DOI: 10.2478/sspjce-2023-0010

Impact of Passive Design Strategies on Environment, Cooling and Lighting Energy Demand. A Weighted Least Squares-Based Approach

Soufiane Boukarta [1*]

[1] Institute of Architecture and Urban Planning, IAU, Blida 1 University
*e-mail: boukarta.soufiane@univ-blida.dz

Abstract

The energy transition requires optimal knowledge of the thermal behaviour of different passive strategies. This paper explores the impact of 28 variables representing 4 shading devices, 5 external wall compositions (U_w), 3 window types (U_w), 4 window-to-wall ratios (WWR), 4 types of climates represented by 4 cities, and 8 orientations. Applying the Latin hypercube sampling method, a campaign of 300 dynamic thermal simulations is performed to assess the impact of the variables selected using the weighted generalised linear regression method for the energy demand for air conditioning, the energy demand for lighting, and the environmental impact expressed in kg of CO_2. The model of energy demand for cooling ($R^2 = 0.951$) shows that the weather data is the variable that most explains energy demand, followed by the glazing ratio, the thermal characteristics of external walls, and shading devices. The model explaining the energy demand for lighting ($R^2 = 0.945$) shows that the WWR and shading devices, the weather data, and the orientation, influence the energy demand for lighting. Finally, the model explaining the embodied carbon footprint (kg of CO_2) ($R^2 = 0.989$) shows that external walls and window type are the main influencing factors. Finally, the best combination for balancing the cooling-lighting-embodied carbon balance equation is discussed.

Keywords: passive design strategies, cooling and lighting energy demand, Latin hypercube sampling, simulation, weighted linear regression modelling

1 Introduction

Climate change has become a phenomenon that is being experienced more than predicted, and its accentuation is corroborated by the unbridled consumption of fossil fuels, which is releasing considerable quantities of greenhouse gases (GHG), destabilising the atmospheric balance and causing temperature spikes in some places and natural disasters in others, at rates that are difficult to prevent and on a massive scale. Cities are primarily responsible for this imbalance, and their activities are responsible for releasing almost three-quarters of energy demand, as well as greenhouse gases [1]. The most important consumption sectors are mobility, industry, agriculture, and construction, specifically, the residential sector, which alone consumes more than 50% of the world's final energy [2] and in Algeria 46% according to the latest figures from the [3].

To combat this phenomenon, the countries of the world, led by the developed countries, which are responsible for more than 70% of greenhouse gases, meet annually at what are known as COPs, conferences of parties, to try to find solutions and adapt to the dynamics of climate change. The main guidelines include stabilising the temperature at 1.5°C above the preindustrial level, and according to COP 21, from 2020 onwards, each signatory country to the COP21 protocol will be required to draw up a report on the actions taken to reduce greenhouse gases [4]. To encourage developing countries to join the fight against climate change, partnerships are planned to help them in terms of technology transfer and financial arrangements. Overall, two major strategies are clear for combating climate change: the gradual introduction of renewable energies RE and energy efficiency EE in consumer sectors. In Algeria, the government is aiming for a 30% introduction of RE by 2030 and energy efficiency in the four consumption sectors. Energy efficiency aims to rethink architectural design in order to reduce the energy demand of buildings. The introduction of the National Energy Management Plan (NEMP) in 2007 [5] led to the construction of 600 high-energy performance (HEP) homes. Several other actions are planned in the various NEMPs, all aimed at improving energy efficiency by improving the thermal insulation of buildings. To help architects and engineers apply the thermal regulations, CNERIB has set up a platform including the Regulatory Technical Document (DTR) on the *RETA.dz* website and CTBAT through APRUE.

In 2016, the APRUE published a guide for the introduction of energy efficiency in the building industry, with a proposal for specifications to help project owners set up a system for assessing projects from the point of view of energy efficiency [6]. For the time being, these guidelines remain proposals that could potentially lead to initiatives, but which remain more or less applicable in the day-to-day practice of architects because of their non-binding and non-mandatory scope, and also because the methods proposed are not in line with the modus operandi of architects, who rely on drawings to develop their projects. In response to the latter concern, this paper focuses on the issue of introducing energy efficiency into architectural practice. It proposes a methodology for multi-performance exploration of the impact of passive design strategies on energy demand and the environment.

2 Literature Review

The review of the scientific literature on energy efficiency clearly shows that it is possible to approach the issue from four possible angles, which in reality are intertwined in a single context, but for reasons of scientific simplification they can be organised as follows [7]:

- The building scale is the largest category in terms of the amount of research carried out. Bioclimatic tools list a number of strategies for improving a building's energy efficiency, depending on the specific climatic context. There are winter strategies and summer strategies. Strategies include the choice of building materials for the envelope, orientation, glazing ratio and type, shading devices, ventilation, and solar heating. The impact of building characteristics can affect energy demand by up to 200% [8].
- The urban scale is a relatively new entry point and studies have been appearing since the end of the last century and the beginning of the 21st century [8]. The urban scale has an impact on the variation in climatic conditions, creating more microclimatic conditions. This variation distorts sizing studies for heating and air conditioning

equipment [9]. Urban scale can be controlled by a number of urban form control parameters, such as built density, vegetation density, building height, prospect, etc. [10].
- The third scale relates to the performance of heating, cooling, and lighting systems [11].
- The fourth input is the occupant [12], who can vary the energy demand from 50 to 200% [13].

In this paper, we will focus on the building scale considering some control parameters. The other scales are considered fixed without variation in order to assess more accurately the impact of the chosen control parameters.

Energy efficiency assessment methods can be grouped into two main categories:

- The historicist approach, or the approach based on actual energy consumption data obtained from existing buildings. This approach has the merit of reducing the gap between the energy obtained from modelling and that obtained from actual consumption, but it does not allow the impact of new technologies to be assessed, as they do not exist in the existing built environment.
- The Engineering approach, which relies on calculation algorithms to assess the thermal behaviour of buildings. This approach is considered to be robust, but some studies have shown that simulations can lead to differences in assessment that can be as much as double [13]. This discrepancy is often caused by a misidentification of the activities of the occupant of the building in question. In order to reduce the size of this discrepancy, a significant evaluation is carried out in terms of parameter variation according to a representative sampling, which would make it possible to incorporate a wide range of possibilities and ipso facto reduce the gap between the simulated and the real energy demand [14, 15, 16]. Some authors prefer to proceed with calibration on an existing case by trying to parameterise the dynamic thermal simulations until calibration of the results and reducing the difference between the simulated and real energy demand to below 10% as a margin of error [17]. In the present study, we choose the dynamic thermal simulation approach while isolating the role of the occupant and varying the energy efficiency control parameters at the building scale by considering a representative sampling of possible combinations.

Among the sampling methods that exist in the scientific literature, we can cite:

- Monte-Carlo sampling, which is based on pseudo-random sequences and whose use is recommended for problems whose space does not exceed 100,000 combinations.
- Sobol and Halton sampling, which are so-called quasi-Monte-Carlo methods based on the use of sequences with low discrepancy [18]. The use of these methods provides a better representation of the space of possible combinations, see Figure 1 below.

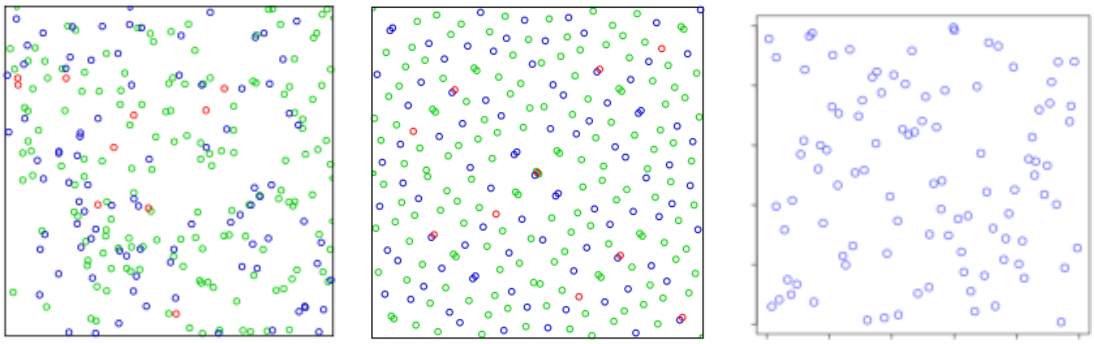


Figure 1: Differences between sampling methods [18]

- Latin Hypercube Sampling (LHS) is a very efficient multi-dimensional sampling method. As a general rule, a sample size of 10 times the number of design variables will be sufficient for the combinations to be modelled accurately, whereas other sampling methods require a minimum of 15 times the number of variables.

The difference between the LHS and Monte Carlo methods lies in the fact that the Monte Carlo method involves generating samples for one variable using a simple random sampling method, while the second method, Latin Hypercube, generates random samples that occur in equal probability intervals with a normal distribution for each range. In this paper, we have chosen the dynamic thermal simulation approach applied to a representative sample of possible combinations by applying the Latin hypercube sampling method in order to reduce the number of samples and gain accuracy.

3 Method

The method chosen to respond to the problem raised is to follow the following points, see Figure 2 below.

- The choice of climatic zones: Algeria is a large country with 4 climatic zones, and we have chosen a representative town for each climatic zone: Algiers for the humid climate, Médéa for the subhumid climate, Sidi-Bel-Abbès for the semi-arid climate and Adrar for the arid climate.
- The choice of control parameters: the choice mainly concerned the control parameters that architects tend to use without really having a quantitative estimate of the energy scope of what they choose as a parameter. We chose 5 control parameters: (a) construction materials for the external walls. We opted for the conventional choice, i.e., a standard double-skinned wall and a double-skinned wall with polystyrene insulation. Then we added materials that are often found locally, limestone, which is abundant in northern regions, and materials obtained from the earth that have been widely used in the south, namely mud-brick and terracotta. The thermal characteristics of each wall composition are presented in Table 1.
- The rate and type of glazing: the choice fell on a variation in terms of thermal performance of the windows, from single glazing to double glazing without and with

rare gas. For the glazing ratio, the choice was made for a variation ranging from 10 to 70% of the external wall surface.

- Shading device: two types of solar protection were chosen. The 0.5 m louvers and the awning for 1 and 2 meters deep and a combination of the two types at 1m deep, see Figure 3.
- Finally, the orientation is considered according to a step of 45° which would give 8 orientations.

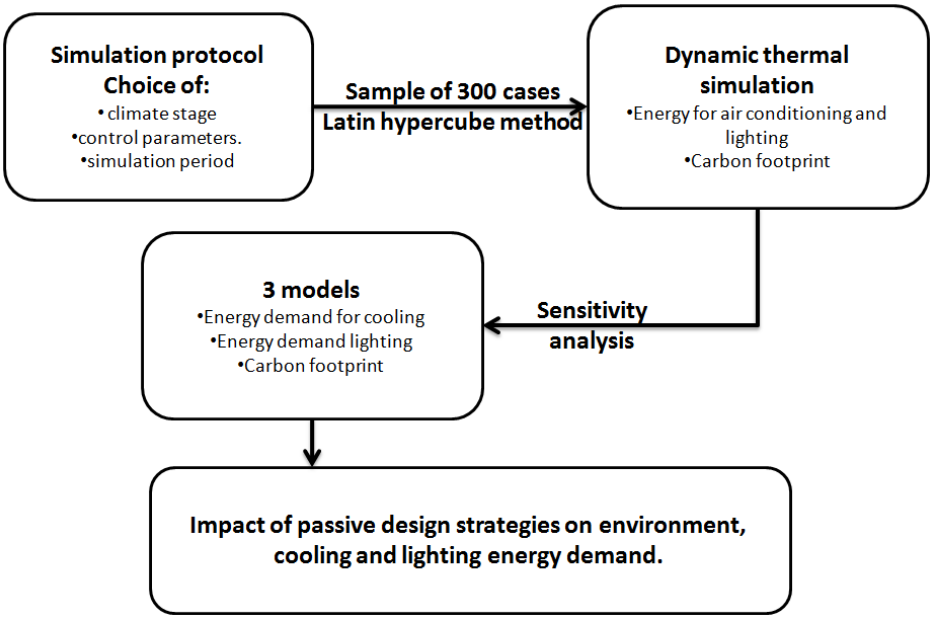


Figure 2: The adopted method

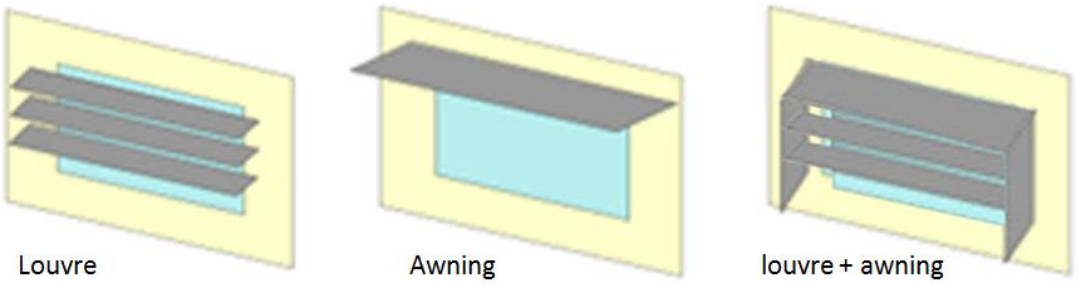


Figure 3: Solar protection considered for the study

This parametric variation is applied to a DOI, Design of Experiment, representing a single residential space (bedroom or living room) measuring 6 x 8 m, see Figure 4 below. One DOI was chosen instead of an entire dwelling in order to be able to correctly assess the impact of the chosen parametric variation on the thermal behaviour of the space in terms of energy demand for air conditioning, natural lighting (with a threshold of 150 Lux) and carbon embodied in the materials (ICE database, Inventory of Carbon and Energy, https://circularecology.com/). We chose embodied carbon instead of a full life cycle analysis to avoid the fact that the carbon cost of transporting materials remains fictitious and difficult to assess in our case.

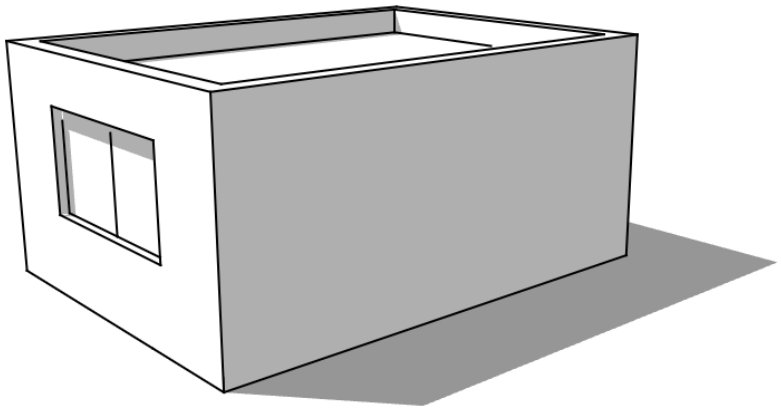


Figure 4: The study design

The simulation campaign is limited to 300 possible combination cases obtained using the Latin Hypercube approach. We introduced 6 explanatory variables and a campaign of 60 simulations would have been sufficient to assess the impact of the various control parameters. We have chosen to extend the sample so that each climate is represented by a minimum of 75 Dynamic Thermal simulations. This paper is therefore mainly concerned with assessing the thermal behaviour of the control parameters chosen for the first two weeks of July, as this is the hottest period according to the meteorological data representing the 15-year climatic variation. The simulations are run under Energy Plus, which is widely used by the scientific community [17]. Based on the methodology described above, three models will be presented in the next section, allowing us to assess the multi-performance of the chosen parameters.

4 Results and Discussion

The sample of 300 possible combinations obtained by the Latin Hypercube method gave us a sample whose descriptive statistics are presented in the Table 1 below.

Table 1 : Descriptive statistics for the sample

Variables	N	Min	Max	Avr	Std dev
City (Médéa, Alger, Sidibelabes, Adrar)	300	1	4	2.50	1.120
Orientation (steps of 45°)	300	0.00	315.00	157.5000	102.68836
Shading device (0.5 m louvers, 1 m awning, 2 m awning, 1 m awning + louvers)	300	1	4	2.50	1.120
U_w (Simple, double with air, double with gas)	300	1	3	2.00	0.818
U_{wall} (Limestone, Double-skinned wall, Double-skinned wall with insulation, mud brick, terracotta)	300	1	5	3.00	1.417
Window to Wall Ratio WWR (10%, 30%, 50%, 70%)	300	10	70	40.00	22.398

The results of the simulations carried out are described in the Table 2 below.

Table 2 : descriptive statistics for the simulation results

Variables	N	Average	Std dev	Minimum	Maximum
Embodied CO_2	300	12863.4282	6488.58188	4803.39	24318.42
Cooling energy demand	300	88.0688	125.63193	0.00	449.47
Lighting energy demand	300	3.4941	1.71647	2.17	9.84

4.1 Sensitivity Analysis

There are several methods of sensitivity analysis. For the present study, we have chosen the generalised linear regression method, as it allows an assessment at two levels:

- Assessment of the importance of each parameter in relation to the other variables, based on the *F* statistics.
- This method also allows us to assess the importance of all the variations per parameter in the three categories of analysis chosen, namely energy demand for air conditioning, energy demand for lighting below the threshold of 150 Lux and the importance of the CO_2 embodied.

The collinearity test is satisfied if all the variables have a VIF of less than 3 and a tolerance well above 0.2, see Table 3 below. The heteroskedasticity test is satisfied by applying the weighted linear regression method, and linearity and normality are also verified.

Table 3: Collinearity test

Variables	Colinearity statistics	
	Tolerance	**VIF**
Shading device	0.975	1.025
U_{wall}	0.991	1.009
U_w	0.989	1.011
Orientation	0.983	1.017
WWR (%)	0.984	1.017
City	0.982	1.018

4.1.1 Modelling Energy Demand for Cooling

The results of the modelling of energy demand for air conditioning gave us an explanatory model with 95.1% accuracy. The details of the model are presented in Table 4 below and the comparison in terms of effect on energy demand is developed from F statistics and the estimated marginal mean of each parameter, see Figure 5 below.

Table 4 : summary of the weighted generalized linear model for energy demand for cooling

	Sum of squares type III	**Degree of freedom**	**Mean square**	***F***	**Signification** (significant within a 0.05 interval)
Corrected model	5836.448*	22	265.293	244.301	0.000
Constant	2139.305	1	2139.305	1970.023	0.000
Shading device	170.866	3	56.955	52.448	0.000

Orientation	54.562	7	7.795	7.178	0.000
U_{wall}	106.857	4	26.714	24.600	0.000
U_w	19.285	2	9.643	8.880	0.000
WWR	206.089	3	68.696	63.260	0.000
City	2529.152	3	843.051	776.340	0.000
Error	300.802	277	1.086		
Total	1613263.622	300			
Corrected total	6137.250	299			

Weighted least squares regression - Weighted by weight_cooling
* R2 = .951 (Adjusted R2= .947)

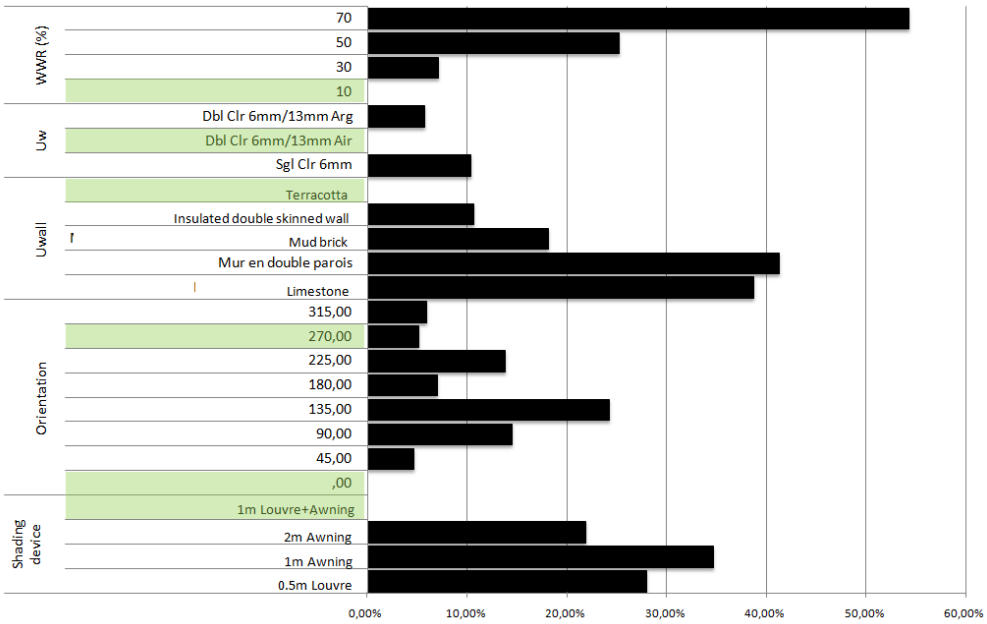


Figure 1. Importance of each in relation to the references (shown in green)

Based on the values of *F* statistics and the estimated marginal average for each variable, it was possible to estimate the percentage importance of each variable in relation to the reference value representing the lowest energy demand per variable, which is shown in green in Figure 5 above. This shows the 6 most effective control parameters for reducing energy demand for air conditioning. Three major parameters stand out on the graph: the climatic stage, the glazing ratio, and the external walls:

- The climatic stage is the first element to have an impact on energy demand. The humid climate appears to be the mildest, with virtually no energy demand for air conditioning. The Adrar climate, on the other hand, which is an arid climate, requires a higher energy demand than the other climates.
- The WWR comes in second place and increases energy demand by up to 54% (the case of 70% WWR) compared with the reference case of 10%.

- In 3rd position is the role of shading devices. The combination of louvres and awning is the best configuration for the overheating season as it reduces solar gains. A solar protection system consisting of an awning 1 m deep would require up to 35% more energy than a combined solar protection system consisting of an awning and louvers 1 m deep. It should be noted that 0.5 m deep louvers are more effective than a 1 m deep awning but are almost 7% less effective than a 2 m deep awning.
- The building material chosen for the external envelope is another important factor. Terracotta is the building material that responds best to the 4 climatic conditions. However, if we look at the details, it becomes clear that each material performs better in the climatic zone to which it belongs: limestone in the north (humid climate), and both bricks, mud, and terracotta perform better in the south (arid climate zone). In the conventional configuration, double-skinned walls have virtually the same thermal transmittance as limestone in the north, and as terracotta if insulation (polystyrene) is added for the arid climate. The main difference is in the embodied CO_2, limestone, terracotta, and mud brick have a very low embodied CO_2 compared with double-skinned walls with and without insulation.
- In fifth place is the type of glazing, and double glazing with air is the best configuration, reducing energy demand for air-conditioning by up to 5 and 10% compared with single glazing and double glazing with argon. This difference can be explained by the thermos effect that seems to form in the case of double glazing with argon, which increases the overheating situation.
- Finally, orientation comes in sixth place, and north orientation is the most favourable for reducing energy demand for air-conditioning, and the difference between north and south-east orientation (135°) can be as much as 25%.

4.1.2 Modelling Energy Demand for Lighting

Modelling energy demand for lighting using weighted least squares regression gave us a model with 94.5% accuracy. The results of the modelling are presented in Table 5 below.

Table 5: Summary of the model for lighting energy demand

Source	**Sum of squares type III**	**Degree of freedom**	**Mean square**	***F***	**Significance** (significant within a 0.05 interval)
Corrected model	7846.256*	27	290.602	173.713	0.000
Constant	4473.368	1	4473.368	2674.043	0.000
Shading device	138.858	3	46.286	27.668	0,000
Orientation	65.205	7	9.315	5.568	0.000
U_w	1.294	2	0.647	0.387	0.680**
WWR	225.780	3	75.260	44.988	0.000
City	126.445	3	42.148	25.195	0.000
Shad device WWR	133.514	9	14.835	8.868	0.000
Error	455.025	272	1.673		
Total	1239897.129	300			
Corrected total	8301.281	299			

Weighted least squares regression - Weighted by weight_lighting
* R2 = .945 (Adjusted R2 = .940)

** not significant

The importance of each control parameter is shown in the graph below (Figure 6).

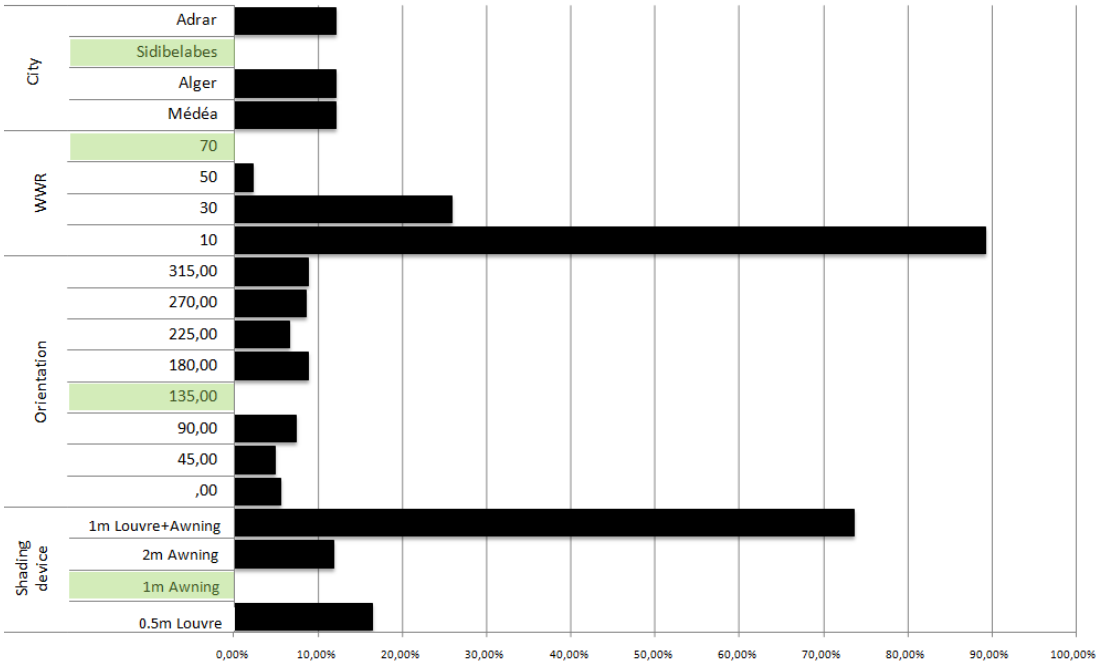


Figure 2 : Importance of lighting control parameters (150 Lux threshold) compared with references (shown in green)

The parametric variation applied shows us that all the variations occur within a consumption range limited to 9 kWh over the two weeks of simulation, which is marginal compared with the energy demand required for air conditioning, especially for cities in southern Algeria.

The WWR is the primary factor impacting lighting and generating or reducing the greatest energy demand to ensure lighting is at the 150 Lux threshold. A glazing ratio of 10% is the most unfavorable situation for natural lighting, and the energy demand is 89% higher than for a glazing ratio of 70%.

In second place comes shading devices, where the best provision for natural lighting is obtained with a 1m awning. The most unfavorable case is the combination of awning and louver, which generates an energy demand 73% higher than that generated by the 1m awning.

In third place comes the combination of shading device and WWR, the effect of which is shown in Figure 7 below. Two observations can be made from the graph: the amount of variation according to the type of shading device and the amount of energy generated. The device generating the least variation is the awning at a depth of 1m, the effect of which does not exceed 16% for a glazing ratio of 10%. However, the most unfavorable case is that of the combination of awning and louver at a depth of 1m, and this scenario has the greatest variation, from 6% (WWR 50%) to over 220% (WWR 10%).

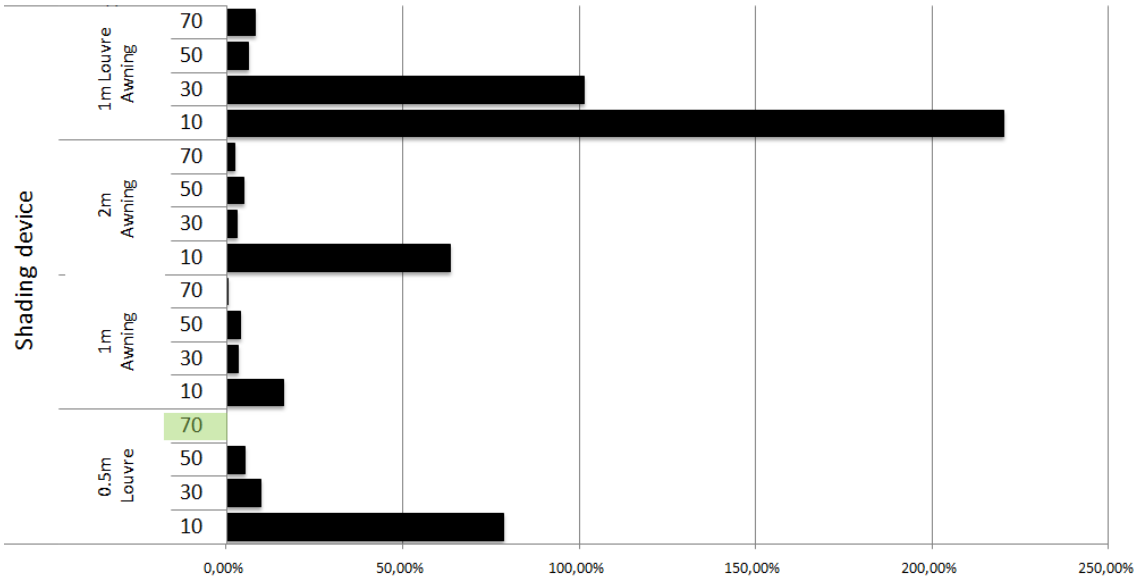


Figure 3. Effect of interaction, shading device, and WWR. (Reference case shown in green)

The impact of climatic conditions has an impact on energy demand for lighting and the effect varies slightly between the 4 cities (0.4 kWh variation) which represents 12% between the town of Sidibelabes and the other cities. In fifth place comes orientation. The most favourable orientation for reducing energy demand for lighting is 135°, i.e., south-east. Other orientations generate between 4% (45°) and almost 9% (180°) more lighting energy than the 135° orientation. The impact of the type of glazing was found to have no statistically significant impact, as the three types of glazing had almost identical transmittance factors.

4.1.3 Modelling the Embodied CO_2

For the embodied CO2, we only considered the part incorporated in the building materials for external walls, windows, and shading devices. The results of the modelling are clear, with external walls coming out top, followed by windows, while shading devices do not have a statistically significant impact, as shown in Table 6 below.

Table 6. Summary of the embodied carbon model

Source	**Sum of squares type III**	**Degree of freedom**	**Mean square**	***F***	**Significance** (significant within a 0.05 interval)
Corrected modem	232782.173*	9	25864.686	18065.979	0.000
Constant	951090.937	1	951090.937	664318.486	0.000
Shading device	7.715	3	2.572	1.796	0.148**
U_w	50.486	2	25.243	17.632	0.000
U_{wall}	232516.452	4	58129.113	40602.053	0.000
Error	415.187	290	1.432		
Total	1303397.976	300			

Corrected total	233197.360	299

Weighted least squares regression - Weighted by weight_CO_2

* R2 = .998 (R2 adjusted = .998)

** not significant

Looking at the details, it emerges that locally available materials are the ones with the lowest embodied carbon footprint. Limestone is the material with the lowest embodied carbon footprint (average of 5076 kg eqCO_2), followed by mud bricks (average of 7164.641 kg eqCO_2). The conventional double-skinned wall comes third (average of 14163.35 kg eqCO_2). In last place comes the double-skinned wall with insulation. Although its thermal resistance is very close to that of the terracotta, its carbon footprint is almost double (14465.433 kg eqCO_2), see Figure 8 below.

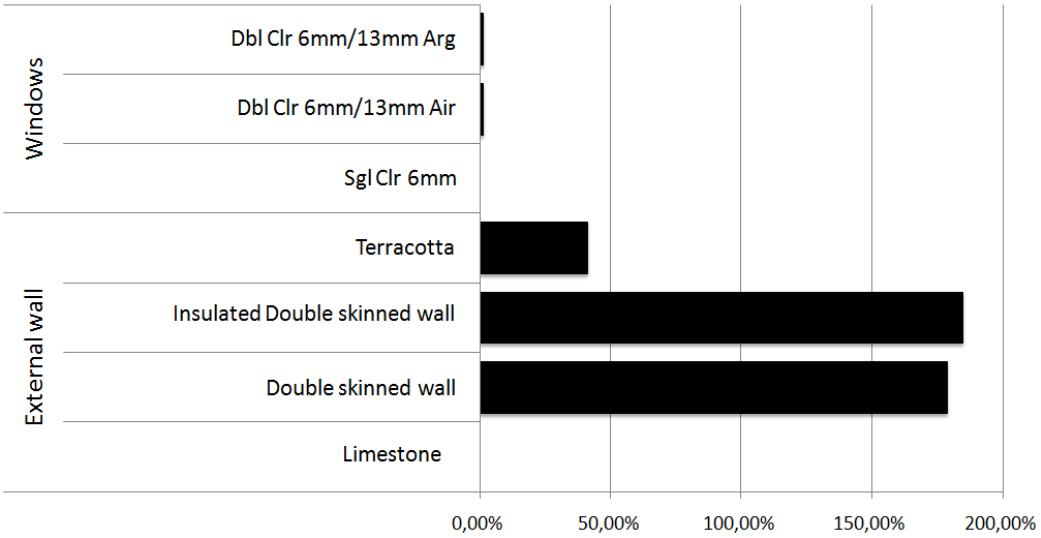


Figure 4. Comparison of the carbon-incorporated balance of different exterior wall compositions and windows

On the other hand, the choice of windows has little impact on the variation in the incorporated carbon footprint. The difference between single-glazing and double-glazing with air and gas is 1% to 1.26%.

5 Conclusion

What provision should be chosen for the lighting-cooling energy and carbon balance?

From the results obtained and presented above, it is clear that if we tend to choose the best configuration while seeking to reduce the energy demand for air conditioning and lighting and the carbon footprint for the 6 control parameters chosen, we will sometimes run into contradictions.

- For shading devices, the control parameters that reduce the energy demand for air conditioning are themselves the most unfavorable for lighting and increase the energy demand for lighting. But if we look at the variation intervals, it is clear that air

conditioning requires more energy than lighting. So, the choice will clearly be for the awning + louver combination for shading devices.

- As regards the choice of materials, it is also clear that locally available materials offer the best performance in terms of both air conditioning and embodied carbon cost. For the northern regions, the stone is the best material, and for the south, raw and fired clay bricks are the most favorable, as both offer the best thermal performance for the climatic conditions, while reducing the embodied carbon footprint.
- The choice of glazing that reduces energy demand for air conditioning is double glazing + air, even though it slightly reduces solar access and increases energy demand for lighting. The embodied carbon of glazing does not significantly affect the overall balance.
- Orientation plays a similar role to the glazing ratio in the energy demand equation for air conditioning. North orientation is the best orientation, but it is not the best orientation for the winter season, so all orientations can be favorable as long as the most appropriate shading device is considered.
- The most favorable glazing ratio for cooling-lighting-carbon balance is 10%, even though it increases the energy demand for lighting. It is also possible to provide a higher glazing rate, if necessary, but it would be necessary to provide a shading device that could reduce solar access and reduce overheating time as well as the energy required for air conditioning. For cities in the south (such as Adrar), characterized by an arid climate, an introverted courtyard design is a very interesting solution, as it works on solar regulation and wind circulation.

Figure 5 shows the distribution of cases in different cities according to their energy demand for air conditioning and lighting. Our results clearly show that it is possible to make a connection in terms of summer design between humid and sub-humid climates, whereas it would be inadvisable to do so with a semi-arid (Sidibelabbes) or arid (Adrar) climate. In a humid and sub-humid climate, with good architectural design, it is possible to achieve zero or nearly zero energy buildings. However, in a hot climate, whether arid or semi-arid, it would be preferable to use other techniques and technologies to reduce the impact of climatic conditions on energy demand for air conditioning. Our future research will therefore focus on this southern region in order to test solutions and assess their energy and environmental costs.

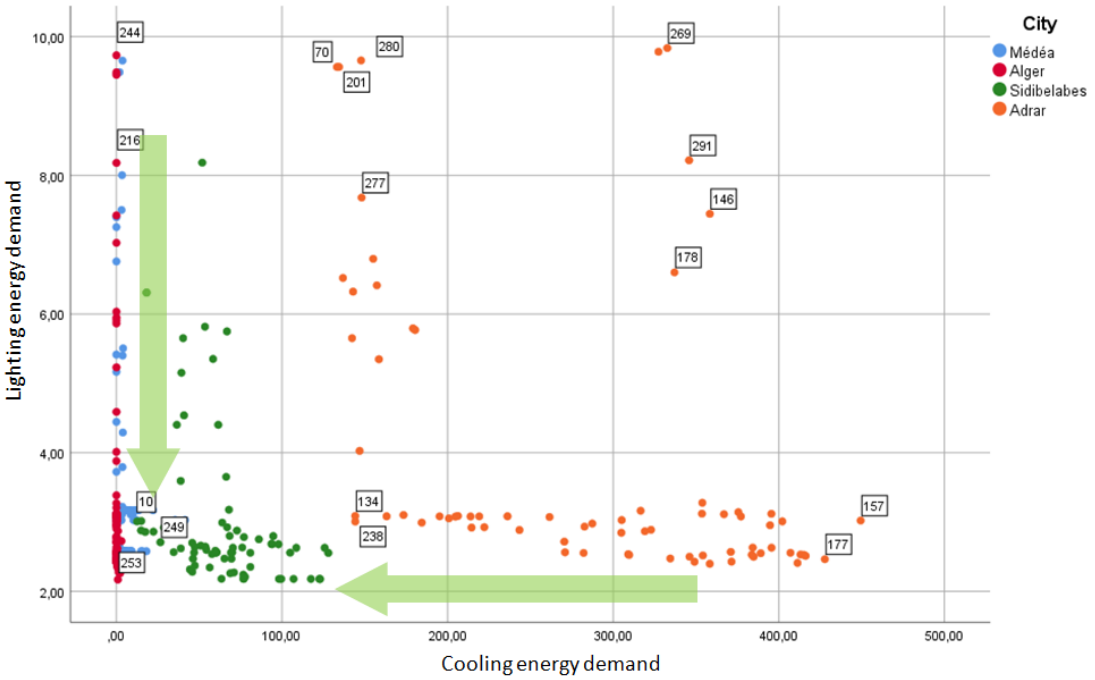


Figure 6. The distribution of cases according to their energy demand for air conditioning and lighting

Abbreviations

U_w: Thermal transmittance
WWR: Window to wall ratio
GHG: greenhouse gases
COP: Conference of parties
RE: Renewable energy
EE: Energy efficiency
HEP: high energy performance
NEMP: National Energy Management Plan
APRUE: National agency for the promotion and rationalization of energy use
RETA: National online thermal calculation software
CTBAT: National online thermal calculation software
DTR: Regulatory technical document
ICE: Inventory of Carbon and Energy
VIF: Variance Inflation Factor

References

[1] Rogers, R. G., & Gumuchdjian, P. (2008). Des Villes durables pour une petite planète. Moniteur.

[2] Fathi, S., et al. (2020). Machine learning applications in urban building energy performance forecasting: A systematic review. *Renewable and Sustainable Energy Reviews*, *133*, 110287.

[3] APRUE. (2021). L'Agence Nationale pour la Promotion et la Rationalisation de l'Utilisation de l'Énergie, La situation énergétique nationale, Chiffre 2019, édition 2019.

[4] Guillemot, H. (2020). 2 degrés, 1.5 degrés, neutralité carbone… Petite histoire des objectifs climatiques à long terme.

[5] Sénit, C. A. (2008). L'efficacité énergétique dans le secteur résidentiel: une analyse des politiques des pays du Sud et de l'Est de la Méditerranée. IIddri, Idées pour le débat, 14.

[6] APRUE & GIZ. (2016). Guide pour une construction Eco-énergétique en Algérie.

[7] Boukarta, S. (2021). Potentiel d'économie d'énergie d'un bâtiment résidentiel. In Confort, Habitat en milieu sensible et Ville Résiliente CHSVR, 13-14 octobre, Université de Guelma.

[8] Salat, S. (2011). Les villes et les formesurbaines: sur l'urbanisme durable. France.

[9] Bozzonnet, E. (2005). Impact des microclimats urbains sur la demande énergétique des bâtiments-Cas de la rue canyon. Diss. Université de la Rochelle.

[10] Wong, N.H., et al. (2011). Evaluation of the impact of the surrounding urban morphology on building energy consumption. *Solar energy*, *85*(1). pp. 57-71.

[11] Dascalaki, E. G., Droutsa, K., Gaglia, A. G., Kontoyiannidis, S., & Balaras, C. A. (2010). Data collection and analysis of the building stock and its energy performance—An example for Hellenic buildings. *Energy and Buildings*, *42*(8), 1231-1237.

[12] Boukarta, S., & Berezowska-Azzag, E. (2018). Energy demand of occupant's spatial modification in residential buildings. Case study of Médéa, Algeria. *Selected Scientific Papers-Journal of Civil Engineering*, *13*(1), pp. 15-28.

[13] Dall'O', G., Galante, A., & Torri, M., (2012). A methodology for the energy performance classification of residential building stock on an urban scale. *Energy and Buildings*, *48* (2012) 211–219.

[14] Boukarta, S. (2021). Exploring the impact of balconies on cooling energy demand in an arid climate zone. *Selected Scientific Papers-Journal of Civil Engineerin*g, *16*(2), 25-35.

[15] Boukarta, S. (2021). Predicting energy demand of residential buildings: A linear regression-based approach for a small sample size. *Selected Scientific Papers-Journal of Civil Engineering*, *16*(2), 67-85.

[16] Amiri, S.S., Mottahedi, M., & Asadi, S. (2015). Using multiple regression analysis to develop energy consumption indicators for commercial buildings in the US. *Energy and Buildings*, *109*, 209-216.

[17] Semahi, S., Zemmouri, N., Singh, M.K., et al. (2019). Comparative bioclimatic approach for comfort and passive heating and cooling strategies in Algeria. *Building and Environment*, *161*, p. 106271.

[18] Kaoula, D., & Bouchair, A. (2019). The pinpointing of the most prominent parameters on the energy performance for optimal passive strategies in ecological buildings based on bioclimatic, sensitivity and uncertainty analyses. *International Journal of Ambient Energy*, 1-28.