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The Synergistic Relationship between Urban Building Energy Performance, Microclimate, and Urban Elements

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ABSTRACT

In recent years, the accuracy of assessing the energy performance of buildings in cities has relied not only on building attributes but also on urban elements (block form, urban canyon, vegetation, blue spaces {refers to water features}, and pavement materials). Approaches to Urban Building Energy Modeling (UBEM) developed to examine energy performance at the urban scale have not given adequate consideration to the impact of urban elements. As a result, the primary aim of the paper is to propose an updated reference matrix for urban planners and architects to use in the initial phases of planning and design processes to improve urban building energy performance by focusing on the effect of urban elements on urban energy performance. This matrix was constructed by analyzing various prior studies that investigated the effect of urban elements on microclimate parameters as well as the impact of microclimate parameters on building energy performance. Then, the matrix clearly displays the indirect influence of urban elements on urban energy performance, particularly cooling and heating loads. New technologies for stakeholders, planners, and architects to enhance the urban energy performance of new urban areas have been developed.

Keywords: Urban building energy modeling, Urban elements, Energy performance, Microclimate parameters.

ABBREVIATIONS

Abbreviation	Description
UBEM	Urban Building Energy Modeling
BEM	Building Energy Modeling
GHG	Green House Gas
UHI	Urban Heat Island

1 INTRODUCTION

The global urban population is expected to be doubled by the year 2050 [1]. The rate of urbanization in Africa will be a threefold increase, while in Asia it will rise by 1.7 times over the next four decades [2-4]. Consequently, this rapid urbanization would necessitate hundreds of new cities and neighborhoods. A substantial rise in global energy usage is anticipated. Hence, the primary focus of contemporary urban planning lies in the development of energy-efficient urban areas, which aims to enhance the thermal performance of buildings and reduce their energy consumption. In order to effectively manage and mitigate energy consumption within urban areas, it is imperative to explore further avenues for enhancing the energy performance of both newly developed and pre-existing neighborhoods [5].

The interplay between building parameters affecting energy performance, microclimate parameters, and urban elements fosters a mutually beneficial interaction that facilitates the advancement of sustainable urban development by affecting the indoor climate of buildings, hence the energy use (see Figure 1). Through the integration of these parameters, urban designers have the ability to create energy-efficient structures that leverage the cooling advantages offered by urban elements.

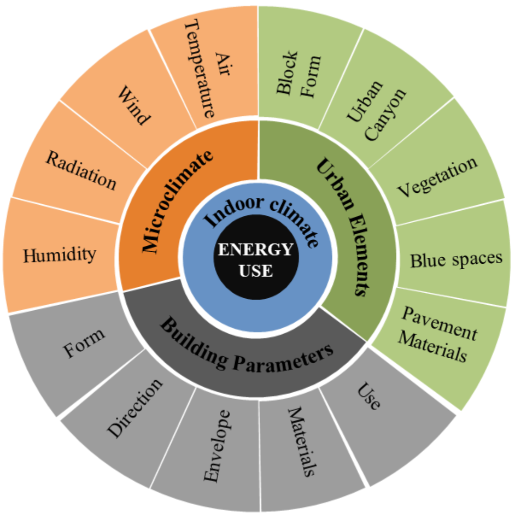

Figure 1:Restructured building energy use diagram. Source: Author.

The microclimate of urban open spaces is influenced by various parameters, including block form, urban canyon, vegetation, blue spaces, and pavement materials. Insufficient implementation of the aforementioned requirements contributes to the exacerbation of environmental conditions, resulting in elevated temperatures in urban regions beyond anticipated levels [6]. According to Wren et al. [7] in Australia, it was discovered that the implementation of a vegetation zone within a city center can reduce the maximum ambient temperature by 0.8°C. Siafi et al. [8] investigated the impact of blue spaces on the immediate vicinity. They observed that the downwind region exhibited a significant reduction in temperature, reaching a maximum decrease of 2.6°C during the peak hours of heat. Conversely, the minimum temperature in this area increased by 0.7°C during the coldest period.

The urban microclimate exerts an impact on the energy perfprmance of buildings through its influence on the indoor climate [9]. Based on Kolokotroni et al. [10], the urban heat island (UHI) effect plays a significant role in the underestimation of energy performance in urban buildings. In accordance with Jusuf et al. [11], the energy performance of heating and cooling buildings is influenced by the ambient temperature of the city as a result of UHI phenomenon.

As highlighted in Figure 2, the focus of this paper is on examining the correlation between urban elements, microclimate, and urban building energy performance using a reference matrix given in this study. However, the investigation does not include an analysis of the connection between building parameters and energy performance. This aspect has been extensively explored by other many researchers, either through individual building analysis, such as BEM [12-14], or through collective analysis, such as UBEM [15-18].

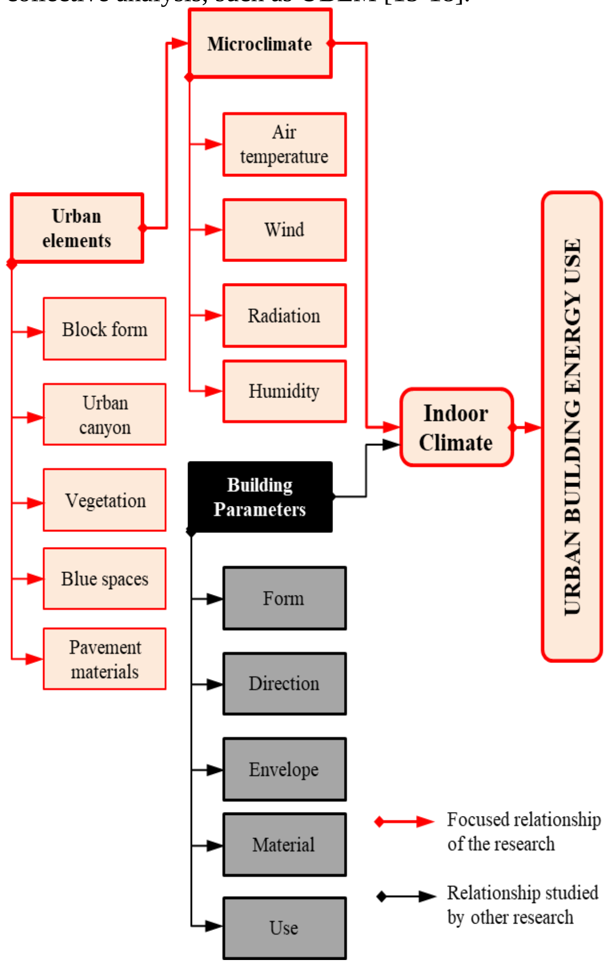

Figure 2: Focused relationship of the paper.

The paper is organized as follows: In Section 2, the methodology of the article is presented, focusing on the examination of parameters that influence urban energy performance. Section 3 provides an analysis of the correlation between urban elements and microclimate parameters. The study investigates the correlation between microclimate parameters and the energy consumption of urban buildings in Section 4. The subsequent section (Section 5) clarifies the indirect impact of urban elements on the energy performance of urban buildings. Furthermore, the correlation between these urban elements, microclimate parameters, and energy consumption is exemplified by a suggested reference matrix outlined in Section 6. Section 7 ultimately provides results of the reference matrix. Finally, Section 8 highlights the conclusion of the paper.

2 METHEDOLOGY

Improving urban energy performance poses novel challenges for urban planners and architects in their efforts to mitigate energy consumption and GHG emissions. This paper examines the various parameters that have been explored in previous studies and research to understand their influence on urban energy performance and then employs them to enhance the energy efficiency of urban areas and decrease the potential dangers associated with CO2 emissions. The main goal of this study is to highlight the indirect relationship between urban elements and urban energy performance by illustrating the influence of urban elements on microclimate parameters and, consequently, the impact of microclimate parameters on urban energy performance, particularly cooling and heating loads. Due to the aforementioned connections between these two interactions, urban elements might indirectly impact the energy performance of urban areas.

The study focuses on mentioned indirect impact of urban elements on urban energy performance in various sorts of climate zones. The proposed hypothesis is not dependent on a certain climate zone but rather aims to demonstrate the existence of the predicted relationship independent of the climate zone. Using the technique described in Figure 3, this hypothesis was tested by examining and gathering data from prior studies and research linked to the paper topic.

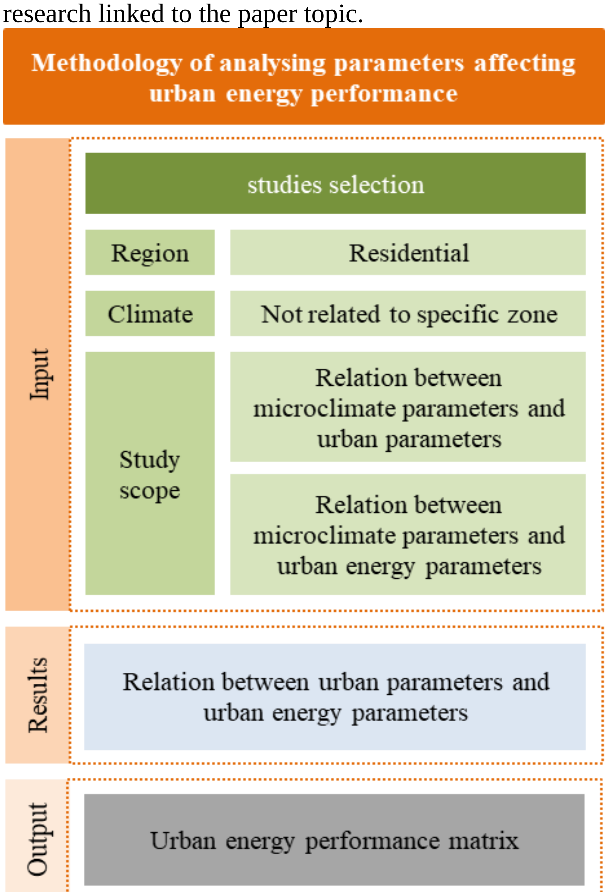

Figure 3: Paper methodology. Source: Author.

The above three relationships will be abstracted and represented in a reference matrix. This matrix would facilitate the assessment of the relationship between microclimate parameters, urban elements, and urban energy performance by considering the findings and suggestions from prior applied and analytical studies [7–79], which have investigated and analyzed the impact of relevant parameters on each other.

3 URBAN ELEMENTS AND MICROCLIMATE

The impact of urban elements on local climate parameters and energy consumption might vary depending on the climate zone and region.

3.1 Block Form

Many studies explore the effects of urban form on microclimate, especially in hot [19-21] and temperate zones [22]; the daytime shading properties of high-rise buildings play an important role in decreasing urban heat. The block form of mid-rise to high-rise buildings along the direction of wind flow contributes to the reduction of daytime temperatures [23]. Block form contains four main types: singular form, linear form, courtyard form, and semi-opened form (see Figure 4). The singular and linear forms result in prolonged exposure to solar radiation in the outdoor environment, leading to the poorest comfort conditions among the models situated at the core of the canyon. On the other hand, courtyards and semi-open forms contribute to the creation of a somewhat sheltered microenvironment, resulting in less exposure to solar radiation during the summer season [24]. The data in Table 1 can be used to assess the impact of block form on the microclimate parameters.

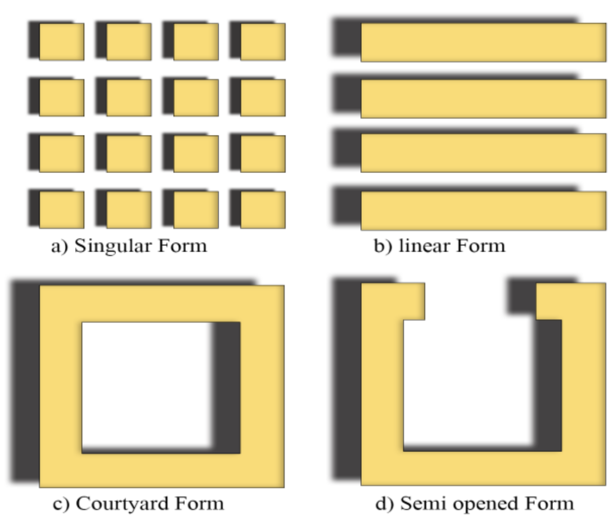

Figure 4: Block form types. Source: Author based on [19].

Table 1. The effect of block form on microclimate. Source: Author based on [19-24]

#	Microclimate	Block form effects
1	Wind	The form of buildings affects wind direction and speed according to building direction, height, and spaces between buildings.
2	Temperature	The relation between the direction of the building axis and the direction of the sun is the main factor that affects the potential air temperature in addition to building height and spaces between buildings.
3	Radiation	The shading of buildings on each other and on surrounding urban spaces affects the radiation of surrounding surfaces and building surfaces.
4	Humidity	Block form has no effect on humidity

3.2 Urban Canyon

Urban canyon is an area formed by two normally parallel rows of buildings separated by a street that serves as the basic unit of modern cities [25]. According to the most recent research, the characteristics of street orientation and urban canyon geometry (height-to-width ratio (H/W) are the key relevant urban parameters that affect the microclimatic variations in a street canyon [26,27]. These variables influence airflow potential at street level, solar access, and hence urban microclimate [28]. These investigations have indicated that the wind speed within deep canyons in Morocco during both the winter in February and summer seasons in July are recorded at 0.4 m/s [29]. While the wind speed within the shallow street canyon exhibited an average of 0.8 m/s during the winter season and 0.7 m/s during the summer season. However, in the typical narrow streets in Dubai, the wind speed was notably greater, surpassing the shallow street canyon by an increment of 5 m/s in summer [30].

The orientation of streets significantly influences the daily and seasonal distribution of solar radiation on the surfaces of the streets. Streets oriented in the north-south direction contribute to enhanced thermal comfort during the autumn, winter, and spring seasons, even in cases where the street width is limited [31]. However, the lack of shade on the streets during the peak summer season makes the experience unpleasant. When comparing streets oriented in a north-south direction to those oriented in an east-west direction, it can be observed that the latter tend to provide a certain degree of shade during the peak hours of the day when temperatures are at their highest. Nevertheless, roads oriented in the east-west direction exhibit significantly higher levels of direct sun radiation during the morning and afternoon in the summer months, in contrast to streets oriented in the north-south direction [32,33]. AS a result, the north-south (N-S) and northwest-southeast (NW-SE) street orientations are generally favored in hot–arid regions [34]. The impact of urban canyons on microclimate characteristics can be inferred based on the data provided in Table 2.

Table 2. The effect of urban canyon on microclimate. Source: Author based on [25-34]

#	Microclimate	Urban canyon effects
1	Wind	The pattern of streets and open spaces affects wind direction. In terms of velocity, canopy airflow may be characterized by being calm at the bottom of deep spaces, strong winds along wind-oriented streets, and eddies across streets perpendicular to winds.
2	Temperature	Street orientation and H/W ratio are the main factors influencing urban canyon temperature. The provided shading area and duration can make air temperature variable within the space.
3	Radiation	While street orientation and ratio affect shading area and duration, they affect the surface radiation of the canyon.
4	Humidity	Urban canyon has no effect of humidity

3.3 Vegetation

Vegetation exerts a substantial impact on wind patterns. The quantity of radiation absorbed and retained within a microclimate is contingent upon various factors, including the specific attributes of the vegetation, the dimensions of the area, the geographical placement, and the alignment of the site. Trees and bushes have the potential to function as physical barriers. The dispersed arrangement of constructed structures facilitates increased airflow unless there is an adequate implementation of tree planting to introduce compensatory surface irregularities. Sparse, lightweight canopies have the capacity to capture approximately 60–80% of solar radiation, whereas thick canopies possess the ability to collect as much as 99% of sunlight.

The mean cooling impact rises from 1.75°C for small green spaces (<4ha) to 2.66°C for medium-sized green spaces (4–10ha) and further to 3.32°C for big green spaces (>10ha). The cooling impact of tiny urban green spaces is shown to be two to four times greater than that of smaller green areas, which typically range in size from 20 to 60 meters. The mean temperature differential across all locations was around 5 °C, with a range spanning from approximately 2 to 7.5 °C [36]. Table 3 abstracts the effects of vegetation on microclimate.

Table 3. The effects of vegetation on microclimate. Source: Author based on [35]

#	Microclimate	Vegetation effects
1	Wind	Trees and shrubs can control the direction and speed of wind according to the used vegetation characteristics.
2	Temperature	Vegetation types have cooling effects on microclimate. It can also reduce the impact of UHI. Shading coverage offsets heating effects, especially in heavy traffic.
3	Radiation	Trees and shrubs decrease the long and short-wave radiation of the sun.
4	Humidity	Transpiration process of vegetation increases the relative humidity of the urban space.

3.4 Blue Spaces

Blue spaces have an impact on the microclimate of residential areas throughout the summer season [36]. Blue spaces have two distribution patterns, scattered and centralized (see Figure 5). Centralized water systems have proven to be quite efficient in regulating the partial microclimate within residential neighborhoods. The capacity of a water body to modify the residential microclimate varies depending on its location, size and shape [37]. When opting for centralized water distribution, it is advisable to position it in close proximity to the windward region, where the prevailing summer winds are most dominant. In this particular scenario, the presence of the water body may result in a broader coverage of the cooling effect within the residential district. The dispersion degree of scattered water can enhance the uniformity of microclimate within the entire residential district.

a)

b)

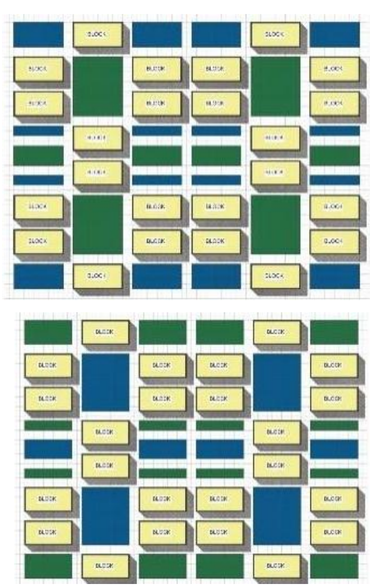

Figure 5: Examples of Blue spaces distribution, a) Scattered distribution. b) Centralized distribution.

When water is dispersed in a residential district, the temperature and relative humidity distribution become more uniform, even as the degree of dispersion of the water body increases. It is imperative that the size of each water region is not excessively tiny, as this would result in a reduction of its regulating function [38]. Table 4 presents the effects of blue spaces on microclimate parameters.

Table 4. The effects of blue Spaces on microclimate. Source: Author based on [36-38]

#	Microclimate	Blue spaces effects
1	Wind	Water bodies do not affect wind direction or speed.
2	Temperature	The evaporative action has a positive effect on the microclimate of the areas surrounding the water body with the relative cooling effect.
3	Radiation	Blue spaces have the capacity to reduce both long-wave and short-wave solar radiation.
4	Humidity	The evaporative process of blue spaces increases the relative humidity of the microclimate.

3.5 Pavement materials

Pavement materials have a significant impact on the microclimates of urban open spaces by influencing ambient temperatures, relative humidity and wind velocity readings, direct and reflected solar radiation, and surface albedo (material reflection), thus influencing pedestrian thermal comfort and energy use in buildings [39-44]. Several researchers have discussed the previously mentioned aspects [45-51]. Chatzidimitriou A et al. [52] reported on microclimate data measurements taken in various open urban spaces over a period of 11 days in mid-summer in July and august in Thessaloniki, northern Greece, such as parks, squares, and courtyards with various ground surface materials, specifically asphalt, concrete, marble, granite, porous stone, cobble stone, ceramic tiles, and gravel. The ambient temperature ranged between 17 °C and 32 °C on the majority of the measurement days, with the exception of a period of severe heat waves when the air temperature reached 44 °C. Santamouris et al. [53] discovered that broad use of reflecting pavements under specified climatic conditions might reduce the peak daily ambient temperature during a typical summer day(4th of august) in the southwestern part of Athens by up to 1.9 K, while surface temperatures could be reduced by up to 12 K. Cool pavements are an effective mitigation approach for reducing the severity of heat islands in urban settings and improving the overall environmental quality of open spaces. Table 5 presents the effects of pavement materials on microclimate parameters.

Table 5. **The effects of pavement materials on microclimate. Source: Author based on [39-55]**

#	Microclimate	Pavement materials effects
1	Wind	The surface temperature is influenced by the process of heat reflection, which subsequently impacts the temperature of the air in direct contact with the surface. Consequently, this interaction affects the circulation and flow of the air above the surface.
2	Temperature	The air temperature during daylight hours exhibits a decrease in response to an increase in the reflectivity of roads or pathways. Higher albedo causes reduction of surface temperature while the lower albedo causes increasement of pavement surface temperature.
3	Radiation	There exists an inverse relationship between the albedo and the radiation emitted by a substance, such that a higher albedo corresponds to a lower level of radiation.
4	Humidity	Pavement materials have no effects on humidity.

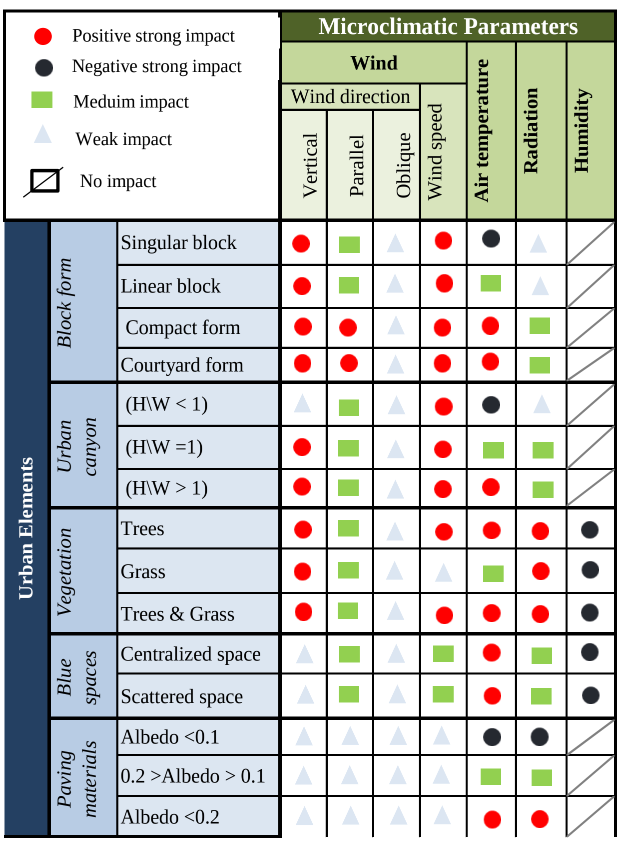

Figure 6: Nexus between urban elements and Microclimate parameters. Source: Author based on [19-55]

Figure 6 depicts the nexus between urban element parameters and microclimate parameters. It determines the microclimate parameters affected by urban element parameters. As shown, there are two approaches to categorizing the correlations between microclimate parameters and urban elements. The first type, which is separated into (strong, medium, and weak), specifies the amount of the correlation and ability of the parameters to impact each other's values.

The second type assesses the impact of the interaction between urban elements and microclimate parameters on energy consumption, which is classified as positive or negative. The positive effect is determined by relationships that work to reduce energy consumption of urban buildings, for example, the relationship of blue spaces with Air temperature or the relationship of vegetation with radiation, while the negative effect is determined by relationships that work to increase energy consumption of surrounding buildings, for example, the relationship of lower albedo paving materials with temperature or radiation, or the relationship of vegetation and blue spaces with humidity).

4 ENERGY PERFORMANCE AND MICROCLIMATE

The energy performance of buildings is significantly influenced by urban microclimate conditions [56]. It was discovered that microclimate parameters had a close association with each other. The key factor influencing building energy consumption is air temperature. Consequently, this section will elucidate the interplay between four significant microclimatic parameters interact with urban building energy consumption.

4.1 Wind

The impact of wind patterns on building energy consumption is constrained primarily to their influence on air temperature and the ventilation-induced air exchange inside indoor environments [57-59]. The significance of effectively designing and utilizing natural ventilation in densely populated urban areas has been proven to have significant effects on enhancing indoor thermal comfort, minimizing energy consumption, and addressing the issue of urban heat islands [60]. Schulze and Eicker [61] assert that a reduction in electricity consumption of 4 kWh/m2 per year is observed due to the absence of fans.

4.2 Temperature

The most important microclimate parameter influencing energy consumption is air temperature. Higher temperatures have a substantial impact on the building energy use, resulting in a large increase in peak and total electricity demand for air conditioning in buildings [62]. The relationship between daily electricity consumption and ambient temperature is not linear. The power demand curve exhibits variation based on the geographical region and time of year. In hot-dominated areas, the highest point on the curve is observed during the coldest winter period, whereas in cooling-dominated areas, it occurs during the warmest summer period. During the winter season, there is a negative correlation between ambient temperature and power consumption due to the fact that higher temperatures lead to a decrease in the need for heating. On the other hand, there exists a positive correlation between the nexus during the summer season and the heightened ambient temperatures, which consequently amplify the demand for cooling. Previous studies examining the influence of ambient temperature on aggregate electricity usage have indicated that the actual rise in electricity demand per unit of temperature increase falls within the range of 0.5% to 8.5% [63].

4.3 Radiation

Radiation is one of the methods by which heat is transferred, along with conduction, convection, phase change, and mass transfer. Any surface with a temperature above 0°K emits thermal radiation. Additionally, they assimilate thermal radiation emanated by their environment. The disparity between the total radiation emitted and absorbed by a surface at a specific time can lead to a net heat transfer, causing a modification in the surface's temperature [64]. Thermal radiation encompasses the wavelengths of the electromagnetic spectrum that can cause a surface to heat up upon absorption, spanning from around 100nm to 100,000 nm. Typically, as the temperature of a surface increases, the average wavelength of the radiation it emits decreases.

Radiation influences outdoor air temperature through the transfer of latent and turbulent heat from the surface to the atmosphere. Additionally, it affects indoor temperature through long-wave radiation emitted by the interior surfaces of a space [65]. The impact of radiation on indoor temperature and, subsequently, energy performance is contingent upon the building envelope material's U value, insulation, and window-to-wall ratio (WWR). Similarly, in the outdoor environment, the albedo of pavement materials, vegetation, and blue spaces influences the radiation impacts on outdoor temperature [66].

4.4 Humidity

The link between air humidity and cooling energy consumption in hot regions is linear, while in cold regions, it is inversely related to heating energy consumption [67].

Figure 7 illustrates the correlation between microclimate parameters and building energy parameters in terms of effect strength. The cooling and heating loads are the primary building energy metrics influenced by the microclimate. The primary determinants of building energy performance are the air temperature, wind speed, and humidity within the immediate microclimate of the buildings.

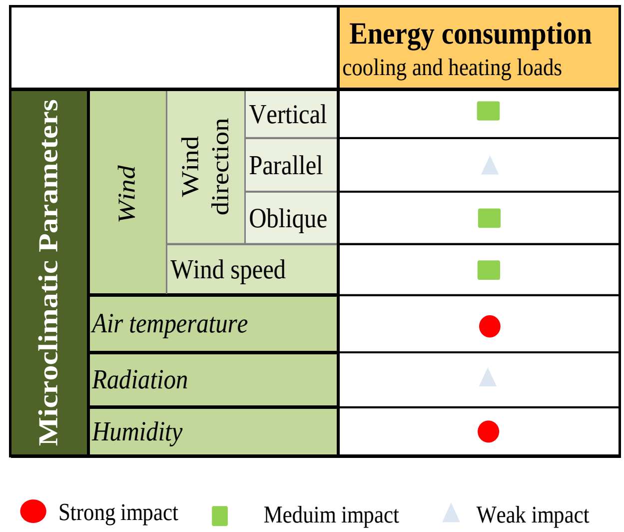

Figure 7: Weighted relation between microclimate and buildings energy consumption. Source: Author Based on [56-67].

5 URBAN ELEMENTS AND URBAN ENERGY PERFORMANCE

Urban planners are aware that the urban form has an impact on transportation energy use, and there are extensive studies to support this claim. Nevertheless, there is a limited number of research that has explored the potential impact of urban elements on the energy efficiency of buildings. The author's study survey reveals a scarcity of research on uncovering the indirect relationship between urban parameters and building energy consumption, as well as the means through which urban elements can impact building energy performance [68, 69].

As shown in Figure 8, the relationship between urban elements and building energy consumption can be inferred from previous research on the impact of urban elements on microclimate, which has been extensively studied for the past five decades [70–76]. The microclimate is influenced by two primary factors: local climate and urban elements. The microclimate, in addition to the building design and its occupancy, affects the indoor climate of the building. These factors, in turn, have a direct impact on the energy consumption of the building [77,78]. The influence of the urban microclimate indirectly impacts energy consumption in buildings, hence establishing a consequential relationship between urban elements and energy use.

This study aims to validate the existing correlation between urban factors and building energy consumption, with the potential to be broadly applied for enhancing energy efficiency in new regions.

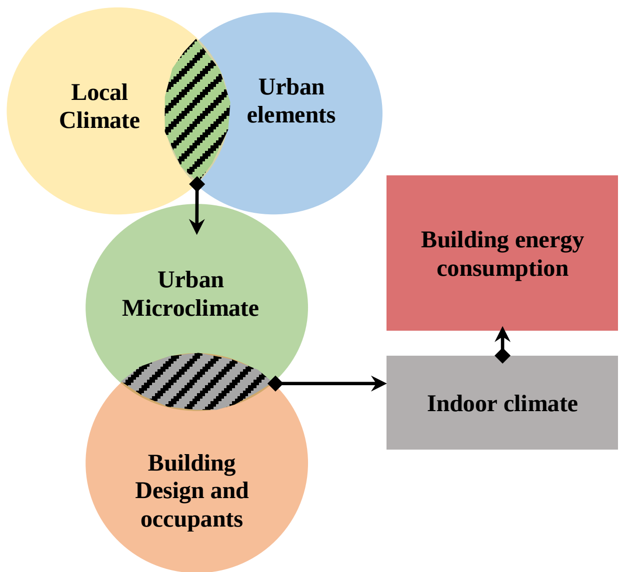

Figure 8. Relationship among microclimate, urban elements and Building Energy consumption. Source: Author based on [79-80].

6 URBAN ENERGY PERFORMANCE MATRIX

Due to the previously referenced illustration of the correlation between microclimate, urban elements, and urban energy performance, this part introduces a reference matrix (see Figure 9) for urban energy performance. The matrix presented in this study primarily outlines the degree of effect strength between microclimate, urban elements, and urban energy performance. This matrix is based on the findings of prior studies and the proven relationship as described in the methodology section of the paper. The matrix comprises two primary axes: the horizontal axis denotes urban elements, while the vertical axis delineates microclimate and building energy consumption factors. Depending on the design and location of urban areas, these parameters can have an impact on urban energy performance, either positively or negatively. The assessment of the relationship of energy consumption to urban elements depends on the strength of the influence of the urban element on microclimate parameters and the strength of the relation of these microclimate parameters to energy consumption. The measurement depends on the strength of the influence of the chosen factors on each other. The positive effects of correlations between urban elements, wind, air temperature, and radiation lead to a reduction in energy consumption. However, the negative effects of correlations between urban elements and humidity have a detrimental effect on decreasing energy consumption in urban buildings due to the inverse relationship between humidity and air temperature. Higher levels of humidity throughout the summer result in increased heat perception and more reliance on HVAC use.

Table 6 shows the impact measurement scale, which displays the relationship between each pair of attributes in the reference matrix. As stated in Section 2, the categorization of the values (strong, medium, weak, and no impact) was determined by taking into account the findings and recommendations from previous applied and analytical studies [7-79], which explored and analyzed the impact of key factors on each other.

Table 6. Measurement scale of the reference matrix. Source: Author.

Scale	Symbol	Description
Strong		Strong positive correlation and ability to affect measured values of selected parameters.
		Strong negative correlation and ability to affect measured values of selected parameters.
Medium		Fair positive correlation and ability to affect measured values of selected parameters.
Weak		Poor positive correlation and inability to affect measured values of selected parameters.
		Poor negative correlation and inability to affect measured values of selected parameters.
No impact		No correlation and inability to affect measured values of selected parameters.

7 RESULTS

The matrix illustrates the significant impact of block form and urban canyons on building energy characteristics. Furthermore, the impact of vegetation and blue spaces on building energy is noteworthy. Previous studies have mostly concentrated on leveraging the significant impact of block morphology and urban canyons to improve urban energy efficiency and incorporate it as the primary input in urban building energy methodologies. In contrast, while the impact of vegetation and blue spaces on building energy is moderate, there is a lack of research investigating their potential as novel strategies for stakeholders, planners, and architects to improve the energy efficiency of newly developed urban areas.

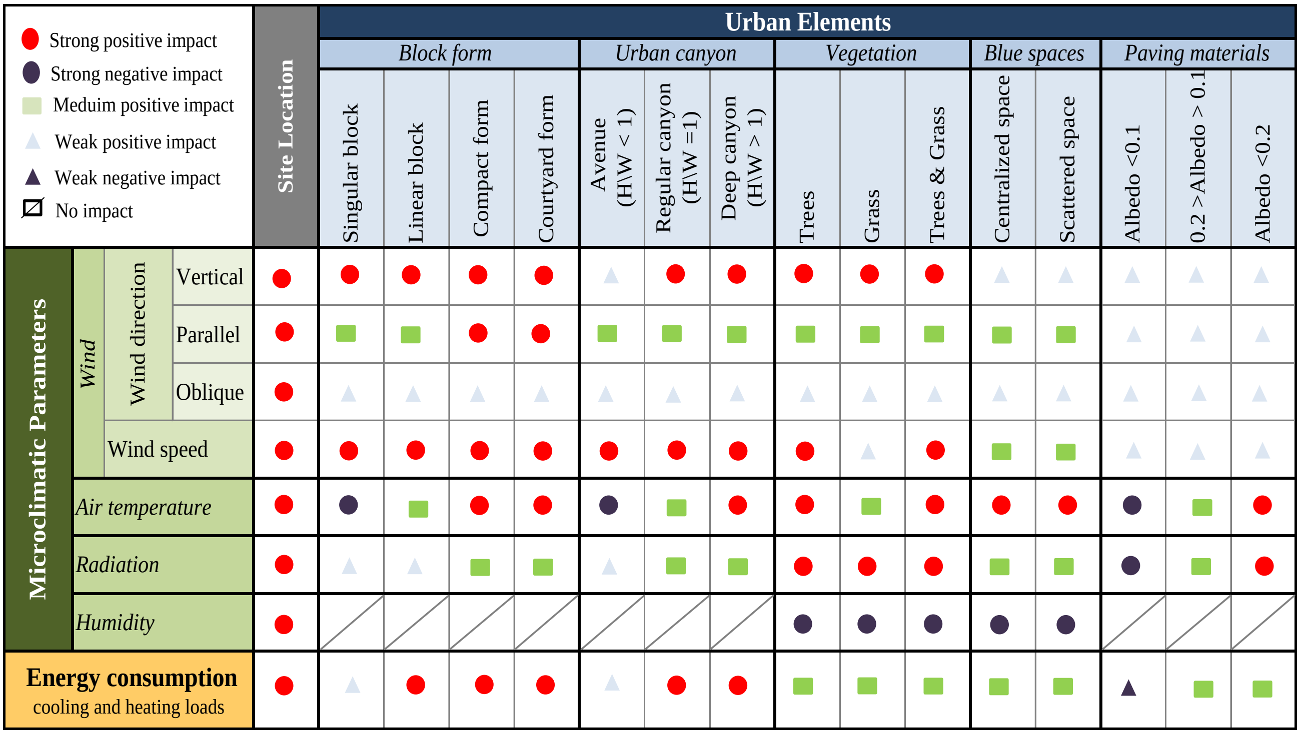

Figure 9: Urban energy performance matrix. Source: Author.

8 CONCLUSION

The persistent consequences resulting from the rise in urban energy use necessitate the development of novel approaches to improve urban energy efficiency. This study examines the correlation between urban elements and reshaping the urban energy performance matrix. The utilization of this matrix can serve as a valuable tool for urban planners and architects in their endeavors to optimize energy efficiency throughout the early stages of urban planning and design. It can also assist stakeholders in making decisions by giving a wealth of data and solutions for improving urban energy efficiency.

The recently updated urban energy performance matrix has unveiled a correlation between urban elements and building energy consumption. The extent of this impact is contingent upon the relationship between the aforementioned urban environment and the various microclimate parameters. The urban elements that significantly influence microclimate, such as wind speed, humidity, air temperature, and radiation, exert a substantial influence on building energy factors, particularly cooling and heating loads. Therefore, the correlation between urban elements and building energy parameters is mostly established through the horizontal axis; they start strongly at the horizontal axis with block form and the urban canyon and end moderately with vegetation and blue spaces.

While researchers have extensively examined the impact of various parameters in urban performance matrices on urban energy performance, certain factors, such as vegetation and blue spaces, have not received adequate attention in terms of their influence on urban building energy modeling. Furthermore, there is a lack of research on appropriate methodologies for incorporating these parameters into urban design.

The paper proposes a thorough examination of the suggested course of action since it holds potential for discovering novel approaches to improving urban energy efficiency.

9 REFERENCES

[1] Heilig, G. K. (2012). World urbanization prospects: the 2011 revision. United Nations, Department of Economic and Social Affairs (DESA), Population Division, Population Estimates and Projections Section, New York, 14, 555.

[2] United nation economic and social council. Available online on: http://www.un.org/en/ecosoc/integration/pdf/fact_sheet.pdf (visited on 15.4.2016).

[3] Smil, V. (2017). Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy. Available online on: https://ourworldindata.org/grapher/global-primary-energy?time=earliest..2019 (accessed on 27 January 2021)

[4] Electric power consumption (kWh per capita) – Africa. Available online on: https://www.indexmundi.com/facts/indicators/EG.USE.ELEC.KH.PC/ map/africa (accessed on 27 January 2021)

[5] Timur Dagon and Christoph Reinhart, 2017, shoeboxer: An algorithm for abstracted rapid multi-zone urban building energy model generation and simulation, Massachusetts institute of technology, Cambridge, MA, USA.

[6] Shishegar, N. (2013). Street design and urban microclimate: analyzing the effects of street geometryand orientation on airflow and solar access in urban canyons. Journal of clean energy technologies, 1(1).

[7] Ren, Z., Wang, X., Chen, D., Wang, C., & Thatcher, M. (2014). Constructing weather data for building simulation considering urban heat island. Building Services Engineering Research and Technology, 35(1), 69-82.

[8] Syafii, N. I., Ichinose, M., Wong, N. H., Kumakura, E., Jusuf, S. K., & Chigusa, K. (2016). Experimental study on the influence of urban water body on thermal environment at outdoor scale model. Procedia Engineering, 169, 191-198.

[9] Liao, F. C., Cheng, M. J., & Hwang, R. L. (2015). Influence of urban microclimate on air-conditioning energy needs and indoor thermal comfort in houses. Advances in Meteorology, 2015.

[10] Kolokotroni, M., Giannitsaris, I., & Watkins, R. (2006). The effect of the London urban heat island on building summer cooling demand and night ventilation strategies. Solar Energy, 80(4), 383-392.

[11] Jusuf, S. K., Wong, N. H., Hagen, E., Anggoro, R., & Hong, Y. (2007). The influence of land use on the urban heat island in Singapore. Habitat international, 31(2), 232-242.

[12] De Wilde, Pieter (2018). Building Performance Analysis. Chichester: Wiley-Blackwell. pp. 325–422.

[13] Griffin, T., & Crutchfield, D. (2012). Understanding Building Energy Models:Speaking your customer's language. District Energy, 98(4), 21.

[14] Harish, V. S. K. V., & Kumar, A. (2016). A review on modeling and simulation of building energy systems. Renewable and sustainable energy reviews, 56, 1272-1292.

[15] Christoph F. Reinhart & Carlos CerezoDavila, 2015, Urban Building EnergyModeling - A Review of a Nascent field, Building and Environment 2016, 97: 196-202.

[16] Johari, F., Peronato, G., Sadeghian, P., Zhao, X., & Widén, J. (2020). Urban building energy modeling: State of the art and future prospects. Renewable and Sustainable Energy Reviews, 128, 109902.

[17] Bemis, J. (2016). Urban building energy modeling as a dynamic tool for sustainability planning (Doctoral dissertation, Massachusetts Institute of Technology).

[18] Davila, C. C., Reinhart, C., & Bemis, J. (2016). Modeling Boston: A workflow for the generation of complete urban building energy demand models from existing urban geospatial datasets. Energy, 117, 237-250.

[19] Middel, A., Häb, K., Brazel, A. J., Martin, C. A., & Guhathakurta, S. (2014). Impact of urban form and design on mid-afternoon microclimate in Phoenix Local Climate Zones. Landscape and Urban Planning, 122, 16-28.

[20] Hyader, S., & Hassan, S. (2022). The Effect of Different Urban Forms on Microclimate in Hot Arid Climates. Kerbala Journal for Engineering Science, 2(1), 1-10.

[21] Al-Mosawy, S. K. A., Al-Jawari, S. M., & Al-Jabari, A. A. (2020, April). The Effect of Urban Form on Temperature for Hot Arid Zones. The Case Study of Baghdad, Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 459, No. 6, p. 062109). IOP Publishing.

[22] Taleghani, M., Kleerekoper, L., Tenpierik, M., & van den Dobbelsteen, A. (2015). Outdoor thermal comfort within five different urban forms in the Netherlands. Building and environment, 83, 65-78.

[23] Costanzo, V., Evola, G., & Marletta, L. (Eds.). (2021). Urban Heat Stress and Mitigation Solutions: An Engineering Perspective. Routledge.

[24] Rida, A. Z. M. I., Koumetio, C. S. T., Diop, E. B., & Chenal, J. (2021). Exploring the relationship between urban form and land surface temperature (LST) in a semi-arid region Case study of Ben Guerir city-Morocco. Environmental Challenges, 5, 100229.

[25] Syrios, K., & Hunt, G. R. (2008). Passive air exchanges between building and urban canyon via openings in a single façade. International Journal of Heat and Fluid Flow, 29(1), 364-373.

[26] Todhunter, P. E. (1990). Microclimatic variations attributable to urban-canyon asymmetry and orientation. Physical geography, 11(2), 131-141.

[27] Arnfield, A. J., & Mills, G. M. (1994). An analysis of the circulation characteristics and energy budget of a dry, asymmetric, east- west urban canyon. I. Circulation characteristics. International Journal of Climatology, 14(2), 119-134.

[28] Nakamura, Y., & Oke, T. R. (1988). Wind, temperature and stability conditions in an east-west oriented urban canyon. Atmospheric Environment (1967), 22(12), 2691-2700.

[29] Johansson, E. (2006). Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. Building and environment, 41(10), 1326-1338.

[30] Al-Sallal, K. A., & Al-Rais, L. (2012). Outdoor airflow analysis and potential for passive cooling

in the modern urban context of Dubai. Renewable Energy, 38(1), 40-49.

[31] Yola, L., & Siong, H. C. (2016). Impact of Urban Canyon Direction on Solar Radiation and Airflow in Hot and Humid Regions. Asian Journal of Behavioural Studies, 3(13), 88-97.

[32] Robins, A., & Macdonald, R. (1999). Review of Flow and Dispersion in the Vicinity of Buildings. Atmospheric Dispersion Modeling Liaison Committee Annual Report.

[33] Erell, E., Pearlmutter, D., & Williamson, T. (2012). Urban microclimate: designing the spaces between buildings. Routledge.p88.

[34] Abd Elraouf, R., Elmokadem, A., Megahed, N., Eleinen, O. A., & Eltarabily, S. (2022). The impact of urban geometry on outdoor thermal comfort in a hot-humid climate. Building and Environment, 225, 109632.

[35] Guedes, M. C., & Cantuaria, G. (Eds.). (2019). Bioclimatic Architecture in Warm Climates: A Guide for Best Practices in Africa. Springer.pp177.

[36] Ampatzidis, P., & Kershaw, T. (2020). A review of the impact of blue space on the urban microclimate. Science of the total environment, 730, 139068.

[37] Li, C., & Yu, C. W. (2014). Mitigation of urban heat development by cool island effect of green space and water body. In Proceedings of the 8th International Symposium on Heating, Ventilation and Air Conditioning: Volume 1: Indoor and Outdoor Environment (pp. 551-561). Springer Berlin Heidelberg

[38] Jin, H., Shao, T., & Zhang, R. (2017). Effect of water body forms on microclimate of residential district. Energy Procedia, 134, 256-265.

[39] Yannas, S. (2001). Toward more sustainable cities. Solar energy, 70(3), 281-294.

[40] Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar energy, 70(3), 295-310.

[41] Doulos, L., Santamouris, M., & Livada, I. (2004). Passive cooling of outdoor urban spaces. The role of materials. Solar energy, 77(2), 231-249.

[42] Akbari, H., Bretz, S., Kurn, D. M., & Hanford, J. (1997). Peak power and cooling energy savings of high-albedo roofs. Energy and Buildings, 25(2), 117-126.

[43] Ca, V. T., Asaeda, T., & Abu, E. M. (1998). Reductions in air conditioning energy caused by a nearby park. Energy and buildings, 29(1), 83-92.

[44] Pearlmutter, D., Berliner, P., & Shaviv, E. (2006). Physical modeling of pedestrian energy exchange within the urban canopy. Building and environment, 41(6), 783-795.

[45] Pearlmutter, D., Berliner, P., & Shaviv, E. (2007). Integrated modeling of pedestrian energy exchange and thermal comfort in urban street canyons. Building and Environment, 42(6), 2396-2409.

[46] Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. Energy and buildings, 37(7), 762-776.

[47] Meir, I. A., Pearlmutter, D., & Etzion, Y. (1995). On the microclimatic behavior of two semi-enclosed attached courtyards in a hot dry region. Building and Environment, 30(4), 563-572.

[48] Akbari, H., & Matthews, H. D. (2012). Global cooling updates: Reflective roofs and pavements. Energy and Buildings, 55, 2-6.

[49] Yaghoobian, N., & Kleissl, J. (2012). Effect of reflective pavements on building energy use. Urban Climate, 2, 25-42.

[50] Nikolopoulou, M., & Lykoudis, S. (2006). Thermal comfort in outdoor urban spaces: analysis across different European countries. Building and environment, 41(11), 1455-1470.

[51] Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. Remote sensing of environment, 86(3), 370-384.

[52] Chatzidimitriou, A., & Yannas, S. (2015). Microclimate development in open urban spaces: The influence of form and materials. Energy and Buildings, 108, 156-174.

[53] Santamouris, M., Gaitani, N., Spanou, A., Saliari, M., Giannopoulou, K., Vasilakopoulou, K., & Kardomateas, T. (2012). Using cool paving materials to improve microclimate of urban areas–Design realization and results of the flisvos project. Building and Environment, 53, 128-136.

[54] Salvati, A. G. N. E. S. E., Kolokotroni, M., Kotopouleas, A., Watkins, R., Giridharan, R. E. N. G. A. N. A. T. H. A. N., & Nikolopoulou, M. (2020). Impact of urban albedo on microclimate: Computational investigation in London.

[55] Merlier, L., Frayssinet, L., Johannes, K., & Kuznik, F. (2019, October). On the impact of local microclimate on building performance simulation. Part I: Prediction of building external conditions. In Building Simulation (Vol. 12, No. 5, pp. 735-746).

[56] Santamouris, M., Papanikolaou, N., Livada, I., Koronakis, I., Georgakis, C., Argiriou, A., & Assimakopoulos, D. N. (2001). On the impact of urban climate on the energy consumption of buildings. Solar energy, 70(3), 201-216.

[57] Ai, ZT, Mak, CM, From street canyons microclimate to indoor environmental quality in naturally ventilated urban buildings: issues and possibilities for improvement, Building and Environment 94 (2015) 489-503

[58] Kolokotroni, M, Aronis, A, Cooling-energy reduction in air-conditioned offices by using night ventilation Applied Energy 63 (1999) 241-253.

[59] Oropeza-Perez, I., & Østergaard, P. A. (2014). Potential of natural ventilation in temperate countries–a case study of Denmark. Applied energy, 114, 520-530.

[60] Schulze, T., & Eicker, U. (2013). Controlled natural ventilation for energy efficient buildings. Energy and buildings, 56, 221-232.

[61] Enshen, L. (2005). Research on the influence of air humidity on the annual heating or cooling energy consumption. Building and Environment, 40(4), 571-578.

[62] Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2015). On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. Energy and Buildings, 98, 119-124.

[63] Pisello, A. L., Castaldo, V. L., Taylor, J. E., & Cotana, F. (2016). The impact of natural ventilation on building energy requirement at inter-building scale. Energy and Buildings, 127, 870-883.

[64] Designing Buildings . 2021 , Radiation, Wiki, Designing Buildings . Available online on : https://www.designingbuildings.co.uk/wiki/Radiation (accessed on 1 August 2021)

[65] Edward P., 2021,climate , Earth Sciences, Earth Science, Geologic Time & Fossils science , Britannica. Available online on : https://www.britannica.com/science/climate-meteorology/Solar-radiation-and-temperature (accessed on 1 August 2021)

[66] Lundström, H., & Mattsson, M. (2020). Radiation influence on indoor air temperature sensors: Experimental evaluation of measurement errors and improvement methods. Experimental Thermal and Fluid Science, 115, 110082.

[67] Ewing, R., & Rong, F. (2008). The impact of urban form on US residential energy use. Housing policy debate, 19(1), 1-30.

[68] Ko, Y. (2013). Urban form and residential energy use: A review of design principles and research findings. Journal of planning literature, 28(4), 327-351.

[69] Emmanuel, R., & Steemers, K. (2018). Connecting the realms of urban form, density and microclimate.

[70] Olgyay, V. (1963). Design with climate: bioclimatic approach to architectural regionalism. Princeton university press.

[71] Golany, G. S. (1996). Urban design morphology and thermal performance. Atmospheric Environment, 30(3), 455-465.

[72] Givoni, B. (1998). Climate considerations in building and urban design. John Wiley & Sons.

[73] Knowles, R. L. (1981). Sun rhythm form. Cambridge, MA: MIT Press.

[74] Martins, T. A. L., Adolphe, L., & Bastos, L. E. G. (2014). From solar constraints to urban design opportunities: Optimization of built form typologies in a Brazilian tropical city. Energy and Buildings, 76, 43–56.

[75] Futcher, J. A., Kershaw, T., & Mills, G. (2013). Urban form and function as building performance parameters. Building and Environment, 62, 112–123.

[76] Kolokotroni, M., Giannitsaris, I., & Watkins, R. (2006). The effect of the London urban heat island on building summer cooling demand and night ventilation strategies. Solar Energy, 80(4), 383-392.

[77] Jusuf, S. K., Wong, N. H., Hagen, E., Anggoro, R., & Hong, Y. (2007). The influence of land use on the urban heat island in Singapore. Habitat international, 31(2), 232-242.

[78] Liao, F. C., Cheng, M. J., & Hwang, R. L. (2015). Influence of urban microclimate on air-conditioning energy needs and indoor thermal comfort in houses. Advances in Meteorology, 2015.

[79] Santos Nouri, A., & Costa, J. P. (2017). Placemaking and climate change adaptation: new qualitative and quantitative considerations for the “Place Diagram”. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 10(3), 356-382.

[80] Skelhorn, C. P. (2014). A fine scale assessment of urban greenspace impacts on microclimate and building energy in Manchester. The University of Manchester (United Kingdom).