Optimise the Specification of a Building Envelope

Introduction

The building under analysis is to be used as a relaxation and study place for the doctors of a major clinic in Santiago, Chile. The first floor is a public area for commercial activity so is much more transparent. But the second floor is the relaxing and study area, so a high level of thermal and daylighting comfort was required by the client, together with high levels of energy efficiency. There also 3 underground levels with meeting rooms and an auditorium.

The design concept was to consider a glazing envelope in both floors. Maintaining a clear facade in the first floor because it contains the commercial and main access areas, while incorporating some sort of external solar protection in the second floor in the northwest and southwest facades.

The initial specifications are described as follows:

OPAQUE ENVELOPE

Element	Composición	U [W/m²K]
Underground Walls	30 cm reinforced concrete	2,8
Main Walls	30 cm reinforced concrete	2,8
Roof	15 cm reinforced concrete with 10 cm insulation	0,37
Slabs	15 cm reinforced concrete with floor finished	2,5

GLAZING ENVELOPE				
Glazing name	Area	SHGC	U (W/m²K)	Tvis
Conventional DVH	All facades and skylights	0,	2,9	0,

HVAC SYSTEM		
System	HEATING COP	COOLING COP
Water source Chiller for cooling and a conventional Boiler for heating	0,8	5,5

LIGHTING SYSTEM	
AREA	LPD (W/m2)*
Relaxing area	13
Office area	12
Meeting rooms	14
Coffee shop	10
Main Access Hall	14
Auditorium	15

* LPD – Lighting Power Density in W/m2

INITIAL ANALYSIS

Since the client was pursuing LEED Certification, a first "base case" was modelled using DesignBuilder against a "baseline case" according to Appendix G of ASHRAE 90.1-2007.

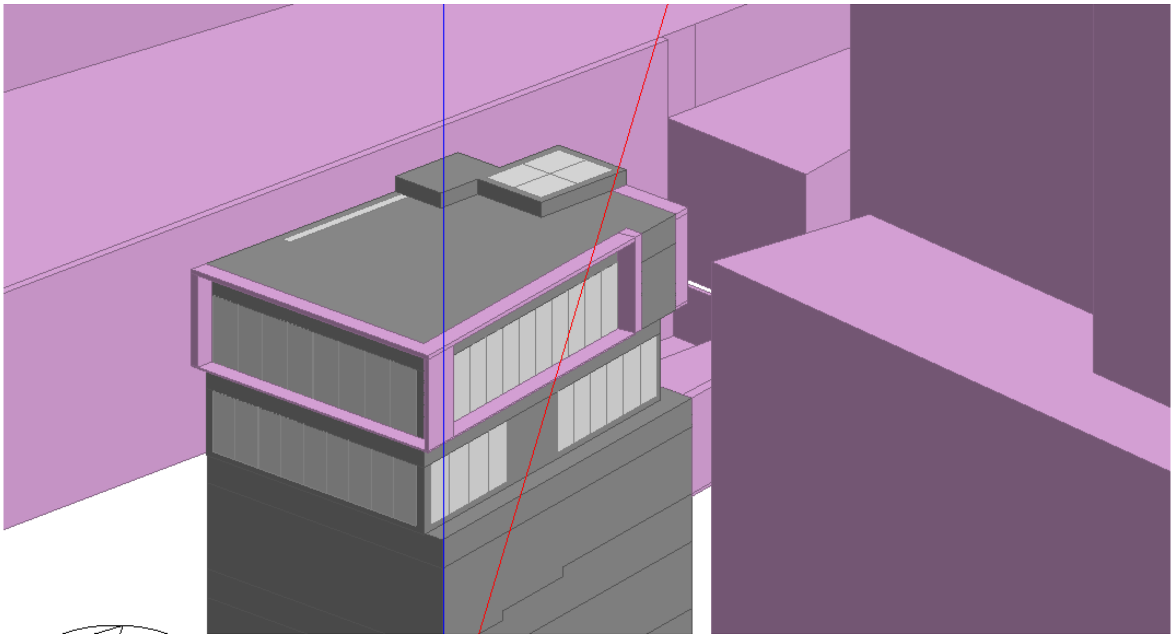

Figure 1: DesignBuilder 3-D model of the project

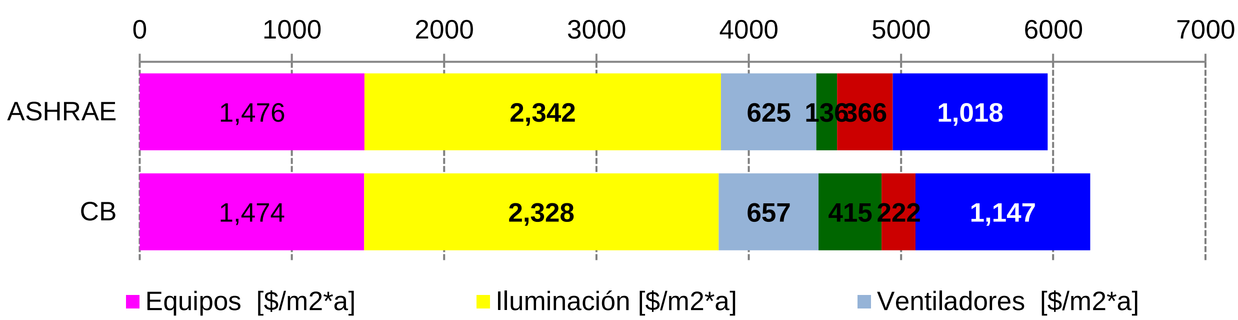

Figure 2: Fuel breakdown created in Excel from DesignBuilder numeric results

The energy results show high artificial lighting consumptions given the high initial LPDs, along with high HVAC consumptions (heating, cooling, fans and pumps). This causes an energy over-consumption (instead of energy saving) relative to the ASHRAE 90.1-2007 Standard.

Complementing this, a heat balance analysis of the first and second floor shows how cooling loads are very high due to high solar gains, occupancy gains and artificial lighting gains. Heating loads are very low as is usual in buildings of this type in Santiago-Chile. Actually, heat losses through the walls and glazing have a positive impact, since it causes a reduction in cooling loads for most of the year. This means no insulation in the walls and high insulation glazing are needed. But solar protection elements along with soft-coated glazing are also important.

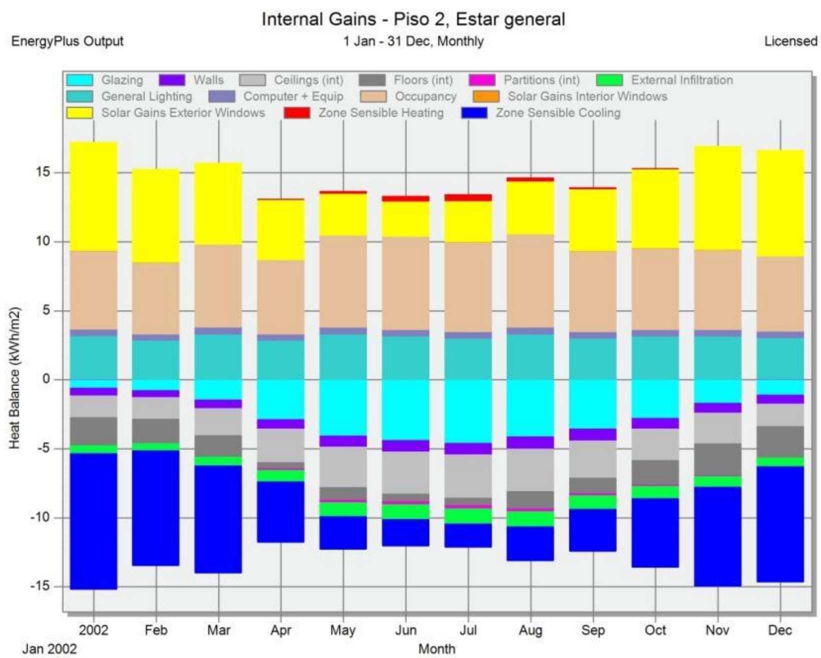

Figure 3: Heat balance of the second floor, created directly from DesignBuilder

Shading analysis using the DesignBuilder visualization tools clearly shows how the north-west and south-west facades will present high levels of solar radiation in the afternoon.

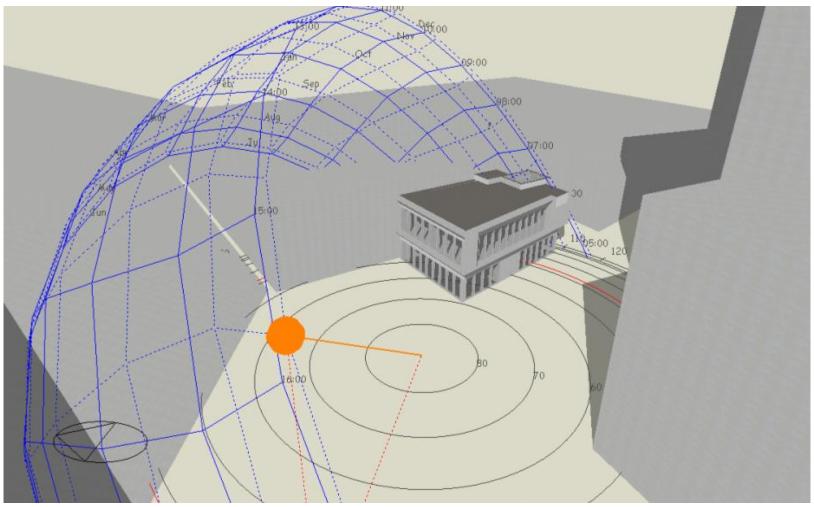

Figure 4: visualization image from DesignBuilder

Complementing the shading analysis, a daylight analysis using the daylight module of DesignBuilder shows how the illuminance levels at 19.00 hrs near the north-west and south-west facades are extremely high.

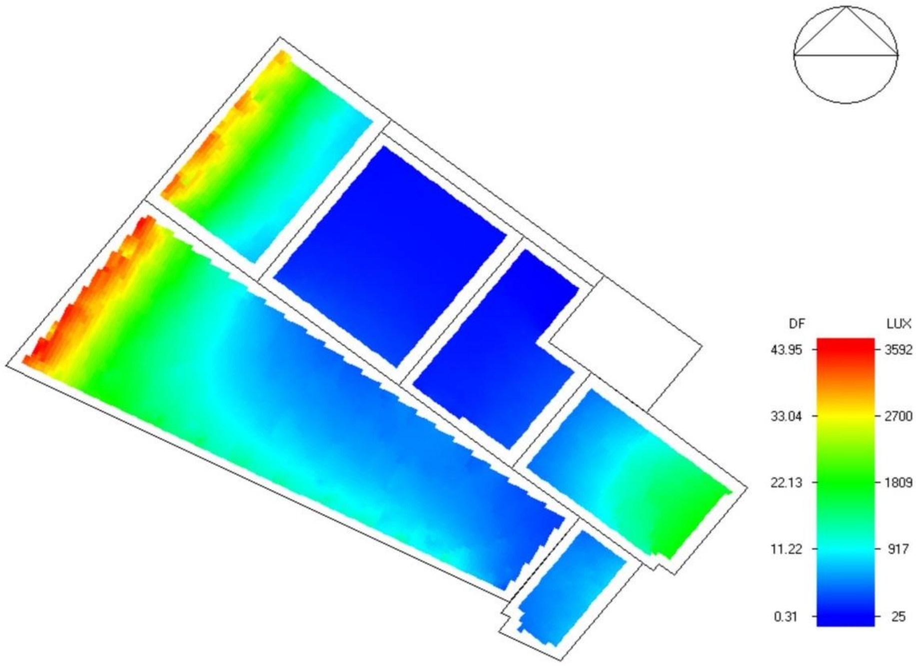

Figure 5: Radiance daylighting image from DesignBuilder, 21 Sept – 19.00 hrs

And a thermal comfort analysis using the DesignBuilder simulation module, shows how the operative temperatures are extremely high due to high radiant temperature of the glazing.

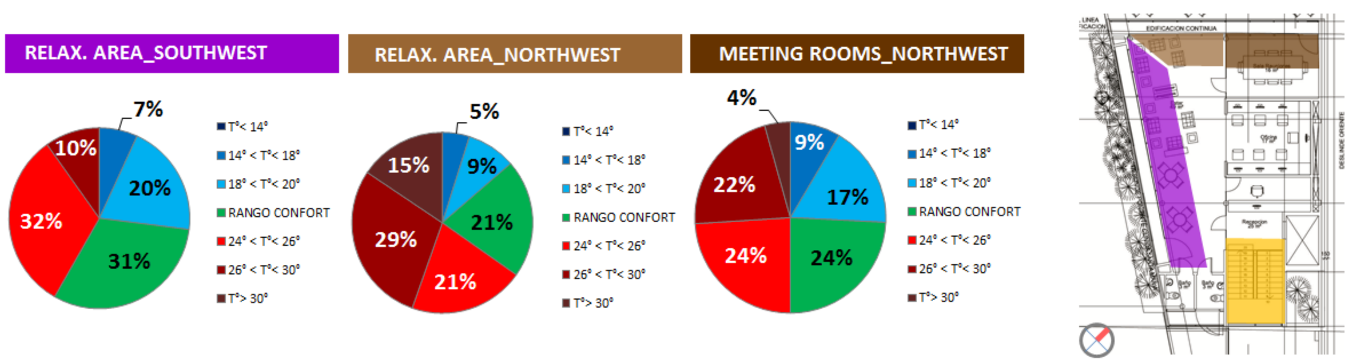

Figure 6: Operative temperature graphics created in excel from DesignBuilder numeric results

Concluding, clearly a solar protection strategy is required in order to achieve an optimum thermal-daylighting comfort.

Optimisation Proposal

After several iterations of energy and thermal-daylighting comfort analysis, a final envelope proposal was achieved along with much lower LPDs through the use of LED technology. The HVAC system was not changed since the buildings was connected to the existing HVAC central plant. The final specifications are as follows:

OPAQUE ENVELOPE		
Element	Composición	U [W/m^{2}K]
Underground Walls	30cm reinforced concrete	2,8
Main Walls	30cm reinforced concrete	2,8
Roof	15cm reinforced concrete with 15 cm insulation	0,24
Slabs	15cm reinforced concrete with floor finished	2,5

GLAZING ENVELOPE				
Glazing name	Area	SHGC	U (W/m^{2}K)	Tvis
Guardian Super Neutral 51	All facades	0,26	1,6	0,5
AGC Stopray Vision 36 T	Skylights	0,2	1,5	0,35

* Additionally, Horizontal aluminium solar protections are added in the northwest and southwest facades.

HVAC SYSTEM		
System	HEATING COP	COOLING COP
Water source Chiller for cooling and a conventional Boiler for heating	0,8	5,5

LIGHTING SYSTEM		
AREA	BASE LPD (W/m2)	FINAL LPD (W/m2)
Relaxing area	13	6,8
Office area	12	9
Meeting rooms	14	10,9
Coffee shop	10	10,7
Main Access Hall	14	9,3
Auditorium	15	9,5

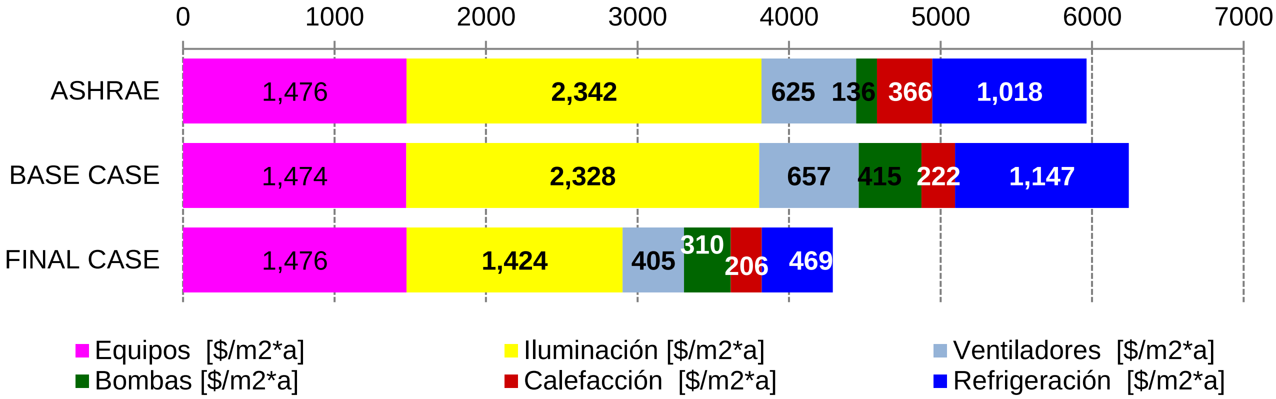

Figure 7: Initial and final fuel breakdowns based on DesignBuilder numeric results

The energy analysis shows how the use of low LPDs together with external solar protection elements and high solar protection glazing (double silver soft-coated), causes a significant reduction in energy consumption. Specifically, the cooling energy consumption is reduced by almost 60% and the lighting consumption is reduced by almost 40%. But the most important thing is the improvement of the thermal and daylighting comfort (the main improvement the client requested).

In the case of the daylighting comfort, the external solar protections along with the 50% Tvis glazing, results in an optimum daylighting comfort.

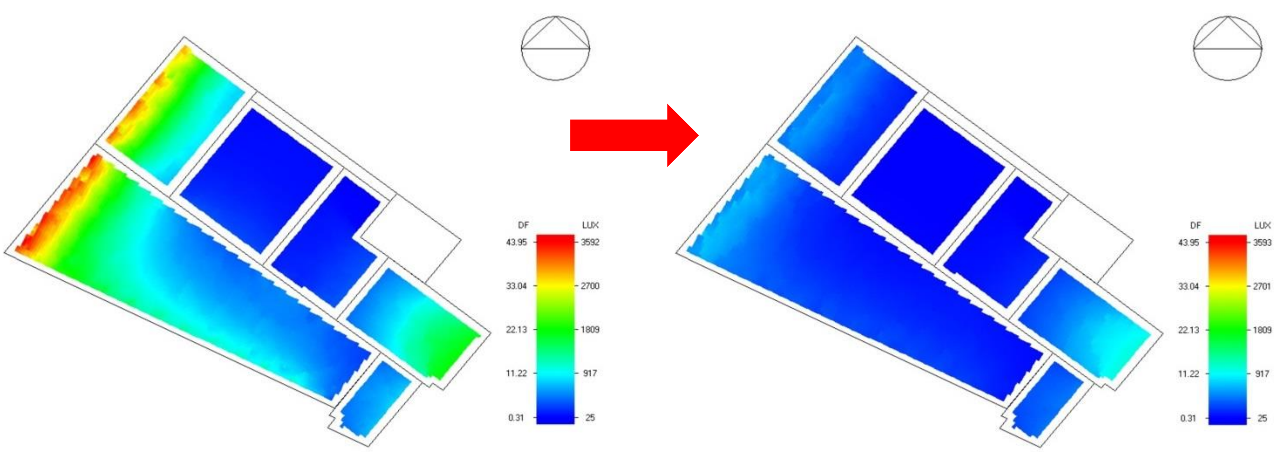

Figure 8: Radiance daylighting images of initial and final results, created with DesignBuilder, 21 Sept – 19.00 hrs

Also, the thermal comfort is almost optimum[1], because high temperatures are eliminated but low temperatures (14ºC to 18ºC) are not.

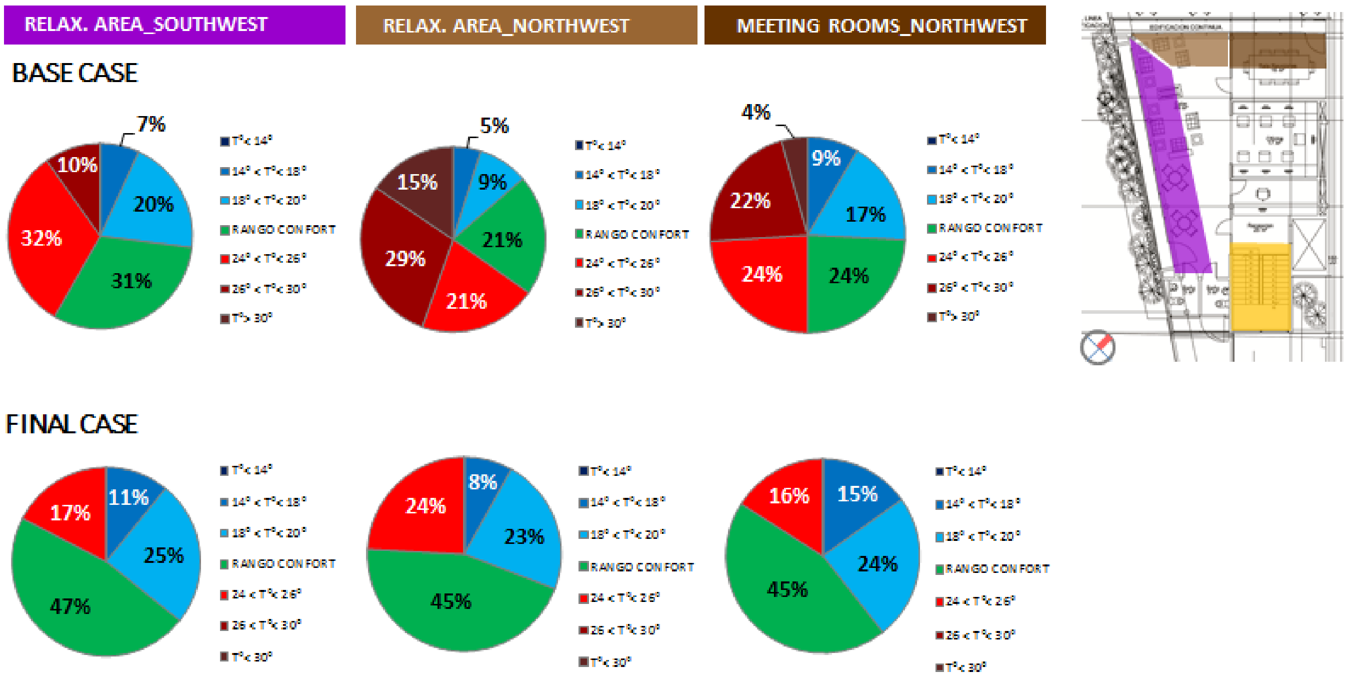

Figure 9: Operative temperature graphics of the initial and final case based on DesignBuilder numeric results

Because of this, a perimeter heating injection system was recommended, in order to avoid very low radiant temperatures during the Winter.

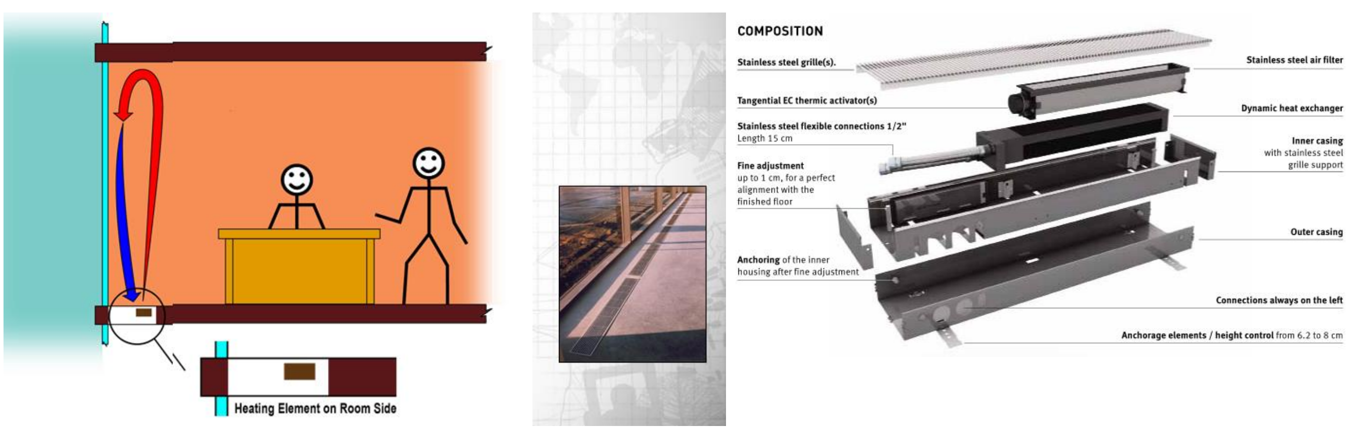

Figure 10: JAGA perimeter heating injection system

[1] EA BUILDINGS considered "optimum" in Santiago-Chile, to achieve operative temperatures between 18ºC and 26ºC.

Conclusion

Through the use of the DesignBuilder software, a full iterative optimization process was possible, improving the energy consumption standard of the building and its thermal-daylighting comfort. The improved building achieves a 30% energy reduction mostly in cooling (and proportionally in fans) and lighting consumptions. It also achieves an excellent thermal comfort standard by eliminating operative temperatures over 26ºC by the use of solar protection and soft-coated glazing and all operative temperatures under 18ºC by the use of perimeter heating injection systems.

It also achieves an excellent daylighting comfort eliminating high levels of illuminance (over 2.000 lux) in the northwest facade in the afternoon.

Use of DesignBuilder

DesignBuilder software allowed us to precisely calculate the impact of every design decision we made, from determining the most optimal measures to assessing their impact in the energy consumption and the daylighting-thermal comfort. Doing all of this through a single model in a single program provided us with an extremely practical and fast workflow.

We used DesignBuilder to calculate the combined impact of a soft-coated glazing with exterior solar protection, as well as the exact dimensions of the solar shades and the level of sophistication of the soft-coated glazing. The software also indicated from the outset that thermal insulation was not needed in the walls, generating investment savings that could be used in other areas.

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