A Localised

Introduction

- Highly glass-based facades are popular for aesthetic appeal and natural light/views.
- Glazing significantly affects building energy performance - insufficient glazing specification can lead to excessive solar heat gain and increased cooling loads, resulting in higher energy costs and greenhouse gas emissions.

- Glazing plays a leading role in providing natural daylight - insufficient glazing can cause glare and uneven distribution of daylight, leading to discomfort.

- Appropriate glazing specifications should be selected based on building's environmental conditions.
- Low-emissivity (Low-E) coatings, can improve thermal and optical performance of glass-based facades and mitigate excessive heating and evenly distribute daylighting, resulting in energy savings.

Low-E Coatings

Low-E coatings are microscopically thin chemical layers applied to glazing during manufacturing to optimize the glass's thermal and optical performance properties.

Low-E glazing limits solar heat gain and thermal energy transfer while providing comfortable levels of daylight transmission. This is achieved through efficient thermal and optical properties of Low-E coatings, which can reduce UV rays, glare and provide spectral selectivity. Low-E Coatings are classified as passive or solar control depending on their spectral selectivity.

Passive low-E coatings: reduce heat gain and retain internal solar heat while maintaining optimum natural daylighting.

Solar control low-E coatings: limit heat gain admitted into the building while maintaining optimum natural daylighting.

Low-E Coatings Manufacturing

Low-E coatings are stacked in layers of silver and dielectric (ceramic) materials and can be applied either on-line or off-line.

Off-line coatings: applied by dipping glass into solutions, firing or evaporating metals onto glass under vacuum. Magnetron sputtering enables various coatings with different colours, reflectivity and thermal properties.

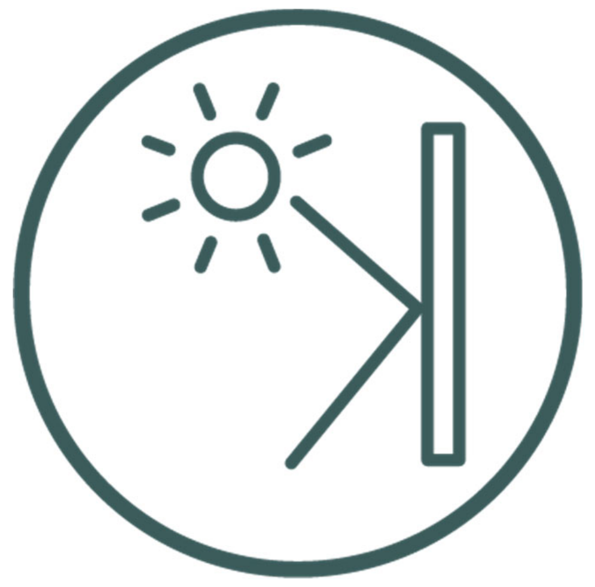
On-line coatings: applied during glass manufacturing, allowing for modifications to improve solar control or reduce emissivity.

Dielectric coatings: produce interference effects, offering higher light transmission with increased select

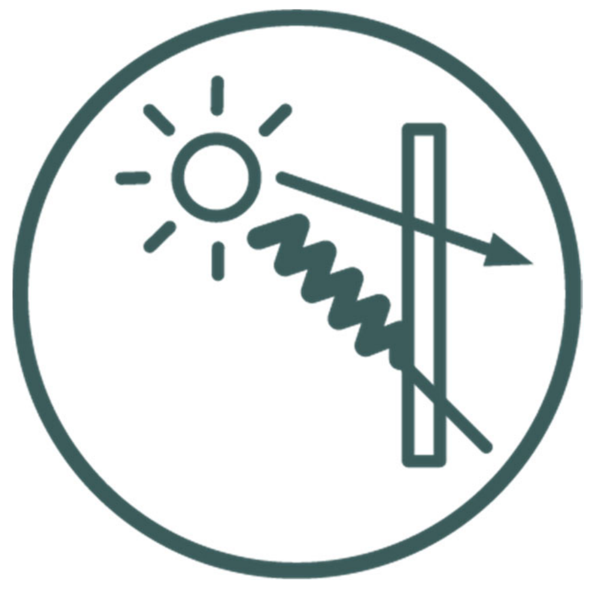
Dichroic coatings: multi-layered coatings that exhibit different colours by reflection and transmission as a function of viewing angle.

Mirror silvering: a chemical process depositing a coating of metal, onto the surface of clear glass, which gives the mirror its reflective properties.

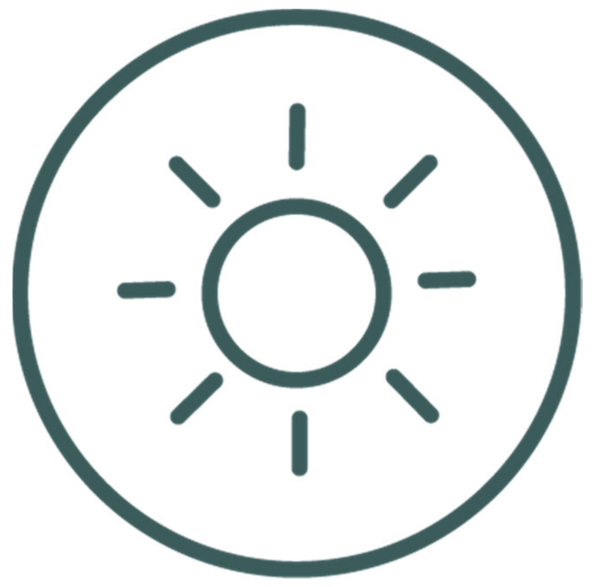
Thermal Insulation



Solar Control: Sunlight passes through while reflecting a large proportion of the sun's heat.



Spectral selectivity



Reducing destructive UV rays and glare

Aims

To evaluate glass coatings on a glass-based façade and study the impact that they have on the solar heat gain and daylighting performances of highly glazed buildings in Ireland.

Objectives

Identify commonly used low-E glazing coating systems used in Ireland and investigate their effects on the thermal and optical performances of a glass-based façade in detail.

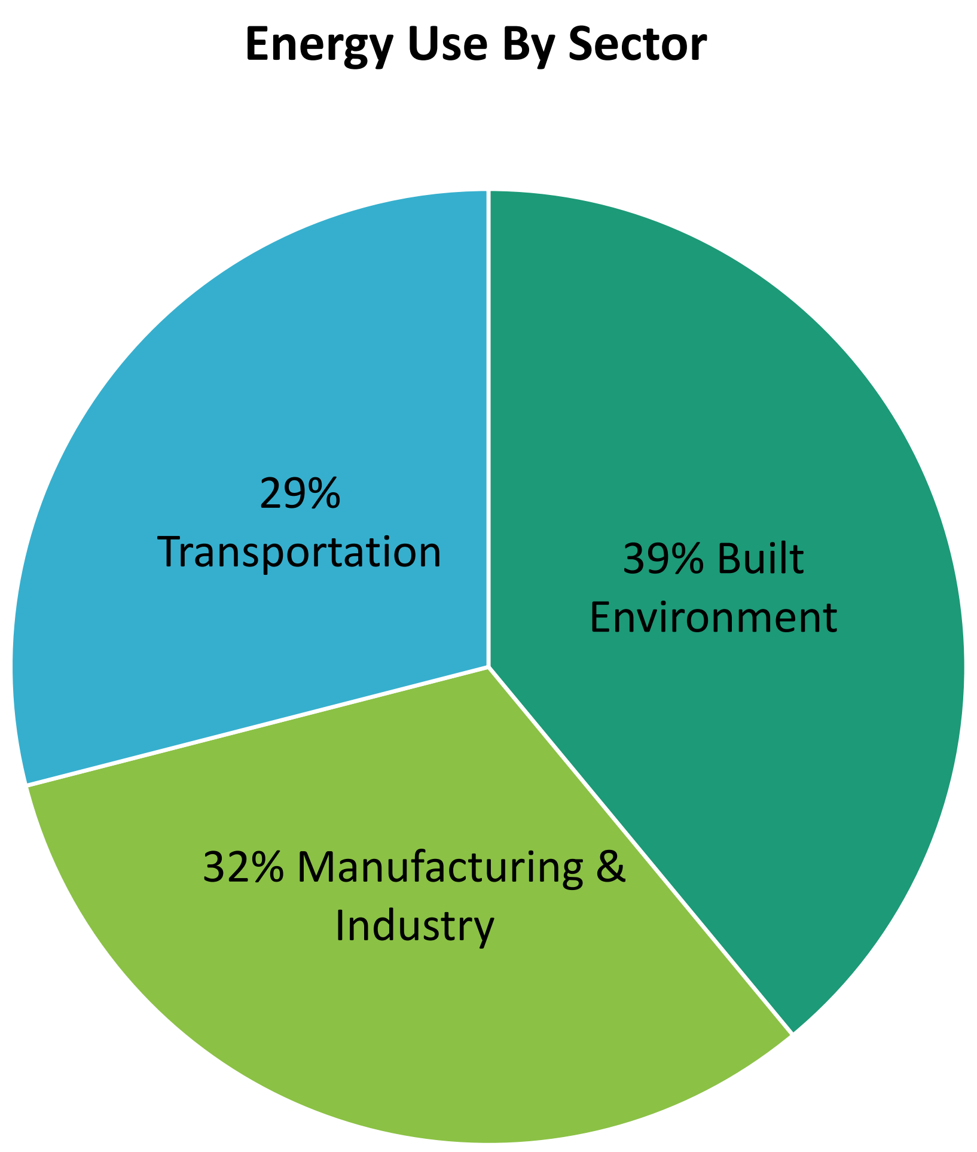
Evaluate the impact of these glazing coating systems on the performance of the localised case study building in terms of solar heat gain and daylighting, using both digital simulation technology and manual calculation.

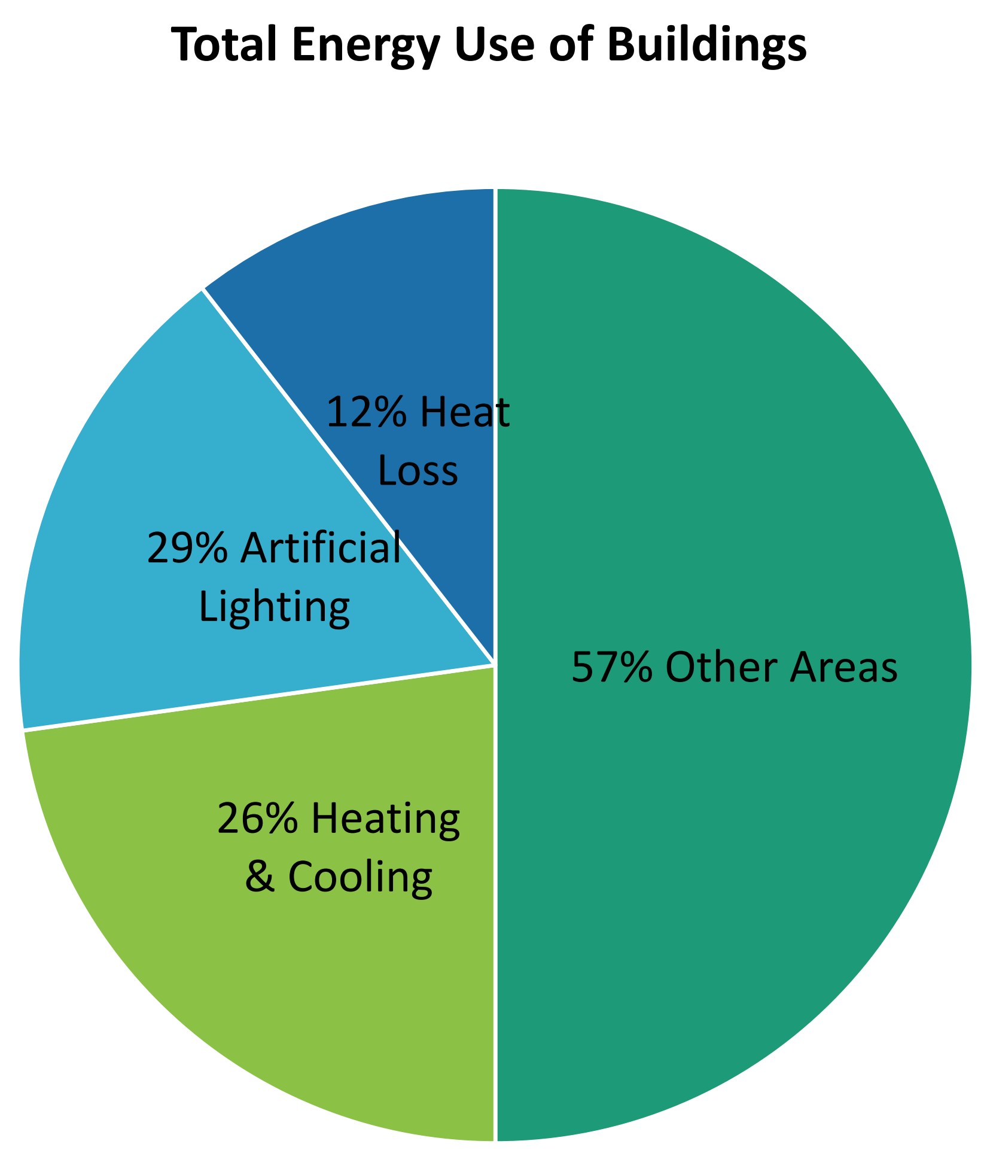
Identify the optimal coating specifications for the specific environmental conditions of the localised building through a comparative analysis.

Provide recommendations for the design and optimization of glazing systems that can be applied in both new and retrofit building projects.

Motivation

- The need to improve energy efficiency of buildings and reduce negative environmental impact (generation of electricity for lighting, appliances, etc. and heating). - Energy use in buildings relating to greenhouse gas emissions: 17.5% (2020)
  - Residential buildings (10.9%)
  - **Commercial buildings** **(6.6%)**
- Lack of localized studies on the effectiveness of glazing coatings on solar heat gain and daylighting.
- The accuracy and efficiency of digital simulation tools in modern energy efficient building design.



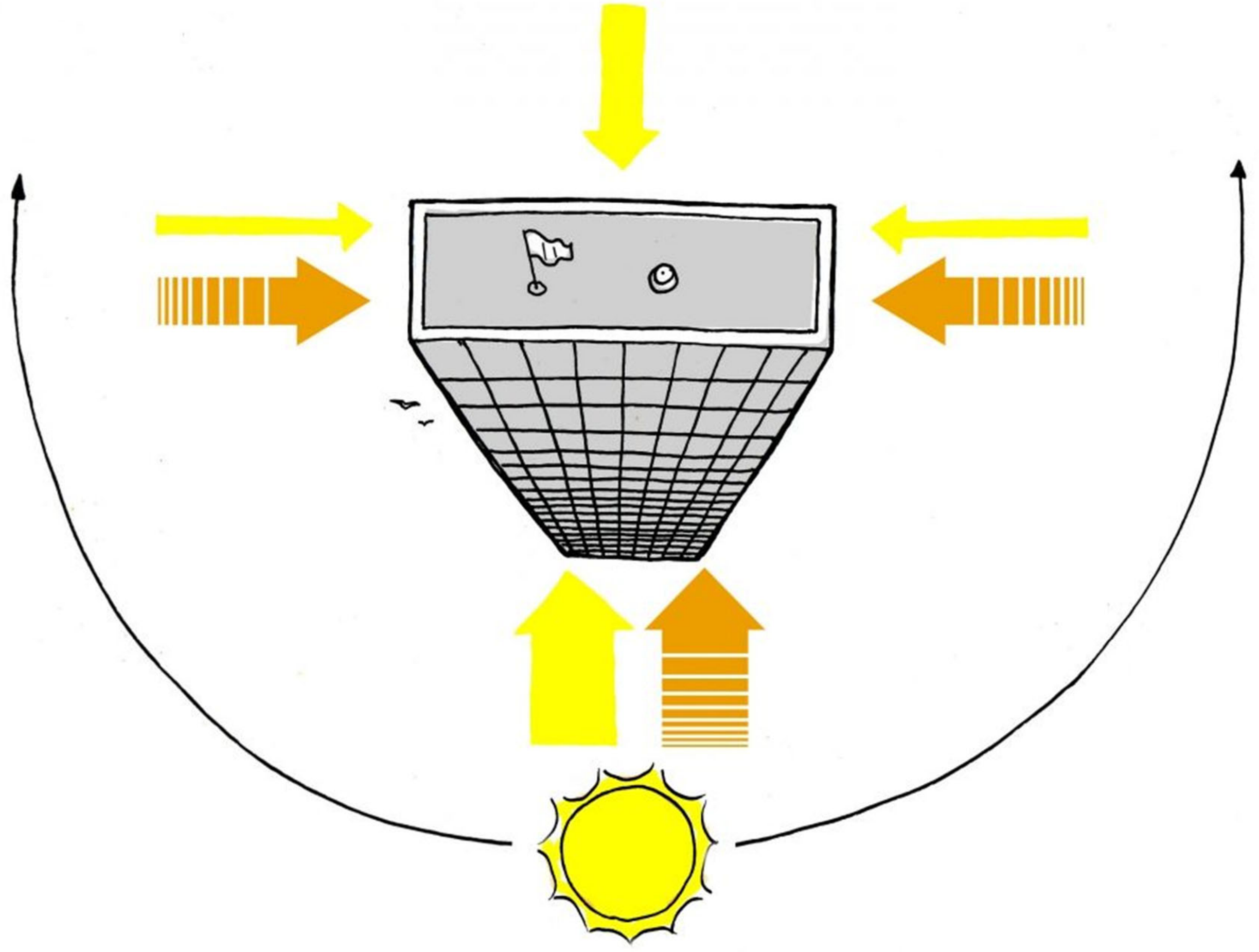


Investigation Into The Effects Of Coatings On A Glass-Based Façade In Terms Of Solar Heat

Factors That Affect Coating Selection

The following are some of the key factors that affect coating selection:

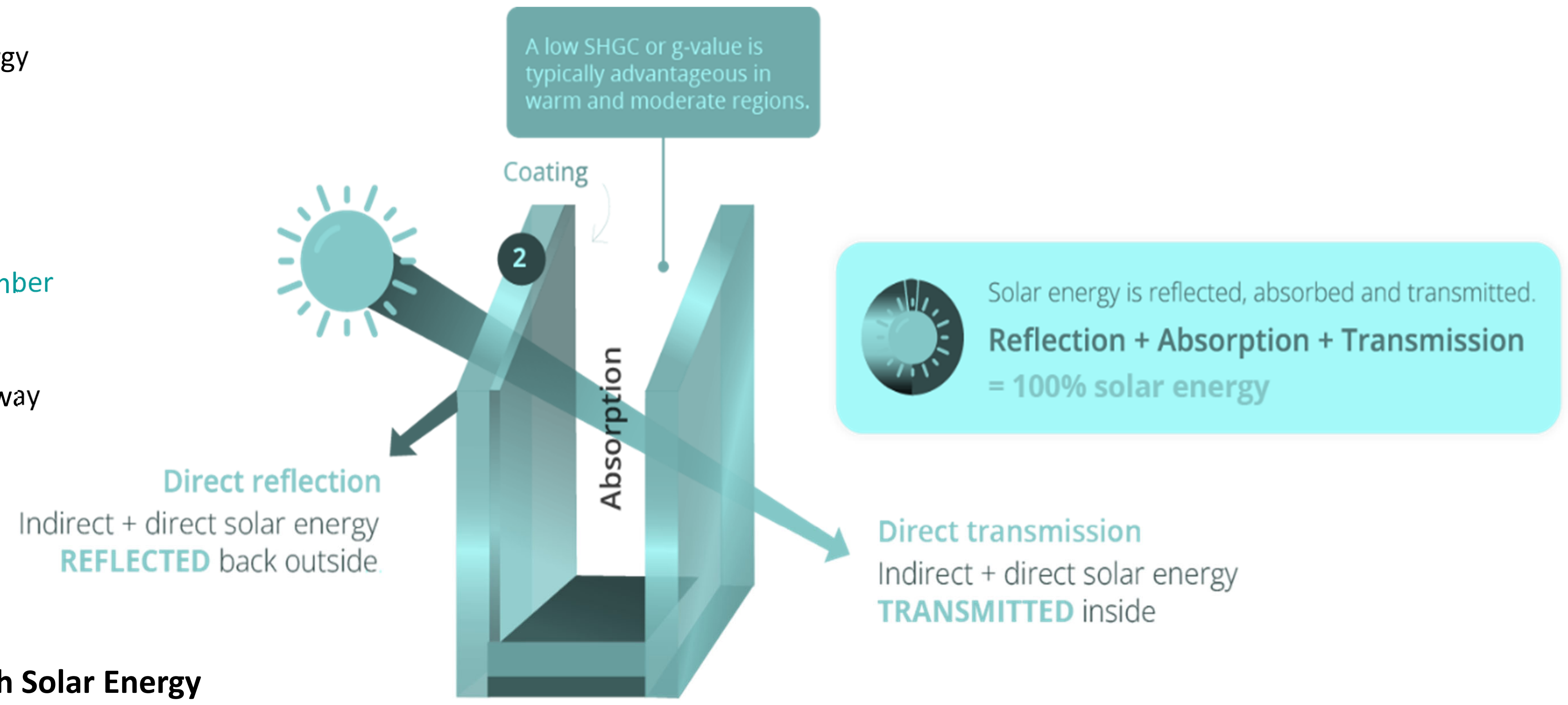
- Climate Conditions
- Orientation of the Glazing
- Desired thermal performance (U-Value)
- **Desired heat gain - Solar Heat Gain Coefficient (SHGC)**
- **Desired daylighting - Visible Light Transmission (VLT)**
- Glare Control



How Glass Interacts With Solar Energy

When ray of electromagnetic energy hits a glass surface, it can reflect, absorb, or transmit.

Placing a low-E coating on the number 2 surface often provides the best performance because it reflects away part of the incoming solar energy before it can enter the glazing.



Low-E Glass Interaction With Solar Energy

Factors That Affect Coating Selection

- Longwave radiation: wavelengths from 5,000 to 50,000 nm. Low-E coatings are designed to slow radiant heat transfer. They reflect longwave radiation (heat) back into the building during cooler periods. – Relates to heat.
- Shortwave radiation: is received at the surface of the earth. It includes ultraviolet, visible, and near-infrared wavelengths – together ranging from 300 to 2,500 nm. Solar control coated glazing can block a significant amount of this energy by reflecting and absorbing part of it. – Relates to both heat and visible light.

Solar Energy (shortwave radiation):

300 – 2,500 nm

Radiation received at the surface of Earth from the Sun

Heat (longwave radiation):

5,000 – 50,000 nm

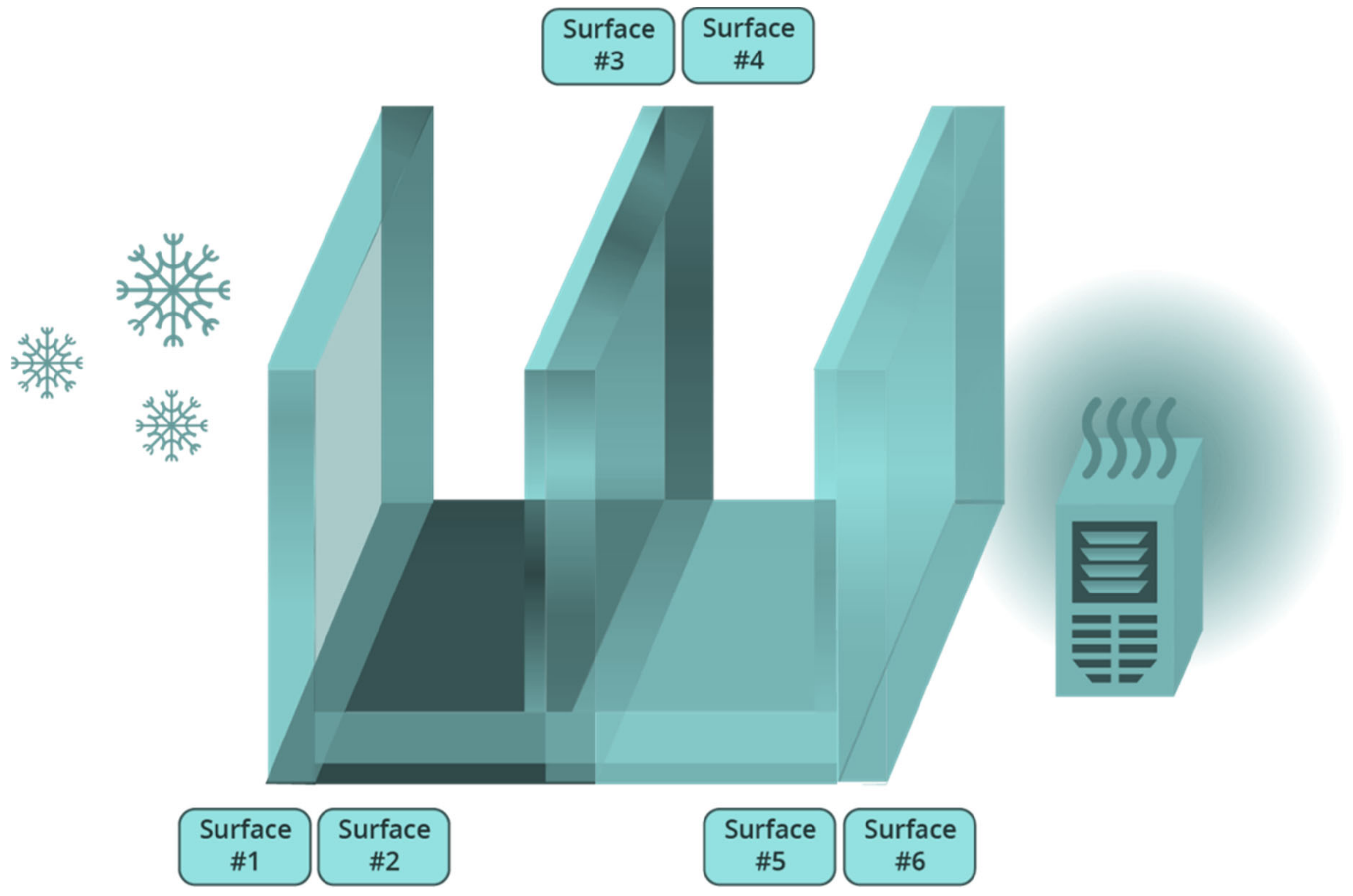
Detectable as light

Solar Radiation Spectrum Diagram

How Glass Interacts With Heat Transfer

Heat is energy transferred between objects due to temperature differences and can be transferred in 3 ways:

- Radiation: Radiation is heat transfer by electromagnetic energy, where longwave energy moves through the glazing assembly.
- Conduction: Conduction transfers heat within a medium due to temperature differences. Argon gas, with lower thermal conductivity than air, reduces this transfer inside the IGU. The edge of the IGU conducts heat from glass to spacer and back to glass, but a warm edge spacer can slow down this transfer.
- Convection: Convection is heat transfer through currents of slowly moving air or gas within the IGU.



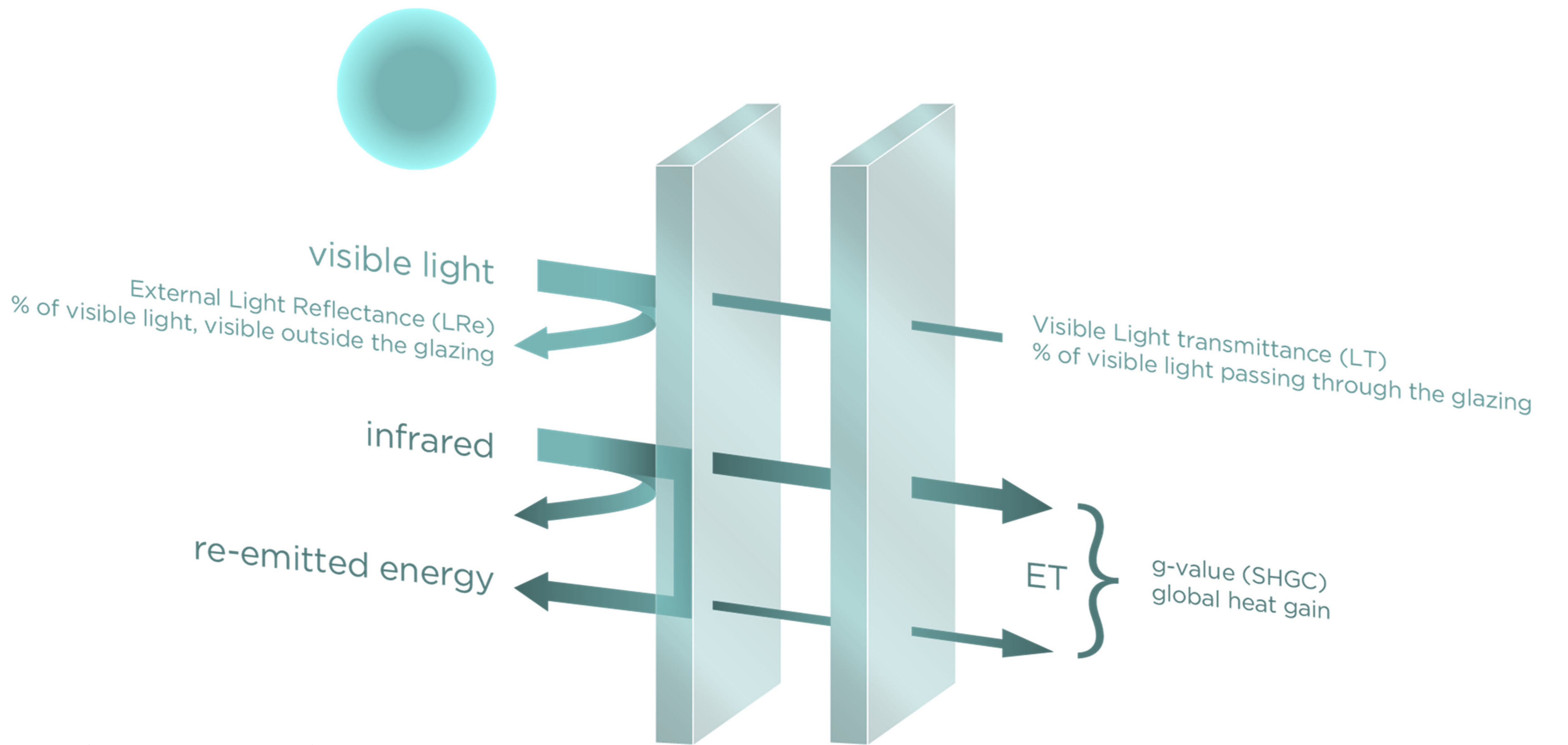
Low-E Glass Interaction With Heat

Low-E Coating Materials Solar and Optical Performance

Low-E Coating Material	Optical Properties	Optical Properties
Metals	Low visible light transmittance (VLT) – reducing natural daylight	Low solar heat gain (SHGC) – reducing solar heat gain
Copper		
Bronze		
Metal Oxides	High or low visible light transmittance (VLT) depending on composition of spectral selectivity – increasing or decreasing natural daylight	
Metal Alloys		
Ceramic Frits		
Organic Materials		

OUTDOOR

INDOOR

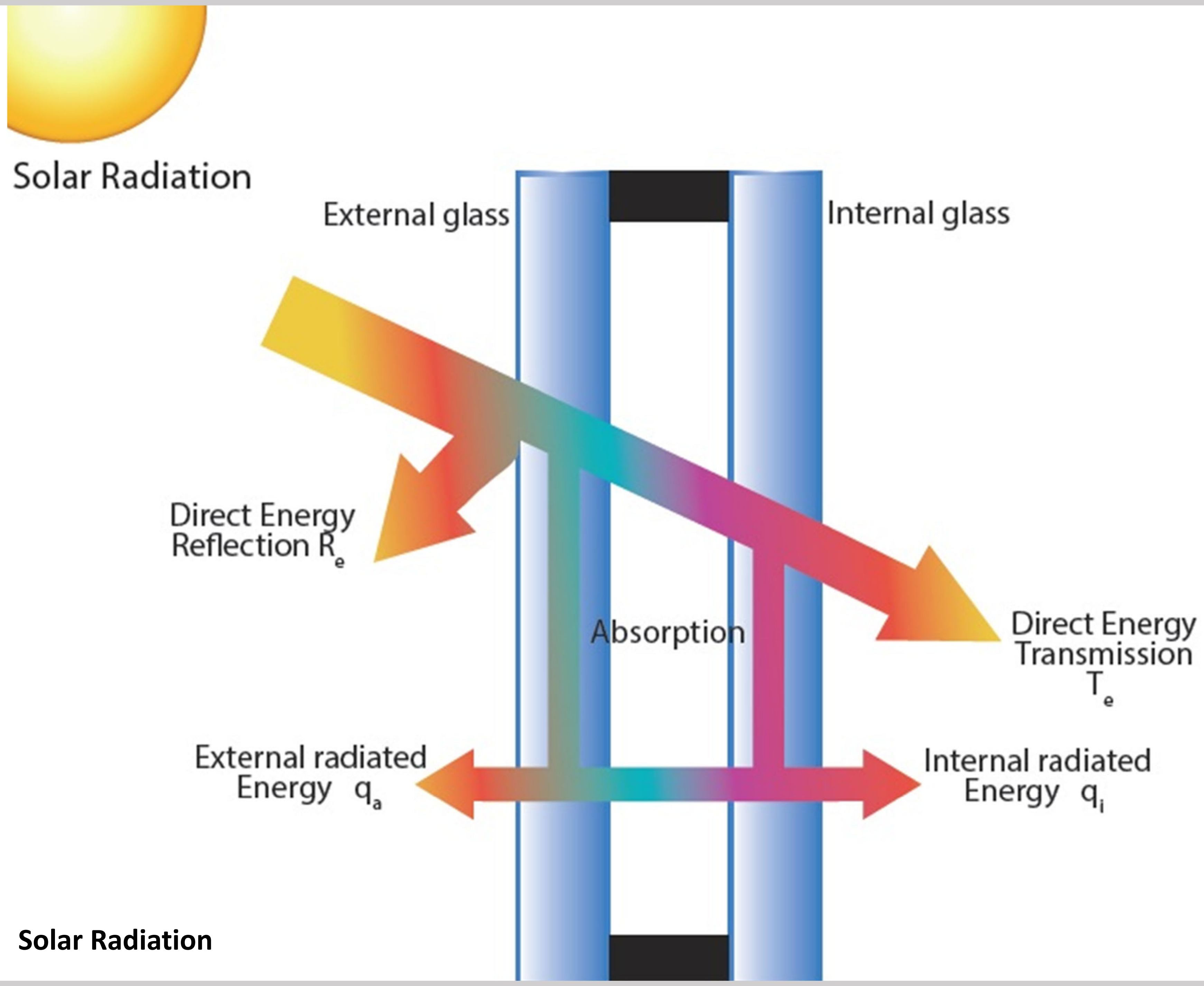


Low-E Glass Interaction With Radiation

Gain And Daylighting

Solar Heat Gain

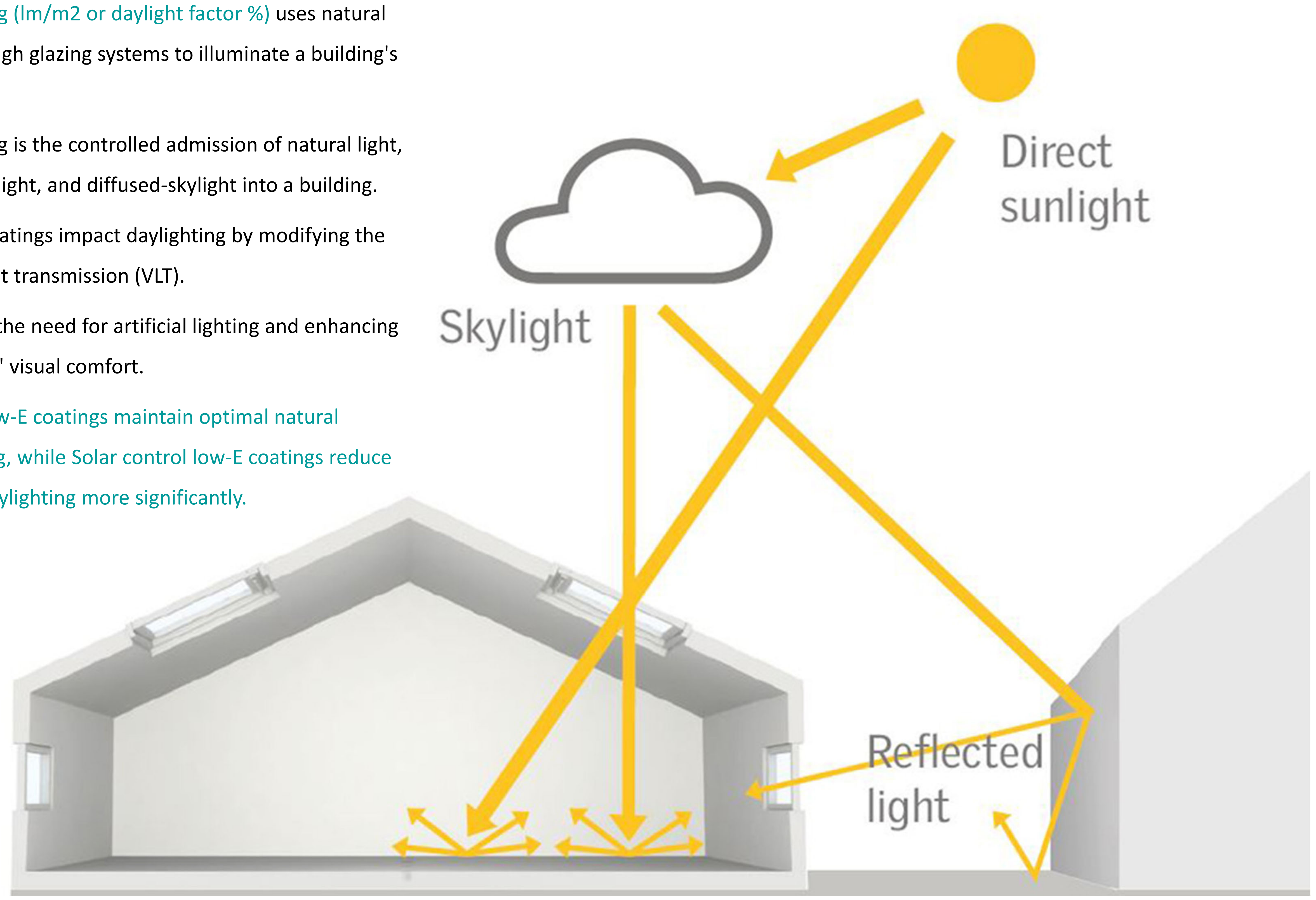
- Solar heat gain (W/m2) is the solar radiation that enters a building through glazing.
- Solar heat gain is caused by the absorption of solar radiation by glazing materials and re-radiation and convection into the building.
- Glazing coatings modify the amount and type of solar radiation entering the building by modifying the solar heat gain coefficient (SHGC).
- Excess gains lead to increased temperature and cooling load requirements.
- Warm/ moderate climates: a low SHGC is preferred.
- Colder climates: a higher SHGC may be beneficial to allow passive heat gains.
- Both passive low-E and solar control Low-E coatings reflect significantly solar radiation.



Solar Radiation

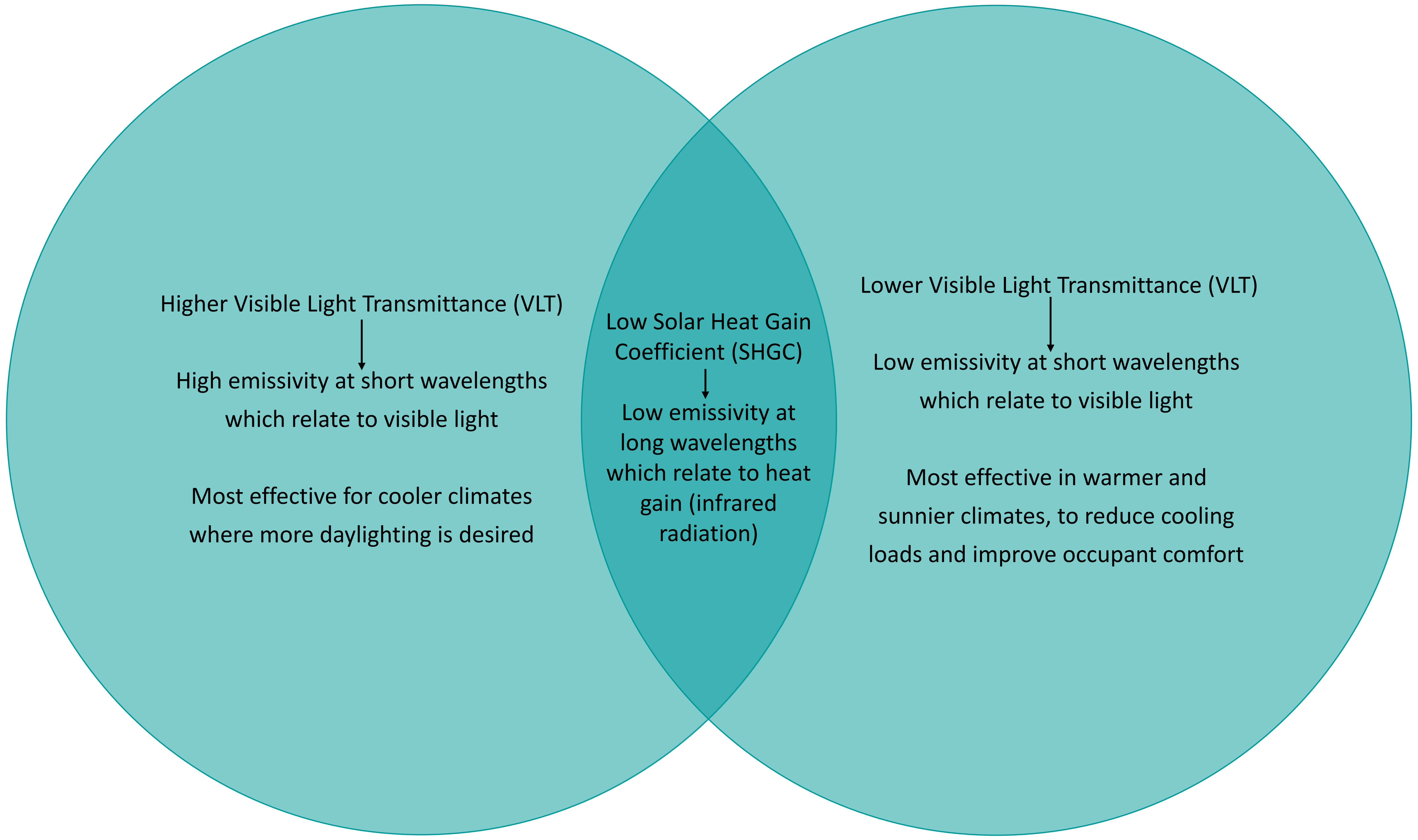
Daylighting

- Daylighting (lm/m2 or daylight factor %) uses natural light through glazing systems to illuminate a building's interior.
- Daylighting is the controlled admission of natural light, direct sunlight, and diffused-skylight into a building.
- Glazing coatings impact daylighting by modifying the visible light transmission (VLT).
- Reducing the need for artificial lighting and enhancing occupants' visual comfort.
- Passive low-E coatings maintain optimal natural daylighting, while Solar control low-E coatings reduce natural daylighting more significantly.



Types of Natural Light

Passive Low-E VS Solar Control Low-E



Passive Low-E

Solar Control Low-E

Higher Visible Light Transmittance (VLT)
↓
High emissivity at short wavelengths which relate to visible light

Most effective for cooler climates where more daylighting is desired

Low Solar Heat Gain Coefficient (SHGC)
↓
Low emissivity at long wavelengths which relate to heat gain (infrared radiation)

Lower Visible Light Transmittance (VLT)
↓
Low emissivity at short wavelengths which relate to visible light

Most effective in warmer and sunnier climates, to reduce cooling loads and improve occupant comfort

Passive low-E coatings: allow a high percentage of visible light to pass through while reflecting and absorbing the amount of solar radiation that enters a building. This can reduce the need for artificial lighting and improve occupant comfort. However, passive Low-E coatings may not reduce solar heat gain as significantly as solar control low-E coatings.

Solar control low-E coatings: reduce both the amount of heat radiation and visible light that enters a building. This is achieved by optimizing the spectral selectivity of the coating to reflect and absorb most wavelengths of solar radiation that cause solar heat gain. This can help reduce cooling loads and improve occupant comfort.

Optimum Daylighting Levels In Open-Plan Office Buildings – CIBSE Recommendations

Recommended maintained illuminance (lux)	300 for screen-based work 500 for paper-based tasks
Recommended cylindrical illuminance (lux)	150 at task area with modelling ratio of 30-60%
Limiting glare rating	19
Recommended daylight factor (%)	2 - 7

Optimum Solar Heat Load Per Unit Floor - FenestraPro

Solar Heat Gain	Solar Heat Load Per Unit Floor (W/m2)
Insufficient	< 15
Optimal	15 - 25
Excessive	> 25

Methodology

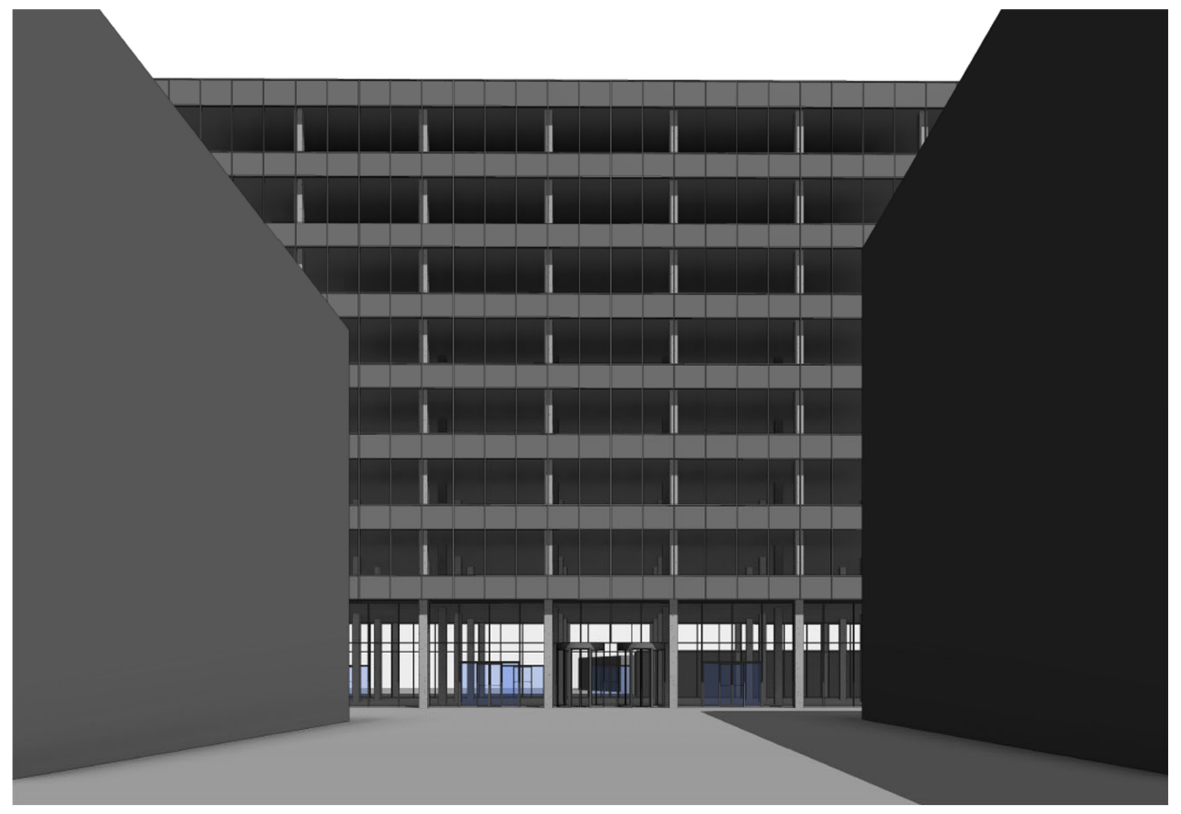
- Building model used for the performance simulations was initially modelled using Revit.
- FenestraPro plugin was then used to analyse the solar heat gain and daylighting levels data of the model.
- Glazing specifications of the glazed facade were changed in each simulation to evaluate the performance of clear glass, passive low-E coatings and solar control low-E coatings.
- Results were qualitatively analysed determine the effects of each glazing system on the solar heat gain and daylighting levels – initial results from the clear glass were used as baseline values.
- Manual solar heat gain and daylighting factor calculations were also performed.

Limitations considered in this research methodology:

- Glazing specifications: The research was limited to one glazing specification for each coated glazing system included in the analysis. There are many different glazing specifications available for each coated glazing system included, each with different performance levels thermally and optically.
- Localised investigation: The results may not be applicable to other locations with different environmental conditions.
- Digital simulation: Simulations may have limitations in calculating accurate solar heat gain and daylighting levees, as the results are solely calculated predictions.

Case Study: Miesian Plaza

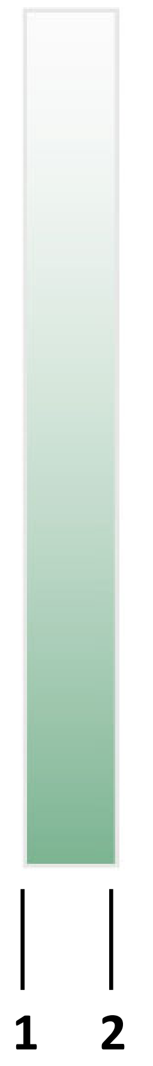
- Location: 50-58 Baggot Street Lower, Dublin 2
- Architects: Scott Tallon Architects
- Façade retrofit consultant: Arup
- Current façade glazing system after retrofit: passive low-E coated glazing



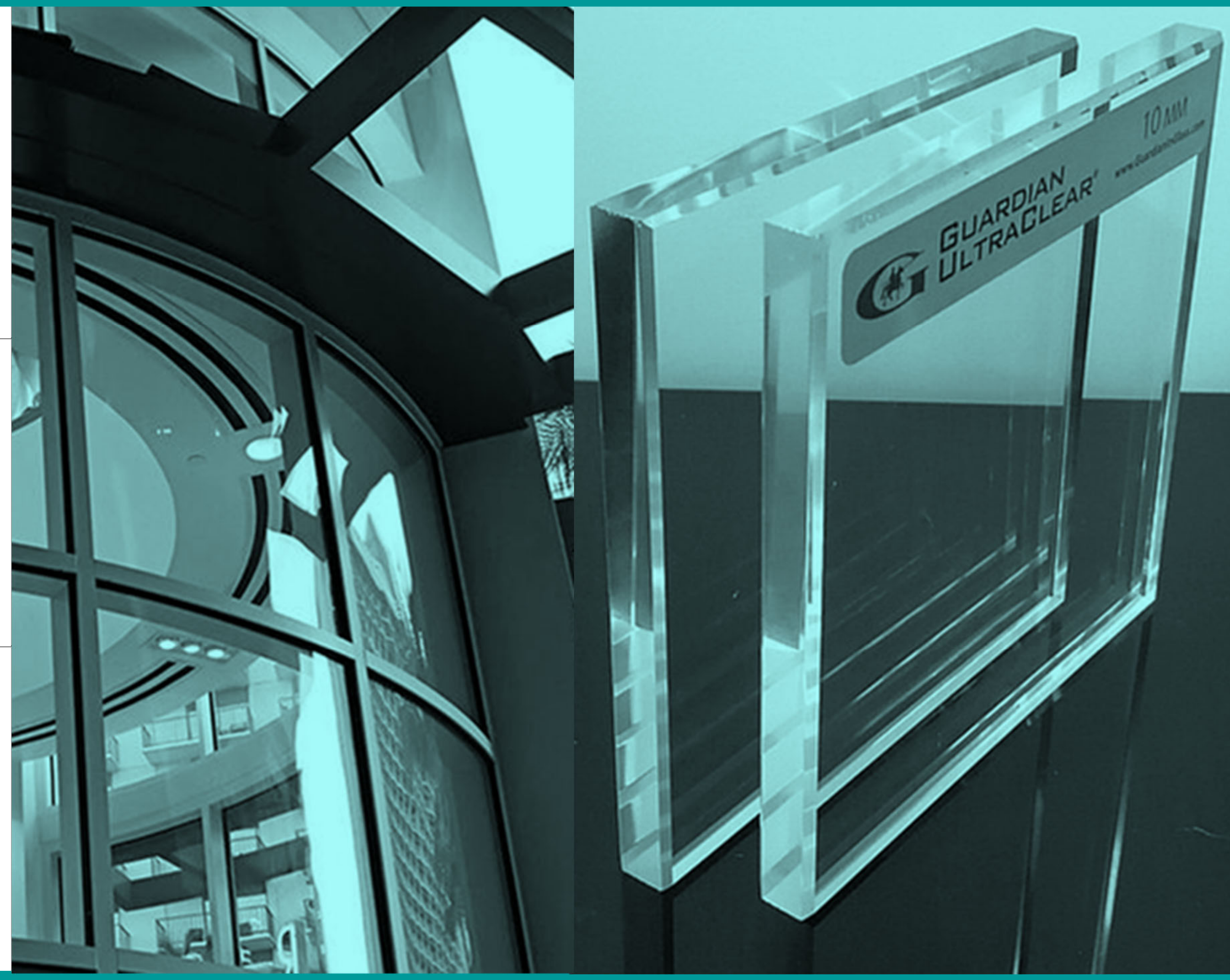
Revit Model View – South-West

Types of Coated Glazing Systems Tested

1. **Clear** (single glazed): Guardian UltraClear® UltraClear

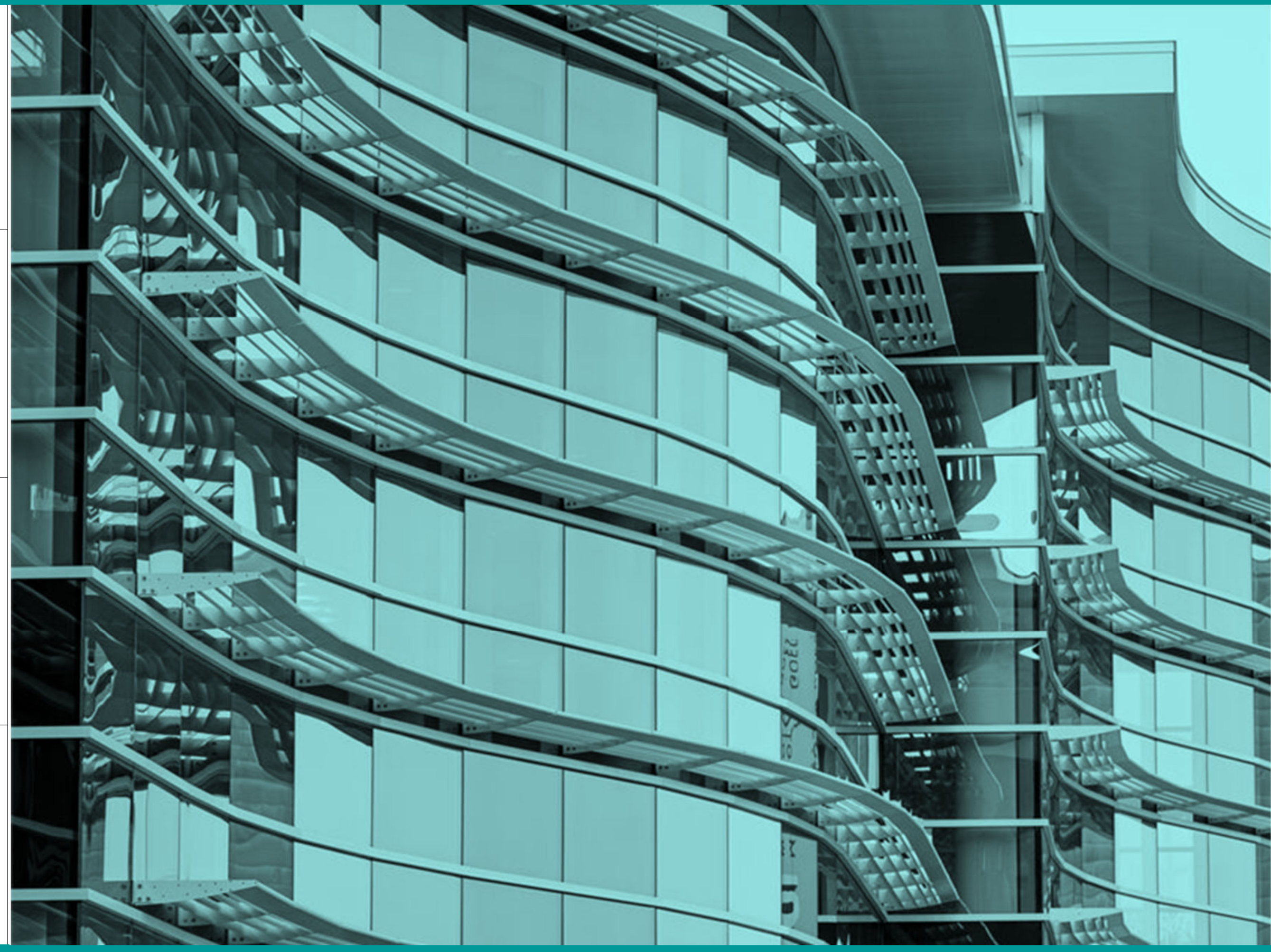


U-Value	5.8 W/m2K
Visible Light Transmittance (VLT)	91 %
Solar Heat Gain Coefficient (SHGC)	0.9



2. **Passive Low-E**: SunGuard® eXtraSelective SNX 51

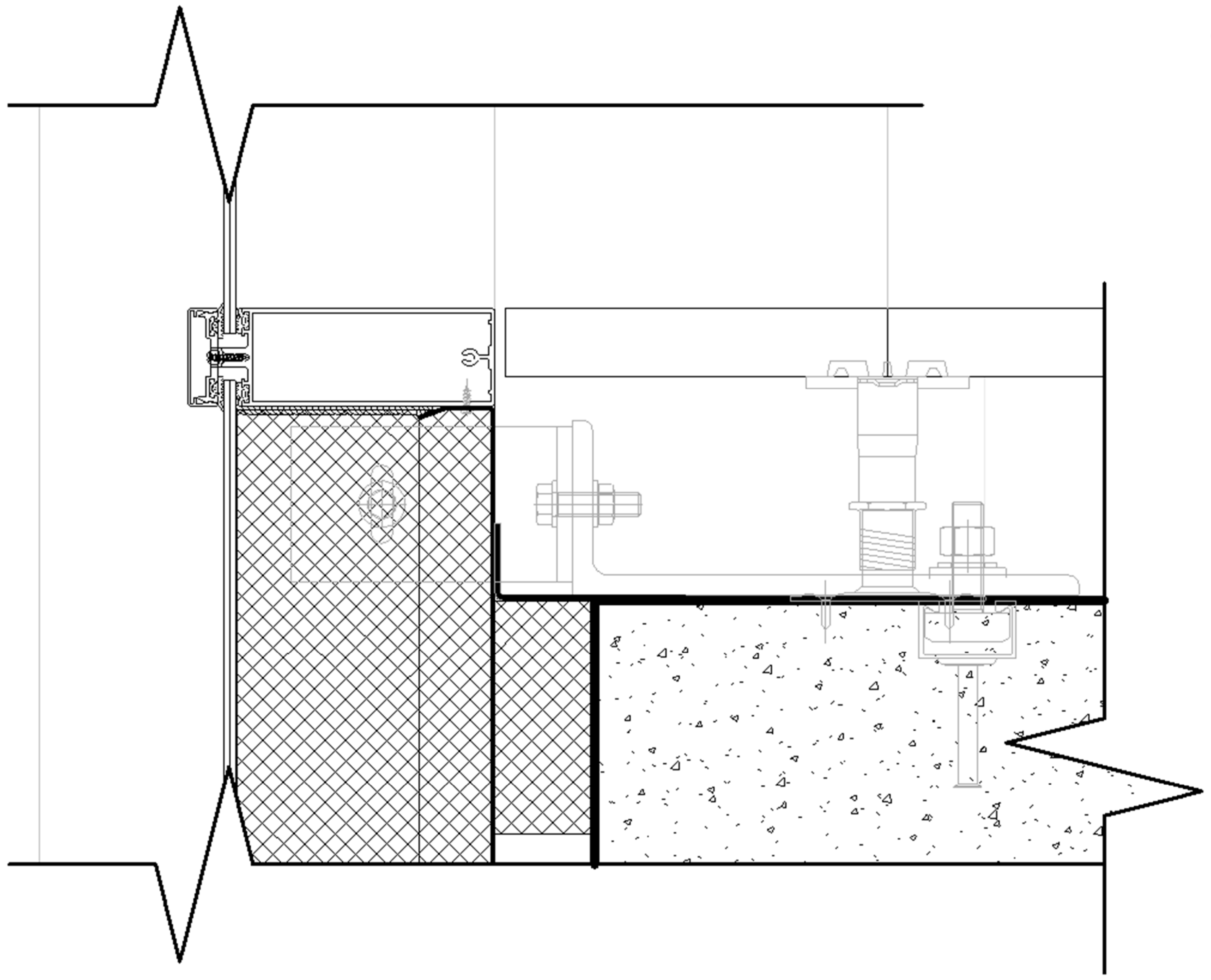
U-Value	0.224 W/m20K
Visible Light Transmittance (VLT)	51 %
Solar Heat Gain Coefficient (SHGC)	0.23
Coating Position	#2 Surface



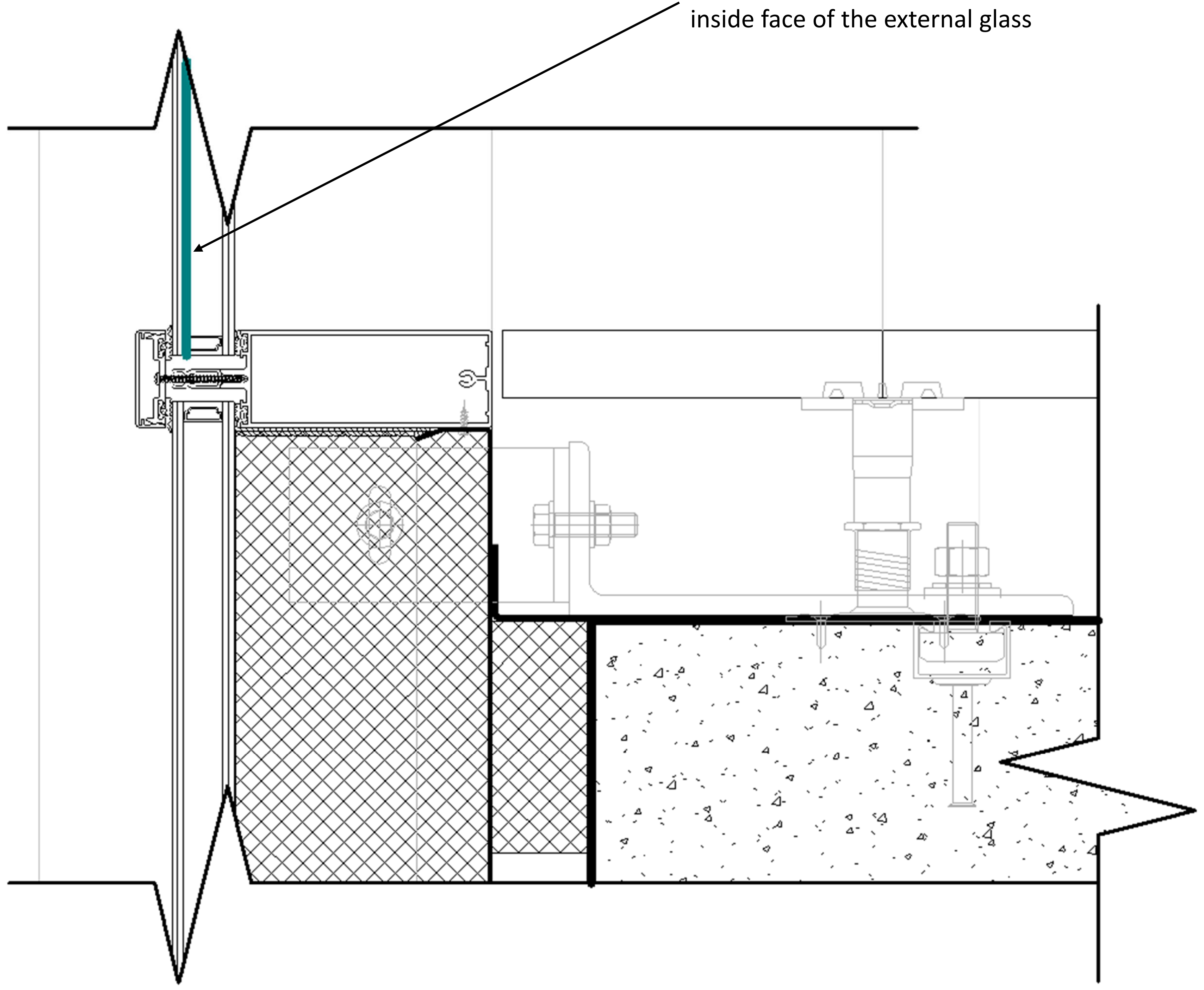
3. **Solar Control Low-E**: SunGuard® SuperNeutral SNR 35

U-Value	0.228 W/m2K
Visible Light Transmittance (VLT)	33 %
Solar Heat Gain Coefficient (SHGC)	0.17
Coating Position	#2 Surface

Miesian Plaza Model/ Section and Details

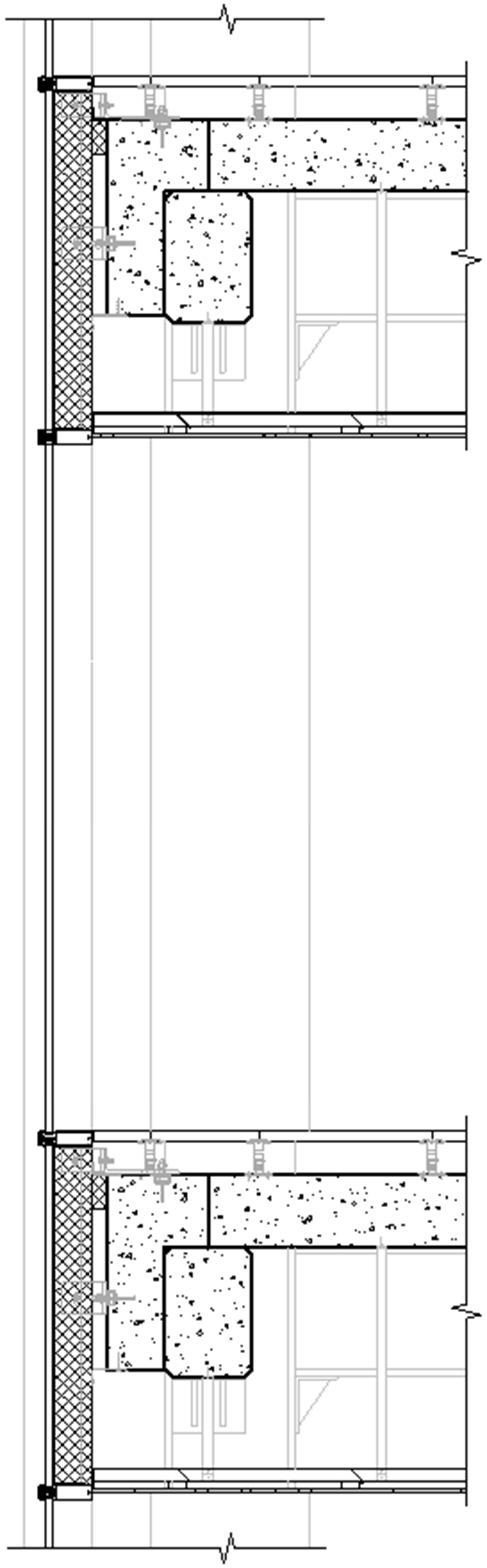


Glazing Detail 1 (Single Glazing Non Coated)

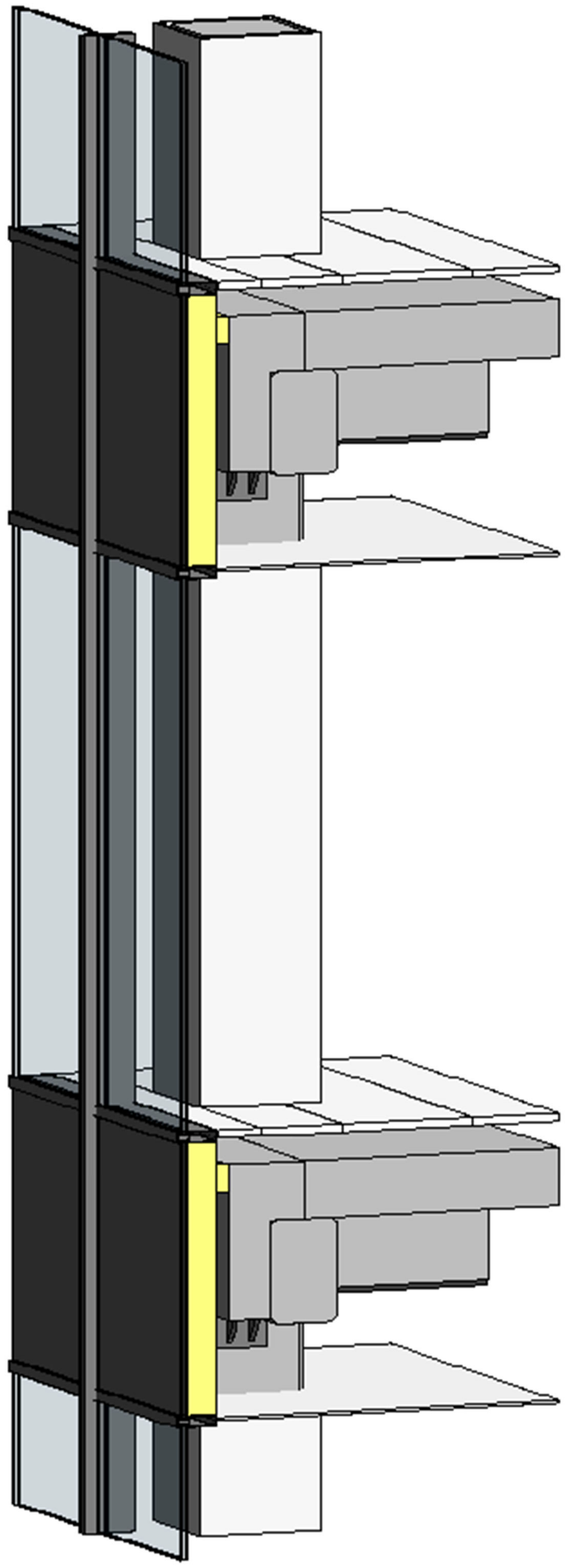


Low-E coatings are positioned on the inside face of the external glass

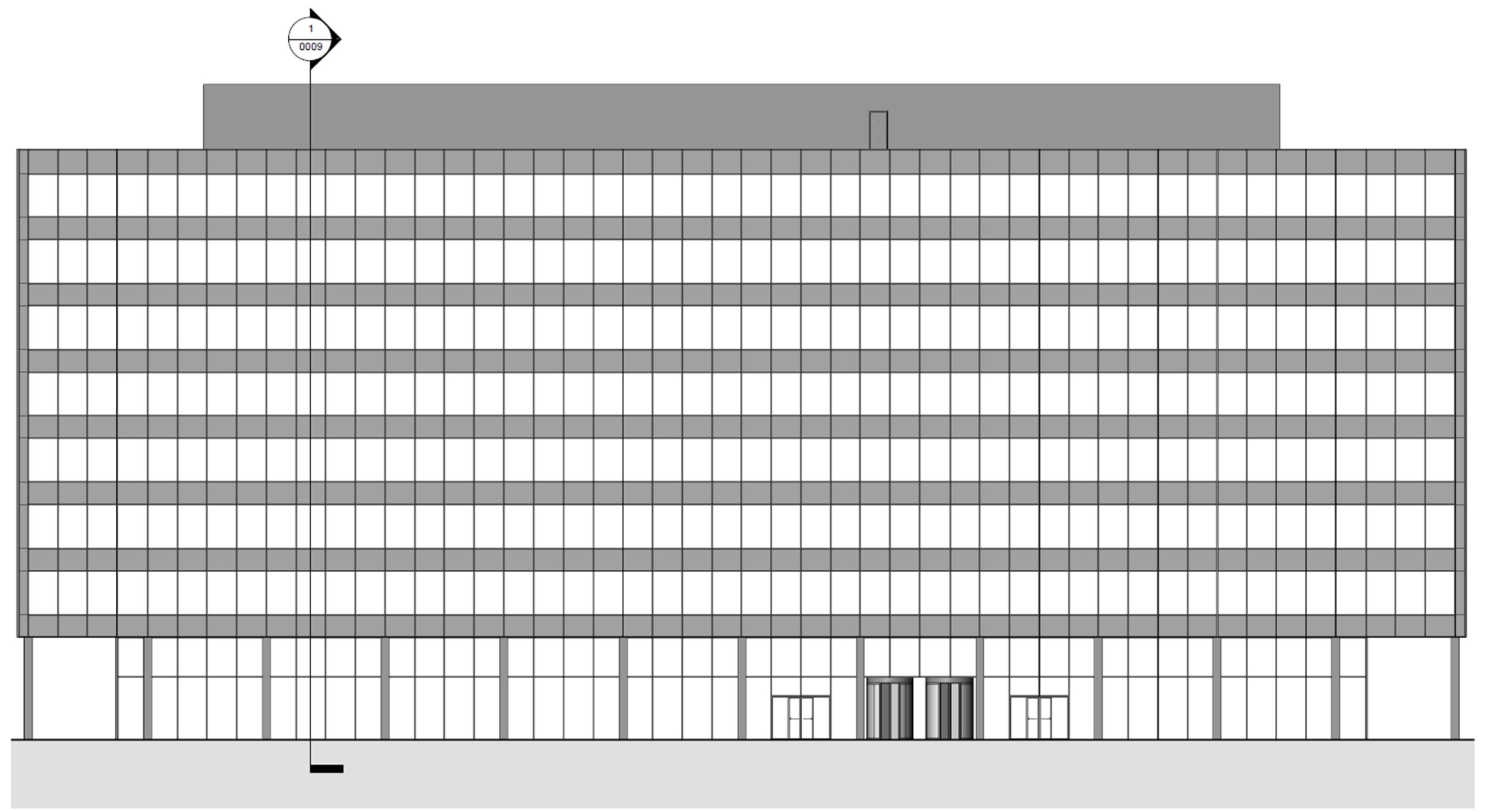
Glazing Detail 2 (Double Glazing Low-E Coating Position)



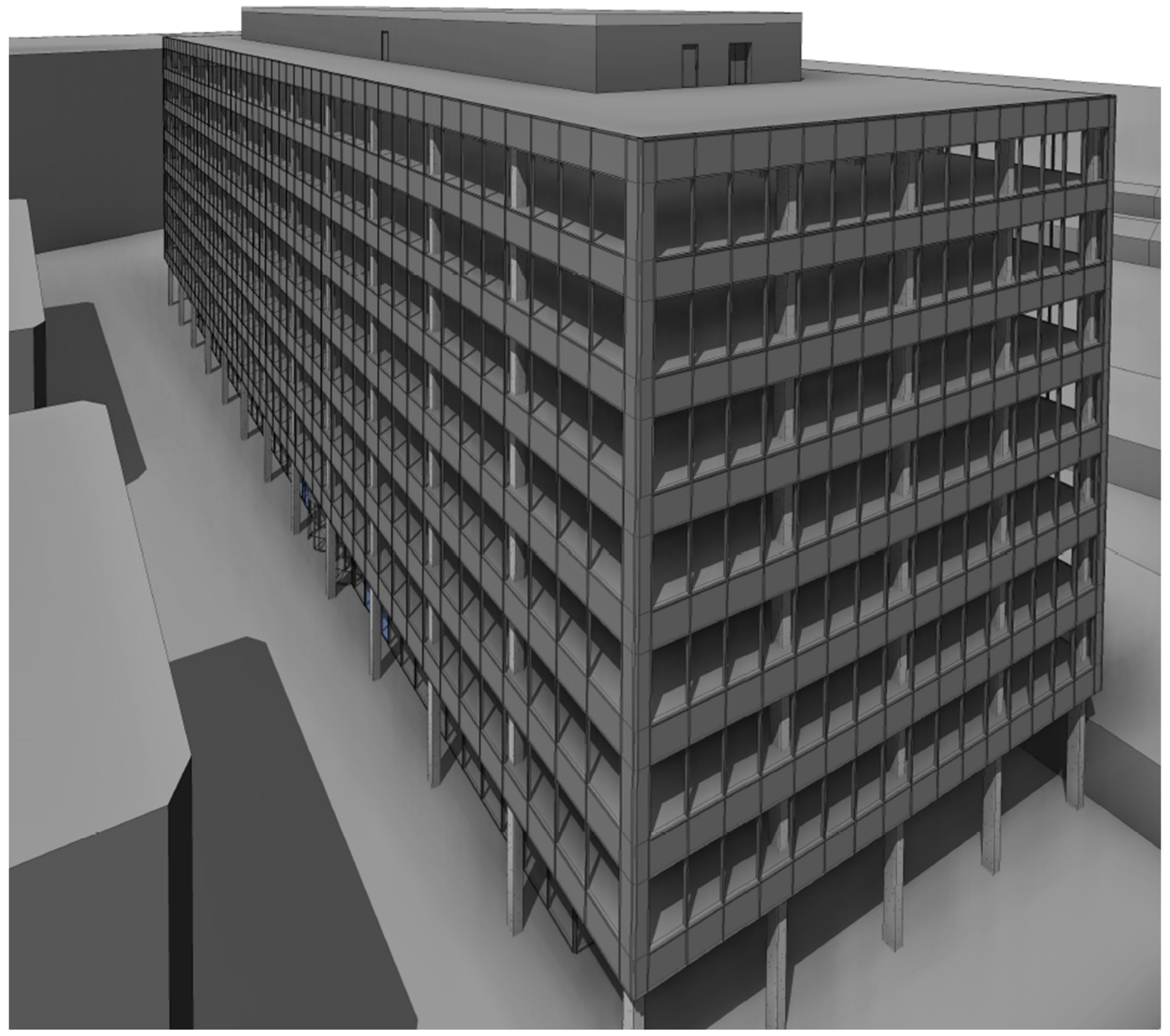
Typical Façade Section



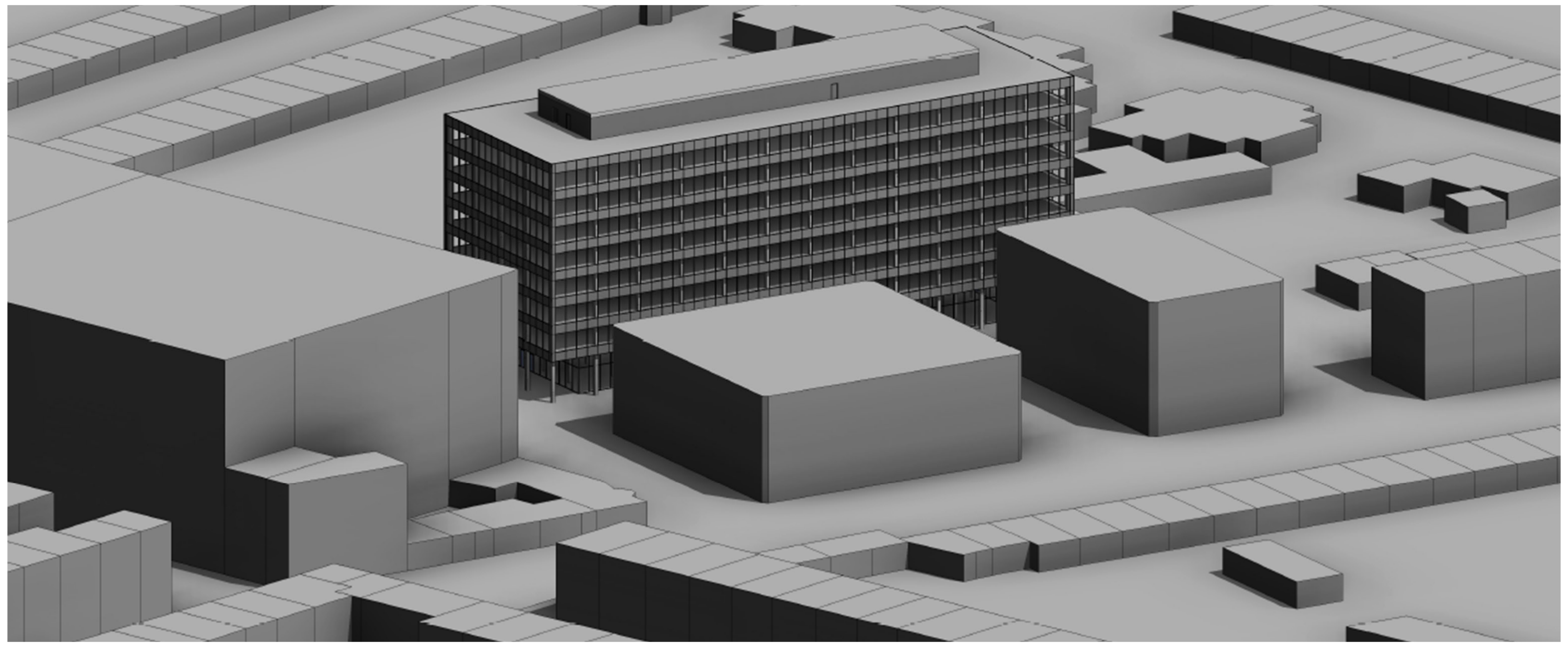
3D Façade Section



Revit Elevation (South-West)

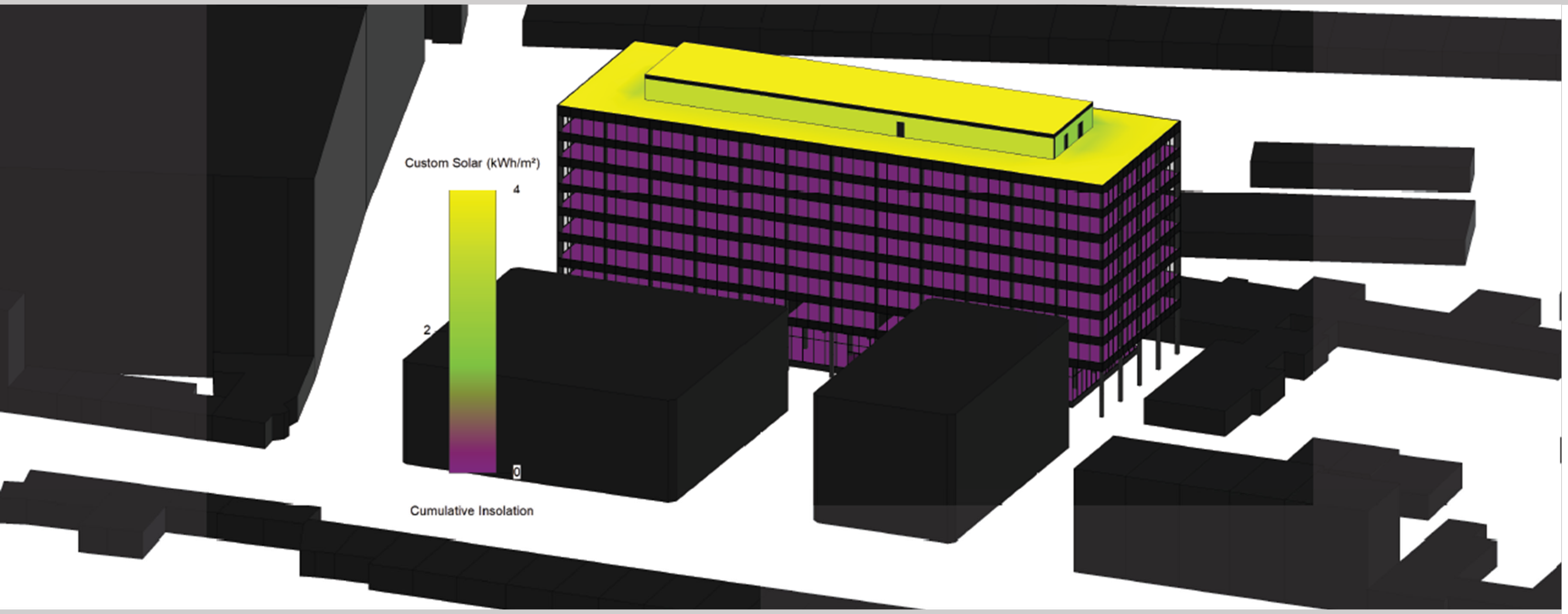


Revit Model View (South)

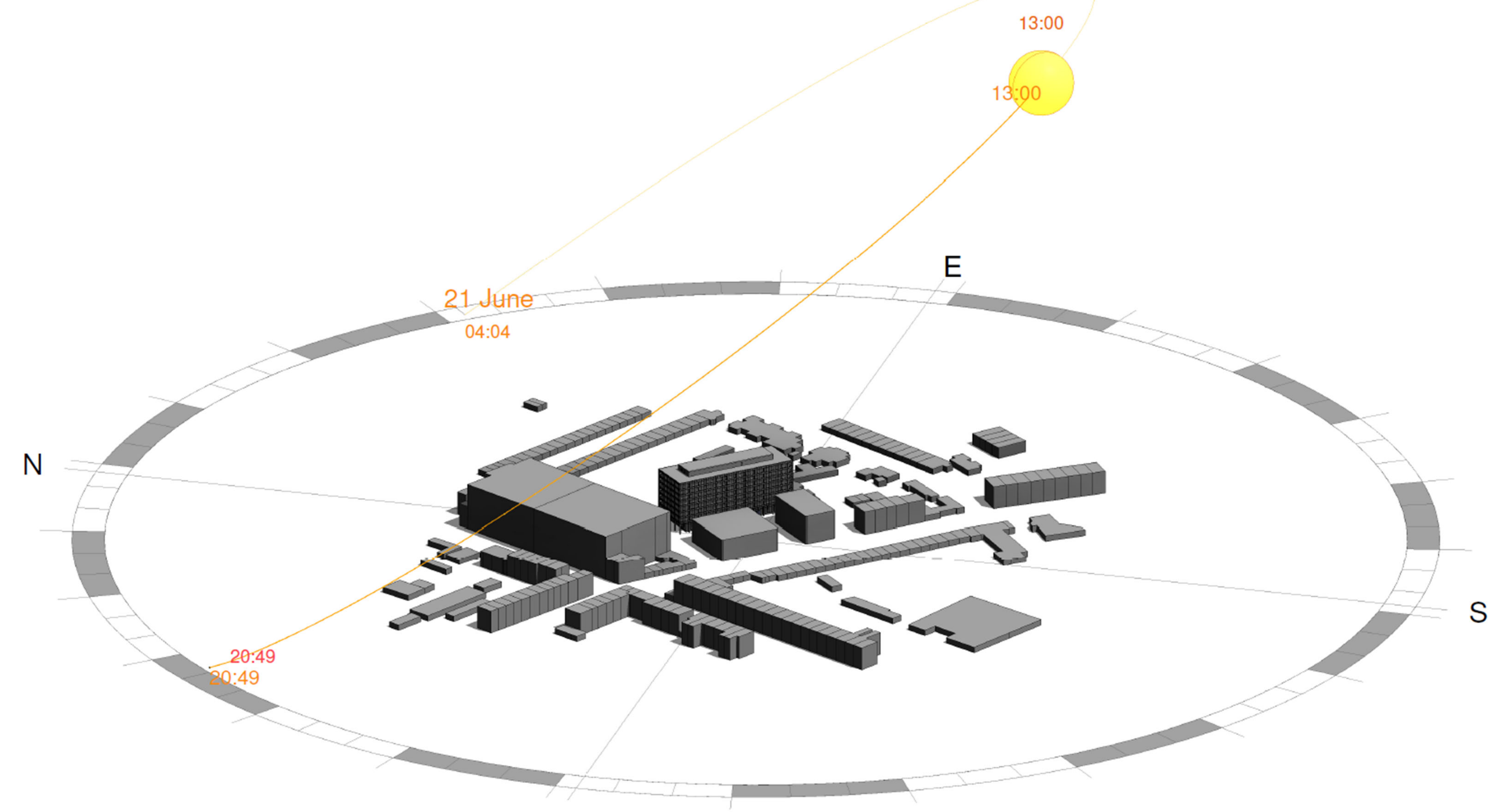


Revit Model View (West)

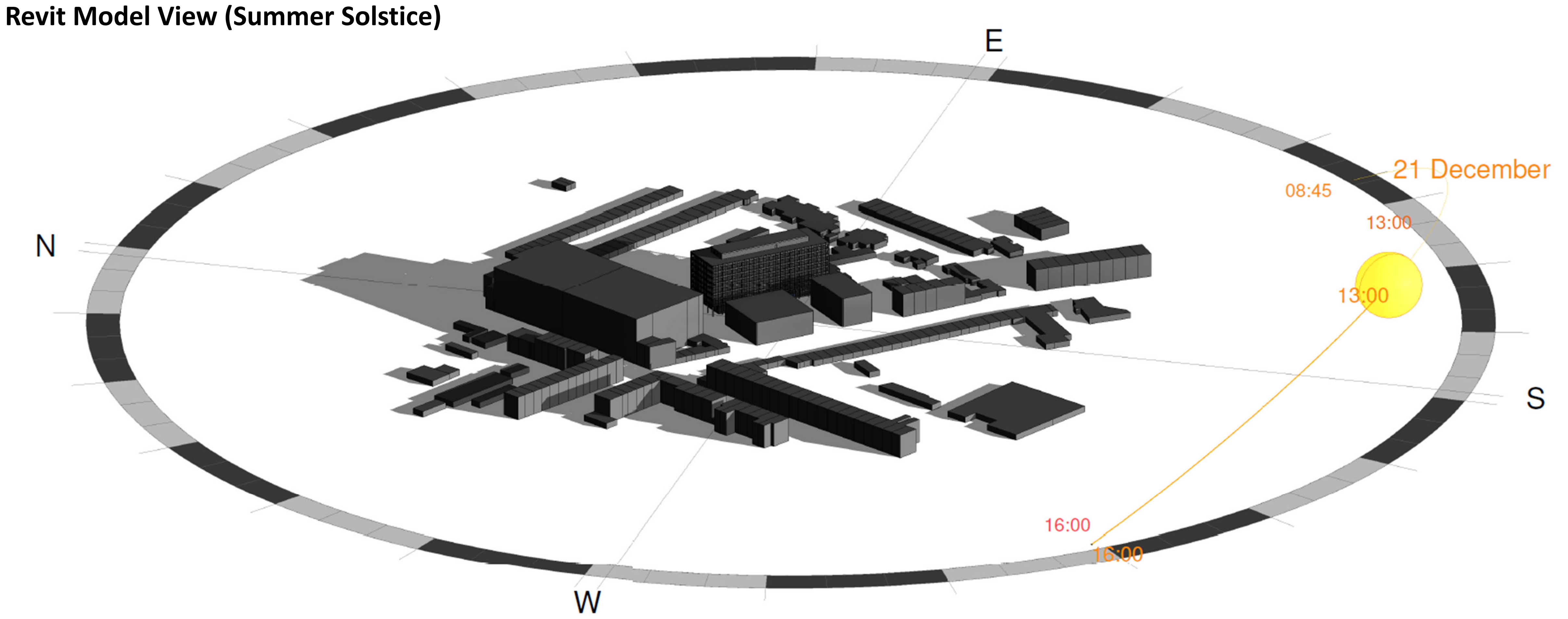
Early Solar Radiation Analysis



Early Daylighting Analysis

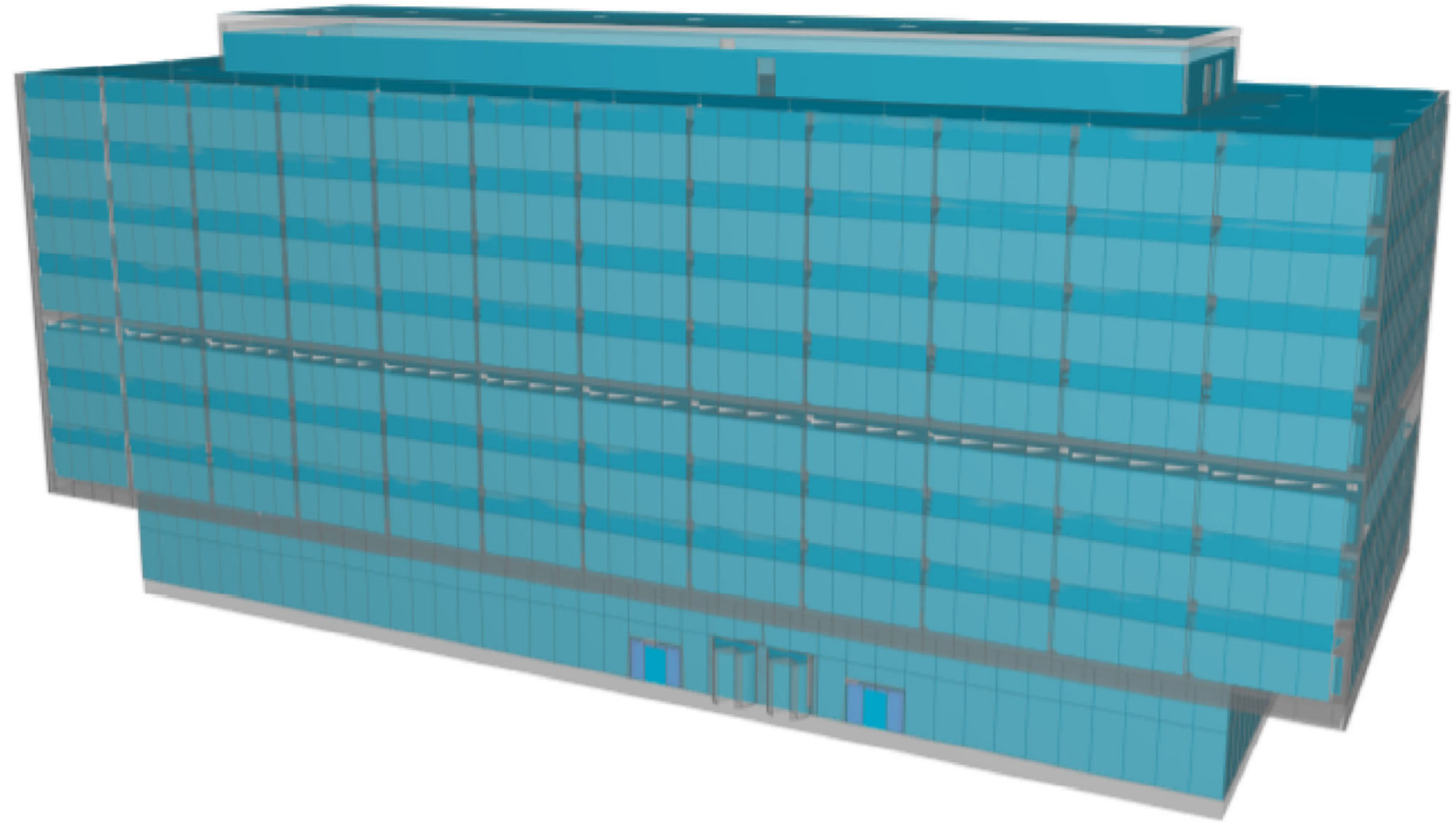


Revit Model View (Summer Solstice)



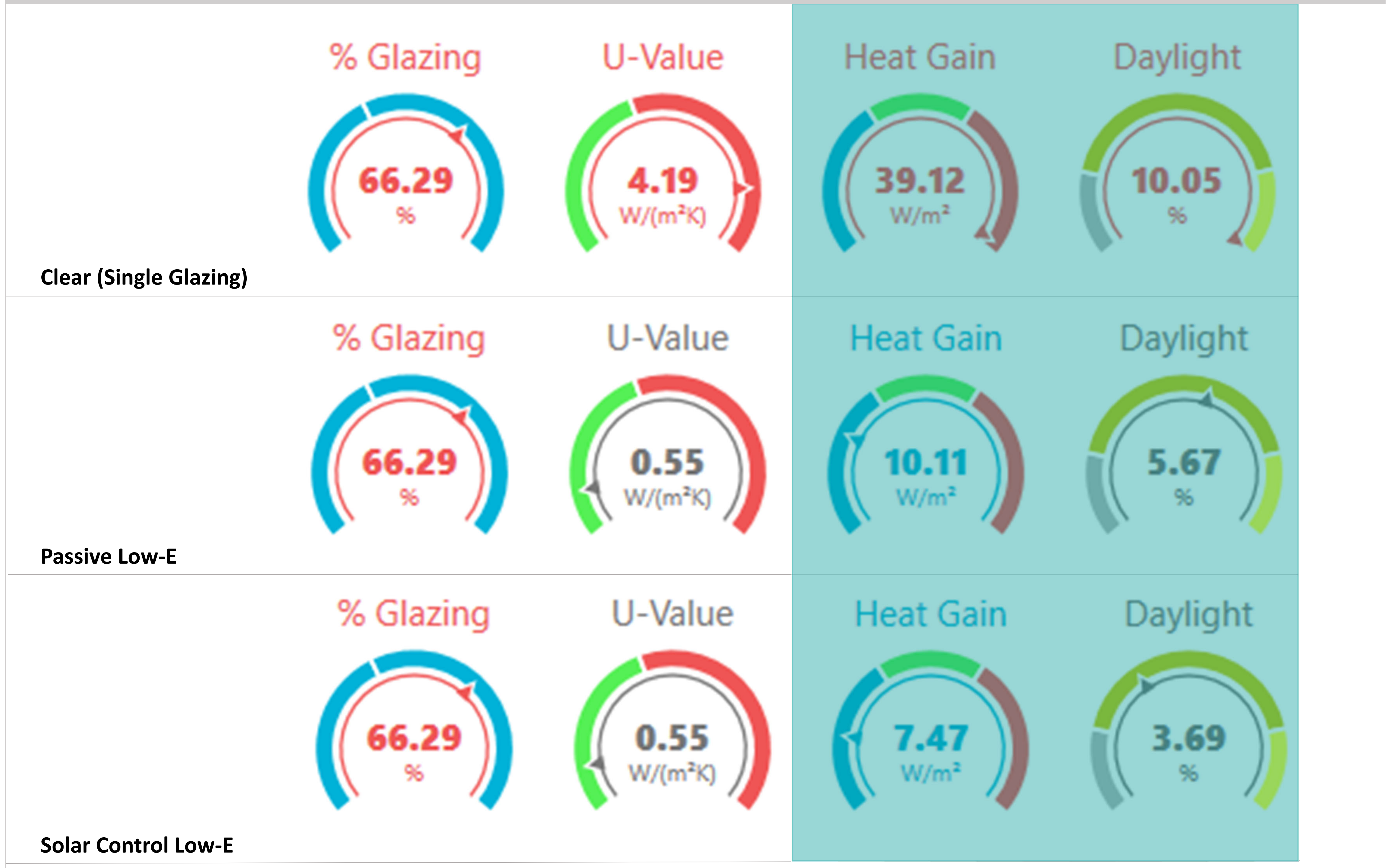
Revit Model View (Winter Solstice)

FenestraPro Analysis



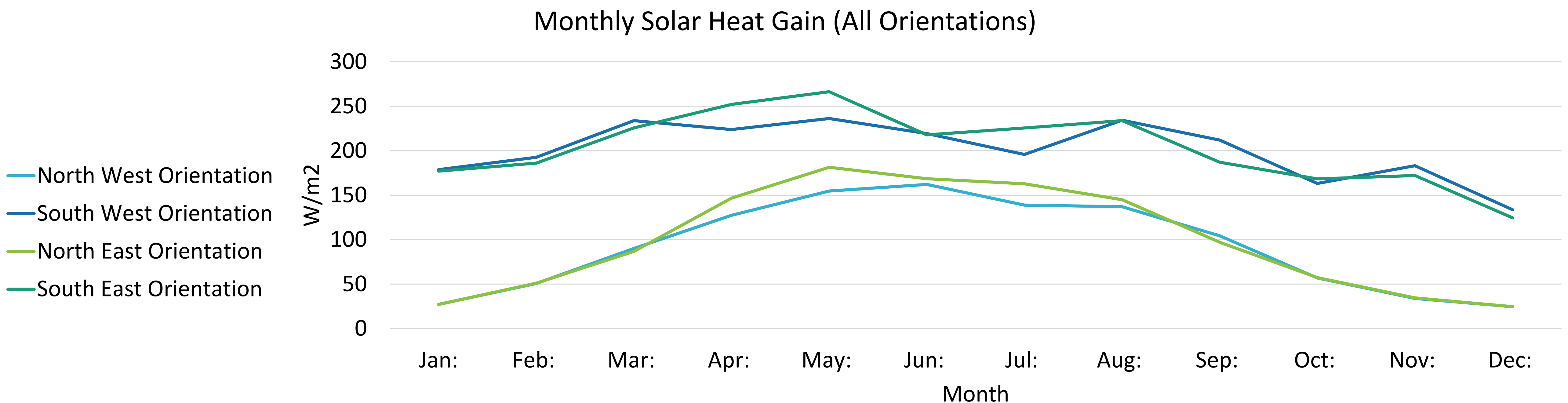
FenestraPro Energy Model View

FenestraPro Dashboard Results



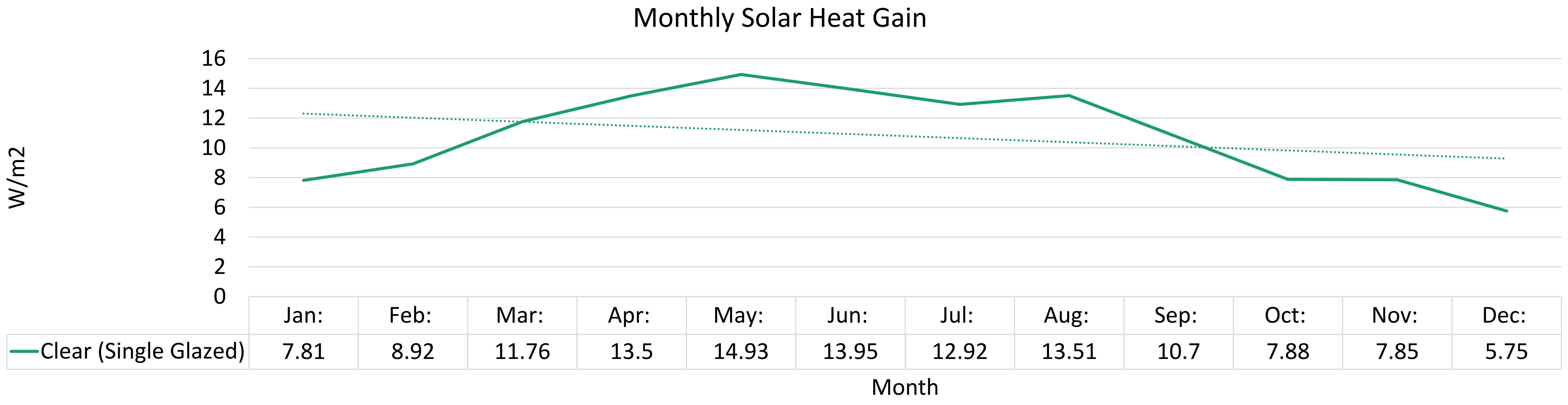
	% Glazing	U-Value	Heat Gain	Daylight
Clear (Single Glazing)	66.29 %	4.19 W/(m^{2}K)	39.12 W/m^2	10.05 %
Passive Low-E	66.29 %	0.55 W/(m^{2}K)	10.11 W/m^2	5.67 %
Solar Control Low-E	66.29 %	0.55 W/(m^{2}K)	7.47 W/m^2	3.69 %

Building Monthly Solar Load



Average Monthly Solar Load: 148.6 W/m2

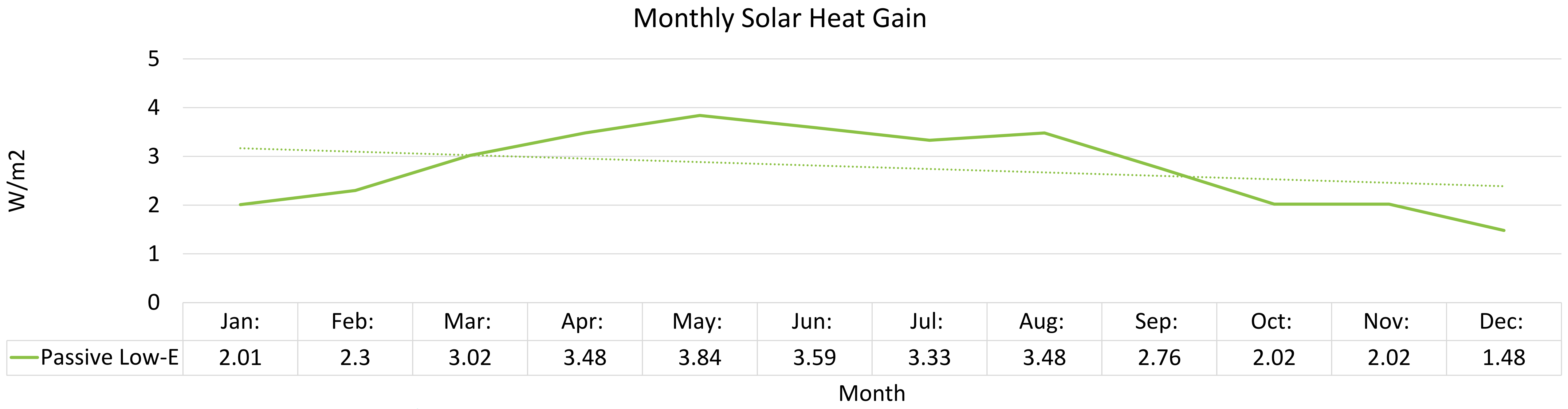
Clear (Single Glazed) – Monthly Solar Heat Gain Results



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
Clear (Single Glazed)	7.81	8.92	11.76	13.5	14.93	13.95	12.92	13.51	10.7	7.88	7.85	5.75

Average Monthly Solar Heat Gain: 10.79 W/m2

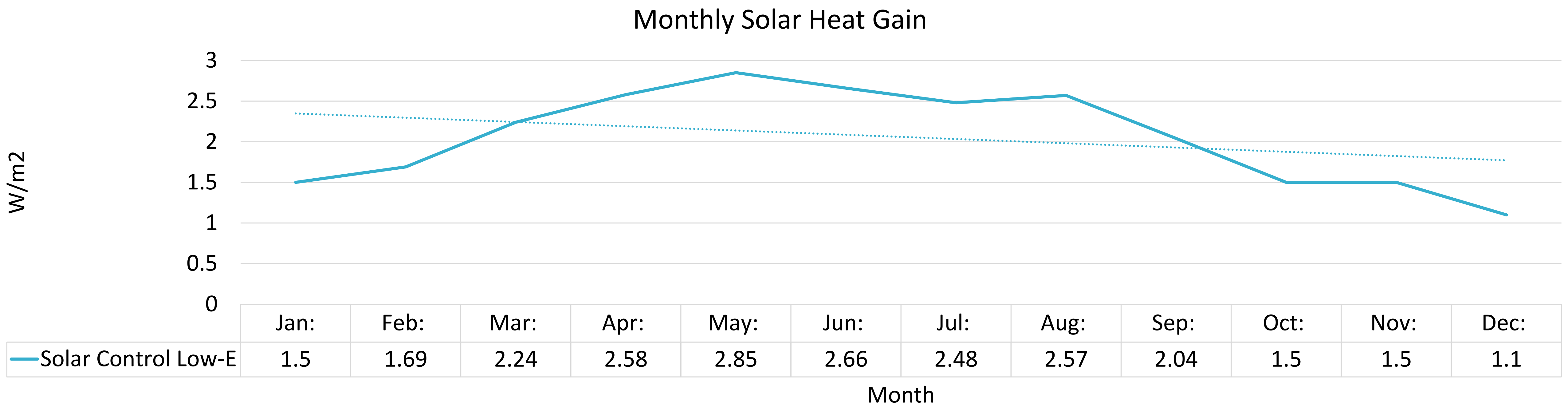
Passive Low-E – Monthly Solar Heat Gain Results



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
Passive Low-E	2.01	2.3	3.02	3.48	3.84	3.59	3.33	3.48	2.76	2.02	2.02	1.48

Average Monthly Solar Heat Gain: 2.78 W/m2

Solar Control Low-E – Monthly Solar Heat Gain Results



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
Solar Control Low-E	1.5	1.69	2.24	2.58	2.85	2.66	2.48	2.57	2.04	1.5	1.5	1.1

Average Monthly Solar Heat Gain: 2.06 W/m2

Solar Heat Gain Results – Manual Calculations

Average solar loads in Ireland between 7.30 and 17.30 for different glazing orientations (TGD Part L, 2008): →

Orientation	Average Solar Load (W/m2)
North	125
North-East & North-West	160
East & West	205
South-East & South-West	198
South	156
Horizontal	327

Formula for Average Solar Heat Load per Unit Floor Area (W/m2):

$$\frac{\text{Area of Glazing x Solar Heat Gain Coefficient x Shading Factor x Average Solar Load}}{\text{Area of Zone}}$$

Clear (Single Glazed)

- Area of Glazing (m2): 4,261
- Solar Heat Gain Coefficient: 0.9
- Shading Factor: 1
- Average Solar Load (W/m2) – FenestraPro results: 148.6
- Area of Internal Zone (m2): 16,822

$$\frac{4{,}261 \times 0.9 \times 1 \times 148.6}{16{,}822} = 33.88 \text{ W/m2}$$

Passive Low-E

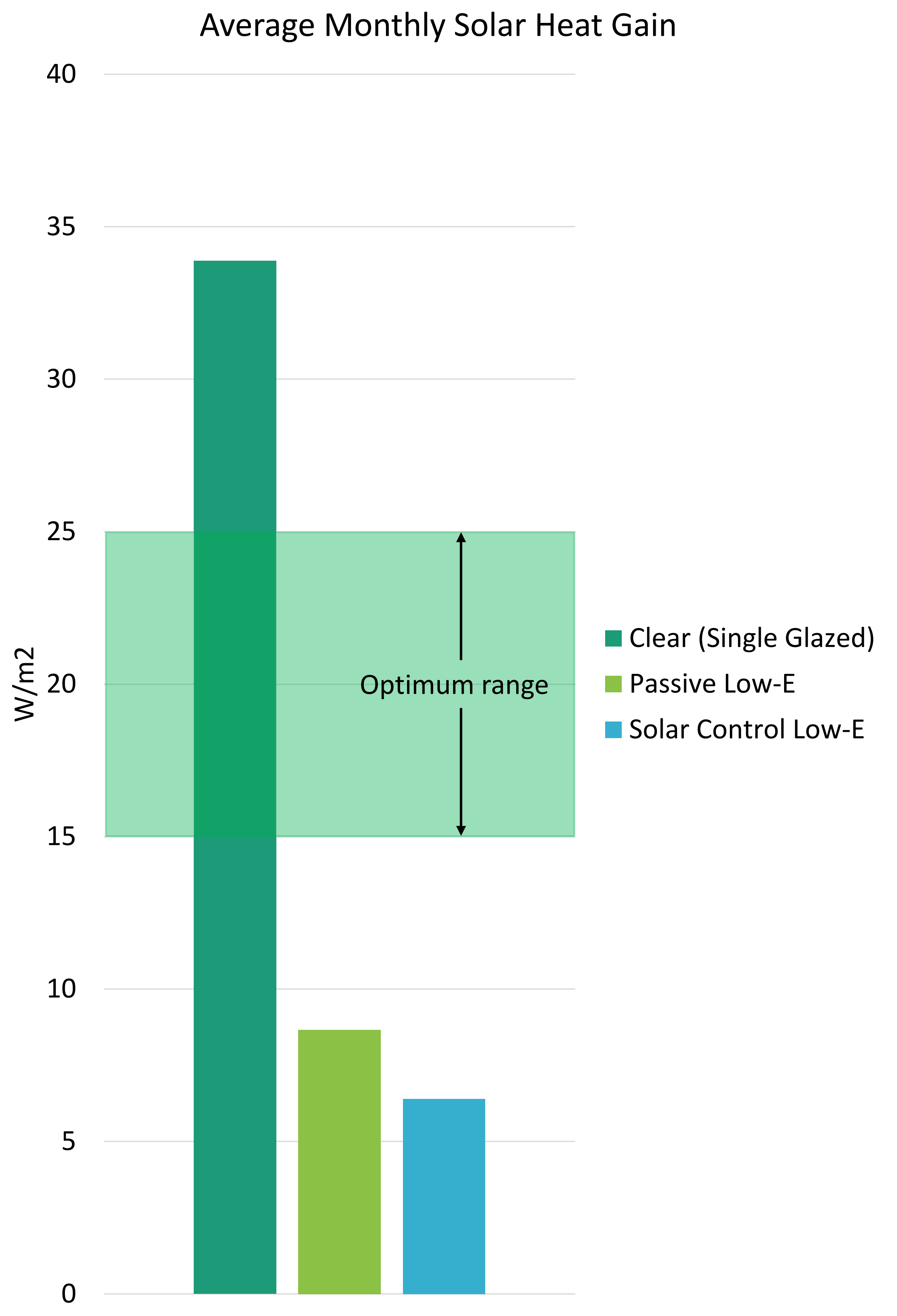
- Area of Glazing (m2): 4,261
- Solar Heat Gain Coefficient: 0.23
- Shading Factor: 1
- Average Solar Load (W/m2)) – FenestraPro results: 148.6
- Area of Internal Zone (m2): 16,822

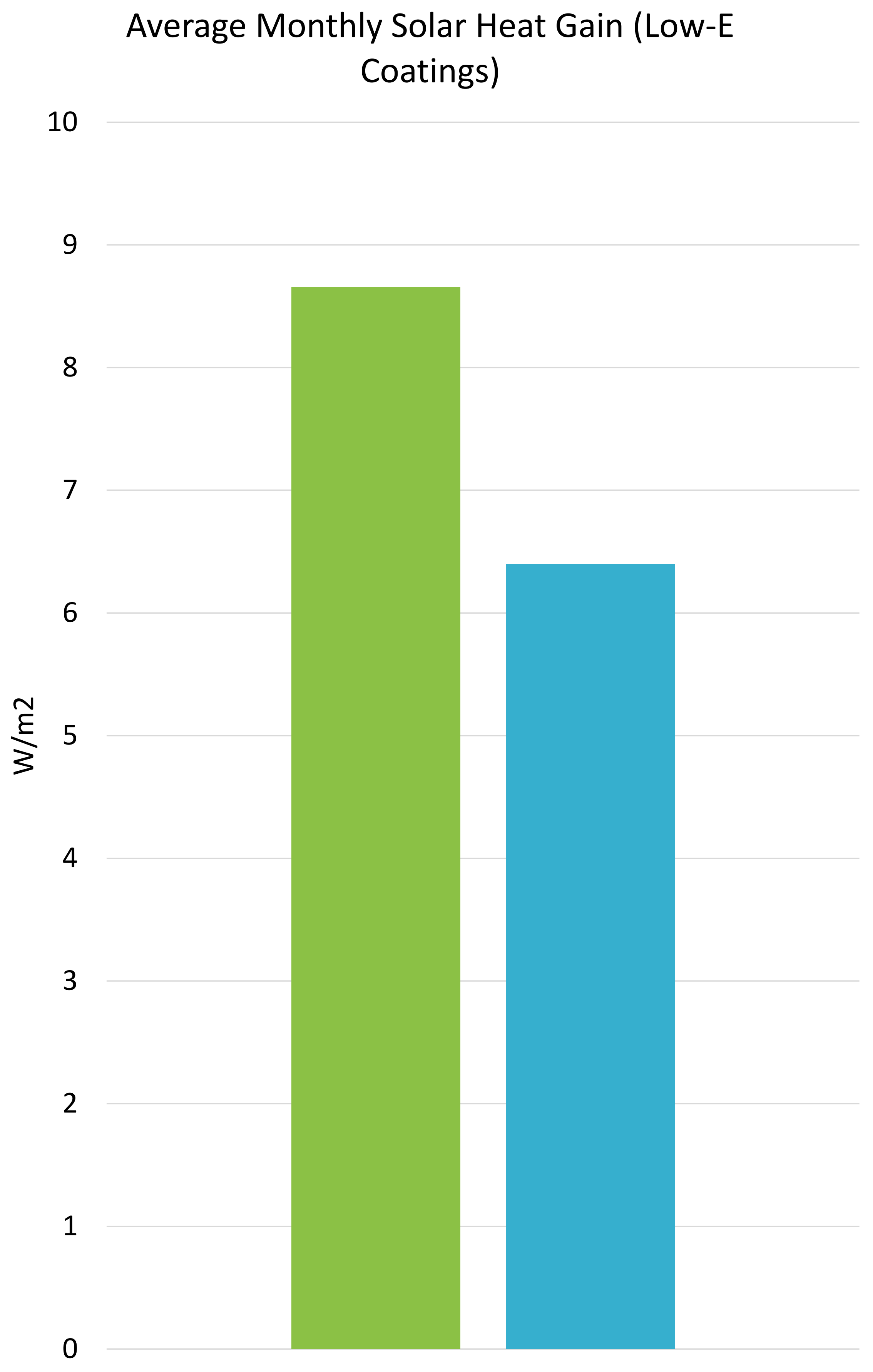
$$\frac{4{,}261 \times 0.23 \times 1 \times 148.6}{16{,}822} = 8.66 \text{ W/m2}$$

Solar Control Low-E

- Area of Glazing (m2): 4,261
- Solar Heat Gain Coefficient: 0.17
- Shading Factor: 1
- Average Solar Load (W/m2)) – FenestraPro results: 148.6
- Area of Internal Zone (m2): 16,822

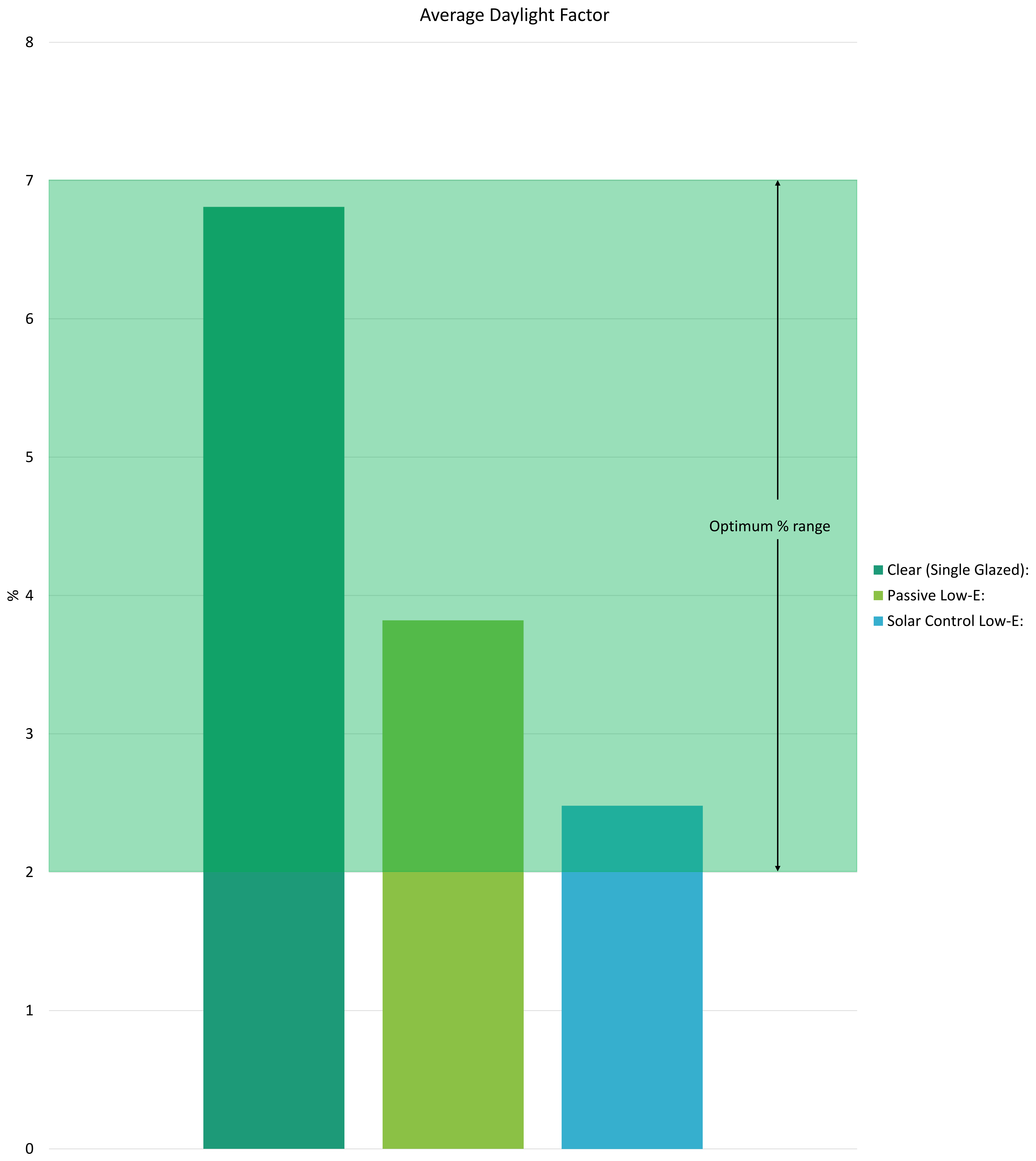
$$\frac{4{,}261 \times 0.17 \times 1 \times 148.6}{16{,}822} = 6.40 \text{ W/m2}$$





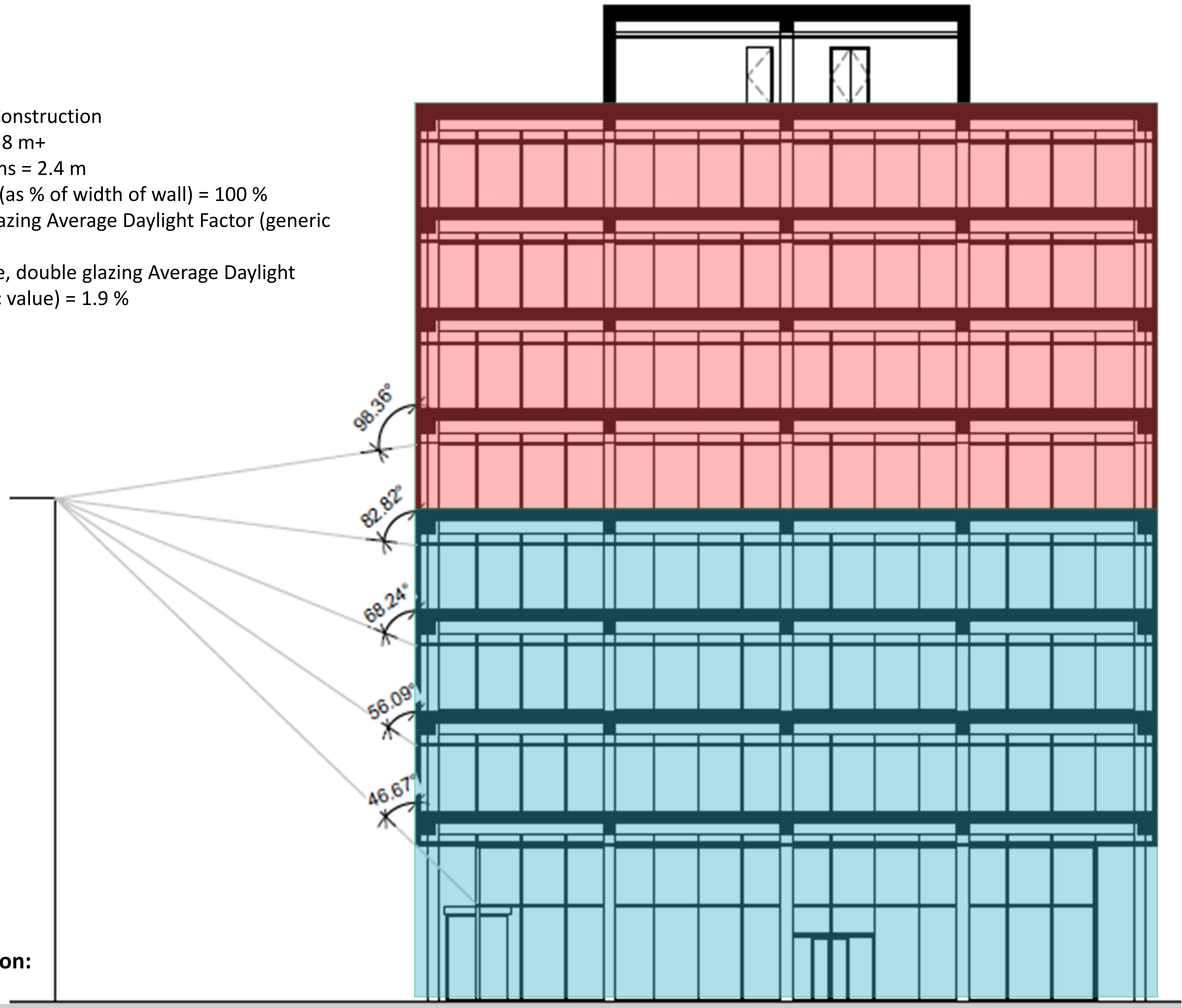
Daylight Factor Results

Glazing Coating	Daylight Factor (%)
Clear (Single Glazed)	**6.81**
Passive Low-E	**3.82**
Solar Control Low-E	**2.48**



Daylight Factor Results – Manual Calculations (Environmental Design Guide)

- Heavyweight Construction
- Room Depth = 8 m+
- Height of Rooms = 2.4 m
- Glazing Width (as % of width of wall) = 100 %
- Single, clear glazing Average Daylight Factor (generic value) = 2.5 %
- Low-E selective, double glazing Average Daylight Factor (generic value) = 1.9 %



Visible Sky Angle Section:

Clear (Single Glazed)

+90 Degree Visible Sky Angle Daylight Factor Calculation:
2.5 % X 1.1 (Width of Floor = 2L) X 1.5 (Visible Sky Angle = 90 degrees) X 1.1 (Window – Height on Wall) X 1.5 (White Reflectance of Internal Surfaces) = 6.806 %

+-60 Degree Visible Sky Angle Daylight Factor Calculation:
2.5 % X 1.1 (Width of Floor = 2L) X 1 (Visible Sky Angle = +-60 degrees) X 1.1 (Window – Height on Wall) X 1.5 (White Reflectance of Internal Surfaces) = 4.538 %

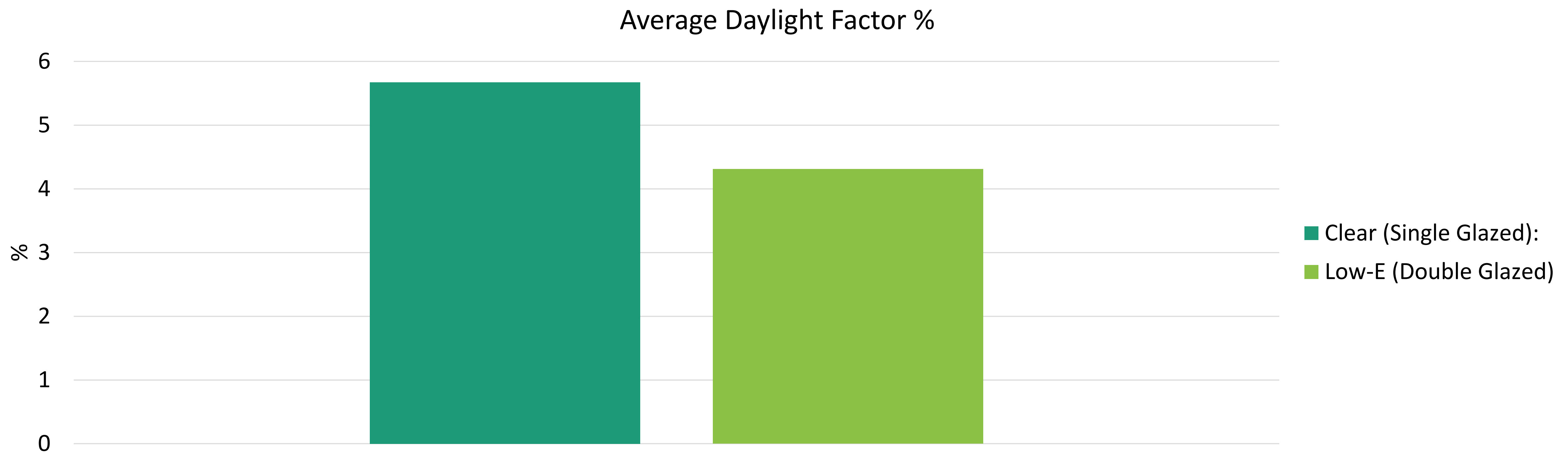
6.806 + 4.538 = 11.344
11.344/ 2 = **5.672 %** (Average Daylight Factor)

Low-E

+90 Degree Visible Sky Angle Daylight Factor Calculation:
1.9 % X 1.1 (Width of Floor = 2L) X 1.5 (Visible Sky Angle = 90 degrees) X 1.1 (Window – Height on Wall) X 1.5 (White Reflectance of Internal Surfaces) = 5.173 %

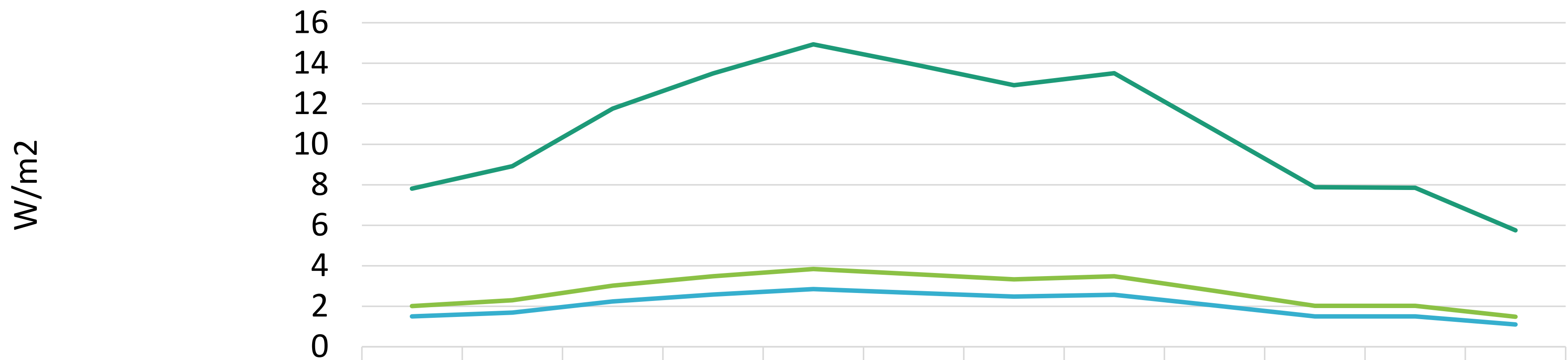
+-60 Degree Visible Sky Angle Daylight Factor Calculation:
1.9 % X 1.1 (Width of Floor = 2L) X 1 (Visible Sky Angle = +-60 degrees) X 1.1 (Window – Height on Wall) X 1.5 (White Reflectance of Internal Surfaces) = 3.449 %

5.173 + 3.449 = 8.621
8.621/ 2 = **4.311 %** (Average Daylight Factor)



Analysis of Findings – Solar Heat Gain

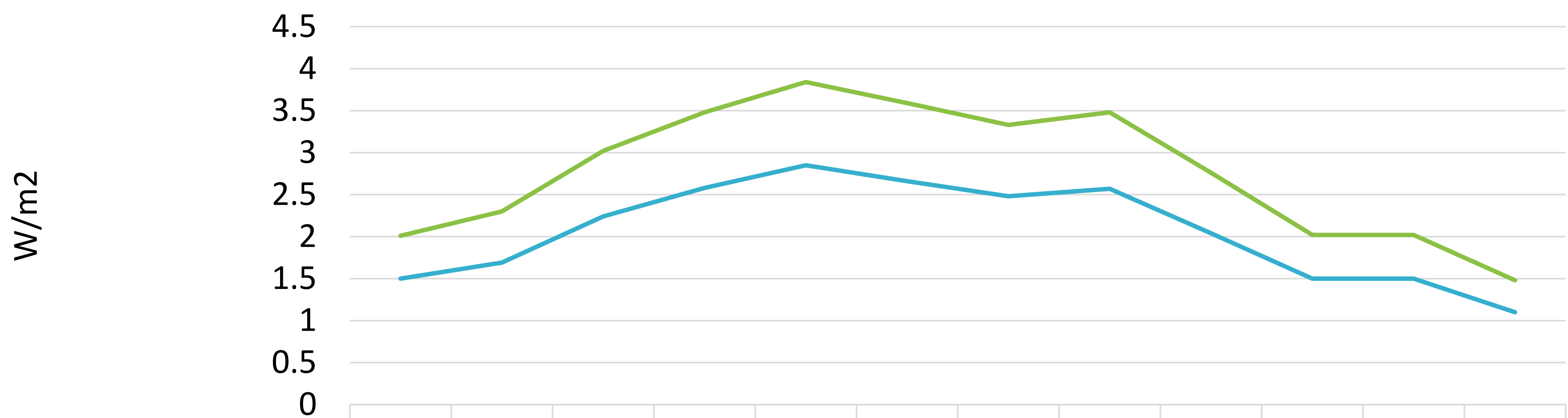
Monthly Solar Heat Gain



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
Clear (Single Glazed)	7.81	8.92	11.76	13.5	14.93	13.95	12.92	13.51	10.7	7.88	7.85	5.75
Passive Low-E	2.01	2.3	3.02	3.48	3.84	3.59	3.33	3.48	2.76	2.02	2.02	1.48
Solar Control Low-E	1.5	1.69	2.24	2.58	2.85	2.66	2.48	2.57	2.04	1.5	1.5	1.1

Month

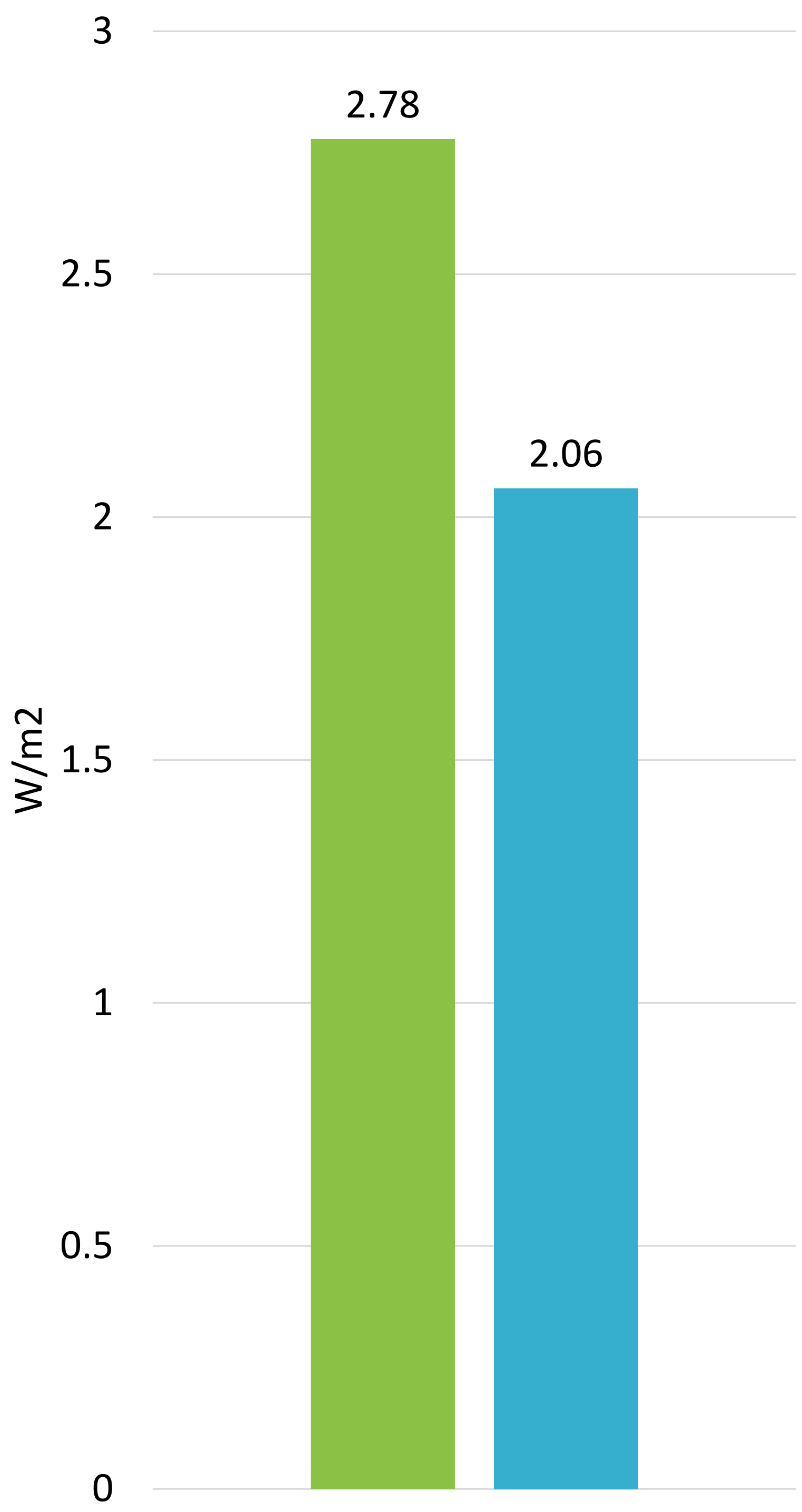
Monthly Solar Heat Gain (Low-E Coatings)



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
Passive Low-E	2.01	2.3	3.02	3.48	3.84	3.59	3.33	3.48	2.76	2.02	2.02	1.48
Solar Control Low-E	1.5	1.69	2.24	2.58	2.85	2.66	2.48	2.57	2.04	1.5	1.5	1.1

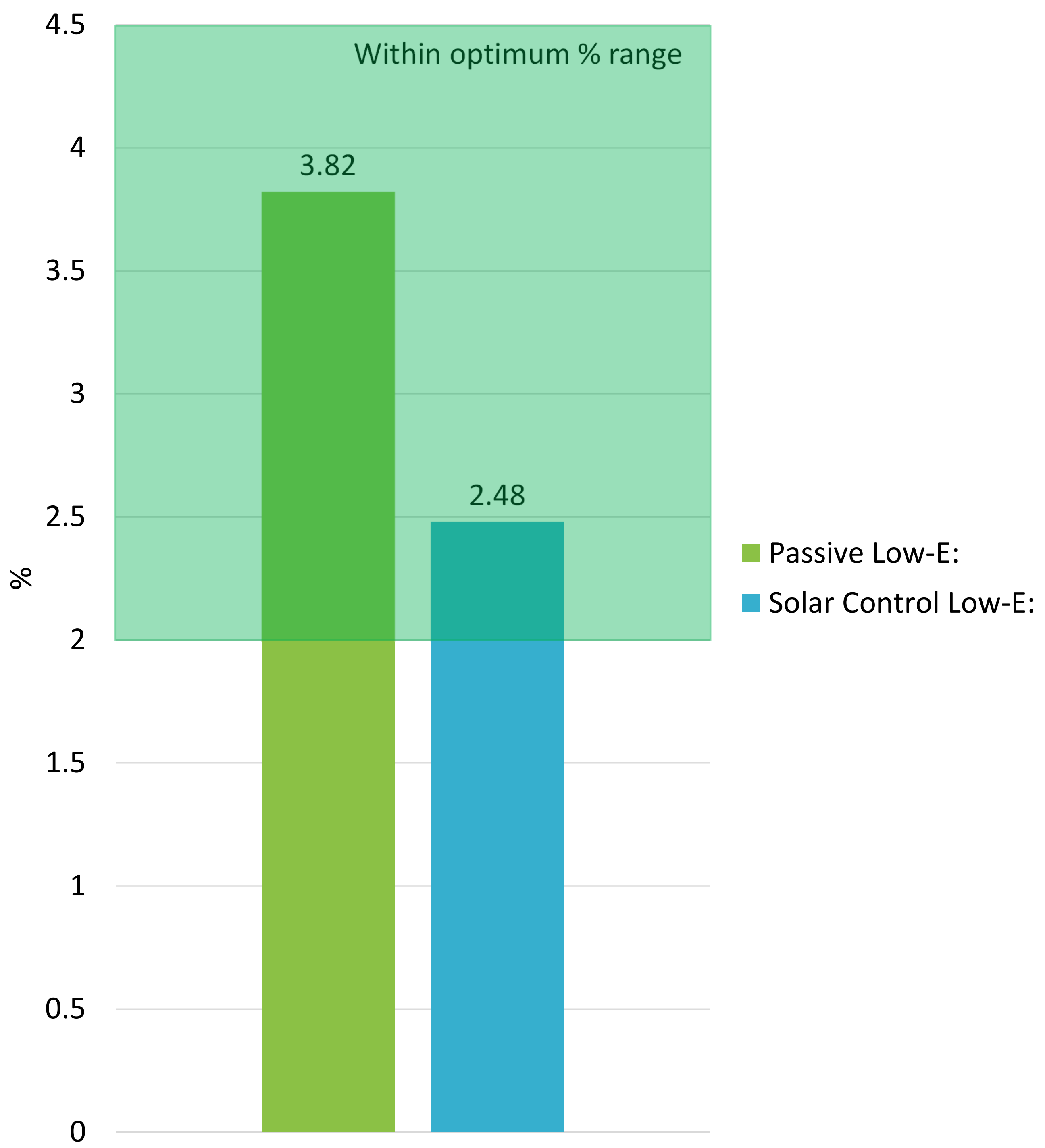
Month

Average Monthly Solar Heat Gain (Low-E Coatings)



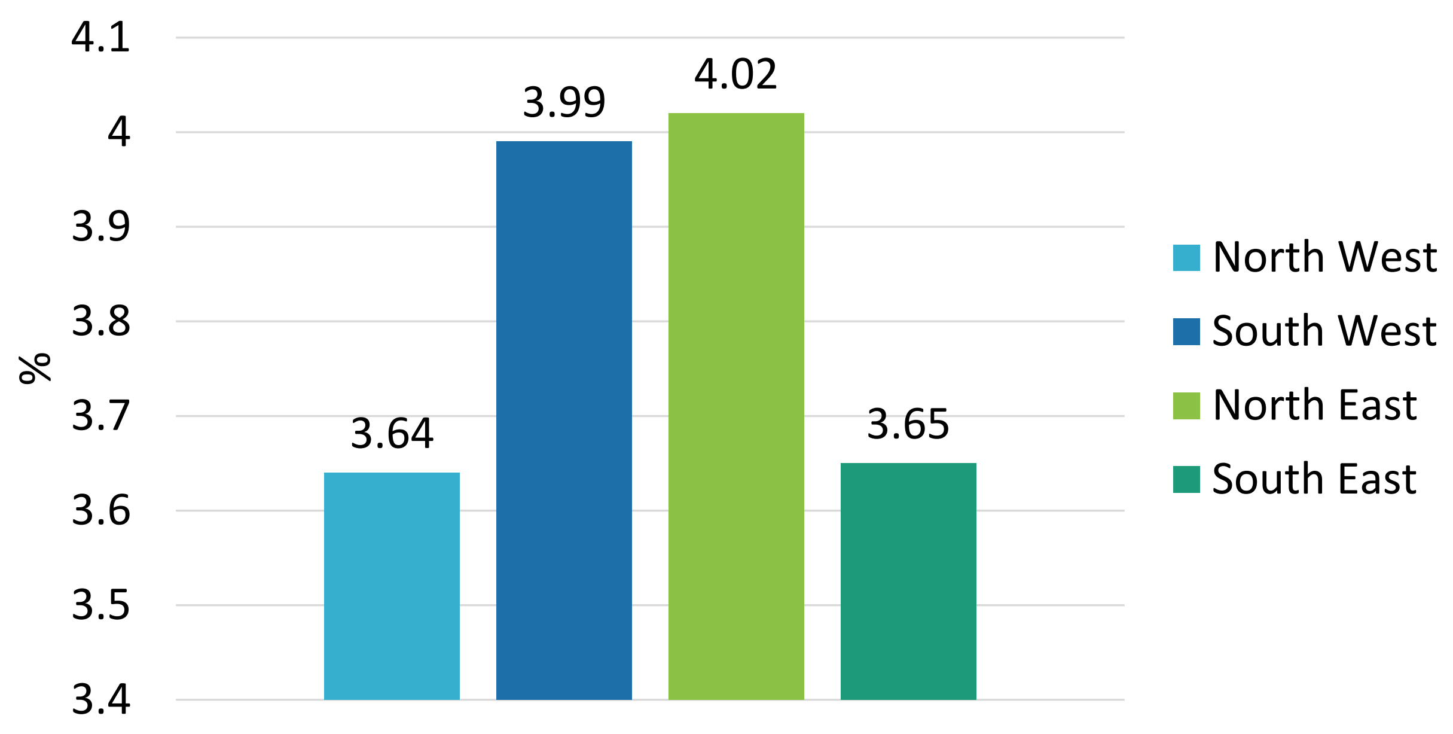
Analysis of Findings – Daylighting

Average Daylight Factor (Low-E Coatings)

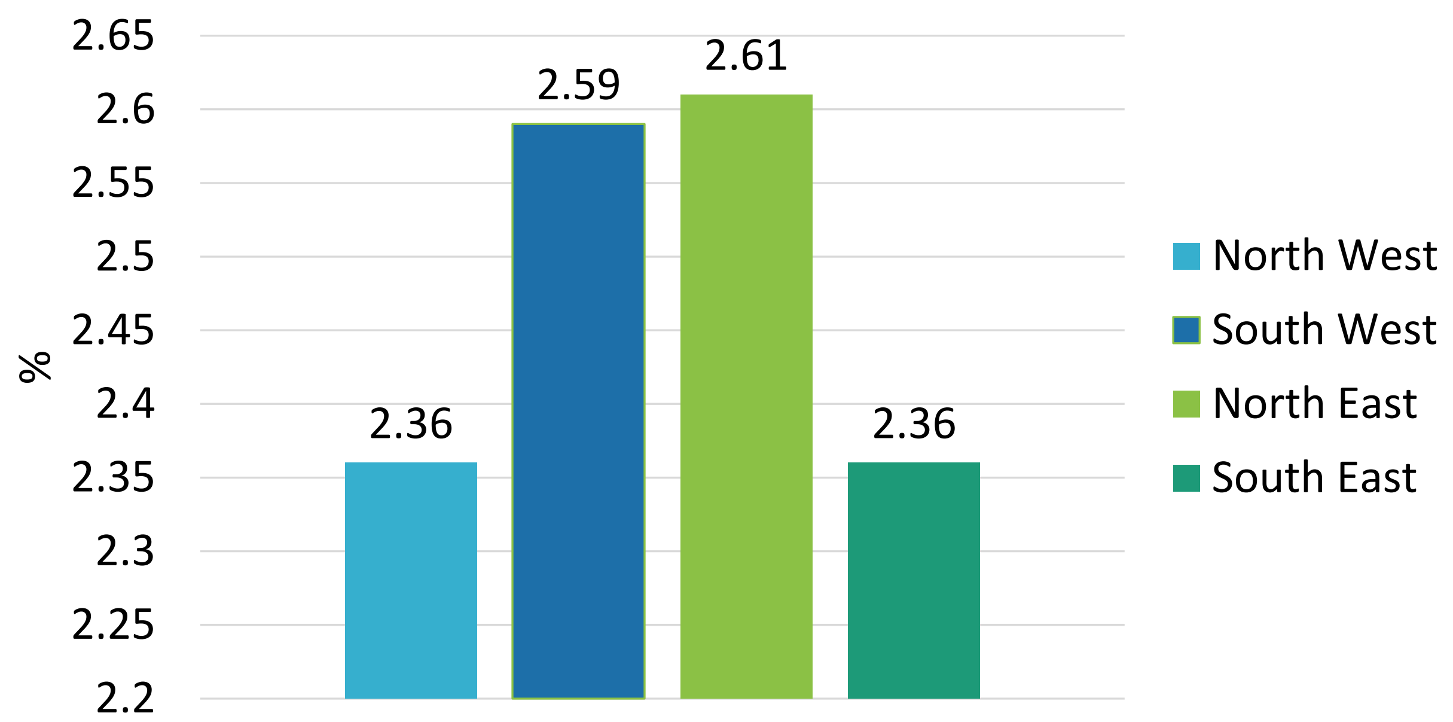


Analysis of Findings – Daylighting By Facade

Passive Low-E Average Daylight Factor (%) - Orientation

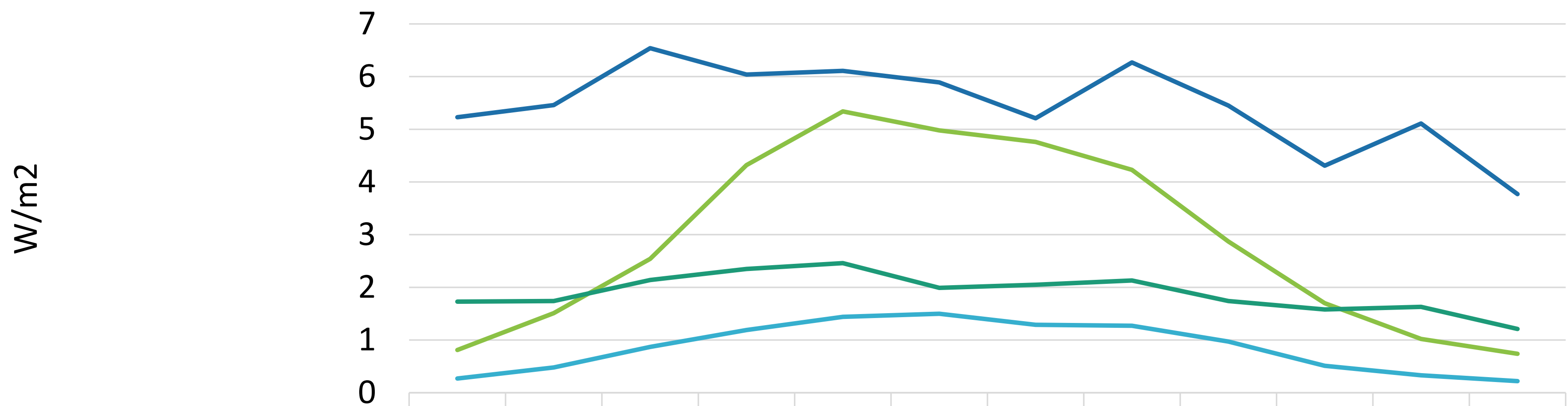


Solar Control Low-E Average Daylight Factor (%) - Orientation



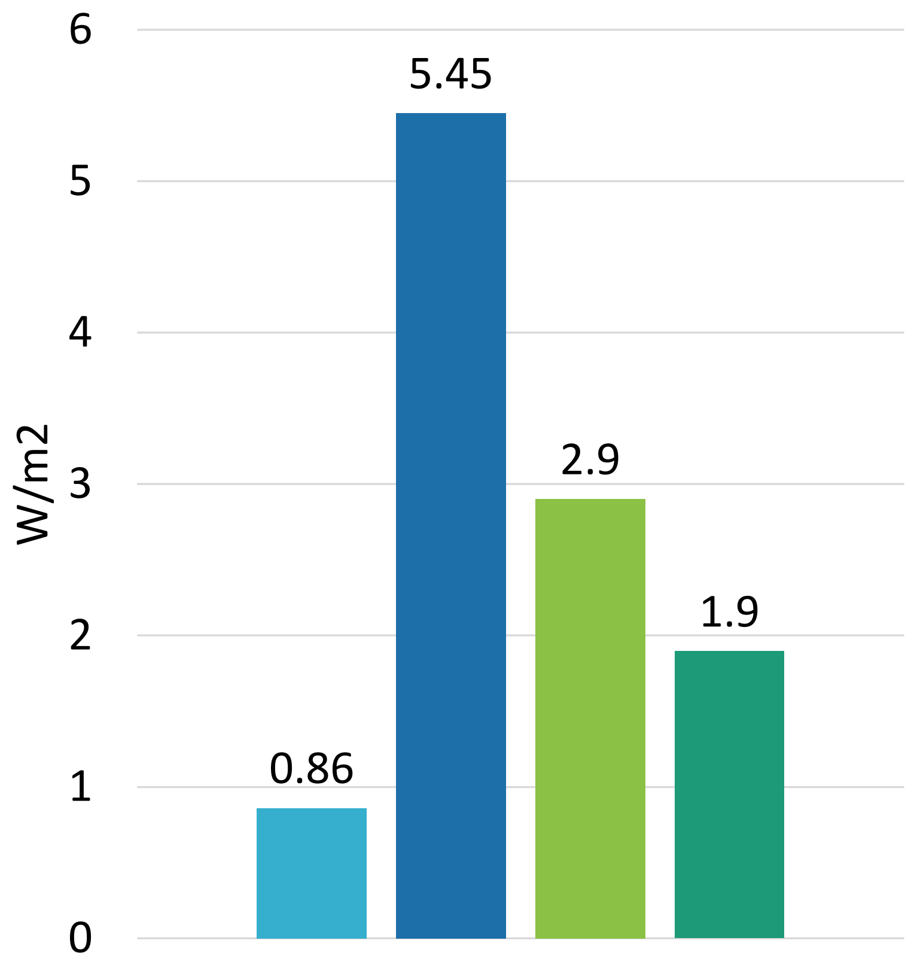
Analysis of Findings – Solar Heat Gain By Façade

Passive Low-E Monthly Solar Heat Gain (All Elevations)

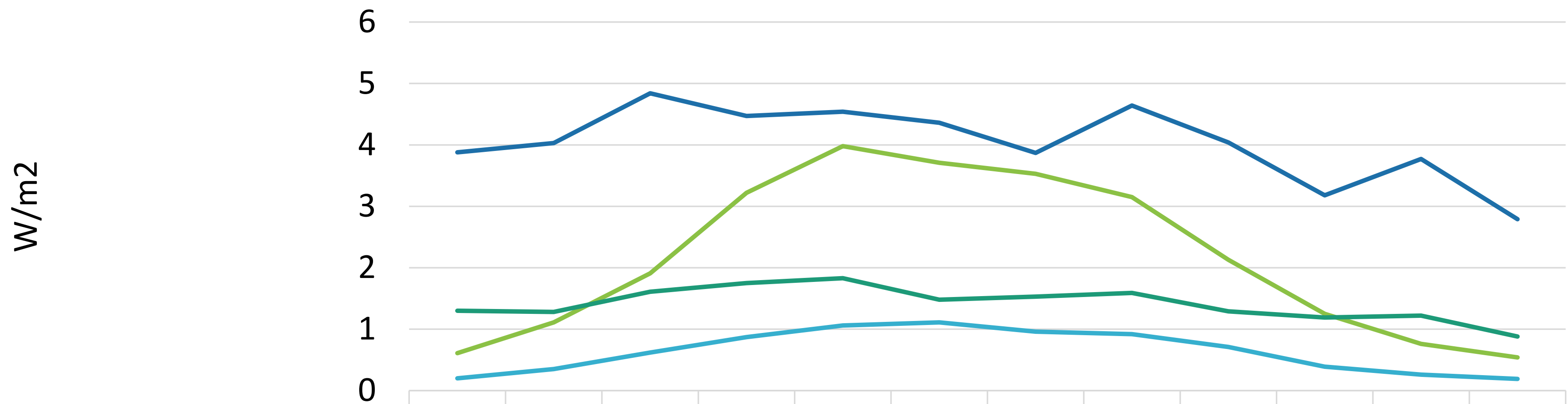


	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
North West Orientation	0.27	0.48	0.87	1.19	1.44	1.5	1.29	1.27	0.97	0.51	0.33	0.22
South West Orientation	5.23	5.46	6.54	6.04	6.11	5.89	5.21	6.27	5.45	4.31	5.11	3.77
North East Orientation	0.81	1.51	2.54	4.32	5.34	4.98	4.76	4.23	2.87	1.7	1.02	0.74
South East Orientation"	1.73	1.74	2.14	2.35	2.46	1.99	2.05	2.13	1.74	1.58	1.63	1.21

Month

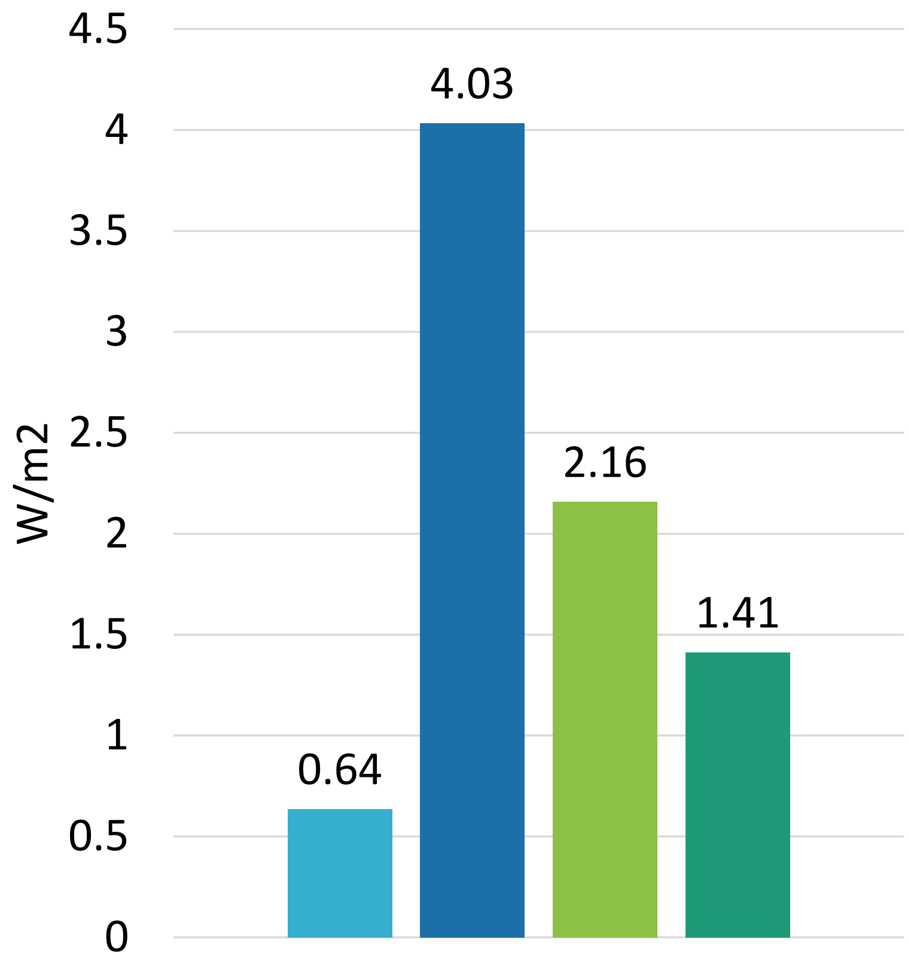


Solar Control Low-E Monthly Solar Heat Gain (All Elevations)



	Jan:	Feb:	Mar:	Apr:	May:	Jun:	Jul:	Aug:	Sep:	Oct:	Nov:	Dec:
North West Orientation	0.2	0.35	0.62	0.87	1.06	1.11	0.96	0.92	0.71	0.39	0.26	0.19
South West Orientation	3.88	4.03	4.84	4.47	4.54	4.36	3.87	4.64	4.04	3.18	3.77	2.79
North East Orientation	0.61	1.11	1.91	3.22	3.98	3.71	3.53	3.15	2.13	1.25	0.76	0.54
South East Orientation"	1.3	1.28	1.61	1.75	1.83	1.48	1.53	1.59	1.29	1.19	1.22	0.88

Month



Conclusion

- Solar control low-E reduced more solar heat gain.
- Both of the specified low-E glazing systems had detrimental effects to the case study building by limiting too much solar heat gain:
  - Both low-E glazing systems fell far outside of the optimum (15 – 25 W/m2) range.
  - The building now requires extra heating loads as a result, which increases cost and building energy usage.
- The South East elevation experienced the most solar heat gain significantly in both scenarios. The level of solar heat gain was consistently high throughout the year, with a decrease between October and December.
  - Perhaps the building requires a low solar heat gain coefficient (SHGC) on the South East elevation and a moderate SHGC on the other elevations, to mitigate the excessive solar heat gain and balance solar heat gain levels throughout the building.
- The North East elevation experienced a sharp spike in solar heat gain between March and September in both scenarios. This was opposed to each of the other elevations which experienced a more consistent level of heat gain annually.
  - Perhaps this spike in solar heat gain experienced on the North East elevation can be mitigated with the use of solar shading devices like solar blinds.
  - The Miesian Plaza currently uses an internal solar blinds system, which is used on specific elevations during periods of the year when excessive solar heat gain is experienced. When these solar blinds are used, the existing passive low-E glazing system's SHGC is reduced from 0.23 to 0.15.

- Solar control low-E reduced more daylighting in comparison to the passive low-E.
  - Solar Control low-E reduced natural daylighting inside the case study building to the low end of the optimum (2 – 7 %) daylighting factor levels, while the passive low-E brought daylighting levels closer to the average value for optimum daylight factor levels.
  - These are both acceptable levels.
- The North East and South West elevations experienced the highest levels of natural daylight.
  - Perhaps in the case where excessive daylighting levels are experienced on building elevations, a lower visible light transmittance (VLT) can be specified to mitigate the excessive daylighting and balance daylighting levels throughout the building.
- The low end of the optimum daylighting factor levels may be more beneficial to glass-based façade buildings, by reducing glare discomfort.
  - Reduced daylighting may require some appropriate artificial lighting for occupant comfort.