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Glass facades, variable and Dubai's climate

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ABSTRACT

Dubai's architectural landscape is defined by the extensive use of glass in its towering skyscrapers. Thus, glass selection is key for thermal performance, solar gain, and indoor comfort (Santamouris et al. 2020). This study examines the various factors that affect glass facade performance, including U-value, Solar Heat Gain Coefficient (SHGC), Shading Coefficient (SC), and Visible Light Transmission (VLT) as mentioned for Dubai climate. It outlines methodologies for optimizing glazing systems suited to Dubai's extremely warm & humid environment and presents a range of data, standards, and cutting-edge technologies such as multilayer glazing, advanced coatings, and gas fills. The primary aim is to enhance decision-making in design while complying with sustainable building codes.

Keywords: *U-value, SHGC, SC, VLT*

2.The aims

Determining the ideal U-value, Solar Heat Gain Coefficient (SHGC), and Shading Coefficient (SC) for the glazing system to enhance thermal efficiency and energy performance in hot and humid climates ultimately leads to a notable decrease in the air conditioning demand within the structure.

3.The objectives

To optimize the process of choosing glazing alternatives, such as multilayer panes and low-emissivity (low-E) that are particularly suitable for the extreme climate of Dubai, it is vital to provide both homeowners and project managers with an in-depth understanding of façade integration through a transparent and organized parametric framework.

4.Foreword

Dubai's skyline is a testament to modern architecture dominated by glass façades (.Al-Kodmany, 2020) These designs, while visually striking, must contend with the region's intense solar radiation, high humidity, and extreme heat. To address these challenges, architects use sustainable materials and innovative technologies in their designs (Chmurny, 2016). Green roofs, solar panels, and energy-efficient systems combat energy consumption and enhance the environmental footprint of new developments.

Furthermore, the skillful regulation of glazing features can substantially decrease heat intake, permitting buildings to uphold a cooler atmosphere without excessive reliance on air conditioning (Memari, 2013), thereby fortifying energy conservation efforts.

These attributes, encompassing U-value, Solar Heat Gain Coefficient (SHGC), and Solar Control (SC), are instrumental in shaping energy consumption and enhancing indoor comfort levels (Lawrence et al., 2021). Ultimately, these characteristics function as pivotal determinants in the operational efficacy of structures and their energy efficiency.

5.U-Value: Thermal Insulation Performance

Passive House certification requires that windows attain a U-value of 0.8 W/m²K for the entire glazing framework, which includes the frame (Schittich et al., 1989). Standards for net-zero energy and sustainable construction endorse the minimization of U-values through the strategic insulation of all building components to reduce thermal losses. The core formula that underpins this principle is $U = 1 / R$, in which an enhancement in resistance results in a lower U-value.

The variable R represents thickness, thermal mass, or conductivity. This straightforward formulation indicates that greater thickness is advantageous.

Table 1 shows the U-value for walls, whether solid or glass, which is considered a vital element of green building facades (ASHRAE,2017). Moreover, it is essential to take solar gain into account, as it can counteract heat loss. Specifically, referring to passive solar design that effectively employs windows, percentage, orientation, size, and shading to maximize heat absorption during the colder months while minimizing the potential for overheating in summer (Anderson et al., 2020).

High-performance insulation materials, such as cellulose, spray foam, or mineral wool, contribute to reducing thermal bridging (Aksamija,2013). Effective integration of geothermal heating can also contribute to achieving net-zero energy goals while aligning with sustainable building practices(Sangiorgio et al., 2022).

Table 1 indicates the U-values of walls as solid or glass (ASHRAE Standards 2017).

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Element	U-value W/m²·K
Insulated walls 20-25 cm	0.1 to 0.2
Non-insulated walls 20-25 cm	0.2 to 0.3
Single glazing 6mm	4.0 to 5.0
Double glazing, no frame, 6mm-12mm-air-6mm	1.1 to 2.5
Triple glazing, no frame, 6mm-12-6mm-12-6mm	0.5 to 1.0
Quadruple glazing, no frame, 6mm-12-6mm-12-6mm-12-6mm	0.3 to 0.5

Low U-values minimize thermal loss and summer heat gain (Walid et al., 2021) Global regulations, including Dubai's, set maximum U-values for building components to promote energy efficiency (Arya, et al., 2019).

These rules ensure construction aligns with sustainability goals to combat climate change. Strict U-value standards also push architects and builders to prioritize better insulation materials and designs (Taleb et al 2023), saving costs and improving occupant comfort. Advanced technologies and innovative building methods achieve efficiency goals, reducing environmental impact. As cities grow, energy-efficient solutions and the pursuit of lower U-values are increasingly important for a sustainable built environment, improving occupants' quality of life.

Online calculators for glazing U-values are used, but they are applicable for specific manufacturers (Jarimi et al., 2019), such as PILKINGTON or (spectrum.pilkington.com). Figure 1 presents images of the mobile application. The first dark blue low-E layer was chosen to meet Dubai's climate requirements, and the next three layers were selected because local workshops could manufacture them economically. The quadruple glazing selected had a 6mm blue-tinted outer pane, followed by a 12mm air gap and two 6mm clear glass panes (Kiatreungwattana et al., These variables are based on a product designed for hot climates and are suitable for local fabrication.

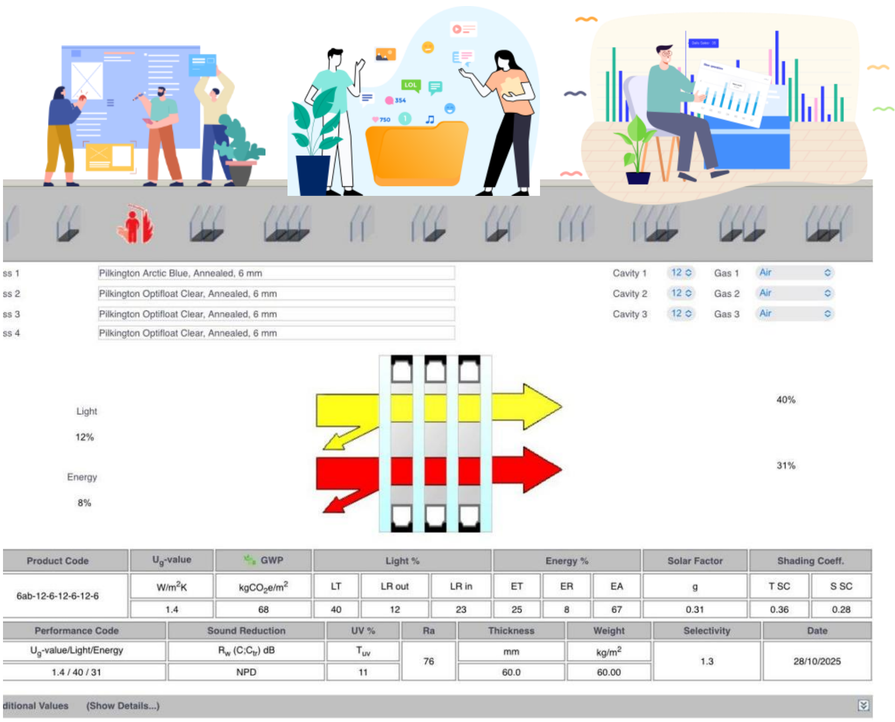


Figure 1 shows the online mobile app for quadruple glass (spectrum.pilkington.com, 2025)

Table 2 displays the parameters affecting U-value and facade relations. Low U-values in hot regions are achieved through design strategies, material selection, and insulation to reduce heat ingress.

Green policies emphasize the importance of using high-performance glazing with low U-values to mitigate heat gain (Oldfield, 2019). Multi-layered windows typically require engineering strategies for extreme climates or specific performance.

Multi-layered windows are employed in curtain walls for high-rise buildings. This application is common in such structures. Contemporary architects use multi-layered windows even in low-rise structures and renovations. These windows offer an easy and compelling way to conserve energy.

Many modern low-rise and high-rise structures use double-glazing systems. These systems can be enhanced by adding supplementary double glazing without needing to demolish the existing frameworks (Tibia et al.). 2015) .

As demonstrated in Table 2, the shift to double glazing was essential. This was followed by the implementation of triple and even quadruple glazing, which improved thermal efficiency and sound insulation. This approach is also suitable for integration with solar energy generation systems (Anderson et al.). 2020).

Table 2 shows factors influencing the U-value and facade (Oldfield, 2019)

Multi-layered glazing or low-E glass windows achieve lower U-values (0.5 to 0.3 W/m² K) using triple or quadruple glazing.

Reflective surfaces can reduce heat absorption, which keeps indoor temperatures lower.

Minimize sun exposure on facades, particularly those facing south and west.

The design of the towering building is streamlined. Additionally, it features a courtyard for low-rise structures, which facilitates their cooling and ventilation.

Green roofs, living wall systems that utilize evapotranspiration, and water features can effectively mitigate ambient temperatures around buildings, and they are highly encouraged. Furthermore, shading pergolas, canopies, eaves, louvers, and external sunshades enhance thermal efficiency.

Mass plays an important role in hot climates; thicker is better, possibly reducing about 10% of energy waste.

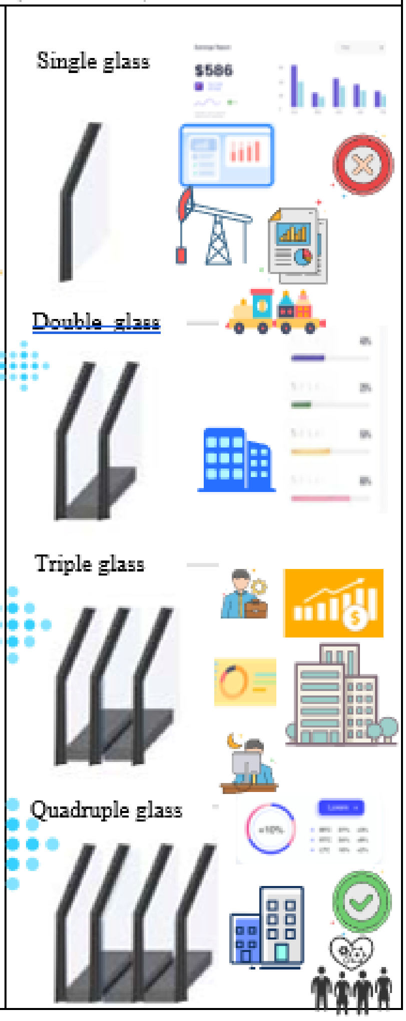


Table 2's findings indicate that modern glazing systems are driven by energy efficiency and the increasing demand for buildings that provide enhanced comfort through less heat absorption and excellent acoustic performance. These requirements, combined with economic value, fundamentally shape the development of innovative glazing systems (Koo et al.). 2023).

Figure 2: Factors influencing the U-value of glass include glass quality and thickness, interstitial gap width, alignment, and the presence of gas or air, all of which control heat gain.

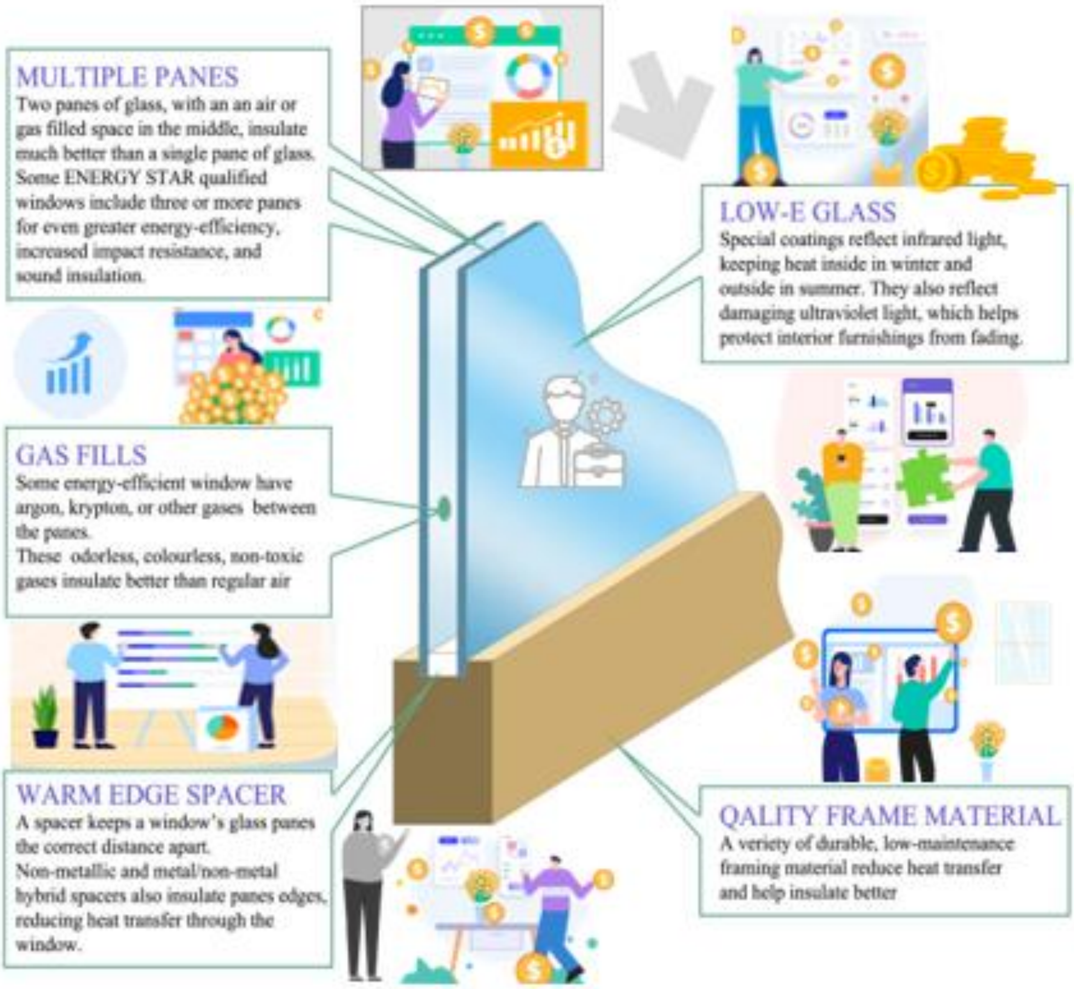
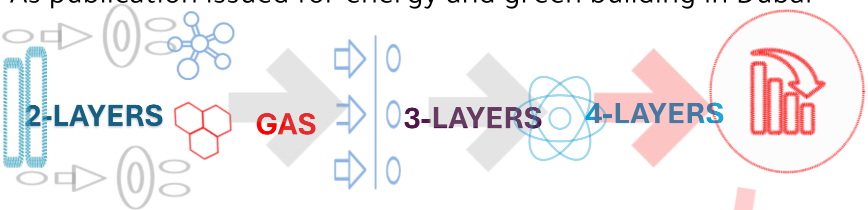


Figure 2: Pressing factors for windows U.S. fenestration standard NFRC 2022.

Incorporating coatings, thermal design engineering, and the assembled glass unit's configuration—including a larger air gap, a thicker glass pane, and double inside and outside coatings—all lower U-values. This reduction denotes higher insulation efficiency (Curcija et al.). 2019) .

Table 3 shows factors that limit power usage, such as the air or gas gap between the glass layers, which is economical from 16mm to 20mm (Duraković, 2020). Fabricated locally, the glass units provide 28mm with 8mm tempered glass for better firefighting control.

Table 3 Multi-Layered Glazing Used for High-Rise Buildings.

Factors	The U-value is measured in W/m² K.		
Single glass	Glazing is responsible for 25% of heat gain in buildings, U-value: 4.0-5.0W/m²·K.		
Multi-layered	Duplicating air gaps or gas-filled spaces, or extra glass thickness and extra space between the layers, offers superior insulation that competes with traditional solid wall systems.		
Glass & Codes.	DGU-double layer	TGU, 3-layer	QGU, 4-layer
U-value W/m²·K	2.1-2.5	1.0-0.5	0.5-0.3
Local code rates	2.2-3.0	1.8-2.2	1.3-1.7
as DM & DEWA	As publication issued for energy and green building in Dubai 		
Gas Filling	The use of inert gases, such as argon, krypton, or xenon, between the layers of glass serves to decrease the U-value. Specifically, krypton and xenon gases have lower thermal conductivities.		
(Low-E) Coatings Tinting	Coatings diminish heat transfer by constraining radiant heat loss through the refraction and reflection of light. Whether they are hard or soft coatings, such as Low-E glass, all enhance thermal efficiency.		
Frame	Improving the quality and materials of the frame can add 30-50% value.		
Spacer Material	Spacers affect thermal heat bridges, providing about 5% reduction.		

6. Solar Heat Gain Coefficient (SHGC)

The SHGC, also known as the G-value, ranges from 0 to 1 and measures the fraction of solar radiation admitted through glazing. A lower SHGC is desirable for Dubai because it means less solar heat, while a higher SHGC means more heat.

The equation is SHGC = T + Q, where T represents direct solar transmittance and Q represents secondary heat transfer (Q = E * F). E is the solar absorption of glass, and F, the inward flow factor, usually falls between 0.1 and 0.5, which is ideal for hot climates.

The optimal SHGC for buildings in warm climates typically ranges between 0.2 and 0.4, according to the U.S.; this is a general guideline National Fenestration Rating Council (NFRC) and the Department of Energy (DOE) for regions of intense thermal exposure.

This factor reduces solar heat accumulation but still allows enough natural light into interior spaces, which is a great balance. An SHGC of 0.3 to 0.4 is considered acceptable in places where daylight is key, but a lower value is better if regulating heat is your main goal. The building codes and regulations in Dubai stipulate SHGC efficiency, meaning an SHGC between 0.1 and 0.2 is preferred. The SHGC values shown in Table 4 are in accordance with ASHRAE Standard 90.1

Table 4 presents the SHGC for different types of glass.

Glass Type	SHGC
Standard Clear Single Glazing	0.8 - 0.9 (high heat gain) for cold climate
Double Glazing with Low-E Coating	0.3 - 0.5 for moderate climate
Triple Glazing with Low-E Coating	0.2 - 0.4 for hot climate
Quadruple Glazing with Low-E Coating	0.15 - 0.3 for hot climate
Reflective or Tinted Glass	0.2 - 0.3 depends on window engineering

Selecting window types and materials, such as efficient low-E glass, reduces solar heat gain while allowing natural light to pass through. Shading devices and building orientation that maximize daylight and minimize direct sunlight also improve energy efficiency while maintaining sustainability in buildings in Dubai. Table 4 shows SHGC by type and climate for different glazing types, demonstrating that selecting suitable coatings plays an important role in achieving an optimal equilibrium between maximizing daylighting and managing heat effectively. (Musgraves,2019)

7.The Shading Coefficient (SC)

SC is derived from SHGC (SC = SHGC / 0.87); it reflects the relative heat gain compared to clear single glass. This metric evaluates a glazing system's effectiveness in mitigating solar heat entering through windows. According to ASHRAM standards, SC values range from 0 to 1.

SC = 1 means the window transmits solar heat like standard clear single glazing.

When SC < 0.5, the window transmits less solar heat in hot climates to reduce cooling loads.

SC > 0.5: The window transmits more solar heat than standard clear glass, which is undesirable in hot climates because it can lead to increased cooling demand.

The coating acts as a key improvement, cutting energy consumption by roughly 40% and offering 70% visibility. These statistics are included in the product name (70/40). Consequently, metallic coatings on façades and roof glazing are now widely accepted (Richet et al., 2021). Figure 2 shows different possible window coatings.

Figure 3 A, B, C. When selecting glass, consider the climate. Low-emissivity coatings work best in warm climates (A), solar control coatings are ideal for cooler regions (B), and energy balance coatings are needed for temperate climates. Glazing saving systems are quality-engineered to fit the location's climate (EMIRI, 2019).

Table 5: SC vs. SHGC. In hot climates, a lower SC is preferable because it keeps indoor temperatures cooler and improves energy efficiency. Low-E coatings reduce the Shading Coefficient (SC). Similarly, an extra layer of glass and gas decreases SC.

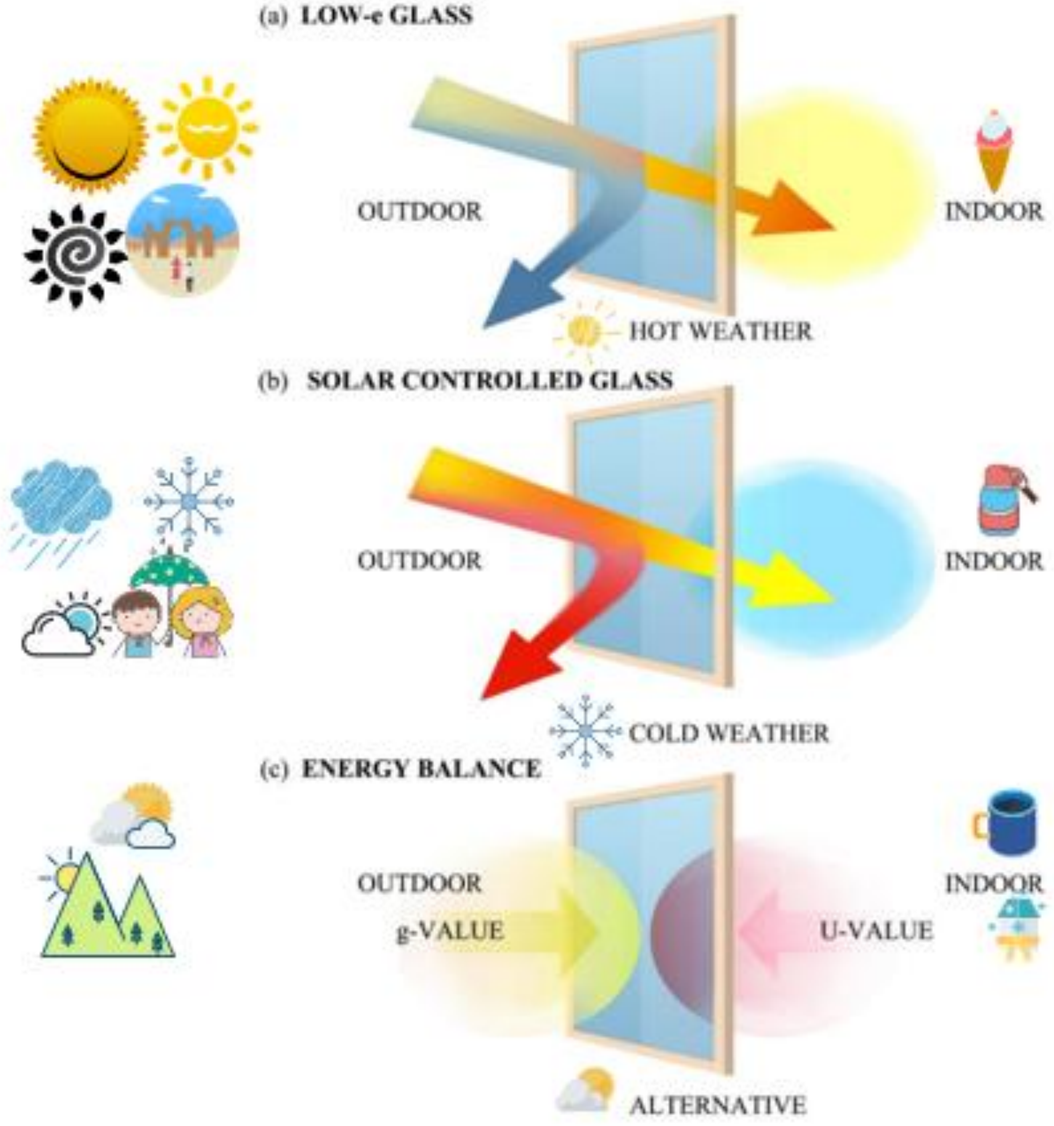


Figure. 3 Glass Coatings Value (EMIRI, 2019) (Energy Material & Industrial Research Initiative, 2019)

Free online glass calculators, such as the W7.4 software and Therm, offer valuable data; however, they require installation despite being free. The data in Table 5 come from W7.4 and other sources. In Figure 4, part A shows three 6mm low-E glass panels paired with 12mm of air, and part B shows four different low-E glass configurations. This information pertains to a product available in Dubai's open policy market. The architect is responsible for selecting the color and thickness of the coating, as well as the application side, whether inside or outside. Through testing various combinations, they can achieve the required specifications.

Table 5 Shading Coefficient vs. Solar Heat Gain Coefficient (SHGC)

Glass Type.	SC= SHGC/0.87	SHGC or G-value = T+Q
Clear Single-Glazed.	1.0	0.87
Low-E Glass Single.	0.3 - 0.5	0.2-0.4
Reflective Glass	0.2 - 0.4	0.2 - 0.3
Double Glazing (DGU)	0.5-0.65	0.3-0.5
Triple Glazing (TGU)	0.3 - 0.55	0.2 - 0.4
Quadruple Glazing (QGT)	0.15 - 0.35	0.15 - 0.3

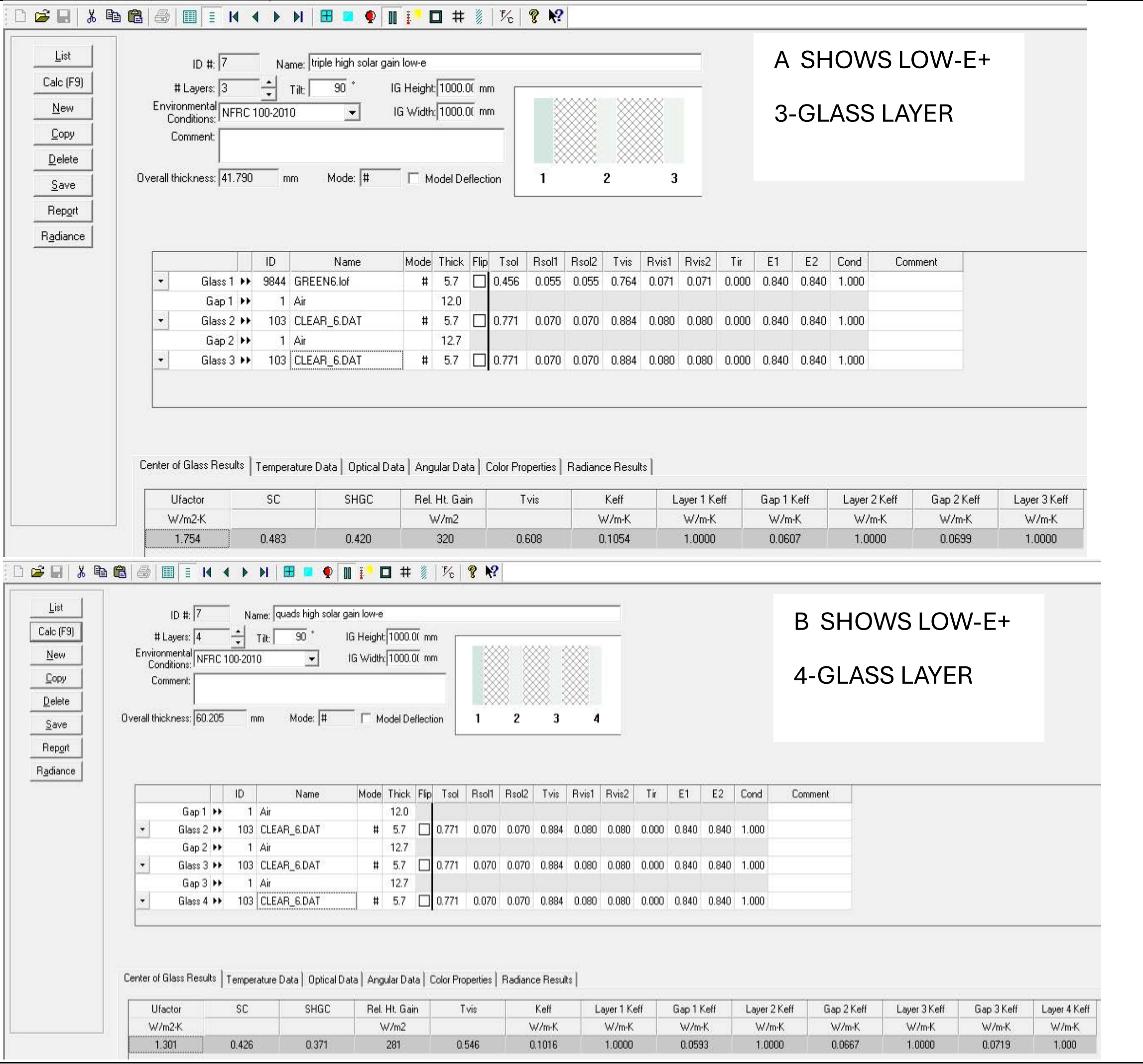


Figure 4: Images of the W 7.4 calculator for glass U-value, SC, and SHGC.
Many glass companies having their own calculators are listed in (Encyclopedia of Glass Science, Technology, History, and Culture, 2021 , page 1144)

8. Visible Light Transmittance (VLT)

VLT quantifies visible light passing through glass. Maximizing daylight trades off against minimizing heat gain. Visibility ranges from 0% to 100%, where 0% means fully opaque. Coatings balance thermal performance and glazing thickness, which affect VLT. Coatings balance thermal performance and glazing thickness, affecting VLT. Double, triple, or quadruple glazing limits VLT, though it's necessary for modern designs. The Daylight

Factor (DF) is a metric for visibility. It measures indoor daylight compared to outdoor, proportional to VIT. (ASHRAE 55)

Facades that optimize daylight and control solar heat define Passive House or green buildings. This is related to occupant comfort, promoting productivity in office buildings and hospitals by allowing natural light without glare or overheating, where the indoor environment is valued.

The VLT = VLT1*VLT2*VLT3*VLT4*VLT5*VLT6 .

In hot climates, specialized glazing lowers VLT light transmission; conversely, in cold climates, a higher VLT allows for passive solar heating. Table 6 provides extra information. The reduced VLT from more layers is not typically a problem in office buildings, but it presents a challenge in residential buildings.

Table 6 shows the visibility of passive glass systems and the number of glass layers.

Glazing type	VLT clear glass, Reflection 4- 10 %	VLT low-E or tinted
Single glazing	85-90%	60-80%
Double glazing (DG)	70-80%	50-70%
Triple glazing (TG)	60-75%	40-60%
Quadruple glazing (QG)	50-65%	30-50%

9. Advanced Fill Materials and Technologies

In addition to glass type and layer count, the infill materials dramatically influence performance. Glass basic variable controls are U-value, SHGC, SC, and VLT for `(DG),(TG) and (QG) with different insulating fillings like argon gas, krypton, xenon gas, vacuum, and paraffin PCM(phase change material). Values vary based on glass configuration and climate.

1. Vacuum glazing provides insulation with a high VLT, suitable for hot climates.
2. Krypton and xenon gas are suitable for limited space and cold climates.
3. Argon gas, ideal for moderate climates, balances U-value, SHGC, and VLT.
4. Paraffin PCM, ideal for thermal energy storage applications with no VLT.
5. Water filling or bio-organic fluids have no clear VLT very experimental.

All water-based experiments require careful evaluation because of the high potential for freezing, and the density of water must be considered. Vacuum glazing requires continuous maintenance, and attention to connection points is needed. Regular inspection is also required; it is suitable for hot weather. Table 7 shows different types of glass with their data. Proper sealing and regular thermal assessments ensure optimal thermal performance; this maintains optimal energy efficiency. These techniques are intended to maintain efficiency and prevent air infiltration (Arya et al., 2019).

High-quality materials and installation improve advanced glazing system longevity and performance. Table 7 shows a few types with their variables, and Figure 5 showcases the conceptual relationship of glass type and U-value, SHGC, SC, and VLT, as calculated by W7.4 software. When the U-value improves, the VLT is reduced unless costly advanced gas or vacuum technologies are used. Vacuum glass exhibits the highest VLT, closely followed by gas-filled double or triple glazing.

Table 7 Glazing Types and Different Infills (Musgraves et al., 2019)

Glass Type	U-value	SHGC	SC	VLT
Vacuum Glass	0.4-0.8	0.3-0.5	0.35-0.55	70-85
Relies on a vacuum gap for insulation and needs continuous maintenance.				
Photochromic Opacity, Changing	0.5-1	0.1-0.50	0.12-0.6	20-60
Thermochromic Changing Glass	0.3-1	0.2-0.50	0.23-0.58	30-70
Double Tempered	1.5-2.0	0.6-0.5	0.7-0.95	40-70
Double Lamination	1.4-2.4	0.2-0.5	0.3-0.5	30-70
Double and Venetian Blinds	1.4-2.3	0.15-0.4	0.2-0.5	10-40
Double (Aergola Solid Fill)	0.4-0.8	0.3-0.6	0.3-0.69	30-50
Aergola is ideal for cold climates, reducing heat loss. It is a lightweight, porous solid with high thermal insulation, acting as a heat barrier but appearing foggy.				
Double (Argon Gas Fill)	1.1-1.3	0.5-0.7	0.46-0.69	65-75
Argon gas fill has no effect on the light transmittance of the window.				
Double (Xenon Gas Fill)	0.9-1.2	0.25-0.45	0.29-0.52	65-75
High cost, lower thermal conductivity & more effective at preventing heat transfer.				
Double (Krypton Gas Fill)	0.8-1.0	0.4-0.6	0.46-0.69	65-75
Krypton is denser and has lower thermal conductivity than argon, providing better insulation in thinner cavities (~10-12 mm).				
Double Glass (Water Fill) Test	1.5-2.5	0.6-0.8	0.69-0.92	40-70
Double & (PCM Fill) Paraffin Test	0.7-1.0	0.3-0.5	0.35-0.57	30-60
Paraffin PCM reduces VLT as it scatters or absorbs light. Experimental				

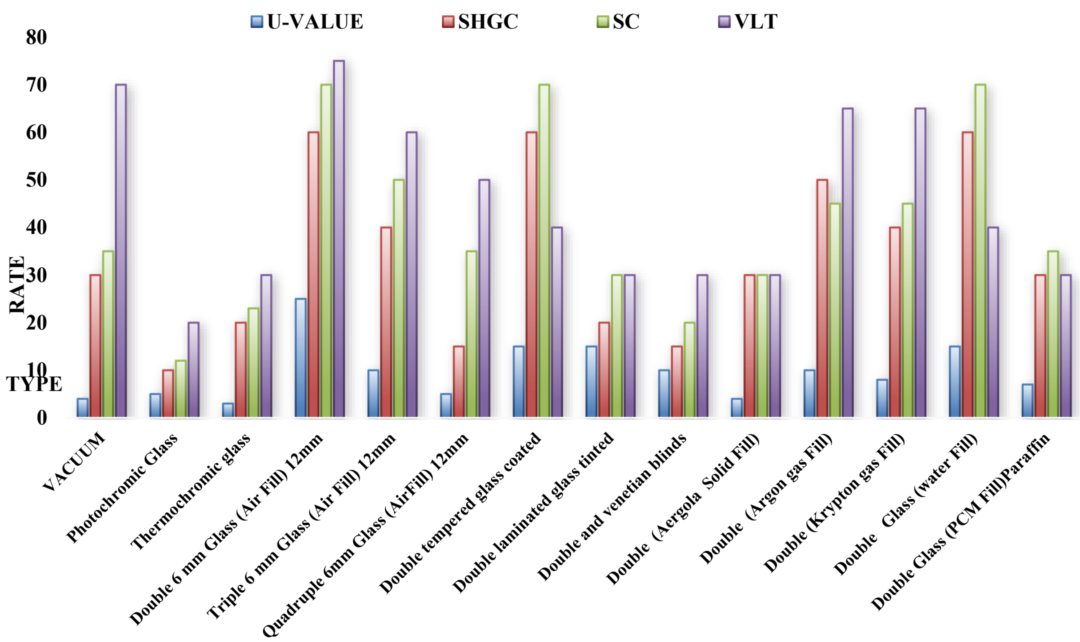


Figure 5 shows the glass types relation with other variable.

Table 8 compares colored glass variables. (Musgraves et al., 2019)

TYPE	U-Value W/m²·K)	SHGC ≤1	SC ≤1	VLT%	UV % Block	%IR
Low-Iron	5.4-5.9	0.85-0.95	0.9-1.05	90	95	85
Dark Blue	5.4-5.9	0.45-0.52	0.52-0.58	55	80	65
Brown	5.4-5.9	0.7-0.75	0.81-0.87	50	85	70
Silver	5.4-5.9	0.85-0.90	0.90-1.05	90	95	85
Reflective Bronze	5.6	0.45	0.52	15	95	50
Tinted Gray	5.6	0.50	0.58	30	80	60
Tinted Blue	5.6	0.65	0.75	60	85	70
Tinted Green	5.6	0.70	0.80	75	90	75
Low-E Glass	1.8-2.2	0.30-0.50	0.35-0.55	80	70-90	60
Laminated Glass	2.0-2.5	0.6-0.7	0.65-0.75	70	70-90	60-90
Tempered Glass	2.0-2.5	0.6-0.7	0.65-0.75	70	70-90	60-90
The dark blue is considered better for energy saving in Dubai						

10. UV and Infrared (IR) Blocking

Effective glass design must block UV (10-400 nm) and IR (700-2500 nm) to protect humans and interiors while reducing heat gain. Table 8 shows the UV and IR blocking capabilities for glass types from local manufacturers in the UAE, while Table 8 compares the color of glass with SHGC, showing that blue is more preferred, being less preferred than other colors.

11. Comfort and Satisfaction Standards

The important comfort standards for architects are PMV and PPD, ensuring occupant well-being and productivity. Table 9 compares PMV for satisfaction and PPD for dissatisfaction.

A 10% dissatisfaction threshold is shown by a red dashed line in Figure 6 as redrawn from the standard. The concept of thermal comfort is characterized by an optimal air temperature range, which is defined as 20-24°C (68-75°F) during the winter months and 23-27°C (73-80°F) in the summer. Humidity levels should ideally be maintained between 30-60% to prevent discomfort. Recommendations for lighting and acoustic comfort suggest an illumination level of 500-750 lux and noise levels below 40-50 dB(A) in open office environments.

Table 9 Comparison of PMV & PPD ASHRAE Standard 55 -2017.

PMV (Predicted Mean Vote) Scale		PPD Predicted Percentage of Dissatisfaction		
PMV Value	Thermal Sensation	PMV Value	PPD (%)	ASHRAE Standard 55 and ISO 7730
-3	Cold	0	5	A PMV between -0.5 and +0.5 is generally acceptable for thermal comfort. This keeps PPD below 10% and optimizes HVAC systems in offices for occupant well-being and productivity.
-2	Cool	±0.5	10	
-1	Slightly-cool	±1.0	25	
0	Neutral	±1.5	50	
+1	Slightly-warm	±2.0	75	
+2	Warm	±2.5	90	
+3	Hot	±3.0	99	

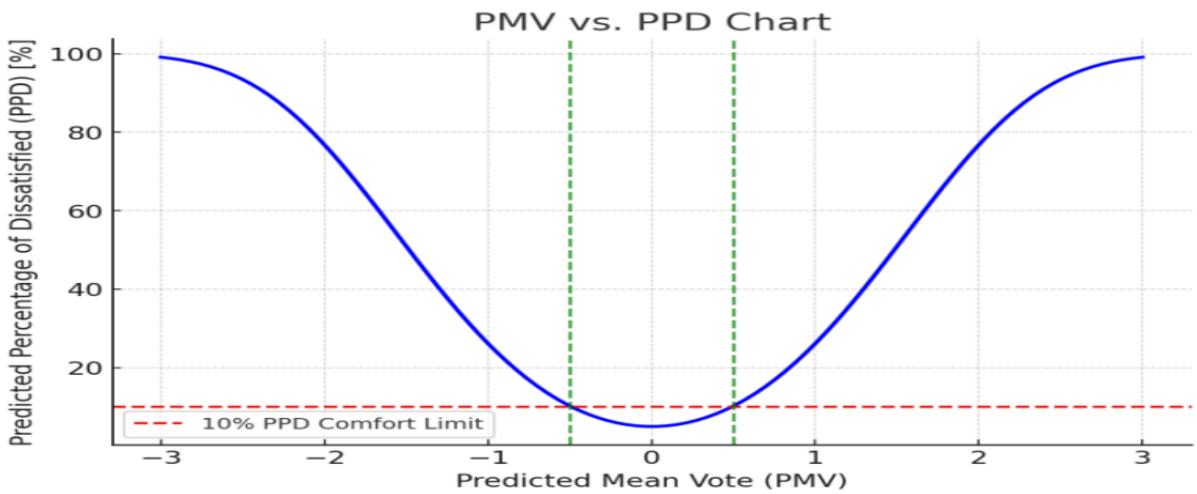


Figure 6 redrawn from ASHRAE 2017

The standards ensure optimal comfort, especially concerning fresh air exchange in office spaces, which should be between 5 and 10 L/s per person. Moreover, carbon dioxide levels must remain below 1,000 ppm to minimize fatigue. The importance of comfortable seating, height-adjustable desks, thoughtful space allocation, and intelligent environmental controls is paramount; each aspect is equally important in cultivating a productive work environment.

12. Conclusion

Selecting glazing systems for Dubai's climate requires a thorough evaluation of many performance variables. While established codes provide a framework, identifying the most suitable option for facade designers is complex. Architectural form and glass types often take priority over other considerations. The most elegant solution requires collaboration across many disciplines. An avant-garde technique is emerging; it promises to eclipse traditional methods of glass enhancement, suggesting that glass will persist as the material of the future because of the broad endorsement of the community (Marriage et al., 2020). Figure 7 shows that people & the economy, along with the material spectrum, are the builders of the city towers.

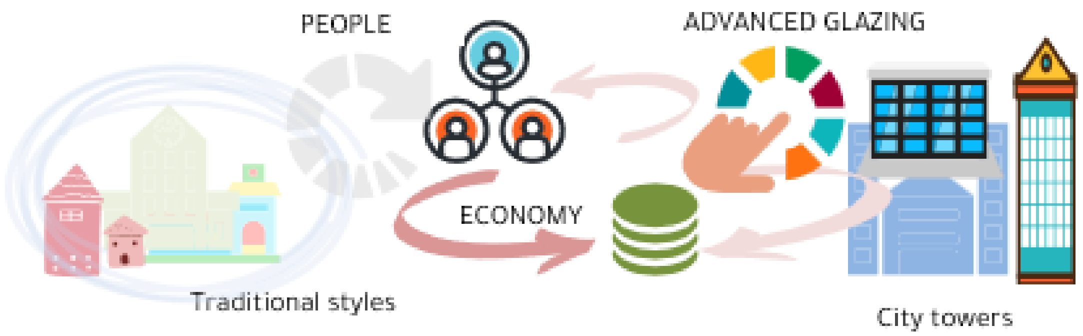


Figure 7 People, Economy, & Material are behind Dubai Towers.

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