PERIODICO di MINERALOGIA
ISSN: 0369-8963

Volume 92, No. 3, 2023

Adaptation of the building envelope through passive bioclimatic strategies to ensure energy efficiency
Study case: individual dwellings (algeria : guelma)

Mokhnache Nardjesse[1], Alkama Djamel[2]
[1] *Department of Architecture, University of Guelma,; Laboratory L.G.C.H Algeria*
mokhnache.nardjess@gmail.com
[2] *Department of Architecture, University of Guelma,; Laboratory L. E.V.E, Algeria*
dj.alkama@gmail.com

Abstract:

The energy consumption is an indicator of the inhabitants' satisfaction with the indoor thermal environment, and it reflects the situation of climate stress in terms of greenhouse gas emissions. Hence, it is crucial to reason the consumption in order to reduce the ecological footprint.

The objective of this research is to demonstrate that the energy efficiency of the building can be improved by addressing its envelope through the adoption of a passive bioclimatic strategy on a sample of houses located in a semi-humid climate in the city of Guelma. The approach by in-situ measurements inside the houses, such as temperature, relative humidity, and air velocity, reveals indoor temperatures beyond the comfort ranges due to the lack of envelope performance. The results of this research demonstrate that a high-performance envelope that taps into the bioclimatic potential by applying passive bioclimatic strategies to provide the necessary thermal corrections for ensuring thermal comfort can improve the building's energy efficiency.

The results of this research demonstrate that a high-performance envelope that taps into the bioclimatic potential by applying passive bioclimatic strategies to provide the necessary thermal corrections to ensure thermal comfort can improve the energy efficiency of the building.

Keywords: *energy efficiency, building envelope, individual dwelling, passive bioclimatic strategies, Guelma.*

1. Introduction

The ultimate goal of any architecture is to ensure the comfort of human beings who seek to meet their thermal needs by resorting to technologies to regulate their thermal environment within their homes. Which can be defined as an industry of protection and comfort. (Marcel.M,1947). It constitutes a place of life where the human being is sheltered from various dangers that he or she feels the need to protect himself or herself from. The role of housing is therefore to ensure human beings protection and comfort. The definition of thermal comfort can be stated as a mental or satisfactory condition that specifies an individual's judgment of comfort (Lin, Z. and S. Deng, 2008). Two people sitting side by side in the same room at the same temperature could have different thermal comfort satisfaction levels from one another

https://doi.org/10.37896/pd92.3/9237

(Alwetaishi, 2016)

To regulate their thermal environment, the inhabitant adopts energy-intensive behaviors, drawing on the fossil energies at their disposal. However, any energy consumption generates an ecological footprint. According to the Global Footing Network, our way of life currently requires 1.75 planets for our resource consumption to be compensated at the global level. Each year, this network calculates the "day of overshoot", the point at which humanity has consumed the resources that the Earth can compensate for in one year. In 2020, the overshoot day was August 22nd."

4.1 Energy efficiency and passive house

In their pursuit of comfort, occupants often adopt energy-intensive behaviors to regulate their thermal environment through the use of air conditioning in the summer, drawing on polluting fossil fuels that emit CO2 resulting from the energy consumption of buildings. In the field of housing, we talk about its insulation or we can compare energy consumption between different buildings, based on a unit of (kW/m^2/year). It is important to note that a building that consumes a lot of energy is typically poorly insulated.

Many buildings have not been designed and constructed with consideration for the specific nature and context of the environment in which they are located. (Tarbouch, H and al), This mismatch between construction and its environment leads to increased energy consumption, which is why it is essential to ensure energy efficiency. Energy efficiency is the ratio between the useful energy produced by a system and the total energy consumed to operate it effectively. This definition can be expanded to encompass all technologies and practices aimed at reducing energy consumption while maintaining an equivalent level of performance, with the goal of achieving more with less.

The concept of energy efficiency is often interpreted in a broader sense to refer to technologies and practices that reduce energy consumption while maintaining an equivalent level of final performance. According to the International Energy Agency (IEA), energy efficiency is considered a means to control and reduce energy consumption.

Energy efficiency involves the use of processes and technologies to meet needs while saving as much energy as possible. The goal is to achieve the same level of service while consuming less energy, or even to do better with less energy. This approach ensures comfortable living spaces while reducing energy consumption and ecological footprint. It involves providing the same services while consuming less energy or doing better with less.

To improve energy efficiency, a bioclimatic approach must be adopted to restores architecture to its relationship with the environment to maintain the dynamic interaction between humans and the environment. It is about ensuring a balance between construction and its environment by placing humans at the center. It is also important to act on the exterior envelope of buildings, which is the conductor of energy consumption, as reducing the surface area of energy loss reduces energy consumption.

Improving energy efficiency in the building sector is a priority in order to preserve the environment, meet needs, and ensure the ability of future generations to meet their own needs. To achieve this, it is essential to consider both the inhabitant and technology as an interaction phenomenon between the two. Energy technologies and occupants' behavior have traditionally been treated as separate actors in the fields of comfort, energy engineering, and social domains. Recent efforts attempt to connect them by considering energy consumption as a result of human activity in a context of interrelationships between users, technologies, skills, and social contexts. (Marco,A.2017).

Passive buildings establish a relatively resilient way of life because they reduce energy consumption by using thermal inertia and appropriate building materials, as well as the orientation and shape of the building, in addition to a range of passive processes. Passive strategies have been used for centuries in some parts of the world, providing both economic and environment-friendly solutions that are adapted to the local context. They take into account temperature, orientation, and wind, and can also take advantage of local orography to regulate indoor temperature or use materials with high thermal mass or high-quality insulation. (FRECHMANN, K et al, 2011) A passive house is a building with a pleasant indoor climate in winter and summer without conventional heating or cooling systems. This is made possible by drastically reducing heating requirements, mainly through architectural and construction measures. (Maisonpassive.be)

To qualify as a passive building, certain technical requirements must be met, including:

- Reinforced thermal insulation and high-quality windows
- Elimination of thermal bridges
- Excellent air tightness
- Double-flow ventilation system (with heat recovery)
- Optimal but passive solar and ground heat capture
- Limitation of household appliance consumption.

Passive buildings do not sacrifice comfort for energy savings; in fact, they increase comfort while reducing energy consumption through their high-performance envelope. According to the 90.1-2016 standard, new technical envelope requirements include:

- Mandatory requirements for verifying the envelope, with particular attention to reduced air infiltration and increased requirements for air leakage to overhead doors.
- Stricter prescriptive requirements for steel construction, roofs and walls, fenestration, and opaque doors.
- Improved clarity of definitions for exterior walls, building orientation, and clarity around the R-value.
- New requirements based on the addition of climate zone 0. (El-Darwish, I.2017)

It is also important to note that passive buildings are adapted to their environment, using appropriate materials, orientation, and renewable energy sources to ensure a comfortable thermal environment while applying heating and cooling strategies to rationalize energy consumption.

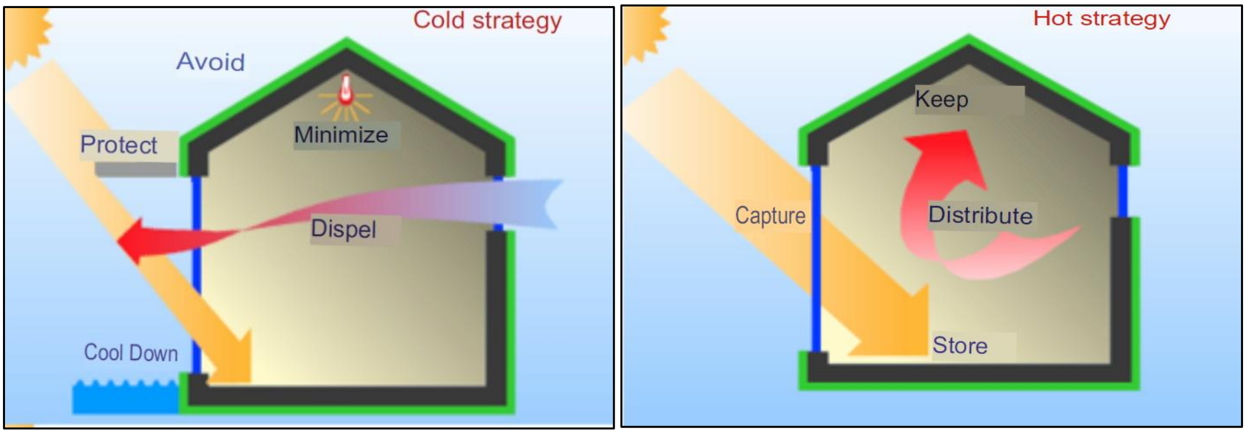


Figure 1 bioclimatique strategys
A. Cold strategy
B. Hot strategy

The bioclimatic cooling strategy consists on following five major steps, avoid: high performance envelope, protect: solar shading, cool: water features, vegetation, minimize internal heat gains, dissipate: natural ventilation. (See figure: 1).

The bioclimatic heating strategy consists of five major steps, capture: optimizing openings, store: in heavy surfaces (walls, floors, and roof), distribute: flow and circulation of air, retain: in heavy surfaces (walls, floors, and roof). (See figure: 1).

A

B

4.1 Retrofitting strategy for building envelope

Unfortunately, retrofitting of existing buildings in the third world countries focuses on structural or aesthetic measures and mainly on historical buildings for conservation. Reducing energy consumption levels is of equal importance due to its financial impact. It should not be

reduces carbon dioxide emissions and pollutes less the environment (B. Basarir, et al, 2016).

According to Joseph Rowntree Housing Trust (JRHT) thermal performance of a building relies on its ability to resist air penetration as well as its ability to prevent heat exchange through structure.

In general, building envelopes include the resistance to air, water, heat, light, and noise transfer. As for thermal envelopes, they include outer walls, roof, foundation, windows and doors. The purpose of the thermal envelope is to prevent heat transfer form interior of a house to its exterior in winter and vice versa in summer. For instance, windows in educational spaces should be located at the sides and if subject to solar gain should be tinted glass with a “low E” rating to reduce heat transfer

The building envelope is the physical barrier between the interior and exterior of a building, and it plays a crucial role in determining the building's energy efficiency. The envelope's design, materials, and insulation can all have a significant impact on the amount of energy required to heat and cool the building. For example, a well-designed envelope with high-quality insulation can help to reduce heat loss in the winter and heat gain in the summer, reducing the amount of energy needed for heating and cooling. On the other hand, a poorly designed or poorly insulated envelope can lead to energy losses and increased energy consumption. Therefore, optimizing the design and construction of the building envelope is an important step in improving the energy efficiency of buildings

1..1. Selected criteria

After reviewing previous studies, it has been determined that improving the building envelope could lead to greater energy efficiency. The modifications to the building envelope could include changes to the design, materials, insulation, or other factors that affect the energy performance of the building. By implementing these modifications, it is expected that the energy efficiency of the building can be improved.

- **Thermal insulation**

Thermal insulation refers to the materials and techniques used to reduce the transfer of heat between the interior and exterior of a building. The goal of thermal insulation is to create a barrier that slows down the transfer of heat, keeping the interior of the building warmer in the winter and cooler in the summer.

Extruded polystyrene has been suggested for thermal insulation on the outside of the building in hot regions. (Atia. S et al , 2009). the thermal resistances (R-values) between 0.90 and 2.3 m2 °C/W for wall and roof sections respectively are recommended. As part of the retrofit plan, edge insulation for window systems are proposed to minimize thermal bridging in the buildings of hot regions.

- **Glazing**

The choice of glazing type depends on several factors, such as the climate, the building orientation, the desired level of natural light, and the energy performance goals. In general, selecting the right type of glazing can help to improve energy efficiency, occupant comfort, and overall building performance.

Currently single-glazed, with clear glass and poorly insulated frames are mostly used in many regions of the world. These have *U*-values of approximately 4.5 watts per square meter Kelvin (W/m^2 K) to 5.6 W/m^2 K. Most of the OECD (Organization for Economic Co-operation and Development) member countries have moved to double-glazed windows with low-e coatings, low conductive frames, and inert gas are used in the residential section that provides lower *U*-values (OECD/IEA

- **Solar protection**

Solar protection refers to the various measures taken to reduce the amount of solar radiation that enters a building through windows, skylights, or other openings. The use of solar shading devices is an important aspect in many energy-efficient building design strategies. Some of the solar control and shading systems according to Whole Building Design Guide (2016) include: external overhangs (fins); horizontal reflecting surfaces (light shelves); low shading coefficient (SC) glass; interior glare control devices such as Venetian blinds or adjustable

https://doi.org/10.37896/pd92.3/9237

louvers; and landscape features such as mature trees or hedge rows

- **Vegetation**

vegetation into buildings can provide several benefits, such as reducing the urban heat island effect, improving air quality, and providing habitat for wildlife

- **Reflective roof**

By reflecting solar radiation, reflective roofs can reduce the amount of heat absorbed by the building, which can help to reduce cooling loads and improve energy efficiency, especially in hot and sunny climates.

2. Method and Materials

The correlation between Givoni's study, which determines large zones of underheating and overheating, and the in-situ measurement approach inside the dwelling (temperature, relative humidity, air velocity) reveals indoor temperatures beyond the comfort ranges, justifying the situations of climatic stress experienced by the occupants. The results of the measurement campaign will be compared with the TRNSYS V 16 software in order to propose bioclimatic correction scenarios to ensure energy efficiency.

- **Used materials**

Temperature and humidity readings were taken using a waterproof portable Thermo-Hygrometer, HANNA humidity ranging from 20% to 95%, and temperature ranging from 0°C to 60°C.9564 (see Figure 2). The HI 9564 model of portable thermo-hygrometers is designed to provide excellent performance in aggressive environments and poorly lit locations. It measures relative humidity and temperature, and features a probe with data calibration storage, as well as a sturdy housing, perfect for on-site measurements. It provides measurements of

Air velocity was measured using a Trotec BA16 thermo-anemometer (see Figure 3) equipped with a vane probe that facilitates measurements at air conditioning and ventilation systems. This anemometer allows for the measurement of wind speed, air flow, ambient temperature, and volumetric flow rate. It provides measurements ranging from 1 m/sec to 30 m/sec, and temperature ranging from -10°C to 60°C.

Figure 3 Thermo-Hygrometer, HANNA 9564

Figure 2 Thermo-Anemometer Trotec BA16

The results of the measurement campaign are compared with TRNSYS V16 software in order to perform simulations and propose thermal correction solutions for the building envelope.

TRNSYS (Transient System Simulation Tool) is a software package used for simulating the dynamic performance of renewable energy and building systems. The software is widely used for building energy simulations, and it can model a wide range of building systems and components, including heating, ventilation, and air conditioning (HVAC) systems, solar collectors, photovoltaic systems, and thermal storage systems.

In this case, the results of the measurement campaign were inputted into TRNSYS V16 software to perform simulations of the building's thermal performance. The simulations allowed for the modeling of various thermal correction solutions for the building envelope, which could be used to improve its energy efficiency. By using TRNSYS V16, researchers and engineers can test different scenarios and evaluate the effectiveness of various solutions before implementing them in the building. This helps to optimize the building's thermal performance and reduce its energy consumption.

3. Presentation of The Case Study

Guelma is a city in northeastern Algeria characterized by the climate of the mountainous coastal hinterland (Zone B), which is semi-arid. The city benefits from a great sustainable potential due to its forest and agricultural coverage, as well as the solar irradiation that covers 243.3 hectares per year. It also has a hydraulic potential with 264.96 million cubic meters of mobilizable water and multiple sources of hot water. The city is surrounded by four mountains, which define the living conditions and microclimate of the city. There are several cities around Guelma, including: Constantine - a major city located about 90 km to the west, Annaba - a coastal city located about 120 km to the north, Skikda - a coastal city located about 100 km to the east of Guelma , Om el bouaghy located about 140 kilometers to the south. (see Figure 4).

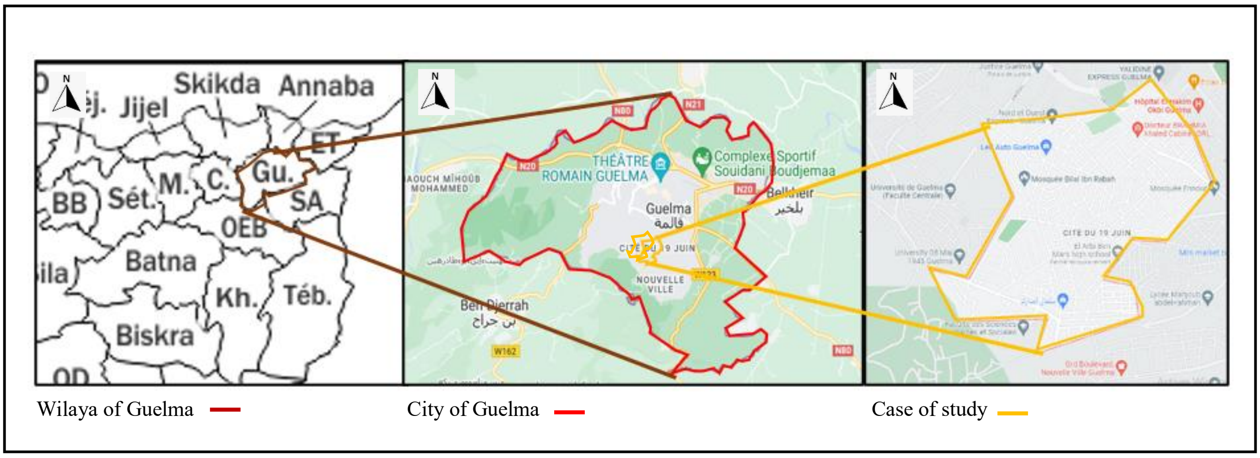


Figure 4 Location of case of study

a) Geographical location of wilaya of Guelma in Algeria
b) Geographical location of Guelma city
c) Geographical location of study case, Source: a) https://d-maps.com (Author's exploration) ; Source: b); c) https://www.google.com/maps Author's exploration)

The choice was made to sample three dwellings (see Table 2, 3, 4) located in the 19 June neighborhood (extension) according to the morphology of the terrain (Figure 5). The first sample is located upstream, while the second is in transit, and the third is located downstream of the slope, following the layout of the subdivision, as well as the parcel occupation and function. The selection criteria are detailed in Table 1. The measurement campaign took place over three consecutive days. The rooms under investigation were chosen according to the floor, orientation, and occupation.

Figure 5 The arrangement of the samples within the subdivision was determined using a modified version of Google Earth 2021 adapted by the author.

Table 1 Criterion for selecting samples

Sample	**Location**	**Morphology**	**Typology**	**Household**	**Function**
Sample 01	Allotment 309 n°289	Upstream	Completed construction	01	Housing
Sample 02	19 June n°321	In transit	Uncompleted construction	01	Housing/Service
Sample 03	19June 2 n°46	Downstream	Completed construction	03	Housing/Servic

Table 2 Sample 01 presentation

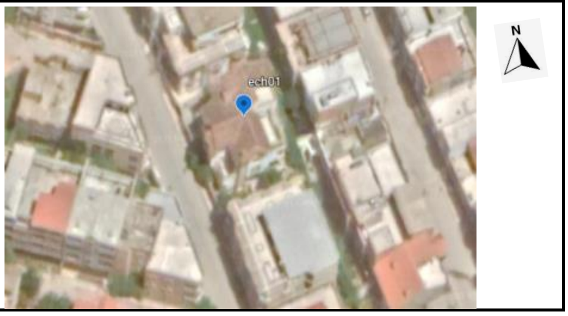
Sample 01	Villa R+2	
Total area	480 m2	
Built area	224 m2	
Ground occupancy coefficient	0.46	

Table 3 Sample 02 presentation

Sample 02	Villa R+2	
Total area	266 m2	
Built area	156 m2	
Ground occupancy coefficient	0.40	

Table 4 sample 03 presentation

Sample 01	Villa R+2	
Total area	280 m2	
Built area	266 m2	
Ground occupancy coefficient	0.40	

https://doi.org/10.37896/pd92.3/9237

4. Results and interpretation

This study aims to investigate how different parameters of the building envelope, such as insulation, glazing, solar protection, vegetation, and reflective roof affect the energy performance of a building. The envelope is the outermost layer of the building, separating the interior from the exterior environment. By studying the influence of these parameters on energy performance, we can gain a better understanding of how to optimize building design and construction for improved energy efficiency.

4.1 Influence of thermal insulation

Thermal insulation allows for a significant reduction in energy needs. In fact, during the winter period, the insulation blocks the transfer of heat to the outside, while during the summer period, thermal insulation reduces the heat transmitted from the outside.

There are several types of insulation available in the market, which are classified into five categories: synthetic insulation, mineral insulation, natural insulation, thin insulation, and new generation insulation. For our study, we will choose four types: rock wool (mineral insulation with λ=0.032 to 0.040 W/m.K), cork (natural insulation with λ=0.032 to 0.042 W/m.K), expanded polystyrene (synthetic insulation with λ=0.029 to 0.038 W/m.K), and aerogel (new generation insulation with λ=0.011 to 0.013 W/m.K).

Figure 6 illustrates the variation in energy consumption for the first sample for different types of thermal insulation. We can see a decrease in heating needs compared to the real case, which ranges from 12% for rock wool to 30% for aerogel. However, a slight increase in cooling needs is observed for the different insulation types. This is due to the glazing not being protected. Solar radiation entering the room causes overheating (greenhouse effect), which is compounded by thermal insulation. Despite this, the annual energy consumption decreases when using thermal insulation.

In summary, the study shows that thermal insulation can significantly reduce energy needs in buildings, and that different types of insulation have different levels of effectiveness. While thermal insulation can lead to increased cooling needs during the summer, the overall reduction in energy consumption and associated cost savings make it a worthwhile investment. Choosing the right type of insulation for a specific building depends on several factors, such as climate, building orientation, and budget. By optimizing the use of thermal insulation, building owners can improve energy efficiency, reduce environmental impact, and enhance occupant comfort.

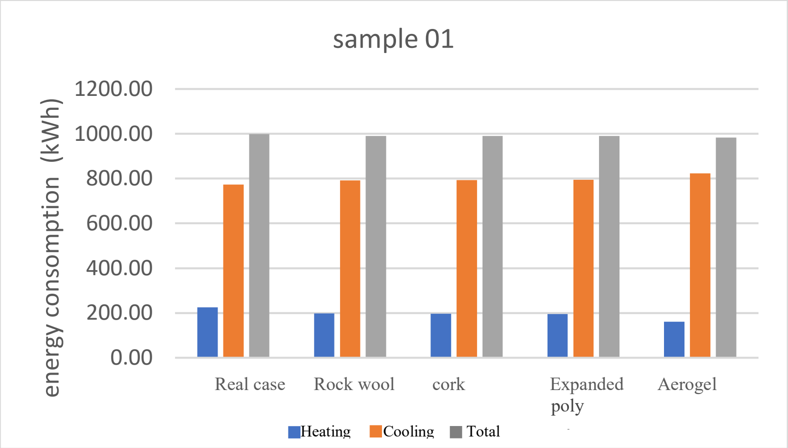


Figure 6 The variation in energy consumption of sample -1- for different types of thermal insulation (source: author)

For sample -2- shown in Figure 7, we observe a decrease in heating requirements ranging from 13% for rock wool to 31% for aerogel. While for air conditioning, we notice a slight increase but overall, the total annual energy consumption decreases for the different types of thermal insulation.

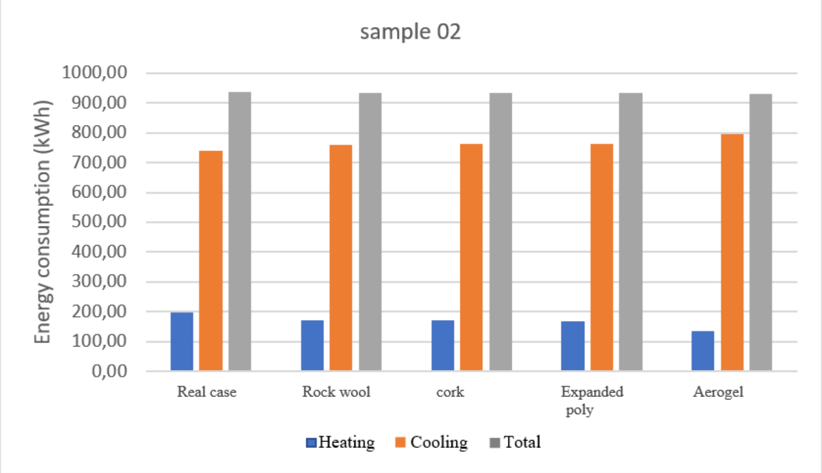


Figure 7The variation in energy consumption of sample -02- for different types of thermal insulation (source: author)

As for sample -3- shown in Figure 8, the decrease in heating requirements varies from 8% for rock wool to 17% for aerogel. A slight increase is obtained for air conditioning. A decrease in the total energy requirements is achieved for this sample.

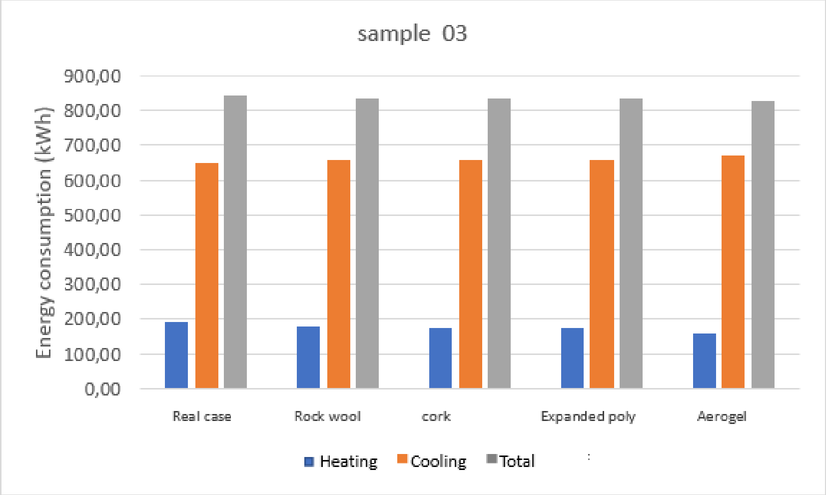


Figure 8 The variation in energy consumption of sample -03- for different types of thermal insulation (source: author)

4.2 Influence of the type of glazing

After studying the influence of thermal insulation on the energy needs of the three samples, we will now study the influence of the type of glazing. For this purpose, several glazing types are studied, namely: a single glazing (real case) (U = 5.74 W/m2.K, Tsol =0.85), a transparent double glazing (U = 2.95 W/m2.K, Tsol =0.72), a triple glazing (U = 2 W/m2.K, Tsol =0.62), a low-emissivity double glazing (U = 1.76 W/m2.K, Tsol =0.54) and a low-emissivity double glazing with argon (U = 1.43 W/m2.K, Tsol =0.54).

The heating and air conditioning needs of sample -1- are shown in Figure 9, which shows a considerable decrease in heating and air conditioning needs when changing the glazing, up to 13.6% for the double glazing. Indeed, for this type of glazing, the heating needs have decreased from 225 kWh to 200 kWh, as it has better thermal insulation than the single glazing with a solar transmission coefficient close to that of the single glazing, while the air conditioning needs decrease from 774 kWh to 633kWh (for the best glazing).

The low-emissivity double glazing with argon gives the lowest heating consumption.

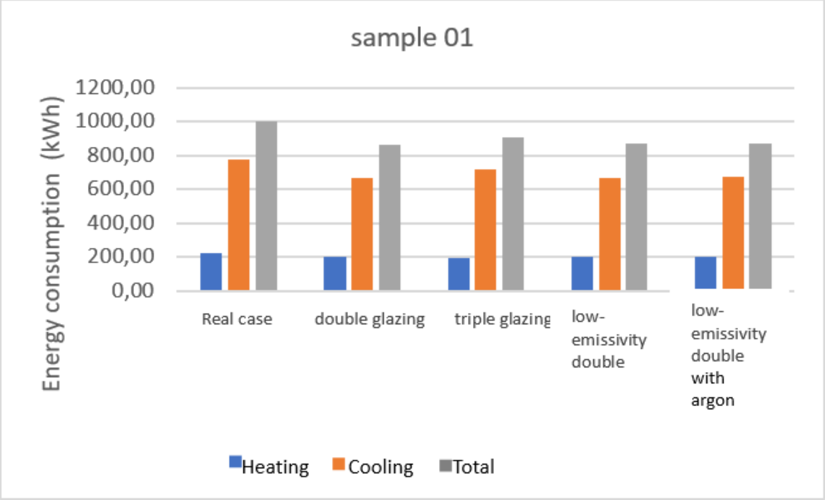


Figure 9 The variation in energy consumption of sample -01- for different types of glazing (source: author).

As for sample -2- shown in Figure 10, we see that the reduction is higher compared to the previous sample due to the presence of a large glazed area. The low-emissivity double glazing with argon is the most efficient in the winter period, while the low-emissivity double glazing is the most suitable in the summer period. However, the former has the lowest annual energy consumption.

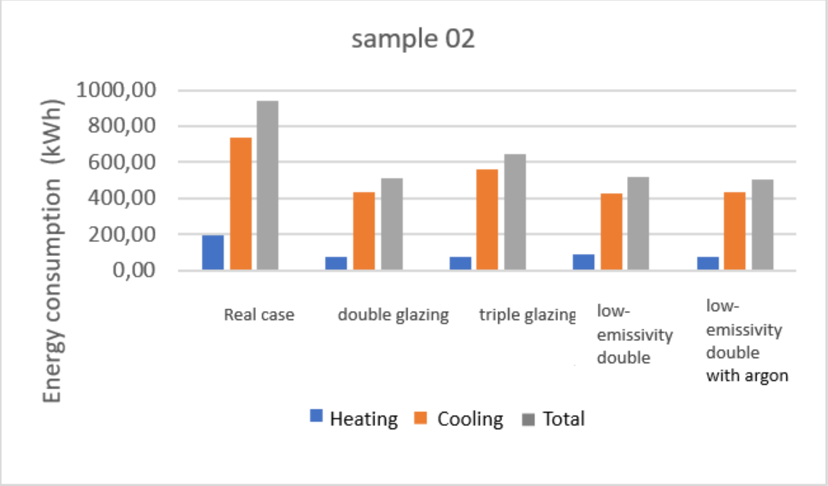


Figure 10 The variation in energy consumption of sample -02- for different types of glazing (source: author).

https://doi.org/10.37896/pd92.3/9237

Figure 11 shows the variation in energy consumption for sample 3. We notice that double glazing has the lowest consumption during the estimated year, at 705 kWh, which represents a 17% reduction compared to the real case. This is due to the insulating characteristics of this glazing (compared to single glazing), which limit heat losses to the outside and its high transmission compared to other types of glazing (low-emissivity double glazing, triple glazing, etc.) for solar radiation, thus reducing the need for heating systems. During the summer, its low thermal resistance allows for quick heat dissipation to the outside (compared to low-emissivity double glazing, triple glazing, etc.)

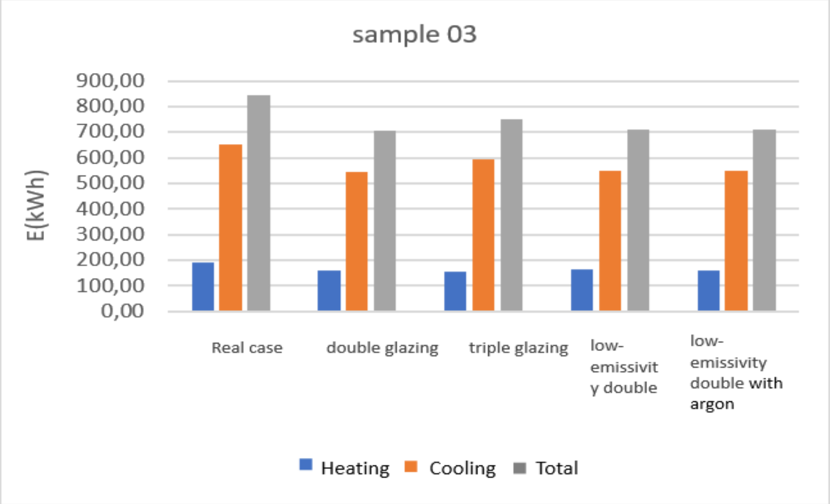


Figure 11 The variation in energy consumption of sample -03- for different types of glazing (source: author).

4.3. Influence of the use of solar shading

After studying the influence of the type of glazing on the energy consumption of the three samples, we noticed that the glazing reduces the heating needs but, on the other hand, the air conditioning needs increase due to solar radiation causing overheating in all three spaces. Solar shading can help solve this problem. Figure12 illustrates the variation in air conditioning requirements for the three samples for two types of glazing (single and double) for cases with and without solar shading. We can see that the use of solar shading has a considerable impact on air conditioning needs. A reduction of 47%

, 75%, and 51% is respectively obtained for samples 1, 2, and 3 for the case of single glazing, and 46%, 78%, and 51% respectively for samples 1, 2, and 3 for the case of double glazing. It is clear that shading the glazing has a considerable influence on air conditioning needs, as solar radiation penetrating inside the space rapidly increases its temperature (direct heating).

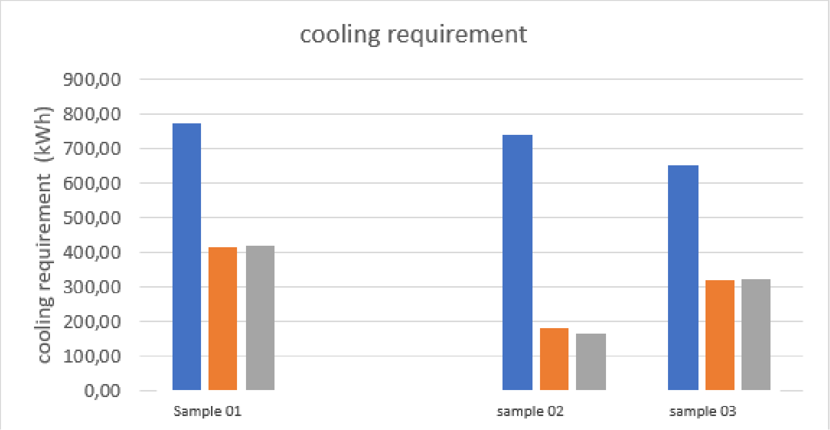


Figure 12 Variation in air conditioning needs for different types of glazing with and without solar shading (source: author

4.4. Influence of vegetation

The influence of vegetation on energy consumption is also discussed. Figure 13 illustrates the variation in heating and air conditioning needs for sample -1- with and without vegetation. It is easy to see that vegetation cover slightly increases heating needs because the walls absorb a reduced amount of solar radiation. However, for air conditioning needs, the reduction is considerable, reaching 33%. A reduction of 19% in annual energy needs is achieved.

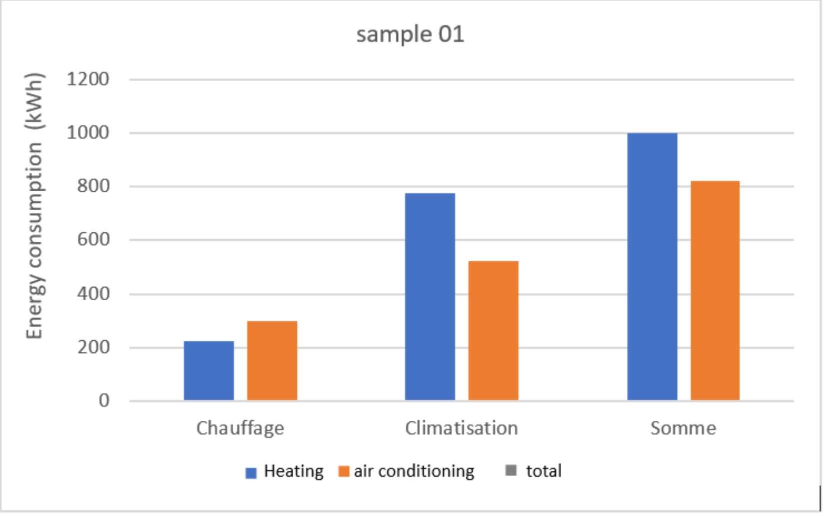


Figure 13 Variation in heating and air conditioning needs for sample -1- with and without vegetation (source: author)

However, for sample 02 Figure 14 we notice that heating needs increase while air conditioning needs slightly decrease due to the large glazed area. Annual energy needs increase by 5% in this case.

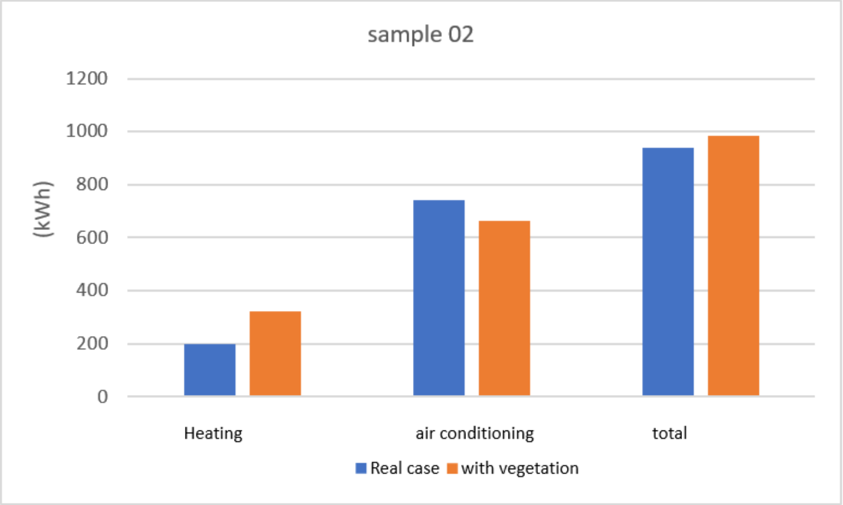


Figure 14 Variation in heating and air conditioning needs for sample -2- with and without vegetation (source: author)

For sample 03 shown in Figure 15, we notice an increase in heating needs by 33% and a decrease in air conditioning needs by 36%. A reduction in annual energy needs by 21% is achieved.

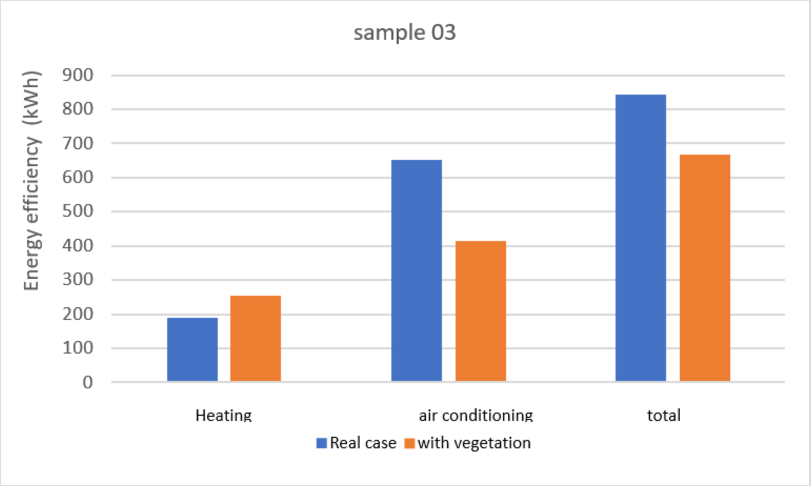


Figure 15 Variation in heating and air conditioning needs for sample 03 with and without vegetation (source: author)

4.5. Influence of reflective roofs

For the first sample Figure 16, we notice that the decrease in roof absorption (increase in reflection) leads to an increase in heating needs, as the absorbed solar radiation is reduced, while for air conditioning needs, we observe a decrease. Annual energy needs for sample 1 decrease by 26% and 34% respectively for absorption coefficients of 0.4 and 0.2. Increasing the roof reflection (reducing absorption) significantly reduces annual energy needs.

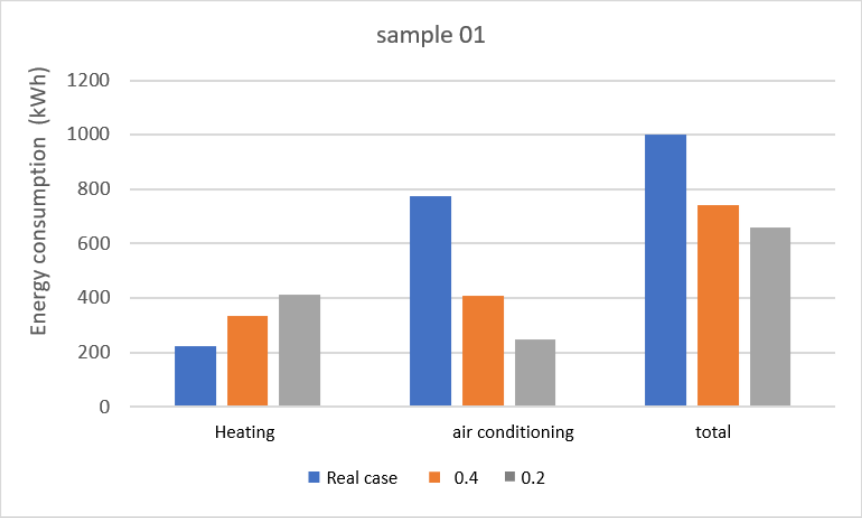


Figure 16 Influence of reflective roofs on the heating and air conditioning needs of sample 01 (source: author)

https://doi.org/10.37896/pd92.3/9237

pFor sample -2- Figure 17, we observe the same trend, where increasing the roof reflection increases heating needs and decreases air conditioning needs. Annual energy needs decrease by 27% and 33% respectively for absorption coefficients of 0.4 and 0.2.

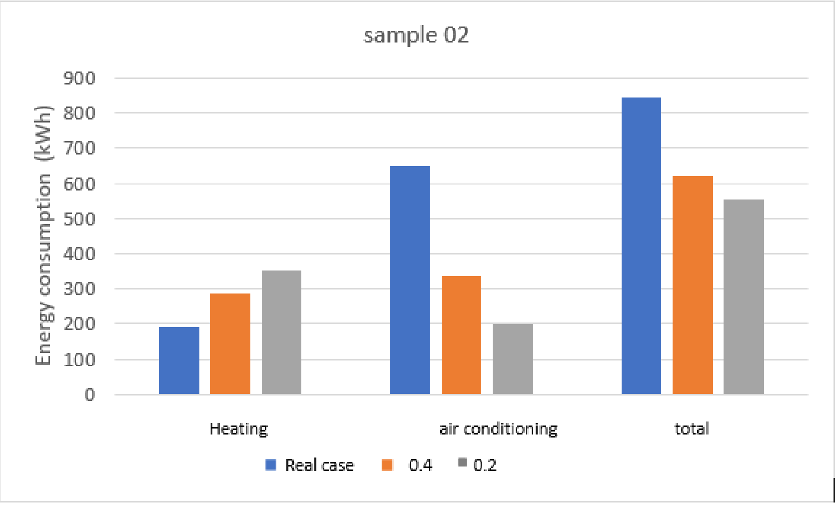


Figure 17 Influence of reflective roofs on the heating and air conditioning needs of sample 01 (source: author)

4.6. Optimized case

After studying the influence of envelope parameters, the combination of the most influential parameters is evaluated. For sample 01 shown in Figure 18, we notice a decrease in heating needs by 51% and a decrease in air conditioning needs by 88%, while the total energy needs have decreased by 80%.

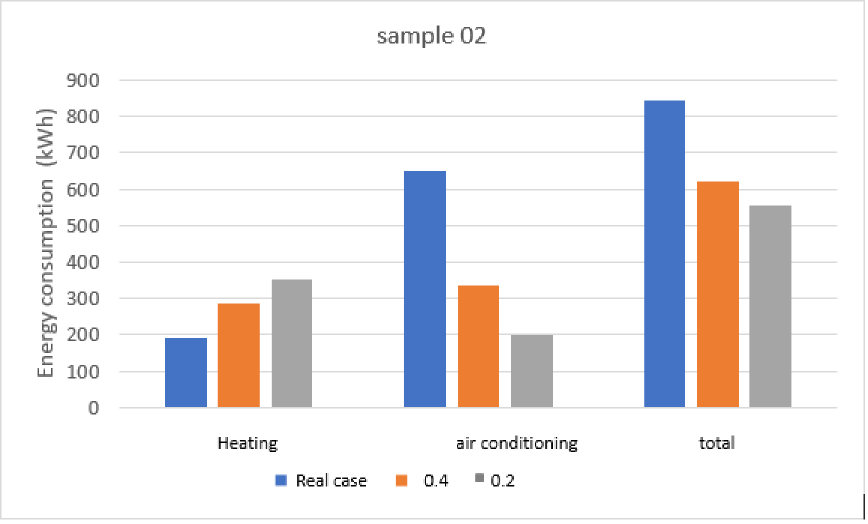


Figure 18 Heating and air conditioning needs for sample 01in the optimized case (source: author)

For the case of sample -2- shown in Figure 19, we also notice a decrease in heating needs by 87% and air conditioning needs by 91%. Total energy needs have decreased by 90%.

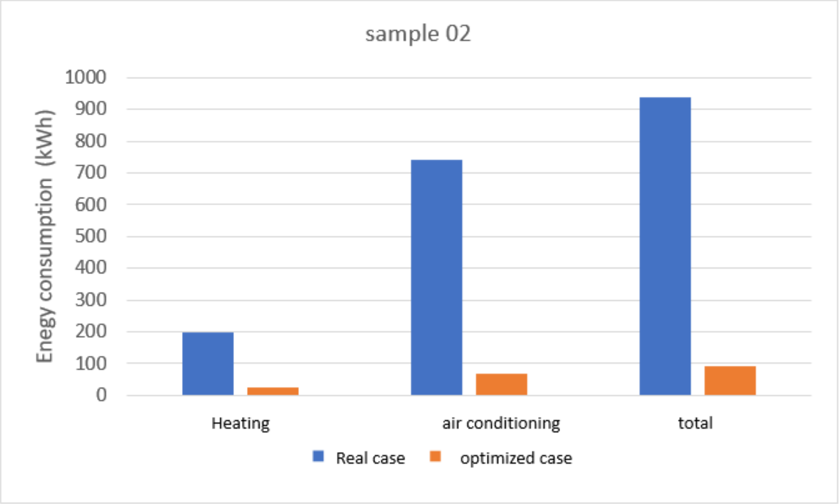


Figure 19 Heating and air conditioning needs for sample 02in the optimized case (source: author)

For sample -3- shown in Figure 20 , the decrease in heating and air conditioning needs is estimated to be 51% and 93%, respectively. The decrease in annual energy needs is estimated to be 85%.

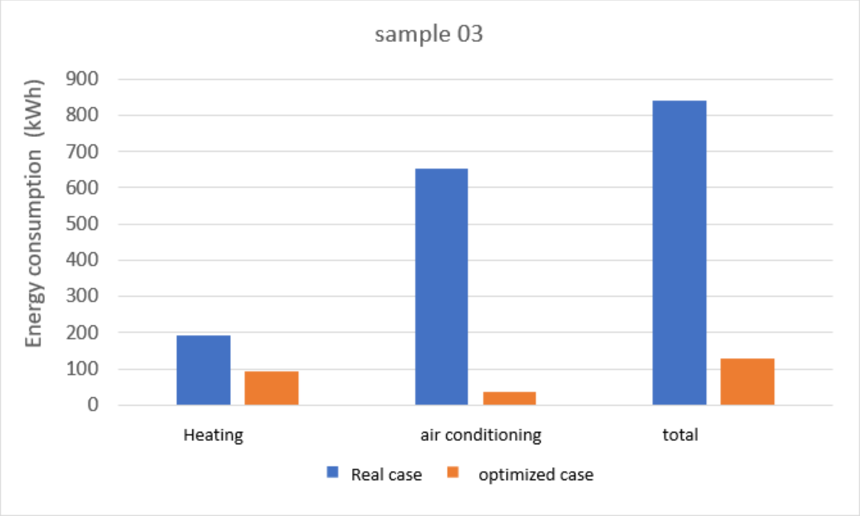


Figure 20 Heating and air conditioning needs for sample 03in the optimized case (source: author)

5. Discussion of The Results

We adopted a strategy to improve energy efficiency through improving the energy performance of the building envelope, by acting on the following points:

- Thermal insulation: We used several insulators and found that aerogel was the best scenario, with a decrease in air conditioning needs of 31% for samples 1 and 2, and 17% for sample 3. However, we noted an increase in heating demand for all three samples.
- Glazing: We proposed several ways to improve glazing performance and found that double glazing with argan gas was the best scenario. We noted a decrease in heating needs of around 14% for all three samples. However, air conditioning needs increased due to solar radiation received on glazed surfaces, hence the need for vegetation.
- Vegetation: The use of vegetation resulted in a decrease in air conditioning needs of 19%, but increased heating demand. For sample 2, annual heating needs increased by 5% due to the large glazed area, while for sample 3, energy demand for heating increased by 33% and air conditioning needs decreased by 36%, resulting in a 21% reduction in annual energy needs.
- Reflective roof: Decreasing the absorption coefficient to 0.4 and 0.2 respectively causes an annual decrease of between 26% and 34% in energy needs, but still leads to an increase in heating demand.

By combining all of these scenarios, we proposed an optimized case where we were able to decreaseheating and air conditioning needs by 51% and 87% respectively for sample 1, and by 88% and 91% respectively for sample 2, resulting in a total energy needs reduction of 93%. For sample 3, we were able to reduce heating and air conditioning consumption by 90% and 85% respectively and achieve an 80% reduction in total annual energy consumption.

Simulation of the various components of the envelope showed that a significant reduction in heating and air conditioning needs is possible thanks to passive techniques. However, some techniques may result in a decrease in heating energy needs and an increase in air conditioning needs, and vice versa. The combination and optimization of different techniques can significantly reduce annual energy needs for the three studied housing samples.

6. Conclusion

The goal of this research is to achieve energy efficiency in buildings through the building envelope. To do so, we proposed scenarios for thermal correction of the building envelope, by acting on thermal insulation, glazing, solar protection, vegetation, and reflective roof.

The simulation of the various components of the envelope showed that a significant reduction in heating and air conditioning needs is possible through passive techniques. However, some techniques may result in a decrease in heating energy needs and an increase in air conditioning needs, and vice versa. The combination and optimization of different techniques can significantly reduce

annual energy needs for the three cases.

Therefore, this research can affirm that the building envelope has a significant impact on its energy efficiency. A poorly performing envelope contributes to an increase in energy consumption, while a high-performing envelope contributes to improving the energy efficiency of the building.

References

1. Cited by Daniel Pinson (2002) in dictionnaire du logement et de l'habitat (directed by Marion segaud, Jacques brun Jean-Claude Briant) Paris Armand Colin 82- 86.
2. Lin, Z. and S. Deng,. (2008). A study on the thermal comfort in sleeping environments in the subtropics - Measuring the total insulation values for the bedding system commonly used in subtropics. 950-916.
3. Alwetaishi, M. S. (2016). Impact of Building Function on Thermal Comfort: A Review. American Journal of Engineering and Applied Sciences, 940, 941.
4. Hocine Tebbouche a , Ammar Bouchair b,Said Grimes c . « Towards an environmental approach for the sustainability ofbuildings in Algeria. ».Energy Procedia 119 (2017) 98-110 pp 05
5. Marco A. Ortiz∗, Stanley R. Kurvers, Philomena M. Bluyssen. « A review of comfort, health, and energy use: Understanding daily energy use and wellbeing for the development of a new approach to study comfort ». Energy and Buildings 152 (2017) 323–335 pp 05
6. FRECHMANN, Kolon . Architecture et énergie un enjeu pour l'avenir _ Paris : place des victoires pp10. 2011.
7. Ingy El-Darwish *, Mohamed Gomaa. « Retrofitting strategy for building envelopes to achieve energy efficiency ». Alexandria Engineering Journal (2017).pp 02
8. B. Basarir, et al., Energy Efficient Retrofit Methods at the Building Envelopes of the School Buildings, Retrieved 10 12, 2016, from <www.academia.edu/Ellipsis/Energy_efficient_retrofit_methods_at_the_building_envelopes>, 2012.

9. JRHT, Temple Avenue Project: Energy Efficiency Refurbishment Homes for the 21st Century, Retrieved 1 17, 2017, from <https://www.jrf.org.uk/sites/default/files/jrf/migrated/files/energy-efficient-refurbished-homes-report.pdf>.

10. Cited by El Darwish Ingy; mohammed gomaa; University of Waterloo, Classroom Standards/ Registrar's Office-University of Waterloo, Retrieved 11 5, 2016, from <https://uwaterloo.ca/registrar/faculty-and-staff/classroom-standards>, 2011.

11. B. Basarir, et al., Energy Efficient Retrofit Methods at the Building Envelopes of the School Buildings, Retrieved 10 12, 2016, from <www.academ00ia.edu/Ellipsis/Energy_efficient_retrofit_methods_at_the_building_envelopes>, 2012.

12. JRHT, Temple Avenue Project: Energy Efficiency Refurbishment Homes for the 21st Century, Retrieved 1 17, 2017, from <https://www.jrf.org.uk/sites/default/files/jrf/migrated/files/energy-efficient-refurbished-homes-report.pdf>..

13. Proceedings of the 3rd CIB International Conference on Smart and Sustainable Built Environment, TU Delft, Delft (2009)

14. OECD/IEA Technology Roadmap IEA, Paris (2013)

15. WBDG Sun Control and Shading Devices International Institute of Building Sciences, Washington DC (2016)

Site web

www.maisonpassive.be