Bagh-e Nazar

Bagh-e Nazar, 17(91), 101-116/ Jan. 2021
DOI: : 10.22034/bagh.2020.215990.4433

Persian translation of this paper entitled:
کمینه‌سازی مصرف انرژی از طریق بهینه یابی مصالح پوسته
خارجی در مقیاس بلوک شهری نمونه موردی: بافت فرسوده
همت‌آباد (منطقهٔ ۶ شهر اصفهان)
is also published in this issue of journal.

Original Research Article

Minimizing Energy Consumption by Optimizing the Exterior Skin Materials on the Scale of Urban Block

A Case Study of a Deteriorated Area (Hemmat Abad, District 6 of Isfahan Province of Iran)

Masoud Shafiei Dastjerdi*[1], Negin Sadeghi[2], Maryam Rafiee[3]

1. Department of Architecture, Dolatabad Branch, Islamic Azad University, Isfahan, Iran.
2. Assistant Professor, Department of Architecture, Isfahan (khorasgan) Branch, Islamic Azad University, Isfahan, Iran.
3. M.A. in Architecture Department of Architecture, Ilam Branch, Islamic Azad University, Ilam, Iran.

Received: 2020/01/18 ; revised: 2020/06/05 ; accepted: 2020/08/16 ; available online: 21/12/2020

Abstract

Problem statement: considering the extent of deteriorated urban areas and ignorance of energy/ climate problems in regeneration of this areas, make this subject, one of the main priorities of studies.

Research objective: comparison between alternatives, it can be observed that considering the principles of climate-friendly design in a small block of urban scale, even with maximum adherence to mass and space principle and the features of approved plan, make it possible to save energy by providing design qualities such as central courtyards.

Research Methodology: The methodological approach of this research is quantitative and its strategy is simulation and modeling using Builder Design software. Also, a comparative study method has been used to compare the energy consumption of three options (current situation, approved plan and proposed plan) for the urban block plan located in the deteriorated area of Hemmatabad.

Conclusion: In a comparative study, it is observed that in an urban block, even with maximum adherence to the mass and space and the orientation of the approved design, it is possible to save more energy consumption by providing design qualities, including private areas (central courtyards). The central courtyard with the outer skin consisting of Heblex blocks has the lowest energy consumption.

Keywords: *Energy Consumption Optimization, Climate Compatible Design, Exterior Skin, Deteriorated Urban Area, Isfahan.*

* author Corresponding: +989132105119، masoud.shafie.da@gmail.com

Introduction

Increasing global awareness of the world's growing population, along with the enormous environmental impacts of resources such as energy constraints, climate change, and greenhouse gas emissions, have attracted much attention to the world's energy consumption problems (Wan, Li, Pan & Lam, 2012; Santamouris, 2016). Based on the current consumption trend, the British Petroleum Company has predicted that oil consumption will increase by up to 30% and the consumption of coal and natural gas will increase by up to 50% by 2035 (Dudley, 2018).

Due to the major role of buildings in energy consumption (up to 40% of total energy consumption in developed countries) and subsequent increase in greenhouse gas emissions (up to 40% of total) (Hong, 2018), today in both developed countries and developing countries, the necessity for the commitment to improving the energy efficiency of buildings and paving the way for the use of renewable energy is of particular importance. Environmental and economic problems have compelled countries to revise and improve consumption practices and environmental standards in order to achieve sustainability. Therefore, in many developed and developing countries, the needs for a committed improvement in the efficiency of energy consumption in buildings and facilitating mechanisms to benefit from renewable energies are very decisive. Given that a significant portion of energy consumption is allocated to buildings, a revision of the building designs could be a step towards achieving sustainability. In this regard, several studies have been conducted to identify the type and size of the buildings and transfer information to software and simulate energy consumption models.

The residential block project, located in the deteriorated area of Hemmatabad with an area of about 1. 3 hectares, has been prepared by Isfahan City Renovation and Improvement Organization under the supervision of Isfahan Municipality Deputy for Urban Development by Sharmand Consulting Engineers and is scheduled to be implemented shortly. Due to the vastness of the deteriorated area and ignoring the issue of energy consumption and climate, the researchers of this study decided to examine and model the approved plan and measure it against existent fabrics from the perspective of exterior skin materials and to offer a proposal with a minimal change in the overall plan. This residential area offers suggestions for achieving minimum energy consumption. In this study, an attempt is made to develop a method for assessing energy demand in terms of building skin optimization. It is expected that the results of this study will be of interest to those in charge of renovating deteriorated structures.

Statement of the problem

The suggestions of energy consumption approaches are different due to each country/city conditions (economy, policy, climate, population growth rate and etc.). While in the most developed countries using systematic policy and guidelines for a long time, it has been the matter of issue in the developing countries just in the last decades (Beradi, 2013, 2015). Given the increase in the share of energy consumption in buildings from 10 percent in 1980 to 30 percent in the recent decade (Zhang & Liu; Si, Tian, Chen, Jin, Zhou, & Shi, 2018), it can be emphasized that the problems associated with high-consumption areas like deteriorated structures have remained as a serious challenge ahead of urban managers, specialists and experts in the field of architecture and urban planning. One of the aspects of this challenge is the high level of energy consumption and energy loss in deteriorated structures and even especially in the recent developments of Isfahan metropolis, part of which can be due to improper use of urban planning and lack of proper materials in the outer skin of buildings.

Energy consumption is one of the key factors in any country's economy. According to the

International Monetary Fund, Iran ranks second in the world in terms of energy subsidies with $ 37 billion. Per capita, energy consumption in Iran is 5 times more than Indonesia with a population of 225 million, 2 times more than China with a population of 1. 3 billion and 4 times more than India with a population of 1.122 billion. A comparison of energy consumption index in Iran with many countries in the world indicates the abnormal state of energy exploitation (Tebyan website). Also, according to the website of Isfahan Electricity Distribution Company on March 26, 2017, Iran is ranked first in the world in terms of fossil resources, but due to high energy intensity, Iran is ranked 11th in the world in terms of energy consumption. Thus it is necessary to reduce energy consumption intensity by increasing export capacity and reducing domestic consumption. The country's energy consumption in 1994 was about $ 124 billion while, according to global standards, the logical estimate of this figure is $ 45 billion. As a result, around $ 80 billion in energy consumption is wasted in Iran (Electricity Distribution Company of Isfahan's website). Despite numerous studies with architectural or urban planning perspectives in the field of construction and energy, these studies are less focused on urban design scales and have an emphasis on building skin features. So adopting an urban perspective seems to be apt and examining and comparing the different scenarios for exterior skins of buildings can result in important findings. Comparing the results can have a significant impact on the decisions of all institutions and individuals involved in the construction of buildings (from single buildings to complexes and settlements), especially on decisions on selected skins materials in deteriorated areas.

Significance of the study

To optimize consumption and mend the country's economy, Iran needs an appropriate consumption model and some changes in the lifestyle of people. This needs some cultural schemas in any society and a vast application of scientific and technological tools to revisit and improve previous systems. Increased consumption of fossil fuels and their non-renewability and increasing demand for energy, as well as the high level of energy consumption in the domestic sector, are several problems that make conducting this study significant in proposing the required solutions. Besides: the vastness of deteriorated urban areas and improper orientation of buildings located in these areas and consequently high energy emissions, the local methods of intervening in deteriorated structures (only on an architectural scale and without considering the dimensions of urban design) on a limited and small scale regardless of ecological and climatic issues could be listed.

So far, much research has been conducted on the sustainable design of buildings using renewable energy, but due to existing obstacles and problems such as high initial costs, low energy efficiency, etc., these studies have not been used effectively (Banihashemi Namini, Shakouri, Tahmasebi & Preece, 2014), on the other hand, the focus of these studies has been on public buildings such as offices and hospitals, while residential buildings constitute huge parts of cities and have more hours of daily use. Especially in the renovation of deteriorated residential areas, the significance of interventions and renovations is considerable; however, this is neglected (at least partly) by institutions and organizations which are in charge of renovating and improving these areas. Therefore, the present study is an attempt to study the existent fabric and the approved plan of the urban deteriorated block in terms of energy consumption and provide the optimal condition of the exterior skin of buildings, which has been simulated in several stages and can lead to revising the quality of these plans in terms of energy consumption and requirements.

Literature review

This research is the second paper concluded from the research project, the aim of which was saving energy consumption, offers approaches to minimize building energy consumption by optimizing the exterior skin materials, on the Hemmatabad eroded texture (Isfahan 6th District). In the first published paper, Sadeghi, et al. (2020) proposed optimising energy consumption, in the urban block of Hemmatabad eroded texture (Isfahan 6th District). This paper studies relation between the building exterior skin materials and minimizing energy consumption, in order to compare the alternatives of building exterior skin materials. Since the period of the energy crisis and modern environmental movements in the 1970s, many researchers in the field of architecture have turned their attention from mere building design to the impact of urban design on urban climate and its effects on the use of energy in buildings. From the late 1970s to the early 1980s, many climate schemes and guidelines for landscape design and planting were studied. In this regard, simulation studies on the effect of variables in a limited scale (such as house size, type, street layout, and tree planting) on the environment (such as sunlight, wind current, and air temperature) were carried out to examine the comfort from climate and energy consumption in buildings.

examined the effects of urban morphology on energy demand. They recognized several influential variables including building proportions and height density, mass-space proportions, and free surfaces of the building. They carried out a comparative study to examine the choice of materials and details of walls on the level of energy demand and the comfort of residents (Martins, Adolphe & Bonhomme, 2013).

analyzed energy consumption with the help of Energy Plus software to determine the characteristics of climate-responsive exterior skin for Turkish residential and educational buildings (Istanbul and Izmir) in cold climates. By examining the effective and common features of buildings, they state that only by predicting the exterior with suitable conditions, the building can reduce energy consumption by up to a quarter (Yildiz, Ozbalta & Z.D. Arsan; Bektash & Aksui, 2005).

examined the conditions of exteriors and openings of various apartments in different directions in Oman. They simulated the amount of energy demand in Builder Design software and emphasized the significance of transparency and the type of exterior materials to construct energy-efficient buildings (Hassouneh, Alshbou & Salaymeh, 2010).

can be seen as a turning point in terms of form variables of research such as housing size, type of housing, and building density which affect building heat and cooling energy consumption. They also used a multivariate statistical analysis (Oing & Rang, 2008). applied an optimally structural simulation with fully insulated elements, three-skinned windows, transparent surfaces, and details concerning light and energy calculations (Mari, Arne & Maria, 2006) .

extensively examined the form of the city concerning energy demand. They considered the components of the shape and pattern of the city, activity, and pattern of the building, distribution, and access networks as factors affecting energy consumption. Furthermore, in their description of the factors affecting the energy consumption of buildings, the exterior, and its materials concerning climate have received special attention (Martins, et al., 2013).

considers the impact of the city on the energy consumption of buildings. It asserts that eight effective factors exist in this regard including form and geometry, building morphology, materials used, internal systems and equipment, user activity and behavior, energy price, infrastructure quality, and comfort conditions. It also mentions the impact of exterior design on all of the above factors (Michel, 2005) .

A few studies in Iran have examined energy consumption in the field of urban buildings. Among them, we can refer to the research study of

Farrokhi, Izadi & Karimi Moshaver (2016) in the field of energy efficiency in the hot and dry area of Isfahan. Naseri and Mehregan (2017) studied the role of the physical features of buildings on the level of energy consumption in Khorramabad city. Abbasi, Hajipour, Lotfi & Hoseynpour (2013) and Barati & Sardareh (2013) analyzed the energy consumption affected by the city form. Sharifian Barforosh et al. (2014) investigated indigenous characteristics of the city and energy consumption. Barakpur and Mosannenzadeh (2011) scrutinized land application and energy consumption in Iran and Britain. Despite emphasizing the importance of building exteriors and prioritizing effective factors and their impact on energy consumption in buildings scaled up to metropolitan levels, they have ended up in purely theoretical discussions and suggestions (Fig. 1).

Building design and modeling are used as a strategy to improve energy performance on a neighborhood and city scale to minimize infrastructure costs of energy and improve building efficiency. In issuing energy certificates, using the tools and programs for predicting and designing single buildings and other common related programs in the field of construction energy efficiency, it seems that there has always been a knowledge gap in the design scale of a part of the city (neighborhood - neighborhood unit) and its impact on energy demand and efficiency. To assess the energy performance of cities, some indices must be defined as evaluation criteria. These criteria are usually categorized into the urban assessment of infrastructure, transportation, energy, and resources. To study and analyze energy in cities or parts of cities, these criteria are categorized by examining the characteristics of urban areas with low energy consumption in the following four classifications: general energy concept with innovation criteria and outstanding projects, energy demand Induced by city and building compression criteria, access to sunlight by defining the main orientation of buildings, shading and locating low-consumption and high-consumption heating areas, renewable energy sources (such as photovoltaic panels) and their efficiency in buildings. For all four categories, indicators are relatively qualitative. However, they are converted to quantitative data for analysis purposes (Eicker, Monien, Duminil & Nouvel, 2015, 325).

Factors influencing residential energy consumption at the urban design scale including daylight, solar radiation (heat), wind current (wind or ventilation shelter), and local temperature (urban heat island) will be studied (Fig. 2).

The exterior of a building is comprised of the roof surface (the fifth dimension of the building), the roof adjacent to the uncontrolled space, the floor adjacent to the outside or adjacent uncontrolled space, the floor on the ground, the wall adjacent to the outer or uncontrolled space, openings including windows, doors and thermal bridges. In addition to the function of comfort and tranquility of residents, the building exterior is the primary thermal barrier between indoor and outdoor space and plays an important role in determining the comfort, natural light and ventilation, and the amount of energy needed to heat and cool a building. The decisive role of the external shell of buildings on energy consumption, adaptability, and optimal use of climatic conditions, and the use of light and proper ventilation in buildings have been investigated in several studies from climatic design and control perspectives to optimize and access design sustainability in the environment.

Optimization of energy consumption in building exteriors is generally done through some solutions such as thermal insulation, control of thermal bridges, and prevention of condensation in the walls of the building. The main challenge is to design the right exterior for the building to reduce energy consumption without harming the needs of residents. Recent construction is an opportunity to take advantage of passive heating and cooling schemes, which minimize the energy needed for heating and cooling by selecting materials

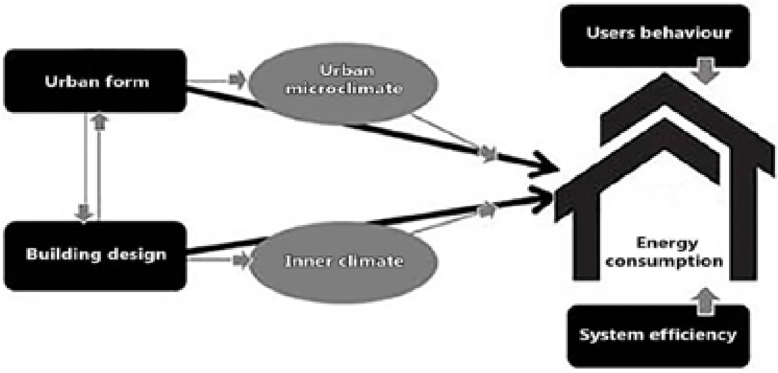

Fig. 1. The "Energy_Efficiency model" for building. Source: Eicker, et al. 2015.

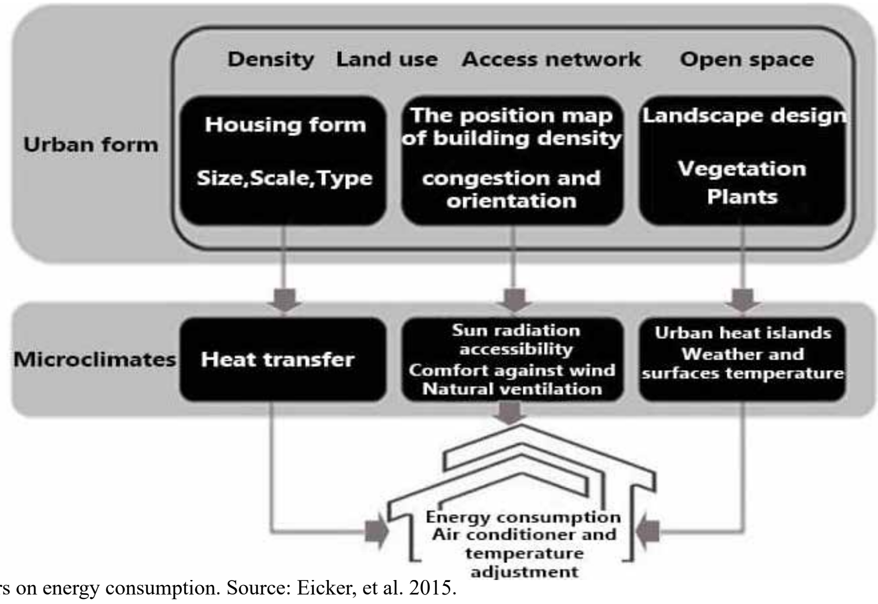

Fig. 2. The effective factors on energy consumption. Source: Eicker, et al. 2015.

and designing buildings. In some developing countries with hot climates, low-cost solutions such as reflective ceilings and walls, porches and canopies and window canopies can reduce energy consumption for cooling.

Methodology

In the present study, a comparative method has been used to analyze several different models in the residential block plan located in the deteriorated area of Hemmatabad with an area of about 1. 3 hectares. Therefore, by examining and modeling the approved plan and comparing it with the existing fabric, from the perspective of outer shell materials and by presenting a proposal with the least change approach in the general plan of this construction complex, this study offers suggestions for achieving minimum energy consumption. In this study, an attempt is made to develop a method for assessing energy demand in terms of building exterior optimization.

In general, for the calculation of energy consumption (modeling of heating, cooling, lighting, ventilation, facilities, water consumption) in the buildings under study, the followings are considered in the model simulation:

'The average number of people in each residential unit is assumed to be four to five. The

number of residents in a building and the impact of human metabolism on needed space is taken into account by Builder Design software (Fig. 3) in analyzing and measuring energy consumption.

According to the performance of a residential building, the average light in each building is considered in terms of luxury, and the time to use this

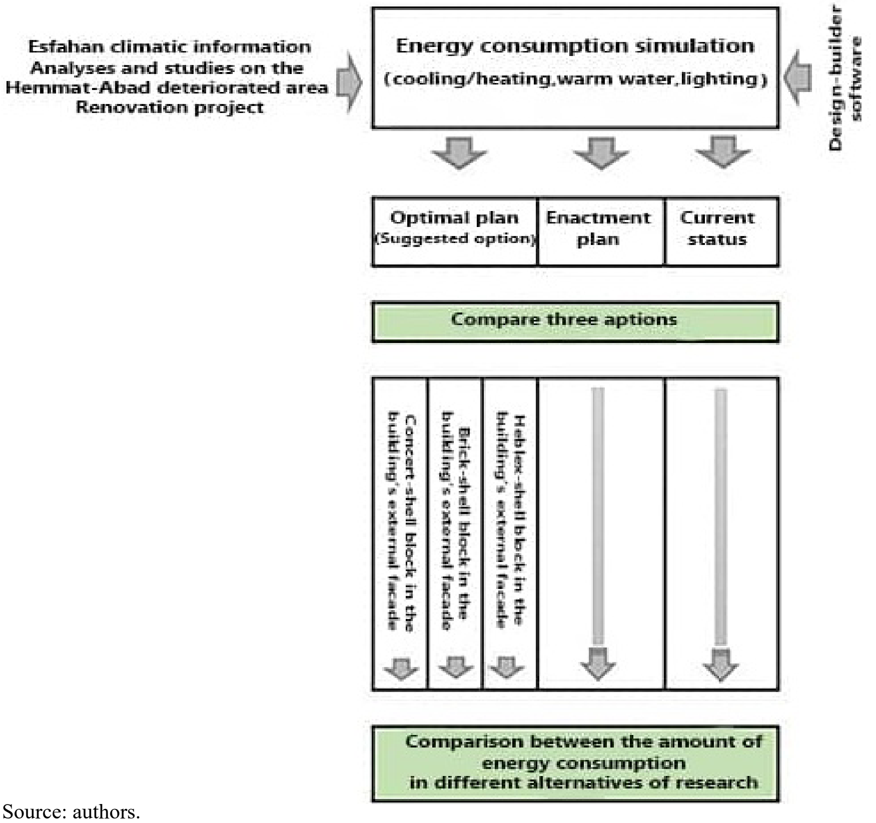

Fig. 3. The research levels. Source: authors.

amount of light is from 7 am to midnight. According to the desired time, the brightness of each space is provided with both natural and artificial light.

The energy efficiency in cooling and heating systems of existing buildings is generally defined in Design Builder software by default as being 85% in the cooling system and 62% in the heating system. However, the cooling and heating system of buildings in the approved design and the proposed research option is Fan Quell with 95% efficiency. This installation system is used 24 hours a day owing to the climate of Isfahan. The temperature of comfort is considered to be 12 to 21 degrees Celsius for starting the heating devices and 24 to 28 degrees Celsius for cooling. In modeling the existent fabric in the region, because different materials are used in different buildings (mostly inefficient in terms of energy consumption) and the researcher's effort to generalize the results of research to all buildings in the region, a general model of an uninsulated wall which is one of the defaults of Design Builder software and has a heat transfer coefficient close to existing non-insulated buildings in Iran has been used for all walls, ceilings, roofs, etc.

To determine the reference heat transfer coefficient of external reference walls and glass in buildings of the approved design, external walls of buildings with insulation have been assumed to have a thermal conductivity of 1. 01 watts per square meter of Kelvin degree. The value of heat transfer coefficient of wall reference in independent buildings is assumed to be 1. 01 W/m2k and the rate of heat transfer coefficient of single-wall glazing in vertical mode and with any thickness is considered to be 5. 8 W/m2k in existing buildings. Also, the glass in the approved design is considered to be the 6 mm double-walled type with 13 mm of air skin. In this study, the thermal conductivity of glass in the proposed design is 2.665 watts per square meter of Kelvin.

- **Location and area of the study**

Hemmat Abad area is located in the southeast of district 6 in Isfahan. This area is bounded on the north by Sepahsalar Street, on the East by Sajjad Street, and the south by Hemmat Highway and a military base, and has been selected as the study area. This deteriorated area in this urban block is a kind of deteriorated areas with an informal settlement background. The study area has an area of 80. 3 hectares out of which 62. 4 hectares belong to the deteriorated area of Hemmat Abad. This deteriorated area accounts for 27.5% of District 6 of Isfahan and about 3% of the total deteriorated area of Isfahan.

The direction of plates has been irregular in all directions, but because most of the passages are north-south, the majority of the residential plates have been oriented east-west. All existing plates are either repaired orde relict and most of the construction materials are in the form of bricks and iron. Also, most plates have an area of less than 200 square meters.

• The study of the renovation plan in the deteriorated area of Hemmat Abad

Hemmat Abad's last renovation plan was presented by Sharmand Consulting Engineers in the spring of (2017) in the form of 9 options. Finally, the following option (Fig. 4). has been selected as the best plan of the consultancy. This plan is used as the approved plan in this study (Figs. 5 & 6).

• Research procedures

After extracting the weather data of Isfahan province from Design Builder software, the following steps were simulated to achieve the objectives of the research:

- Investigating and analyzing energy consumption in existing buildings.
- Investigating and analyzing the amount of energy consumption in the approved plan.
- Provide the suggested option using the output of Design Builder software.
- Comparative study of three situations: existent fabric, approved plan, and optimal situation (proposed plan).

In the following, the results of each of the above steps are presented:

• Extraction of weather data

In the first stage of the calculations, the weather charts of Isfahan province are extracted in the following order (Fig. 7).

Fig. 4. Location of the study (area about 13,000 square meters). Source: authors.

Fig. 5. Approved design. Source: Sharmand Consulting Engineers, 2017.

Fig. 6. Three-dimensional approved design.
Source: Sharmand Consulting Engineers, 2017.

The daily of the climate in question shows the air temperature, wind speed, wind direction, air pressure, direct and scattered sunlight, respectively, from which the followings are inferred:

‘The prevailing wind speed in the area is 2 to 3 meters per second which can be effective in natural ventilation and reduction of energy consumption in spaces while windows are open.

portal of Isfahan Meteorological Department (Fig. 8).

Discussion: The analysis of energy consumption

The analysis of energy consumption in the form of hot water consumption, lighting, heating and cooling in different situations (existent fabric, approved and optimal proposal plan) was carried out. Furthermore, in optimal proposed mode, this analysis was done for the exterior of building with three types of materials including Heblex, brick and cement blocks.

- **Analyzing the amount of energy consumption in the existent fabric**

Using this model, the energy consumption of buildings that are currently used in the deteriorated fabric of Isfahan can be estimated (Fig. 9).

At this stage, after examining the study area, all destroyed buildings and barren lands were removed from the map of the existent fabric and only the remaining buildings were simulated (Fig. 10). These buildings are generally one-story or two-story, with single-glazed doors and windows facing their courtyards. Also, the walls of the buildings are completely made of bricks and some of them have cement facades.

The energy simulation of these buildings was based on the above-mentioned information and the following results were observed. After simulating annual energy (Fig. 11). was extracted. In the obtained results, it was observed that the highest amount of energy consumption of buildings is related to the gas consumption of buildings for providing heating. The annual amount of gas consumption in this area is 218. 37 kw/h per square meter in the heating sector and the annual electricity consumption in the cooling section of these buildings is 171. 56 kw/h per square meter. Obviously, in the future design of this area, the reduction of energy consumption in the cooling and heating buildings should be considered. Fig. 11 shows the annual consumption of different parts of these buildings in terms of Watts per square meter.

- **Analysis of energy consumption in the approved plan of the study area**

At this stage, in the study area, the density of buildings, the number of floors and transparent surfaces were modeled according to the approved plan, according to (Fig. 12).

After simulating the annual energy, a graph was extracted (Fig. 13). In the obtained results, it was observed that the highest energy consumption of buildings is related to energy consumption for heating which is 133. 44 kw/h per square meter and energy consumption in the cooling sector is 134. 7 4 kw/h per square meter. This shows that energy consumption

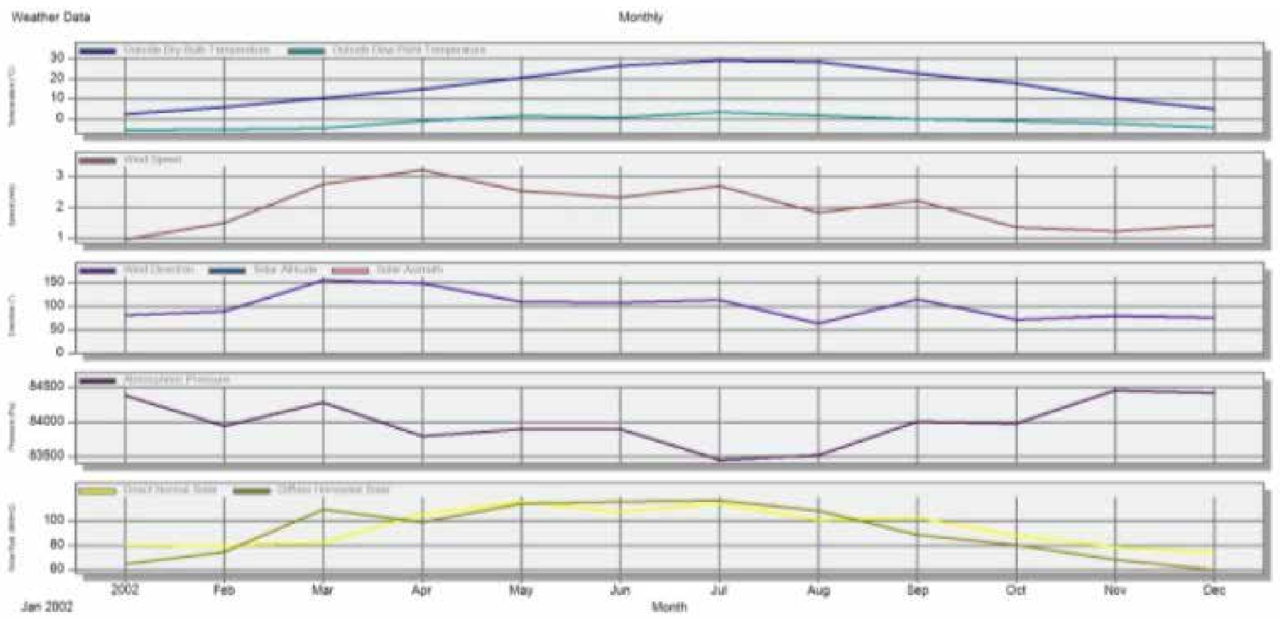

Fig. 8. Monthly chart of Isfahan climate: air temperature, wind speed, wind direction, air pressure, direct and scattered sunlight are shown respectively. Source: portal of Isfahan Meteorological Department.

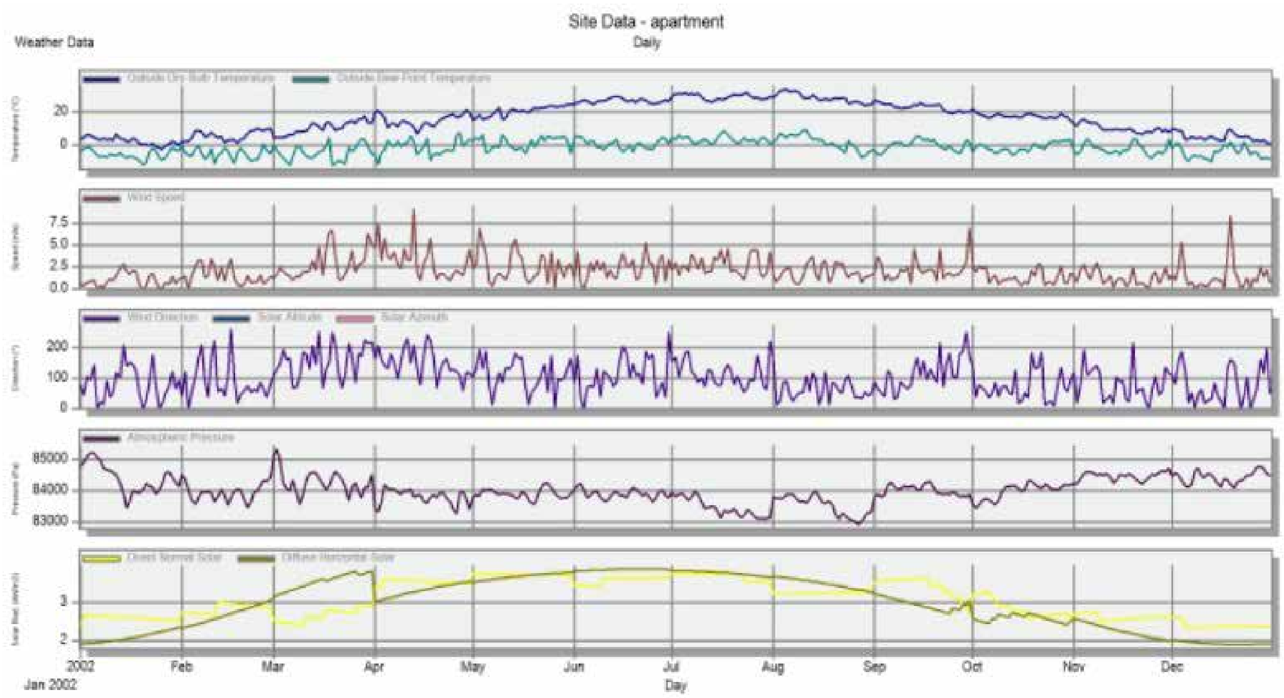

Fig. 7. Daily graph of Isfahan climate: air temperature, wind speed, wind direction, air pressure, direct and scattered sunlight are shown respectively. Source: Portal of Isfahan Meteorological Department.

has decreased in comparison to the existing fabric. The annual electricity consumption of this area is 44. 93 kw/h per square meter in the heating sector and the annual electricity consumption in the cooling section of these buildings is 36. 79 kw/h per square meter. Obviously, in the future design of this area, the reduction of energy consumption in the cooling and heating of the building should be considered. The chart below shows the annual consumption of different parts of these buildings in terms of watts per square meter.

Given that in the energy simulation in the approved

Fig. 9. The area of study in Hemmat Abad. Source: Portal of Isfahan Meteorological Department.

Fig. 10. Three-dimensional survey of the study area in Hemmat Abad. Source: authors.

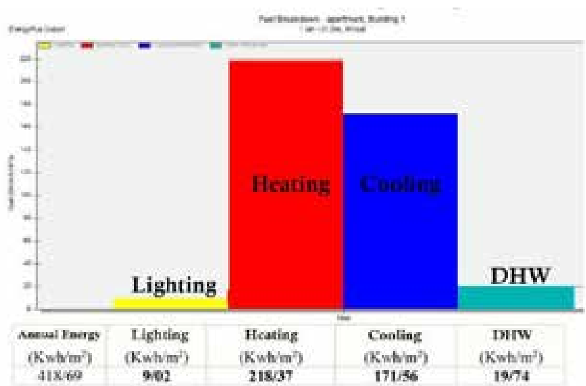

Fig. 11. Annual energy consumption of existing buildings in the study area. Source: authors.

Fig. 12. 3D modeling of the approved plan in the study area. Source: authors.

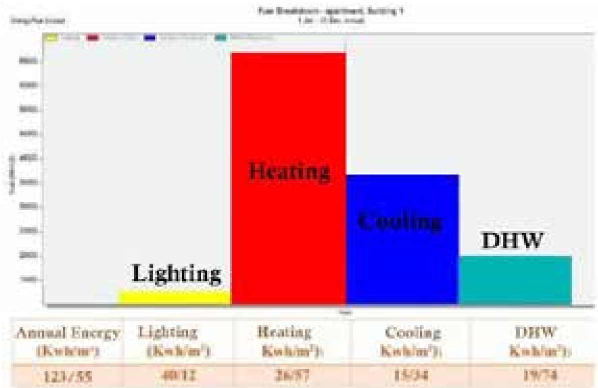

Fig. 13. Annual energy consumption of buildings proposed by the approved plan of the study area. Source: authors.

plan is based on optimal conditions and modern technology and in compliance of the nineteenth principle of national regulations, it is obvious that the energy consumption in per square meter of the approved plan is less than existing buildings in this area; However, it should be noted that the implementation of these measures requires a very high initial cost and there is no sufficient guarantee for its implementation. As a result, it is necessary to reduce this amount of energy consumption as much as possible by using cost-free design solutions.

• Proposing a desig with an energy consumption reduction approach using Design Builder software output

At this stage of the research,to have minimal intervention in the approved plan, the alternative of the approved plan (Fig. 14). was presented by observing the followings:

-'The plan of buildings is as dense and compact as possible to minimize the external surface of buildings about its volume to produce the greatest possible shade on the external surfaces.'

Features	Subject	No
Central courtyard pattern according to the geometry	Proposal Plan	1

Fig. 14. 3D modeling of the proposed plan. Source: authors.

Annual Energy (Kwh/m²)	Lighting (Kwh/m²)	Heating Kwh/m²))	Cooling Kwh/m²))	DHW Kwh/m²))
130/56	12/48	61/77	36/57	19/74

Fig. 15. Energy consumption in different parts of the proposed option, in conditions similar to the approved design conditions. Source: authors.

As a result of this density and compactness of the plan, the following outcomes have been obtained:

a. The delay time has reached the desired level.

b. Attention has been paid to the public and private hierarchy in the combination of mass and space.

c. A suitable microclimate has been produced on the scale of building blocks (yard-by-yard idea, central courtyards).

d. Appropriate view and scenery are exploited

The proposed alternative was simulated and optimized based on the following steps:

Step 1) The proposed option was simulated in completely similar conditions (in terms of materials, glass surface, installation system and lighting, use, etc.) of the approved plan.

Step 2) Energy simulation of the proposed option was examined by changing the building materials of the building exterior in three states: brick, cement, and Heblex block.

- Step 1) Energy simulation in approved design conditions.

At this stage, the proposed option was simulated in the same conditions as the approved energy simulation scheme, and the results were obtained according to Fig 15. It is observed that the lowest amount of energy consumption is in the cooling section and the highest amount of energy consumption is in the heating section and the annual energy level has increased by 17. 52 kW/h per square meter compared to the approved plan. Considering that this plan can be optimized and it can create less annual energy consumption compared with the approved plan, the steps of its optimization and the final result of energy consumption of this plan will be presented.

Based on the above diagram, the amount of energy consumption in the heating sector is 156. 6 and in the cooling sector is 134. 99 and the annual energy consumption is 288. 13 kW/h per square meter compared to the existent fabric. By optimizing the building exterior, this amount of consumption can be reduced in the next steps.

- Step 2) Energy simulation of the proposed option by changing the materials of the building exterior in three modes of cement, brick, and Heblex block.

Use of cement blocks in the outer skin

At this stage, cement blocks were used instead of bricks in the construction of the outer shell of the buildings. This change reduced the thermal conductivity of the outer walls from 1. 01 to 0.829 watts per square meter of Kelvin and the following results were observed.

In this case, the highest and lowest energy consumption in different parts of the building is similar to the previous case, but they have been significantly reduced. The amount of annual energy has decreased from 130. 56 to 123. 55 by 7. 01 kWh per square meter (Fig. 16).

According to the Fig. 16 above, similar to the previous step, the highest energy consumption is in the gas heating section, and the energy consumption

Fig. 16. Energy consumption in different parts of buildings in the proposed design, with concrete blocks in the outer skin. Source: authors.

in the electric cooling section is significantly lower than the consumption in heating section.

- Using brick blocks in the outer skin

At this stage, in the construction of the outer skin of the buildings in proposed design, brick blocks were used instead of cement blocks, which reduced the thermal conductivity of external walls from 0.829 to 0.622 watts per square meter of Kelvin, and the following results were observed: In this case, the highest and lowest energy consumption in different parts of buildings is similar to the previous case, but they have been significantly reduced. The amount of annual energy has decreased from 123. 55 to 116. 37 by 7. 18 kW/h per square meter (Fig. 17).

According to the Fig. 17 above, similar to the previous step, the highest energy consumption is in the gas heating section, and the energy consumption in the electric cooling section is significantly lower than in the heating section.

- Using Heblex block in external skin

At this stage, in construction of the outer skin of buildings in proposed designHeblex blocks were used instead of brick blocks. In this case, the highest and lowest energy consumption in different parts of buildings is similar to the previous case, but they have been significantly reduced. The annual amount of energy consumption has been reduced from 113. 63 to 100. 80 by 12. 69 kW/h per square meter. It has also been found that the amount of annual energy reduction compared to the existing fabric has decreased by 317/89, and compared to the approved plan, by 12. 24 kWh per square meter. This amount will be a significant number considering the whole area in per square meter. The use of new materials can reduce the thermal conductivity set in Article 19 of the National Regulations at a lower cost, which will also reduce energy consumption (Fig. 18).

According to the Fig. 18 above, similar to the previous step, the highest energy consumption is in the gas heating section, and the energy consumption in the electric cooling section is significantly lower than that of the heating section.

Conclusion

Despite being one of the major producers of energy in the region and the international arena, Iran is facing the problem of unfavorable increase in energy demand, especially in the construction sector. Given the major share of energy demand in Iran, addressing the issue of energy, especially in the field of construction and architecture at all stages of planning, design, construction and operation is very important. Efforts to integratebuildings with

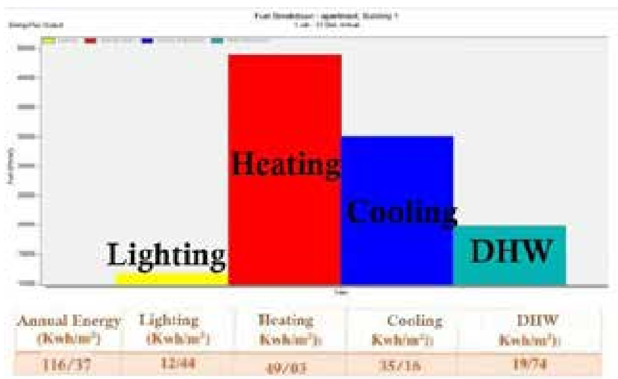

Fig. 17. Energy consumption in different parts of buildings in proposed design with brick blocks in the outer skin. Source: authors.

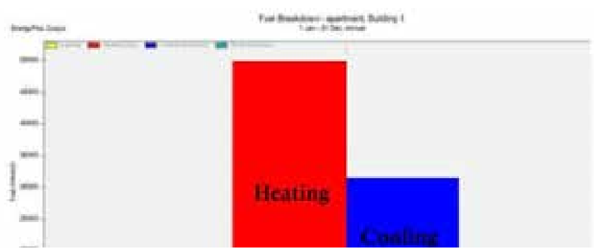

Fig. 18. Energy consumption in different parts of buildings in proposed design with Heblex blocks in the outer skin. Source: authors.

the surrounding environments are always one of the foundations of construction sustainability. Like natural ecosystems, the building and the artificial environment must be able to adapt to the surrounding environment by using special arrangements and predictions. In order to achieve sustainability and optimize energy consumption, paying attention to the middle area of urban design (in the middle scale between the architecture of single buildings and urban planning of neighborhoods) can be effective and responsive as a coordinator of various economic, social, cultural, functional and environmental dimensions. Due to Iran's status and importance, high energy consumption in it, long hours of use and high percentage of urban land allocation for residential use in cities, addressing the issue of energy in residential buildings and facade effectsis an important issue in building energy consumption in Iran.

In this study, with the aim of emphasizing the issue of saving energy, one of the residential projects being implemented by Isfahan Municipality in the deteriorated urban context was selected and recreating the deteriorated urban context with emphasis on energy and climate-friendly design was considered. In this comparative study of the three conditions including the existent fabric, the approved plan and the optimal situation (alternative model), according to the Fig. 19 below, it is observed that by observing the principles of climate-friendly design in a small block of urban scale, even with maximum adherence to mass and space principle and the features of the approved plan, it is possible to save energy by providing design qualities such as central courtyards. The highest amount of energy consumption is observed in existing buildings, approved plan, a proposed option with cement skin, a proposed option with brick skin, and finally the proposed option with a skin consisting of Heblex blocks respectively. Therefore, the proposed option with a central courtyard pattern with an outer skin consisting of Heblex blocks has the lowest energy consumption. It should be noted that the modeling of the approved plan was done according to the requirements of Article 19 in the National Building Regulations. When the energy consumption analysis was based on the specifications in the approved plan, the energy consumption would be much higher.

To summarize and compare the energy consumption in each of the research steps, the following diagram is presented, which is the highest energy consumption in the current state (42%), the proposed design with an external skin similar to the approved design (13%), the proposed design with cement shell (12%), the proposed plan with brick shell (12%), the plan approved by the Renovation and Improvement Organization (11%) and the lowest energy consumption for the proposed plan with Heblex block (10%) (Fig. 20).

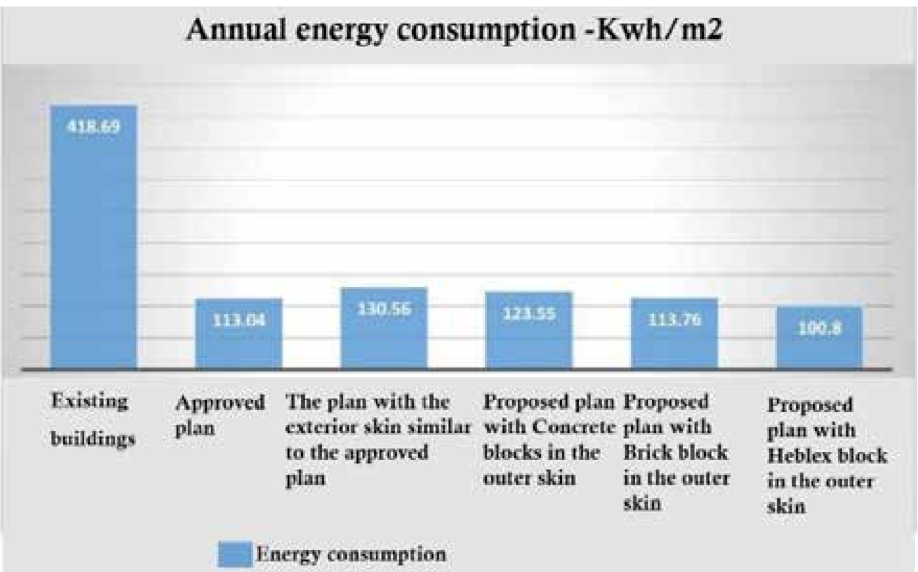

Fig. 19. Comparison of energy consumption in different research situations. Source: authors.

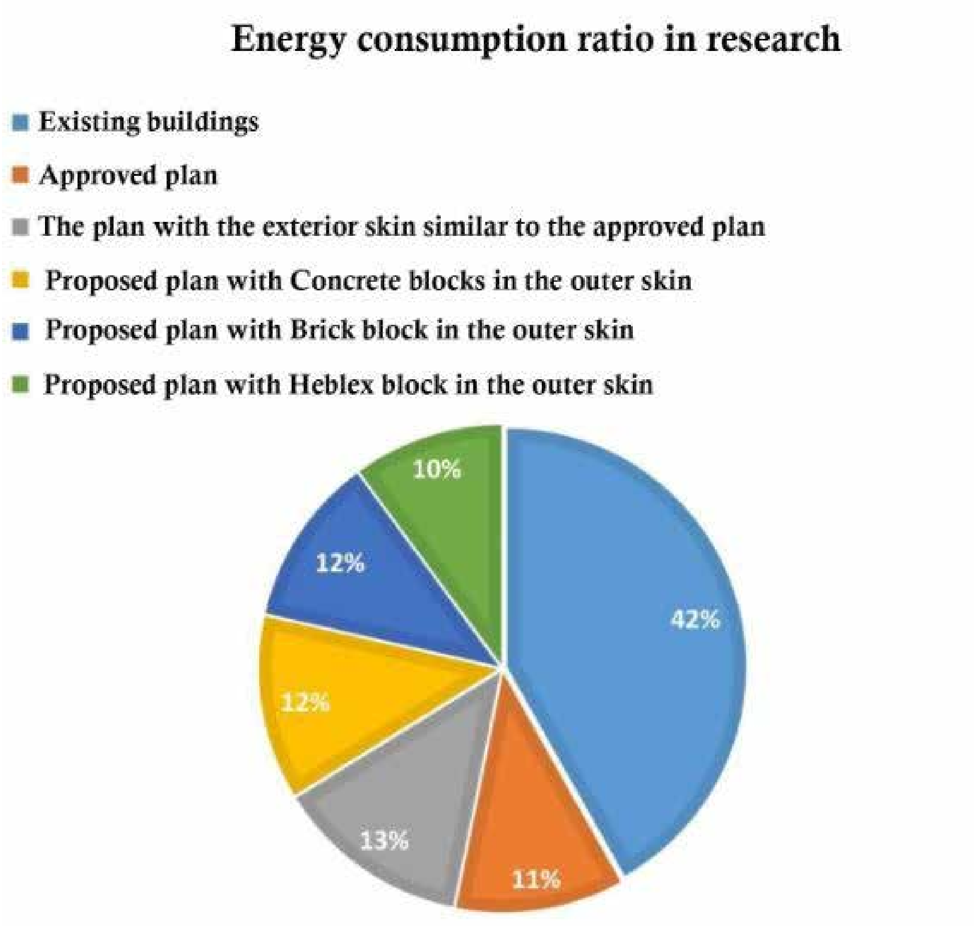

Fig. 20. Energy consumption ratio in research. Source: authors.

Reference list

• Abbasi, H., Hajipour, K., Lotfi, S., & Hoseynpour, M. (2012). Explanation of Effective Urban form Factors on Households Fuel Consumption in Transportation Sector. *Studies and New Technologies of Architecture and Planning*, 2(2), 19-30.

• Banihashemi Namini, S. B., Shakouri, M., Tahmasebi, M. M., & Preece, C. (2014). Managerial sustainability assessment tool for Iran's buildings. *In Proceedings of the Institution of Civil Engineers-Engineering Sustainability* 167(1), 12-23.

• Barakpur, N., Mosannenzadeh, F. (2012). Comparative Study on Energy Efficiency Policies in the Area of Land Use Planning in Iran and England. Urban Studies (Persian), 1(1), 41-60.

• Barati, N., Sardareh, A. (2013). Effects of urban form on automobile dependency and energy consumption in Tehran residential regions. The Monthly Scientific Journal of Bagh- e Nazar, 10(26), 3-12

• Bektas, B. & Aksoy, T. (2005). Energy Performance of Window Systems of Buildings in Cold Climate Regions. *Science and Engineering Journal of F rat University,* 17(3), 499-508.

• Berardi, U. (2013). *Moving to Sustainable Buildings: Paths to Adopt GreenInnovations in Developed Countries*. London: Versita.

• Berardi, U. (2015). Building energy consumption in US, EU, and BRIC countries.*Procedia Eng*, (118), 128–136.

• Dudley, B. (2018). *BP. statistical review of word energhy. BP. statistival review.* London: UK.

• Eicker, U., Monien, D., Duminil, É., & Nouvel, R. (2015). Energy performance assessment in urban planning competitions. *Applied Energy,* (155), 323-333.

• Oing, R. & Rong, F. (2008). The impact of urban form on US residential energy use. *Housing policy debate*, 19(1), 1-30.

• Farrokhi, M., Izadi, M. S. & Karimi Moshaver, M. (2018). Analysis of Energy Efficiency of Urban Fabrics in the Hot and Dry Climates, Case Study: Isfahan; *Journal of Iranian Architecture studies*, 7(13), 127-147.

• Hong, T. (2018). IEA EBC annexes advance technologies and strategies to reduce energy use and GHG emissions in buildings and communities. *Energy and Buildings*, (158), 147-149.

• Hassouneh, K., Alshbou, A., & Salaymeh. A. A. (2010).

Influence of windows on the energy balance of apartment buildings in Amman, *Energy Conversion and Management*, 51, 1583-1591.

• Hong, T. (2018). IEA EBC annexes advance technologies and strategies to reduce energy use and GHG emissions in buildings and communities. *Energy and Buildings*, (158), 147-149.

• Koeppel, S. & Ürge-Vorsatz, D. (2007). *Assessment of policy instruments for reducing greenhouse gas emissions from buildings*, UNEP–Sustainable Buildings and Construction Initiative, Budapest: UNEP.

• Mari, LP., Arne, R. & Maria, W. (2006). Influence of window size on the energy balance of low energy houses. *Energy and Building,* 38, 181-188.

• Martins, T., Adolphe, L., & Bonhomme, M. (2013). Building Energy Demand Based on Urban Morphology Analysis: Case Study in Maceió, *Sustainable Architecture for a Renewable Future*, 10-12.

• Mitchell, G. (2005). *Urban development, form and energy use in buildings: A review for the solutions project.* EPSRC SUE SOLUTIONS Consortium.

• Naseri, A. & Mehregan, A. (2017). An Investigation into the Effects of Physical Properties of Residential Buildings on the Amount of Energy Consumption (A Case Study Of Khoramaabad City). Journal of Iranian Architecture & Urbanism, 8(2), 59-73. doi: 10.30475/isau.2018.62065.

• Sadeghi, N., Shafiei Dastjerdi, M. & Rafiee, M. (2020). Optimization of Building Energy Consumption by Optimizing the Transparency Area of Outer Shell in Urban Block Scale: Case of Hemmatabad Worn-Out Area in Isfahan, Iranian Journal of Energy 23 (1), 161-191.

• Santamouris, M. (2016). Innovating to zero the building sector in Europe: Minimising the energy consumption, eradication of the energy poverty and mitigating the local climate change. Solar Energy,(128), 61-94.

• Sharmand Consulting Engineers. (2017). *Hemmatabad worn-out texture organization plan*. Isfahan: Municipality Renovation and Improvement Organization.

• Si, B., Tian, Z., Chen,W., Jin, X., Zhou, X. & Shi, X. (2018). Performance Assessment of Algorithms for Building Energy Optimization Problems with Different Properties. *Sustainability*, 11 (1), 18.

• Sharifian Barforoush, S. & Mofidi Shemirani, S. (2015). The morphological criteria of Ecocity from the perspective of theorists. The Monthly Scientific Journal of Bagh- e Nazar, 11(31), 99-108.

• Wan, K.K.W., Li, D.H.W., Pan, W. & Lam, J.C. (2012). Impact of climate change on building energy use in different climate zones and mitigation and adaptation implications. *Appl. Energy,* (97), 274–282.

• Yildiz, Y., T.G. Ozbalta & Z.D. Arsan. (2011). Impact of Window-to-Wall Surface Area for Different Window Glass Types and Wall Orientations on Building Energy Performance: A Case Study for a School Building Located in zmir, Turkey. *Megaron*, 6(1), 30-38.

• Zhang Ji, R., He, Z., Liu, J. & Qu, S., (2017). Simulating the effects of anchors on the thermal performance of building insulation systems. *Energy Build*, (140), 501–507.

HOW TO CITE THIS ARTICLE

Shafiei Dastjerdi, M., Sadeghi, N. & Rafiee, M. (2020). Minimizing Energy Consumption by Optimizing the Exterior Skin Materials on the Scale of Urban Block A Case Study of a Deteriorated Area (Hemmat Abad, District 6 of Isfahan Province of Iran). *Bagh-e Nazar*, 17(91), 101-116.

DOI: 10.22034/bagh.2020.215990.4433
URL: http://www.bagh-sj.com/article_118621_en.html