FACA-DE-LIT

Facade optimisation for visual comfort by controlled daylight distribution in high rise office buildings

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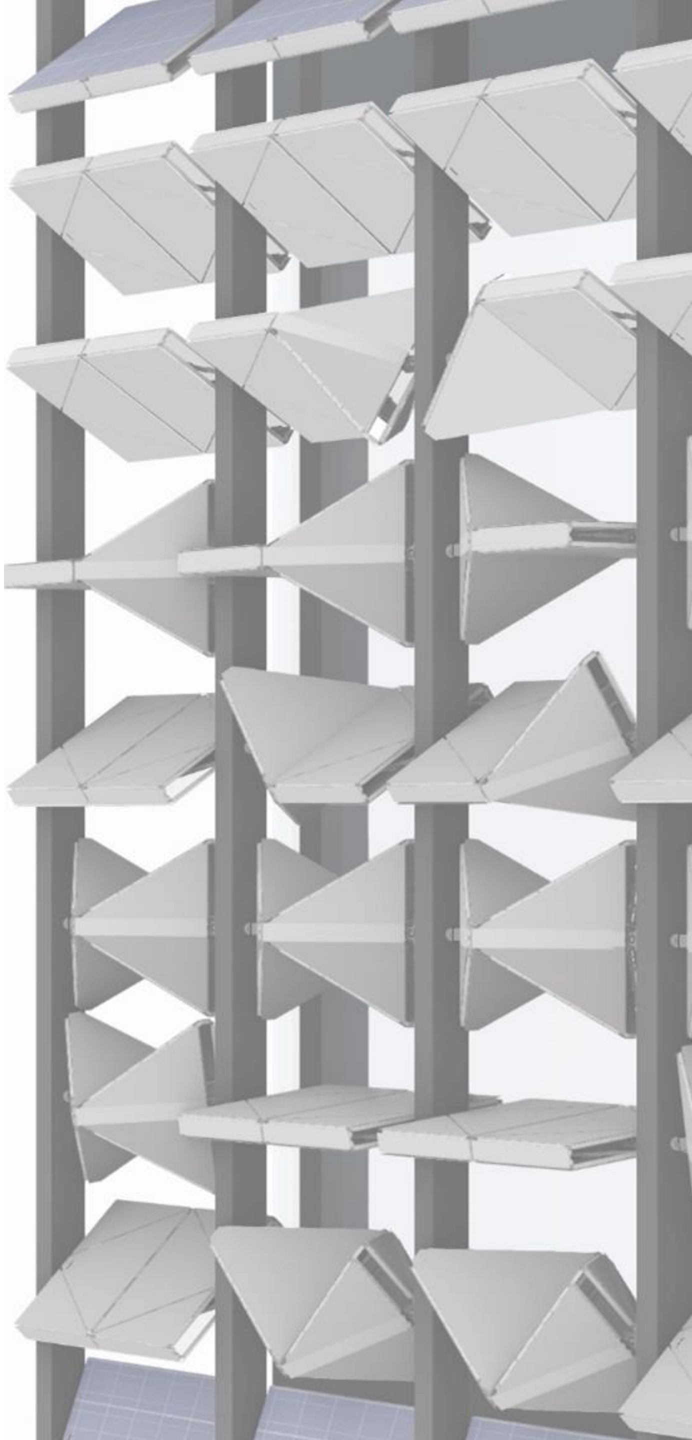
Akash Changlani // 4813715 // 2019-2020



Framework

Literature

Computation Design

Façade Scheme

FACADE + DAY**LIT**

↓

FACA-DE -**LIT**

Facade *is part of building envelope that allows the penetration of light and influences the performance of daylight. (Rush, 1986)*

Daylit *is a term used for the amount of daylight that is visually comfortable for a humans eye. (Chauvel, 1982)*

Framework

Urbanisation

Population Rise

Growth of High-Rise

Urbanisation

Population Rise

Growth of **High-Rise**

↓ (Demands)

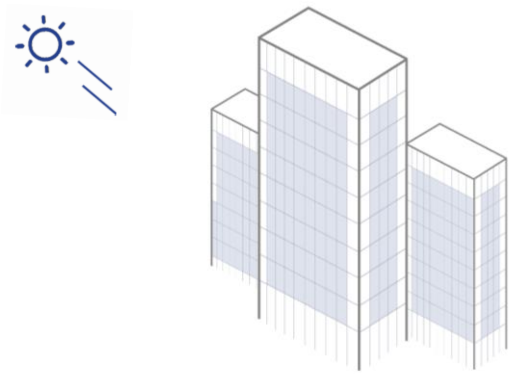
Indoor **Human comfort**

(Thermal, Air quality, Acoustic, Visual)

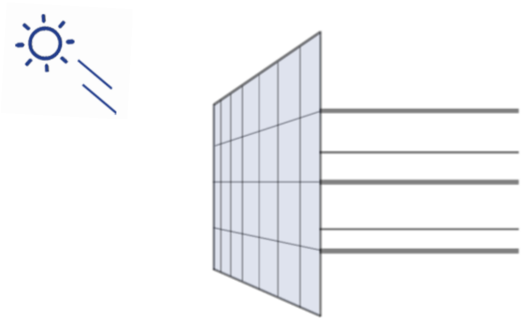
Major issue in high rise

Poor Daylighting

Visual **discomfort**



Daylight in **high-rise** building is **challenging**



Side walls are the only option

In **deep floor plans** of Office Buildings in a high-rise

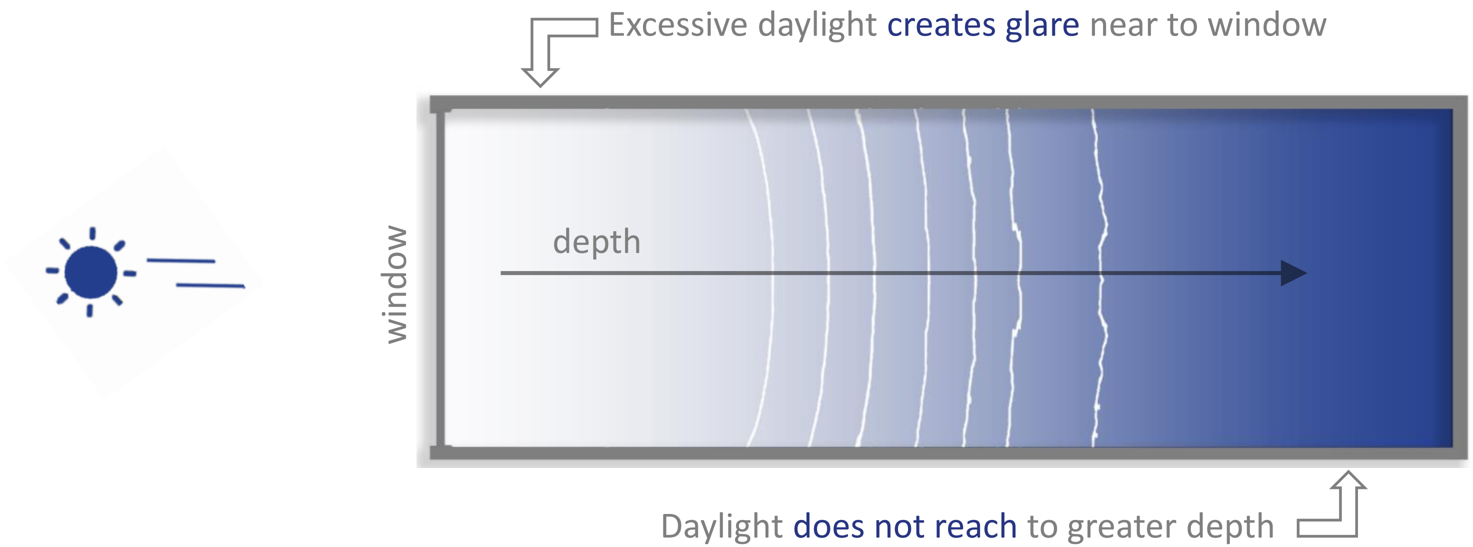
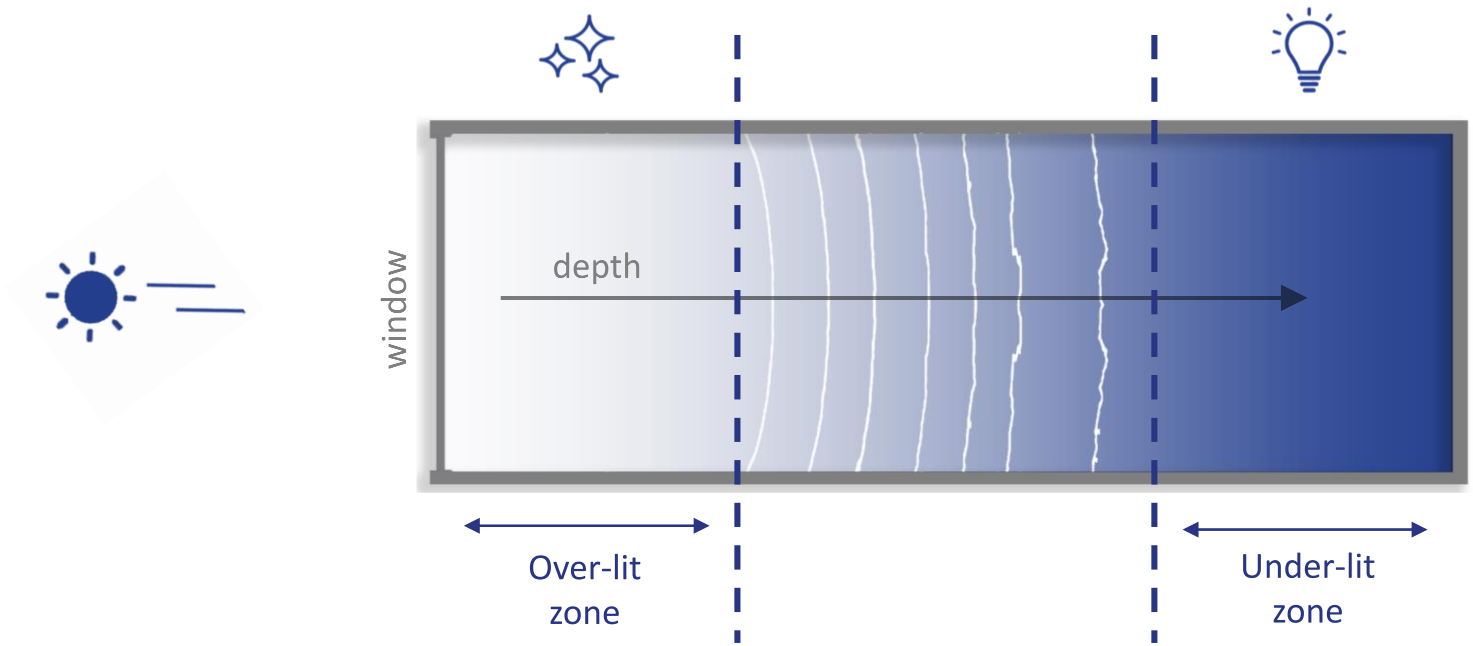
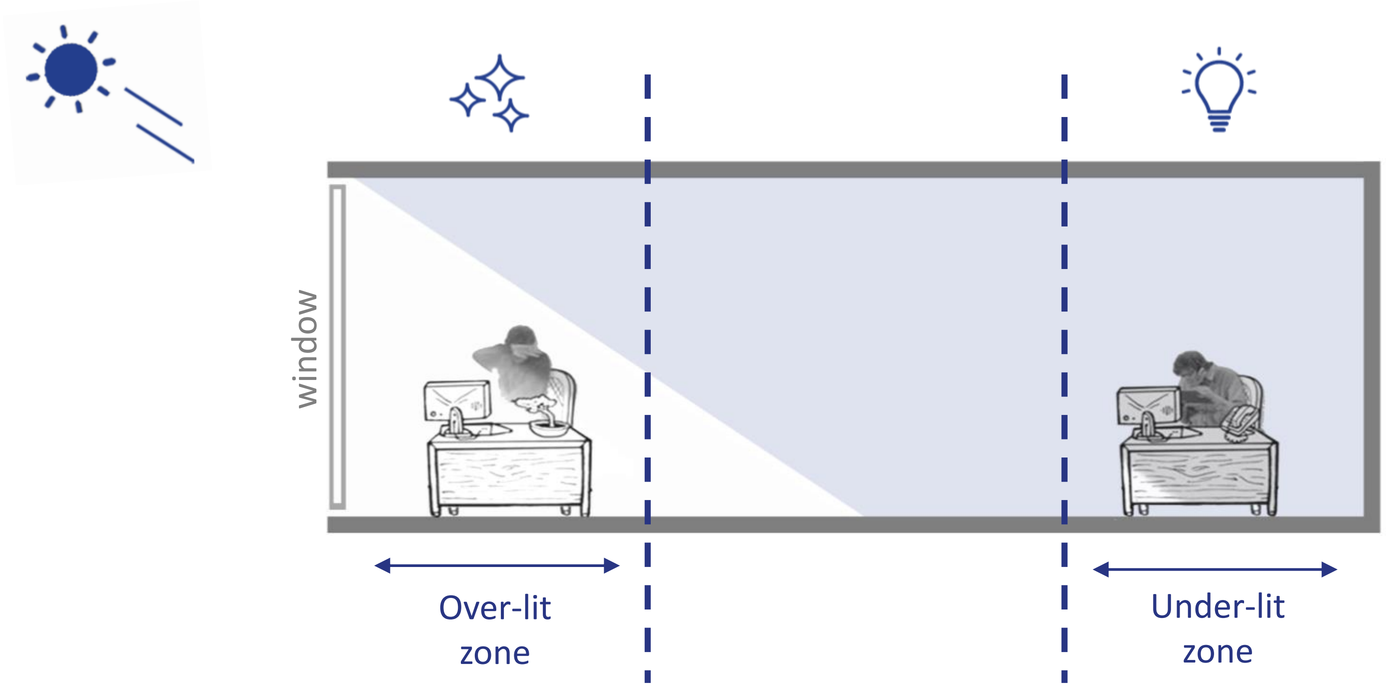


Figure showing

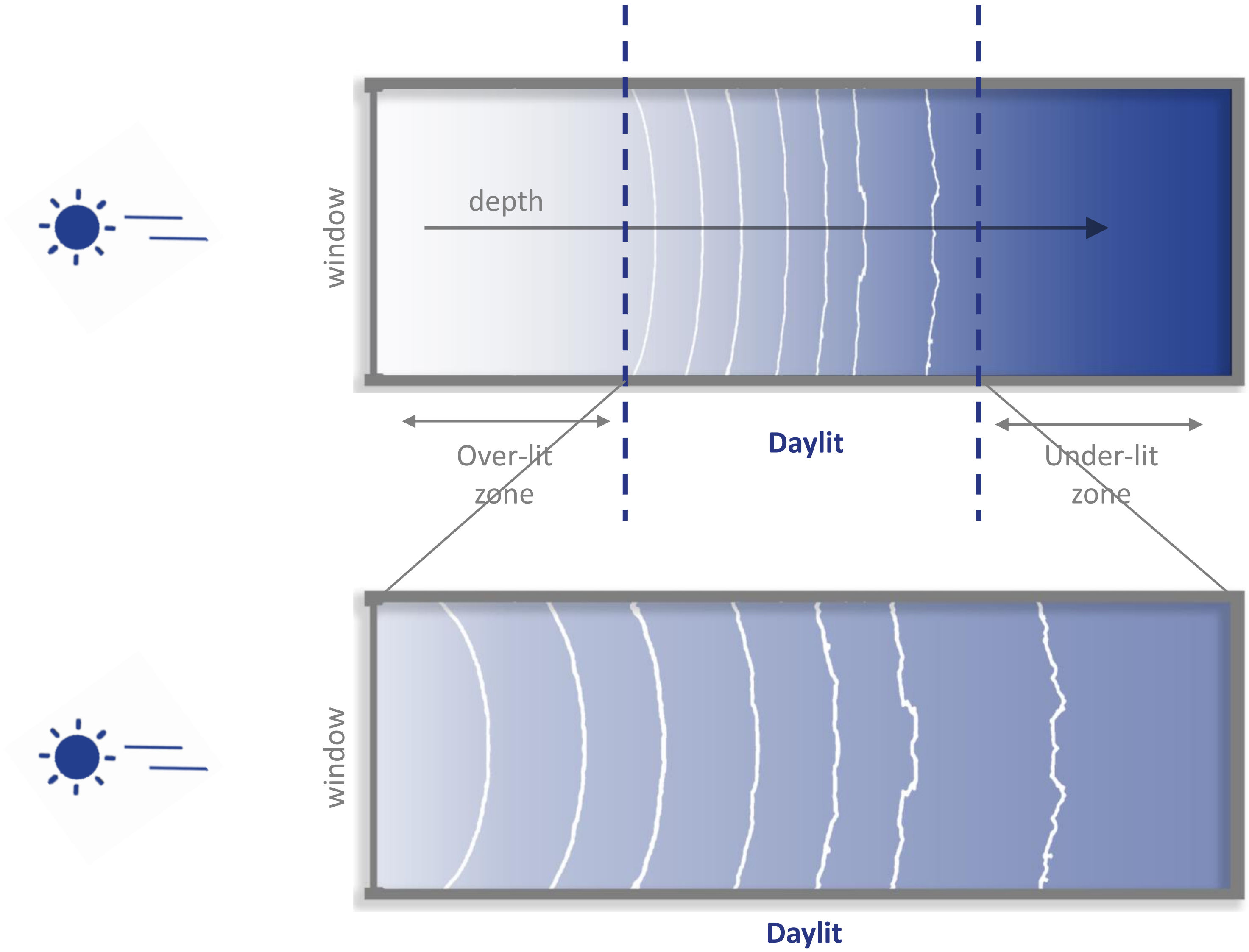
Gradient of intensity of light going dark towards greater depth



Non-uniform distribution of daylight



Visual Discomfort



Need more Balanced distribution of light

Solution is **difficult**

↓

Daylight is **Dynamic in Nature**

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Complexity in designing

↓

Difficult with **conventional** Design **method**

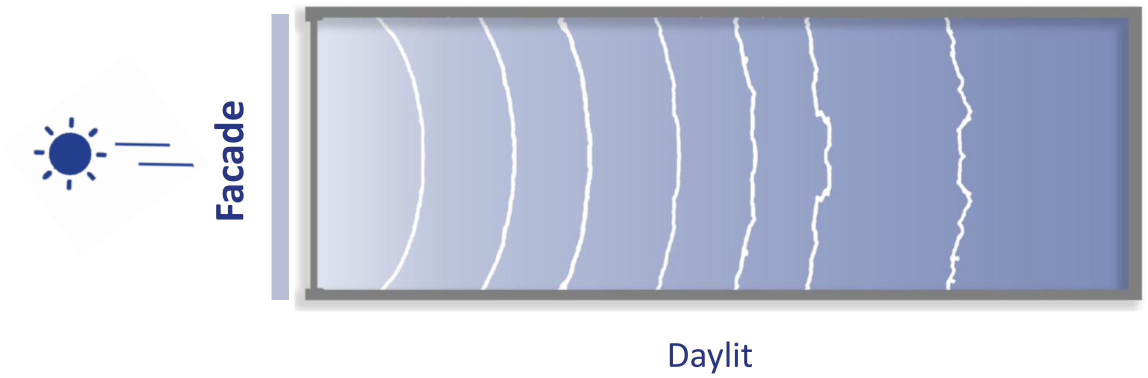
↓

Computational Design method

↓

Improve Performance

Main Objective



With help of **Computational Design Methods**

↓

Develop a **Façade System**

↓

Bring **balance** of light intensity by **distributing** light **homogeneously** throughout the **depth**

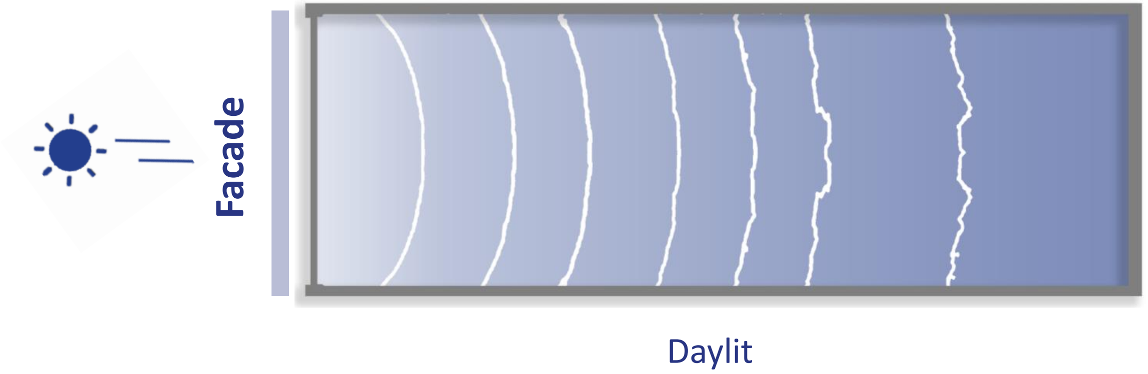
↓

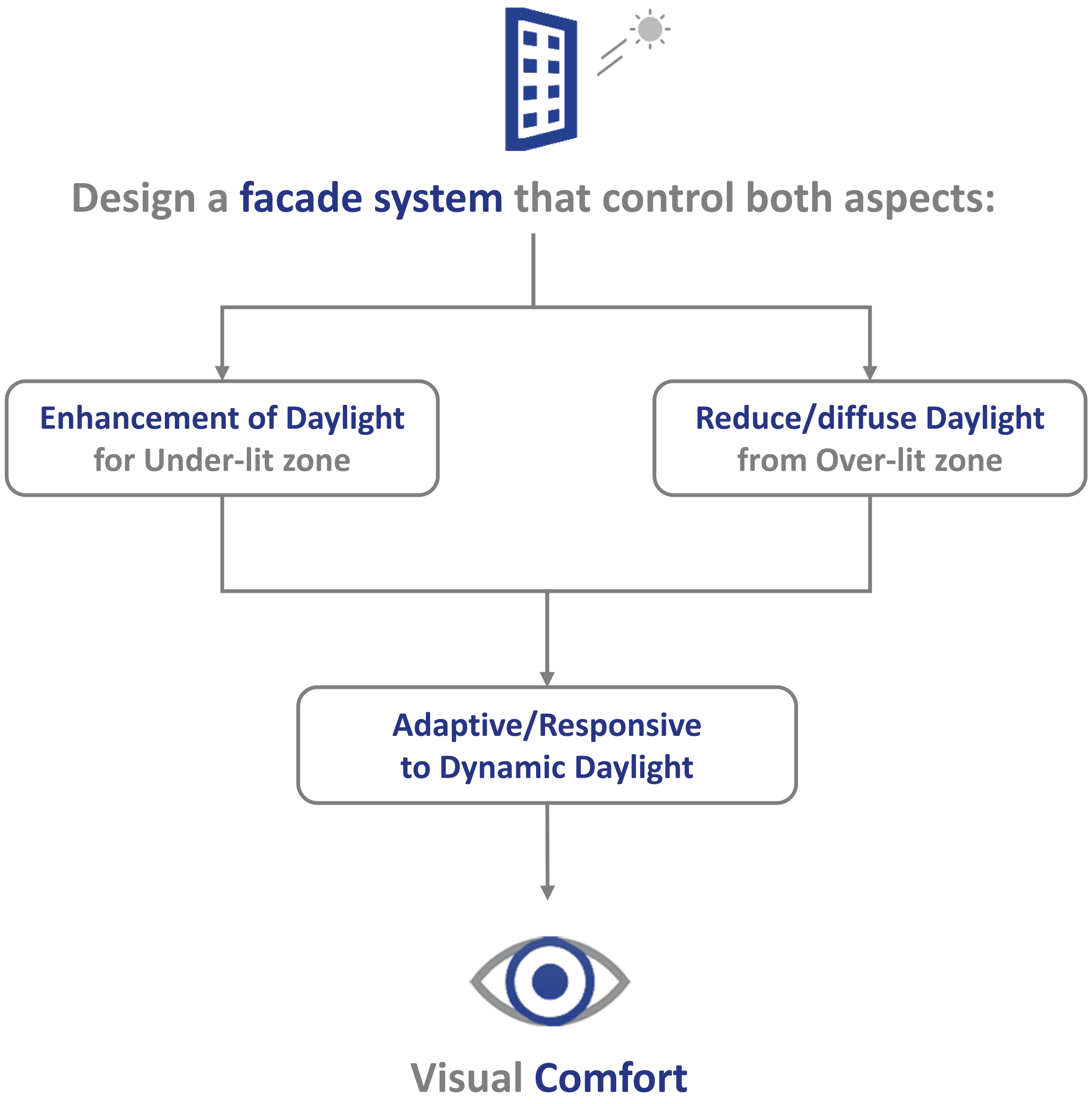
Adapts to different **daylight conditions**

↓

Visual **Comfort**

Design Objective





Q

Based on **computational design methods and techniques**, how can **a façade system** allow for **indoor visual comfort**, by **daylight's controlled distribution** throughout the **depth of a room**, in a high rise office building?

Q

Based on **computational design methods and techniques**, how can **a façade system** allow for **indoor visual comfort**, by **daylight's controlled distribution** throughout the **depth of a room**, in a high rise office building?

Sub Questions

Literature

1. What are the **parameters and requirements** that characterize the space and its occupants for **visual comfort**?

Q

Based on computational design methods and techniques, how can a façade system allow for indoor visual comfort, by daylight's controlled distribution throughout the depth of a room, in a high rise office building?

Sub Questions

Literature — **Visual Comfort Criteria**

2. How a façade system **can be assessed** that control daylight's distribution along the depth coping with **dynamic behaviour of daylight**?

Q

Based on computational design methods and techniques, how can a façade system allow for indoor visual comfort, by daylight's controlled distribution throughout the depth of a room, in a high rise office building?

Sub Questions

Literature — Criteria — Case Study

3. **What is the state of art in facades to control daylight distribution?**

   2a. What are the façade systems that deals with **daylight enhancement** in an indoor space?
   2b. What are the façade systems that deals with **daylight reduce/diffuse** in an indoor space?

Q

Based on computational design methods and techniques, how can a façade system allow for indoor visual comfort, by daylight's controlled distribution throughout the depth of a room, in a high rise office building?

Sub Questions

Literature — Criteria — Case — Design Concept

4. What **design approach** could be best to avoid glare at the same time while gaining more daylight? Or how to **bring balance between over-lit and under-lit situation** through the design?

Q

Based on computational design methods and techniques, how can a façade system allow for indoor visual comfort, by daylight's controlled distribution throughout the depth of a room, in a high rise office building?

Sub Questions

Literature — Criteria — Case — Concept — **Computational Workflow**

5. How **computational design method** will help to **achieve** the most **optimal solution** in this case?

Q

Based on **computational design methods and techniques**, how can **a façade system** allow for **indoor visual comfort**, by **daylight's controlled distribution** throughout the **depth of a room**, in a high rise office building?

Sub Questions

Literature — Criteria — Case — Concept — Workflow — **Performance Evaluation**

6. To what extent a **balanced distribution** of daylight within a spaces can be achieved **throughout the depth** for indoor visual comfort **through the designed facade**?

Q

Based on **computational design methods and techniques**, how can **a façade system** allow for **indoor visual comfort**, by **daylight's controlled distribution** throughout the **depth of a room**, in a high rise office building?

Sub Questions

Literature — Criteria — Case — Concept — Workflow — Evaluation — **Final Facade**

Final Result as Façade Product

Literature — Criteria — Case — Concept — Workflow — Evaluation — Final Facade

Literature

What are the factors that defines Visual comfort in a space ?

Amount of Daylight/ Distribution of Daylight

Glare

Contrast

Colour Temperature

View to outside

Evaluation

Evaluation Criteria

Distribution of Daylight	**1.Average Illuminance (Lux)**	**: 300 – 750 Lux**
	2.Daylit Area (%)	**: 300-2000 lux for >95%** (Criteria 01) **Minimum lux >100** (Criteria 02)
	3. Uniformity Ratio	**: > 0.3**
Glare	**4. Daylight Glare Probability, DGP**	**: 0.45 - 0.35** or **<0.35**
Contrast	**5. Contrast Ratio**	**: < 3.0**

Design Standards- NEN EN 17037 (2018) and BREEAM (2016);
and Design Guidelines

- **Daylight Range by Chauvel (1982)**

< 300 lux	**:**	**Under-lit**
300 – 2000 lux	**:**	**Daylit (Useful Daylight)**
>2000 lux	**:**	**Over-lit**

What are the external factors that influences Daylight levels ?

N
W
S
E

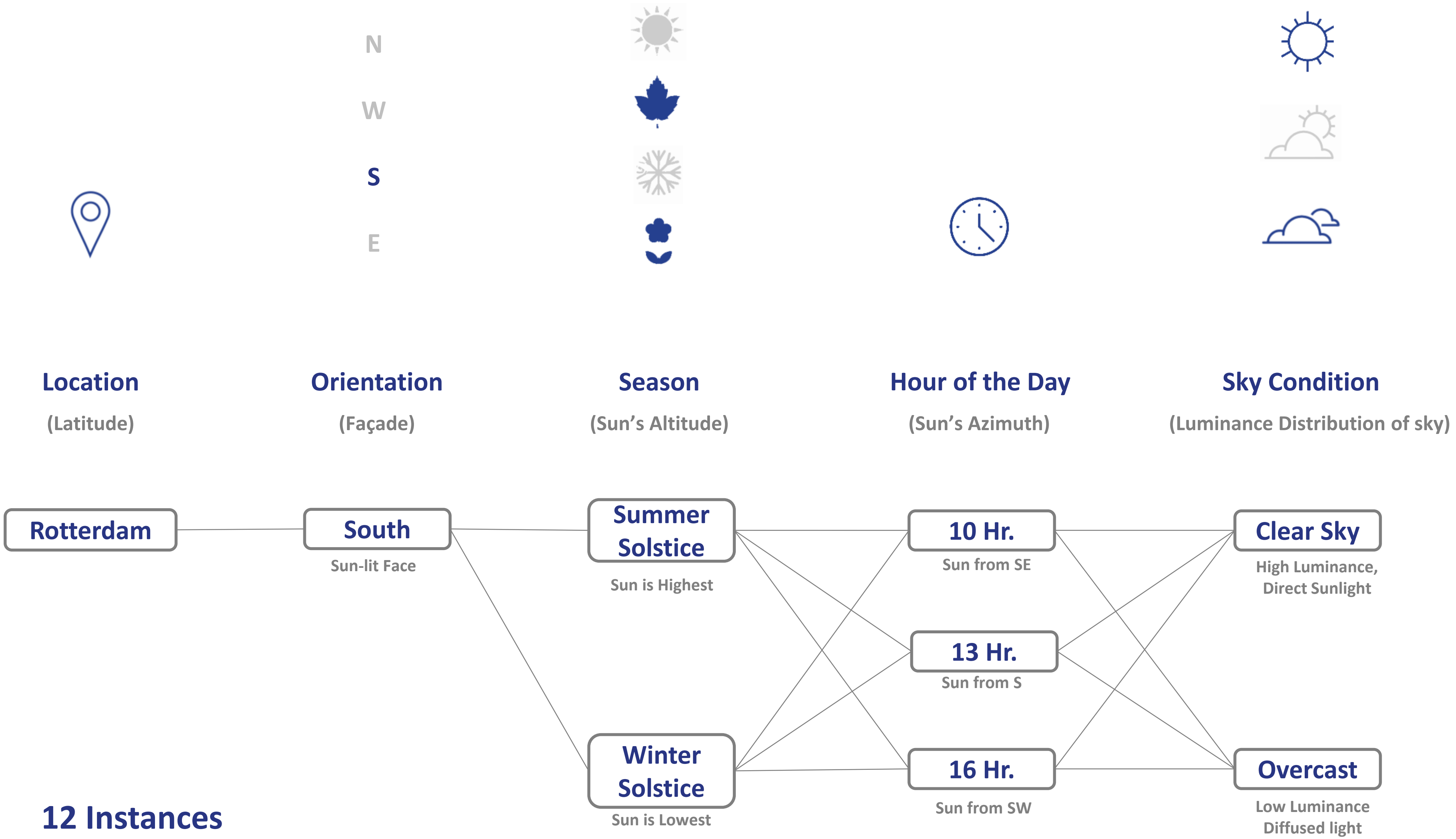
Location
(Latitude)

Orientation
(Façade)

Season
(Sun’s Altitude)

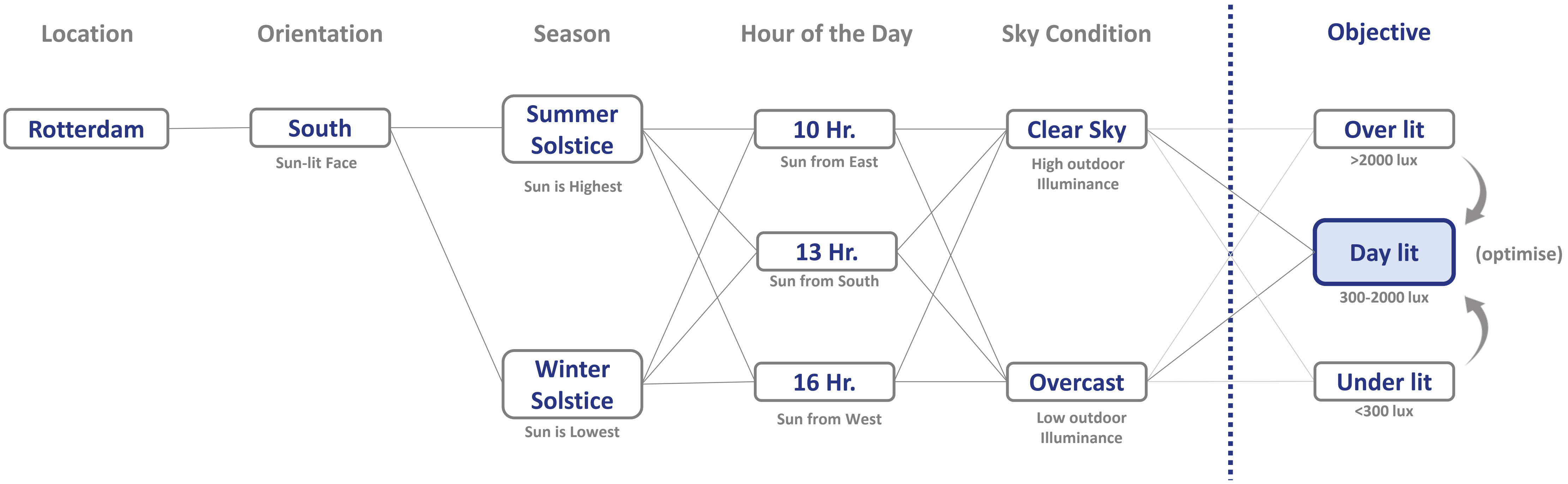
Hour of the Day
(Sun’s Azimuth)

Sky Condition
(Luminance Distribution of sky)



12 Instances

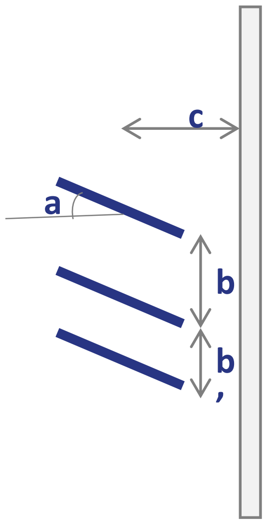
Instances and Objective



Case Study

Case 01

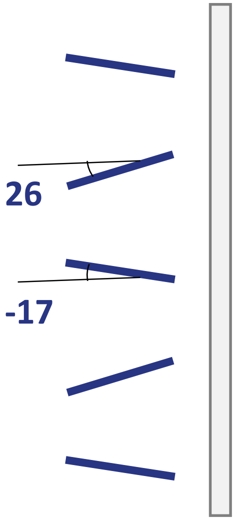
(Samadi et al., 2019)



Parameters

Case 02

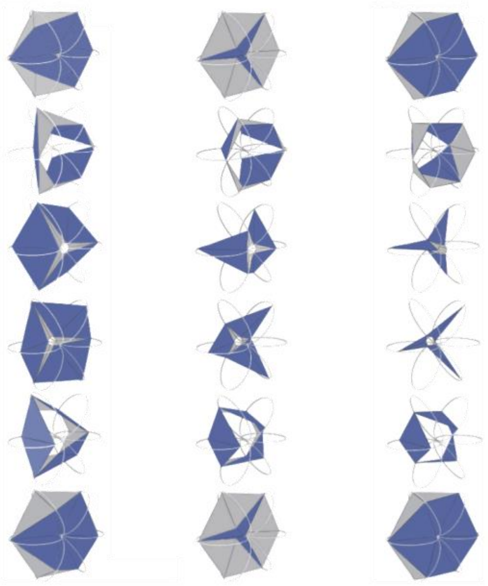
(Sheikh, 2014)



Configuration

Case 03

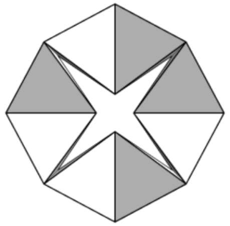
(Tabadkani et al., 2019)

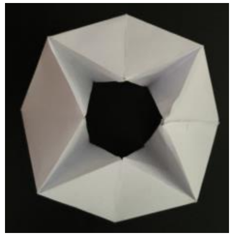


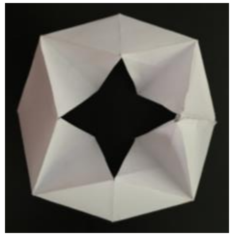
Material

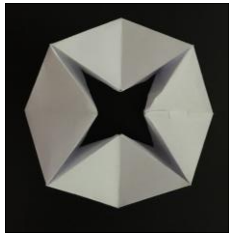
Design Concept

Geometry **Selection**

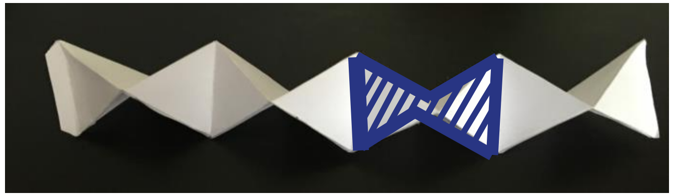




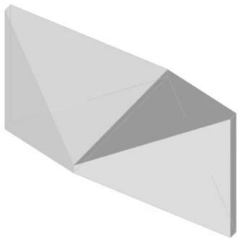


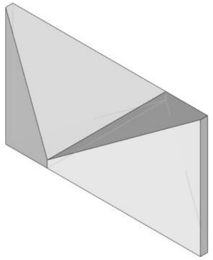


Origami based **octagonal Kaleidocycle**



Opening up the Kaleidocycle

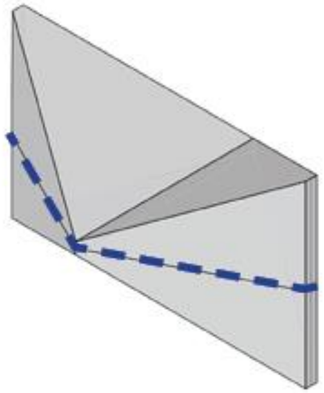




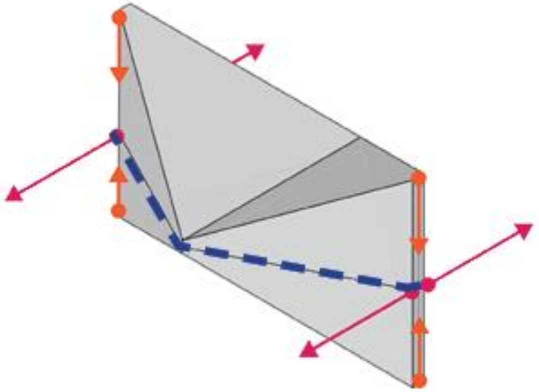
Selecting one repetitive module – **a pair of tetragonal disphenoid**

Geometry Modification

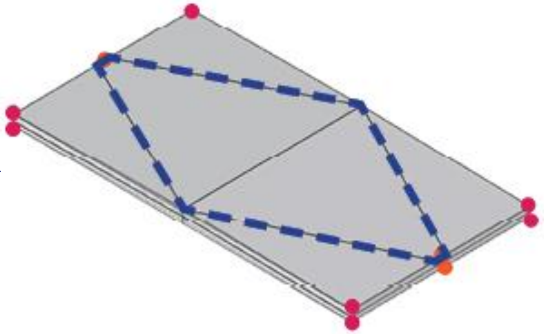
- **Adding Fold**



Adding a cut



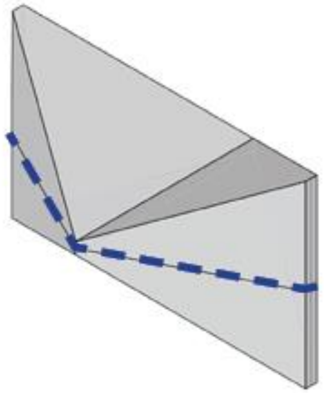
Folding Motion



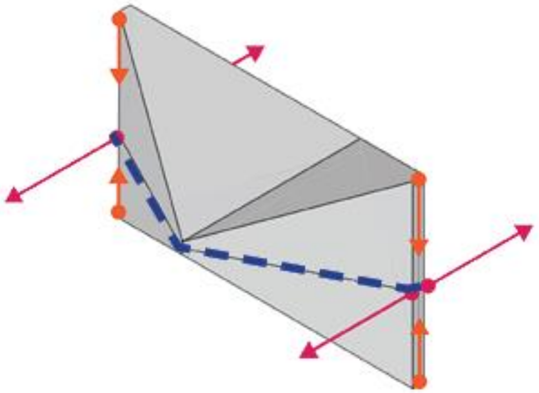
Geometry after fold

Geometry Modification

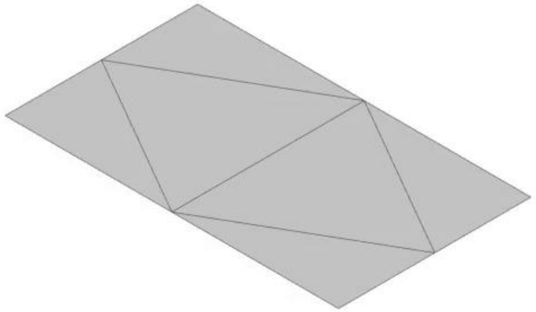
- **Adding Fold**



Adding **a cut**



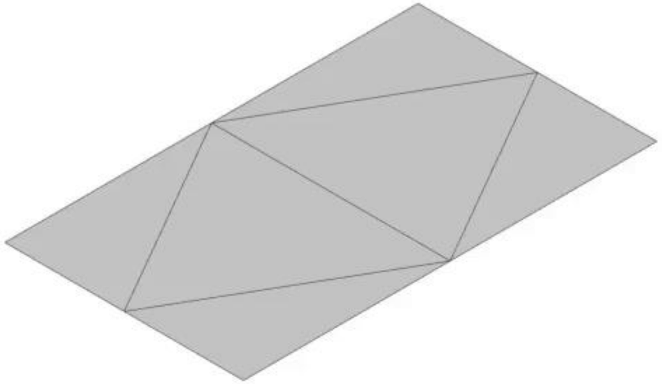
Folding Motion



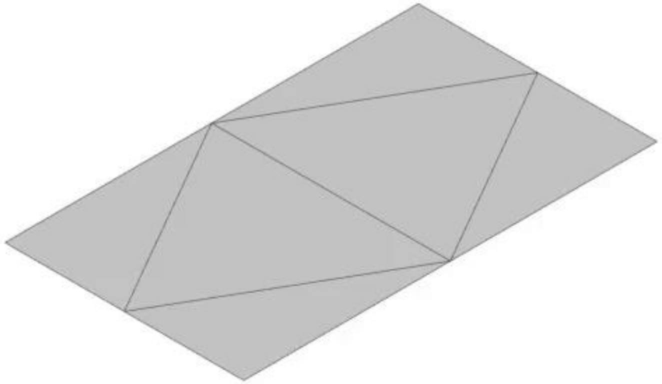
Geometry **after fold**

Geometry Modification

- **Separating Fold**



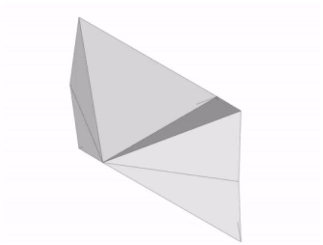
Fold/Unfold

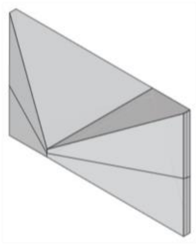


Separate Fold

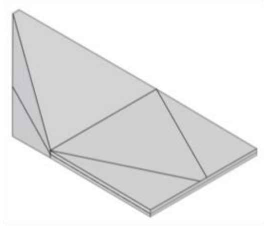
Geometry **Variations**

- **Module Types**

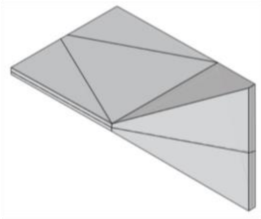




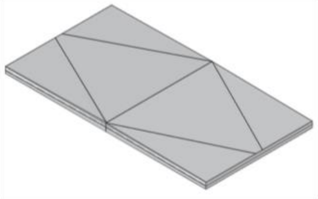
[A]



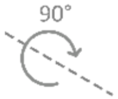
[B]

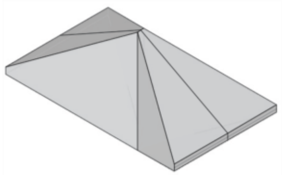


[C]

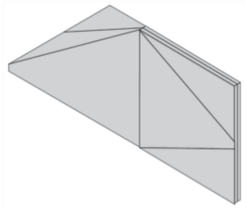


[D]

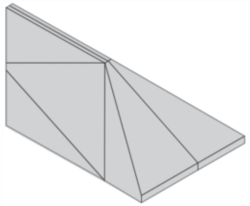




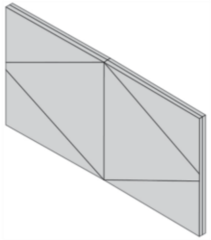
[A’]



[B’]



[C’]

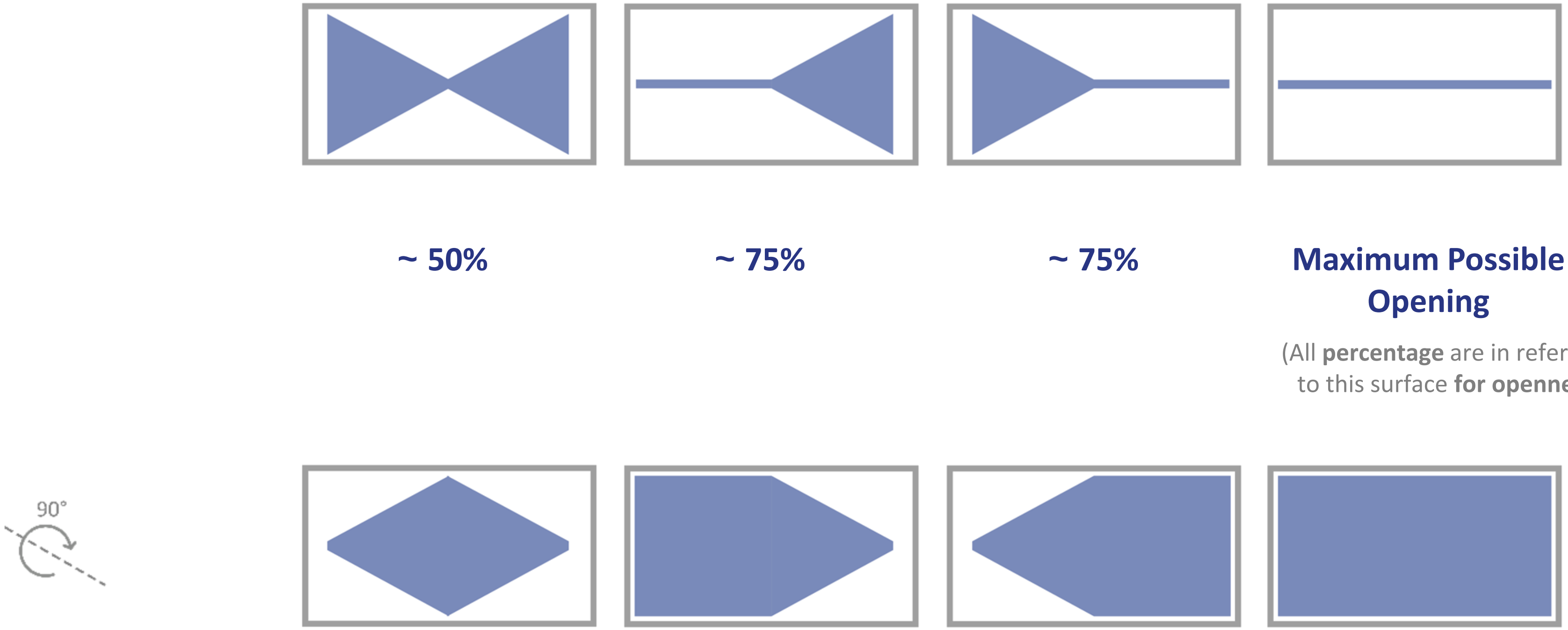


[D’]

Geometry's Advantages

Geometry's **Advantages**

- Percentage of **Openness/Closeness** – To control Penetration of light inside



Module type: A, B, C, D

Range: 0-50%

~ 50% | **~ 75%** | **~ 75%** | **Maximum Possible Opening**

(All **percentage** are in reference to this surface **for openness**)

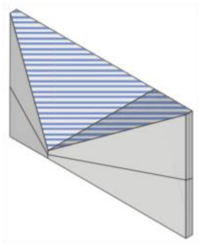
Module type: A', B', C', D'

Range: 50-100%

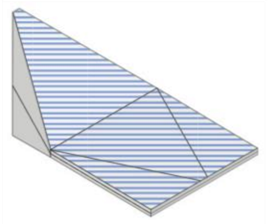
~ 50% | **~ 25%** | **~ 25%** | **Minimum Opening**

Geometry's Advantages

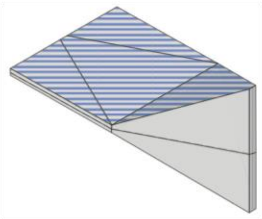
- **Percentage of Surface available – to control redirecting or blocking of incoming light**



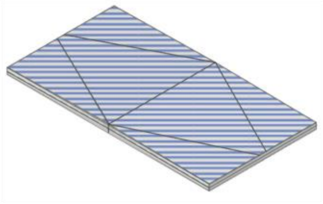
~ 50%



~ 75%



~ 75%

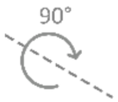


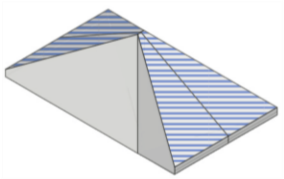
Maximum Surface available

(All percentage are in reference to this surface)

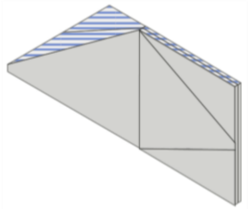
Module type: **A, B, C, D**

Range: **50-100%**

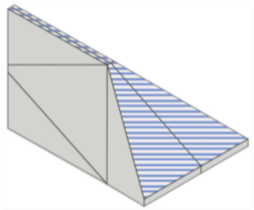




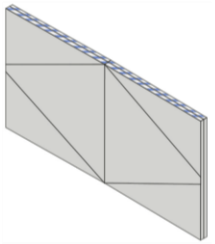
~ 50%



~ 25%



~ 25%



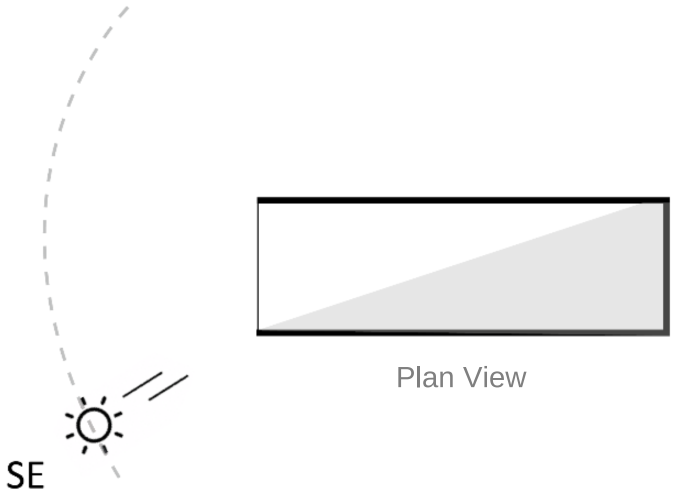
Minimum Surface available

Module type: **A', B', C', D'**

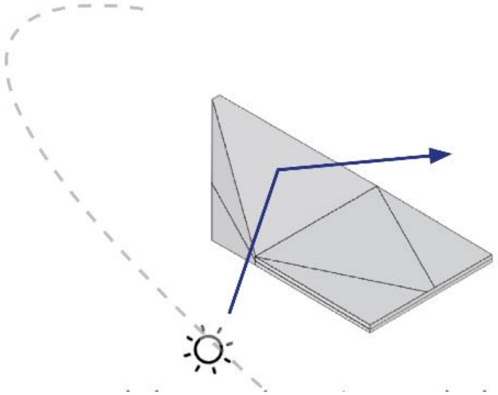
Range: **0-50%**

Geometry’s **Advantages**

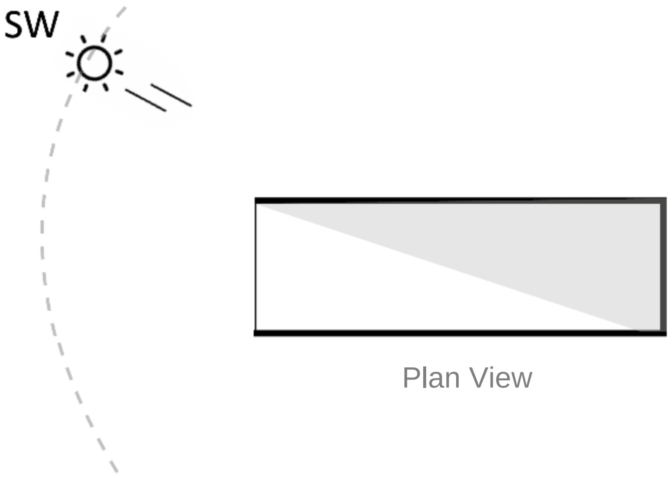
- Light **Redirecting** Benefit



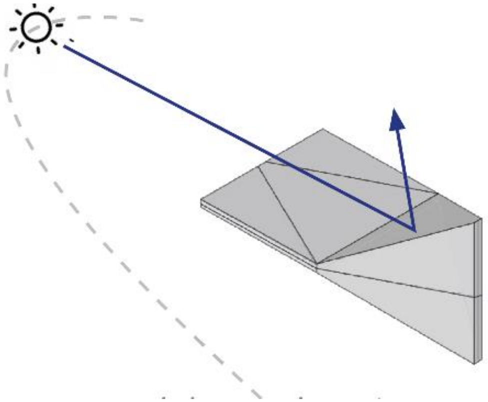
Plan View



Module [B]



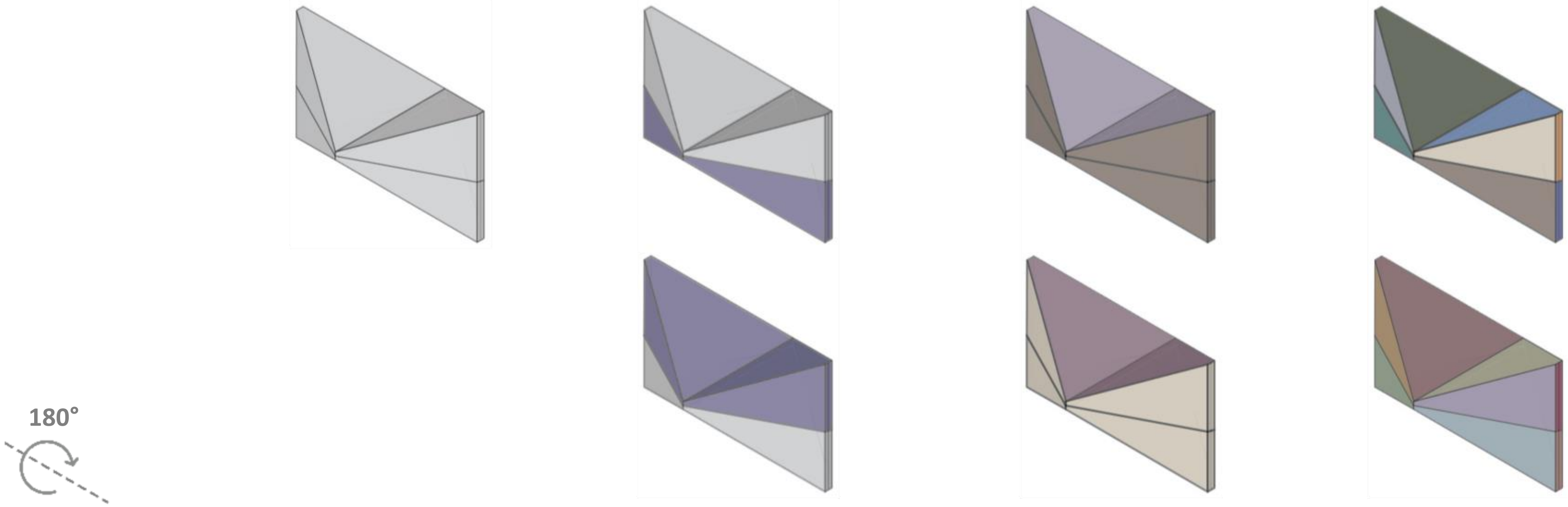
Plan View



Module [C]

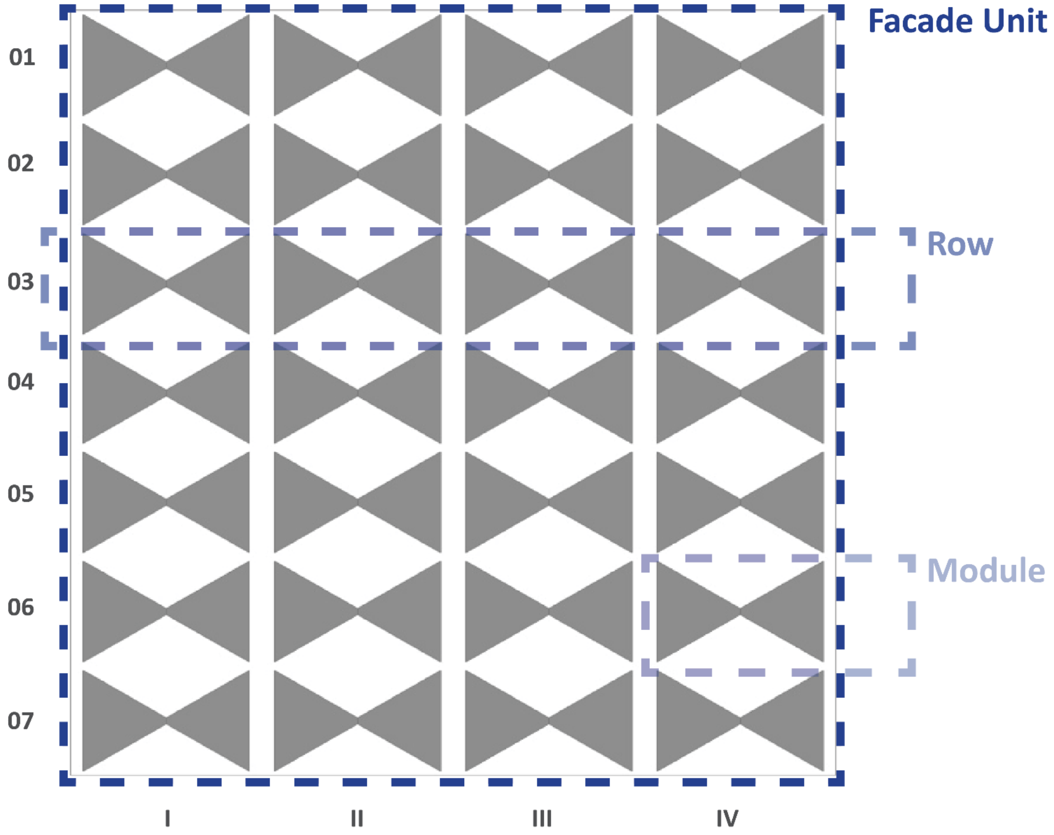
Geometry's **Advantages**

- **Material** Variations



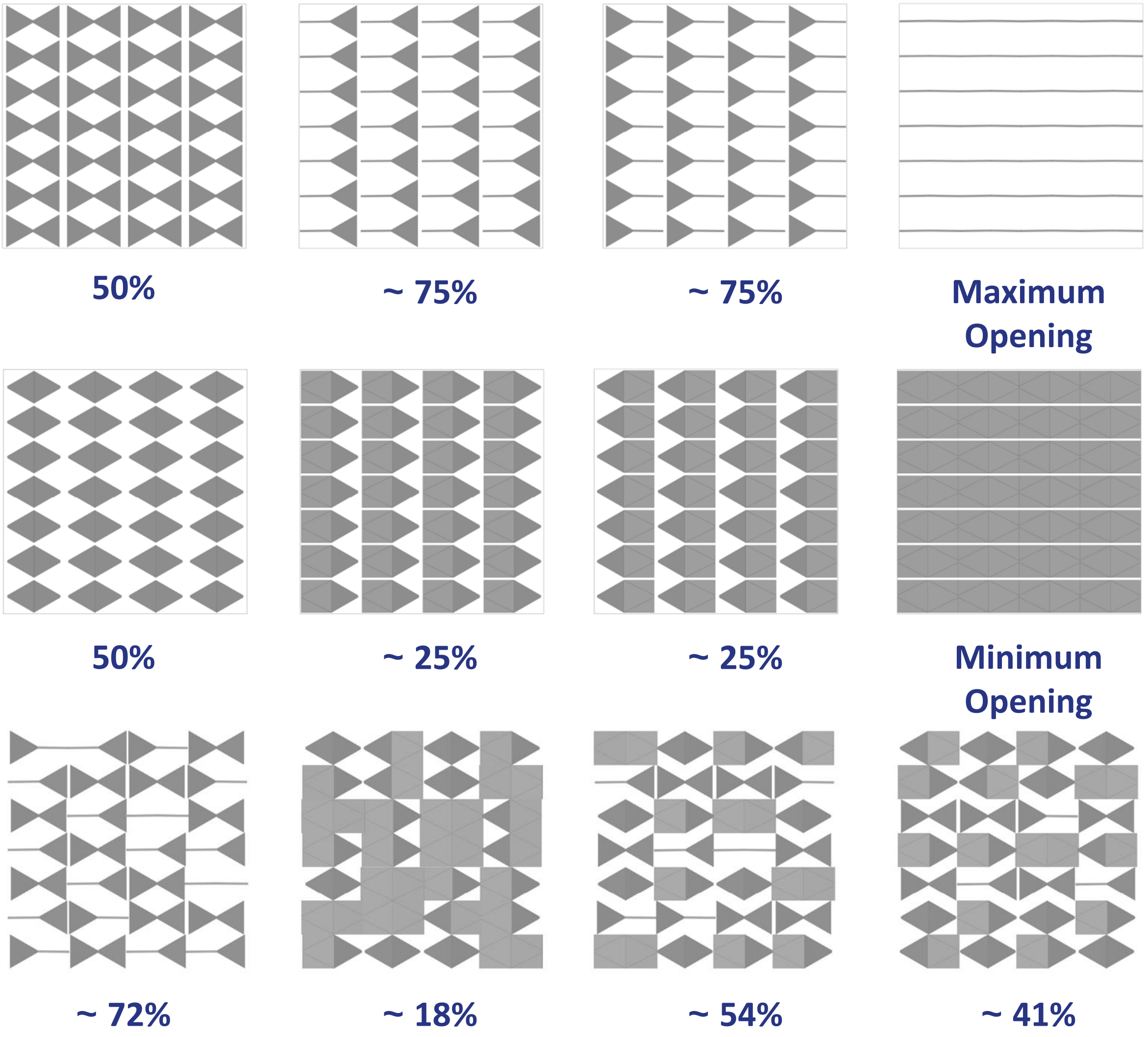
1- Material **2- Material** **4- Material** **All surface with separate material**

Façade Configuration



Façade Configuration

- Percentage of **Openness**



Module type: **A, B, C, D**

Range: **50% and above**

Module type: **A’, B’, C’, D’**

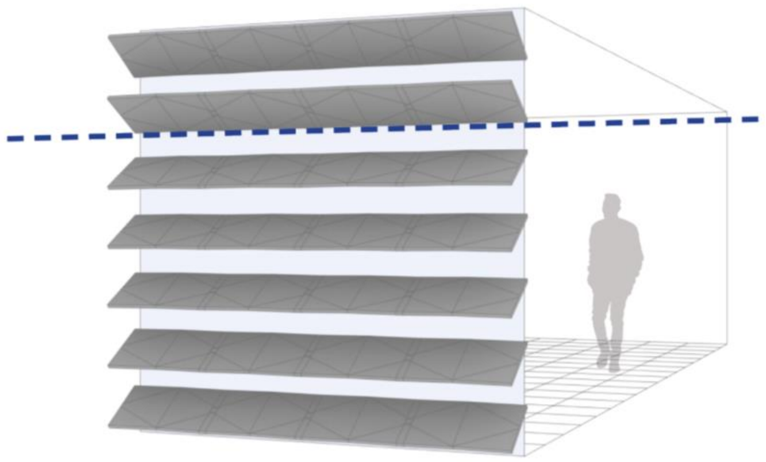
Range: **50% and below**

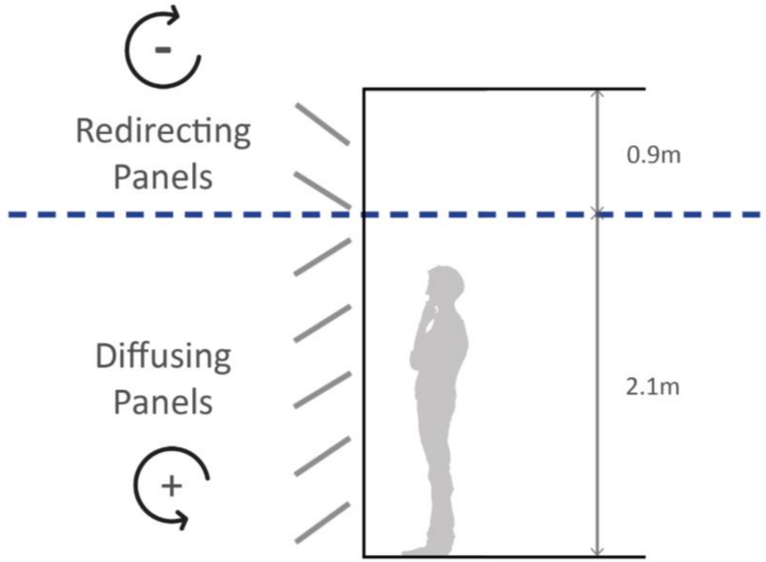
Module type: **Randomly**

Range: **Maximum to Minimum**

Façade Modification

- **Dividing façade** into two parts

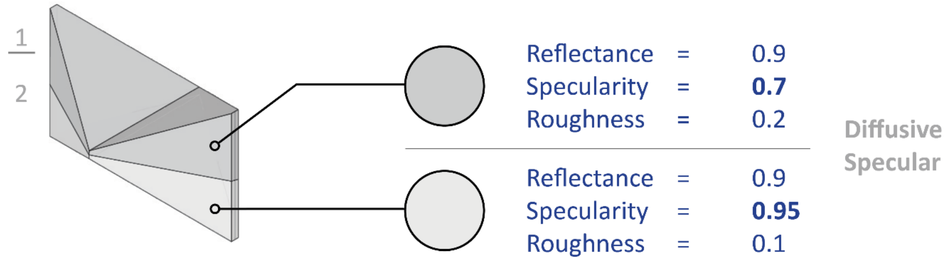




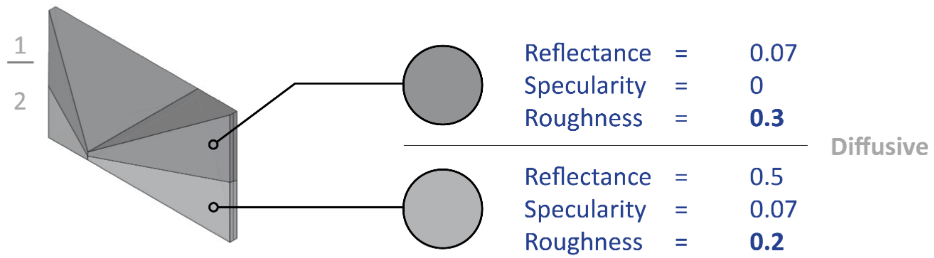
- ## Material Applied - Based on Optical Properties

Two- set of Material

Redirecting Modules (Panels 1-2)

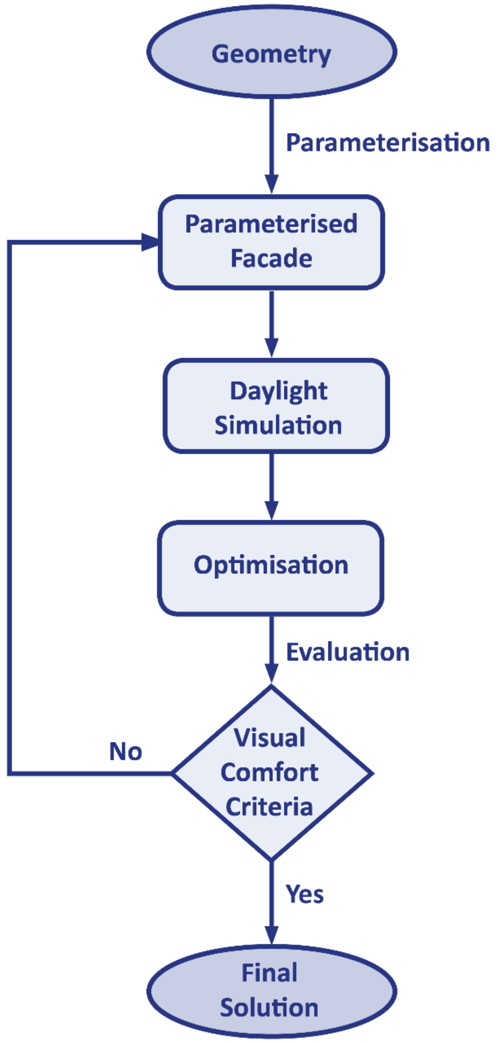


Diffusing Modules (Panels 3-7)



Computation Design

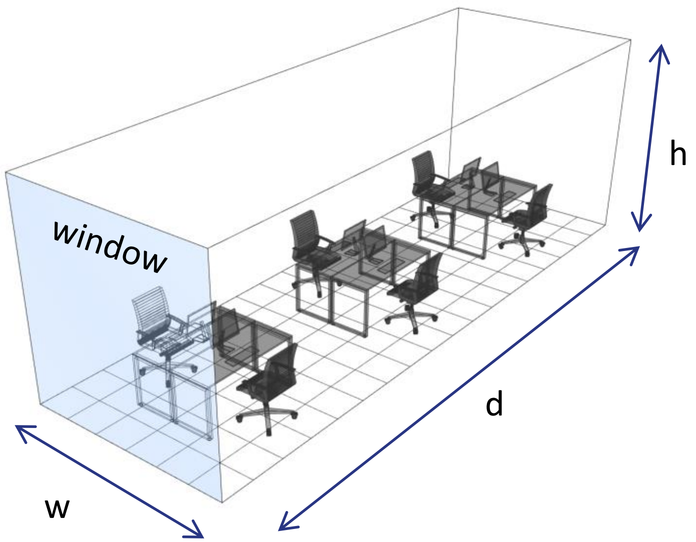
Computational Workflow

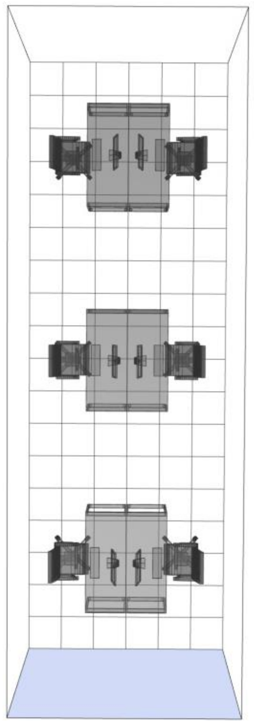


01

Parametric Modelling

Room Setup



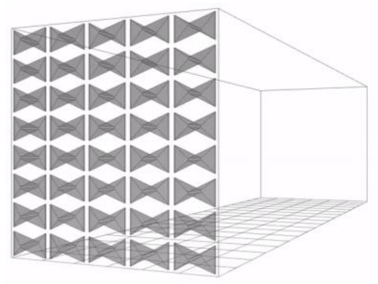


Narrow and Deep Room

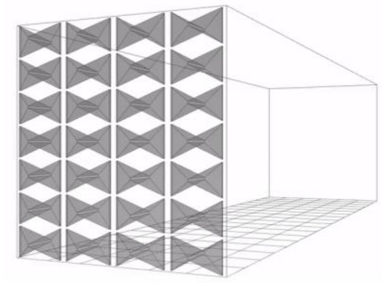
Depth (d) : 9m
Width (w) : 3m
Height (h) : 3m clear

Typology :Office
Activity :Workplace
Interior :Open plan

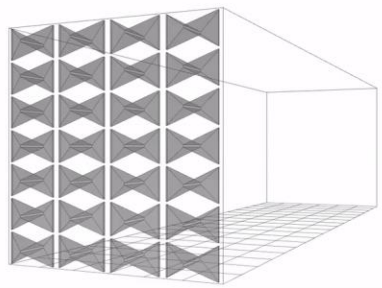
Façade Parameters – Possibilities



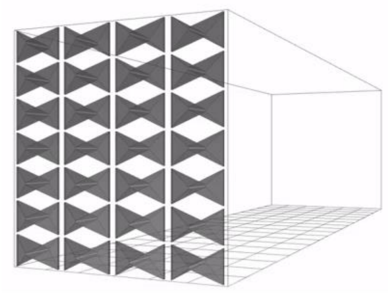
No of Columns



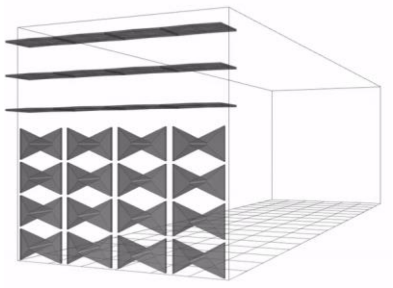
Uniform



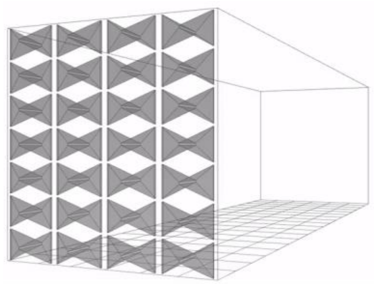
Similar Rotation



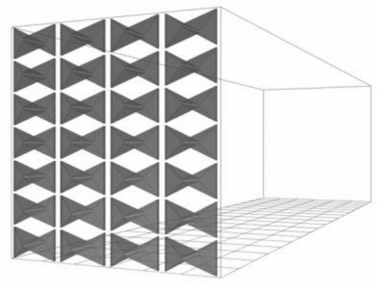
Non Uniform



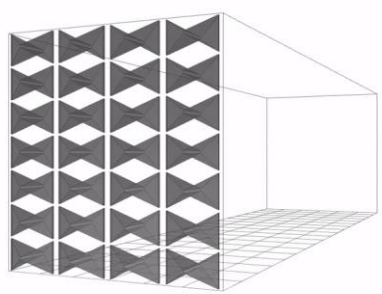
Opposite Rotation



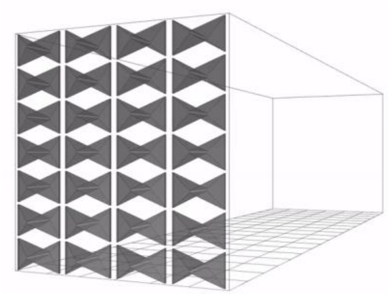
Spacing between Modules



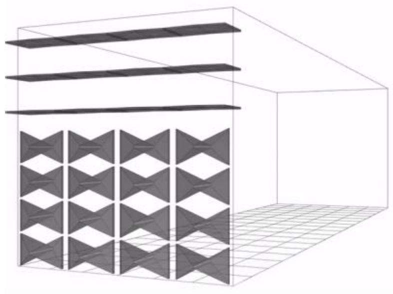
Non-Uniform



Separate Rotation

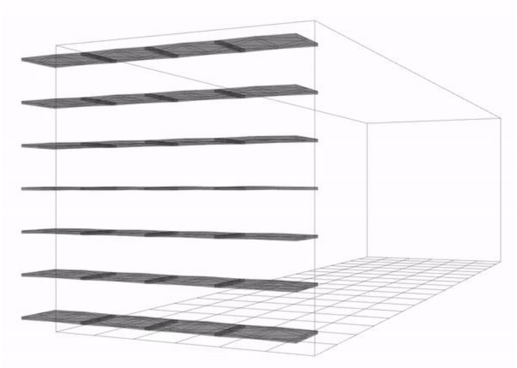


Non Uniform



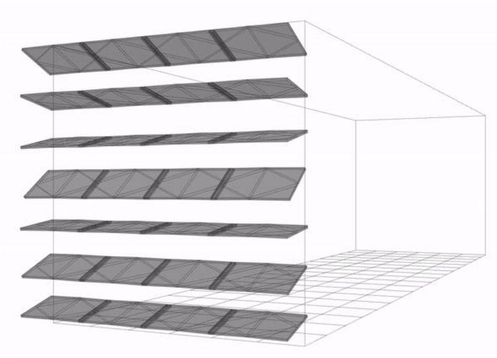
Opposite Rotation

Façade Parameters – Finalised



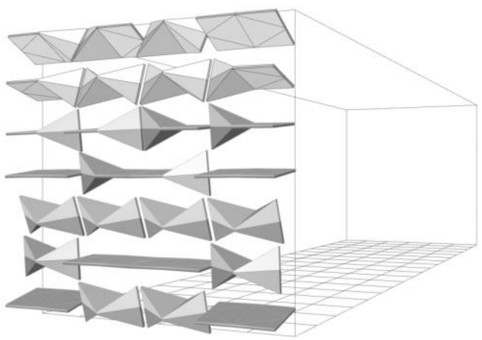
01

Rotation
Separated by Row



02

Module Type
Change Individually



03

Material Set
2- Options

02

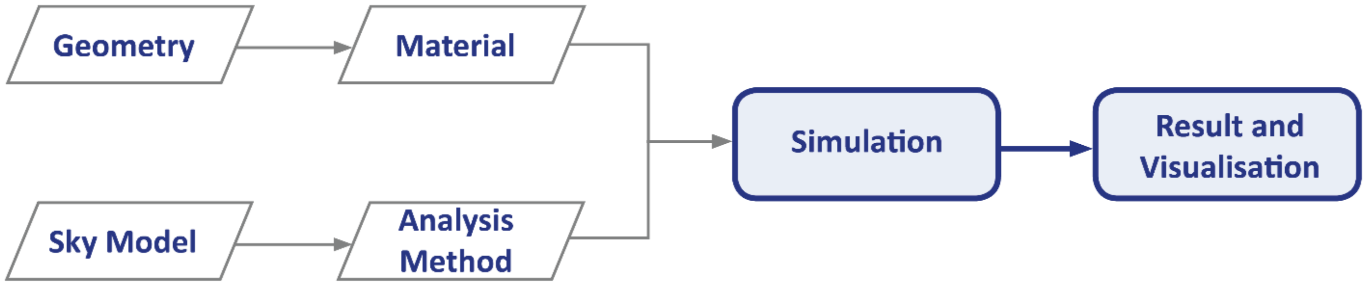
Daylight Simulation

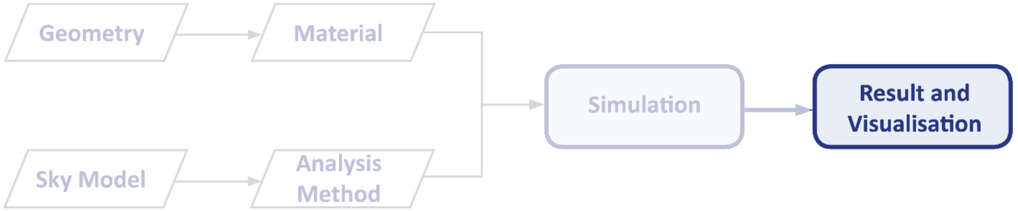
Daylight Simulation Tool

HB+/LB+

Environmental Design Tools

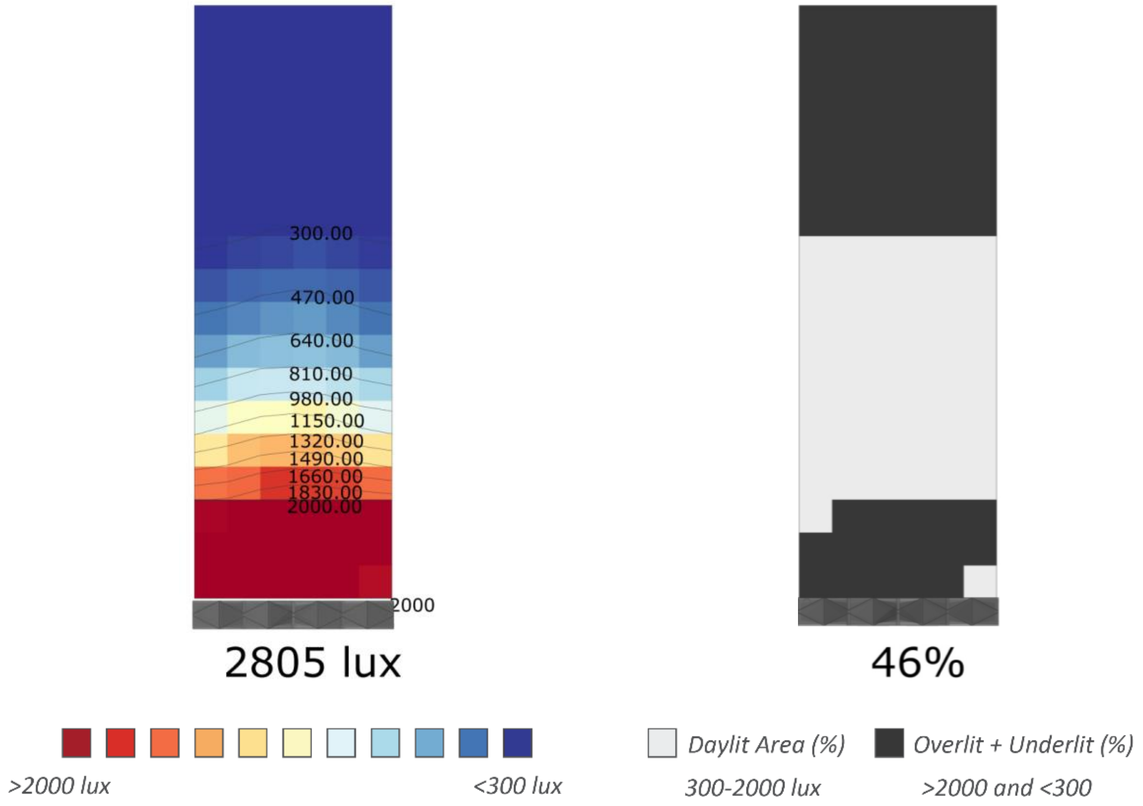
Daylight Simulation Workflow



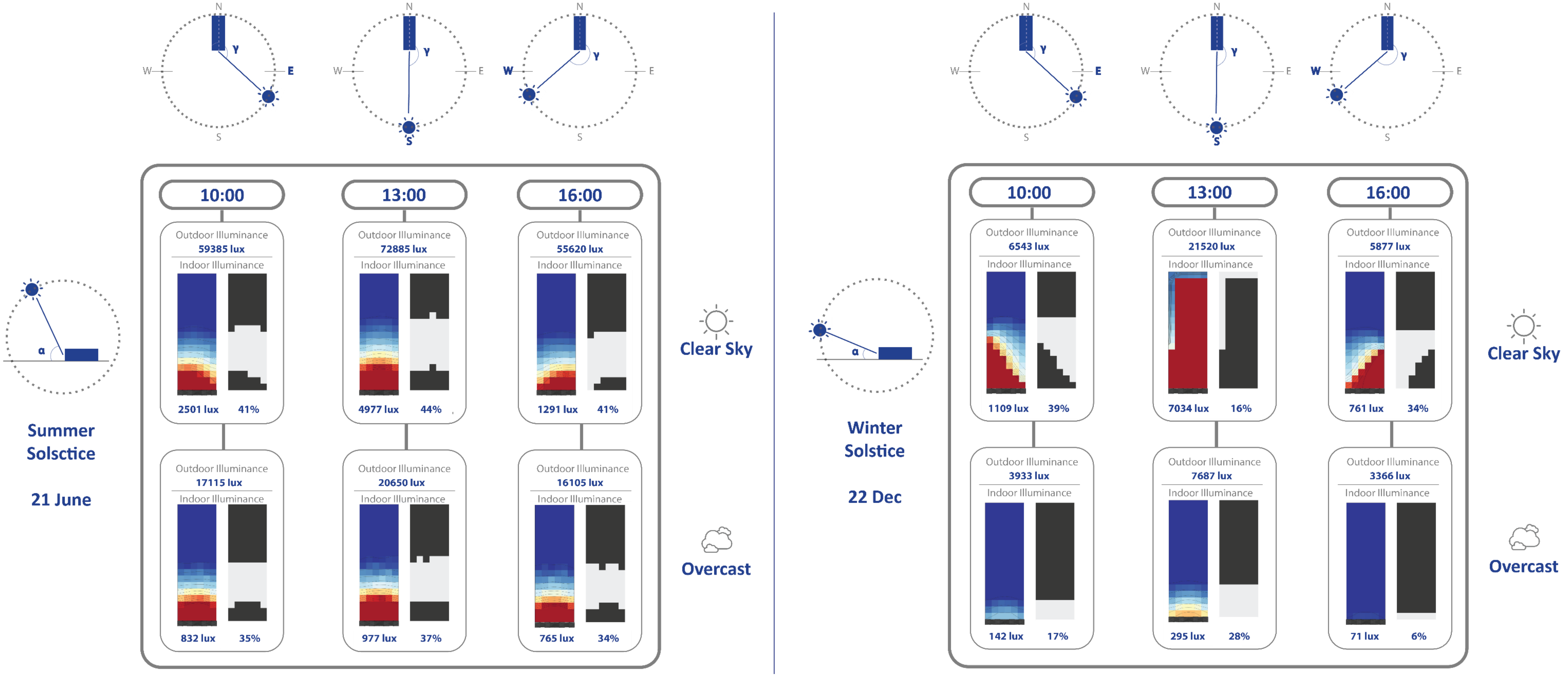


Illuminance **GridBased Output**

- **Reference Plane : 0.7m (Desk height)**
- **Grid : 0.5x0.5m**



Daylight Availability



NOTE: All values for indoor illuminance are with Glazing having VT 0.65

>2000 lux — *<300 lux*

Daylit Area (%) 300-2000 lux

Overlit + Underlit (%) >2000 and <300

03

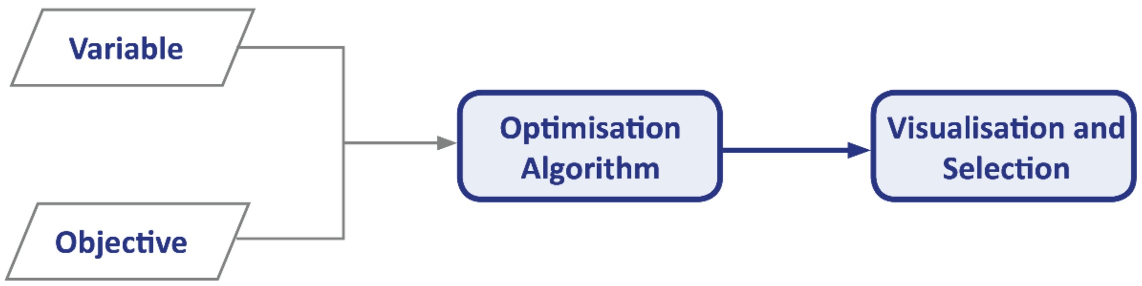
Optimisation

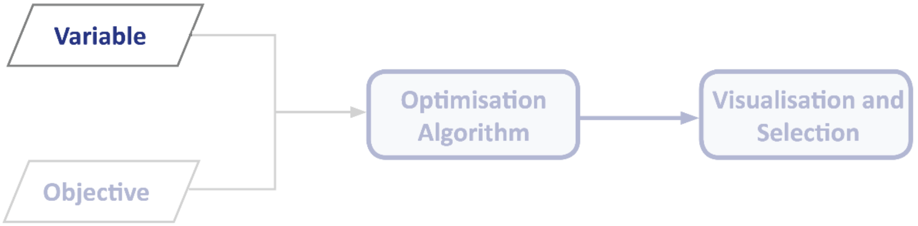
Optimisation Engine

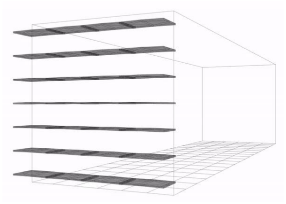
Wallacei

Evolutionary engine – NSGA II Algorithm

Optimisation Workflow

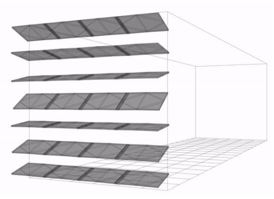






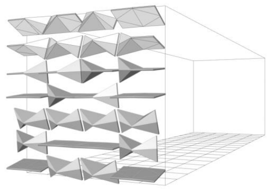
01

Rotation
Separated
by Row



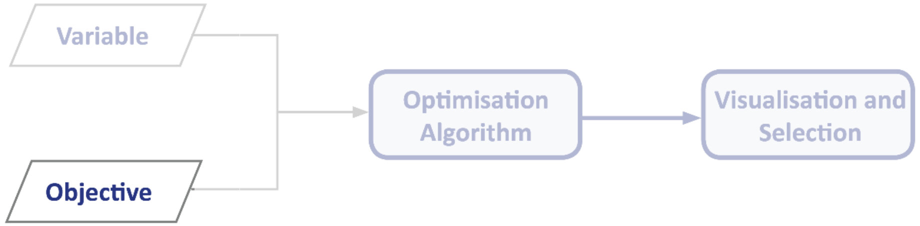
02

Module Type
Change
Individually



03

Material Set
2-Options



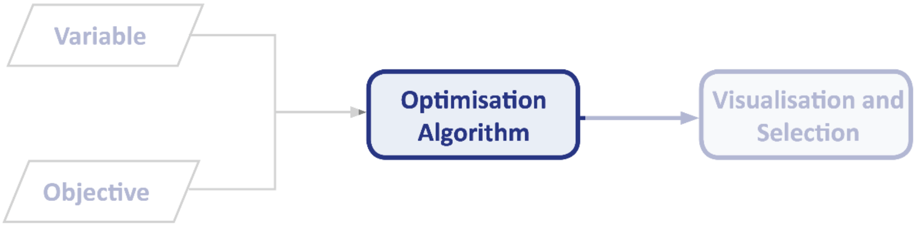
Objectives

One-Main Objective

1. **Maximise** overall **Daylit area % (300-2000 lux)**

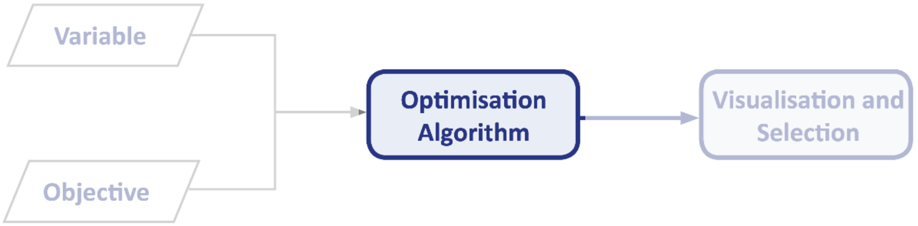
Two-Supportive Objective

2. **Maximise Illuminance** where **lux is <300**
3. **Minimise Illuminance** where **lux is >2000**



Attempt	Facade Segment	Optimisation Parameters		Population	Optimisation Run Time	Daylit % Achieved
01	Redirecting	Rotation	Separated by Row	2500	3+ Days	57%
		Module	Individual			
		Material	M11/M22			
	Diffusing	Rotation	Separated by Row			
		Module	Individual			
		Material	M11/M22			

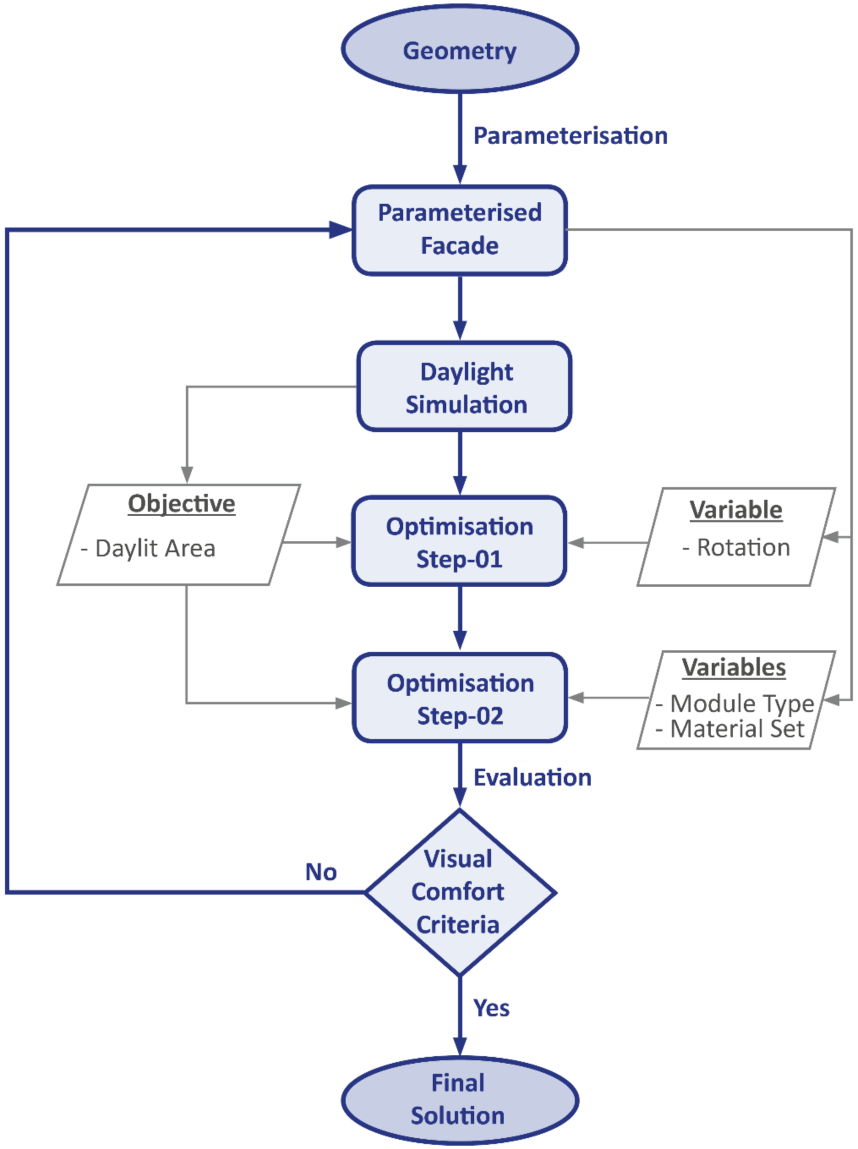
Wegdy (2016)



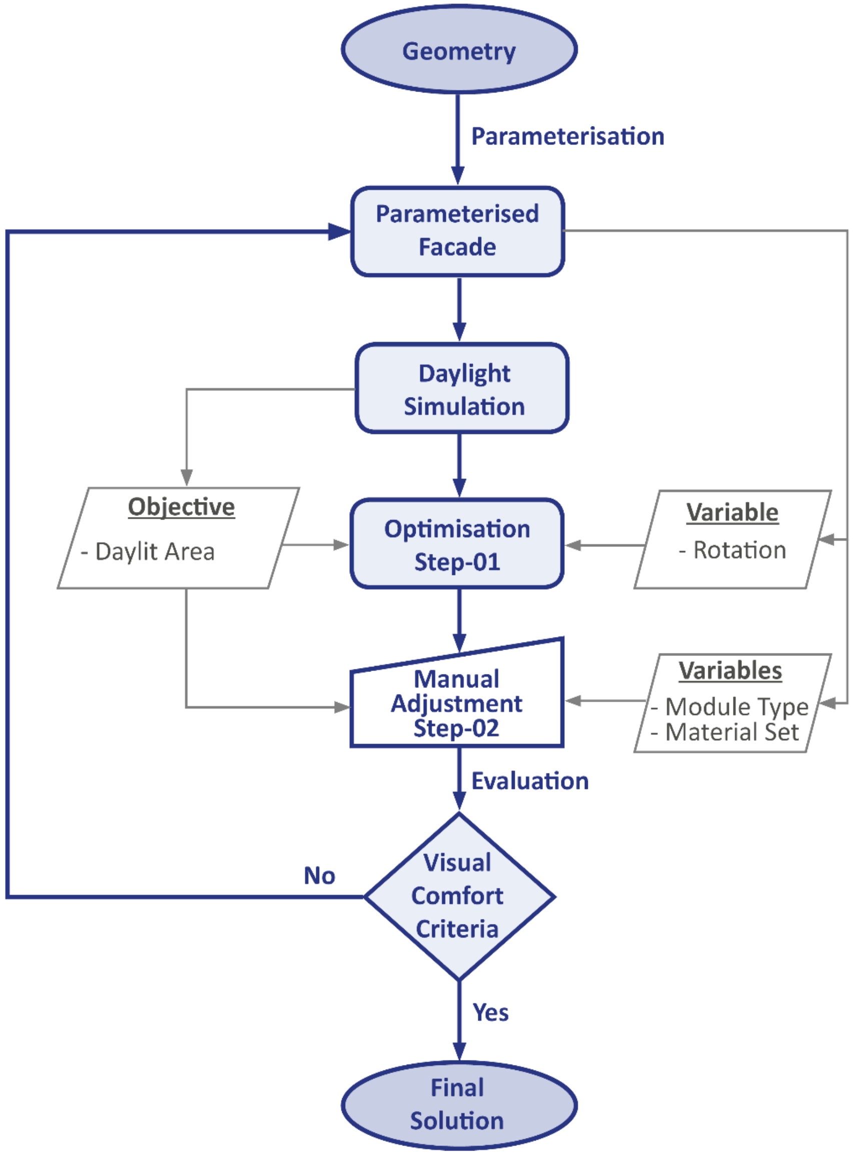
Attempt	Facade Segment	Optimisation Parameters		Population	Optimisation Run Time	Daylit % Achieved
01	Redirecting	Rotation Module Material	Separated by Row Individual M11/M22	2500	3+ Days	57%
	Diffusing	Rotation Module Material	Separated by Row Individual M11/M22			
02	Redirecting	Rotation Module Material	Separated by Row Separated by Row (Fixed M11)	2500	2+ Days	61%
	Diffusing	Rotation Module Material	Separated by Row Separated by Row (Fixed M11)			
03	Redirecting	Rotation Module Material	Separated by Row (Fixed Type D) (Fixed M11)	2500	1+ Days	72%
	Diffusing	Rotation Module Material	Separated by Row (Fixed Type D) (Fixed M11)			

- **Optimisation in two steps**

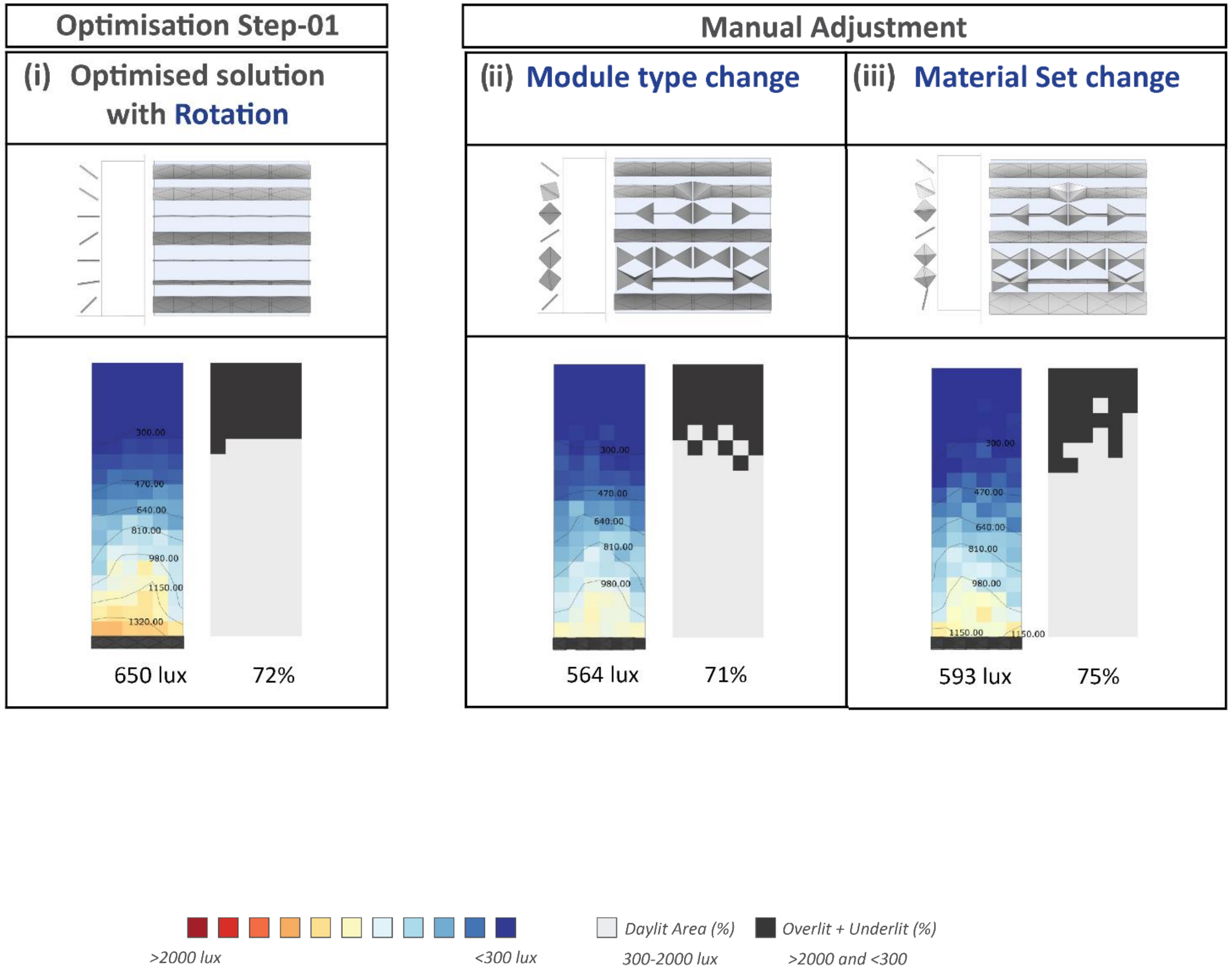
12- instances Twice

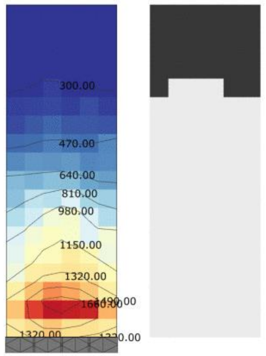


- **Workflow– limited to this study**



Solution from Optimisation

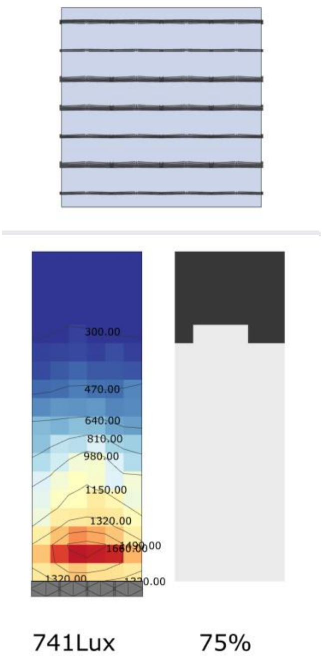


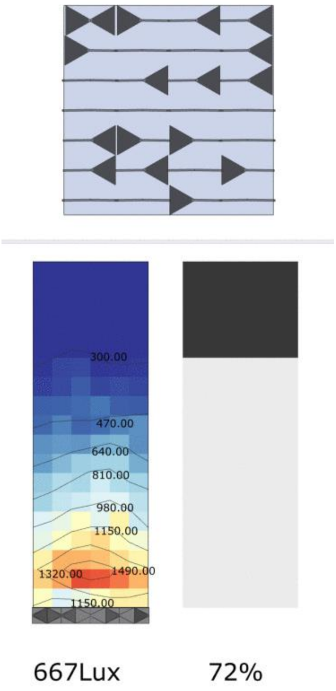


741Lux 75%

Rotation

Daylight Reach





Rotation

↓

Daylight Reach

Module Type

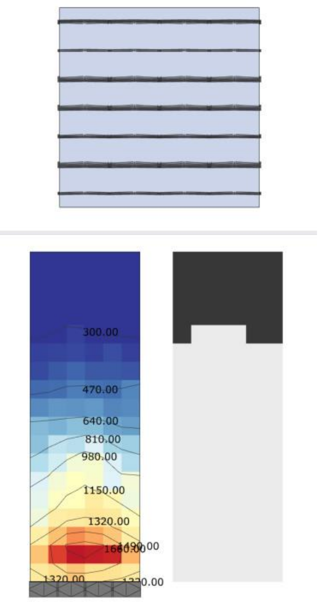
↓

Uniform intensity of light

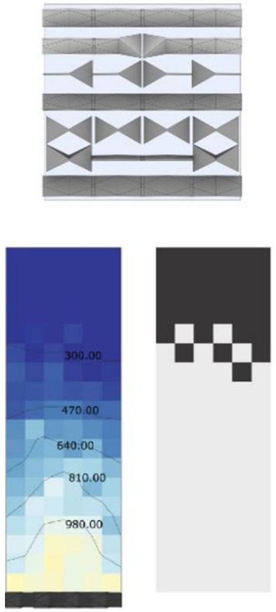
>2000 lux <300 lux

Daylit Area (%) 300-2000 lux

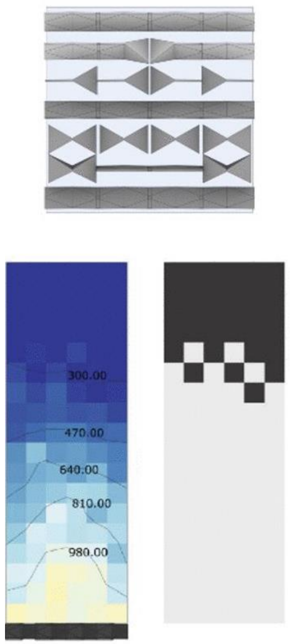
Overlit + Underlit (%) >2000 and <300



741Lux 75%



564 lux 71%



564 lux 71%

Rotation

↓

Daylight Reach

Module

↓

Uniform light intensity

Material Set

↓

Light Enhance

>2000 lux … *<300 lux*

Daylit Area (%) *300-2000 lux*

Overlit + Underlit (%) *>2000 and <300*

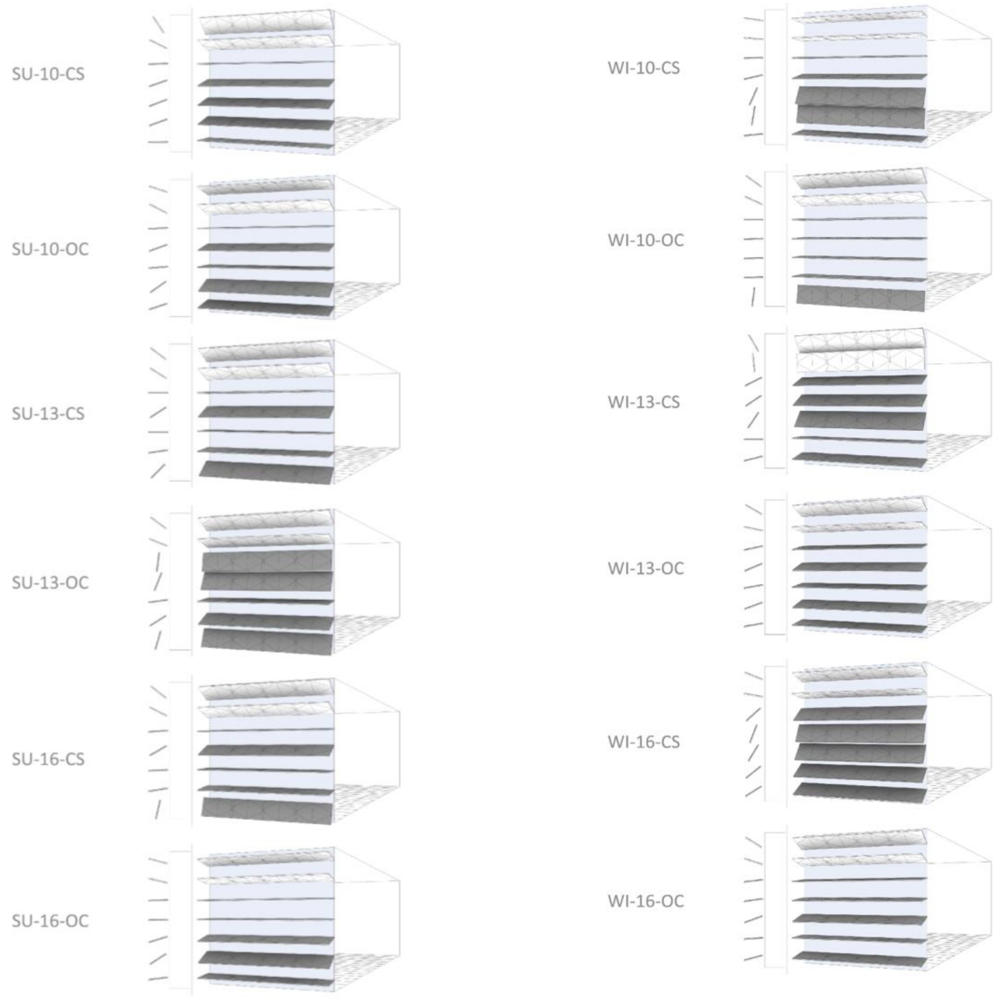
Optimisation Step-01

Optimisation Step-01

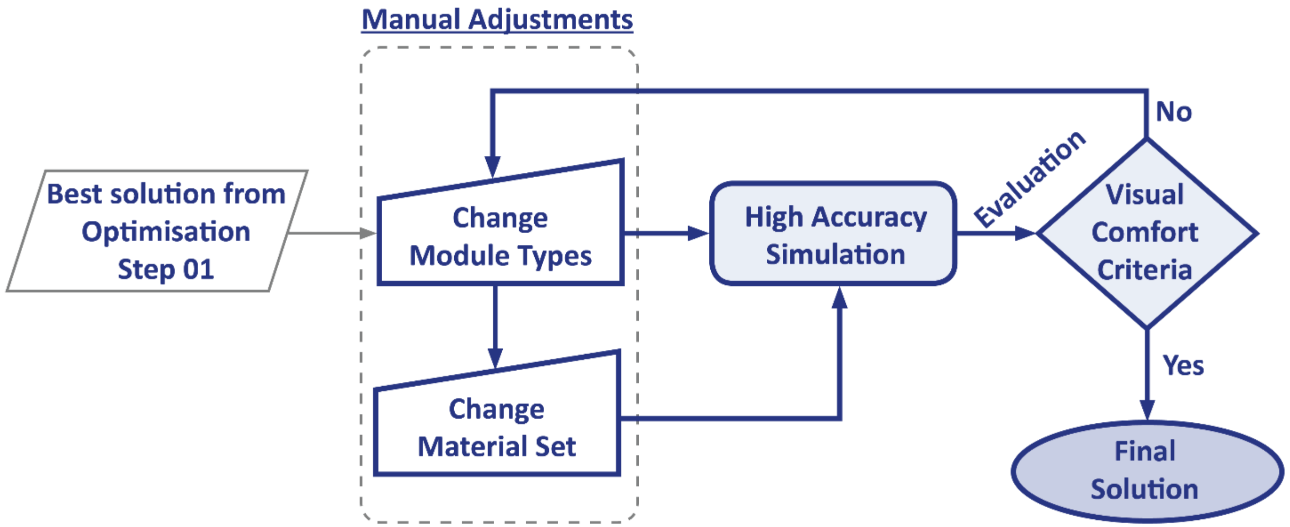
- ## Results

Panel No.	SU					
	10		13		16	
	CS	OC	CS	OC	CS	OC
1	-56	-18	-37	-36	-38	-15
2	-26	-27	-32	-22	-27	-13
3	2	3	0	83	4	2
4	19	20	33	68	30	1
5	21	4	0	8	2	17
6	20	35	8	32	9	33
7	1	18	45	74	77	7

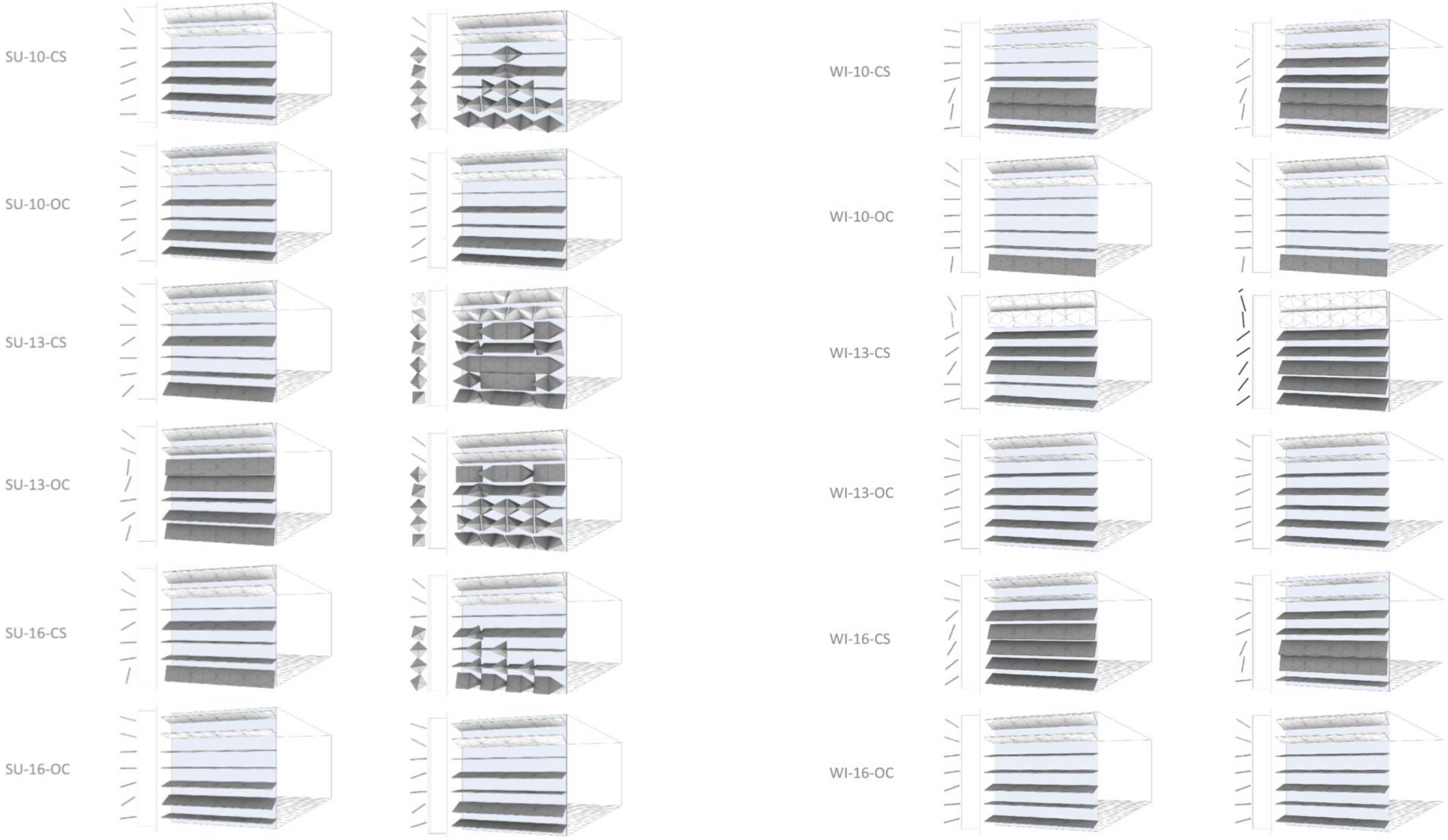
Panel No.	WI					
	10		13		16	
	CS	OC	CS	OC	CS	OC
1	-8	-36	-60	-30	-22	-32
2	-5	-25	-85	-12	-10	-18
3	1	0	27	12	42	7
4	13	3	34	23	69	8
5	66	2	56	10	59	20
6	81	2	0	20	39	4
7	6	83	14	10	32	15



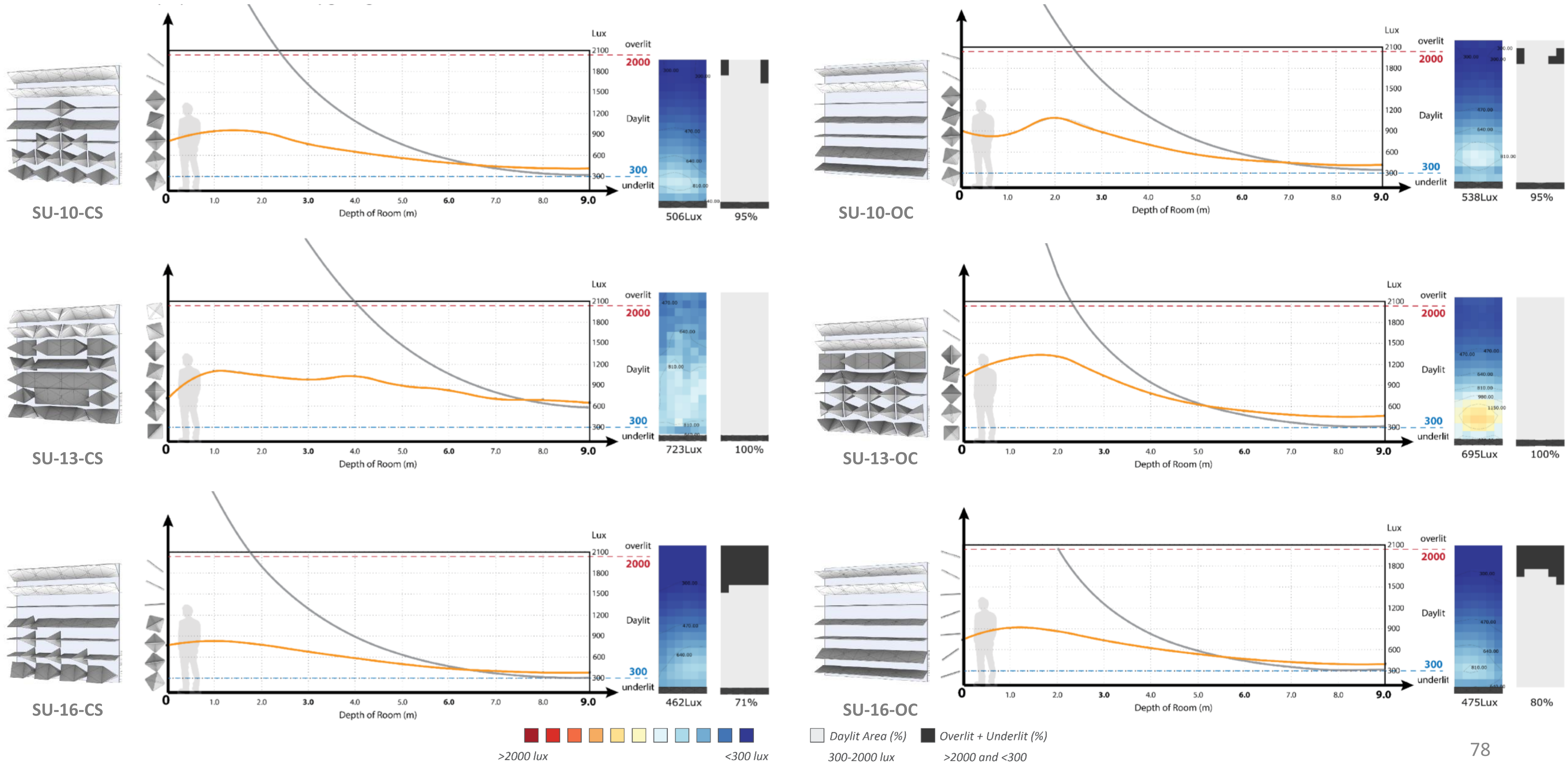
Step-02 Manual Adjustments



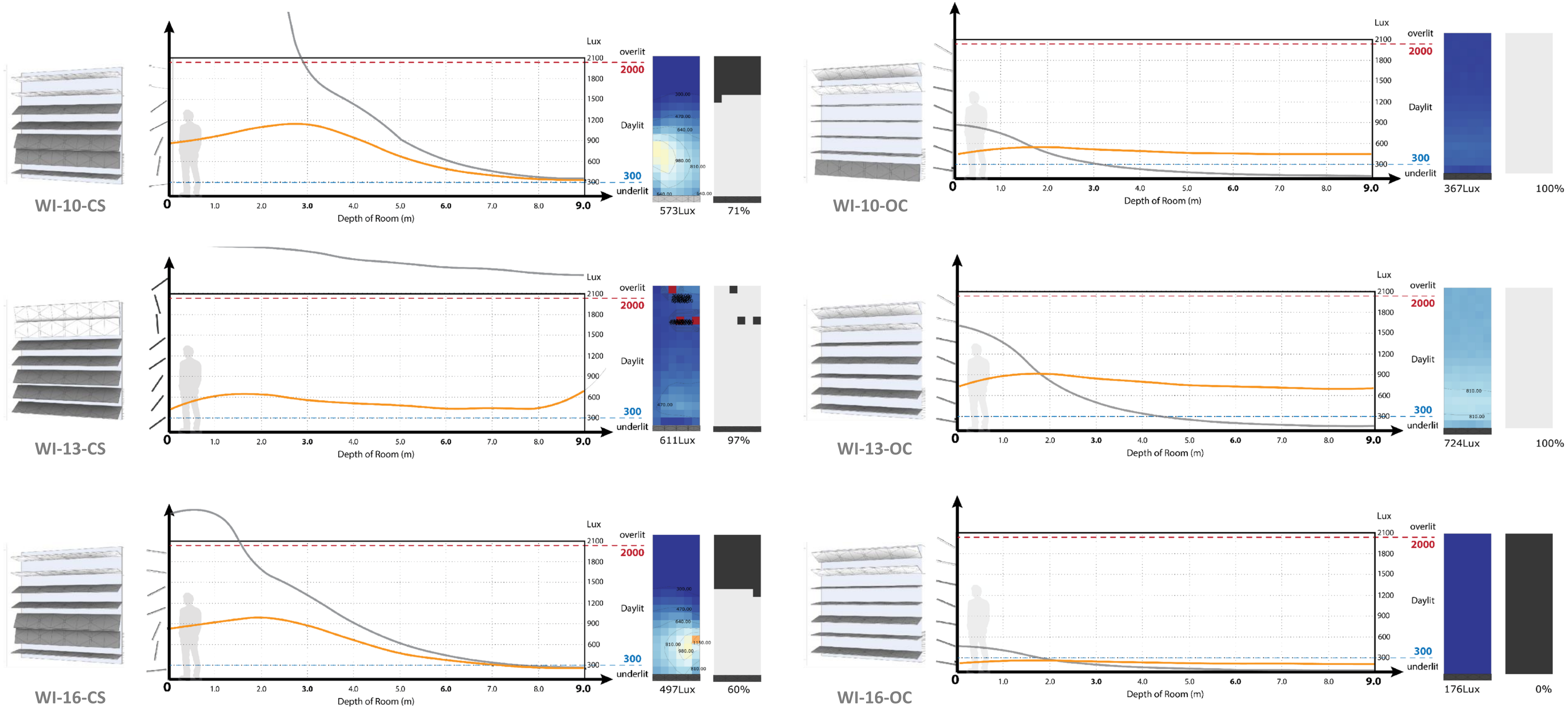
- **Final Optimised Solution and corresponding modified solutions**



Illuminance Distribution along Depth– Summer Condition



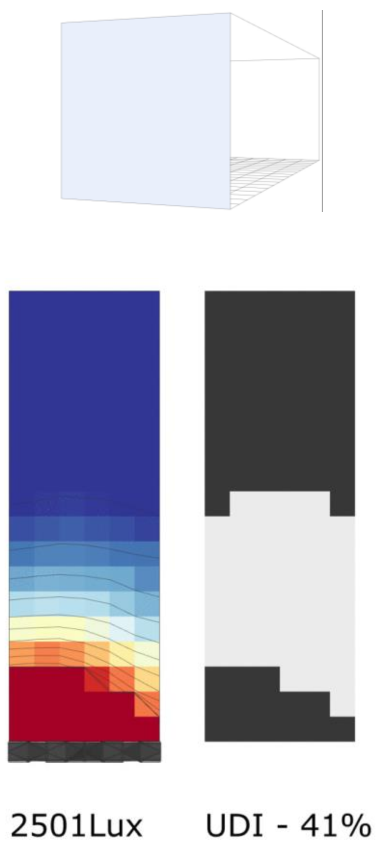
Illuminance Distribution along Depth– **Winter** Condition



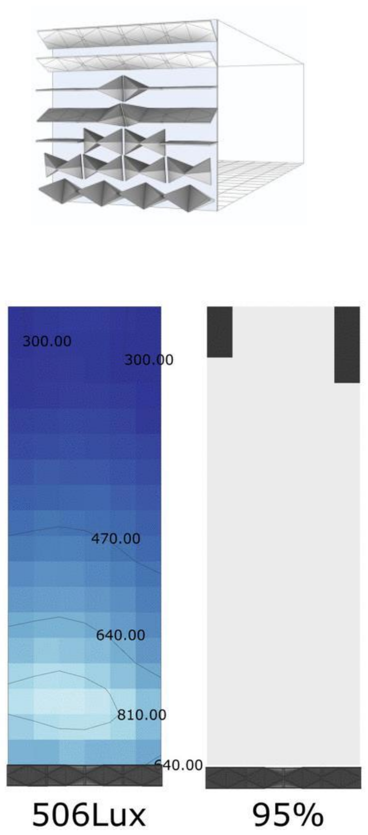
>2000 lux <300 lux

Daylit Area (%) 300-2000 lux

Overlit + Underlit (%) >2000 and <300



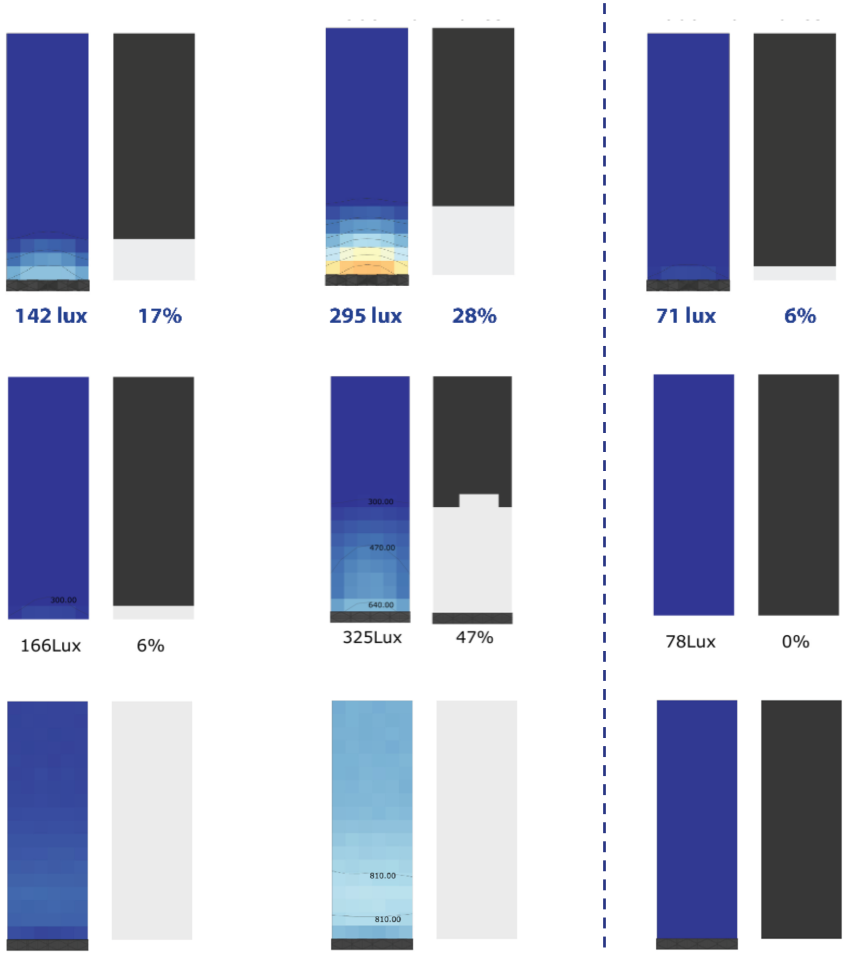
With only Glazing



With final solutions of Facade

Winter Condition – Overcast Sky

	WI-10-OC		WI-13-OC		Exceptional Case: WI-16-OC	
Available Daylight – without Facade	142 lux	17%	295 lux	28%	71 lux	6%
Façade with material set M11/M22	166Lux	6%	325Lux	47%	78Lux	0%
With Higher reflective material (Making diffusive panels 3-7 more reflective)	367 lux	100%	724 lux	100%	176 lux	0%



Façade with material set M11/M22:

Redirecting Panels,
Reflectance = 0.9
Specularity = 0.97
Roughness = <u>0.1</u>

Diffusing Panels,
Reflectance = <u>0.5</u>
Specularity = <u>0.07</u>
Roughness = 0.1

With Higher reflective material:

Redirecting Panels,
Reflectance = 0.9
Specularity = 0.97
Roughness = <u>0</u>

Diffusing Panels,
Reflectance = <u>0.8</u>
Specularity = <u>0.5</u>
Roughness = 0.1

Evaluation

Result Values

Instances	Avg Lux	Daylit%	Uniformity Ratio	O11	O12	C1	C2	Highest lux	lowest lux	Avg lux/mt.	Overlit	Underlit	Material Set
	Distribution of Daylight			DGP		Contrast							
SU-10-CS	506	95	0.56	0.25	0.26	2.3	2	915	284	59	0	5	M11
SU-13-CS	723	100	0.62	0.24	0.23	2.59	0.96	1002	447	50	0	0	M11
SU-16-CS	462	71	0.55	0.23	0.25	2	2.5	807	252	52	0	29	M11
SU-10-OC	538	95	0.53	0.23	0.23	2	2	979	286	75	0	5	M11
SU-13-OC	695	100	0.51	0.23	0.23	1.86	2	1336	353	98	0	0	M22
SU-16-OC	475	80	0.54	0.22	0.23	1.9	2	846	258	57	0	20	M11
WI-10-CS	573	71	0.35	0.2	0.22	1.98	2.24	1137	200	62	0	29	M22
WI-13-CS	611	97	0.5	0.2	0.21	0.85	0.37	607	305	4	3	0	M11
WI-16-CS	497	60	0.3	0.21	0.2	2.98	1.97	1483	147	40	0	60	M22
WI-10-OC	367	100	0.89	0.12	0.12	1.89	1.56	441	326	12	0	0	Higher reflectivity
WI-13-OC	724	100	0.88	0.19	0.19	2.12	2.1	863	640	24	0	0	Higher reflectivity
WI-16-OC	176	0	0.89	0.03	0.03	1.4	1.21	211	156	6	0	100	Higher reflectivity
Average*	561	88	0.57	0.21	0.22	2.04	1.79	946	318	48	0	13	-

Performance Results

(Average of all Instances)

Daylit Area

88%

Avg. Illuminance

561 lux

(300-750 lux)

Uniformity Ratio

0.57

(>0.3)

DGP

0.21

(<0.45)

Contrast Ratio

1.9

(>3.0)

Performance Results

(Average of all Instances)

Visually comfortable environment achieved

Daylit Area

88%

Avg. Illuminance

561 lux

(300-750 lux)

Uniformity Ratio

0.57

(>0.3)

DGP

0.21

(<0.45)

Contrast Ratio

1.9

(>3.0)

Performance Results

(Average of all Instances)

Daylit Area

88%

Use of artificial light can be reduced by 88%

Reduces concerning lighting consumption by 88%

Avg. Illuminance

561 lux

Close to 500 lux

(requirement for an office workplace by CIBSE, 2015)

Uniformity Ratio

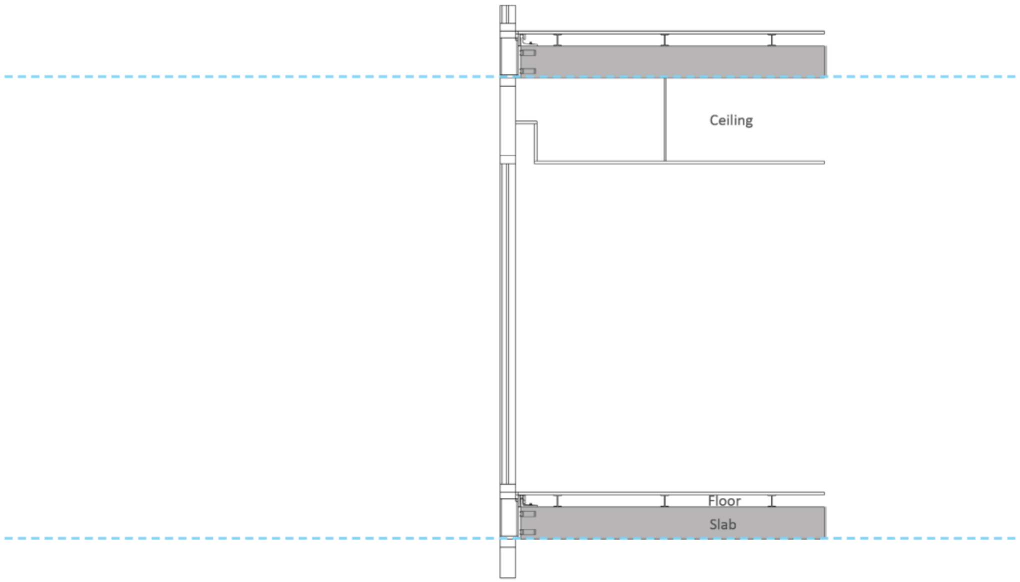
0.57

0.5 - 0.7 for artificial lighting (BREEAM, 2016)

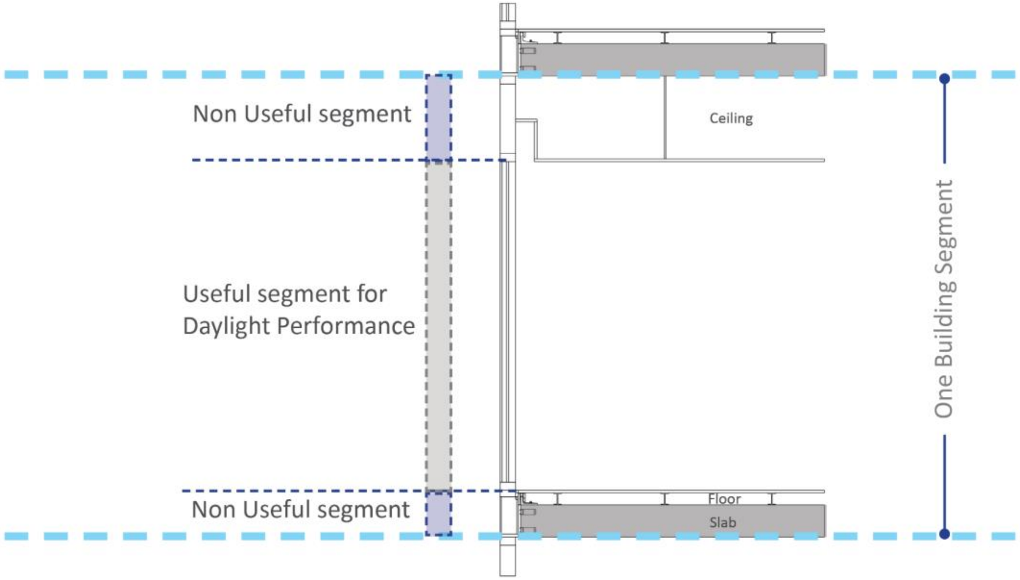
Use of artificial light can be neglected

Façade Scheme

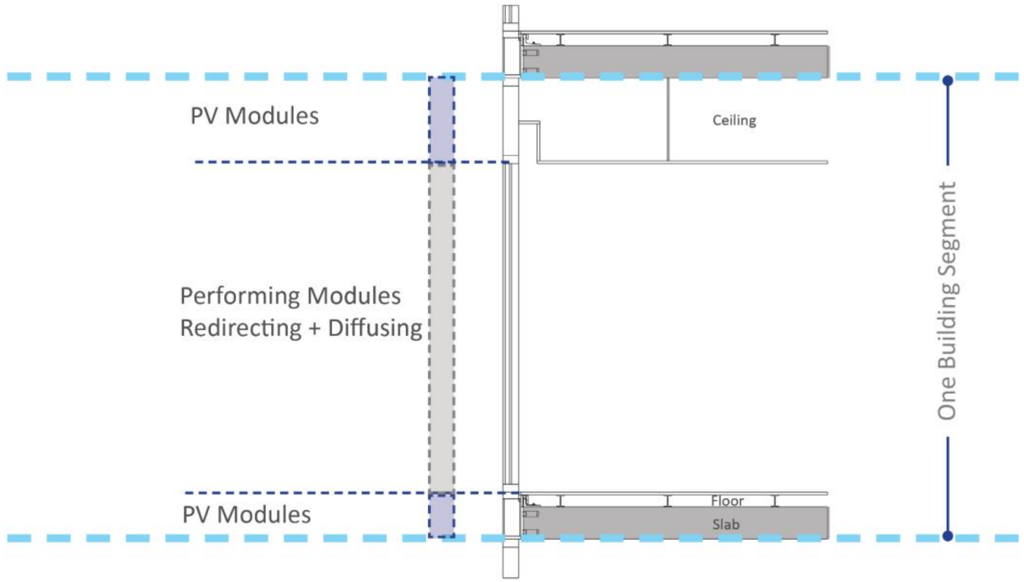
- **Building Segment - (Slab bottom to Slab bottom)**

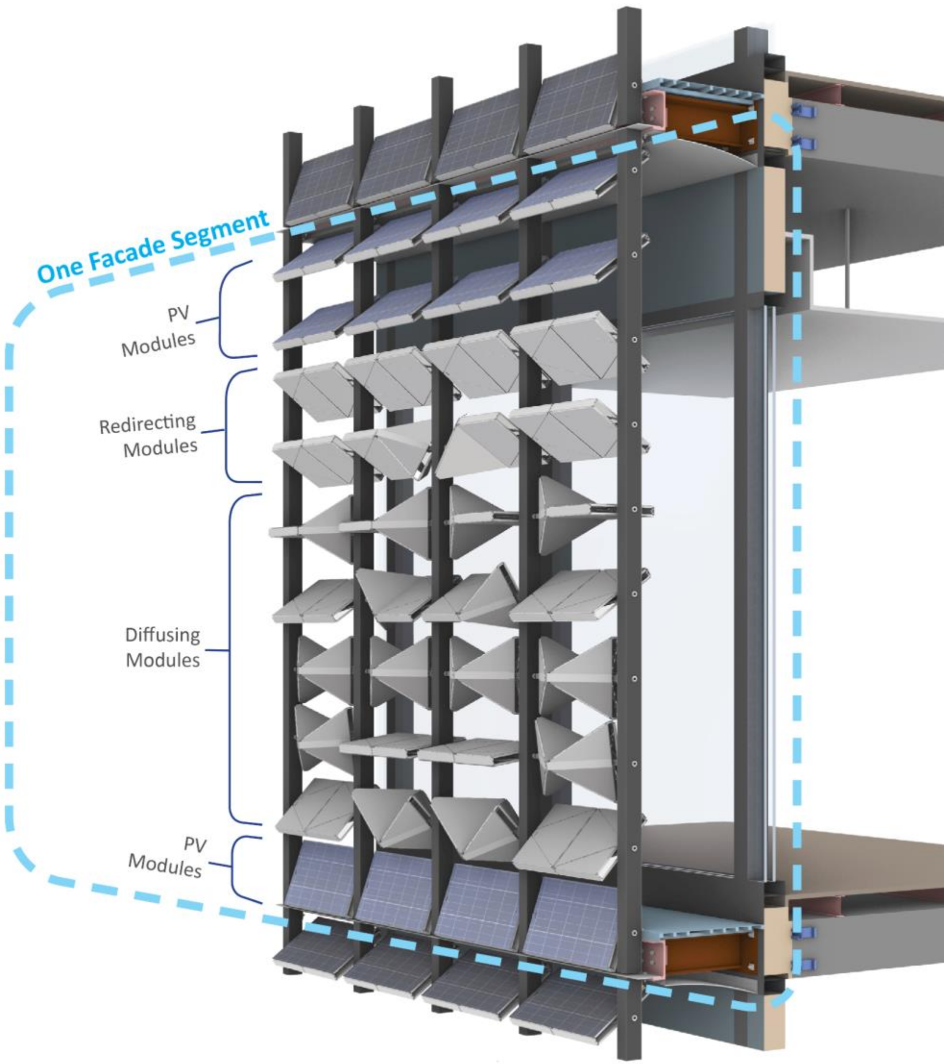


- **Building Segment - (Slab bottom to Slab bottom)**



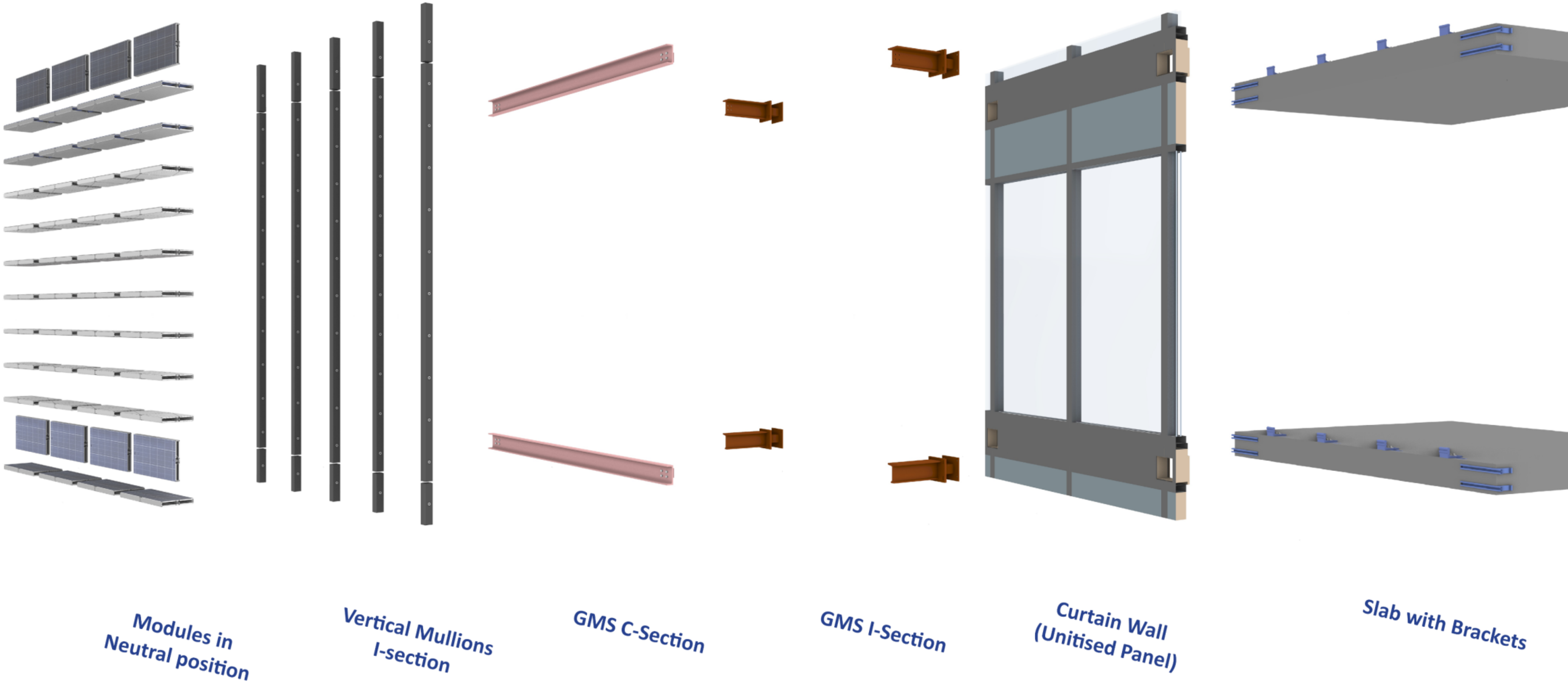
- **Final Facade Segment**





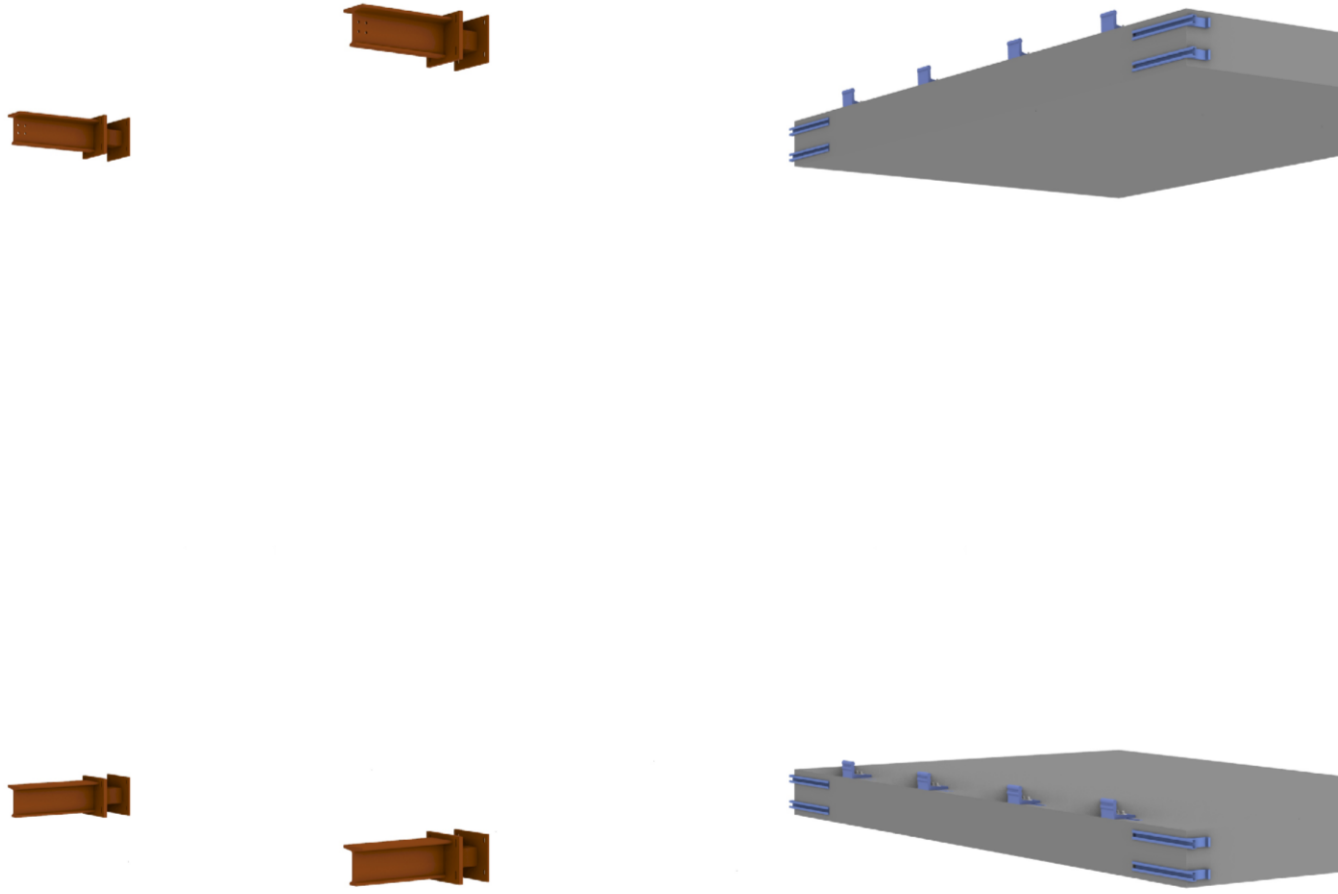
**30% surface
on Building envelope for PV**

- **Exploded View**



- ## Assembly Sequence

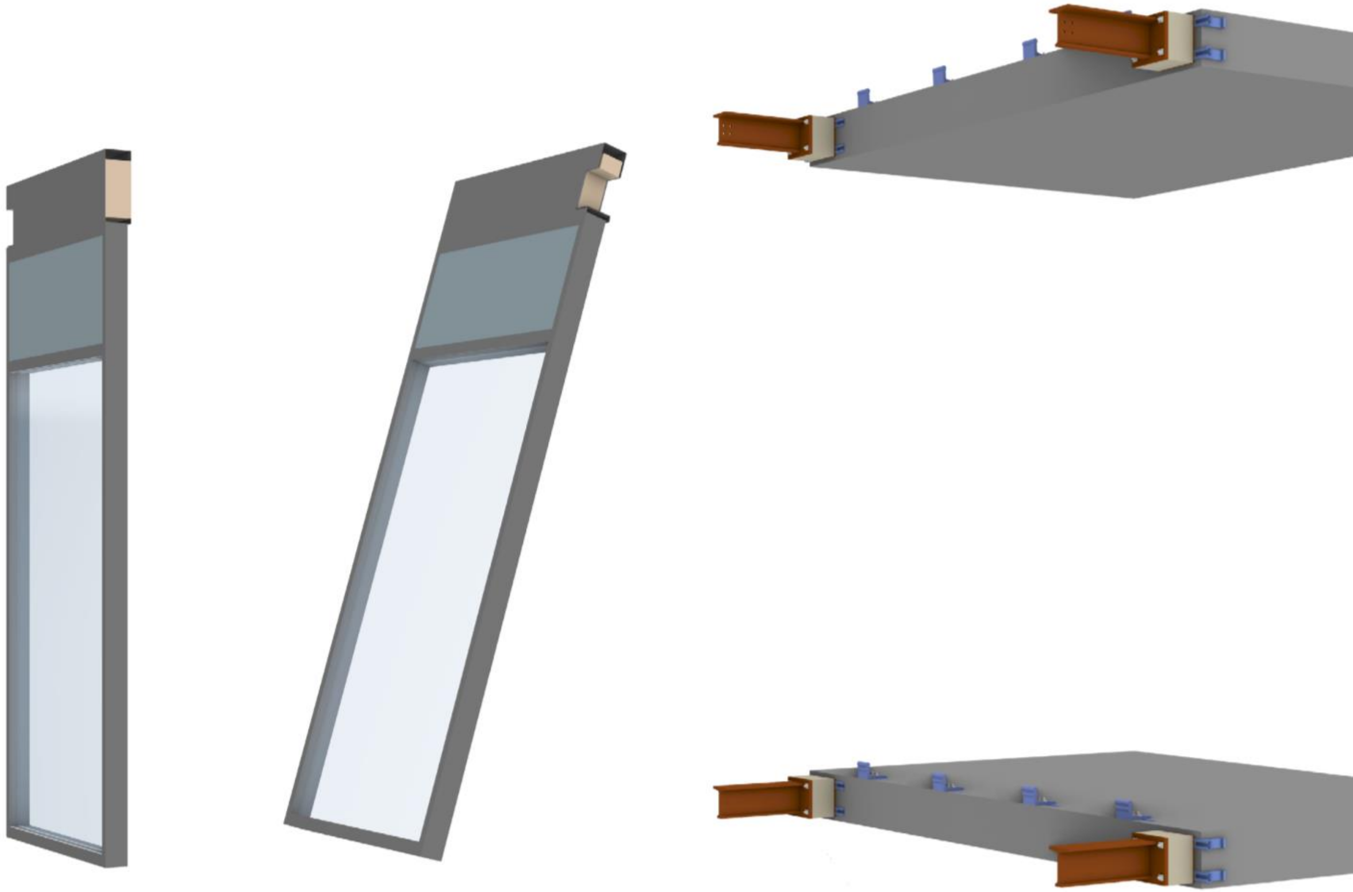
(i) Installation of GMU I Section with Halfen Channel



- **Assembly Sequence**

(i) Installation of GMU I Section with Halfen Channel

(ii) Fixing Curtain wall panels

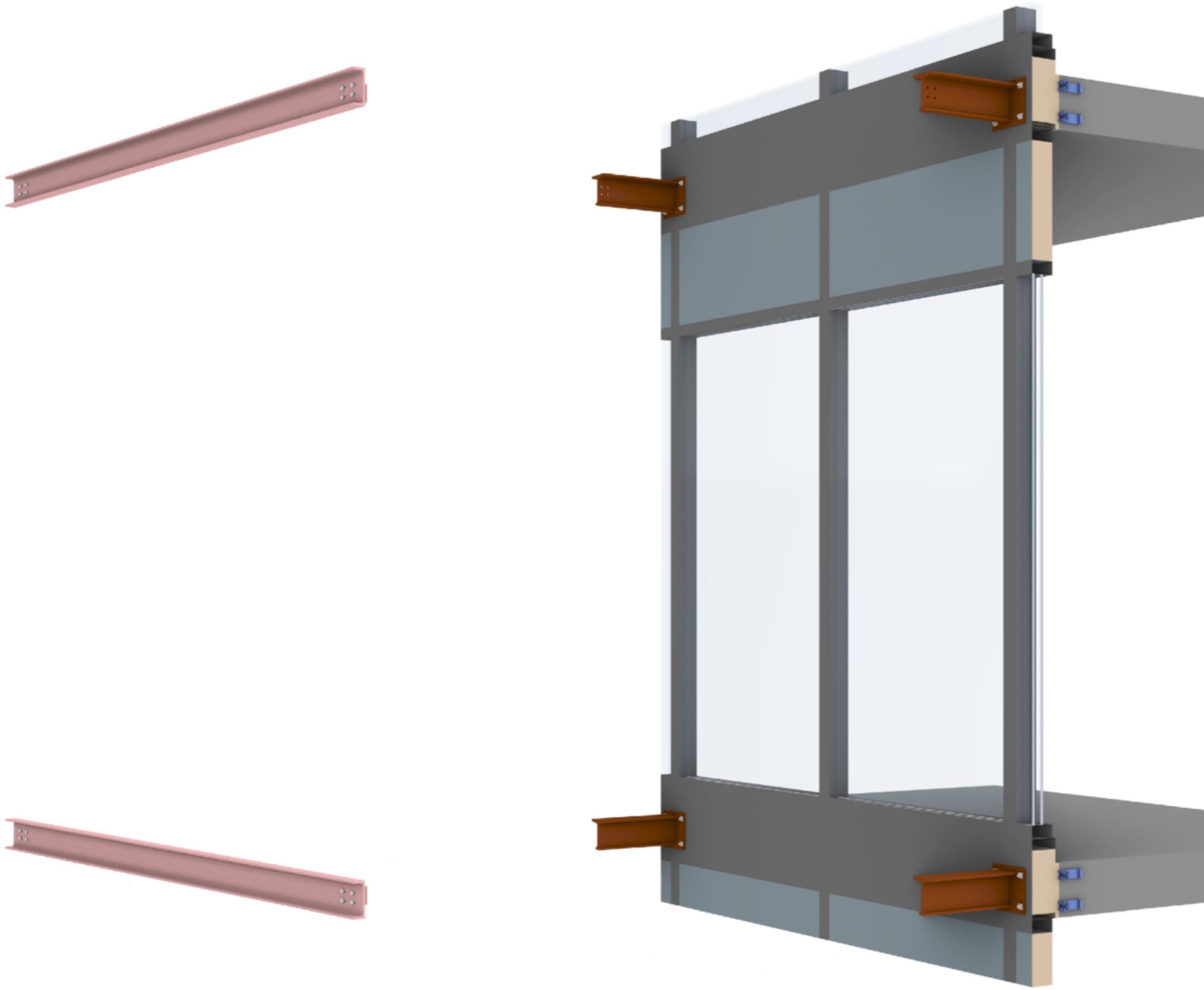


- **Assembly Sequence**

(i) Installation of GMU I Section with Halfen Channel

(ii) Fixing Curtain wall panels

(iii) Installation of GMU C-section



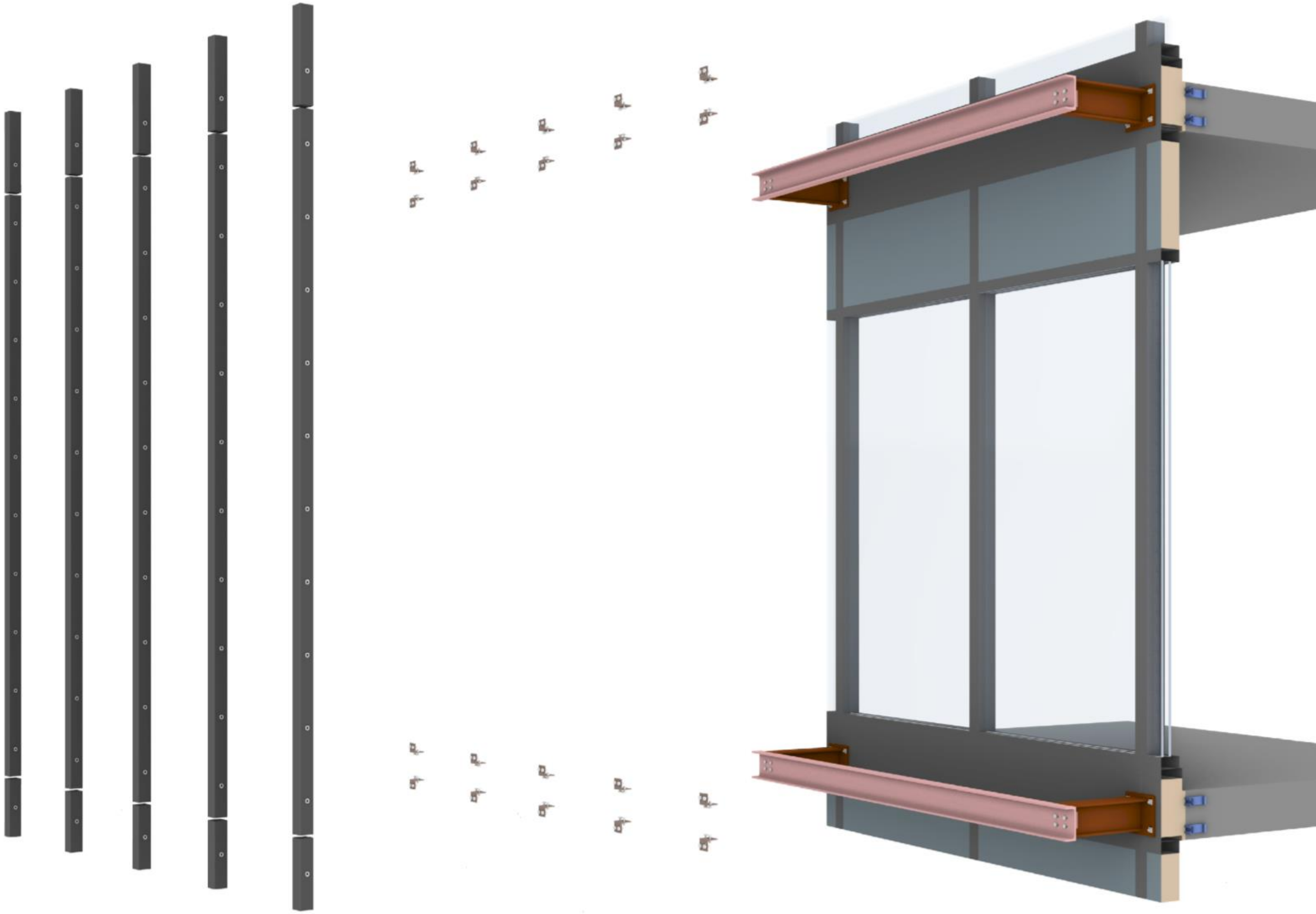
- ## Assembly Sequence

(i) Installation of GMU I Section with Halfen Channel

(ii) Fixing Curtain wall panels

(iii) Installation of GMU C-section

(iv) Installation of Vertical Mullions



- **Assembly Sequence**

(i) Installation of GMU I Section with Halfen Channel

(ii) Fixing Curtain wall panels

(iii) Installation of GMU C-section

(iv) Installation of Vertical Mullions

(v) Fixing of Modules in Neutral position

- ## Assembly Sequence

(i) Installation of GMU I Section with Halfen Channel

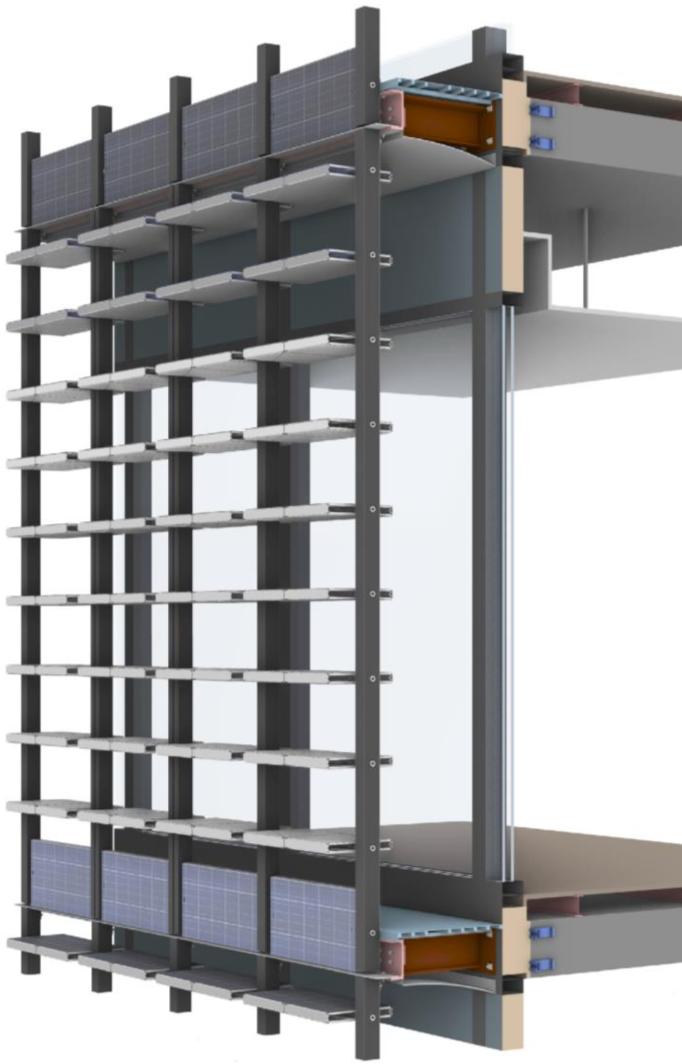
(ii) Fixing Curtain wall panels

(iii) Installation of GMU C-section

(iv) Installation of Vertical Mullions

(v) Fixing of Modules in Neutral position

(vi) Façade in Neutral State



- ## Assembly Sequence

(i) Installation of GMU I Section with Halfen Channel

(ii) Fixing Curtain wall panels

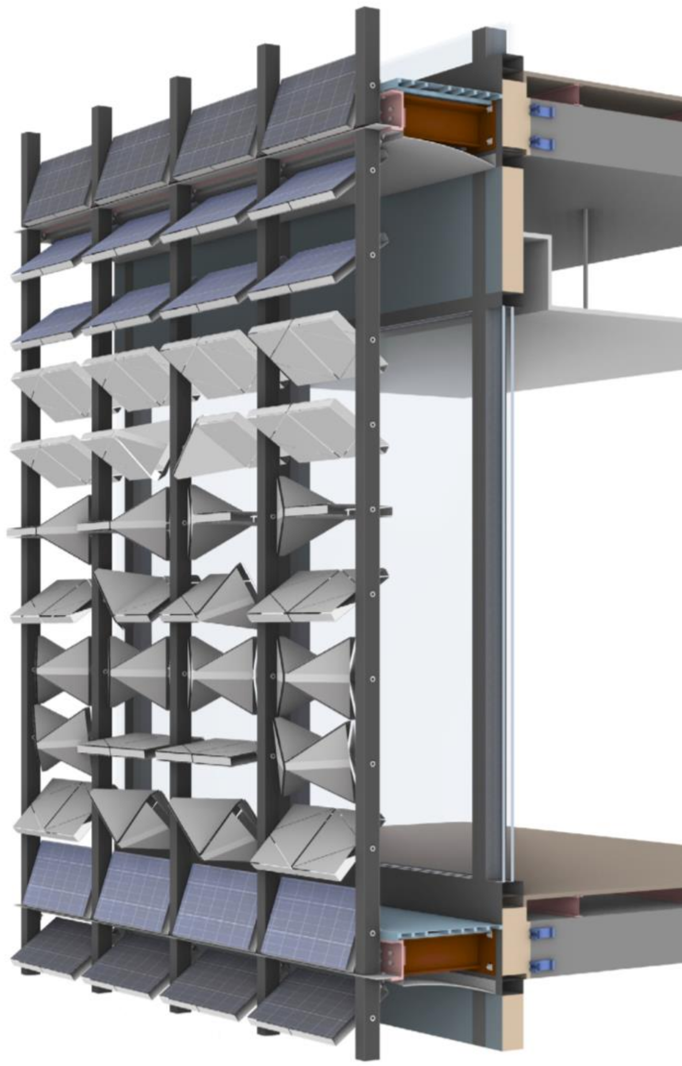
(iii) Installation of GMU C-section

(iv) Installation of Vertical Mullions

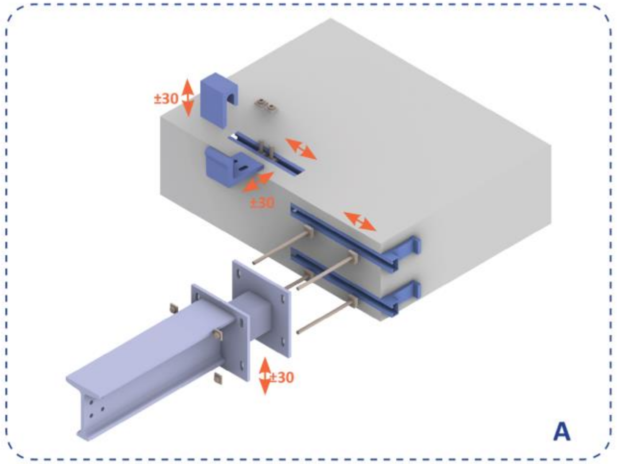
(v) Fixing of Modules in Neutral position

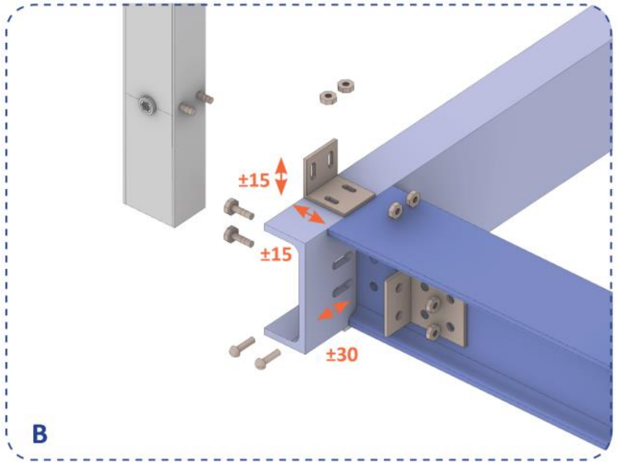
(vi) Façade in Neutral State

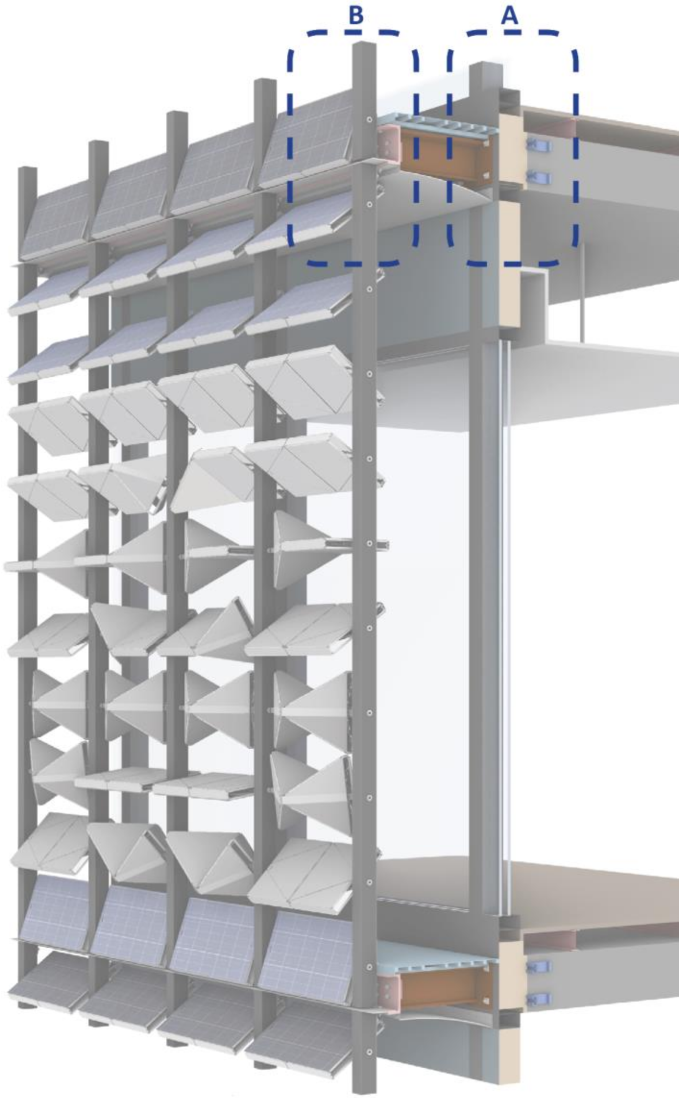
(vii) Façade in Motion



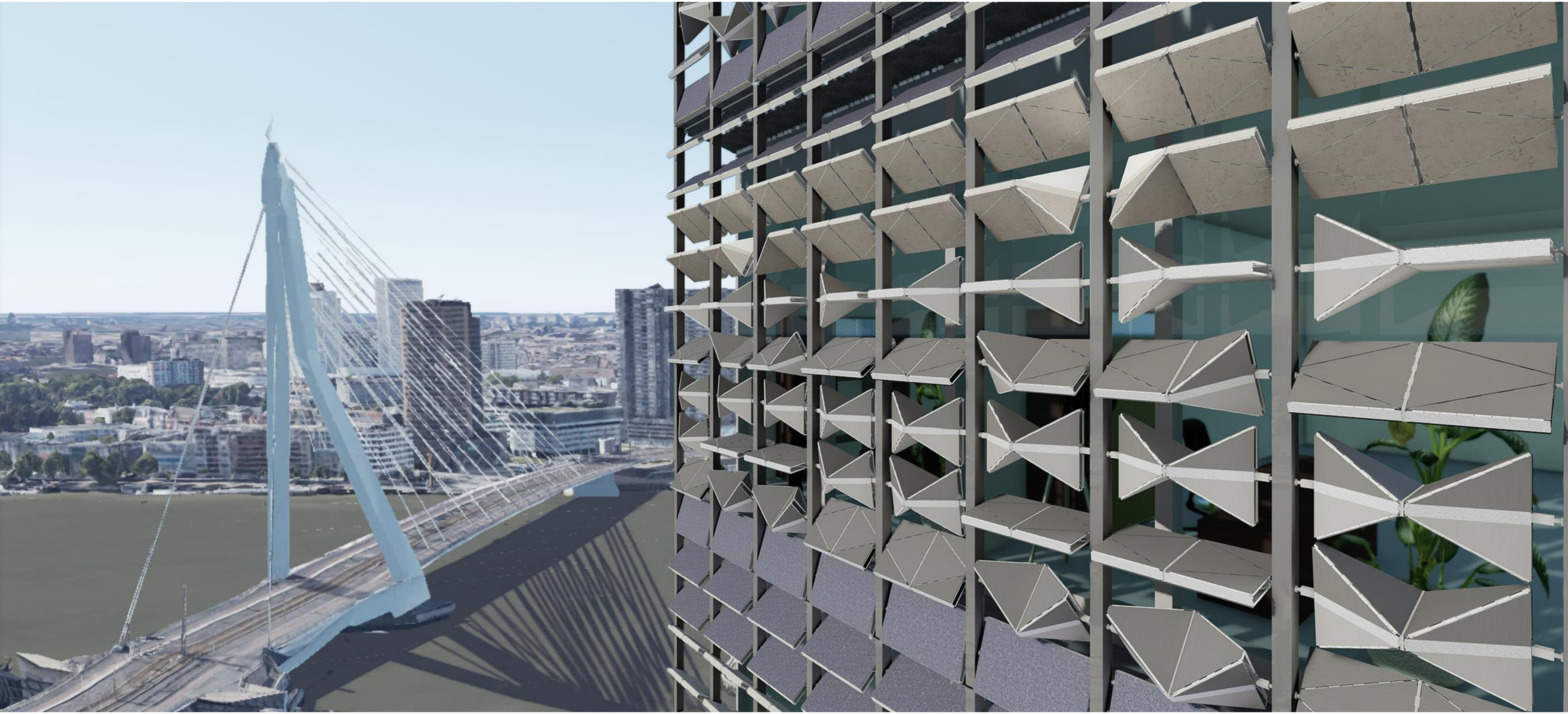
- **Tolerances**





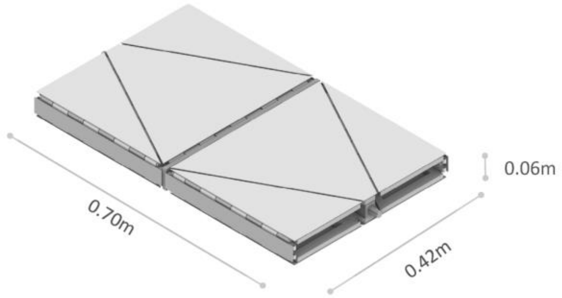


- **View from Outside**

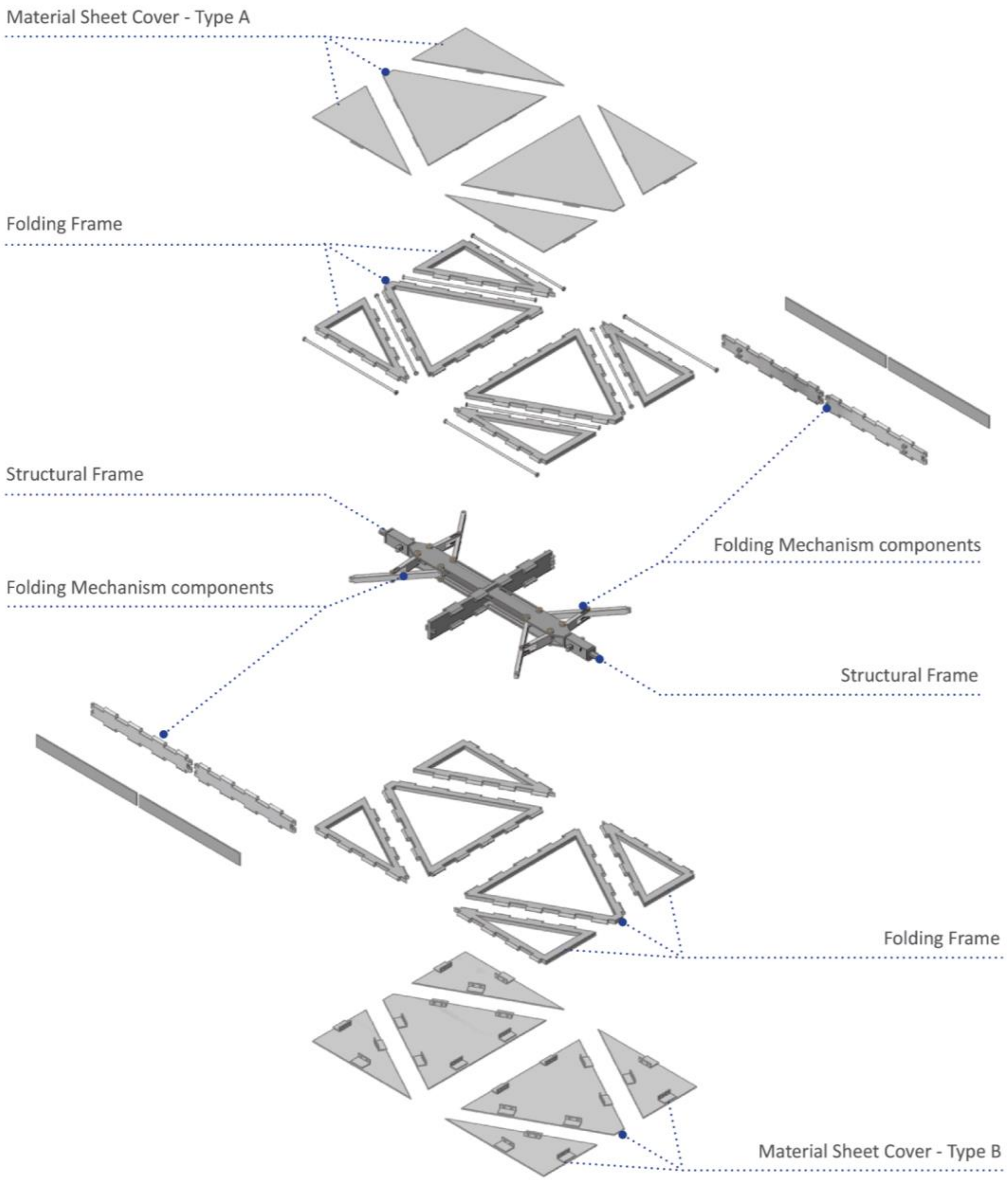


- **View from Inside – Finalised configurations**

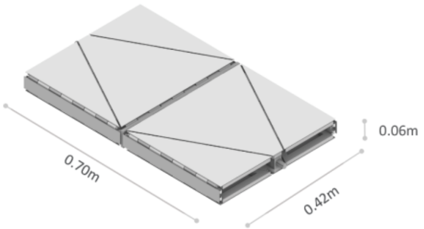
Module



- **Exploded view**



- **Components**

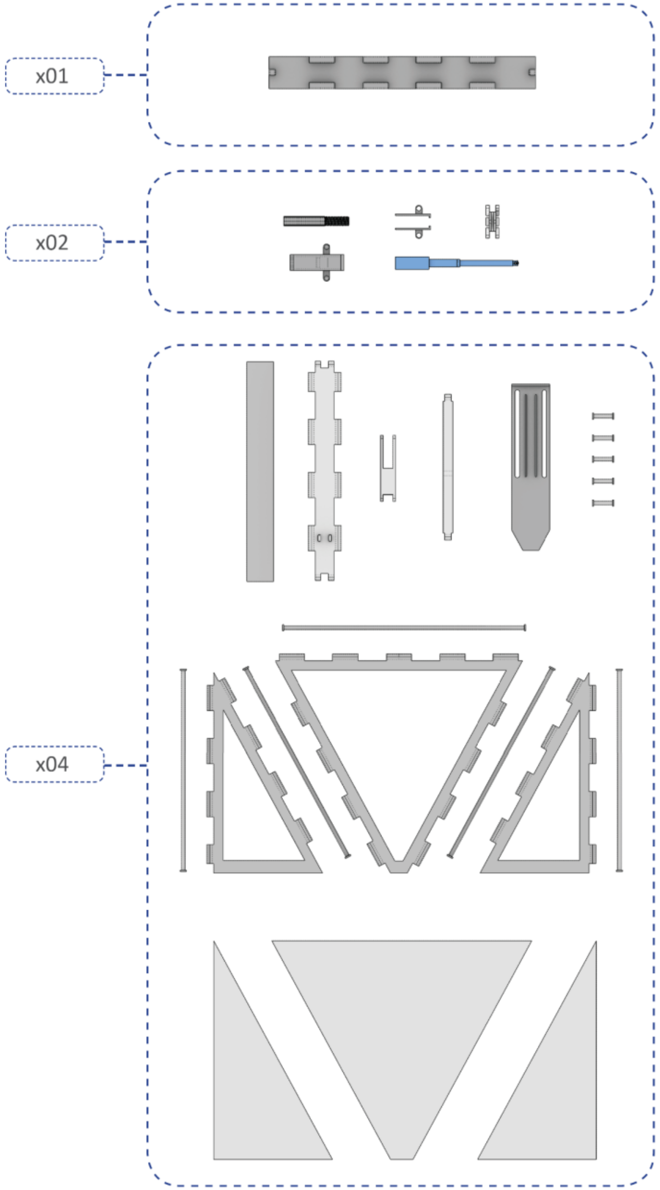


Anodised Aluminium
(Material)

↓

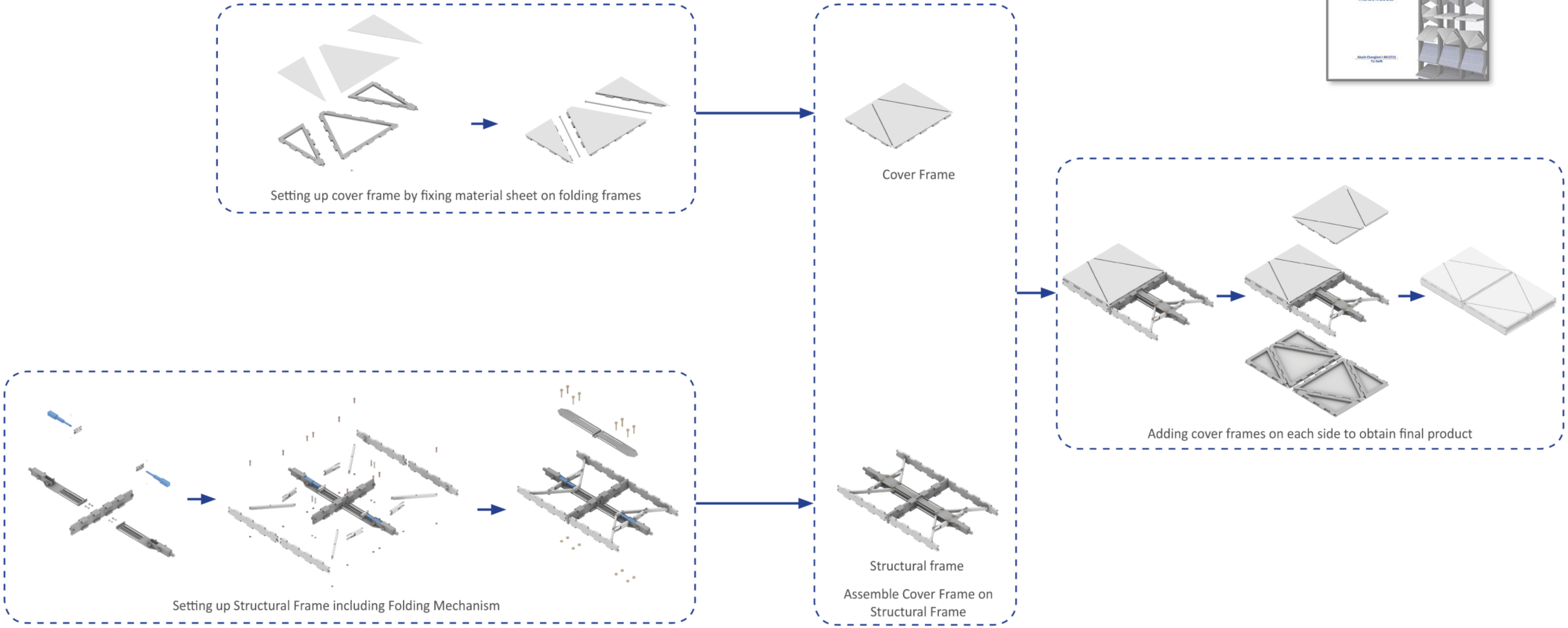
Light Weight

Corrosion Resistant

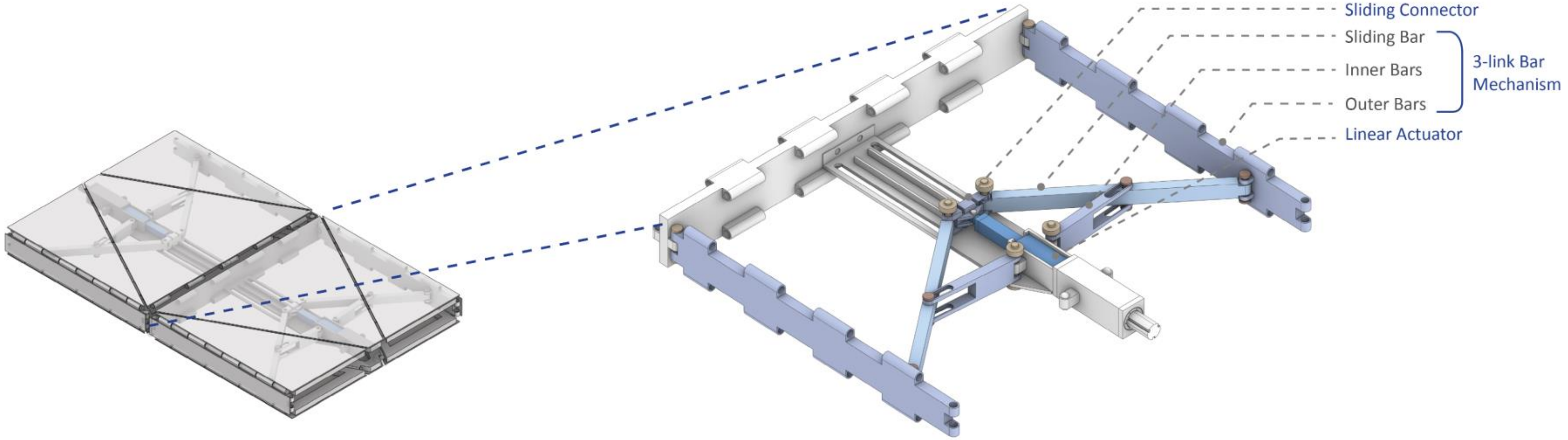


- ## Assembly Sequence

Assembly Instruction Manual
For Façade Module

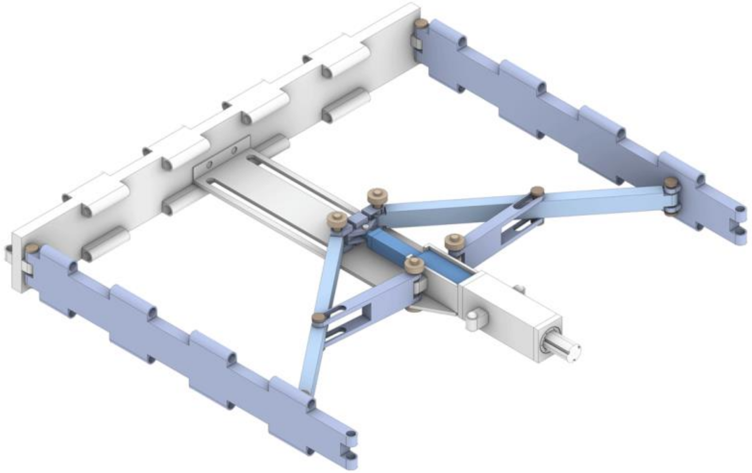


- **Folding Mechanism**



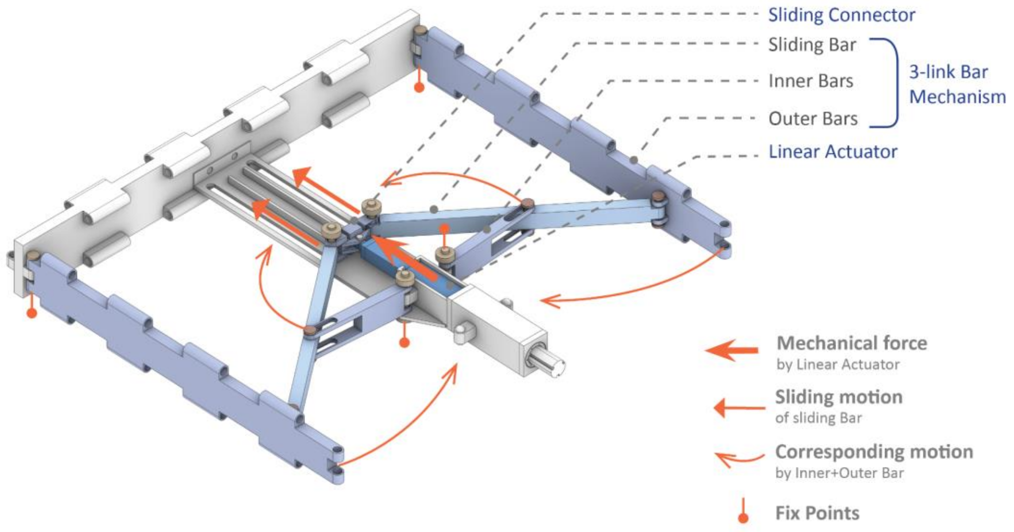
Linear actuator + 3-link Bar Mechanism

- **Folding Mechanism**

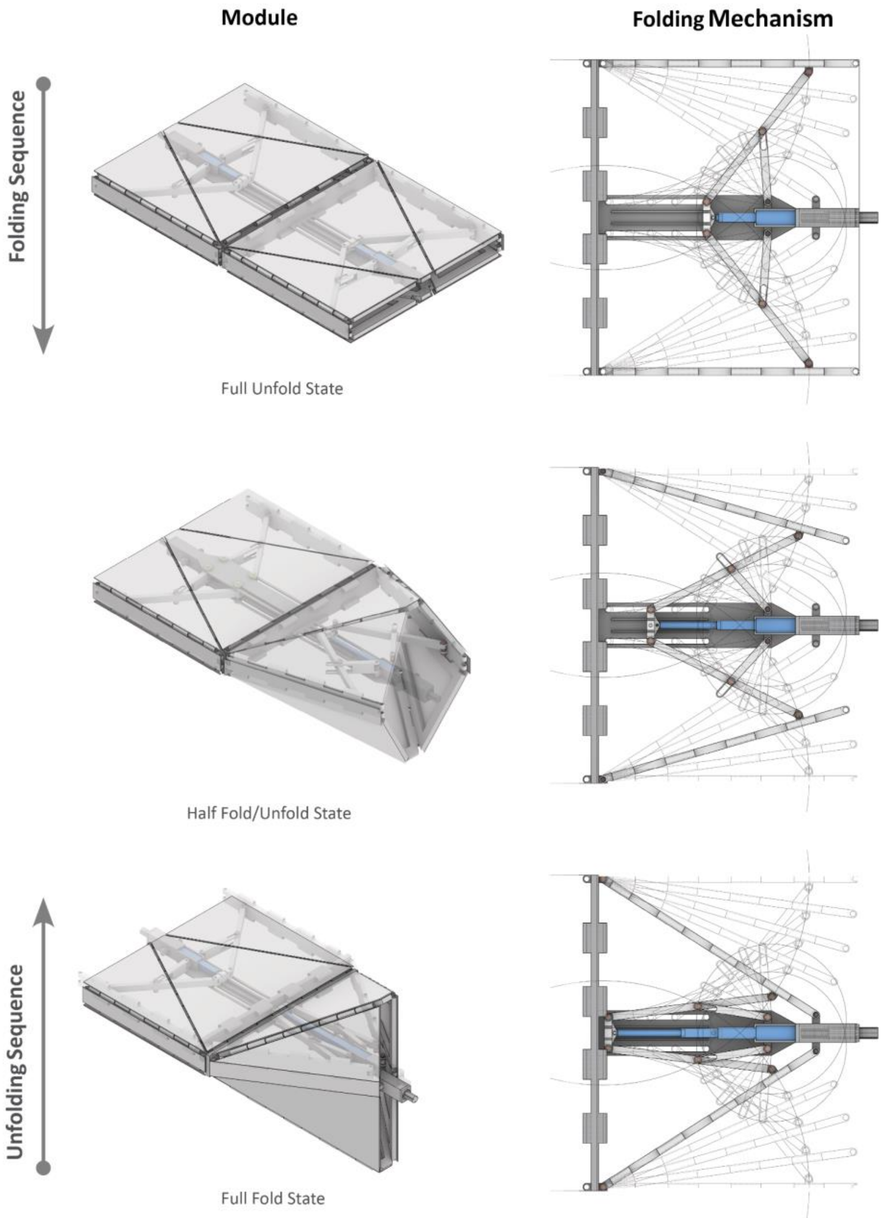


Linear actuator + 3-link Bar Mechanism

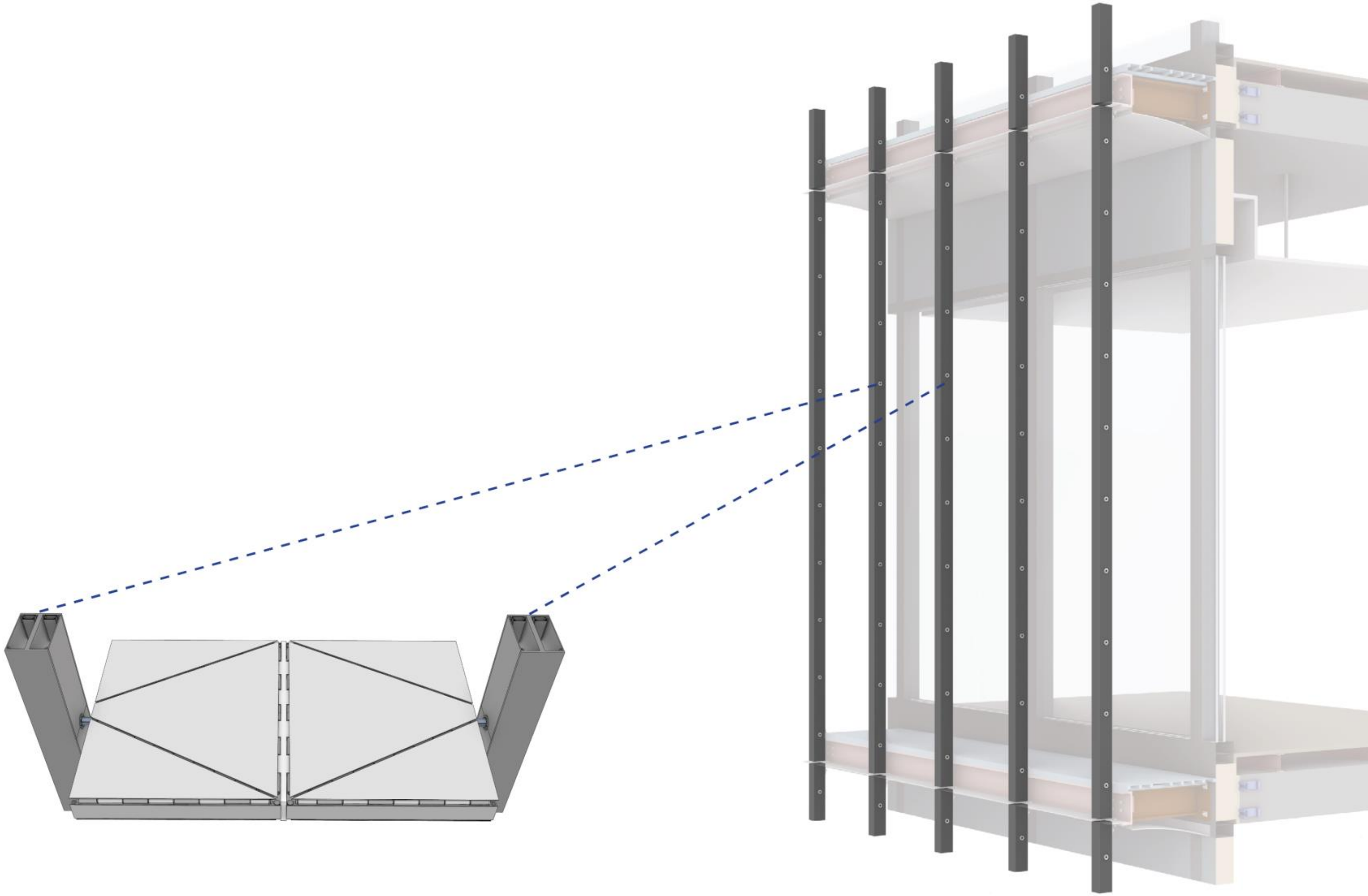
- **Folding Mechanism**



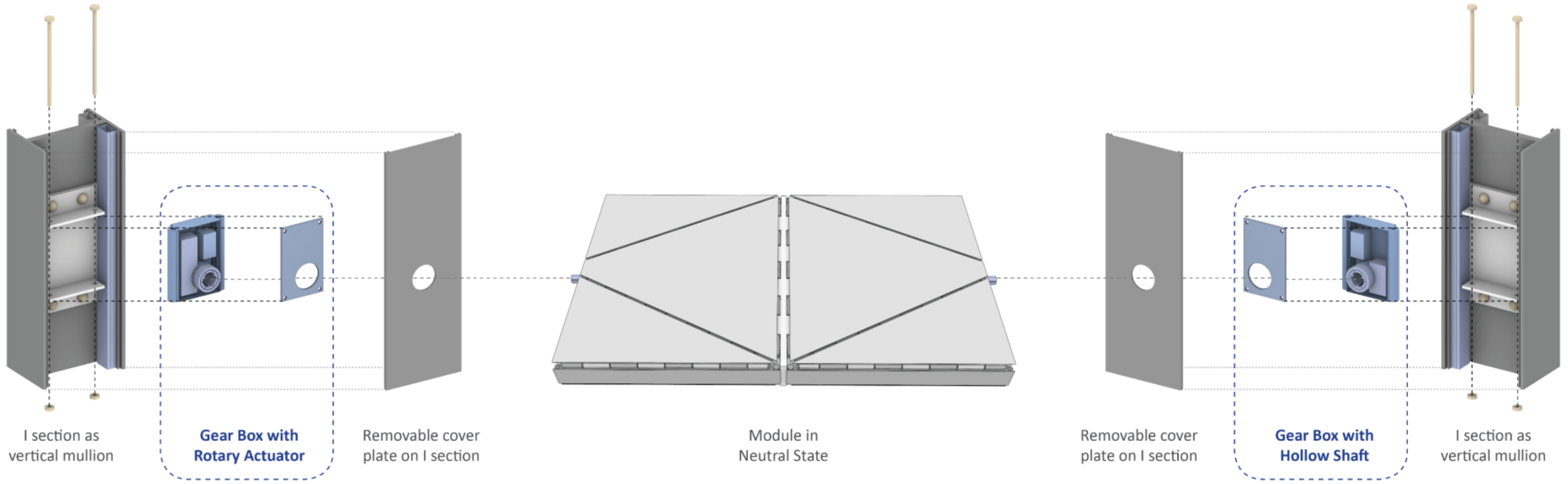
- **Folding Sequence**



- **Rotation Mechanism**



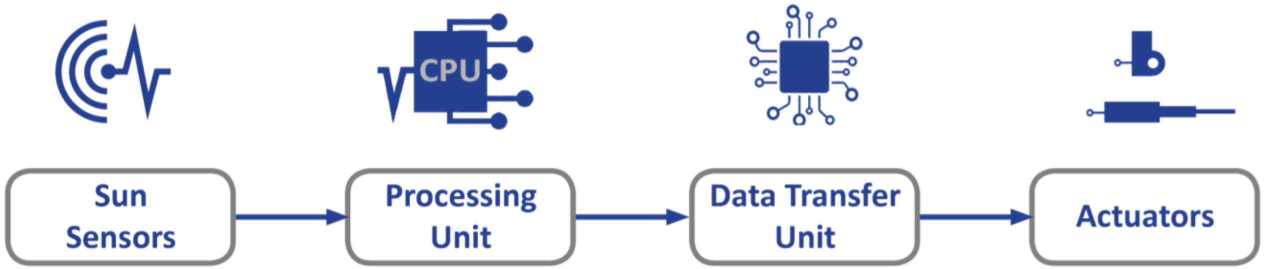
- **Rotation Mechanism**



Feasibility

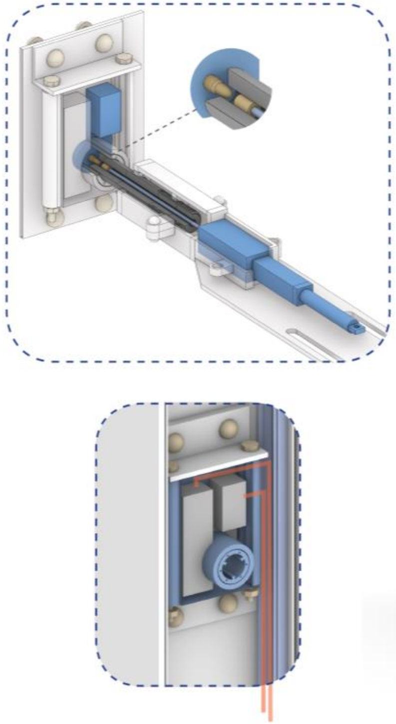
(Façade Scheme)

- **Automation**

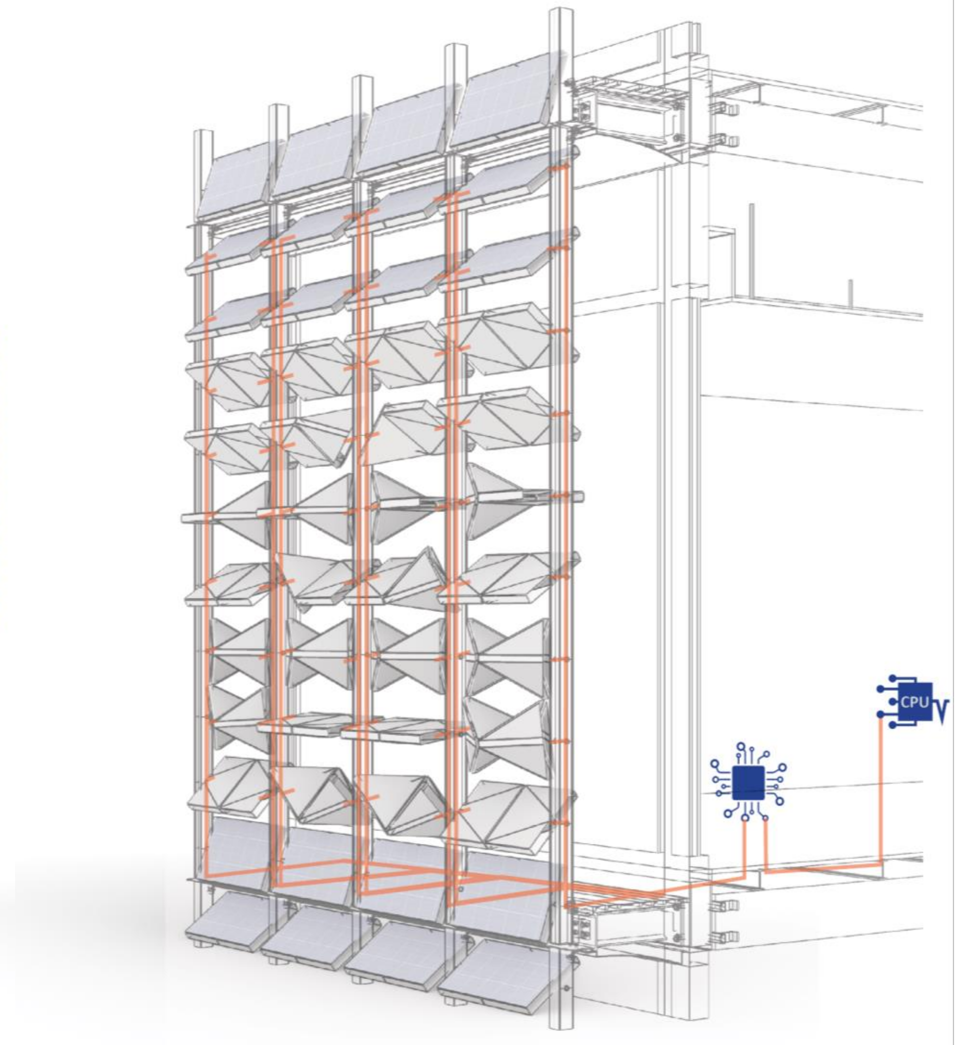


Automation Process

- **Automation**



Connection to Actuators



Connection to Processing unit

- **Automation**

Time consumed in motion

Rotation 0-90°

9 sec.

10°/sec.

(4.5 sec Gap)

Folding

6.5 sec.

20mm/sec.

→

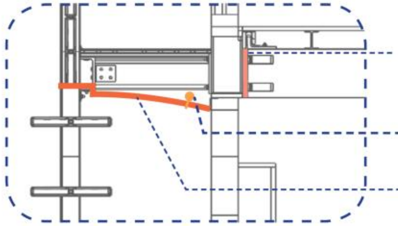
Time taken for one Transition

20 sec.

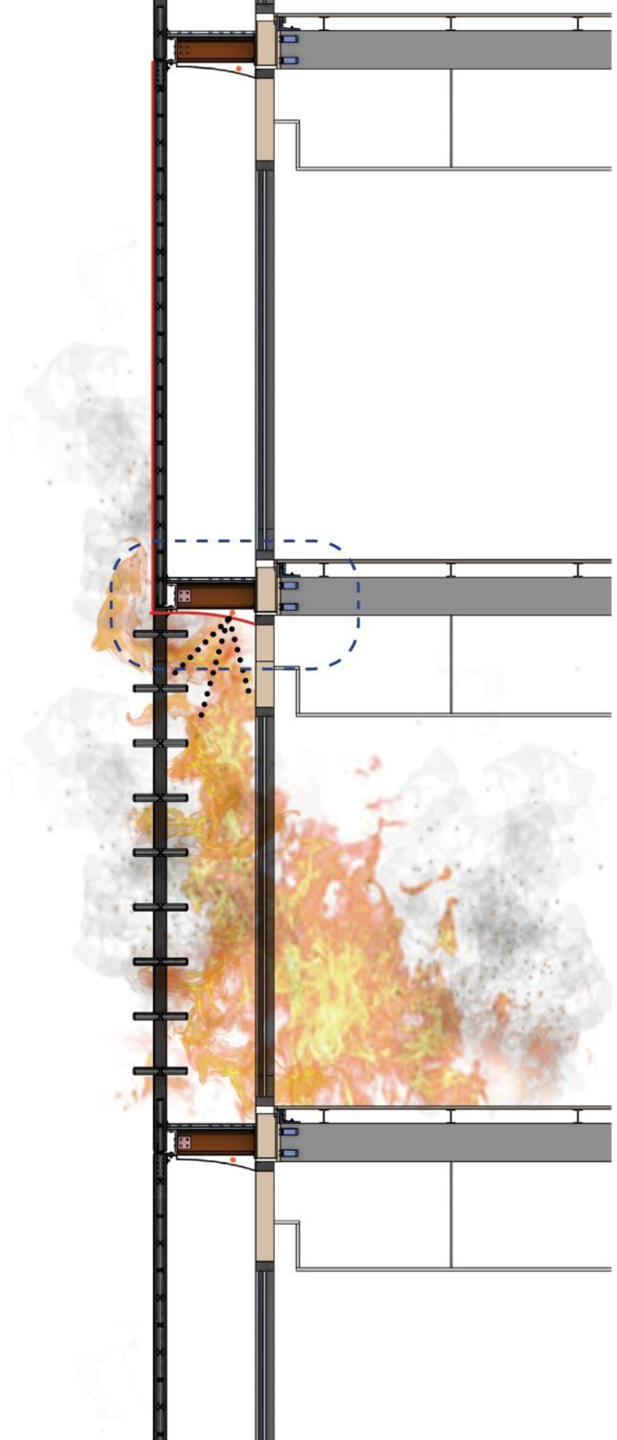
- Automation
- **Fire Safety**

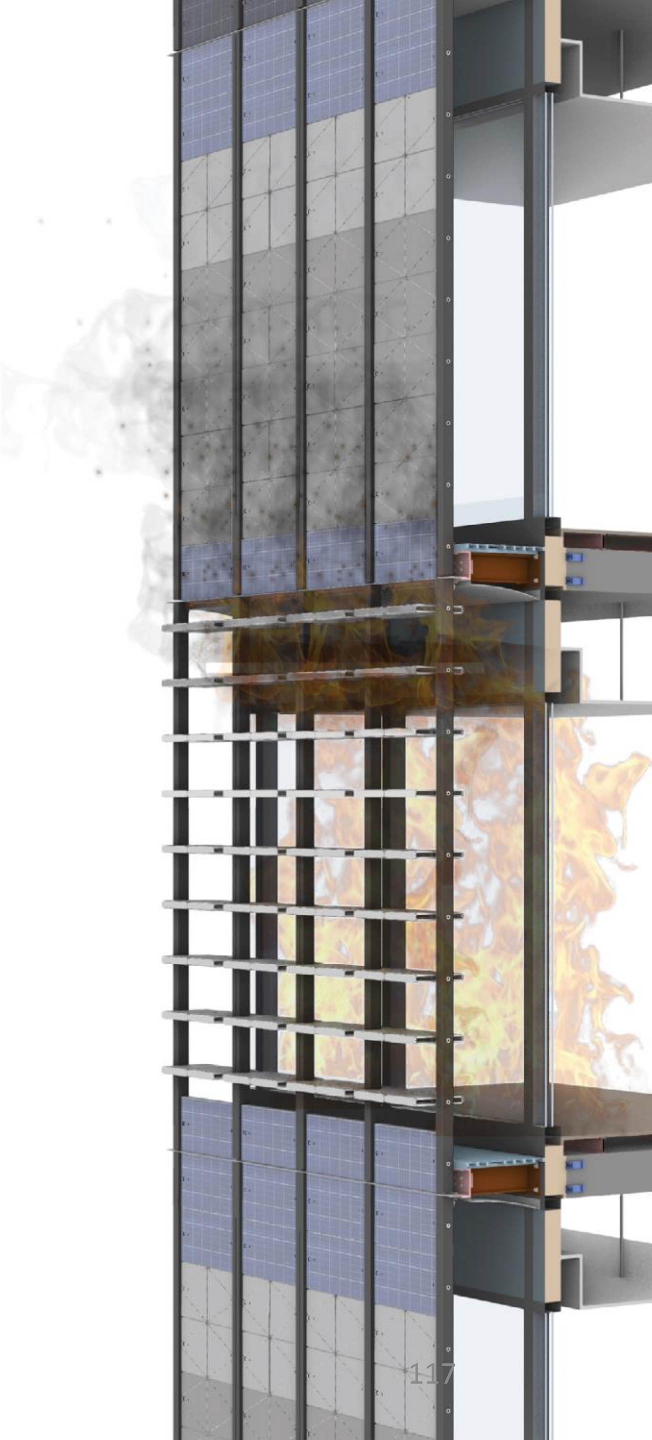
- Automation

- **Fire Safety – (i) Fire near window**



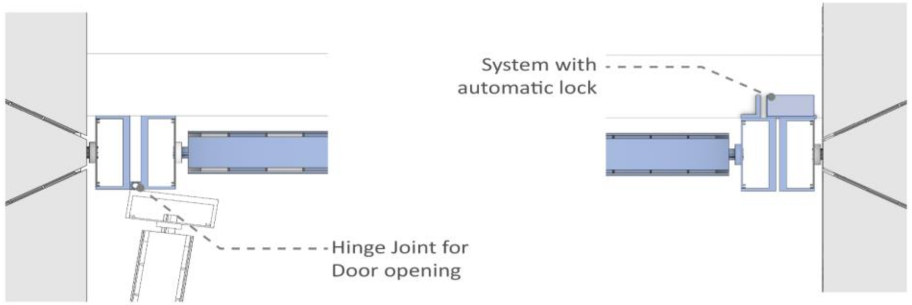
Fire protection in Cavity

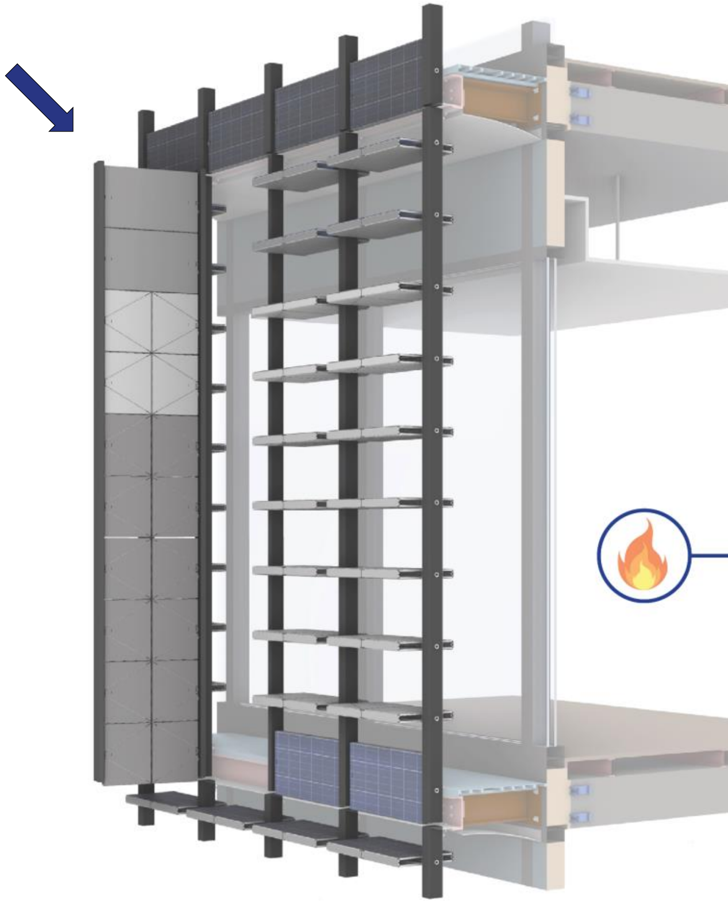




- Automation
- **Fire Safety – (ii) Fire inside the building**

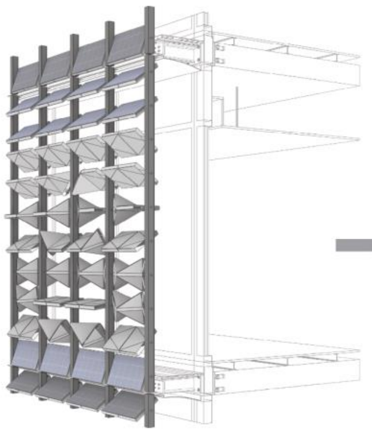
Door like Opening



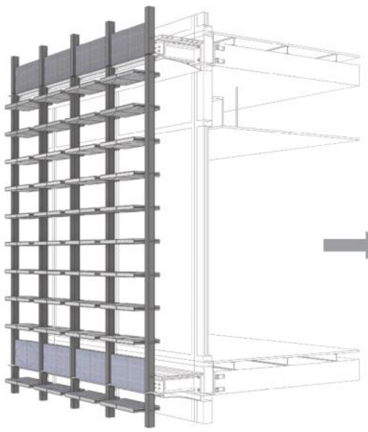


- Automation
- **Fire Safety**

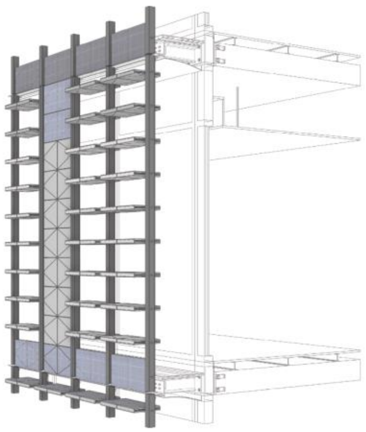
Fire Escaping



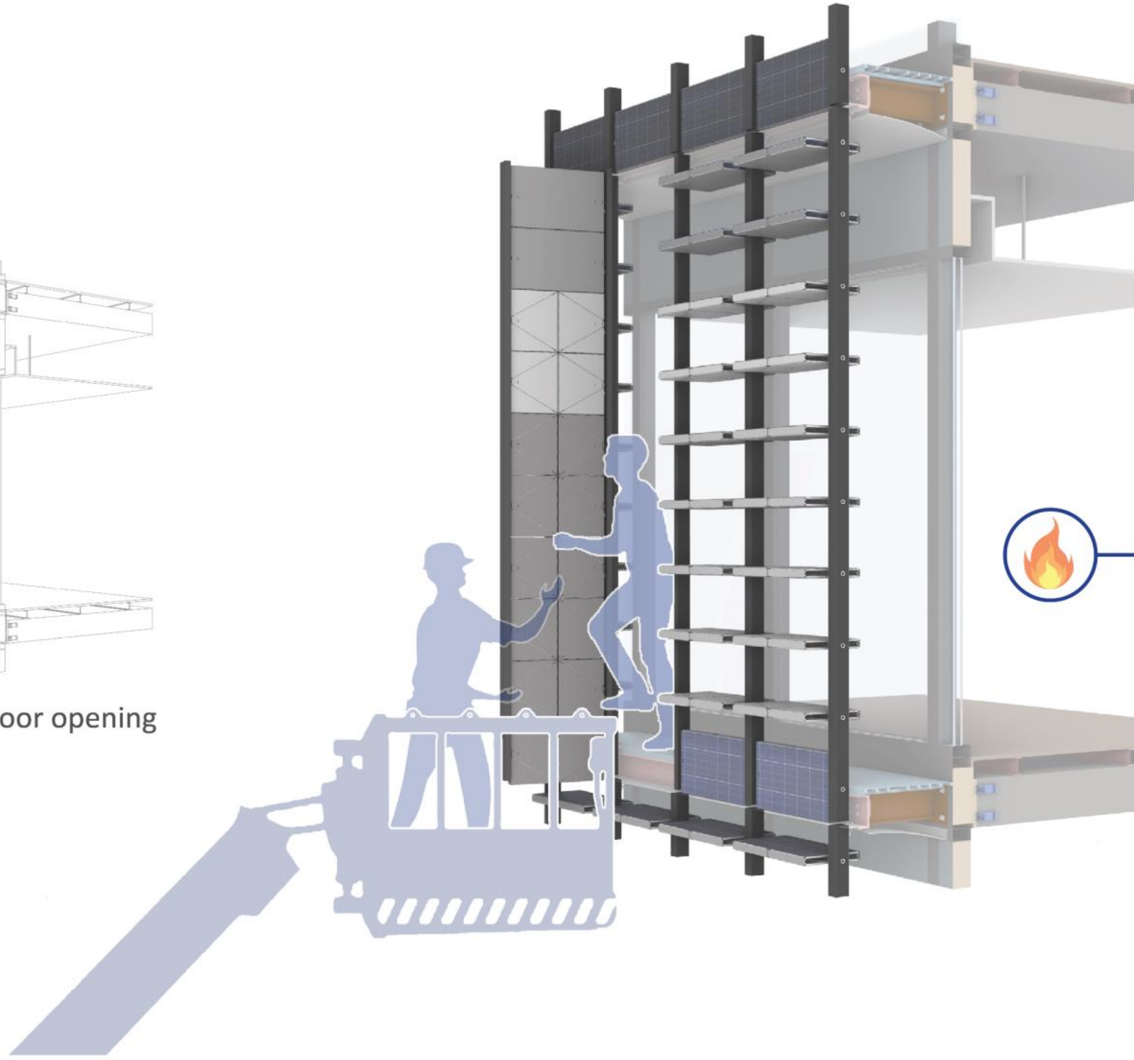
Performing state



Neutral state



Preparing for door opening



- Automation
- Fire Safety
- **Maintenance – Cleaning**

Outside – Cradle system (BMU)
Whole envelope cleaning

Inside – Maintenance Walkway
Small cleaning

Two time cleaning required
Surface on both sides of Module

Inside
small cleaning

Outside
Whole envelop

- Automation
- Fire Safety
- Maintenance
- **Energy Performance (PV Modules)**

Lighting Energy Consumption (LEC)

(Office Room + Automation)

1498 kWh

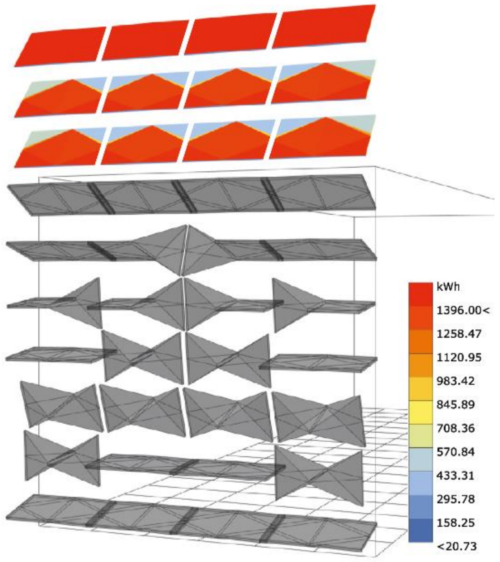
(Annual)

PV Potential

1083 kWh

(Annual)

72% of LEC



- Automation
- Fire Safety
- Maintenance
- Energy Performance (PV Modules)
- **Structural Performance**

Deflection

15.2 mm

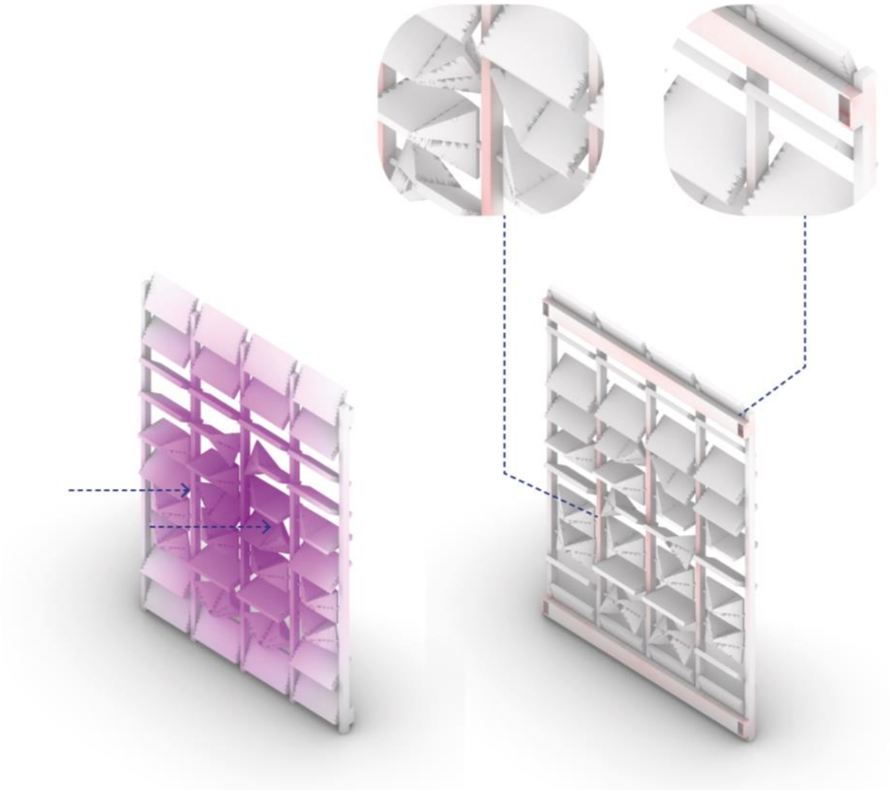
Stress

243 Mpa

Compressive

3.28 MPa

Tensile



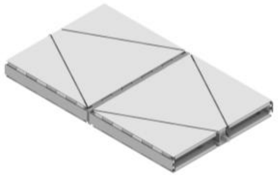
Impact of Deflection

Impact of Stress

- Automation
- Fire Safety
- Maintenance
- Energy Performance (PV Modules)
- Structural Performance
- **Weight**

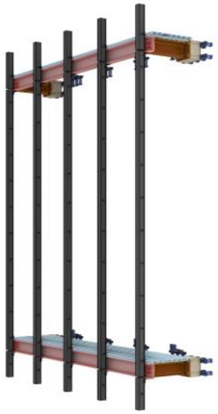
One Module

8.6 Kg



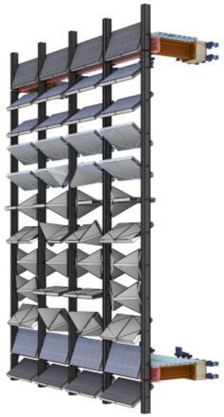
Supporting Structure

728 Kg



Façade Scheme

1080 Kg = **72** kg/m2



- Automation
- Fire Safety
- Maintenance
- Energy Performance (PV Modules)
- Structural Performance
- Weight
- **Sustainability and Circularity**

Demountable

97.7 %

(% of Mass weight)

Recyclable

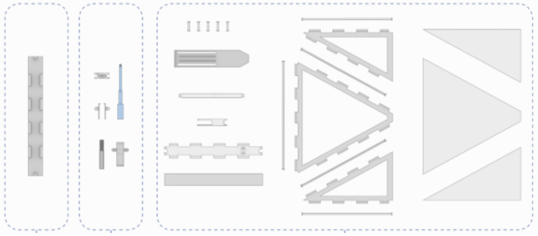
99.5 %

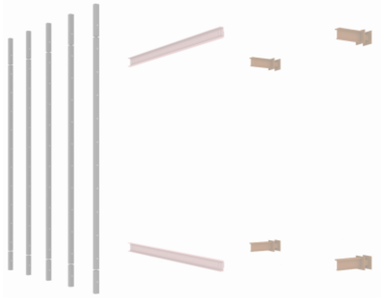
(% of Mass weight)

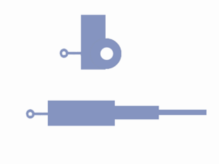
Directly Reusable

96.9 %

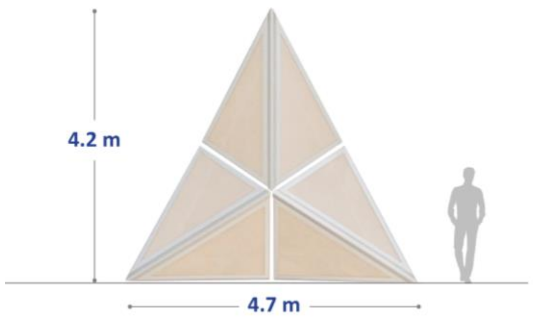
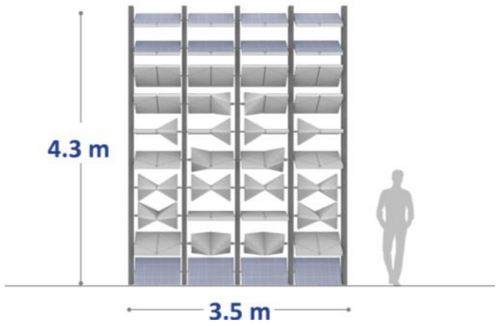
(% of Mass weight)







- Automation
- Fire Safety
- Maintenance
- Energy Performance (PV Modules)
- Structural Performance
- Weight
- Sustainability and Circularity
- **Comparison**

	Al Bahr Tower, Dubai	**FACA-DE-LIT**
		
Segment →	**One Mashrabiya Panel** Large scale Panel	**Proposed Façade Segment** Small scale modules
Weight →	**1500 kgs/segment** ↓ **152 kg/m2**	**1080 kgs/segment** ↓ **72 kg/m2** → **53% Lighter**
Cost →	(not available)	**50% lesser assumed**
Visual Comfort →	**40%** (as per occupant's experience) (Attiya, 2017)	**88%** (as per results obtained) → **48% Higher**

Conclusions

Answer to Main research question

"Based on **computational design methods and techniques**, how can **a façade system** allow for **indoor visual comfort**, by **daylight's controlled distribution** throughout the **depth of a room**, in a high rise office building?"

(External Factors)		Façade System		(Indoor Performance)
Major impacts from:		Three Features:		Responsible for Controlling
Altitudes	←	**Rotation**	→	**Daylight Reach**
Azimuths	←	**Module Types**	→	**Uniformity**
Sky condition	←	**Material Sets**	→	**Enhancement**

Computational Design methods helps to **bring best possible configuration** in combination of all three features **to achieve visual comfort.**

Conclusion

- The outcome of this study is a **dynamic façade for an office space**, that **adheres to visual comfort criteria** by adapting to **diverse external daylight conditions**.

- **The façade is Suitable for deep floor plans.**

- The façade is **feasible for new construction** and **renovation projects** that can withstand extra load of the facade.

Conclusion

- **Resulted with reduction of using artificial light by 88%.**

- **PV generates energy equivalent to 72% of total lighting consumption.**

- **Potential gain of +60% of energy above total consumption.**

Conclusion

- Computational workflow can be used **to evaluate any design** and **increase performance efficiency of a Façade.**

- Computational workflow can be used **to develop several alternatives of design solutions that deals with visual comfort.**

Future Research Possibilities (All separate or combination of some)

I. **Rooms at different level** of a high rise. As the amount of daylight illuminance could be different for different level.

II. **Rooms facing in different orientation.** Comparative analysis between S/W/E/N and/or SE,SW,NE,NW.

III. **Different Location/ Different climate.** Comparative assessment for high rise buildings in different locations and/or different climate zones.

IV. **With surrounding Context.** Comparative assessment between high, mid and low dense context around a high rise.

V. **Different Program/function** with varied illuminance requirement.

VI. **Different typology.** Other than high rises like residential, commercial etc.

VII. **Thermal Insulation for indoor comfort.** With the most optimized façade solution.

VIII. **Material Variations** for the façade elements.

IX. **Optimizing Interior Ceiling.** Shape/slope/material

X. **Module/Panel size variation.**

XI. **Different design/geometry/Patterns.** Coping with same concept, method and workflow.

XII. **For curved faced facades.**

XIII. **For outdoor glare check** caused by Façade and its improvement.

XIV. **Optimisation for Better view to outside** using same facade system.

XV. **Make a Tool.** Make computational method smart enough, Code it in python for generative solutions.

- Reduce runtime for optimization.
- Artificial Intelligence (AI), Machine learning (ML), Deep Learning (DL). Can adapt to various parameters like regulations, climate etc.

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"The history of architecture is the history of the struggle for light."

Le Corbusier – Architect

FACA-DE-LIT