RE-INVENTING THE IIT TOWER

Aarzoo Baharani Masters Project 2011

Project: **Re-inventing the IIT Tower**

Project Statement: The building systems, envelope performance and building use efficiency of the IIT Tower will be analyzed for evaluation of the current building energy use and occupant comfort levels. Energy modeling tools will be used to demonstrate the achievement of superior building performance and better occupant comfort levels through proposed design interventions. The transformative design will also result in a holistic improvement in building performance.

Goals of Project Selection:

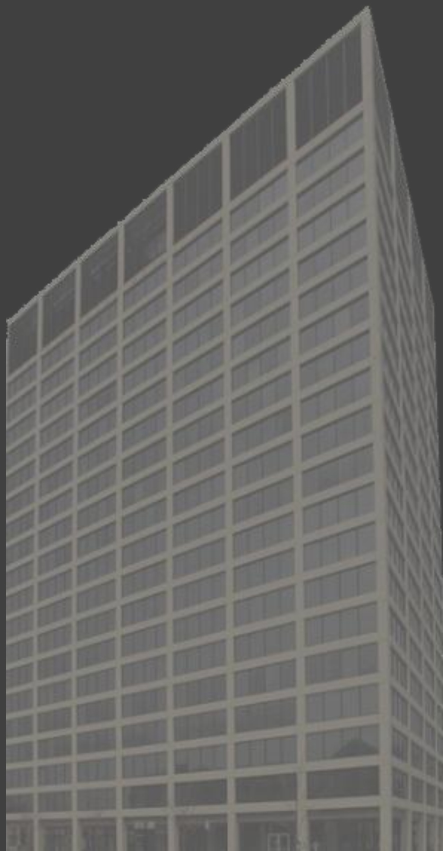
- Energy modeling tools and mechanical system calculations to be utilized for evaluating current building performance metrics in terms of the building envelope and systems.
- Investigation of the probable design interventions and evaluation of the results using energy modeling.
- Proposal for design interventions that prove better building performance.

Value of Research: The study should demonstrate the importance of energy modeling in a new or renovation project, by an objective evaluation of building energy performance metrics for improvement in occupant comfort levels.

Criteria for Project Success: The design interventions should result in superior building system performance resulting in a lower energy use intensity of the building and higher occupant satisfaction. The proposal should demonstrate better building performance metrics. It is anticipated that the transformative design will increase building efficiency and the usable area.

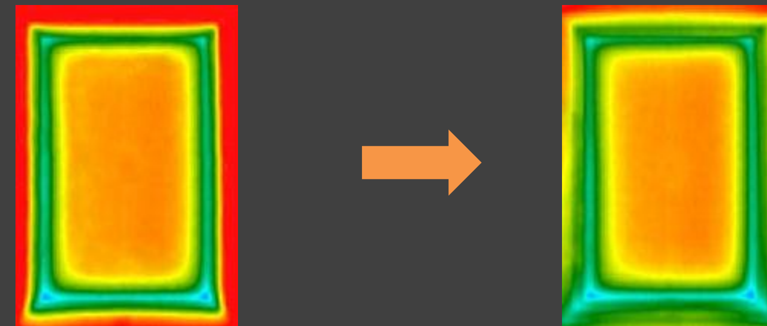
Project Deliverables:

Existing building energy model
Upgraded building energy model
Proposed intervention studies [façade, material, vertical transportation, envelope components]
Proposed design intervention drawings
Proposed building renderings
Brochure
Graphs showing the energy performance metrics comparison



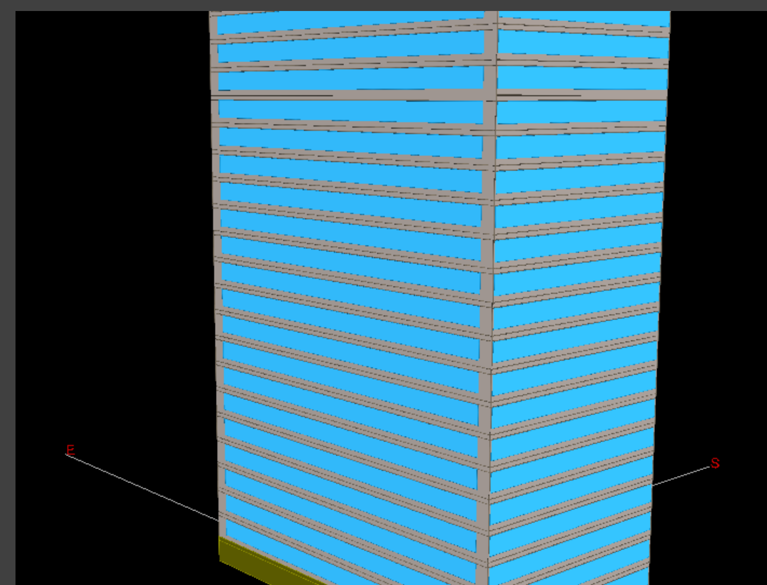
WHY?

- It is a 50 year old building with low energy performance due to thermal bridging and oversized mechanical systems.
- It has numerous possibilities for improvement in value that it provides to the school and the neighborhood.
- With the availability of analysis software and new systems there can be tremendous improvement in building performance.

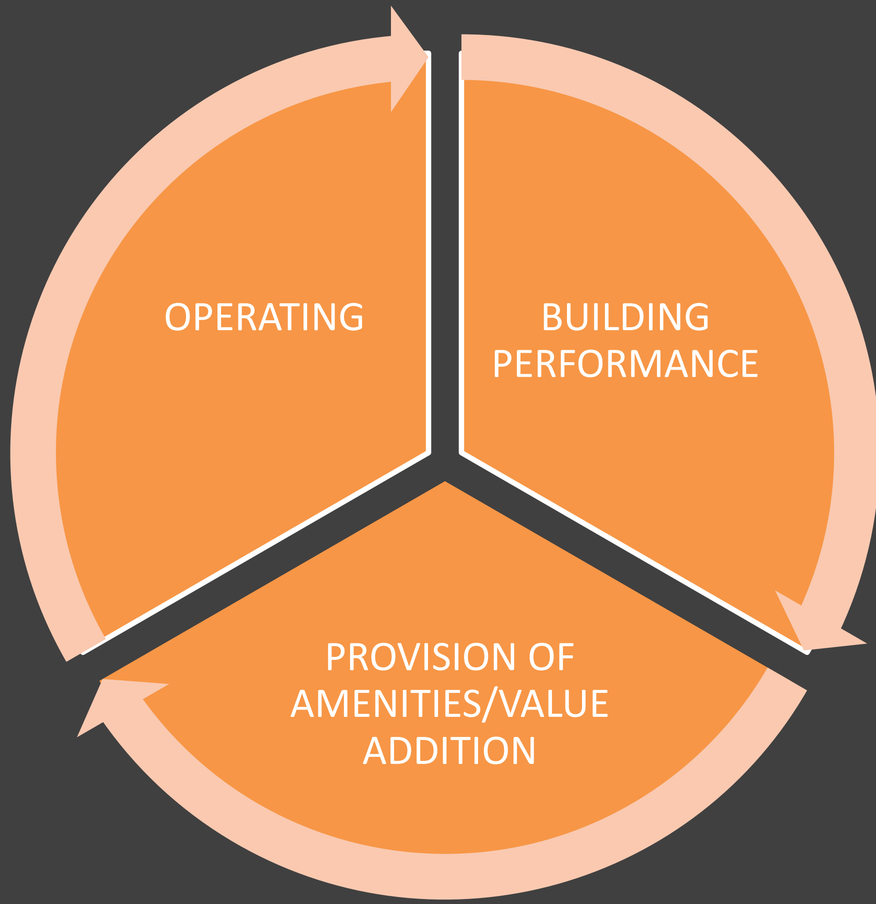


HOW?

- Analysis of existing conditions-energy modeling, façade studies
- Testing design proposals using simulation and modeling tools
- Selection of optimum choices for the new façade, mechanical system



BASIS OF STUDY



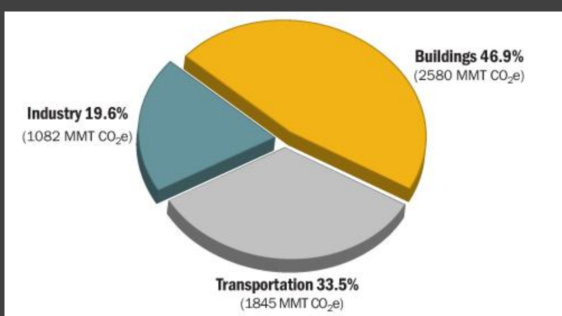
WHY THE PROJECT IS IMPORTANT…

- The Building Sector is responsible for:
  50.1% of total annual U.S. energy consumption
  49.1% of total annual U.S. GHG emissions
  74.5% of total annual U.S. electricity consumption
  (Source-Architecture2030)
- As of 2003, existing buildings in the U.S. 4.9 million, new buildings 57,000
- 39,408 LEED certified buildings (not including LEED for Homes)
- For each $1 sf/yr (per square foot, per year) of energy saved, a commercial building will increase in value about $11.75 per square foot at a capitalization rate of 8.5%. For example, if a building owner of a 10,000 square foot building saved $10,000 on annual energy expenses, the building would increase in value $117,500.
  (Source-Architecture2030)

Existing Building Renovations

3-Year	Minimum Energy Reduction Target
Maximum annual tax deduction per square foot of floor area	Percentage better than ASHRAE 90.1-2004
$4.50	30%
$6.00	50%
$7.50	75%
$9.00	Zero-Net-Energy

COMMERCIAL REAL ESTATE SOLUTION
-ARCHITECTURE 2030



U.S. CO_2 Emissions by Sector
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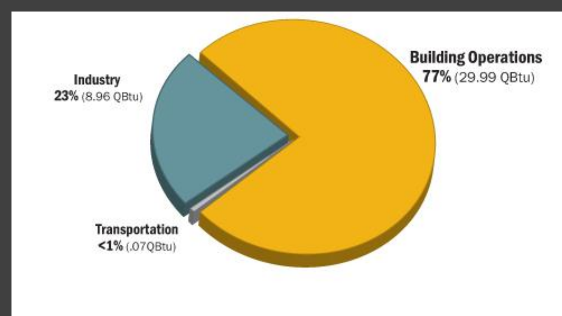
Data Source: U.S. Energy Information Administration (2009)



U.S. Electricity Consumption by Sector
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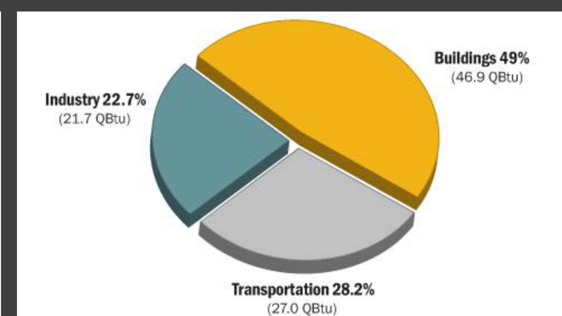

U.S. Energy Consumption by Sector
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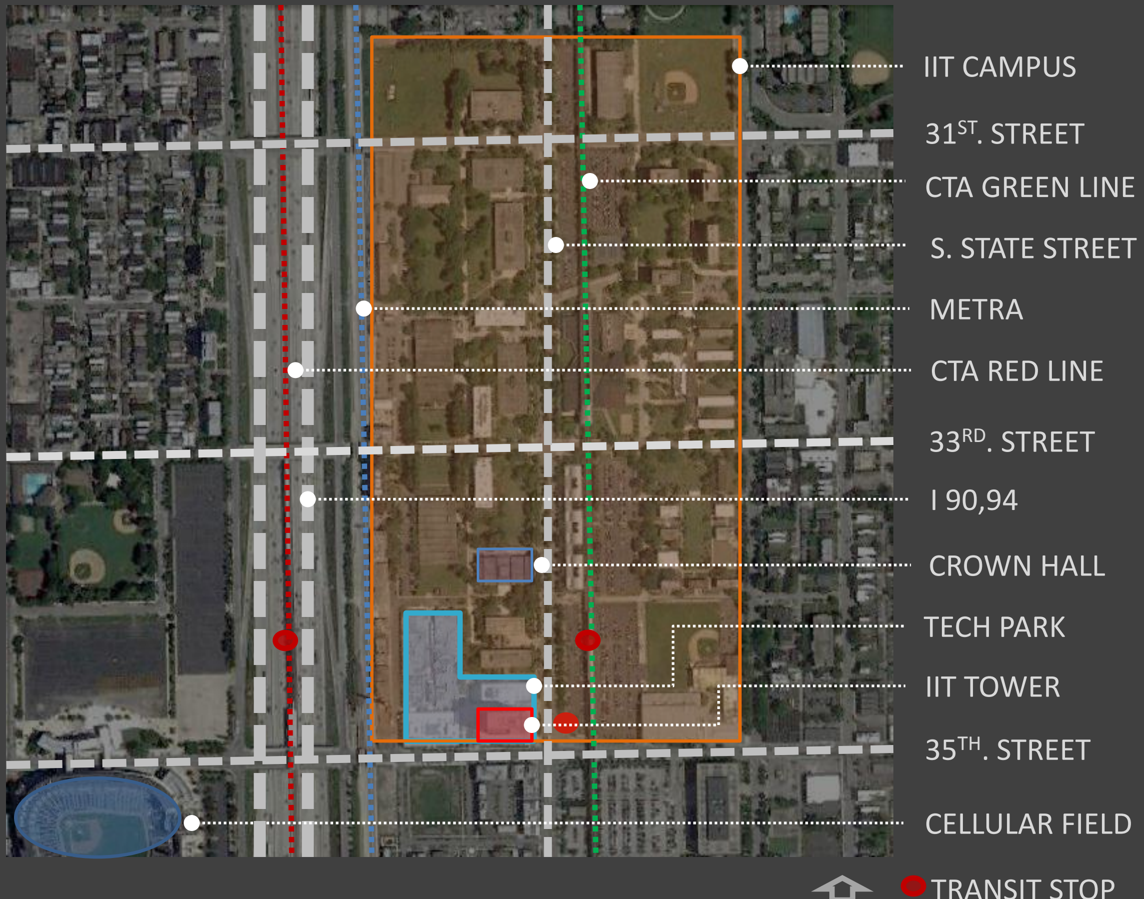
IIT TOWER



Built: 1963-1964
Designed by: Schmidt, Garden, and Erikson
Type: Skyscraper
Maximum Height: 237 feet / 72 meters
Location: IIT Campus, Chicago, United States

IIT TOWER

at the crossroads of activity and transformation

UNIVERSITY TECHNOLOGY PARK

CAMPUS SUSTAINABILITY AT IIT

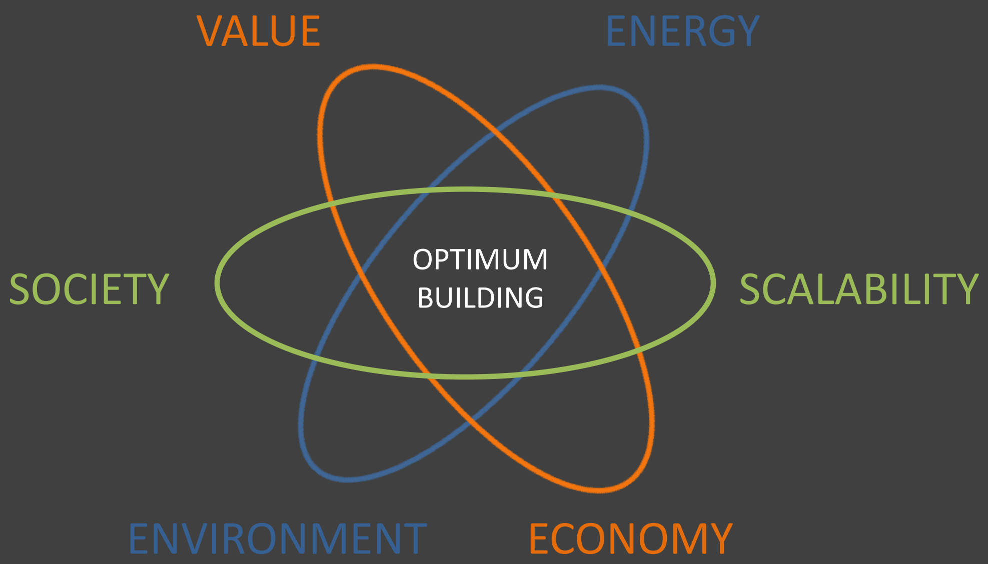
Program Area	2020 Goal	Primary Metric	Baseline	Target	Secondary Metric	Baseline	Target
Transportation	Increased alternative transportation (non-single-occupancy vehicle travel)	Commuter miles	5%	33%	Embodied Energy	TBD	TBD
	Use electric vehicles on campus	Number of electric vehicles	15%	100%	Embedded Water	TBD	TBD
	Mitigate impact of non-commuter travel (all forms)	Non-commuter miles mitigated	0%	100%	Engaged Community	5%	100%
Supply Chain/ Waste Management	Reduce flow of materials	Weekly, per capita waste	3.5 lbs.	0.9 lbs	Embodied Energy	TBD	TBD
					Embedded Water	TBD	TBD
		Paper purchasing	TBD	25% reduction	Engaged Community	5%	100%
Green Building	All new buildings/spaces LEED Gold	LEED-Gold new buildings	0%	100%	Embodied Energy	TBD	TBD
	Existing floor space LEED Gold EBOM	LEED-Gold floor space	0%	75%	Embedded Water	TBD	TBD
	All spaces comply with ASHRAE & IES	Compliant floor space	UNK	100%	Engaged Community	5%	100%
Stormwater/ Landscape	Net all stormwater managed on site	Stormwater runoff	est. 15%	100%	Embodied Energy	TBD	TBD
		Off-site stormwater infiltration			Embedded Water	TBD	TBD
					Engaged Community	5%	100%
Emissions	Eliminate all harmful emissions	Catalogue harmful emissions	TBD	None	Embodied Energy	TBD	TBD
	Reduce carbon emissions	CO2E (2008 baseline)	34 kton	17 kton	Embedded Water	TBD	TBD
					Engaged Community	5%	100%
Energy	Eliminate wasted energy	Energy not serving core mission	220MMBtu	20MMBtu	Embodied Energy	TBD	TBD
	Eliminate lost heat from energy transfer	Waste heat related to energy use	616MMBtu	236MMBtu	Embedded Water	TBD	TBD
					Engaged Community	5%	100%
Food	Increase organic food offering	Percentage of food organic	4%	100% comply with 1 of these 3	Embodied Energy	TBD	TBD
	Increase fair trade food offering	Percentage of food fair trade	1%		Embedded Water	TBD	TBD
	Increase local food offering	Percentage of food grown locally	7%		Engaged Community	5%	100%

By 2020, IIT will reduce primary energy waste by ninety percent (90%) compared with fiscal year 2010

Reduce secondary energy waste (waste heat) by thirty percent (30%) compared with fiscal year 2010.

Energy density of about 113 kBtu/square foot/year The average building in the Midwest (according to CBECS by the DOE) is about 94 kBtu/sf/year, an efficient building is around 60 kBtu/sf/year, and the ideal building around 40 kBtu/sf/year.

THE PROJECT



VALUE
ENERGY
SOCIETY
OPTIMUM
BUILDING
SCALABILITY
ENVIRONMENT
ECONOMY

THE PROJECT

IIT TOWER

BUILDING COMPONENT	EVALUATION BASIS	PERFORMANCE EVALUATION METHODOLOGY	BENCH-MARK	RE-DESIGN	PERFORMANCE EVALUATION	BENEFITS
BUILDING SKIN	U-VALUE	ENERGY SIMULATION	ASHRAE STANDARDS	HIGH PERFORMANCE/DOUBLE SKIN FACADE		INCREASED OCCUPANT COMFORT, REDUCED ENERGY USE, REDUCED ENERGY DEMAND, ENVIRONMENTAL BENEFITS
SYSTEMS-ELEVATORS, MECHANICAL	EFFICIENCY	ENERGY SIMULATION	ASHRAE STANDARDS (NET ZERO?)	HIGH PERFORMANCE SYSTEMS		INCREASED OCCUPANT COMFORT, REDUCED ENERGY USE, REDUCED ENERGY DEMAND, ENVIRONMENTAL BENEFITS
BUILDING AESTHETICS/FUNCTIONALITY	CURRENT BUILDING USE	BUILDING FUNCTION STUDY		BUILDING ENTRANCE, LOBBY, OPEN SPACE DESIGN, CORE		SOCIAL BENEFITS- VALUE TO IIT, IITRI, CAMPUS SUSTAINABILITY GOALS AND THE NEIGHBORHOOD
USABLE AREA	CURRENT USABLE AREA	AREA CALCULATION	POSSIBLE USABLE AREA	INCREASED USABLE AREA		SOCIAL BENEFITS- RETURN ON INVESTMENT

GOALS

RE-SKINNING

HIGH PERFORMANCE MECHANICAL SYSTEMS

IMPROVED VERTICAL TRANSPORTATION SYSTEM

SOCIAL AMENITIES

FUNCTIONALLY COMPOSED LANDSCAPE

RENEWABLE ENERGY GENERATION

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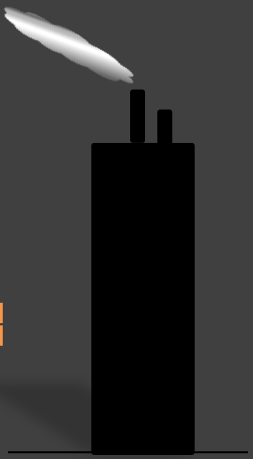


REDUCED ENERGY CONSUMPTION

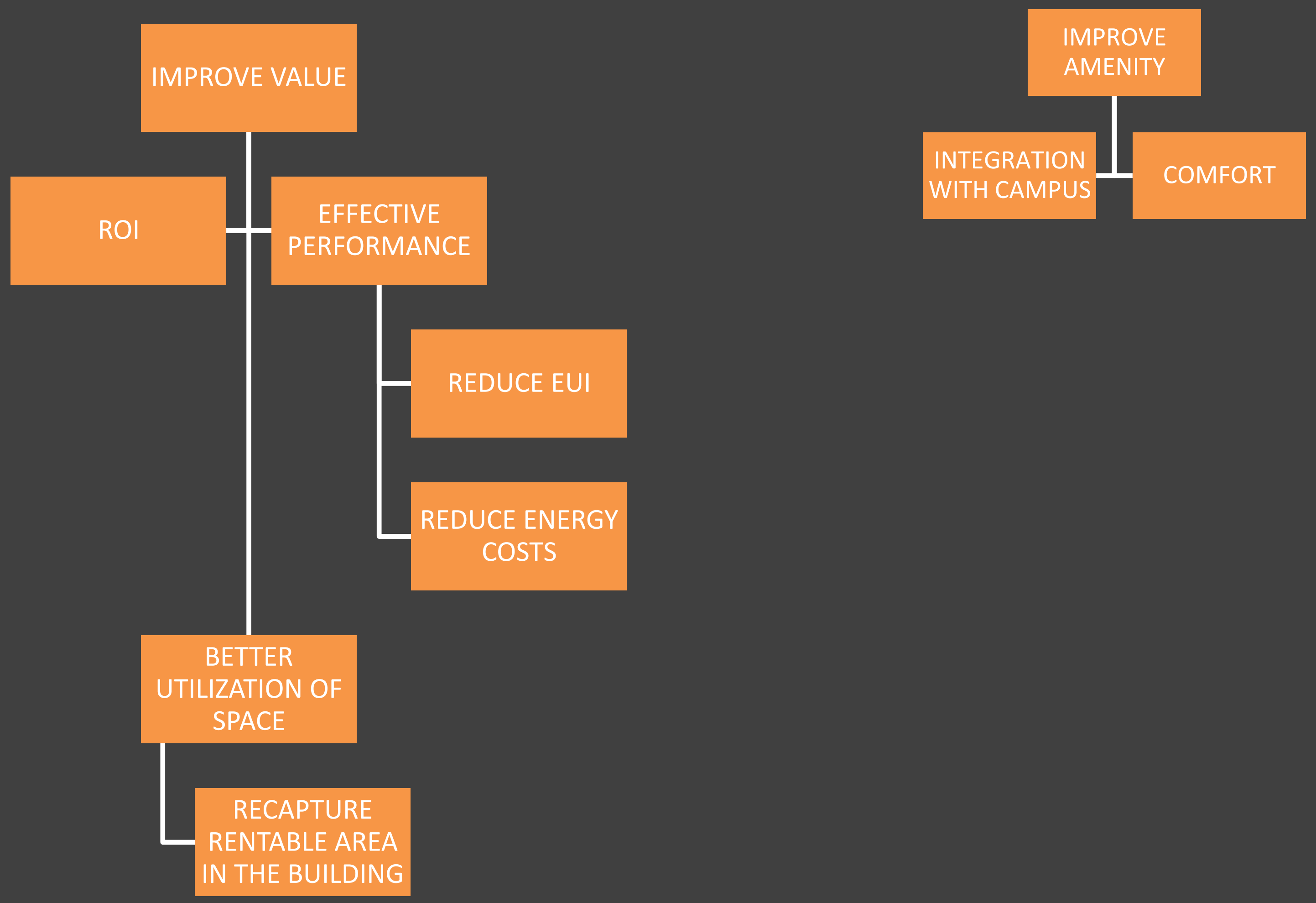
INCREASED RENTABLE SPACE

HIGHER OCCUPANT SATISFACTION

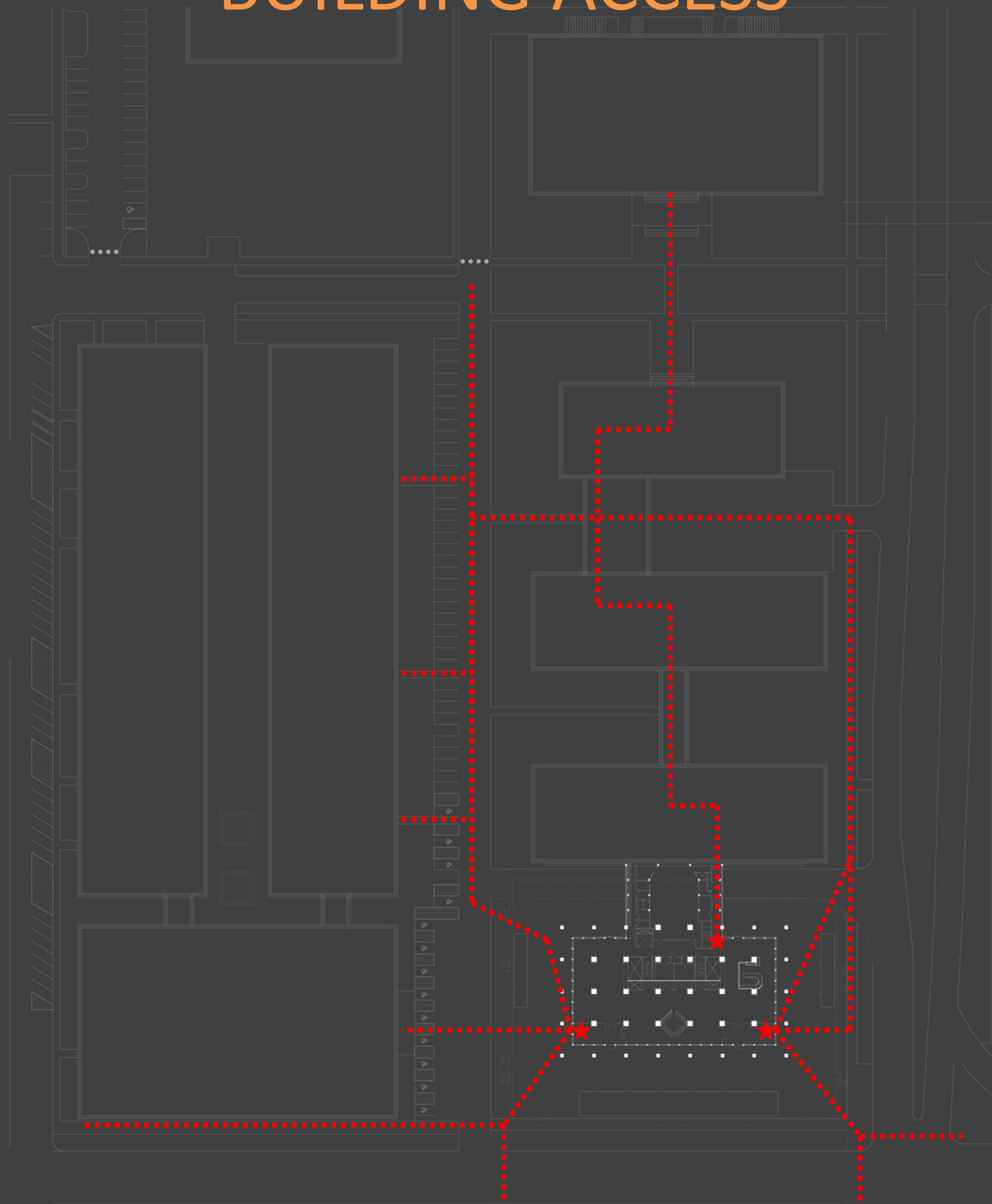
REDUCED MAINTENANCE COSTS

REDUCED POWER GENERATION NEEDS

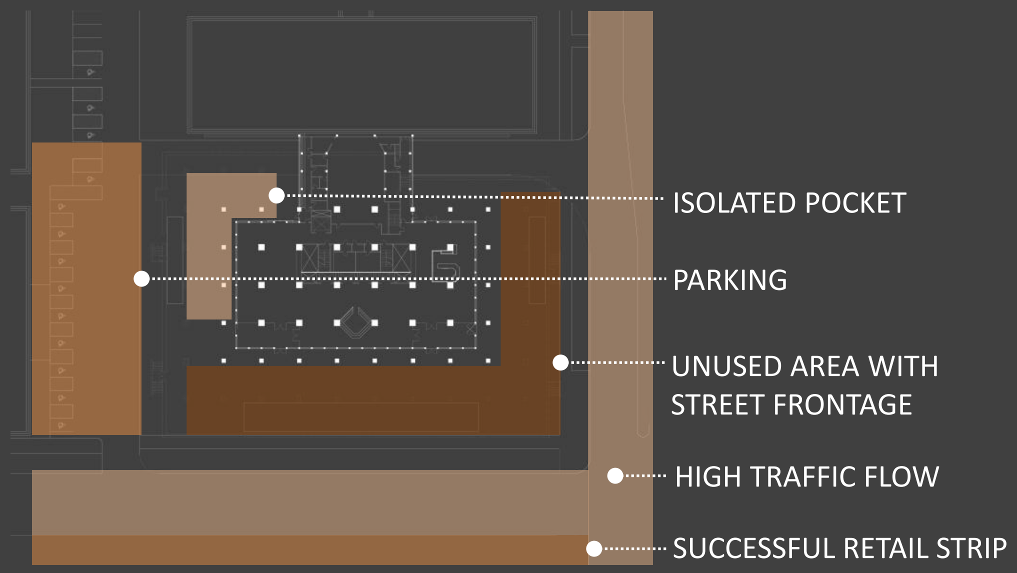
IMPROVE VALUE AND AMENITY



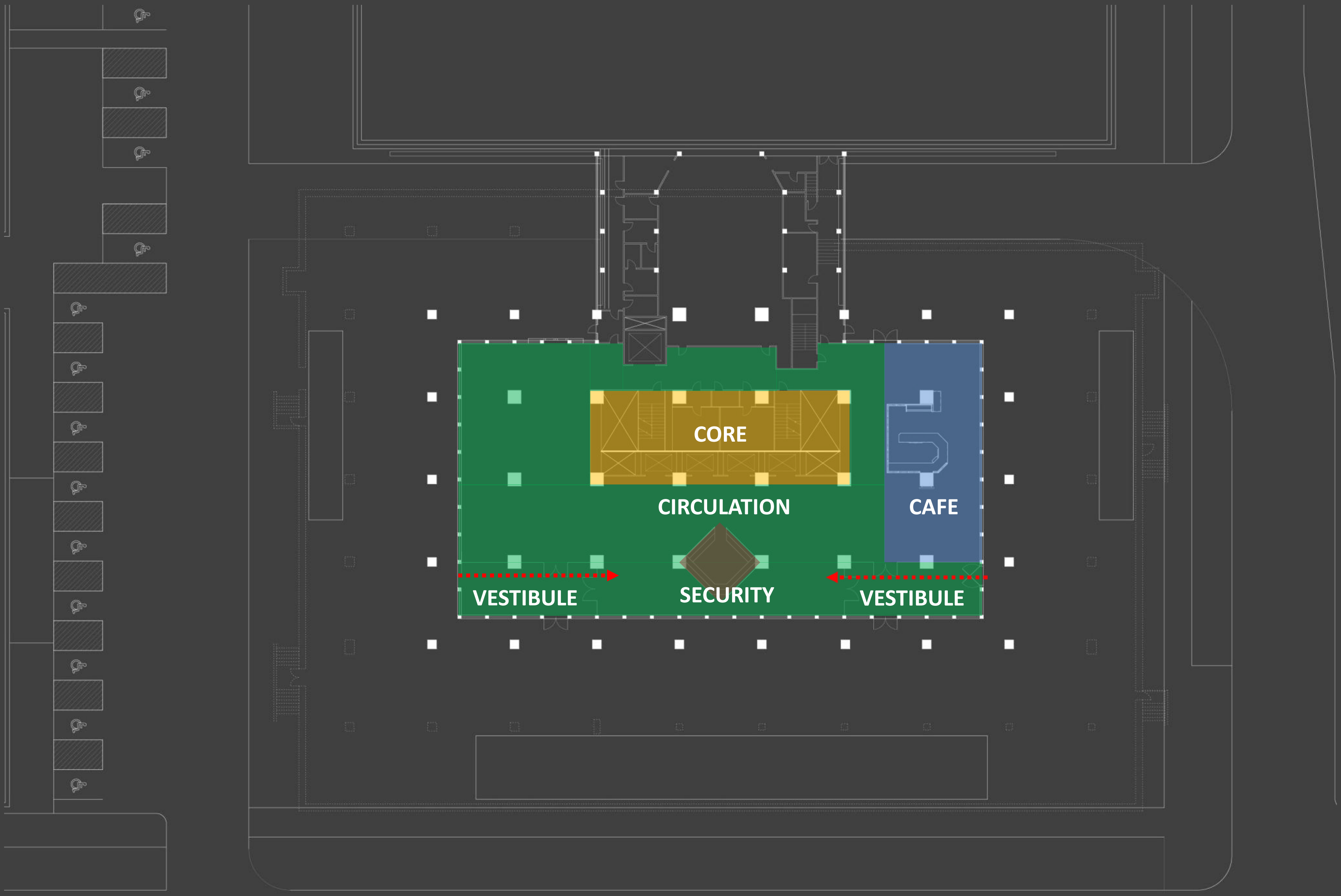
BUILDING ACCESS



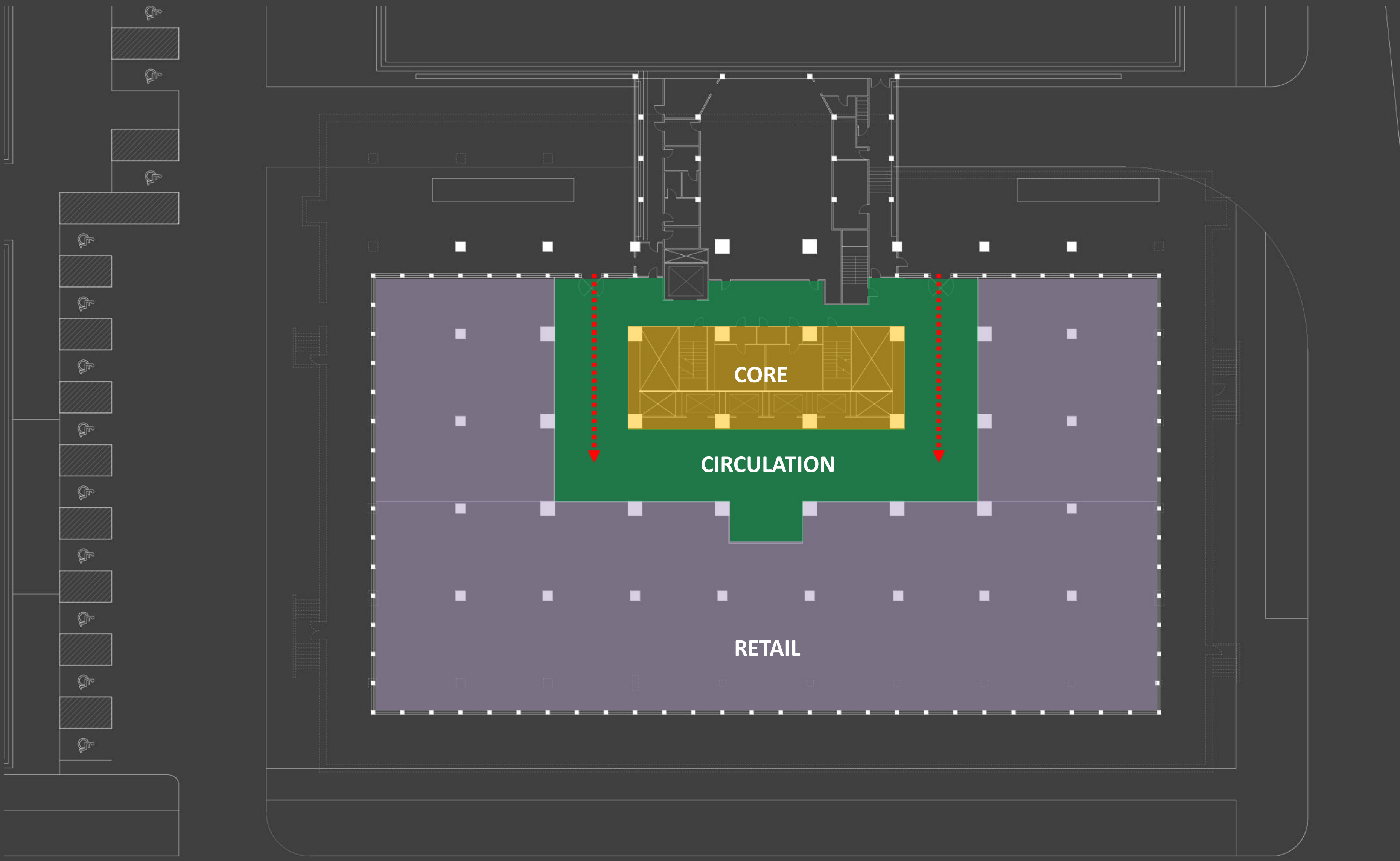
EXISTING CONDITIONS



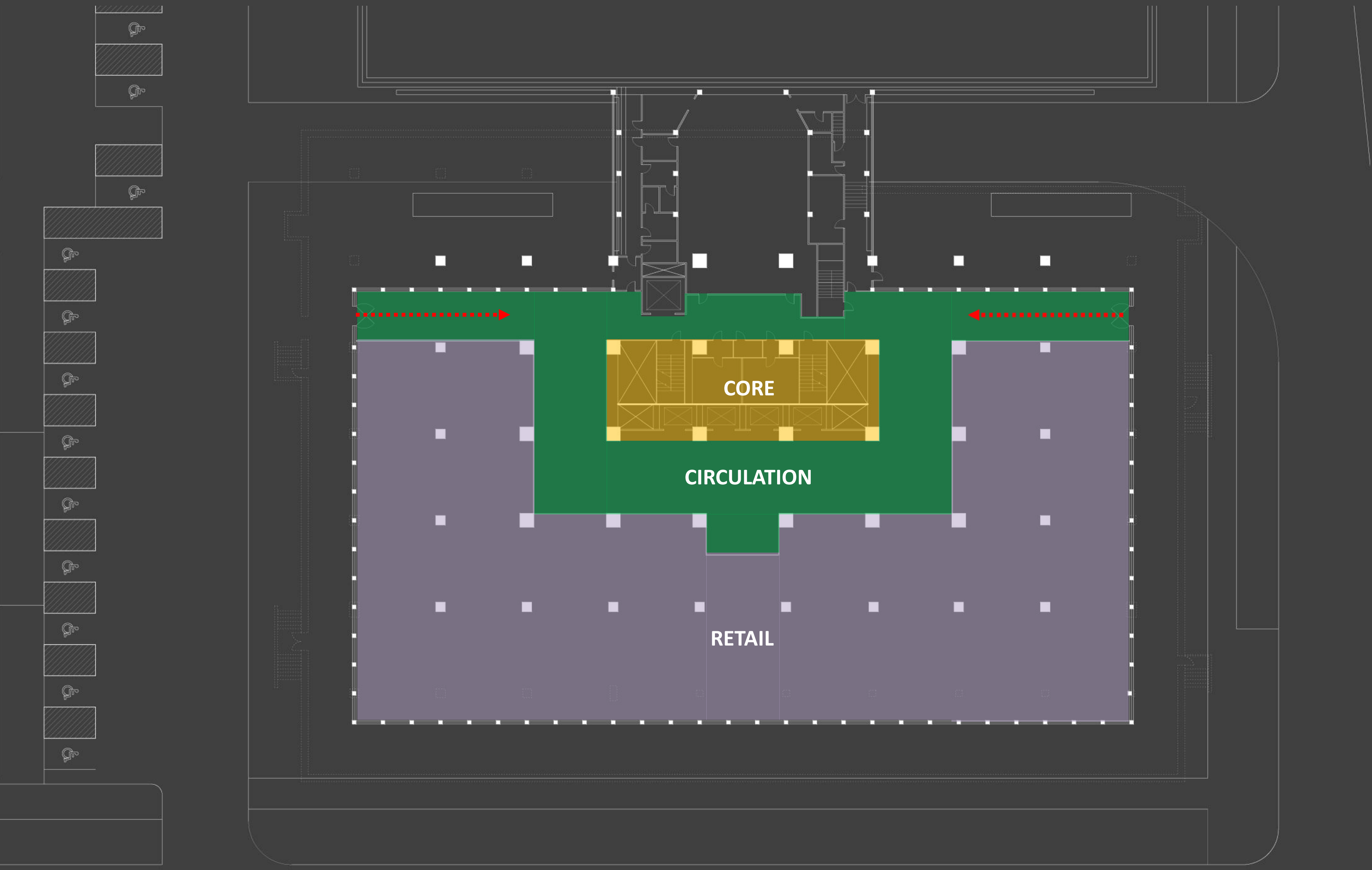
THE LOBBY



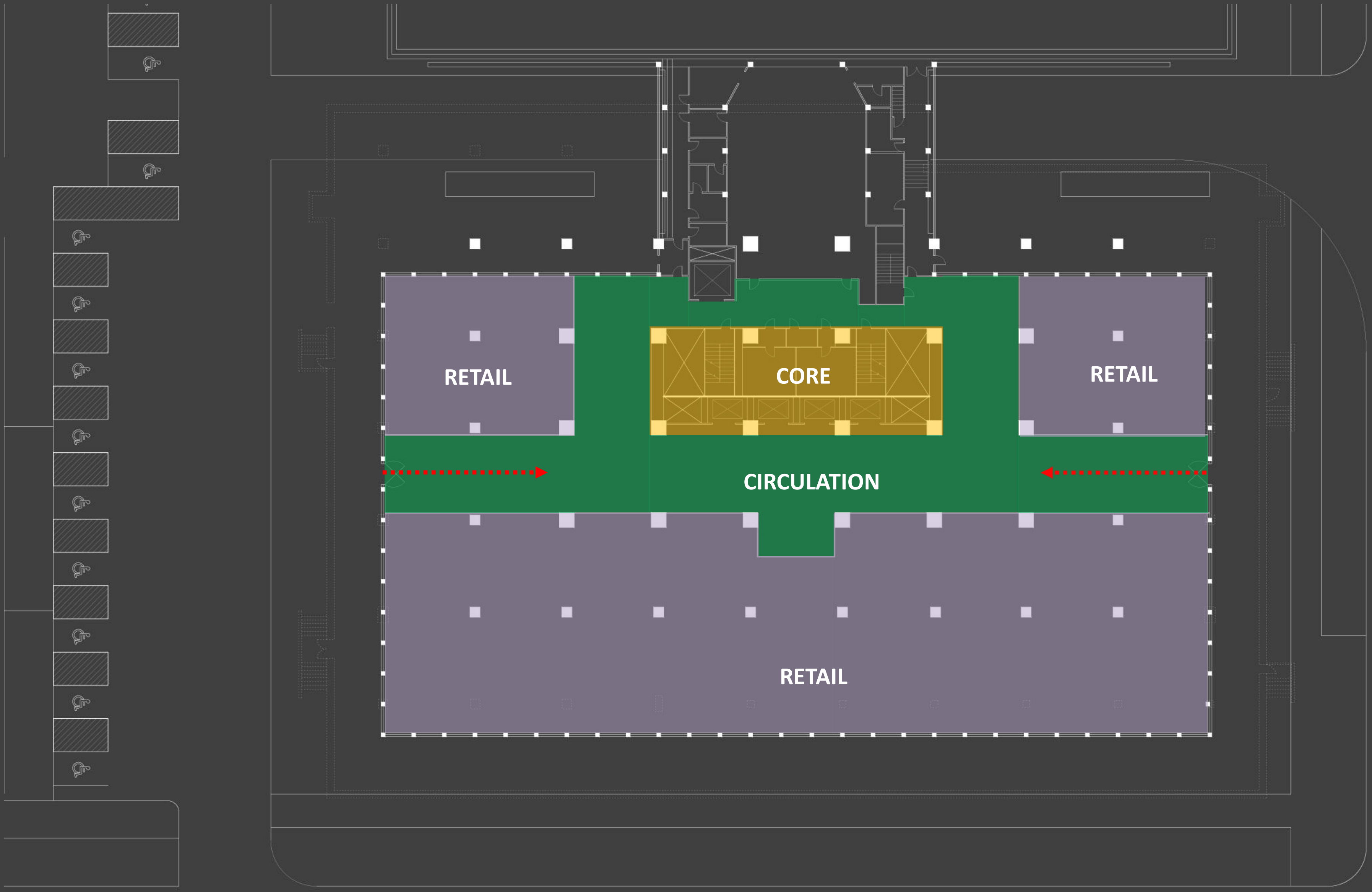
OPTION 1 RETAIL SQUARE FOOTAGE 18,500 S.F. AT $19-$21 PER S.F. PER YEAR



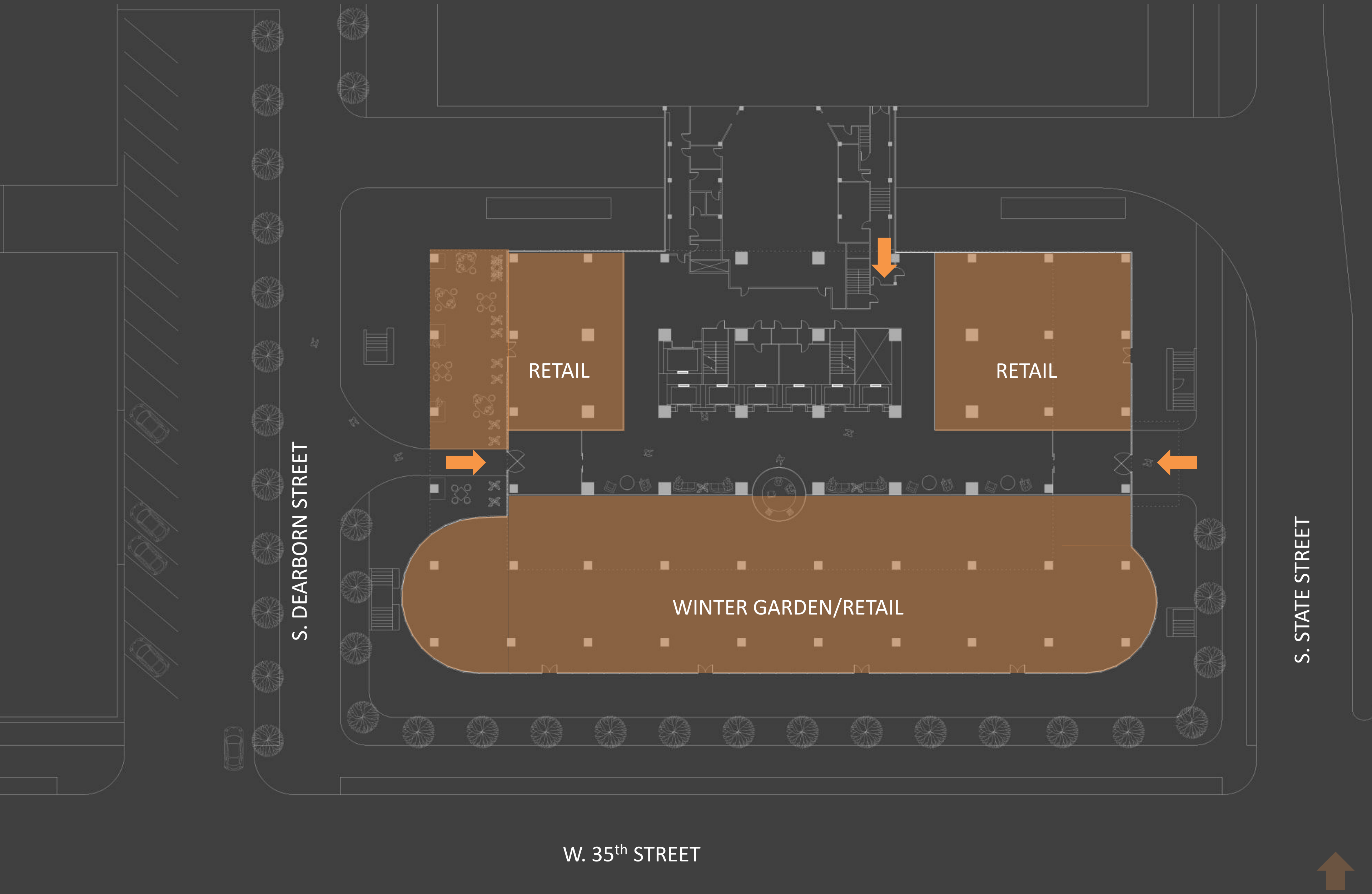
OPTION 2 RETAIL SQUARE FOOTAGE 16,900 S.F. AT $19-$21 PER S.F. PER YEAR



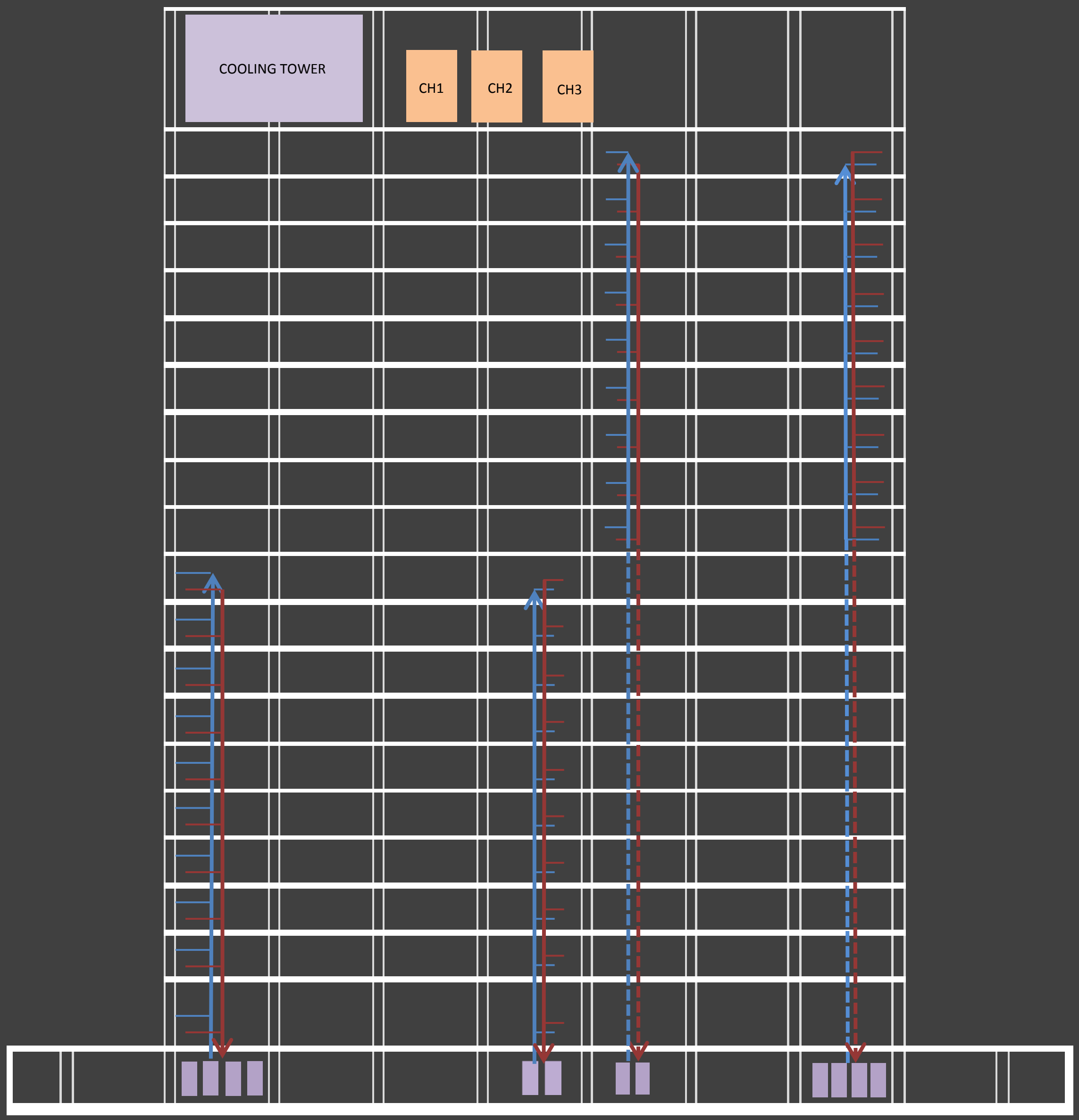
OPTION 3 RETAIL SQUARE FOOTAGE 16,100 S.F. AT $19-$21 PER S.F. PER YEAR



SITE PLAN

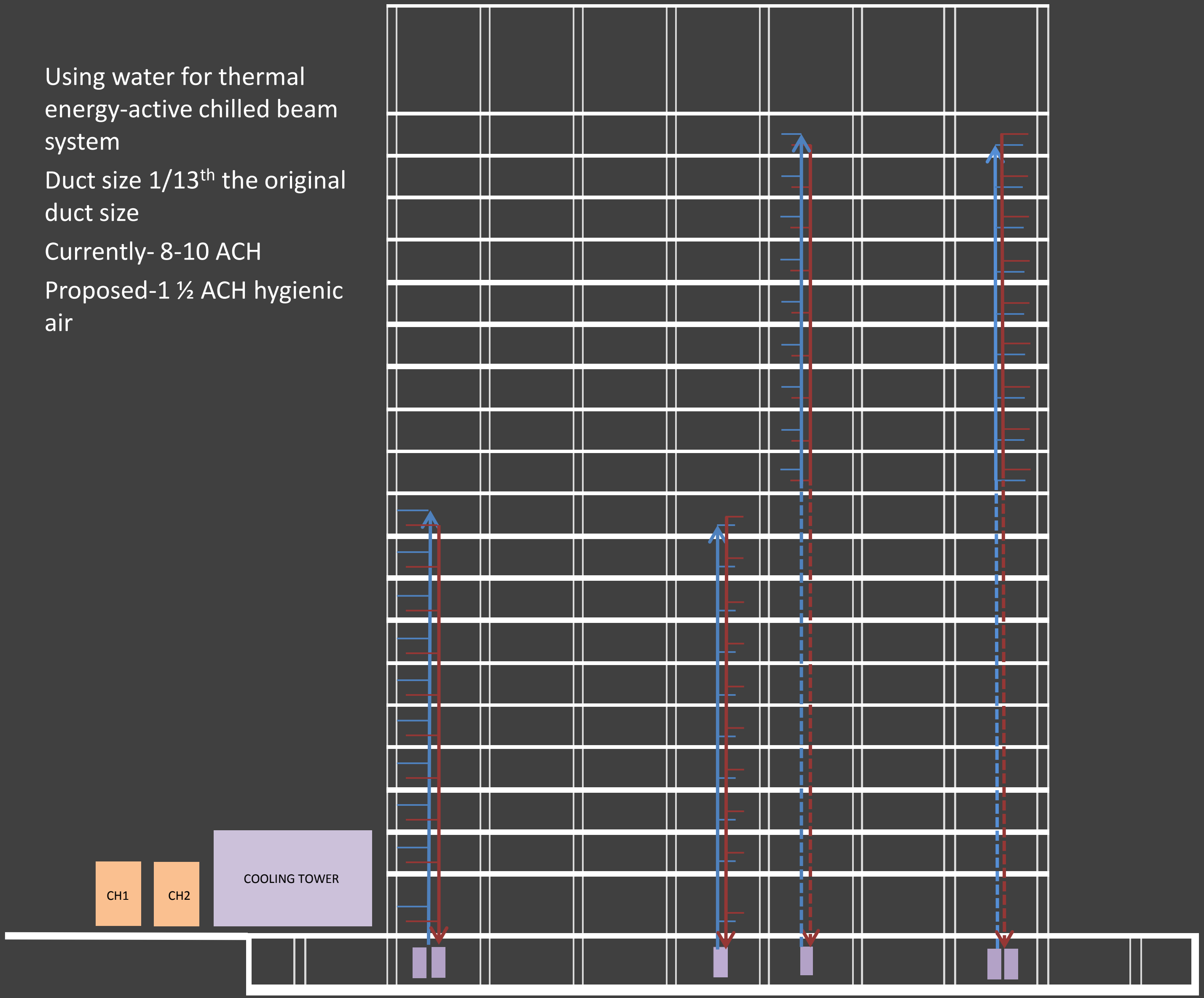

RETAIL
RETAIL
WINTER GARDEN/RETAIL
S. DEARBORN STREET
S. STATE STREET
W. 35th STREET

EXISTING MECHANICAL SYSTEM



OPTIMIZED MECHANICAL SYSTEM

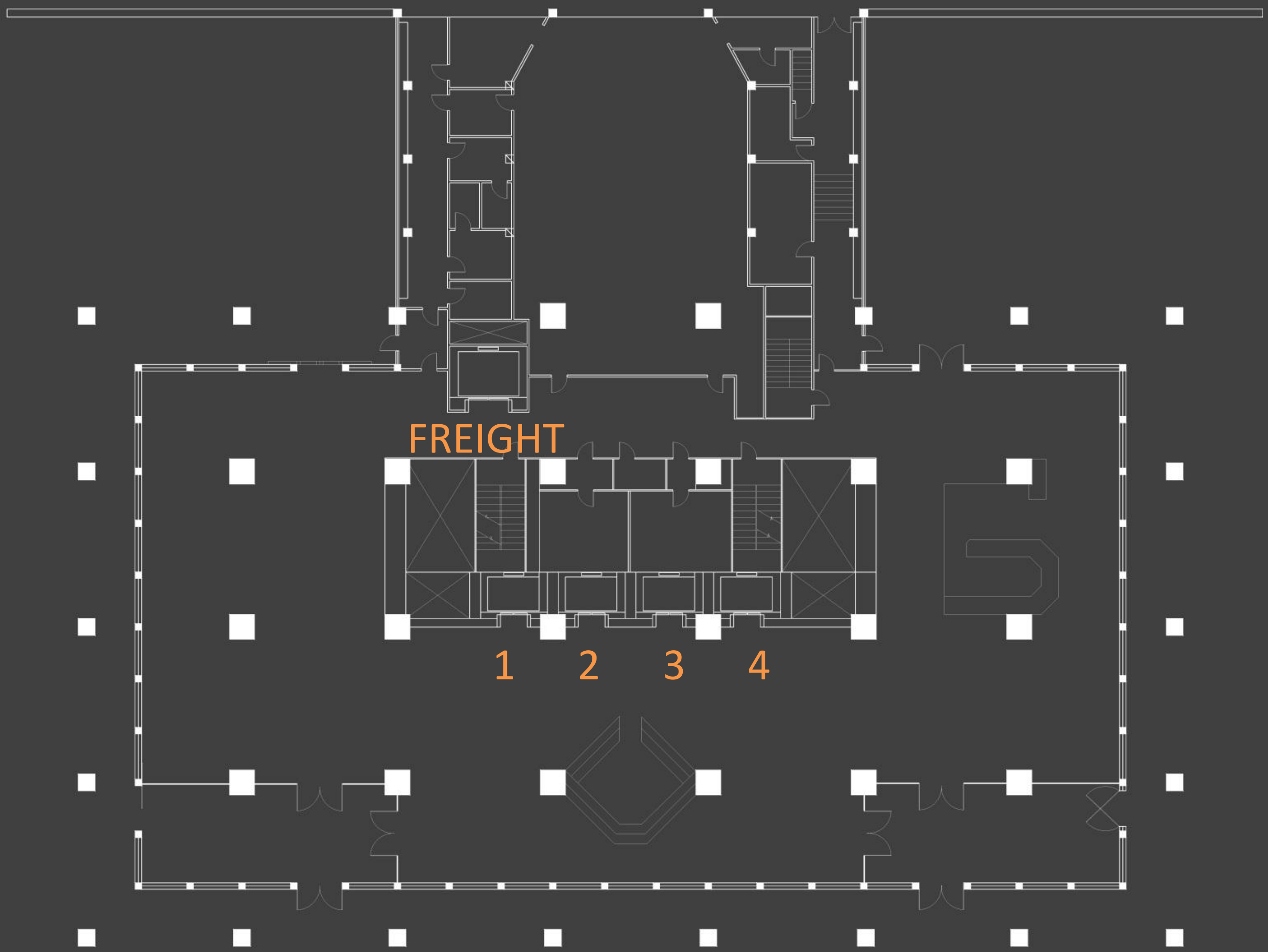
- Using water for thermal energy-active chilled beam system
- Duct size 1/13th the original duct size
- Currently- 8-10 ACH
- Proposed-1 ½ ACH hygienic air



VERTICAL TRANSPORTATION SYSTEM

EXISTING CONDITIONS

- Equipment-
- Cars-4
- Floors-20+basement
- Stops-20



VERTICAL TRANSPORTATION SYSTEM

EXISTING CONDITIONS

EXISTING CONDITIONS

- 18 leasable floors with a total of 252,000 sq. ft. of leasable space – 5 elevators required
- With the addition of 2 floors, new leasable area 317,520 sq. ft. – 7 elevators required

EXISTING ISSUES

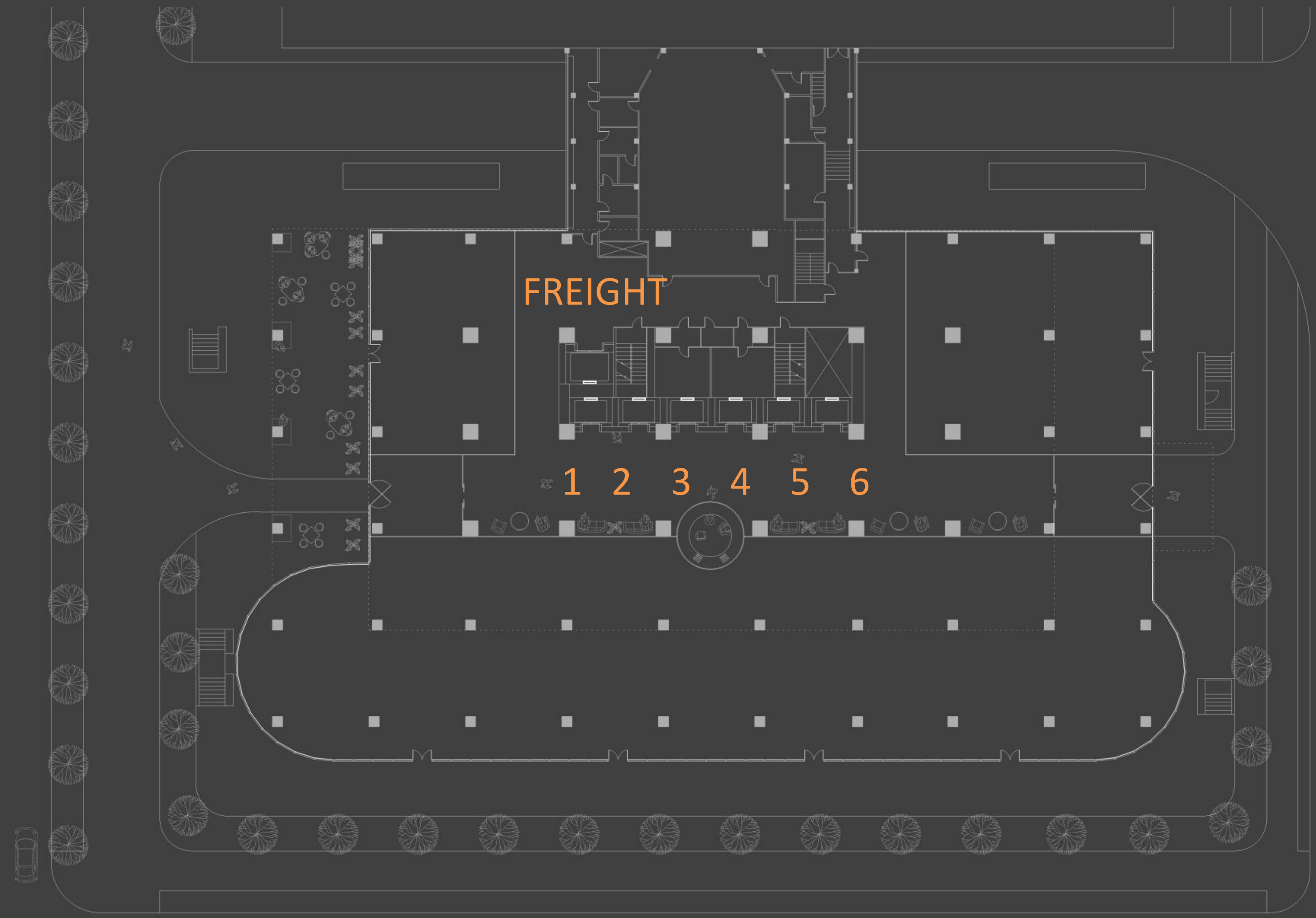
- Breakdown and wait time complaints
- Freight elevator taking up leasable area on floors

REQUIREMENTS

- 1 elevator/ 50,000 sq. ft. of leasable space
- Every elevator run not more than 15 floors

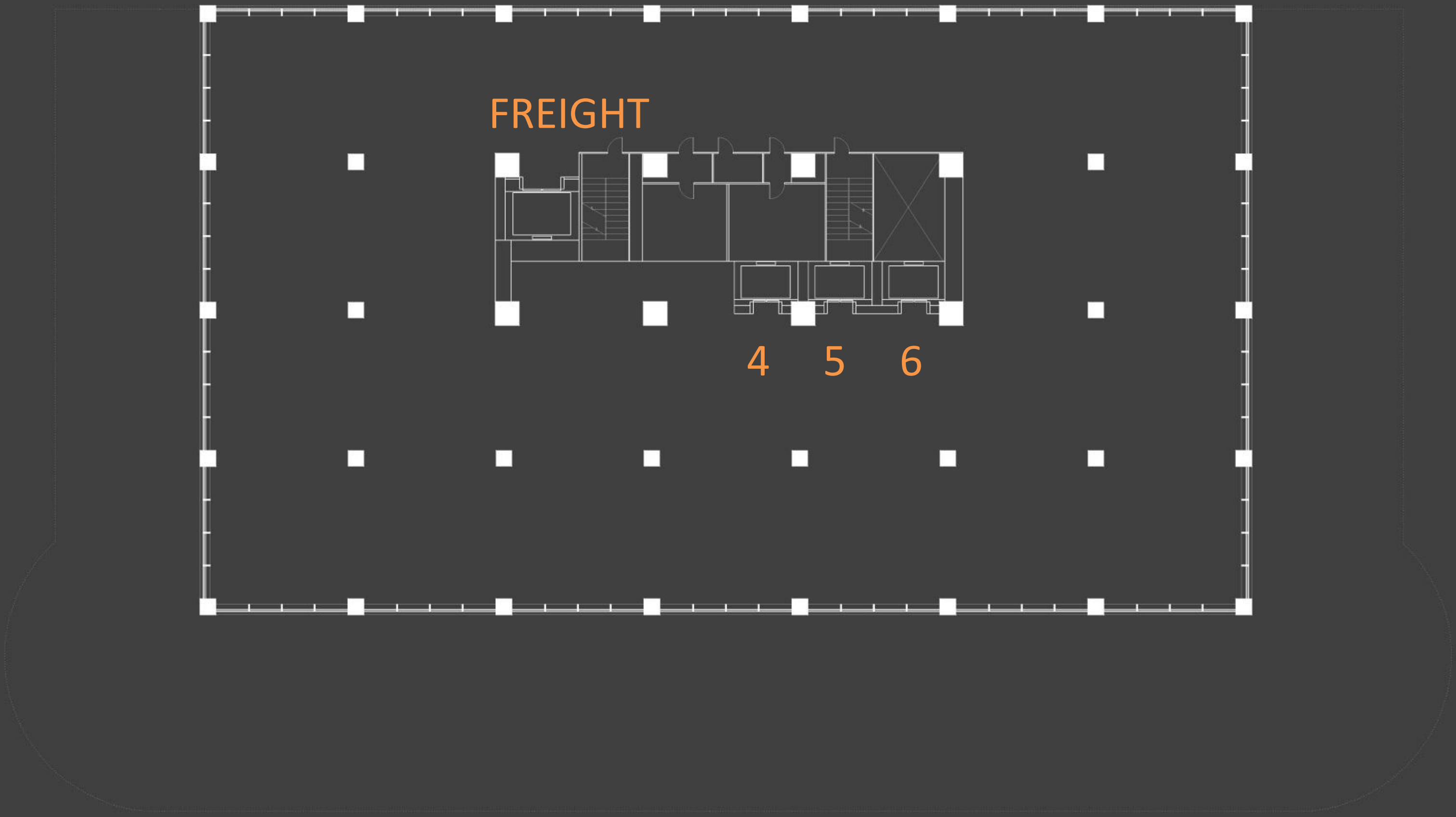
VERTICAL TRANSPORTATION SYSTEM

PROPOSED GROUND FLOOR LEVEL

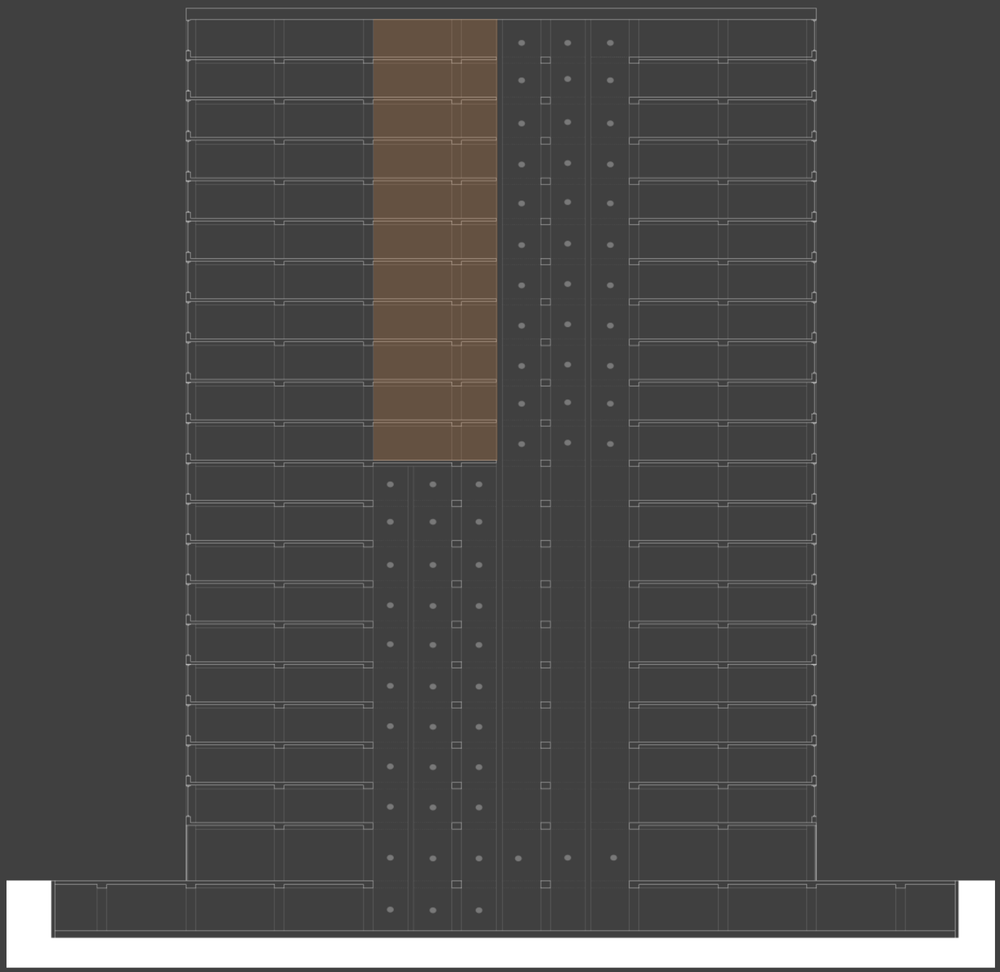


VERTICAL TRANSPORTATION SYSTEM

PROPOSED 11-21 FLOOR LEVEL

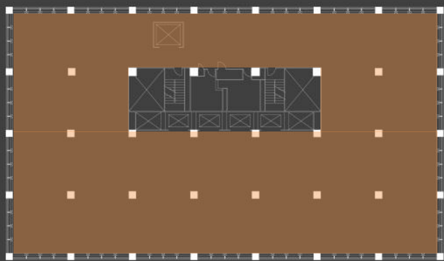


VERTICAL TRANSPORTATION SYSTEM



INCREASE IN BUILDING EFFICIENCY BY 2% PER FLOOR (11-21)

VALUE ADDITION



Recapturing the 20th floor and addition of a floor at the 21st level: 14,000 x 2 S.F.

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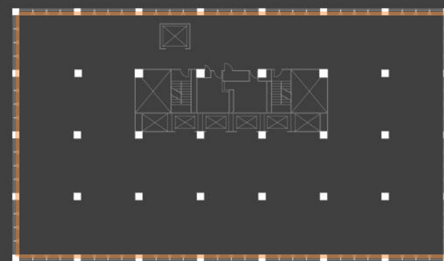

Recapturing the perimeter induction unit and duct area from 2-19 floors: 500 x 18 S.F.

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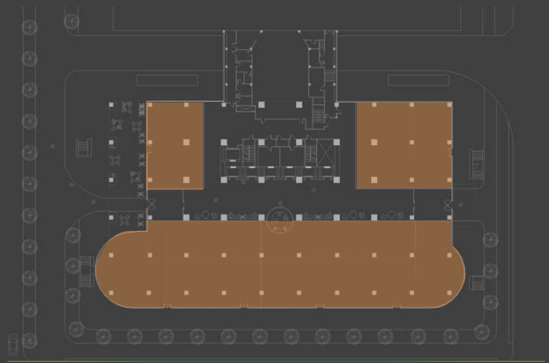
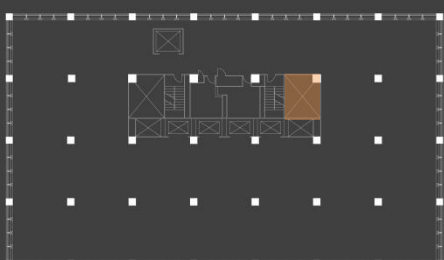


Recapturing the lobby and addition of new retail : 21,000   S.F.



Recapturing the air shaft area on 20 floors and basement: 320 x 21 S.F.

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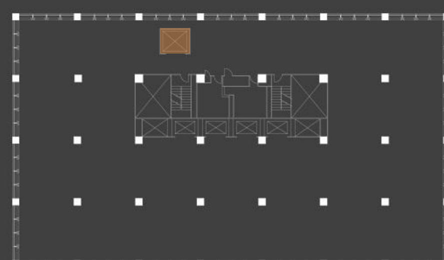

Recapturing the freight elevator area on 20 floors and basement: 140 x 21 S.F.

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INCREASE IN LEASABLE SPACE BY 26% AT $19.00-21.00 PER S.F.

VALUE ADDITION

METHODOLOGY FOR BUILDING SKIN DESIGN

Climate Analysis

- Ecotect
- Climate Consultant

Façade Analysis

- Comfen
- Window 6

Glass Selection

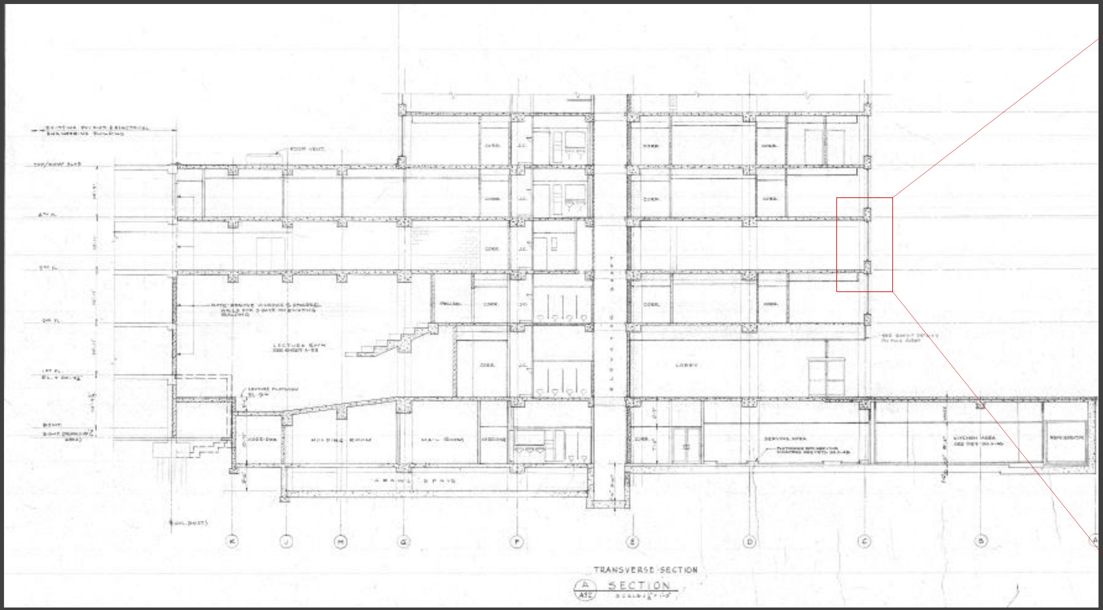
- Comfen
- Window 6
- Equest

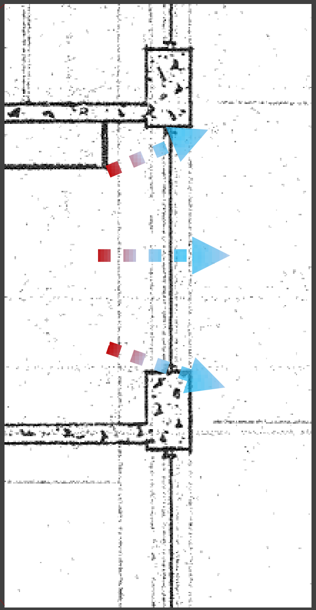
Proposed Building Skin Analysis

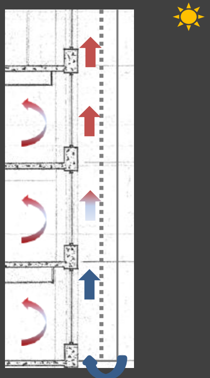
- Comfen
- Window 6
- Equest

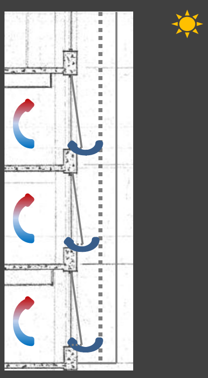
BUILDING SKIN

- Window-wall ratio: 63% (N&S) 68% (E&W)
- ¼” single pane glass without thermal breaks

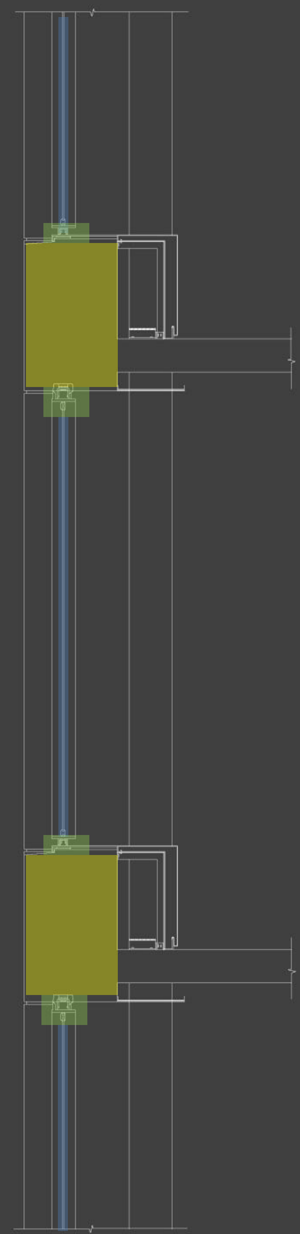




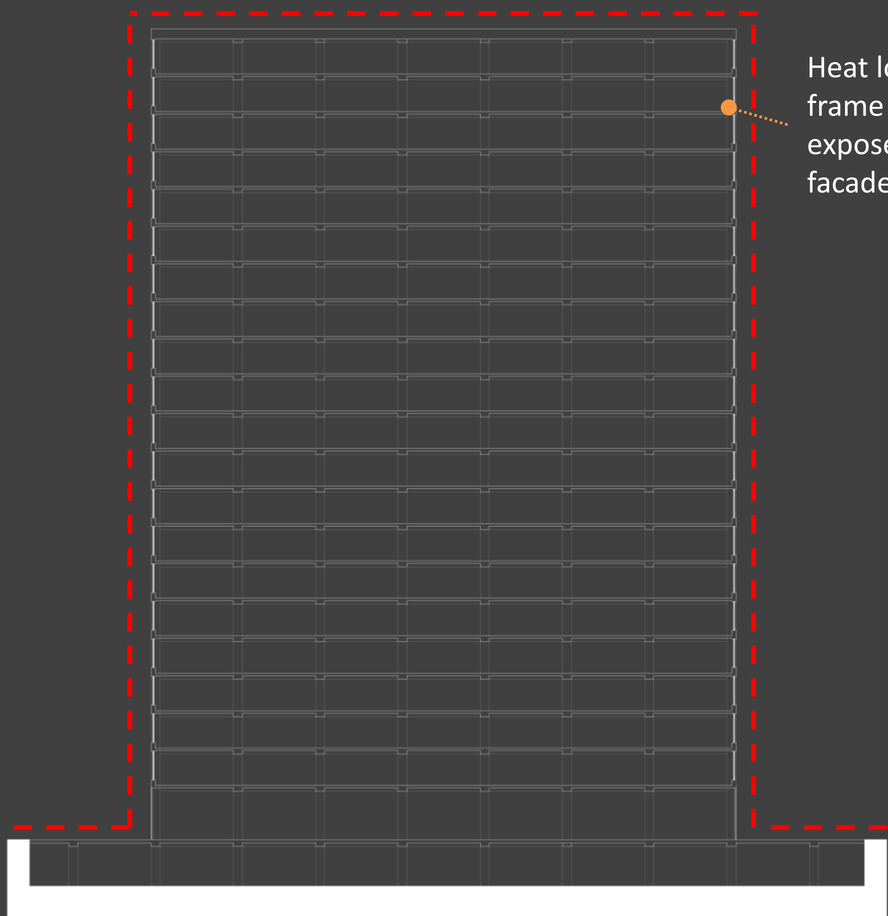


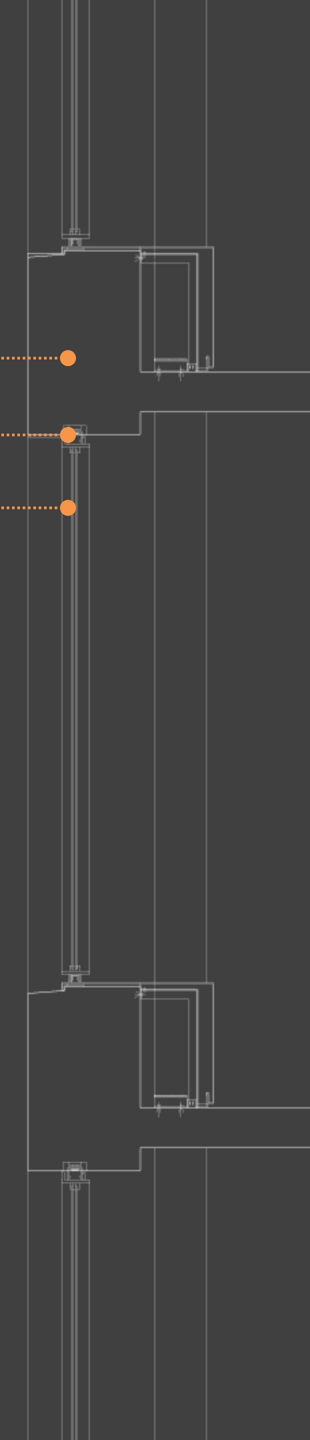


EXISTING BUILDING SKIN

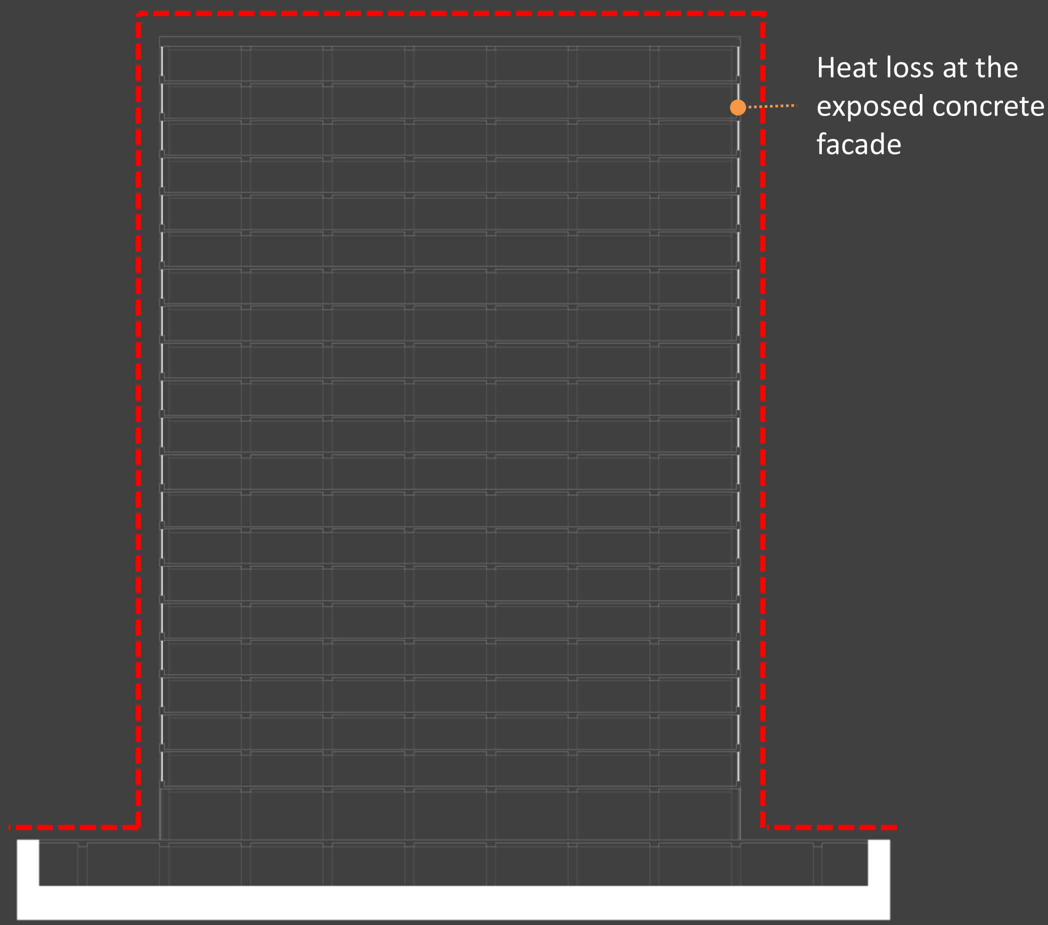


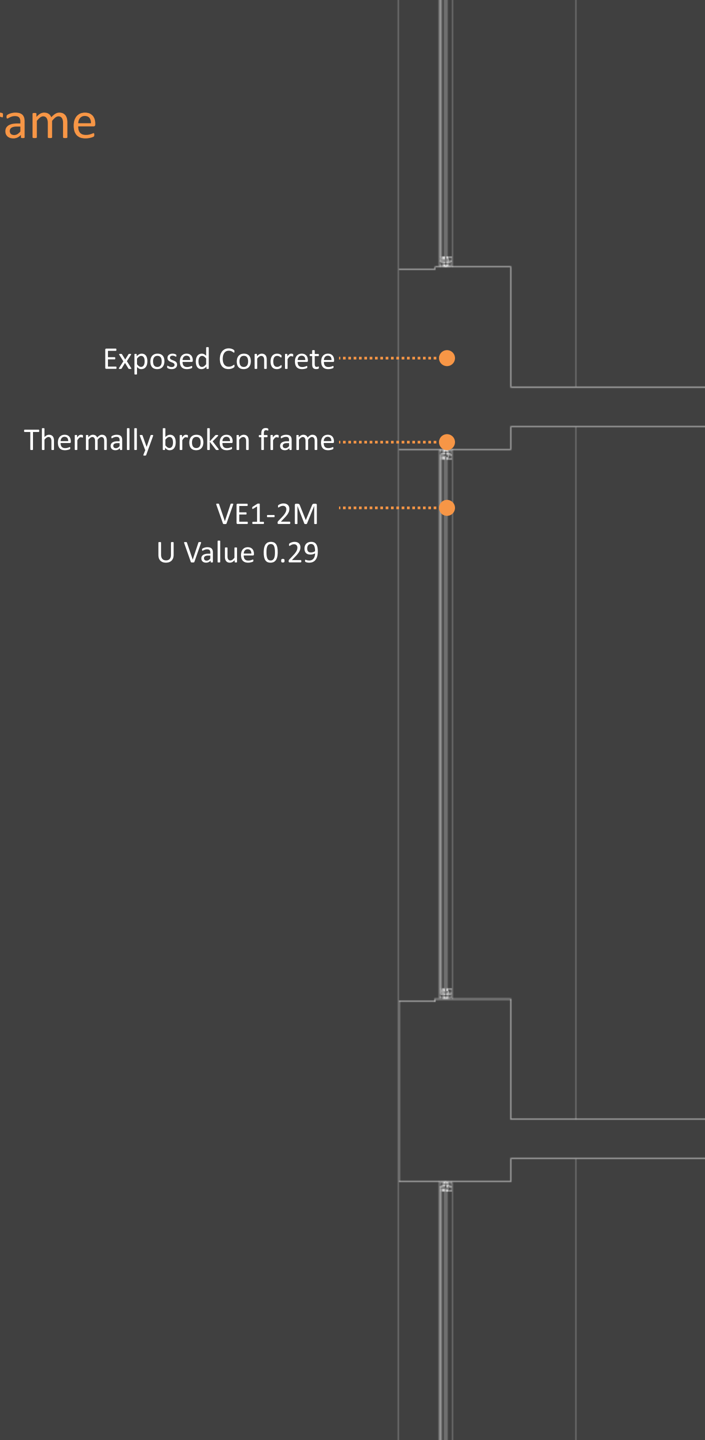
Option 1 New Glass with Old Frame



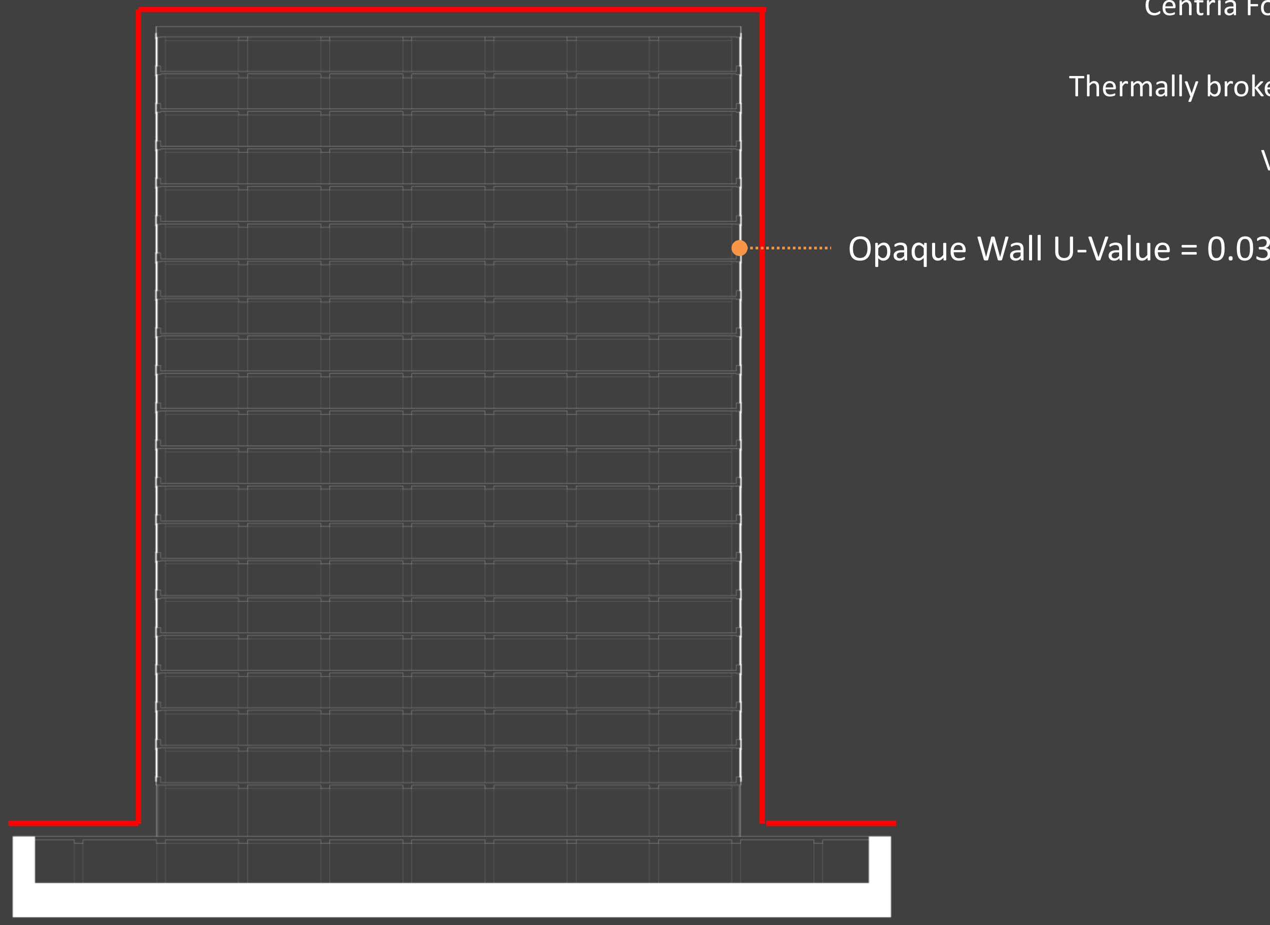


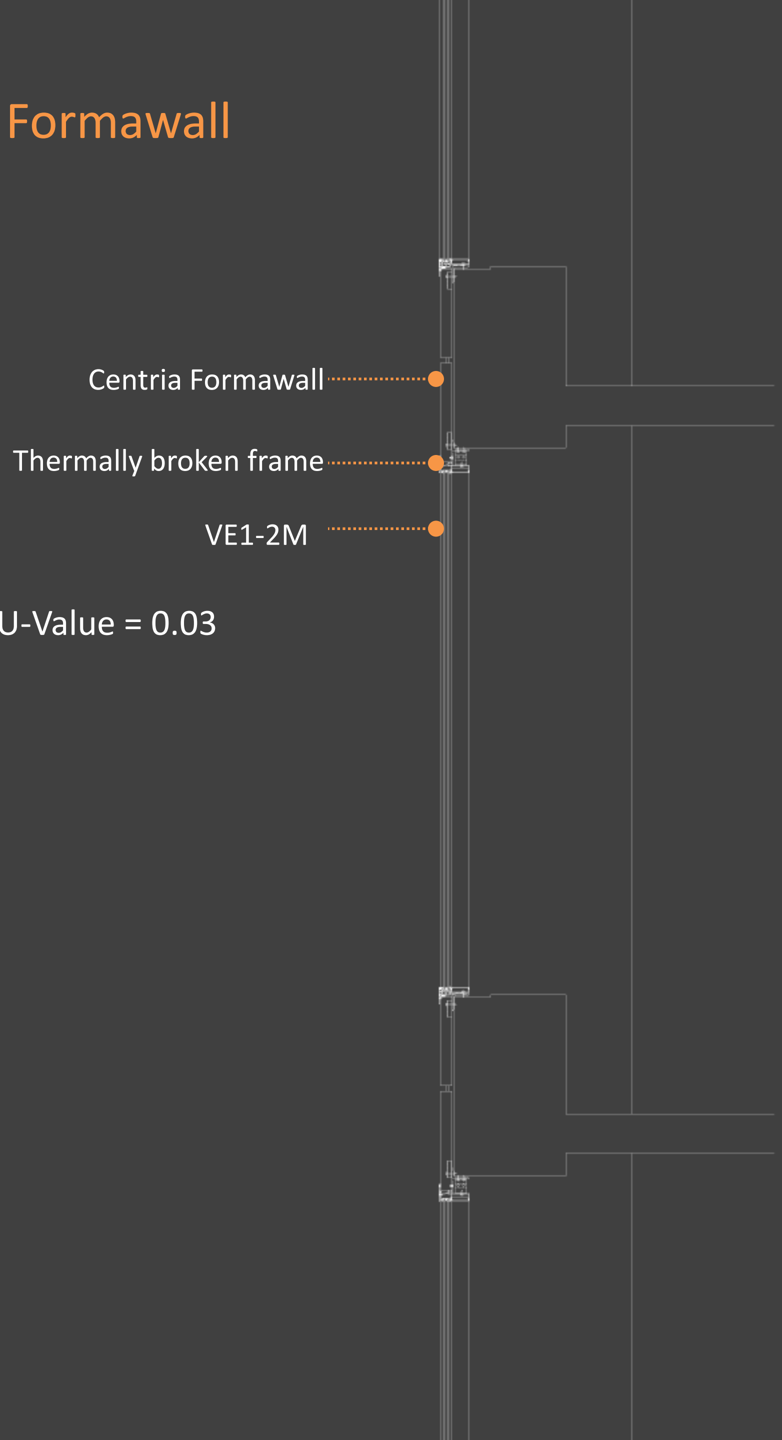
Option 2 New Glass +New Frame



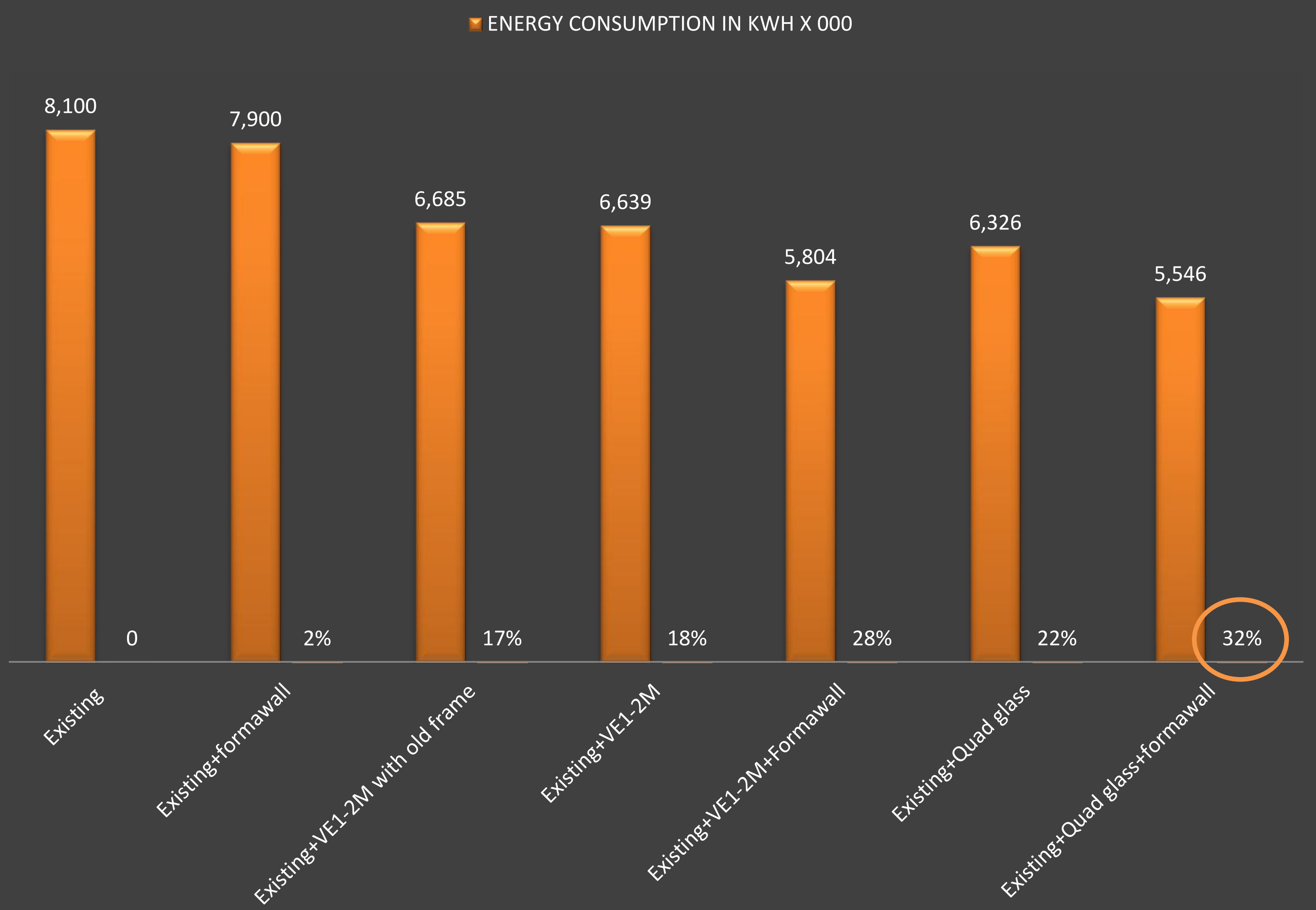


Option 3 New Window and Formawall

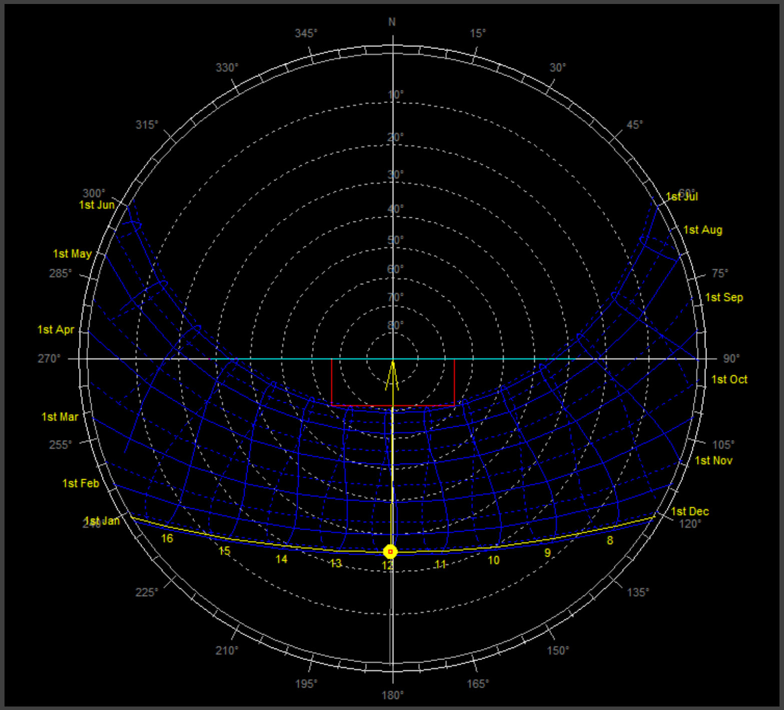




GLASS SELECTION ANALYSIS



CLIMATE


N
345°
15°
330°
30°
315°
45°
300°
1st Jun
60°
1st Jul
1st Aug
1st May
285°
75°
1st Sep
1st Apr
270°
90°
1st Oct
1st Mar
255°
105°
1st Nov
1st Feb
1st Jan
1st Dec
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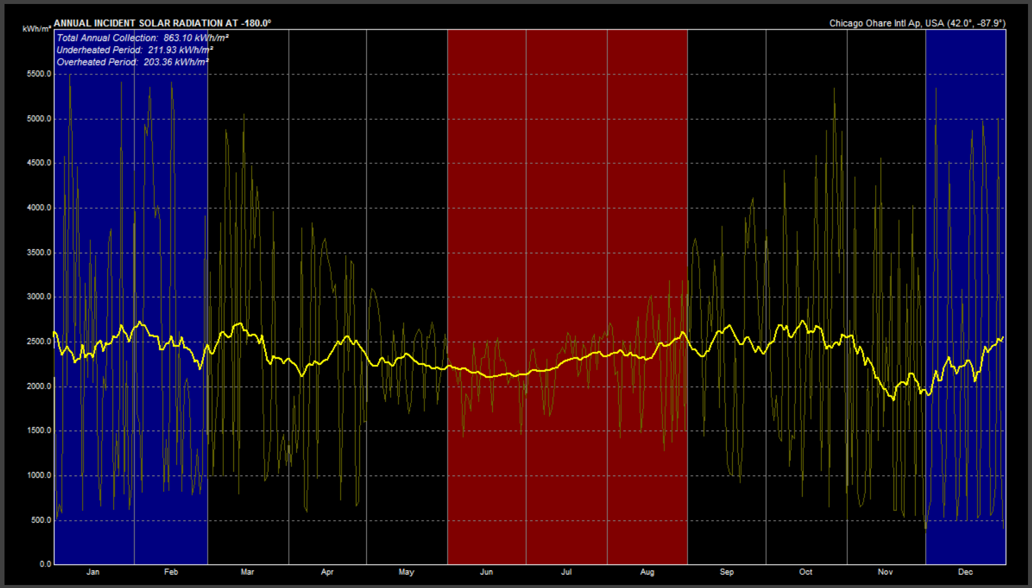
11
10
9
8
225°
135°
210°
150°
195°
165°
180°


ANNUAL INCIDENT SOLAR RADIATION AT -180.0°
Chicago Ohare Intl Ap, USA (42.0°, -87.9°)
kWh/m²
Total Annual Collection: 863.10 kWh/m²
Underheated Period: 211.93 kWh/m²
Overheated Period: 203.36 kWh/m²
5500.0
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
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Jan
Feb
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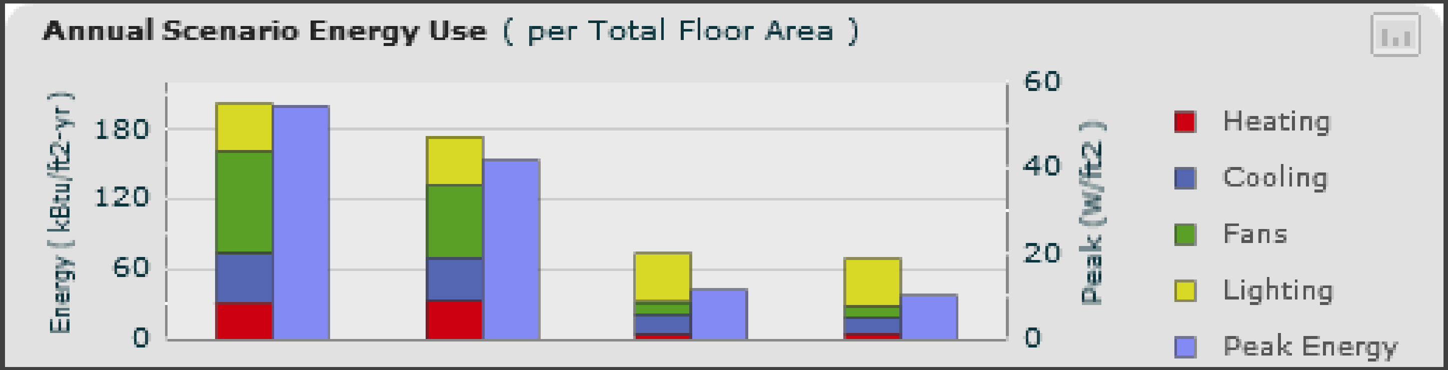
Nov
Dec

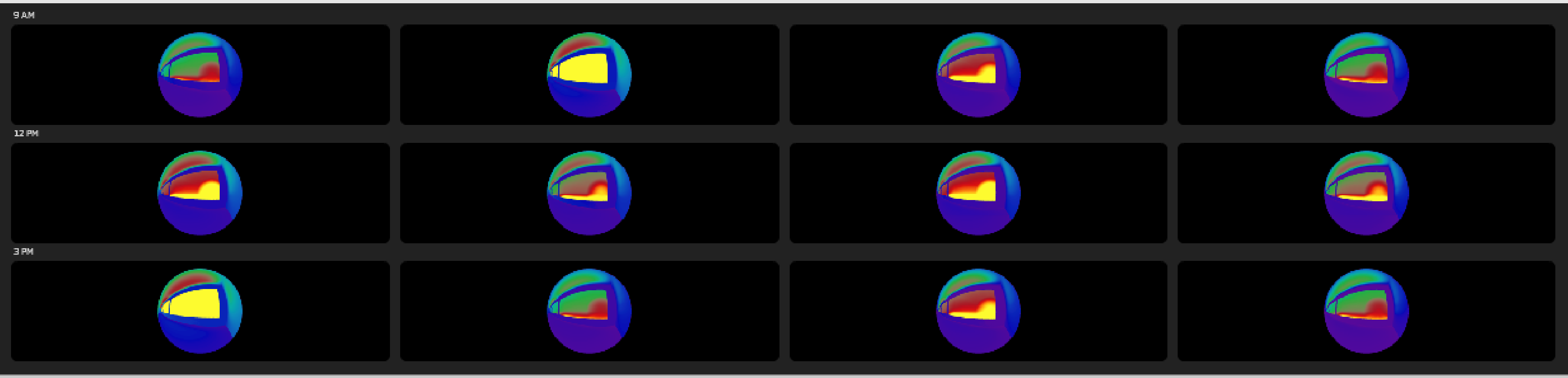
FAÇADE ANALYSIS



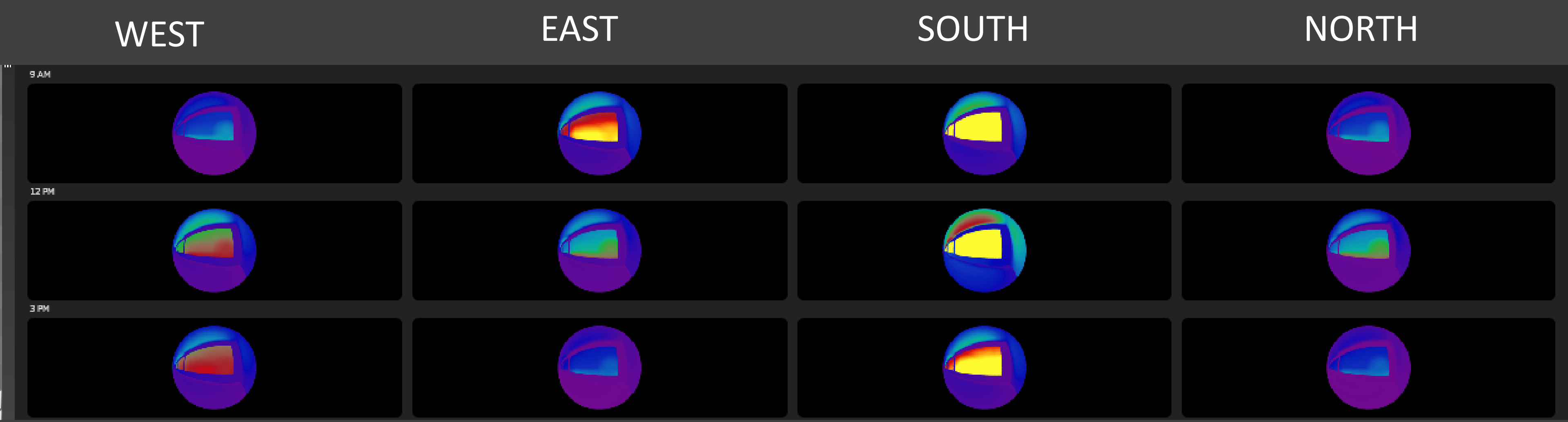
WEST EAST SOUTH NORTH

SUMMER

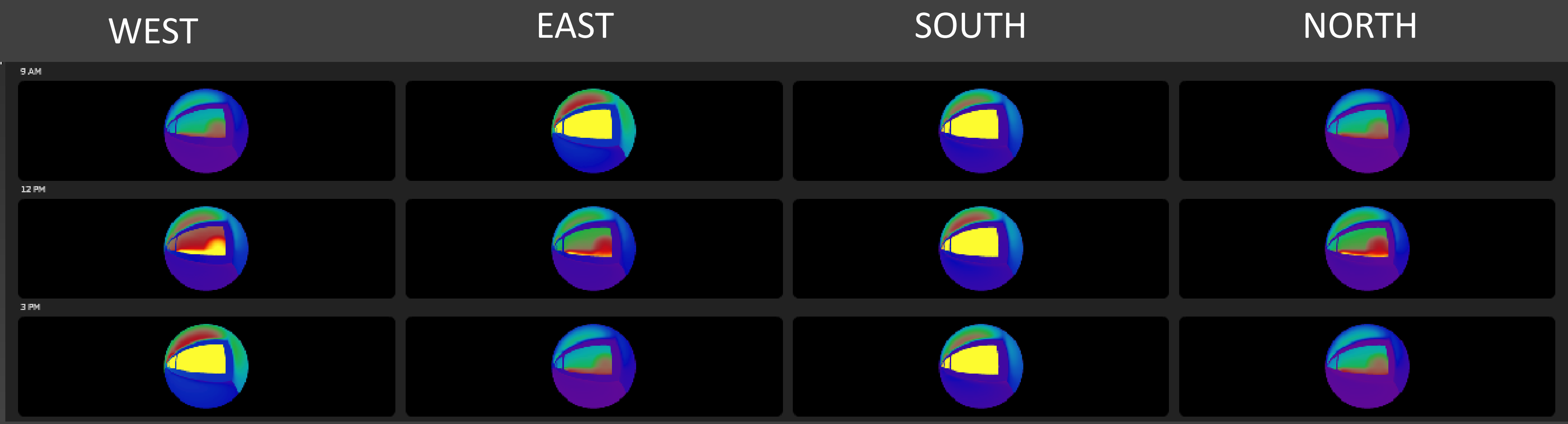
WEST EAST SOUTH NORTH



WINTER



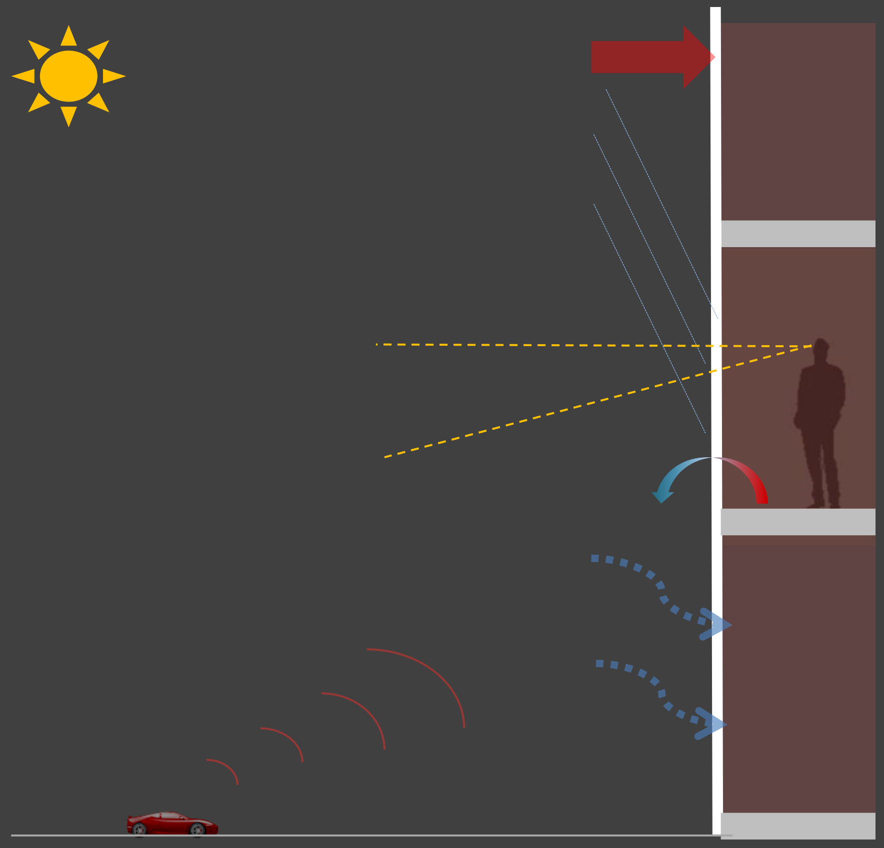
SWING SEASON



FAÇADE REQUIREMENTS

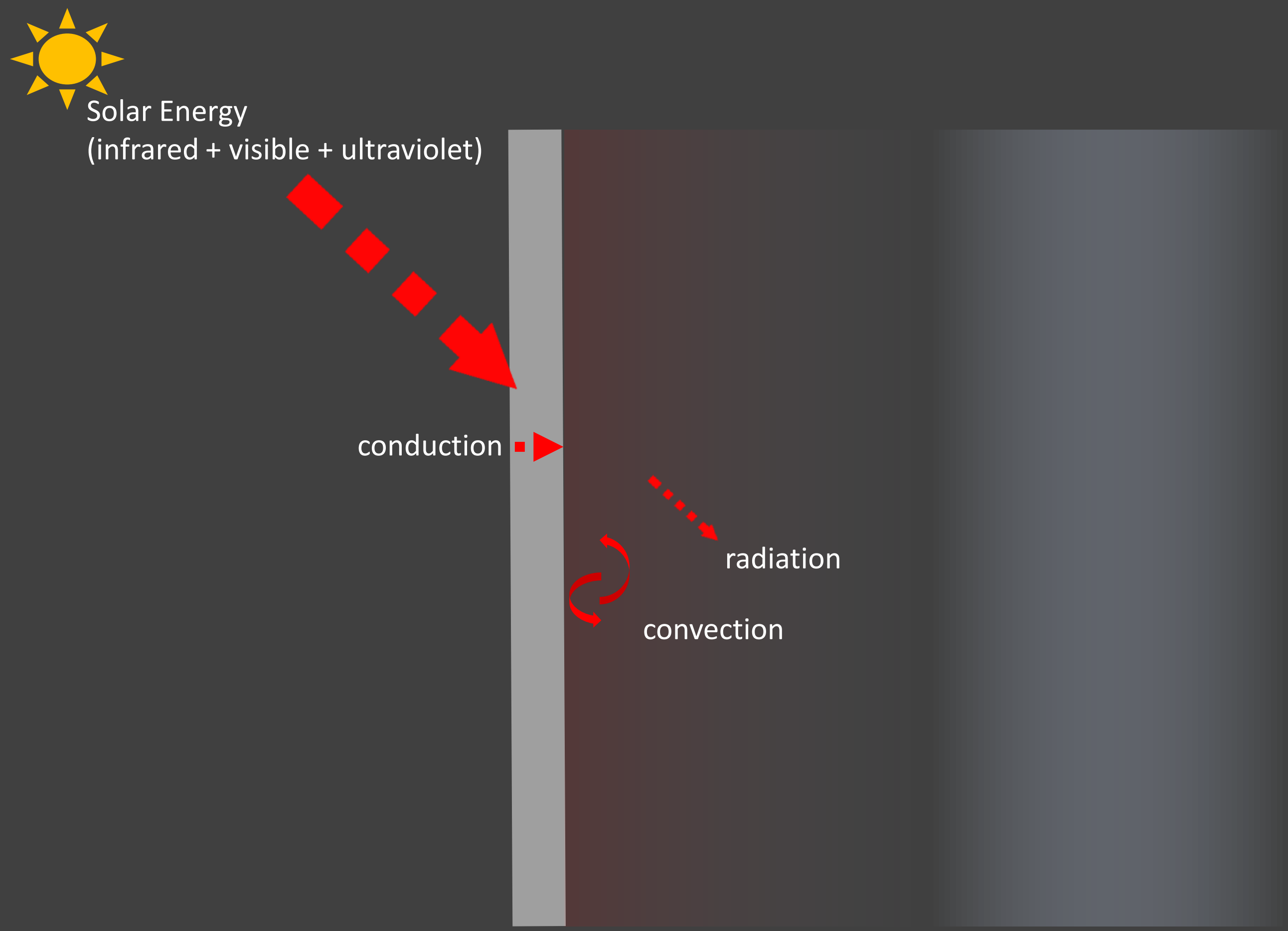
	NORTH	SOUTH	EAST/WEST
SUMMER	Control lighting (glare)	Control lighting (glare) Control heat gain	Control lighting (glare) Control heat gain
WINTER	Prevent heat losses (day & night) Allow adequate light levels	Control lighting (glare) Prevent heat losses (night) Capture solar heat	Prevent heat losses (night)
SWING SEASON		Control lighting (glare)	Control lighting (glare)
POSSIBLE SOLUTIONS	1. Interior shading devices 2. Improve U-Value of glass: • Add coatings (inside layers) • Add panes	1. Exterior shading devices (reflective) 2. Improve U-Value of glass: • Add coatings • Add panes	1. Exterior shading devices 2. Improve U-Value of glass: • Add coatings • Add panes

FAÇADE FUNCTIONS

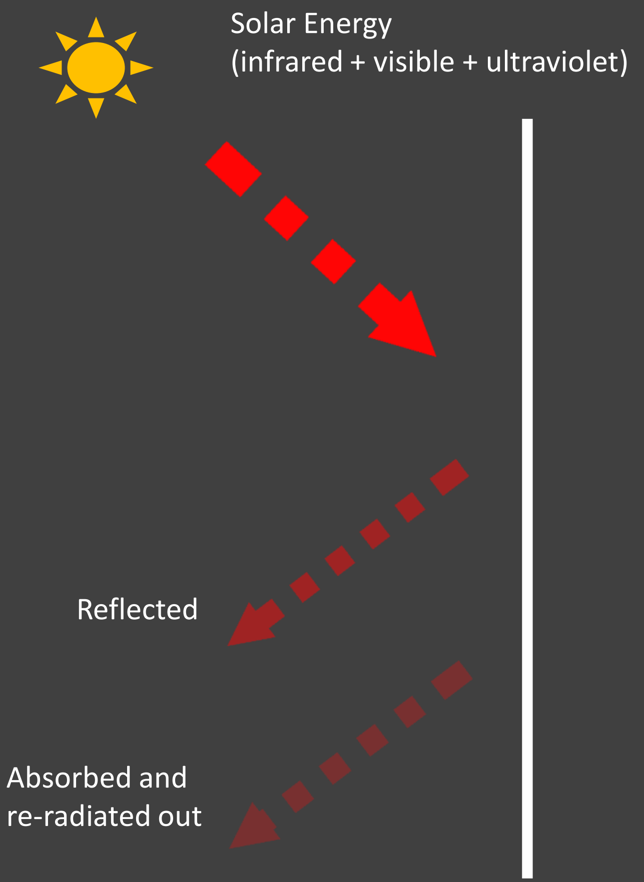


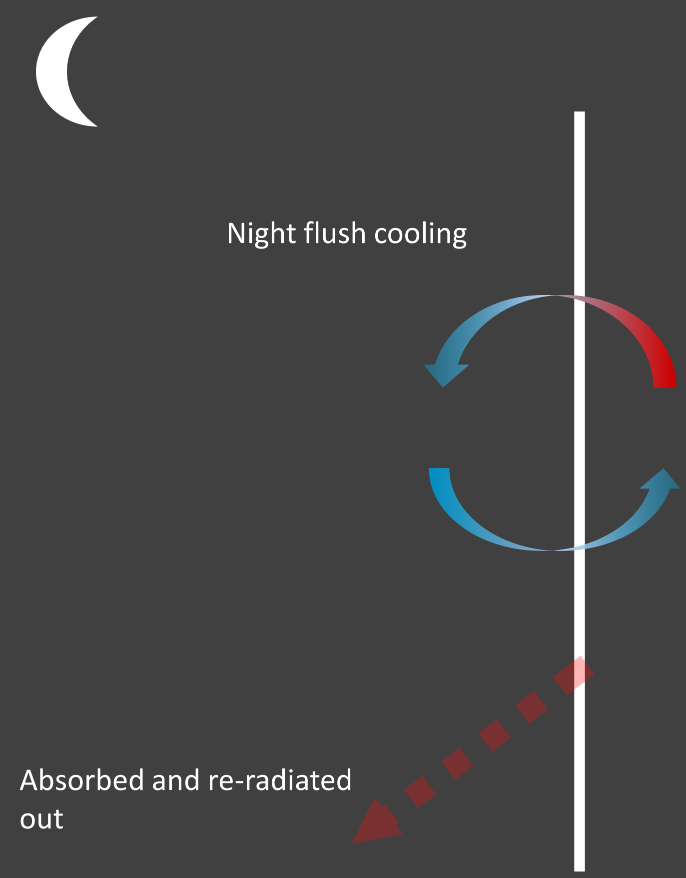
- Protection from solar energy
- Waterproofing
- Ventilation
- Interior loads
- Thermal insulation
- Acoustic
- Wind loads
- Views
- Building appearance

HEAT TRANSFER AT THE FACADE



SUMMER Strategies

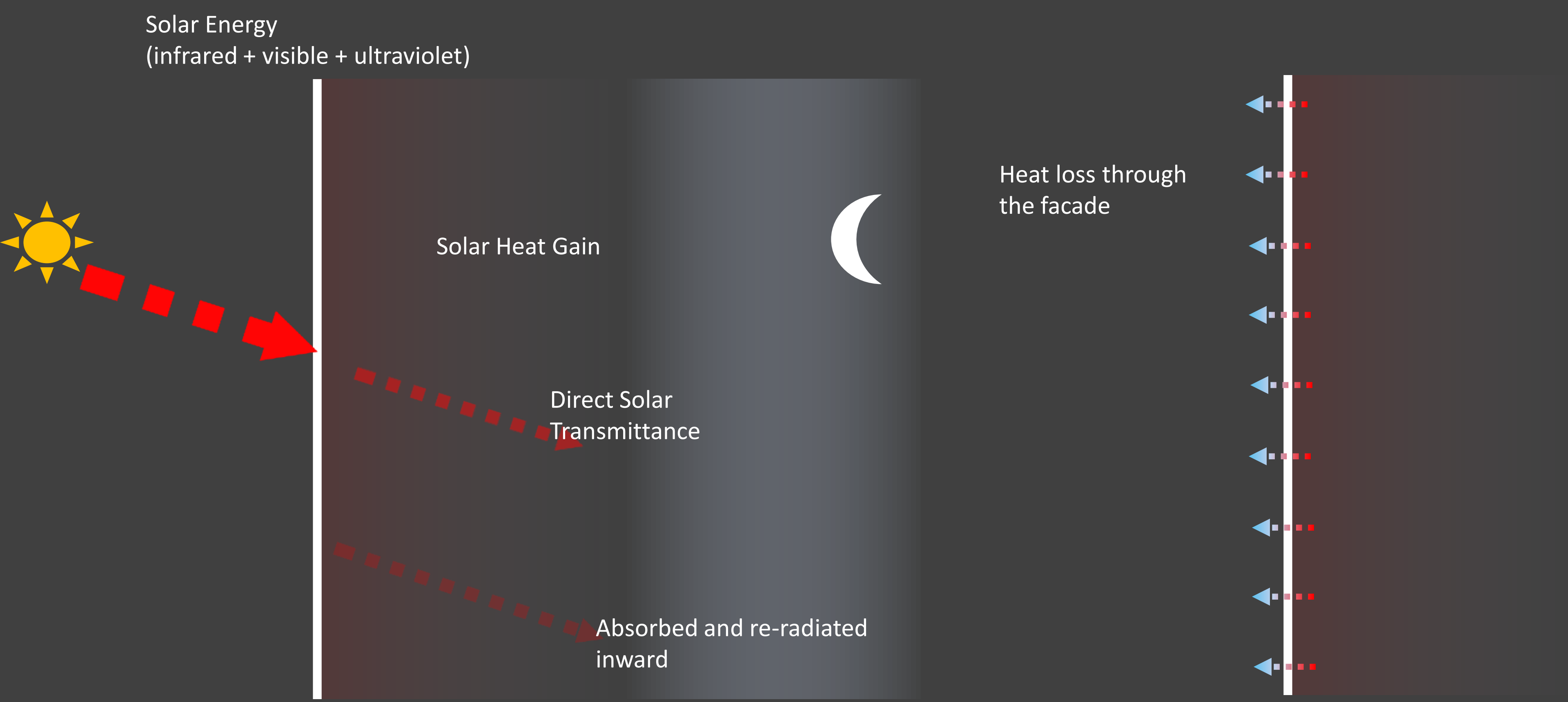




- Direct solar transmittance and absorbed and re-radiated inward need to be minimized
- Reflected and absorbed and re-radiated out need to be maximized
- Indoor daylight levels need to be balanced
- Possibility for natural ventilation with shading

- Night flush cooling to release heat built up during daytime
- Radiation to lose heat built up needs to be maximized

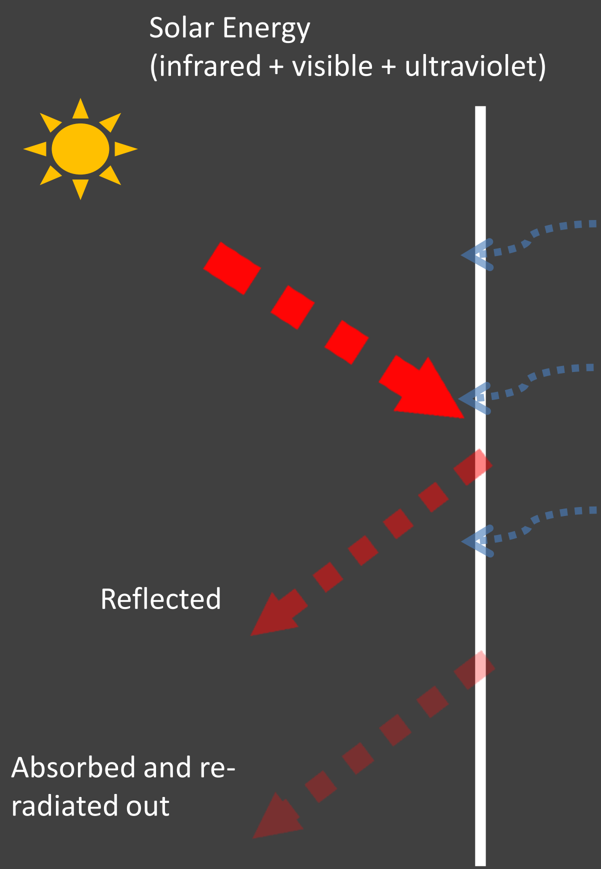
WINTER Strategies



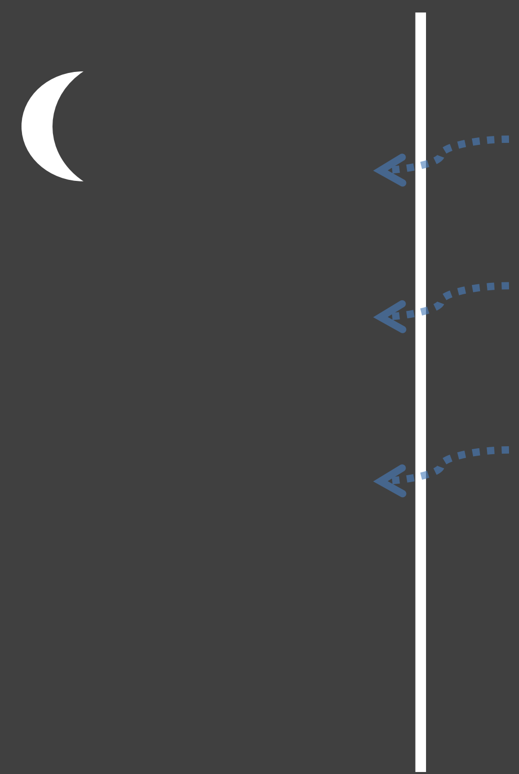
- Direct solar transmittance and absorbed and re-radiated inward needs to be maximized
- Reflected and absorbed and re-radiated out needs to be minimized
- Indoor daylight levels need to be balanced

- Heat losses through building skin need to be minimized

SWING SEASON Strategies

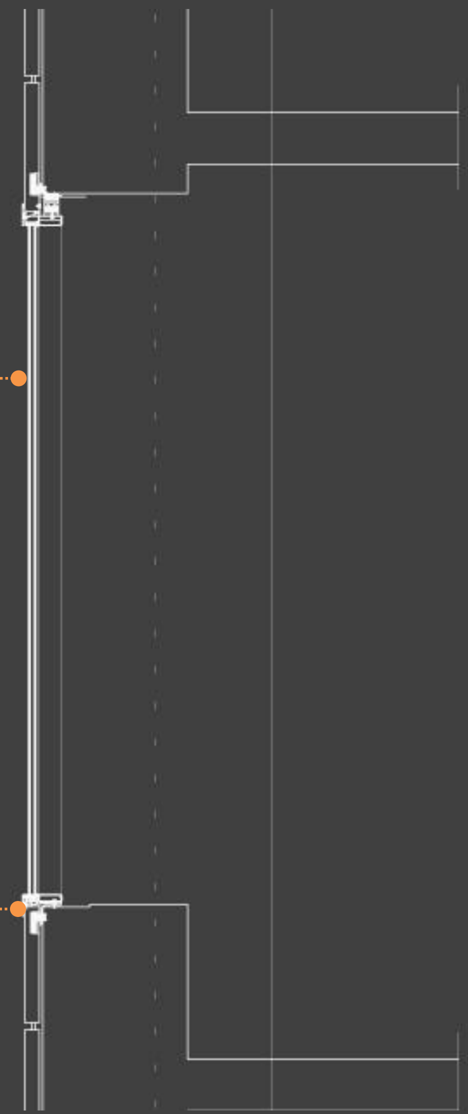


- Natural Ventilation strategies
- Adequate adaptability for increased/decreased shading/solar transmittance



- Natural Ventilation strategies
- Maximize adaptability of the facade

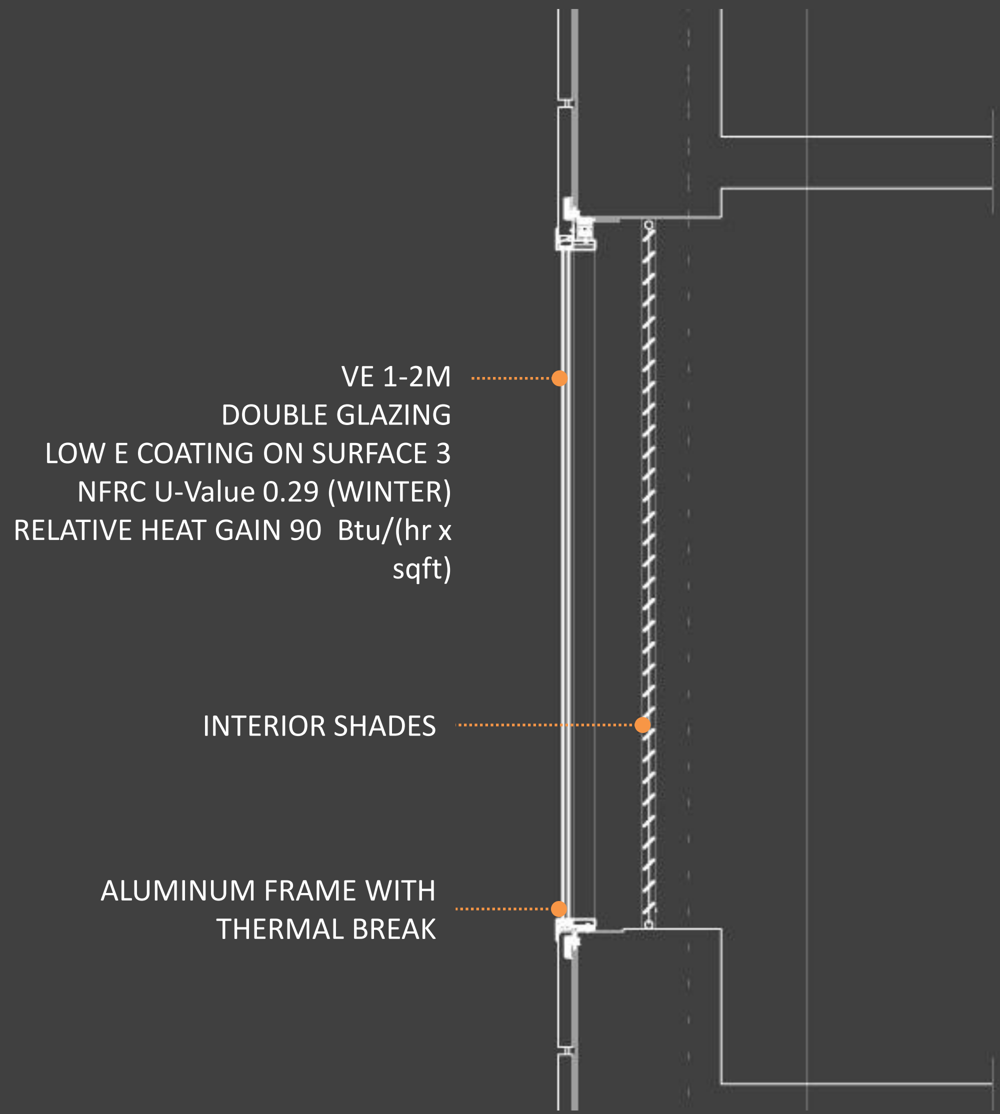
NORTH FAÇADE
Option 1



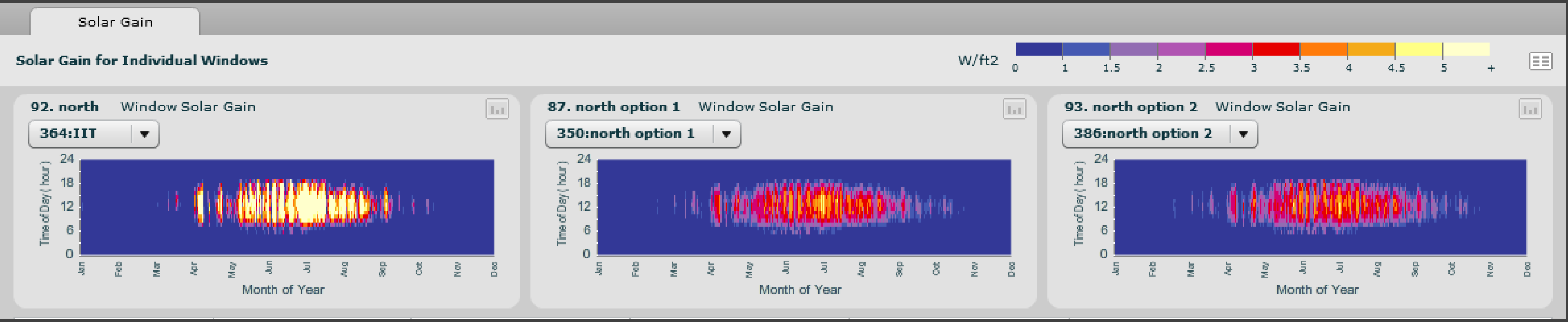
VE 1-2M
DOUBLE GLAZING
LOW E COATING ON SURFACE 3
NFRC U-Value 0.29 (WINTER)
RELATIVE HEAT GAIN 90 Btu/(hr x sqft)

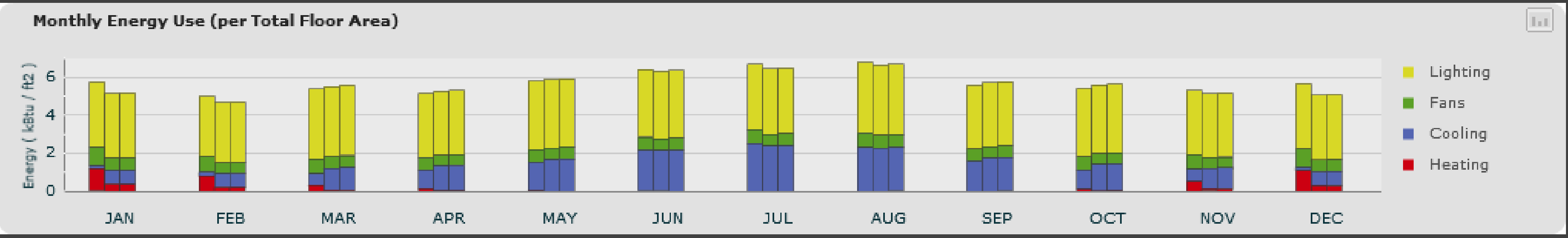
ALUMINUM FRAME WITH THERMAL BREAK

NORTH FAÇADE
Option 2

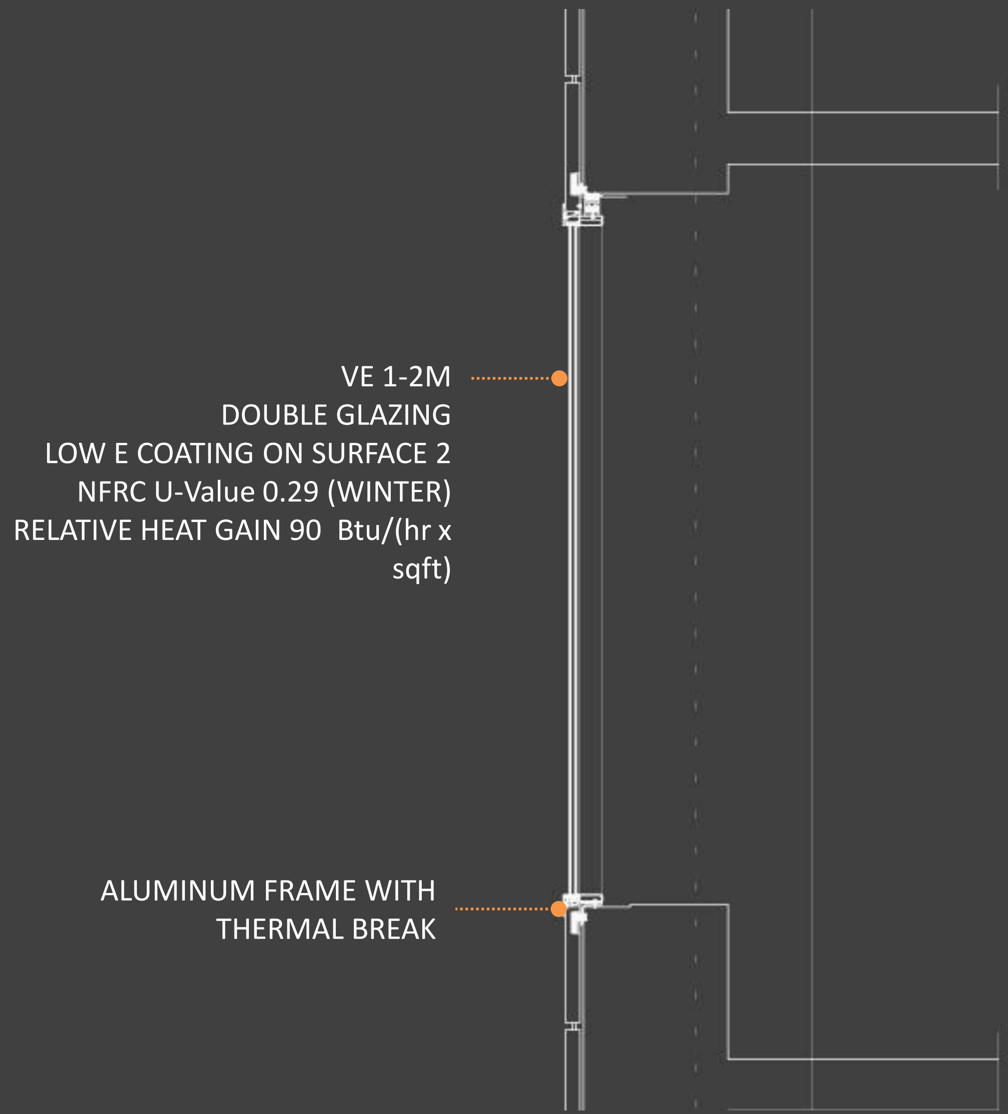


NORTH FAÇADE
Evaluation

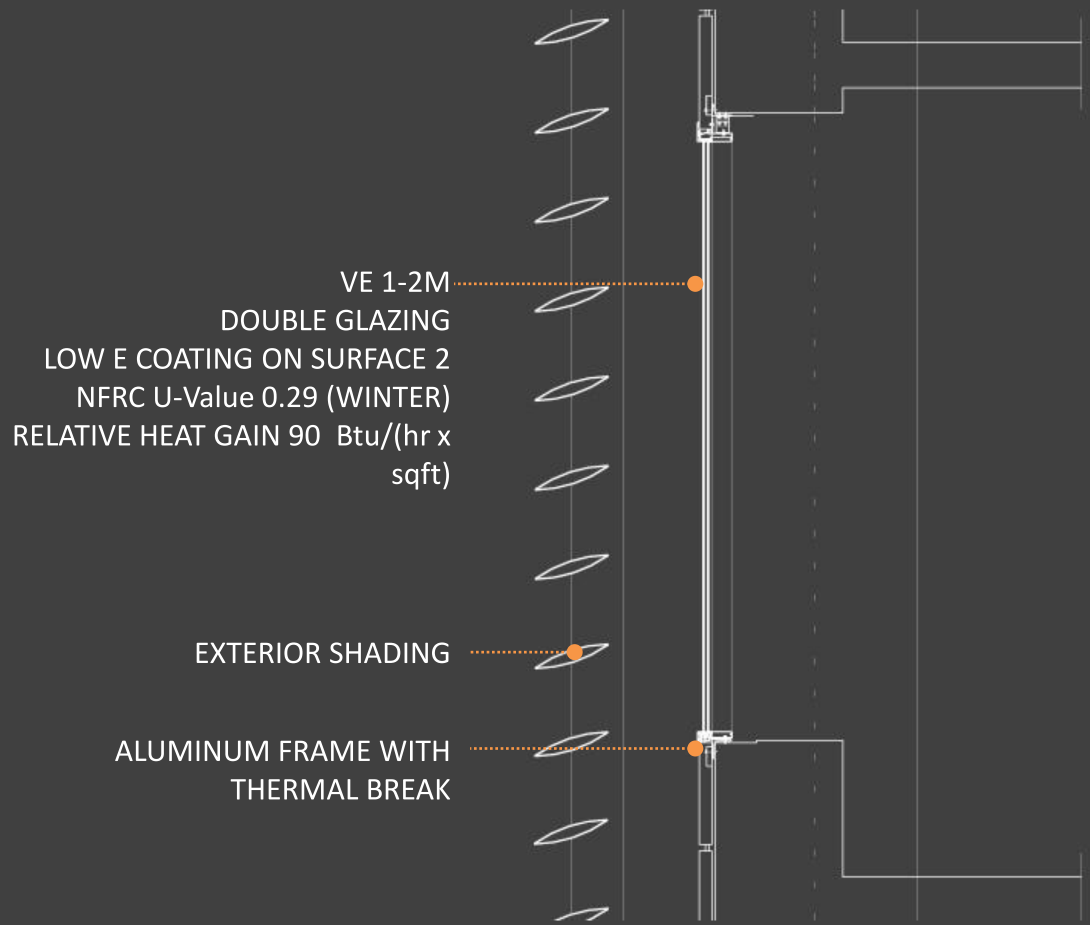




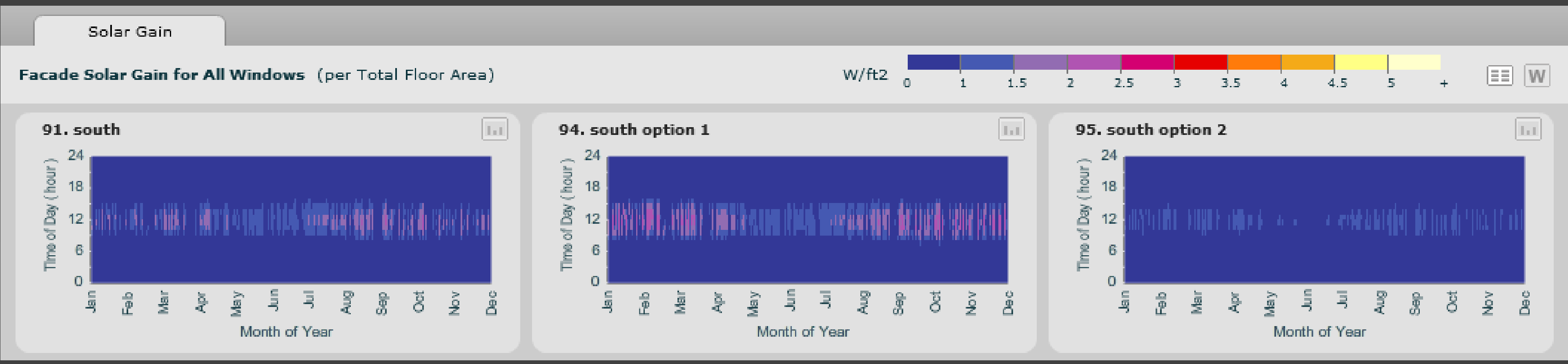
SOUTH FAÇADE
Option 1

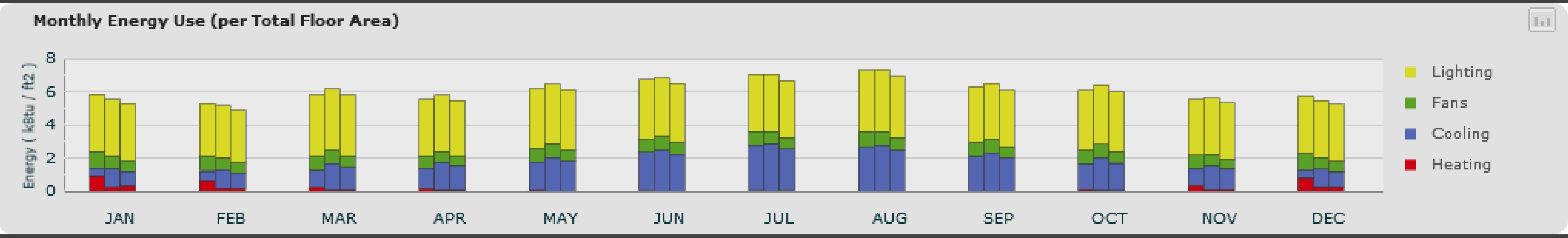


SOUTH FAÇADE
Option 2

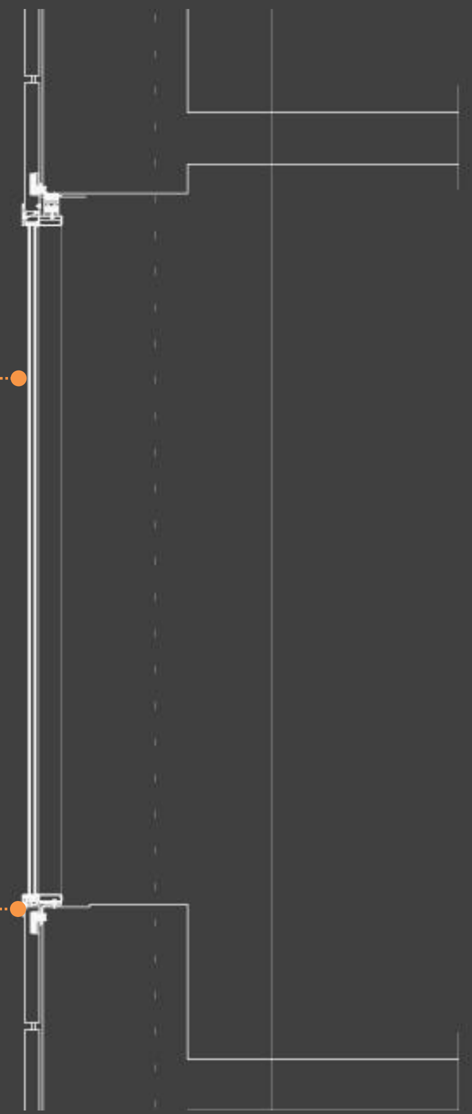


SOUTH FAÇADE Evaluation





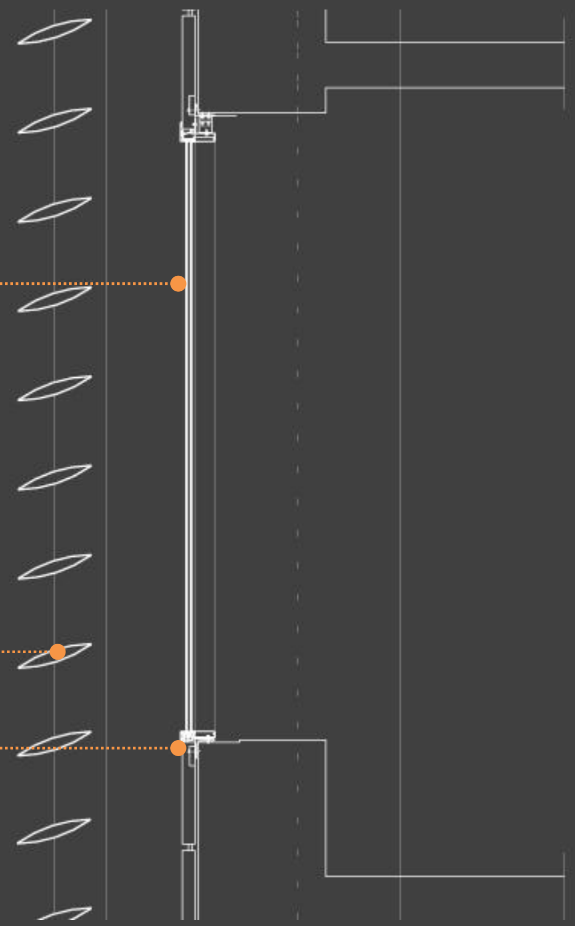
EAST/WEST FAÇADE
Option 1



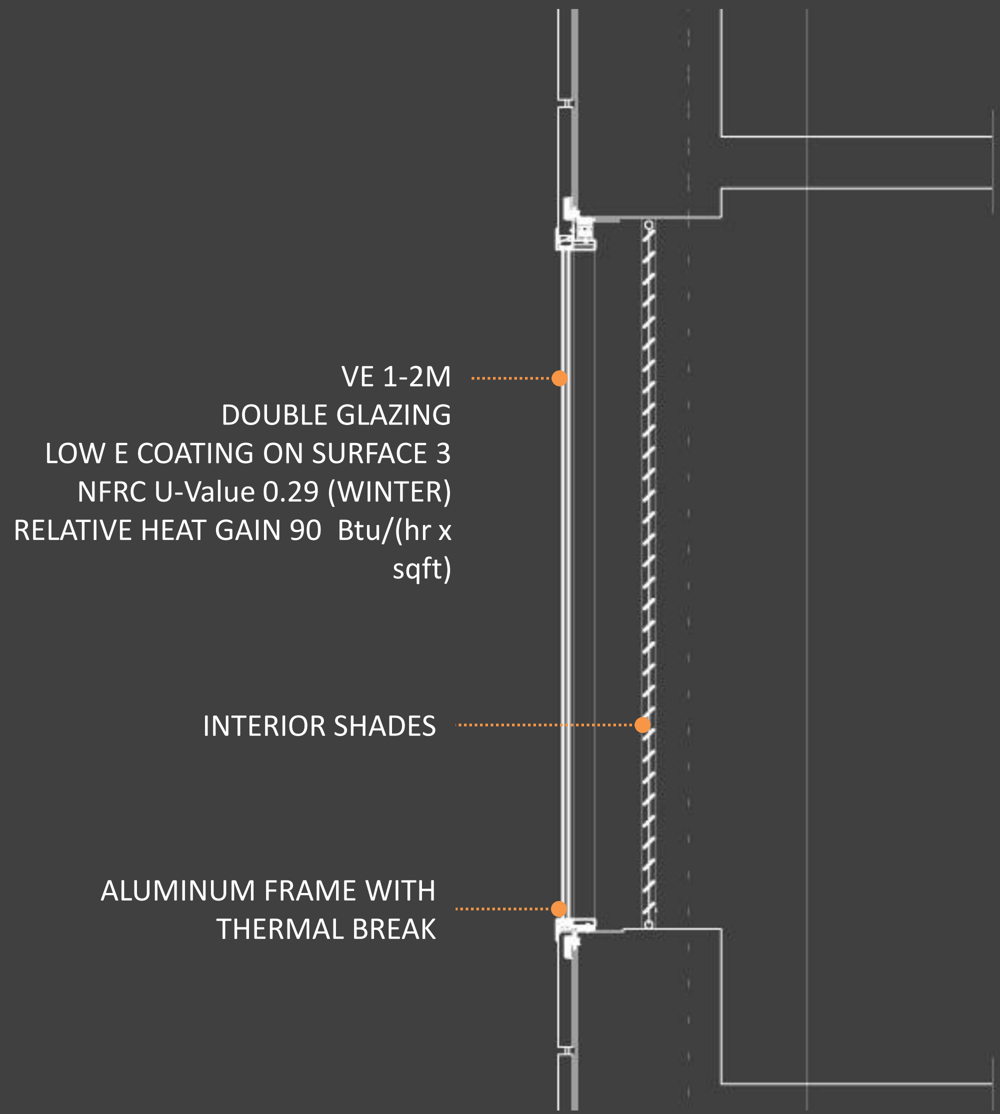
VE 1-2M
DOUBLE GLAZING
LOW E COATING ON SURFACE 2
NFRC U-Value 0.29 (WINTER)
RELATIVE HEAT GAIN 90 Btu/(hr x sqft)

ALUMINUM FRAME WITH THERMAL BREAK

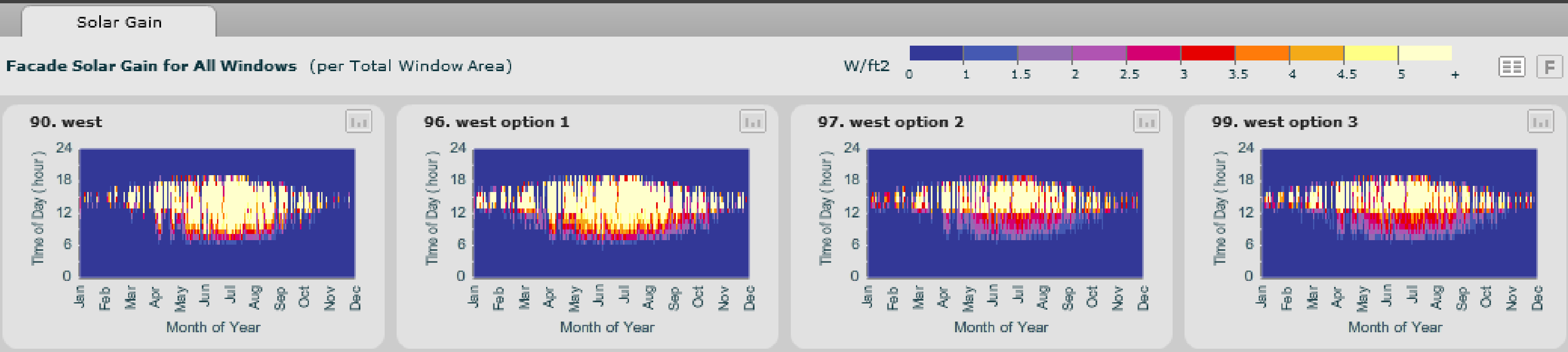
EAST/WEST FAÇADE
Option 2

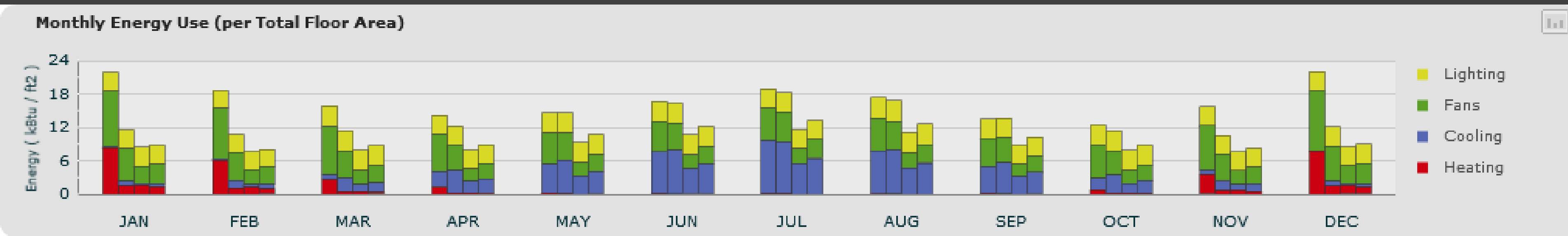


EAST/WEST FAÇADE
OPTION 3

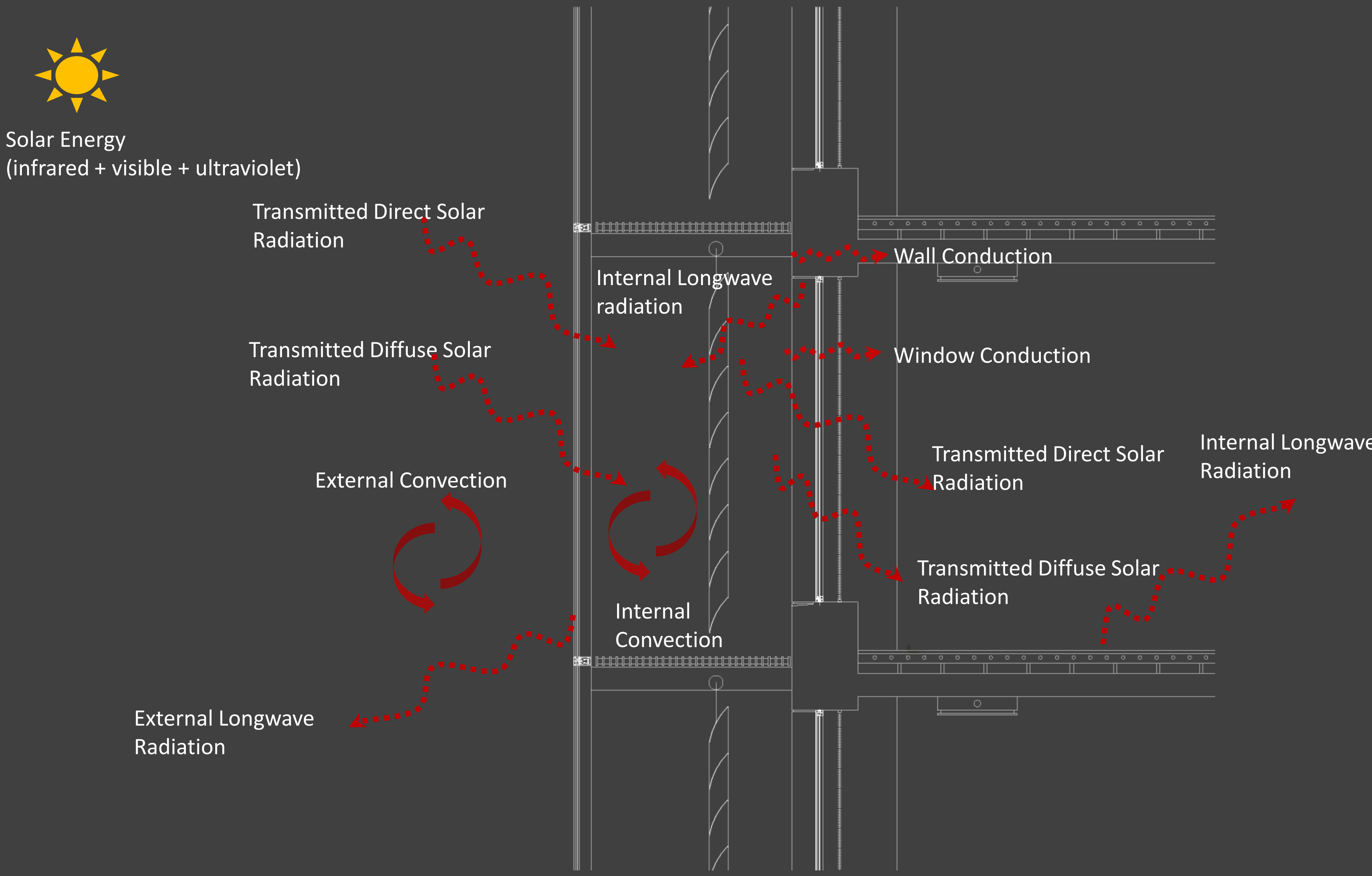


WEST FAÇADE
Evaluation

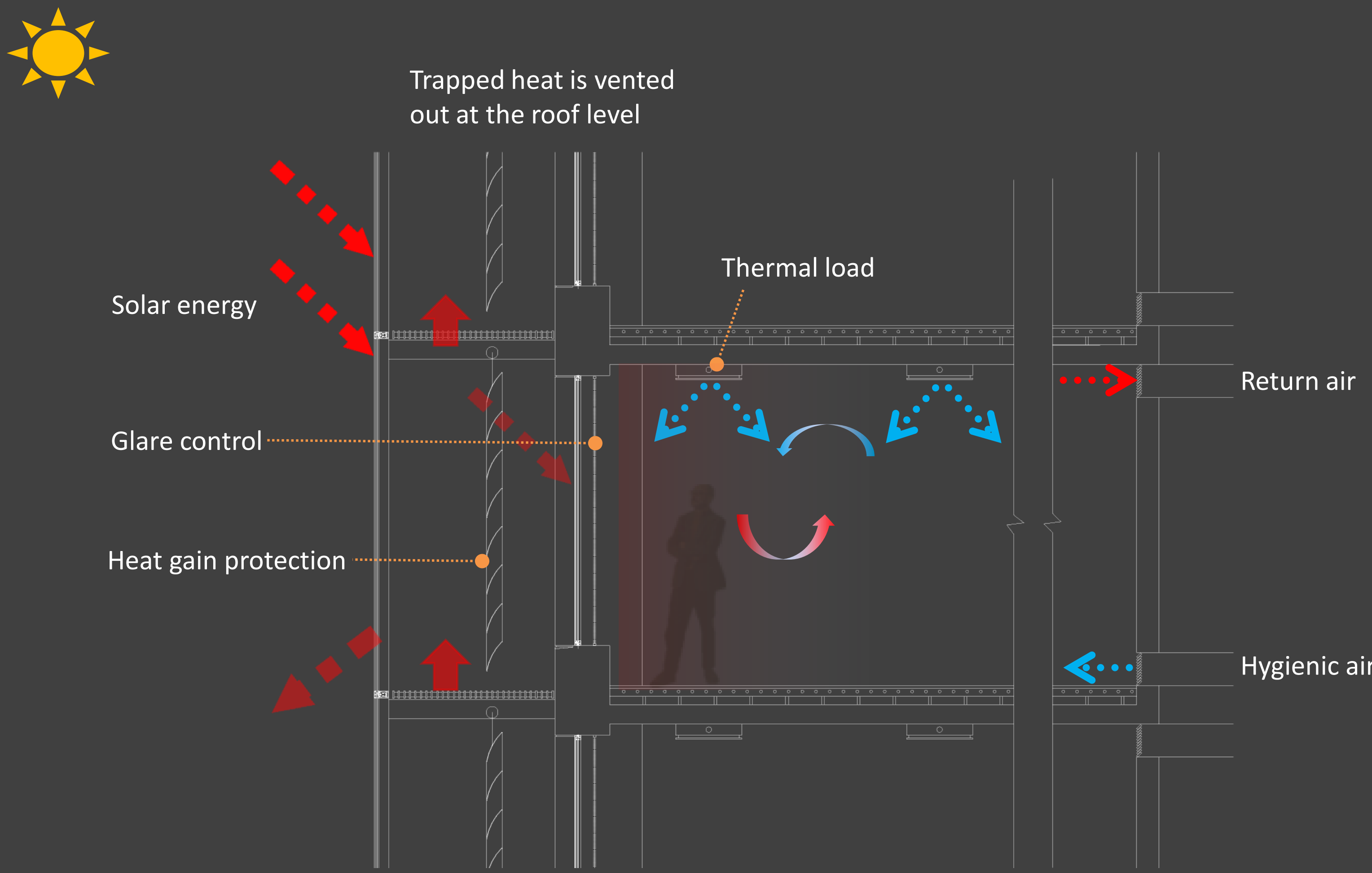




ENERGY FLOWPATHS and DOUBLE SKIN

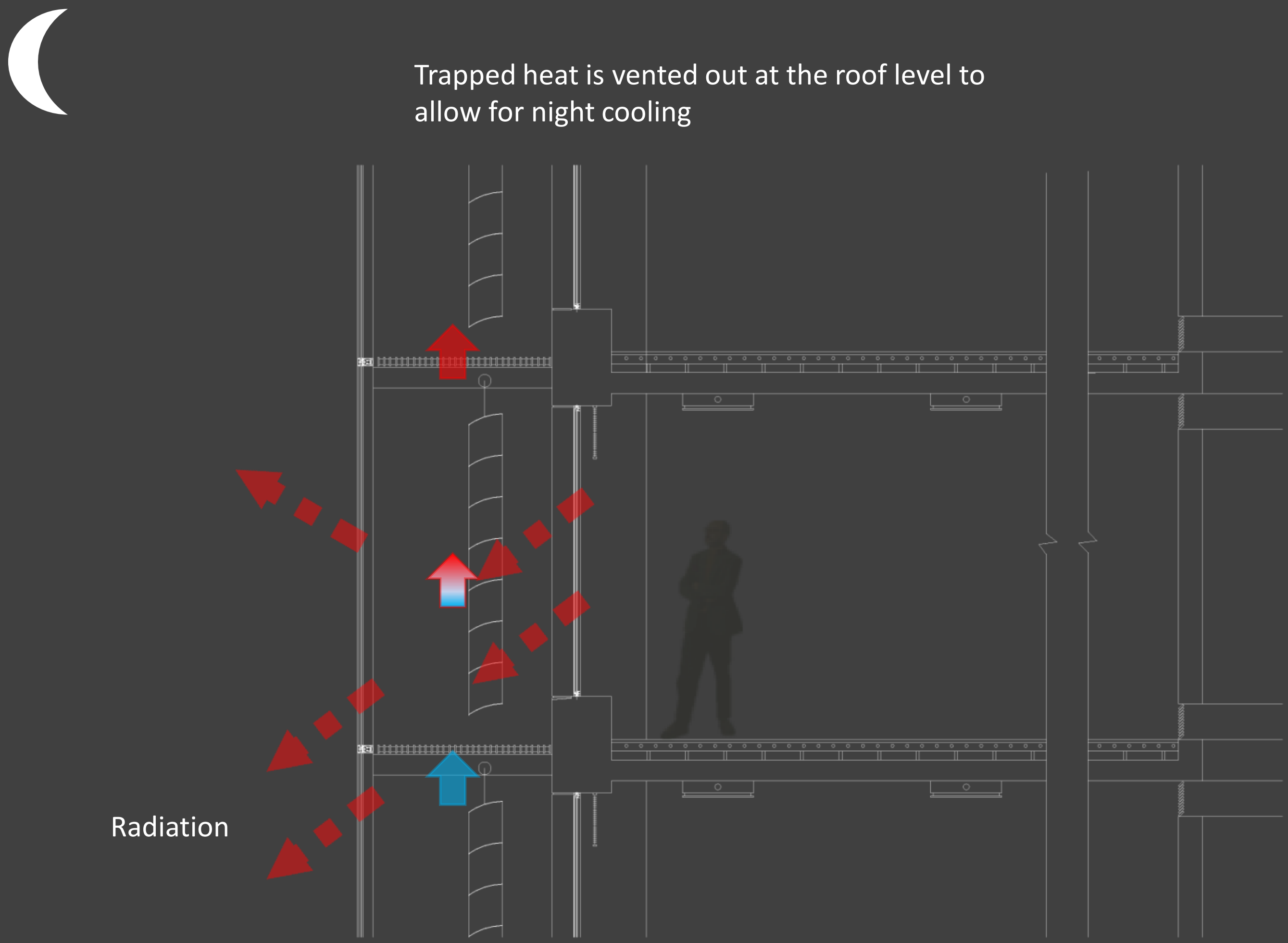


DOUBLE FAÇADE OPTION 1
Summer Day



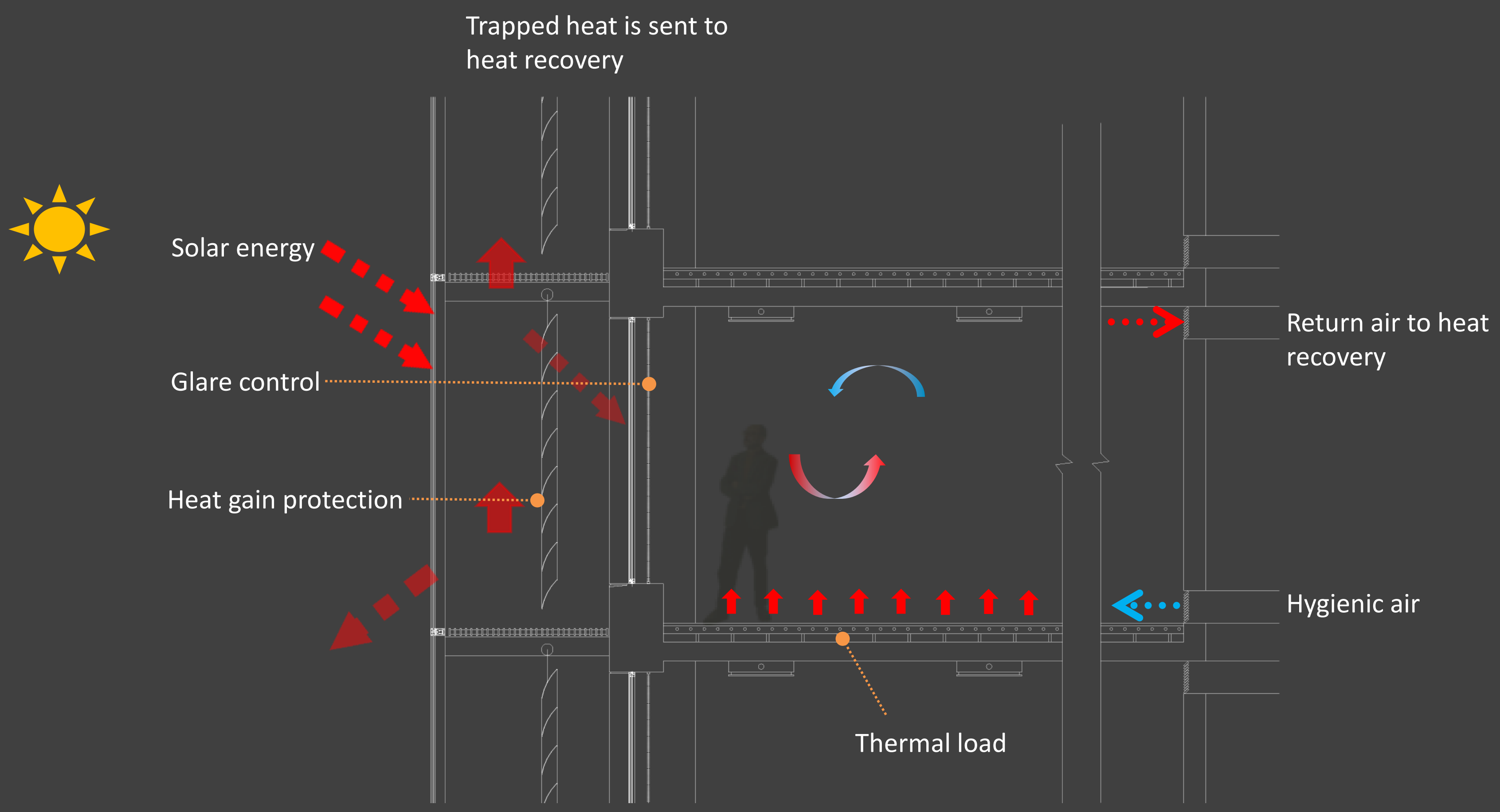
DOUBLE FAÇADE AS A MECHANISM TO REDUCE SOLAR HEAT GAIN

DOUBLE FAÇADE OPTION 1
Summer Night



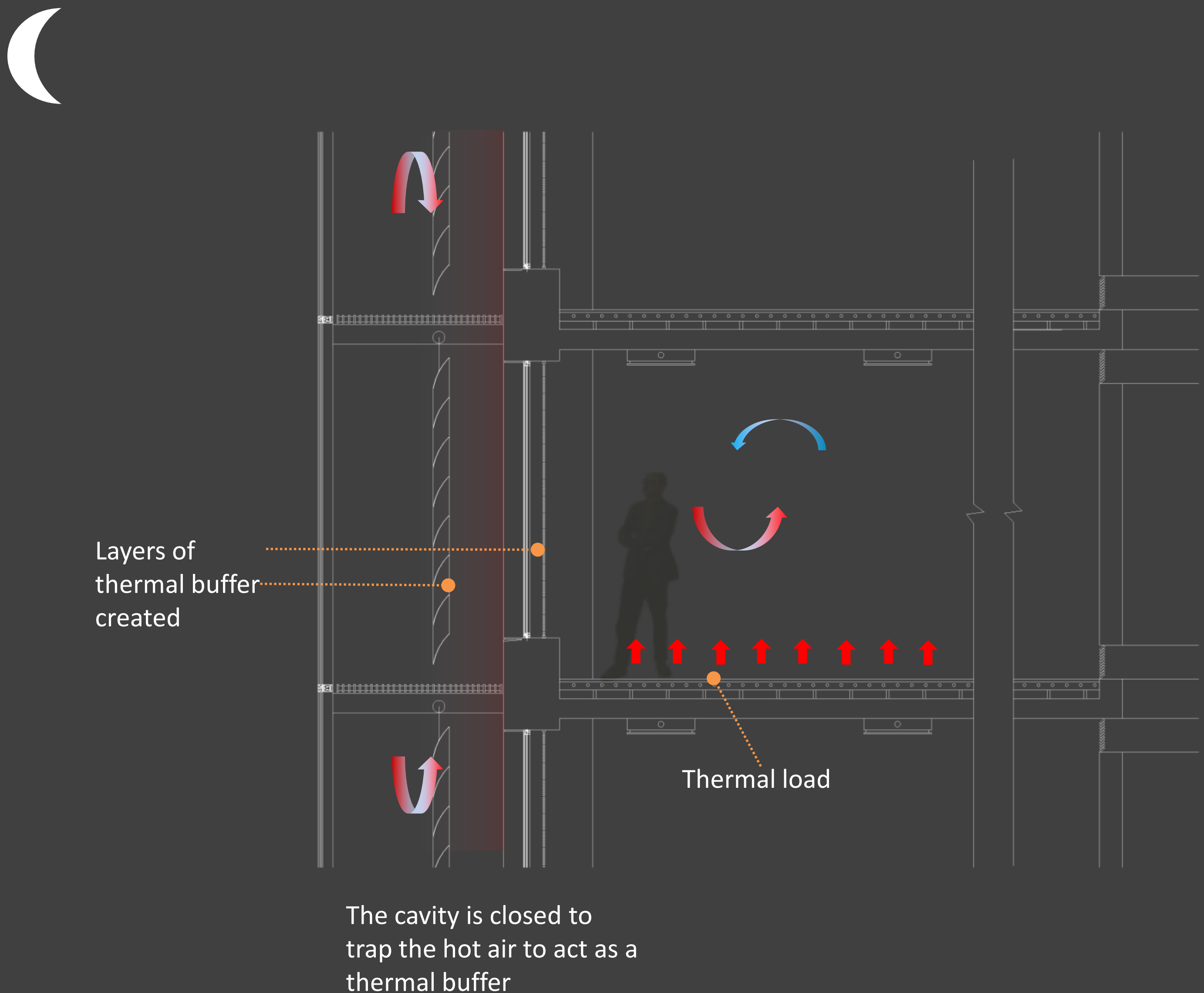
DOUBLE FAÇADE AS A NIGHT COOLING MECHANISM

DOUBLE FAÇADE OPTION 1
Winter Day



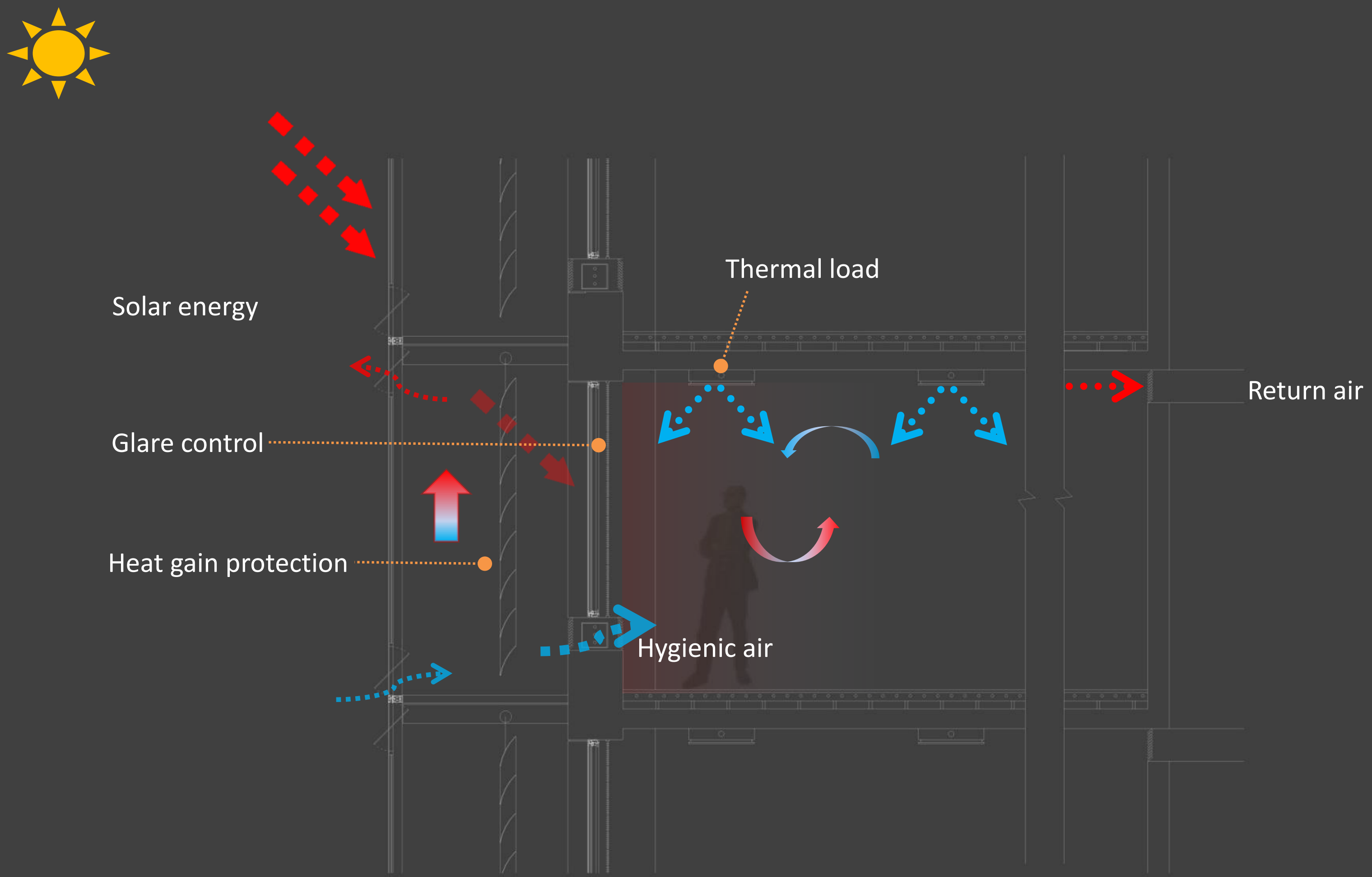
DOUBLE FAÇADE AS A MECHANISM TO INCREASE SOLAR HEAT GAIN

DOUBLE FAÇADE OPTION 1
Winter Night



DOUBLE FAÇADE AS A THERMAL BUFFER

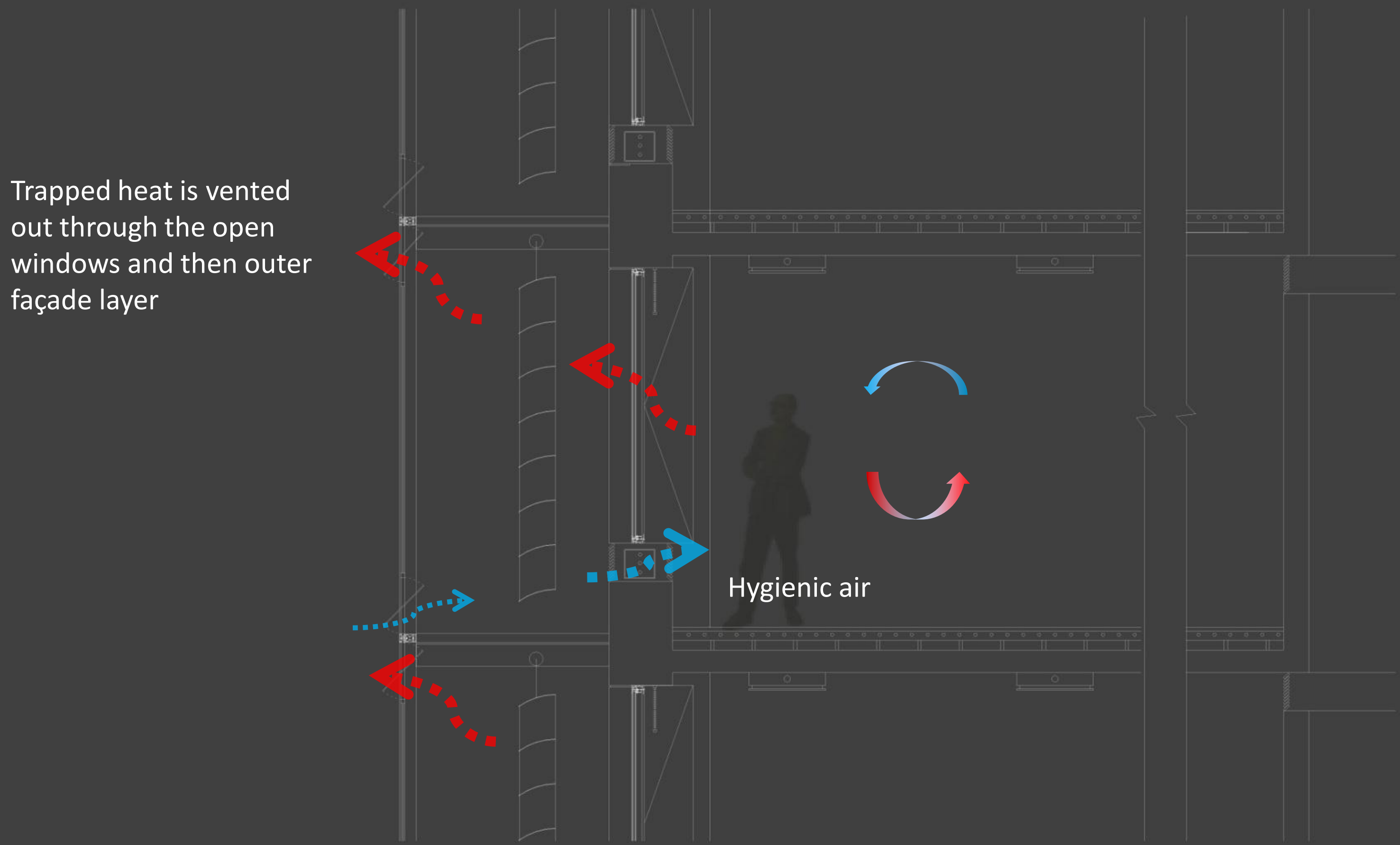
DOUBLE FAÇADE OPTION 2
Summer Day



DOUBLE FAÇADE AS A MECHANISM TO
REDUCE SOLAR HEAT GAIN

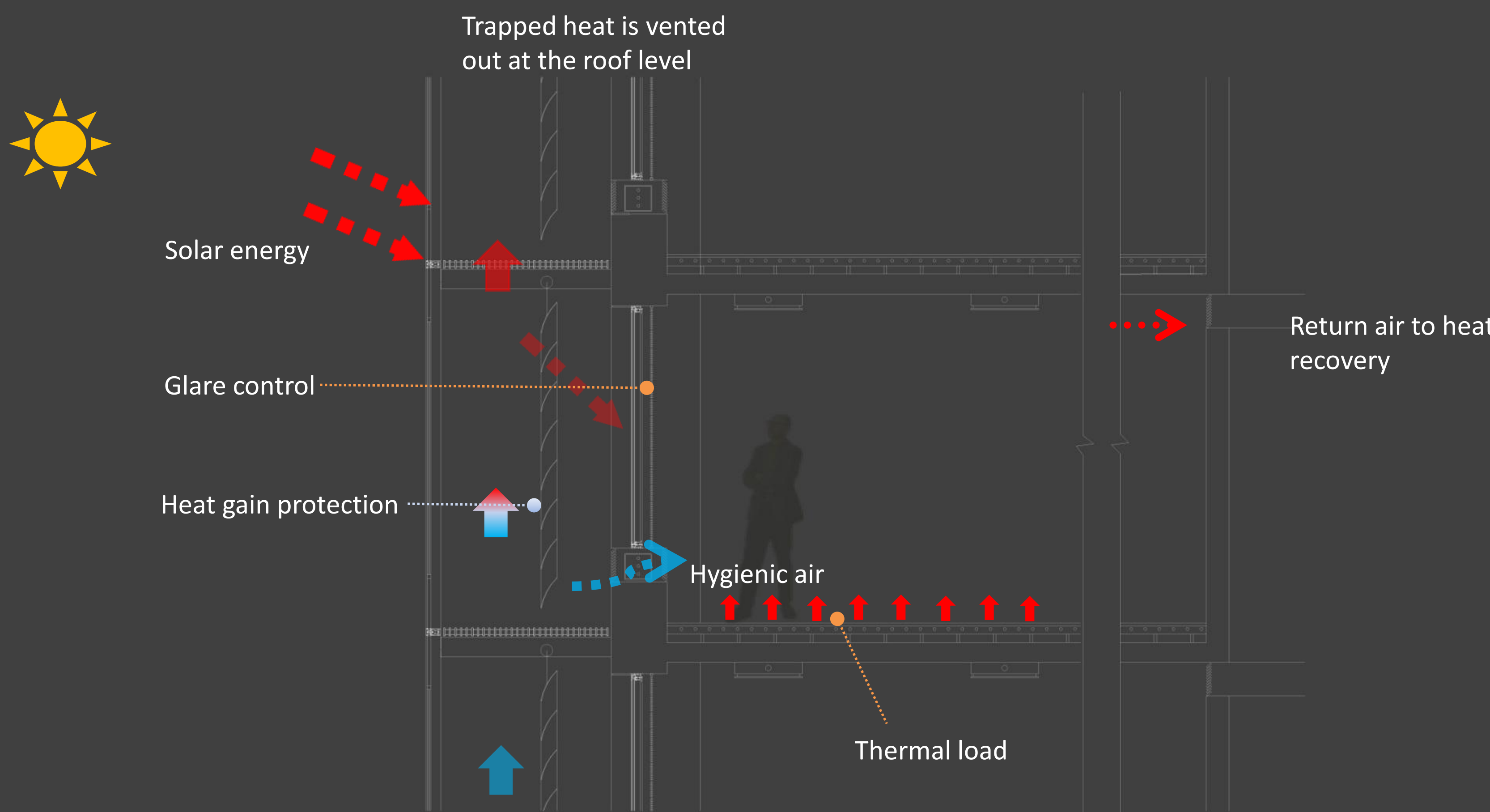
DOUBLE FAÇADE OPTION 2

Summer Night



DOUBLE FAÇADE AS A NIGHT COOLING MECHANISM

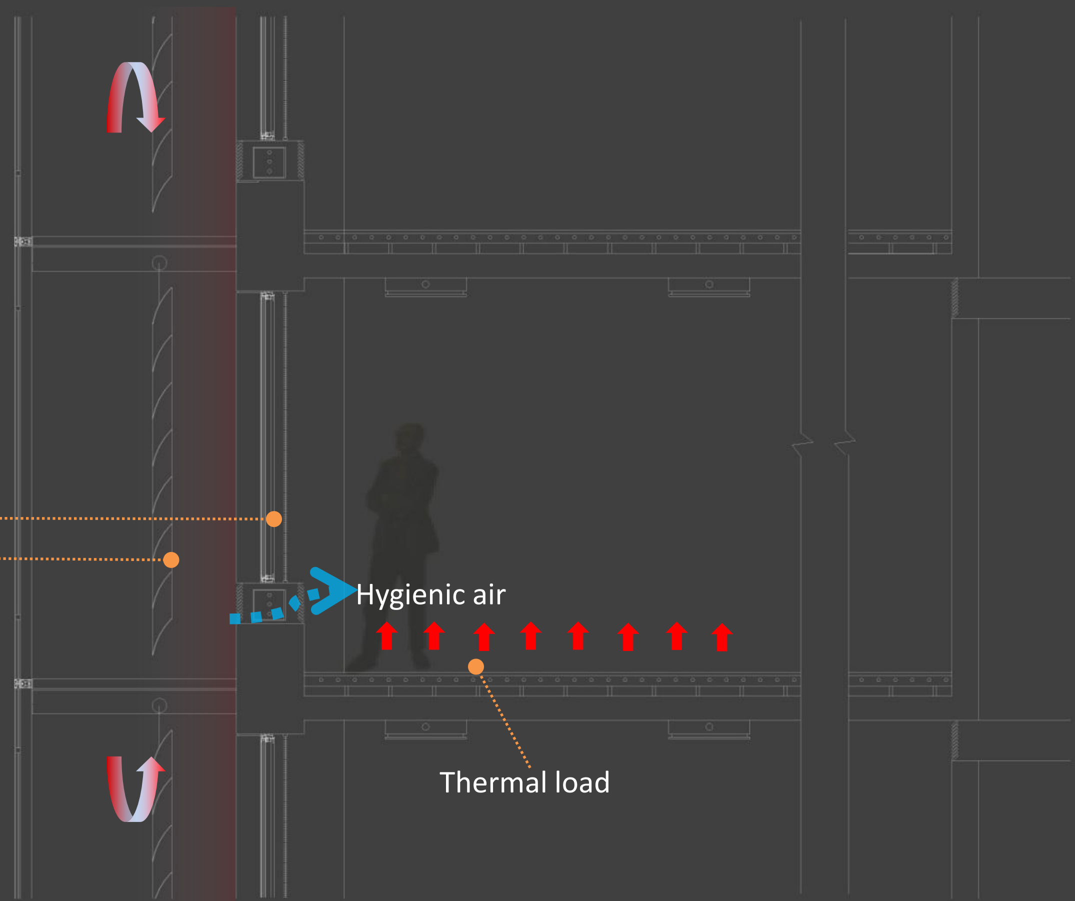
DOUBLE FAÇADE OPTION 2
Winter Day



Air let in at the ground level heats up and rises, provides for warmer hygienic air intake

DOUBLE FAÇADE AS A MECHANISM TO PRE-HEAT HYGIENIC AIR INTAKE

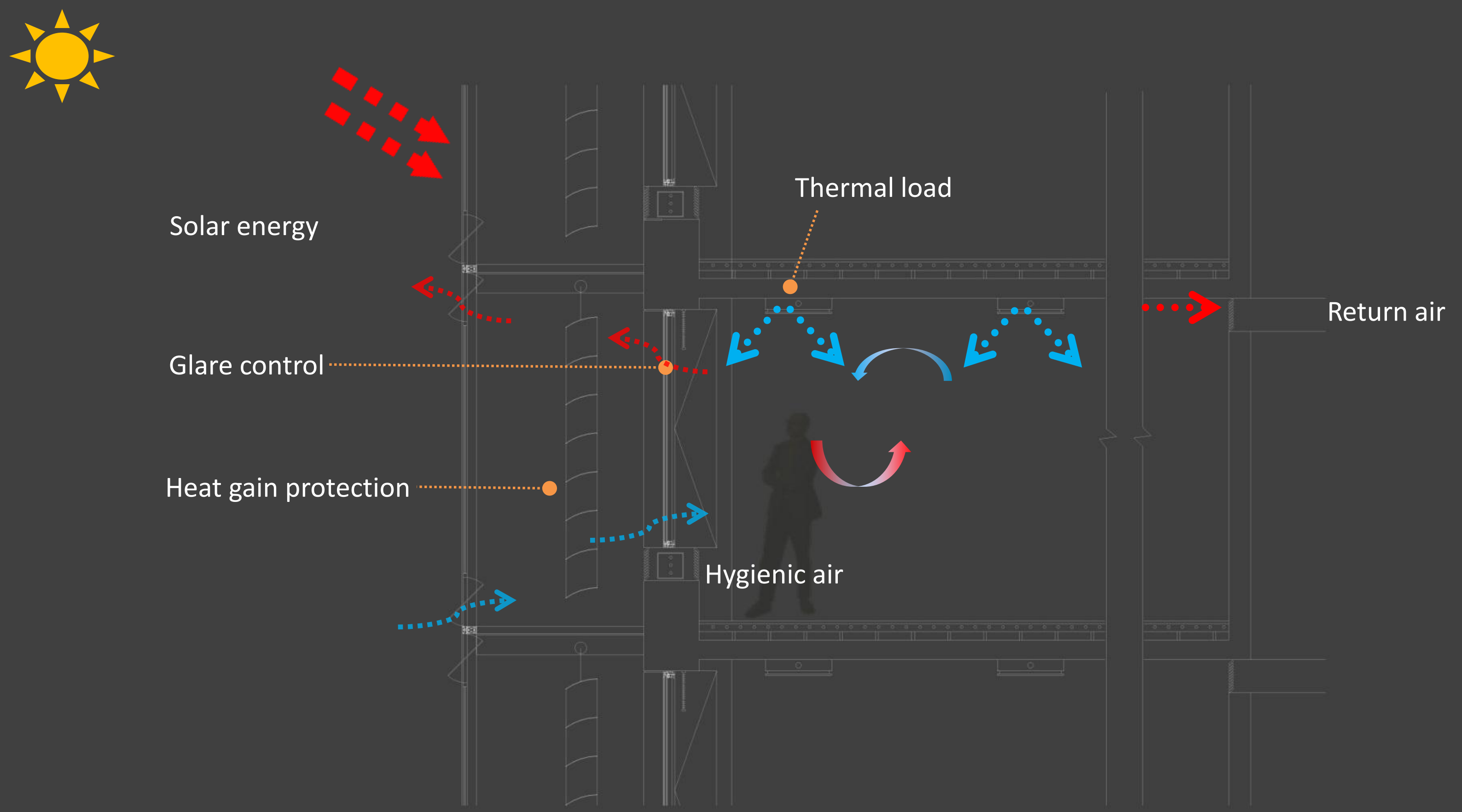
DOUBLE FAÇADE OPTION 2
Winter Night



The cavity is closed to trap the hot air to act as a thermal buffer to prevent heat losses

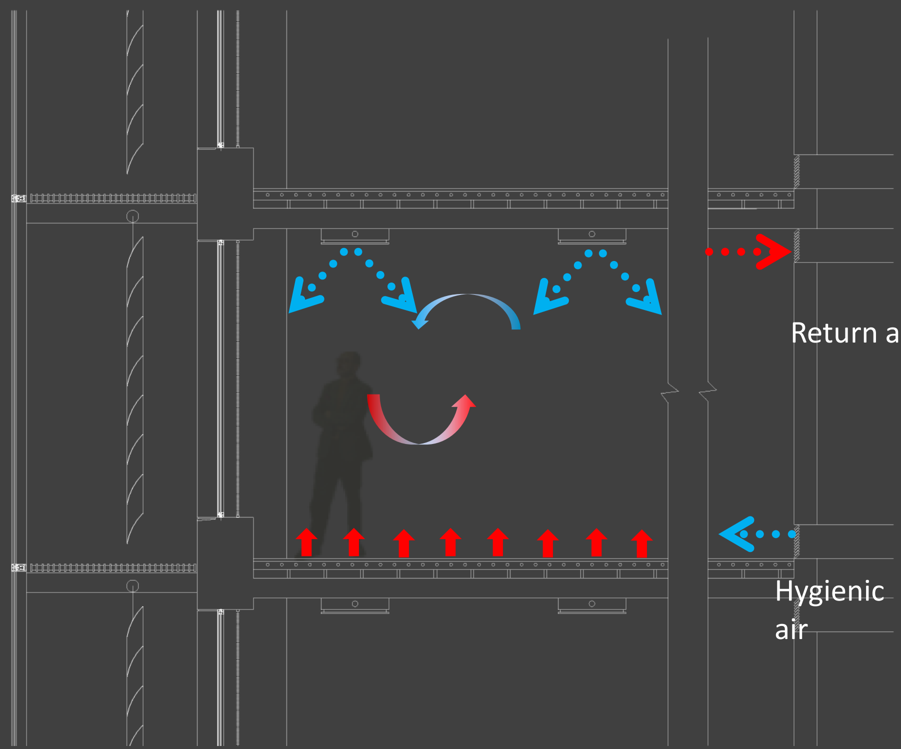
DOUBLE FAÇADE AS A THERMAL BUFFER

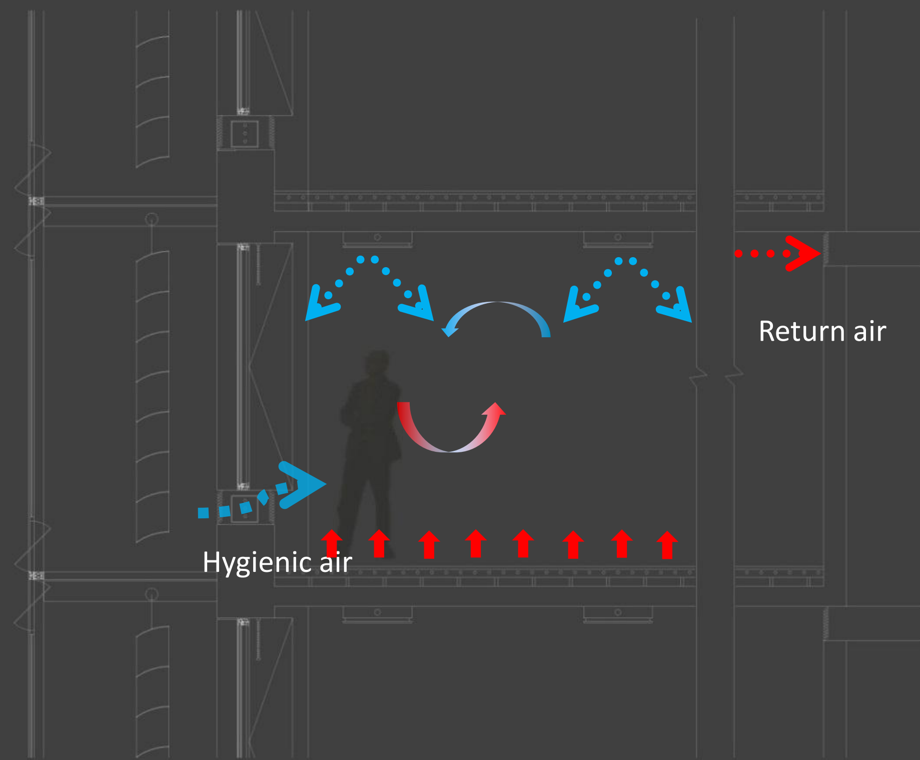
DOUBLE FAÇADE OPTION 2
Swing Season Day/Night



Adaptability of the façade to allow for natural ventilation

OPTIONS 1 & 2 - CONCLUSIONS

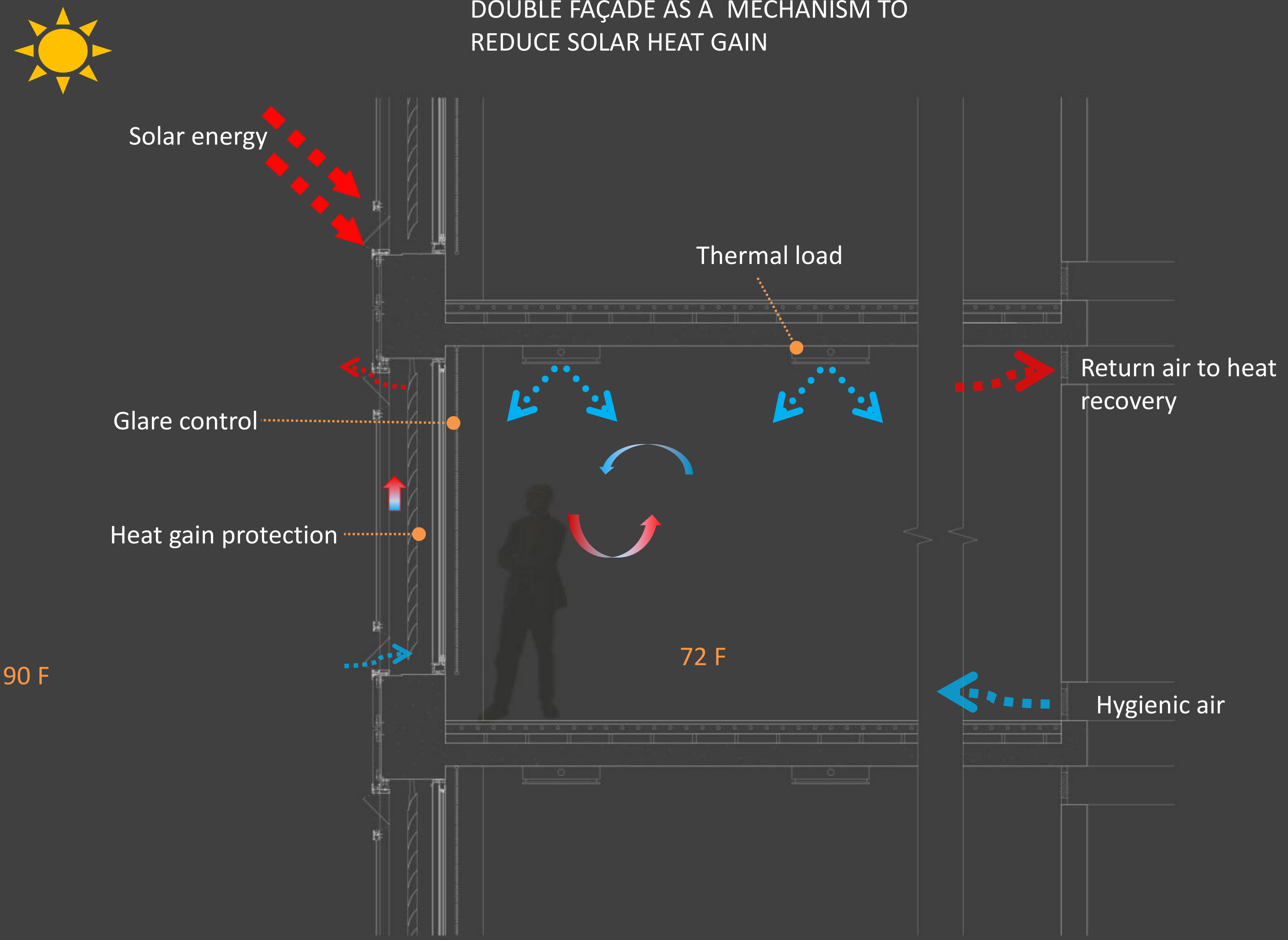




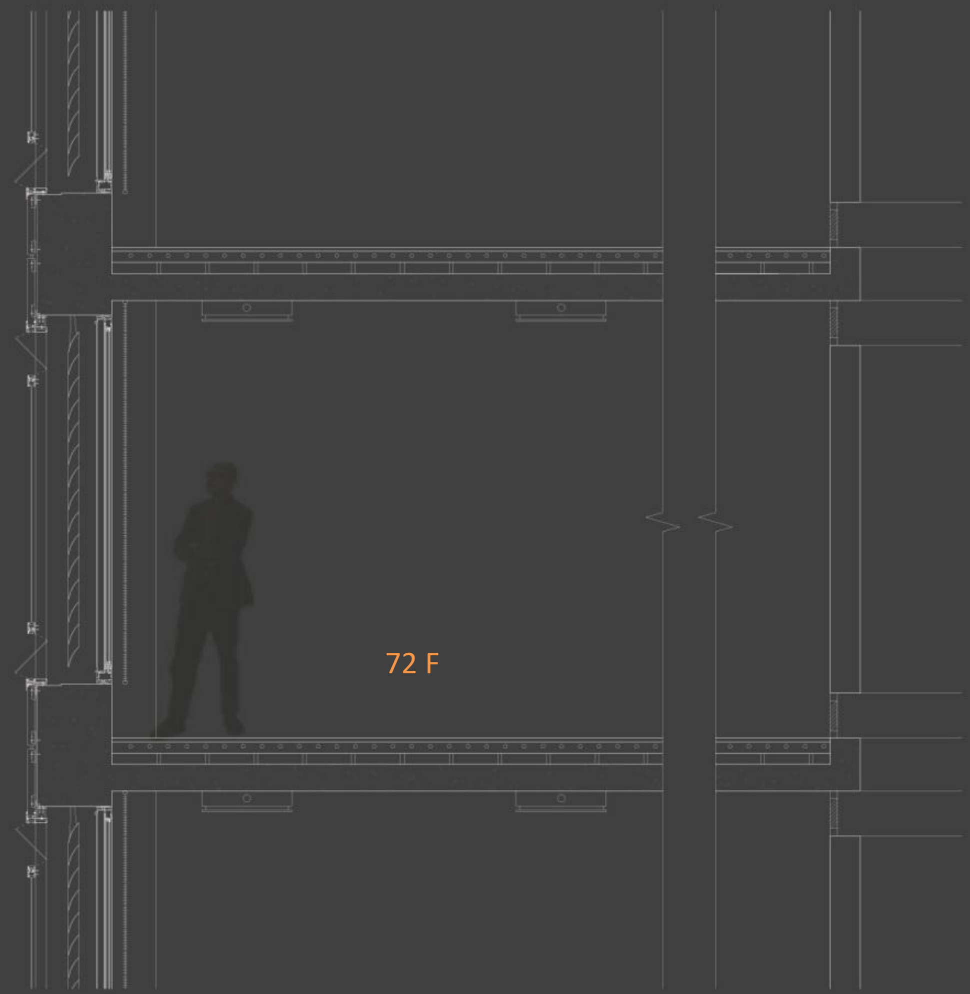
- Due to smaller diurnal range in temperature in the Summer, night cooling does not work very well
- The building having 15+ floors, the multistorey double wall does not work very well
- More adaptability for natural ventilation/hybrid mode

DOUBLE FAÇADE OPTION 3
Summer Day

DOUBLE FAÇADE AS A MECHANISM TO REDUCE SOLAR HEAT GAIN



DOUBLE FAÇADE OPTION 3
Summer Night



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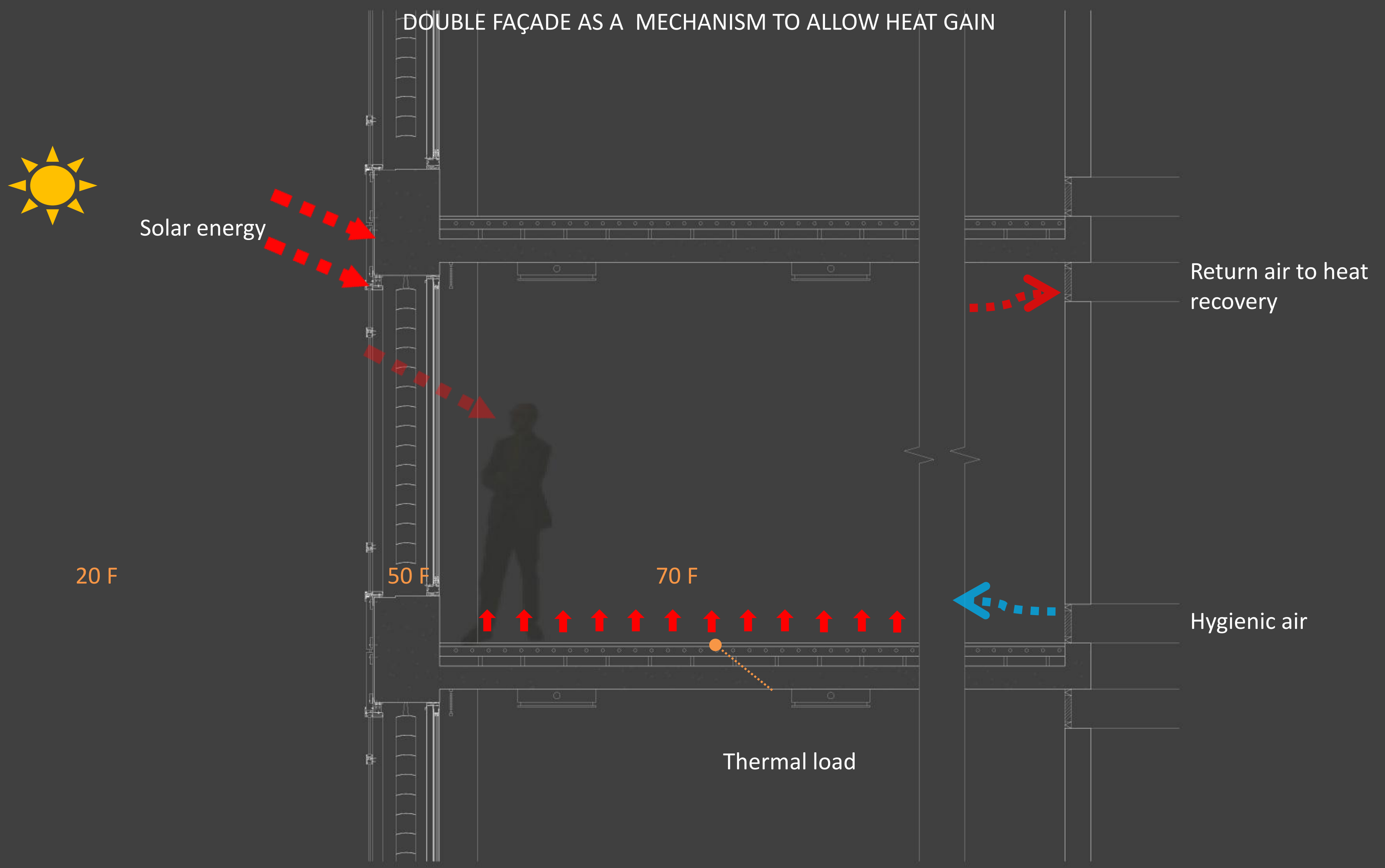
DOUBLE FAÇADE OPTION 3

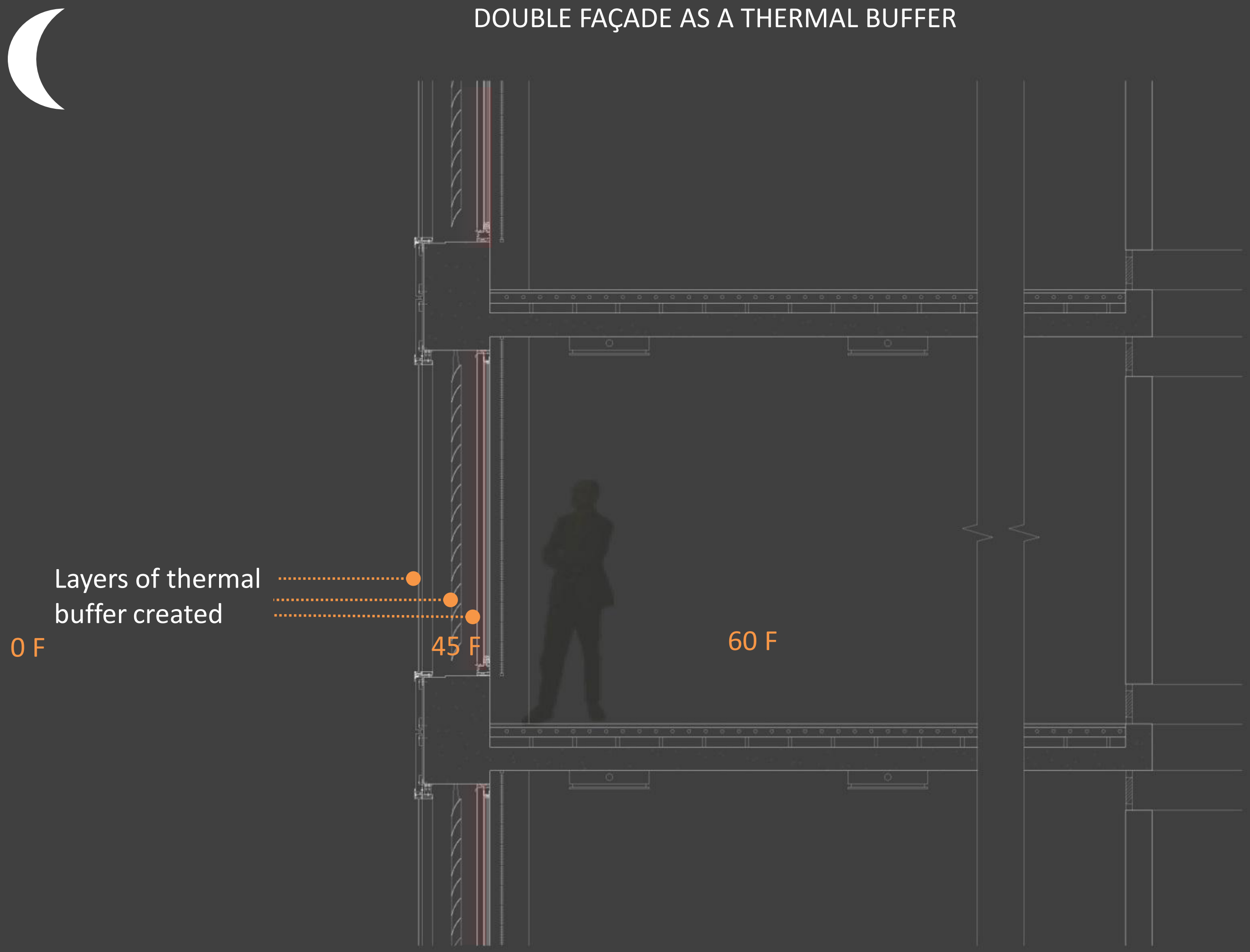
Winter Day



DOUBLE FAÇADE OPTION 3

Winter Night

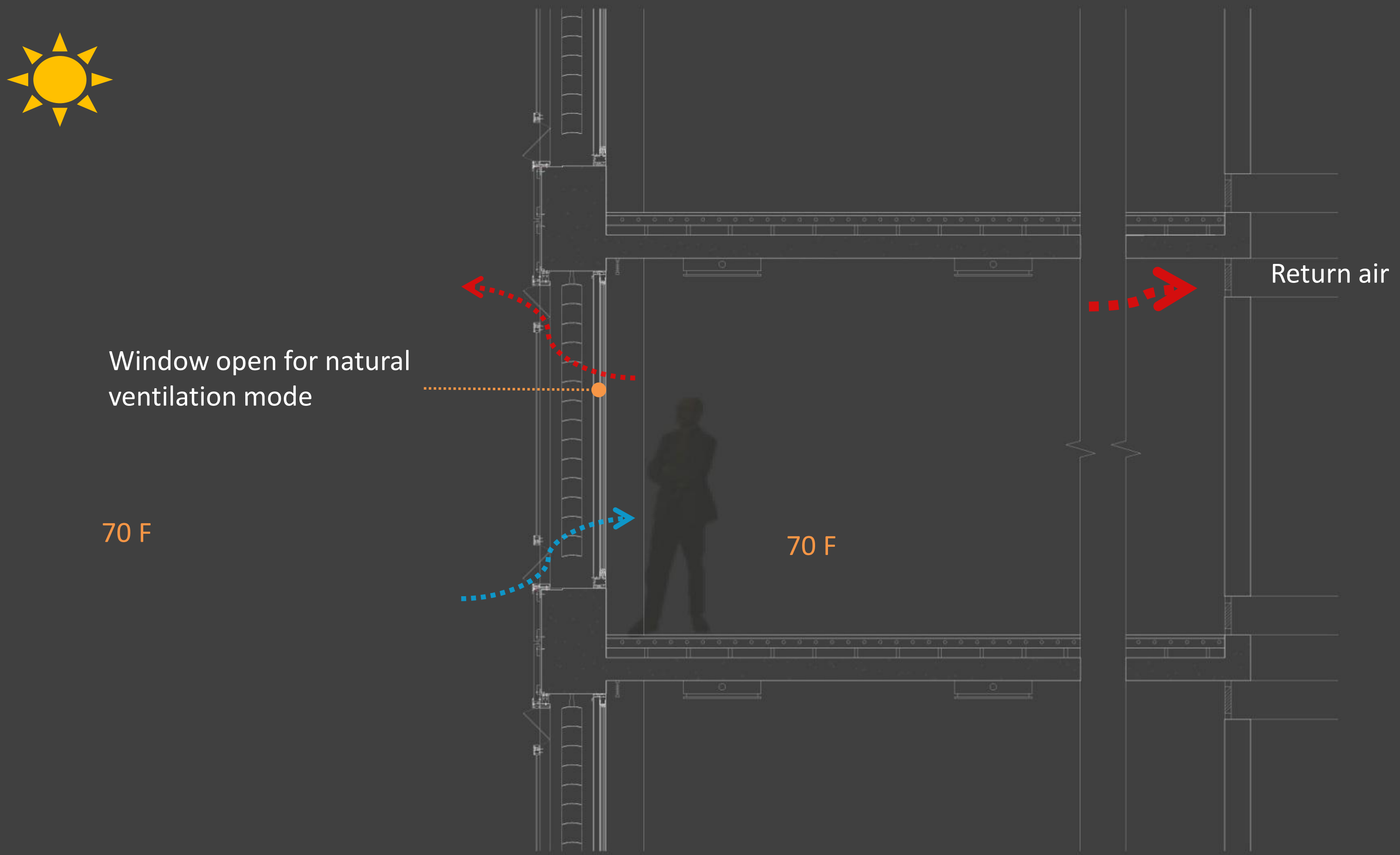
DOUBLE FAÇADE AS A THERMAL BUFFER



The cavity is closed to trap the hot air to act as a thermal buffer to prevent heat losses

DOUBLE FAÇADE OPTION 3
Swing Season Day

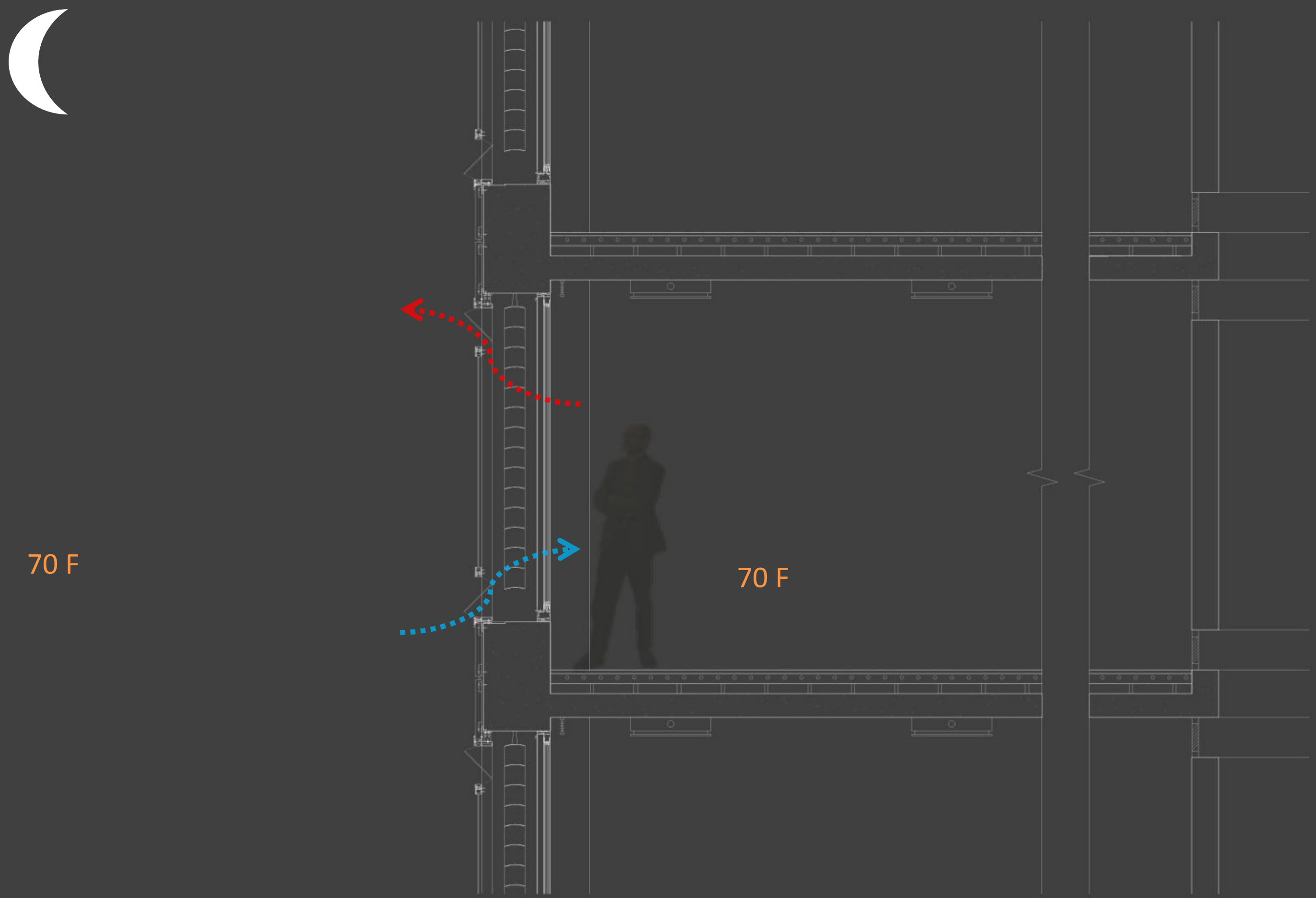
Adaptability of the façade to allow for natural ventilation



DOUBLE FAÇADE OPTION 3

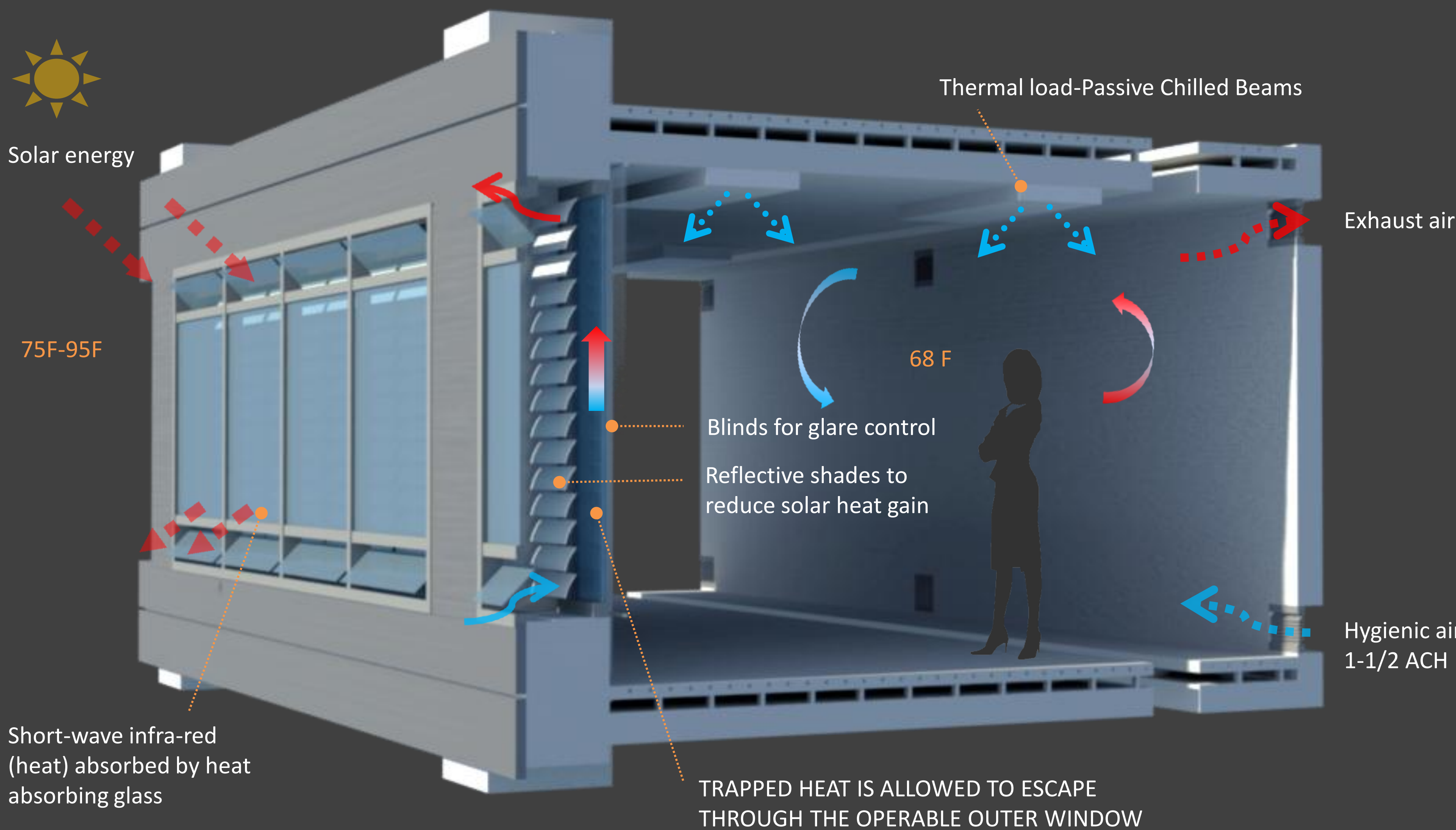
Swing Season Night

Adaptability of the façade to allow for natural ventilation



BUILDING SKIN AND ENVIRONMENTAL CONTROLS

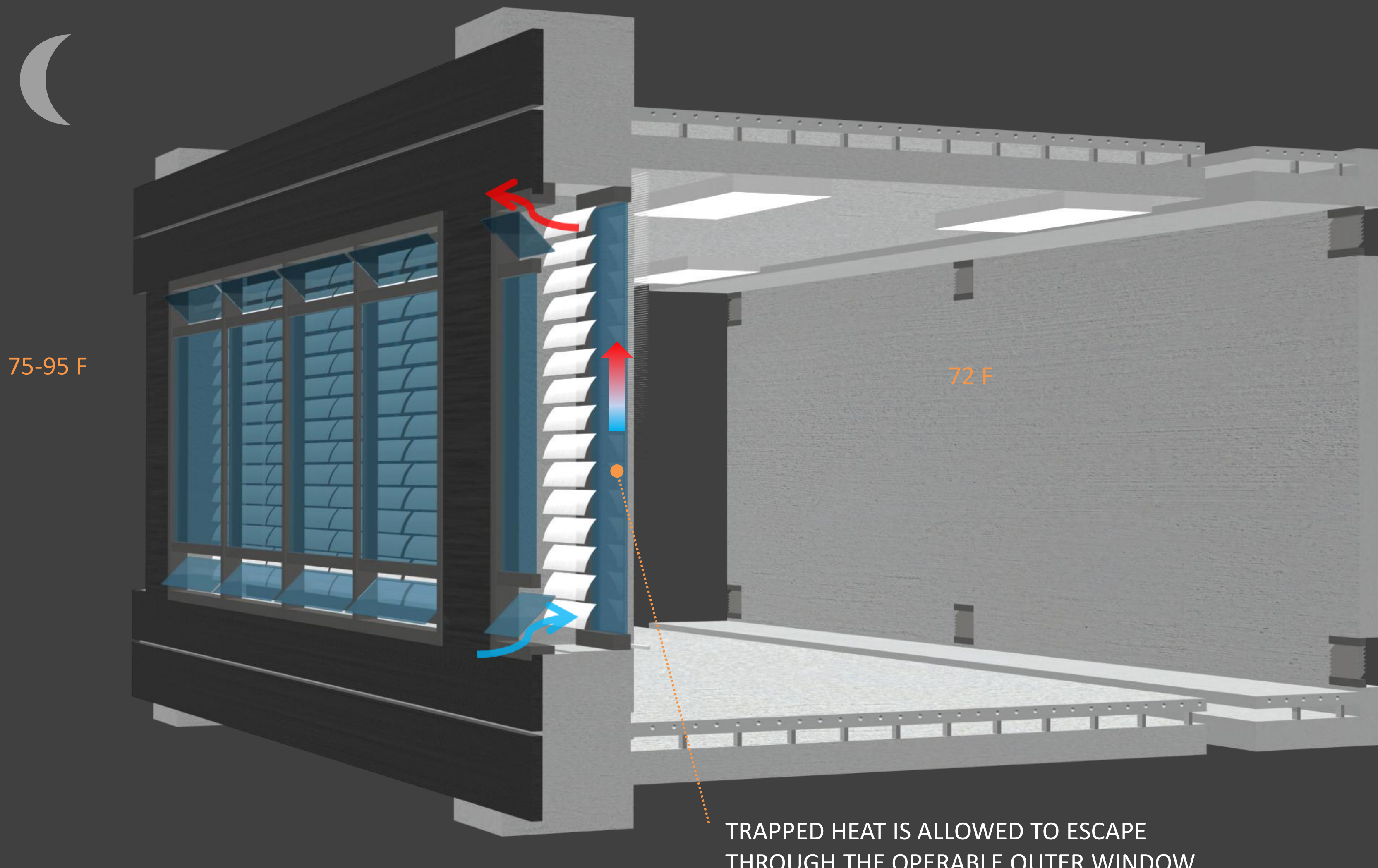
Summer Day (Operational days of the year in cooling mode-50 days)



DOUBLE FAÇADE AS A MECHANISM TO REDUCE SOLAR HEAT GAIN

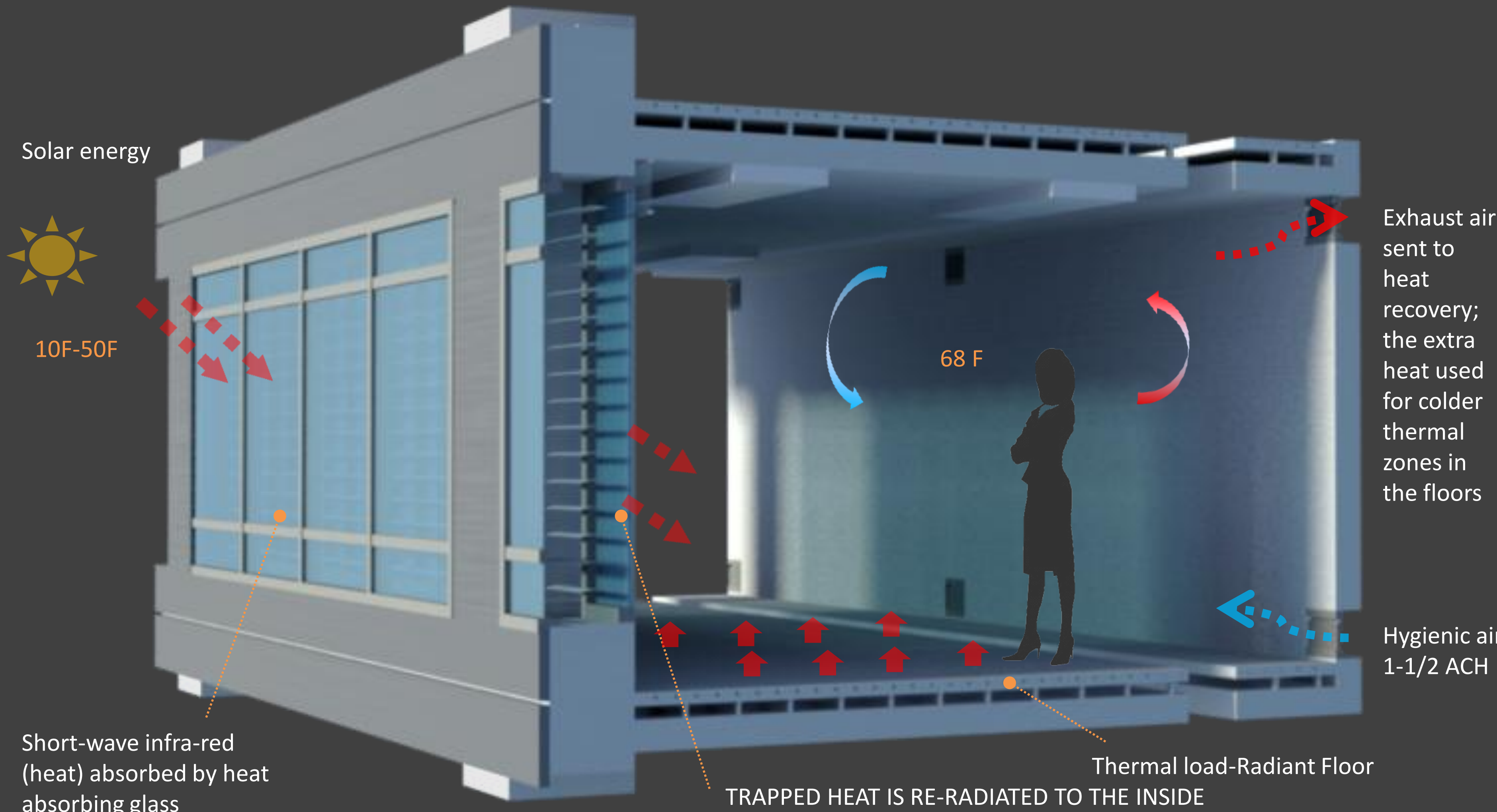
BUILDING SKIN AND ENVIRONMENTAL CONTROLS

Summer Night



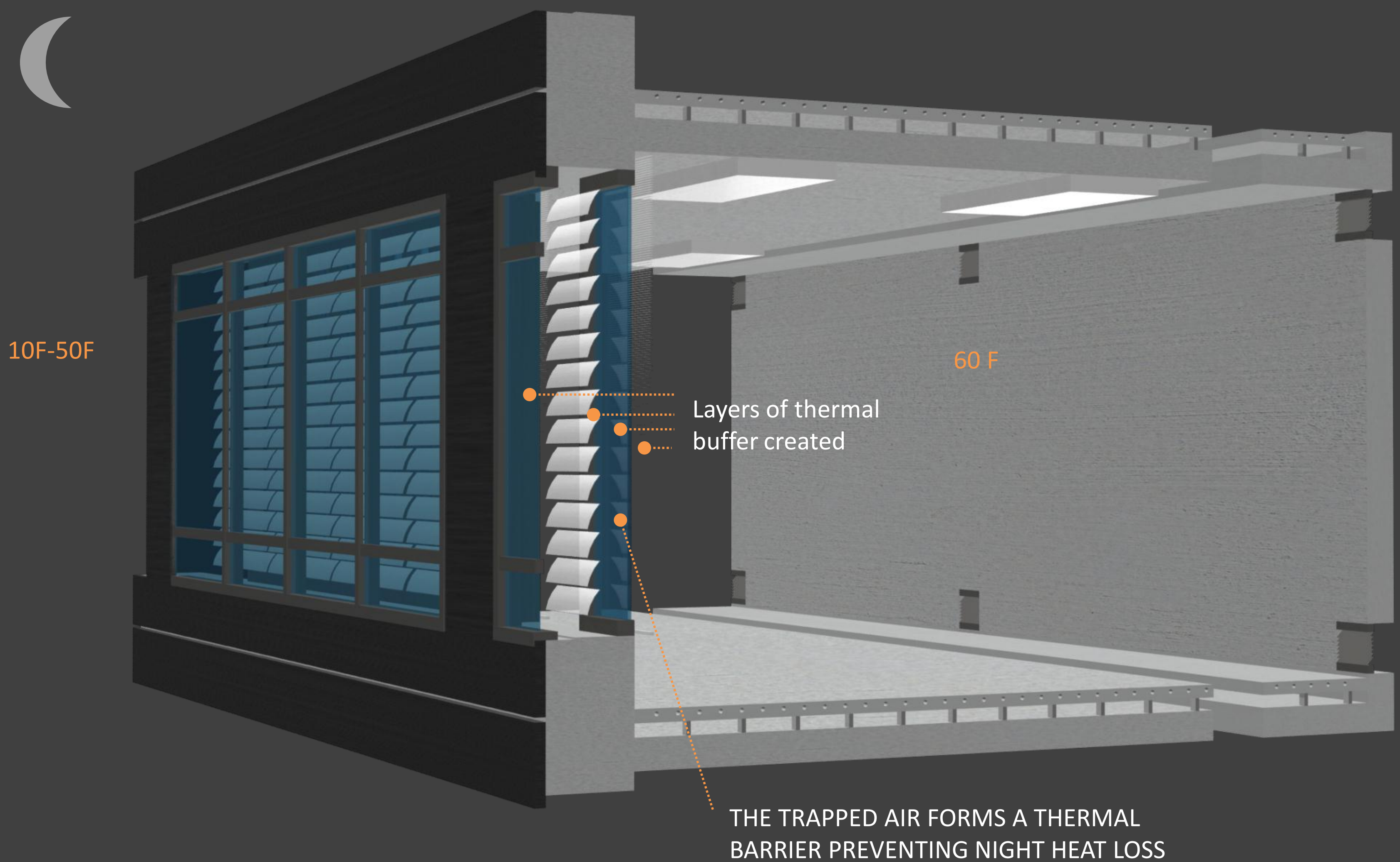
BUILDING SKIN AND ENVIRONMENTAL CONTROLS

Winter Day (Operational days of the year in heating mode-202 days)



DOUBLE FAÇADE AS A MECHANISM TO TRAP SOLAR HEAT

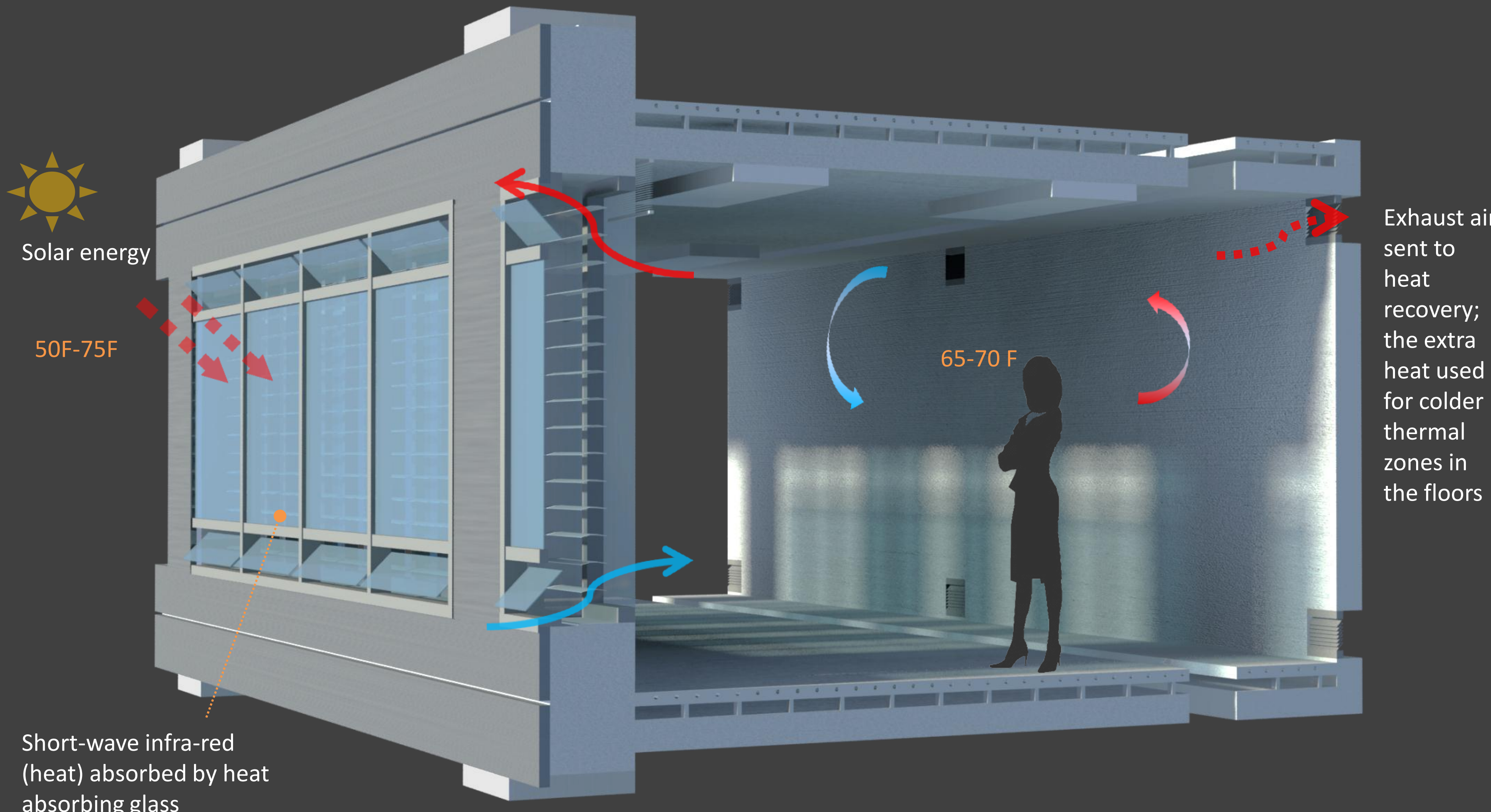
BUILDING SKIN AND ENVIRONMENTAL CONTROLS
Winter Night



DOUBLE FAÇADE AS A THERMAL BUFFER

BUILDING SKIN AND ENVIRONMENTAL CONTROLS

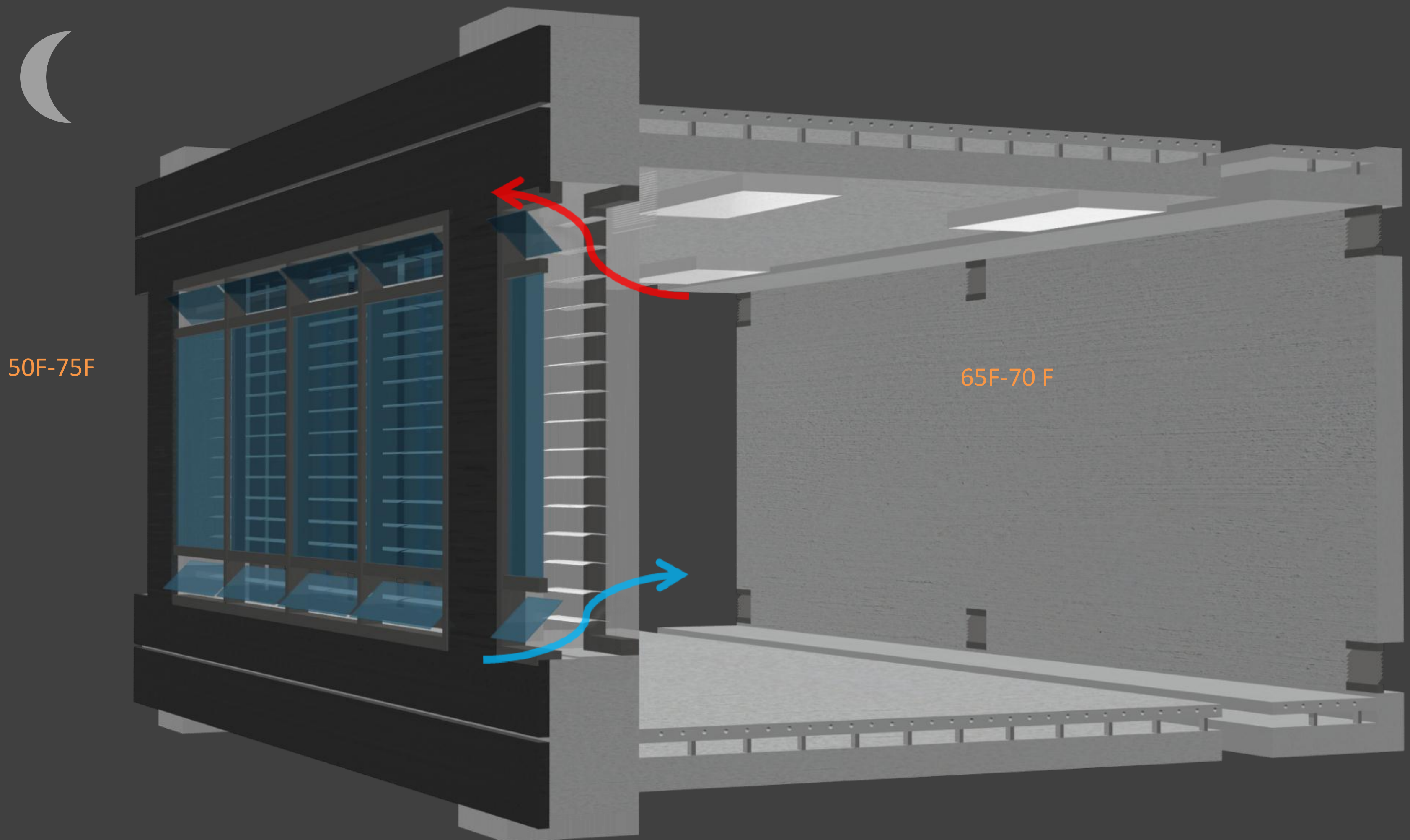
Swing Season Day (Operational days of the year in hybrid/natural vent mode-114 days)



ADAPTABILITY OF THE FAÇADE TO ALLOW FOR NATURAL VENTILATION MODE

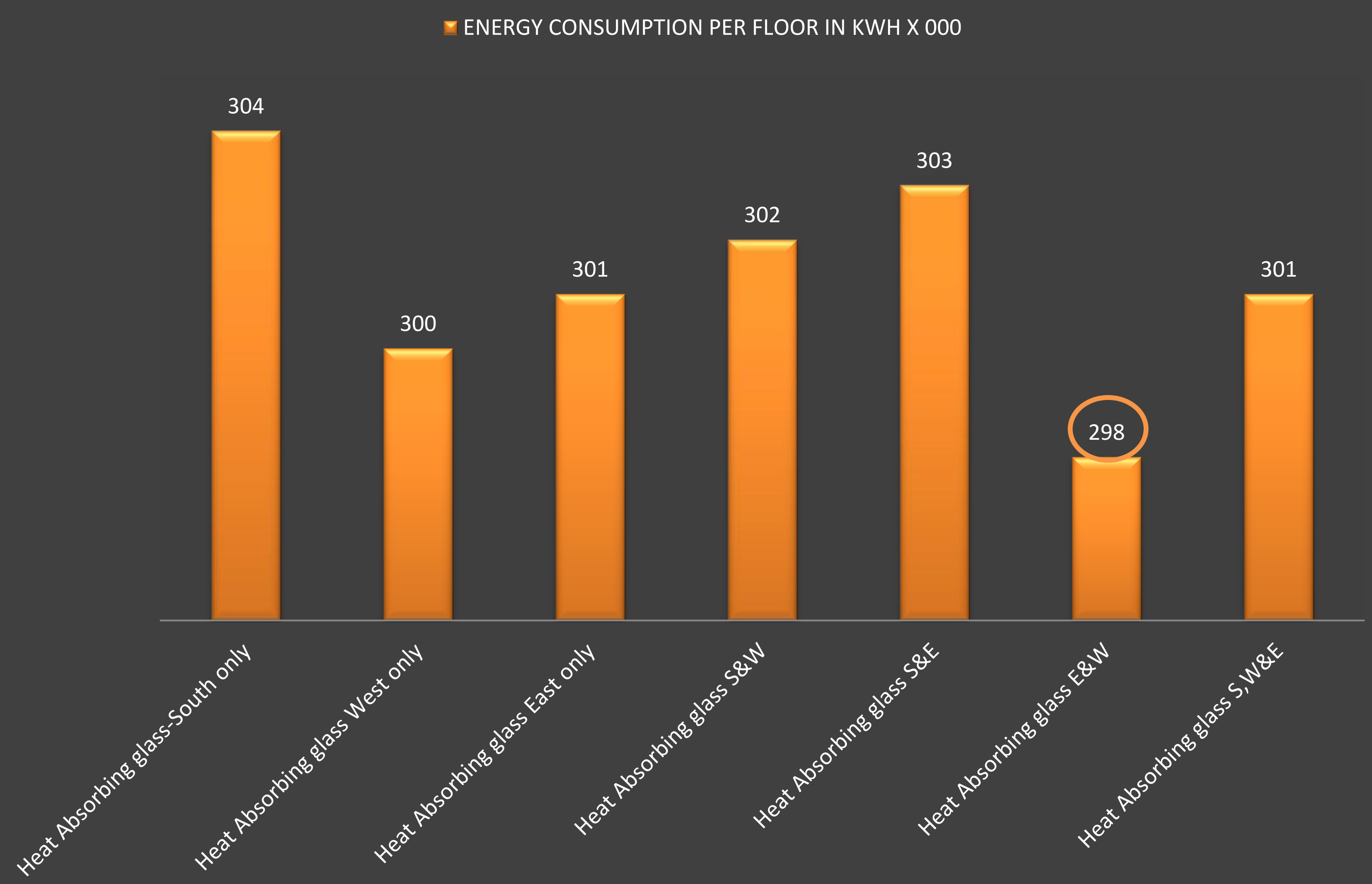
BUILDING SKIN AND ENVIRONMENTAL CONTROLS

Swing Season Night

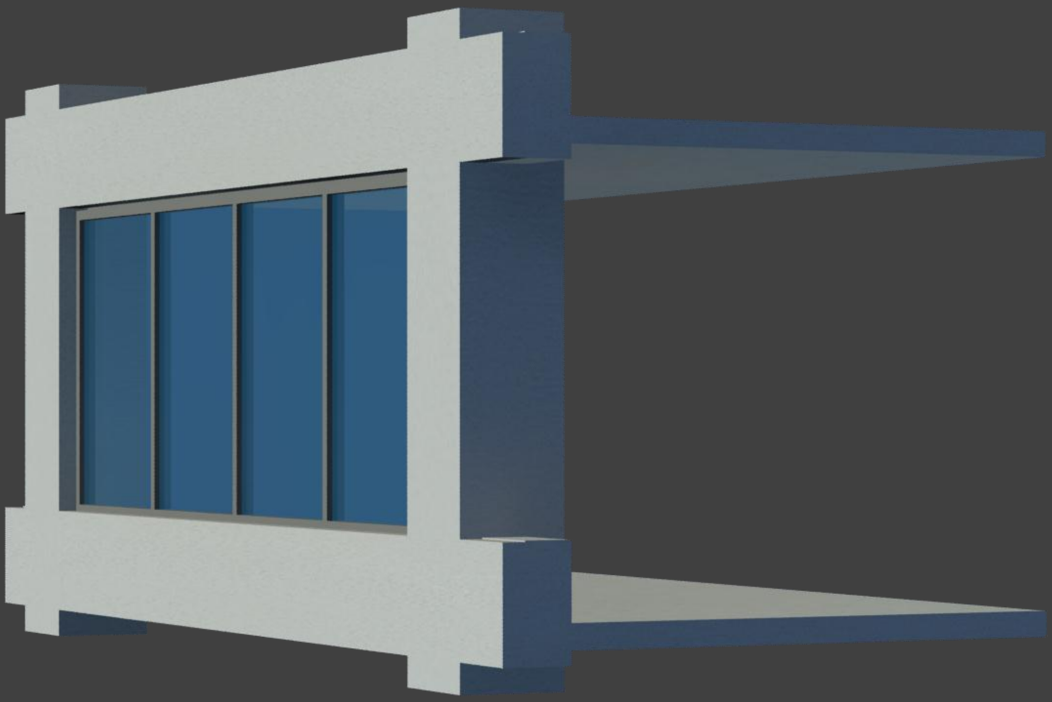


ADAPTABILITY OF THE FAÇADE TO ALLOW FOR NATURAL VENTILATION MODE

ANALYSIS OF HEAT ABSORBING GLASS ON DIFFERENT FACADES

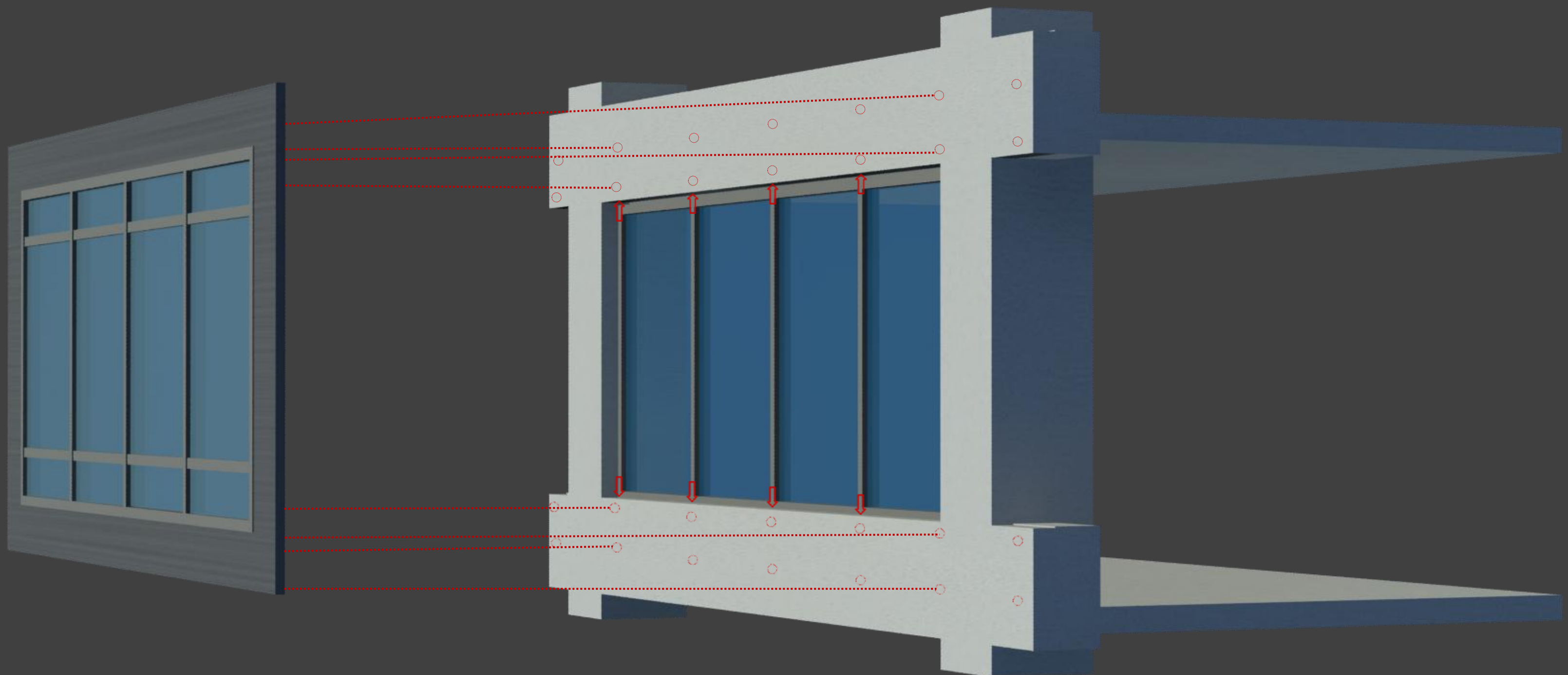


CONSTRUCTIBILITY



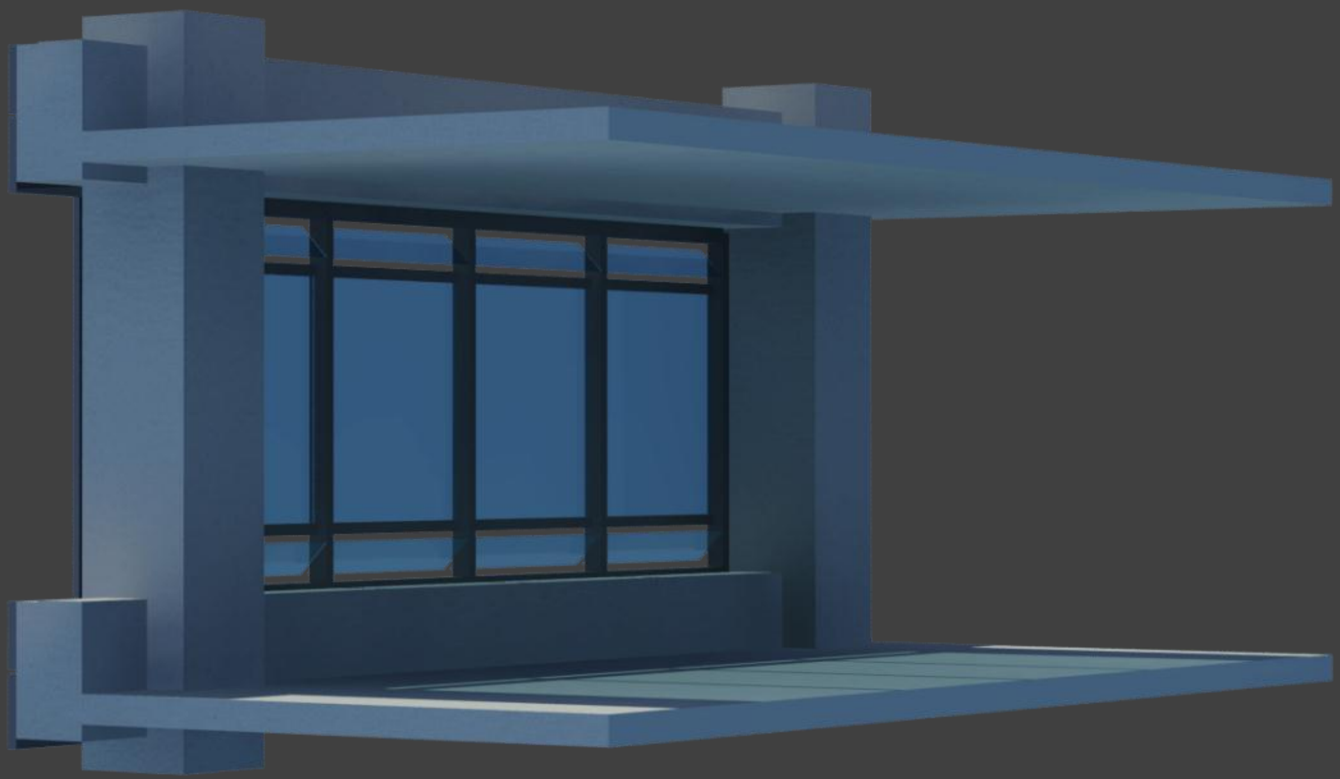
EXISTING SKIN

CONSTRUCTIBILITY



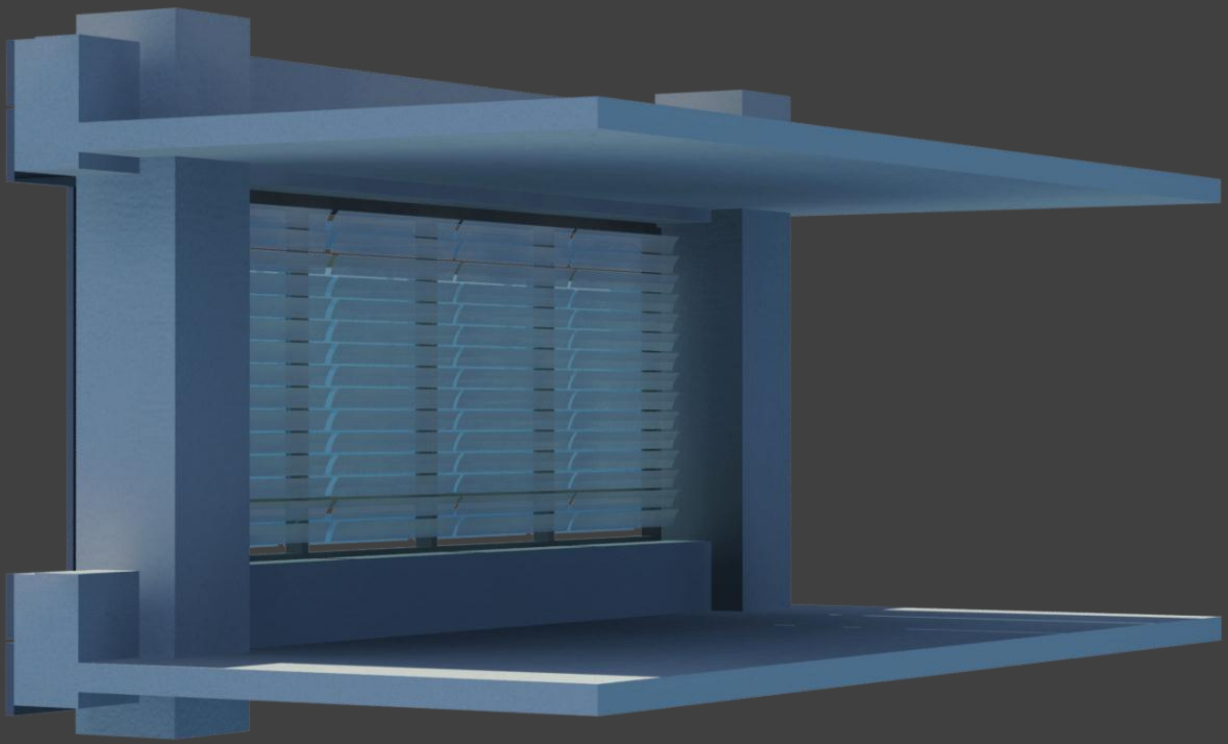
NEW OUTER SKIN-PREFABRICATED CENTRIA WINDOW-WALL PANEL SYSTEM

CONSTRUCTIBILITY



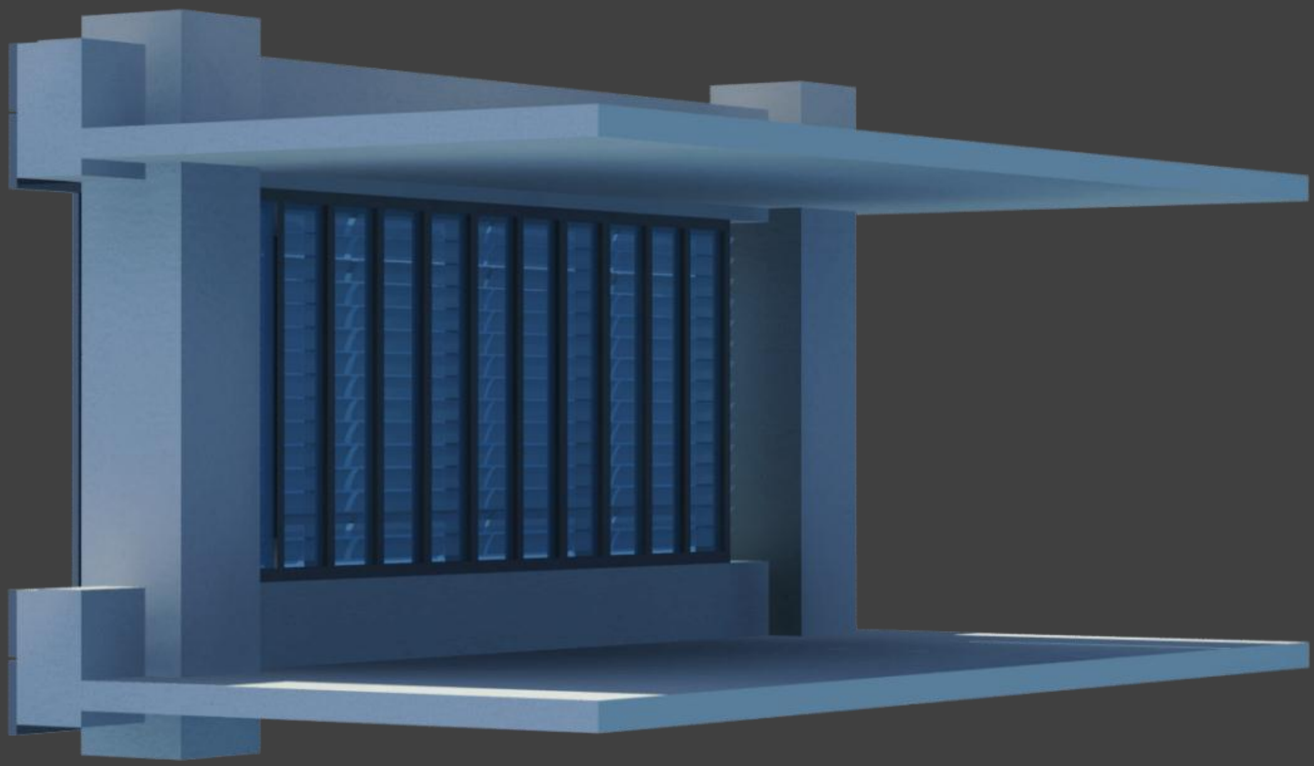
REMOVE EXISTING WINDOWS

CONSTRUCTIBILITY



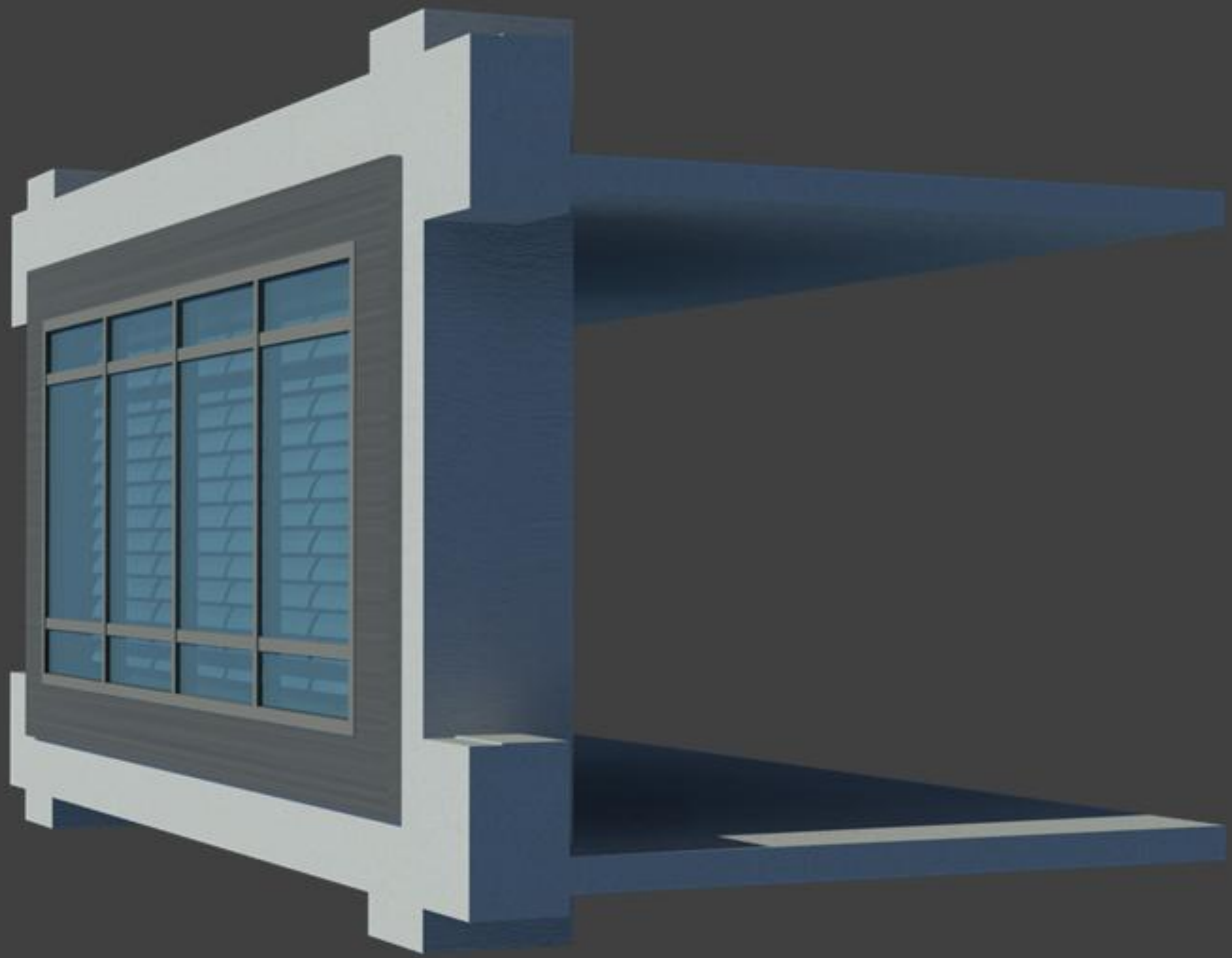
ADD MOTORIZED SHADES

CONSTRUCTIBILITY



ADD INTERNAL SLIDING WINDOWS

CONSTRUCTIBILITY



SCALABILITY

Building Selection-Target-Older buildings in institutional settings

- Campus surveys
- Campus sustainability drives

Building Assessment and Analysis

- Existing Architecture/Engineering Student body with DOE support

Target Setting

Based on Local codes/requirements for campus buildings

Methodology Selection

- Including related software

Application of retrofits, their evaluation and effects on the campus/society

INTERSECTION OF S STATE STREET AND W 35TH STREET

WINTER GARDEN

VALUE

- HIGHER MECHANICAL SYSTEM EFFICIENCY
- 26% / 67,000 S.F. MORE LEASABLE SPACE
- HIGHER ELEVATOR EFFICIENCY
- $1.4 MILLION PER YEAR MORE IN RENT
- THE NEW FACE OF IIT AND THE NEIGHBORHOOD
- INTEGRATION WITH THE CAMPUS
- 32% / 8.7 BILLION BTU REDUCTION IN ENERGY CONSUMPTION
- INCREASE IN VALUE TO IIT AS A SUSTAINABLE CAMPUS
- $91,705 SAVINGS IN ENERGY COSTS PER YEAR
- HIGHER OCCUPANT COMFORT LEVELS
- CAMPUS RETROFIT PROTOTYPE – SCALABILITY
- NEW CAMPUS POCKET PARK AND COLLECTIVE INDOOR SPACE - WINTER GARDEN

CONCLUSIONS

- A comprehensive approach to achieving better value and amenity in existing conditions
- An iterative performance based approach to building skin design helped understand the methodology for achieving reduced energy consumption in buildings with high window to wall ratios
- The different façades should be able to adapt to the different conditions throughout the year
- A step-by-step approach can improve building performance by almost 30% over time and increase in leasable area by 26%
- Result-an iconic building for the landmark Mies campus and the historic Bronzeville district, providing improved amenity to its occupants
- The study demonstrates the importance of energy modeling by an objective evaluation of building energy performance metrics for improvement in occupant comfort levels