An Optimal Model for Designing and Executing Windows in Tabriz Residential Buildings to Reduce Energy Consumption

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INTRODUCTION

According to the literature, 78% of the world’s energy consumption is depending on fossil fuels [1]. Based on implemented researches, buildings consume about 40% of the total ultimate fossil fuel [2]. Residential energy consumption represents more than a quarter of building fossil fuel consumption [3]. However, the thermal performance of glazing systems is generally very poor due to the large heat transfer coefficient and small thermal mass [4]. Besides, the cold and dry climate of Tabriz needs high energy consumption...
for heating. Diverse researches have been done in the field of optimal proportions for designing windows which are provided based on historical concepts. Zekraoui and Zemmouri [5] investigated the effect of window specifications on the building energy demand. Results show that orientation had a large effect on the energy loads.

Lechoweska et al. [6] centralized on the window frames. Simulated results show that the air gap filling with polyurethane foam in window frames can reduce heat loss of frames by about 27%.

Khalesi and Goudarzi [7] assessed smart windows. It can be concluded from the results that substitution of clear glazing with smart electrochromic glazing; window-to-wall ratio (WWR) can be an enhancement.

Hasan et al. [8] focused on building simulation. They came to the conclusion that WWR should be determined based on its floor area.

Potrc et al. [9] studied the best orientation of windows. South front, with a swirl of about 1-24 degrees, is suitable for the windows to get maximum availability to solar energy.

Kaasalainen et al. [10] focused on the architectural window design. They concluded from the outputs that increasing window size on average also increased energy consumption, especially in cold conditions.

Zhou and Zheng [11] studied aerogel glazings and found that the aerogel granulate glazing systems can reduce heat flux.

Abdoli Naser et al. [12] studied the optimal execution model for windows. For optimization, triple-glazed glazing with low emission coating $e = 0.1$ is recommended.

Saadatian et al. [13] investigated window systems and found that winter-appropriate glass is triple-glazed glazing.

Jiang et al. [14] assessed residential energy consumption in cold climates. Results indicated that the north WWR of the residence should not be less than 0.1.

Sadafi et al. [15] concentrated on the optimization of building envelopes. It can be concluded from the results that the larger WWRs improve factors such as view and natural lighting. On the other hand, the smaller WWRs, address privacy and energy saving.

Abdoli Naser et al. [16] assessed on the thermal performance of windows in intermediate housing. They found that the gas consumption is reduced if the WWR decreased from 50% to 20%.

Huang et al. [17] concentrated on vacuum glazing. They concluded from the outputs that vacuum glazings save more energy consumption in terms of heating and cooling load.

Tushar et al. [18] studied the window systems. Analysis specifies the provision of glazing 40-68% of WWR feasible for optimal trade-offs.

Abdoli Naser et al. [19] studied on the evolution of windows from Qajar to Pahlavi era. They concluded from the outputs that by minimizing the area of the openings (WWR), the amount of heat transfer during the cold winter of Tabriz is reduced.

Bagheri Sabzevar and Erfan [20] investigated on effect of shading devices on thermal efficiency and found that in terms of thermal efficiency, the distance between the blinds on the south facade and the angle between them on the east and west facades of a window louver are the most significant factors.

The contents show this fact; research about windows; fundamentally is about suitable orientation for windows, the better location of the window in building facades, and the ratio of the total area of the window to the shell. The discrepancy and innovation of the present research can be intended in the assessment of the impact of window proportion, a number of windows by considering a fixed area (total area-fixed-for window- (fixed WWR)) and the number of glazings, coating, the gas between glazing of windows on the quantity of heat dissipation in the translucent walls of the residential buildings and annual natural gas consumed for heating.

So, the aim of this research is to provide adequate proportion and glazing for windows in Tabriz residential buildings to decrease energy consumption.

**RESEARCH METHODOLOGY**

The work is based on the objectives of the research, of the type of "application" and also based on the nature. This is "simulation" and will be based on logical reasoning. The research method is quantitative. The statistical society is a residential building in Tabriz and the objective society is the gas consumption for heating the building. The autonomous variable of the research will be different window proportions of design models and the affiliate variable will be the amount of natural gas and annual electricity consumptions for heating and cooling the building.

The first action in this research procedure is collection of data. Climatic data of Tabriz city has been received from Tabriz Meteorological Department and building physics data such as plan and HVAC system, building facade by field survey in the building; collected. The proceeding of simulation in EnergyPlus engine and gaining results in the DesignBuilder software is as follows:

1. Entering the climatic data of Tabriz (The average climate of 11 years);
2. 3-D modeling of the building;
3. Enter fixed specifications of the building (executive details, windows specifications, HVAC system).

After importation of the fixed specifications of the basic research model and it’s simulation on the EnergyPlus engine, the amount of gas used for heating will be received from the National Iranian Gas Company to Reliability the accuracy of the results obtained from the
DesignBuilder software. Then, the form and number of windows (fixed area for the windows) will be changed and the building simulation will be executed according to the mentioned changes. Figure 1 shows the implementation model of the research.

Reason for choosing DesignBuilder software
A building energy simulation technique using DesignBuilder software (EnergyPlus simulation engine) will be used to estimate heating, cooling, and total energy requirements. The simulated daily consumption compared better with daily measured consumption. The maximum error is about 5% in cooling load and 3% in heating load [21]. For the above reason, this software has been selected for simulation.

Average climate of Tabriz (11-years)
The average minimum, average and maximum air temperature of Tabriz Synoptic Station in the statistical period of 2009-2020 on a monthly time scale are presented in Figure 2.

Basic research model
In order to study and test the research variables, it is necessary to simulate the model to measure the impact of variables. The simulated model is located in Tabriz (Figure 3). The model is a residential building and has a rotation of 35 degrees to the southwest as can be seen in Figure 3. The building is located on a plot of land with an area of 420 m². The building has an area of 237.5 m².

![Figure 1. The applied process of research (Source: Authors)](image)

![Figure 2. Average of minimum, average, and maximum air temperature in the statistical period of 2009-2020 in Tabriz (Source: Tabriz Meteorological Department, 2021 [22])](image)

![Figure 3. Basic research model (Source: Authors)](image)

SIMULATION OF BASIC RESEARCH MODEL

Modeling
Figures 5 and 6 show the perspectives of the building which is modeled in DesignBuilder.

Fixed parameters
The fixed specifications of the building are provided in Table 1.

![Figure 4. (a) Aerial photograph (Source: Google Earth, 2020 [23]); (b) Plan (Source: Authors)](image)
Table 1. Characteristics of basic research model (input data related to intervention variables)

| Specifications (Input Data) | Performance Coefficient |
|-----------------------------|-------------------------|
| Number of residents         | 4                       |
| Density of People (m² per person) | 16                     |
| Exterior Walls              |                         |
| Travertine stone (0.015 m) + Cement mortar (0.02 m) + Brick (0.15 m) + Gypsum plastering (0.015 m) | U-Value (W/m²K) (Heat Transfer Coefficient) 2.270 |
|                            |                         |
|                           | R-Value (m²K/W) (Heat Resistance) 0.440 |
| Interior Walls             |                         |
| Gypsum plastering (0.01 m) + Brick (0.08 m) + Gypsum plastering (0.01 m) | U-Value 2.239 |
|                            |                         |
|                           | R-Value 0.447           |
| Internal Floor             |                         |
| Parquet (0.025 m) + Foam under parquet (0.025 m) + Gypsum and cement mixture (0.03 m) + Cement mortar (0.02 m) + Lightweight concrete (0.1 m) | U-Value 0.919 |
|                            |                         |
|                           | R-Value 1.088           |
| Flat Roof                  |                         |
| Bitumen/felt layers (0.05 m) + Cement mortar (0.02 m) + Light concrete (0.05 m) + Brick (0.06 m) + Beam (0.02 m) + Cement mortar (0.03 m) + Gypsum plastering (0.02 m) | U-Value 1.363 |
|                            |                         |
|                           | R-Value 0.734           |
| Frames                     | Aluminium               |
|                            | U-Value 5.876           |
|                            | R-Value 0.170           |
| Dividers                   |                         |
| Width                      |                         |
|                            | Distance (m) 0.08       |
|                            |                         |
|                            | Projection (m) 0.01     |
| Type of Glazing            | Clear double glazing (6 mm + 13 mm Air + 6 mm) |
|                            | SHGC (Solar Heat Gain Coefficient) 0.706 |
|                            | T_v (Visible Transmittance) 0.781 |
|                            | DST (Direct Solar Transmission) 0.604 |
| Elevation                  | Area (m²) 56            |
| South Windows              | Area (m²) 10.5          |
| North Windows              | Area (m²) 4.5           |
| WWR                        | Percentage (%)          |
|                           | 8.04 % (North)          |
|                           | 18.75 % (South)         |
| Sill                       | Height (m) 0.8          |
| Reveal                     | Outside Depth (m) 0.1   |
| Heating System             | System Type Convection – Central Engine Natural Gas |
| Fuel Type                  | Maximum amount of moisture that can be provided by the system 0.016 |
| Heat Distribution Units    | Radiator                |
| Fluid type                 | Maximum temperature that can be provided by the system (C) 35 |
| Lighting                   | Suspended LED           |
|                            | Radiant Fraction 0.420  |
|                            | Visible Fraction 0.180  |
| Cooling                    | Cooler (Electricity - Inverter) |
|                            | COP (Coefficient of Performance) 4.5 |

(Source: DesignBuilder software, 2020)
**Variable parameters in parametric optimization**

At this stage, after adapting the simulation results and the real consumption of the building, the form of designing the windows (Proportions and number of windows with the fixed area) will be changed and the simulation will be performed again. Variable parameters for re-simulation in parametric optimization are presented in Table 2.

### Table 2. Variable parameters (resize and changing the number of windows) for re-simulation

| Design Form | Different Window Designs on Different Fronts | Number of Windows on Different Fronts of the Building Shell | Dimensions of Windows (m²) | Distance Between the Windows in Each Part of the Façade (m) |
|-------------|---------------------------------------------|-------------------------------------------------------------|-----------------------------|----------------------------------------------------------|
| 1 (Basic Research Model) | ![North](1.png) ![South](1.png) | North: 1 1.2 * 1.5 | | |
| | | South: 2 1.2 * 2.5 | | |
| | | North: 1 1.2 * 3.75 | | |
| | | South: 1 1.2 * 3.75 | | |
| 2 | ![North](2.png) ![South](2.png) | North: 1 1 * 3 | | |
| | | South: 2 1 * 3 | | |
| | | North: 1 1 * 4.5 | | |
| | | South: 1 1 * 4.5 | | |
| 3 | ![North](3.png) ![South](3.png) | North: 1 1.5 * 2 | | |
| | | South: 2 1.5 * 2 | | |
| | | North: 1 1.5 * 1 | | |
| | | South: 1 1.5 * 1 | | |
| 4 | ![North](4.png) ![South](4.png) | North: 1 1.74 * 1.74 | | |
| | | South: 2 1.74 * 2.59 | | |
| | | North: 1 1.74 * 1.74 | | |
| | | South: 1 1.74 * 1.74 | | |
| 5 | ![North](5.png) ![South](5.png) | North: 2 1.5 * 1 | 0.5 | |
| | | South: 4 1.5 * 1 | 0.5 | |
| | | North: 1 1.5 * 1 | | |
| | | South: 2 1.5 * 1.5 | 0.5 | |
| 6 | ![North](6.png) ![South](6.png) | North: 3 1.5 * 0.67 | 0.5 | |
| | | South: 1 1.5 * 1 | | |
| | | North: 6 1.5 * 0.67 | 0.5 | |
| | | South: 3 1.5 * 1 | 0.5 | |
| 7 | ![North](7.png) ![South](7.png) | North: 4 1.5 * 0.5 | 0.25 | |
| | | South: 8 1.5 * 0.5 | 0.25 | |
| | | North: 1 1.5 * 0.5 | | |
| | | South: 4 1.5 * 0.75 | 0.25 | |
| 8 | ![North](8.png) ![South](8.png) | North: 5 1.5 * 0.4 | 0.25 | |
| | | South: 1 1.5 * 0.4 | 0.25 | |
| | | North: 10 1.5 * 0.6 | 0.25 | |
| | | South: 5 1.5 * 0.6 | 0.25 | |

(Source: Authors, DesignBuilder software, 2020)
Reasons for selecting variable parameters (window proportions) in parametric optimization

The proportions presented in Table 2 for windows have been selected as variable parameters for the following reasons:
- Due to the aesthetics of the building facade, the least height for the window is equal to 1.2 meters and due to the difficulty of implementing high-height windows, the greatest height for the window is 1.74 meters. So, the suggested height for the windows is in the range of 1.2 to 1.74 meters.
- The number of windows has been increased from one window to five, taking into account the total fixed area, to examine the effect of increasing the number of windows on the amount of solar energy received.

Variable parameters in genetic algorithm

Genetic algorithms are incidence search algorithms whose base is taken from nature. In this algorithm, the offspring genes inherit some aspects of the father and some aspects of the mother gene in a new complex of different gene structures at incidence. In this method, the variables will be randomly selected and simulated. The types of glazing (with aluminium frame) and frame selected for the genetic algorithm are presented in Table 3.

1. Clear double-glazed glazing (6 mm + 13 mm Air + 6 mm)
2. Clear double-glazed glazing (6 mm + 13 mm Argon gas + 6 mm)
3. Clear double-glazed glazing (6 mm + 13 mm Argon gas and 10% Air + 6 mm)
4. Reflective double-glazed glazing - Tint - (6 mm + 13 mm Argon gas + 6 mm)
5. Clear triple-glazed glazing (3 mm + 13 mm Argon gas + 3 mm + 13 mm Argon gas + 3 mm)
6. Low emissivity triple-glazed glazing e = 0.1 (3 mm + 13 mm Argon gas + 3 mm + 13 mm Argon gas + 3 mm)
7. Change the frame from aluminium (basic research model) to UPVC. (glazing: (6 mm + 13 mm Air + 6 mm)).

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

| Type of Glazing & Frame | DST | SHGC | Tᵢ | U-Value |
|-----------------------|-----|------|-----|---------|
| 1                     | 0.604 | 0.706 | 0.781 | 2.665   |
| 2                     | 0.604 | 0.704 | 0.781 | 2.511   |
| 3                     | 0.604 | 0.704 | 0.781 | 2.526   |
| 4                     | 0.119 | 0.242 | 0.163 | 2.268   |
| 5                     | 0.595 | 0.685 | 0.738 | 1.620   |
| 6                     | 0.458 | 0.579 | 0.698 | 1.058   |
| 7                     | -    | -    | -    | 3.476   |

(Source: DesignBuilder software, 2020)

Low-emissivity glazing specifications intended for this research

Low-emissivity (Low-E) glazing was created to minimize the amount of infrared and ultraviolet light that comes from glass, without minimizing the amount of light that enters the home. Low-E coatings minimize heat loss by reflecting back thermal energy which is in the form of long-wavelength radiation back into a building and trap the heat inside. This is favorable for cold conditions. Low-E glazing windows have a microscopically thin coating that is transparent and reflects heat. Transmission and reflectance of Low-E glazing is shown in Figure 7.

It is better that the low-E coating is placed on the surface shown in Figure 8. The cross-section perspective of frames is presented in Figure 9.

RESULTS OBTAINED FROM SIMULATION OF BASIC RESEARCH MODEL IN DESIGNBUILDER SOFTWARE

Table 4 indicates the results of simulation in the DesignBuilder software.

Validation of results obtained from simulation

In order to ensure the exactitude of software results and their reliability, the natural gas amount consumed for...
heating in the building understudy has been attained from the National Iranian Gas Company. As respects that the figures presented by the Gas Company are in m³ and the software outputs are in kWh; with the following process, the software results are converted from kWh to kg and then kg to m³. The heating value of natural gas is 22500 Btu/lb (5225 kJ/kg). Based ideal gas law, assume natural gas is mainly contained methane; 1 kg of natural gas at standard conditions have volume of 1.3966 m³.

Table 5 indicates the results presented by the National Iranian Gas Company in 11-years (average) and also the simulation outputs of the building.

By reference to the result gained from the conversion of the unit, the actual average annual building consumption is 7590 m³ and the amount received by the EnergyPlus engine is 8300 m³. the discrepancy in values is 8.56%. This indicates that DesignBuilder software computes the gas consumption of building with allowable precision.

Results obtained from parametric optimization

Results obtained from the simulation in DesignBuilder software (which has been tested based on changing form of windows), Presented in Table 6. It shows the fact that by changing the design form of windows with the total fixed area of windows in the building, the amount of energy consumption changes.

Table 7 shows the graphically of light coming in from the windows (daylighting) and indicates that the height of 1.5 to 1.74 meters is the most suitable height for the window in terms of sunlight entering the interior. In addition to the above, increasing the number of windows with a total fixed area reduces the entry of sunlight into the interior during the day.

### Table 4. Simulation results

| Simulation results (kWh)                  |
|------------------------------------------|
| Heat loss                                | 24.74 |
| Heating (gas)                            | 53147.76 |
| Lighting                                | 2083.5 |
| Computer & Equip                        | 2836.75 |
| DHW (Electricity)                       | 17715.92 |
| Zone Sensible Heating                    | 34428.18 |
| Cooling (Electricity)                    | 1231.08 |

(Source: DesignBuilder software, 2020)

### Table 5. Building gas consumption

| Validation of the Results, Average Annual Gas Consumption - m³ (11-Year Average) | Simulation of Basic Research Model Based on Average Climate of Tabriz - kWh (11-Years) |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 7590                                                                            | 53147.76                                                                         |

(Source: National Iranian Gas Company, 2020) (Source: Design Builder Software, 2020)

### Table 6. Results obtained from simulation in software based on fixed and variable parameters

| Design Form | Heat Loss from Windows (Wh) | Annual Gas Consumption for Heating (kWh) | Annual Electricity Consumed for Cooling (kWh) | Annual Electricity Consumed for Lighting (kWh) | Annual Solar Gains Exterior Windows (kWh) |
|-------------|------------------------------|------------------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------|
| 1           | 970                          | 53147.76                                 | 1231.08                                       | 2083.50                                       | 4329.68                                   |
| 2           | 980                          | 53290.10                                 | 1225.31                                       | 2099.60                                       | 4136.77                                   |
| 3           | 960                          | 53079.25                                 | 1231.05                                       | 2025.03                                       | 4367.68                                   |
| 4           | 960                          | 53073.30                                 | 1231.02                                       | 2003.25                                       | 4383.32                                   |
| 5           | 990                          | 53529.82                                 | 1197.69                                       | 2153.21                                       | 3458.85                                   |
| 6           | 1020                         | 53823.49                                 | 1169.20                                       | 2214.87                                       | 2785.78                                   |
| 7           | 1050                         | 54159.56                                 | 1140.15                                       | 2307.54                                       | 2049.02                                   |
| 8           | 1080                         | 54453.99                                 | 1115.70                                       | 2388.96                                       | 1414.74                                   |

(Source: DesignBuilder software, 2020)
Table 7. Solar gains exterior windows

| Design Form | Solar Gains Exterior Windows | Lux |
|-------------|------------------------------|-----|
|             | North Front of the Building |     |
|             | South Front of the Building |     |
| 1           | ![Image 1](image1.png)       |     |
| 2           | ![Image 2](image2.png)       |     |
| 3           | ![Image 3](image3.png)       |     |
| 4           | ![Image 4](image4.png)       |     |
| 5           | ![Image 5](image5.png)       |     |
| 6           | ![Image 6](image6.png)       |     |
| 7           | ![Image 7](image7.png)       |     |
| 8           | ![Image 8](image8.png)       |     |

(Source: DesignBuilder software, 2020)
Results obtained from genetic algorithm
Results obtained from the simulation in Design Builder software (which has been tested based on changing the glazings), provided in the Table 8.

Results analysis
Figure 10 indicates the ascending trend of heat loss from windows based on increasing the number of windows (with the total fixed area). Due to the cold climate of Tabriz, forms 3 and 4 (See Table 4) are the best design to decrease the amount of heat leakage from the windows, and Figure 11 shows a comparison of the monthly gas consumption for heating the building in simulated designs. Due to the cold climate of Tabriz, forms 3 and 4 are the most suitable design form, and form 8 is the most unsuitable form to reduce the amount of gas consumed for heating.

Figure 12 shows descending trend of heat loss from windows based on changing the glazing, and figure 13 indicates a 7.21% reduction in heat loss by changing the window frame (considering the same glass).

Results index (sensitivity index)
In order to investigate the impact of the variables presented in Tables 2 and 3, results from index analysis has been used.

\[ \text{Index} = \frac{\text{Maximum} - \text{Minimum}}{\text{Maximum}} \times 100 \]  

Table 8. Results obtained from simulation in software based on fixed and variable parameters

| Type of glazing & frame | Heat Loss from Windows (Wh) | Annual Gas Consumption for Heating (kWh) | Annual Electricity Consumed for Cooling (kWh) | Annual Electricity Consumed for Lighting (kWh) | Annual Solar Gains Exterior Windows (kWh) |
|-------------------------|----------------------------|-----------------------------------------|---------------------------------------------|---------------------------------------------|-------------------------------------------|
| 1                       | 970                        | 53147.76                                | 1231.08                                     | 2083.50                                     | 4329.68                                   |
| 2                       | 930                        | 53121.37                                | 1229.51                                     | 2088.31                                     | 4291.72                                   |
| 3                       | 940                        | 53129.20                                | 1229.51                                     | 2088.31                                     | 4291.72                                   |
| 4                       | 790                        | 54340.35                                | 1102.78                                     | 5083.25                                     | 226.03                                    |
| 5                       | 700                        | 52760.56                                | 1199.87                                     | 2102.35                                     | 4135.99                                   |
| 6                       | 530                        | 52643.54                                | 1204.59                                     | 2451.33                                     | 3091.42                                   |
| 7                       | 900                        | 53094.47                                | 1230.61                                     | 2083.50                                     | 4329.68                                   |

(Source: DesignBuilder software, 2020)

Figure 10. Heat loss from windows (Source: Authors, DesignBuilder software, 2020)

Figure 11. Monthly gas consumption (Source: Authors, DesignBuilder software, 2020)
Table 9. Results index based on variables

| Variables                      | Window height (m) | Window proportions (m²) | Percentage decrease (↓) - increase (↑) in heat loss (%) | Percentage decrease (↓) - increase (↑) in the amount of solar energy received annually (%) | Percentage decrease (↓) - increase (↑) in annual electricity consumption for cooling (%) | Percentage decrease (↓) - increase (↑) in annual electricity consumption for lighting (%) |
|--------------------------------|-------------------|-------------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Changing window proportions   |                   |                         |                                                          |                                                                                         |                                                                                        |                                                                                       |
|                                | 1.2               | 1.2 * 2.5               | -                                                       | -                                                                                       | -                                                                                       | -                                                                                       |
|                                | 1                 | 1 * 3                   | 1.021 % ↑                                               | 4.46 % ↓                                                                                | 0.47 % ↓                                                                                | 0.77 % ↑                                                                               |
|                                | 1.5               | 1.5 * 2                 | 1.031 % ↓                                               | 0.87 % ↑                                                                                | 0.003 % ↓                                                                               | 2.81 % ↓                                                                               |
|                                | 1.74              | 1.74 * 1.74             | 1.031 % ↓                                               | 1.23 % ↑                                                                                | 0.005 % ↓                                                                               | 3.86 % ↓                                                                               |
| Changing number of windows     |                   |                         |                                                          |                                                                                         |                                                                                        |                                                                                       |
|                                | 1                 | 2 * 1.5                 | -                                                       | -                                                                                       | -                                                                                       | -                                                                                       |
|                                | 2                 | 1 * 1.5                 | 3.031 % ↑                                               | 20.81 % ↓                                                                               | 2.71 % ↓                                                                                | 5.96 % ↑                                                                               |
|                                | 3                 | 0.67 * 1.5              | 5.89 % ↑                                               | 36.22 % ↓                                                                               | 5.03 % ↓                                                                                | 8.58 % ↑                                                                               |
|                                | 4                 | 0.5 * 1.5               | 8.58 % ↑                                               | 53.09 % ↓                                                                               | 7.39 % ↓                                                                                | 12.25 % ↑                                                                               |
|                                | 5                 | 0.4 * 1.5               | 11.11 % ↑                                              | 67.61 % ↓                                                                               | 9.37 % ↓                                                                                | 15.24 % ↑                                                                               |
| Changing the type of glazing and frame |                   |                         |                                                          |                                                                                         |                                                                                        |                                                                                       |
| Glazings                       |                   |                         |                                                          |                                                                                         |                                                                                        |                                                                                       |
|                                | 1                 | -                       | -                                                       | -                                                                                       | -                                                                                       | -                                                                                       |
|                                | 2                 | 4.12 % ↓                | 0.87 % ↓                                               | 0.12 % ↓                                                                                | 0.23 % ↑                                                                                |                                                                                        |
|                                | 3                 | 3.09 % ↓                | 0.87 % ↓                                               | 0.12 % ↓                                                                                | 0.23 % ↑                                                                                |                                                                                        |
|                                | 4                 | 18.55 % ↓               | 94.77 % ↓                                              | 10.42 % ↓                                                                               | 59.01 % ↑                                                                               |                                                                                        |
|                                | 5                 | 27.83 % ↓               | 4.47 % ↓                                               | 2.53 % ↓                                                                                | 0.89 % ↑                                                                                |                                                                                        |
|                                | 6                 | 45.36 % ↓               | 28.59 % ↓                                              | 2.15 % ↓                                                                                | 15 % ↑                                                                                  |                                                                                        |
| Frames                         | 7                 | 7.21 % ↓                | -                                                      | 0.04 % ↓                                                                                | -                                                                                       |                                                                                        |

(Source: Authors)

**CONCLUSIONS**

The main target of this research was to ameliorate the decision-making process in the residential building design and execution in a cold climates. The most impressive decisions for the building design process are taken in this step to develop environmentally responsive objectives. Due to the fact that Building facades play an
effective role in reducing natural gas and electricity consumption because they are the boundary between the interior and exterior of the building and considering that about a third of the heat loss of buildings from windows occurs and if the serious mensuration is not taken, it will afford heat dissipation. So, efforts to decrease energy consumption in residential buildings are focused. Therefore, the research objective was accessing the suitable model of fenestration pattern by using parametric optimization and genetic algorithm. Meanwhile, DesignBuilder software facilitates to assessment of heat dissipation of different sections of the building.

In accordance with the gained outputs, the third and fourth design type and triple-glazed glazing with Low-E coating filled with argon gas and UPVC frame are the best types of window design and performance to diminution window heat dissipation, decrease gas consumption and reduce CO₂ emissions. Therefore, to reconsider the design and execution of windows and reduce fossil fuel consumption, the following offers are presented in window design and performance in the building facades:
- By changing the height of the window from 1 meter to 1.5 meters, heat loss is reduced by 2.04% per hour.
- By changing the number of windows from one window to two windows (with the equal total area), heat loss increased by 3.03%, and by changing the number of windows from one window to five windows, the amount heat losses increased by 11.11% per hour.
- Changing the height of the window from 1 meter to 1.74 meters increases the solar energy rate received annually by 5.62%.
- Changing the number of windows (from one window to five windows with the equal area) reduces the amount of solar energy received annually by 67.61%.
- Considering the fixed area, windows with a height of 1.5 to 1.74 meters should replace windows with a height of 1 or 1.2 meters.
- By replacing triple-glazed glazing with low emission coating e = 0.1 (3 mm + 13 mm Argon gas + 3 mm + 13 mm Argon gas + 3 mm) with current windows (clear double-glazed glazing filled with air) reduces heat dissipation by 45.36%.
- Window arrangements have a substantial effect on energy efficiency. Therefore for each space, one window should replace by 2, 3, 4, or 5 windows.

Changing the design form of windows from form 8 (the most inappropriate form) to form 3 (the most appropriate form) causes a decrease in annual gas consumption by 2.5%, annual carbon dioxide emitted from the building as a result of gas consumption for heating by 1.26%. Form 8 compared to form 3 reduces the annual electricity consumption for space cooling by 9.37% and is suitable for hot climates.

In order to reduce heat loss, it is better to use triple-glazed glazing with low emission coating and UPVC frames in cold and dry climates.

The mentioned contents proved that due to the fact that several alternatives are derived from the parametric optimization and genetic algorithm, designers can freely choose an alternative according to requirements that are appropriate to any specific design project. The limitation of this research based on the influential variables in the search is as follows: Because the parametric optimization and the genetic algorithm methods require a lot of time and robust computer hardware to accomplish computational models in order to be comprehensive and complete, it is essential to simplify the basic research model by contemplation the assumptions that compute the computational models. Actually does it with less precision.

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