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Providing an Optimal Execution Model for Windows Based on Glazing to Reduce Fossil Fuel Consumption (Case Study: Asman Residential Complex of Tabriz)

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P A P E R I N F O

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A B S T R A C T

According to statistics provided by the Iranian Statistics Center,40% of energy consumption is related to the housing sector. Windows as a component of exterior wall, Responsible for 20-30% of all energy infiltration. Therefore, the purpose of this study, is to optimize residential windows in cold and dry climate of Tabriz in order to reduce energy consumption. The research method is based on simulation with two methods "parametric optimization" and "genetic algorithm". The research tool is Design Builder software. So, the amount of annual gas consumption in the case study was received from the National Iranian Gas Company and then the basic research model is modeled in software and after converting the unit from kWh to m^3 and validating the obtained results from simulation, in the next step, the type of glazing and frame are changed and then the sensitivity is analyzed by the two mentioned methods. The results showed that by replacing windows with triple glazed-glazing with low emission coating filled with argon, krypton and xenon gas and UPVC frame with clear double glazed-glazing filled with argon gas and iron frame, annual gas consumption for heating decreased by 52.43%, 55.34% and 56.60% and the heat loss from the windows is reduced by 7.97%, 9.54% and 10.49%, respectively.

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NOMENCLATURE

U-Value	W/m^2k	UPVC	Unplasticized Poly Vinyl Choride
R-Value	m^2k/W	T_v	Visible Transmittance
SHGC	Solar Heat Gain Coefficient	DST	Direct Solar Transmission

INTRODUCTION

According to statistics on the growth of urbanization in all parts of the world, especially in developing countries as well as in Iran, it is clear that for the next 20 years, about 60% of the world's population will live in cities. This statistic is predicted to be about 70% in Iran. Addition of each household to the population of the city has different consequences, the most important of which is an increase in housing [1]. With an increasing influx of people from rural to urban areas, the number of consumers of fossil fuels is increasing [2]. On the other hand, Iran is the country with the highest resources of oil and natural gas and is ranked fourth among the countries with the highest source of natural gas. Due to the existence of this rich source, 98.4% of the country's energy demand is allocated to this sector. From 1970 to 2017, the main demand for natural gas has increased from 25 million tons to 175 million tons; that is predicted that by 2030, the demand in the natural gas sector will increase to 260 million tons and in the oil sector to 100 million tons [3].

Buildings can be considered as one of the influential sectors in the field of energy [4]. The home sector is one of the main sectors of energy consumption, whose function is mainly heating, cooling and cooking. Energy consumption in this sector, with the exception of some years, has always had an upward trend of approximately 7.8% [5]. As the average energy consumption in this sector in Iran is more than 2.5 times the global average consumption [6].

Meanwhile, windows have a significant effect on the thermal characteristics of the building shell due to low thermal resistance along with the direct passage of

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radiant energy [7]. There are many important reasons for the high heat loss from windows: - Window to wall ratio; Window orientation; - Type of window glazing [8]. Due to its low thickness, glazing has the highest heat transfer coefficient among the constituent elements of the building's outer shell [9]. Various researches have been conducted in the field of optimal criteria for designing translucent walls in different climates Which is presented in relation to the historical sequence.

Citherlet et al. [10] studied window and advanced glazing systems life cycle assessment with the outcome of as window is very important element that should meet the following heterogeneous goals: - Thermal insulation, - Sunlight, - Daylight, - Protection against excessive cold, - Protection against noise, - Security".

Danny and Lam [11] studied zero energy buildings and sustainable development implications. They have come to the conclusion that to reduce window to wall ratio and double or triple glazed glazing to reduce heat losses.

Long and Ye [12] focused on smart and energy efficient with a general discussion on thermochromic windows having suitable glazing for winter should be able to transmit long-wavelength solar radiation.

Banihashemi et al. [13] studied on Climatic, parametric and non-parametric analysis of energy performance of double-glazed windows in different climates. It was found out that in cold climates where the heating load of the building is predominant, the use of double-glazed windows is more effective only in the months when intense heating is required.

Kim et al. [14] assessed the impact of window size, position and orientation on building energy load. They have come to the conclusion that the opening is located in the middle of the building facade in all directions, the annual energy consumption would be at its lowest.

Acosta et al. [15] studied window design in architecture for analysis of energy savings for lighting and visual comfort in residential spaces. They have concluded that windows with horizontal openings save more energy than other forms of windows with other openings.

Namazian and Sepehri [16] investigated on fenestration through the ages and its role in today's energy dilemma. They have concluded that smart glass and double glazing with PVC frames and thermal break are suitable technologies in the glass and window industry which reduce energy losses.

Valladares-Rendon et al. [17] studied on energy savings by solar control techniques and optimal building orientation for the strategic placement of façade shading systems. They found that double glazed windows and higher insulation have a direct impact on heat loss.

Rezaei et al. [18] investigated on advanced and smart glazing technologies to improve building energy efficiency. They found the best type of glazing for use in cold climates is double-glazed and aerogel glazing.

Kalinovic et al. [19] studied the influence of windows geometrical parameters on calculations of the heat conduction coefficient. The lowest thermal conductivity was obtained when plastic material is used for the window frame.

Khalesi and Goudarzi [20] defined thermal comfort in a climate-adaptive building with smart windows having clear glass replaced with smart electrochromic glass; the window to wall ratio has increased.

The effect of physical features of window protective covers on thermal performance of tehran's residential buildings was studied by Vahabi and Mahdavinia [21]. The heat transfer coefficient by energy simulation programs led to reduce the window heat transfer, control and reduce solar heat reception are very effective in energy efficiency in residential buildings.

Potrc et al. [22] studied on influence of the orientation on the optimal glazing size for passive houses in Europe. The southern front, with a rotation of about 1 to 24 degrees, is the most suitable front for the openings in order to get maximum access to solar energy.

Somasundaram et al. [23] investigated on energy saving potential of low coating based retrofit double glazing for tropical climate. They found double-glazed glazings are suitable for buildings enclosed in cold climates.

The contents presented reflects this fact; research in the field of glazing; mainly in the field of glazing properties. The difference and innovation of the present study can be considered in the study of the effect of thickness and type of gas between the glasses in double and triple glazed glazing and glazing coating on the amount of heat loss in windows of residential buildings. Therefore, considering the importance of the issue, the windows of residential buildings in Tabriz will be optimized in order to reduce energy loss. So, the purpose of this study is to present the glazing and the frame for windows in residential buildings with the approach of reducing fossil fuel consumption.

MATERIAL AND METHODS

The present research is based on the objectives of the research, of the type of "application" and based on the nature, is "simulation" and will be based on logical reasoning. The structure of the research is in the field of energy. The research method is quantitative and its inference requires analysis. The statistical population is the Narenjestan tower of Aseman residential complex in Tabriz and the target population is the annual gas consumption for heating the building. The independent variable of the research will be different types of glazing-frame and the dependent variable will be the amount of gas consumed annually for heating the building. The first step in this research process is data collection. Climatic information of Tabriz city from Tabriz Meteorological

Department and information related to building physics such as architectural plans, structures, mechanical and electrical installations, building facade structure from the construction company (Northwest Housing Investment Group) and also referring to Aseman Tabriz residential complex and field survey Collected. The process of simulation and obtaining results in software is as follows: 1. Enter the climatic information of Tabriz; 2. Modeling; 3. Zoning interior spaces of the building; 4. Specify the use of the building (residential); 5. Enter fixed parameters -basic research model (number of people living in the building, executive details of the building, specifications of openings, lighting specifications, heating and cooling system of the building).

After entering the exact specifications of the building, the basic model of the research will be simulated and the amount of natural gas consumed will be received from the National Iranian Gas Company to validate the accuracy of the results obtained from the software. Then, using a genetic algorithm, the software randomly combines the different defined modes of each variable with other combinations of other variables. In addition, the simulation results are in fact case studies of the genetic algorithm with the lowest energy consumption. Finally, the results obtained, which is the amount of energy consumption were compared and analyzed. Also, an optimal model is proposed.

BASIC RESEARCH MODEL

The desired model of Narenjestan block is Aseman residential complex (Figure 1). The twin tower has 15 floors with ground floor and first and second basement (parking). The total area of the building is 1150 m^2. The ground floor consists of 6 residential units and floors 1 to 5 of each of twin towers, including 4 units (2 two-bedroom units with an area of 112 to 114.5 m^2 and 2 three-bedroom units with an area of 142 m^2) and floors 6 to 15 of each of twin towers include 2 units (2 two-bedroom units with an area of 112 to 114.5 m^2 and 2 three-bedroom duplex units with an area of 223 m^2).

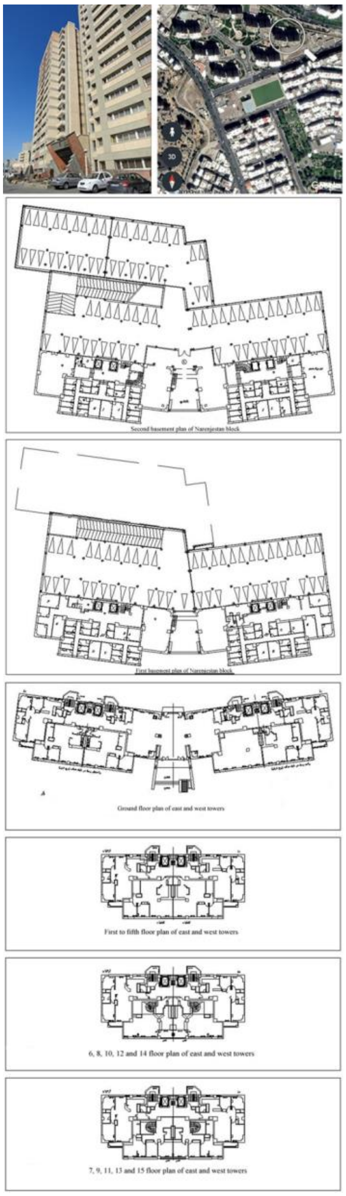


Figure 1. Aerial photo, image and plans and simulated image of Narenjestan block of Aseman residential complex of Tabriz (Source: Building Image: Researchers Field Survey, Aerial Photo: Google Earth Website, Simulated Image: Researchers, Plans: Northwest Housing Investment Group)

Reasons for choosing the basic research model

In addition to the problem of increasing energy consumption, two very important reasons have caused the mentioned building to be selected as a study sample:
1) Tabriz, more than other cities in the country, is witnessing the growing growth of high-rise residential complexes.
2) Field surveys and the opinions of the residents of the complex indicate a low temperature around the windows in winter.

Fixed parameters

The activity of people living in the location is considered light activity. The density of people is 16 square meters per person. The normal temperature is 18 degrees Celsius for winter and 25 degrees Celsius for summer and it is assumed that by reducing the ambient temperature from 12 degrees Celsius in winter, the mechanical heating system will start working. Execution details with the thickness of each component (meters), the heat transfer coefficient (U-Value) and thermal resistance (R-Value) are as follows:
- Exterior walls: concrete block (0.05m) + cement mortar (0.04m) + masonry block (0.28m) + cement mortar (0.04m) + gypsum plastering (0.02 m) + gypsum plasterboard (0.02m), (U-Value (Heat transfer

coefficient): 0.482 (w/m^{2}k)), (R-Value (Heat resistance): 2.074 (m^{2}k/w)).
- Interior walls: gypsum plasterboard (0.01m) + gypsum plastering (0.02 m) + masonry block (0.24m) + gypsum plastering (0.02 m) + gypsum plasterboard (0.01m), (U-Value (Heat transfer coefficient): 0.61 (w/m^{2}k)), (R-Value (Heat resistance): 1.64 (m^{2}k/w)).
- Internal floor: ceramic/clay tiles (0.01m) + cement mortar (0.02m) + concrete, medium density (0.05m) + concrete, reinforced (0.35m) + gypsum plastering (0.02 m) + gypsum plasterboard (0.01m), (U-Value (Heat transfer coefficient): 1.696 (w/m^{2}k)), (R-Value (Heat resistance): 0.589 (m^{2}k/w)).
- Flat roof: asphalt (0.02m) + bitumen/felt layers (0.03m) + cement mortar (0.02m) + concrete, reinforced (0.35m) + gypsum plastering (0.02 m) + gypsum plasterboard (0.01m), (U-Value (Heat transfer coefficient)t: 1.867 (w/m^{2}k)), (R-Value (Heat resistance): 0.536 (m^{2}k/w)).

In order to reduce the consumption of electrical energy, low-consumption LED lamps are used, which are of the hanging type and the radiant fraction of the lamps is 0.42 and its visible fraction is 0.18. The heating system is a central engine with a boiler and fan coil units will be used to distribute heat to different parts of the building. The efficiency of seasonal heating system is 0.83 and the maximum temperature and maximum humidity relative to the air that the system can supply, are equal to 35 degrees Celsius and 0.0156 gram to gram, respectively. The fixed parameters of the basic research model (window specifications) are presented in Table 1.

At this stage, after adapting the simulation results and the actual consumption of the building and converting the units and verifying the simulation results, the type of glass and the frame will be changed and the simulation will be performed again.

TABLE 1. Specifications of windows in the basic research model

Window specifications		Performance coefficient		Unit
Window to wall ratio	Elevation	Area	4147	m^2
	South windows	Area	1164	m^2
	North windows	Area	1188	m^2
	Wwr	Percentage	28	%
Sill	Height	Distance	0.8	m
Reveal	Outside Depth	Distance		m
Type of glazing	Clear double glazed filled with argon gas	U-Value (Heat transfer coefficient)	2.511	w/m^{2}k
Frame	Iron	U-Value (Heat transfer coefficient)	5.823	w/m^{2}k
	Width	Distance	0.08	m
	projection	Distance	0.02	m
Divider	Width	Distance	0.05	m

(Source: DesignBuilder software, 2020)

Variable parameters

The optimization of architectural variables is done by various methods (Table 2). Simulation can be examined in two methods, parametric and genetic algorithm, and the results compared in order to achieve objectives.

Parametric method

In this method, the research variables are simulated step by step to provide the optimal state in terms of minimum initial energy. By doing this for each variable, by keeping the first variable constant, the second variable is optimized and this process continues until the last research variable to consider the effect of each parameter. The types of glazing (with iron frame) selected for parametric optimization is presented:

1. Basic research model, Clear double glazing (6 mm + 13 mm argon gas + 6 mm)
2. Clear double glazing (6 mm + 6 mm argon gas + 6 mm)
3. Clear double glazing (6 mm + 20 mm argon gas + 6 mm)
4. Clear triple glazing (3 mm + 13 mm argon gas + 3 mm + 13 mm Argon gas + 3 mm)
5. Clear double glazing (6 mm + 13 mm 90% argon gas and 10% air + 6 mm)
6. Clear double glazing (6 mm + 13 mm 95% argon gas and 5% air + 6 mm)
7. Double glazing with a transparent glass and a glass of reflective coating (6 mm + 13 mm argon gas + 6 mm)
8. Double glazing with a transparent glass and a low emission coating glass e = 0.1 (6 mm + 13 mm argon gas + 6 mm)
9. Clear triple glazing (3 mm + 13 mm air + 3 mm + 13 mm air + 3 mm)

TABLE 2. Variable parameters of windows

Variable parameters	Range of changes
The distance between the glazing	6 mm
	13 mm
	20 mm
Number of glazing	2
	3
Gas between the glazing	Air
	90% Argon + 10% Air
	95% Argon + 5% Air
	Argon
	Krypton
	Xenon
Cover of glazing	Clear
	Low-Emissivity
	Reflective
	Tint-Reflective
Frame materials	UPVC
	Aluminium (with thermal break)

10. Clear triple glazing with low emission glass e = 0.1 (3 mm + 13 mm argon gas + 3 mm + 13 mm argon gas + 3 mm). Important properties of glass and frame are presented in the Table 3.

Genetic algorithm

Genetic algorithms are random search algorithms whose idea is derived from nature. In the genetic algorithm, the offspring genes inherit the parent gene and therefore will have some features of the father gene and some features of the mother gene in a new combination of different gene structures at random. However, this method, uses the best variables to achieve the best possible design for the early stages. But it takes the authority from the designer to use her analysis to determine which variable has the most impact and which has the least impact. Finally, the best combination for the structure of the new gene is selected.

However, this method is the best possible design for the early stages, out of a large number of integration modes using various variables. But it takes the authority from the designer to use her analysis to determine which variable has the most impact and which has the least impact. Therefore, by choosing the parametric method, the designer can combine the variables with her point of view and evaluate them. The types of glazing (with iron frame) selected for genetic algorithm is presented.

11. Double glazing with a transparent glass and a glass of gray reflective coating (6 mm + 13 mm argon gas + 6 mm)
12. Clear double glazing (6 mm + 13 mm krypton gas + 6 mm)
13. Clear double glazing (6 mm + 13 mm xenon gas + 6 mm)
14. Double glazing with a transparent glass and a low emission coating glass e = 0.1 (6 mm + 13 mm krypton gas + 6 mm)
15. Double glazing with a transparent glass and a low emission coating glass e = 0.1 (6 mm + 13 mm xenon gas + 6 mm)
16. Clear triple glazing (3 mm + 13 mm krypton gas + 3 mm + 13 mm krypton gas + 3 mm)
17. Clear triple glazing (3 mm + 13 mm xenon gas + 3 mm + 13 mm xenon gas + 3 mm)
18. Clear triple glazing with low emission glass e = 0.1 (3 mm + 13 mm krypton gas + 3 mm + 13 mm krypton gas + 3 mm)
19. Clear triple glazing with low emission single glazing e = 0.1 (3 mm + 13 mm xenon gas + 3 mm + 13 mm xenon gas + 3 mm)

Frames

20. Change the frame from iron (basic research model) to UPVC. [glazing: (6 mm + 13 mm argon gas + 6 mm)]
21. Change the framework from iron (basic research model) to thermal break aluminum [glazing: (6 mm + 13 mm argon gas + 6 mm)].

Important properties of glass and frame are presented in the Table 4.

Specifications intended for low-emissivity glazings in this research

Low-Emissivity glazings are glasses that have less heat transfer than ordinary glass and act as a thermal insulator. These glasses do not change the quality of the incoming light. The efficiency of these glasses depends on their normal emission coefficient. The efficiency of these glasses depends on their normal emission coefficient, and the lower this coefficient, the less infrared waves pass through them. The normal diffusion coefficient of ordinary glass is about 0.89, while this coefficient for Low-e glass is between 0.05 to 0.2 [18].

The main materials used on the surface of low-emission glass are metal oxides. In this research, the following materials are used on the glass surface and its specifications are as follows:

- Nio/Ag/Silica and Tantalum
- Transmittance rate: 0.698
- Reflectance rate: 0.88 [24].

TABLE 3. The type of glazing and frame selected and their properties for simulation and comparison

Type of glazing	DST	SHGC	T_v	U-Value
1	0.604	0.704	0.781	2.511
2	0.604	0.702	0.781	2.829
3	0.604	0.704	0.781	2.552
4	0.595	0.685	0.738	1.620
5	0.604	0.704	0.781	2.526
6	0.604	0.704	0.781	2.519
7	0.053	0.131	0.072	2.014
8	0.474	0.568	0.745	1.493
9	0.595	0.684	0.738	1.757
10	0.458	0.55	0.698	1.110

(Source: DesignBuilder software, 2020)

TABLE 4. The type of glazing and frame selected their properties for simulation and comparison

Type of glazing	DST	SHGC	T_v	U-Value
11	0.032	0.136	0.045	2.028
12	0.604	0.705	0.781	2.466
13	0.604	0.568	0.745	1.308
14	0.474	0.568	0.745	1.407
15	0.474	0.568	0.745	1.308
16	0.595	0.686	0.738	1.560
17	0.595	0.686	0.738	1.538
18	0.458	0.553	0.698	1.035
19	0.458	0.554	0.698	0.982
20	-	-	-	3.476
21	-	-	-	4.719

(Source: DesignBuilder software, 2020)

In order for low-emission glass to have the necessary effectiveness, it is necessary that the low-emission coating be placed on the surface shown in area with high heat requirements (cold regions) (See Figures 2 and 3).

RESULTS AND DISCUSSION

Simulation of basic research model

The image below shows a perspective of the Narenjestan twin tower of Aseman Tabriz residential complex in DesignBuilder software (Figure 4).

Results obtained from simulation of basic research model in DesignBuilder software

The results obtained from the simulation in Design Builder software are presented in following diagrams.

Figure 2. Low emission glass mechanism in winter and summer (The visible beam passes, the winter heat is reflected inside, the summer heat is reflected outside)

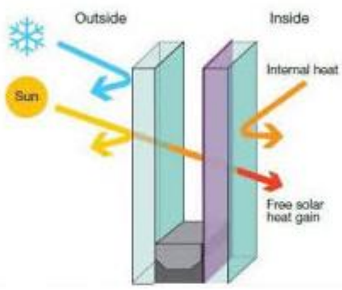


Figure 3. Location of low emission cover in cold regions [25]

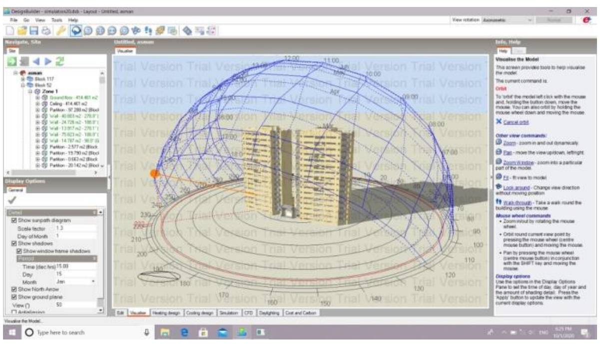
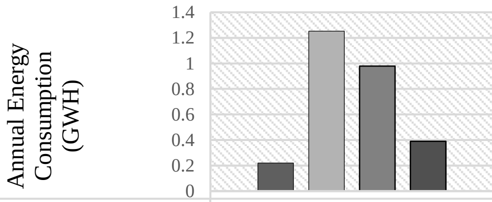


Figure 4. Simulated perspective of Narenjestan twin tower of Aseman residential complex of Tabriz (Source: DesignBuilder software, 2020)

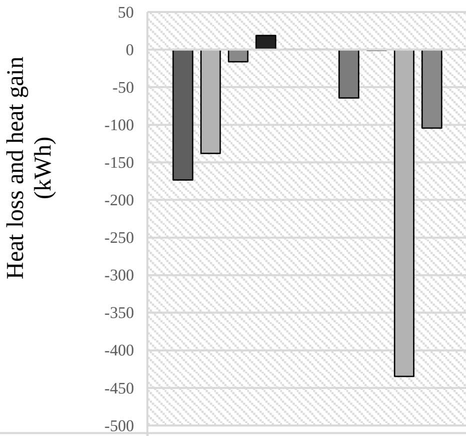
Diagram 1 shows annual energy consumption that indicates the high amount of natural gas consumption for heating the building.

Diagram 2 shows heat loss and gain from different parts of the building that indicates a very high heat loss from the translucent shells (windows).



Lighting	0.22
Heating (gas)	1.25219
Zone Sensible Heating	0.98
DHW (Electricity)	0.39

Diagram 1. Annual energy consumption (Source: DesignBuilder software, 2020)



Glazing	-173.52
Walls	-137.88
Ceilings (int)	-15.99
Floors (int)	18.64
Ground Floors	0.14
Partitions (int)	0.05
Roofs	-64.16
Floors (ext)	-1
External Infiltration	-434.63
External Vent	-104.19

Diagram 2. Heat loss and heat gain from different parts of the building (Source: DesignBuilder software, 2020)

Validation of the results obtained from the simulation of basic research model

In order to ensure the accuracy of the results obtained from the simulation of the building and their validation and verification, the amount of natural gas consumed annually in this building has been received from the

National Iranian Gas Company. Considering that the figures provided by the National Iranian Gas Company are in m^3 and the results obtained from the software are in kWh. Based on the following trend, the simulation results are converted from kWh to m^3.

1kWh = (4.005540202721551 e – 11) kg

(e = 2.7182818284590452353602874713526)

1kg = 1.39664804 m^3

Table 5 shows the figures provided by the National Iranian Gas Company in the mentioned time periods and also the figures obtained from the simulation of the basic research model.

At this stage, the figure obtained from the software (annual consumption) is converted from GWh to kWh and from kWh to m^3 according to the presented formulas to verify the verification of the figures obtained from the simulation.

TABLE 5. Gas consumption in the building

Validation of the results (Source: National Iranian Gas Company, 2020)		Simulation of basic research model (Source: DesignBuilder software, 2020)	
Building gas meter reading Time period	Figures recorded by gas meter (m^3)	Time period of simulation results	Figures obtained from simulation in software (MWH)
97/10/11 to 98/01/24	92076	January (97/10/11 to 97/11/11)	347.00
		February (97/11/12 to 97/12/09)	259.76
98/01/25 to 98/02/31	16550	March (97/12/10 to 98/01/11)	171.93
		April (98/01/12 to 98/02/10)	64.24
98/03/01 to 98/04/16	3585	May (98/02/11 to 98/03/10)	9.05
		June (98/03/11 to 98/04/09)	0.04
98/04/17 to 98/05/26	2951	July (98/04/10 to 98/05/09)	0.00
		August (98/05/10 to 98/06/09)	0.00
98/05/27 to 98/08/25	22869	September (98/06/10 to 98/07/08)	0.00
		October (98/07/09 to 98/08/09)	8.56
98/08/26 to 98/10/11	43044	November (98/08/10 to 98/09/09)	111.90
		December (98/09/10 to 98/10/10)	279.71
Annual	181075	Annual	1252.19

1kWh= 4.005540202721551* 2.7182818284590452353602874713526 – 11 = 0.11181286 kg

0.11181286 * 1.39664804 = 0.156163211

0.156163211 * 1252190 = 195546 m^3

According to the result obtained from the conversion of the unit, the actual annual consumption in the building is 181075 m^3 and the amount calculated by the software is 195546 m^3. the difference in values is 7.4%. This reflects the fact that DesignBuilder software calculates building energy consumption with acceptable accuracy.

In a study conducted by Neto and Fiorelli [26] in Brazil, they found that differences of up to 13% in experimental and simulation results were acceptable.

Results obtained from parametric optimization and genetic algorithm

Results obtained from the simulation in Design Builder software (which have been tested based on changing the glass and frame in the shells, Presented in the following tables.

Tables 6 and 7 show the amount of heat infiltration from external windows and the amount of annual gas consumption, respectively; In the basic research model (No. 1) and in other simulations performed. The results show this fact that if the glazing changed from clear double-glazed glazing filled with argon gas to triple glazed glazing with low emission coating filled with xenon gas, heat loss decreased by 48.21% and annual gas consumption Reduced by 8.94%. The tables show the fact that reflective coatings on the surface of the glass reduce the receipt of solar energy by 90.86% and therefore this type of glazing should not be used in cold climates.

Results analysis

Diagram 3 shows that if the distance between the double glazing is 13 mm, the heat loss compared to the other two cases (6 and 20 mm) will be at its lowest.

Diagram 4 shows it is better to replace gas between double glazed-glazing Instead of air or a combination of air and argon gas with argon, krypton or xenon gases and xenon gas is the most suitable type of gas between the glazing in order to reduce heat loss in winter. In addition to the above, Diagram 3 shows the optimization of the windows by replacing the triple glazing (3 mm glass thickness) with double glazing (6 mm glass thickness).

Another effective factor in reducing the amount of gas consumed in heating the building is the glazing coating. Diagram 5 confirms that in order to reduce heat loss, clear glass can be replaced with glass with low emission coating.

Sensitivity analysis

In order to investigate the effect of the variables introduced in Tables 3 and 4, sensitivity analysis has been used, which is the result of dividing the difference of the parameter changes by the maximum ratio.

$$\text{Sensitivity Index} = \frac{\text{Maximum}-\text{Minimum}}{\text{Maximum}} * 100$$

The simulation results show that the sensitivity index:
- By increasing the thickness between the double-glazed glazing from (6 mm + 6 mm argon gas + 6 mm) to (6 mm + 13 mm argon gas + 6 mm) the annual reduction of gas consumption is 2.3%.
- By changing the gas between the double-glazed glazing from (6 mm + 13 mm, 90% argon gas and air 10% + 6 mm) to (6 mm + 13 mm xenon gas + 6 mm), the annual reduction of gas consumption is 1.3%.

TABLE 6. Results obtained from parametric optimization

Type of glazing	Heat Loss (kWh)	Annual Gas Consumption for Heating (MWh)	Annual Solar Gains Exterior Windows (MWh)	Annual electricity consumed for cooling (MWh)
1	173.52	1252.19	437.58	110
2	191.22	1281.4	440	110
3	173.9	1245.28	437.58	110
4	128.12	1185.09	422.26	110
5	174.31	1253.45	437.58	110
6	173.92	1252.85	437.58	110
7	145.85	1382.61	40	60
8	115.57	1185.06	336.86	100
9	135.55	1198.88	422.26	110
10	97.34	1164.74	315.82	100

(Source: DesignBuilder software, 2020)

TABLE 7. Results obtained from Genetic Algorithm

Type of glazing	Heat Loss (kWh)	Annual Gas Consumption for Heating (MWh)	Annual Solar Gains Exterior Windows (MWh)	Annual electricity consumed for cooling (MWh)
11	146.66	1377.79	20	60
12	170.1	1240.62	437.58	110
13	168.79	1238.36	437.58	110
14	110.63	1162.64	336.86	100
15	106.71	1157.56	336.86	100
16	123.32	1172.18	422.26	110
17	122.37	1169.22	422.26	110
18	92.12	1144.72	315.82	100
19	89.88	1140.25	315.82	100
20	156.80	1237.81	435.88	110
21	163.94	1245.07	442.69	110

(Source: DesignBuilder software, 2020)

- By changing the glazing cover from clear double-glazed glazing (6 mm + 13 mm argon gas + 6 mm) to double-glazed glazing with low emission, the annual reduction of gas consumption is 5.4%.
- By changing the type of glass from double glazing (6 mm + 13 mm argon gas + 6 mm) to triple glazing (3 mm + 13 mm argon gas + 3 mm 13 mm argon gas + 3 mm), the annual reduction of gas consumption is 5.4%.

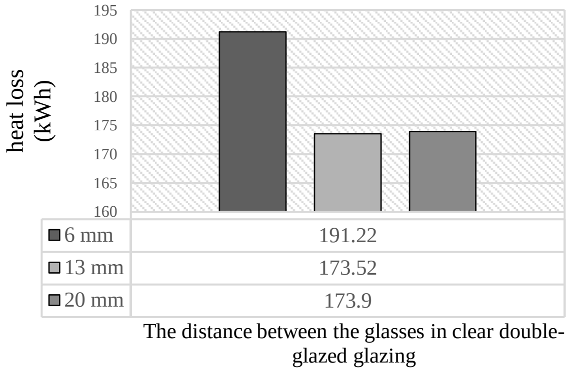


Diagram 3. The downward trend of heat leakage from windows as a result of the thickness change between the double-glazed glazing

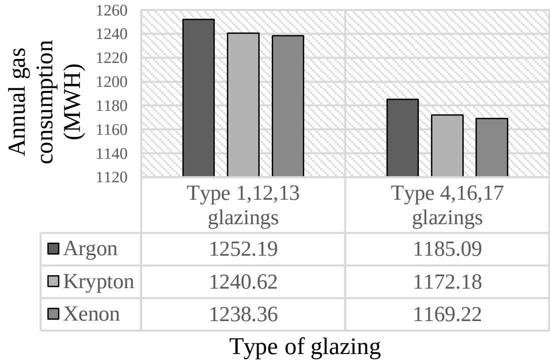


Diagram 4. The effect of changing double-glazed glazing to triple-glazed glazing (Source: DesignBuilder software, 2020)

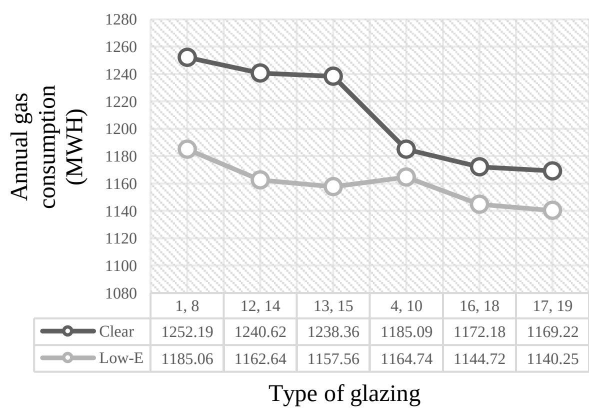


Diagram 5. Impact of changing the glazing cover (Source: DesignBuilder software, 2020)

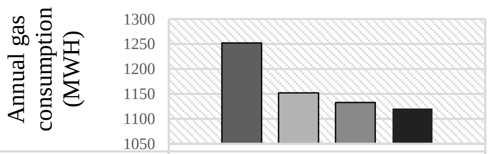
According to the results of sensitivity index analysis, Table 8 shows the similarities between the optimal results for the characteristics of window variables in the parametric method and the genetic algorithm.

Optimal models exposure

For optimization, triple-glazed glazing with low emission coating e = 0.1 filled with argon, krypton or xenon gas and UPVC frame are recommended. the Diagram 6 shows the annual gas consumption for heating in the basic research model and optimal models.

TABLE 8. Comparison of optimal variables for both parametric methods and genetic algorithms

Window variables	Parametric method	Genetic algorithm
Number of glazing	Double or triple-glazed glazing	Triple-glazed glazing
Gas between the glazing	Argon gas	Argon, Krypton or Xenon gas
Cover of glazing	Low-Emissivity	Low-Emissivity
The distance between the glazing	13 mm	
Frame materials	UPVC	



Clear double glazing (6 mm + 13 mm argon gas + 6 mm) & Iron frame	1252.19
triple glazing with low emission glass e = 0.1 (3 mm + 13 mm argon gas + 3 mm + 13 mm argon gas + 3 mm) & UPVC farme	1152.3
triple glazing with low emission glass e = 0.1 (3 mm + 13 mm krypton gas + 3 mm + 13 mm krypton gas + 3 mm) & UPVC farme	1132.67
triple glazing with low emission glass e = 0.1 (3 mm + 13 mm xenon gas + 3 mm + 13 mm xenon gas + 3 mm) & UPVC farme	1120.82

Diagram 6. Annual gas consumption in the basic research model and in the optimal models is proposed (Source: DesignBuilder software, 2020)

Results validation

In the validation of the results of the research, the method of comparing the simulation results of this research with previous researches have been used. Table 9 shows the similarity of the results with previous research which was done in cold and dry climate and similar to the climate of Tabriz.

TABLE 9. Previous research results and validation of current research results

Method	Results	Ref.
Building simulation	In cold climates that require predominant heating, the best option is to use triple-glazed glazing windows.	[27]
Descriptive-analytical & simulation	To reduce heat loss, it is better to use double or triple-glazed glazing	[28]
Analytical-comparative	Argon, krypton or xenon gas can be used between the glazing to reduce the heat transfer coefficient.	[29]
Analytical	The best type of glass for use in cold climates should have a low U-value of about 2 W/m^2k and a visible light transfer rate of approximately 0.7.	[30]

(Source: review and processing of research from writers)

CONCLUSIONS

Building shells play an effective role in reducing energy consumption because they are the boundary between the interior and exterior of the building. Window as one of the components of the outer shell of the building in terms of thermal energy loss is the weakest part of the building and if the necessary measures are not taken, it will cause problems such as heat loss, high heat in summer and rapid cooling of spaces in winter. Meanwhile, simulation software helps us to assess heat loss and increase the positive thermal performance of the building shell.

In this paper, the effect of the type of glazing on heat loss, annual heating demand and annual solar energy received in the cold climate of Tabriz was investigated. According to the simulations, in order to optimize the translucent shells to reduce energy consumption for heating the building. The following suggestions are presented:

- Replacing triple-glazed glazing with low coating e = 0.1 (3 mm + 13 mm xenon gas + 3 mm + 13 Mm xenon gas + 3 mm) and UPVC frame with current windows (clear double-glazed glazing filled with argon gas and iron frame) reduces heat loss by 56.60% and annual gas consumption by 10.49%.

Xenon gas is expensive but considering the price of energy, the time required to return the initial investment is short and it will bring significant benefits at the national level. what seems to be fruitful is the implementation of subsidy policies on construction materials. in this way, the government will encourage the consumer by accepting part of the costs of optimizing fuel consumption in the building. Also, financial support, advice and information on the construction of buildings with lower energy consumption, will attract public interest in the construction of energy efficient buildings.

Argon or krypton gas should be used if the cost of running with xenon gas between the triple-glazed glazing is high.

By replacement triple-glazed glazing with low emission coating e = 0.1 (3 mm + 13 mm argon gas + 3 mm + 13 mm argon gas + 3 mm) and UPVC frame with current windows (clear double-glazed glazing filled with argon gas and iron frame) reduces heat loss by 52.43% and annual gas consumption by 7.97%.

By replacement triple-glazed glazing with low emission coating e = 0.1 (3 mm + 13 mm krypton gas + 3 mm + 13 mm krypton gas + 3 mm) and UPVC frame with current windows (clear double-glazed glazing filled with argon gas and iron frame) reduces heat loss by 55.34% and annual gas consumption by 9.54%.

The results obtained from the simulation in the field of the amount of solar energy received annually, show the fact that in the residential buildings of Tabriz, clear glass or glass with low emission coating should be used and reflective coating glass should not be used. reflective coating is more suitable for use in areas where cooling is predominant and the annual electricity consumption for cooling spaces is reduced by 45% and 40%, respectively, compared to clear and low-emission glazing.

The limitations of this research with respect to software limitations and other dependent or influential variables in the research are as follows:

Optimization results in the parametric method Since it optimizes only one variable and then goes to the next variable, it cannot simulate all the combined states of the variables and report the results.

The results of optimizing the architectural variables resulting from the genetic algorithm and random selection by this algorithm in the first generations as parents of the next generations, lead to a variety of answers that, although it has the best performance of its kind, may not be the best possible solution.

- Due to the parametric optimization method and genetic algorithm for comprehensiveness and completeness require time and strong computer hardware to perform, it is necessary to simplify computational models by considering the assumptions that meet the computational conditions and Performs less accurately than reality.

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Persian Abstract

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چکیده

طبق آمار ارائه‌شده از طرف مرکز آمار ایران، ۴۰٪ از مصرف انرژی، مربوط به بخش مسکن است. پنجره‌ها به عنوان یکی از اجزای جداره‌های خارجی، مسئول ۲۰-۳۰٪ از اتلاف انرژی هستند. بنابراین، هدف از این پژوهش، بهینه سازی پنجره‌های بناهای مسکونی در اقلیم سرد تبریز در راستای کاهش مصرف انرژی می‌باشد. روش تحقیق، مبتنی بر شبیه‌سازی با دو روش «بهینه‌سازی پارامتریک» و «الگوریتم ژنتیک» و ابزار تحقیق نرم افزار دیزاین بیلدر می‌باشد. بنابراین، میزان گاز مصرفی سالانه در بنای مورد مطالعه، از شرکت ملی گاز ایران دریافت و سپس مدل پایه تحقیق در نرم‌افزار مدل‌سازی شده و پس از تبدیل واحد ازکیلووات‌ساعت به مترمکعب و اعتبارسنجی نتایج بدست آمده ازشبیه‌سازی، در مرحله بعد، نوع شیشه و چهارچوب تغییر داده شده و سپس با دو روش مذکور، مورد بررسی و تحلیل حساسیت قرار می‌گیرند. نتایج یافته‌ها نشان می‌دهد با جایگزینی پنجره‌های با شیشه سه‌جداره با پوشش کم‌گسیل روی شیشه داخلی پرشده با گاز آرگون، کریپتون و زنون و چهارچوب یوپی‌وی‌سی با شیشه دوجداره شفاف پرشده با گاز آرگون و چهارچوب آهنی، گاز مصرفی سالانه جهت گرمایش به ترتیب به میزان ۵۲/۴۳٪، ۵۵/۳۴٪ و ۵۶/۶٪ و اتلاف حرارت از پنجره‌ها نیز به ترتیب به میزان ۷/۹۷٪، ۹/۵۴٪ و ۱۰/۴۹٪کاهش می‌یابد.