Journal of History Culture and Art Research (ISSN: 2147-0626)

Tarih Kültür ve Sanat Araştırmaları Dergisi
Revue des Recherches en Histoire Culture et Art
مجلة البحوث التاريخية والثقافية والفنية

Vol. 6, No. 3, June 2017

http://kutaksam.karabuk.edu.tr

DOI: 10.7596/taksad.v6i3.884

Citation: Foroughian, S., & Taheri Shahr Aiini, M. (2017). Comparative Study of Single-glazed and Double-glazed Windows in Terms of Energy Efficiency and Economic Expenses. Journal of History Culture and Art Research, 6(3), 879-893. doi:http://dx.doi.org/10.7596/taksad.v6i3.884

Comparative Study of Single-glazed and Double-glazed Windows in Terms of Energy Efficiency and Economic Expenses

Samaneh Foroughian*[1], Masoud Taheri Shahr Aiini[2]

Abstract

Saving fossil fuels and the use of clean sources of energy lead to reduce in building operating costs, protect the environment and people's health. Windows are the most vulnerable part of building where energy loss occurs. Double-glazed windows are very effective in keeping inside temperature isolated from outside; thereby, saving electrical and thermal energy. The current study estimates the numerical changes in cooling and heating load in case of replacement double-glazed window with single-glazed window and calculates saving level for this replacement. In this context, this paper presents a model of real samples taken in Mashhad climate. To ensure the accuracy of the simulation results, real results were compared with electricity and gas bills. To calculate energy related parameters such as cooling load, heating load, the consumption of gas and electricity, the energy simulation software (Design Builder) was used. The research method was a quantitative analysis based on energy consumption modeling, associated with building windows which comes in four sections. The field study was also used to compare with real electricity and gas bills. As the first stage, samples of the plan were identified, based on the observation of climate models and library studies. Then, simulation parameters such as window materials and internal and external walls were considered. The simulation was performed based software's parameters and model limitations were determined based on thermal, lighting, climatic and architectural parameters. Finally, the experimental and practical data were used to determine the validity of the model under Mashhad climate conditions. Overall, the results indicated that double-glazed windows could save 50% of entire building loads, 0.2% on power consumption, 16.2% on gas and 12.4% on overall households' energy consumption.

Keywords: Builder Design, Single and double-glazed window, Energy saving, Economic saving, Cooling load, Heating load.

[1]Corresponding author. M.A. of Architecture engineering, Shahrood University of Technology, Iran. E-mail: Foroughian_samaneh@yahoo.com

[2] Professor, College of Architecture, Shahrood University of Technology, Iran. E-mail: mtaheri87@yahoo.com

Introduction

The issue of non-renewable energy use has become so important in recent years. Given that the windows are the main part of the building in terms of thermal dissipation, one way to optimize energy consumption and prevent the completion of fossil energy is to design types of windows that waste less energy than does the common kind. In energy balance sheets published in 2011 by the Deputy of Energy in the Ministry of Energy, energy consumption in Iran is 40.6% belonging to residential and commercial consumption and almost 99% of the energy consumption of these buildings comes from oil and gas production that is fossil fuel component. In addition, the highest share of this energy consumption within the building is to provide thermal comfort (Balance Sheet Energy, 2013). According to figures provided, we can see that if we can make scientific way to reduce energy loss in buildings, this leads to savings in energy consumption and to reduce environmental pollution caused by excessive use of fossil fuels and thereby returning on investment.

Basic Studies

Of the factors affecting energy consumption in buildings, geometry and design of various components as well as the climatic conditions is concerned the most that this will be possible through careful analysis of the site. Windows, as one the most important buildings features, play a key role in saving energy, either in terms of heating and cooling load or in terms of design, which can reduce energy loss through capturing more sun light. Depending on the size and orientation of windows, different behaviors are deemed. For simulating windows and their efficiency, different energy simulation software are used, because windows are the most important part of building in terms of absorbing solar radiation.

Some energy simulator software:

Considering the main goal of this study which is investigating the effect of windows on optimizing energy use, four different packages of software were applied. The position of the sun in each region is generally given as an altitude (elevation) and azimuth (side) angle. Altitude angle is the angular height of the sun in the sky measured from the horizontal. Azimuth angle is defined as the angle a horizontal projection of a direct ray from the Sun makes with the true north-south axis. Annual and daily changes of the angle depend on latitude of the location (Table 1) (Qiyabkoloo, 2010).

Mashhad Climatic Data:

To achieve accurate results from simulation software for the investigated building, Mashhad climatic data was used as apw file format. This file format has been approved by Design Builder manufacture and is available online (Design Builder, 2010).

Background of the research

A copious amount of studies has been done on energy saving solutions, most of which were in the field of sustainable design. Studies differ from the most general issues of sustainable design to providing the most partial solutions to save energy and reduce fossil fuel consumption and replacing it with sustainable solar energy. These include the impact of green roofs design and etc. But given the importance of energy loss by windows and on the other hand their vital role in receiving sun light, this construction element which seems of no importance is the main concern of discussion in terms of saving energy. To measure the amount and type of saving and achieve savings figures there are different mathematical selected and compared, among which Design Builder software was selected as the most appropriate software. Design Builder was used to calculate and simulate windows. The results were presented as graphs.

The effect of climate on architecture:

To launch a climate-compatible project, paying attention to regional climate and climate-compatible materials to gain better establishment, using methods and technique software have great importance (Tommerup & Svendsen, 2005). For this purpose, two typical residential buildings were examined and the results were represented in graphical form. (Krarti *et al.,* 2005) has also dealt with the need to provide a way to estimate the energy saving. He also analyzed four geometry of buildings with different coverings and expressed a close connection between window and their frame in energy-savings (Krarti *et al.*, 2005). In addition to these methods provided, there are packages of software that enable us to investigate energy efficiency and the efficacy of windows and canopies in terms of type, material, number of chamber, direction, and etc. Among which Design Builder is the most completed software. Several studies in this field have been performed to measure how to reduce energy consumption in buildings, such as control of air conditioning, sunlight, glass coating, orientation and etc (Florides *et al.,* 2002). Orientation plays a major role in saving energy. In a study, six cities from six different climates of Iran (hot, humid, cold, mountainous, warm, and dry) were selected and optimal orientation for each city was examined. The results indicated that, southern direction was appropriate for cold, cold and mountainous, hot and humid and mild and wet climates, and the northern direction was more suitable for hot and dry and mountainous climates (Akbar Azimi Hosseini, 2011).

A number of detailed reviews have been conducted on windows and their overall behavior (when opened or closed) such as their impact on thermal comfort of residents (Rijal *et al.,* 2007), energy consumption by letting the daylight enter into living or working places, which helps to reduce energy consumption by 50-80% (Bodar t& De Herde ,2001; Pyonchanihm *et al.,* 2008) and finally the effect of chamber number on reducing energy consumption in buildings. In a study, different types of glass and their walls and also difference air type used between the walls were studied. The studied windows included single-glazed windows, 3 mm double glazed with 13 mm air, 3 mm double glazed windows with 13 mm Oregon, double glazed windows coated with light controller with 13 mm air and finally double glazed windows coated with light controller with 13 mm Oregon. Finally, the best type was also introduced (Barjastehbaf *et al.,* 2012).

In another study, eight types of double-glazed windows were compared including 6 mm clear windows on both side filled with 12 mm air, 6 mm clear windows on one side and on the other side 6 mm clear window coated with light controller filled with 12 mm air, 6 mm blue window on one side and 6 mm transparent window on the other side filled with 12 mm air (yalcin *et al.,* 2012). Another research was done on eight types of windows oriented towards four main geographical directions and ultimately the most appropriate direction for each type of window was determined (Hassouneh *et al.,* 2010). Furthermore, the impact of window fittings on saving energy was studied. The results indicated that by choosing the best fitting we can save energy up to 12% (Rayment *et al.,* 1985). Moreover, studies have shown that for a specific climate, energy loss from the pop-up windows is directly related to the percentage surface but not to the direction of windows. However, in terms of solar energy absorption, windows opening towards south do better than those opening towards south (Hussain Zadeh *et al.,* 2013). In addition, the influence of smart glasses to increase energy efficiency was noted. Smart windows are made in such a way that turns dark and light as sun light increases and decreases, respectively and as such causes thermal comfort of residents (Heydari, 2013). Another form of windows includes windows which have ability to rotate 180 degrees during the years. These windows absorb a considerable amount of heat in summer and by rotating it out in the winter, rays pass through. The amount and type of impact of these windows have been compared for different climates (Feuermann & Novoplansky, 1997). As mentioned above, a variety of researches have been done on various parameters in different types of windows. In the current study, the main goal was to gain a numerical number equals to power and gas consumption and calculate the monetary cost of family in case of using single-and double-glazed windows. In this study, after obtaining the quantity of monetary savings, this value was compared to the cost of purchasing and installing double-glazed windows, and the results were presented.

Review model

Considering the aim of this study which was to evaluate the effect of window on energy exchange, computations were done on an actual sample building. This model was a residential building in a 5-story apartment on the third floor with an area of 105 square meters having two bedrooms (Figure 1). The residential unit had skylights facing north and south directions and had neighborhood from up, down, east and west so no heat exchange was occurred in this directions (Figure 2). The materials of the walls and the ceiling are described in this study, the only variable in the building was windows' type. The windows' information in two cases of single-glazed (Figure 4) and double-glazed (Figure 5).

Results and discussion

At first, the cooling and heating load parameters were studied alone to calculate the total amount of saving for the loads (heating and cooling), (Table 2).

According to the percentage formula of saving:

Savings percentage= the basic Mode-Strategy mode

Basic Mode

The saving percentage in the total load when double-glazed windows were used, was found to be 49.9%. So far, only the load required for heating and cooling is considered. However, consumption of equipment is effective in electricity and gas consumption too. Here, we have calculated the annual total energy consumption saving percentage for the family in which, in addition to cooling and heating load, fuel consumption and lighting equipment has also been taken into account. Initially, the model was evaluated by single-glazed window and electricity and gas consumption was estimated in terms of kilowatt-hours (Table 3). These data were obtained during 12 months (kWh). The following, data are presented in graphical form for better understanding (Figure 6), (Figure 7).

As can clearly be seen from the Table 3, installing of double-glazed windows is more effective in gas consumption than electricity consumption, especially in January. The effect of double-glazed windows on cooling load saving was negligible. In the following, annual electricity and gas consumption are presented and in the end total electricity and gas consumption are summed in kWh, and finally the total amount of consumption in both modes, using single-glazed the annual saving in electricity consumption and gas consumption was 0.2% and 16.2%, respectively. In case of double-glazed windows, the amount of annual saving in total energy consumption could increase by windows and double glazed windows, are compared (Table 4).

The main issues in energy saving strategies are prices and initial costs which are imposed to employers. In the table below the amount of electricity and gas has been converted in to Iranian Rials (Table 5- Table 6), (Figure 8), (Figure 9). Annual monetary value of electricity and gas saving are 16,924 and 72,222 Rials, respectively.

As a result, the percentage of annual monetary for electricity and gas saving was 0.7% and 10.3%, respectively. The total amount of saving was equal to 89146.3 Rials and the total annual saving in case of double-glazed windows increased by 2.9%. As found in this study, using double-glazed windows in this building in Mashhad climate could lead 12.4 and 2.9%saving in terms of energy and household economy, respectively. The reason why energy saving percentage is higher than that of economy saving is that gas is much cheaper than electricity in Iran. So far, only electricity and gas costs were compared. Therefore, more precise calculations can be performed when the purchasing and installing costs for double-glazed windows are calculated too. So considering the high initial cost for purchasing double-glazed windows, which saves 89,146 Rials per year, we need to calculate back period of initial costs to find that whether using this windows are economical. According to the dimensions of the doors and windows in this sample residential unit, the purchasing and installing cost for double-glazed windows was calculated as IRR 31130374. The initial purchasing and installing costs for double-glazed windows is very low compared to the annual monetary saving.

Conclusion

Considering the shortage of fossil fuels, if we consider design criteria based on energy saving strategies, installing double-glazed windows would be definitely reasonable as these windows save up to 50% in total load of the building it means having more fossil fuels for longer years. However, it cannot be ignored that these windows are not really compatible with family economy.

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Appendix

Table1. Climate data table (The Ministry of Roads and Urban Development Meteorological Organization)

Number of snowy days	Number of cloudy days	Total monthly sunny hours	Monthly raining	Minimum relative humidity average	Maximum relative humidity average	Relative humidity average	Daily temperature average	Maximum daily temperature	Minimum daily temperature
15	52	3122.7	168.9	%30	%69	%49	15.7	22.6	9.2

Table 2. Total load of electricity and gas (kw/h)

single-glazed window	kilowatt-hours	double glazed window	kilowatt-hours
Total load of electricity	549	Total load of electricity	543
Total load of gas	3562	Total load of gas	1765
Total	4111	total	2308
amount of saving is equal to 1803 kWh			

Table 3. Electricity and gas consumption in (kw/h)

	March	April	May	June	July	August	September	October	November	December	January	February
Electricit	244	285	344	387	386	345	260	238	238	238	238	233

single-glazed window	y												
	Gas	809	651	630	630	630	630	634	834	1284	1711	1568	1111
double glazed window	Electricity	244	289	343	380	378	349	262	238	238	238	238	233
	Gas	695	631	630	630	630	630	630	668	929	1240	1146	866

Table 4. Total consumption of electricity and gas in kilowatt-hours

single-glazed window	kilowatt-hours	double glazed window	kilowatt-hours
Total consumption of electricity	3437	Total consumption of electricity	3430
Total consumption of gas	11122	Total consumption of gas	9325
Total	14559	total	12755
amount of saving is equal to 1804 kWh			

Table 5. Electricity and gas consumption using one -glazed window

Gaz	Heating	equipment	total	Rial
March	179	630	809	31589.52
April	21	630	651	70932

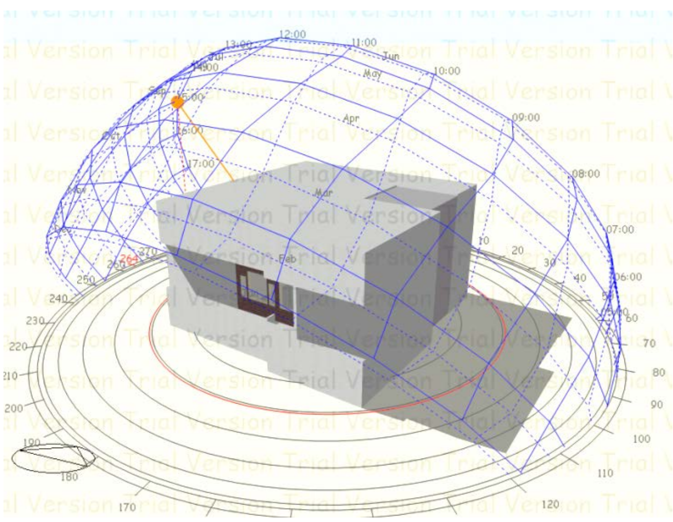
	May	0	630	630	68310	
	June	0	630	630	68310	
	July	0	630	630	68310	
	August	0	630	630	68310	
	September	4	630	634	68809.43	
	October	204	630	834	32565.71	
	November	654	630	1284	50137.14	
	December	1081	630	1711	66810.48	
	January	938	630	1568	61226.67	
	February	481	630	1111	43381.9	
Electricity		cooling	Lighting	equipment	total	Rial
	March	0	161	83	244	133612
	April	41	161	83	285	175555
	May	100	161	83	344	271904
	June	143	161	83	387	351067
	July	142	161	83	386	349226
	August	101	161	83	345	273745
	September	22	155	83	260	149980
	October	0	155	83	238	127474
	November	0	155	83	238	127474
	December	0	155	83	238	127474
	January	0	155	83	238	127474
	February	0	150	83	233	122359

Table 6. Electricity and gas consumption with the use of the double-glazed windows

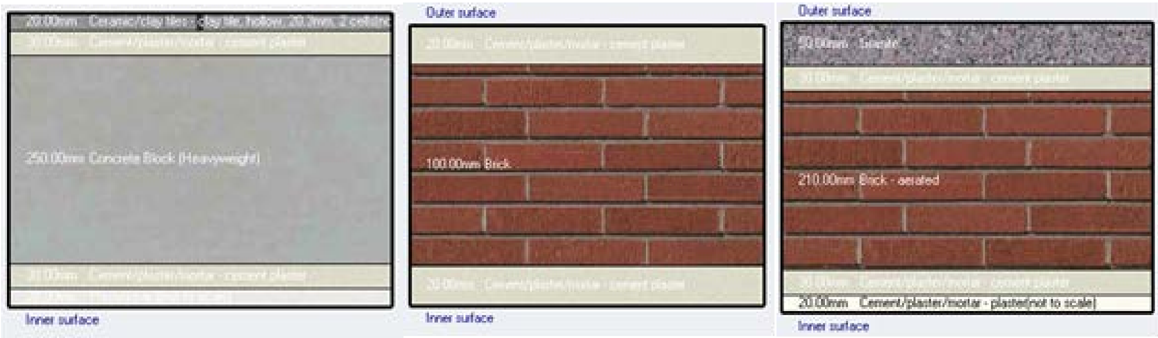
Gaz	Heating	equipment	total	Rial	
March	65	630	695	27138.1	
April	1	630	631	68434.9	
May	0	630	630	68310	
June	0	630	630	68310	
July	0	630	630	68310	
August	0	630	630	68310	
September	0	630	630	68310	
October	38	630	668	26083.8	
November	299	630	929	36275.2	
December	610	630	1240	48419	
January	516	630	1146	44748.6	
February	236	630	866	33815.2	
Electricity	**cooling**	**Lighting**	**equipment**	**total**	**Rial**
March	0	161	83	244	133612
April	45	161	83	289	179647
May	99	161	83	343	270063
June	136	161	83	380	338180
July	134	161	83	378	334498
August	105	161	83	349	281109
September	24	155	83	262	152026

October	0	155	83	238	127474
November	0	155	83	238	127474
December	0	155	83	238	127474
January	0	155	83	238	127474
February	0	150	83	233	122359

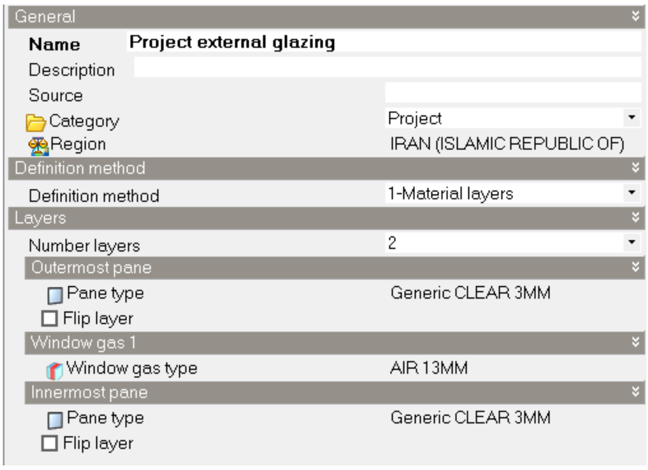
(Fig 1). Review model



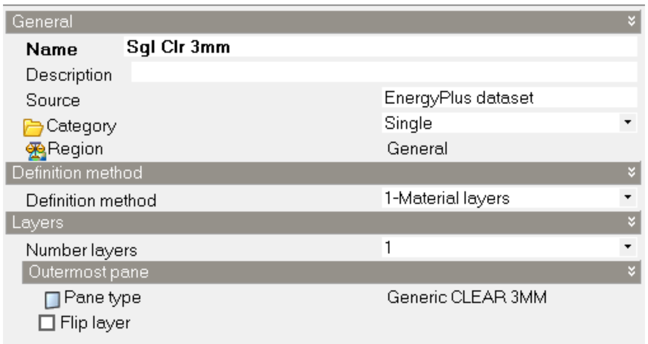
(Fig 2). Review model



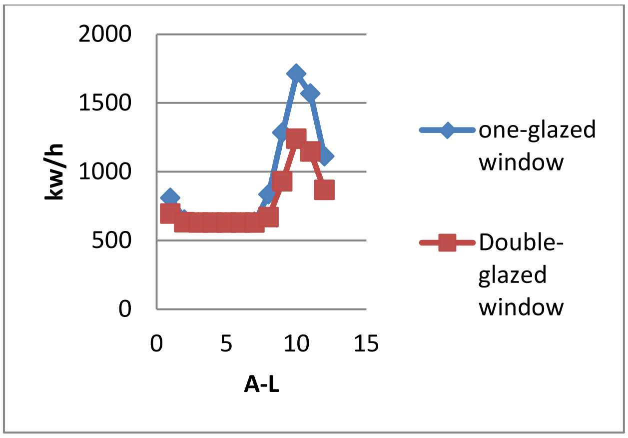
(Fig 3). The materials of the walls and the ceiling



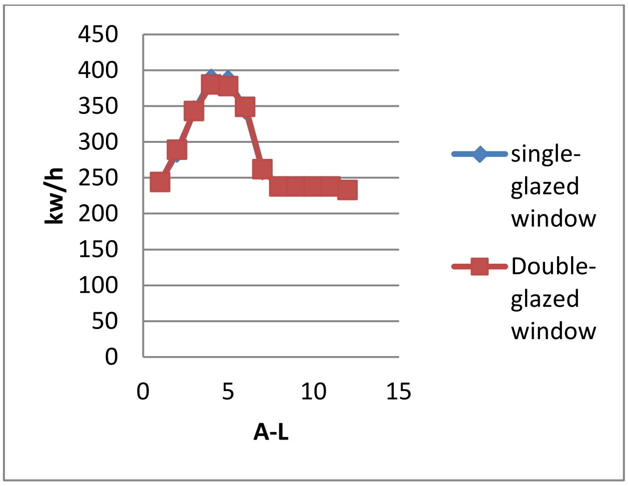
(Fig 4). Single-glazed



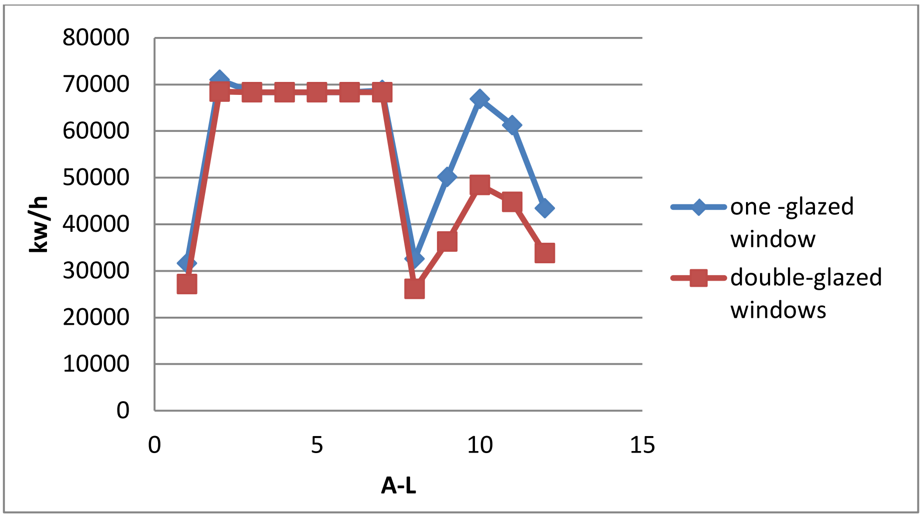
(Fig 5). Double-glazed



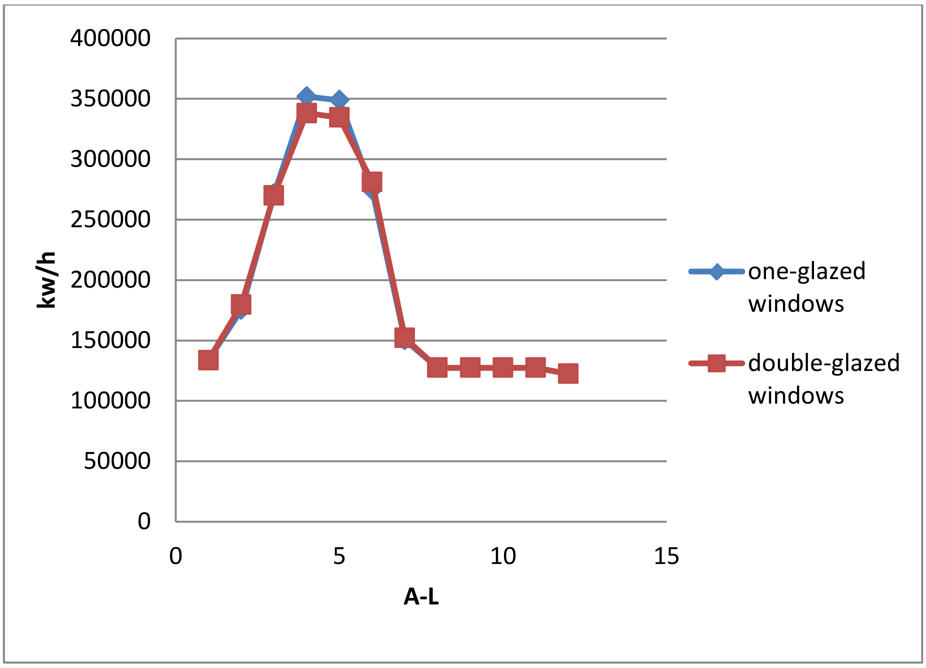
(Fig 6). The amount of gas consumption in both Double- and single-glazed window.



(Fig 7). The amount of electricity consumption in both Double- and single-glazed window



(Fig 8). Rials gas consumption in two states of single-glazed and Double-glazed windows



(Fig 9). Rials electricity consumption in two states of single-glazed and Double-glazed windows