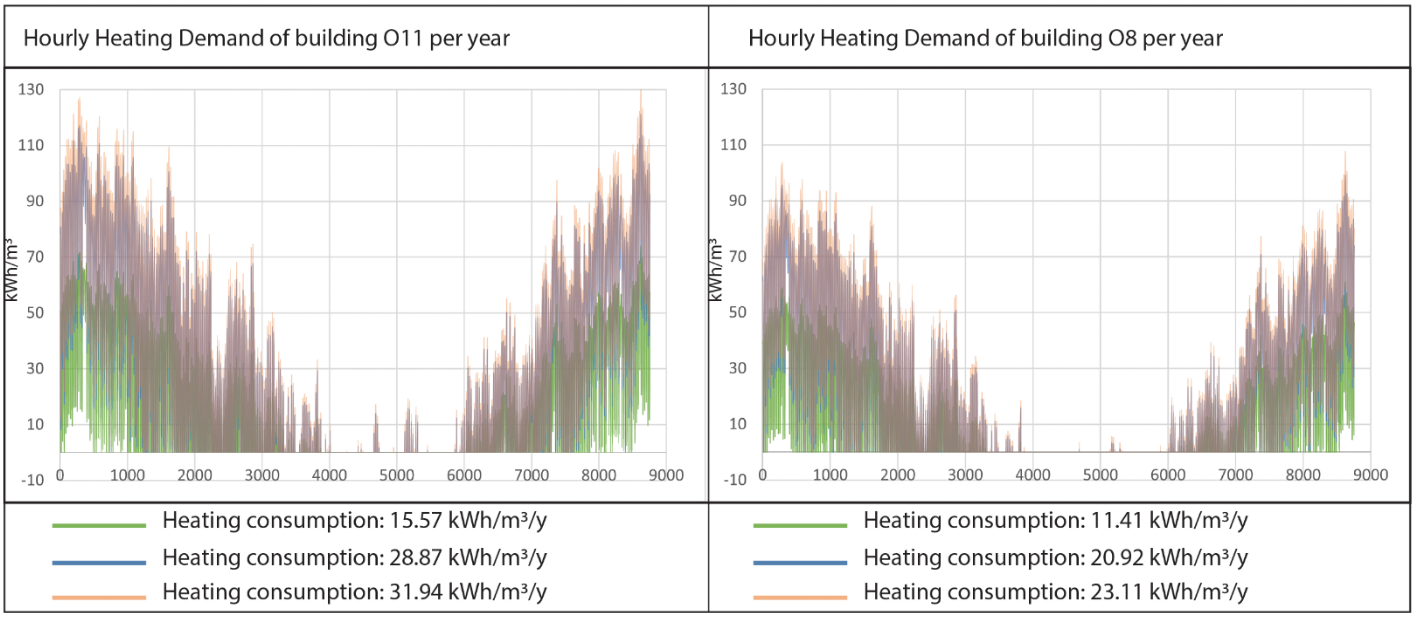


Fig. 164. **Hourly heating consumption of buildings O11 and O8 according to three window U-values during a year.**

15th of December. The graphs show that for the two selected residential structures, the opaque envelope's thermal transmittance that is equal to 4.90 {W/m^2. K}, represented in orange, had constantly the highest warmth utilization, while the lowest window's U-value (2.15 {W/m^2. K}), represented in green, consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), both structures, regularly consumed more heating Energy with the highest window U-value equivalent to 4.90 {W/m^2. K} (represented in orange), compared to lower values of 4.40 {W/m^2. K} (represented in blue), and 2.15 {W/m^2. K} (represented in green) (Fig. 164.).

Adding to that, the cooling Energy consumptions of building O11 and O8, were analyzed as well. In fact, the first deducted monthly results represented in Fig. 165., show that, when the window's U-value of the building increased, on the opposite of the heating consumption results (previously discussed), the cooling Energy demand decreased for structures. Adding to that, an hourly Energy consumption was conducted for O11 and O8 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 166.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 5th of June. In fact, in August, for both residential structures, with a window U-value equivalent to 4.90 {W/m^2. K} represented in orange, the energy consumption was higher compared to values equal to 4.40 and 2.15 {W/m^2. K}, even though the yearly energy cooling consumption of this range was the lowest with -16.35 kWh/m^3/y for O11 and -20.07 kWh/m^3/y for O8 (Fig. 167). However, during the months

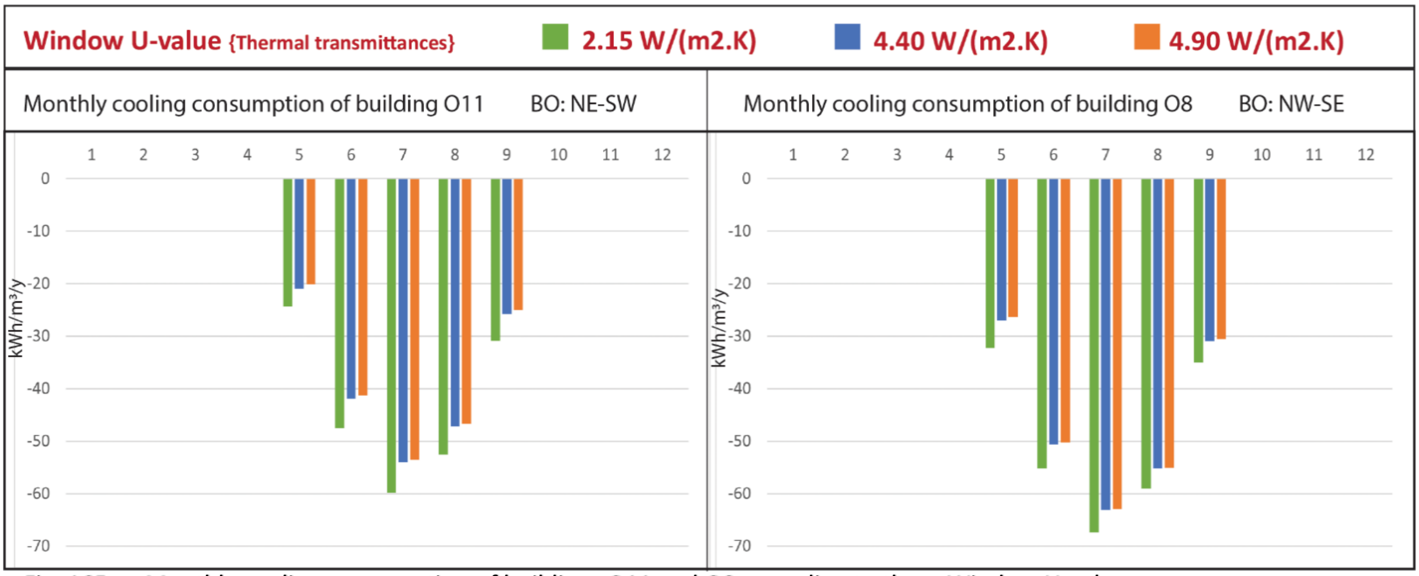


Fig. 165. Monthly cooling consumption of buildings O11 and O8 according to three Window U-values.

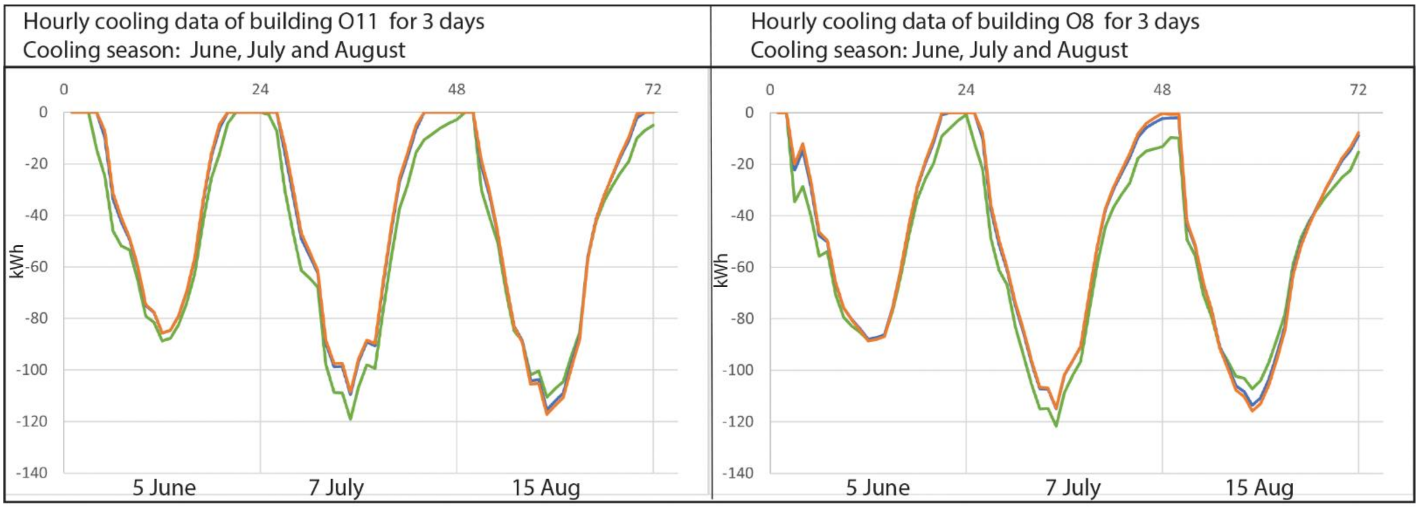


Fig. 166. **Hourly cooling consumption of buildings O11 and O8 according to three Window U-values during three days.**

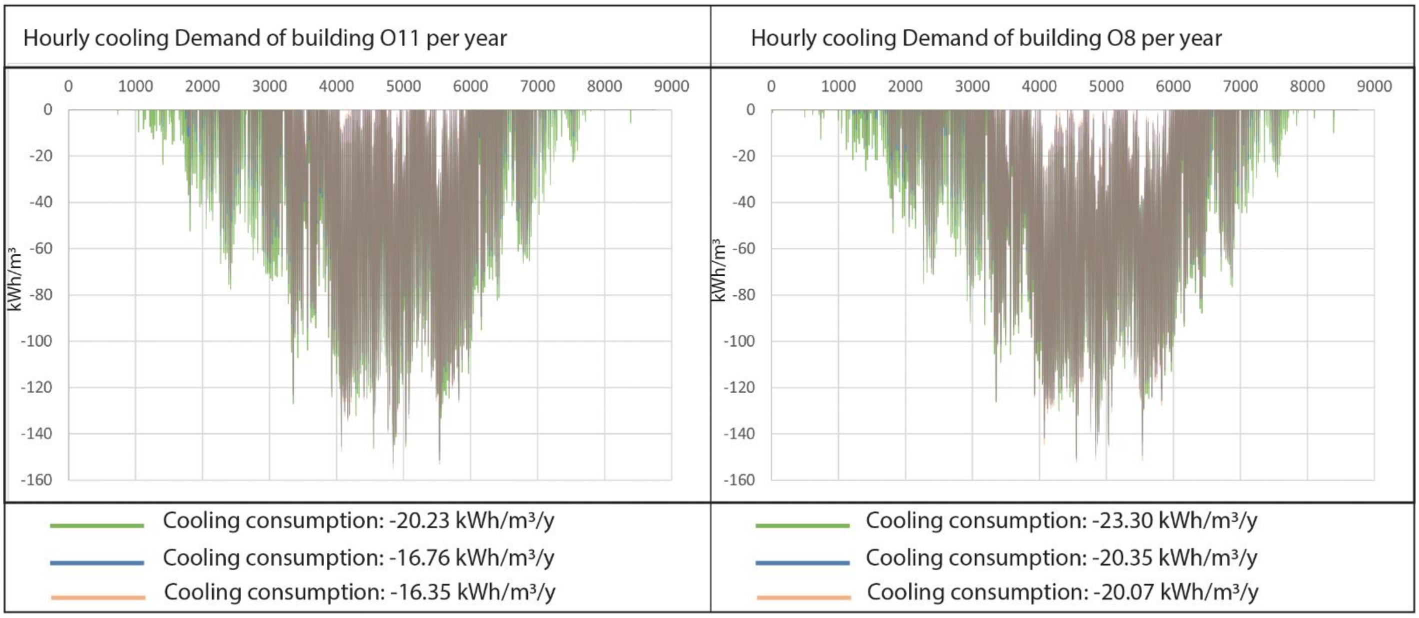


Fig. 167. **Hourly cooling consumption of buildings O11 and O8 according to three Window U-values during a year.**

June and July, the lowest thermal transmittance of the opaque envelope (2.15 {W/m^2. K}) had the highest Energy cooling utilization for both buildings O11 and O8.

Table. XXXVIII. Buildings O11 and O8 Heating and Cooling Energy consumptions depending on window U-values equal to 2.15, 4.40, and 4.90 W/m^2. K.

Window U-value W/(m2.K)	Building O11 Heating Consumption (kWh/m³/y)	Building O11 Cooling Consumption (kWh/m³/y)	Building O8 Heating Consumption (kWh/m³/y)	Building O8 Cooling Consumption (kWh/m³/y)
2.15	15.57	-20.23	11.41	-23.30
4.40	28.87	-16.76	20.92	-20.35
4.90	31.94	-16.35	23.11	-20.07

Table. XXXVIII. Shows the variations in the heating and cooling energy consumptions of buildings O11 and O8, depending on three changed window's thermal transmittances values equivalent to 2.14, 4.40 and 4.90 {W/m^2.K}. In fact, O11 characterized by a {NE-SW} building orientation, had an increase of 105% in its highest value (with a window U-value equal to 4.90 {W/m^2. K}), regarding its lowest consumption of 15.57 kWh/m^3/y (with a window U-value equal to 2.15 {W/m^2. K}), while O8 with a (NW-SE) had a lower warmth energy impact with 102% between the lowest and highest reached value respectively equal to 11.41 kWh/m^3/y and 23.11 kWh/m^3/y. Fig. 168., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of O11 {NE-SW} had a higher Energy cooling impact compared to O8 with a building orientation of {NW-SE}. Therefore, we can conclude that when the window's U-value increased, the energy heating demand is higher, while the energy cooling consumption is lower.

Heating consumption *Cooling consumption*

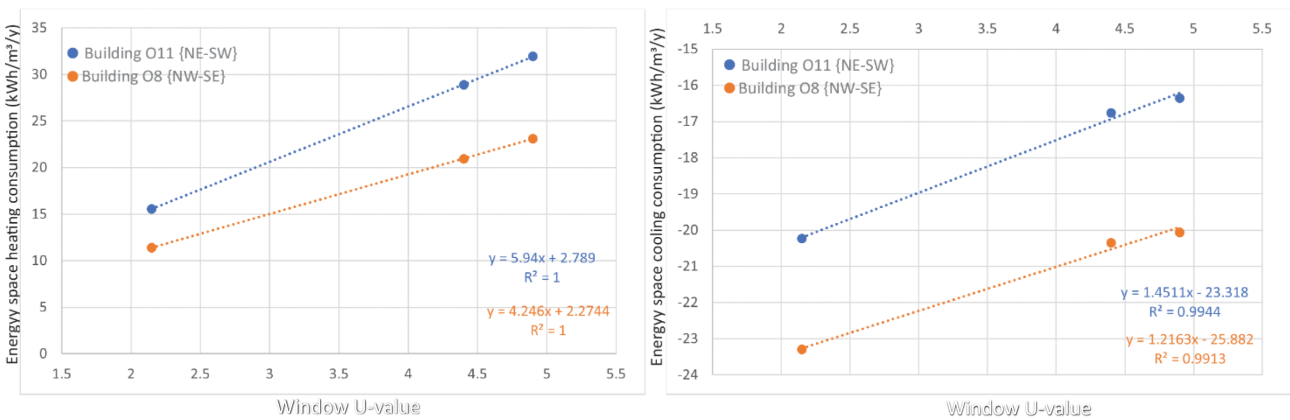


Fig. 168. Energy space heating and cooling demands of buildings O11 and O8 depending on window U-values.

5.4.4.2- Wall's U-value (U_{wall}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the wall's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.10, 0.9 and 0.67 expressed in {W/m^2. K}. Table. XI. (previously shown) reflects the three examined walls composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.10 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a wall code of MLP02. The second studied value is

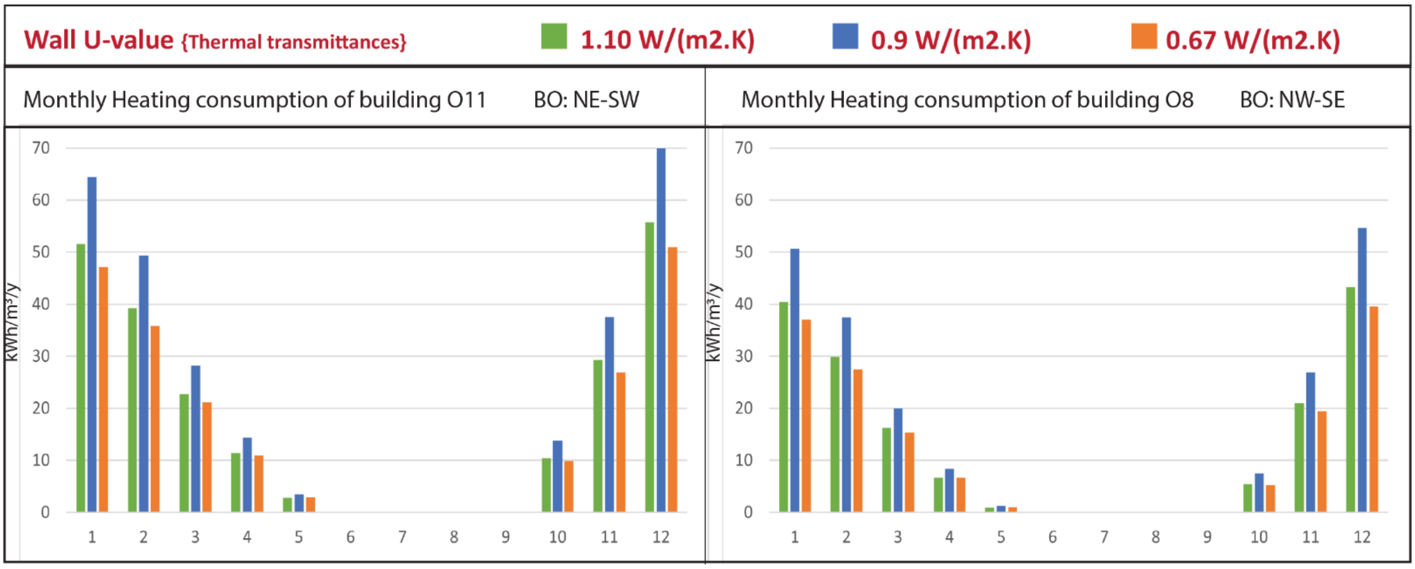


Fig. 169. Monthly heating consumption of buildings O11 and O8 according to three wall U-values.

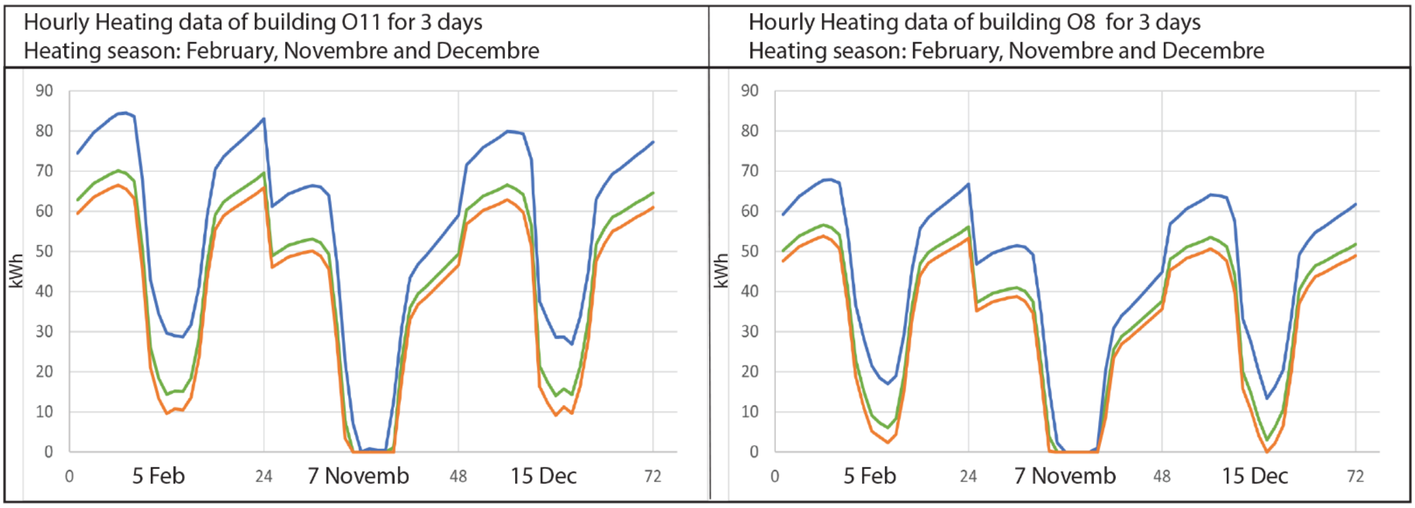


Fig. 170. Hourly heating consumption of buildings O11 and O8 according to three wall U-values during three days.

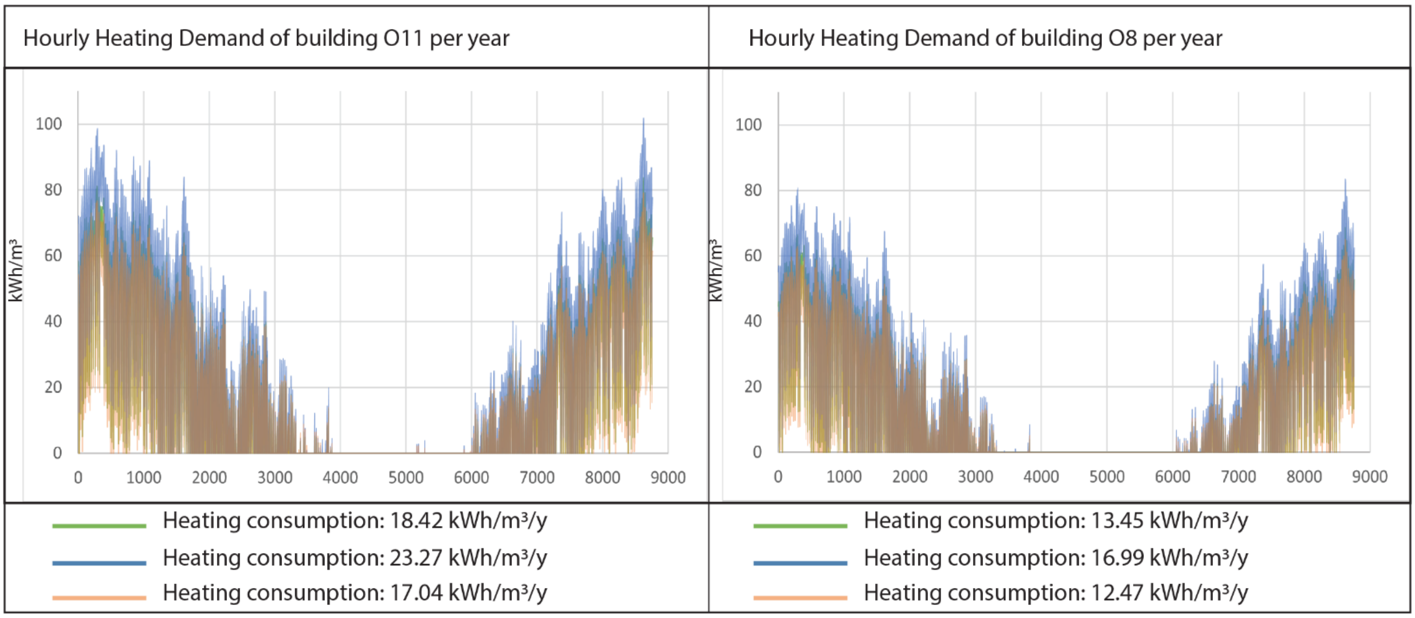


Fig. 171. Hourly heating consumption of buildings O11 and O8 according to three wall U-values during a year.

0.9 {W/m^2. K}, with a wall code of MLP03 (constructed between 1961 and 1970). And the most recent wall composite is MPF03 (1990-2005), with a thermal transmittance value equivalent to 0.67 {W/m^2. K}. In fact, the first heating Energy utilization results are shown in Fig. 169. The monthly warmth demand of both structures O11 and O9, had the highest energy utilization with a wall U-value equivalent to 0.9 {W/m^2. K} (indicated in blue), and the lowest one represented with the most recent wall composite MPF03 with a thermal transmittance of 0.67 {W/m^2. K}. We can visualize a huge gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 170., represents the hourly heating data of the two analyzed residential buildings, in regard to three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the wall's thermal transmittance that is equal to 0.9 {W/m^2. K} (MLP03, represented in blue), had constantly the highest warmth utilization, while the lowest wall's U-value (0.67 {W/m^2. K}, represented in orange), consumed the least heating demand. Adding to that, the 5th of February showed the most energy need, however, on the 7th of November, it was considerably lower compared to the other analyzed days. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings O11 and O8, both regularly consumed more heating Energy with a wall U-value equivalent to 0.9 {W/m^2. K} (represented in blue, MLP03), compared to values of 1.10 {W/m^2. K} (represented in green, MLP03), and 0.67 {W/m^2. K} (represented in orange, MPF03) (Fig. 171.).

Adding to that, the first deducted monthly results represented in Fig. 172., show that, when the wall's thermal transmittance of the building was equal to 0.9 {W/m^2. K} (MLP03), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures O11 and O8 were the highest compared to the two other wall composites (MLP02 and MPF03). However, the most recent wall configuration, MPF03, with a U-value equivalent to 0.67 {W/m^2. K} (represented in orange), consumed more cooling energy compared to the oldest wall code, MLP02 (1919-1945), represented on the graph in green. Adding to that, an hourly Energy data was conducted for O11 and O8 for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 173.). Results show that, for both buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for both analyzed residential structures, during the whole yearly cooling season, the buildings with the wall's thermal transmittance equal to 0.9 {W/m^2. K} (MLP03), constantly had the highest cooling Energy consumption (represented in blue).

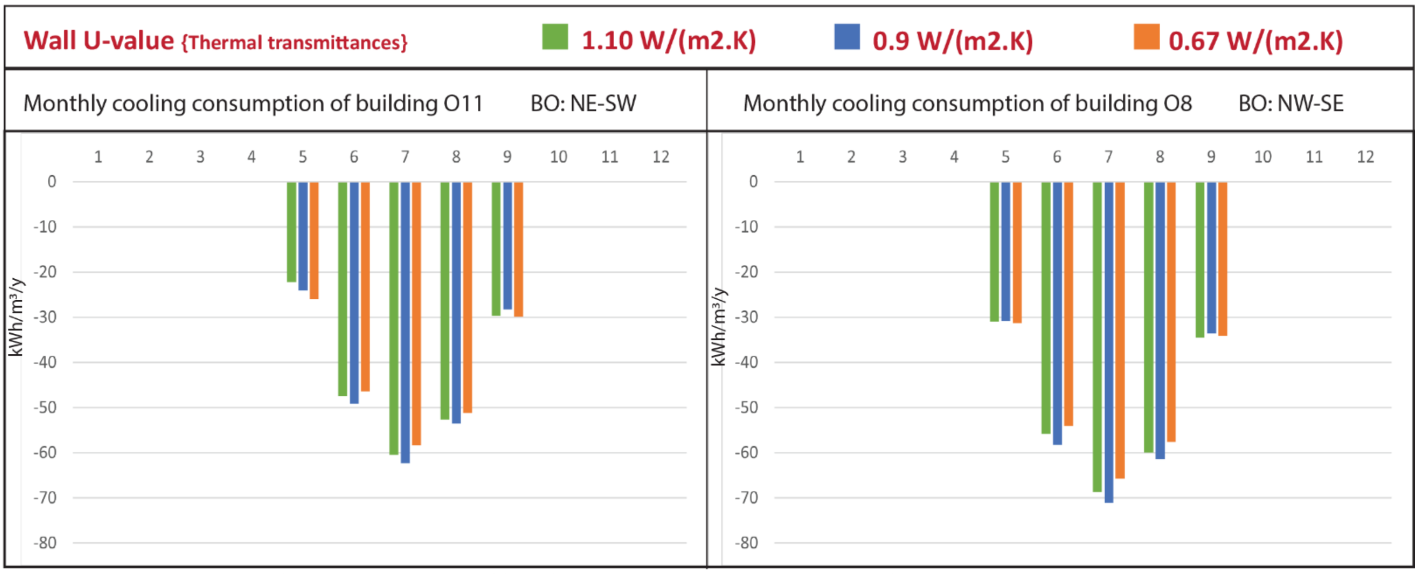


Fig. 172. **Monthly cooling consumption of buildings O11 and O8 according to three wall U-values.**

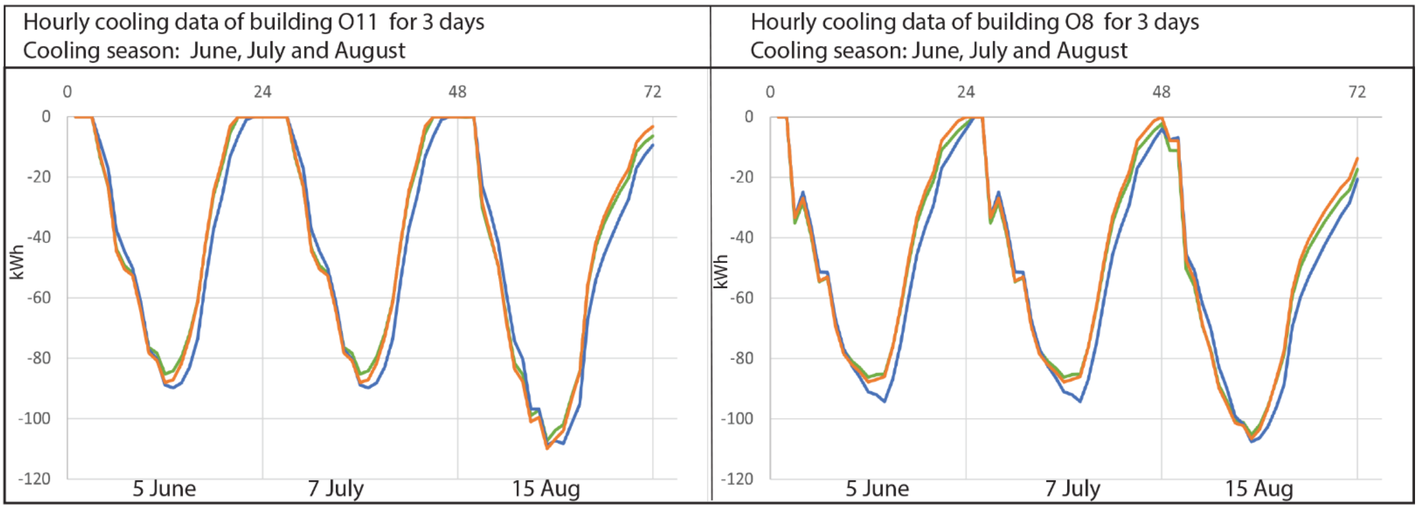


Fig. 173. **Hourly cooling consumption of buildings O11 and O8 according to three wall U-values during three days.**

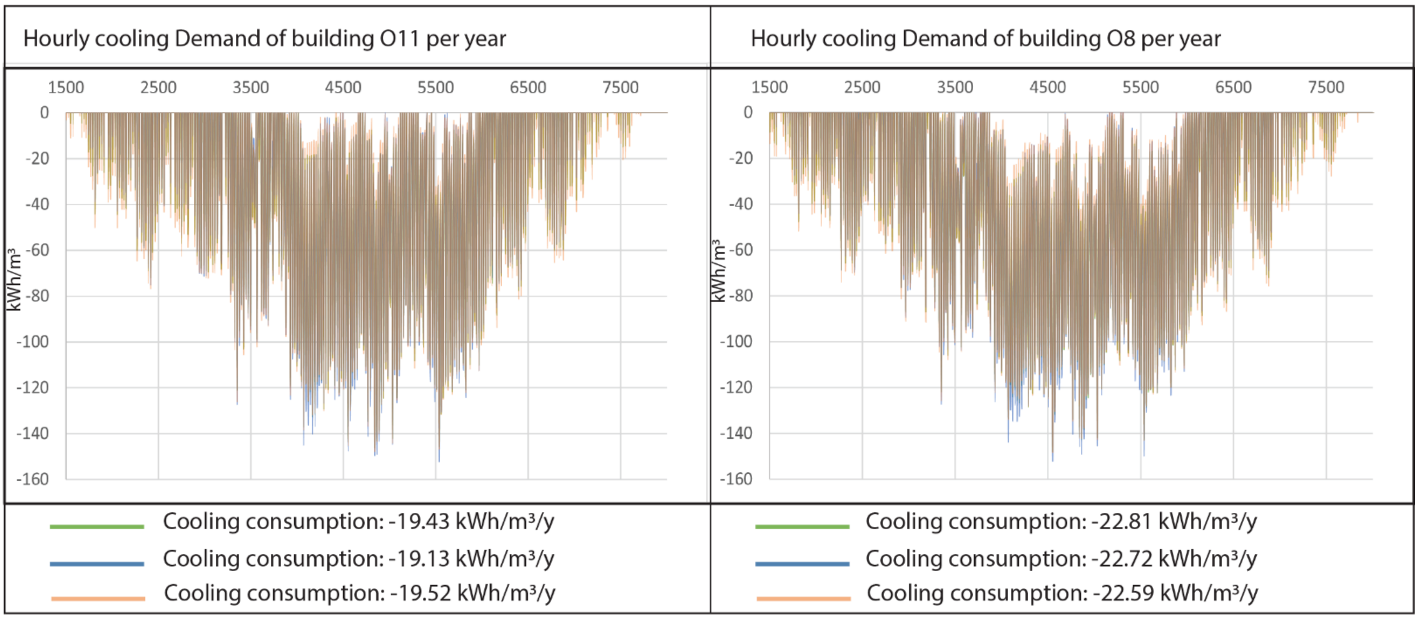


Fig. 174. **Hourly cooling consumption of buildings O11 and O8 according to three wall U-values during a year.**

Table. XXXIX. Buildings O11 and O9 Heating and Cooling Energy consumptions depending on walls U-values equal to 1.10, 0.9, and 0.67 W/m^2. K.

Wall U-value W/(m2.K)	Building O11 Heating Consumption (kWh/m³/y)	Building O11 Cooling Consumption (kWh/m³/y)	Building O8 Heating Consumption (kWh/m³/y)	Building O8 Cooling Consumption (kWh/m³/y)
1.10	18.42	-19.43	13.45	-22.81
0.9	23.27	-19.13	16.99	-22.72
0.67	17.04	-19.52	12.47	-22.59

Table. XXXIX. Shows the variations in the heating and cooling energy consumptions of buildings O11 and O8, depending on three changed walls thermal transmittances values equivalent to 1.10, 0.9, and 0.67 W/m^2. K. In fact, O11, characterized by a {NE-SW} building orientation, had an increase of 36,5%, with a wall U-value equal to 0.9 {W/m^2. K}, in regard to its lowest heating energy Consumption of 17.04 kWh/m^3/y (with a wall U-value equal to 0.67 {W/m^2. K}). while O8, with a (NW-SE) had approximately the same warmth energy impact with 30% between the lowest and highest reached value respectively equal to 12.47 kWh/m^3/y and 16.99 kWh/m^3/y. Fig. 175., shows the Energy space heating and cooling utilizations of both buildings. When compared, the cooling demand of O11 {NE-SW} was more impacted compared to a building orientation of {NW-SE}, with a higher linear equational value (presented in blue). Therefore, we can conclude that the most recently used walls composite (MPF03, 2001-2005), consumed the least yearly energy demand, while composite MLP03 showed the highest one for both heating and cooling energy utilization during both seasons.

Heating consumption *Cooling consumption*

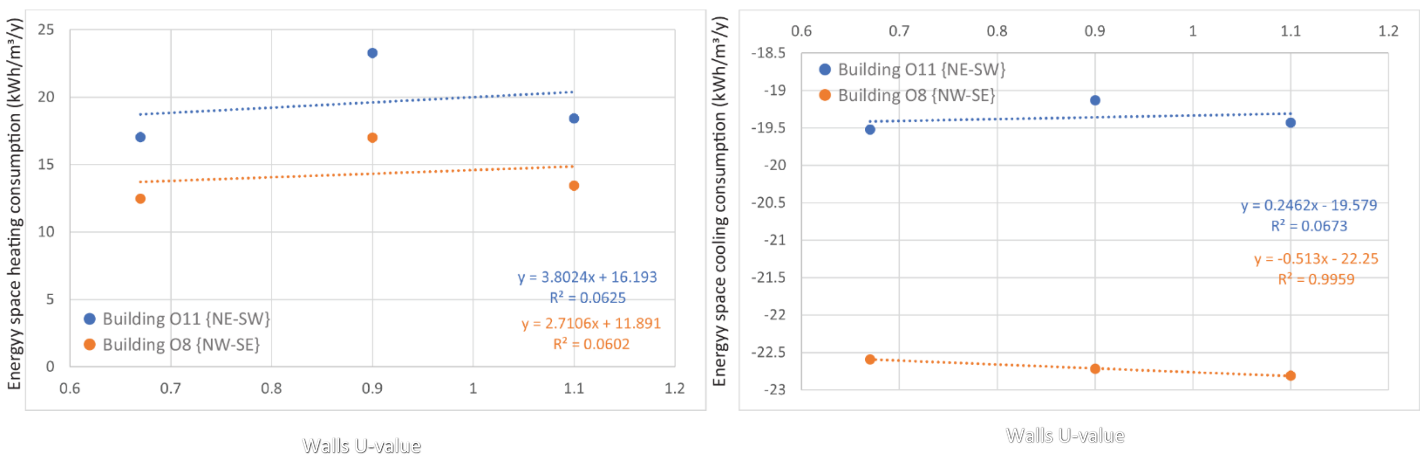


Fig. 175. Energy space heating and cooling demands of buildings O11 and O8 depending on wall U-values.

5.4.4.3- Roof's U-value (U_{roof}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with walls U-values varying according to the building's construction period. In fact, the lower the roof's U-value the more the building is insulated from the outdoor factors. In this variable, three main values were analyzed: 1.60, 1.27 and 0.53 expressed in {W/m^2. K}. Table. XVI. (previously shown), reflects the three examined roof composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.60 {W/m^2. K} characterized by the oldest built period ranging between 1919 and 1945 with a roof code of COP01. The second studied value is 1.27 {W/m^2. K}, with a roof code of COP04 (constructed between 1961 and 1970). And the most recent roof composite is COP03 (1990-2005), with the lowest thermal transmittance value equivalent to 0.53 {W/m^2. K}. These different ranges, were inserted in the engineering software CitySim Pro, were simulated results were compared and analyzed to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (O11 and O9) in Olympic Village neighborhood characterized by a period of construction ranging between 2001 and 2005.

In fact, the first heating Energy utilization results are shown in Fig. 176. The monthly warmth demand of both structures O11 and O8, had the highest energy utilization with a roof U-value equivalent to 1.27 {W/m^2. K} (indicated in blue), and the lowest one represented with the newest roof composite COP03 with a thermal transmittance of 0.53 {W/m^2. K} (indicated in orange). Adding to that, Fig. 177., represents the hourly heating data of the two analyzed residential buildings, regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for buildings O11 and O8, the roof's thermal transmittance that is equal to 1.27 {W/m^2. K} (COP04), had constantly the highest warmth utilization. While, for the residential structure O11 characterized by a NE-SW orientation, and building O9, with a NW-SE orientation, the newest roof composite {COP03} consumed the least heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours), buildings O11 and O8, both regularly consumed more heating Energy with a wall U-value equivalent to 1.27 {W/m^2. K} (represented in blue, COP04, according to Fig.178.).

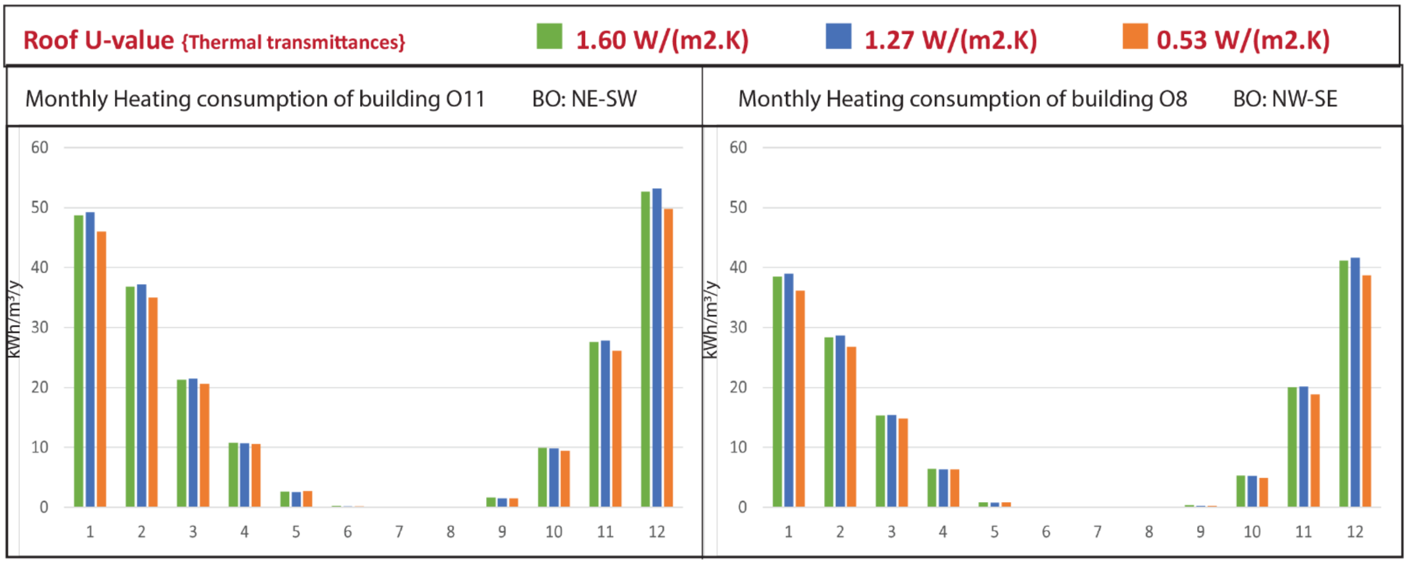


Fig. 176. Monthly heating consumption of buildings O11 and O8 according to three Roof U-values.

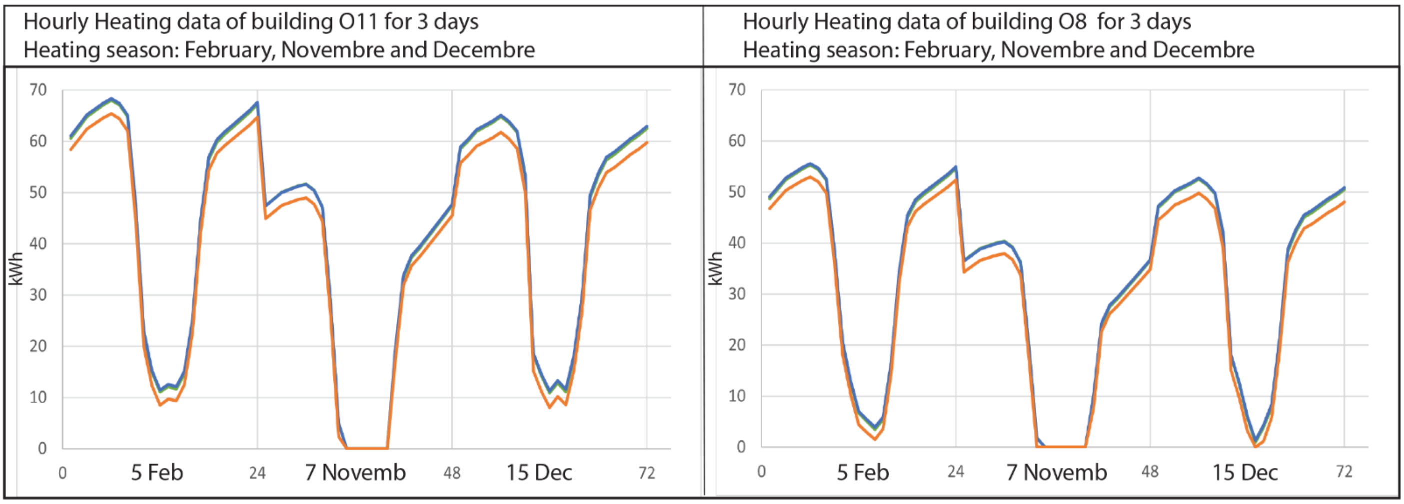


Fig. 177. Hourly heating consumption of buildings O11 and O8 according to three Roof U-values during three days.

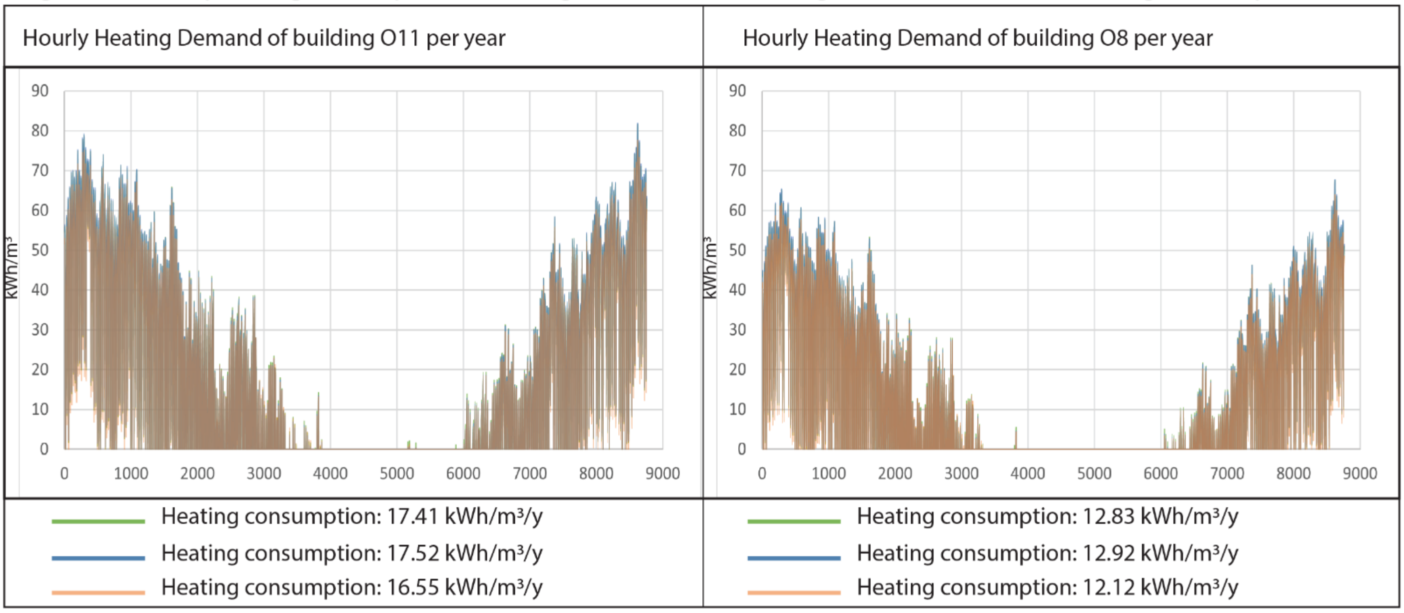


Fig. 178. Hourly heating consumption of buildings O11 and O8 according to three Roof U-values during a year.

Adding to that, the cooling Energy consumptions of building O11 and O8 were analyzed as well. In fact, the first monthly results represented in Fig. 179., show that, when the roof's thermal transmittance of the building was equal to 1.27 {W/m^2. K} (COP04), similarly to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures had the highest simulated results, compared to the two other roof composites (COP01 and COP04). while the most recent roof configuration, COP03, with a U-value equivalent to 0.53 {W/m^2. K} (represented in orange), consumed the least cooling energy compared to the oldest roofs' composites. Adding to that, an hourly Energy data was conducted for both analyzed buildings for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 180.). Results show that, for both constructions, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building O11 characterized by a NE-SW orientation, and O8 with a NW-SE orientation, during the whole yearly cooling season (equivalent

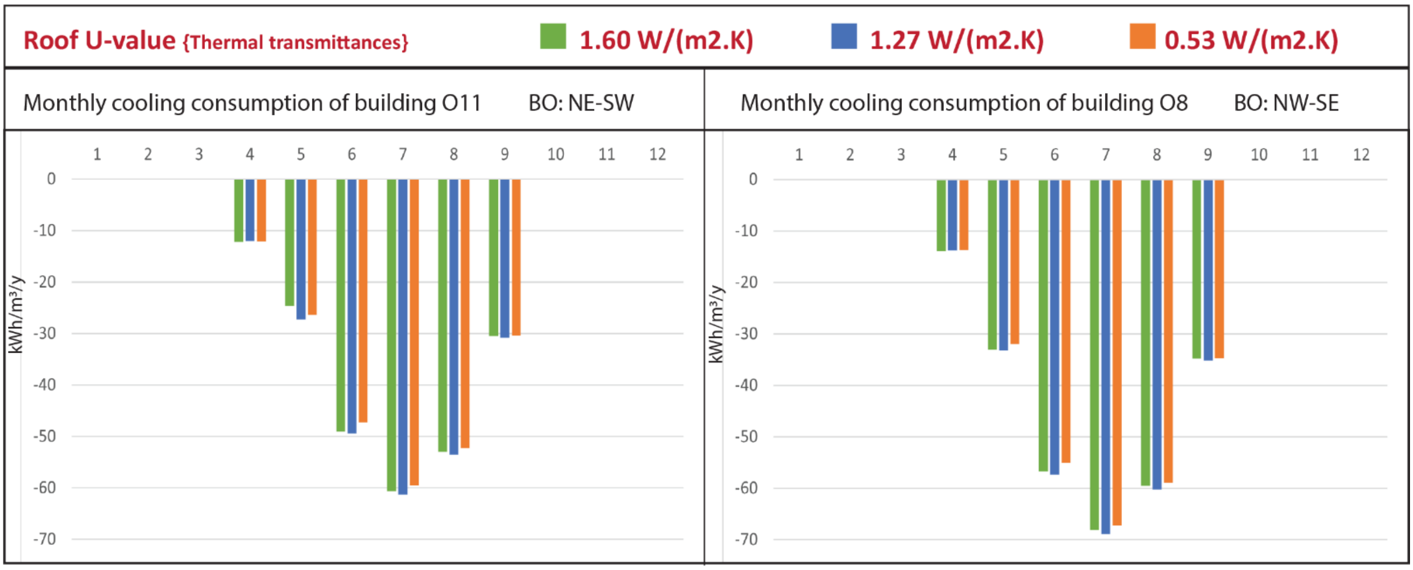


Fig. 179. Monthly cooling consumption of buildings O11 and O8 according to three Roof U-values.

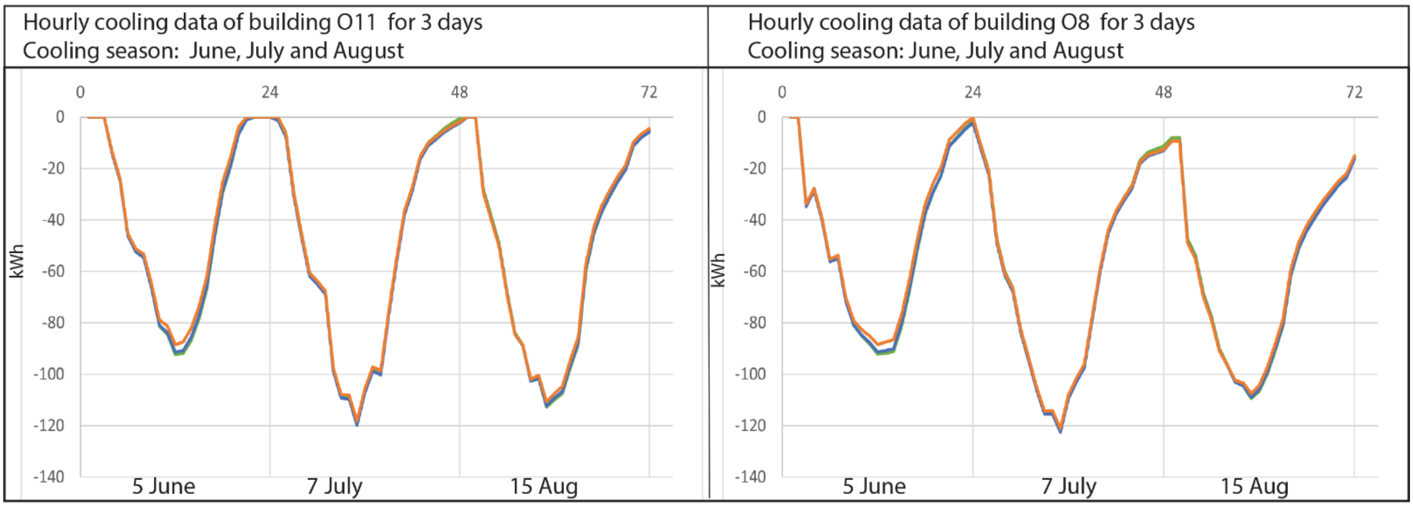


Fig. 180. Hourly cooling consumption of buildings O11 and O8 according to three Roof U-values during three days.

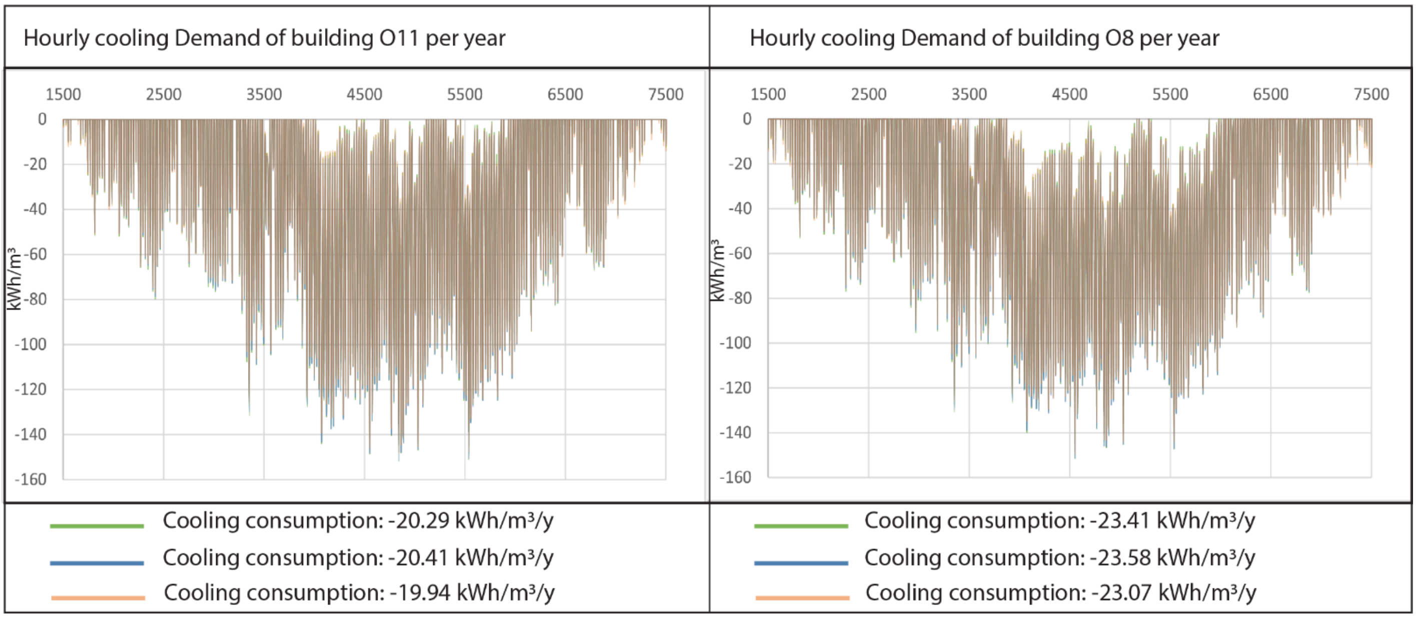


Fig. 181. Hourly cooling consumption of buildings O11 and O8 according to three Roof U-values during a year.

to 8761 simulated hours), both structures with the roof thermal transmittance equal to 1.27 {W/m^2. K} (COP04), constantly had the highest cooling Energy consumption (represented in blue, Fig. 181). Fig. 182., shows the Energy space heating and cooling utilizations of both buildings. Therefore, we can conclude that COP04 roof composite consumed the highest heating and cooling energy demand, while the newest roof composite COP03, had the lowest yearly energy Utilization.

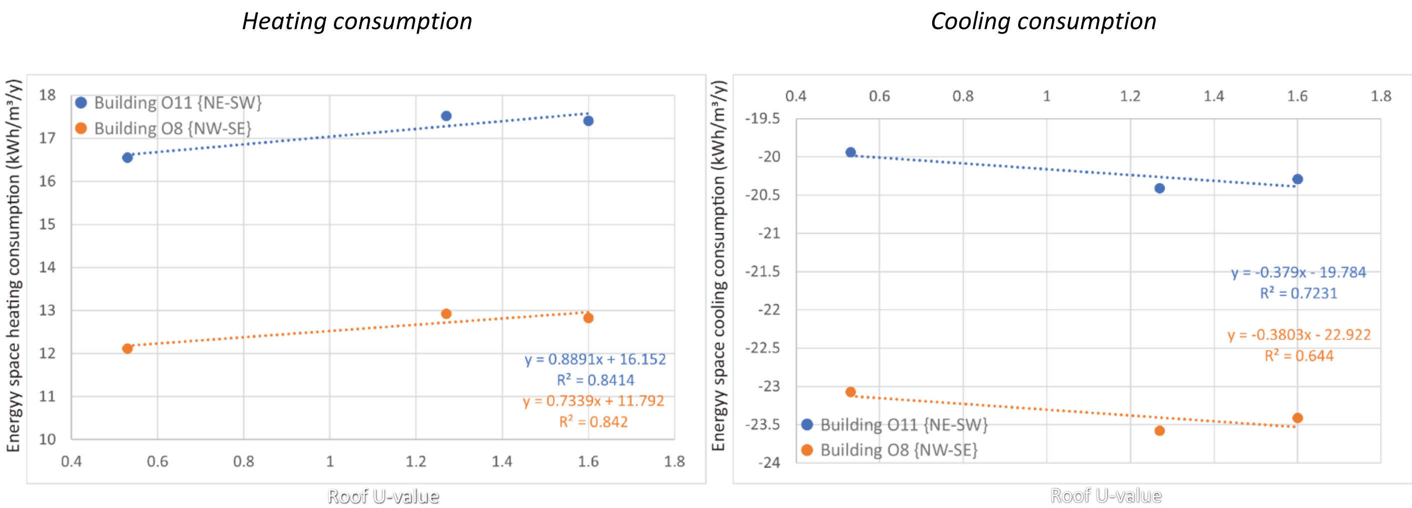


Fig. 138. Energy space heating and cooling demands of buildings A1 and A9 depending on roof U-values.

5.4.4.4- Floor's U-value (U_{floor}, W/m²/K)

Building's Materials and composites are retrieved from UNI/TR 11552 with floor U-values varying according to the building's construction period. In fact, the lower the floor's U-value the more the building is insulated from the ground factors. In this variable, two main values were analyzed: 1.16, and 1.25 expressed in {W/m^2. K}. Table. XX. (previously shown), represents the two examined floor composites along with their respective thermal transmittances and periods of construction. The highest analyzed U-value is equal to 1.25 {W/m^2. K} characterized by the newest built period ranging between 1961 and 2005 with a floor code of SOL04. The second studied value is 1.16 {W/m^2. K}, with a floor code of SOL03 (characterized by a constructed period varying between 1919 and 1960). These different ranges were inserted in the engineering software CitySim Pro, where simulated results were compared and analyzed to understand the impact of this changed variable on the heating and cooling consumptions of the two chosen residential buildings (O11 and O8) in Arquata neighborhood characterized by a period of construction ranging between 2001 and 2005.

In fact, the first heating Energy utilization results are shown in Fig. 183. The monthly warmth demand of both structures O11 and O8, had the highest energy utilization with a floor U-value equivalent to 1.25 {W/m^2. K} (indicated in orange), and the lowest one represented with the oldest floor composite SOL03 with a thermal transmittance of 1.16 {W/m^2. K}. We can visualize a small gap in between the structure with the highest and the lowest consumption. Adding to that, Fig. 184., represents the hourly heating data of buildings O11 and O9, regarding three chosen days during the heating season: 5th of February, 7th of November and the 15th of December. The graphs show that for the two selected residential structures, the floor's thermal transmittance that is equal to 1.25 {W/m^2. K} (SOL04), had constantly the highest warmth utilization. While SOL04 that is characterized by the most recent period of construction {1961-2005}, consumed more heating demand. As for the hourly warmth consumption over the course of a year (with 8761 resulted hours) buildings O11 and O8, both regularly consumed more heating Energy with a floor U-value equivalent to 1.25 {W/m^2. K} (represented in orange, SOL04) in accordance with the hourly results shown in Fig. 185.

Adding to that, the cooling Energy consumptions of buildings O11 and O9 were analyzed as well. In fact, the first monthly results represented in Fig. 186., show that, when the roof's thermal transmittance of the building was equal to 1.25 {W/m^2. K} (SOL04 represented in orange), similarly

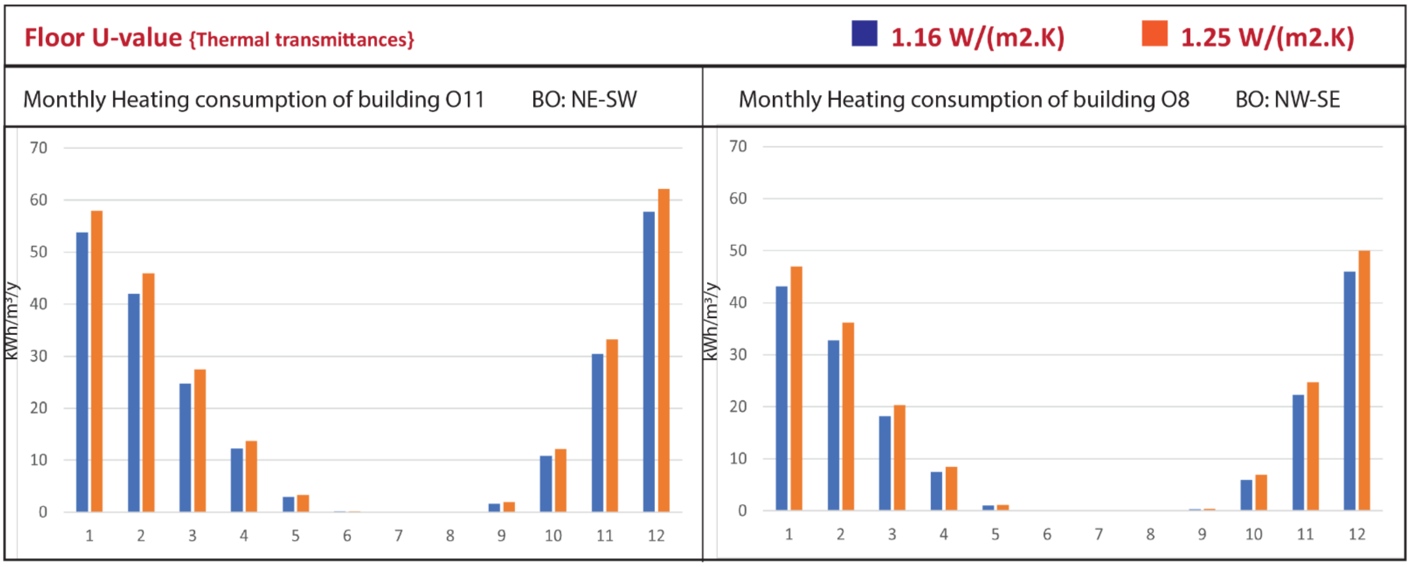


Fig. 183. **Monthly heating consumption of buildings O11 and O8 according to two floor U-values.**

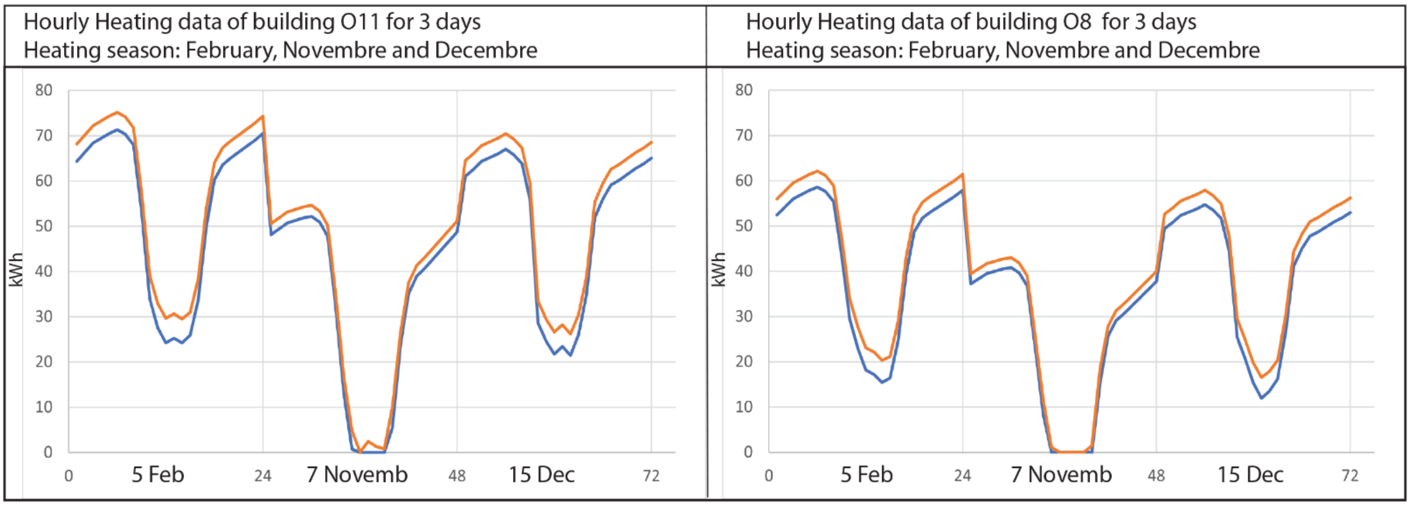


Fig. 184. **Hourly heating consumption of buildings O11 and O8 according to two floor U-values during three days.**

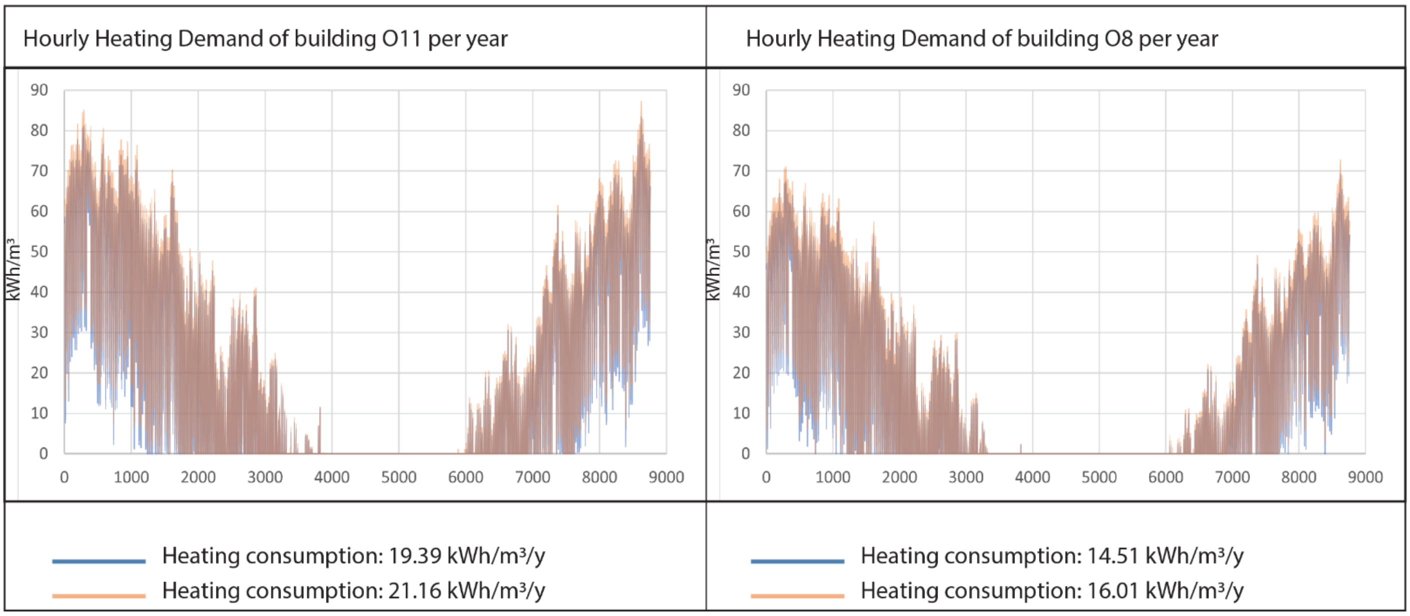


Fig. 185. **Hourly heating consumption of buildings O11 and O8 according to two floor U-values during a year.**

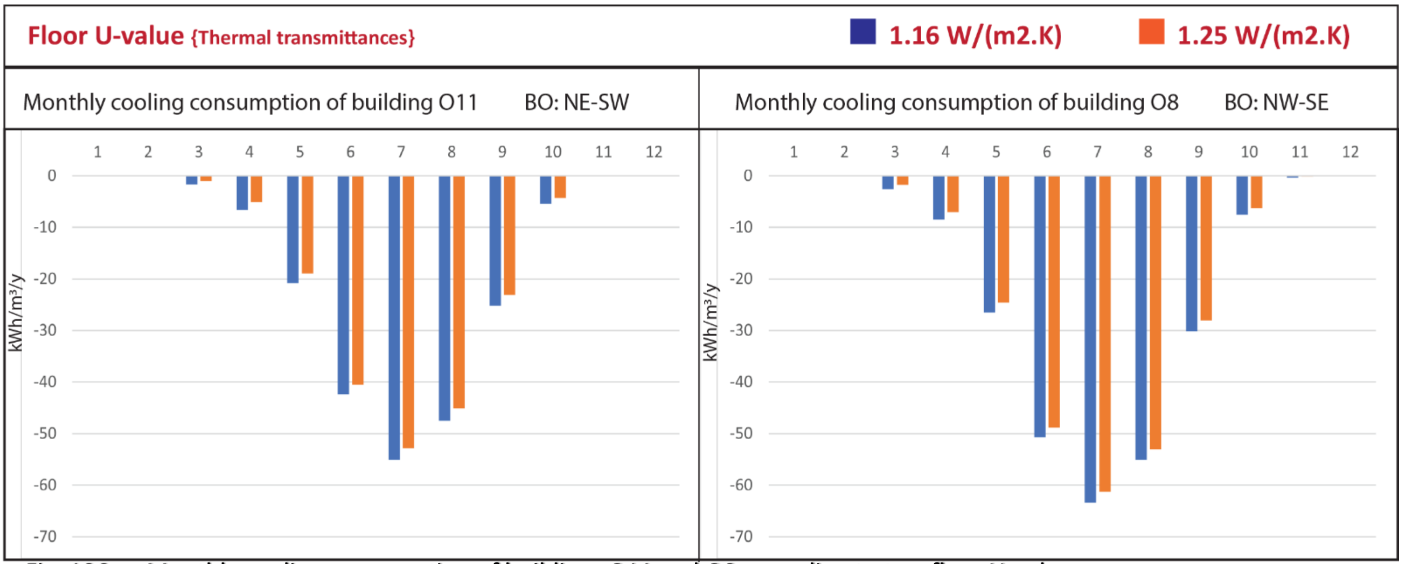


Fig. 186. Monthly cooling consumption of buildings O11 and O8 according to two floor U-values.

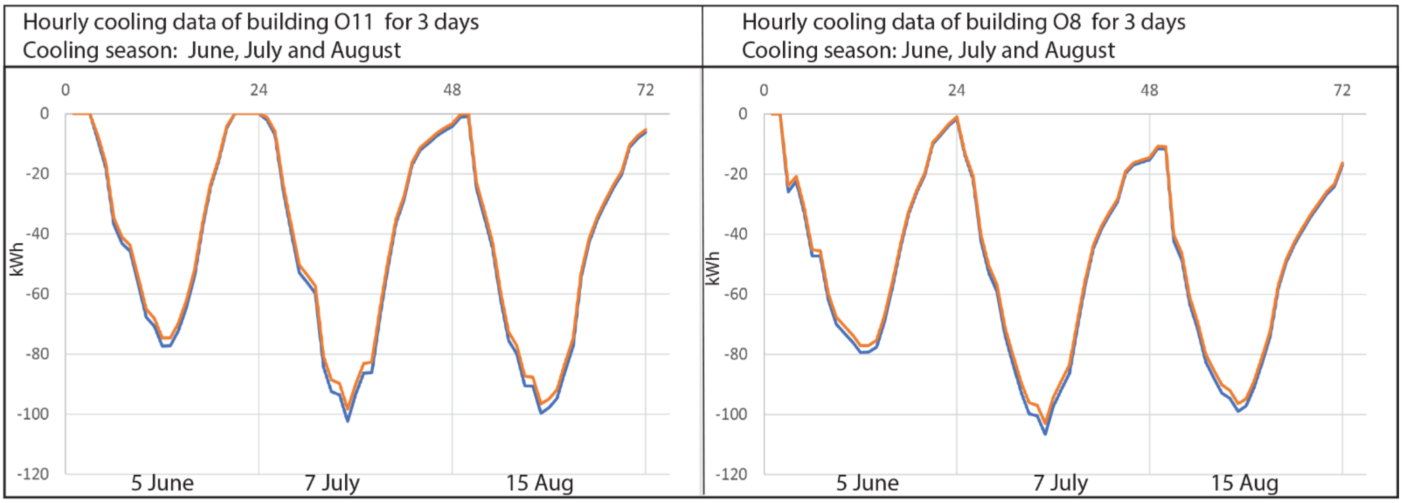


Fig. 187. Hourly cooling consumption of buildings O11 and O8 according to two floor U-values during three days.

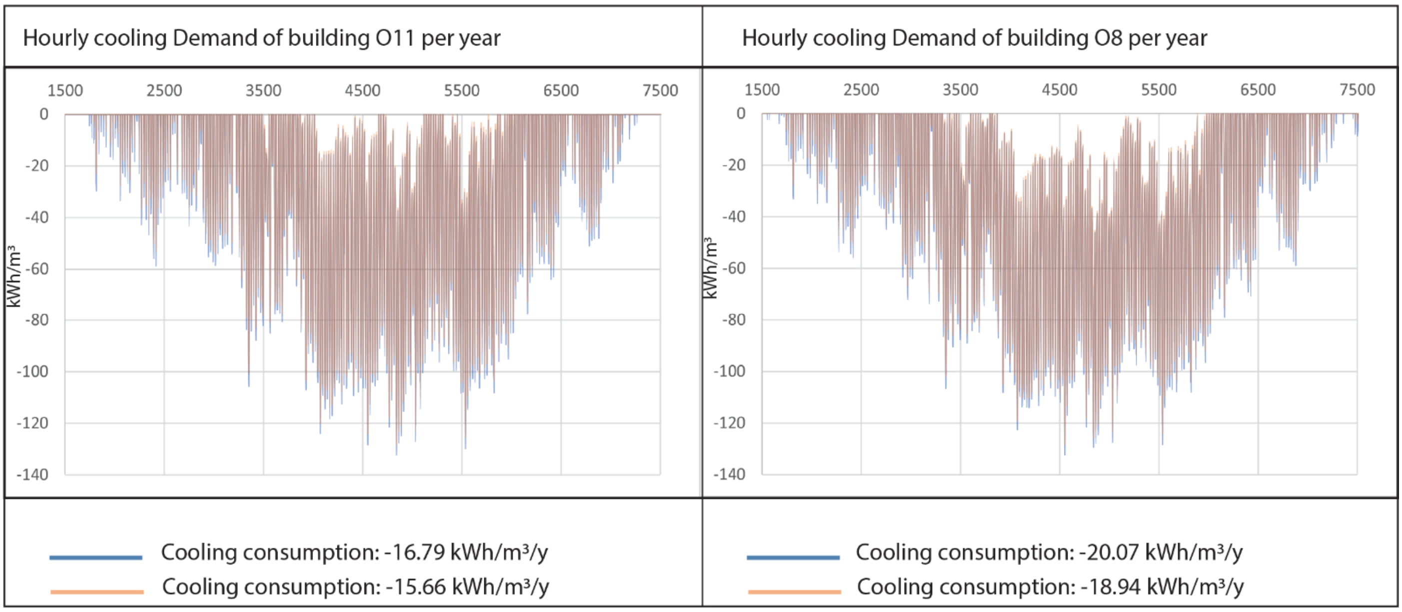


Fig. 188. Hourly cooling consumption of buildings O11 and O8 according to two floor U-values during a year.

to the heating consumption (previously analyzed), the monthly cooling Energy demands of both structures were the highest compared to the other roof composite (SOL03, represented in blue).

Adding to that, an hourly Energy data was conducted O11 and O9, for three days during the cooling season: 5th of June, 7th of July and 15th of August (Fig. 187.). Results show that, for both analyzed residential buildings, the highest Energy Utilization was on the 15th of August, while the lowest one is represented on the 7th of July. In fact, for building A1 characterized by a {NE-SW} orientation, and A9 with a {NW-SE} orientation, during the whole yearly cooling season (equivalent to 8761 simulated hours), both structures with the most recent floor composite (1961-2005), characterized by a thermal transmittance equal to 1.25 {W/m^2. K}, (represented in orange), constantly had the highest cooling Energy demand.

6-DISCUSSION

In this conducted sensitivity analysis, different results were visible regarding six studied building variables. In fact, the simulated chosen building results, are separated into several categories: Infiltration rate, Glazing ration and composite and materials thermal transmittances. Fig. 189. Reflects the heating and cooling energy consumptions results of the simulated residential structures

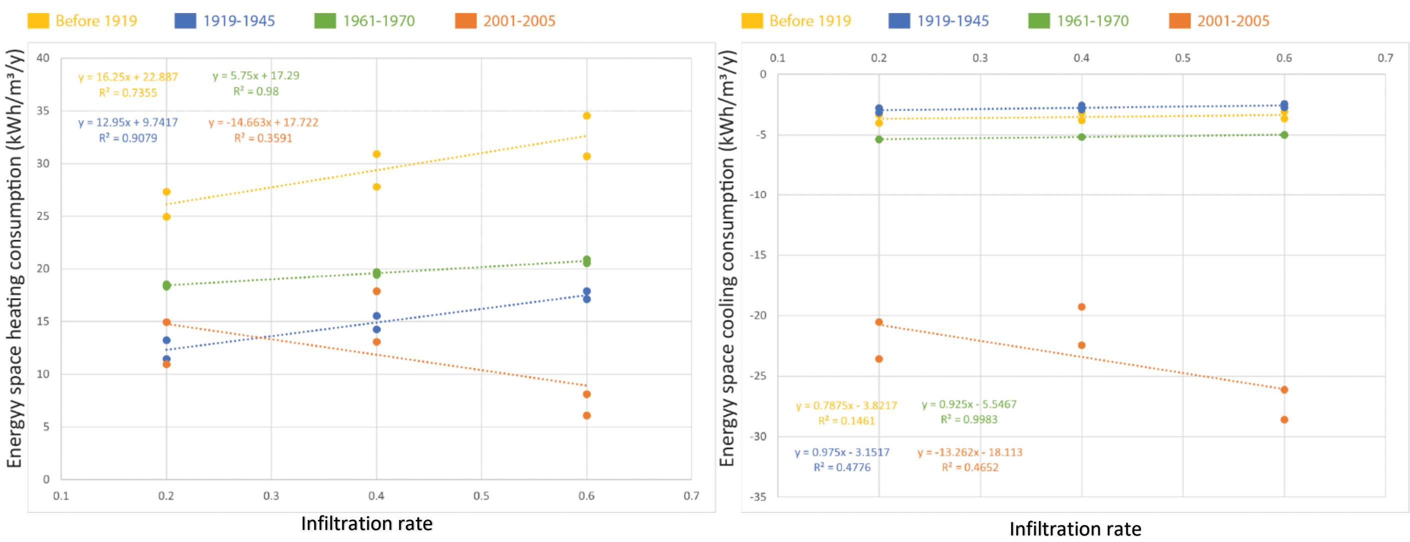


Fig. 189. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on the infiltration rate.

in Sacchi {illustrated in yellow}, Crocetta {illustrated in blue}, Arquata {illustrated in green}, and Olympic Village neighborhood {illustrated in orange}. In fact, when the infiltration rate increased, mostly all the results show a higher energy utilization. Therefore, having the smallest infiltration rate (0.2 in this case), is the ideal range to have regarding the energy consumption. Adding to that, the buildings characterized by the oldest period of construction {before 1919}, had the highest impact in the heating and cooling demand compared to periods ranging from 1919 until 1970. However, when this rate was equal to $0.6h^{-1}$, the newest built constructions, {2001-2005} in Olympic village district, the heating Energy utilization of the residential structures, considerably decreased compared to infiltration rates equal to 0.2 and 0.4.

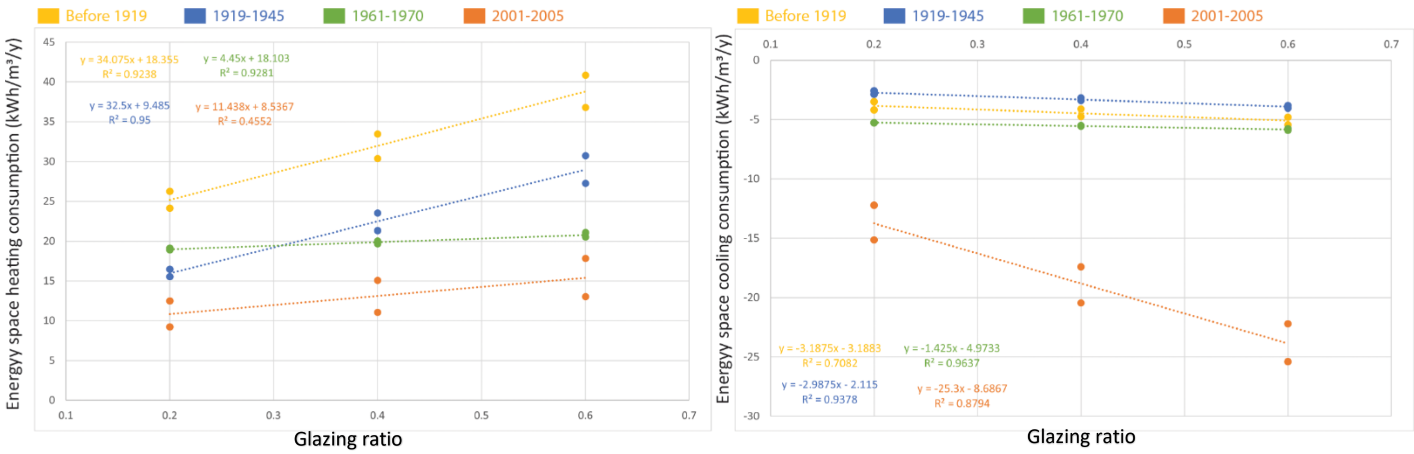


Fig. 190. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on the glazing ratio.

Fig. 190. Represents the combined heating and cooling energies of the analyzed building with different periods of construction, depending on the glazing ratio, in the four respectively studied neighborhoods. In fact, results show, that whenever the window to wall ratio increases, all the residential structures' energy consumption increased simultaneously. Therefore, the best range in this study for the glazing ration in relation to energy utilization, is equal to 0.2. Adding to that, buildings that are characterized by an older period of construction, (before 1919, and 1919-1945), had a higher impact in heating energy demands, compared to newer residential buildings (1961-2005). However, for the cooling Energy demand, results completely differed. In fact, newly constructed structure {2001-2005} had a much higher impact compared to older ones such as structures that are located in Sacchi and Crocetta districts.

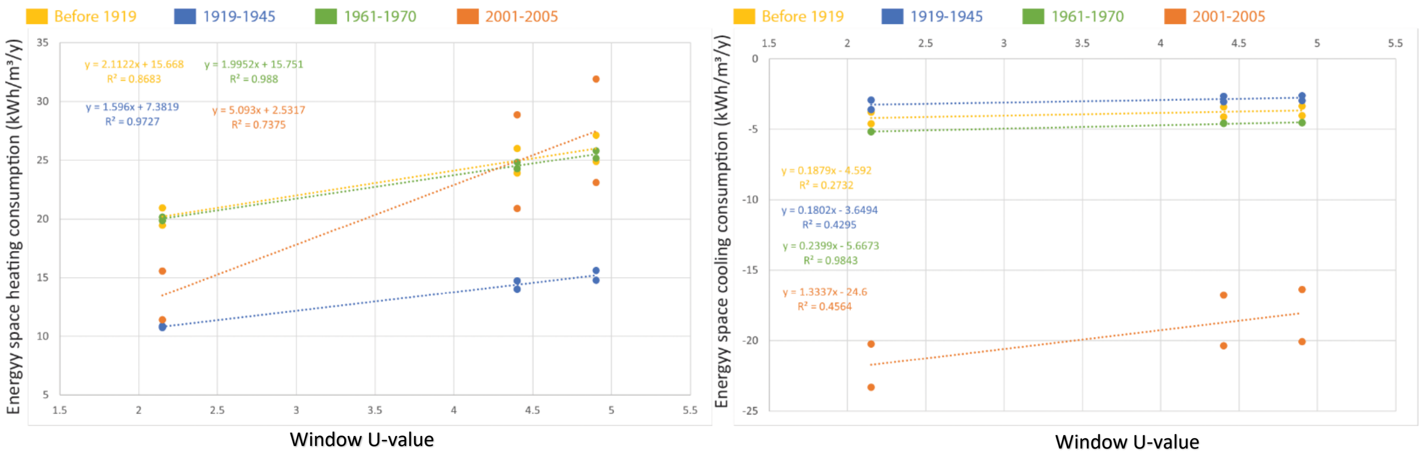


Fig. 191. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on windows U-values.

Fig. 191. Represents the combined heating and cooling energies of the analyzed building with different periods of construction, depending on the windows U-value, in the four respectively studied neighborhoods. In fact, results show, that whenever the window's U-value increased, all the examined residential buildings' heating energy consumption simultaneously increased as well, while the cooling energy demand decreased. This is mainly due to the lower windows insulation, and thus the unwanted penetration of the outdoor air into the building during the heating and cooling seasons. Therefore, the best range in this study of the windows U-value, in relation to energy utilization, is equal to the lowest studied value of 2.15 {W/m^2. K}, generally used in recent constructions {2001-2005}, due to the much higher impact in heating demand, compared to the cooling energy utilization. Adding to that, in this variable, the heating and cooling energy consumptions, when the windows U-values increased, had the highest impact in the most recently constructed residential building {2001-2005, in this case}, found in Olympic Village neighborhood.

Fig. 192. Represents the combined heating and cooling energies of the analyzed building with different periods of construction, depending on the walls U-value, in the four respectively studied neighborhoods. In fact, results show, that aal of the studied residential buildings, had the highest increase in heating and cooling demands, with a wall thermal transmittance equal to 0.9 {W/m^2. K}, that represents a wall composite of MLP03, generally used in constructions periods ranging between 1961 and 1970, in comparison to MLP02 (with U-value equal to 1.1 {W/m^2. K}, used in construction periods between 1919-1945), and MPF03 (with U-value equal to 0.67 {W/m^2. K}, used in construction periods between 2001-2005) walls composites. While with a wall thermal transmittance of 0.67 {W/ (m^2. K)}, buildings consumed the least energy heating demands.

Therefore, the best range in this study of the walls U-value, in relation to energy utilization, is equal to the lowest studied value of 0.67 {W/m^2. K}, generally used in recent constructions {2001-2005}, due to the much higher impact in heating demand, compared to the cooling energy utilization. Adding to that, the buildings characterized by the oldest period of construction {before 1919 and 1919-1945}, had the highest impact in the heating and cooling demand compared to more recent periods of constructions, ranging from 1961-1970 and 2001-2005, according to this case study.

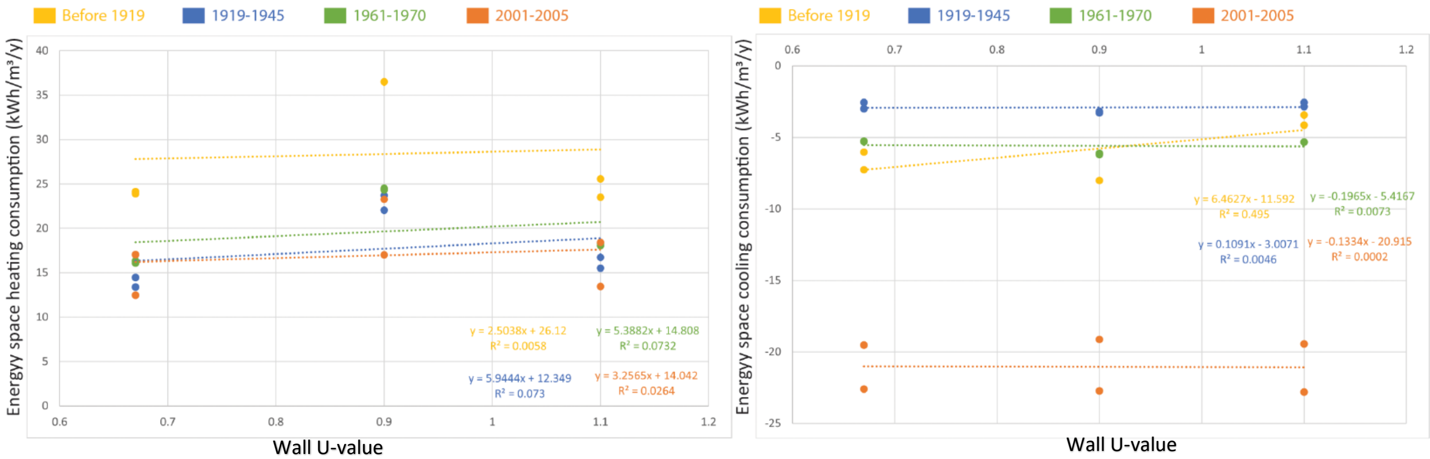


Fig. 192. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on walls U-values.

Fig. 193. Represents the combined heating and cooling energies of the analyzed building with different periods of construction, depending on the roof U-value, in the four respectively studied neighborhoods. In fact, results show, that all the studied residential buildings, had the highest increase in both heating and cooling demands, with a roof thermal transmittance equal to 1.27 {W/m^2. K}, that represents a roof composite of COP04, generally used in constructions periods ranging between 1961 and 1970, in comparison to COP01 (with U-value equal to 1.60 {W/m^2. K}, used in construction periods between 1919-1945), and COPO03 (with U-value equal to 0.53 {W/m^2. K}, used in construction periods between 2001-2005) walls composites. While with a wall thermal transmittance of 0.53 {W/ (m^2. K)}, buildings consumed the least energy heating demands. Therefore, the best range in this study of the walls U-value, in relation to energy utilization, is equal to the lowest studied value of 0.53 {W/m^2. K}, generally used in recent constructions {2001-2005}. Adding to that, the buildings characterized by the oldest periods of construction {before 1919 and

1919-1945}, had the highest impact in the heating and cooling demand compared to more recent periods of constructions, ranging from 1961-1970 and 2001-2005, according to this case study.

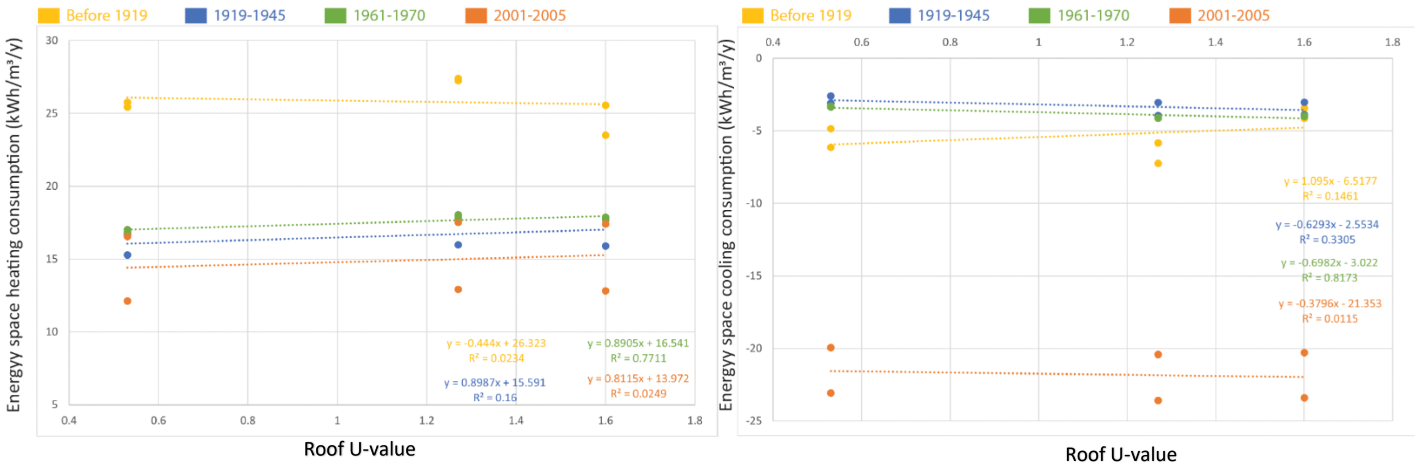


Fig. 193. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on roof's U-values.

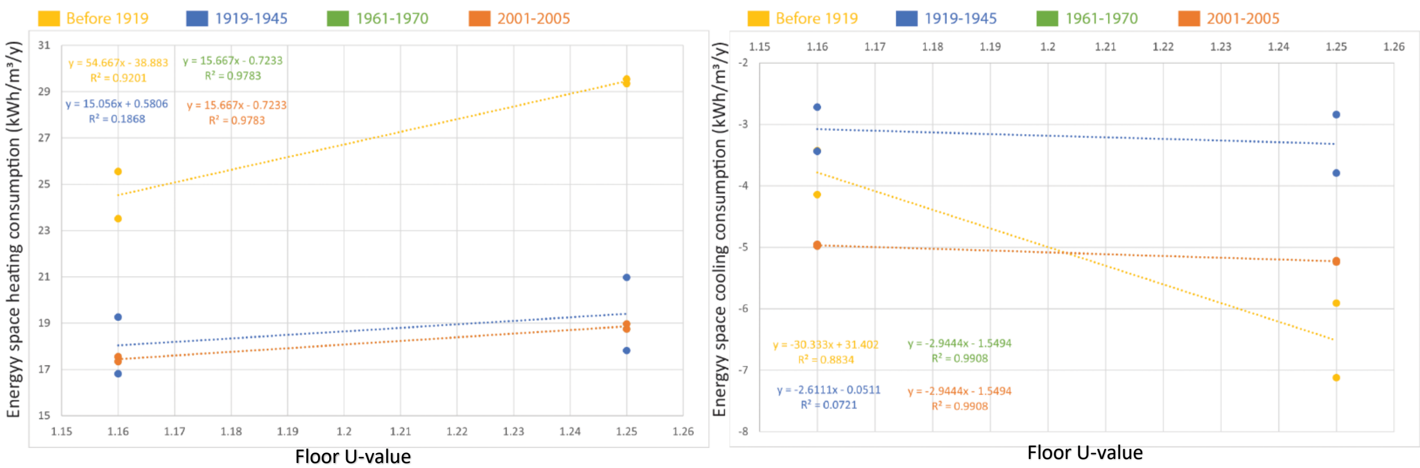


Fig. 194. Combined heating and cooling energies of the analyzed building with different periods of construction, depending on floor U-values.

Fig. 194. Represents the combined heating and cooling energies of the analyzed building with different periods of construction, depending on the floor U-value, in the four respectively studied neighborhoods. In fact, results show, that all the studied residential buildings, had the highest increase in both heating and cooling demands, with a floor thermal transmittance equal to 1.25 {W/m^2. K}, that represents a floor composite of SOL04, generally used in constructions periods ranging between 1961 and 2005, in comparison to SOL0301 (with U-value equal to 1.16 {W/m^2. K},

used in construction periods between 1919-196). While with a floor thermal transmittance of 1.16 {W/ (m^2. K)}, buildings consumed the least energy utilization. Therefore, the best range in this study of the U-value, in relation to energy utilization, is equal to the lowest studied value of 1.16 {W/m^2. K}, generally used in older constructions {1919-1961}. Adding to that, the buildings characterized by the oldest period of construction {before 1919}, had the highest impact in the heating and cooling demand compared to more recent periods of constructions.

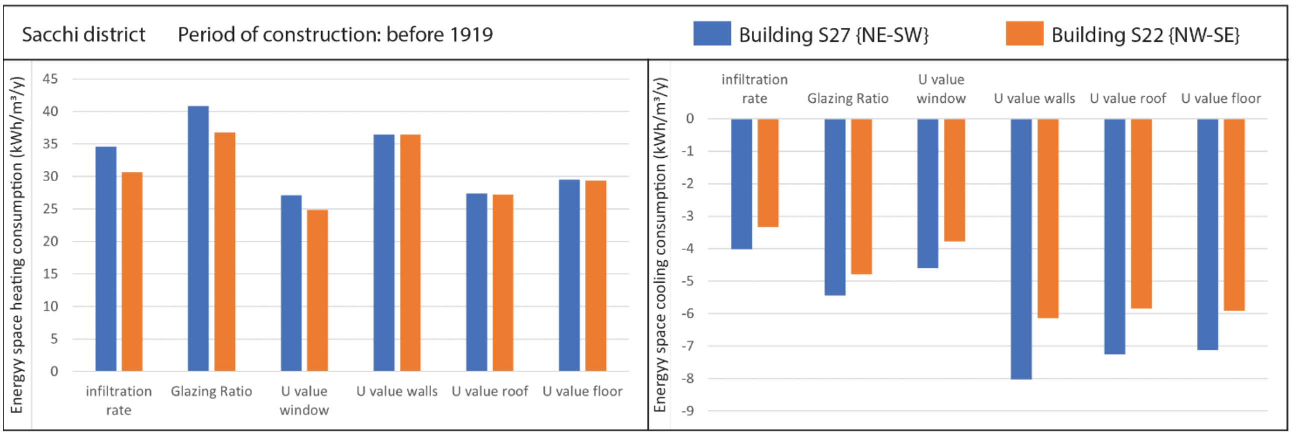


Fig. 195. **Impact of the six analyzed building variables, in Sacchi neighborhood.**

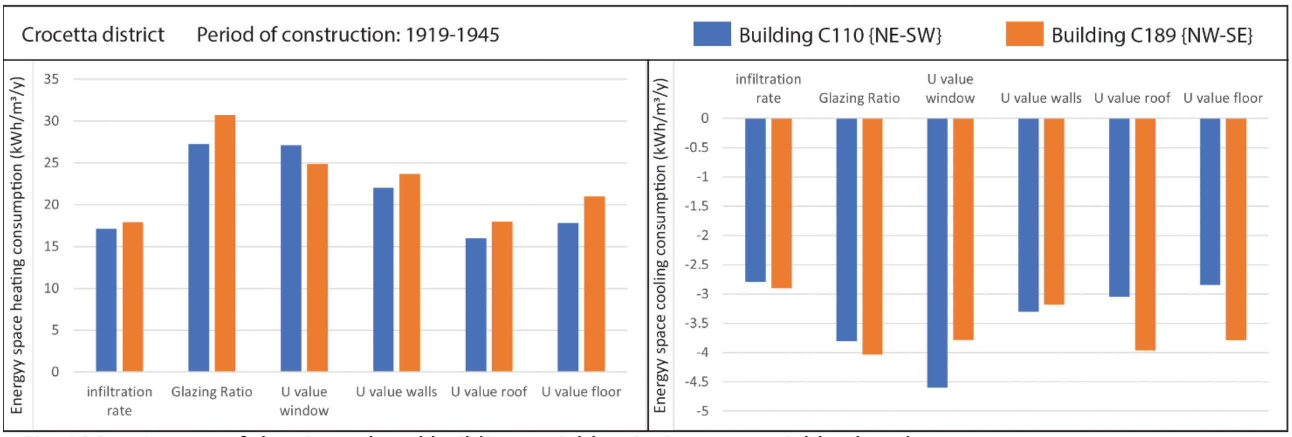


Fig. 196. **Impact of the six analyzed building variables, in Crocetta neighborhood.**

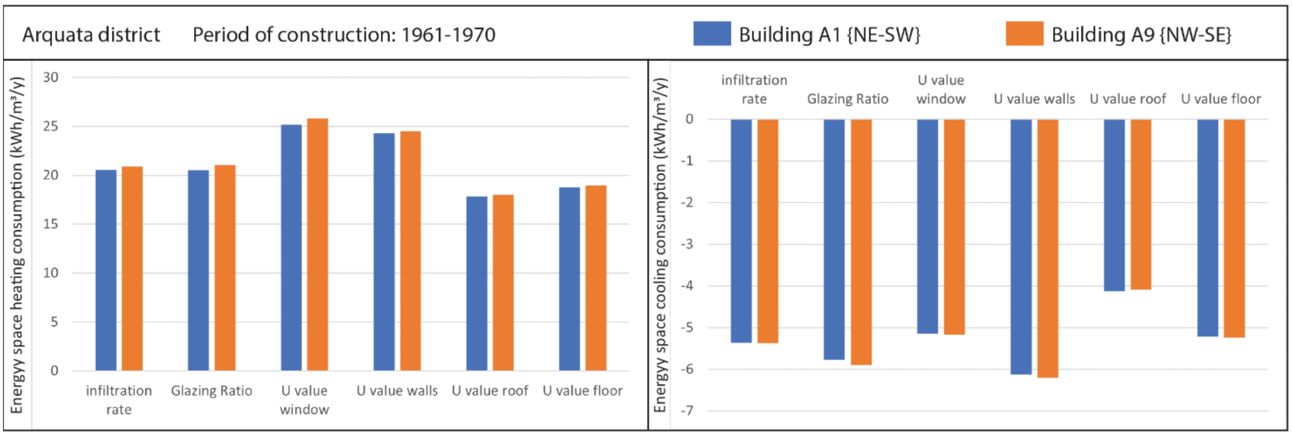


Fig. 197. **Impact of the six analyzed building variables, in Arquata neighborhood.**

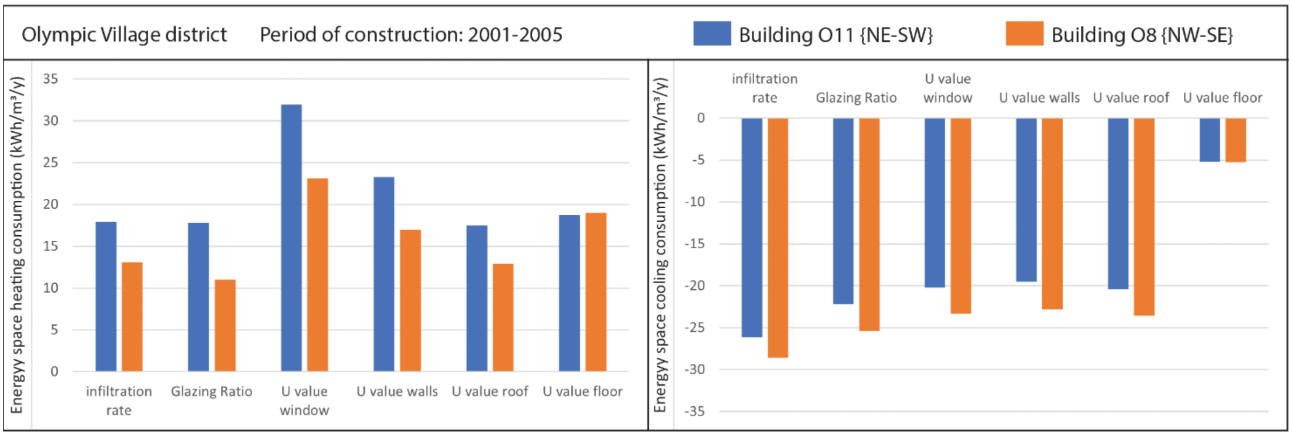


Fig. 198. Impact of the six analyzed building variables, in Olympic Village neighborhood.

From Fig. 195., until Fig. 198., shows the energy heating and cooling consumption of each examined building located in the four districts, in the city of Turin (Sacchi, Crocetta, Arquata and Olympic Village neighborhood), depending on the changed ranges of the six studied building variables: infiltration rate, glazing ratio, Windows U-value, Wall, roof and floor U-values. Results show that, for the oldest two examined buildings, in sacchi {constructed before 1919}, and Crocetta district {constructed in 1919-1945}, the variable that had the most impact on the heating utilization, is the structure's glazing ratio {window to wall ratio}. Whereas for the more recent periods of constructions (Arquata and Olympic Village in this case), the windows U-value, played the biggest role in impacting the building's warmth energy consumption.

Adding to that, residential structures that are characterized by periods of constructions of before 1919 and, 1961-1970, had the highest impact in cooling energy utilization in regard the building's walls U-value. While the most recent construction of 2001-2005 in Olympic Village neighborhood, had the highest cooling Energy demand with the change of the infiltration rate. Whereas the floor U-value, had the least impact in comparison to the other examined building variables.

7-CONCLUSION

Nowadays In metropolitan settings, the utilization of energy in buildings is one of the fundamental drivers of ozone depleting substance discharges. In fact, the atmosphere and the ambient air quality of urban communities that have a warm equilibrium relying upon the Thermal utilizations of structures cause an expansion of two main phenomena in metropolitan areas: urban heat island mitigation and climate change. The aim of this work had been to showcase how different building variables and urban parameters can impact the residential buildings Energy heating and cooling Consumptions. In fact, the results of this examination show an immediate connection between the energy consumption of these residential structures and the six main Analyzed variables at building and neighborhood scale: infiltration rate, glazing ratio, and buildings composites and materials thermal transmittances. It has been showed that, when the infiltration rate, the glazing ratio, windows U-value, walls, roof, and floor's U-values increased, the buildings tend to consume more yearly energy demands. Adding to that, buildings that are characterized by older periods of constructions {before 1919, and 1919-1945, in this case}, had a higher warmth energy demand impact compared to more recent constructions {1961-1970, and 2001-2005, in this case}. However, the cooling energy consumption had a higher impact on newly built structures in regard to older ones. Adding to that, according to the simulated results, the heating energy consumption are much higher than cooling demands for all buildings. the oldest two examined buildings, in sacchi {constructed before 1919}, and Crocetta district {constructed in 1919-1945}, the variable that had the most impact on the heating utilization, is the structure's glazing ratio {window to wall ratio}. Whereas for the more recent periods of constructions (Arquata and Olympic Village in this case), the windows U-value, played the biggest role in impacting the building's warmth energy consumption. However, residential structures that are characterized by periods of constructions of before 1919 and, 1961-1970, had the highest impact in cooling energy utilization in regard the building's walls U-value. While the most recent construction of 2001-2005 in Olympic Village neighborhood, had the highest cooling Energy demand with the change of the infiltration rate. Whereas the floor U-value, had the least impact in comparison to the other examined building variables. In order to have the least possible yearly powered energy utilizations for residential buildings, in this case study, several ideal ranges were found for each studied variable: 0.2 h^{-1} for the infiltration rate, 0.2 for the window to wall ratio, 2.15 $W/(m^2. K)$ for the windows' U-value, 0.67

W/(m^2. K) for the walls' U-value, 0.53 W/(m^2. K) for the roof's U-value, and finally 1.16 for the floor's U-value. This sensitivity analysis approach can help in understand how different building's Energy-based variables can impact the residential structures heating and cooling yearly energy utilization differently according to the building's period of construction. The results of this study can be used as tool to support the futural built constructions, at the earliest possible design phase of the building in order the optimize the structure's energy consumptions.

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