

Research Article

Int J Energy Studies 2025; 10(3): 929-949

DOI: 10.58559/ijes.1725783

Received : 24 June 2025

Revised : 20 July 2025

Accepted : 23 July 2025

Reassessing vernacular building envelopes for energy efficiency in hot-dry climates: A case study from Diyarbakır

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Highlights

- Basalt stone provided the lowest energy consumption.
- Local materials reduce carbon emissions.
- Material thickness affects energy efficiency.
- Modern materials are not sustainable.
- Traditional architecture offers climate-responsive solutions.

You can cite this article as: Akalp S, Kakdaş Ateş D. Reassessing vernacular building envelopes for energy efficiency in hot-dry climates: A case study from Diyarbakır. Int J Energy Studies 2025; 10(3): 929-949.

ABSTRACT

The building sector is a sector that consumes high levels of energy and has intensive environmental impacts throughout its entire life cycle, from design to construction, use, demolition and recycling. According to the International Energy Agency (IEA), the share of the residential sector in global energy consumption has increased significantly. This situation necessitates sustainable design strategies to increase energy efficiency and a re-evaluation of local building cultures. The study presents a comparative analysis of local (basalt, limestone, adobe) and modern (brick, reinforced concrete) materials used in the building envelope under constant thermal conductivity conditions, taking only the thickness parameter as variable, in terms of energy loads and carbon emissions, based on a traditional courtyard housing typology in Diyarbakır Suriçi, located in a hot-dry climate zone. According to the findings obtained with the DesignBuilder simulation program, basalt stone showed the best performance in terms of both heating-cooling loads and CO₂ emissions. The high thermal masses, low embodied energy values and region-specific production advantages of local materials support energy efficiency, while increasing the thickness of modern materials leads to economic and structural limitations. In this context, the study reveals the impact of building envelope material choices on both operational energy and environmental performance and provides recommendations for future hybrid strategies where modern and local materials are considered together.

Keywords: Local building materials, Energy efficiency, Carbon emissions, Building envelope performance, Hot-dry climate

1. INTRODUCTION¹

Buildings are responsible for a significant portion of energy consumption and greenhouse gas (GHG) emissions, accounting for 30% of global energy consumption and 26% of energy-related emissions by 2024. In this framework, an important part of the energy consumption chain consists of the construction sector. Especially after the 1990 energy crisis, the performance of the building envelope has come to the forefront in the building sector. Contrary to popular belief, the building envelope, which is a multi-layered component that controls moisture, air and heat transfer between the indoor and outdoor environment and provides indoor comfort conditions, is not a mantle that protects the building from external influences [1]. According to International Energy Agency (IEA) reports, the building envelope, which is a critical element in energy efficient building design, plays an important role in reducing heating and cooling loads. In the IEA's Net Zero Emissions by 2050 scenario, it is stated that building envelope performance standards in new buildings should be updated in line with the net zero energy target by 2030 [2]. The most important factor on energy consumption in buildings is climatic conditions. Per capita building energy consumption in cold climate regions in developed countries is 5 to 10 times higher compared to low-income regions in warm climates [3]. In energy-efficient building solutions that focus on the building envelope, differentiations in the changing consumption-production sector in the 21st century have brought contemporary material alternatives to the forefront. The use of different building materials has started to have negative effects on climate change and carbon emissions, which are the biggest problems of the 21st century. Modern buildings have increased environmental pressure with high energy consumption and greenhouse gas emissions throughout their life cycle. Today, traditional buildings that are sensitive to the local climate have started to be abandoned. Since the early 2000s, there has been an 89% increase in the use of materials with high embodied energy, such as concrete, and a 76% increase in metal/asbestos-containing roof systems instead of natural and low carbon footprint cover materials [4]. In this context, it has become necessary to return to solutions that reference traditional building materials and construction techniques. In other words, traditional architecture has the potential to find solutions to many problems such as uncontrolled depletion of natural resources, high energy use, and greenhouse gas emissions [5]. Traditional architecture ensures energy efficiency without relying on mechanical systems by integrating passive design strategies that are responsive to the climatic characteristics of the region. Passive methods commonly employed in traditional architecture have been widely examined in the

¹ This study was developed from the full paper titled "*The Influence of a Local Building Envelope Material on the Energy Load: A Case Study for a Traditional Diyarbakır House*", which was prepared by the authors and presented at the 5th International Multidisciplinary Eurasia Conference held in Barcelona on July 24–26, 2018.

academic literature. In his seminal study, Fathy (1986) demonstrated that high thermal mass in adobe structures significantly reduces daily temperature fluctuations [6]. Similarly, Zhao et al. (2024) found that courtyard houses contribute to thermal comfort throughout the year by creating shaded areas that moderate indoor conditions. Furthermore, the iwan—a semi-open space frequently used in traditional Middle Eastern architecture—has been shown to enhance indoor thermal comfort due to its ability to provide shade to adjacent rooms [7]. This passive function of the iwan has been emphasized in several studies, including the work of Kuloğlu Yüksel et al. (2024), who highlight its role in reducing solar heat gain and supporting seasonal adaptability [8]. These passive strategies embedded in vernacular design demonstrate the effectiveness of traditional spatial solutions in minimizing energy consumption and responding to environmental conditions. In this context, scientific research on the fact that climate-responsive traditional materials have an important place in energy efficiency by reducing the carbon footprint has been quite high in recent years. In particular, the fact that topral-based materials have high thermal inertia and low embedded carbon emissions brings energy efficiency to the forefront. In addition to all these, the fact that they delay the temperature during daytime hours and direct heat flow throughout the day makes these materials stand out in terms of energy efficiency [9,10]. Various studies have shown that local materials also have significant advantages on the carbon footprint scale. For example, stabilized adobe walls have been reported to reduce embodied energy by 66-85%, and adobe walls provide thermal stability due to their lower thermal conductivity compared to concrete [11,12,13,14]. Studies have also been carried out on the energy efficiency of natural stone materials used in traditional buildings. Natural stone applications have traditionally been considered as low energy materials, especially in some types [15,16], where insulation plays an important role. In particular, basalt stone, which has a volcanic origin, has been determined to be effective in providing thermal comfort indoors by providing very good insulation with a thickness of 100 cm [17]. Limestone, another traditional stone material, has been found to help reduce indoor heat waves through its high thermal mass [18,19].

Within the scope of this study, a traditional residential building with a courtyard, which is one of the characteristic elements of Diyarbakır's historical Suriçi urban fabric, is taken as an example. The effects of local (traditional) and modern building materials used in the building envelope on energy performance are evaluated. For this purpose, the effects of different thicknesses of local and modern material types on heating and cooling loads were analyzed using the DesignBuilder energy simulation program and CO₂ emission values were determined to calculate their environmental impacts. As a result of the study, basalt, one of the local materials, produced both

the lowest heating-cooling loads and the lowest carbon emissions, followed by adobe and limestone, respectively. On the other hand, the modern materials reinforced concrete and brick produced the most negative results in terms of both energy consumption and carbon emissions. These findings suggest that local building materials offer a more efficient energy performance and support environmental sustainability in hot-dry climates, thanks to their high thermal mass, low embodied energy value and natural climate-compatible properties. In addition, it has been determined that although the increase in thickness of modern materials contributes positively to energy performance, it does not constitute a sustainable solution due to structural and economic limitations; on the other hand, local materials reveal the potential to reduce both energy efficiency and carbon footprint more effectively with the increase in thickness. Accordingly, the study points to the importance of re-evaluating the use of local materials in contemporary construction processes and contributes to design approaches for climate-compatible hybrid building strategies with low carbon footprint.

2. THE ROLE OF THE BUILDING ENVELOPE IN ENERGY PERFORMANCE

Designing an energy efficient building envelope to reduce the overall energy demand of the building is one of the fundamental steps in sustainable building design. In particular, limiting air leakages and heat transfers allows the building envelope to play a critical role in increasing indoor thermal comfort by adapting to natural environmental conditions [20]. In this context, the choice of materials with high thermal resistance (R-value) in building elements such as roofs, floors and walls will minimize heat loss in cold weather and heat gain in hot weather [21,22]. In this way, the choice of building envelope that optimizes energy efficiency will be realized. It is important that the selected building materials not only provide adequate insulation, but also are cost accessible, suitable for the local climate and compatible with existing construction practices [23,22].

Advanced materials used in building materials and production, especially by integrating different active systems, maximize energy efficiency in regions with different climatic conditions. Photovoltaic integrated systems (BIPV) that can directly use sunlight and phase change materials (PCM) that can compensate for variable temperatures enable building shells to become dynamic [1]. In order for the aforementioned technologies to yield positive results, the climate characteristics of the locality must be analyzed correctly and incorporated into the design. In other words, it is an important issue to start designing a building in a region by considering the local climate design inputs. The building sector, which started with wood and other natural materials, has been differentiated in order to reach a faster production process in order to meet the supply-

demand balance. In other words, modern building materials such as concrete or earth-based bricks, steel and glass have replaced traditional building materials such as wood and bamboo [24]. The preference of these materials, especially in tropical climates, without proper determination of climatic characteristics, has negatively affected the thermal perception of users [25]. Especially materials with high thermal mass such as brick and reinforced concrete absorb solar radiation and store heat. This leads to an increase in annual heating and cooling costs.

For centuries, local materials with high durability such as stone, brick and limestone, which are naturally found in the environment, have been used as basic building elements in the construction of many civil and monumental buildings [26,27]. These solid stone building materials with high thermal capacity are used in walls, foundations and building elements. Thanks to their high thermal resistance (R), they store the solar radiation falling on the building during the day, and after sunset, they transmit the heat in their structure to the outdoor environment, providing thermal balance between indoor and outdoor and helping to provide thermal comfort indoors [28,29].

Environmental impacts throughout the entire life cycle of buildings are determined by indicators such as air pollution index, energy consumption, global warming potential, resource use, solid waste emissions and water pollution index [30]. After the construction of the building, the energy demand during the use phase is significantly influential in the evaluation of sustainability criteria [31]. In addition to all these, a large number of studies have been carried out showing that concrete-based structures, which are also the most widely used building material of the 21st century, cause high environmental impacts. When the reinforced concrete construction system is considered within the framework of climate-responsive design, it has been determined that it causes negative structural and environmental impacts in tropical and continental climatic conditions [32,33,23,34]. Locally sourced traditional materials are not only characterized by their thermal performance. The fact that they have low embodied energy proves that they are an important representation of sustainable construction [35,36]. As a result, it is possible to develop climate-responsive and energy-efficient design approaches by considering the environmental impacts and embodied energy levels during the building life cycle in the selection of building materials. Thus, climate-responsive and energy-efficient design can be achieved by selecting materials based on environmental impacts and embodied energy across the building life cycle.

3. MATERIALS AND METHODS

Within the scope of the research methodology, EnergyPlus based DesignBuilder simulation program was used. In the simulations, both traditional building materials (adobe, limestone and

basalt) and reinforced concrete and brick materials, which are widely used in the building sector today, were preferred. A representative example of a traditional courtyard housing typology in Diyarbakır was selected as the study area. Building envelope materials of different thicknesses with the same thermal resistance value were determined and five different building envelope scenarios were created with these materials: basalt, adobe, limestone, reinforced concrete and brick. Within the scope of the study, five different building envelope scenarios (basalt, adobe, limestone, reinforced concrete, and brick) were modeled using materials of varying thicknesses, each adjusted to achieve an equivalent thermal resistance (R-value). While this approach ensures thermal equivalence among the materials, the simultaneous variation of both material type and thickness limits the ability to isolate the effect of a single parameter. Therefore, the primary aim of the study is not to analyze individual parameter changes in isolation, but rather to provide a holistic comparison of energy and environmental performance under realistic wall thickness conditions. This methodological choice also constitutes one of the limitations of the study. During the modeling process, a three-dimensional digital model of the dwelling was first created and zoned according to functional use. Then, the materials for each building envelope alternative were introduced to DesignBuilder and the heating and cooling loads were calculated separately. Thus, the energy performances of different materials were evaluated comparatively. IWEC (International Weather for Energy Calculations) dataset was used as the climate data used in the simulations and meteorological data specific to Diyarbakır was integrated into the program. The definition of the HVAC system is based on the conventional heating systems commonly used in the traditional fabric. In this context, no mechanical heating system was envisaged on the ground floor; coal was selected as the energy source and electrical energy was selected as the cooling system.

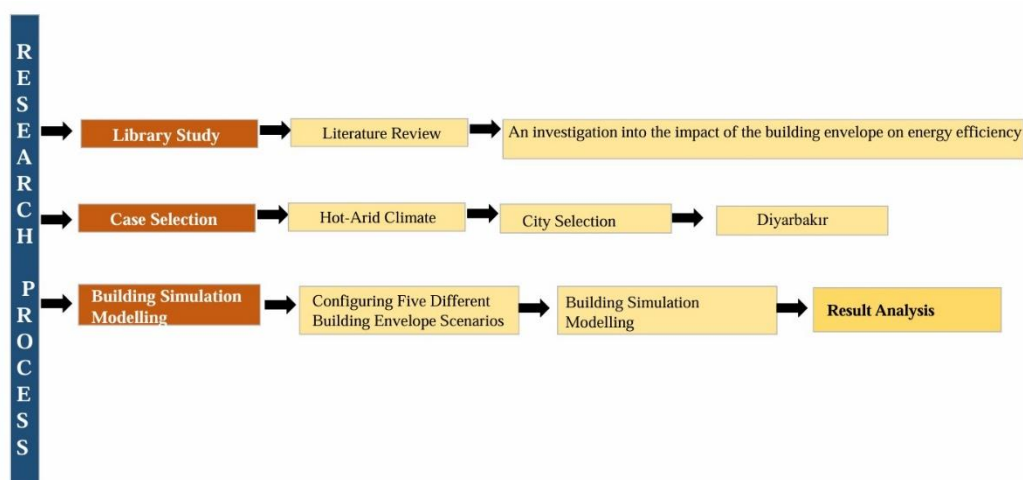


Figure 1. The frameworf of research

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3.1. Case Study: Traditional Diyarbakır Suriçi Urban Fabric Components and Climatic Characteristics

Diyarbakır is a city located in the Southeastern Anatolia Region of Turkey, which is located on the northern hemisphere and divided into 7 geographical regions. The total surface area of Diyarbakır, which constitutes approximately 2% of Turkey's total surface area, is 15,355 km². Diyarbakır is surrounded by Mazıdağı in the south, Batman Stream in the east, Karacadağ in the west and Taurus Mountains in the north [37]. Based on the Köppen climate classification, Diyarbakır is characterized by a hot, dry-summer Mediterranean climate (Csa), marked by arid summers and wet winters [38]. In this framework, the cooling period lasts longer than the heating period for the city of Diyarbakır, which is located in the hot-dry climate zone. In addition to all these, the annual insolation rate is high and the precipitation rate is quite low.

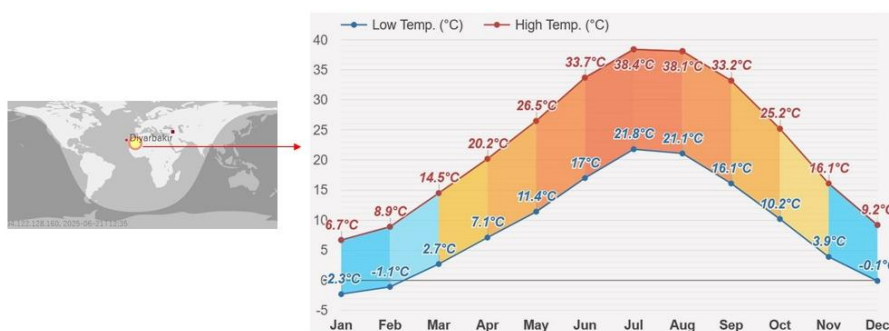


Figure 2. Location of the city of Diyarbakır and annual temperature values [39] [40]

The summer months in Diyarbakır are quite hot, with average maximum temperatures reaching 38.4 °C and 38.1 °C in July and August, respectively. In the same season, night temperatures are above 21 °C, indicating that cooling is limited during the night. Considering the high temperature averages, it can be concluded that the summer seasons are long and cooling loads will be high in this context. In December, January and February, temperatures drop to low values of -0.1 °C, -1.1 °C and 2.3 °C, respectively. This is a short but effective winter period in which heating requirements come to the fore (Figure 2). Considering the climatic characteristics, the high annual average temperature differences for the city of Diyarbakır (e.g. day-night difference of about 17

°C in July) make the use of building shells with high thermal mass (e.g. basalt) functional. In this framework, courtyard organizations, narrow streets and space organizations according to summer and winter periods that will help the shading effect have been used as important passive housing strategies for the region [40].

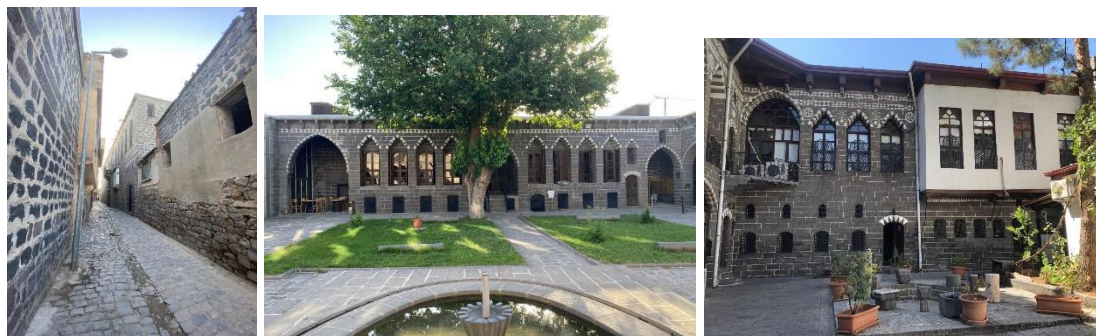


Figure 3. An example of street texture and courtyard in the Suriçi district of Diyarbakir

The traditional Suriçi urban fabric has been home to many civilizations in the past and has survived to the present day by preserving the culture of civilizations. Especially in the context of urban design and architecture, it is possible to see many civil and monumental architectural elements that both refer to climatic features and reflect the socio-cultural structure of the period with the trial-and-error methods of architects [41,42]. The fact that it is located in the hot-dry climate zone is an important factor in the formation of the traditional Suriçi urban fabric. In the region, shaded surfaces that prevent solar radiation, increasing the effect of natural ventilation, thermal comfort independent of all spatial systems has been provided and these design inputs have survived until today. In particular, the organic urban texture that contributes to the formation of the urban form in the region has helped to provide climatic comfort both indoors and outdoors by creating narrow streets and shaded areas [43]. In particular, street widths ranging from 1.5-3 meters can be shown among the best examples of both urban identity and climate responsive design. Design inputs that take into account passive cooling strategies at the street texture scale are encountered at the plan scale. The most common building form in the traditional urban fabric of Suriçi, Diyarbakır, is the courtyard house. The design of the houses in the form of courtyards is also shown as passive design strategies that minimize the negative effect of solar radiation and create the shadow effect. Apart from the courtyard form in the housing unit, the orientation of the building orientations according to the summer and winter seasons, and the addition of different space organizations such as iwan and gezemek are intended to cool down by reducing the sun effect that is exposed to a lot during the day [44].

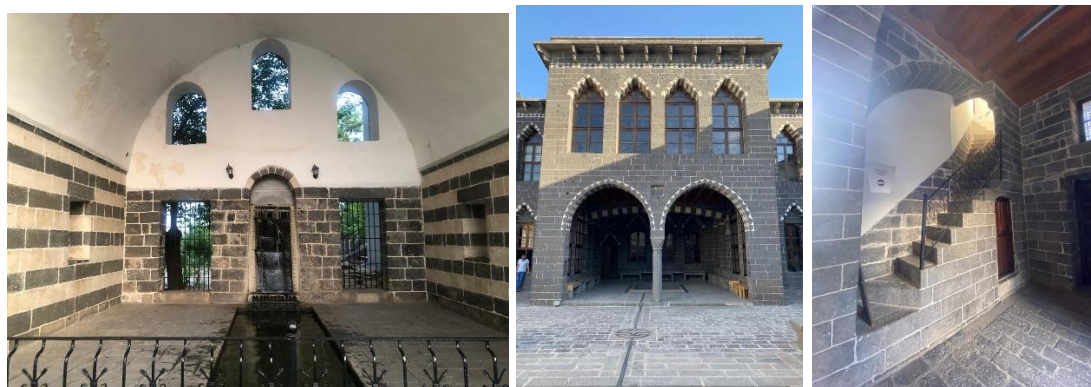


Figure 4. Examples of iwan and interior spaces of traditional houses in Diyarbakir

Diyarbakır is located on a plateau shaped by basalt lava formed as a result of Karacadağ volcanism, about 650 meters above the Tigris River valley [45]. Accordingly, the topographical structure of the city indicates that the building material commonly used in the region is basalt, a black colored volcanic stone. The most common material in monumental and civil architecture examples in the traditional Diyarbakır urban fabric is basalt stone, which has high heat capacity and strength. In addition to basalt stone, mudbrick, brick, and soil were also preferred from time to time [42]. Traditional Diyarbakır houses are organized as basement+ground+upper floor. In building foundations built on bedrock, the main bearing walls can be thinned with recesses such as niches and cupboards towards the upper level, starting with a cross-section of up to 100 cm in the basement. The thickness of the load-bearing walls is 40-90 cm on the upper floors, while the non-bearing intermediate walls consist of basalt stone 15-20 cm thick [46]. Traditional Diyarbakır houses are designed to take into account the local and climatic characteristics of the region with their structure, form, orientation, space organization, building-construction techniques and material selection.

3.2. Building Energy Simulation Modelling Process

After the Brundtland Report of 1987, which laid the foundations of the sustainability approach, the development of approaches that promote energy efficiency in many areas, especially in the building sector, has gained great importance. Accordingly, Building Energy Modeling (BEM) simulation tools have been developed in the building sector to assess the energy balance of buildings throughout their life cycle through computer-based software [47]. In other words, in the early design phase of a building that has not yet been built, it has become possible to perform analyses such as form, material, building envelope, heat transfer and phase change through these software [48]. Building Performance Simulation (BPS) is considered as a sub-category of BEM

and analyzes building costs and energy consumption by simulating them with mathematical models based on specific algorithms [49,50]. BPS tools provide accurate and realistic feedback on thermal comfort in line with passive and active design strategies, taking into account existing environmental and climatic conditions. While these tools are used by experts and designers from different disciplines, only less than 40 of the 389 BPS tools listed on the US Department of Energy (DOE) website in 2010 were targeted for use by architects at early design stages [51]. In this context, the main BPS tools widely used today include EnergyPlus, ESP-r, eQUEST, TRNSYS, DesignBuilder and EDSL-TAS [51,53]. In this framework, DesignBuilder Simulation program, which can use climate data in detail at the regional level through its comprehensive simulation engine and performs effective analysis in a short time, was preferred within the scope of the study. The program's ability to work with real-time meteorological data and its capacity to evaluate energy performance according to environmental conditions make it particularly prominent in supporting early design decisions, and its reliability has been proven in numerous academic studies [54,55,56].

Within the scope of the study, a traditional house with an inner courtyard plan type located in Diyarbakır Suriçi region was used. In this building, which consists of 2 parts as north and south wings, the south-facing façade of the north wing consists of 2 floors, while the sections on the south wing consist of a single floor (Figure 5). The summer-winter sections previously mentioned in Diyarbakır traditional houses are also encountered in this housing example. The ground floor of the façade, which is oriented to the south on the north wing, has a kitchen, living areas and wc, while the upper floor has an iwan and rooms around it.



Figure 5. Location of the Study Area and Floor Plans (3d modeling via Designbuilder Simulation Software)

Cahit Sıtkı Tarancı house, one of the traditional Diyarbakır courtyard houses, was modeled through DesignBuilder Simulation program. Cahit Sıtkı Tarancı house, one of the traditional Diyarbakır courtyard houses, was modeled through DesignBuilder Simulation program. Taking into account the original wall thickness of the case study building, the basalt material was modeled at 0.90 m. Other building materials were modeled at varying thicknesses to ensure an equivalent thermal transmittance value (U-value). This approach was chosen to enable a technical comparison of the energy and carbon performance of different materials. However, the inability to apply the original wall thickness to all materials constitutes one of the limitations of the study. As explained in the previous section, the design of the building was completed with 90 cm thick basalt stone with original materials and transparency ratios. Climatic data of the city of Diyarbakır was introduced to the IWECC program. The thermal conductivity and thermal conductivity coefficient of all materials were kept equal and material thicknesses were determined as variable. The main purpose of this research is to analyze the effects of different types of materials used in the building envelope and the thickness values of these materials on the energy performance (heating-cooling loads) and environmental impacts (carbon emissions) of the building in the city of Diyarbakır, which is located in the hot-dry climate zone.

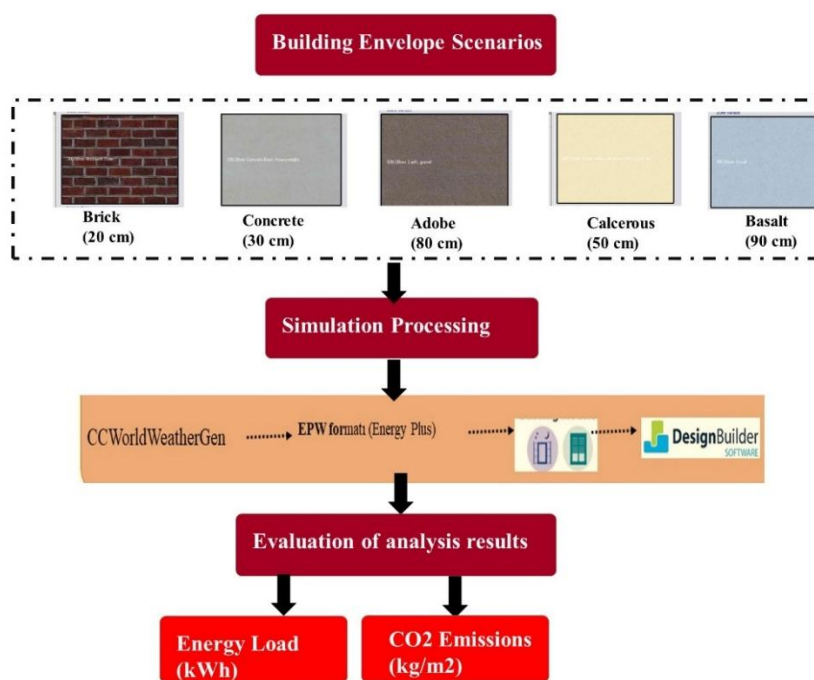


Figure 6. Building simulation process

In the study, a total of five different building materials, traditional (basalt, limestone, adobe) and modern (brick, reinforced concrete), were considered and no insulation material was used; the

thermal conductivity coefficient of all materials was kept constant and only their thickness was considered as a variable parameter. With this approach, the relationship between material thickness and energy and environmental performance is demonstrated through numerical simulation using real climate data (IWECC) for Diyarbakir.

Table 1. The thermal conductivity and thermal resistance of the building envelope alternatives

Components	Material Type	Material	Thickness (m)	Thermal Resistance (R- m ² K/W)	Thermal Transmittance (U- W/m ² K)
Walls	Local	Basalt	0.9	0.460	2.17
	Local	Limestone	0.5	0.460	2.17
	Local	Adobe	0.8	0.460	2.17
	Alternative	Brick	0.2	0.460	2.17
	Alternative	Concrete	0.3	0.460	2.17

Local and modern building materials with the same thermal conductivity but differing in terms of thickness were compared and it was investigated which one is more advantageous in terms of energy consumption and carbon emission. The thermal conductivity and thermal resistance of the building envelope alternatives are shown in the Table 1.

4. RESULTS AND DISCUSSION

In the analysis performed by evaluating the thicknesses of different building materials under constant thermal conductivity coefficient, brick material produced the highest total energy consumption with 5092 kWh heating and 4982 kWh cooling load. This was followed by reinforced concrete with 5011 kWh heating and 4751 kWh cooling load. Limestone material produced 4950 kWh heating and 4597 kWh cooling load, while adobe showed slightly lower values with 4847 kWh heating and 4266 kWh cooling load. The lowest energy loads were recorded for basalt material with 4772 kWh heating and 4151 kWh cooling values. These results show that local materials (basalt, adobe, limestone), especially those with higher thickness values, provide lower energy consumption compared to modern building materials and are advantageous for passive energy strategies in hot-dry climates. These findings reveal that not only the type but also the thickness of the material used in the building envelope is a determining factor in energy performance, and show that modern materials with low thickness have the potential to increase energy consumption, especially in uninsulated conditions.

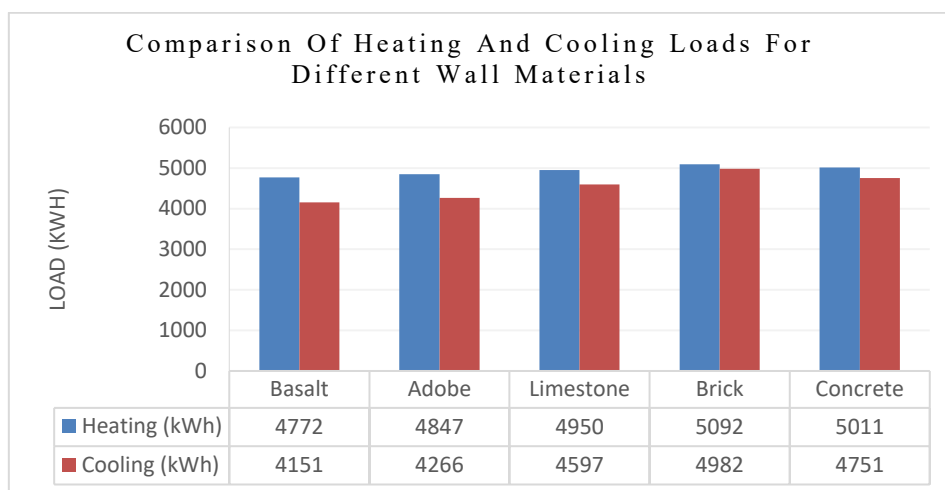


Figure 7. Comparison Of Heating And Cooling Loads For Different Wall Materials

When CO₂ emission values are analyzed, it is clearly seen that local building materials (basalt, limestone, adobe) produce lower carbon emissions compared to modern materials (reinforced concrete and brick).

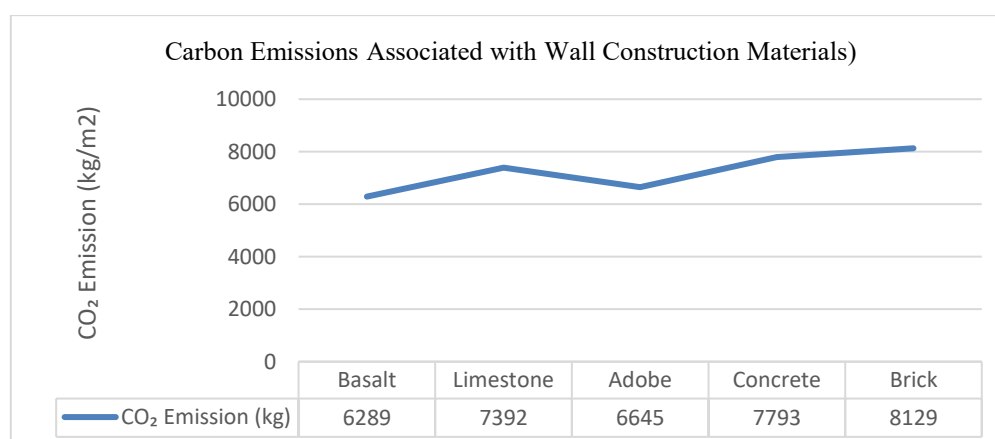


Figure 8. CO₂ gas emission values according to local and alternative materials

The lowest carbon emission belongs to basalt material with 6289 kg/m², followed by mudbrick 6645 kg/m² and limestone 7392 kg/m². In contrast, reinforced concrete material produced 7793 kg/m² and brick produced the highest value of 8129 kg/m². This difference can be explained by the fact that local materials generally have low embodied energy, their production processes are less industrialized and they are more likely to be sourced on-site. In contrast, modern materials such as bricks and reinforced concrete increase carbon emissions due to high-energy production techniques, transportation processes and chemical additives. These data reveal that local materials are more advantageous not only in terms of energy burden but also in terms of environmental

sustainability, and suggest that local building materials should be re-evaluated in strategies to reduce carbon footprint.

Table 2. Comparison of Heating and Cooling Loads and Carbon Emissions for Different Building Envelope Materials

	Basalt	Adobe	Limestone	Brick	Concrete
Heating Load (kWh)	4772	4847	4950	5092	5011
Cooling Load (kWh)	4151	4266	4597	4982	4751
Carbon Emissions (kg/m ²)	6289	6645	7392	8192	7793

As a result of the simulations, the heating and cooling energy loads and associated carbon emissions for five different building envelope materials were determined. These values are summarized in Table 2 to enable a comparative evaluation of energy and environmental performance.

5. CONCLUSION

The process of mechanization that emerged with the Industrial Revolution paved the way for the rural population to migrate to the cities, which in time led to the need for a large amount of housing stock in parallel with the growing population of cities. In this framework, in order to respond to the need for housing rapidly, mass and rapid production techniques were developed to ensure a balance between supply and demand, and modern material types and technologies became widespread in building production. In particular, industrial building materials such as reinforced concrete and brick are among the most preferred materials in the building sector today; however, the environmental impacts of these materials during the production processes and building life cycle are often ignored. The thermal comfort provided by these materials is mostly supported by externally added insulation systems. On the other hand, Diyarbakır's historic Suriçi district stands out as one of the most distinctive urban fabrics in the region, characterized by its unique courtyard-based layout and the use of local materials such as basalt stone. The survival of this local material and architectural heritage can be explained not only by its aesthetic values and urban identity, but also by design strategies that are compatible with the climate and consider environmental conditions. These design decisions, developed at both urban and architectural scales in Suriçi, constitute early examples of today's "climate responsive design" approach. However, over time, the replacement of local and natural materials with industrial modern materials for faster and more

economical substitution of local and natural materials has caused the traditional sustainable building culture to be forgotten and in this context, global environmental problems such as climate change have deepened. In this context, the study comparatively analyzed the energy efficiency and environmental impacts of different materials used in the building envelope through a traditional courtyard housing typology in Diyarbakır Suriçi, located in a hot-dry climate zone. Local materials such as basalt, limestone, adobe, and brick and reinforced concrete materials, which are widely used in the building sector, were evaluated under a constant thermal conductivity coefficient and only the thickness parameter was considered as a variable. Cooling and heating loads were calculated through Designbuilder Simulation program and carbon emission values were quantified in order to observe the environmental impacts.

Within the scope of the study, a comparative analysis was conducted on the energy and environmental performance of different building envelope materials, based on a traditional courtyard house located in Diyarbakır's Suriçi district (Cahit Sıtkı Tarancı House). Simulation results revealed that basalt stone, with a thickness of 90 cm and a fixed thermal transmittance value ($U = 2.17 \text{ W/m}^2\text{K}$), exhibited the lowest energy loads (4772 kWh for heating and 4151 kWh for cooling) and the lowest CO₂ emissions (6289 kg/m²), thus demonstrating optimal thermal performance. Among modern building materials, 20 cm thick brick walls resulted in 5092 kWh heating and 4982 kWh cooling loads, with a total carbon emission of 8129 kg/m². Similarly, 30 cm thick reinforced concrete walls produced 5011 kWh heating and 4751 kWh cooling loads, corresponding to 7793 kg/m² in emissions. These findings indicate that, given the hot-dry climatic conditions of Diyarbakır and the extended summer period, the use of materials with high thermal mass is essential. The massive thermal capacity of basalt was found to delay daily temperature fluctuations and promote nighttime passive cooling, as confirmed by simulation data. Additionally, earthen (adobe) and limestone walls with thicknesses of 80 cm and 50 cm, respectively, produced relatively low environmental impacts, with carbon emissions of 6645 kg/m² and 7392 kg/m². However, they did not match the superior performance of basalt. The low carbon emissions associated with basalt are not solely due to its thermal behavior. The proximity of the Karacadağ region—where basalt is locally sourced—to the project site reduces transport-related energy consumption, thereby lowering the overall embodied carbon throughout the building's life cycle in terms of logistics, cost, and resource management. Although increasing the thickness of contemporary wall materials theoretically contributes to improved energy performance, this approach is not practically sustainable due to its impact on construction costs, increased foundation loads, and reduced usable interior space. In contrast, basalt stands out as a regionally sustainable

material due to its low extraction and processing energy, geographic accessibility, and compatibility with traditional construction techniques.

The findings indicate that energy performance is influenced by both material thickness and material type. However, since these two parameters varied simultaneously in the current study, their isolated effects could not be evaluated independently. With this study, the necessity of re-evaluating the use of local materials in contemporary construction processes is emphasized once again, contributing to the understanding of climate-compatible design with a low carbon footprint. As a result, this study reveals that local building materials- especially basalt, limestone and adobe- can increase energy efficiency with increasing thickness and are more advantageous in terms of environmental performance thanks to their low carbon emissions. On the other hand, it was observed that increasing the thickness of modern building materials (reinforced concrete and brick) increases both structural loads and construction costs, which is not in line with sustainability criteria. In line with these findings, it is emphasized that a significant portion of the carbon emissions from the building sector is caused by building envelope choices; therefore, it is necessary to re-evaluate traditional local materials in a holistic manner with contemporary design approaches. This study has once again demonstrated that the building envelope is a determining factor not only in energy efficiency but also in environmental impact and carbon footprint. Although hybrid building envelope scenarios were not simulated in this study, it is recommended that future research explore hybrid solutions that combine local and modern materials. Such investigations may contribute to a more effective utilization of the energy efficiency potential offered by local materials. It is recommended that future research investigate hybrid solutions that integrate traditional and modern materials. Such studies may contribute to a more effective utilization of the energy efficiency potential offered by local materials. In addition, testing the optimum thicknesses of local building materials across different climatic regions could offer new perspectives for both regional material strategies and climate-responsive design criteria. Specifically in the context of Diyarbakır, based on the simulation results, promoting the use of 90 cm thick basalt stone in the restoration of historic buildings is presented as a critical recommendation to ensure both cultural continuity and energy efficiency.

ACKNOWLEDGMENT

This study was developed from the full paper titled “The Influence of a Local Building Envelope Material on the Energy Load: A Case Study for a Traditional Diyarbakır House”, which was

prepared by the authors and presented at the 5th International Multidisciplinary Eurasia Conference held in Barcelona on July 24–26, 2018.

In this study, AI-based language processing tools were utilized for translation, text editing, and ensuring terminology consistency.

DECLARATION OF ETHICAL STANDARDS

The authors declare that none of the procedures or requirements necessary for the completion of the manuscript necessitated approval from an ethics committee.

CONTRIBUTION OF THE AUTHORS

Sevilay Akalp: Designed the research methodology, conducted the data analysis and interpretation, prepared the simulation models, and contributed to the writing and critical revision of the manuscript

Dilan Kakdaş Ateş: Performed an extensive literature review, developed the theoretical framework, supported data interpretation, and contributed to the writing and final editing of the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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