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Cooling Load Reduction in a Single–Family House, an Energy–Efficient Approach

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Abstract

Energy depletion is considered one of the greatest challenges facing the planet. One way towards solving this challenge involves architectural adaptations to the local climate to decrease energy use. This study looks at the city of Erbil, located in northern Iraq. The city has seen rapid population growth that has resulted in an increased demand for housing. Unfortunately, most of the new houses are designed without considering the local climate conditions. As a result, people depend extensively on air conditioning systems that result in higher energy consumption. This study proposes implementing passive cooling techniques in residential buildings to decrease cooling energy consumption. Our methodology consisted of an energy simulation using the DesignBuilder program's comparative thermal dynamic analysis. Using this simulation, we assessed the effects of passive cooling techniques on the reduction rate of cooling loads in an air-conditioned house. The simulation results illustrate that the proposed passive techniques lower the cooling load significantly, from 6997 kW/h to about 4461 kW/h during the peak-cooling load in July. This represents a 47.28% reduction of the total cooling load. The significance of this impact suggests that architects should be more mindful about utilizing passive cooling methods in residential buildings, reducing the consumption of energy for residents and prompt accomplishing environmental friendly buildings.

1. INTRODUCTION

Energy depletion, climate change and global warming are some of the greatest challenges facing the planet. Architecture can contribute to the sustainability of our planet by using local climate-based adaptive components in their buildings. According to the International Energy Agency, the construction sector is responsible for nearly 40% of total CO2 emissions and for 36% of the total energy consumption globally [1]. The residential buildings in Erbil are responsible for nearly 65% of energy consumption for that city [2]. New construction in residential housing has increased energy demand for the city of Ebril since 2003. In spite of the city's hot summer, new housing units are located within large paved areas that have increased exposure to solar radiation (see Figure 1). Most of the structures have been built with large single glass openings and thin, uninsulated walls that significantly increase the heat flow entering the building. Without a purposeful design to combat the heat, dwellers have no choice but to turn on air conditioning, thus increasing their cooling energy consumption. Without a solution, these issues will continue to plague future housing development in areas with high solar exposure. Therefore, architects for these regions need to use designs that increase comfort without the energy expense. In contrast to modern architecture, vernacular architecture in hot climate regions are more adaptable and highly appropriate for hot and arid climates in terms of both energy efficiency and harmony to the local environment [3]. Many researchers [4, 5, 6, 7] have proposed vernacular architecture design methods as a fundamental approach towards energy savings for residential buildings. Additionally, research studies [8, 9, 10, 11] considered passive cooling methods as the main strategy to provide indoor thermal comfort. For thousands of years, there were no air conditioning technologies to provide thermal comfort for building occupants. In hot climate regions, Arab, Roman and Greek architects used passive design methods as the only means for cooling buildings [12].

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***Figure 1.** (a, b, c) Different new residential projects built with low quality construction in Erbil*

Comprehensive sources have documented useful knowledge on passive cooling in recent decades, including many with the aim of energy-savings [12-14]. Samuela et al (2013), categorized passive cooling methods into radiant cooling, comfort ventilation, evaporative cooling, nocturnal ventilation cooling, and employing the earth as the passive cooling source [15]. Geetha and Velraj (2012), reviews different possible strategies of passive cooling for buildings and presents how each strategy can be utilized [16]. However, after the industrial revolution, passive cooling has become marginal as developed countries replaced passive cooling with HVAC systems [16]. Today, HVAC systems are widely used in domestic buildings in order to control their internal conditions by providing adequate amounts of ventilation rates, heating, and cooling loads within the buildings. Additionally, they are significant contributors to greenhouse gas emissions and global warming due to CO2 emissions. According to the International Energy Agency (IEA), rising demand for space cooling in the Middle East shows nearly more than 70% of energy consumption is due to residential demand on hot summer days [1]. Despite the advantages of the passive cooling methods in hot climate regions, there has been a little research regarding this topic in Iraq, a country with extremely hot temperatures. Therefore, the motive behind this work is to find a potential solution for reducing the extremely high amounts of energy used for cooling houses during the hot summer days. This work does not aim to cover all passive cooling strategies, but rather it concentrates on the two principle classes of worldwide acceptable passive cooling systems: 1) prevention of external heat gains, and 2) modulation of heat gains. Both methods have been reviewed in detail by Geetha and Velraj [16]. In addition, the proposed passive cooling techniques can be implemented into both current and future housing projects. The first proposed solution in this study works to prevent heat from reaching the building through the use of the Mashrabiya screen, a shading device inspired by vernacular architecture in Iraq. A Mashrabiya is a flat box used as a shading element in the vernacular architecture of hot climate zones such as Iraq, Syria, and Egypt [17]. Its value comes from the several functions it offers to provide thermal comfort. For example, the lattice openings on its surfaces (see Figure 2) allow natural fresh air and daylight to pass through. Additionally, it has the added function of providing inhabitants with privacy [18]. With vernacular architecture proving to have positive effects on the internal climate of buildings, the use of these methods has become more popular [19].

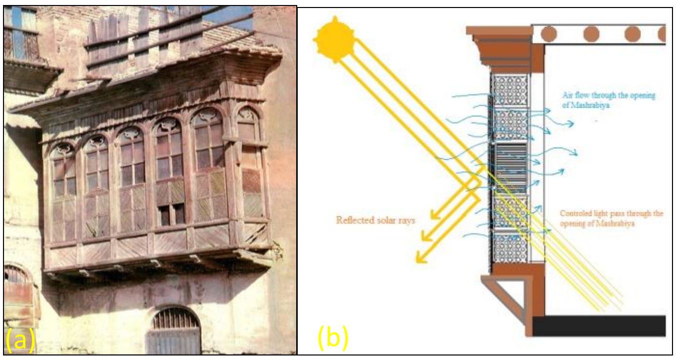


***Figure 2.** (a) Traditional wooden Mashrabiya located on the upper floor of Iraqi traditional house. (b) Section showing airflow through openings and shading of solar by Mashrabiya*

Many scholars have studied the issue of energy conservation and thermal insulation of the building envelope [20, 21, 22]. All of them have come to the conclusion that modifications to the building envelope is the best way to save energy that would be spent on thermal comfort. Considerable studies have been undertaken for evaluation of energy behavior depending on wall and roof thermal insulation position. A study carried out by Ozel (2014) to investigate the optimum location of the insulation layer concludes that the worst insulation location occurs when there was a minimum time lag and maximum decrement factor, while the best insulation location occurred when there was the opposite case [23]. Another study by Al-Sanea and Zedan (2011) recommended placing a thermal insulation layer on the inner face of the wall if the HVAC operation system switched on and off intermittently [24]. The results of the energy simulation in this work have shown a considerable reduction in cooling load by using the proposed passive cooling techniques. This study is significant because it provided simulation-based findings as an urgent solution for lowering energy consumption in housing units not limited to Erbil case but to other similar climate characteristics cities. Lastly, the study identified a group of recommendations for designing a low cooling energy house building in hot climate cities as a contribution to the current field literature.

2. METHOD

The aim of this study is to test the implementation of several passive cooling strategies to prevent overheating of the building envelope and reduce the cooling load in a two-story house located in Erbil, Iraq. To investigate the impact of these techniques on the reduction rate of the cooling loads, our methodology uses an energy simulation by the DesignBuilder program. DesignBuilder is a graphical visualization interface of a dynamic thermal simulation engine called EnergyPlus, developed by the U.S. Department of Energy (DOE) [25]. The simulation process occurred as a sequence of two related phases. The first phase involved a test room to model scenarios for the simulation of the house model in the second phase (see Figure 3). The main structure of the simulation process in this study clarified as follows:
<u>First</u>: The small test room model, which is conducted for the specific following purposes:

1. To find out the best wall materials by analyzing the thermal mass performance of different common wall construction materials in Erbil.
2. To investigate the thermal insulation layer position (outside or inside) in the building walls and roof. This investigation will help architects make better decisions regarding the placement of an insulation layer.
3. To identify the best glass of four different type to utilize in the actual house simulation phase

<u>Second</u>: The house model, which is conducted for the specific following purpose:

1. To develop a real house base case (as built) and compare it with the low cooling energy model in order to find out the cooling load reduction rate.

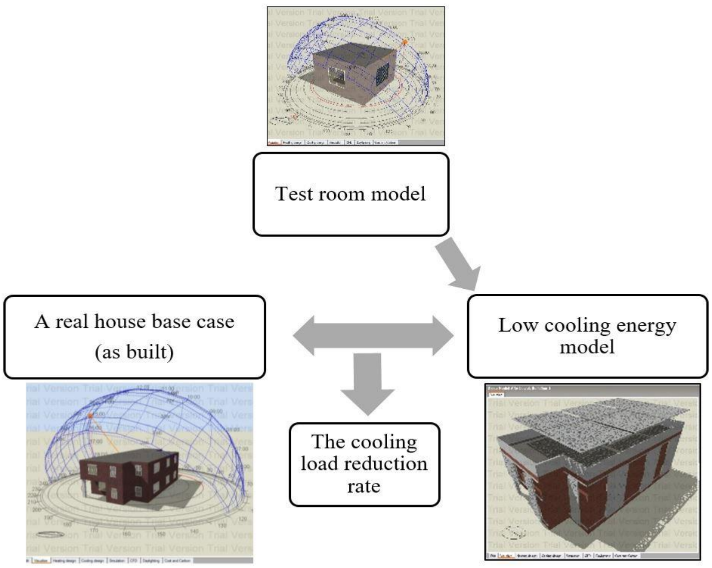


Figure 3. *A diagram shows the methodology steps of the energy simulation process and the scenarios of each phase*

3. RESULTS AND DISCUSSION

3.1. Test Room Model and Its Simulation Result

The modeled small test room as a case study used in the energy simulation process (see Figure 5) representing a residential thermal zone within the weather conditions of the Erbil city (latitude 36.2° degrees north and 44° E) (see Figure 4a). The climate of Erbil city is described by great temperature variations between night and day as well as between summer and winter. Summer is dry and hot, the temperature reaches about 45º in the daytime of July and August as the hottest months, while winter described as cold and wet (see Figure 4b) [26]. However, Indoor operative temperature and cooling loads are the main key parameters of the energy simulation to be compared before and after applying the passive cooling techniques in the test room.

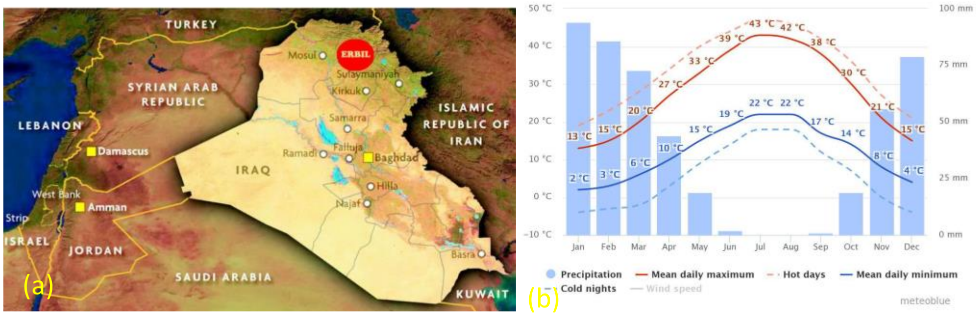


Figure 4.(a) Iraq map showing the location of Erbil city in the norten part and (b) climate graph showing the temperature average and precipitation of annual record [26]

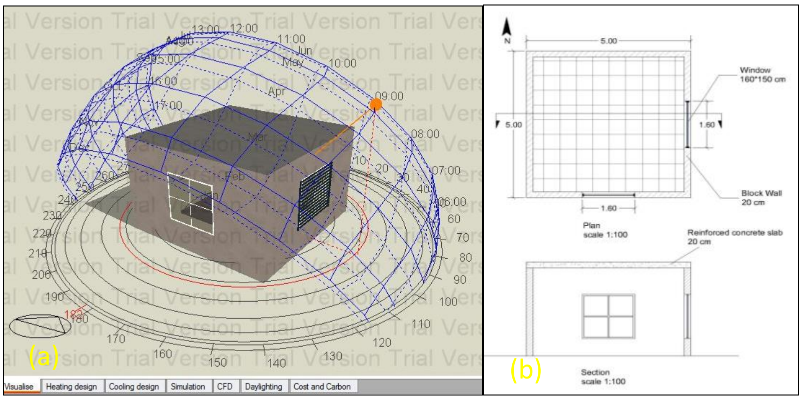


Figure 5. *(a) The test room model perspective view and (b) two-dimensional drawing*

3.1.1. Simulation Result of the Glazing Scenarios

Treating the building windows with solar shading screen or reflective film coatings are a passive solution which could significantly reduce the solar heat gain through windows [27]. For the dynamic thermal simulation process, four rooms were modeled as reflected in Table 1.

Table 1. *Room types and glazing characteristics to be used in the simulation process*

Room	Glazing type	SHGC	U value
Base case	Single clear glass (6mm)	0.819	5.778
Room 1	Double clear glass (6mm/13mm air)	0.704	2.511
Room 2	Double low-e glass (3mm/13mm air)	0.684	1.757
Room 3	Triple low-e colored glass (6mm/6mm air)	0.16	2.325

Figurers 6, 7, 8 and 9 illustrate the heat balance results. Simulation result shows that there is a variation between the four type's modeled rooms in terms of solar gain through the exterior windows and its effects on zone sensible cooling rate. The best performance was detected in room 3 due to the glass type used (see Figure 10).

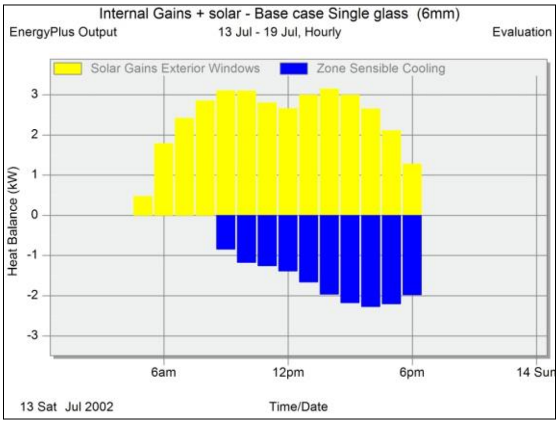


__Figure 6.__ Base case room simulation result showing the solar gain through the exterior windows and its effects on cooling load

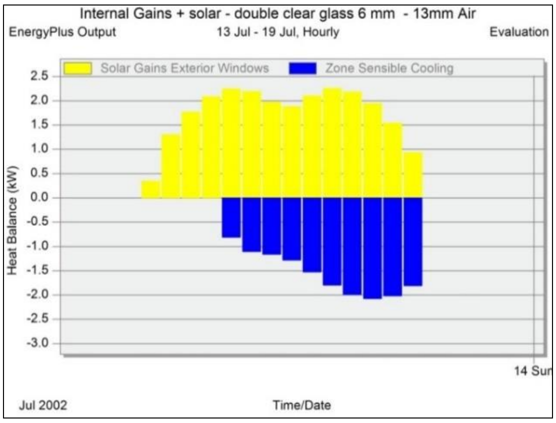


__Figure 7.__ Room 1 simulation result showing the solar gain through the exterior windows and its effects on cooling load

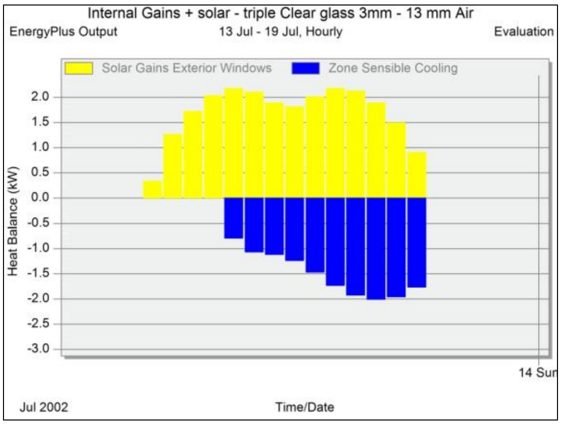


__Figure 8.__ Room 2 simulation result showing the solar gain through the exterior windows and its effects on cooling load

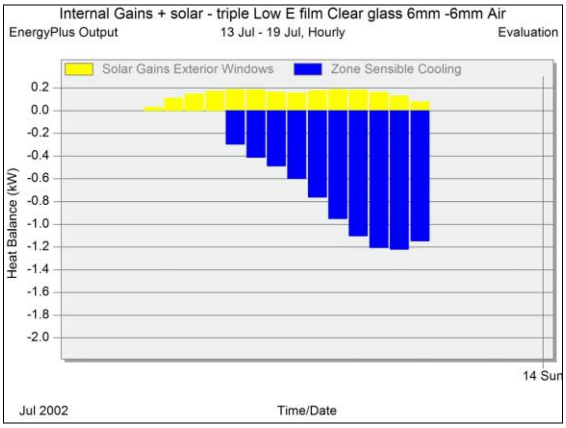


__Figure 9.__ Room 3 simulation result showing the solar gain through the exterior windows and its effects on cooling load

3.1.2. Thermal Mass Performance Analysis of Wall (Assessment of Insulation Layer Position in Five-Wall Scenarios)

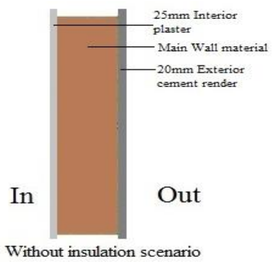
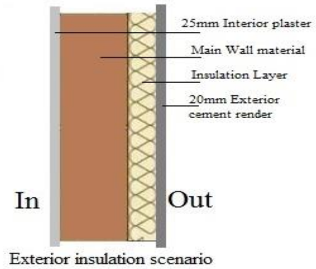
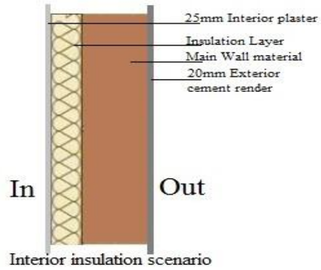
The simulation in this step is seeking to identify the best wall construction material and the best position of thermal insulation layer to utilize in the actual house simulation phase. The most commonly used construction materials in Iraq shown in Table 2. The thickness of the wall finishing materials and the insulation layer positioning scenarios shown in Table 3. Thermal insulation selected to be EPS Expanded polyurethane with 50 mm thickness accordıng to its availability and economic concern in the Iraqi market.

***Table 2**. Currently wall construction materials in Iraq and its main characteristics*

External wall materials	U value (W/m^2 K)	Density (kg/m^3)	Render view
Solid brick	0.85	1360	
Hollow brick	0.77	1040	
Solid concrete block	1.49	2300	
Hollow concrete block	1.28	1440	
Thermostone	0.21	760	

The simulation performed by carrying out five wall composition scenarios. Each wall composition analyzed in three different rooms as follows: room with exterior insulation, room with interior insulation and room without insulation as illustrated in Table 3.

***Table 3.** Three different scenarios of external walls showing the position of the insulation layer*

	Scenarios		
	Room-without insulation	Room- with exterior insulation	Room-with interior insulation
Wall Section			
Details and Thickness	1. Exterior cement render 20mm 2.Main wall material 3.Interior plaster render 25mm	1.Exterior cement render 20mm 2. Main wall material 3. Insulation layer 50mm 4.Interior plaster render 25mm	1.Exterior cement render 20mm 2. Insulation layer 50mm 3.Main wall material 4. Interior plaster render 25mm

The outputs of the simulation show that the Thermostone wall with exterior insulation has recorded the lowest cooling load recording 1.67 (kw/h) as shown in Table 4.

***Table 4**. Wall thermal mass type and simulation scenarios showing the cooling load reduction in each scenario*

Wall thermal mass type	Simulation scenarios	Total cooling load (kw/h)
Solid brick wall	Base case room without insulation	3.55
	Room with exterior insulation	2.76
	Room with interior insulation	2.85
Hollow brick wall	Base case room without insulation	3.18
	Room with exterior insulation	2.74
	Room with interior insulation	2.81
Solid concrete block wall	Base case room without insulation	4.00
	Room with exterior insulation	2.75
	Room with interior insulation	2.92

Table 4.*(continuous) Wall thermal mass type and simulation scenarios showing the cooling load reduction in each scenario*

Hollow concrete block wall	Base case room without insulation	3.74
	Room with exterior insulation	2.79
	Room with interior insulation	2.88
Thermostone block wall	Base case room without insulation	2.71
	Room with exterior insulation	1.67
	Room with interior insulation	1.79

As clearly can be seen in Table 4 the results show that the best thermal insulation layer position is achieved in all scenarios when it was located in the outer surface of the wall section. Accordingly, all wall type with only exterior insulation scenarios was simulated again to find out the best wall material type in terms of cooling load reduction. Result graph in Figure 10 shows that the Thermostone wall with exterior insulation scenario is the best comparing with other scenarios so as it will be used in the next actual case house simulation.

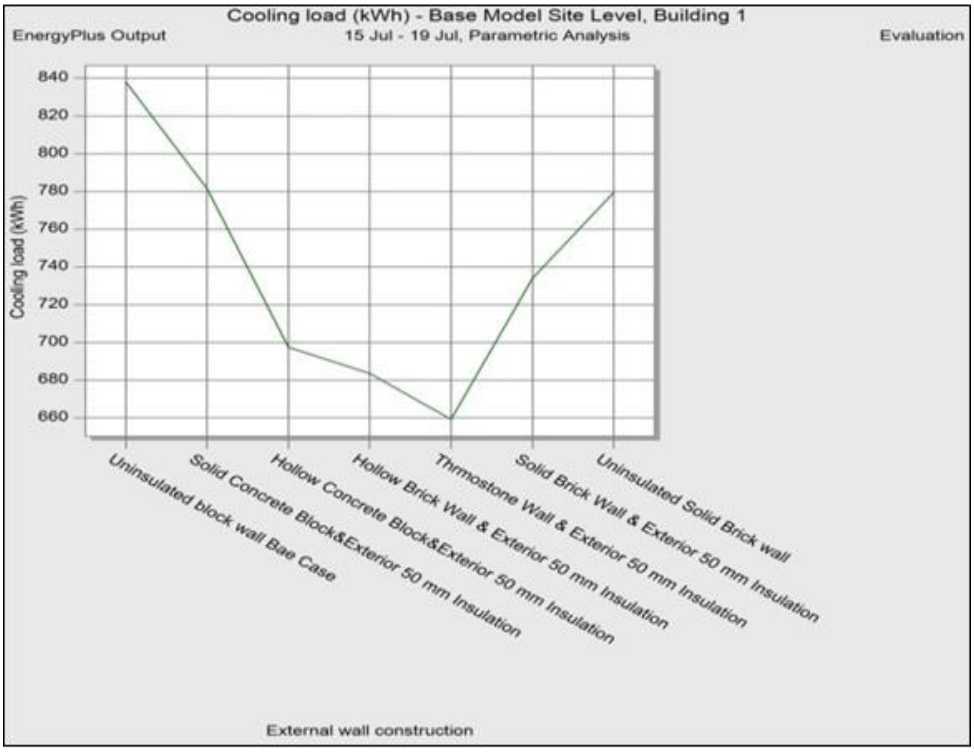
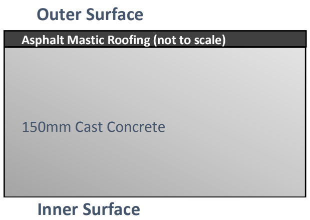
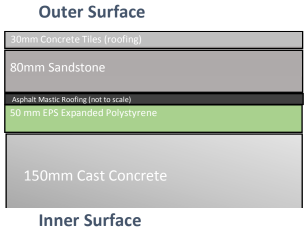
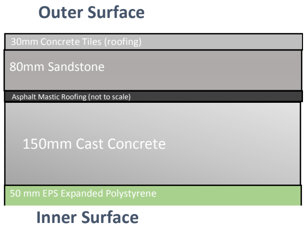


Figure 10. *Comparative simulation analysis of all proposed wall thermal mass with exterior insulation in relation with cooling load calculation*

3.1.3. Thermal Mass Performance Analysis of Roof (Assessment of Insulation Layer Position in Two Roof Scenarios)

Roof simulation analysis held by considered two different scenarios of thermal insulation layer position as reflected in Table 5. Scenario A applying 50 mm of expanded polystyrene that is placed above the concrete slab and scenario B applied the same thickness of the thermal insulation but located under the concrete roof slab.

Table 5. *Base case type and tow roof scenarios with roof section details.*

Scenario	Base case: Roof without thermal insulation	Scenario A: Roof with applying exterior 50 mm thermal insulation	Scenario B: Roof with applying interior 50 mm thermal insulation
Roof section			
Total roof thickness	150 mm	215 mm	215 mm
U value (W/m^{2}K)	3.655	0.566	0.566

Simulation graph in Figure 11 shows that the indoor operative temperature dropped down after 8:00 am because of the effect of mechanical air conditioning, which was designed to be turned on from 8:00 am with sunrise until 6:00 pm with sunset. The averages of the indoor operative temperature of scenario A fluctuate between about 31-31.8°C where the base case wall showing a different range of indoor operative temperature fluctuates between 31.5-37.5°C which is approximately in the range of 0.5-6.5 K comparing with the base case roof scenario.

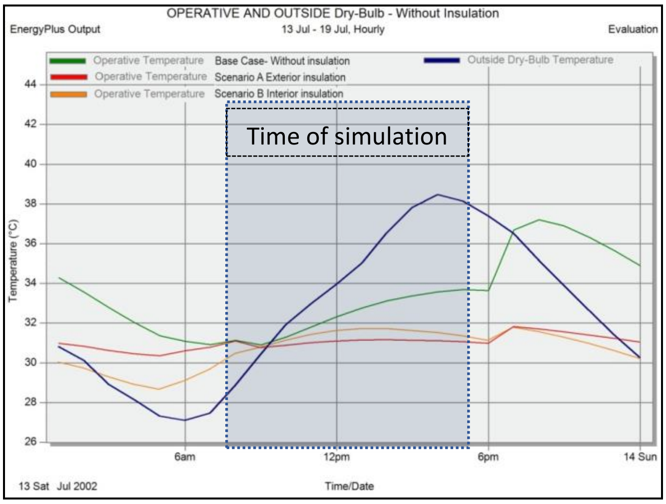
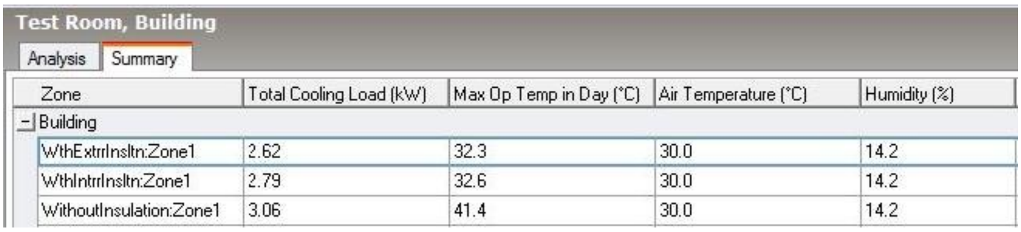


Figure 11. *Simulation results showing the effect of all roof thermal insulation scenarios on indoor operative temperature*

There is a noticeable effect in lowering indoor operative temperature about 0.1 ~ 0.8 K in scenario A comparing with scenario B. According to the result in Figure 12, the lowest cooling load achieved in scenario A recording 2.79 kW which slightly lower than scenario B. Therefore, roof with exterior insulation will be used in the next actual case house simulation.



Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)
Building				
WthExtrnInsltn:Zone1	2.62	32.3	30.0	14.2
WthIntrrInsltn:Zone1	2.79	32.6	30.0	14.2
WithoutInsulation:Zone1	3.06	41.4	30.0	14.2

Figure 12. *Simulation result showing the total cooling load and maximum operative temperature in three different roof scenarios*

3.2. Actual House Model and Its Simulation Result

The energy simulation in this phase based on a comparative analysis method between the base case and the proposed case model after applying the proposed cooling techniques through different scenarios.

3.2.1. The Base Case (As Currently Built)

Modelling

The house used as the base case for energy modeling in this study is a typical contemporary two-story building occupied by one family (detached house) located in Erbil city. Its main construction materials are the ones generally used locally such as solid block walls and reinforced concrete roof slabs. Table 6 describes the base case main construction features.

Table 6. *The general components descriptions of base case model*

Building Details	Descriptions
Main structure type	Heavy weight concrete structure
Plot area	300 m² with front garden and car park
Built area	192 m²
Ground Floor	Descriptions
Glazing template	Single glazing, clear, no shading
Exterior wall materials	Solid concrete block
Roof materials	Reinforced concrete slab
Thermal zone	7 Thermal zones (Entrance, living zone, kitchen zone, circulation zone, two bed rooms and bath room zone)
First Floor	Descriptions
Exterior wall materials	Concrete block
Roof type	Flat roof
Roof materials	Reinforced concrete slab
Thermal zone	6 Thermal zones (Balcony, living zone, circulation zone, two bed rooms and bath room zone)

The first step of the modelling process started with drawing a two-dimensional house plan (see Figure 13-a) by using AutoCAD and converting the file to DXF format to be imported into DesignBuilder program.

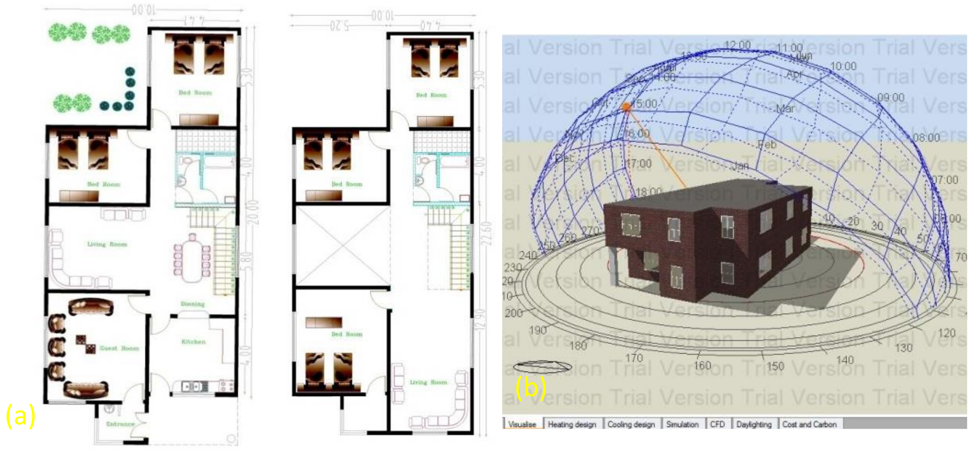


Figure 13. *(a) Two dimensional drawing of the energy simulation by using AutoCAD, (b) 3d view of the actual house modeled using DesignBuilder*

Simulation template

The challenge of energy simulation processes arises in identifying the simulation utilization parameters; such as the ventilation system parameters, cooling and heating set-points temperature and occupancy operation schedule. These parameters have a significant impact on the average of indoor operative temperature, overall cooling load and the energy consumption of any simulated model [28]. As this simulation work concerns with cooling load, summer month profile (from 1 April till 30 of September) was selected to determine the total cooling energy consumption during summer season. However, the parameters and thermal characteristics of both base case house and the proposed low cooling energy house are briefly described in Table 7.

***Table 7**. The simulation templates details of the two house scenarios*

Simulation templates		Base case house	Proposed low cooling energy house
Construction data	Wall	Uninsulated concrete block wall	Thermostone block wall with 50mm exterior insulation (EPS Expanded Polystyrene)
	Roof	Uninsulated cast concrete slab	Cast concrete slab with 50mm exterior insulation (EPS Expanded Polystyrene)
	Infiltration	0.7 on 24/7	0.7 on 24/7
HVAC template		• Split no fresh air with 1.8 cooling systems seasonal coefficient. • Operation schedule: turn on from 8:00 am-6:00 pm. • Cooling set point temperature: 26 ◦C. • Cooling setback : 32 ◦C	• Split no fresh air with 1.8 cooling systems seasonal coefficient. • Operation schedule: turn on from 8:00 am-6:00 pm. • Cooling set point temperature: 26 ◦C. • Cooling setback : 32 ◦C
Activity template	Standard template	ASHRAE 62.1 - residential - dwelling unit (with kitchen) space by space definition for lighting, occupation, and gains	ASHRAE 62.1 - residential - dwelling unit (with kitchen) space by space definition for lighting, occupation, and gains
	Occupancy profile	Four members, single family	Four members, single family
Opening template	Glazing type	Single glazing /clear /no shading	Triple low-e colored glass 6mm/6mm air
	Windows to wall ratio %	30%	30%

For the purpose of the energy simulation process, the energy model was designed to be mechanically ventilated using air conditioning units (AC with no fresh air) to calculate the cooling loads reduction rate. Air changes rate per hour (ac/h) under AC with no fresh air operating pressures (Pa) is left as the DesignBuilder program automatically calculated as 1.7 ac/h @ 50 Pa. DesignBuilder calculates the air rate flow in accordance with ASHRAE standards.

Simulation Results of the Base Case House

As can be seen from the graph results in Figure 14, the peak cooling load of the base case house during summer recorded in July month that is about 6997.36 kWh. This high amount of cooling load resulted in increasing electricity usage, which recorded the highest rate of energy consumption in amount of 9408.98 kWh in July as shown in Figure 15.

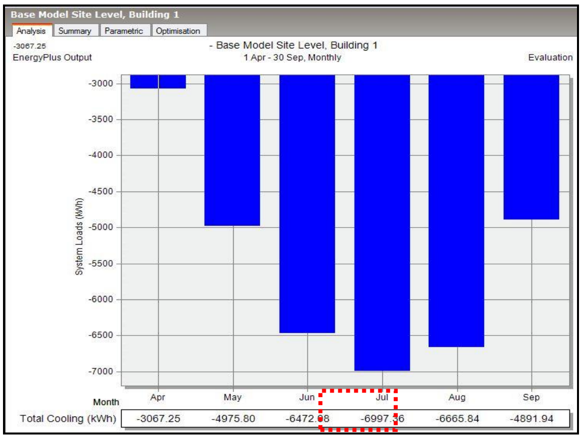


__Figure 14.__Total cooling load performance of the base case house during summer from April to September showing the peak cooling load in July

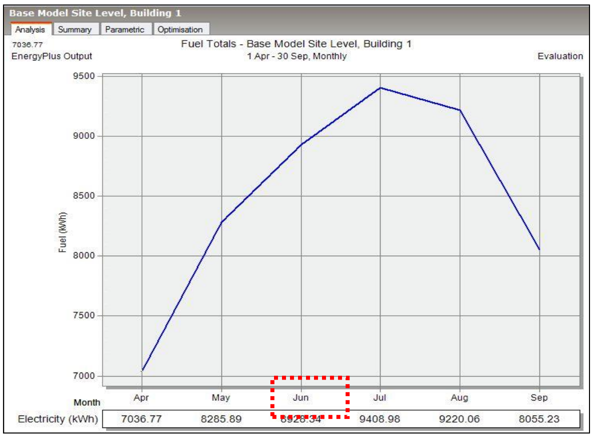


***Figure 15.** The total energy consumption (Electricity) during the summer season of the base case house showing the highest amount of energy consumption in July*

3.2.2. Simulation Results of the Proposed Low Cooling Energy House Model

As mentioned before in the methodology section the proposed passive cooling techniques mainly held under the first two stages of the passive cooling strategies (prevent heat gain and modify heat gains). Table 8 shows the determined strategies and the explained the proposed passive cooling techniques under each one.

***Table 8**. The proposed passive cooling techniques to be applied in the low cooling energy house model*

Passive cooling strategy	Applied passive cooling techniques	Simulation scenarios
Prevent heat gains	1. Shading by using the Mashrabiya	a) Windows shading b) Roof shading
Modify heat gains	1. Improving windows glazing	Triple clear glass, 3mm/13mm
	2. Wall thermal mass	Thermostone wall with 50 mm (EPS Expanded polyurethane) exterior thermal insulation
	3. Roof thermal mass	Roof with 50 mm (EPS Expanded polyurethane) exterior thermal insulation

Prevent Heat Gains Strategy (Assessment the Effect of Using Mashrabiya on Cooling Load)

The flat roofs of the houses located in Iraq are considered to have the most exposed building envelope component with the impacts of solar radiation. In this situation, it is necessary to apply or suggest a solution for preventing heat flux from flat roof surface toward indoor spaces. This work proposed a re-designing model of the traditional Mashrabiya elements (see Figure 16). This design concept corresponds with the philosophy of Hassan Fathy as he encourages architects to learn lessons from vernacular architecture and holds it as a source of inspiration in the modern architecture context [4].

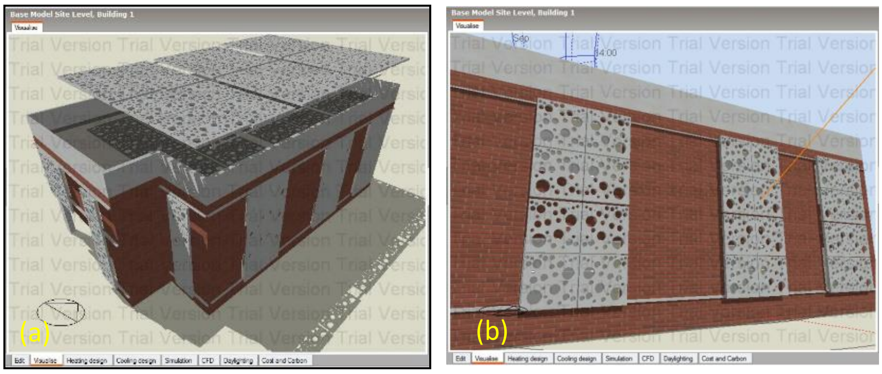


Figure 16. *The proposed movable Mashrabiya screen as external shading device of roof (a) and windows (b), modeled by using DesignBuilder*

The proposed Mashrabya was positioned in the South, East, and Western façades of the modeled house building in order to block direct solar gain during daytime. The proposed Mashrabiya screen was designed in a flexible way; it is a movable screen designed to blocks the direct solar radiation in summer, yet it allows light to pass through its opening mesh during the winter season as can be seen in Figure 16-b. The effect of using Mashrabiya as a shading screen on the exterior windows was effective in reducing the cooling load from about 6997 kWh in the base case house (see Figure 16) to approximately 6117 kWh (see Figure 18). Whereas applying Mashrabiya above the flat roof had less effect in lowering the cooling load to approximately 6497 kWh as shown in Figure 17.

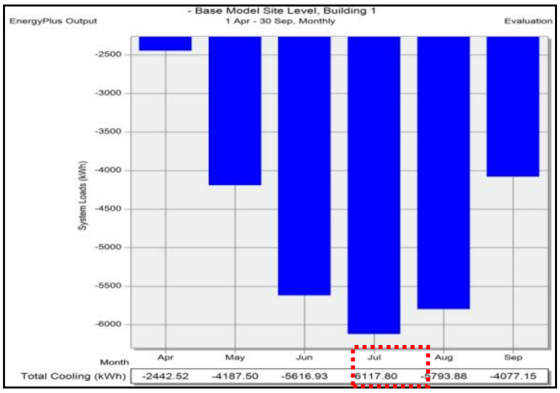


Figure 17. *Total cooling load result after applying Mahrabyiya covering the exterior windows*

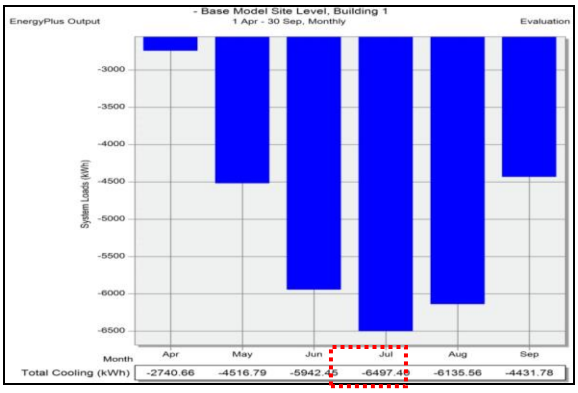


Figure 18. *Total cooling load result after applying Mahrabyiya to cover the flat roof*

Modify Heat Gains Strategy (Assessment the Effect of Building Envelope on Cooling Load)

Based on the results of the previous test room simulation, the best glass scenario was noticed with the room of triple clear glass, 3mm/13mm. In terms of the best wall scenario the Thermostone block wall with exterior 50mm expanded polystyrene insulation was specified as the best scenario. As well as, the best roof scenario was recorded to the concrete slab with exterior 50 mm expanded polystyrene insulation as mentioned earlier in the test room simulation result. The simulation is running in this step to illustrate the effect of combination scenario between best glass, wall and roof scenarios on the cooling load reduction. The graph in Figure 19 illustrates the great effect of improving the building envelope thermal properties which reflected in reducing the cooling load from 6997.36 kWh in the base case house (see Figure 13) to 4984.71 kWh during the peak cooling load in July.

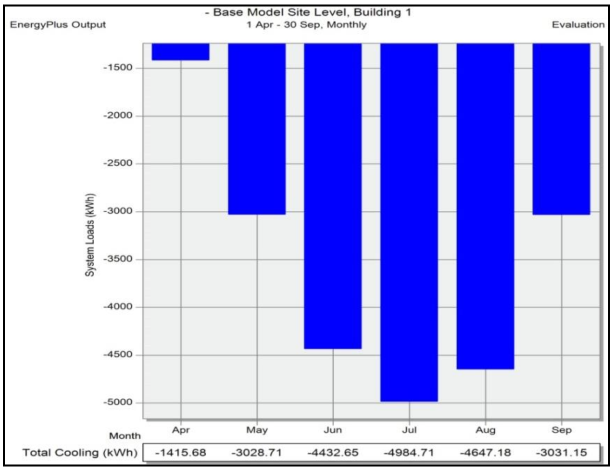


Figure 19. *Total cooling load result after applying the proposed modify heat gains scenarios*

Combination of all passive cooling scenarios

After running the simulation for each proposed passive cooling technique scenarios separately, the next step is to combine all scenarios in one case in order to evaluate the cooling load reduction compared with the base case house. Integrated all of the scenarios in one case was titled low cooling energy house model. The resulted of the simulation shows a great reduction rate of cooling load from 6997.36 kWh in the base case house to 4461.28 kWh in the low cooling energy house model during the peak cooling load in July as shown in Figure 20. The result of combining all proposed passive cooling scenarios at the same time shows that the electricity has been reduced in July from 9408.98 kWh in the base case (see Figure 14) to 7562.32 kWh (see Figure 21) which is about 47.28% of total cooling load reduction (see Table 11).

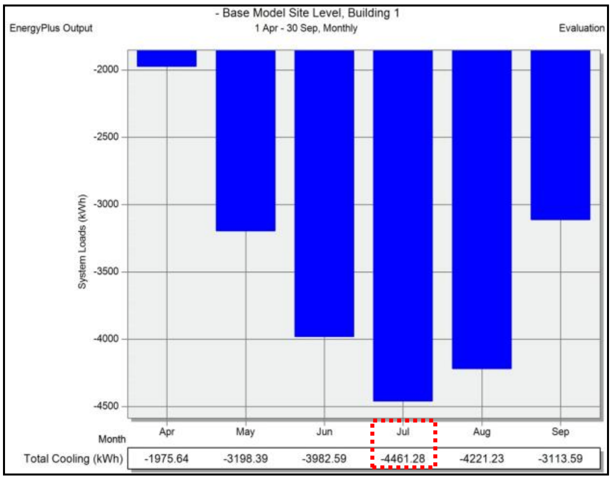


Figure 20*. Total cooling load result after applying all proposed passive coolıng techniques*

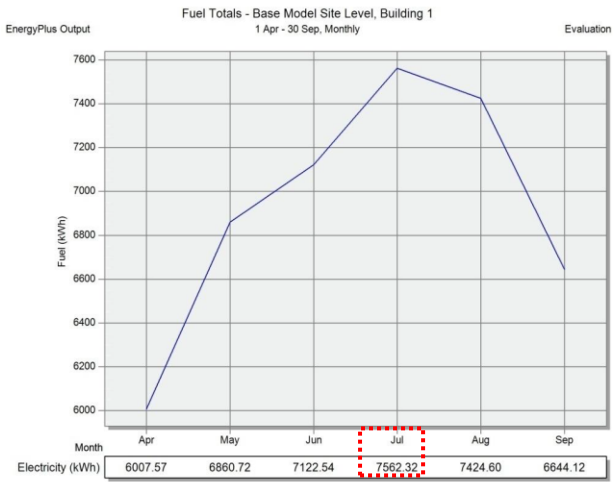


Figure 21. *Total energy consumption (Electricity) result after applying all proposed passive coolıng techniques*

To clarify the above simulation result generally, Table 9 shows the total cooling load reduction in each proposed passive cooling techniques separately. Improving thermal performance of the building envelope has recorded the lowest cooling load among other passive cooling techniques scenarios. In spite of this fact, minimizing heat gain from solar absorption is the key point to enhance thermal comfort and reduce cooling load respectively.

Table 9. *Comparative analysis of the all proposed passive cooling scenarios*

<table>
<tr><th>Energy simulation Scenarios</th><th>Simulation Phase</th><th colspan="2">Proposed passive cooling techniques</th><th>Total cooling load in July (kWh)</th><th>Total cooling load reduction rate</th></tr>
<tr><td>Base case house</td><td>As built currently</td><td colspan="2">Non passive cooling techniques</td><td>6997.36</td><td>-</td></tr>
<tr><td rowspan="5">Low cooling energy house model</td><td rowspan="2">Prevent heat gain techniques</td><td colspan="2">Windows shading</td><td>6117.80</td><td>12.56%</td></tr>
<tr><td colspan="2">Roof shading</td><td>6497.40</td><td>7.14%</td></tr>
<tr><td rowspan="3">Modify heat gains techniques</td><td>Glazing</td><td>(Triple Low-E Colored Glass 6mm/6mm Air)</td><td>6162.75</td><td>11.96%</td></tr>
<tr><td>Wall</td><td>Thermostone wall with exterior insulation</td><td rowspan="2">4984.71</td><td rowspan="2">33.76%</td></tr>
<tr><td>Roof</td><td>Concrete slab with exterior insulation</td></tr>
<tr><td colspan="4">Combination of all scenarios (Total)</td><td>4461.28</td><td>47.28%</td></tr>
</table>

4. CONCLUSION & RECOMMENDATIONS

The goal of this study is to demonstrate the usefulness of re-introducing passive cooling techniques to diminish cooling energy consumption in modern houses**.** The results of this study highlight that passive strategies are effective for reducing the cooling load in mechanically air-conditioned houses. This investigation is the first of its kind in Iraq to determine the capability of re-introducing passive cooling techniques in mechanically air-conditioned residential building. Most of the related studies tested passive cooling techniques in naturally ventilated or non-air-conditioned buildings. Furthermore, the author chose to study passive techniques that would be accessible, easy to implement, and effective for reducing the cooling load in the present and future residential buildings.

The energy simulation used assesses different passive cooling techniques in terms of cooling load reduction rate. The simulations' findings show that the application of the external thermal insulation leads to a noticeable reduction in the cooling load compared to internal insulation when applied on the wall and roof of a building. Additionally, the implementation of the Mashrabiya prompts a noticeable decrease in the cooling load; however, higher sunlight needs in the winter to warm the building envelop can be allowed by structuring a movable Mashrabiya screen. Using these simulations, the author found that designers of modern residential buildings could potentially increase the peak cooling load (that occurs in July) by about 47.28 % using passive techniques. The potential for cooling load reduction using each passive cooling techniques scenario is shown separately in Table 9.

The study's results identify a group of recommendations for designing a low cooling energy house building, which are summarized below:

1. Understanding thermal properties of building materials is essential for evaluating thermal performance of a residential building. Therefore, architects should select insulation materials that are great at resisting the flow of heat (low U-value and high R-value).
2. According to the simulation results, an exterior insulation layer is a more effective location for insulation materials to reduce the cooling load.
3. Highly insulated thermal mass in the walls should be integrating with a highly insulated roof to avoid heat flow through the building envelope components.
4. To avoid solar heat gain, shading of the flat roof and windows is a critical component to consider in the early stage of the design process. The size, position, and type of glazing work together with insulation to significantly reduce absorption of solar rays.

5. For local architect and housing development companies in Erbil, the study suggests the re-designed Mashrabiya is an effective external shading screen that can cover the flat roof and windows to reduce the cooling load during the summer. Additionally, the study's findings are not limited to Erbil. It offers a proposed model to be used as a reference for other cities in similar climate conditions throughout the Middle East.

This research is significant because it offers an effective and implementable solution for diminishing cooling energy utilization, accomplishing another step towards a sustainable environment for future generations. In addition, this work also contributes to the literature on passively energy saving: first, by implementing a traditional architecture element in an innovative way; second, by comparing the cooling load reduction rate of different passive techniques.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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