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THE IMPACT OF EXTERIOR CERAMIC CLADDING AND TRIPLE-GLAZING ON THE ENERGY AND THERMAL ASPECTS OF COLLECTIVE HOUSING IN SKIKDA

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ABSTRACT

The interrelated issues of climate change and energy saving have become increasingly significant in the present era and are likely to remain so in the future. This is largely due to the complex and far-reaching impacts these topics have on our society and the environment. Furthermore, these issues align with the needs of people who seek comfort in the indoor spaces where they live or work. In this study, a climatic, energetical and thermal examinations were carried out on a multi-family housing structure in Skikda, basing on actual historical energy data from 2022 for calibration and validation of energy models, using principally CEA and METEONORM tools. This last-mentioned climate simulation tool was also used to generate future meteorological data for 2060 and 2100. Two scenarios were studied: the addition of a ceramic exterior cladding and the replacement of single-glazed windows with triple-glazed windows. The aim was to examine the impact of climate change across three time periods (2022, 2060 and 2100) and the influence of the two techniques on energy efficiency and interior comfort. The results showed that the ceramic cladding reduced electricity and natural gas consumption by 10% and 34% respectively, by insulating the interior from outside temperature variations. Triple-glazed windows reduced natural gas consumption by 27%, but did not reduce electricity consumption due to increased artificial lighting requirements. Analysis of thermal comfort showed that both two intervention scenarios resulted in enhanced conditions. These results are important for guiding energy renovation decisions for buildings in similar climatic zones.

KEYWORDS

Climate Change, Energy Consumption, Thermal Comfort, Envelop Interventions, Collective Housing, Skikda

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1. INTRODUCTION

The present state of global ecological and energy challenges is characterised by an urgent necessity for action. This must be considered alongside the imperative to address issues of indoor and outdoor thermal comfort and wellbeing (Khelifa et al., 2024). These challenges include global warming, a substantial rise in the Earth's global average temperature, as well as the depletion of specific natural resources, particularly within the energy sector regarding the utilization and production of fossil fuels (Larrère, 2009; Khelifa, 2024). Additionally, the worldwide market for petroleum has seen significant disruptions in recent years due to the growing awareness that the fossil fuel era is coming to an end. These disruptions have put oil-producing countries like Algeria, where it is predicted that some fossil fuels will run out by 2030, in financial threat (Bekhtache, 2012). Additionally, Algeria has seen rapid demographic growth over the past 60 years, and there has been a notable shift in building sectors, especially in the residential one, which, according to 2015 data, accounts for 43 % of the country's total energy use (Ahmari & Korichi, 2019). Algeria's Mediterranean north-eastern town of Skikda reflects its reality and deals with the same energy along with ecological problems as the rest of the country (Hadef, 2020). The building industry revolution in Skikda, as well as throughout Algeria, has ignored and rarely used traditional solutions created over centuries to improve their liveable environment, pushing aside the subtle specificities of the country's varied climate. The use of artificial lighting, heating, and cooling has made this issue worse, and it has led to an excessive and unjustified use of energy supplies (Latreche & Sriti, 2018). In addition to demonstrating the enormous contribution of the residential sector to the massive energy consumption based on fossil fuel sources, the aforementioned highlights the state of ecological and energy vulnerability on a global scale, including in Algeria as demonstrated in Skikda (Khelfa et al., 2024). This indicates that the residential sector also plays a significant role in the disruption of the environmental together with climatic state, directing research into the impact of tangible changes on the urban components by means of buildings' renovation, as part of the energy transition. This present study aims to examine the influence of the external ceramic cladding technique and the replacement of existing glazing with tripled glazing on two key performance indicators, namely energy consumption and thermal comfort. To this end, the study will draw upon data collected from a collective housing unit situated in Skikda, a Mediterranean city in the northeastern region of Algeria, which will be utilized as the case study. This study will also examine the impact of climate change on the building in its initial conditions, as well as its state following the implementation of the two proposed renovation techniques. This will be achieved through the simulation on the basis of current and future meteorological data.

2. METHODOLOGY

2.1 Study context

Skikda is a city in the north-eastern region of Algeria. It has an altitude variation of between 0 and 150 meters above sea level and a population density of 3,896 people per square kilometre (ANIREF, 2020).

According to measurements of diurnal temperatures and meteorological conditions over the period 1991 to 2020 (Site Climats et voyages, 2020), the geographical area is categorized as belonging to the temperate Mediterranean climate zone, which is typically humid. While the summer months are characterized by relatively high temperatures, the wintertime is generally not severe. During the coldest period of the year (February), the typical lowest temperature is 9°C, and during the summer's hottest month (August), the mean highest temperature is 30°C.

The considerable annual temperature fluctuations in Skikda necessitate the implementation of tailored strategies to guarantee optimal thermal comfort within buildings. Prior investigations indicate that Skikda's multi-family dwellings are in a degraded state due to historical and weather-related factors. Additionally, the lack of housing has resulted in rapid urbanization without the application of bioclimatic principles (Brighet, 2018). The aforementioned factors have collectively resulted in the creation of residential units that are unable to provide their occupants with an adequate level of comfort and that fail to meet the current energy saving standards (Kassis, 2012). As a consequence, these buildings are required to contend with both the daily and annual fluctuations in weather patterns, necessitating the extensive use of artificial methods that are both detrimental to the environment and energy-intensive (Boulkenafet, 2014).

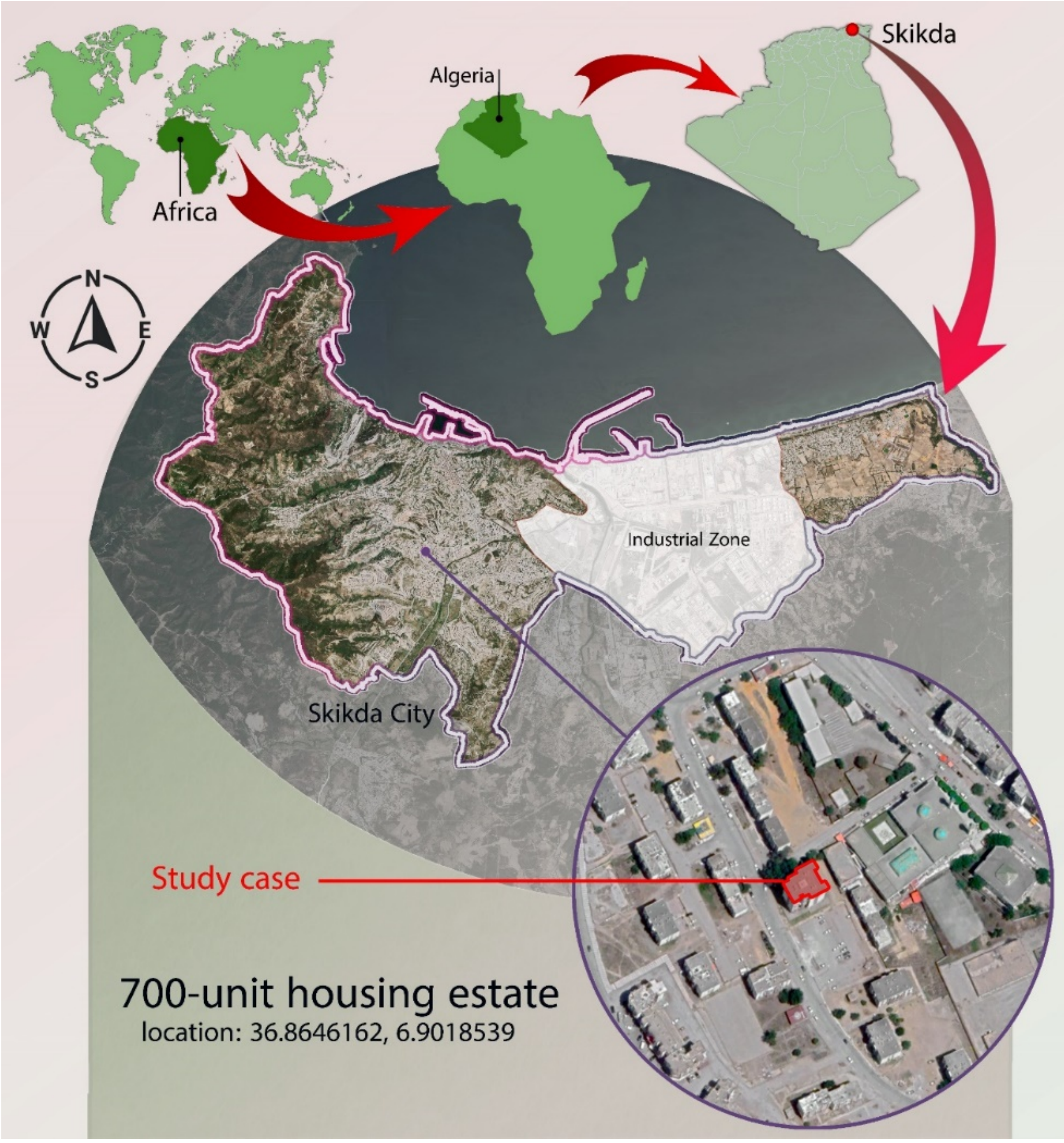

Fig. 1. Identification of the study case's location relative to the entire world.

The case study focuses on a multi-family housing complex with 30 flats spread across ten stories. The relevant property is located in a 700-unit housing neighbourhood in the heart of the urban region. (Figure 1) depicts the precise place in question. The building was chosen because of its age and size, making it an ideal sample for reflecting the habits of energy use in Skikda, with 30 families in existence.

The technical along with administrative details for the case studies were gathered from a variety of agencies involved with the Wilaya of Skikda, that include the town's municipal hall, the OPGI (the Real Estate Promotion and Management Office), and the principal contractors' design offices.

The data presented in (Table 1) pertains to the construction year, geometry, height, and thermal transmittance (U-value) of the building. This information was utilized to develop a model of the building envelope and incorporate its distinctive characteristics through the use of the provided simulation tools.

Table 1. Key properties and data associated with the archetype.

Year of occupancy		1978
Geometry	Number of floors	10
	Height	30 m
	Surface area	295.9 m²
	Number of apartments / floors	3 apartments / floor
	Volume	8 877 m3
Site altitude		11 m
Exterior wall	Components	The construction of sandwich panels comprising prefabricated elements of reinforced concrete and plastering, with painting subsequently applied.
	U-value [W·m−2 K−1]	2.30
Glazing	Components	Single glazing
	U-value [W·m−2 K−1]	6.00
Roofing	Components	The construction comprises prefabricated sandwich panels made of reinforced concrete and multi-layer bituminous waterproofing.
	U-value [W·m−2 K−1]	1.20

2.2 Study workflow

(Figure 2) provides a summary of the methodological process undertaken in this study. This commenced with an exploration of existing literature within the same field of enquiry, following which the present case study was selected for analysis.

This study's approach is based on numerical modelling and simulation, with simulated findings calibrated using real energy consumption data obtained from the regional commercial office of SONELGAZ (National Company for Electricity and Gas) at Skikda.

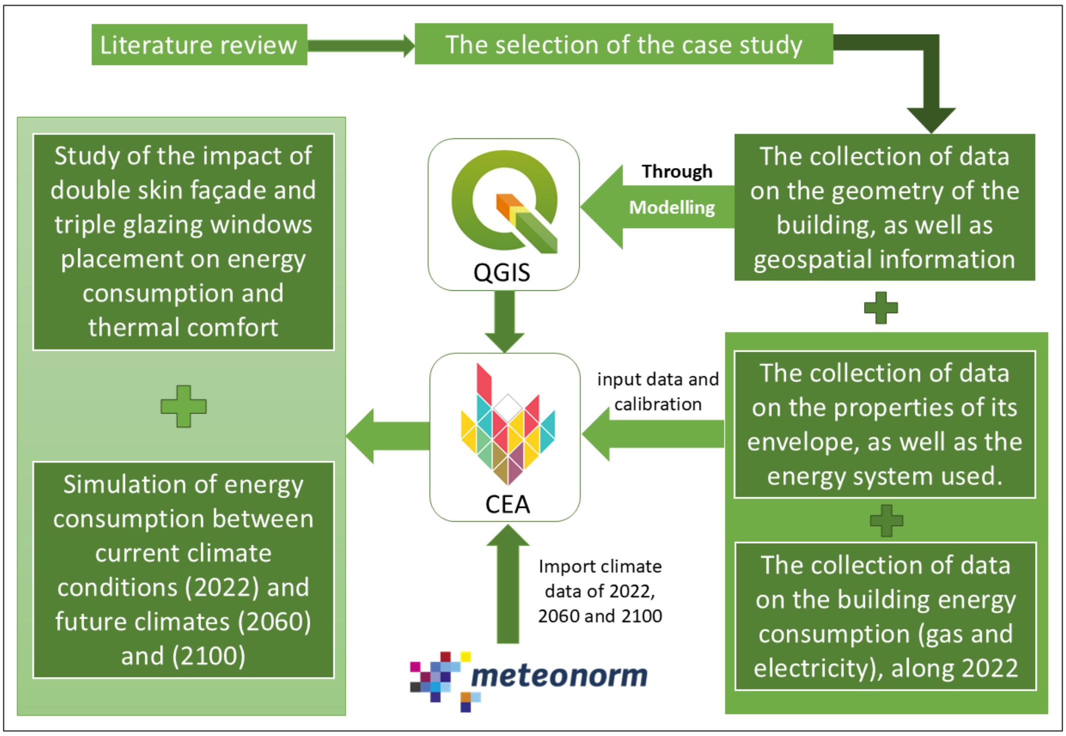

Fig. 2. Methodology workflow

Geometrical forms modelling was done out employing the QGIS tool, which extracted a "Shapefile" that included geometrical along with geographic details regarding the case study and its surroundings, which was then imported into the CEA simulation tool before bringing in climatic data for the environment of Skikda according to on the EPW file brought in using the METEONORM 8.0, which is a meteorological software program that was utilized to create climate data for the years 2022, 2060, and 2100. These data were then imported into the CEA software, and employed also to generate graphs of temperatures and solar radiation.

The CEA simulations of initial state were calibrated and validated by the use of real historical electricity and gas consumption data. Afterwards, two techniques were used, including external ceramic cladding and the replacement of existing single glazing with triple glazing in a different scenario, to simulate their effect on energy and thermal aspects, at present and future.

The two scenarios, in addition to the collective housing structure selected as the case study, are presented in Figure 3.

The scenario (1) was modelled using the properties of the cladding mounted on the exterior of the envelope. This comprises polyurethane adhesive, plaster, insulation, a rain screen and ceramic. The thermal transmittance coefficient was established as 0.3 [W-m-2 K-1], while the solar absorption, emissivity of external surfaces and reflectance in the red spectrum values for the ceramic material were also entered.

Concerning scenario (2), the existing simple glazing with a thermal transmittance coefficient of 6 [W-m-2 K-1], solar heat gain coefficient (SHGC) of 0.85, and an emissivity of external surface coefficient with a value of 0.89. While the new implemented triple glazing was characterized by a thermal transmittance coefficient of 0.9 [W-m-2 K-1], a SHGC of 0.70, and a coefficient of emissivity of external surface that is around 0.89 also.

Fig. 3. Photographic shot of the case study,
with the two scenarios for intervention on the building's external envelope.

2.3 Overview on the building energy data and system

It is necessary to obtain a corpus of authentic data regarding energy consumption in order to perform the necessary calibrations and validations of the building's energy model. The data regarding energy consumption were gathered from a local commercial entity situated Skikda, that is associated with the national electricity and gas distribution company (SONELGAZ). These data are in the form of energy bills for the entire 2022 calendar year, covering 10 apartments. The apartments in question were selected through a sampling process that involved choosing units of varying floor heights and orientations. The total energy usage of the entire building was then subtracted from the individual apartment energy usage figures in order to isolate the energy consumption of the apartments themselves.

It is crucial to acknowledge that, in Skikda, as is the case throughout Algeria, natural gas is predominantly utilized for heating systems, domestic hot water, and cooking, whereas electricity is primarily employed for lighting, cooling, as well as domestic appliances such as televisions, dishwashers, computers, cooling systems, refrigerators, and freezers, among others.

2.4 Materials

Several tools were used in this research, and they are defined below:

2.4.1 QGIS tool

QGIS (Quantum Geographic Information System), released in 2002, is an open-source geographic information system that is freely available, and is distributed under the GNU General Public License. This application is well-known for its extensive tool set, large number of supported formats, and simplicity. Among its benefits will be access to the features of other free software included with the installation (such as GRASS as well as SAGA) or added independently (for example, PostgreSQL). QGIS works with Unix systems, Linux, Mac OS X, and Windows (Demougeot-Renard, 2016). It allows users to generate, modify, visualize, evaluate, and also publish geographic and spatial data. The program provides numerous free internet materials and maps for download; it also supports a variety of vector file types. There are several plug-ins available for usage, and new plug-ins are constantly being developed (Palino & Sparks, 2021).

In the present study, the QGIS software was used to create a file (Shapefile) containing all the necessary spatial and geographical data, which was then used for the modelling of the case study and its surrounding urban context.

2.4.2 Meteonorm

METEONORM is an extensive database of meteorological information. It also includes algorithms for generating weather files from measurements collected from anywhere on the planet (Batiactu website, n.d.).

In this research, the data was employed for the extraction of graphical representations of temperature and solar radiation data on a monthly basis. Additionally, it was utilized for the extraction of climatic data in the file format EPW, spanning the years 2022, 2060, and 2100, pertaining to the city of Skikda. This data was then imported into the CEA software.

2.4.3 City Energy Analyst (CEA)

CEA was created as a software application for making time- and labour-saving estimations about the energy consumption and improvements of city housings and neighbourhoods (CEA official website, n.d.). Its primary goal is to compare several urban energy production scenarios in order to assess energy efficiency data. CEA provides default information systems on the occupancy rate schedules, internal energy loads, interior temperature variables, building structure systems, envelope construction properties, as well as emissions systems depending on building stock archetype data to offer energy demand projections for merely unidentified city periods with no accessibility to specific construction and building plans, as well as building system properties (Willmann et al., 2019). CEA adheres to the reduced-order UBEM approaches, which refers to Urban building energy modelling tools, it's commonly used for performing fast studies of building efficiency. This method requires a smaller amount of input in comparison to the physical as well as data-based methods (Hong et al., 2020). Only general information on the construction's geometry (including the number of floors as well as height), construction year along with renovation year(s), building system typology, and the principal building function are necessary to match the archetype data to the actual building (Willmann et al., 2019).

CEA was employed in this study to generate an initial simulation based on the present meteorological conditions. This involved modelling the physical and behavioural properties in relation to the existing energy, spatial and physical data. Subsequently, interventions were implemented on the external envelope, and future climatic data was imported into the model using this same tool.

3. Results and discussion

3.1. Climate analysis

The Figure (4) below illustrates the monthly fluctuations in temperature and solar radiation for the years 2022, 2060 and 2100, respectively. It demonstrates that temperatures increased in both 2060 and 2100 compared to 2022, with a higher temperature rise during the summer months in 2060.

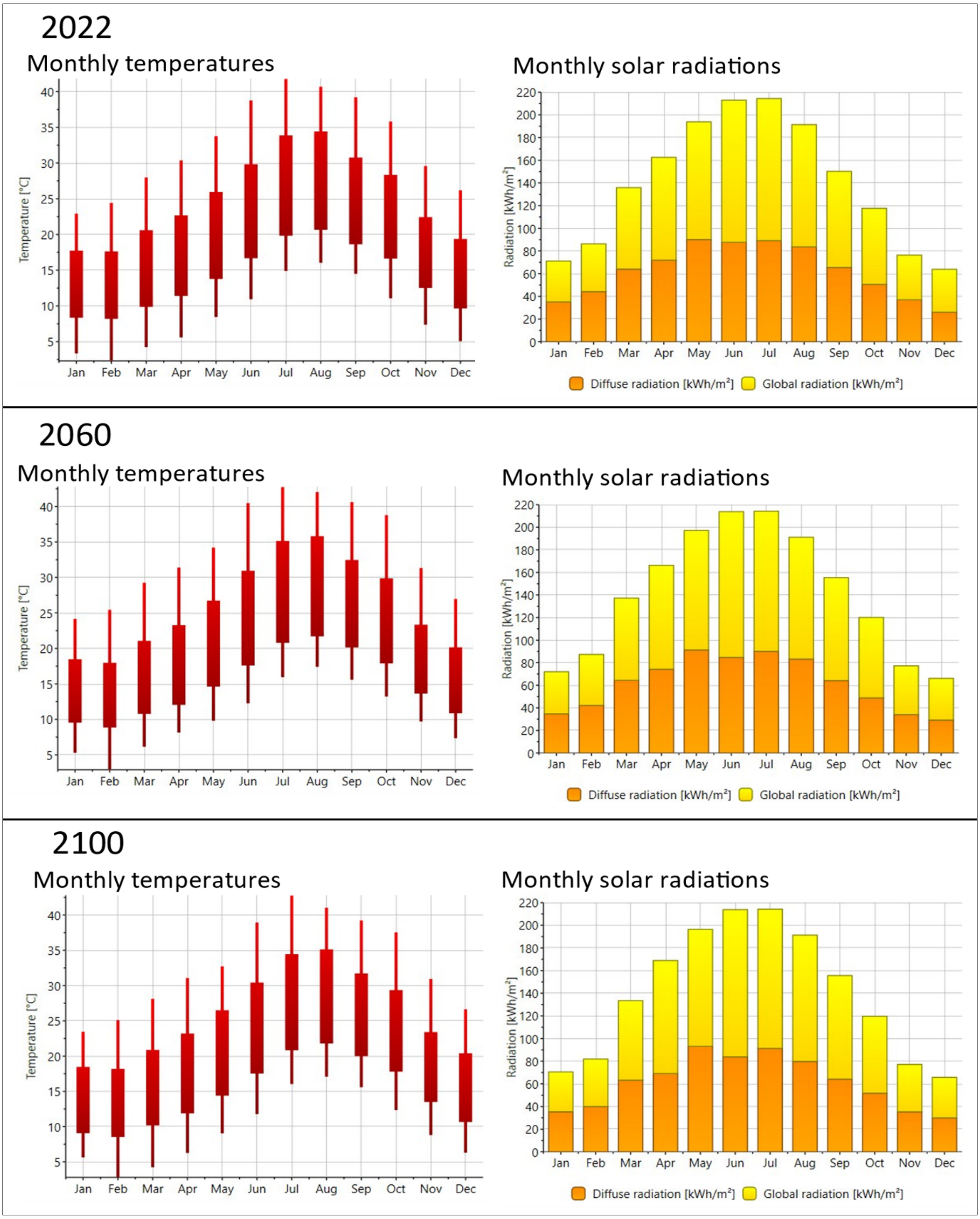

Fig. 4. Graphical representation of the monthly temperatures and solar radiations in the study area (the city of Skikda), during the years 2022, 2060, and 2100.

Conversely, a slight increase was also observed during the winter period in 2100, compared to the 2060 wintertime, which is also increased in regard to 2022.

With regard to solar radiation, a general similarity was noted in the overall solar radiation levels over the three-year period under investigation. However, a notable discrepancy was observed in the diffuse radiation, with a continuous slight decline in the amount of diffuse solar radiation recorded in the months of June in both

2060 and 2100, respectively. On the other hand, the amount of diffuse solar radiation in the month of December increases continuously and slightly in 2060 and 2100.

3.2. Energy analysis

Figure (5) below, which graphically represents the annual energy consumption of the collective housing building studied, before and after interventions on the building's external envelope, according to different climatic conditions, both present and future, has led to several observations.

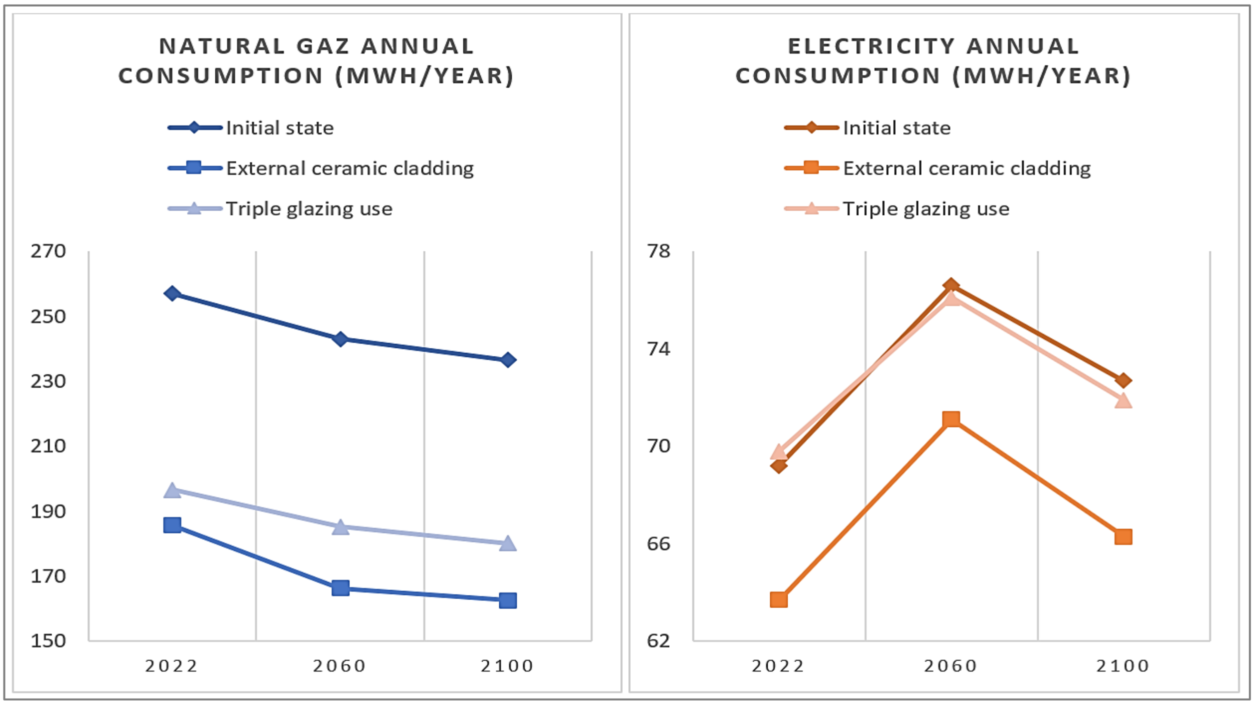

Fig. 5. Graphical representation of the annual consumption of natural gas and electricity according to the scenarios, and on the basis of the present and future climate data

Starting with the annual consumption of natural gas, there is a continuous reduction in consumption between the years 2022, 2060 and 2100, and this may be due to the rise in temperatures during these years respectively, which has led to a reduction in the need for heating, and natural gas use as a result.

After interventions according to scenarios (1) and (2), reductions in gas consumption ranging from 27 to 34%, seeing that exterior ceramic cladding was slightly more efficient. This was related to the very big surface of application of the cladding, in comparison with the surface of windows.

Despite this big difference in surface of application, the reduction in gas consumption according to these two scenarios in each of the 3 studied years was not significant, met by big difference in the thermal transmittance coefficient between initial existing simple glazing considered as heat sieve, and the triple glazing which is very performant.

As regards the annual energy consumption of electricity, in the initial state, it was increased in 2060 compared to 2022. Consumption then falls in 2100 compared to 2060, but remains higher than it was in 2022. This can be justified by the comparison with the climate analysis, which showed that the summer of 2060 is hotter than the other two years studied. This has led to additional use of cooling equipment.

Following installation of the exterior ceramic cladding, reductions in electricity consumption have been observed, at levels reaching 10% in present and future climatic conditions. This can show the impact of external ceramic cladding in protecting the interior of the building from overheating, and therefore less use of air-conditioning.

With regard to electricity consumption after the use of triple glazing, there was a slight increase in consumption in 2022 compared to the initial state. This was accompanied by a reduction in the amount of natural light entering the buildings due to the additional glass panes, which made the interiors of the buildings darker and gloomier (Khelfa, 2024), requiring more energy to be used for artificial lighting. This was also accompanied, without doubt, by a reduction in heat transmission between the exterior and interior of the building, which helps to reduce overheating in the dwellings. However, the graphs obtained indicate that the necessity for artificial illumination was greater in terms of its impact on electricity consumption.

Contrary to 2022, in 2060 and 2100 there is a slight decrease in electricity consumption, which means that the thermal insulation effect of triple glazing is greater than its effect in reducing natural light, since there is an increase in future temperatures but almost the same rates of solar radiation, except for diffuse solar radiation, with tiny differences that are only present in some months of the year. And that helped to get electricity use reductions in 2060 and 2100.

3.3. Thermal comfort analysis

To get an idea of the impact of the external ceramic cladding and the triple-glazed windows on the thermal comfort inside the building during one year, Figure (6) illustrates the comfort level in terms of operating temperature and humidity, according to the occupancy schedule in summer and wintertime, in 2022.

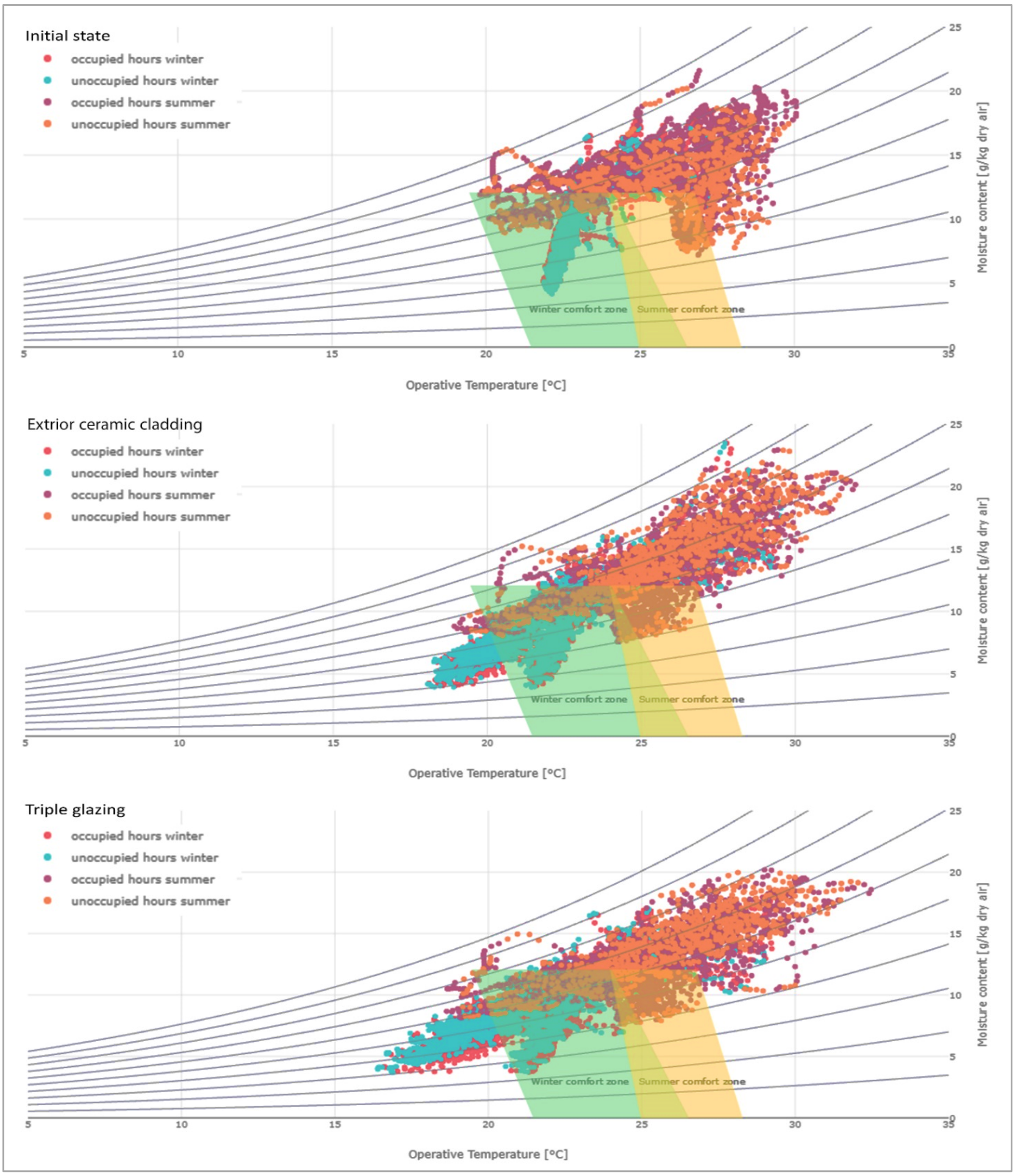

Fig. 6. Degree of comfort in terms of operational temperature and humidity, according to the occupancy schedule in summer and winter, during 2022.

The three graphs demonstrated that the addition of exterior ceramic cladding or triple glazing resulted in a notable enhancement in thermal comfort. This was evidenced by a marked increase in the points related to occupied and unoccupied hours in both summer and winter, which exceeded the initial levels observed in the summer and winter comfort zones. This outcome substantiates the efficacy of the two techniques in promoting thermal comfort.

It is possible that the thermal comfort was not ideal, seeing that the other parameters (physical or behavioural) remaining unchanged. This may have been the cause of the degree of discomfort existed per unit of occupancy time.

4. Conclusions

With the aim of improving energy efficiency and indoor comfort, the present study was carried out to perform climate, energy and thermal analysis of a collective housing structure located in the Algerian city of Skikda, with its moderate Mediterranean climate. This analysis is based on real historical measured energy data for the year 2022, using the UBEM methodology. The electricity and gas data were obtained from SONELGAZ in order to calibrate and validate the energy models generated by CEA tool, before entering the interventions on the external envelope to study their impact of both energetical and thermal aspects. The interventions are represented by two scenarios; the first was the implementation of external ceramic cladding, while the second was the replacement of existing single-glazed windows with triple-glazed ones.

Furthermore, the Meteonorm tool was employed to extract data and graphs pertaining to three distinct periods: 2022, 2060, and 2100. This was done with the objective of studying climate change in terms of temperature and solar radiation. Following this, the data was entered into the CEA tool for analysis. The aim of this analysis was to investigate the impact of climate change over time on the initial state of the building and the performance of exterior envelope interventions.

The energy analysis demonstrated that the exterior ceramic cladding contributed to a reduction in electricity and natural gas consumption by 10% and 34%, respectively. This was attributed to the cladding's ability to insulate the interior from overheating and excessive cold, which can occur due to external conditions throughout the year. While triple glazed windows did contribute to a reduction in natural gas consumption of approximately 27% across the three periods, this was not accompanied by a corresponding reduction in electricity consumption. This was due to the adverse impact of the three panes on natural lighting, which resulted in an increased reliance on artificial lighting. The analysis of thermal comfort demonstrated that the two techniques employed resulted in improvements, albeit imperfect, given the presence of additional shortcomings on the physical side or concerning the behaviour of users of the space.

REFERENCES

1. Ahmari, I., & Korichi, A. (2019). Simulation de l’impact de l’inertie thermique sur la consommation énergétique d’un bâtiment résidentiel dans un climat méditerranéen. 16.
2. ANIREF, A. N. d’Intermédiation et de R. F. (2020). MONOGRAPHIE WILAYA DE SKIKDA - Ministère de l’Industrie—Agence Nationale d’Intermédiation et de Régulation Foncière. 29.
3. Batiactu website. (n.d.). Meteonorm—Logiciel—Batiactu. produits.batiactu.com. Retrieved August 9, 2023, from //produits.batiactu.com/produits/cstb-Editions-logiciel-meteonorm-187592.php
4. Bekhtache, R. (2012). La transition énergétique via le gaz au service du développement durable en Algérie : Étude analytique sur la période (2000-2014). Journal of Economic Studies, 6(3), 01–13.
5. Boulkenafet, N. (2014). Gestion et Optimisation de la Réhabilitation Thermique des Bâtiments [Pour obtenir le titre de Magister]. Université 20 Août 1955-Skikda Faculté de Technologie Département de Génie Civil.
6. Brighet, K. (2018). Etude de l’ambiguïté du statut de l’espace social parties communes dans l’habitat collectif : Cas de Skikda cité du 20aout – cité camus rossi [Thesis]. http://dspace.univ-setif.dz:8888/jspui/handle/123456789/2260
7. CEA official website. (n.d.). City Energy Analyst. City Energy Analyst. Retrieved February 23, 2023, from https://www.cityenergyanalyst.com
8. Demougeot-Renard, H. (2016). Qu’est-ce que QGIS et pourquoi se former ? eOde. https://www.eode.ch/2016/05/06/quest-ce-que-qgis-et-pourquoi-se-former/
9. Hadef, H. (2020). LA VILLE FACE AUX RISQUES : VERS UNE MAÎTRISE DU RISQUE INDUSTRIEL, CAS DE SKIKDA. Revue des Sciences Humaines & Sociales, 6(2), 560–584.
10. Hong, T., Chen, Y., Luo, X., Luo, N., & Lee, S. H. (2020). Ten questions on urban building energy modeling. Building and Environment, 168, 106508. https://doi.org/10.1016/j.buildenv.2019.106508
11. Kassis, F. (2012). Haute qualite environnementale dans les espaces domestiques collectifs cas d’étude à skikda [Mémoire pour l’obtention du diplôme de magister en architecture]. Universite ferhat abbas– Setif.

12. Khelfa, I. eddine. (2024). Hybrid energy renovation of existing buildings: A case study of collective housing in Skikda [Thesis]. http://dspace.univ-guelma.dz/jspui/handle/123456789/16175
13. Khelfa, I. eddine, Lazri, Y., Alkama, D., & Toumi, R. (2024). An Energy and Ecological Assessment of The Prior and Post-Hybrid Renovation State of Multi-Dwelling Building in the Algerian City of Skikda. Indonesian Journal of Social Science Research, 5(1), Article 1. https://doi.org/10.11594/ijssr.05.01.12
14. Khelifa, F. (2024). Paramétrage de microclimat urbain par la végétation et les plans d'eau. Cas de la ville Souk Ahras [Thesis]. http://dspace.univ-guelma.dz/jspui/handle/123456789/16198
15. Khelifa, F., Mahimoud, A., Alkama, D., & Hanafi, A. (2024). The role of trees in enhancing outdoor thermal comfort during warm season in a sub-humid climate. Case: Souk Ahras City. Bulletin of the Serbian Geographical Society, 104(1), Article 1.
16. Larrère, C. (2009). La justice environnementale. Multitudes, n° 36(1), 156–162.
17. Latreche, S., & Sriti, L. (2018). Optimisation énergétique d'un bâtiment résidentiel autoproduite à Biskra à travers ses caractéristiques matérielles. Journal of Renewable Energies, 21(3), Article 3.
18. Palino, G., & Sparks, E. (2021). QGIS: An Introduction to an Open-Source Geographic Information System | Mississippi State University Extension Service. http://extension.msstate.edu/publications/qgis-introduction-open-source-geographic-information-system
19. Site Climats et voyages, C. du monde. (2020). Climat Skikda : Températures, précipitations, conditions météo prévalentes, quand partir. https://www.climatsetvoyages.com/climat/algerie/skikda
20. Willmann, A., Katscher, L., Leiser, T., & Voelker, C. (2019). A Comparison of Bottom-up and Top-down Modelling Approaches in Urban Energy Simulation for the Assessment of City District Data Models. 3303–3310. https://doi.org/10.26868/25222708.2019.210424