



TRUE STORY OF A SUCCESSFUL FAÇADE:

Solarban[®] Glass Powering KOI Tower

A Proven Case of Savings, Comfort and Aesthetics



Vitro[®]
Architectural Glass

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Executive Summary



TRUE STORY OF A SUCCESSFUL FAÇADE:

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With a track record of over 100 years of experience in innovation and continuous improvement processes, we at **Vitro Architectural Glass** challenge ourselves to break paradigms and demystify the belief that selecting a high-performance glass makes initial investment costs rise and extends the return-on-investment process.

In 2020 we selected **Three Consultoría Medioambiental**, a firm dedicated to energy efficiency and sustainability consulting, to analyze the economic and energy impact of the case study for KOI Tower, located in the Metropolitan Area of Monterrey, Nuevo León. We also had the support of **Internacional de Inversiones (IDEI)** to provide us with information and costs of the tower, along with its energy consumption.

What makes this case study different?

We present information of the actual energy consumption of the project, its annual operating costs and the initial investment costs in order to obtain the tangible savings of the project, as well as a calculation of the return on investment (ROI).

In addition, we analyze in depth the comfort level of its inhabitants from a thermal and lighting point of view.

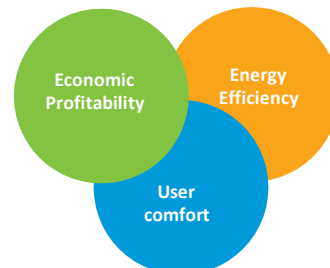
To achieve the above, we compare the current condition of the tower to the variations that would have occurred if another type of glass had been selected for its façade.

The objective of the study is to make clear the impact of good decision making on the glazing system: measurable, real and immediate savings for the investor, in addition to constant long-term benefits for the users.

About KOI Tower

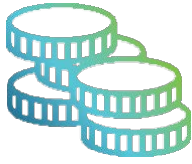
The façade of KOI Tower is composed mainly of our **Solarban® R100 Optiblue® glass** double glazing, so its thermal and optical characteristics are fundamental to the achievement of the building's efficiency and high-performance objectives.

In the analysis process, we considered three aspects:



With the KOI Tower success story, we intend to show that a higher initial investment is not necessary to have a high-performance sustainable building.

Immediate Return on Investment (ROI)



*Savings of \$362,000
from the first minute*

28% reduction in HVAC equipment capacity compared to a 12mm monolithic clear glass system, due to the high performance of the installed glass.

Thermal Comfort



*Solarban® R100
Optiblue® glass provides thermal comfort for building users 90% of the time the space is occupied throughout the year.*

Lighting Comfort

13% decrease of glare areas compared to 12mm clear glass.



Impact on Annual Operating Costs



*Savings of more than
\$595,000 per year
in HVAC operating costs.*

Considering 40 years as the average lifespan of the building, only in operational savings, this glass avoids an expense of more than **\$24 million!**

Emission Reduction



*More than 1,833 tCO₂e/year
were reduced.*

Over the lifespan of the building, a total of 73,355 tCO₂e will be reduced, which would be equivalent to removing 36,979 vehicles from circulation.

The study also includes a comparison with other types of glass systems known in the market to provide a detailed analysis of the benefits provided by the different options.

Glass Type	Product	Thickness (mm)	Initial Investment Cost: Glass & HVAC System (USD)	Annual Operating Cost (USD)	Percentage of Hours in Thermal Comfort	Percentage of Area with Glare	Emissions (Tons of CO ₂ e/year)
Monolithic	Clear	12	\$10,723,669	\$2,028,656	74%	38%	6,022
Double	Clear + Clear	25	\$10,750,828	\$1,757,606	78%	37%	5,258
Double	<i>Solargray®</i> + Clear	25	\$9,932,227	\$1,627,780	81%	31%	4,831
Double	<i>Solarban® 60</i> + Clear	25	\$10,262,700	\$1,517,119	86%	33%	4,512
Double	<i>Solarban® R100 Optiblue®</i> + Clear	25	\$10,357,839	\$1,409,568	90%	25%	4,188

We hope that after reading our study you will feel confident when using high-performance glass for the façade of your next project, knowing it will give you savings from the moment you specify the glass and throughout the life cycle of the building.

Don't miss out on the benefits – unleash the potential of your project with *Solarban®* glass!

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The selection of the right architectural glass provides significant improvements for both people and the environment, in addition to reducing initial investment and annual operating costs.

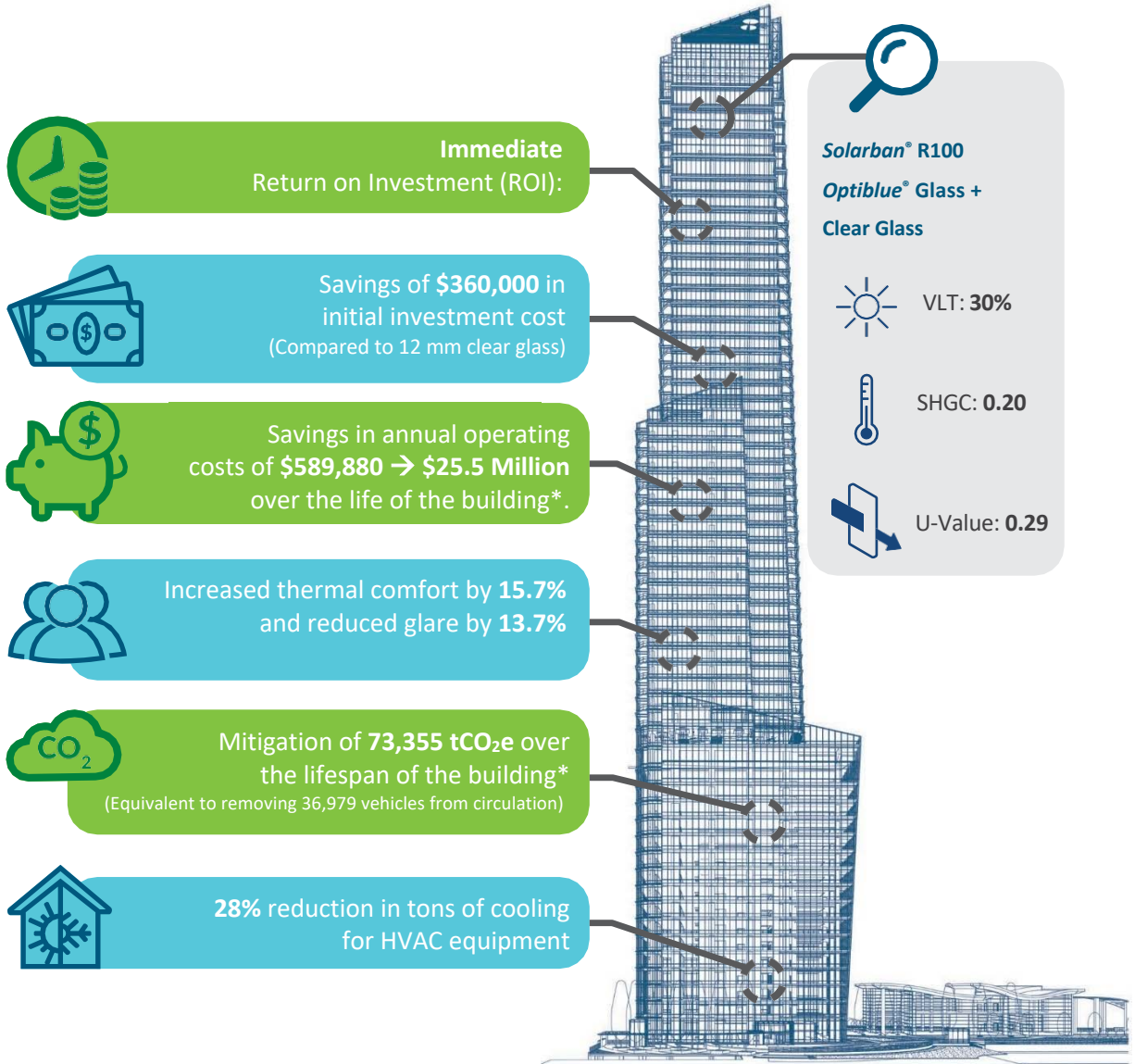
The success case of **KOI Tower** demonstrated the following tangible benefits of selecting the **Solarban[®] R100 Optiblue[®] glass** system versus the baseline 12mm monolithic clear glass.

TRUE STORY OF A SUCCESSFUL FAÇADE: Solarban[®] Glass Powering KOI Tower

A Proven Case of Savings, Comfort and Aesthetics

Benefits of Solarban[®] R100 Optiblue[®] + Clear Glass

-  Economic Profitability
-  Energy Efficiency
-  User Comfort



Immediate
Return on Investment (ROI):



1. Evolution: A True Case of Savings

What's the first thing that comes to mind when you think of a sustainable, energy-saving building?

Other than its benefits and aesthetics, you probably think sustainable buildings will be considerably more complex and require very expensive technologies.

At Vitro Architectural Glass, we challenge ourselves to break paradigms and demystify the belief that when selecting a high-performance glass, the initial investment costs rise, and it takes a long time to recover the return on investment.

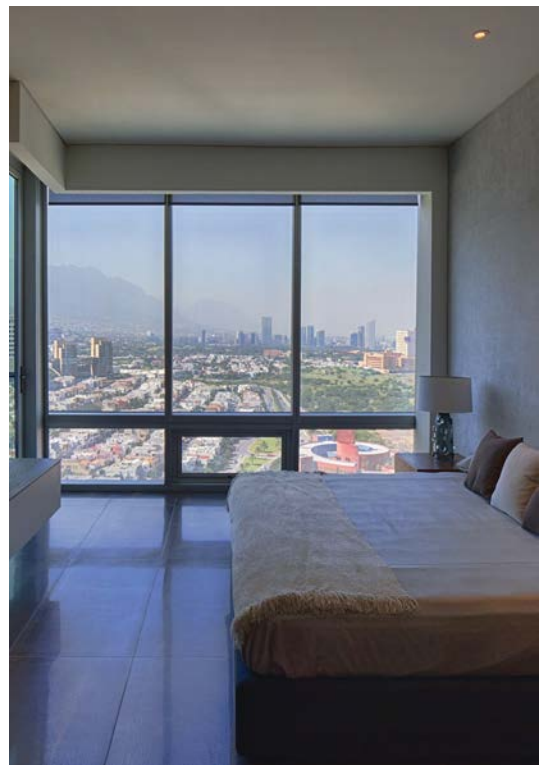
We hope that after reading our study, you will feel confident in using high-performance glass for the façade of your next project, knowing it will provide savings from the moment of selection and throughout the life of the building.

This case study is an evolution of the publication “Low-E Architectural Glass and Solar Control: Energy, Economic and Environmental Benefits”, which was published by Vitro in 2019.

Unlike the previous report that used energy modeling in different cities in Mexico to calculate savings in initial investment and operating costs in a simulated building, this report focuses on studying and presenting the real and tangible benefits in economic profitability, energy efficiency and user comfort in a real building operating for more than three years.

Real information on energy consumption (electricity costs), mechanical equipment costs (HVAC) and glazing types, as well as the comfort level of its occupants were used to obtain quantitative conclusions and monetize the benefits obtained thanks to a good selection of glass by the developer and architect.

Therefore, *KOI Tower was selected for this Study*. In addition to serving as an emblematic building in the metropolitan area of Monterrey, it is one of the tallest buildings in Latin America. Its architectural facades are coated with our *Solarban® R100 Optiblue®* low-emissivity, high-performance glass.



2. KOI Tower: An Emblematic Vertical City

KOI Tower is the second-tallest building in Mexico.

RESIDENTIAL 36,000 m²
of sellable space on
37 floors

COMMERCIAL 55,400 m²
of leasable space on
27 floors

After a thorough selection process, the decision was made to specify and install a high-performance double-glazing system featuring **Solarban® R100 Optiblue® glass** by Vitro Architectural Glass.

In the design of the building, 100% of the total façade is covered with architectural glass, so the choice of glass was of utmost importance and contribution to the building.

For this analysis, the technical properties as shown in Image 1 were considered. These in turn allow the benefits of the **Solarban® R100 Optiblue® glass** system to be realized, in terms of reduced energy consumption, savings in initial investment and operating costs, thermal comfort and natural lighting. In addition, this double-glazing system (also known as insulated glass) solves the structural challenge posed by the impact of wind speed in tall buildings such as KOI.

At 279.5 meters tall, the skyscraper is considered mixed-use as it is comprised of offices and apartments.

It has been in operation since 2017 and has been recognized as an exemplary building by receiving the LEED® C&S¹ v2009 Silver Level certification in 2018.



KOI Tower

**SOLARBAN® R100
OPTIBLUE® + CLEAR Glass**



VLT: **30%**



SHGC: **0.20**



U Value: **0.29**

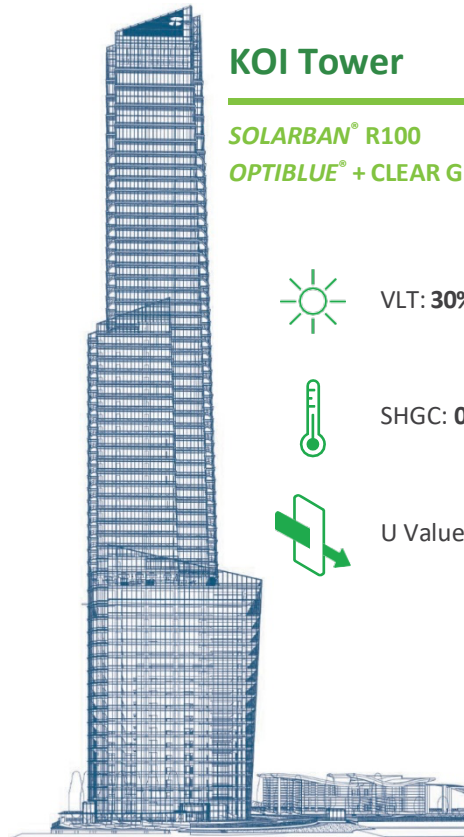


Image 1. Thermal and optical properties of the glass in the project.

¹ LEED: Leadership in Energy and Environmental Design Core and Envelope Certification. | LEED® and its related logo are trademarks owned by the U.S. Green Building Council® and are used with permission.

2.1 Local Climate of the Case Study

According to the ASHRAE 90.1² standard, the Monterrey Metropolitan Area (ZMM) belongs to a 2B climate zone.

The predominant climate in the ZMM, of which San Pedro Garza Garcia is part, is "dry, hot and extreme", with irregular rainfall in late summer. The average temperature is above 71°F with oscillations between 44.6°F and 57.2°F, and there is also midsummer heat.

These conditions usually require the implementation of cooling and heating systems (HVAC) to achieve thermal comfort.

The use of these systems translates directly into energy consumption; therefore, the search for strategies to reduce such consumption is crucial to achieve the best performance of buildings.

**For more information on Mexico's climates, please refer to Annex 1 of this document.*

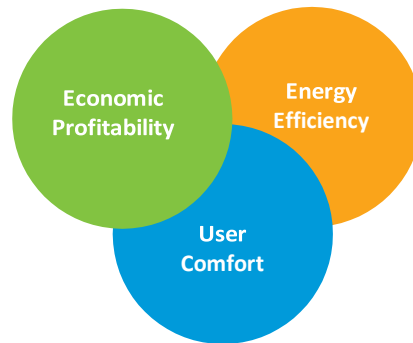


Image 2. Monterrey Climate Zone (Monterrey Metropolitan Area)

²ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) 90.1: International Energy Efficiency Standard on Energy Requirements for Buildings Except Low-Rise Residential Buildings, which is used as a reference for LEED certification.

2.2 Key Factors for a High-Performance Building

The selection of appropriate materials for a project should consider the following factors:



A building envelope is made of the elements that separate the interior environment from the exterior: walls, roofs, floors, windows, skylights, etc. A good design of the envelope and the proper selection of materials can impact the heat gain in a project, affecting comfort and energy consumption.

role in determining the heat gains of the building. Therefore, its performance was evaluated according to the three factors mentioned above, as they determine the energy performance of the building and the quality of life of the people who live in it.

In the case of KOI Tower, glass is the predominant element of the envelope and plays an essential

Regarding economic profitability, we found two important elements:

Economic Profitability



Initial Investment Costs

Directly related to the reduction in the need for equipment for the cooling and heating system (HVAC) as a result of having an envelope with high thermal efficiency materials.



Operating Costs

Related to economic savings, due to a decrease in energy consumption, reflected in a lower monthly electricity bill.

Energy efficiency is directly related to economic profitability and environmental impact. With the correct selection of materials for the building envelope, it is possible to reduce electrical energy consumption from the source and

Therefore, reduce greenhouse gas (GHG) emissions to the environment, thanks to a lower consumption of heating and cooling systems needed to provide thermal comfort inside the building.

The glazed system influences user comfort in three main factors³:



Luminous and Radiant Light Comfort

How natural light is perceived by sight, where lighting conditions such as levels, uniformity, color and radiation diffusion play an important role in achieving the comfort necessary to perform the activity intended for the interior space.



Acoustic Comfort

The overall level of satisfaction of an occupant in a given environment caused by sound or noise produced inside or coming from the outside.



Thermal Comfort and Thermal Radiation

When the occupants of a given interior space do not feel cold or hot: factors such as temperature, air and humidity are ideal for carrying out the activity intended for the space.

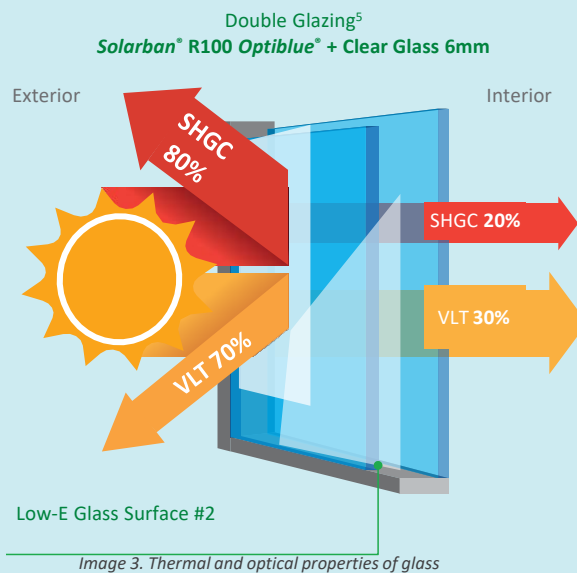
Although double glazing such as that used in KOI Tower improves acoustic comfort, for the purposes of this study this factor is not analyzed. Should you require specific information on this subject for any project, please contact Vitro Architectural Glass.

2.3 Technical Characteristics of Glass Systems

The aspects to consider during the selection of glass for the project, which directly affect the comfort of the spaces and energy consumption, include the following:

VLT⁴
(Visible Light Transmission):

Refers to the amount of light that a glazing system allows to enter the interior space in proportion to what the human eye can perceive. The range is from 0 to 1, where the higher the value, the more visible light enters the interior space.



SHGC⁶

(Solar Heat Gain Coefficient):

Determines the ability of a glazing system to reject the amount of solar radiation entering the interior space. It has a range from 0 to 1, where the lower the value, the less heat will pass into the interior.

U-Value

(Overall Heat Transfer Coefficient):

A characteristic that determines the amount of energy that a material can transmit from an exterior space to the interior and vice versa. The lower the U-value, the better the insulation provided by this material. In this study, the winter air values are considered.

⁴ VLT: Visible Light Transmission

⁵ 25 mm (1 inch) double glazing (UD) with 13 mm (1/2 inch) intermediate air space and two 6 mm (1/4 inch) monolithic glass.

⁶ SHGC: Solar Heat Gain Coefficient

2.4 Methodology

In December 2020, Vitro Architectural Glass commissioned **Three Consultoría Medioambiental**, based in Monterrey, to study the economic, social and environmental impact of the **Solarban® R100 Optiblue® glass** selected for the KOI Tower case study, compared to four other glass systems.

Aluminum was considered in all five scenarios for window and door frames, as it is the framing material most commonly used in Mexico.

For the purposes of this study, two specialized software were used:

- The **Trace 700** software to evaluate energy consumption.

- The **IESVE⁷** program to evaluate thermal comfort, natural lighting and solar radiation.

The analysis was carried out taking into consideration the two types of use of the building: commercial and residential, as well as the different floors of the building in each of the levels as presented in *Image 4*.

To determine the annual energy savings of the case study, the company **Internacional de Inversiones (IDEI)**, developer of KOI Tower, kindly and voluntarily shared the required information, including actual records from one year of energy consumption (electricity bills).

These were used to calibrate an energy simulation that allowed calculating the different energy consumptions that would have been generated in the building in case of using different glass in the façade.

Thermal comfort was analyzed using the Comfort Zone Analytical Method described in **ASHRAE 55⁸ Standard**. This methodology considers the six components of thermal comfort and the effect of direct solar radiation on occupants to simulate how people would respond if they were asked whether they were hot or cold.

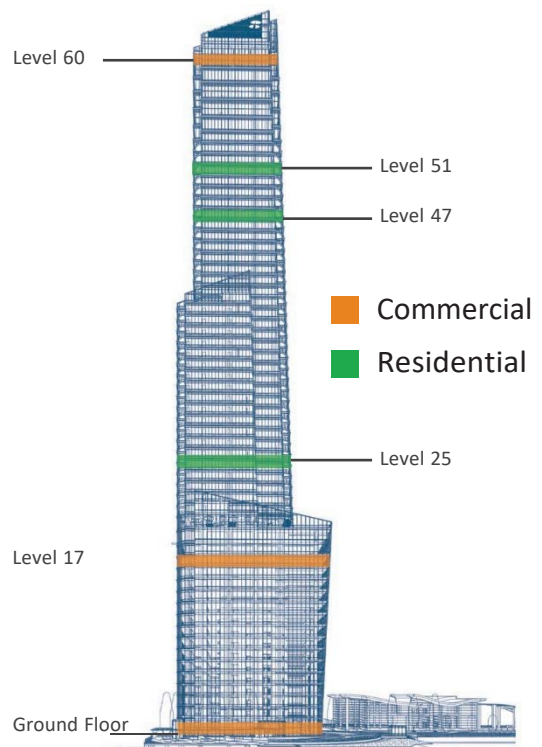


Image 4. Architectural elevation case study Torre KOI

⁷ IESVE - Integrated Environmental Solutions Virtual Environment.

⁸ ANSI/ASHRAE Standard 55-2017 - Standard for Thermal Environmental Conditions for Human Occupancy, which is used as a reference for LEED certification.

2.5 Comparison of Glass Systems

Table 1 shows the five glass systems that are part of this analysis along with their physical, thermal and optical characteristics, in order to compare the performance of each of these in the same architectural and climatic conditions.

Table 1. Glass systems to be analyzed with their physical, optical and thermal properties.

Glass Type	Product	Thickness (mm)	VLT %	U Value (W/m ² *K)	SHGC
Monolithic	Clear	12	83%	5.60	0.72
Double	Clear + Clear	25	78%	2.69	0.70
Double	Solargray® + Clear	25	40%	2.69	0.46
Double	Solarban® 60 Clear + Clear	25	70%	1.65	0.39
Double	Solarban® R100 Optiblue® + Clear	25	30%	1.65	0.20



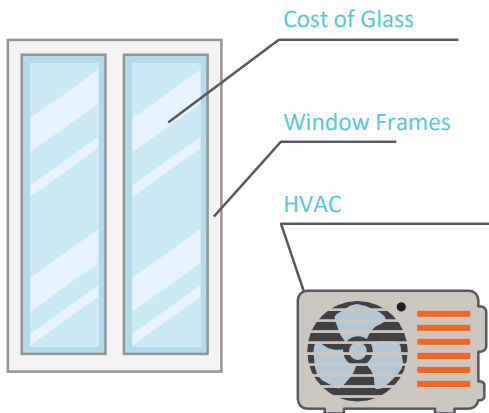
3. Finance & Profitability

In this section we will analyze from a financial point of view why **Solarban® R100 Optiblu® glass** was the best decision for KOI Tower.

We will break the paradigm that by selecting low-emissivity (low-e) and solar control glass, which has a much higher performance than traditional clear glass, our project will automatically become more expensive or even unfeasible.

The evidence collected with this study demonstrates that it is possible to have a high-performing glazing system and recover your investment immediately, in addition to enjoying the constant savings and qualitative benefits (comfort) that this type of glass provides.

To obtain the profitability of each of the options considered, the **initial return on investment** of the case study was analyzed by comparing the initial investment costs:



The selection of the **Solarban® R100 Optiblu® glass** system resulted in a reduction in the need for the cooling and heating capacity required to achieve comfort; resulting in considerable and immediate savings for the developer by reducing the investment in mechanical equipment capacity, duct sizes, electrical installations that supply power to the systems; labor during installation; and subsequently, in the energy bills of tenants and users.

3.1 Initial Investment Costs



Five glass systems were compared, including the one installed in KOI Tower, versus a baseline of 12mm monolithic clear glass. The latter is the most basic system that could be used for this type of building considering structural issues, architectural design and wind loads.

The costs involved in each type of glazing were considered, which is composed of the sum of the cost of the type of glass (including window frames) and the cost of the air conditioning (which depends on the tons of cooling required).

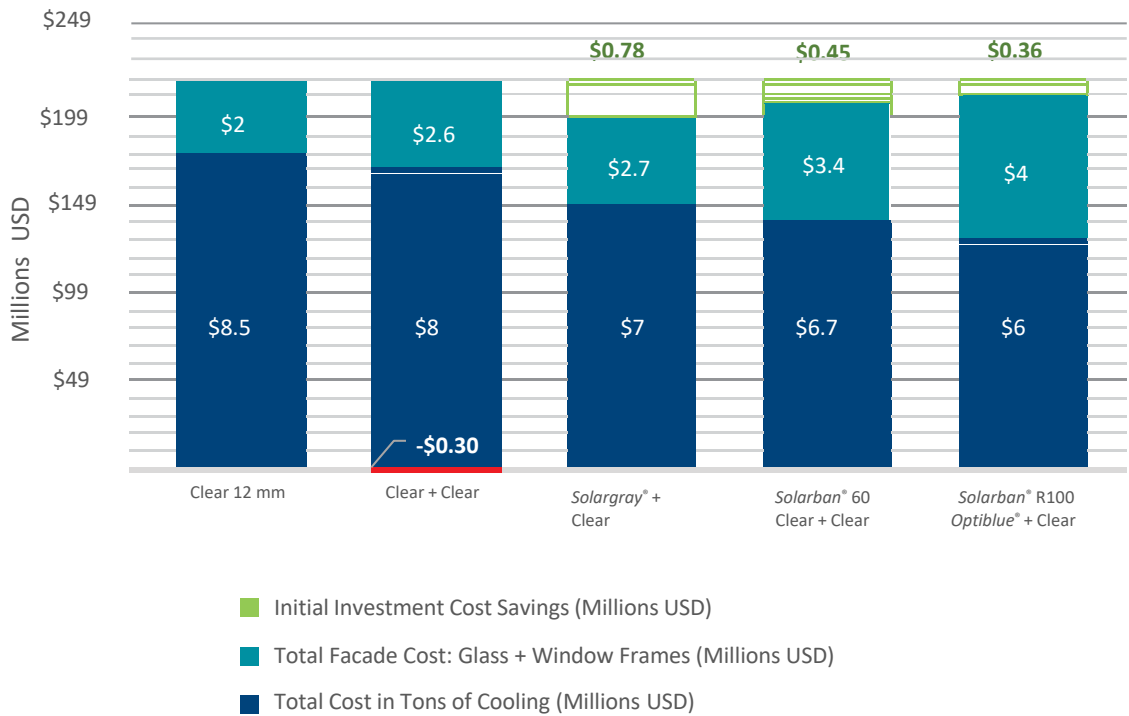
Table 2. Initial investment cost per glass and HVAC system.

Glass Type	Product	Thickness (mm)	Total Cost in Tons of Cooling (USD)	Total Cost Façade: Glass + Framing (USD) ¹⁰	Total Initial Investment Cost: Glass & HVAC System (USD) ¹¹	Initial Investment Cost Savings (USD)
Monolithic	Clear	12	\$8,653,312	\$2,071,643	\$10,728,147	\$0.00
Double	Clear + Clear	25	\$8,112,569	\$2,642,225	\$10,758,702	-\$30,250
Double	Solargray® + Clear	25	\$7,144,910	\$2,790,943	\$9,939,502	\$788,795
Double	Solarban® 60 Clear + Clear	25	\$6,781,543	\$3,484,961	\$10,270,256	\$458,106
Double	Solarban® R100 Optiblue® + Clear	25	\$6,242,192	\$4,119,960	\$10,365,797	\$362,915

⁹ The estimated cost of **\$2,997 per ton of cooling** installed was provided by the contractor who installed the HVAC system at KOI Tower. The equipment used is water-cooled VRF with closed-loop cooling towers. The tons of cooling required for each glass system are referenced in Graph 4. The façade area considered in the energy modeling was 29,262 m².

¹⁰ The estimated cost of each glass system considers the glass and framing.

¹¹ The capital cost estimates for both the glass and HVAC systems were calculated using current 2020/2021 costs.



Graph 1. Initial Investment Costs per Glass System and corresponding HVAC System

Table 2 and Graph 1 summarize the reduction in initial investment costs due to the implementation of efficient glass systems. If KOI Tower had installed a 12mm¹² monolithic clear system, the investor would have lost more than

\$347, 050



(2020 current costs) since the initial investment compared to selecting the high thermal performance **Solarban® R100 Optiblue®** glass system.

In addition, a translucent envelope allows natural daylight to enter, helping to reduce the

hours of operation of the electric lighting systems, generating an additional economic benefit during the operation of the building.

In addition to the large initial investment savings, we must remember that, during the operation stage, **air conditioning equipment of lower capacity will consume less energy** and will be needed for fewer hours per year to provide **thermal comfort** to users. This allows for economic savings in operating costs and reduction of greenhouse gas (GHG) emissions throughout the life of the building.

¹²Due to wind loads, glass specifications should be a minimum of 12mm Clear monolithic glass.

3.2 Operating Costs

Table 3. Annual operating costs per glass system.

Glass Type	Product	Thickness (mm)	Estimated Annual Operating Cost (USD)	Estimated Annual Operating Cost Savings (USD)	Project Lifecycle Operating Cost Savings (USD)
Monolithic	Clear	12	\$2,007,848	\$0.00	\$0.00
Double	Clear + Clear	25	\$1,739,544	\$268,221	\$10,738,227
Double	Solargray® + Clear	25	\$1,611,052	\$396,677	\$15,876,395
Double	Solarban® 60 Clear + Clear	25	\$1,501,008	\$506,511	\$20,258,965
Double	Solarban® R100 Optiblue® + Clear	25	\$1,394,774	\$612,913	\$24,525,433

Table 3 shows how the annual operating costs are directly related to the thermal properties (U- value and SHGC) of the glass system, where the low solar heat gain value (SHGC) of **Solarban® R100 Optiblue® glass** results in large savings. Similarly, we can see that without **Solarban® R100 Optiblue® glass, the building operator could have lost over**



\$620,000

per year that would have been required if a

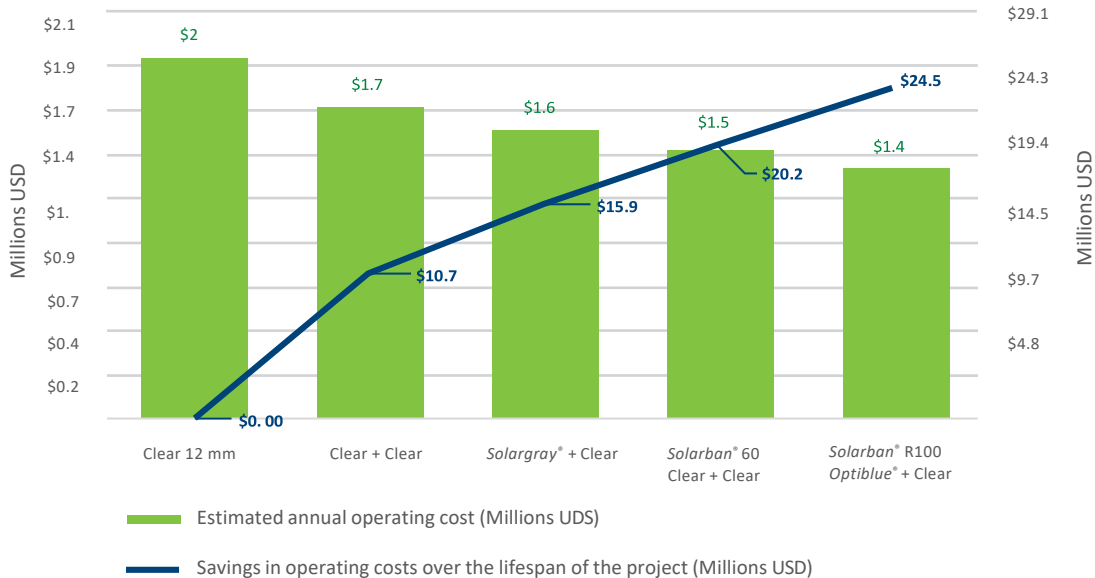
traditional glass system (12mm monolithic clear) had been installed, in terms of operating costs.

As shown in Table 4, the return on investment (ROI) of **Solarban® R100 Optiblue® glass** is immediate, in addition to all the operational savings that are generated as a direct gain for the operator. This results in **savings of more than**

\$24.8 Million



over the lifespan of the building (40 years).



Graph 2. Annual operating costs per glass system.



Table 4. Initial Return on Investment (ROI).

Glass Type	Product	Thickness (mm)	Total Initial Investment Cost of Glass & HVAC System (USD) ¹³	Initial Cost Savings: Glass & HVAC System (USD)	Annual Operating Cost Savings (USD)
Monolithic	Clear	12	\$10,612,156	\$0.00	N.A.
Double	Clear + Clear	25	\$10,642,077	\$0.00	\$268,838
Double	Solargray® + Clear	25	\$9,831,756	\$780,525	\$397,041
Double	Solarban® 60 Clear + Clear	25	\$10,158,926	\$453,303	\$506,976
Double	Solarban® R100 Optiblue® + Clear	25	\$10,254,671	\$359,105	\$613,475

As shown in Table 4 and Graph 2, the **Solarban® R100 Optiblue® glass** system provides an **immediate ROI** by obtaining economic savings since the initial investment (3.4%) and subsequently in annual operating costs (30.5%) compared to 12mm clear glass.

In addition, **Solarban® R100 Optiblue® glass** significantly reduces environmental impacts throughout the life of the project, as will be shown later in the section "Reduction of CO₂ emissions to the environment".

¹³ The re-estimation of the initial costs for both the glass and HVAC systems were calculated with current 2020/2021 costs.

4. Occupant Comfort Level

In this section, we will understand why the more often our glass is specified for the climate where our project is located, and according to the needs of the building, the lower our energy consumption will be.

There is a direct relationship between the following three elements: thermal loads,

desired level of interior comfort for users and the necessary capacity of the air conditioning systems.

In addition, we will analyze the glare control that **Solarban® R100 Optiblu® glass can offer, which has a direct impact on the level of lighting comfort for the building's users.**

Thermal Loads

What are they?

Thermal loads are the energy (heat) gains or losses of a space and are mainly generated by the building **envelope**, as shown in *Image 5*. However, other aspects of the building, such as artificial lighting, household appliances and electronic devices, as well as the number of people and the activities they perform within the space also generate heat.

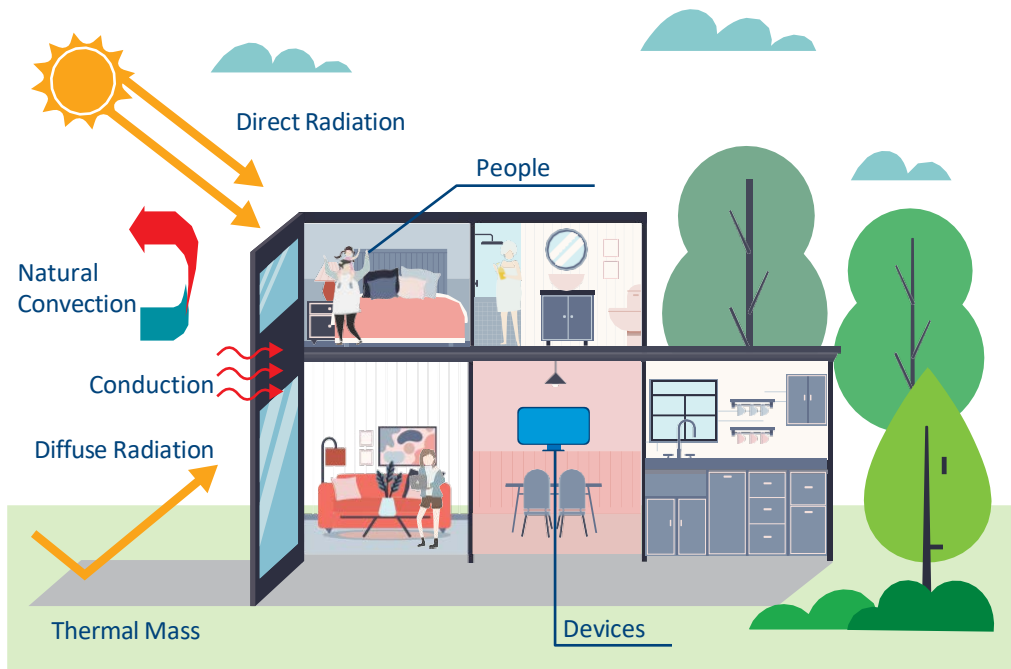


Image 5. Visual representation of the thermal loads of a space.

What does the HVAC system have to do with the building's energy consumption?

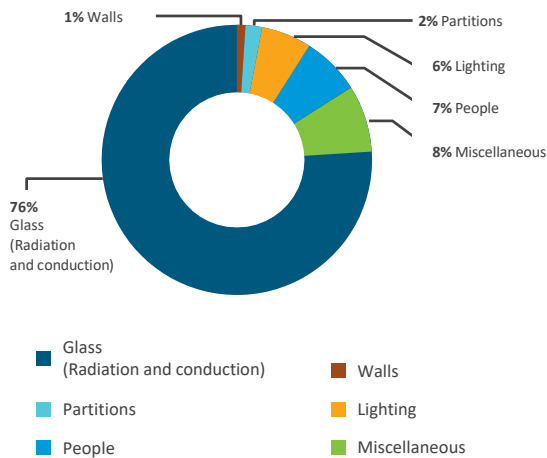
As mentioned in the previous section, thermal loads determine the size of the heating, ventilation and air conditioning (HVAC) systems. The more heat the building absorbs, the more tons of cooling will be required to maintain a comfortable indoor temperature. As a result, the capacity of this HVAC equipment will define the energy consumption of this system during the operation of the building, which can be at least the next 40 years of life of the building.

What role does glass play in reducing thermal loads?

Image 6 shows the thermal loads of a typical level. In this case we take the 60th floor in KOI Tower, where the glazing system plays a transcendental role.



12mm clear monolithic



Solarban® R100 Optiblu®

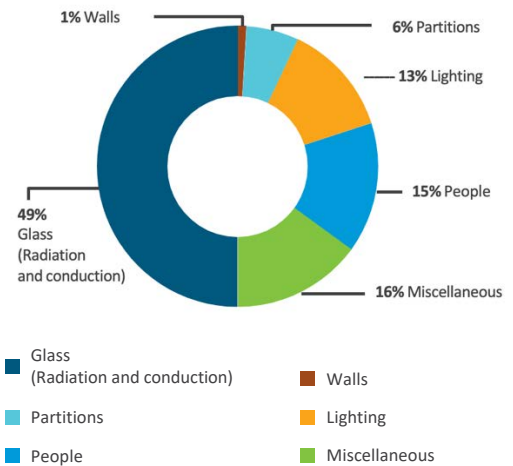


Image 6. Thermal load distribution on Level 60 (KOI Tower) with 12mm monolithic Clear glass vs. Solarban® R100 Optiblu®.

Our baseline, the 12mm monolithic clear glass system, shows that 76% of the total floor thermal load enters through the glass façade. On the other hand, in the case of **Solarban® R100 Optiblu®** glass, only 49% of the heat gain enters through the glass.

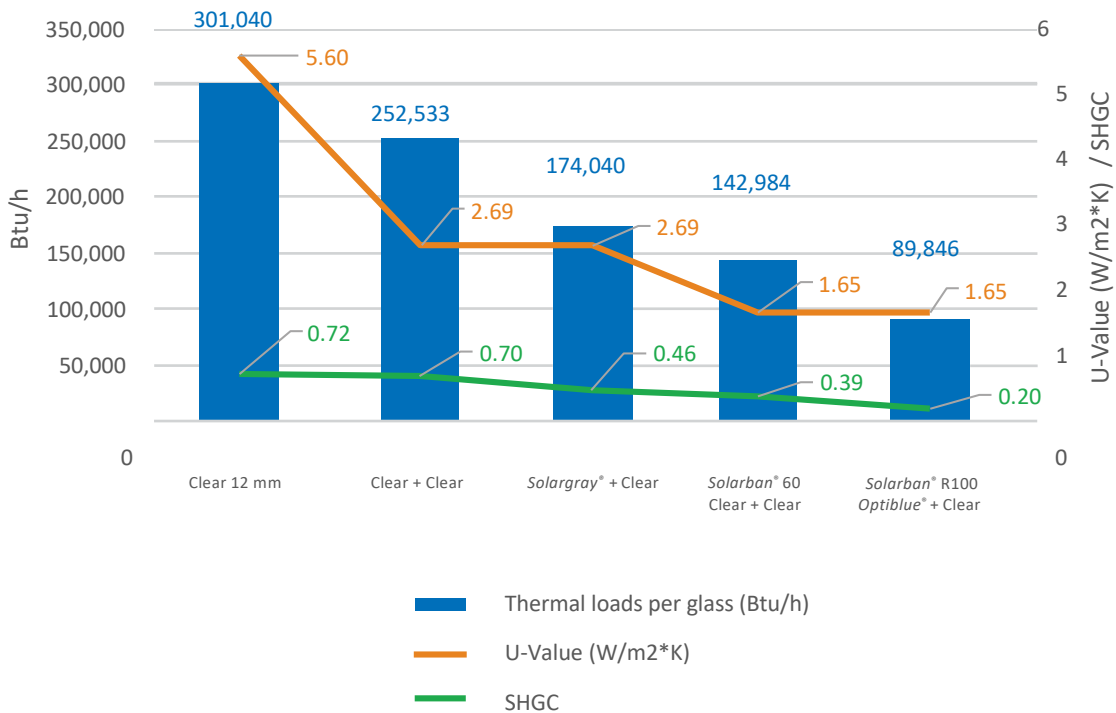
In other words, a 27-percentage point reduction in solar gain is achieved by selecting low-e glass.

As we can see, selecting a high thermal efficiency glass system has important consequences on the heat gain of the building. *Table 5* shows a comparison of the five glazing systems, showing the amount of heat that enters the building through conduction and radiation.

Table 5. Results of thermal loads based on the thermal properties of the glass system at a typical level (Level 60).

Glass Type	Product	Thickness (mm)	Thermal Properties		Thermal Loads			Percentage Decrease in Thermal Loads ¹⁴
			U-Value (W/m ² *K)	SHGC	Conduction (Btu/h)	Radiation (Btu/h)	Totals (Btu/h)	
Monolithic	Clear	12	5.60	0.72	74,486	226,554	301,040	0%
Double	Clear + Clear	25	2.69	0.70	41,090	211,443	252,533	16%
Double	Solargray® + Clear	25	2.69	0.46	41,090	132,951	174,040	42%
Double	Solarban® 60 Clear + Clear	25	1.65	0.39	29,117	113,867	142,984	53%
Double	Solarban® R100 Optiblue® + Clear	25	1.65	0.20	29,117	60,729	89,846	70%

We can conclude that our **Solarban® R100 Optiblue® glass** helps to reduce up to **70% of the heat input through the windows**, equivalent to approximately 28% of the required capacity of the air conditioning system - see *Graph 3*. This results in **annual energy (monetary) savings equivalent to 31% compared to clear 12 mm glass** (see *Table 3*).



Graph 3. Thermal loads per glass based on its thermal properties

¹⁴ This percentage only includes the thermal loads of the glass (conduction and radiation), because the thermal loads per ceiling, wall and internal (lighting, miscellaneous and people) are the same in the five scenarios analyzed. It should be remembered that the tons of cooling are calculated with all internal and external loads.

South and West Facade

North and East Facade

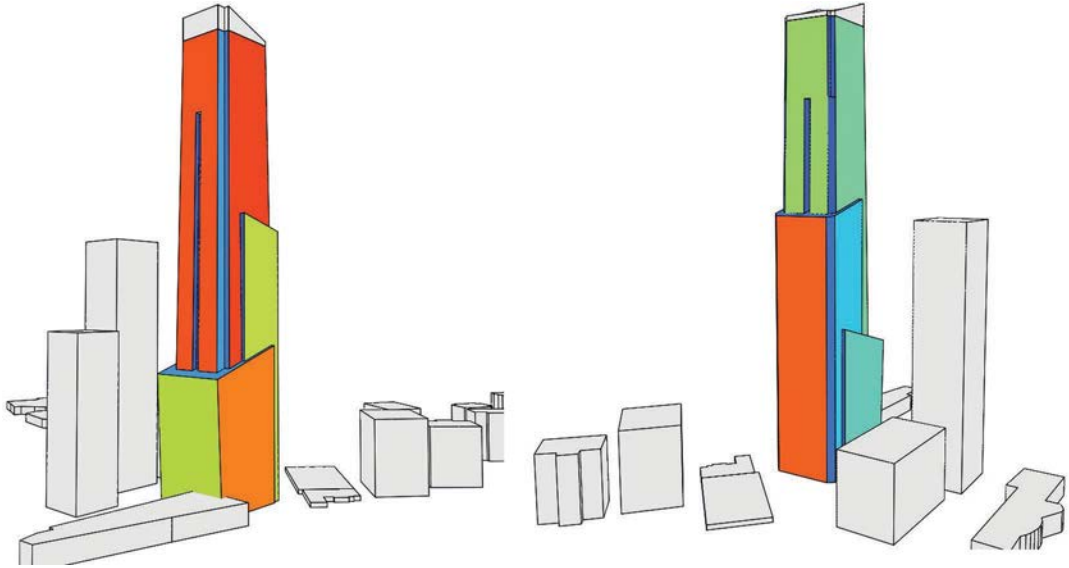
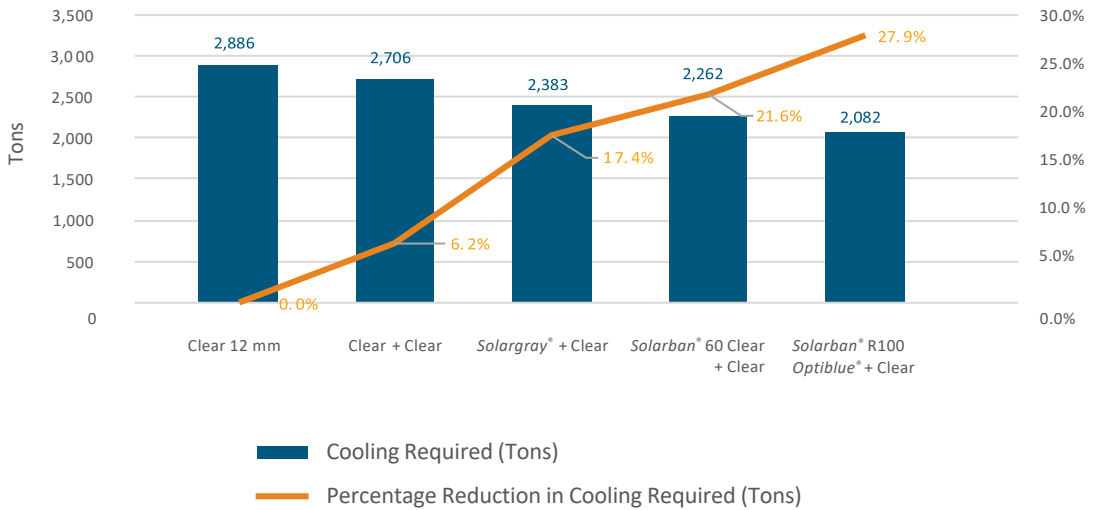


Image 7. Solar incidence (heat) on facades of Torre KOI



Graph 4. Cooling required (Tons) per glass system to provide comfort to building users, based on ASHRAE 55.

Graph 4 shows the tons of cooling required for the building are directly related to the thermal characteristics of the glass. The lower the U-Value and SHGC, the higher the savings. By installing **Solarban® R100 Optiblu® glass** managed to reduce

804.2 tons of cooling 

which represents **savings of more than**

\$2.3 Million¹⁵ 

in air-conditioning system, achieving an enormous savings on the initial investment cost of the project.

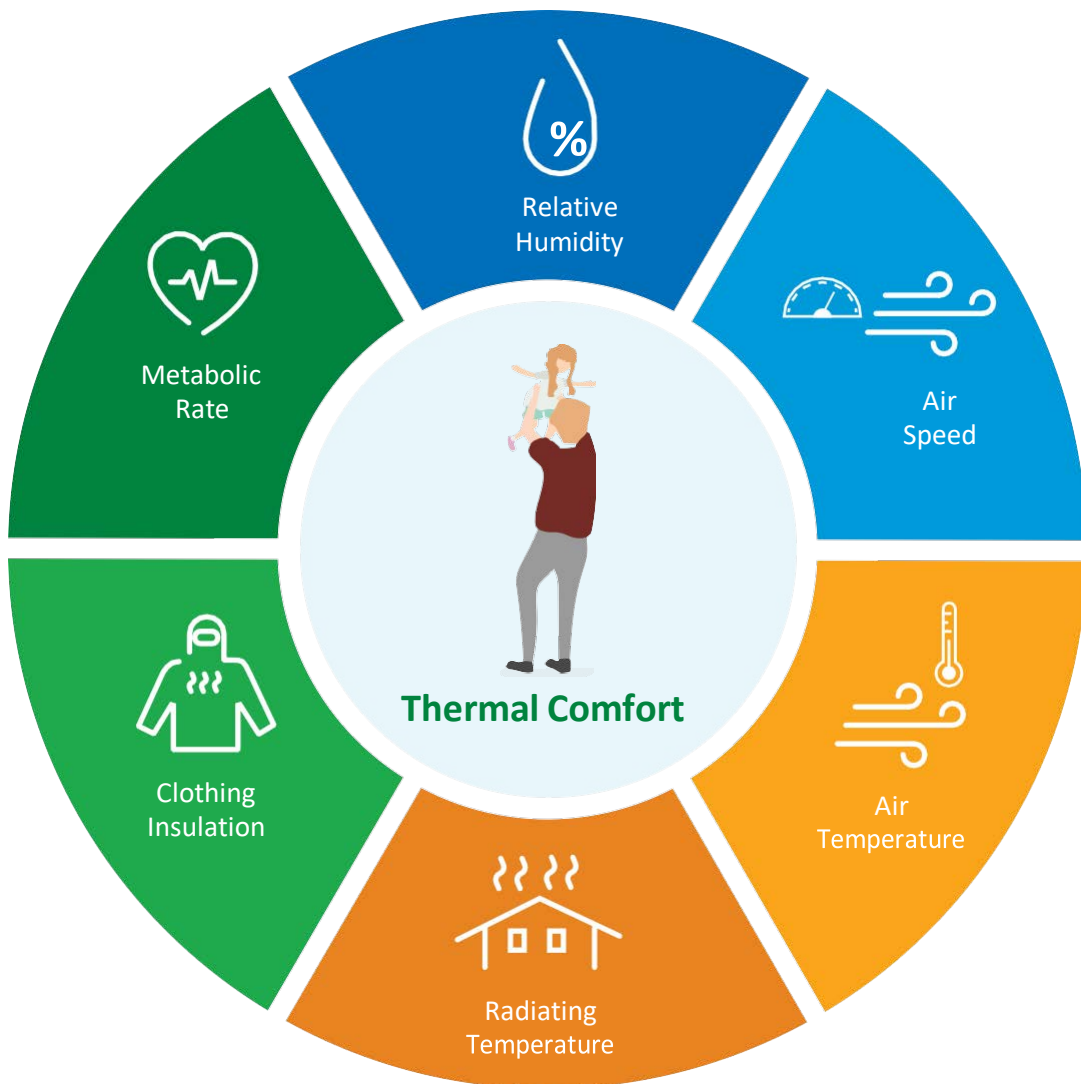
¹⁵ An estimated cost of \$2,967 per ton of cooling installed was considered. This cost was provided by the contractor who installed the HVAC system for KOI Tower.

4.1 Thermal Comfort: Heat Gain Control

It has been proven that people inside a thermally comfortable space **increase their productivity by 9-11%**. This translates into large indirect economic benefits for companies, as well as health and wellness benefits for occupants.

According to standard ASHRAE 55¹⁶, thermal comfort refers to the state of mind in which a person can express satisfaction with their thermal environment.

The following six main components define thermal comfort:



¹⁶ Estándar ANSI/ASHRAE 55-2007: Standard for Thermal Environment Conditions for Human Occupancy, which is used as a reference for LEED certification.

In this case study, we compared the five different glass systems to evaluate the percentage of hours the spaces are at a comfortable temperature for their users without the need to use air conditioning equipment.

The thermal comfort of a space is directly related to the U-value and SHGC characteristics of the glass. This is especially relevant in warm climatic zones, as is the case in the Monterrey Metropolitan Area, where the case study is located.

Table 6. Thermal Comfort

Glass Type	Product	Thickness (mm)	U Value (W/m ² *K)	SHGC	Percentage of Hours in Thermal Comfort	Thermal Loads Per Envelope (BTU/h)
Double	Clear + Clear	25	2.69	0.70	78%	254,721
Double	Solargray® + Clear	25	2.66	0.46	81%	176,228
Double	Solarban® 60 Clear + Clear	25	1.65	0.39	86%	145,172
Double	Solarban® R100 Optiblue® + Clear	25	1.65	0.20	90%	92,034

As can be seen in Table 6, **Solarban® R100 Optiblue® glass** provides **15.7% more hours of thermal comfort** for building occupants compared to our baseline 12mm clear monolithic glass. This demonstrates that the higher the SHGC and U-Value values, the lower the percentage of hours occupants are in thermal comfort without the support of air conditioning systems.

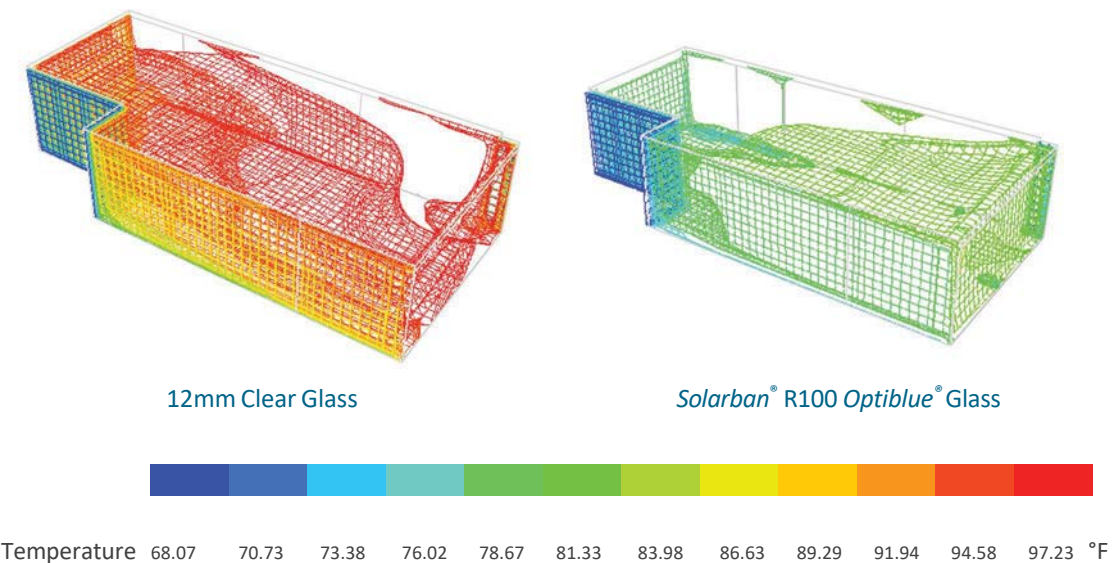


Image 8. Interior temperatures of a space based on the glass system

In Image 8 we can observe the behavior of temperatures in a similar space with two different glass systems: 12mm clear monolithic and **Solarban® R100 Optiblue® glass**. On the right, we can observe a **temperature decrease of 39.2°F**, which translates into **lower energy consumption to condition the spaces, and therefore in a reduction of the costs of operation of the building.**

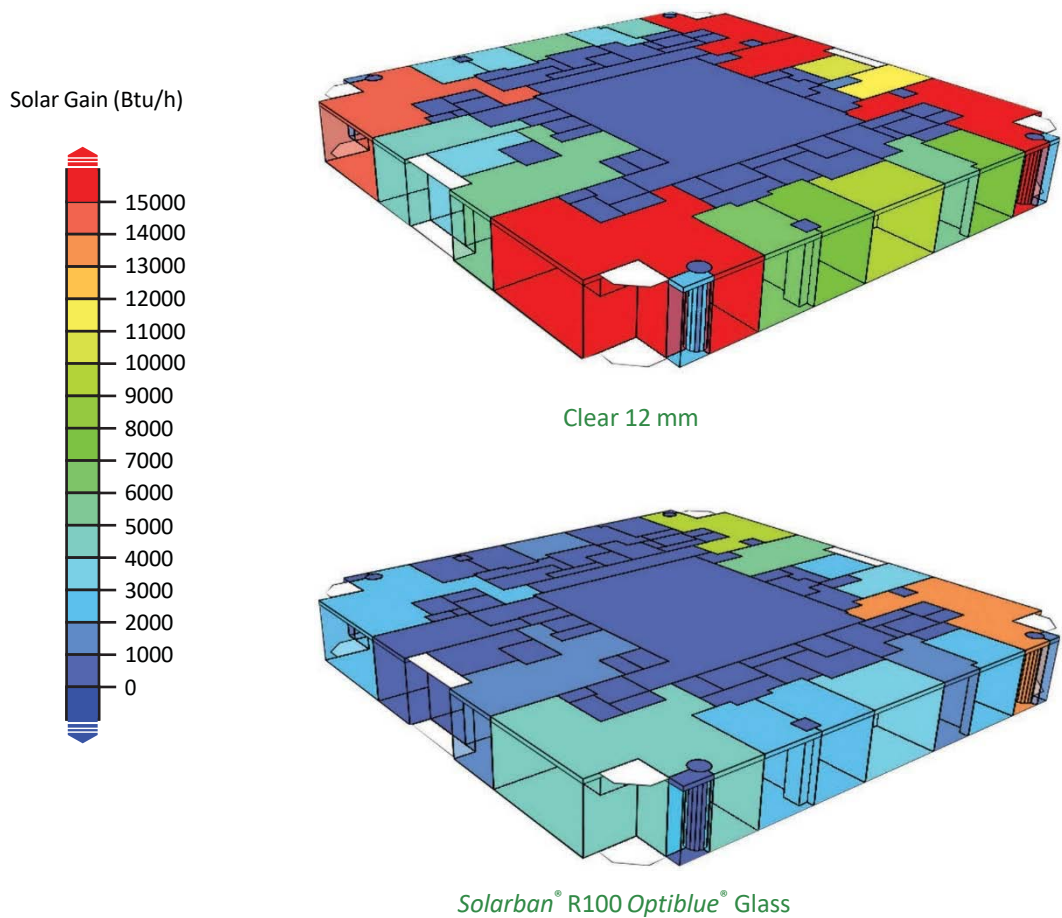


Image 9. Solar gain per glass system (level 60).

Image 9 shows the northeast façade of Level 60 of the building, with solar incidence (heat gain¹⁷) at 9:30 a.m. on March 21¹⁸. The colors indicate the heat gains of spaces: **the redder it gets, the greater the heat gain.**

In these results, it is important to note that a low SHGC value, such as that of *Solarban*® 60 glass and *Solarban*® R100 Optiblue® glass helps to control solar gains into the building. The use of low-e glass such as *Solarban*® glass increases the thermal comfort of building users, while lowering the initial investment cost by reducing the capacity of HVAC equipment and saving on operating costs by reducing monthly electricity costs.

¹⁷ Solar gain is the solar radiation (heat) absorbed by glass and transferred to spaces. This value is affected by external conditions and the properties of the installed glass and can be expressed in Btu per hour.

¹⁸ It is the spring equinox, and the sun is over the Equator, this whole day was used as a reference point for the study.

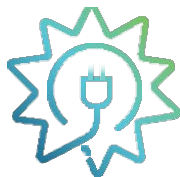
4.2 Lighting Comfort: Glare Control

Naturally lit spaces offer direct benefits to the health and well-being of occupants, improving the functioning of the organism, increasing their productivity¹⁹ and allowing the connection of the inhabitants with the outside, reinforcing their circadian rhythms.

According to the National Institute of General Medical Sciences (NIGMS²⁰), the circadian rhythm is composed of physical, mental, and behavioral changes that follow a 24-hour cycle. These natural processes respond primarily to light and dark and influence the quality of sleep and physiochemical processes in the body that are necessary for health.

Natural Light

Solar radiation has two important properties:



Thermal energy (heat): The amount of energy obtained from solar radiation and the most common unit of measurement is Btu/h.



Light: It is the amount of illumination obtained from the sun, its unit of measurement is Lux.

Did You Know?

People who have access to natural light can sleep on average **46 minutes longer** each night, improving their health and increasing their well-being.



It is important for our health to obtain natural lighting in interior spaces. However, we must keep in mind other factors during glass selection such as thermal performance and glare in spaces to ensure lighting comfort.

¹⁹ *Occupant Productivity and Indoor Environment Quality: A case study of the Global Sustainability Assessment System (GSAS).*

²⁰ *NIGMS: National Institute of General Medical Science*

Glare can cause an undesirable effect on building users. This term refers to the brightness that occurs when light strikes a surface directly, and it can be distracting to the eye due to excessive light. The optical property of glass that is related to this phenomenon is the percentage of Visible Light Transmission (VLT), where a lower value will reduce the possibility of glare in spaces.

According to the LEED BD+C v4 guide, it is considered that from lighting levels equal to or

greater than 1,000 Lux, there is a high probability of glare, so it is recommended to reduce the hours of the year where this level is exceeded.

To compare the glare control performance of the glasses, a level 17 analysis was performed. This analysis shows the percentage of regularly occupied areas (space where one or more persons spend at least one hour a day) with glare.



Table 7. Percentage of area with glare as a function of VLT.

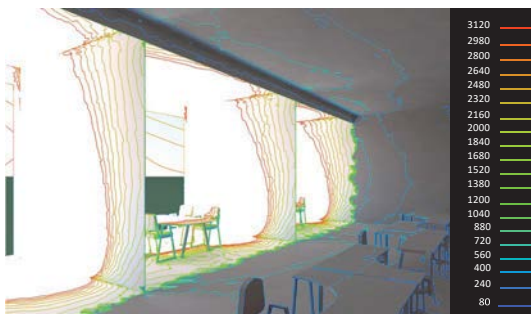
Glass Type	Product	Thickness (mm)	VLT	Area with Glare (%)
Monolithic	Clear	12	83%	38%
Double	Clear + Clear	25	78%	37%
Double	Solargray® + Clear	25	40%	31%
Double	Solarban® 60 Clear + Clear	25	70%	33%
Double	Solarban® R100 Optiblue® + Clear	25	30%	25%

Table 7 shows how glass systems with low VLT values have a lower percentage of glare area, which is equivalent to spaces with greater lighting comfort for users.

Solarban® R100 Optiblue® glass is the glass that provides the best performance in glare control. As can be seen in Image 10, **Solarban® R100 Optiblue®** glass is the best option for reducing glare inside the building, which, in some cases, can avoid the use of interior blinds, resulting in savings in materials, a more homogeneous façade from the outside and better use of the views to the outside.



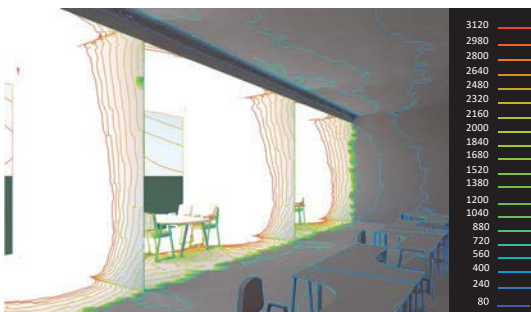
Solarban® R100 Optiblue® + Clear VLT= 30%



Solarban® 60 + Clear VLT= 70%



Solargray® + Clear VLT= 40%



Clear + Clear VLT= 78%



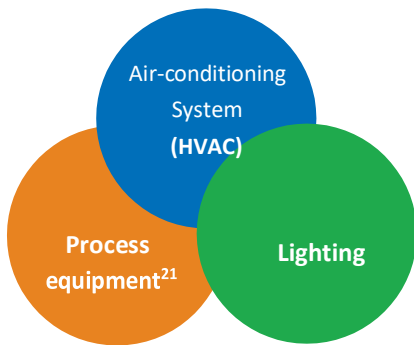
Clear VLT= 83%

Image 10. Perspective view with lighting levels of different glass systems.

5. How Much Energy Does a Vertical Architectural Glass City Consume?

Consumption Characteristics

The total energy consumption of a building is composed of the electricity and/or fuel consumption of each of the building's own systems, where the most common general consumptions are:



For the KOI Tower success story, the energy consumption with *Solarban*[®] R100 *Optiblue*[®] glass versus clear 12mm glass can be observed in Image 11:

Annual Energy Consumption Distribution

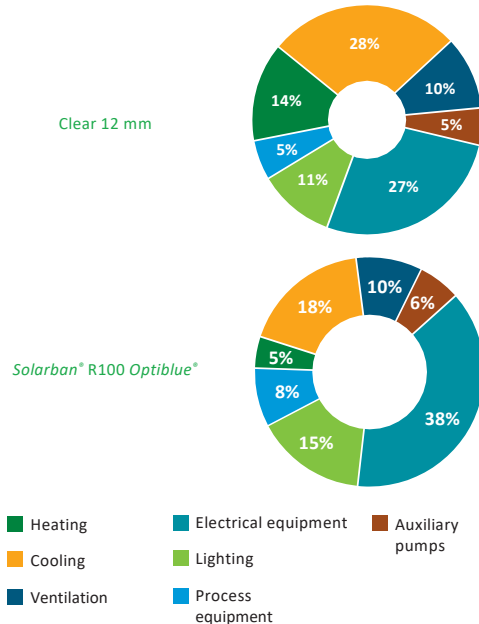


Image 11. Distribution of Annual Energy Consumption of KOI Tower

Table 8. Annual energy consumption distribution

Type of Use	Clear 12 mm		<i>Solarban</i> [®] R100 <i>Optiblue</i> [®] + Clear	
	Energy Consumption Per Year (kWh)	Consumption Percentage	Energy Consumption Per Year (kWh)	Consumption Percentage
Heating	1,702,091	14%	388,632	5%
Cooling	3,388,507	28%	1,539,853	18%
Ventilation	1,249,737	10%	814,958	10%
Auxiliary pumps	630,713	5%	515,301	6%
Process equipment	3,258,848	27%	3,258,848	38%
Lighting	1,302,458	11%	1,302,458	15%
Various electrical devices	658,373	5%	658,373	8%
Total	12,190,727	100%	8,478,423	100%



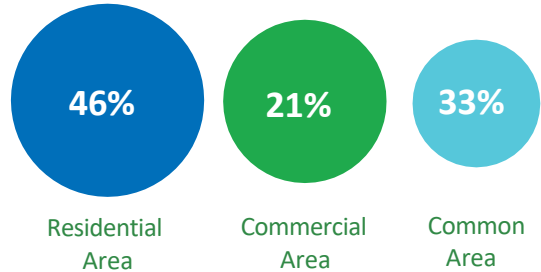
As shown in *Table 8*, the largest percentage of energy consumption, equivalent to 39%²² for *Solarban*[®] R100 *Optiblue*[®] glass and 57% for clear 12 mm glass, corresponds to the air conditioning system (HVAC). Therefore, the correct selection of the glass system is of utmost importance to obtain an efficient envelope and reduce the building's operating costs.

²¹ Process equipment in KOI Tower: elevators, hot water service, hydraulic pumps and equipment necessary to perform the functions of those who inhabit these spaces, such as computers, appliances, among others.

²² HVAC consumption consists of the consumption of heating, cooling, ventilation and auxiliary pumps.

5.1 Consumption Percentages by Type of Use

Using actual electrical energy consumption of the building, estimates were made to calculate the annual energy consumption of the building for each type of glass system using Trace 700 software. In this study, the annual energy consumption is composed of the sum of the three types of uses of the building:

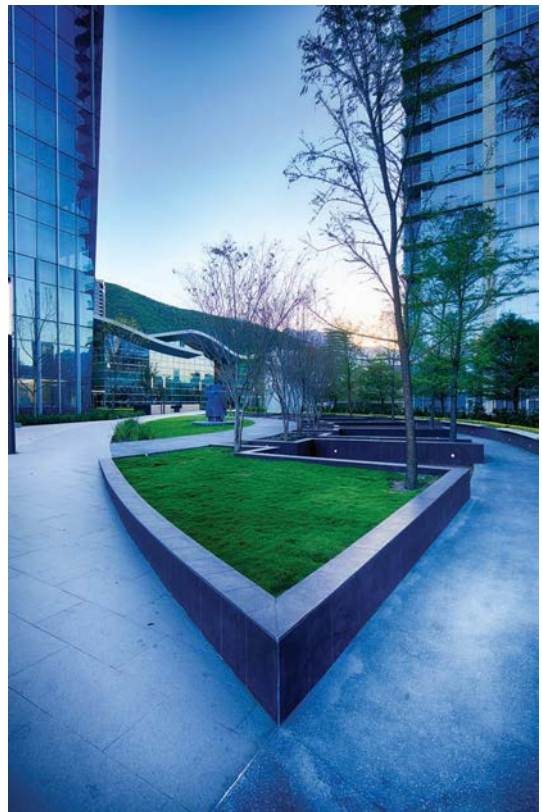


5.2 Reduction of CO₂ Emissions

The growing environmental crisis has caused the reduction of emissions to be considered in the decision-making process to carry out developments that reduce or eliminate negative impacts on the environment.

The selection of glass in the façade of a building has the potential to make a great environmental contribution, as was the case in this success story of using **Solarban® R100 Optiblue® glass** in KOI Tower.

Let us not forget that buildings are immovable assets with a long lifespan, which is why they have the “*Lock-in Effect*”²³. This means that the decisions we make in the design of our buildings will have long-term repercussions for as long as they are used. In other words, if we consider the selection of an efficient glass system from the beginning, we will be generating a positive effect on the environment throughout its lifespan.

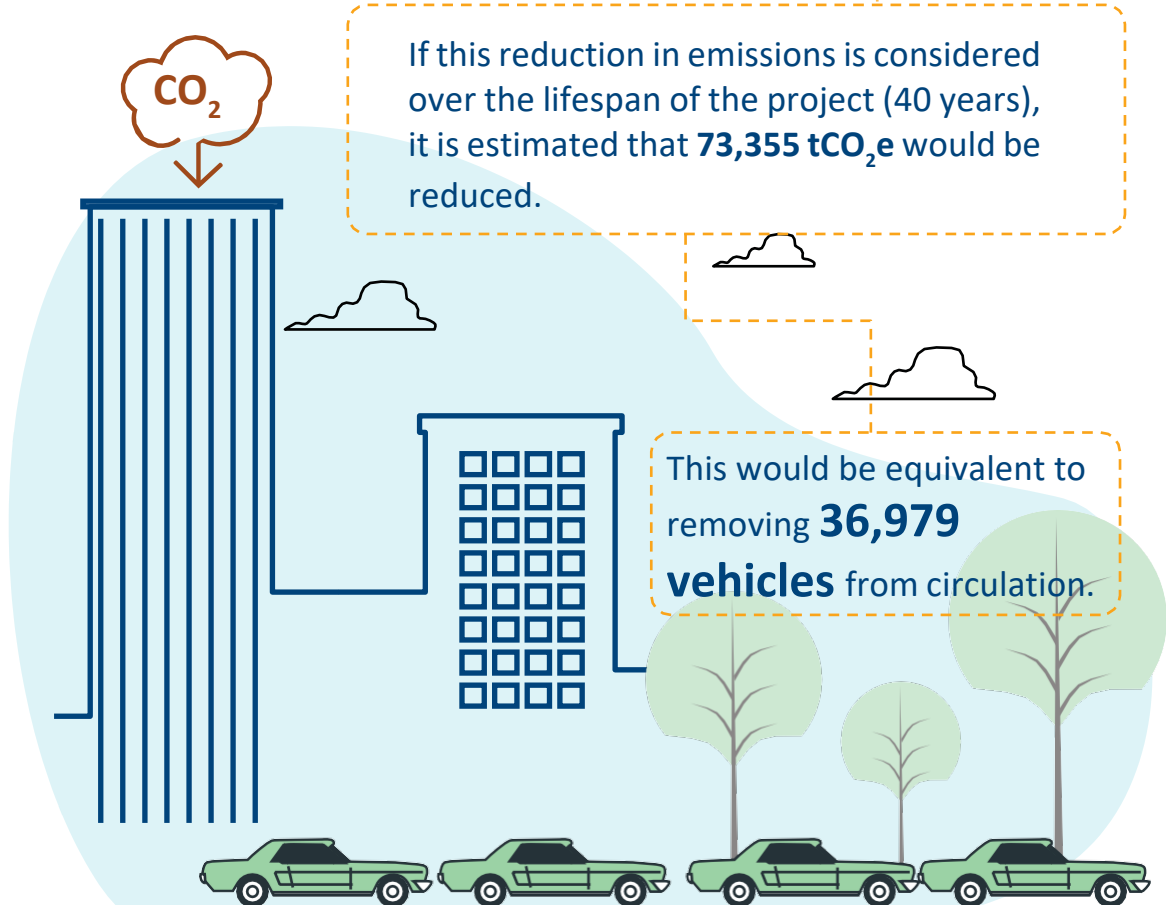
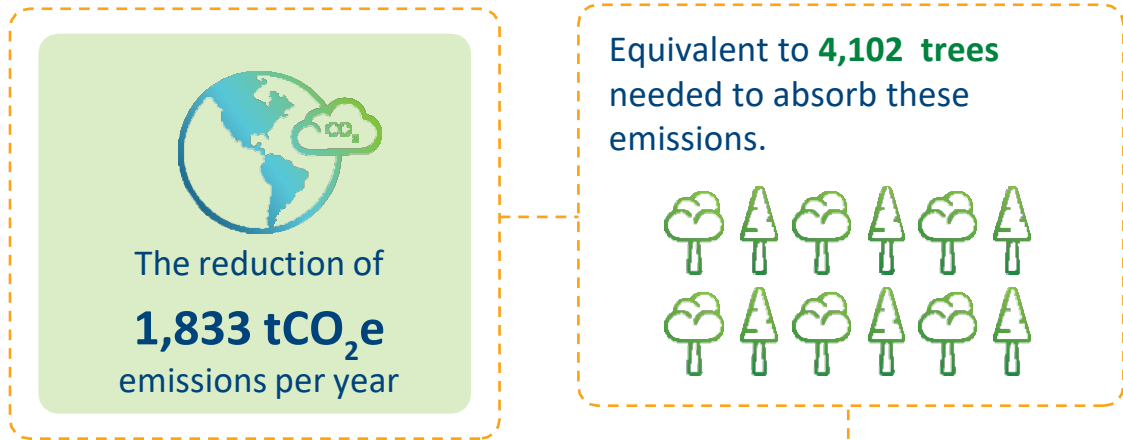


²³ Definition of “Lock-In” and Passivhaus construction, in the Green Building Advisor, by Matthew Omalia

In this regard, *Solarban® R100 Optiblue®* glass provides energy savings of **3,712,302 kWh**

 **(\$613,000)** per year.

Taking as a reference the *Emission Factor of the National Electric System of 2021*, which considers that to produce one MWh (1,000 kWh), 0.494 tons of CO₂ equivalent (tCO₂e) are emitted, the following was achieved:



6. Conclusions

The *World Green Building Council* (World GBC)²⁴ joined the efforts of the United Nations in supporting the Sustainable Development Goals. Nine of the 17 Sustainable Development Goals²⁵ are directly impacted by buildings and should therefore be promoted by all organizations that are part of the building team.

The present study demonstrates quantitatively and realistically the positive impacts that can be obtained by having a proper selection of glass:

Economic Benefits



• **Initial Investment Cost:** Assuming a 12mm clear glass was chosen for the building instead of **Solarban® R100 Optiblu® glass**, the initial investment cost of the project would have increased by more than 7 million pesos due to the need for a higher investment cost in HVAC equipment to achieve indoor comfort.



• **Operating Costs:** Assuming a 12mm clear glass was chosen instead of **Solarban® R100 Optiblu® glass**, the annual operating cost would have increased by over \$612,600 per year, due to the need for higher capacity air conditioning equipment and longer use. Considering an average lifespan of the building of 40 years, this glass would be avoiding an expense of more than \$24.5 million.

In economic terms, we can conclude that the selection of the **Solarban® R100 Optiblu® glass** system was an excellent decision, providing total savings of around **\$24.9 million** over the lifespan of the project compared to 12mm clear glass.

²⁴ World Green Building Council.

²⁵ 1. Health and well-being, 2. Affordable and clean energy, 3. Decent work and economic growth, 4. Industry, innovation and infrastructure, 5. Sustainable cities and communities, 6. Responsible production and consumption, 7. Climate action, 8. Life of terrestrial ecosystems and 9. Partnerships to achieve the goals.

User comfort

• **Thermal comfort:** *Solarban® R100 Optiblue®* glass provides 15.7% more hours of thermal comfort to occupants compared to 12mm clear glass, increasing the perception of satisfaction while reducing the hours required to use mechanical cooling systems.

• **Glare control:** *Solarban® R100 Optiblue®* glass also reduced glare areas by 13.65% compared to 12mm clear glass, providing users with better natural lighting comfort by avoiding unwanted glare.

Emission Mitigation

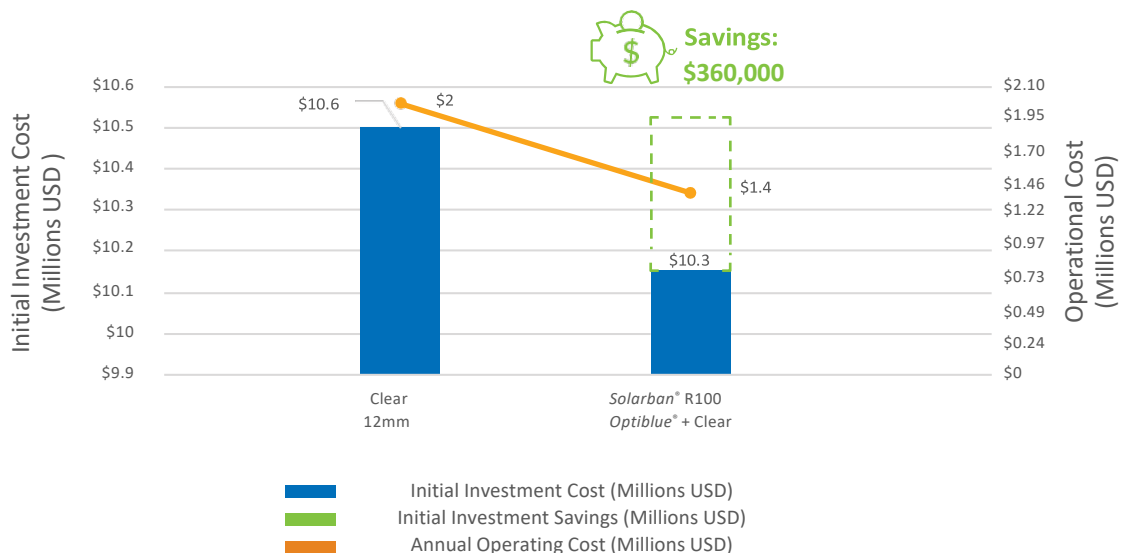
Finally, the selection of *Solarban® R100 Optiblue®* glass reduced the number of emissions to the environment from electric power generation by more than 1,833 tCO₂e per year.

Over the life of the building, this translates into a reduction of 73,355 tCO₂e, equivalent to removing 36,979 vehicles from circulation.

In this case study, we prove that *Solarban® R100 Optiblue®* glass is the option that generates the greatest economic, social (user comfort) and environmental benefits.

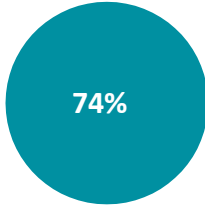
Table 9. Comparison of *Solarban® R100 Optiblue®* vs Monolithic Clear 12mm

Glass Type	Product	Thickness (mm)	Initial Investment Cost: Glass & HVAC System (USD)	Annual Operating Cost (USD)	Percentage of Hours in Thermal Comfort	Percentage of Area with Glare	Air Emissions (Tons of CO ₂ e/year)
Double	<i>Solarban® R100 Optiblue®</i> + Clear	25	\$10,245,971	\$1,394,036	89.9%	25%	4,188
Benefits			\$359,041	\$613,117	15.7%	14%	1,834

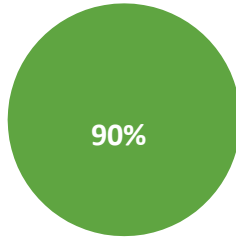




Percentage of Hours with Thermal Comfort



12 mm Clear Glass



Solarban® R100
Optiblue®
Glass



Percentage of Area with Glare



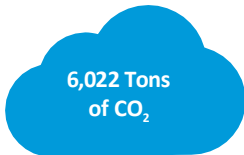
12mm Clear Glass



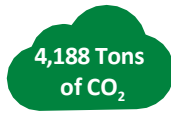
Solarban® R100
Optiblue®
Glass



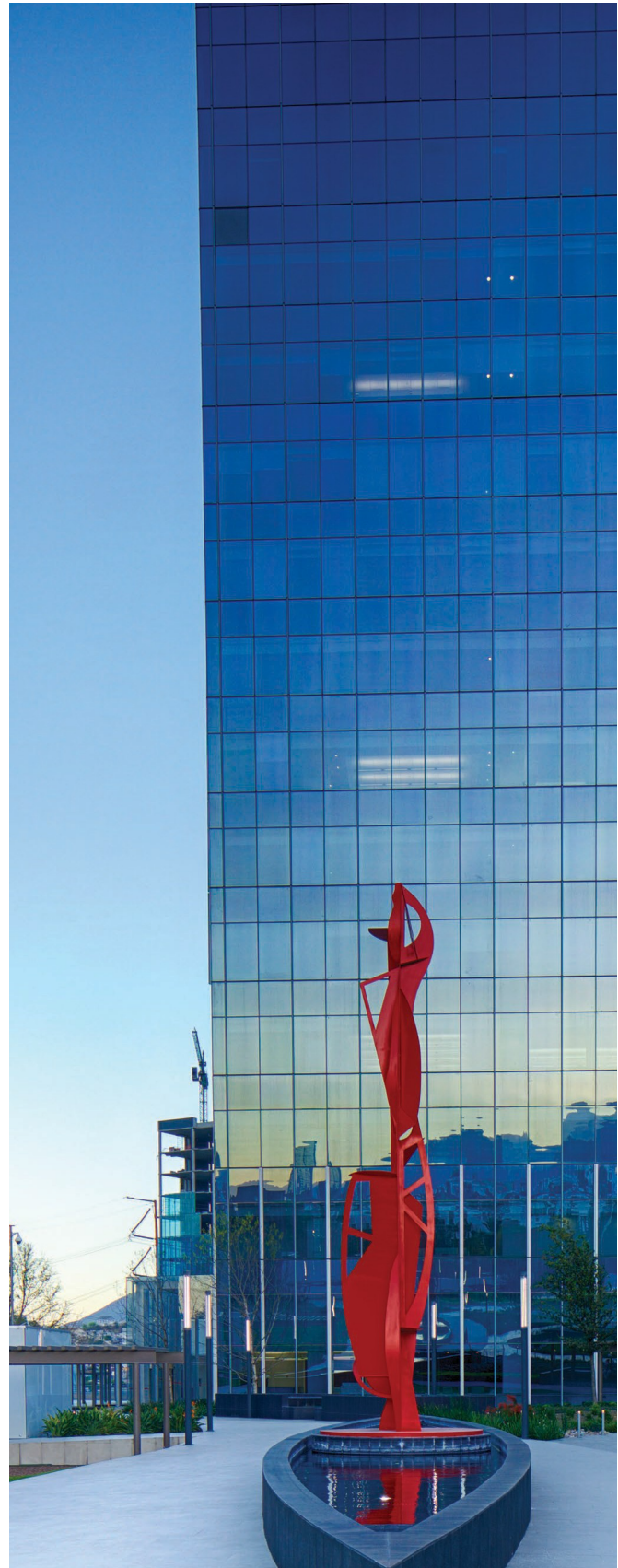
Annual CO₂ Emissions



12mm Clear Glass



Solarban® R100
Optiblue®
Glass



Annex 1:

Climate Zones in Mexico

The ASHRAE 90.1-2016 standard recognizes at least five climate zones in Mexico: from climate zone 0 to 4. In general terms, it is considered that the lower the thermal zone number, the higher the energy consumption derived from air conditioning and ventilation.

Thermal zones are defined according to degree days and rainfall. Degree days are a measure of how much (expressed in degrees) and for how long (expressed in days) the outdoor air temperature will be above (cooling degree days) or below (heating degree days) a specific reference temperature. In other words, degree days express the need to air condition the environment in a location by either cooling or heating. In locations with high cooling degree days, cooling equipment will have higher energy consumption.

In addition, the ASHRAE climate classification also includes a subcategory of humidity level denoted by the letters A (humid), B (dry) and C (marine). Typically, locations with higher relative humidity will have higher cooling consumption due to the latent heat load associated with high humidity.

ASHRAE 90.1-2016 outlines certain energy measures according to the thermal zone of each location. *Annex Table 1.1* shows the requirements for glazing system properties by thermal zone: as the thermal zone becomes more temperate, the U-value requirement decreases and the SHGC value increases. The ratio of visible transmittance to overall solar gain remains the same in all thermal zones.

Annex Table 1.1. Property requirements for glazing systems by thermal zone

Thermal zone	U-Value (Btu/hft ² °F)	SHGC	VLT /SHGC
0 (A,B)	0.50	0.22	1.10
1 (A, B)	0.57	0.25	
2 (A, B)	0.54		
3 (A, B, C)	0.45	0.36	
4 (A, B, C)	0.38		

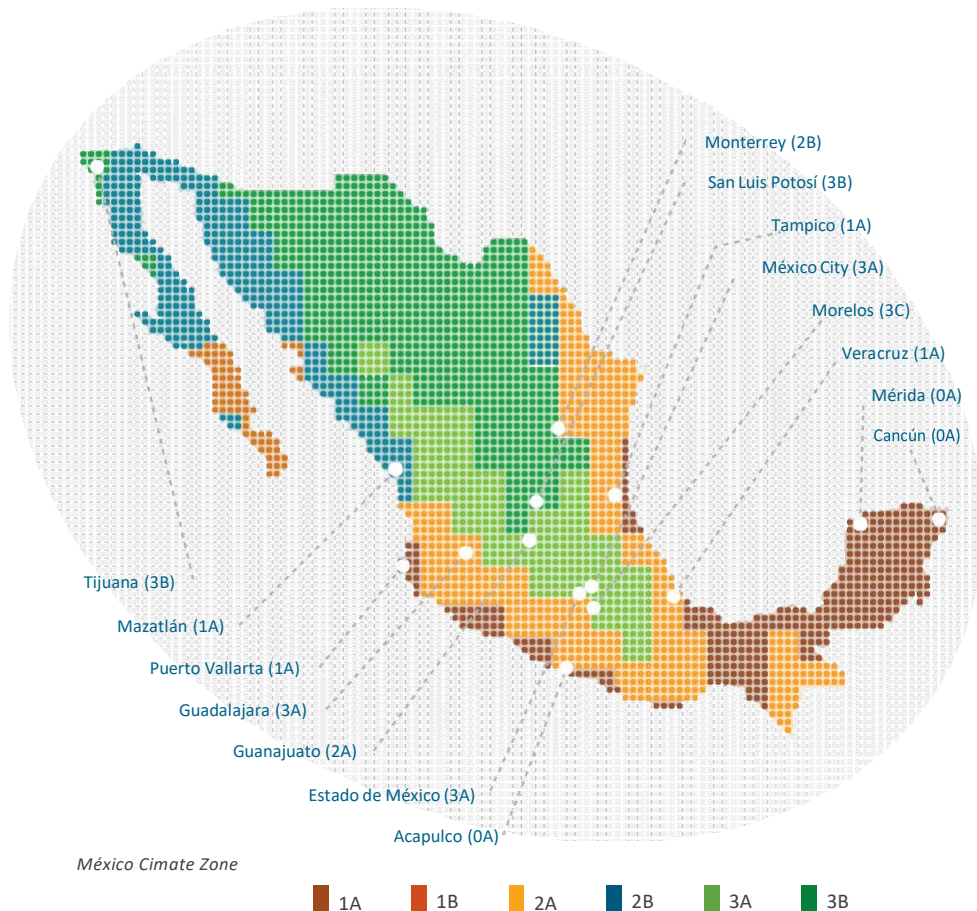
For the purposes of this study, we will focus on the properties of the glazing system for the Monterrey Metropolitan Area, where KOI Tower is located, which is considered climate zone 2B, according to ASHRAE 90.1-2016

Annex Table 1.2 Thermal properties of the glazing systems analyzed

Glass Type	Product	Thickness (mm)	U-Value (W/m ² *K)	SHGC
Monolithic	Clear	12	5.60	0.72
Double	Clear + Clear	25	2.69	0.70
Double	Solargray® + Clear	25	2.69	0.46
Double	Solarban® 60 Clear + Clear	25	1.65	0.39
Double	Solarban® R100 Optiblue® + Clear	25	1.65	0.20

As we can see in Table Annex 1.2, the thermal properties requirement for the glazing system in Monterrey (2B) indicates that a low U-Value and SHGC is required, since it is a warm climate zone. Based on this requirement, we can highlight that the **Solarban® R100 Optiblue® glass** system meets and improves the requirements established by **ASHRAE 90.1-2016**.

Annex Image 1.1 Map of Mexican Climate Zones



Annex 2:

Thermal Comfort Analysis

To analyze the thermal comfort in the spaces, and its variations with different glasses, the Comfort Zone analytical method described in **Standard ASHRAE 55-2010** was used. This methodology considers direct solar radiation on the occupants and the six determining components of thermal comfort:



Metabolic Rate

(Heat generated by the human body while performing an activity)



Relative Humidity



Air Speed



Clothing Insulation



Radiating Temperature



Air Temperature

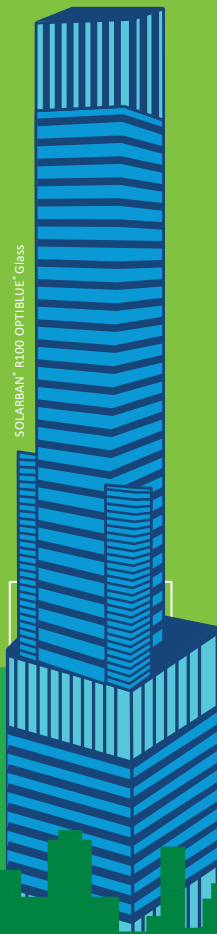
With these parameters, the model establishes the functions that relate to them to predict under what conditions the building occupants would feel comfortable and when they would not. This is categorized through a simulated voting system, called PMV, or Predicted Mean Vote, in which a rating greater than -0.5 and less than 0.5 is considered to be in comfort.

With this methodology, and using the **IESVE 2021 software**, the simulation was carried out. According to this methodology, results were obtained per space and per hour, and a percentage of hours per year that the spaces are comfortable was obtained.



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