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INVESTIGATION OF THE EFFECT OF COURTYARD DIRECTION AND WIDTH ON ENERGY LOADS OF BUILDINGS[1]

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Abstract
Despite the global trend to reduce and rationalize all kinds of energy consumption, building production in Iraq continues without awareness of energy efficiency. Conservation of energy in the built environment should become one of the most important topics of both political and scientific programs in Iraq as a global trend issue. Iraq's growing population and declining fossil-based energy sources are emerging as important catalysts for energy efficiency in buildings. In addition, cost efficiency, the need to reduce carbon emissions, and the demand to reduce reliance on energy consumption are the main reasons for energy savings. The reason for the uncomfortable interiors that occur during use and excessive energy use throughout the year is the thermal calculations and related parameters that are not taken into account from the early stages of the design. From this point of view, ensuring the energy efficiency of buildings in the city of Kirkuk is of critical importance due to the ongoing energy crisis. Courtyards, which are open in the middle of a building or building group and surrounded by the building itself or the walls, have been an important architectural component from traditional settlements to today's buildings. This architectural element, which assumes different functions according to the needs of the buildings it is in, also has important effects on the physical conditions of the building. This study aims to investigate the effect of courtyard width and direction on building energy loads in the climatic conditions of Kirkuk in buildings with courtyards. For this purpose, the energy performances for different scenarios of a selected school building were calculated by simulation (Revit and green building studio) and the results were evaluated comparatively. In this way, it is aimed that the study will guide the designers for the Kirkuk/Iraq settlement at the point of energy-efficient building design.

Keywords: *Courtyard, Energy Load, Energy Efficiency, Energy Simulation.*

AVLU YÖNÜ VE GENİŞLİĞİNİN BİNALARIN ENERJİ YÜKLERİNE ETKİSİNİN İNCELENMESİ

Özet
Her türlü enerji tüketimini azaltma ve rasyonelleştirme yönündeki küresel eğilime rağmen, Irak'ta yapı üretimi enerji etkinliği ile ilgili farkındalık olmadan devam etmektedir. Binalarda enerjinin korunması, küresel bir trend sorunu olarak Irak'taki hem siyasi hem de bilimsel programların en önemli konularından biri haline gelmelidir. Irak'ın artan nüfusu ve azalan fosil temelli enerji kaynakları binalarda enerji verimliliği için önemli katalizörler olarak ortaya çıkmmaktadır. Buna ek olarak maliyet verimliliği, karbon emisyonlarını azaltma ihtiyacı ve enerji tüketimine olan bağımlılığın azaltılması talebi enerji tasarrufu için temel nedenlerdir. Kullanım esnasında ortaya çıkan konforsuz iç mekanların ve yıl boyunca aşırı enerji kullanımının nedeni tasarımın erken aşamalarından itibaren dikkate alınmayan ısıl hesaplar ve buna bağlı olan parametrelerdir. Buradan hareketle Kerkük şehrinde binaların enerji verimliliğinin sağlanması, süregelen enerji krizi nedeniyle kritik öneme sahiptir. Bir yapı veya yapı grubunun ortasında yer alan üstü açık ve çevresi binanın kendisi ya da duvarlarla çevrili olan avlular geleneksel yerleşimlerden günümüz yapılarına kadar önemli bir mimari bileşen olmuştur. Bünyesinde bulunduğu binaların ihtiyaçlarına göre farklı fonksiyonlar üstlenen bu mimari unsurun bina fiziksel koşulları üzerinde de önemli etkileri bulunmaktadır. Bu çalışmanın amacı avlulu yapılarda avlu genişliği ve yönünün bina enerji yükleri üzerindeki etkisinin Kerkük iklimsel koşullarında araştırılmasıdır. Bu amaçla seçilen bir okul yapısının farklı senaryoları için enerji performansları benzetim yoluyla (Revit and green building studio) hesaplanmış olup sonuçlar karşılaştırmalı olarak değerlendirilmiştir. Bu sayede çalışmanın enerji etkin yapı tasarımı noktasında Kerkük/Irak yerleşimi için tasarımcılara yol gösterici olması hedeflenmiştir.

Anahtar Kelimeler: *Avlu, Enerji Yükü, Enerji-Etkinliği, Enerji Benzetimi.*

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1. INTRODUCTION

The building/construction sector is one of the major consumers of natural resources such as land, water, and manufactured materials. It also produces a large number of pollutants and solid waste as a result of the materials and energy used. Many countries have taken precautions to diminish pollution and energy consumption by enacting mandatory regulations to eliminate these negative effects.

Especially in architecture, new concepts and methods have emerged that are familiar in architectural thought such as building energy-efficient designs and green architecture, which shows the relationship between buildings and the environment. There are many definitions of sustainability and in the case of energy efficiency in buildings, the term is often used interchangeably with energy efficiency or "eco-buildings" (Estidama, 2008). These concepts respect the environment and the right to a healthy and decent life for future generations. Reflecting the growing interest of the building sector in the protection of the environment, the optimal utilization of natural resources reduces energy consumption and raises the belief in the usage of renewable energy sources. It is known that energy-efficient architecture has many successful and effective samples. However, it is evident that these examples are still ignored and this situation is leading to significant environmental problems in many parts of the world.

Experts emphasize that if today's society does not take the design of energy-efficient buildings seriously as a way of life, they may jeopardize the lives of future generations. The development of energy efficiency is the product of society's efforts through long-term, holistic lines toward achieving and developing a balanced society based on all-considered environmental, economic, social, and political policies. The appropriate thermal design of the building envelope reduces the heating and cooling loads required for heating and air conditioning. This determines the use of low-cost, low-operational heating and cooling devices (Alwetaishi et al., 2018). The objective is to reduce costs and energy consumption and provide a comfortable building environment. There are several things to consider when designing the exterior sides of the building, both environmentally and thermally such as the thermal insulation of the external structural elements, the correct selection of the external windows in the different types, areas, orientations and the closure of their joints in front of air leakage (Breeam, 2009). It also includes natural ventilation to provide thermal comfort and attention being paid to the integration of natural lighting systems when designing openings, which has a key role in reducing the energy consumption used in artificial lighting (Herrmann & Bucksch, 2014).

The courtyard plan scheme, which is encountered in many traditional and contemporary architectural structures, starting with ancient buildings, incorporates many social, cultural, religious and environmental benefits (Abass et al., 2016). While it is widely used to optimize thermal loads, especially in different climatic regions (Abdulkareem, 2016; Chi et al., 2022; Chi et al., 2020), some studies state that the use of courtyards contributes to the natural lighting performance as well as reducing the cooling loads of the buildings. (Acosta et al., 2018; Asfour, 2020). In terms of building form, it is stated that buildings with courtyards and atriums provide significant benefits in terms of benefiting from the sun and using daylight (Muhaisen & Gadi, 2006; Tabesh & Sertyesilisik, 2015). For this reason, in the study, the building sample was determined as an educational structure with a courtyard in a way that would be suitable for the Kirkuk climate.

Determination and optimization of building energy performances by simulation depending on passive design variables is the subject of many studies in the literature. Abanda and Byers (2016); examined the effect of orientation on energy consumption in small-scale construction and they assessed how building information modeling (BIM) is used to facilitate this process. Harmati and Magyar (2015) presented a detailed analysis in an attempt to improve building energy performance in terms of the impact of the building envelope on the annual demand for heating and cooling. The envelope of the building was examined to determine the proportion of the windows-to-wall ratio (WWR). Window geometry (WG) in the function of indoor daylight quality in offices was analyzed by the numerical simulation of the Radiance engine, followed by the evaluation of the effect of glazing on annual energy demand. Ouf and Issa (2017), aimed to measure historical energy consumption over 10 years from a sample of 30 school buildings in Manitoba, Canada. It showed that the average energy consumption of these schools was higher than that of other Canadian standards. Gil-Baez et al. (2017) carried out experimental tests on two school buildings in southern Spain that analyzed the effectiveness of air regeneration through a mechanical ventilation system compared to the natural ventilation system. They studied indoor CO_2 concentration, temperatures and humidity in terms of classroom occupation. After the analysis, the measured data was validated by running the simulations in the third school building where Natural Ventilation Systems (NVS) redesigned and overlapped with the stacking effect. Heydari et al. (2021) investigated how building energy needs vary according to window distribution and type. In the simulation-based study they carried out with the Design-Builder program, they determined the energy saving and recycling times that can be achieved by the use of different gases between single glass, double glass and double glass. Marwan (2020) proposed an innovative brick material to reduce the amount of energy consumption by reducing cooling loads in Indonesia's hot climate. The performance of the composite material, which is stated to be 16.89% more advantageous in terms of reducing energy costs than the traditionally used brick, was evaluated over the cooling cost calculated with a mathematical model developed by the author. Pajek, Potocnik,& Kosir (2022) calculated the energy needs of a detached residential building by considering eight different design measures (opaque components U-value, U-value of windows, SHGC, window/floor ratio, shape factor, diurnal heat storage capacity, surface absorptivity, natural ventilation cooling rate). They emphasized that among the parameters examined in the study, in which the climatic conditions of five different settlements in Europe were taken into consideration, the most determinant for heating was the U value of the opaque components,and the window/floor area for cooling. Liao et al. (2022) analyzed the performance of the radiant ceiling system in different climatic conditions under three different types of building envelope transparent windows by means of experiment and simulation. As a result, they stated that triple silver low-e insulating glass is capable of providing significant energy savings in regions where both heating and cooling are important. Mushtaha et al. (2021) aimed to optimize the thermal performance by reducing the cooling loads of the buildings depending on the shading element, natural ventilation and thermal insulation applications. They concluded that the building energy consumption can be reduced by 59% by taking into account the passive design parameters.

The education sector is known as the locomotive of countries that aim to grow economically, socially and culturally (Allab et al., 2017). For this reason, school buildings have become one of the most important structures in the world over time due to the necessity of providing educational services to students and controlling indoor comfort conditions. In particular, the benefits that can be obtained by choosing the passive design parameters correctly are discussed through an example of a public school building. In this study the energy performance of a courtyard plan building was evaluated by a simulation based work. The effect of courtyard direction and width on building heating, cooling and lighting loads will be calculated by simulations, and scenarios created for different situations of the building example will be discussed comparatively. The scenarios developed with different window/floor ratios are employed to check the effect of the transparency ratio on building energy loads. There are a limited number of studies that take into account passive design parameters in the Kirkuk region. For this reason, the study is important in terms of guiding designers in the context of passive variables and energy efficiency involved in working in a region where passive applications are generally ignored. The simulations will be made with Revit and Green Building Studio (GBS) and the climatic and geographical data of Kirkuk / Iraq will be used in the calculations.

2. ENERGY REQUIREMENTS FOR SCHOOL BUILDINGS

Schools use a lot of energy to ensure that the facility is safe, secure, comfortable and conducive to learning for students. Everything from lighting to climate control adds to the electrical expenses related to running a school. Owing to the containment of a large number of occupants (students and trainers) for long periods leads to the depletion of large amounts of energy and resources to provide a comfortable indoor environment for the users. Children spend long periods in classrooms and a good internal environment can help improve student performance. The improvement of educational conditions is considered to be the cornerstone for advancing society towards comprehensive development as it is the first basis for raising future generations.

One of the main requirements of school buildings is thermal satisfaction which is related to the ambient air temperature, relative humidity, air movement, average radiative temperature, clothing, the student's activity nature and the design of the heating and cooling temperature. Thermal comfort is a basic requirement that must be provided in buildings and is one of the most important factors affecting human activity and its productivity in terms of quantity and quality. It is necessary for the students to feel comfortable inside the building as contemporary kids spend most of their day in school. Heating and cooling indoor environments to provide thermal comfort in buildings is the main reason for energy use. İzmir Chamber of Mechanical Engineers (2015), stated that it is comfortable for schools to keep the ambient temperature between 20-24 degrees Celsius during the heating period and 24-27 degrees during the cooling period. They stated that keeping the ambient relative humidity between 40% and 60%, regardless of the heating and cooling periods, would be appropriate in terms of the thermal comfort of the classrooms. The school building envelope does not conserve energy inside the building, causing an uncomfortable and unhealthy indoor climate for the students.

In addition to thermal comfort in school buildings, the factor that leads to energy use is lighting. The directivity of light in the space of the worksite has a great impact on the visual comfort to be achieved within the space. Every human activity needs a certain amount of lighting. The level of lighting required is affected by the activity type and the completion speed. The level of illumination required is affected by the type of activity and the speed required to complete it. A significant portion of the energy consumed in schools is used for lighting purposes, especially in order to carry out educational activities in a healthy way. Daylighting can reduce the use of artificial light and its electrical equipment. In all of the spaces in the school building model, it provides daylighting and an architect can choose glazed areas for the facades of the exterior building to ensure that there is plenty of daytime lighting and distribution.

In addition to these, indoor air quality and the establishment of an effective ventilation system (natural/artificial) in order to ensure this is extremely important. The crowded classrooms and the fact that children are more sensitive and open to pollutants in the air than adults necessitate sensitivity in this regard (Karaca, 2022).

3. MATERIAL AND METHOD

The study aimed to constitute an energy-efficient school model located in Kirkuk, Iraq where there are no regulations for educational buildings concerning providing comfortable indoor conditions for children in order to improve the performance of learning facilities. For this purpose, a sample school building form having a courtyard is taken into consideration. 3D view and the floor plans are shown in Figure 1. The energy performances of different building models created were compared in terms of energy requirements. Among the scenarios created, it is aimed to determine alternatives with minimum energy consumption in Kirkuk conditions. To enhance the comfort conditions of the selected model, cases according to different dimensions, orientations and window areas were constituted.

The building envelope is the physical separator between the exterior and interior environments. In general, the building envelope consists of a set of components and systems that protect the interior from environmental influences such as precipitation, wind, temperature, humidity and ultraviolet radiation. The study focuses on the effect of insulation materials used in walls, roofs, floors and windows in buildings in Iraq on energy consumption and reveals the energy savings resulting from insulation applications in buildings. The indoor environment consists of occupants, furniture, building materials, lighting, machinery, equipment, and HVAC systems. Syrian Thermal Insulation Codes (URL-1) based on Table (4.6), according to Iraq Thermal Insulation Regulation (2013), the minimum U value that roofs should provide is 0.5 W/m^{2}K, while this value is 1 W/m^{2}K for floors adjacent to the ground and for floors separating stories is 1 W/m^{2}K.

Figure 1. 3D Model and the floor plans of the school building (Najib, 2019)

Therefore, in the study, the recommended values for the relevant items were used while determining the U values of the building components. There are no other binding regulations/standards, etc. restrictions in Kirkuk/Iraq for the construction of school buildings. The U values of the building components preferred in the simulations are given in Table 1.

Building Component	Materials	Thickness (mm)	Thermal Conductivity (W/mK)	Density (kg/m³)	U value (W/m²K)
Wall	Plaster Cement Insulation Plaster Cement Masonry-Block Gypsum plaster	30 50 30 200 20	1.50 0.019 1.50 0.76 0.51	1900 32 1900 780 1120	**0.336**
Floor (ground)	Ceramic Tile Concrete-Cast In Situ Insulation	50 100 50	1.20 1.5 0.019	2000 1900 32	**0.365**
Floor (intermediate story)	Ceramic Tile Concrete-Cast In Situ Air Gypsum Board	50 100 200 10	1.20 1.5 0.025 0.65	2000 1900 1.20 1100	**0.122**
Roof	striker concrete Soil Insulation Concrete-Cast In Situ	30 100 50 200	1.046 0.837 0.019 1.5	2300 1300 32 1900	**0.343**
Door	Hollow core wood				**3.180**
Window	Double glazing - domestic				**3.129**
Entrance Door Windows	French door, metal frame with double glass				**4.381**
Door Windows	Wood frame, double glass door				**3.128**

Table 1- Physical properties of building components

3.1. The Climatic and Geographical Properties of Kirkuk City

Kirkuk is one of the hottest cities in the world. The temperatures may exceed 49 °C mid-summer. The monthly change in temperature at the meteorological station shows that for the period from (2012-2018), it is clear that the value of the temperatures in the city of Kirkuk was the highest in July and August. The lost quantity was in January and December. The measurements of the meteorological records show that the temperature of the city of Kirkuk for the year (2017) had a significant variation in temperature between night and day and between summer and winter. The average temperature for the whole year was (24.44 °C), where the lowest value in temperature was (-1.7 °C) in February and the maximum value was in August (49.3°C). The monthly change in solar radiation, ambient temperature, humidity and prevailing wind speed and directions are shown in Figure 2.

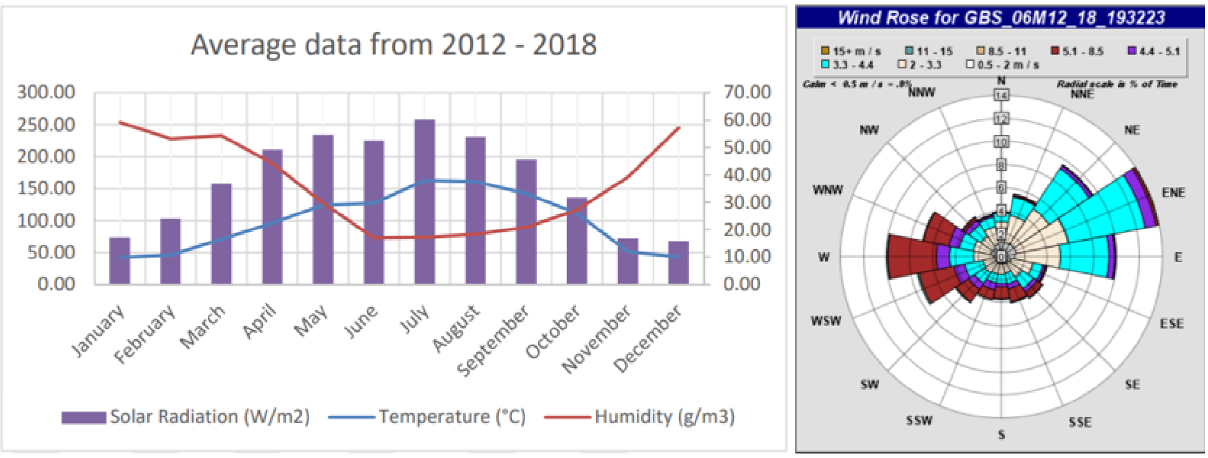

Figure 2. Annual climatic data for Kirkuk/ Iraq

3.2. Different Courtyard Dimension and thermo-physical properties for the Sample Building

How the energy performance of the U-plan school building changes depending on the courtyard dimensions has been examined. For this purpose, four different plan-handling schemes, in which the width of the courtyard is designed as 5, 10, 15 and 20 m, are discussed. The visuals of these situations and the changing floor area values of the building are as shown in Figure 3**.**

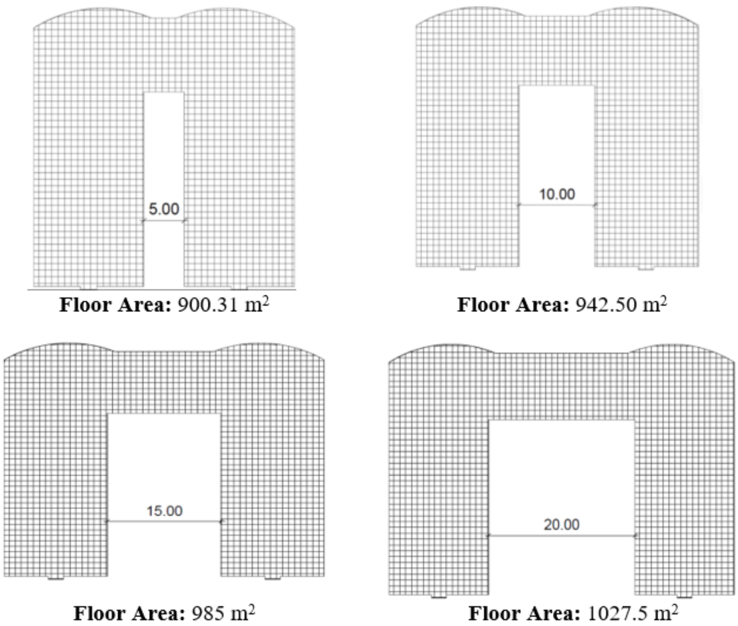

Figure 3. Building scenarios created with different courtyard widths (Najib, 2019)

3.3. Different Orientation Alternatives for the Sample Building

Orientation has an impact on the overall thermal performance of the building when designing heating, cooling and lighting to achieve the optimum level of thermal comfort for the occupants. In a hot, dry climate, the orientation of the structure ensures that the building elements reach the amount of sunlight they need during the day. while being oriented by considering the sun rather than the wind considerations to protect from the sun during the summer months. To get some solar heating in winter. The shape and orientation of the building block should help achieve the lowest possible amount of heat in summer and the highest amount of heat in winter. After the school model was created with the Revit program, the location of the building was determined and the building sample was oriented in four main directions (north, east, south and west) for only one courtyard size. To see the effect of the orientation on the energy balance of the buildings, simulations are performed using the analysis tool for each orientation situation as seen in Figure 4. The area of the transparent surfaces is also given in the figure.

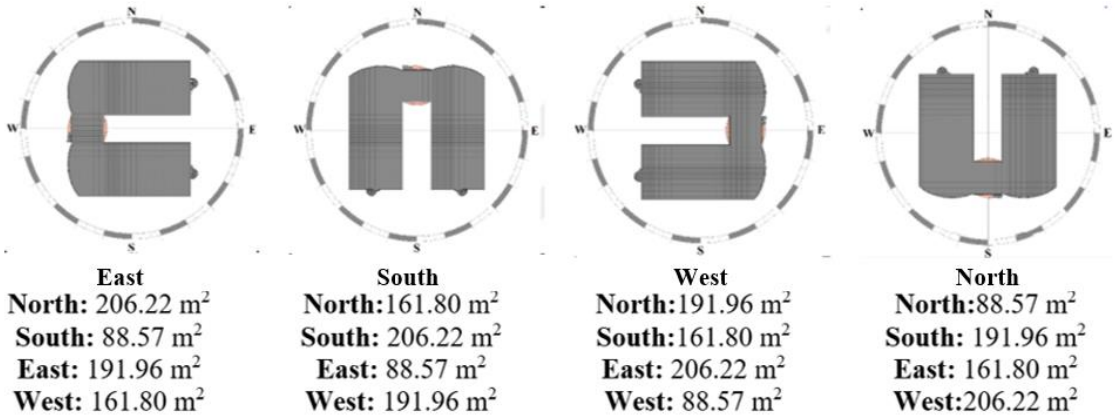

Figure 4. Window areas of different oriented building samples (Najib, 2019)

3.4. Different Window Area Alternatives for the Sample Building

In order to evaluate the effect of the transparent surfaces on the buildings' energy needs, the Window/Floor area (W/F) ratio was used in this study. In the simulations, the energy needs of the scenarios where the window/floor area is accepted as 5%, 10%, 15% and 20% are determined only for the building situation where the courtyard is oriented to the east. Building models for these four different scenarios are shown in Figure 5.

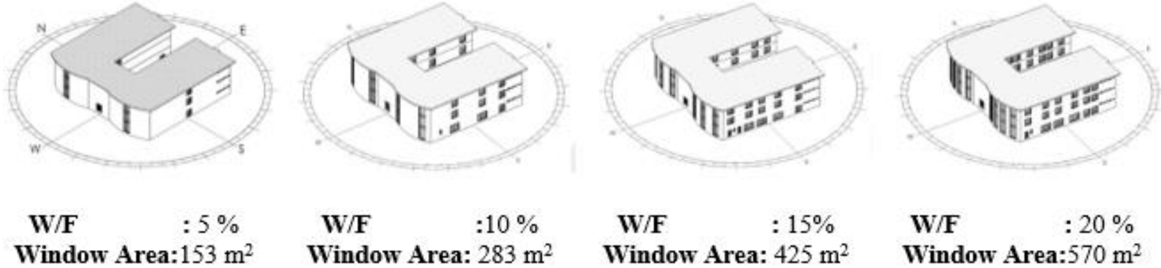

Figure 5. W/F ratios and window areas of different scenarios (Najib, 2019)

4. RESULTS AND DISCUSSION

Models were created in the Revit environment for different scenarios of the building example. Energy simulations were carried out with Autodesk Green Building Studio for the models obtained. Validity analysis was performed to confirm the accuracy of the results obtained as a result of the simulation. For this, calculations were made for the sample scenario of the building sample with HAP (Hourly Analysis Program). The annual total heating and cooling loads obtained from each calculation tool are given in Table 2 comparatively. Accordingly, the heating load results obtained from the Autodesk Green Building Studio tool were approximately 14.5% higher than the results obtained from the HAP tool, while this rate was determined as 2.89% in the cooling load results. As in the studies of Kürekçi and Kaplan (2014), it has been observed that the values converge and are acceptable.

Software	**Heating (MJ)**	**Cooling (MJ)**
Revit analysis and Green Building Studio	173162	55094
HAP (Hourly Analysis Program)	147960	53500
	14.5%	**2.89%**

Table 2. Analysis results obtained from both Autodesk Green Building Studio and Hap software

To examine the possible effect of widening the courtyard that causes an increase in the building floor area on the energy loads, simulation results were compared. As can be seen in Figure 6, the heating requirement of the building is 6.73% by increasing the width of the courtyard from 5 m to 10 m, and by increasing it to 15 m, it is 10.8%. There was an increase of 15.78% by increasing the width of the courtyard from 5m to 20m. When the change in building cooling loads is examined, these increase rates are 1.52%, 3.09% and 6.12%, respectively. From this point of view, the floor area of the building and the correspondingly increased volume mean the increase in the surface area on which the heat losses and gains (solar gains) will take place, thus causing an increase in the heating and cooling loads of the building. When the lighting loads are evaluated, the lighting loads also increase due to the increase in the building interiors that need to be illuminated with the increase in the floor area. The artificial lighting energy requirement of the scenario with 5m courtyard width is calculated as 27288 kWh/year. With the increase in the size of the courtyard as 10, 15 and 20 m, the lighting energy increased as 28658 kWh/year, 29356 kWh/year and 31201 kWh/year.

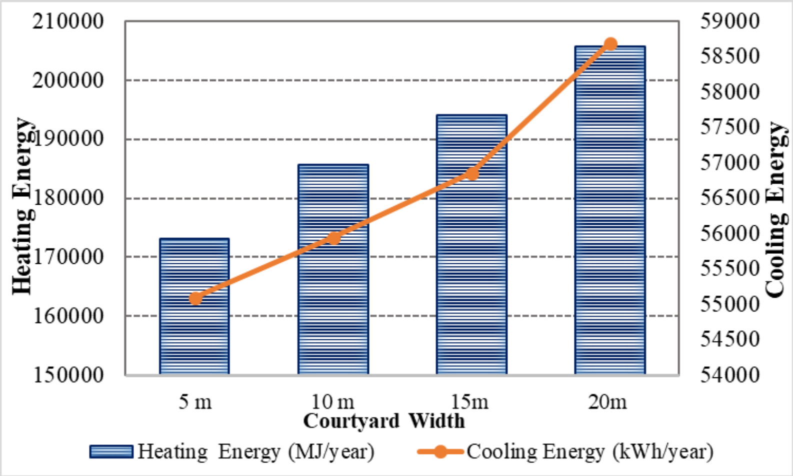

Figure 6. Effect of courtyard width on heating and cooling energy requirements

Energy simulations were made for the examples of buildings with the courtyard oriented in four main directions and the results are given in Figure 7. Accordingly, the highest heating energy requirement (143857 MJ) is in the example where the courtyard is oriented to the north and the southern openings that can provide useful solar gains in the south direction are less than the other surfaces (161.80 m^2). This situation is followed by the cases where the courtyard is oriented to the south with 133377 MJ and to the west with 131340 MJ. The lowest heating energy requirement was obtained from the example where the courtyard was oriented to the east.

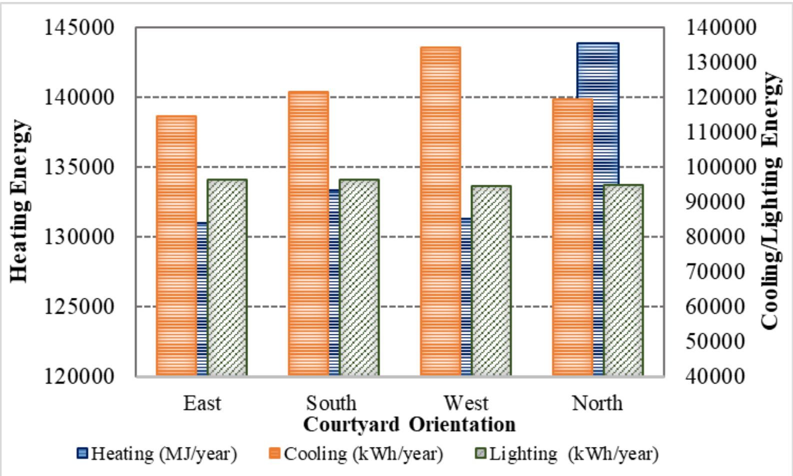

Figure 7. Energy requirements of the building samples oriented to cardinal directions

Considering the cooling loads, it is seen that the highest values are observed in cases where the window areas in the east and west directions are 294.79 m^2 and 280 m2, respectively, and the courtyard is oriented to the west and south (134339 kWh/year and 121473 kWh/ year respectively). For other examples, the cooling load is 119603 kWh/year when the courtyard is oriented to the north, while it is 114662 kWh/year when oriented to the east.

In terms of lighting loads, it is seen that the highest value is in the example with the court directed to the east (96425). This is thought to be because in the relevant example, the areas of the north windows have the highest value and the areas of the south windows have the lowest values compared to other directions. The lowest lighting energy requirement (94778 kWh/year) was obtained in the scenario in which the courtyard is oriented towards the west direction. It is thought that the reason for this situation is the high glazing rate in the east and west directions. However, in this case, it would be appropriate to control glare to create a comfortable interior for lighting.

The results of the insulation applications assumed to be applied on the school building were compared. The results showed that a building without insulation consumes a lot of energy. The amount of energy used will reduce when increasing the thickness of the insulation applied as in Figure 8. The cooling and heating energy requirement of the building sample decreased in percentages of 3.5%, 2.44%, 0.20%, and 0.03% respectively for increases of 5 cm insulation in 5 steps from (0 - 20) cm insulation for the building envelope. The highest amount of advantage between insulation applications and non-insulated building models was achieved in the application where the thermal insulation increased from 0 cm to 5 cm.

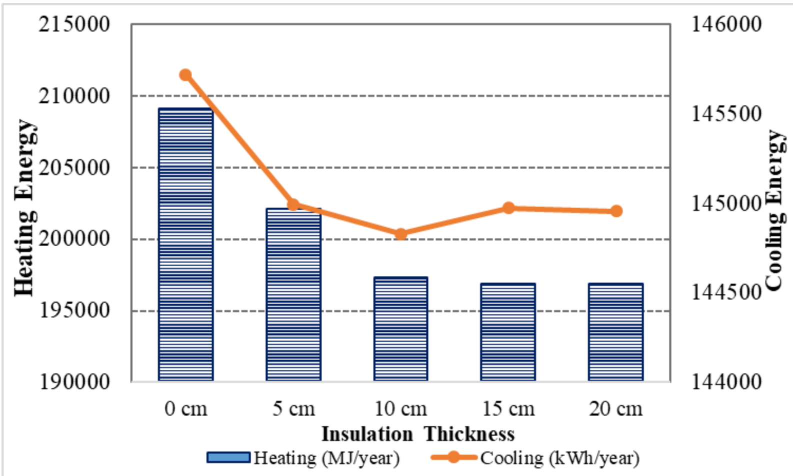

Figure 8. Variation of Energy requirements with insulation thickness

Orientation and sizing of Windows and transparent surfaces have great importance in building design. They are required for physical and visual connections with the outdoors but their interaction with heat gain/ loss and natural ventilation makes them and their design critical to a building's passive design. A window-to-floor ratio provides a rough approximation base for determining the optimum areas of the window in relation to the floor area of a room or building. As with all rules of thumb, it is used as a starting point for design and in this study, it was used for confirming through the school building model. The results in Figure 9 show the variation of energy requirements with the W/F ratio. Performances of four different cases with W/F's of 5%, 10%, 15%, and 20 % were determined.

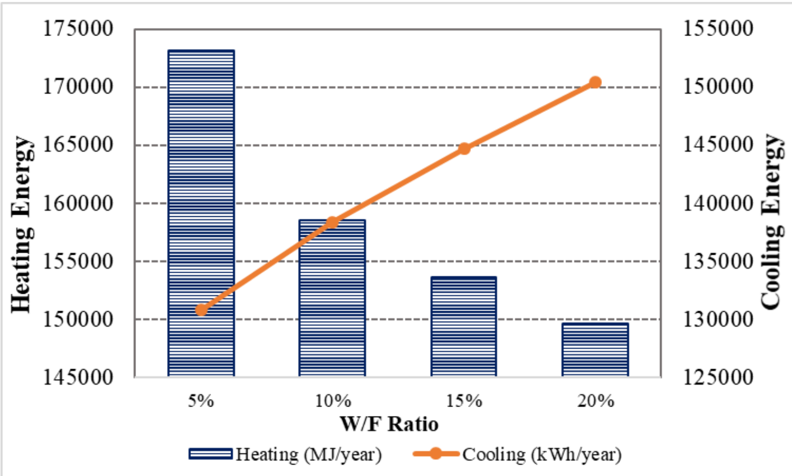

Figure 9. Variation of heating and cooling energy requirements with W/F ratio

The results showed that the building heating load is 173172 MJ/year and the cooling load is 130788 kWh/year when the W/F is 5%. In cases where W/F is 10%, 15% and 20%, it was observed that the heating loads decreased by 8.42%, 11.27% and 13.59% compared to the first 5% situation, due to beneficial solar gains. In cooling loads, this situation has emerged in the direction of an increase in energy demand due to the increase in solar gains during the cooling period. Cooling loads for 10%, 15% and 20% W/F values are determined as 138352 kWh/year, 144703 kWh/year and 150412 kWh/year, respectively.

5. CONCLUSION

This study aims to describe the parameters affecting the performance of courtyard buildings. The effects of courtyard width, orientation, insulation thickness and window /floor ratio were evaluated separately. According to the results, the following outcomes were obtained.

- Increasing the size of the courtyard will also increase the floor and surface areas of the building, thus increasing the amount of energy needed to make the indoor environment comfortable. However, by optimizing the courtyard direction and the dimensions of the windows opening to the courtyard, it will be possible for the buildings to gain beneficial solar gains during the heating period.
- Determining the appropriate transparent component sizes on the surfaces that are heavily exposed to solar radiation will allow keeping the cooling loads at a certain level by preventing excessive gains. While increasing the transparency ratio may be a suitable solution for passive heating of buildings, ignoring the direction factor causes high heat losses and heating energy needs in winter. Conversely, windows located in the east and west directions and providing low

solar gain in winter months are the most important determinants of the cooling loads of buildings in summer months.

- Finally, it is clear that as the insulation thickness increases, the thermal resistance of the shell element will increase in the insulation applications carried out to reduce the energy consumption for heating and cooling, and the energy needs will also decrease. However, since insulation has a significant initial investment cost, it is possible to find an economical solution by determining the optimum insulation thickness.

However, more importantly, the absence of any binding mandatory enforcement mechanism during the construction phase is not an acceptable situation. For this reason, it is important to create awareness on issues such as energy efficiency and sustainability, especially in the region where the study is carried out, and to create guiding tools for different occupational groups taking part in every stage of the building production process.

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