The Effects of Physical Parameters of Buildings on Energy Consumption

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Abstract

Nowadays, over 40% of energy consumption in the world occurs in the building sector. Given such a significant impact, designing buildings with long-term energy efficiency is of substantial importance. The purpose of the present study is to assess the thermal performance of a vast spectrum of parameters, including building orientation, window-to-wall ratio, transparency, and geographical direction in a cold and temperate climate. To this end, a case study is conducted on eight samples of prevalent building plans in Ilam city, located in the west of Iran. The results of the data analysis were written as mathematical functions, and ultimately, the proposed pattern function related to the four selected criteria of the optimal pattern was presented by comparing the functions of thermal comfort and natural lighting. In conclusion, square-shaped plans are the most optimal, and higher length-to-width ratios lead to higher energy consumption.

Keywords : Physical Parameters; Residential Buildings; Energy Consumption; Square-shaped Plans; Building Designing

Introduction

In every country, the building sector is responsible for more than one third of the total energy consumption (1). As a result, the amount and methods of energy consumption in buildings have always been a concern in construction projects. However, such a concern can be considerably mitigated by using modern technologies and adhering to the existing construction standards. In many countries, the shape and form of buildings are chosen based on climate conditions, which in turn affect how energy is consumed; in other words, the forms of buildings are selected through strategies that are suitable to the climate (1). Accordingly, the most important related indices include the type of materials, building orientation, thickness of walls, openings, and type of ceiling (2, 3). Attention has been paid to these indices, and today, architects also take them into account when reviewing the rules and changes to optimize energy consumption and lessen the consequences of unregulated consumption.

The direct or indirect consumption of fossil fuels in buildings emits a large amount of CO2 into the atmosphere. Contemplating and recognizing the means to reduce CO2 production and consume energy in an optimal manner are instrumental to confronting the incorrect use of energy (4-6). This amount of emission amounts to nearly 40% of the entire CO2 (i.e., 842 million tonnes per year) (7), which entails 36% of the global energy consumption (8-10). Today, energy saving refers to the implementation of solutions specified under various regulatory frameworks (11, 12). Global guidelines on the energy performance of buildings require the adoption of tools for calculating energy consumption performance, applying the minimum performance standards during the design process, operating the construction, licensing the building, and ensuring control over heating and cooling systems (13-15). In fact, interior thermal comfort is considered the main driver of energy consumption in buildings (11, 16, 17), which can be of importance in two areas, including the type of consumed and the physical factors involved in energy consumption and suitable efficiency.

Due to the inevitable degradation in their physical performance, many of the existing buildings are unlikely to be regarded as “green” buildings in terms of energy consumption. The physical performance of buildings should be specified in detail prior to any construction or system maintenance operations (18-20). There are numerous studies conducted on areas such as consumer behaviour, construction operation and system repair and maintenance, envelope function, lighting, hot water and heating systems, building materials, and HVAC (heating, ventilation, and air conditioning); these studies have offered a variety of models on energy reinforcement strategies and economic assessment of different types of existing structures in residential and non-residential buildings (21, 22).

In Europe, the AR ranking, which assesses the physical performance of buildings, is used to enhance the energy performance of degraded buildings. This method provides reliable information regarding how energy is consumed or wasted in these types of buildings, with the ultimate purpose of reducing energy consumption and specifying the effect of each physical dimension on the amount of energy consumption. Nonetheless, collecting consistent data on the existing buildings is difficult, and the energy performance assessment of these buildings is commonly done using simplified data obtained from refined data and tables from different sources (23, 24). The same approach is adopted in this study.

Numerous studies conducted in this area have examined optimal building designs; therefore, many more passive solutions have been proposed regarding energy reduction and efficiency in the building sector. Studies have shown that the energy performance of buildings depends on five factors, including weather, building design, urban geometry, system efficiency, and residents' behaviour (25). According to evidence, the architectural design helps to reduce energy consumption (26, 27). In design and construction principles, inactive design strategies and bioclimatic designs are the main solutions to minimize energy demand (28). Studies have classified building designs into six parameters, which include the shape of the building, transparent surfaces, orientation of the building, thermal-physical features, building materials, and distances between buildings (29, 30).Clearly, energy source provision is one of the future concerns of mankind. The essential actions to mitigate these concerns may include controlling energy consumption, using clean energies, and employing modern knowledge for constructions with minimum energy consumption (31).

In the present study, the design and construction of buildings in cold, temperate, and Mediterranean climates are highlighted. The empirical designing and constructing of buildings via different materials has, in many cases, offered substantially suitable potentials to create buildings that consistently involve optimal energy consumption. These indices have been mostly related to available materials, consistency between the climate and buildings, and the method of using renewable energies through building architecture, acquired through experiment over time. Given changes in lifestyle, fuel diversity, economic costs, family behaviour, available materials, and climate change, it appears that previous methods cannot meet the requirements of optimal energy consumption. Given such a fact, it is necessary to employ the technology of today's world to optimize these indices and make use of new energy consumption methods in buildings. All in all, reducing energy consumption in buildings requires accurate, practical answers to the issue. As a result, the present study seeks to examine the effect of buildings' physical features on the extent of energy consumption; further, different types of buildings and prevalent architectures in this study were compared to calculate energy consumption in various forms and provide suitable strategies for optimizing energy consumption in these buildings.

Materials and Methods

The present research is an applied, design-based study conducted using the analytical approach. The purpose of the study was to evaluate the physical parameters of residential buildings with the prevalent edge ratios in Ilam City – located in Iran – in order to provide an optimal pattern relative to the assessed parameters. Accordingly, eight prevalent residential building plans with the same total area (156 m^2) were taken into account (Samples A, B, C, D, E, F, G, and H).

Generally, the A/C and lighting systems in a residential building account for 40% and 11% of the total energy consumption, respectively. The eight samples in this study were examined in terms of thermal performance and lighting of the entire building. The physical characteristics of buildings, such as materials and the type of openings, were considered the same across all eight samples in the data analysis. Materials used in this study are as follows:

Autodesk Ecotect™ Analysis 2011 software

Autodesk Ecotect™ is a BIM environmental simulation tool that can be used for analysis of thermal loads, lighting design, shadows and reflections, shading devices, and solar radiation. Ecotect Analysis offers a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs. Online energy, water, and carbon-emission analysis capabilities integrate with tools that enable you to visualize and simulate a building's performance within the context of its environment. Calculate total energy use and carbon emissions of your building model on an annual, monthly, daily, and hourly basis, using a global database of weather information. Ecotect™ was developed by architects with its application in architecture and the design process in mind. Ecotect™ can also be used by engineers, local authorities, environmental consultants, building designers, owners, builders, and environmental specialists. Ecotect™ uses the CIBSE Admittance Method to calculate heating and cooling loads and daylight factor method to calculate illuminance levels (32).

Energy Plus 8.2.0 software

EnergyPlus, the simulation engine used within the ACCIS framework, is an open-source BES software developed by both the Lawrence Berkeley National Laboratory and the U.S Department of Energy. It is used by engineers, architects, and researchers to model both energy consumption and water use in buildings. This software is a console-based program which reads inputs and writes outputs to text files. It was originally written in FORTRAN programming language; however, it is written in C++ since version 8.2.0. This software and its programming language are difficult to understand, so some graphical user interfaces, such as DesignBuilder or OpenStudio (33), have been developed to be used by people with no programming experience.

This study was conducted in three parts which are as follows:

First, the physical models of the samples were simulated using the Ecotect Analysis11A building simulation software 2011 software; moreover, the amount of consumed by each sample, given the total area of openings, were calculated via Energy Plus22A fuel consumption simulation software 8.2.0 software, with respect to the climate conditions of sample city—Ilam City. The openings in these eight samples were evaluated from 0 to 100% in terms 10-100% wall transparency so as to analyze energy consumption at peak hot and cold periods as well as the thermal comfort and air conditioning. Furthermore, to gain a better understanding of the results, software outputs were inserted into Excel at each stage and the results were presented as charts.

Next, given the significance of the amount of received solar energy as a natural energy source, it was analyzed both as a thermal and lighting source and the quantitative results were provided for all eight samples. Then, the results were expressed as mathematical functions33In hot and cold conditions, comfort period, and air conditioning along with the amount of natural lighting and the results of previous stages were transformed into assessable mathematical charts44Calculations were transformed into a quadratic function using Excel and the best modes of energy consumption and opening percentage were specified relatively followed by optimization.; ultimately, the optimal transparency and lighting in each sample followed by the optimal extent of energy consumption were measured using the defined parameters.

Finally, to offer an optimal building pattern based on the selected parameters in this study, the most optimal models related to transparency, openings, plan, and building orientation were offered; subsequently, the extent of energy consumption was analyzed based on these models to ensure the optimality of the proposed model.

This study represents parameters such as plan, the total areas of openings, the extent of wall transparency and building orientation relative to geographical direction in relation to energy consumption in residential buildings of Ilam City which has a cold, temperate climate (Figure 1).

Figure 1.: Physical parameters of buildings that affect energy consumption in this study

Eight samples were examined in this study and their geometric shapes were analysed relative to the geographical south. The geometric specifications of these samples, located in Ilam City, are listed in Table 1.

Table 1.: Geometric specifications of the samples and their directions relative to geographical directions

Samples	Length	Width
A	15	10.50
B	12.50	12.50
C	13.60	11.50
D	14.20	11

Samples	Length	Width
E	17	9.20
F	18.73	8.35
G	21	7.45
H	26	6

Results and Discussion

To discuss this issue, first the space should be specified as a whole, in terms of volume dimensions and design details. Subsequently, based on the Ilam municipality database, the majority of residential houses were divided into five groups which are presented in Tables 1 and 2 entailing exact or close specifications. Accordingly, the examined samples encompass eight types of residential houses with prevalent volumes and details in the city; they were all the same in terms of total area and air volume, yet different in edge ratios. It should be noted that all eight samples examined were in the same geographical direction.

Initially, it was attempted to examine the thermal and lighting performance of the building in one space regarding the different dimensions presented in Figure 1. The quantitative features of the total area of window opening related to each sample listed in Tables 1 and 2 were analyzed with respect to indices including the amount of consumption at the peak hot and cold periods, the number of comfort days and air conditioning.

Table 2.: The specifications of the eight examined samples in Ilam City

Samples	Length (m)	Width (m)	Height (m)	Total Area of the Floor (m^2)	Total Area of the Wall (m^2)	Length-t
A	15	10.50	3	156	148	1.75
B	12.50	12.50	3	156	148	1
C	13.60	11.50	3	156	150.13	1.18
D	14.20	11	3	156	147	1.3
E	17	9.20	3	156	156	1.84
F	18.73	8.35	3	156	164.23	2.24
G	21	7.45	3	156	169.58	3
H	26	6	3	156	187	4.33

The Amount of Energy Consumption for Heating

In Ilam, the icy and cold weather conditions occur from January 5 until February 4. In this study, the peak cold period occurs on January 1511The physical models of the samples were simulated using the Ecotect Analysis software and the amount of energy consumption in these samples were calculated via Energy Plus.. Accordingly, meteorology data were examined and the temperature on January 15 in Ilam was found to be -2.6. Subsequently, the selected samples were simulated using the Ecotect Analysis software by considering the chosen indices shown in Figure 1; next, the energy consumption of the samples was calculated using the Energy Plus software. According to the analysis results of the peak cold temperature recorded in Ilam, Sample H had the highest amount of energy consumption with respect to the physical features listed in Table 2.

[CHART]

Figure 2.: The amount of heating energy consumption of samples during the peak cold period (average temperature of -2.1)

The Amount of Energy Consumption for Cooling

The examination of the cooling energy consumption performance in peak hot weather conditions in Ilam (32.5 at its peak hot weather on July) was done similar to that of the heating energy consumption. Analysis results showed that Sample H had the highest amount of energy consumption. Evidently, given the specifications listed in Table 2, Sample H with a length, width and total area of 26m, 6m and 156m^2, respectively, showed the worst energy consumption performance in terms of both heating and cooling.

[CHART]

Figure 3.: The amount of cooling energy consumption of samples during the peak hot period (average temperature of 32.5)

As previously expressed, following the selection of the eight building samples in the first stage, the amount of energy consumption of the samples during peak hot and cold periods and the wall transparency range of 0-100 were calculated and shown as charts.

As can be seen in Figure 2, increase in wall transparency at the peak cold period reduced the total energy consumption in Samples A, B, D, E, G, and D; in addition, increase in wall transparency compared to dark surfaces led to increased energy consumption. Such reduction and increase in consumption considering wall transparency for Sample E are shown based on Figure 2.

Chart 2 demonstrates that with increased total area of windows as the transparency factor in building walls followed by increase in the received solar energy, the heating energy of the house is somewhat provided by the sun, resulting in lower energy consumption for heating. With the lowest extent of transparency, Sample E had the highest amount of energy consumption.

In contrast, increase in the extent of openings increased the amount of energy waste and subsequently, energy consumption. As shown in Figure 2, increase in the openings by a specific limit in all samples raised the amount of energy consumption significantly.

Figure 3 represents the amount of energy consumption and building performance during the peak hot weather across five selected samples. According to the chart, increase in wall transparency raised energy consumption. The reason behind this is that in hot seasons, increase in the openings would raise the amount of received sunlight and subsequently, more heat is received; in turn, this raises the amount of energy consumption for cooling to lower the building temperature to a desirable degree.

Here, the following question can be posed: What is the cause behind such an increase in energy consumption in Sample E compared to the other samples? To answer this query, Figure 2 should be compared with Figure 3; according to the former, the lower the extent of openings (transparency) in the building, the lower the amount of received solar energy. In this case, considering the difference in temperature between day and night in the examined climate, the amount of received energy during the day is lower than the energy wasted at night; as a result, more energy would be required for heating. By increasing the transparency (total area of openings), the amount of received solar energy is increased by 10-20%; and through the gradual compensation for the lost energy, the chart gained a similar procedure to other samples.

Nonetheless, Chart 3 shows that in the hottest day of the year with 10% transparency accompanied by intense sunshine and insignificant temperature difference between day and night, the temperature of the building interior raised which necessitated a large amount of energy to lower the temperature. Notably, the higher the difference between the interior and exterior of a building, the more the energy exchanged between the two environments; in such cases, more energy would be required to reach the desirable temperature.

However, given the ratios between the building and total areas of openings (transparency) in other samples, there is a proper proportion between received and wasted energy; consequently, the energy consumption of samples has a similar chart. In other words, lower ratio of openings to the building volume in Samples A, C and B had a better performance compared to Sample E in terms of received and wasted energy.

The other samples including D, G, F and H received more solar energy due to larger surfaces of openings and west-east stretch (being in the direction of sunshine).

Thermal Comfort

Thermal comfort refers to a period of desirable temperature in a given climate. In this section, this interval in Ilam City was examined with respect to the climate placement. The range of thermal comfort in this city is 17-25. Accordingly, the number of days during which the temperature in Ilam is within this range were specified and examined based on the data obtained from Ilam Meteorological Organization11http://www.ilammet.ir/ . As shown in Figure 4, the results demonstrated that Sample F had the best performance due to its extent of transparency and thermal comfort conditions.

Given the suitable proportion between wall transparency and the total area of the building, Sample F was found to have the best adaptability to the natural environment under thermal comfort conditions during both hot and cold periods of the year.

[CHART]

Figure 4.: The extent of each sample's placement within the temperature range of thermal comfort in Ilam City during a year.

Thermal Discomfort

Up to this stage, the amount of energy consumption was examined during peak hot and cold periods as well as within the thermal comfort range. In this section, other time periods during which the samples are within the thermal discomfort range are examined. The samples were categorized into two groups including 'very hot and 'very cold; the former refers to hours during the day when the samples are under a temperature of over 25 while the latter refers to below 17. Accordingly, the thermal performance of the samples in hot and cold periods of the year can be demonstrated. As previously mentioned, the extent of thermal comfort in any climates depends on the extent of openings (doors and windows) in a building. The calculations in this section are based upon the natural heating and cooling systems.

According to the results of analyses, the samples demonstrated similar performances in the cold period; increased wall transparency in all samples led to the maximum and minimum periods of comfort. The stretched samples in length showed more desirable performances; accordingly, the closer the shape of the building to a square, the lower the thermal comfort (e.g., Sample B). Similar to other samples, due to having the same width and length, Sample B did not have the major differences of 10-60% transparency.

Additionally, results showed that in this interval, increase in the number of openings increased the thermal comfort, except for cases with the transparency of above 80%.

Air Conditioning for Heating and Cooling

Evidently, the highest percentage of home energy consumption belong to the heating and cooling systems. In this section, a comparison is made between the heating and cooling performances of energy consumption with respect to the physical conditions of buildings. Both criteria were used 24 hours a day during a year, given the type of climate; accordingly, the building's temperature remained within the range of 17-25 during hot and cold periods.

Figure 4 shows the energy consumption in samples with the heating system in operation during the cold period of the year. There are no significant differences between the amounts of energy consumption in samples that included below 20% openings. However, the amount of consumption changed by transforming the lengths into widths and increasing the openings. In other words, increase in the openings results in increased absorption of sunlight which reduces energy consumption. In this regard, Samples B, C and S showed the same amount of consumption while Sample H demonstrated the highest consumption amount. Nonetheless, this analysis did not hold true for Sample B at the transparency range of above 80%; subsequently, due to the square shape of this sample in this time period, the required heat reaches its maximum limit, as can be seen in Figure 5.

[CHART]

Figure 5.: The amount of energy consumed by the A/C system for heating during a year, in the examined samples.

The examination of the required energy for cooling by the A/C yielded similar results. Samples B, C and E showed similar amounts of energy consumption while Samples D and E demonstrated higher energy consumption given their longer lengths. Accordingly, it can be concluded that the extent of transparency in a building can have the highest effect on the amount of energy consumption for air conditioning.

Considering Figure 5 which was related to A/C for heating and cooling, the total amount of energy consumed by this system is shown in Figure 6. Findings suggest that samples with longer lengths and more openings have a higher energy consumption; moreover, samples with proportions closer to a square demonstrated better performances.

As can be seen in Figure 6, there are disorders in Samples B and E at 80-100% and 20-40% transparency ranges, respectively. It was previously pointed out that the reason behind such a disorder in Sample B involves the amount of energy consumption for A/C heating during a year; accordingly, consumption raises when wall transparency is increased and there would be an abrupt jump in the 80-100% range. The cause behind this disorder in Sample E is also the same; the only difference here is the transparency range. The overall results of analyses on transparency of walls and its role in energy consumption are listed in Table 3.

[CHART]

Figure 6.: The amount of energy consumed by the A/C system for heating and cooling during a year, in the examined eight samples.

Table 3.: The overall results of samples' performances regarding the amount of energy consumption considering wall transparency.

The Amount of Energy Consumption	Peak Hot, July 21 (31.4)	Peak Cold, December 29 (2.4)	Comfort Range 18-27
Samples' Performances			
Desirable Performance	-	B	F, G
Poor Performance	H	H	-

The Amount of Received Solar Energy

Given the obtained results on energy consumption, thermal comfort and wall transparency, Sample B with the dimensions of a square was found to be the best option for a building plan. As previously pointed out, lighting in a residential building with dimensions similar to the examined samples accounts for 11% of energy consumption. There are minimums and maximums defined for energy consumption in residential buildings by a number of credible institutions for evaluating energy consumption in buildings such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment). In the present study, the amounts of received natural light by the samples were evaluated in a range of 0-100 (Table 4); this parameter depends on items such as the ratio between edges, orientation, and the total areas of openings. Gaining awareness on the amount of received sun light through each opening can be of significant importance in achieving an optimal building pattern.

Table 4.: The lowest value of received solar energy considering the transparency levels of the eight samples (based on IUX).

Wall Transparency	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
A	0	432	598	834	1151	1392	1734	2009	2231	2412	2561
B	0	331	620	881	1137	1395	1641	1887	2132	2375	2485
C	0	330	622	888	1143	1403	1652	1897	2139	2380	2520
D	0	351	652	919	1187	1462	1717	1989	2278	2432	2599

Wall Transparency	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
E	0	371	643	917	1181	1443	1706	1955	2205	2464	2586
F	0	352	664	945	1218	1492	1764	2022	2286	2541	2626
G	0	35	661	951	1214	1484	1763	2052	2291	2621	2656
H	0	390	742	1058	1353	1660	1964	2247	2546	2825	2893

Optimizing the Desirable Building Pattern

Given the fact that the selected samples represented a large number of buildings throughout the city, they can be used to obtain the optimal dimensions in order to offer a suitable building pattern with desirable physical features. To this end, first the building data were written as mathematical functions in order to apply optimization on the data (Table 4). Next, the obtained functions were used to calculate energy consumption for the A/C and wall transparency which are listed in Tables 5 and 611In these tables, samples were shown with 1 and 2 superscripts to avoid errors. . Accordingly, Table 4 shows that a building with the lowest transparency percentage consumes the lowest amount of energy.

Table 5.: The mathematical functions compared with the existing building data to achieve the samples' performances in energy consumption (the average energy consumption of A/C system).

Sample	The Average Value of Natural Lighting	Min	The Lowest Energy Consumption	Percentage of Opening	Ranking	Consumed Amount (KWH/m^2)
A^2	y = -0.1721x2 + 1.0358x + 0.0056	X= 2.99	Y=1/58	38.5	4	6.573
B^2	y = -0.1876x2 + 1.0558x + 0.0056	X= 2.81	Y=1/49	34.5	3	6.443
C^2	y = -0.1707x2 + 1.0435x + 0.0093	X= 3.00	Y=1/60	37.2	1	6.925
D^2	y = -0.1912x2 + 1.1246x + 0.0037	X= 2.51	Y=1/51	37.2	6	6.876
E^2	y = -0.1832x2 + 1.0826x + 0.0087	X= 2.95	Y=1/60	36	2	6.925
F^2	y = -0.2434x2 + 1.1735x - 0.0026	X= 2.41	Y=1/41	29.9	4	6.102
G^2	y = -0.1902x2 + 1.1235x + 0.0046	X= 2.34	Y=1/39	29	7	6.891
H^2	y = -0.2969x2 + 1.3285x - 0.0064	X= 2.23	Y=1/47	28	8	6.362

Table 6.: The mathematical functions compared with the existing building data to achieve the samples'

performances in energy consumption (the average value of natural lighting)

Sample	The Function of Average Energy Consumption of A/C System	Min	The Lowest Energy Consumption	Percentage of Opening	Ranking	Consumed Amount (KWH/m^2)
A	y = 0.1231x2 + 0.2162x + 0.5121	X= -1.54	Y=0/5721	0	3	57.11
B	y = 0.1138x2 + 0.3132x + 0.5251	X= -1.37	Y=0/5251	0	2	55.12
C	y = 0.1146x2 + 0.2799x + 0.5199	X= -1.22	Y=0/5199	0	1	54.57
D	y = 0.2236x2 + 0.1658x + 0.5743	X= -1.61	Y=0/5325	0	5	57.45
E	y = 0.2105x2 + 0.1378x + 0.5677	X= -1.32	Y=0/5677	0	6	59.59
F	y = 0.1369x2 + 0.2589x + 0.5325	X= -1.94	Y=0/5325	0	4	55.90
G	y = 0.2012x2 + 0.2241x + 0.5341	X= -1.76	Y=0/5132	0	7	55.12
H	y = 0.1475x2 + 0.2885x + 0.5724	X= -1.93	Y=0/5724	0	8	60.08

At this stage, the lighting charts (Table 6) were normalized and then subtracted from A/C functions (Table 5) and finally, the algebraic addition of the two functions was carried out in The analyzed information as a whole and the results listed in Table 6 show that the square shape (Sample B) is the most optimal condition followed by the rectangular shape. In other words, the higher the length-to-width proportion, the higher the energy consumption. Accordingly, Sample H's plan (length-to-width ratio of 4.1) compared to Sample B's plan (length-to-width ratio of 1) raises the building energy consumption by more than 10 KWH/m2.

Suitable Orientation of the Building

The orientation of the building towards sunshine significantly affects its energy consumption. Consequently, the desirable proportion and transparency of each sample (the results listed in Table 7) were selected as the optimal pattern of the samples. These patterns involved 90° orbits towards east and west with 10° distance from the south. The required energy consumption for air conditioning was calculated and demonstrated according to this assumption.

Table 7.: The most optimal transparency level of the eight samples and their amounts of energy consumption according to the optimal extent of openings (after applying the minimum natural lighting).

Sample	The Function of Average Energy Consumption of A/C System	Min	The Lowest Energy Consumption	Percentage of Opening	Ranking	Consumed Amount (KWH/m^2)
A	y = 0.1231x2 + 0.2162x + 0.5121	X= -1.54	Y=0/5721	0	3	57.11
B	y = 0.1138x2 + 0.3132x + 0.5251	X= -1.37	Y=0/5251	0	2	55.12
C	y = 0.1146x2 + 0.2799x + 0.5199	X= -1.22	Y=0/5199	0	1	54.57
D	y = 0.2236x2 + 0.1658x + 0.5743	X= -1.61	Y=0/5325	0	5	57.45
E	y = 0.2105x2 + 0.1378x + 0.5677	X= -1.32	Y=0/5677	0	6	59.59
F	y = 0.1369x2 + 0.2589x + 0.5325	X= -1.94	Y=0/5325	0	4	55.90
G	y = 0.2012x2 + 0.2241x + 0.5341	X= -1.76	Y=0/5132	0	7	55.12
H	y = 0.1475x2 + 0.2885x + 0.5724	X= -1.93	Y=0/5724	0	8	60.08

Figure 7 presents the analysis of all eight samples within the proposed pattern with respect to geographical directions; Samples A, B, C. D, and F were found to be the most optimal, respectively, and the most undesirable performances in energy consumption were found in Samples E, G and H. Table 7 entails a comparison of the amount of energy consumption before and after applying the proposed pattern in terms of thermal performance of the samples. Results showed that Sample B with a square shape, 34.5% transparency and orientation of 8° towards south-east had the lowest amount of energy consumption. Samples C, and F with 37.2 and 36.5% transparency levels and orientations of 8° and 8.1° towards south-east, respectively, were the subsequent optimal samples.

[CHART]

Figure 7.: Optimal energy consumption performances of the eight samples within the proposed pattern during a year.

The final results of the analysis are listed in Table 8. Under real conditions, Samples C and E had the lowest (54.57 KWH/m2 and 8185.5 KWH energy consumption in a year) and highest (60.08 KWH/m2 and 9012 KWH energy consumption in a year) energy consumption, respectively. In contrast, after applying the proposed optimal pattern with regards to the openings, Samples C and H had the lowest (50.51 KWH/m2 and total consumption of 7576.5 KWH energy consumption in a year) and highest (61.68 KWH/m2 and 9252 KWH energy consumption in a year) energy consumption, respectively. The same change was also observed after applying the proposed optimal pattern regarding geographical directions. Accordingly, Sample B had a consumption of 49.90 KWH/m2 and 7485 KWH energy consumption in a year.

Table 8.: Energy consumption comparison between the times before and after the application of the proposed pattern in terms of thermal performance in the eight samples.

Sample	Functions	The Amount of Consumption at 0 Transparency KWH/m^2	The Percentage of Optimal Opening in
A	R1-R2	54.58	8
B	A1-A2	50.51	8
C	B1-B2	53.56	8
D	X1-X2	55.38	8
E	C1-C2	57.09	8.6
F	D1-D2	55.98	8
G	M1-M2	57.88	8
H	E1-E2	61.68	8

By applying the proposed pattern based on optimal physical features of a building, the total amount of energy consumption in a year in Sample B was reduced to 91.5 KWH. Such a reduction shows the direct effect of optimal physical condition on thermal performance of buildings. Subsequently, indicating the size of openings in a building is of considerable importance; these openings can be a means for both receiving and wasting energy. Therefore, the specification of the total area of windows (regarding the type of the examined climate, it is effective as a main index) gains substantial significance. The optimal percentages of openings based on length-to-width ratio in Ilam City's climate are listed in Table 9, with regards to the proposed optimal pattern.

Table 9.: The extent of the transparency of openings and the building plan's length-to-width ratio in Ilam City's climate (%).

The plan's length-to-width ratio	Wall transparency percentage for optimal reception of energy
34.5	1
37.2	1.24
36	1.85
29.9	2.34
28	4.1

Conclusion

Residential buildings are major consumers of energy which are responsible for greenhouse gas emissions as well (34). In today's world, population growth is one of the main reasons behind the increase in demands for fossil fuels in the building sector; this involves certain significant consequences such as air pollution, global warming, and greenhouse gas emissions. Optimal climatic design is one of the best strategies to reduce the demand for energy and costs in buildings; in this strategy, designs are carried out proportionate to weather conditions to facilitate the increase in energy efficiency. The first defensive step against weather is a suitable design that is mainly under the influence of climatic factors. When buildings are designed by paying attention to weather conditions, the need for acquiring thermal comfort through mechanical cooling and heating devices decreases. Consequently, it can be used to create a pleasant interior space in buildings where maximum energy is used. Since the most effective parameters for reducing energy consumption include design parameters, building's shape and direction, and transparency, paying attention to the optimal pattern for these parameters is of utmost importance regarding the amount of energy consumption under any climates.

The present study was conducted to examine the physical parameters of residential buildings and offer an optimal pattern for these parameters in Ilam City; final results showed that square shaped buildings had the lowest amount of energy consumption and increased length-to-width ratio raises energy consumption.

The results of this study can be applicable in two forms. Regarding the already constructed buildings, the findings of this study on the issue of transparency show that energy consumption can be reduced by offering optimal changes in the openings. As for the buildings that are planned to be constructed, the results of this study can definitely be considered and employed. Moreover, using these softwares in the construction process of a building can be effective in reducing energy consumption. Given the physical parameters of buildings mentioned in this study, the common construction materials in Ilam City and single glazed windows were taken into account.

It should also be noted that the results of this study can be different for various climates and construction styles; therefore, the results are specific to Ilam City. Ultimately, it is recommended to review the parameters in case of applying the recommended pattern on a different climate or geographical situation.

Declarations section:

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