# Energy Efficiency Evaluation of Different Glazing and Shading Systems in a School Building

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**Abstract.** The energy conversations methods and techniques take a significant role in the energy performance of the buildings. Façade and shading systems are in continuous development, and recent studies are showing the importance of implementation of such systems to reduce energy consumption and enhance the effectiveness of the building performance. School buildings are mostly being used during daytime, hence, require active use of sunlight. A measure that is taken on a school building envelope can prevent overheating and overcooling and reduce the heating and cooling energy consumption but at the same time can increase the lighting energy consumption vice versa. Thus, it is necessary to optimise the energy required for climatisation of a building with lighting energy demand. The main aim of the paper is to provide analysis for façade and shading systems applied to a school building and study the effectiveness of it on energy consumption and conservation. The case study for this paper is a typical building project designed to be located in Istanbul, Turkey and has a traditional façade system which is clear double layer windows without any shading devices. The analyses of the energy efficiency of these systems will be presented. The different glazing types and shading systems alternatives will show the most efficient one to be used as some optimised alternatives for the systems. Findings indicate that proper glazing and shading systems can reduce the needed energy for heating and lightening and thus total energy consumption of a school building significantly.

## 1 Introduction

Building openings, in general, are the connection to the outside world; those openings are windows, doors, curtain walls, and skylights, etc. Openings play a significant role in achieving the comfort for the residents of the building, as they continuously exposed to the sun and exterior climate, building users might be exposed to the direct sun rays, glare, UV and heat gain.

The glass is highly used as a cover for these openings due to its low cost and high transparency. Glass nowadays has different types and categories. In this report, the thermal characteristics and the used techniques to reduce the heat gain on the glass is discussed. In addition to that, shading systems also can be used to cover the openings of buildings, it also reduces the heat and sun glare and there are many types of shading systems with different materials and mechanism that can be used as this paper will discuss.

Façade systems development nowadays is mainly focusing on its energy efficiency that can provide for the building; it also concerns in developing a system that reduces the heating, cooling, and lighting energy loads and enhances the thermal and visual human comfort, in addition to architectural design and cost. Many prototypes have been developed by Johnson [1] through glazing for a facade and delivering an optimisation alternative; this leads to generate the importance of simulation for buildings integration that has been proposed by Clarke [2], and followed by a more detailed methodology and analysis by Citherleta [3]. More detailed integrated simulation methodology for glazing systems and its energy performance delivered by Citherlet and Scartezzini [4]. In considering the lighting and comfort for building users [5] proposed a methodology to optimize the design of fenestration and shading systems, following this; [6] provided a simulation-based study for the different types of façade glazing, shading and lighting systems to be considered while the design stage in order to provide an optimal energy efficiency.

Facades types that most likely manufactured as Single Skin Façade (SSF), Double Skin Façade (DSF) and Triple Skin Façade (TSF) have different cost and energy efficiency values. For example, according to Cetiner [7], DSF is 22.84% more energy efficient than the SSF; meanwhile, SSF is 24.68% more cost efficient than DSF. Many studies applied laboratory and indoor climate environment associated with HVAC systems simulator cabins to analyse the efficiency of the DSF and the characteristics of this system [8], other research was made by defining the model through mathematical formulas to measure the energy efficiency of a simulation model containing DSF and HVAC system [9]. DSF or TSF include a fluid between layers. By the Computational

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Fluid Dynamics (CFD) methods the energy efficiency of the façade will vary as well. Iyi [10] showed by the CFD method that there is no significant improvement in energy versus cost efficiency for the fluids and gases to be infused between the layers of the facades. Zollner [11] proposed that the solar radiation can be managed according to a specific ratio for the gap between the internal and external façade glass layers that vary from 0.3 to 0.9m and the height of the window box. Glazing systems can also improve thermal comfort and increase efficiency [12]. Window-to-wall ratio can reduce or increase the energy consumption for lighting and heating up to 40% [13]. Gas-filled double or triple facades made a concern for researchers to find its embodied energy and life cycle assessment. Argon filled window can enhance the U-value from 1.63 W/m².K to 1.3 W/m².K, but its embodied energy produces 94.7 kg.$CO_2$ according to G. Weir [14]. Arıc [15] showed that U-value could be reduced up to 0.4 W/m².K by using low emissivity coating and argon gas filling for the DSF. Marcel D. Knorr [16] studied the gas losses and leakage from the double façade, stating that climate loads and edge sealing are the main reasons for the loss of gasses and suggested some improvements to be applied and examined to reduce this leakage.

For any façade system that contain mainly the windows, curtain walls and shading systems, each part of these systems has various types and categories, these categories, can perform differently than other its type categories on the consumption of the building energy and its efficiency. By looking at the windows and curtain walls, we can find the various types of glazing, coating, and components that can be applied to these windows, energy efficiency will be significantly increased in the case if using a combination from a glazing façade system with shading devices [17]. Shading devices such as louvres can reduce up to 34% of building needed energy for lighting [18]. Aside from the energy savings by using the shading systems, the latest dynamic louvre devices can provide the ultimate thermal and visibility comfort for the building users [19]. Other types of windows that contain tinted films such as ceramic thin-film electrochromic (EC) windows can save the needed energy for lighting up to 59% [20]. More advance processed optical crystalised glass can reduce the required energy with higher values up to 68% [21], but it did not show that it provides a better thermal and vision comfort rather than the others. According to ASHRAE Handbook [22], in term of solar heat gain minimisation, glazed and shaded facades obtain up to 80% of this heat gain. Other energy savings can be obtained from the various shading systems. Conventional louvres can save up to 10%, and overhang devices can save ups to 11% of the required energy for cooling considering the slat angle and depth of the blind components according to Kim [23].

By combining more sophisticated combined systems in the façade, that aim to reduce the heat gain, heat loss and energy needed. Some reasonable amount of reductions can be obtained, an example of these sophisticated systems is the switchable exhaust air windows with triple glazed skin façade and Venetian blinds, this system can reduce the heat gain up to 73.5%, and heat loss up to 74% [24], consequently the needed energy for cooling will be reduced up to 56.4% and up to 46.9% for heating [25]. Other types such as thermochromic glazing glass that can reduce the energy consumed by 30% Carl M. Lampert [26], other types such as thermochromic laminated glazing (TLG) that doped with Fe and Cr metals can shows the similar reduction of consumed energy and provide more ultra-violet rays stability according to Ruben Arutjunjan [27]. Photovoltaic facade combined with water and heat devices to increase the system's efficiency was examined by Tripanagnostopoulos [28]. The study shows that the effectiveness of the façade was improved; however, to be applicable, specific criteria has to be considered in the architectural design, which adds a limitation for it. Another study showed that using photovoltaic double façade integrated with automated blinds can enhance the thermal and energy efficiency up to 60% [29]. Photovoltaic facades are also examined for their energy efficiency, although facades can additionally generate electricity, in high-temperature regions, its functionality becomes low [30].

This study aims to provide analysis for the different types of façade and shading systems and obtain the energy conservation and efficiency for each system and to make a comparison between systems in term of total energy consumed per meter square for cooling energy, heating energy, and lighting energy. Gathering and plotting the extracted data can provide a guideline for designers to choose the most energy efficient and proper facade system type according to building design criteria, this study can be expanded in the future to study the building energy cost analysis and efficiency for the different kinds of façade systems.

## 2 Methodology

For the evaluation of the glazing and shading systems, a typical school project is used. The school building for this project contains three floors excluding the basement floor. The total area of the school building is approximately 5350 m$^2$. There are 20 classes, two dining halls, laboratories, teacher rooms, a gym, and an amphitheatre as well. For the heating of the school building, radiators which are supported by a hot water plant loop are used. All the zones except WCs in the building are heated by the same system provided. On the other hand, since the building itself is a typical school building, it is more advisable to don't use any cooling system due to the absence of the people in summer seasons; thus, there is no loop for cooling in the building.

For the analysis of the different glazing types and shadings for façade, several types of glazing and shading were chosen. Table 1 shows used glazing types and shading on the school building. For comparison, all the combinations of glazing types and shadings were evaluated regarding total energy used per meter square (kWh/m$^2$), heating energy per meter square (kWh/m$^2$) and lighting energy per meter square (kWh/m$^2$). The combinations are made by matching one glazing type with one shading. Since there are ten glazing types and ten shadings, all these combinations were analysed, and comparison between them is made concerning energy usage, heating energy, and lighting energy.

**Table 1**. Glazing types and shadings used for project.

| Glazing Types | Shadings |
|---|---|
| Dbl Clr 6mm/13mm Air | 0.5m projection Louvre |
| Dbl Clr 6mm/6mm Air | 1.0m projection Louvre |
| Dbl LoE (e2=2) Clr 6mm/13mm Air | 1.5m projection Louvre |
| Sgl Clr 3mm | 0.5m Overhang |
| Sgl Clr 6mm | 1.0m Overhang |
| Sgl LoE (e2=2) Clr 6mm | 1.5m Overhang |
| Trp Clr 3mm/13mm Air | 2.0m Overhang |
| Trp Clr 3mm/6mm Air | Overhang + side fins (0.5m projection) |
| Trp LoE (e5=1) Clr 3mm/13mm Air | Overhang + side fins (1.0m projection) |
| Thermochromic Glazing | No Shading |

Following part explains the steps made, arrangements and assumptions to create the model of the school building. To evaluate different combinations of the glazing types and shadings on the school building, a highly beneficial computer program, DesignBuilder, is used. DesignBuilder is a software that can provide sophisticated modelling tools in a simple way of the interface. DesignBuilder can quickly offer the whole modelling of the building, material selections, analysis, and simulations. To create the school building's model, 2D AutoCAD drawings of the school building is simply imported to the DesignBuilder. All the walls, zones and the openings of the building are modelled in the related software. Figure 1, indicates the zoning and arrangements of the first floor modelled in the software.

Once the layout of the model is completed, options concerning activity must be done. For the school, a new schedule of occupancy is created as well to have more reliable energy calculation. The schedule is created considering the daily routine of one day spend in the school.

For instance, when the occupancy of the school building is increasing after 08.00 am mostly; only 75% of the occupancy is included for energy calculation. On the other hand, since the school building reaches its full capacity after 09.00 am; 100% of the occupancy is included for energy calculations. Finally, while the occupancy of the building is decreasing through the evening, a reduction on the percentage of the occupancy is provided. Besides, the absence of the people for weekends and holidays are also included in the schedule. The schedule for the occupancy is provided in Table 2.

**Table 2**. occupancy pattern schedule.

| Occupancy of Weekdays | Occupancy of Weekends | Occupancy of Holidays |
|---|---|---|
| Until: 07:00 is 0.00<br>Until: 08:00 is 0.75<br>Until: 09:00 is 1.00<br>Until: 17:00 is 0.75<br>Until: 18:00 is 0.25<br>Until: 24:00 is 0.00 | Until: 24:00 is 0 | Until: 24:00 is 0 |

Arrangements regarding the metabolic activity of the people, environmental properties such as heating and cooling temperatures, humidity, and office equipment for precise energy calculation are made. For lighting, the target illuminance is changed to 300 lux as well.

The construction materials of the school building are obtained from the technical drawings. All the external walls, below grade walls, roofs, and internal partitions are included within the software. The detailed explanation of the external wall is presented in Figure 2. For other components, it is presented in Table 3.

**Table 3.** Properties of the walls, roofs and internal patricians.

| | |
|---|---|
| **Below Grade Walls** | Reinforced Concrete (200mm), Water Insulation, Gypsum Board |
| **Flat Roof** | Clay tiles (25mm) on air gap (20mm) on roofing felt (5mm) |
| **Pitched Roof (occupied)** | 130mm concrete slab with floating screed |
| **Internal Patricians** | 220mm medium weight concrete block |

The schedule for the lighting and HVAC systems is harmonised with the previously created schedule for the occupancy. The necessary amount of the simulations was made to get data regarding total energy usage (kWh), heating energy (kWh) and lighting energy (kWh).

The simulation of the created model on DesignBuilder is conducted as daily, monthly and annually. All the data regarding weather conditions, movement of the sun, the angle of the glare and other aspects of the environment are used by the software to conduct realistic simulations and to have reasonable output. For a simulation of a year, the start date is chosen as 1$^{st}$ of January, and the last date is selected as 31$^{th}$ of December. As output for the simulations, internal gains, energy used, HVAC systems, latent loads, environmental aspects, temperature changes, heat balance, fresh air, and fuel usage can be obtained. The summary table of a simulation of Double Clear (6mm/13mm) glazing without shading and the processes of evaluation and analysis are described in Figure 4 and 5.

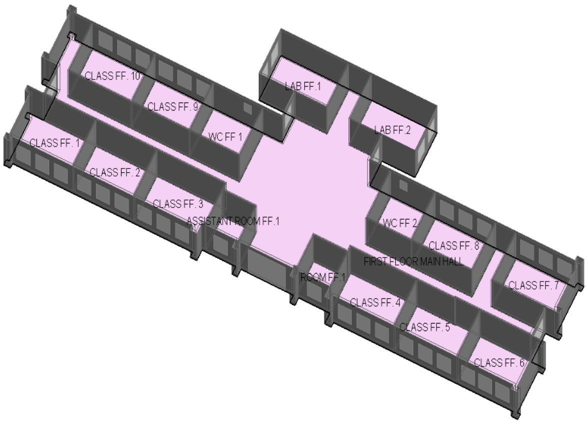


**Fig 1**. Zones and arrangements of the first floor.

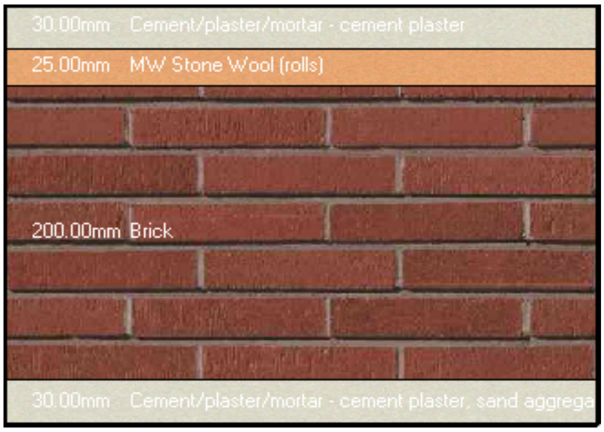


**Fig 2**. Cross section of external wall.

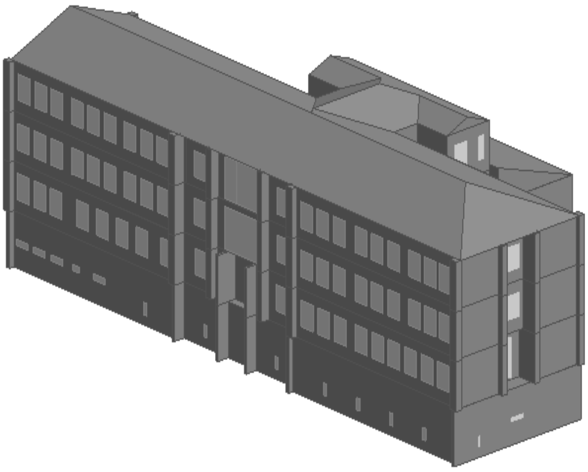

**Fig 3.** Whole model of the school building.

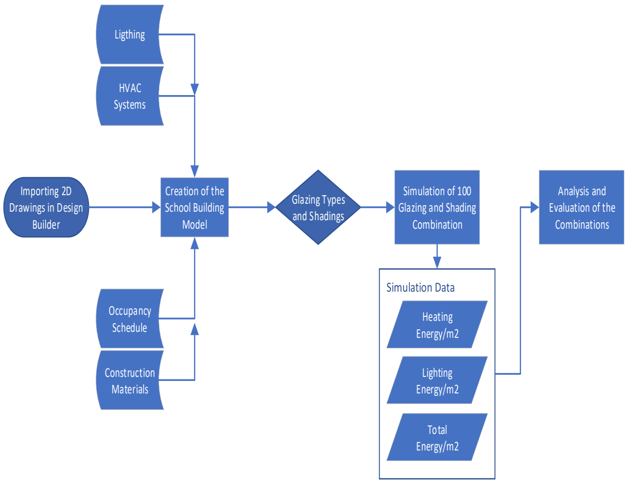


**Fig 4.** Summary of the processes.

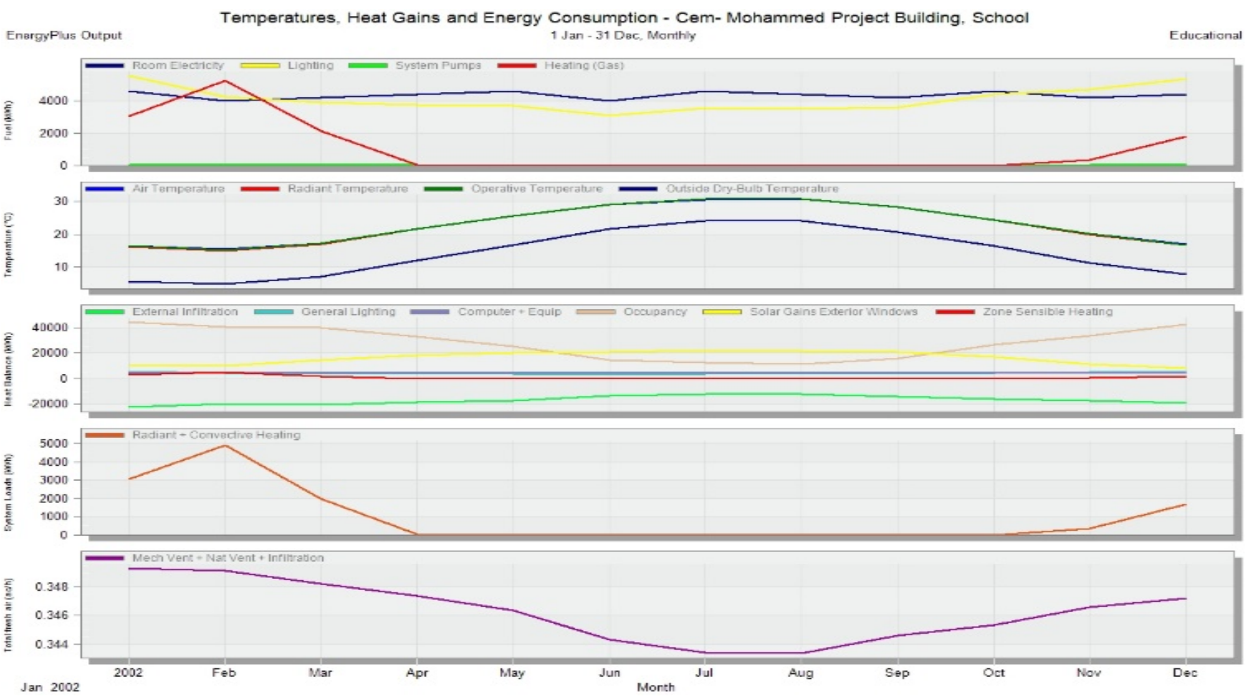


**Fig 5.** Simulation results (Dbl Clr 6mm/13mm – No Shading)

## 3 Results and Discussion

In this section, simulation results will be indicated and discussed for the considerable data that was generated from the DesignBuilder software (DB) output. The main output of simulation was a time based (commonly was annual graph) showing the energy performance and consumption of the building according to the selected period. It also provides detailed tables about the amount of energy consumed for each zone, a comprehensive data for each type of energy such as fuel, gas, and electricity that building requires for its function like heating, cooling, and lighting. Our main concern was to look at the total energy, heating energy and lighting consumed per year. These results were showing the annual consumption for the whole building, by dividing this amount of energy we got the needed energy per square meter for the results since the building model has no mechanical system that consumes energy for cooling, the results for cooling energy were zero in all the simulation runs. Three values for each combination that shows the total energy, heating energy and lighting consumed per year for the square meter of the building.

Solar heat loss can be significantly reduced by using the proper type of glazing for the façade [31]. Table 4 verifies the fact that by using the SSF and clear glazing facades the value of heat energy required is the highest, due to the highest values in solar heat gain coefficients as also mentioned by Bhandari [32].

Meanwhile, the values of heating energy are gradually decreased by increasing the number of glass layers; the lowest needed energy for heating was found by using the TSF with gas-filled. It is also essential to annotate that the type of shading does not play a significant role in reducing the needed energy for the heating. While the kind of glazing is an essential factor for reducing heating energy. Figure 6 shows the required heating energy for the façade and shading systems. Energy values for heating for each system combination were determined. It can be concluded that the single skin clear facades are not an energy efficient option to be used. Trp LowE glazing requires less heating energy among all glazing systems regardless of the shading system to be applied. We also can notice that the glazing system has the crucial role in preserving the building heat more than shading, which means the proper choice for glazing can be more effective in reducing the needed energy for heating rather than any applied shading system. It is logical to find that the no shading façade combination systems have the lowest values in the required energy for lighting the building as shown in Table 5 since the sun rays and light will penetrate the building the most, but this will lead to glare problem and non-convenience for the residents.

As it is evident in the spider Figure 7, the glazing type does not change the needed energy for lighting in a noticeable amount. However, we can notice how the SSF lies in the inner circle in the spider figure, has the lowest value of lighting energy, and how the Thermochromic facades have the highest lighting values due to its tinted films and coating that reduce the sunlight penetration into the building.

The only variable energy values between each combination simulation results are the heating and lighting energy since the needed energy for interior equipment, and pumps kept the same for all of the combinations. Lighting energy needs were much higher than the required energy for heating in each façade combination. The total lighting energy consumption results for the combination without shading, not surprisingly, was the lowest among all of the cases as shown in Table 5.

The total energy consumption per square meter results are shown in Table 6; it includes mainly the energy for:

- Heating
- Lighting
- Interior equipment
- Pumps

Figure 8 also shows the total energy per each combination of glazing systems versus the overhang and without shading. Since these shading systems provided the lowest values of building energy needed. The graph comparison shows how combinations' energy values react according to the glazing types and shading systems. It can be observed clearly that the "no shading" option has the lowest value as justified earlier, also by the increase in the depth of the overhang shading device, the value of total energy will be increased because of the escalation in interrupting the sunlight.

**Table 4**. Heating energy per square meter (kWh/m²) for each combination.

| Glazing \ Shading | 0.5m projection Louvre | 1.0m projection Louvre | 1.5m projection Louvre | 0.5m Overhang | 1.0m Overhang | 1.5m Overhang | 2.0m Overhang | Overhang + sidefins (0.5m proj.) | Overhang + sidefins (1.0m proj.) | No Shading |
|---|---|---|---|---|---|---|---|---|---|---|
| Dbl Clr 6mm/13mm Air | 2.26 | 2.41 | 2.51 | 2.16 | 2.24 | 2.3 | 2.36 | 2.27 | 2.42 | 2.06 |
| Dbl Clr 6mm/6mm Air | 2.48 | 2.64 | 2.74 | 2.38 | 2.46 | 2.52 | 2.59 | 2.48 | 2.64 | 2.27 |
| Dbl LoE (e2=2) Clr 6mm/13mm Air | 1.92 | 2.04 | 2.13 | 1.84 | 1.9 | 1.95 | 2 | 1.92 | 2.05 | 1.74 |
| Sgl Clr 3mm | 3.45 | 3.71 | 3.85 | 3.30 | 3.42 | 3.52 | 3.61 | 3.45 | 3.69 | 3.15 |
| Sgl Clr 6mm | 3.47 | 3.71 | 3.85 | 3.33 | 3.44 | 3.53 | 3.62 | 3.47 | 3.69 | 3.18 |
| Sgl LoE (e2=2) Clr 6mm | 2.48 | 2.65 | 2.76 | 2.37 | 2.46 | 2.53 | 2.59 | 2.48 | 2.69 | 2.25 |
| Trp Clr 3mm/13mm Air | 1.86 | 2.00 | 2.09 | 1.78 | 1.85 | 1.90 | 1.96 | 1.87 | 2.08 | 1.69 |
| Trp Clr 3mm/6mm Air | 2.07 | 2.21 | 2.30 | 1.98 | 2.05 | 2.11 | 2.17 | 2.08 | 2.46 | 1.89 |
| Trp LoE (e5=1) Clr 3mm/13mm Air | 1.70 | 1.81 | 1.87 | 1.64 | 1.69 | 1.73 | 1.78 | 1.71 | 2.10 | 1.56 |
| Thermochromic Glazing | 2.16 | 2.26 | 2.34 | 2.10 | 2.15 | 2.19 | 2.24 | 2.18 | 2.52 | 2.01 |

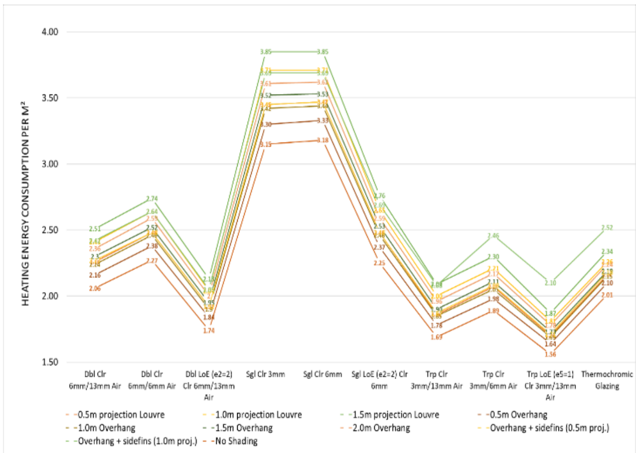


**Fig 6.** Glazing systems effect of the heating energy demand.

**Table 5**. Lighting energy per square meter (kWh/m²) for each combination.

| Glazing \ Shading | 0.5m projection Louvre | 1.0m projection Louvre | 1.5m projection Louvre | 0.5m Overhang | 1.0m Overhang | 1.5m Overhang | 2.0m Overhang | Overhang + sidefins (0.5m proj.) | Overhang + sidefins (1.0m proj.) | No Shading |
|---|---|---|---|---|---|---|---|---|---|---|
| Dbl Clr 6mm/13mm Air | 9.80 | 11.61 | 11.79 | 9.42 | 9.94 | 10.35 | 10.55 | 9.56 | 10.48 | 9.26 |
| Dbl Clr 6mm/6mm Air | 9.80 | 11.61 | 11.79 | 9.42 | 9.94 | 10.35 | 10.55 | 9.56 | 10.48 | 9.26 |
| Dbl LoE (e2=2) Clr 6mm/13mm Air | 10.00 | 11.86 | 12.05 | 9.62 | 10.13 | 10.55 | 10.75 | 9.76 | 10.72 | 9.45 |
| Sgl Clr 3mm | 9.43 | 11.13 | 11.31 | 9.08 | 9.61 | 9.98 | 10.19 | 9.22 | 10.09 | 8.91 |
| Sgl Clr 6mm | 9.47 | 11.19 | 11.37 | 9.13 | 9.65 | 10.02 | 10.23 | 9.26 | 10.14 | 8.95 |
| Sgl LoE (e2=2) Clr 6mm | 9.67 | 11.44 | 11.62 | 9.31 | 9.83 | 10.23 | 10.43 | 9.45 | 10.34 | 9.14 |
| Trp Clr 3mm/13mm Air | 9.96 | 11.83 | 12.01 | 9.58 | 10.09 | 10.51 | 10.71 | 9.72 | 10.64 | 9.42 |
| Trp Clr 3mm/6mm Air | 9.96 | 11.83 | 12.01 | 9.58 | 10.09 | 10.51 | 10.71 | 9.72 | 10.64 | 9.42 |
| Trp LoE (e5=1) Clr 3mm/13mm Air | 10.12 | 12.03 | 12.20 | 9.73 | 10.23 | 10.67 | 10.87 | 9.88 | 10.77 | 9.57 |
| Thermochromic Glazing | 10.83 | 12.88 | 13.02 | 10.44 | 10.87 | 11.37 | 11.54 | 10.61 | 11.53 | 10.37 |

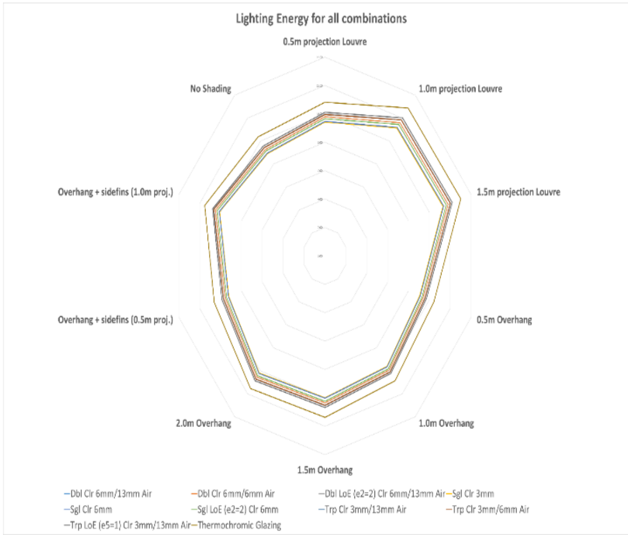


**Fig 7**. Glazing type effect on the lighting energy.

**Table 6**. Building total energy consumption (kWh/m²) for all the combinations.

| Glazing \ Shading | 0.5m projection Louvre | 1.0m projection Louvre | 1.5m projection Louvre | 0.5m Overhang | 1.0m Overhang | 1.5m Overhang | 2.0m Overhang | Overhang + sidefins (0.5m proj.) | Overhang + sidefins (1.0m proj.) | No Shading |
|---|---|---|---|---|---|---|---|---|---|---|
| Dbl Clr 6mm/13mm Air | 26.12 | 28.09 | 28.37 | 25.65 | 26.25 | 26.71 | 26.98 | 25.89 | 26.97 | 25.38 |
| Dbl Clr 6mm/6mm Air | 26.34 | 28.31 | 28.59 | 25.87 | 26.47 | 26.93 | 27.2 | 26.11 | 27.19 | 25.6 |
| Dbl LoE (e2=2) Clr 6mm/13mm Air | 25.98 | 27.97 | 28.24 | 25.52 | 26.09 | 26.57 | 26.82 | 25.75 | 26.84 | 25.26 |
| Sgl Clr 3mm | 26.94 | 28.90 | 29.23 | 26.45 | 27.09 | 27.56 | 27.86 | 26.74 | 27.84 | 26.12 |
| Sgl Clr 6mm | 27.01 | 28.96 | 29.28 | 26.52 | 27.15 | 27.62 | 27.92 | 26.80 | 27.90 | 26.20 |
| Sgl LoE (e2=2) Clr 6mm | 26.22 | 28.15 | 28.45 | 25.75 | 26.36 | 26.82 | 27.09 | 26.00 | 27.10 | 25.46 |
| Trp Clr 3mm/13mm Air | 25.89 | 27.89 | 28.16 | 25.43 | 26.00 | 26.48 | 26.73 | 25.65 | 26.75 | 25.17 |
| Trp Clr 3mm/6mm Air | 26.10 | 28.10 | 28.37 | 25.63 | 26.21 | 26.68 | 26.94 | 25.86 | 26.95 | 25.37 |
| Trp LoE (e5=1) Clr 3mm/13mm Air | 25.89 | 27.90 | 28.14 | 25.43 | 25.99 | 26.46 | 26.71 | 25.65 | 26.70 | 25.19 |
| Thermochromic Glazing | 27.05 | 29.21 | 29.43 | 26.60 | 27.08 | 27.63 | 27.85 | 26.85 | 27.90 | 26.45 |

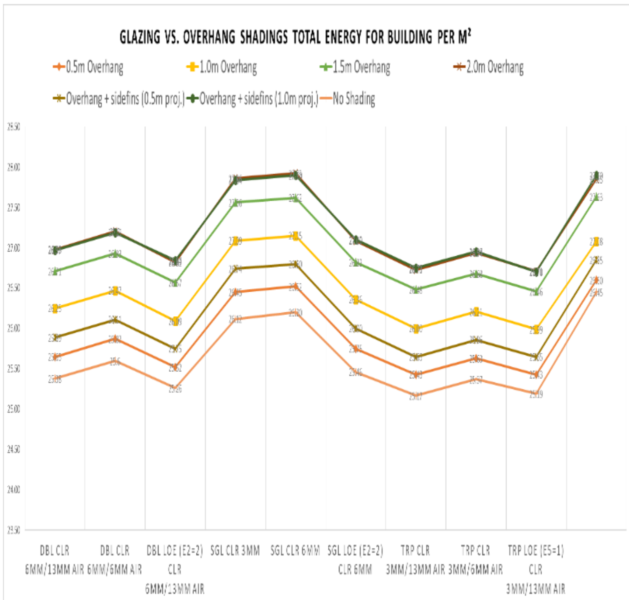


**Fig 8**. Various glazing vs. overhang shading systems total energy for building per m².

## 4 Conclusion

The evaluation regarding glazing types and shadings are made on a typical school building. To have better analysis for the effect of glazing types and shading systems on energy efficiency, one hundred combinations of the ten selected glazing types and the ten selected shading systems are matched one by one for comparison purposes. For this comparison, the school building is firstly modelled in DesignBuilder, and necessary adjustments regarding HVAC systems, occupancy schedules, construction materials and lighting arrangements in the building are all entered within the software. Finally, by the set of simulations made; analysis on energy efficiencies for the set of façade systems combinations regarding glazing types and shading systems are evaluated.

As we can understand from the results, the school building with the combination of Trp LoE (e5=1) Clr 3mm/13mm Air glazing type and no shading consumes the lowest energy for heating; meanwhile, both the combinations of Sgl Clr 3mm and Sgl Clr 6mm glazing with 1.5 projection louvre consume the highest energy for heating. For the consumption of the lighting energy, the school building that includes Sgl Clr 3mm as glazing with no shading consumes the lowest energy for lighting while the combination of thermochromic glazing with 1.5 projection louvre is consuming highest energy for illumination. Finally, for the total energy consumed; the building with Trp Clr 3mm/13mm Air glazing without shading consumes lowest total energy and the building with thermochromic glazing with 1.5 projection louvre consumes highest total energy. From these data, the most energy efficient combination for total energy is Trp Clr 3mm/13mm Air with no shading, most energy efficient combination for heating energy is Trp LoE (e5=1) Clr 3mm/13mm Air glazing with no shading and most energy efficient combination for lighting energy is Sgl Clr 3mm with no shading. Last but not least, since the energy efficiencies of the glazing types and shading systems are evaluated, the variants in costs for different combinations of glazing types and shading systems could be analyzed and evaluated as a future work of this research as well.

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