LIFE CYCLE COST ANALYSIS BETWEEN A DOUBLE GLAZED AND A TRIPLE GLAZED WINDOW TO A PROPOSED STUDENT HOUSE IN A SUB-TROPICAL ENVIRONMENT

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Abstract
Windows typically occupy about 15 to 20 percent of the surface area of outer part of building walls. Windows not only add to the aesthetics, they are often a very important aspect of a building; and also, a very significant component of building heating and cooling costs. Windows lose more heat per square meter of area in cold season and gain more heat in summer days than any other surface in the building if not they are energy efficient. When it comes to fitting new windows, there are lots of things to consider. One of the main debates is whether to choose double glaze or triple glazed window in temperate or sub-tropical climates. Homes can lose up to 25% - 30% of energy through the windows alone, however a double layer of glass or triple layered glass window will have prevented much of the energy from escaping the interior spaces of house. Heat retention can save you money on your electricity bills in the long run and means you are running a more environmentally friendly home, as you are wasting less heat and using less energy which will pay back in the long run. This paper takes a case study for this experiment which is setup for a proposed student house for Eastern Mediterranean University located in Famagusta, North Cyprus. The house is 350 meters square with openings on each side. The price of a double or triple glazed window will depend on its quality, in terms of window frames. Aluminum and composite window frames are usually cheaper than timber-framed windows.

Keywords: Double Glazed Window, Triple Glazed Window, Energy efficiency, Cost calculation, Life cycle Analysis

Introduction

In sub-tropical climate region, an average home loses up to 25% - 30% of its heating and cooling energy through its windows and doors. If you have inefficient windows installed in your building, you also have rising energy costs because of the energy that you will use for the heating and cooling of the house. An energy efficient home is a comfortable home, as it is one that is easier to heat or cool. Making sure your home is energy efficient will not only improve comfort but will also save money on energy consumption. Insulation, location, and the materials used in home construction will all help to increase energy efficiency. The window type you use in your home is also critical when it comes to energy efficiency. If you are deciding between single glazed and double glazed windows, it's important to know the differences, and which option is better for your home efficiency.

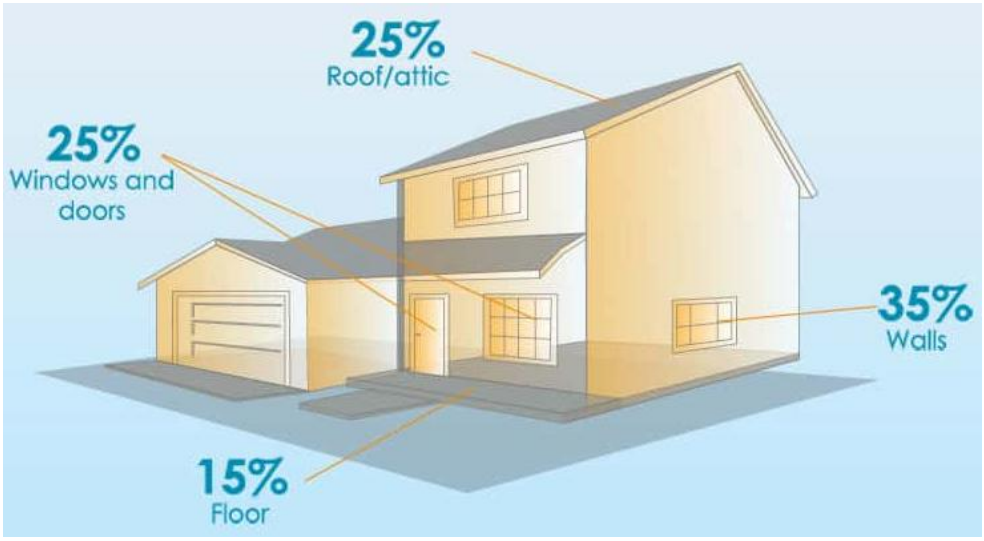

Figure 1: Mapping out home heat lose through the building envelope
Source: https://www.greenhomegnome.com/wp-content/uploads/2013/08/energy-loss-insulation-infographic-cover.jpg

By installing energy efficient window or upgrading your older windows to energy-efficient windows with Low-E coatings, you can lower your energy bills up to 15% to 20% a year, according to the Efficient Windows Collaborative, a coalition of government agencies, research organizations, and manufacturers that promote efficient window technology. A recent study by Energy Star (2023) revealed that by switching out your single glazes or even your newer double glazed, clear-glass windows to energy-efficient windows, you can easily achieve a very good energy efficient comfortable home that can save a lot and payback in long run by the energy bills.

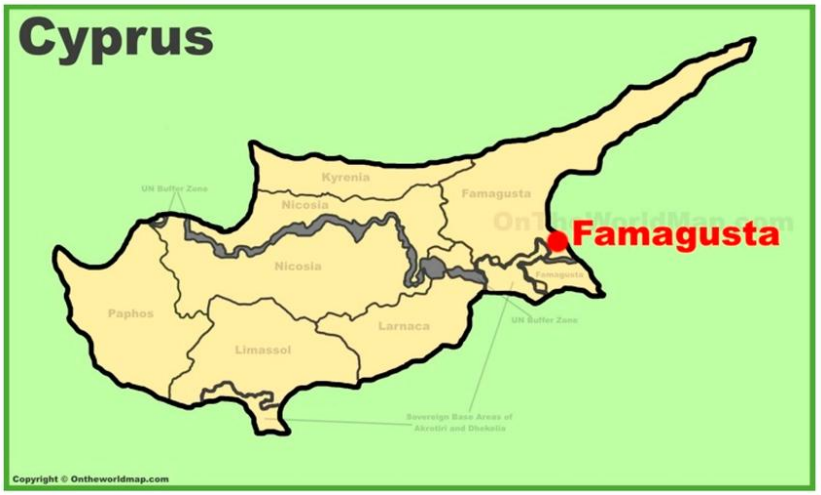

Figure 2: Map of North Cyprus Showing Famagusta.
Source: https://www.researchgate.net/publication/Location-of-Famagusta-city-in-Cyprus.tif

Methodology

This research focuses on the following two questions:

1. The energetic performance of window types: does double glazed or triple glazed window reduce required heating and cooling energy
2. Life Cycle Cost analysis of the two types: is it financially beneficial and feasible to invest in triple glazed or double glazed window

The energetic performance is measured using computer analysis software (Energy Plus), which also gives us our usage cost. Using life cycle analysis data, a comparison is made concerning the environmental costs of the product itself, and a quick cost comparison shows the financial benefits and drawbacks between the two products and the payback period of the two different window types.

Double Glazed Window

Double-glazed windows have two panes of glass fitted into a window frame. An inert gas such as argon is filled between the two panes in order to increase insulation. Double glazed glass is perfect for weather conditions, especially where there are scorching summers and moderate winters. The double windowpanes not only provide relief from extreme temperatures outside, but also insulate your space from the noise outside. They are also very hard to break through and therefore provide you with ample security against intruders.

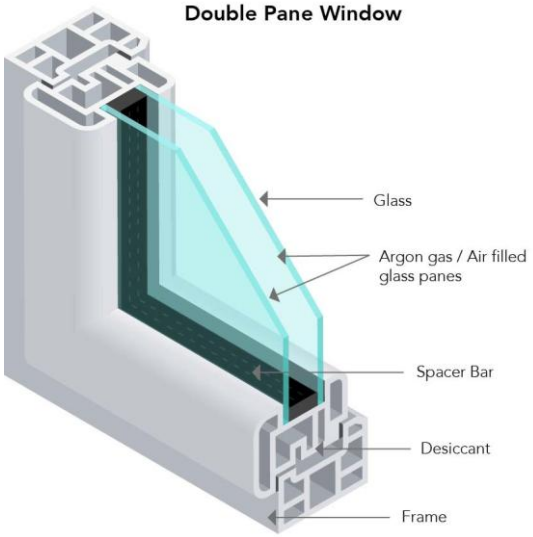

Figure 3: double glaze window property
Source: https://www.efficientwindows.org/img/glazing_single.jpg

Double glazed windows utilize two separate pieces of glass, separated by a vacuum. The vacuum layer acts as an insulation barrier. The glass used can be laminated or UV tinted but is otherwise similar to the glass used in single glazed windows. When double glazing is retrofitted to an existing window installation, the thermal efficiency can be improved by up to 80%. Factory made double glazed windows can be up to 100% more efficient than a single glazed alternative.

How a Double Glazed Window Works?

A single pane of glass provides very poor insulation because glass is a good conductor of heat. So much of the heat in your room literally goes out through the window. It is therefore advisable to install double glazing with a layer of air or argon gas trapped between two panes of glass. Because air or argon gas is a poor conductor of heat, much less heat is lost through such a window. If the inside of one sheet has Low E coating, even less heat is lost, because the coating reflects heat back into the room. A house with double glazed window operates just like fiberglass batts and woolen clothing. It traps a layer of air or argon gas between two panes. Air or argon gas is a very poor conductor of heat, so the trapped layer sets up a blanket of protection between cold air on one side and warm on the other. Glass itself is a very good conductor. So in a sub-tropical home without

double glazed window, heat is going straight out of the window. As shown in the figure 3. Argon gas is an inter gas.

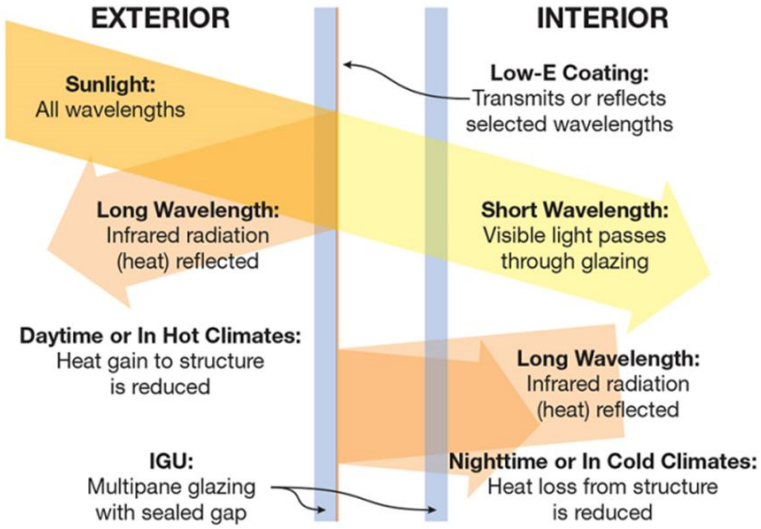

Figure 4: how double Glazed window works
Source: https://www.efficientwindows.org/img/glazing_single.jpg

What Benefits Does Double Glazing Provide?

The most obvious benefit to be gained from double glazed windows, is the increase in energy efficiency. This means that it will be easier to maintain the temperature inside your home. This is especially beneficial to families with air conditioners, or central climate control systems.

An example would be a home that is using a split type of air conditioner/heat pump to warm a living room during winter. Without double glazing, the warmth inside is easily lost. This means that the indoor unit is forced to work harder to maintain a comfortable temperature in the room.

With double glazing, heat loss can be reduced by half in optimal conditions. When combined with insulated curtains covering the windows, the heat loss becomes even less.

I. The biggest attraction of double glazing is its capacity for insulation and heat retention. The layer of insulative air trapped between the two panes helps reduce heat loss, acting as a barrier that keeps in the warm air.
II. Double glazing can save you money on your energy bills due to the increase in the thermal efficiency of your home. Less energy output is needed to heat up your home, resulting in lower bills.
III. Condensation is limited in homes with double glazing. The insulative layer of gas or air between the panes prevents condensation by inhibiting the build-up of moisture caused by cold weather. This effect is enhanced by the effective seals found on double glazed windows.
IV. If you live on a noisy street upgrading to double glazing can be a godsend. The added thickness works wonders at noise reduction, helping to block out the sound of traffic and roadworks from outside.
V. Safety is improved with double glazed windows, as they are tougher than their single glazed counterparts. This makes it more difficult for would-be criminals to break into your home.

Triple Glazed Windows

Triple-glazed windows, as the name suggests, have three panes of glass fitted into a frame. The three sheets of glass have two air gaps filled with argon.

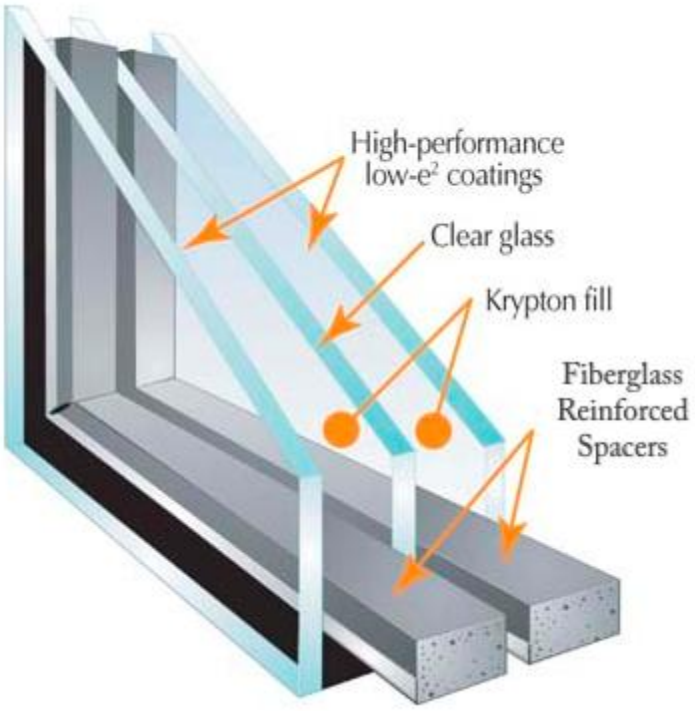

Figure 5: Triple glazed window
Source: http://www.newquayplastics.biz/wp-content/uploads/2013/05/triple_glaze_pic.jpg

These window offer 28% - 30% (approximate) more insulation than double-glazed window (S. Forughain 2017). It also decreases thermal transfer by 75% - 80% making it the most energy-efficient option around. It also mitigates noise. Therefore, triple-glazed windows perform all the functions of double-glazed windows, but with more effectiveness. They are just marginally more expensive by 20%.

How a Triple Glazed Window Works?
Windows have many uses such as allowing light into a building. Windows also enable us to see outside from the home and, at the same time, keeping inclement weather out. All this be achieved by a window with a single pane of glass. Triple glazed units provide the more insulation against the loss of heat, wind, rain and reduce noise levels from outside the home.

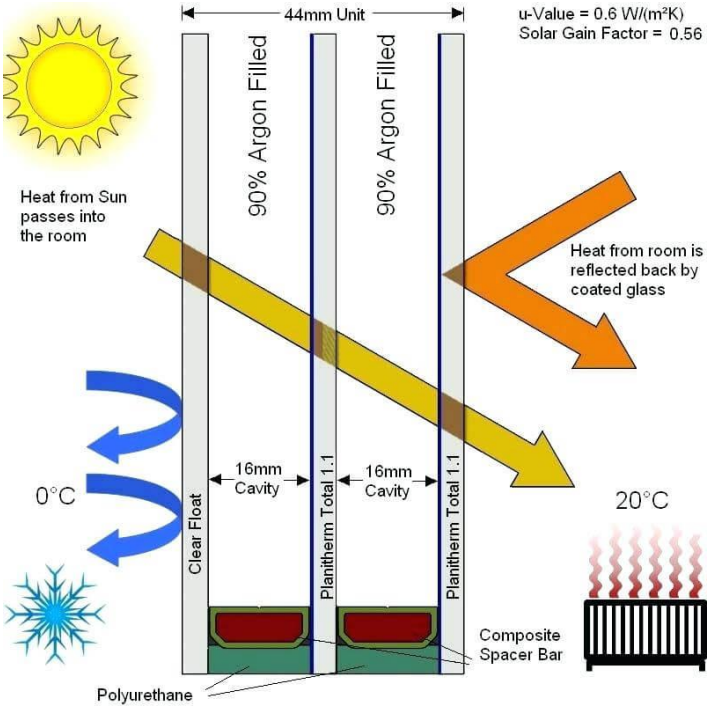

Figure 6: how triple glazed window works
Source: http://www.newquayplastics.biz/wp-content/uploads/2013/05/triple_glaze_pic.jpg

The three panes of glass may be treated with a low-emissivity (low E glass) metallic coating that reflect some of the heat back into the home in order to increase their energy efficiency and are incorporated within a rigid sealed unit with an air gap between each sheet of glass. Thereby, instead of having one air gap in the case of double glazed window, there would be two air gaps in a triple glazed window. The air gap may be filled with an inert gas such as xenon, krypton or argon to reduce the heat loss even further. The sealed unit is normally constructed of wood or uPVC (Un-plasticized polyvinyl chloride).

Benefits Of Triple Glazed Windows

These windows, when properly installed, have an extensive array of benefits. More rigid and durable than traditional windows, triple glazed windows have an outstanding insulation performance, especially in areas with extreme weather. They also are resistant to condensation and reduce sound transmission.

Their three layers of glass also provide increased security the thicker area is harder for vandals to break. Additionally, they offer great energy savings when compared to regular and double glazed windows.

Installing triple glazed windows is equivalent to upgrading your walls and ceilings from R-20 to R-40 (in certain circumstances), and they can decrease relative heat loss, which increases thermal comfort inside.

To cut costs, a combination of double glazed windows and triple glazed windows can be used with the building orientation. This is achieved by installing the triple glazed windows on the sunny part of the building and installing the double glazed windows where there is no direct sun radiation. Consider insulated hollow frames when installing your windows, as they can increase their performance, which can save you money in the long run.

Comparative Cost Of Double And Triple Glazing

When you start shopping for double glazing and/or new windows, you'll find the following affect the cost:

I. The material the window frames are made from
II. The window style

III. The type of glazing used
IV. The size of your installation
V. Existing building codes or municipal regulations.

The price of a double glazed window will depend on its quality, but you can expect to pay at least 25% - 35% more than for single glazed windows. In terms of window frames, aluminum and composite window frames are usually cheaper than timber-framed windows.

Material		
Material	**Double glazing cost**	**Triple glazing cost**
White uVPC	€350 - €430	€460 - €570
Woodgrain uPVC	€570 - €680	€680 - €770

Table 1: cost difference between double glazed and triple glazed window
Source: Leroy Merlin Company (https://www.leroymerlin.com.cy/)

Case Study

The case study of this experiment is setup for a proposed student house for Eastern Mediterranean University Located Famagusta North Cyprus. The house is 350 meters square with openings on each side. It consists of 6 bedrooms 3 livings and a study room whereby most of the living spaces are oriented to face the south side for passive solar energy gain during winter, and this can also reduce the heating load as well.

Case study Types

TYPE A (with Double Glazing Window): 20% north glazing, 10% East/west glazing, 90% South glazing 150mm EPS wall insulation

TYPE B (with Triple Glazing Window): 20% north glazing, 10% East/west glazing, 90% South glazing 150mm EPS wall insulation

Figure 7: Case study model showing the south and north façade of the model.
Source: By Author (2020)

Weather Conditions

The weather in the Famagusta area during the summer is hot and reliably sunny and during the winter is cool and humid. Following the list, you will find the average climate condition of the area.

I. Hot season / summer is in June, July, August and September.
II. Most rainfall (rainy season) is seen in October.
III. Famagusta has dry periods in April, May, June and July.
IV. On average, the warmest month is July.
V. On average, the coolest month is January and December.
VI. October is the wettest month.
VII. June is the driest month.

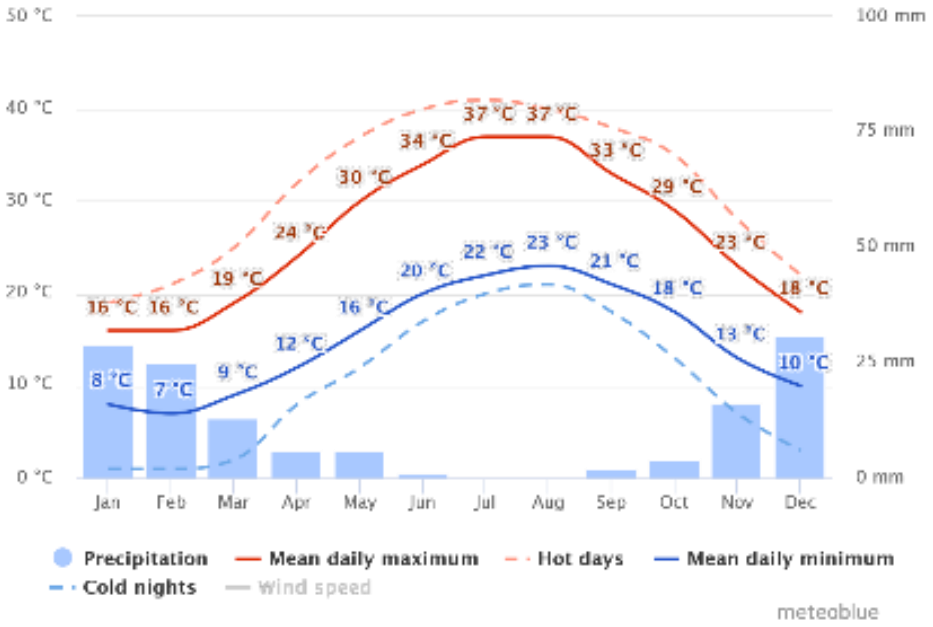

Figure 8: Graph showing the climate condition of case study location (Famagusta North)
Source: www.meteablue.com

These houses were then outfitted with various double and triple glass types, and one single glass plate type as a reference, and were then modelled and analysed using Energy Plus, a comprehensive environmental calculation and analysis algorithm for buildings. This method generates a variety of data, among which total energy use for gas and electricity, solar gains, and CO2 generation. The advantage of using such an analytical model is that various other parameters are taken into account, such as airtightness, real-world climate data on a day-to-day basis, usage characteristics, etc. Reliable and repeatable experiments can be performed in for regression testing. An experiment was done by A. Rana (2018) on an investigation on the thermal performance of double and triple glass window, the research takes into account the temperature measurements from in-situ tests that are carried in actual houses as well as laboratory experiment similar to Hot Box test. The method of this experiment is shown in the figure below;

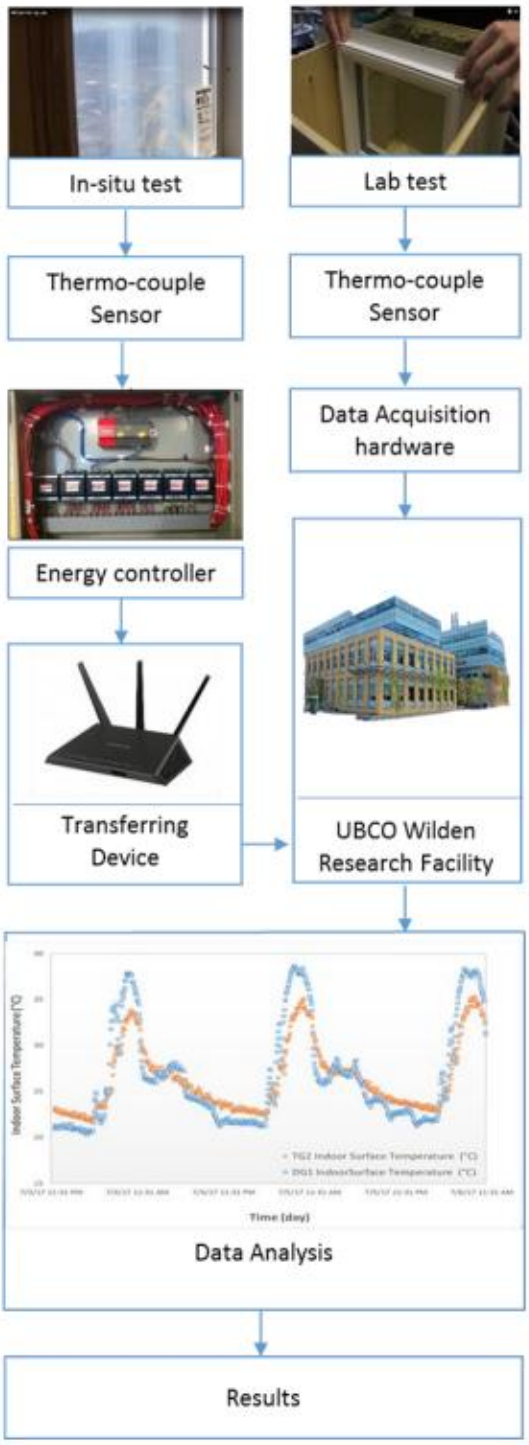

Figure 9: An investigation on the thermal performance of double and triple glass window
Source: Chen, Y. *et al.* (2025) 'Seasonal thermal performance of double and triple glazed windows with effects of window opening area.

Energy Plus does not take into account all possible physical processes that are taking place, such as temperature gradients over the glass surface, or angle dependence for solar energy transmittance'', which we predict for this experiment does not influence the results in a significant way.

Tested Glazing Type For The Scenario

There are many types of available glass that can be compared. Double glazed and triple glazed are chosen for this research. For this research, five types were tested, all commonly used products in building industry, and standardized for energy-plus calculation (energy calculation software or

simulators). A single plate glass type is used as a reference, and for each double and triple glazing unit a high performance variant is added. "UGlass" is the insulation value, and "Trans" is the transmission value. The once with "HR" means glazing with Low-E Coating in the middle of the glaze.

Type:	Single	Double	Double HR	Triple	Triple HR
Glass:	6mm helder	6mm/13mm	3mm/13mm	6mm/13mm	6mm/13mm
Filling:	-	Air	Argon	Air	Argon
Characteristics:	Uglass = 5.36 Trans. = 0.351	Uglass = 2.45 Trans. = 0.216	Uglass = 1.60 Trans. = 0.688	Uglass = 1.21 Trans. = 0.303	Uglass = 0.78 Trans. = 0.470

Figure 10: types of glasses tasted for this research

Energy Calculation

From the calculation of the energy efficiency of glass type and their application on south façade 30% is taken as a base case for the calculation and compared with the case study model that is used for the research.

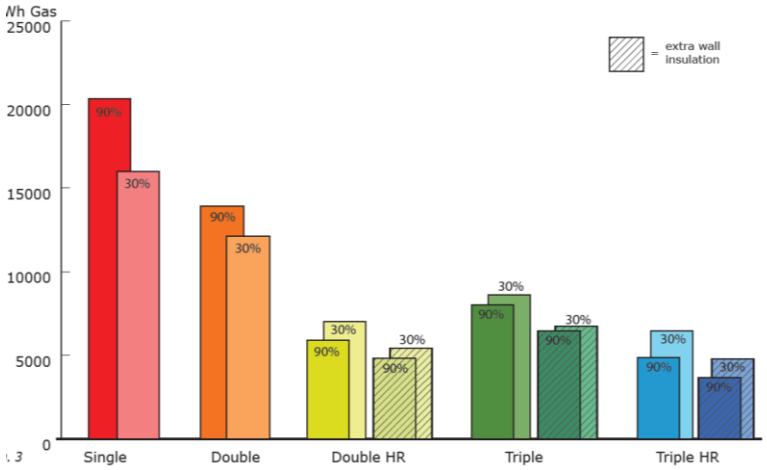

Figure 11: Energy usage of different type of glazed window.

Findings; The graph in figure 11 above shows the total energy usages of the various glazing types and for the 30% and 90% south glazing houses, as well as the models with increased wall insulation. It's immediately clear that there are large benefits to using double glazing types and beyond. It's also clear that the double HR glass outperforms the normal triple glazed unit. The double HR glass have an additional Low-E coating while the normal triple glazed only have the argon gas filled in between.

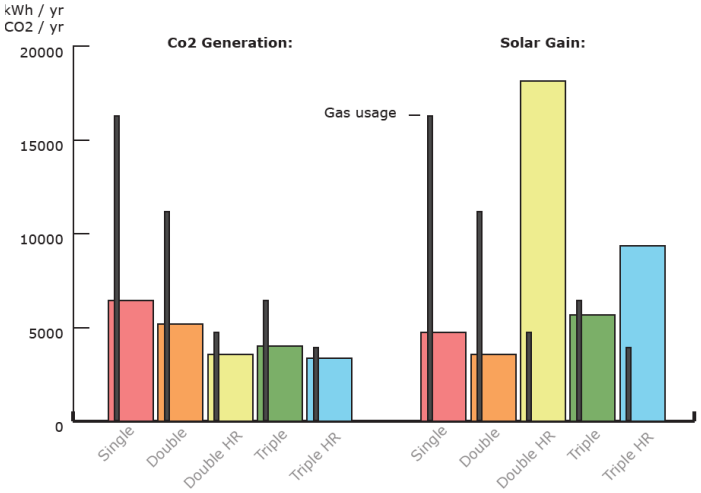

Figure 12: Graph showing gas usage and CO2 emission with solar gain of different types of glazed window.

From figure 12 above, it shows that the left side of the figure shows the gas usage versus CO2 emissions. We can see that they are related, but that CO2 emissions are not decreasing by as much as the gas usage of the entire house. This is due to other forms of energy use within the house such as electricity and water. This means that only 15% to 25% amount of CO2 reductions can be affected by glazing types.

On the right of figure 12 we can see a large difference in solar gains between the different glazing types due to the difference in transmission values. Glass with a higher transmission value admits more light and heat from the sun. In winter this has a direct effect on gas usage, and the effect is in the same order of magnitude as the gas usage itself. This explains why the double HR glass outperforms the normal triple glazing types, despite the higher insulation value of the triple glass types, because the double HR glass allows more solar energy to enter the house, which will help in heating the building interior during the wintertime of the year. Which will also drastically reduce the use of gas itself.

Recommendations

According to the tested glasses and window types, it clearly shows that in terms of energy saving as shown in figure 11, double glazed HR and Triple Glazed HR are saving more than the other types of window glazing, and they can save up to 80% more than normal single glass which is used as a reference.

In terms of solar gain, the result shows very clearly that double glazed HR has the maximum solar gain than all the other types of the glazing.
For this project, the double glazed HR glass is chosen because in term of energy saving and heat loss saving it is very efficient while the solar gain is high. This can save up to 20% to 30% of the total energy use in a building.

Cost Calculation

When you start investing for double glazing and/or new windows, you will find the following affect the cost:

I. The material the window frames are made from
II. The window style
III. The type of glazing used
IV. The size of your installation

The price of a double glazed window will depend on its quality. However, you can expect to pay at least 25% - 35% more than for single glazed windows. In terms of window frames, aluminum and composite window frames are usually cheaper than timber-framed windows.

Material		
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Table: cost difference between double glazed and triple glazed window
Source: Leroy Merlin Company (https://www.leroymerlin.com.cy/)

All houses lose heat through their and windows. It's a natural thing. But double glazing or triple glazing keeps your home warmer or cooler – as well as reducing your energy bills for heating and cooling through that. The costs and savings will be different for every home, depending on its size and the quality of the glazing types. It's expected that on a standard house, you can save

approximately 200-250euro per year, with double glazing and 250-280euro per year with triple glazing.

Scenario

Following a simplified version of the proposed case study models, I am comparing the implementation costs with the benefits gained during the life span of the products. The double glazed and triple glazed (HR) products are chosen for a period of 20 years. For the proposed student house with south glazing (12 glass openings of 2.1 x 1.2m). I am using a value of 350euro for double glazed window and 460euro for triple glazing with an interest rate of 6%.

S/no	Cost	Double Glazed Window	Triple Glazed Window
1.	Investment Cost	350 x 12 = 4200euro	460 x 12 = 5520euro
2.	Implementation cost	7 x 12 = 84 euro	10 x 12= 120 euro
3.	Maintenance cost	5euro/year	5euro/year
4.	Electricity bill saving	200euro/year	200euro/year
5.	Life span	15years	15years

Cost Calculation

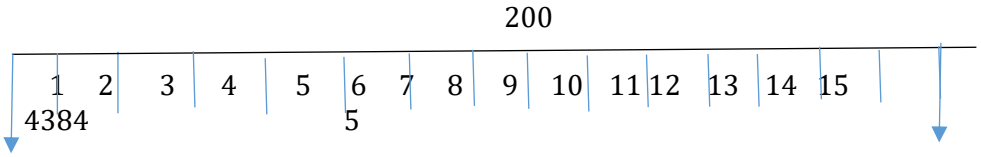
Initial cost = investment cost + Implementation cost

I. Double glazed = 4200 + 84 = 4284 euros
II. Triple glazed = 5520 + 120 = 5640 euros

Cost difference between Double and triple is 1356 euros

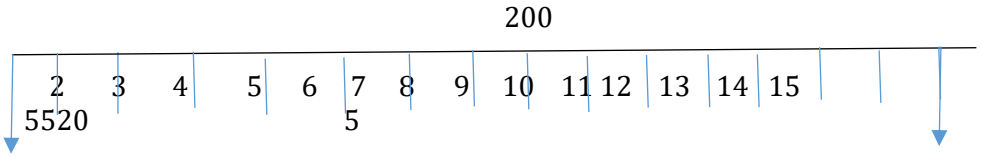
Solution

Double Glazed window



- 4384 + 5(P/A, 6%, 15) - 200(P/A, 6%, 15)
- 4384 + 5(9.712) – 200(9.712)
- 4432.56 – 1942.4
- 2490.16 euros

Triple Glazed Window



- 5520 + 5(P/A, 6%, 15) - 200(P/A, 6%, 15)
- 5520 + 5(9.712) – 200(9.712)
- 5520.56 – 1942.4
- 3626.16 euros

Cost difference = 3626.16 – 2490.16 = 1136 euros

Result And Conclusion

From the result, it shows that double glazed window is cheaper than triple glazed window with a difference of 1136 euros from the lifecycle cost calculation.

Furthermore, for the proposed case study model, it is feasible to choose double glazed window than triple glazed window according to the following terms

1. Cost lesser than triple glazed window
2. Cost of energy saving is almost the same as triple glazed
3. Have more solar gain than triple glazed

4.

S/No	DOUBLE GLAZED WINDOW	TRIPLE GLAZED WINDOW
1.	Cost less than triple glazed window	Most energy efficient glazed window
2.	Can reduce up to 50% heat loss	Lower U value than double glazed
3.	Weight less than triple glazed	Heavier than double glazed
4.	More popular than triple glazed	Safer than double glazed
5.	Less energy efficient	More expensive
6.		Better for extreme weather condition

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