Parametric Study in Office Building for Daylighting Performance and Energy Saving

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***Abstract:** This paper utilized simulation techniques for identifying the most efficient glazing with a good WWR and a proper daylight autonomy by controlling the thermal heat gain and reducing cooling load as well as energy consumption .daylighting inside space specially offices is one of the most important concerns because of its significance role in energy consumption and its ability to provide a comfort environment inside space for occupants and Productive workers. Utilization of daylight in buildings may result in reduction in electricity consumption for lighting but also in high cooling demand if excessive solar gains are admitted in the working space. Moreover, visual comfort should be ensured especially for perimeter office spaces. Window size and type should be considered as an integral part of fenestration system design for office buildings in order to balance daylighting requirements versus the need to reduce solar gains. performance predictions and simulations can help in identifying strategies for reducing energy consumption and improving building performance by rigorous analysis process and that's what is this research method ,The implementation of the simulation process is carries out by using Rhinoceros 3D modeling which supports DIVA for rhino (a plugin for rhinoceros modeling software) and DIVA uses RADIANCE and DAYSIM and its basic daylight as a simulation engine to space with southern orientation in Alexandria, Egypt. The simulation process performed by using daylight autonomy and thermal analysis. The outcome of this research is as expected choosing the proper glazing type is a huge factor of reducing energy, controlling heat gaine and providing a good thermal comfort . Glazing with less u -value and less visual transmittance are more savers for the energy as a result of less gaining of the heat and less cooling energy. the single pan glazing and the double pan clear glazing are the least energy savers glazing with a higher monthly energy use 379 kwh and 353 kwh in the same order and the higher illuminance in the room , the ElectrochromicGlazings is giving a good illuminance for the space but a high energy use 319 kwh . then the coming three glazing are very similar to each other coming in the first place the Glazing_DoublePane_LowE with 261 kwh and then Glazing_DoublePane_LowE_Argon with 268 kwh and the last is the TripleGlazing_TriplePane_Krypton with 263 kwh with least illuminance between 300 and 3000 lux which is the Useful daylight illuminance range 29.2 % .*

***Index Terms:** Daylighting, Glazing System, Cooling Energy, Energy Consumption.*

I. INTRODUCTION

A considerable reduction in artificial lighting and energy consumption can be achieved by maximize the use of natural day lighting. [1]. Daylighting is the general practice of having vertical windows and openings in a wall exposed to incoming solar radiation to receive natural light inside the room during the day time. [2].Daylighting is the use [i]of light from the sun and sky to complement or replace electric light. With proper window shapes, size (window to wall ratio) and glazing types. Daylight can also significantly reduce the need for artificial lighting. Integration of daylighting strategies with electrical lighting controls can provide automatic adjustments to provide minimum light levels with minimum electricity use. [3].windows shape , size (window to wall ratio) and glazing types. Should be considered as an integral part of fenestration system design for office buildings, in order to balance daylighting requirements versus the need to reduce solar gains. Utilization of daylight in buildings may result in reduction in electricity consumption for lighting but also in high cooling demand if excessive solar gains are admitted in the working space [4].Appropriate fenestration and lighting controls are also used to modulate daylight admittance and to reduce electric lighting, while meeting the occupants' lighting quality and quantity requirements. Daylighting is a beneficial design strategy and important especially in office buildings for several reasons:

- Pleasant, comfortable daylighted spaces may increase occupant and owner satisfaction and may decrease absenteeism. Productive workers are a valuable business asset.
- Energy-efficient daylighted buildings reduce adverse environmental impacts by reducing the use and need for power generating plants and their polluting by-products
- Saving money [5].

Considerable time and money can be saved by providing architects with guiding principles on the design of atria from the very beginning of a project, which greatly increases the potential for an optimized solution. More attention can then be given to more detailed matters, resulting in a higher quality outcome many different daylight simulation programs are available to designers. [6]. This paper utilize a simulation program DIVA for rhino to get the optimum glazing type for office room model with a 45% wwr window with a optimum daylight autonomy > 50 % by comparison the energy consumption results between six different glazing with different U value and transmittance.

II. OBJECTIVES

The aim of this paper to evaluating the potential of daylighting to save energy use and reduce solar gain associated with window glazing impact on daylighting performance and energy consumption are investigated for several window glazing types and utilized to operate lighting fixture illuminating an office space. This evaluation comes from an integrated approach combining daylighting and the thermal aspects, the study is based on daylighting simulation results called (diva for rhino), an office room of typical size have been modeled for the south orientation and 45 % wwr with 6 different types of glazing.

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III. AN OVER VIEW ON PREVIOUS STUDIES

The daylight autonomy and the useful daylight illuminance produced have been quantified by Acosta(2016)inside a room for different models of windows, and to conduct an analysis of the results obtained. The shape, size and place of the window are inconstant, as is the reflectance of the inside surfaces of the room. the daylight autonomy is measured in the study points show that independence of artificial lighting in the room and therefore the relative energy saving in power consumption. A proper value of daylight autonomy is located between 50 and 100%.and it show that The higher the UDI value between 100 and 2,000 lux, the better the visual comfort. More over , the UDI values lower than 100 lux and higher than 2,000 lux are also measured. A proper value of useful daylight illuminance is located between 70 and 100%.. [7].Krarti, M(2005) had investigated the impacts on daylighting performance for several arrangements of building geometry, window size (WWR), and glazing type for four different geographical locations in the United States. Krarti also defined the daylighting aperture as the product of window visible transmittance and window to perimeter floor area ratio—was found to have a significant impact on energy savings from daylighting. He found that increasing daylighting aperture (either by increasing glazing transmittance or window area) leads to better daylighting benefits. It has been shown that a daylighting aperture greater than 0.3 will yield diminishing returns on energy savings. And he determined that for most commercial buildings with glass transmittance values above 0.5, increasing window area to floor area ratio above 0.5, daylighting does not provide significant additional lighting energy savings [8].Bodart and De Herde (2002) in their study attempt evaluate an integrated approach combining the daylighting and the thermal aspects.. Several façade configurations have been modeled, for the four main orientations and three combinations of internal wall reflection coefficients. The results was found that The global primary energy saving coming not only from the reduction of the lighting consumption but also from the reduction of lighting internal loads could then reach 40%, for a type of glazing usually used in office buildings. And they suggest that the potential of energy savings by integrating the daylighting availability in the electric lighting management is high. [9].While LEE(2013)in his study presents and optimizes the annual heating, cooling and lighting energy consumption associated with applying different types and properties of window systems in a building envelope. Through using building simulation modeling, various window properties such as U-value, solar heat gain coefficient (SHGC), and visible transmittance (Tvis) are evaluated With a computer simulation program. based on the U-value effect on heating and cooling energy consumption, from hot areas to cold areas, triple glazing to reduce thermal conductivity offers a performance advantage, particularly in saving heating energy.. [10]. Yun, G and kim(2014) suggested lighting and shading control strategies which helps visual comfort and building energy savings. This research intends to achieve visual comfort and energy savings in an office building. they used HDR images captured in real scene and simulation (DIVA-for-Rhino) for glare evaluation. Building energy consumption is presented according to three building orientations, and 10 control strategies of lighting and shading. And as expected the daylighting is considered as an important source of visual comfort and energy savings. The proper facade design, and control strategies for shading devices or electric lights can greatly help in reducing not only lighting energy use, but also HVAC energy use. *[11]*.
research by Hee, W.J (2015) he showed that Optimization techniques offer a balance solution for the contradictions in selecting a window glazing of energy-efficient building. he revealed the impacts of window glazing on the energy and daylighting performances of building through the previous researches. However, compared to dynamic glazing, designing a static glazing window usually needs more substantial consideration of optimization. Generally, the qualities and performances of glazing are proportional to the costs. It is wise to perform techno-economics evaluation to obtain the suitable glazing for a building. Due to the higher costs of dynamic glazing, it is more suitable to be installed in the building which needed high performance in term of daylighting and energy saving such as commercial buildings. [12].

IV. DAYLIGHT AUTONOMY

It was the first of a string of annual daylight metrics, now commonly referred to as ‘dynamic daylight metrics’. It is signified as a percentage of annual daytime hours that a given point in a space is above a specified illumination level. the Association Suisse des Electriciens originally proposed it in 1989 and was enhanced by Christoph Reinhart between 2001-2004. It is a major innovation since in considers geographic location specific weather data on an annual basis. It also has power to relate to electric lighting energy savings if the user defined threshold is set based upon electric lighting criteria(13). It was defined by (Hegazy,2013) as ‘the percentage of the year when a minimum illuminance threshold is met by day lit alone’ (Association Suisse des Electriciens 1989). This definition returns back to the late 80s by the Swiss norm. This term concerns the daylight factor and a minimum threshold of illuminance. However, the definition was redefined to be measured according to defined sensors in the floor area with a certain height. It calculates the amount of daylight illuminance required for that specific task over the occupied times of the year. The minimum threshold of illuminance is then specified by any reference document for lighting such as the IESNA lighting Handbook.(14).

V. METHODOLOGY

A. Simulation and Input Data

The research methodology is carried out through tow main sections, first one concentrate on different glazing type to evaluate the appropriate performance criteria for glazing systems in buildings, a computer simulation tool for the design and selection of fenestration systems is used. It calculates heating, cooling and lighting energy use, window heat gain and heat loss. a reference office model located on Alexandria, Egypt with 45%wwr with daylight autonomy > 50% as shown in Figure 2 based on a previous research for Acosta (2016) which resulting A proper value of daylight autonomy is located between 50 and 100%.and it show that

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The higher the UDI value between 100 and 2,000 lux, the better the visual comfort[7] were modeled. The simulations were performed with the Alexandria weather file data,. all the analysis were performed in the south facing orientation . Figure 1 illustrates the size and plan of the office model The dimensions of the office were 4.5 m ˆ 6.0 m and the room height was 2.8 (m).

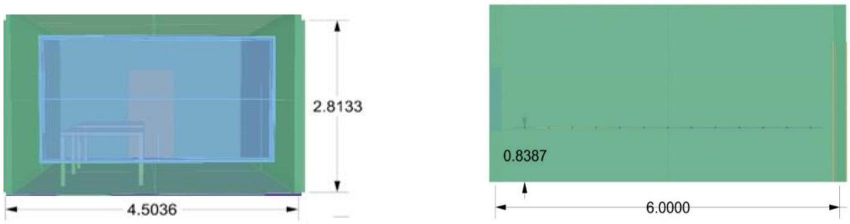

Figure 1. The Dimensions of the Office Room

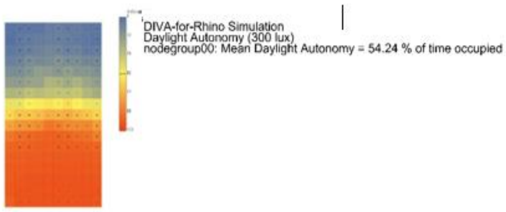

Figure 2. The Office Room Daylight Autonomy Results

DIVA Setting Was Determined As Follows, in Table 1.

Diva setting	
simulation type	Climate based
occupancy schedule	8 am to 6 pm with DST.60 min
Minimum Illumination	300 lux
Program version	EnergyPlus-Windows-OMP-32 7.2.0.006, YMD=2018.03.08 10:15
Environment	Alexandria Al Iskandariyah EGY ETMY WMO#=623180
Weather condition	Clear sky with sun (CIE clear sky)
Lighting (w/m2)	1.2432
People (m2 per person)	5
Plug and process (w/m2)	11

Model Materials Was Determined as Follows, in Table 2.

model	**material**	**reflectance**
Ceiling	GenericCeiling_80	This is a purely diffuse reflector with a standard ceiling reflectance of 80%.
Floor	GenericFloor_20	This is a purely diffuse reflector with a standard floor reflectivity of 20%.
Wall	GenericInteriorWall_50	This is a purely diffuse reflector with a standard grey wall reflectivity of 50%.
Glazing	Different types of glazing	

Window to Wall Ratio Parameter, Table 3

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	15.97	0.00	0.00	15.97	0.00
Window Opening Area [m2]	7.11	0.00	0.00	7.11	0.00
Window-Wall Ratio [%]	44.55	0.00	0.00	44.55	0.00

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The analysis procedure is as follows:
1) Set the building module and envelope properties for the input data
2) input Alexandria weather data .
3) Select window with WWR 45% with daylight autonomy > 50% with variations of glazing (6 types)
4) Conduct a data analysis based on the overall energy consumption output data
5) Construct a chart of the simulated data by heating, cooling and lighting loads and by variation in U-value, SHGC, and Tvis
6) Optimize the window proper type for the proper wwr that have been chosen based on the optimum daylight autonomy for Alexandria office buildings.

This section describes the optimal window type for reducing building energy loads. The larger the window, the more important glazing selection are to control glare and solar heat gain [14].. The simulation variables and setting are shown in Table 1. And the model's materials are shown in Table 2, variations are chosen based on 1 main factors: window properties (WWR, U-value, SHGC, and Tvis). As the output data, building energy consumption consists of 3 elements: heating, cooling and lighting loads.

Table 4. Types of Glazing Properties Used in Simulation

Glazing type	**Tau_vis**	**SHGC**	**U-Value W/m2K**	**visual transmittance**	**Visual transmissivity**
Glazing _single pan_88	0.88	0.82	5.82	88%	96%
Glazing _double pan_clear 80	0.80	0.72	2.71	80%	87%
Glazing_DoublePane_LowE	0.65	0.28	1.63	65%	71%
Glazing: Tau_vis	0.70			70%	76.3%
Glazing_DoublePane_LowE_Argon	0.65	0.27	1.32	65%	71%
Triple Glazing_TriplePane_Krypton	0.47	0.23	0.57	47%	96.2%
ElectrochromicGlazings				60%	65.4047 %

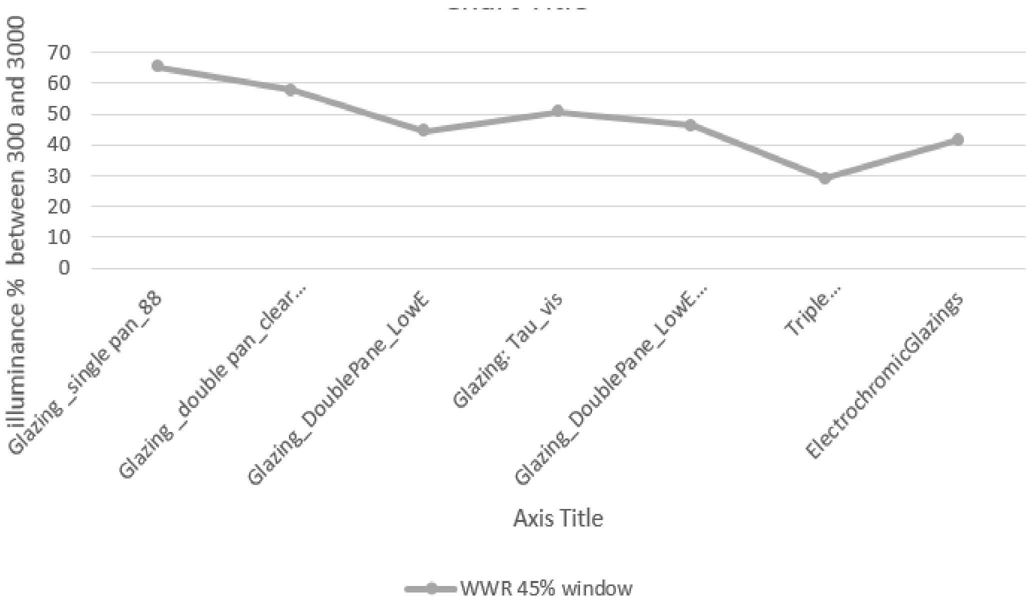

Figure 5. Different Glazing Illuminance % between 300 and 3000 lux

Windows with more WWR defiantly gives more illuminance and more daylighting distribution in the room and some times even the shape of the glazing playing a very big role in that and therefore a lighting energy consumption but depending on the orientation and the position of the building in some cases big window mean more glare and heat so as we can see in Figure 5 that different glazing type can play a very big role in reducing the glare and the lighting entering the room, the single pan glazing is catching the biggest amount of daylighting 65% illuminance between 300 and 3000 lux, The double pan clear glazing coming in the second place 57.7 % and the least glazing that preventing the light is the triple pan *Krypton* glazing with 29.2 % , double pan low E, double pan low E argon and the tau vis glazing they all in a very close percentage from 40 % to 60% witch is the preferable percentage for the illuminance witch giving a good daylighting autonomy and reducing the energy consumption.

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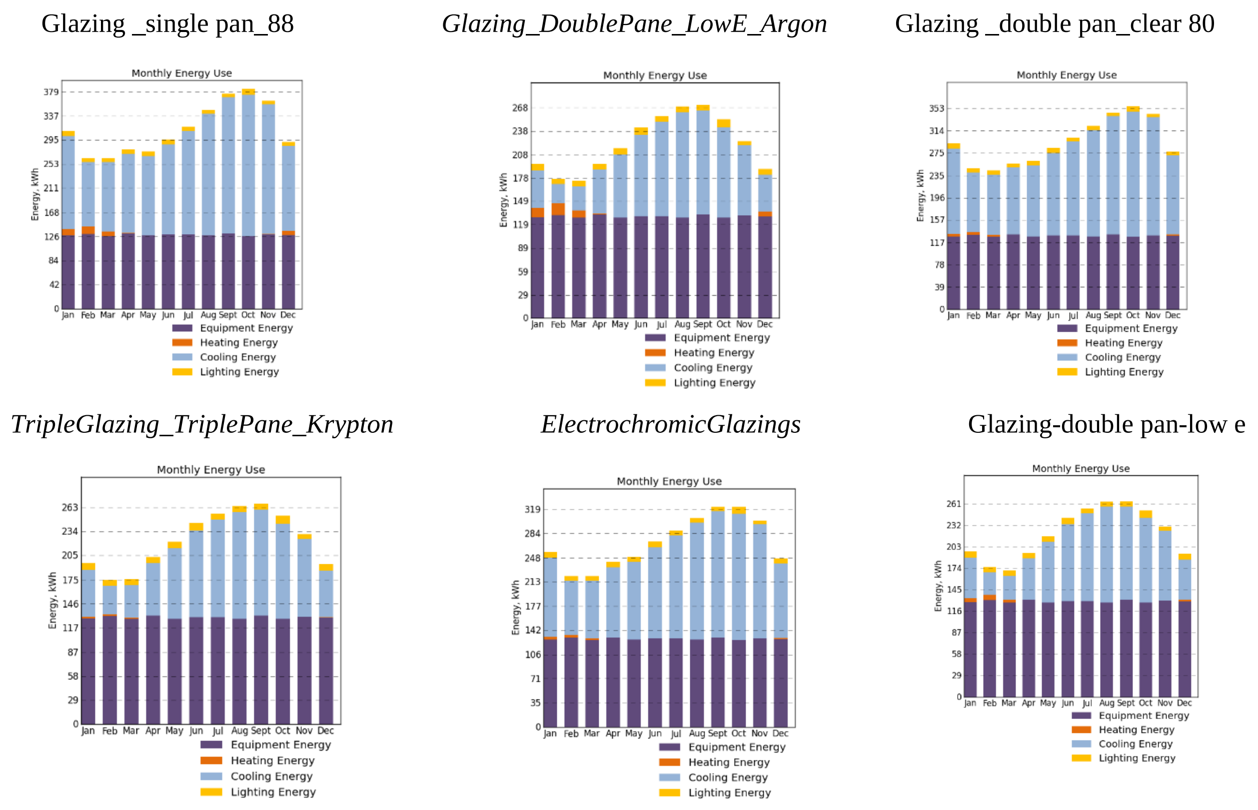


Figure 3. The Energy use for the Equipment, Heating, Cooling and Lighting for the Office Room Model.

Figure 3 show the annual energy use in the office room with a different type of glazing to investigate the best glazing system to reduce thermal gaining and cooling load.as we can see in Figure 4 that the annual average heat gaining for the single pan glazing is about 632.35 w and the annual average of sys sensible cooling energy is 6252.98 kw shown in Figure 5 which cause monthly energy in the max month of the year 379 kwh. double pan clear glazing average heat gain is about 518.40 w the cooling energy load is 5627.43 kw with a monthly energy use 353 kwh next to it in heat gaining the ElectrochromicGlazings with 405.13 w and the cooling load is 4799.99 kw and the monthly energy use 319 kwh and again with a very close results to each other comes the Glazing_DoublePane_LowE_Argon with 140.11 w , Glazing-double pan-low e with 168.66 w and the TripleGlazing_TriplePane_Kryptonwith 159.8 w with cooling load in the same order 2942.44 kw ,2995.12 kw and 3094.55 and the last thing the monthly energy use for the three of them in the same order is 268 kwh , 261 kwh and 263 kwh . The people heat gain , lighting heat gain and the equipment heat gain in constant as follow in the same order 3382.27 kw, 90.92 kw and 1550.21 kw in all types of glazing because of the constant parameter shown on Table 1 as follow 5 person per m2 lighting is 1.2432 (w/m2) and plug and process is 11 (w/m2).

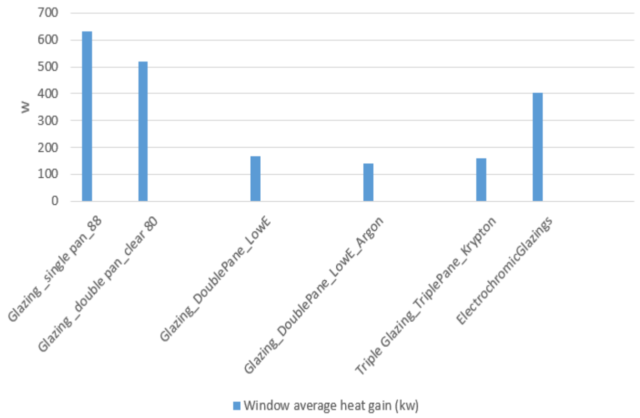


Figure 4. The Window Annual Average Heat Gain to the Different Types of Glazing.

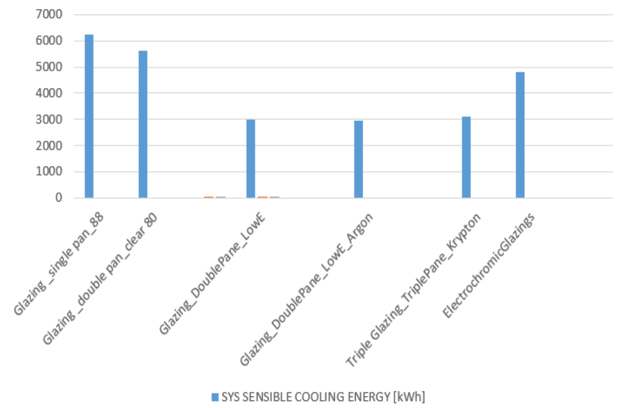


Figure 5. The Annual Average of Sys Sensible Cooling Energy [kWh]

VI. CONCLUSION

In this research, the effect of window glazing type on the energy consumption of buildings in Alexandria, Egypt has been investigated by a daylighting and thermal analysis in a computer simulation program named DIVA for rhino. Various performance properties of window systems that can lead to energy saving buildings have been discussed for 6 types of glazing with different U value , visual transmittance and SHGC. According to the simulation results, the optimal window system such as type, size can be summarized as follows:

First, the window size (or WWR in the building envelope) must be utilized in one of the daylighting simulation in the early stages of designing because of its impact on the daylight autonomy witch has huge effect on the energy saving and the thermal comfort in the buildings.

Second, good daylighting has a very huge impact on energy saving but can cause a thermal problems with more solar gain so one of the very important factor is the glazing type that can avoid glare and reduce the heat gaining and saving more energy and the most important a comfort zone with a proper thermal specially in office buildings .

Third, according to the comparison of different types of glazing with different U value and transmission , for hot climate as Alexandria , Egypt higher U value and transmission window properties are beneficial for saving energy.

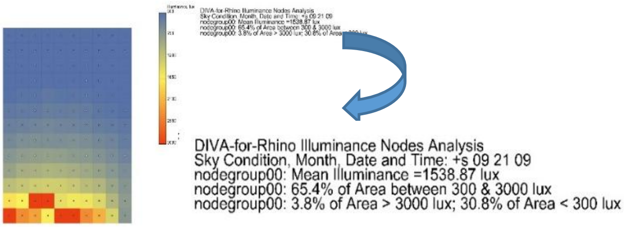
Fourth, based on the U-value effect on heating and cooling energy consumption, , Glazing-double pan-low e , Glazing_DoublePane_LowE_Argon and TripleGlazing_TriplePane_Krypton they are the most effecting glazing on saving energy and reduce heat gaining and the priority comes in the same order .

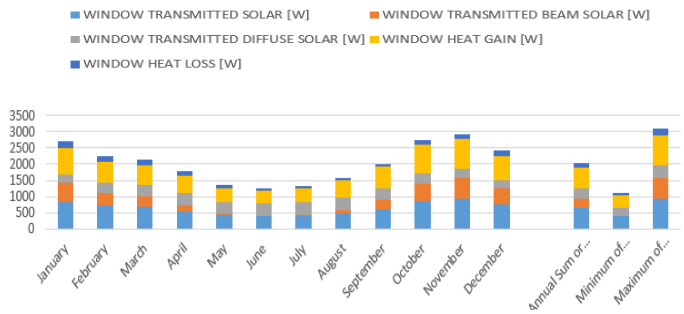
Fifth, the Electrochromic Glazings has a good daylight illuminance in the room but not its not great at saving energy so not all the glazing that gives a good daylighting to the room could also saving the energy.

APPENDIX

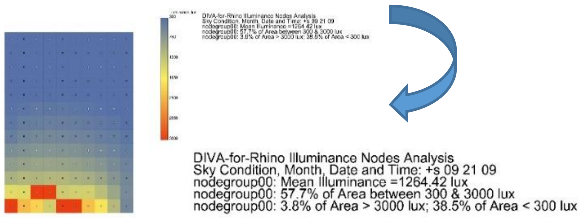
45% WWR illuminance between 300 and 3000 lux different glazing annual heat gain and heat loss

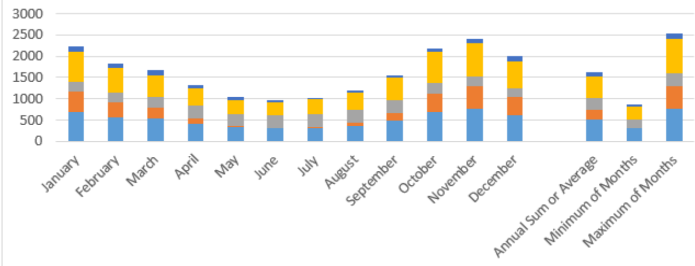
1) *Glazing _single pan_88*



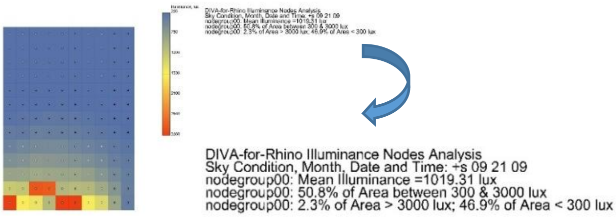


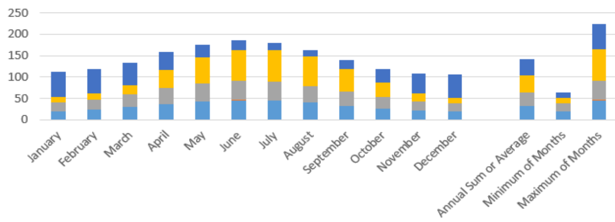
2) *Glazing _double pan_clear 80*



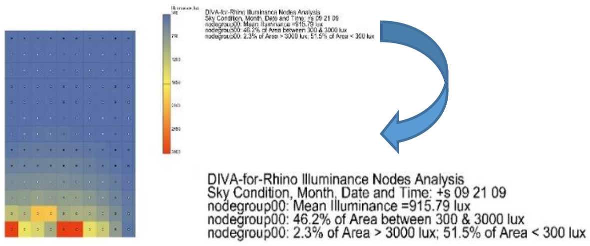


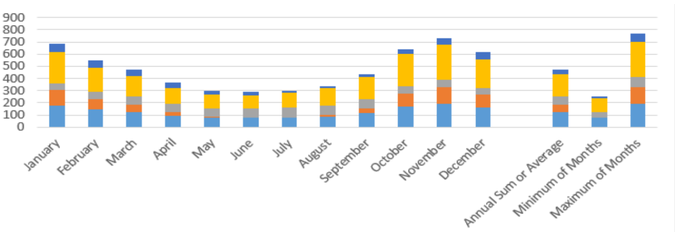
3) Glazing_DoublePane_low E



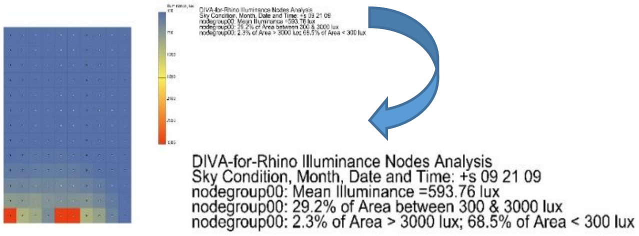


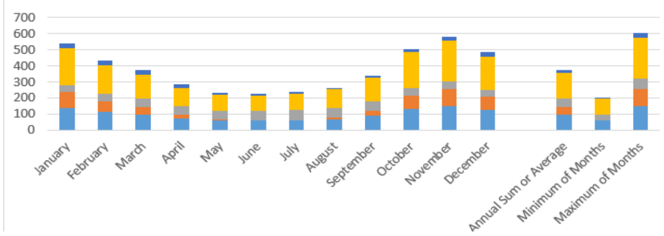
4) Glazing_DoublePane_LowE_Argon



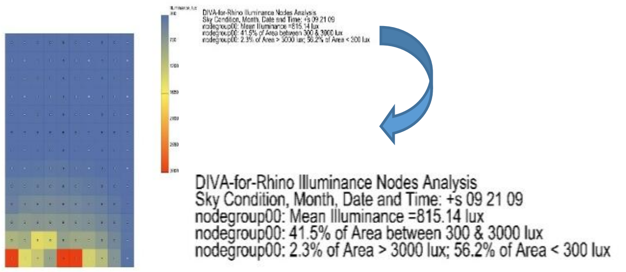


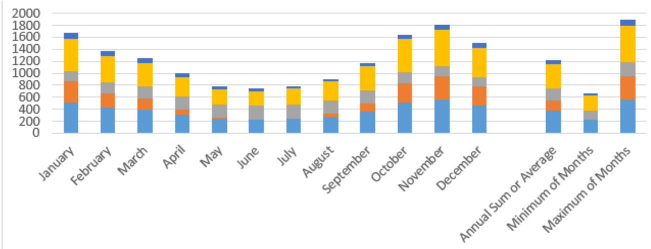
5) Triple Glazing_TriplePane_Krypton





6) Electrochromic Glazings





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