Environmental Education and Sustainable Development

Available online at www.ap.iauardabil.ac.ir

Islamic Azad University, Ardabil Branch

Anthropogenic Pollution Journal, Vol 6 (1), 2022: 8-20

ISSN: 2783-1736- E-ISSN: 2588-4646

I.A.U Islamic Azad University Ardabil Branch

ORIGINAL RESEARCH PAPER

# Zoning and Modeling of Energy Consumption in Human Settlements and Explaining the Effective Components in the Design of Green Buildings (Case study: Mashhad)

**Najyeh Abavisani Joghtaee[1], Amir Farajollahi Rod[2,3*], Mansour Yeganeh[4,5]**

[1] Department of Architecture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

[2] Department of Architecture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

[3] Department of Architecture, Faculty of Architecture and Urbanism, Tarbiat Modarres University, Tehran, Iran

[4] Department of Architecture, Mashhad Branch, Islamic Azad University, Mashhad, Iran

[5] Department of Architecture, Faculty of Architecture and Urbanism, Tarbiat Modarres University, Tehran, Iran

## ARTICLE INFORMATION

**Received:** 2022.01.10
**Revised:** 2022.02.13
**Accepted:** 2022.03.03
**Published online:** 2022.05.05

**DOI:** 10.22034/AP.2022.1949527.1126

## KEYWORDS

Adsorption
Optimal Energy Consumption
Green Building, Modeling
Zoning
Mashhad Metropolis

## ABSTRACT

The purpose of this study is to achieve the effective components and criteria in the design of green residential settlements with an environmental protection approach in Mashhad. Using the TM sensor and LANDSAT satellite, satellite images of the study area were prepared and modeled by superimposing data related to energy consumption through GIS tools and Arcview, version 9.2 software to final synthesis and mapping. Then, using the opinions of experts to extract and prioritize the appropriate components and criteria from each of the mentioned systems. Data were analyzed by structural equation method with least squares approach and Smart - PLS2 software was used for final analysis. Then, after explaining the components and criteria, according to the available data, the optimal limit (10% - 20%) for 10 components was proposed as a scenario. Then modeling was done through Design Builder software. The results showed that a total of 4 categories of macro variables have been identified as the main components affecting energy consumption, which are: "management", "environmental performance", "economic performance" and "social performance" variables, all of which have divergent validity. Also, 11 topics and 61 criteria were extracted and explained as components for assessing the sustainability of residential buildings. Finally, it was found that with the implementation of energy optimization strategies, the heating system will be reduced by 36%, the cooling system energy by 41% and the total cooling and heating energy by 38% compared to the base state.

**How to Site:** Abavisani Joghtaee N. Farajollahi Rod A. Yeganeh M., Zoning and Modeling of Energy Consumption in Human Settlements and Explaining the Effective Components in the Design of Green Buildings (Case study: Mashhad), Anthropogenic Pollution Journal, Vol 6 (1), 2022: 8-20, DOI: 10.22034/AP.2022.1949527.1126.

**Corresponding author:** amirfrod@modares.ac.ir

## 1. Background

Global resources are being used up at an alarming rate through Man's over exploitation (Li et al., 2014; Zuo & Zhao, 2014; Ayokunle Olubunmi et al., 2016). With the increased development of urbanization, environment and energy issues have drawn additional attention from the public and society (Ding et al., 2018).

The expansion of urbanization and the tendency of people to modern life and the increase in the price of energy tariffs, has led to the introduction of new methods to reduce energy consumption. Achieving this important goal in the construction industry, which is directly related to the economy and the environment, should be considered in the macro policies of each country (Raeisi, 2016; Gurgun, 2018). The construction industry has 40% of resources, 12% of water reserves, 55% of wood products and 60% of global waste, and 40% of raw materials are used in this industry and also the production of greenhouse gases in this industry is 48% (Castro, 2002; Roodman, 1995). Also, the type of design perspective of buildings based on the climatic conditions of each region, which corresponds to the volume, topography and type of materials in order to provide human comfort with minimal environmental effects, should also be considered. Today, due to many constructions in cities, we face the phenomenon of thermal islands, although it is one of the topics of urban planning, but buildings play an influential role as part of the city (Bareshadat, 2019; Ghalambaz (a), 2021).

**Table 1.** Details of international green building rating tools

| Description | LEED | Green Star | BREEAM |
|---|---|---|---|
| Parent Organisation | United States Green Building Council | Green Building Council of Australia | Building Research Establishment |
| Type of Ratings | · LEED Certified<br>· LEED Silver<br>· LEED Gold<br>· LEED Platinum | ·One Star -Not eligible for certification<br>·Two Star-Not eligible for certification<br>·Three Star -Not eligible for certification<br>·Four Star-Green star certified rating " Best Practice"<br>·Five Star-Green star certified rating " Australian Excellence"<br>·Six star Green star certified rating " World Leader" | · Unclassified<br>· Pass<br>· Good<br>· Very good<br>· Excellent<br>· Outstanding |
| Type of schemes available (latest in use) | LEED version 4<br>· Building Design and Construction (BD+C),<br>· Interior Design and Construction (ID+C),<br>· Building Operations and Maintenance (O+M),<br>· Neighbourhood Development (ND)<br>· Homes. | ·Design and As built<br>·Interiors<br>·Communities<br>·Performances | BREEAM International<br>· BREEAM International New Construction (NC)<br>· BREEAM International Refurbishment & Fit-Out<br>· BREEAM In-Use International<br>· BREEAM Communities Bespoke International. |
| Widely used scheme Relevant scheme for operational evaluation | Building Design and Construction (BD+C) | Design and As built | BREEAM International New Construction (NC) |
| Main credit categories Operational schemes | · Location and transport<br>· Sustainable sites<br>· Water efficiency<br>· Energy & atmosphere<br>· Material and resources<br>· Indoor Environmental quality<br>· Regional priority<br>· Innovation | · Management<br>· Indoor environment quality<br>· Energy<br>· Transport<br>· Water<br>· Material<br>· Land use & ecology<br>· Emissions<br>· Innovation | · Management<br>· Health & wellbeing<br>· Energy<br>· Transport<br>· Water<br>· Material<br>· Waste<br>· Land use & ecology<br>· Pollution<br>· Innovation |

Developed from (Si et al., 2016; Ding et al., 2018)

Today, the design of sustainable buildings in harmony with nature is felt more than ever. Green buildings are a set of techniques implemented in the life cycle of a building that aims to minimize the differences created in the environment. Green building strongly emphasizes resource utilization, waste disposal, and the use of renewable energy sources (Kosheleva, 2006; Ghalambaz (b), 2021).

Green building is the practice of creating structures and using processes that are responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, and renovation (Shi, 2010; Ayokunle Olubunmi et al., 2016).

The source of green building is the process of constructing environmentally friendly buildings and conserving energy. The value of a green building in the design and construction cycle until the end of a building's life can be examined (Ahmadi, 2017; Mokheiri, 2017), while according to the International Energy Agency, 40% of per capita energy consumption is consumed by buildings (LEED, 2013). Green buildings are designed to reduce the overall impact of the human environment on human health and the environment. This is done through the following methods:

- Optimal use of energy, water and other resources
- Protecting environmental health and improving resource efficiency
- Reducing pollution and environmental degradation (Goodhew, 2016).

Saving money is possible by using water and electricity more efficiently, which reduces the cost of energy bills. It is estimated that different regions can save $ 130 billion by reducing energy bill costs (Miller et al., 2018). Studies over a 20-year period have shown that some buildings generate a return on investment of between $ 53 and $ 70 per square foot (equivalent to 5.30 square centimeters) (Liu et al., 2016). Over the past several decades, a large number of engineering and management systems have been introduced to control energy consumption in residential and office buildings. Various models have also been introduced for environmental design and green buildings (Najam, 2005). In 1998, for example, the American Green Building Association released the first version of the LEED to evaluate green buildings.

United States Green Building Council launched LEED in 1994 (USGBC, 2015). LEED is the most widely used green building rating system in the world with 1.85 million square feet of construction space certifying every day and accepted in more than 150 countries worldwide (Song et al., 2016) and also considered to be the most perfect, influential evaluation system among all the green building assessment systems worldwide (Huo & Yu, 2017).

The HQE system was introduced in France, the CASBEE system in 2001 in Japan, and the STAR¬ GREEN system in Australia in 2002 (Niksima, 2009). The first systems efficiency survey was conducted in 2009 on more than 100 LEED-certified buildings, which showed 25% to 35% energy savings over similar items (Newsham, 2009).

Each of these tools has different schemes and various criteria. All these are illustrated in Table 1 as follows.

Green architecture is not really a new trend because it has existed in many ancient civilizations and traditional architectures, including traditional Iranian architecture. But looking for a way to minimize the negative effects of buildings on the environment, green architecture is in fact an attempt to harmonize with nature by increasing efficiency and optimizing the consumption of materials, energy and expanding space (Darban & Javadnia, 2019).

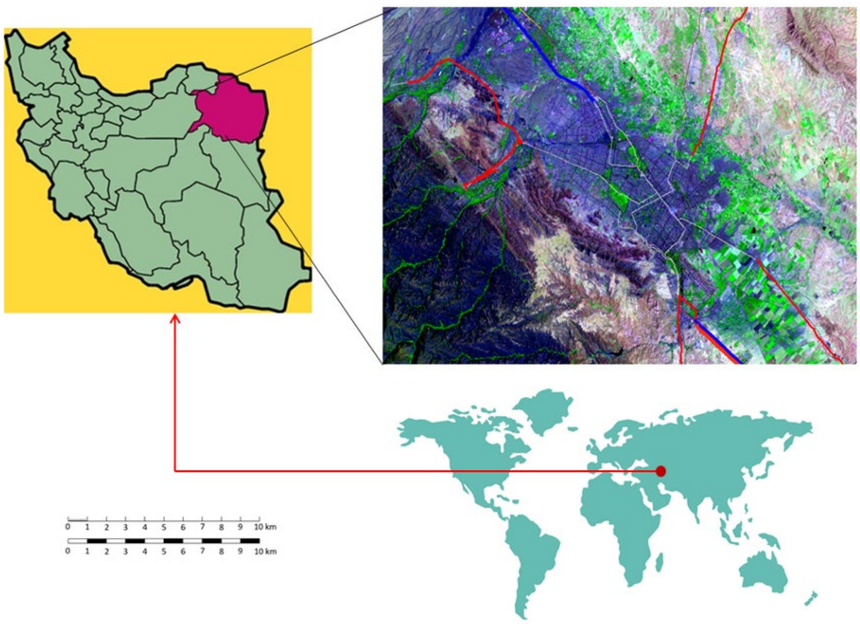

**Figure 1.** Location of the study area on the map of Iran and the world

According to estimates, the total energy consumption of the IRAN in 1992 was more than 12 billion dollars. In 2002, this amount reached 20 billion dollars and it is predicted that in 2022, the amount of energy consumption in the country will be equal to the amount of its production, which will no longer be able to export energy (Ahmadi, 2017; Mokheiri, 2017). This is very evident in the construction sector, because most of the buildings in the country do not have known technical criteria to prevent energy loss (Ghiabaklou, 2017). Since in each of the sectors of the construction industry, by making a physical change in the living and working environment of human beings, it will have a significant impact on human welfare and health, the need to pay attention to this industry from an environmental perspective is felt.

In recent years, many researchers have studied the traditional Iranian architecture and green building and sustainable architecture. These include the following:

Hosseini & Darskhan, 2017; Mohaghegh & Naderi, 2014; Torkani et al., 2014; Setayeshzadeh et al., 2021.

The purpose of this study is to identify and introduce the leading components and criteria in the design of green buildings with emphasis on energy efficiency in Mashhad. Since Mashhad is the largest religious metropolis in the world and the second largest metropolis in Iran, in recent decades in terms of population and size has grown rapidly. Therefore, in order to avoid wastage of capital and energy and also to provide a practical model for implementing the principles of green building in this city, components and criteria affecting the design of green building and optimizing energy consumption in human settlements are developed (Figure 1).

The population of this area is about 3 million people. The metropolis of Mashhad has an area of about 351 square kilometers. The city has grown significantly in recent decades (Figure 2). About 27 million domestic religious tourists and 2 million foreign tourists enter it every year. The climate of this city is temperate with cold and dry winters and its maximum altitude is 1150 meters (IMO, 2020).

## 2. Methodology

The research method is applied and in terms of implementation is descriptive-analytical. Also, the method of data collection was library and through documentary studies. The current situation is assessed through the database of the Ministry of Roads and Urban Development, the Meteorological Organization and other official organizations. In the section of developing the optimal model, the Delphi method has been used to collect the opinions of experts. The Delphi research panel includes specialists and experts related to the topics of sustainability, energy, environment and green building in the country, especially in the metropolis of Mashhad, who were appointed in the number of 15 people. Also, analytical studies and logical reasoning have been done using statistical analysis software. Initially, satellite images of the study area were obtained through the TM sensor and LANDSAT satellite. Then, the distribution map of human settlements and population density was extracted and modeled by superimposing data related to energy consumption through GIS tools and Arcview software (version 9.2) to final synthesis and mapping. In this way, the amount of energy consumption in the metropolis of Mashhad was zoned. Then, the 3 main energy management systems that are highly regarded worldwide such as LEED, BREEAM, CASBEE as well as 3 internal regulations, 2 national standard regulations 14253 and topic 19 national building regulations as the basis of the initial research model are cited and examined. Then, using the opinions of experts to extract and prioritize the appropriate components and criteria from each of the mentioned systems.

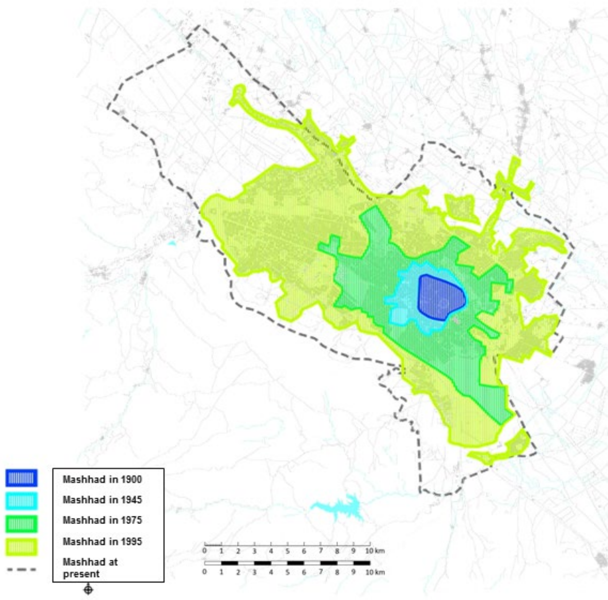


**Figure 2.** Development trend of Mashhad city in the period of 1900 to 2021 (Moradi et al., 2020)

Data were analyzed by structural equation method with least squares approach and SMART-PLS2 software was used for final analysis. The Fornell-Larcker criterion for calculating divergent validity in the structural equation model of least squares is partial. Fornell and Larker (1981) proposed this index to calculate the divergent validity of each structure in the partial least squares model. In partial least squares analysis, which is usually analyzed with SMARTPLS software, the Fornell and Larker criteria are used for divergent or diagnostic validity, which indicates the existence of minor correlations between indices of one structure and indices of other structures (Moradi et al., 2020).

Then, after explaining the components and criteria, according to the available data, the optimal limit (10% -20%) for 10 components was proposed as a scenario. The reason for choosing the optimal limit in the range of 10-20% was that according to experts, in the short term it will not be possible to achieve the optimal limit of more than 20% for Mashhad, and in fact this range as an achievable limit, and not an ideal hand Unattainable, defined.

Then modeling was done through Design Builder software.

## 3. Results

According to the official data and basic maps of the study area, and through Arcview software, a population zoning map was prepared in the metropolis of Mashhad. As shown in Figure 3, dark areas indicate higher population density. It includes parts of 1-2-10-11 and 12 municipal areas. The study area was then divided into equal networks to enable data validation. Using the layer superimposing technique and based on the statistics of the Ministry of Energy, the final map of energy consumption in the metropolitan area of Mashhad was drawn (Figure 4).

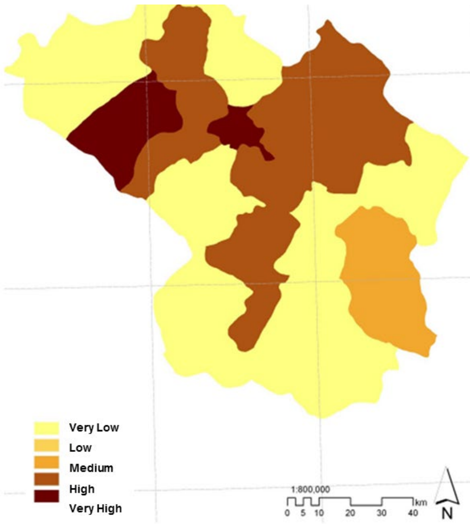


**Figure 3.** Population zoning map in Mashhad metropolis (Source: Research Findings)

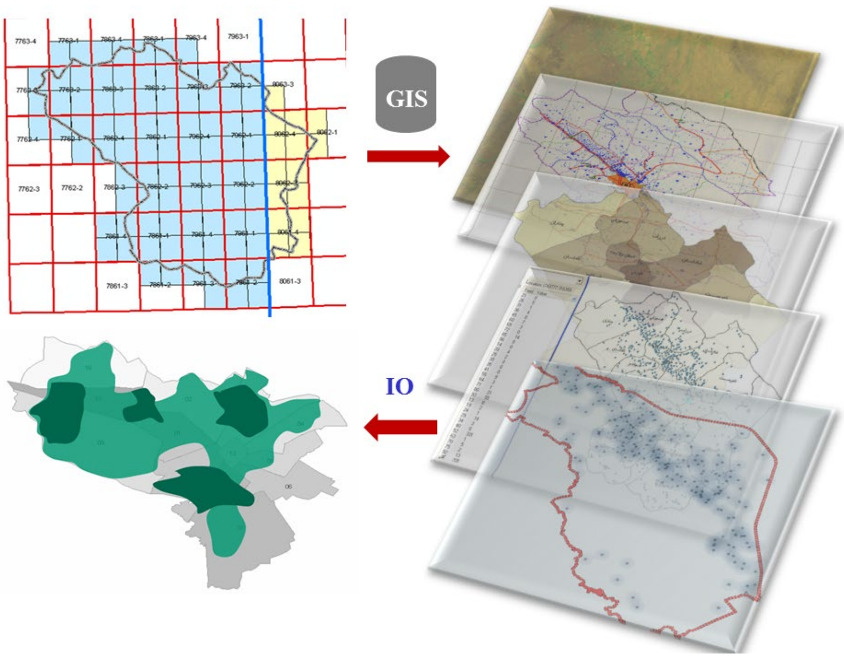


**Figure 4.** Using the networking and layering technique for energy consumption zoning in the metropolis of Mashhad (Source: Research Findings)

The information layers used were:

- Demographic zoning
- Building Density
- Zoning of energy-intensive industries and uses
- Meteorology data
- Topography (slope, direction and height)

As shown in the figure above, the areas marked with a darker color indicate the points where the energy consumption is highest. The reason for this is the existence of residential complexes, high building density, and the establishment of administrative and commercial units that consume energy.

The results of the questionnaires showed that a total of 4 categories of macro variables have been identified as the main components affecting energy consumption, which are: "management", "environmental performance", "economic performance" and "social performance". Table 2 show that all the studied variables have divergent validity.

Figure 5 shows the fitting result of the model and the factor load and its path coefficient. Finally, Table 3 presents the criteria and components for assessing the sustainability of residential buildings for the metropolis of Mashhad. In total, it can be said that 11 topics and 61 criteria were extracted and explained as components of the residential building sustainability assessment.

The 4 categories of macro factors identified along with the relevant components have a factor load higher than 0.4, which indicates a significant relationship and high validity of variables.

Then, using Design Builder software, the optimal mode was modeled. Based on this, an optimistic scenario was designed. In this section, in accordance with each of the variables that had reliable data, the optimal state was considered as (10-20%). Table 4 shows the variables used in the modeling based on the percentage change. It is emphasized that in this section, only variables were used for modeling that had citationable data that could be used and entered into the software.

The results of statistical data of Mashhad are presented in the following figures.

This diagram shows the relationship between temperature and humidity in Mashhad.

The diagram shows that the prevailing wind direction in Mashhad is from southeast to northwest and most of the year is calm.

On the other hand, the winds that blow in the city of Mashhad mainly have a speed higher than 1.35 m/s.

The results showed that by insulating the walls and ceiling, the amount of heat transfer from these walls is reduced as shown below.

**Table 2.** Fornell and Larker matrices for divergent validity (Moradi et al., 2020)

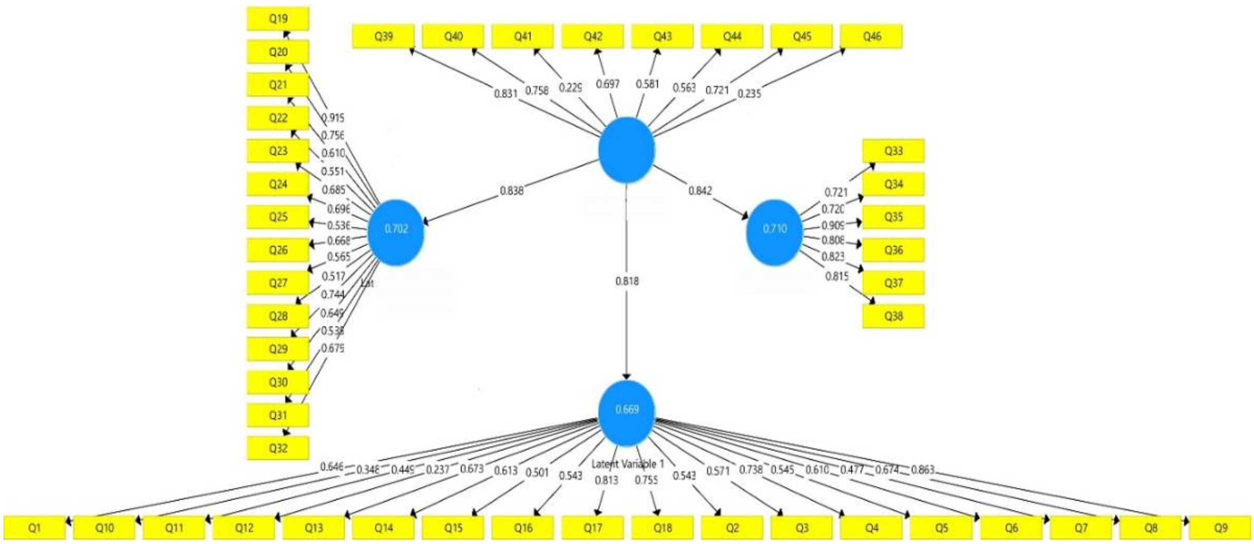


**Figure 5.** Research model based on expert statistics (Source: Research Findings)

**Table 3.** List of criteria and components for assessing the sustainability of residential buildings in the metropolis of Mashhad

| Heading | Criteria | Sub criteria (components) |
|---|---|---|
| Energy | 1. Optimizing energy performance | • Optimal energy consumption in exterior and interior lighting Optimal energy<br>• consumption in the air conditioning system<br>• Optimal energy consumption in cooling and heating systems<br>• Optimal energy consumption in hot water supply system<br>• Use of miscellaneous equipment and appliances with optimal energy<br>• Control and energy and power consumption during operation<br>• Energy saving |
| | 2. Improve the ability of the building to reduce energy demand | • Climatic and static design<br>• Utilizing the appropriate form and volume for the optimal use of natural energies Proper design of shutters<br>• Building shell performance<br>• Improving the air impermeability in the walls<br>• Proper design of awnings |
| | 3. Energy production | • Utilization of renewable energy (solar energy) |
| | 4. Management on energy consumption | • Setting up equipment and training the user<br>• Use of energy management equipment |
| | 5. Utilization of equipment with minimal emissions | • Reduce CO2 and SO2 emissions from energy consumption<br>• Fundamental management of coolers |
| Water | 6. Optimize water consumption | • Reduce water consumption to irrigate the area<br>• Use of native cultivation to reduce water consumption for irrigation<br>• Reduce water consumption for domestic use<br>• Reduce water consumption for sanitary purposes<br>• Separation of drinking water from sanitary uses<br>• Utilization of appropriate installation components and connections<br>• Reduce water consumption during execution |
| | 7. Management of sewage, rainwater and gray water | • Water storage<br>• Rainwater harvesting<br>• Gray water recycling |
| | 8. Water protection | • Use of tanks in cases such as sanitary consumption and irrigation |
| | 9. Monitoring water consumption | • Use of water metering equipment<br>• Water leak detection<br>• Use of water flow regulating devices |
| site | 10. Site selection | • Select a pre-made background<br>• Site risk control |
| | 11. Access to facilities and infrastructure | • Proximity to the required welfare facilities<br>• Access to infrastructure |
| | 12. Access to public transport | • Proximity to public transport facilities<br>• Proximity to cycling facilities |
| | 13. Impacts of site selection | • Respect the right of indigenous peoples to enjoy light, tranquility, landscape, health<br>• Controlling the effects of the implementation process on residents |
| | 14. Optimal site design | • Influence of site features (topography, vegetation, soil, etc.)<br>• Increase land productivity<br>• Proper landscaping<br>• Predict the appropriate play space for children |
| | 15. Proper design and installation of the building on the site | • Establishment of the building in order to make maximum use of solar energy<br>• Proper installation of the building for maximum use of natural ventilation<br>• Proper design on shading surfaces |
| | 16. Upgrading the site through proper landscaping | • Creating a sub-climate<br>• Yard design<br>• Creating a satisfying visual environment in the yard<br>• Upgrading the ecological features of the site<br>• Reduce negative environmental impacts<br>• Use a green roof<br>• Use the green wall<br>• Use of permeable materials in the area to exploit groundwater |

| Heading | Criteria | Sub criteria (components) |
|---|---|---|
| site | 17. Protection of ecological values of the site | • Preservation of existing species<br>• Reconstruction of contaminated soil<br>Establishment of surface water management system |
| | 18. Site protection during execution | • Protection of existing species during implementation |
| Environmental loads | 19. Reduce greenhouse gas emissions | • Use of low-escalation equipment<br>Control of emissions from materials during execution |
| | 20. Reduce thermal islands<br>21. Reduction of contaminants during execution | Reduce the effect of thermal islands on the roof and enclosure<br>• Reduce noise pollution during performance<br>• Reduce visual disturbance and pollution during execution<br>• Prevent water pollution during execution<br>Controlling the effects of the implementation process on land erosion |
| | 22. Reducing the negative effects on the environment and the indigenous inhabitants around the site | • Reduce light pollution<br>• Prevention and reduction of noise pollution<br>• Prevention and reduction of visual pollution<br>• Prevention and reduction of odor pollution<br>• Prevention of earthquake damage<br>Reduce the negative effects on the environment |
| | 23. Reducing the impact on the environmental characteristics of the site (water, soil, air) | • Reuse of excavated soil during implementation<br>• Prevent air pollution during operation<br>• Prevent water pollution during execution<br>Dust damage control |
| Materials and resources | 24. Responsible sourcing and extraction | • Application of materials with renewable sources<br>• Use of local materials to reduce transportation costs<br>Use standard and certified materials |
| | 25. Material efficiency | • Use materials with suitable components and combinations<br>• Use of materials with low latent energy<br>• Use of insulation materials<br>Use of materials with high heat capacity |
| | 26. Durability of materials | • Use of durable materials to reduce replacement frequency<br>Use of flexible materials against climate change |
| | 27. Use of recycled materials | Use of existing recycled materials as structural and non-structural materials |
| | 28. Reuse of building components | Use of recyclable materials |
| | 29. Reduce material waste during implementation | • Construction waste management and demolition<br>Proper protection and storage of materials during execution |
| | 30. Reduce environmental destructive effects and eruptions | • Use of materials with minimal environmental impact<br>• Use of materials free of substances and compounds harmful to health<br>• Use materials with minimal site contamination<br>Use materials with a minimum amount of carbon dioxide emissions |
| Solid Waste | 31. Execution of waste management | • Management of waste collection, segregation and grouping in the workshop<br>• Recycling of construction waste in the workshop<br>• Use of new methods (prefabricated) to reduce the production of workshop waste<br>• Applying design principles with a view to reducing the production of waste during the implementation phase<br>Make the necessary arrangements for hazardous waste of the facility |
| | 32. Waste management during operation | Applying design principles with a view to reducing the production of waste during the operation phase |
| Interior quality | 33. Indoor air quality during execution | • Indoor air quality management during implementation |
| | 34. Interior quality from the perspective of user comfort | • Ambient temperature control<br>• Using static methods to provide thermal comfort<br>• Optimal building shell performance air conditioning<br>• Natural ventilation<br>• Humidity control<br>• Ability to use daylight in spaces<br>• Proper design and installation of openings (direction, number and position)<br>• Use of sound insulation in spaces<br>• Indoor air quality control<br>Building aeration |
| | 35. Quality of indoor environment from the perspective of user health | • Achieving health conditions<br>• Indoor air purifier<br>• Improving the quality of drinking water<br>• Improving the quality of the building's internal water network and protecting it<br>• Maintain and control the temperature of the hot and cold water network<br>• Application of materials with minimal emissions |
| | 36. User quality control of the environment | • Thermal zoning of spaces<br>• Provide the possibility of selection and control for the user in determining indoor air quality |
| | 37. Indoor air quality assessment | • Use of comfort monitoring equipment<br>• Application of air quality sensors |
| | 38. Quality of vision and landscape | • Access to the exterior<br>• landscape Create an interior landscape |
| | 39. Quality of open and semi-open spaces | • Design and implementation of open and semi-open spaces adjacent to closed spaces |
| | 40. Interior quality from a security perspective | • Maintain space safety tips<br>• Observe safety tips in accessing spaces<br>• Maintain security |

| Heading | Criteria | Sub criteria (components) |
|---|---|---|
| Socio-cultural issues | 41. Aesthetic quality in space | • Observe spatial proportions<br>• Proper interior design |
| | 42. Improving the appearance and urban landscape | • Design and execution of a facade in harmony with the texture |
| | 43. Attention to social aspects | • Design and implementation of unobstructed space for ease of use for the disabled<br>• Ensuring the rights of neighbors during construction and operation |
| | 44. Attention to cultural and ritual aspects in the design of spaces | • Observance of nobility and privacy in spaces<br>• Design of private open spaces |
| | 45. Paying attention to historical issues and preserving identity | • Pay attention to the historical identity of the neighborhood<br>• Preservation and preservation of cultural heritage values |
| Technical quality - functional | 46. Flexibility of operation of spaces | • Flexibility in operation<br>• Flexibility in the structure<br>• Flexibility in the body |
| | 47. Functionality of spaces | • Useful dimensions of spaces<br>• Optimal design and provision of spaces<br>• Adaptation of facilities to the needs of users |
| | 48. Technical quality and safety of the building against earthquake and fire | • The ability of the building to maintain its performance in the event of crises and natural disasters<br>• Building adaptability to natural hazards or climate change<br>• Fire safety<br>• Earthquake resistance of structures |
| | 49. Quality of components and equipment | • Insulation of spaces (thermal and sound)<br>• Building shell quality<br>• Quality of service and service<br>• Adaptability of technical systems |
| | 50. Technical quality of construction and execution | • Utilizing new construction methods for optimal execution<br>• Utilizing modern manufacturing methods to be able to separate components and parts<br>• Observe safety issues during execution |
| | 51. Cleanliness | • Necessary cleaning equipment during execution |
| | 52. Ease of maintenance | • Ensuring the performance of the building during operation<br>• User access to systems and ease of troubleshooting<br>• Utilizing materials and components that are easy to maintain during execution |
| | 53. Quality of service of components and equipment and their renewability | • Service life of components, systems, equipment and services<br>• Observe the necessary distances for renewal of internal and external joinery |
| Economic quality | 54. Reduce costs and return on investment | • Reduce life cycle costs (operating and maintenance costs) |
| | 55. Utilizing the costing mechanism throughout the life of the building | • Site related costs<br>• Material costs<br>• Energy-related costs during operation<br>• Water related costs<br>• Waste related costs |
| Sustainable management and planning | 56. Integrated project planning and design | • Integrated project design and planning Increase partnerships between stakeholders, designers and all stakeholders and consulting<br>• Designed for easy maintenance<br>• Sustainable construction process planning |
| | 57. Construction process management and construction workshop | • Responsible construction methods<br>• Quality assurance of construction Control of energy and water consumption during execution<br>• Control of environmental conditions during construction<br>• Safety in construction<br>• Controlling the social effects of the workshop on the adjacent spaces<br>• Utilizing sustainability experts in the project process |
| | 58. Setup, delivery and user guide | • Systematic startup<br>• User guidance and training |
| | 59. Management and operation | • Monitoring energy consumption, water and waste generation during operation<br>• Provide appropriate conditions for monitoring the performance of equipment and troubleshooting them<br>• Ability to adjust and control comfort conditions by the user and local control<br>• Continuous monitoring and review of performance, production and disposal of waste |
| | 60. Creating innovation and incentives | • Creativity in design<br>• Participation in achieving new solutions to create a sustainable building |
| | 61. Localization of requirements based on regional conditions | • Pay attention to regional priorities |

**Table 4.** Variables used in optimal consumption modeling in Mashhad metropolis

| Row | Variable | Percentage change (improvement) |
|---|---|---|
| 1 | Optimal energy consumption in cooling and heating systems | 20% |
| 2 | Optimal energy consumption in the air conditioning system | 20% |
| 3 | Optimal energy consumption in the hot water supply system | 20% |
| 4 | Energy saving | 15% |
| 5 | Building shell efficiency | 10% |
| 6 | Utilization of renewable energies | 10% |
| 7 | Use a green roof | 10% |
| 8 | Use of insulation materials | 10% |
| 9 | Use of materials with high heat capacity | 10% |
| 10 | Optimal building shell performance | 10% |

**Defaults:**
Maximum temperature: 38 °C
Minimum temperature: -1 °C
Average humidity: 72
Wind direction: West
Wind speed: 1 meter per second Number of sunny days: 297 days

(Source: Research findings)

A further explanation for this diagram is that the greater the distance between the peak point of the curve and its amplitude, the greater the energy loss. On the other hand, the curve, which has a lower height and is wider, shows the optimal energy consumption. As can be seen, the red curve shows the optimal state in the simulation, which is lower than the blue curve (base state) and has less energy loss.

The energy consumption of the optimal cooling and heating system has significantly decreased during the year compared to the baseline mode as shown below.

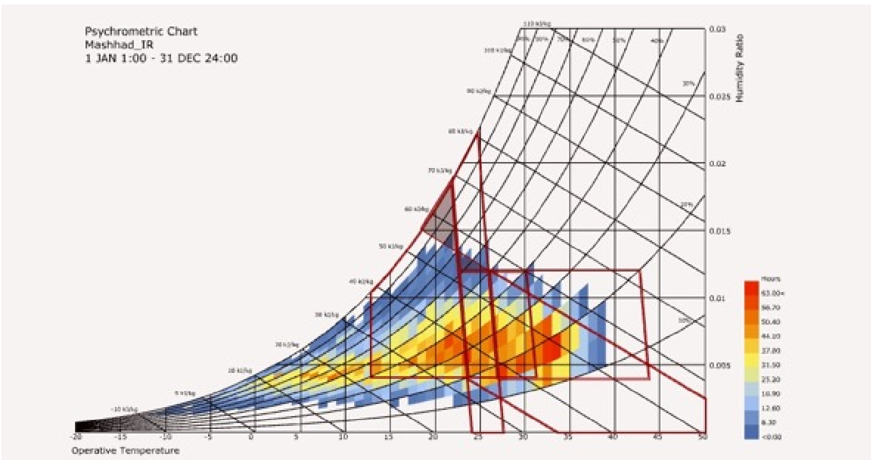


**Figure 6.** Psychometric diagram of Mashhad (Source: research findings)

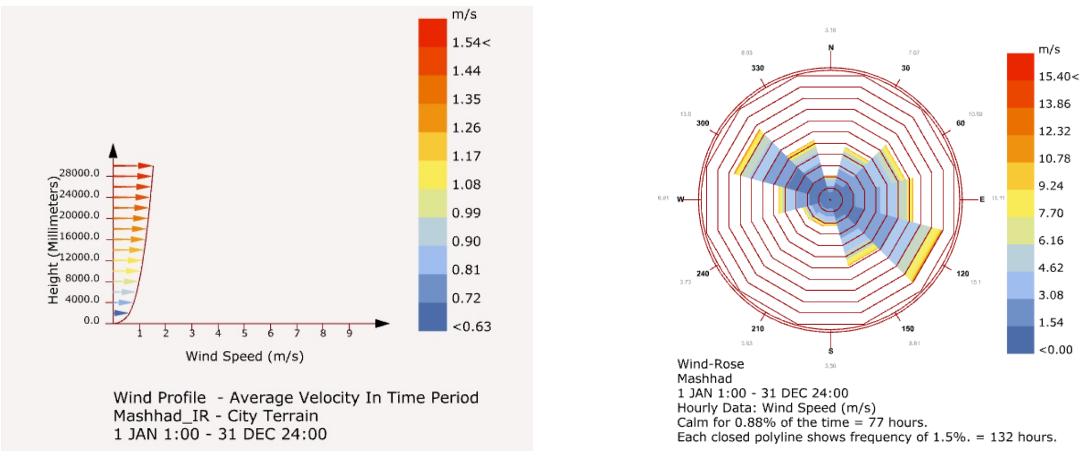


**Figure 7.** Mashhad Golbad diagram (right) and average wind speed diagram (left) (Source: research findings)

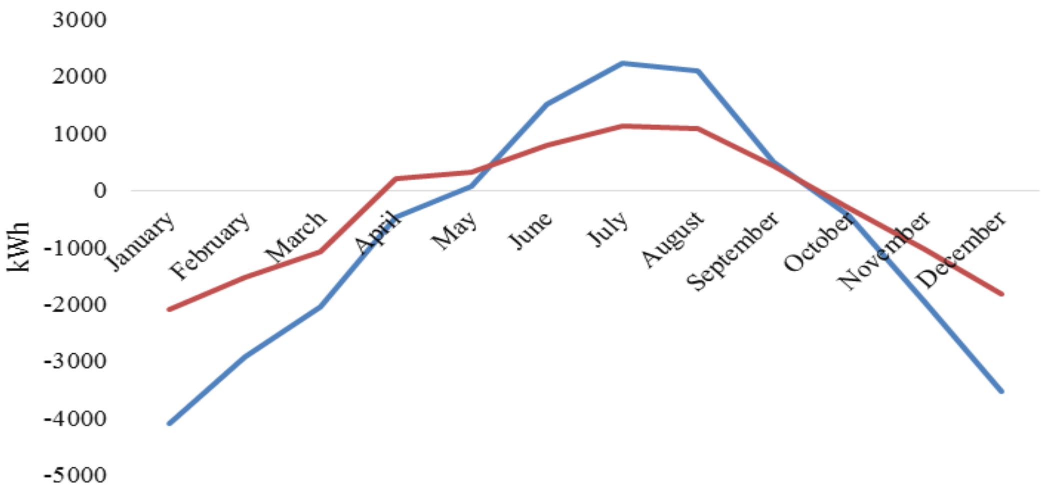


**Figure 8.** Heat transfer from the wall (Red line: optimal mode - Blue line: base mode)

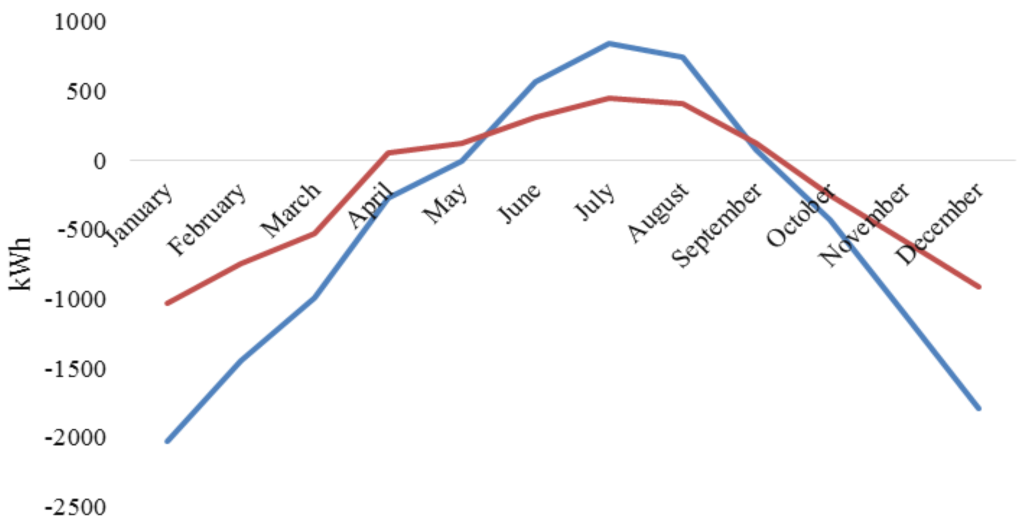


**Figure 9.** Heat transfer from the ceiling (Red line: optimal mode - Blue line: base mode)

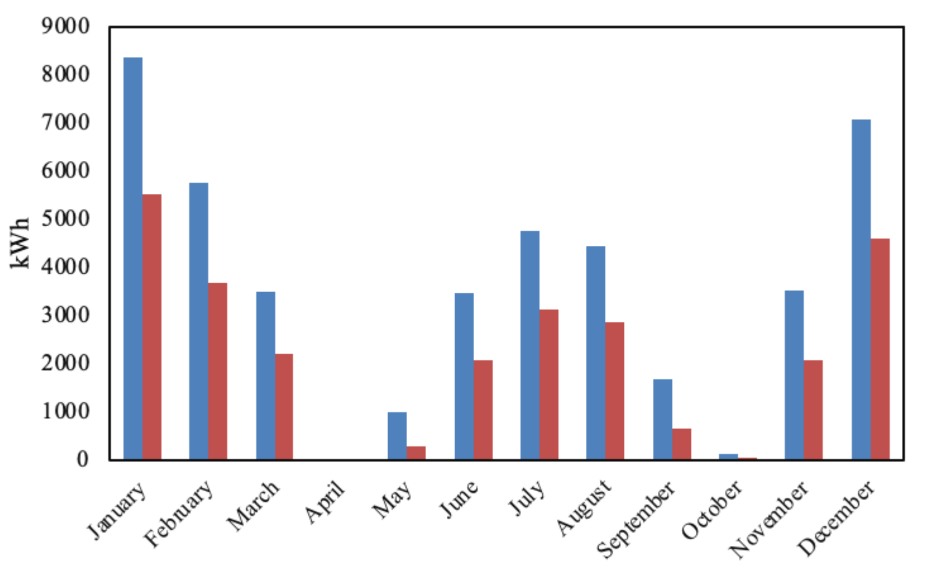


**Figure 10.** Comparison of total energy consumption of cooling and heating systems (Red line: optimal mode - Blue line: base mode)

As shown in the figure above, in all months of the year, the red graph is lower than the similar state (blue graph), which indicates that the cooling or heating energy consumption is lower than the corresponding month.

## 4. Conclusion

Studies by international and reference organizations have shown that energy efficiency optimization is an engineering and management necessity in metropolitan areas (Kellert, 2005). Findings showed that the presentation and implementation of optimal energy consumption pattern in this metropolis is a requirement that in addition to reducing energy consumption will also reduce the production and emission of various pollutants.

A total of 4 categories of macro variables have been identified as the main components affecting energy consumption in the field of sustainable construction, which are: variables "management", "environmental performance", "economic performance" and "social performance".

Obviously, the 61 identified components are very difficult to achieve, on the other hand, some of them overlap. However, if each of these components is implemented properly, they will reduce energy consumption, although the implementation of some of them will impose a relatively high cost on management, which will be compensated in the long run. Finally, it was found that with the implementation of energy optimization strategies, the heating system will be reduced by 36%, the cooling system energy by 41% and the total cooling and heating energy by 38% compared to the base state. However, if baseline data are available for other variables, more accurate modeling can be provided, which certainly shows higher efficiency.

## Acknowledgments

No cases have been reported by the authors.

## Ethical endorsements

No case reported by the authors.

## Conflict of interest

No case reported by the authors.

## Contribution of authors

Najieh Abouisani Joghtaei (first author) lead researcher (50%), Amir Faraj Elahi Rad (second and responsible author) author of main discussion (30%), Mansour Yeganeh (third author) analyst (20%).

## Financial resources

This article is taken from the dissertation of Dr. Najieh Abovisani Joghtaei on "Explaining the leading components and criteria in environmental design and energy for residential use, based on environmental characteristics (Case study: residential buildings in Mashhad) It is done in the Islamic Azad University of Mashhad and by the authors and all related expenses are paid by the student and no organization or institution is considered as a sponsor.

## References

1. Ahmadi M, Maleki A, Vedadi Kalantar S, Karimi, MS (2017). Energy Efficiency Improvement in Iran: Policy documents and Barriers in the Building Sector. Strategic Studies of public policy Journal. 7(22):131-142.
2. Ayokunle Olubunmi, O., Bo Xia, P., Skitmore, M. 2016. Green building incentives: A review, Renewable and Sustainable Energy Reviews, 59(2016)1611–1621
3. Bareshadat N, shoaei H, Reznani A (2019). Evaluation of Environmental Sustainability Components and Architecture Design of Iranian Educational Buildings. geores. Geographical Researches Journal. 34(4):559-566.
4. Castro Lacouture D, Sefair JA, Florez, L, Medaglia AL, (2009). Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. Building and Environment Journal. 44(6):1162-1170.
5. Darban, A., Javadnia, M. 2019. Green architecture is a step towards sustainable development, Architecture, first year, number 5, 8 pp.
6. Ding, Z., Fan, Z., W.Y. V., Yu Bian, T., Li, I.M. Chethana S. 2018. Green building evaluation system implementation, Building and Environment, Accepted Date: 8 February 2018.
7. Ghalambaz M (a), Jalilzadeh YR, Davami AH.(2021) Building energy optimization using butterfly optimization algorithm (BOA). Thermal Science. 2021(00):306-.
8. Ghalambaz M (b), Yengejeh RJ, Davami AH.(2021) Building energy optimization using grey wolf optimizer (GWO). Case Studies in Thermal Engineering.;27:101250.
9. Ghiabaklou, Z., 2017. Investigating the Effect of Changing the Transmitted Light's Color on Thermal and Visual Comfort. Naghshejahan 4, no. 6 (2017): 1-14.
10. Goodhew S. (2016). Sustainable Construction Processes A Resource Text. John Wiley & Son.
11. Gurgun AP, Arditi D (2018). Assessment of Energy Credits in LEED-Certified. Buildings Journal. 8(29):2-20.
12. Huo, X., Yu, A.T.W. 2017. Analytical review of green building development studies, Journal of Green Building, vol. 12, pp. 130-148, 2017.
13. IMO. 2020. Iran Meteorology Organization.
14. Kellert, Stephen R. (2005), Building for Life, ISLANDPRESS, Washington
15. Kosheleva E, Elliott J (2006). Green Building in the Russian Context: An Investigation into the Establishment of a LEED®-based Green Building Rating System in the Russian Federation. Journal of Green Building. 1(3):105–123.
16. LEED. (2013). U.S. Green Building Council. www.usgbc.org. Archived from the original on 2013-12-19.
17. Li, Y. et al. 2014. Green building in China: needs great promotion. Sustain Cities Soc 2014; 11: 1–6.
18. Liu, Lei; Ledwich, Gerard; Miller, Wendy. (2016). Community centre improvement to reduce air conditioning peak demand. doi:10.4225/50/58107ce163e0c.
19. Miller, Wendy; Liu, Lei Aaron; Amin, Zakaria; Gray, Matthew. (2018). Involving occupants in net-zero-energy solar housing retrofits: An Australian sub-tropical case study. Solar Energy. 159: 390. Bibcode:2018SoEn..159..390M. doi:10.1016/j.solener.2017.10.008.
20. Mokheiri H, Jameie F (2017). Review of conventions, treaties and environmental policies of governments at the international level to deal with the environmental crisis. tehran, Association for the Development and Promotion of Basic Sciences and Technologies.
21. Moradi, A., Daneshpoor, A.H., Daneshvar, M., Bahmanpour, H. 2020. Determining the range of tourism and recreation range of natural areas of Mashhad in line with sustainable urban and suburban planning, Journal of Geographical Research, Vol. 33, 446-454 pp.
22. Najam A (2005). Developing Countries and Global Environmental Governance: From Contestation to Participation to Engagement. Int Environ Agreements Journal. 5:303-321.

23. Newsham, G. R., Mancini, S. & Birt, B. J., 2009. Do LEED-certified buildings save energy? Yes, but …. Energyand Buildings Journal. 41(8):897-905.
24. Niksima v (2009). A look at energy management system and environmental design (LEED system). tehran, Housing and Building Research Center.
25. Raeisi Z, Nikravan M (2016). Review and comparison of common building scoring systems based on sustainability indicators and comparison with national regulations. Architecture in hot and dry climate. 4:1-14.
26. Roodman DM, Lenssen N (1995). A Building Revolution: How Ecology and Health Concerns Are Transforming Construction. 124 ed. Washaington: Worldwatch Institute.
27. Setayeshzadeh, A., Moosavi Shaker, S.H., Kazemzadeh, M.A. 2021. Feasibility study of the emergence of eclectic architecture influenced by traditional climatic architecture Iran and Western Green Architecture, Shabak Scientific and Specialized Journal, Year 6, Serial Issue 5 (56): 16 pages.
28. Shi, Q. 2010. Green building assessment in China: present and future; 2010.
29. Si, J., Marjanovic-Halburd, L., Nasiri, F., Bell, S. 2016. Assessment of building-integrated green technologies: A review and case study on applications of Multi-Criteria Decision Making (MCDM) method, Sustainable Cities and Society, vol. 27, pp. 106-115, 2016/11/01/ 2016.
30. Song L., Zhang C., LI H. 2016. Statistical report of the label of national green building evaluation in 2015, Construction Science and Technology, pp. 12-15, 2016.
31. USGBC. 2015. United States Green Building Council. LEED. Available: http://www.usgbc.org/
32. Zuo J, Zhao, Z.Y. 2014. Green building research–current status and future agenda: a review.RenewSustainEnergyRev2014; 30: 271–81.