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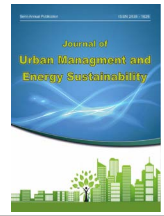

ORIGINAL RESEARCH PAPER

Studying Energy Consumption in Built Educational Spaces with Approach of Sustainability and Optimization

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ABSTRACT

Sustainable architecture is one of the important developments in the field of architecture, and its purpose is designing based on optimization of energy consumption and sustainability principles. Today, one of the tools available to check and optimize different parts of a project is the use of computer simulations, which can bring the project as close as possible to sustainability indicators in the design stage. In this article, as an experimental example, firstly, the space and structural features of one of the classes of Azad University, Hashtgerd branch, were modeled with the help of Grasshopper plugin and energy and also light simulations were done by Ladybug and Honeybee add-ons. Considering the fact that the project has been built, it is more difficult to make changes in it and they must be applicable. The variables considered in the simulations are: applying insulation on the walls from the inside, changing the type of windows to double-glazed and low-emissivity, applying shades and changing the type of air conditioning system. Analyzes show that applying internal insulation to the walls and changing the type of window to a low-E double-glazed window will reduce energy consumption in the heating sector by 12%, in the cooling sector by 17%, and using smart lighting systems will reduce energy consumption by 28%. Furthermore, the option of changing the air conditioning system and applying shadings is completely rejected, based on the results of the simulations.

Running Title: Energy Consumption in Built Educational Spaces

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12

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1. Introduction

According to the International Energy Agency, energy consumption and especially non-renewable and fossil fuels in recent years have led to an increase in greenhouse gas emissions and thus global warming. Consumption is increasing and the amount of energy is also decreasing. This level of energy consumption in developing countries, including Iran, is increasing. Withconsidering the importance of the issue, finding suitable solutions for managing and controlling it, is obvious. The alignment of these strategies with the definitions of sustainable development can play an important role in optimizing energy consumption (Sedric, 2004). Today, sustainable development is more important than ever to energy consumption and the environment. The verb "Sustain" has been used in the English language since 1920 and comes from the Latin root′ s "sub" and "Ten ere" which means to keep or maintain. The Oxford dictionary has estimated the history of the adjective "Sustainable" to be about 1400 years. But it is only during the last few decades that this word has been used with its current meaning, which means "that which can continue in the future" or "sustainability" (Perizadeh, 2013).

The United Nations′ (2015) Sustainable Development Goals (SDGs) articulates the critical importance of sustainable design in the architectural, engineering and construction (AEC) industry [1] . Buildings and construction generate 36% of global energy use and 39% of energy-related carbon dioxide (CO2) emissions [2] (Abergel et al., 2017). These emissions have increased in recent years, reaching 10 GtCO2 in 2019, the highest level on record. Sustainable design for the built environment seeks to reduce the ecological footprints of national and regional economies (Yu et al., 2021).

Sustainable development is not a tool, a move, or a new debate; in fact, it is a smart and wise way of developing life and a different way of thinking. What`s about sustainability is to increase efficiency and improvement. In fact, sustainable development is a development that can meet the current needs without compromising the ability of future generations to meet their needs (Mofidi, 2004).

Sustainable development is a move to do things properly and in a way that improves the quality of current and future generations (Iniax, 2001). The consumption of energy in public and residential areas, especially educational spaces, is more than others and consumption control and optimization in these places are also much more important than the other ones and in Iran where is one of the most energy-consuming countries in region, paying attention to this method of consumption and providing architectural solutions which are in line with the foundations of sustainable development are very important and significant.

On the other hand, educational spaces are very important public spaces that most of the energy in these areas is being consumed today. Therefore, it is necessary to study and suggest the solutions in these spaces.

Hashtgerd town in Alborz province is also one of the industrialized and expanding towns in Iran. Due to the geographical location and physical expansion of this town, as well as the amount of its immigrant populations, the need for educational spaces is felt more and more and because of the lack of previous researches in this field, it has been selected as the case study of this research.

1.1. Energy and Sustainability in Architecture

Due to the increasing importance of the global warming crisis and its tangible consequences, and on the other hand, the expensive and limited fossil fuels, paying attention to climatic design and adjusting the amount of energy consumed in buildings and using as much natural resources as possible are very important. In this regard, architecture in compatible with the climate is a suitable solution to achieve more comfortable conditions, which will result in the use of cooling and heating devices and energy consumption, and ultimately the reduction of pollution (Esmaili et al., 2009). In recent years, numerous articles and papers have been written by researchers from all over the world on the principles of sustainable development and related architectural and urban planning. Often, these statements have

1- Website of United Nations' Documents: https://www.unodc.org/roseap/en/sustainable-development-goals.html
2- Website of World Green Building Council: https://www.worldgbc.org/news-media/global-status-report-2017

argued, with little difference, about encouraging designers to protect energy, and also to consider local features of work and location with building users and communities around them (Yannas, 2003).

One of the most important tools for providing comfort for humans and helping to conserve energy, is the design of basic architecture and with the relevant terms and conditions of the buildings as a place to conserve or waste energy. It is also very important to pay attention to the type of building used and its private or public usage (Wilson, 2000).

Educational spaces are one of the most commonly used public buildings that study the energy consumption and provide solutions for their systematic design, in order to achieve sustainable development goals, can greatly prevent the loss of energy in this region (Ghazizadeh, 2003).

Cities as human ecosystems, which have a major contribution in terms of population acceptance and land occupation, are not focused on natural systems and focus on changes in the human made environment and buildings (Azizi, 2001).

The word "sustainability" has been used in legal areas and there have been other meanings and forms of this term for centuries, but in the last few decades the term sustainability has been used with three meanings: keep alive, backing up and what can be continued in the future.

This word is one of the clearest concepts that well describes what is in the minds of many people, and for this reason, the term is so widespread and widely used, although it has critics, that some others believe that the term “sustainable” or “sustainability” does not mean the real meaning of the subject, and we should look for another term (Singeri, 2007).

1.2. Sustainable Development Goals

In order to achieve sustainable development goals, some special steps are required.

The first step is efficiency and energy saving (Salfaee, 2001). Secondly, we must try to use renewable energy, such as the sun, wind and water, in buildings and cities, and other developments. Encouragement should be given to the use of systems that create the lowest contamination. Systems that use fossil fuels are the most polluting environmental factors (Disani, 2002). In the fourth stage, the recycling issue is raised. In general, waste from non-renewable resources is also produced. The conversion of linear development into adversarial or circular development is suggested. In the fifth stage, the theme of clean air is raised. The discussion of the thinning of the ozone layer and the warming of the earth, which is most often produced in urban development, are raised and finally at the seventh stage, it is argued that we are allowed to use existing resources, regardless of the fact that future generations also have the right to use these resources (Mofidi, 2004).

1.3. Sustainable Design Factors

Sustainable design must consider the long-term environmental, economic and human elements and also the basics of it such as understanding the environment, relationship with nature, understanding the trends in nature, understanding the environmental impact, participatory design process and user’s understanding.

Non-intermediate sustainability is the same path that architecture should access in the near future. This type of architecture should be a manifestation of human feelings about nature (Razjuyan, 2000).

We can`t overlook the effect of the ecosystem of the environment. The way we live and the choices we have to meet our needs have a dramatic effect on the quality of life. How to design our homes and materials is one of the most important issues that affect the future of our buildings (Singeri, 2010).

Sustainable architecture has had remarkable success in recent years. These achievements include the diffusion of new structural techniques and materials that are in accordance with energy and building. In fact, the sustainable architecture combines several values, including aesthetics, environment, society, politics, and designing and building in harmony with the environment (Camberly, 2006).

1.4. Sustainability in Architecture of Educational Spaces

The indicators which effect the design of sustainable educational spaces are divided into two categories: a) climate indicators and b) architectural indicators. Climate Indicators are: Pressure, Wind (dominant direction, wind speed), Temperature (daily temperature, maximum and minimum daily temperature), Moisture and Precipitation (rainfall, maximum and minimum rainfall, number of rainy-snowy days) and Architectural Indicators are: general characteristics of the building (area, space division, energy systems and information about the users of the building), the angle and orientation of the building, form and volume of the building, number, direction, angle and height of openings and windows, the shape and direction of the yard, the elongation of the building, direction, angle and depth of the facade, type of materials used and the amount and the manner of use of green space in the area and the interior (Abbaspour, 2009).

Moreover, the role of occupants in energy consumption is less-regarded in commercial and educational buildings. Studying occupant-driven energy loads in public types of buildings will have a significant impact on future of building design because individual occupants do not have full control of a building's energy and lighting systems in these buildings. This can enhance the potential for other forms of interaction with the building to provide comfort conditions (Torabi et al., 2021).

1.5. Computational simulations and building energy performances

Among all the methods of investigating the performance of energy and light in a space, the implementation of full-scale models is very expensive. Although this process is usually time-consuming, the results are often reliable and practical because they involve real technologies and materials under the real conditions. Small-scale models are a smaller version of real building models, which are usually made in desired scales and similar to architectural models, and they are easier and cheaper to make, and they are also easily used. However, the difficulties of making a small-scale model are not less than making a full-scale model. Another solution is to use simulation programs. Building energy simulation programs are a valuable tool in the design phase of new buildings and are used to evaluate and optimize building energy performance (Wong, 2017). Computer simulation is the process of modeling using mathematical and logical relationships, as well as the implementation of the model by computer, and it is a method to know the results of the proposed ideas before their implementation (Qiyabaklo, 2019). Computer simulation that uses mathematical models, in addition to the ability to simulate and predict the real performance of buildings, has also shown its effectiveness through high computing power. In addition, it provides a fully controlled environment that also facilitates dynamic optimization (Al-Masrania and Al-Obaidib, 2019).

In this study, we focus on these factors in our selected case-study in Hashtgerd town to find solutions to optimize energy consumption in educational centers.

2. Materials and Methods

Due to the increase in energy consumption in different sectors according to Iran's energy balance sheet [3], presented for 2018, compared to previous years, all energy consuming sectors have faced an increase in consumption. Considering that this increase in energy consumption ultimately leads to an increase in pollution in the environment, it is necessary to reduce energy consumption and bring it closer to its optimal level by using sustainable development methods. One of the important types of energy consuming uses is the educational buildings sector. The implementation of such methods should be considered in pre-design and construction studies, and if we are faced with energy wastage in existing and used buildings, we should reduce the amount of consumption to the optimal amount by making possible changes. Let's approach it. In this context, activities including technical simulations by related software and plugins, architectural analysis, the type of use of floors and classes, the number of users, working days and hours, the location of the building and room, the details of openings, etc. can be effective.

3- The website of the Ministry of Energy of Iran: https://isn.moe.gov.ir

2.1. General Specifications of Hashtgerd Town

Hashtgerd or Hashgard is one of the important cities of Savojbolagh in the province of Alborz, Iran. According to the comprehensive survey of 2020, the city's population is "500,000". The Hashtgerd town is built on the land of the ancient village of Fashand (Azizi, 2006).

Due to its geographical location and position between the two metropolises of Karaj and Qazvin, Hashtgerd town has suitable potential for immigration, economic investment, industrial attraction, student and academic attraction and other related users. In addition to being the main industrial centers of the province and the region and the main pole of agricultural products in the province, this town also is one of the most important cities in the field of science and knowledge production and university centers. Islamic Azad University, the major universities in this city, is one of the major centers of higher education that has been selected as the case study of this research.

2.2. Architectural Details of Case Study

Islamic Azad University, Hashtgerd Branch, which has been established since 2006 in the Northern part of Hashtgerd district, in Alborz province in Iran is considered to be the most important center for higher education in terms of the size and number of students in west part of this province. The initial design of the university is set up on an area of 77750 square meters and has two educational-administrative brigades of 6145 square meters, designed and built in 3 floors. In addition to educational-administrative buildings, buffets, guardians, teachers and students' parking, and also publications center, are the main spaces available on the premises of this educational space (Figure 1).

Another important factor which should be studied in architectural details of the case-study is the number of classes and floors information which have been shown as Table 1.

According to available data, in the Islamic Azad University, there are 68 classes in 3 floors and a ground floor in two buildings, with the lowest number of classes are on the ground floor and the highest number of classes are in the first and second floors of the existing one. There are also 14 classes in the ground floor. The diagram of the ground floor of the building can be seen in the Figure 2.

2.3. Details of Energy Consumption in Case Study

In exploring the relationship between energy and architecture, attention to several important factors can be effective. One of these factors is space user. Given that the case samples are educational, their users are divided into two

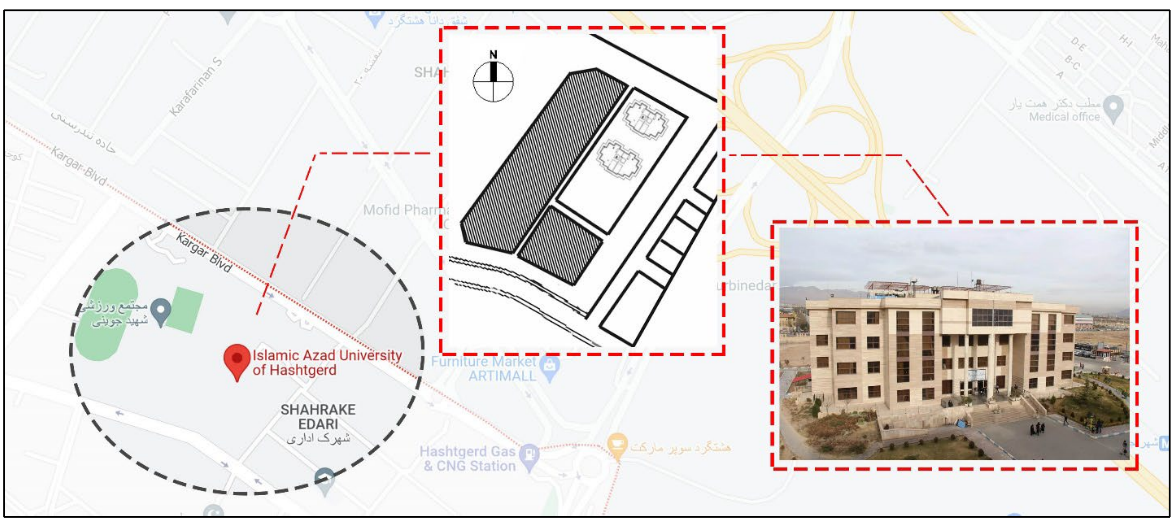

Figure 1: Islamic Azad University of Hashtgerd (Source: https://hashtgerd.iau.ir and https://google.com/maps/)

Table 1: Total classes in two administrative-educational buildings of Islamic Azad University of Hashtgerd Branch (Source: Hashtgerd Azad University of Architectural Design Unit)

Total	Number of Classes in Building 2	Number of Classes in Building 1	Floor
12	6	6	Ground
20	10	10	First
20	10	10	Second
16	8	8	Third
68	Total Classes in 2 Buildings		

Figure 2: (Source: Hashtgerd Azad University Architectural Design Unit)

Table 2: Number of Users of Islamic Azad University of Hashtgerd (Source: Islamic Azad University, Administrative Unit)

Variable / Fixed	Numbers	Users
Variable	6700	Students
Fixed	70	Administrative staff
Variable	350	Lecturers
Fixed	56	Faculty Members

groups according to the seasons. These users include students, administrative staff, academic professors and faculty members (Table 2).

2.4. Days and hours of work

Another important issue in the discussion of the details of energy consumption is the discussion of days and hours in case study. Islamic Azad University, according to the decisions of the board of directors, has a working day of 5 days a week and is closed on Thursdays and Fridays. The working hours of the educational and administrative unit are as Table 3.

2.5. Direction of Placement

According to the climatic and geographical conditions of the region, the best direction of placement is East-West and this is because of the lowest consumption of per class per capita and per square meter (Figure 5).

2.6. Openings

One of the important factors in the energy exchange in building architecture is the exchange of openings, dimensions, sizes, material and type of construction. According to studies on openings in the case study of this project, single-leaf wooden doors with a width of one meter for classroom and two-leafed wooden doors with a width of 2 meters to enter the enclosure spaces and aluminum or metal doors for wet spaces, toilets or utility spaces were used and the details are reported as follows.

2.7. The Amount of Energy Consumption

Energy consumption in all buildings is directly related to the factors which were mentioned in architectural details and energy consumption details above. According to these factors, the amount of energy consumptions changes.

In one hand, the type of heating and cooling system and the amount of water, electricity and gas used in these spaces are depended to the mentioned factors and how much the building needs, in the other hand based on sustainability factors, depends how the users act and use energy correctly or waste. In the research case study, the main heating system is the central heating system, which is the most efficient system for controlling and managing energy.

In the next step of the research, we have

Table 3: Working hours of the administrative and educational departments of Islamic Azad University ofHashtgerd (Source: Islamic Azad University, Administrative Unit)

<table>
<tr><th>Hours of Work</th><th>Name of Unit</th><th>Name of University</th></tr>
<tr><td>8:00-19:00</td><td>Educational</td><td rowspan="2">Islamic Azad University</td></tr>
<tr><td>8:00-16:00</td><td>Administrative</td></tr>
</table>

Table 4: Amount of annual consumption of energies of the case study based on bills (Source: Islamic Azad University, Administrative Unit)

<table>
<tr><th>Balance Recorded in Bills/ Low Consumption User</th><th>Average Annual Consumption</th><th>Type of Energy</th><th>Name of University</th></tr>
<tr><td>124 Cubic meter</td><td>327 Cubic meter</td><td>Gas</td><td rowspan="3">Islamic Azad University</td></tr>
<tr><td>36000 Liters</td><td>46000 Liters</td><td>Water</td></tr>
<tr><td>3500 kw</td><td>5730 kw</td><td>Electricity</td></tr>
</table>

Table 5: Finding the Solution in a Built Educational Center

<table>
<tr><th>Availability of any Changes / Solution</th><th>Current Situation</th><th>Detail / Factor</th><th></th></tr>
<tr><td>Smart Elevations can be studied</td><td>Built</td><td>Plans-Forms-Elevations</td><td rowspan="7">Architectural & Energy Consumption Details</td></tr>
<tr><td>Changing the functions of some rooms can be studied</td><td>Built-Planned</td><td>Number of Floors and Classes</td></tr>
<tr><td>May be changed each semester</td><td>Planned</td><td>Number of Users</td></tr>
<tr><td>Can be reduced</td><td>Planned</td><td>Days and Hours of the Work</td></tr>
<tr><td>No need to change</td><td>Selected</td><td>Direction of Placement</td></tr>
<tr><td>Promote the insulation of the outer walls of buildings and the use of double-glazed windows and doors</td><td>Built-Planned</td><td>Openings</td></tr>
<tr><td>Adopting with SUSTAINABILITY rules / Changing</td><td>Central/ Using energy more than limited amount</td><td>The Energy System and Consumption</td></tr>
</table>

focused on the average annual consumption of water, electricity and gas in the case study samples based on the required bills. According to the studies of Iran Energy Institute, for each energy type in different seasons and different functions, there is a low consumption amount which all of them are mentioned as Table 4.

The conclusions of Table 4 shows that the consumptions of all energy types are more than low consumption amount and this is the main problem of the project and according to the mentioned analysis and simulations, we will try to suggest solutions and reduce and optimize the energy consumption.

2.8. Finding the Solution in a Built Educational Center

What we did in this research was studying the current conditions of the case study both in architectural and energy consumption which were built before.

Therefore, finding the solutions for such a project which was built before is harder than the project which is in design process.

In design process, by studying all needed details, the architect tries to manage and add all needed factors to have the best energy optimization and move toward the goals of the sustainability but after designing and construction the conditions change.

In the other hand, we have some sustainable design rules and also especial policies which are suggested by Ministry of Power and Energy of the country, which some of them can be done and some other changes may be unavailable because of the built situation of the building.

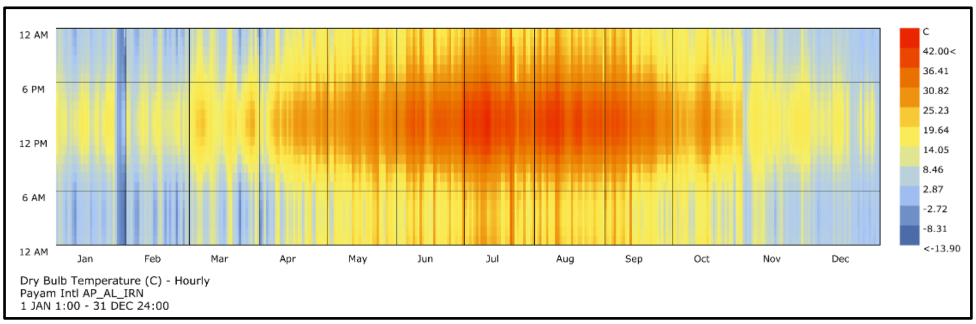

Figure 3: Payam Airport hourly dry bulb temperature diagram (Source: Authors)

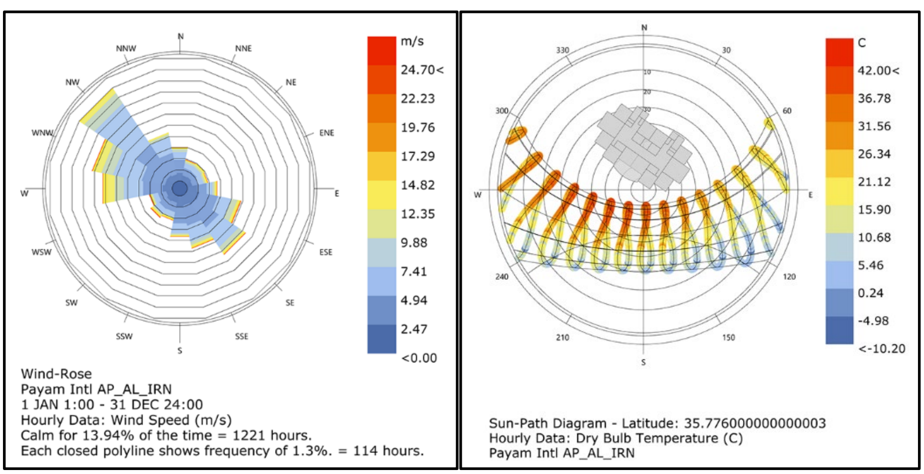

Figure 4: Left: wind-rose diagram, Right: Sun-path diagram of Payam Airport area (Source: Authors)

According to the data collections of the research, for finding the solution we should check out the positive and negative points of the architectural and energy consumption details of the project and test the available options (Table 5).

2.9. Checking Out the Options

Based on the findings presented in Table 5, there are options that we can consider the changes resulting from its implementation in the case study environment: such as changing the type of windows, applying insulation to the walls and etc. One of the tools that allows researchers to do this before they are implemented in space is computer simulation. The simulations used in this research are done in the framework of Grasshopper and Ladybug and Honeybee plugins. Energy-Plus and Open Studio simulation engines are responsible for energy simulation in these plugins and Radiance and Daysim engines are responsible for daylight simulations.

In this study, the building that used as a case study has built a few years ago and is now using by the Hashtgerd branch of Azad University and we want to check with computer simulations whether the application of some changes in the characteristics of the building (compared to what it is now) is effective in reducing energy consumption in this building or not.

The workflow steps of this section include the following sequential steps: checking the location of the site, weather data, creating geometry, determining the materials, performing energy simulations, adding shadings and simulating daylight.

2.10. Location

The building in the research is located in Hashtgerd city, which is one of the cities of Alborz province. This project belongs to Azad University and was opened in 2006.

2.11. Climate Data

The climate data used in this study is the standard Energy Plus climate file for Payam Airport, which can be downloaded from www.ladybug.tools. According to the Koppen climate classification, this section is located in Cfa or humid subtropical climate category. Diagrams of annual dry temperature, sun path and its wind-rose of the city can be seen in the Figures 3-5.

2.12. The geometry

The case study block is a four-floor building, each floor has an area of more than 1000 square meters and includes at least 6 number of classrooms, a few office rooms and supportive spaces. As can be seen in Figure 12, one of the classes in the first floor of the building is considered as the case study space for this study, which is directly related to the southern facade.

2.13. Materials and Physical Properties

First, the study space was created through Rhino software, then this section is entered into

Figure 5: Satellite image of the location of the building (Source: satellites.pro)

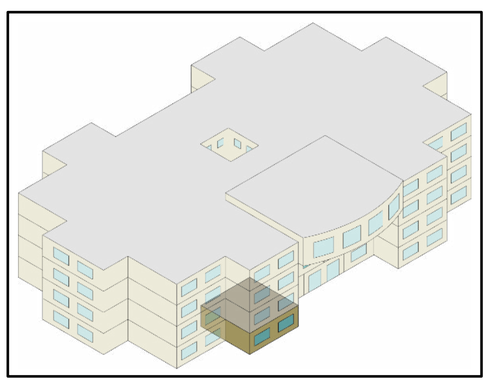

Figure 6: Location of the case study space in the building (Source: Authors)

Grasshopper as inputs and is introduced as a zone with the physical program of a classroom to Honeybee plugin. The materials that have been considered for the surfaces of this classroom have been considered in accordance with the actual specifications of this building, which is mentioned in the Table 6.

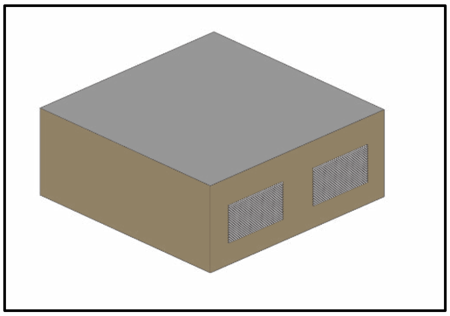

Figure 7: The case study space with the louver shadings (Source: Authors)

After fixing the materials of the classroom surfaces, it seems necessary to mention that the interior surfaces of this space are considered adiabatic and only the walls that are in contact with the exterior space have energy exchange with the outside environment.

It should also be noted that to reduce energy waste in the educational space, we set an intelligent system for automatically turning off the classroom lights when students are not in class and also when receiving more than 500 lux of daylight from the sun.

Table 6: Materials and physical properties (Source: Authors)

Surface Type	Surface Name
Exterior walls	Concrete block without insulation
Interior walls	10 cm lightweight blocks
Floor	Concrete slabs
Ceiling	Concrete slabs with gypsum acoustic tiles
Single-glazing window	Single-glazing window with metal - U-value: 5.8 (according to factory specifications)
New exterior walls	Concrete block with internal insulation
Double-glazing window	Double-glazed window with air gap - low-E, UPVC frame - U-value: 1.13 (according to factory specifications)
Shadings	Metal louvers with a width of 5 cm with a reflectance of 0.8

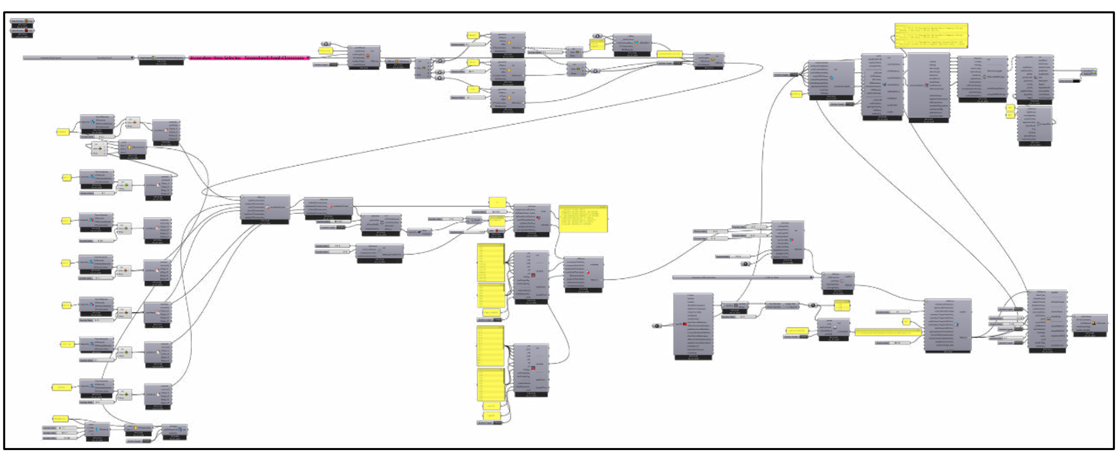

Figure 8: Honeybee algorithm of the defining the classroom geometry and energy simulation part (Source: Authors)

2.14. External Shading System

This building has a southwestern orientation, so due to the penetration of disturbing light from the west, the presence of a shading in this wall seems necessary. The shading is a type of smart louvers which blades are spaced 5 cm apart and designed to provide suitable lighting conditions (range 300 to 500 lux) in the working surface of the classroom (Figure 13).

2.15. Energy Simulation

After specifying the zones, we should set the zone loads, to do this, based on the usage type of the building (educational building), we set the equipment load per area on 11 w/m^2, infiltration rate per area on 0.0003, lighting density per area on 10 w/m^2 and the number of people per area on 0.79 ppl/m^2 and the other inputs are the default. Then, based on the hours and days of the presence of people in this educational building, a schedule of space occupation was set.

In the lighting setting section, the light level was set at 500 lux and the luminous efficiency was set at 92 units.

The next step involves our variable part of the simulation, which is related to determining the HVAC system of this building. The air conditioning system in this building is the fan coil system, but

Table 7: Energy simulation of the classroom with single-glazing window, without wall insulation and with fan coil air conditioning system info (Source: Authors)

Time	Type of consumption (kWh/m^2)		
Month	Heating	Cooling	Lighting
January	104.47	0	3.38
February	84.84	0	3.12
March	45.40	-0.05	3.51
April	24.75	-1.55	3.38
May	2.14	-5.55	3.38
June	0.39	-9.96	3.38
July	0.02	-14.64	3.38
August	0	-12.49	3.51
September	1.33	-9.35	3.38
October	8.37	-1.71	3.38
November	48.58	0	3.38
December	89.94	0	3.51
Total	410.23	-55.3	40.31

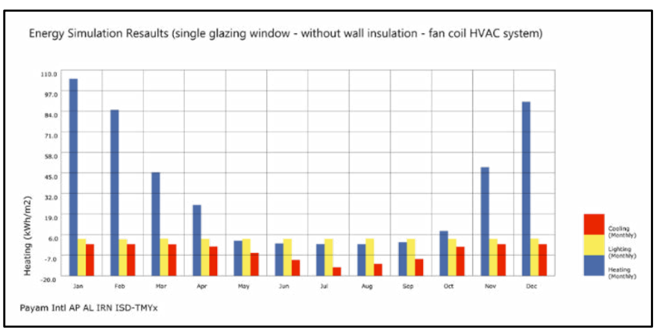

Figure 9: Energy simulation of the classroom with single-glazing window, without wall insulation and with fan coil air conditioning system diagram (Source: Authors)

to determine whether the change in this system will affect energy consumption, three different air conditioning systems were applied for this simulation: The fan coil system, active chilled beams + DOAS system and VAV w/reheat system. The results of each simulation are noted in the Table 7. It should be mentioned that the set point for cooling and heating in space is set at 25 and 20 degrees Celsius.

Finally, we import all the inputs to the Open Studio simulation engine, which is one of the most powerful energy simulation engines and is considered for this purpose in the Honeybee plugin. The data analysis period in this study is set monthly and covers the period from January to December.

In order to perform energy simulation and observe the effect of changes in energy consumption of this classroom, first, this process was implemented for the existing conditions and then three more times by changing the condition of the walls to concrete walls equipped with internal insulation, changing simple windows to low-emission double-glazed windows and changing the air conditioning system (to the widely used types of these systems in educational buildings). The results and graphs are as Figures 9-13 and Tables 7-11.

Table 8: Energy simulation of the classroom with double-glazing window, with wall insulation and with fan coil air conditioning system info (Source: Authors)

Time	Type of consumption (kWh/m^2)		
Month	Heating	Cooling	Lighting
January	90.50	0	2.52
February	72.22	0	2.36
March	40.90	-0.04	2.49
April	23.19	-1.26	2.35
May	2.61	-4.35	2.36
June	0.67	-8.26	2.35
July	0.08	-12.70	2.34
August	0.04	-10.76	2.33
September	1.94	-7.80	2.22
October	8.98	-1.33	2.37
November	41.51	0	2.55
December	77.38	0	2.73
Total	360.2	-46.50	28.97

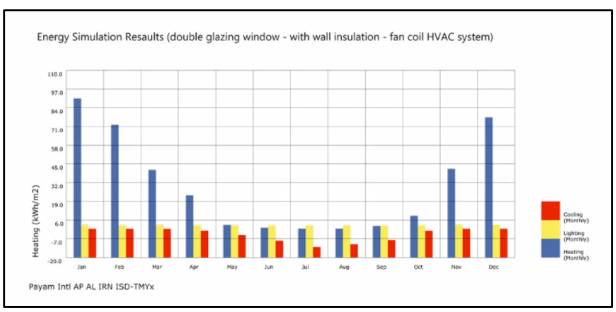

Figure 10: Energy simulation of the classroom with double-glazing window, with wall insulation and with fan coil air conditioning system diagram (Source: Authors)

Table 9: Energy simulation of the classroom with double-glazing window, with wall insulation and with active chilled beams + DOAS air conditioning system info (Source: Authors)

Time	Type of consumption (kWh/m^2)		
Month	Heating	Cooling	Lighting
January	91.09	0	2.52
February	72.64	0	2.36
March	41.15	-0.04	2.49
April	23.30	-1.15	2.35
May	2.61	-3.97	2.36
June	0.67	-7.00	2.35
July	0.08	-10.16	2.34
August	0.04	-8.70	2.33
September	1.94	-6.43	2.22
October	9.02	-1.23	2.37
November	41.78	0	2.55
December	77.85	0	2.73
Total	362.13	-38.68	28.97

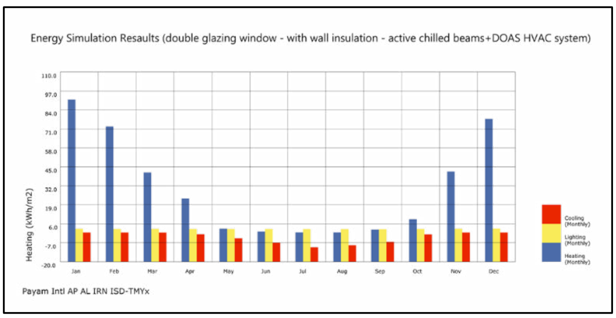

Figure 11: Energy simulation of the classroom with double-glazing window, with wall insulation and with active chilled beams + DOAS air conditioning system diagram (Source: Authors)

Table 10. Energy simulation of the classroom with double-glazing window, with wall insulation and with

Time	Type of consumption (kWh/m^2)		
Month	Heating	Cooling	Lighting
January	134.76	-0.07	2.52
February	117.00	0	2.36
March	78.06	-2.13	2.49
April	46.04	-7.28	2.35
May	10.61	-16.02	2.36
June	3.60	-22.13	2.35
July	0.45	-32.11	2.34
August	0.45	-28.34	2.33
September	7.10	-20.42	2.22
October	26.16	-8.98	2.37
November	81.87	-0.51	2.55
December	130.08	-0.03	2.73
Total	636.18	-138.02	28.97

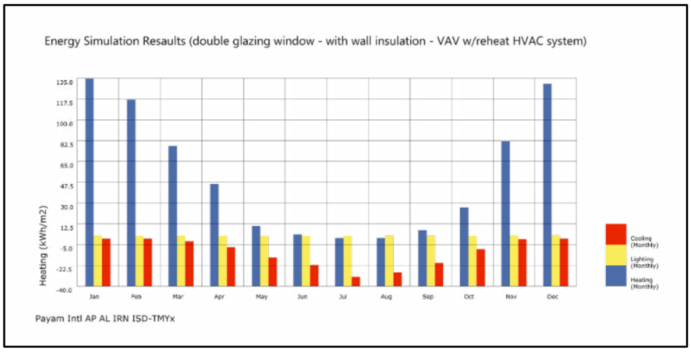

Figure 12: Energy simulation of the classroom with double-glazing window, with wall insulation and with VAV w/reheat air conditioning system diagram (Source: Authors)

Table 11: Energy simulation of the classroom with double-glazing window, with wall insulation and shading system and with fan coil air conditioning system info (Source: Authors)

Time	Type of consumption (kWh/m^2)		
Month	Heating	Cooling	Lighting
January	90.91	0	3.10
February	72.80	0	2.79
March	41.06	-0.04	3.10
April	23.17	-1.19	3.09
May	2.72	-4.16	3.09
June	0.73	-8.10	3.13
July	0.08	-12.45	1.99
August	0.04	-10.46	1.89
September	2.03	-7.61	3.01
October	8.98	-1.24	3.05
November	41.75	0	2.97
December	77.72	0	3.21
Total	361.99	-45.25	34.42

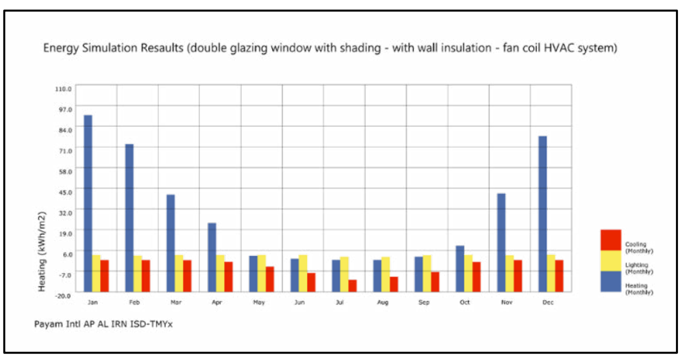

Figure 13: Energy simulation of the classroom with double-glazing window, with wall insulation and shading system and with fan coil air conditioning system diagram (Source: Authors)

Table 12: Shading openness conditions (Source: Authors)

The Amount of Openness	Condition
Open	Receiving 0 to 1000 lux of light by sensors applied to the work surface
Two thirds of openness angle	Receiving 1000 to 2000 lux of light by sensors applied to the work surface
One thirds of openness angle	Receiving 2000 to 3000 lux of light by sensors applied to the work surface
Closed	Receiving 3000 to 10000 lux of light by sensors applied to the work surface

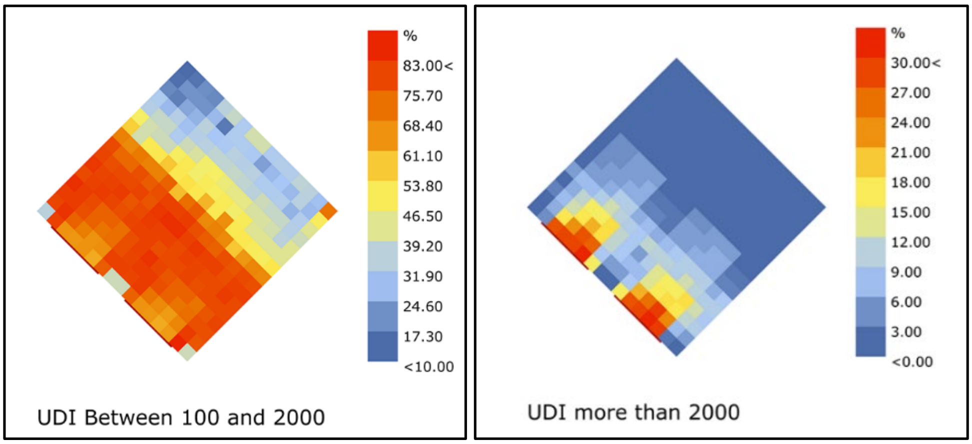

Figure 14: Diagrams of Useful Daylight Illuminance amounts in the classroom (Source: Authors)

2.16. Daylight Simulation

In order to perform daylight simulations, a smart shading device was applied on the surface of the windows. This shading is made of metal louvers and its blades have a width of 5 cm with a distance of 5 cm from each other. For this shading, 4 positions were considered for the conditions of openness, which are as Table 12.

The physical conditions considered for the classroom include the specifications of the default materials for the type of surface that found in the Radiance library, and for the window, we took the same specifications applied in the energy section with a reflectance of 0.65 for each color.

The working surface is 80 cm above the floor of the classroom same as the level of the students' desk, and 256 sensors have been applied to this level at a distance of 50 cm from each other to measure the amount of different light factors.

The report of the results obtained in the daylight simulation section and related diagrams can be seen in the Figure 16.

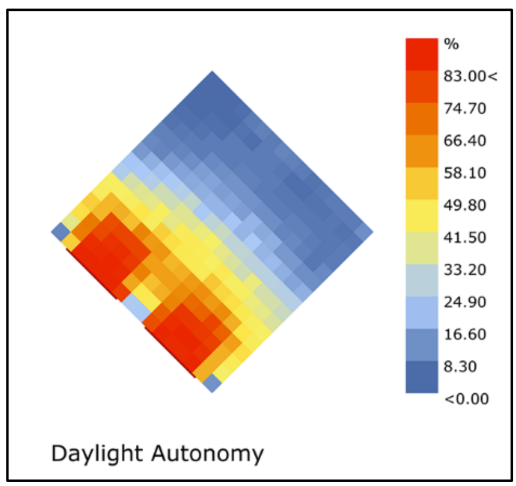

Figure 15: Diagram of Daylight Autonomy in the classroom (Source: Authors)

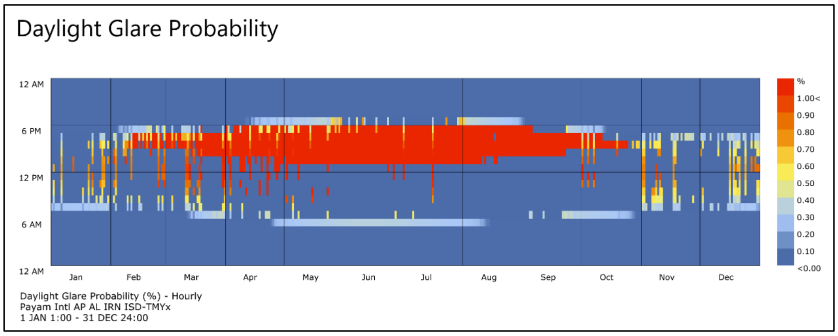

Figure 16: Diagram of the occurrence of glare in the classroom based on hourly data (Source: Authors)

3. Result and Discussion

If we pay attention to the results obtained in the energy simulation section, we find that the application of internal insulation for exterior walls and changing the type of window to low-emission double-glazing window, reduces energy consumption in the heating sector by 12%, energy consumption in the Cooling sector by 17% and the use of intelligent lighting systems have reduced energy consumption by 28%. But if we look at the results of changing the air conditioning system, we find that doing this change not only does not help to reduce energy consumption, but in the case of the VAV system also increases energy consumption by almost two times, so it is quite clear. The option to change the air conditioning system is completely rejected.

In the daylight simulation section, two factors, Daylight Autonomy and Useful Daylight Illuminance, were used to evaluate the adequacy of light, and in the glare section, the Daylight Glare Probability factor was used.

According to the final report of daylight simulation, based on the UDI factor, the classroom space receives 100 to 2000 lux of light in 57% of the occupied hours (which seems appropriate for this factor, but according to the light standards in the educational spaces at least 300 to 500 lux are required at the work surface and practically some part of this 57% does not provide the required light minimum). For the DA factor, in 50% of the occupied hours during the year, only 30% of the space area receives 300 lux or more of daylight, which is even possible with the full openness of the shadings. As a result, according to the DA factor definition, this amount of light supply will unfortunately not be enough in this space. The full opening of the shading, also raises the possibility of glare, especially in the afternoon until sun set, which is another matter and need a solution.

To investigate the effect of the shadings on energy consumption, energy simulation has been performed again with the presence of shadings, the results show a 20% increase in energy consumption, so according to the orientation of the building to the southwest, the application of louvre shading is not suitable for daylight control and another solution should be searched to improve the lighting conditions of the classrooms in terms of providing sufficient light with no glare on the sunny side in this building.

4. Conclusion

What was explored and studied in this research was first a review of the issue of sustainability, definitions, theoretical foundations, goals and basics. Then, as the energy debate is considered as the main principle of this topic, we focused on the sustainable architecture and energy debate in the building. Next, as the studies carried out in the field of sustainability in educational spaces, the indicators that influence the design of these spaces were studied. Then, general specifications, geographic and urban area, the climate and architectural elements of Hashtgerd town were studied. By studying different elements that influence the architecture and energy consumption of the case study, despite the positive points in designing of the project, such as its establishment or location or their internal spatial relationships, based on the documents and statistics presented, the negative points also have led to high energy consumption in the case study.

The simulations used in this research were done in the framework of Grasshopper and Ladybug and Honeybee plugins. Furthermore, Energy-Plus and Open Studio simulation engines were responsible for energy simulation in these plugins and Radiance and Daysim engines were responsible for daylight simulations. The results shows that according to the mentioned factors, analysis and simulations the application of internal insulation for exterior walls and changing the type of window to low-emission double-glazing window, reduce energy consumption in the heating sector by 12% and energy consumption in the Cooling sector by 17%, and the use of intelligent lighting systems have reduced energy consumption by 28%. Besides, the option to change the air conditioning system and daylight situation are completely rejected as the simulations confirms.

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