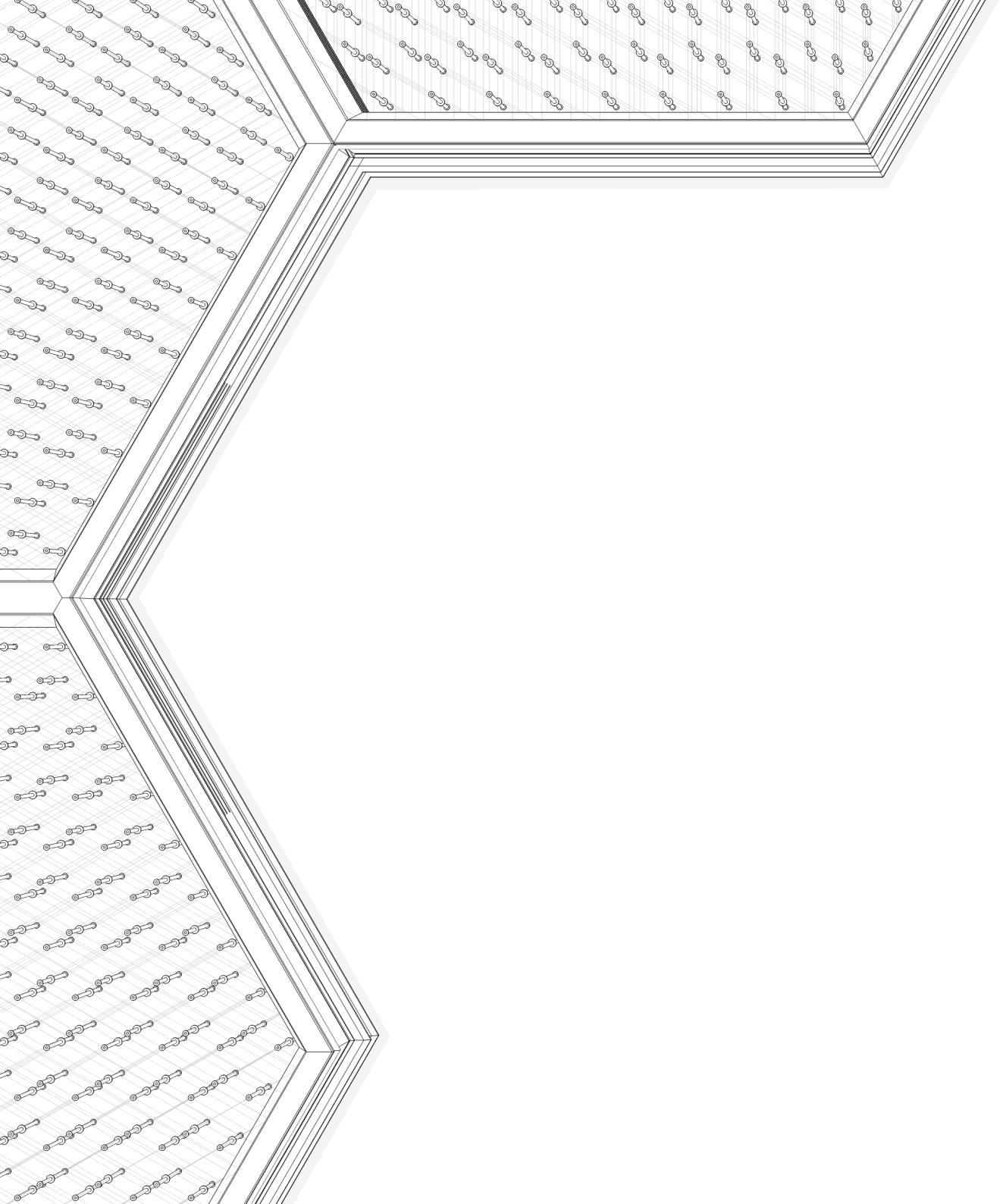


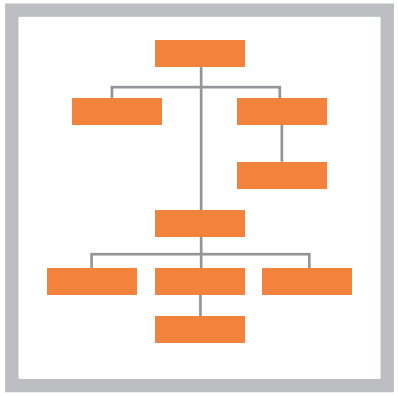
UNITIZED MEMBRANE ENVELOPE

FOR HIGH-RISE BUILDINGS IN TROPICAL CLIMATES

MITCHELL EVERTS, 4415531

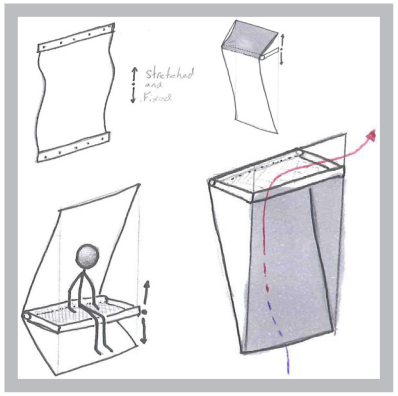
INDEX

Research framework

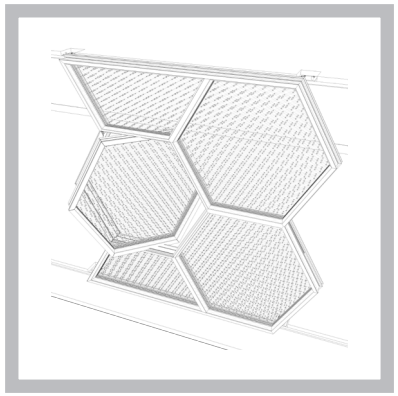


Literature study

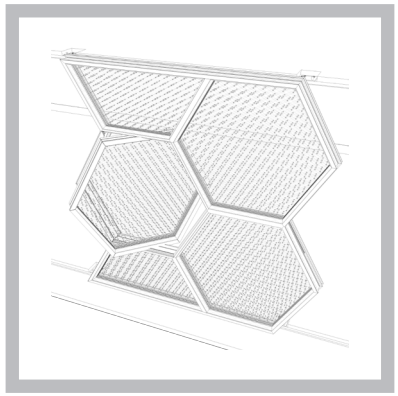
Preliminary designs



Calculations and testing



Final design



Conclusion

Questions and goals

Main research question

How can an adaptive unitized façade be designed by utilizing the advantages of membrane envelopes for residential high rise buildings in Singapore?

Sub-questions

What are the properties required of a façade for residential high rise buildings in Singapore?

Which types of membranes or membrane systems have the desired properties, as defined in the first sub-question?

What types of membrane envelopes have been built and how are they materialized, detailed and constructed?

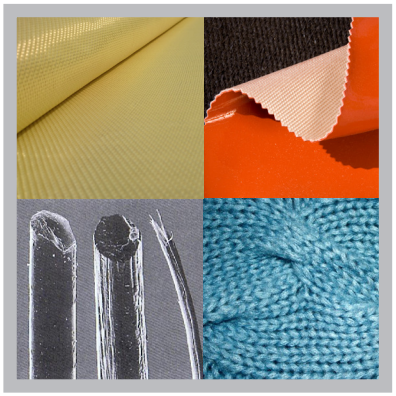
What types of unitized façades are used on high rise buildings and how are they materialized, detailed and constructed?

What are the advantages of membrane envelopes compared to commonly used unitized façade systems?

LITERATURE STUDY

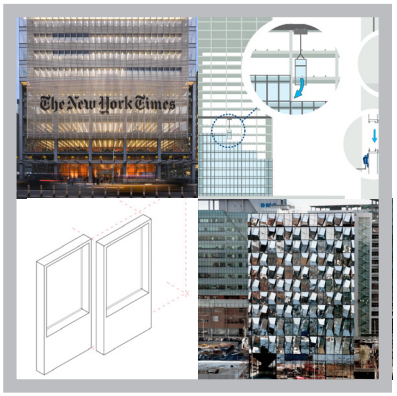
Context and conditions

Membrane materials

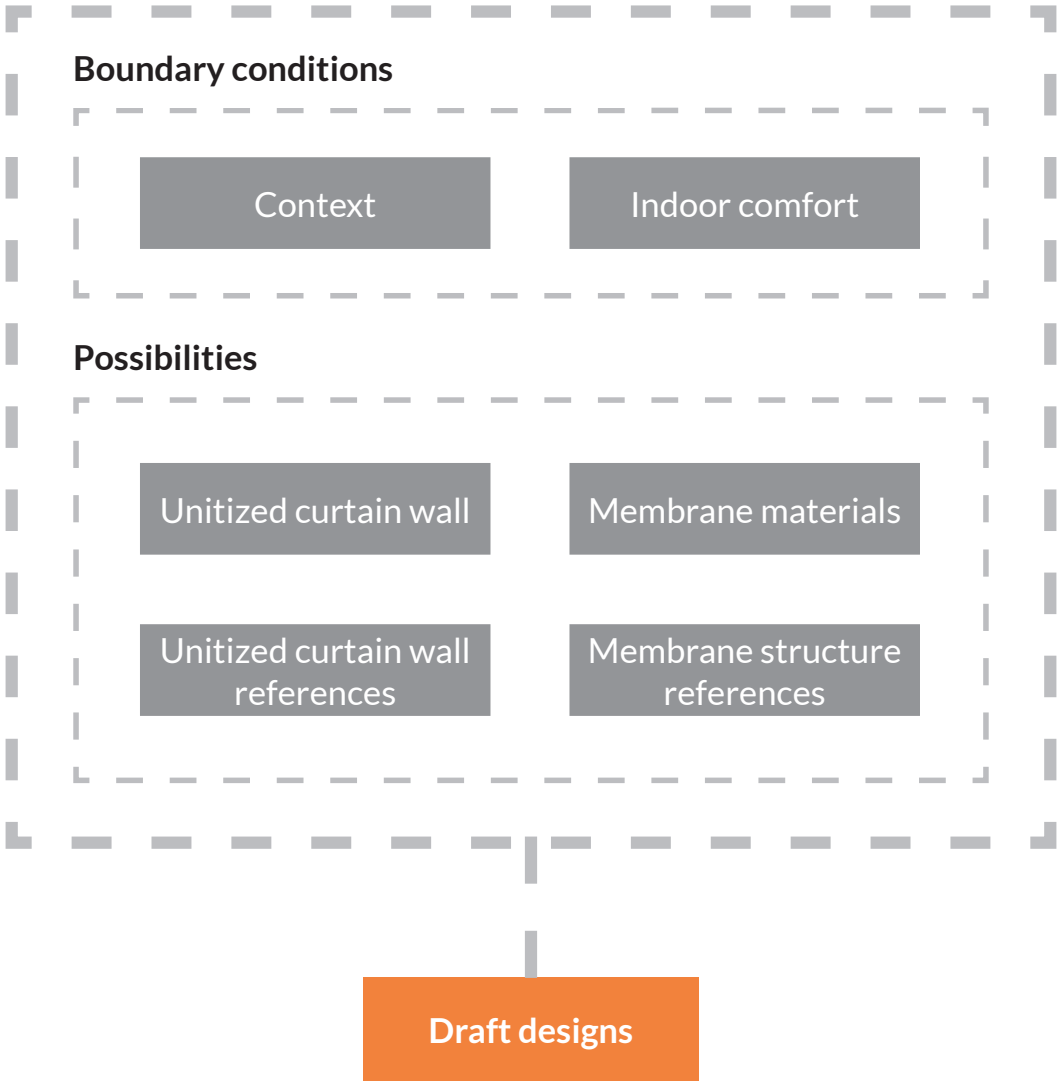


Membrane structures

Unitized curtain walls



Outline of the design task



Sail at Marina bay

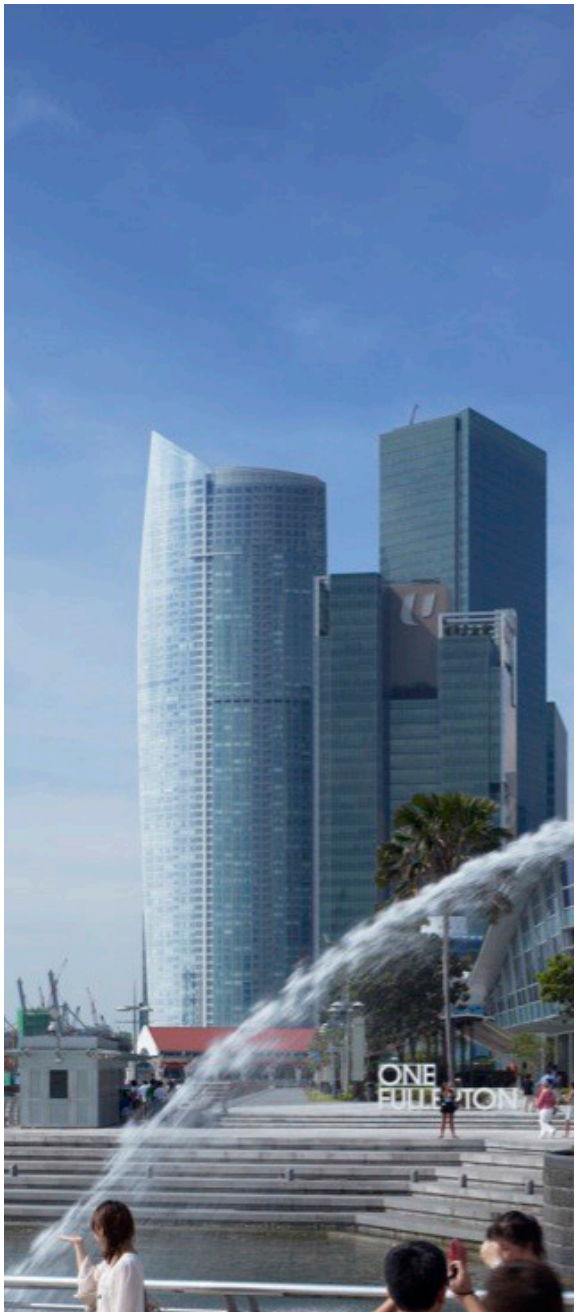
Highest residential tower

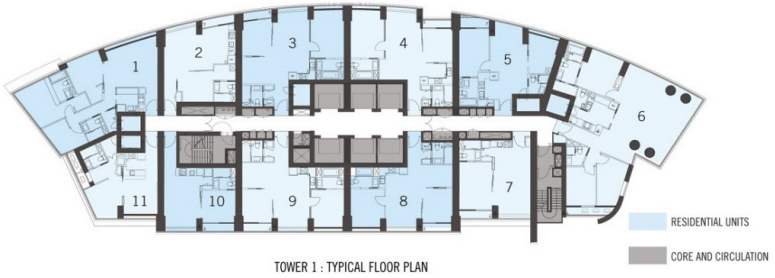
245m tall

70 storeys

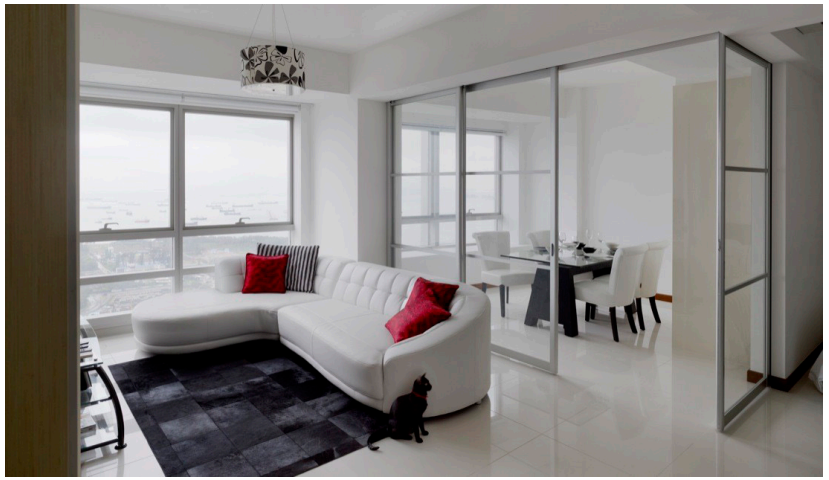
Sail like curve in front facade

Glass unitized curtain wall with windows





TOWER 1 : TYPICAL FLOOR PLAN

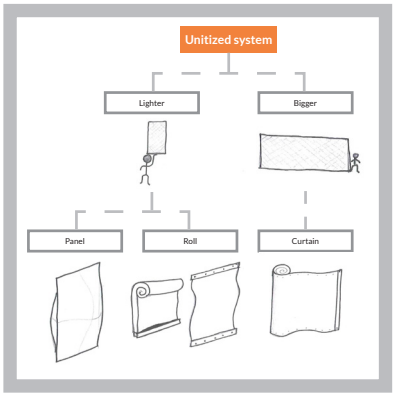


PRELIMINARY DESIGNS

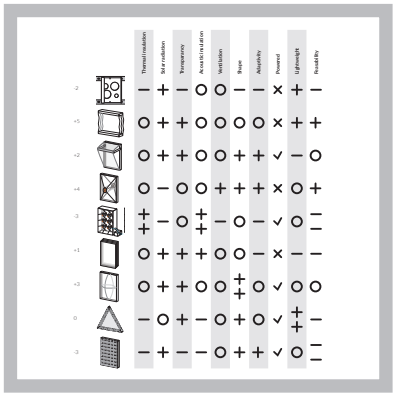
Development

Additional research

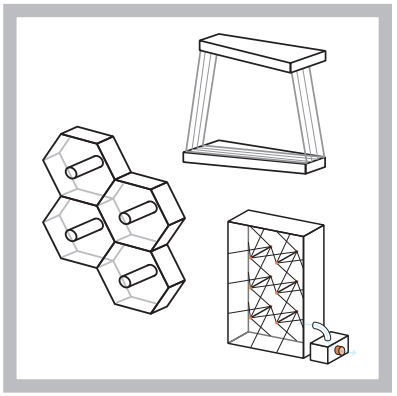
Brainstorming



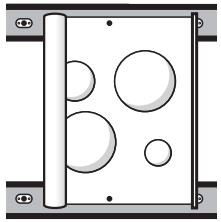
Sketch designs



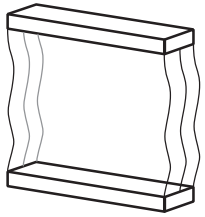
Preliminary designs



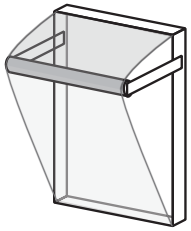
Draft designs



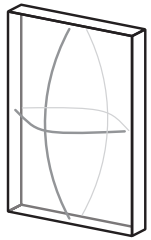
Rollable envelope



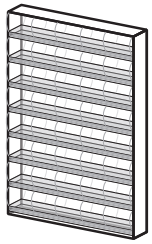
Fold-out façade



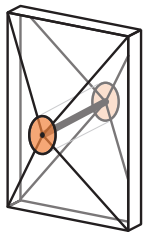
Shaped shading



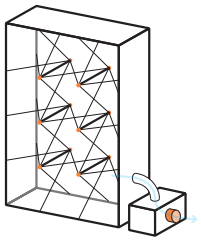
Shaped inflatable



Selective inflation

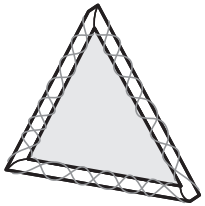


Mechanical cushion



Unitized vacuum

Media façade



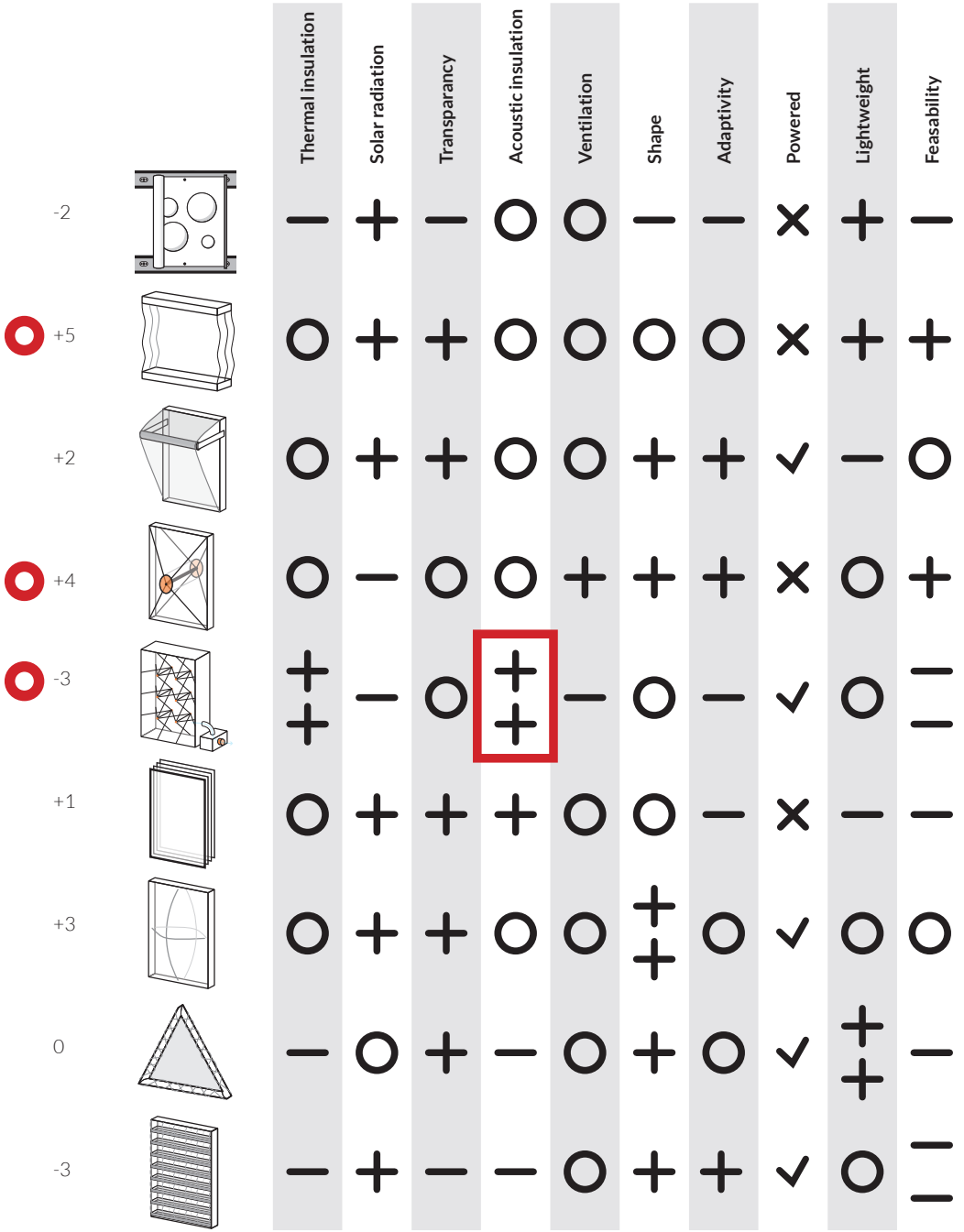
Structural tubes

Draft choice

Fold-out facade

Mechanical cushion

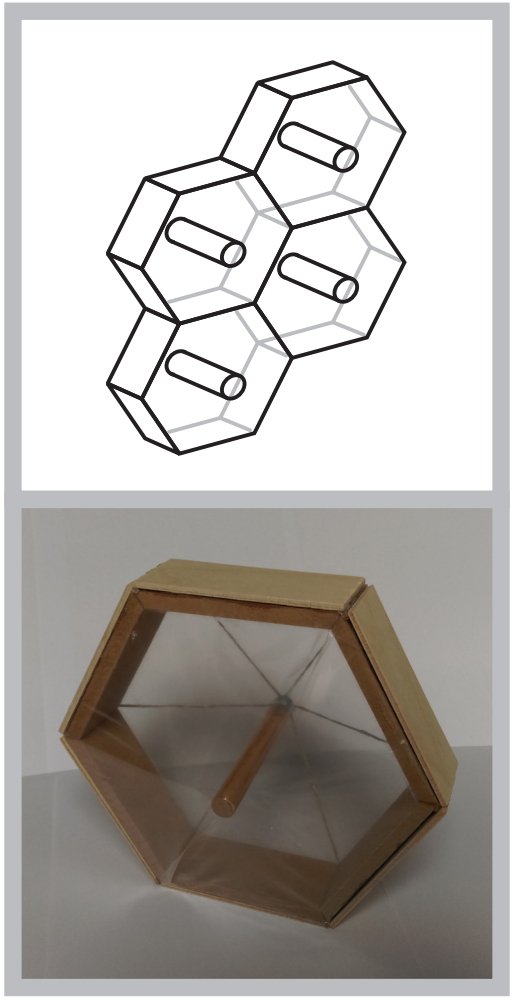
Unitized vacuum



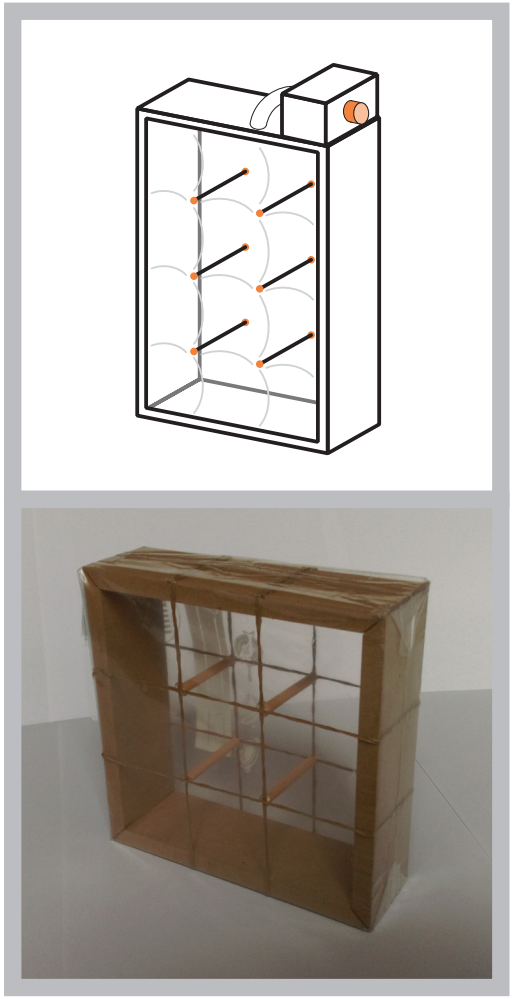
Preliminary designs

Fold-out facade

Mechanical cushion



Unitized vacuum ←



CALCULATIONS AND TESTING

Thermal insulation

Thermal insulation

Low pressure ineffective

No effect on conduction

and convection

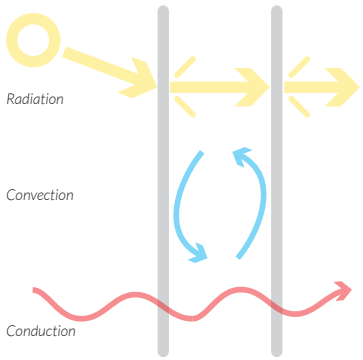
Low e-coating

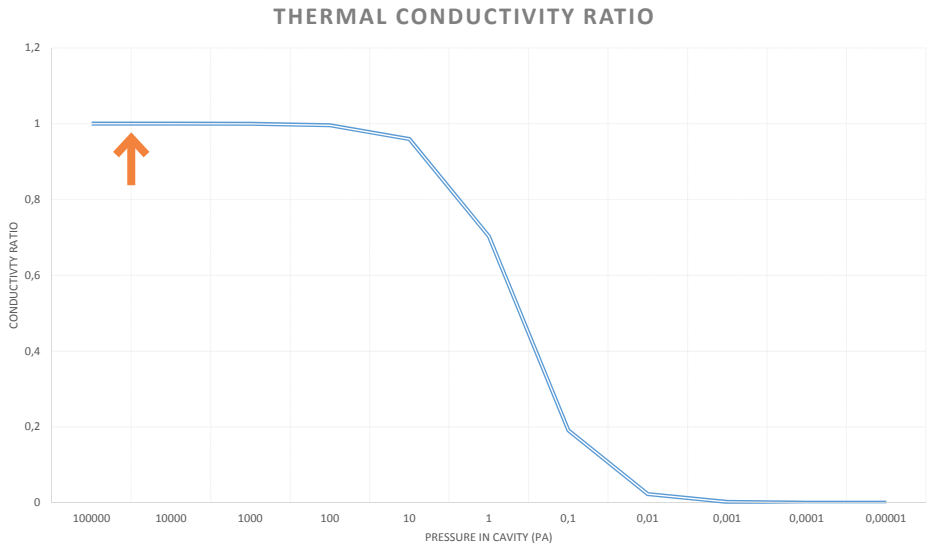
Three cavities and spacers
U-value 0.88 W/m²K

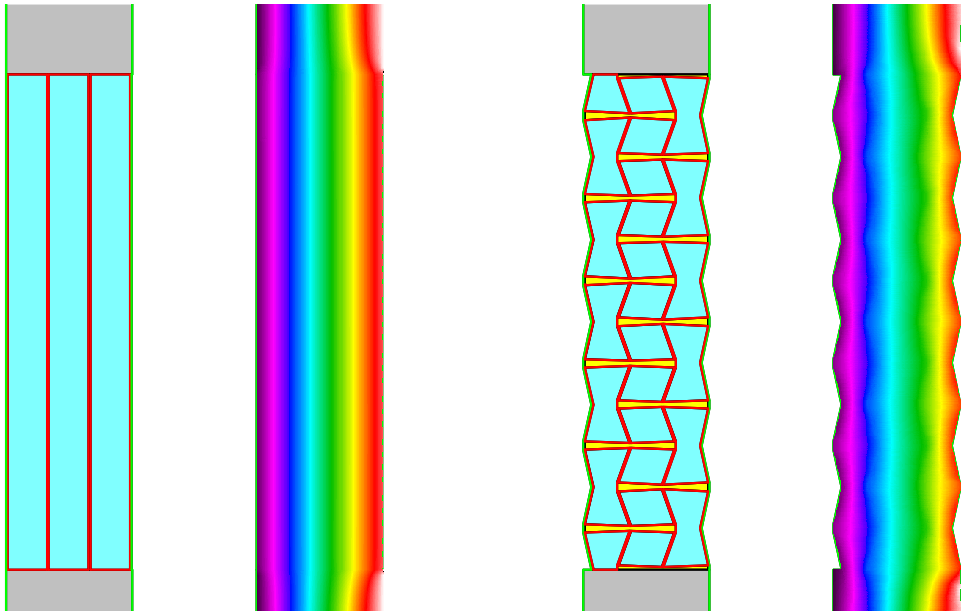
Therm calculation software

Empty cavities
U-value 0.79 W/m²K

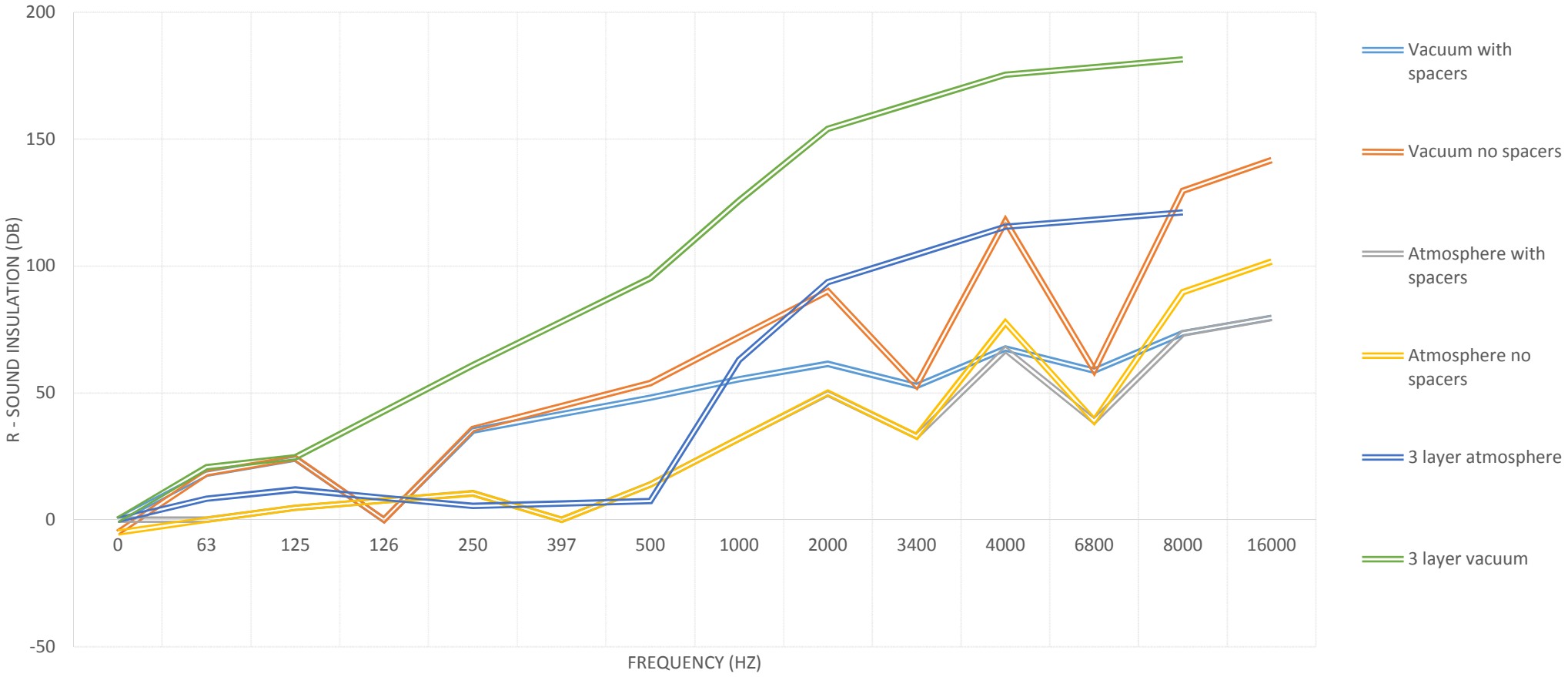
Three cavities and spacers
U-value 1.17 W/m²K







Acoustic insulation



Spacer calculations

Pressure creates force

Puncture

Buckling

Pattern

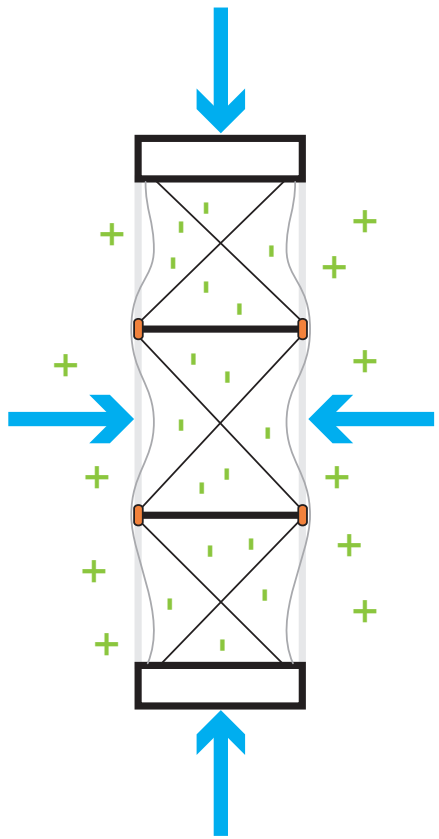
Sizes at high windforce

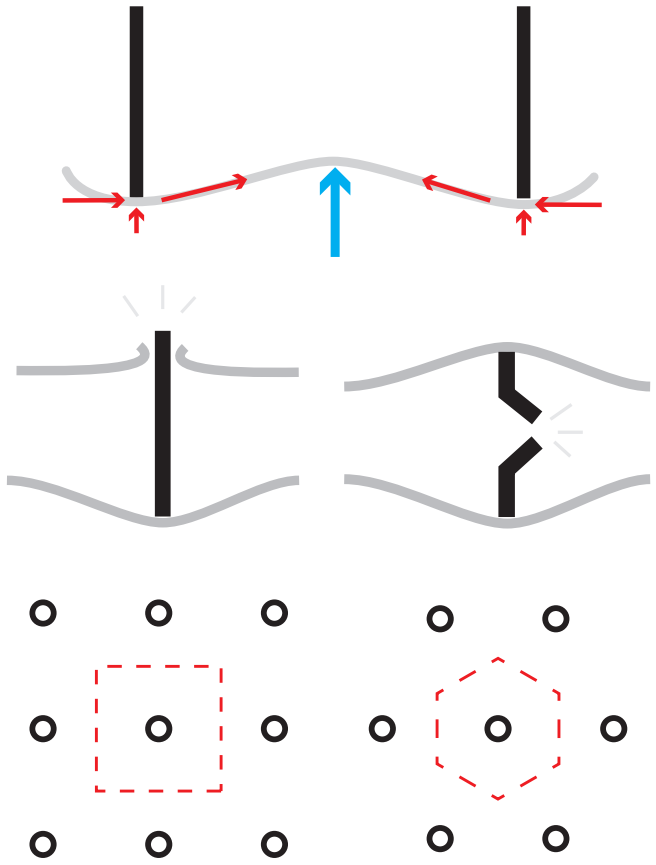
Spacing (mm)	Diameter (mm)
50	1
100	7
150	25
200	50

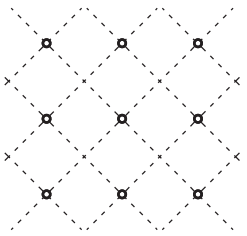
Sizes at extreme windforce

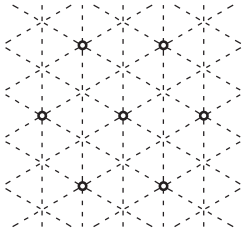
Spacing (mm)	Diameter (mm)
50	1
100	10
150	40
200	80

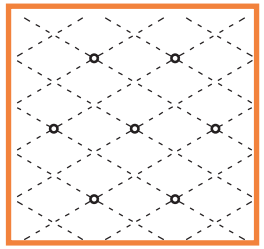
Reinforcement pattern

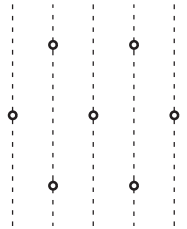






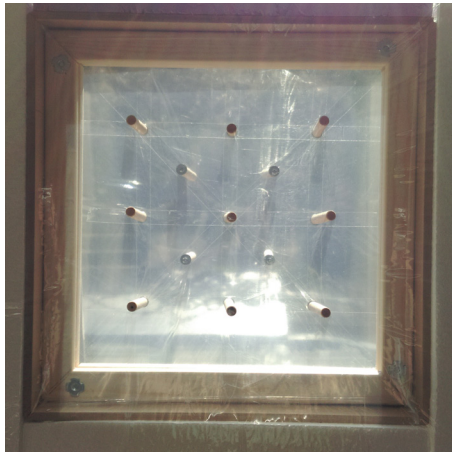


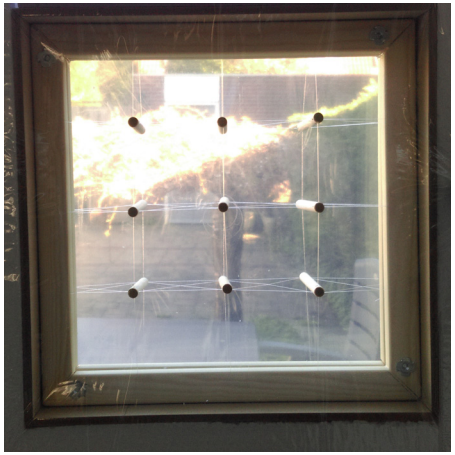




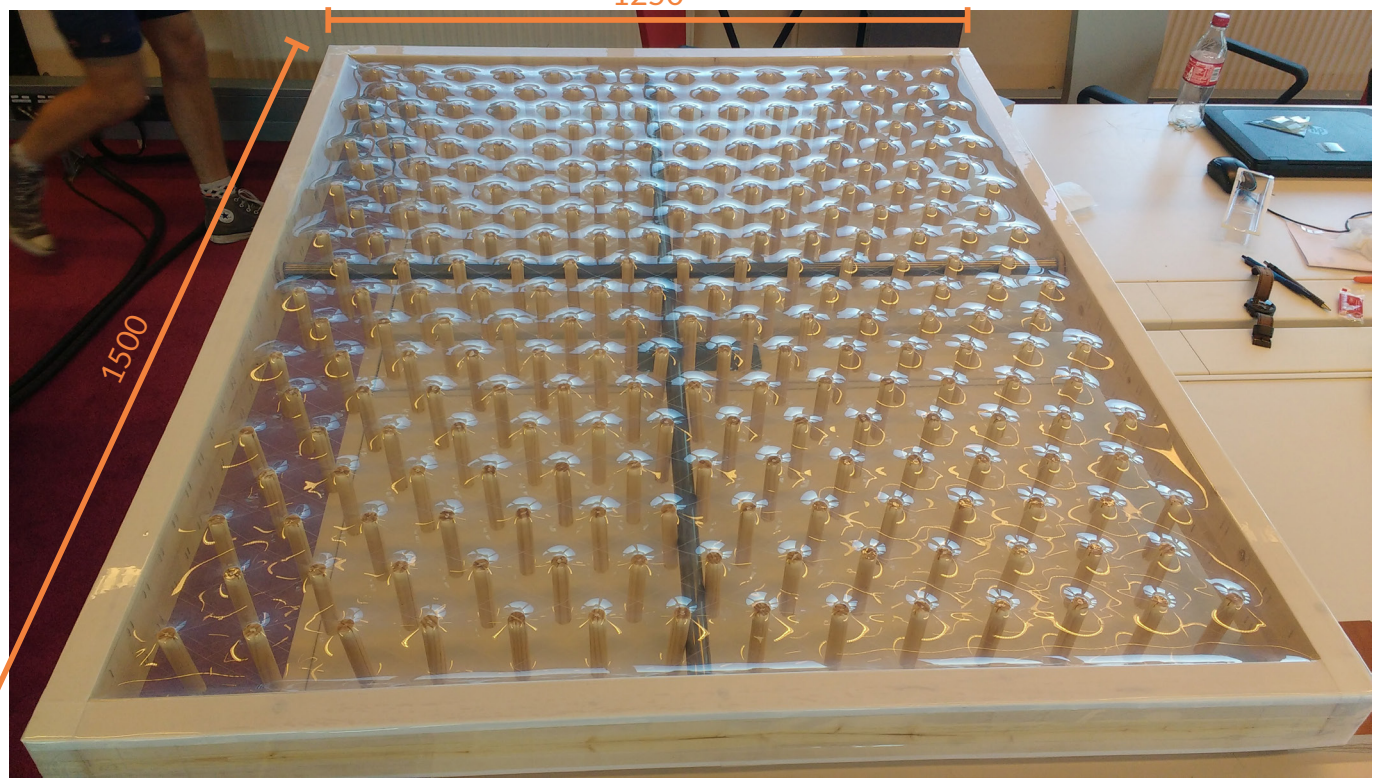
Spacer mock-ups

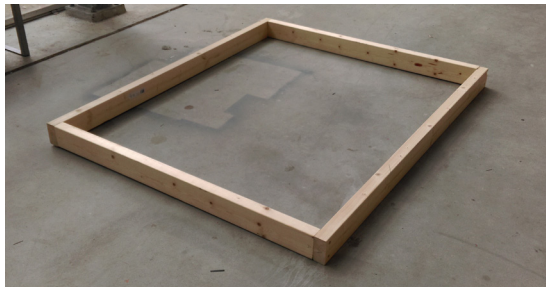
Spacer mock-ups

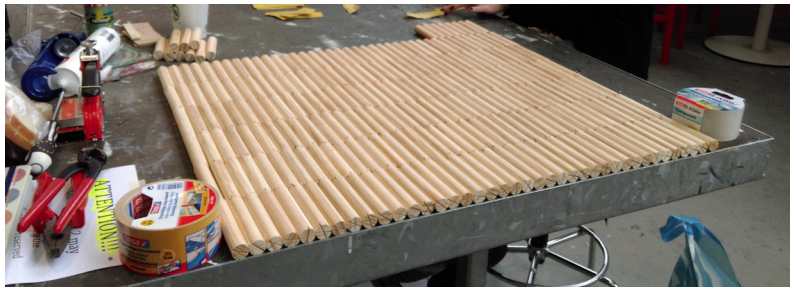




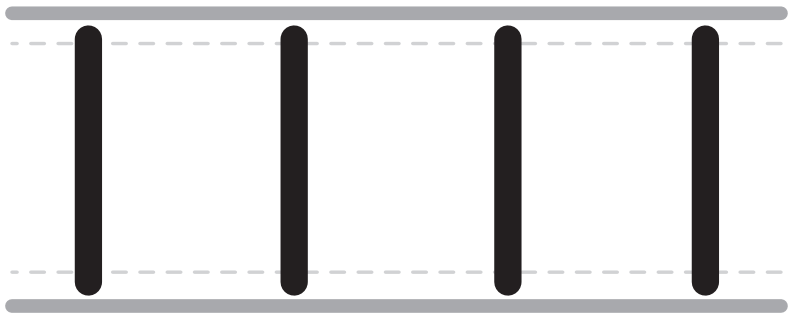
Acoustic performance test

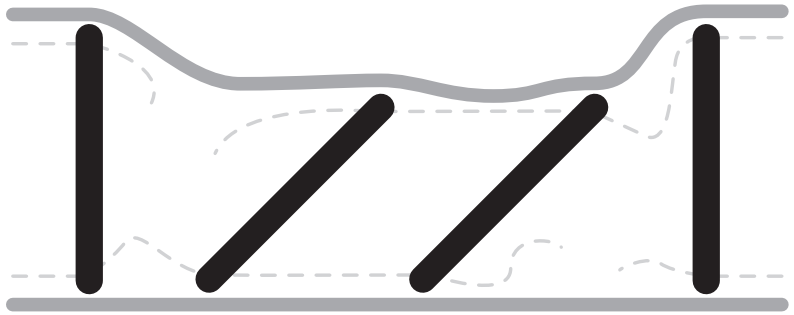




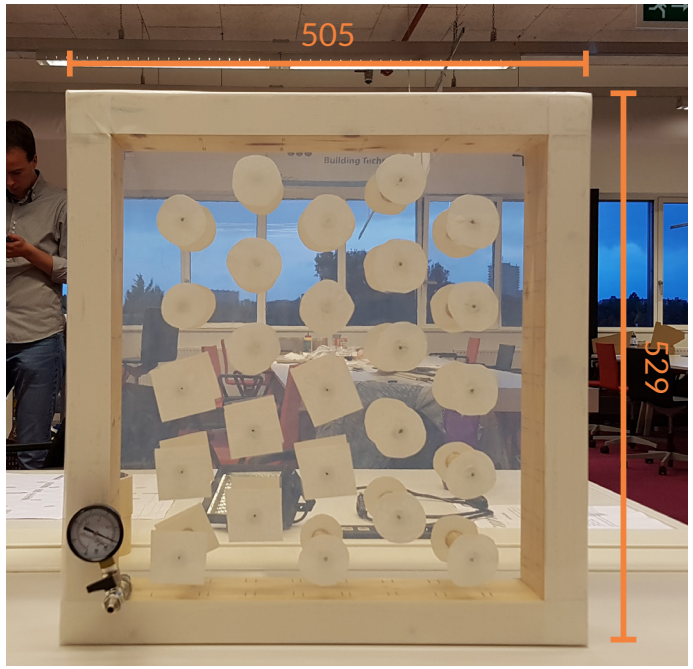


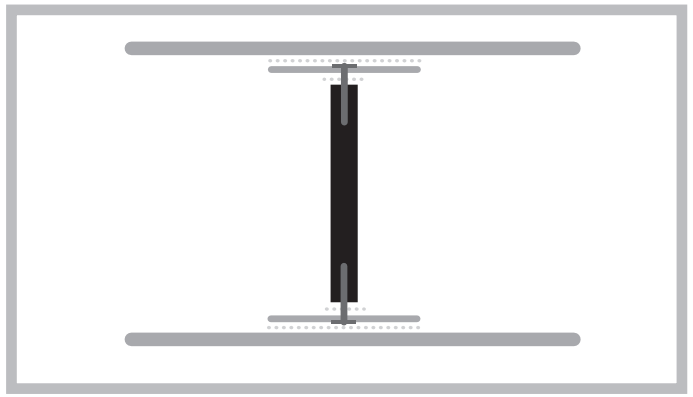
Test model failure



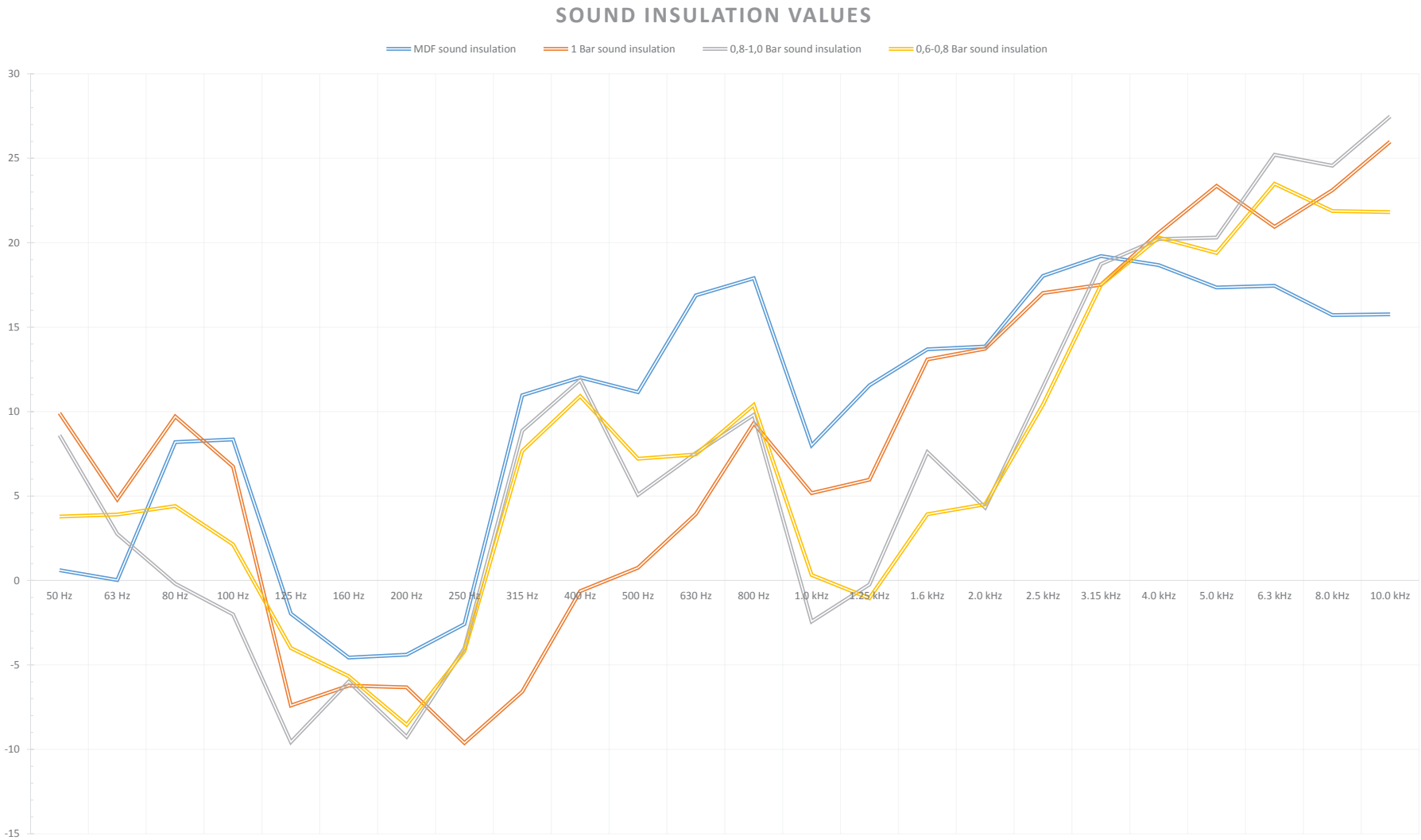


Second test model



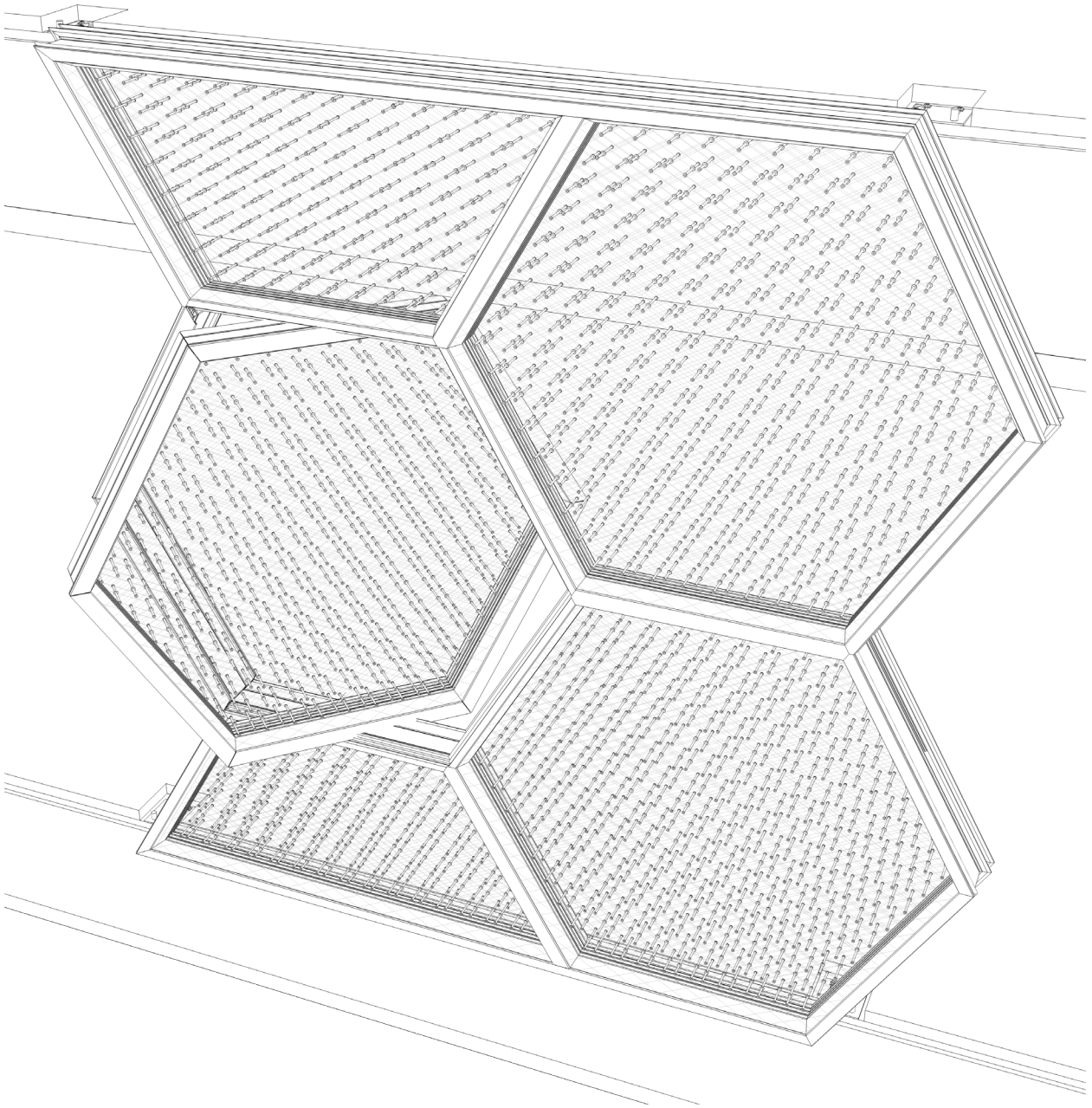


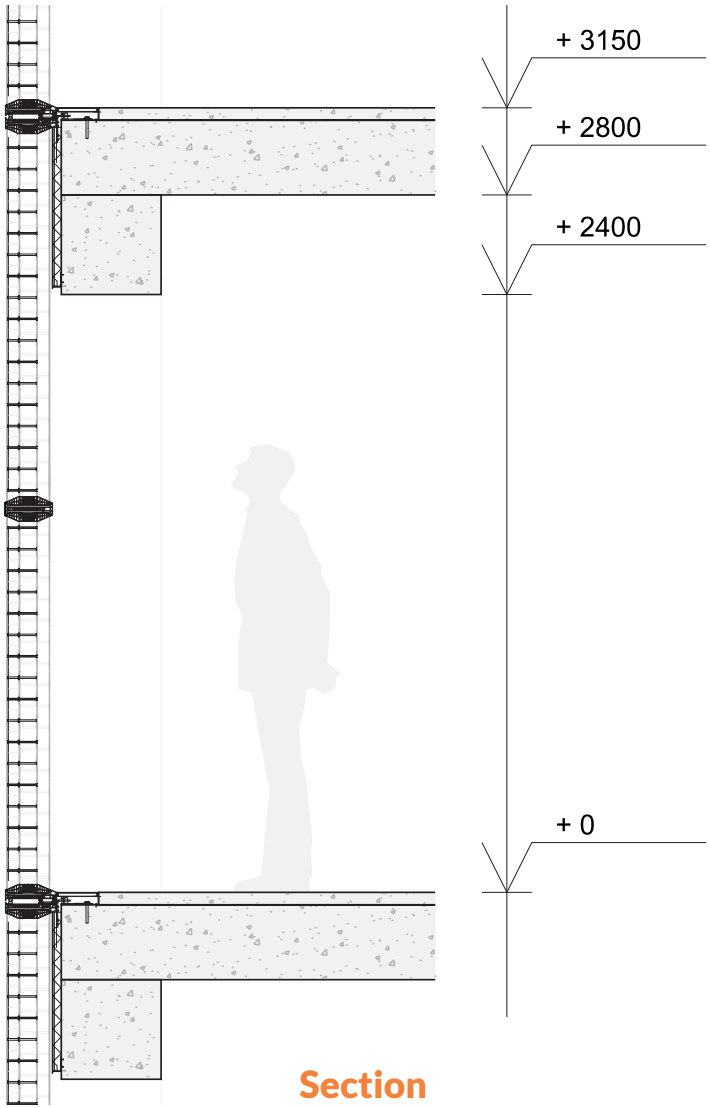
Inconclusive results



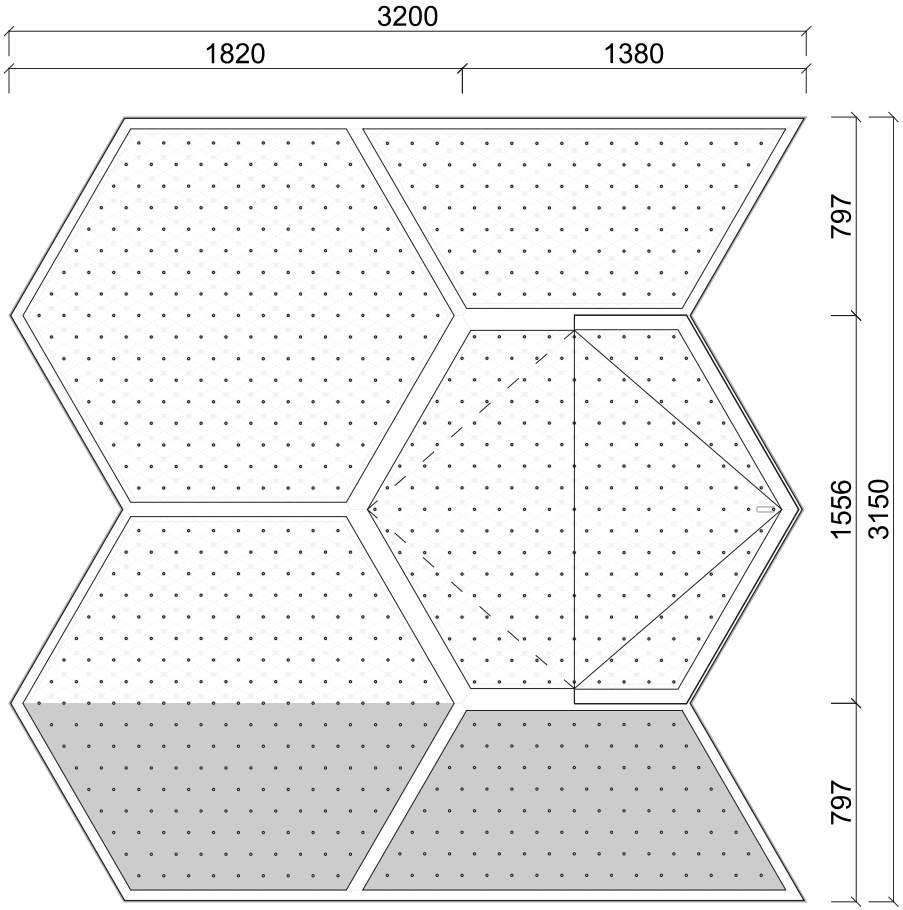
FINAL DESIGN

Unitized vacuum membrane envelope

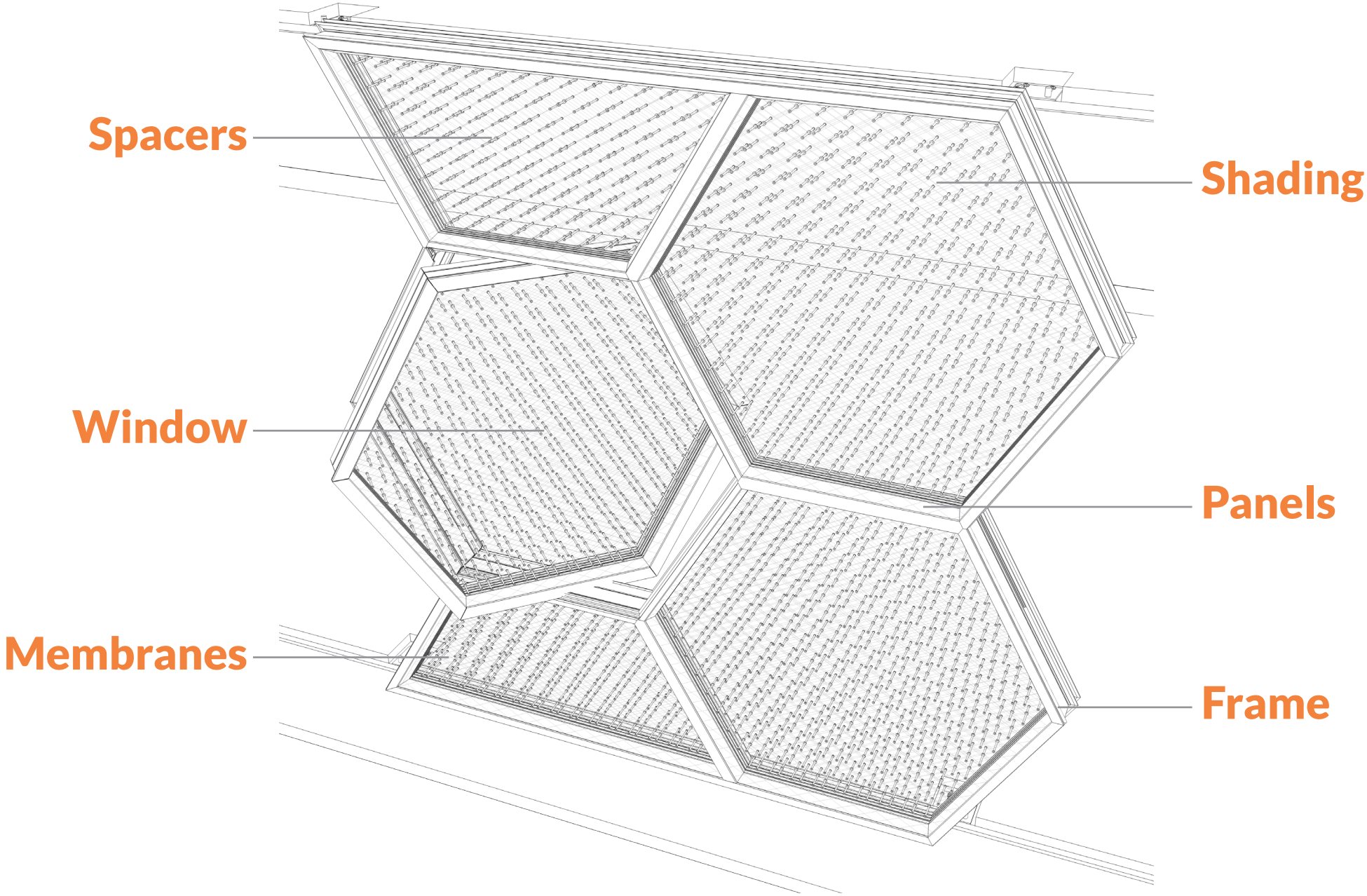




Section



Front view


Spacers
Shading
Window
Panels
Membranes
Frame

Membranes

Materials and material combinations have been chosen to account for numerous complications. Including fire, creep and transparancy

1 Glass fibre reinforced ETFE 0.3 mm with ETFE reinforcement at spacer points

2 Sunshading system

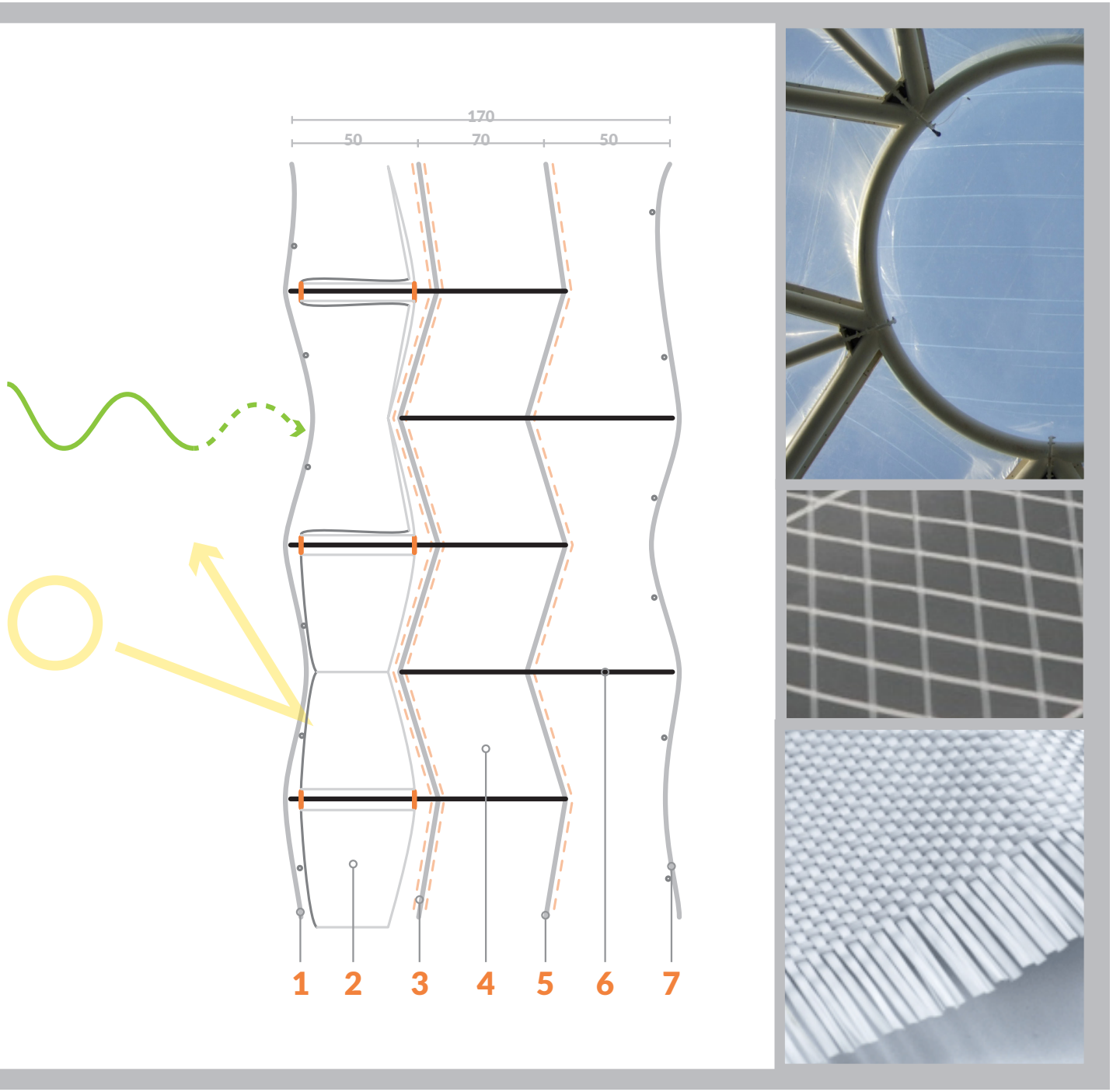
3 Glass fibre reinforced ETFE 0.3 mm with ETFE reinforcement at spacer points and low-e coating on both sides

4 Low vacuum at 0.1 Bar

5 Glass fibre reinforced ETFE 0.3 mm with ETFE reinforcement at spacer points and low-e coating on one side

6 Spacers

7 Glass fibre reinforced ETFE 0.3 mm with ETFE reinforcement at spacer points



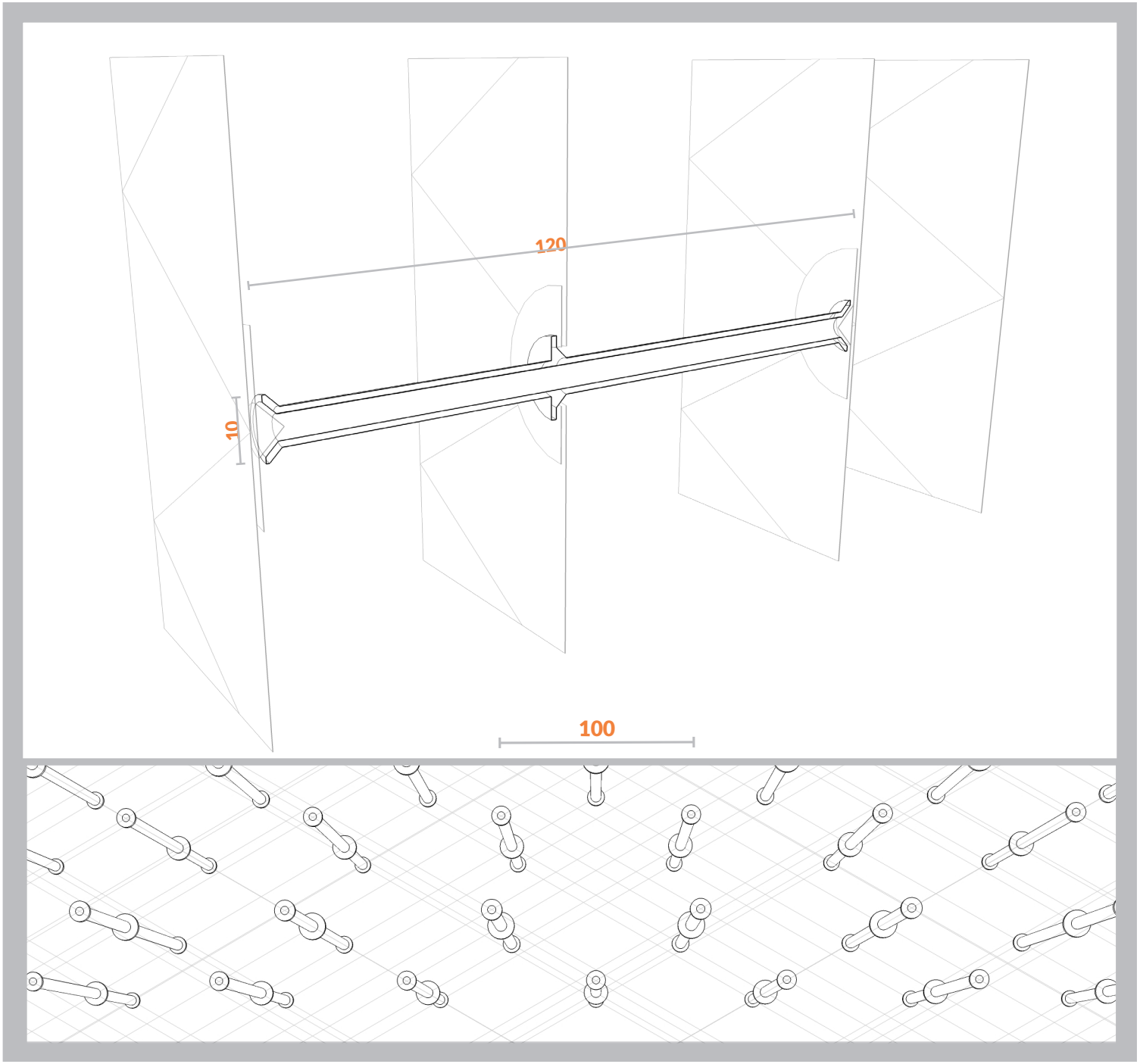
Spacer design and placement

Large at ends

Slim in the middle

Hollow

Pressure locks it over reinforced cone

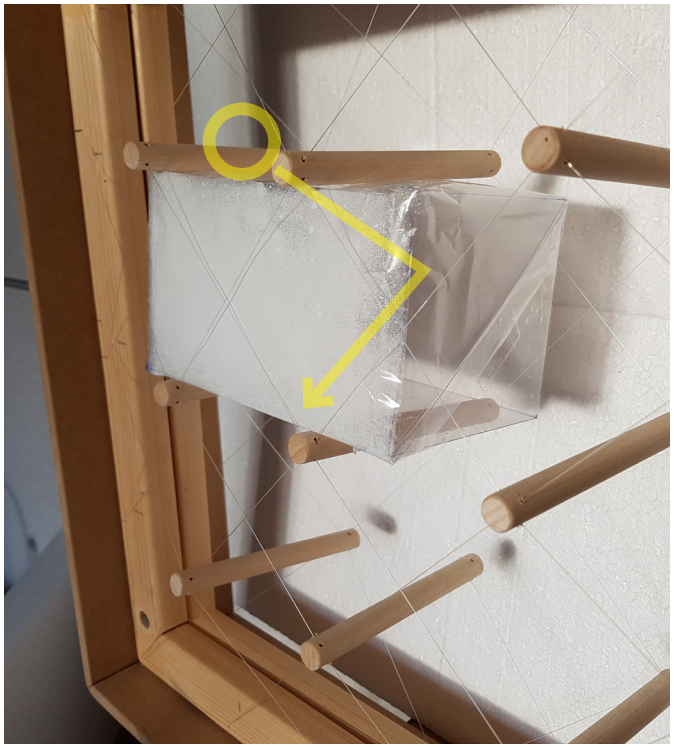


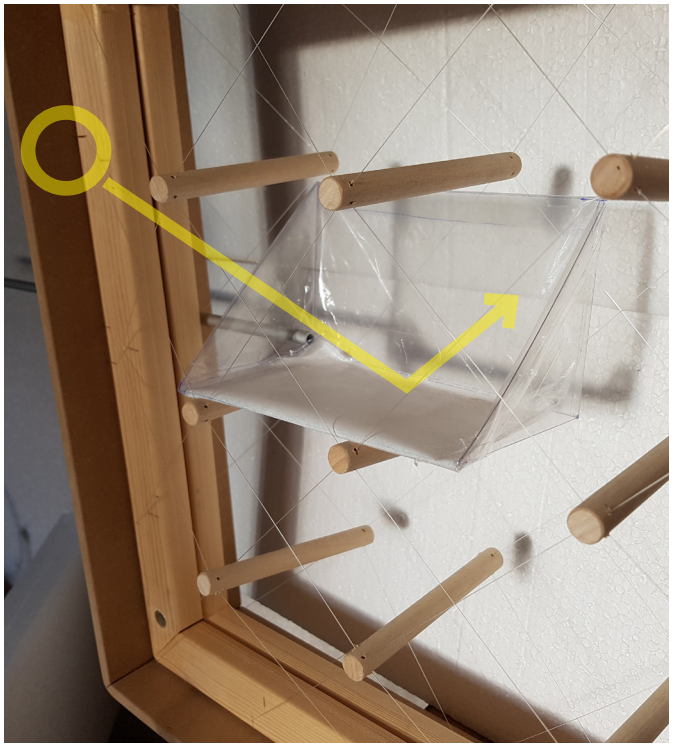
Sunshading

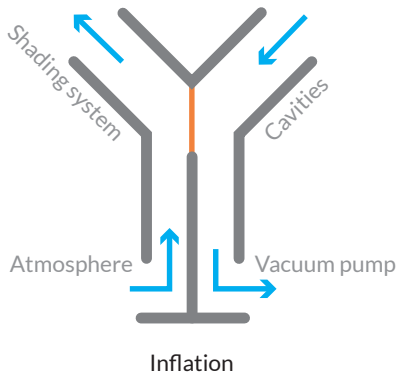
Alternate between

- Complete shading
- Horizontal louvres

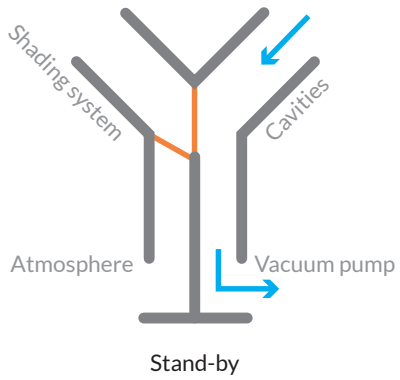
Can be controled by same vacuum pump with custom valve.



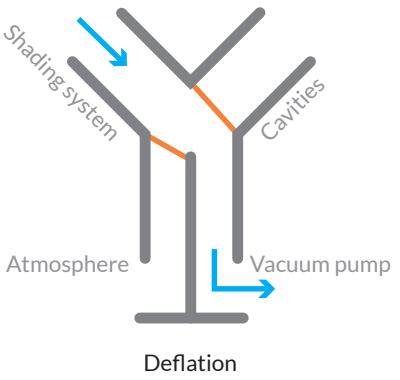




Inflation



Stand-by



Deflation

Panel

Panel 3x1m

Deflection 500mm

Panel hexagon

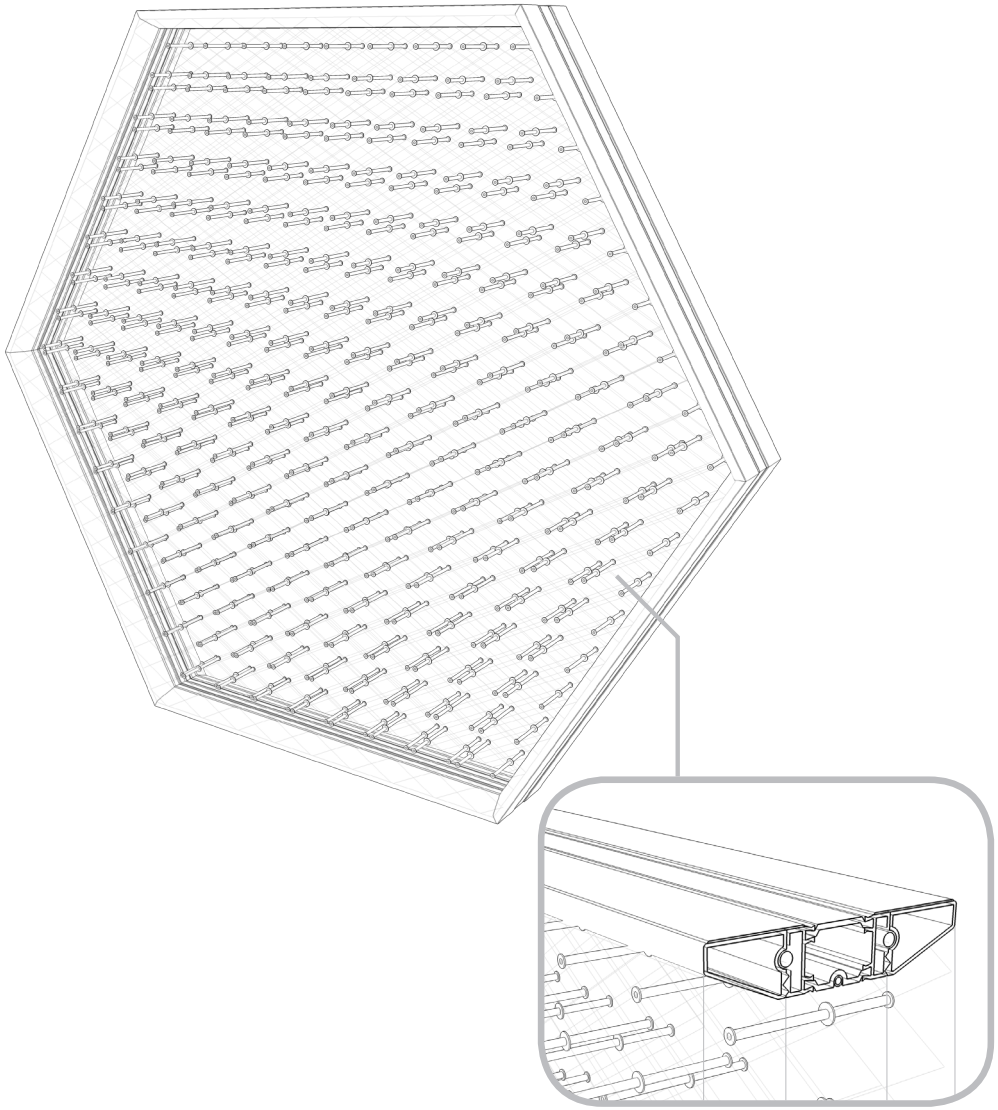
Deflection 8 mm

Divided unit into panels

Lower deflection

Sepperate vacuum

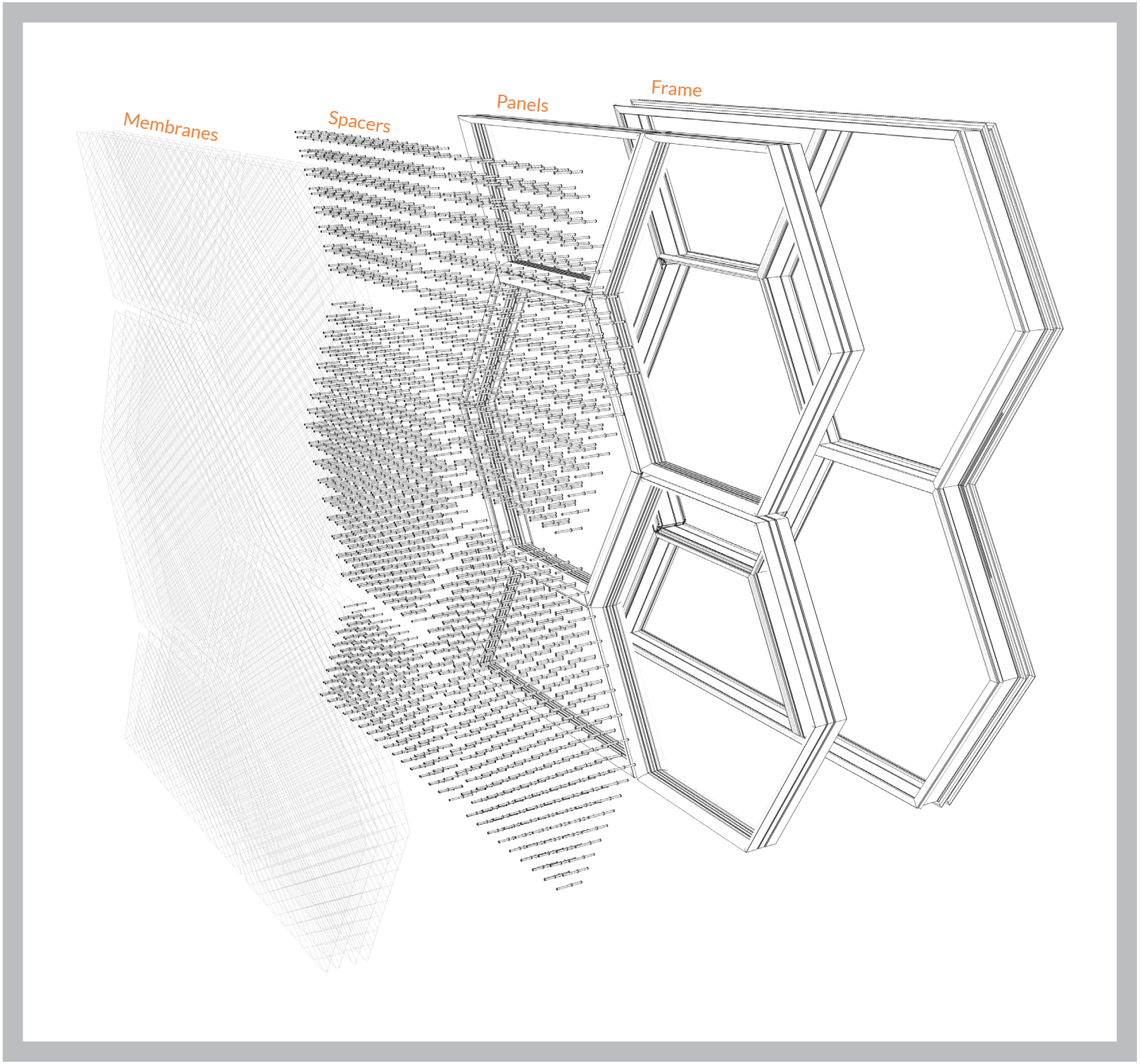
Smaller window



Frame

The frame holds the differnt layers and parts together

Structural stability through panels



Additional design aspects

Window
Vertical pivot window

Air evacuation system
Gas permeability
0.8 liters/hour/panel

Moisture permeability
8 grams of water/day if submerged

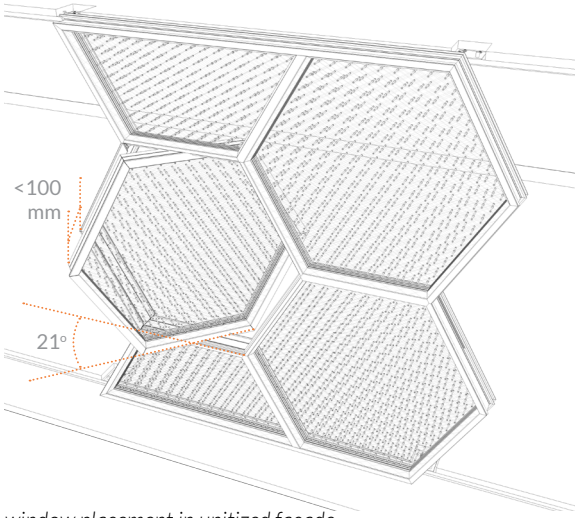
pumped out by one 12W pump in 8 min. per day.

Requires 10cm^2 thin PV cell per unit

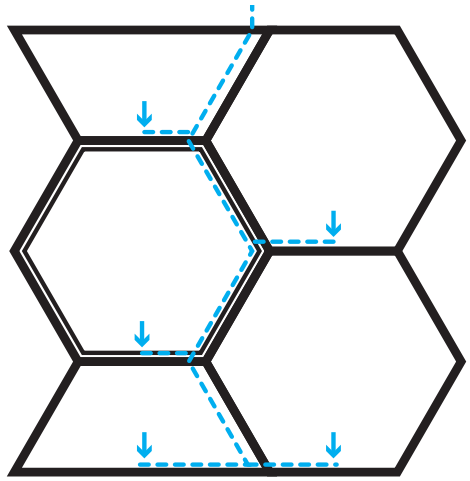
Weight
3.15*3.2m unit weighs 203Kg

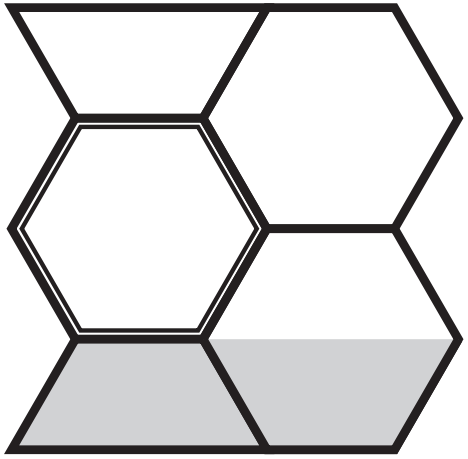
Replacing 1 into glass window increases weight by 35Kg

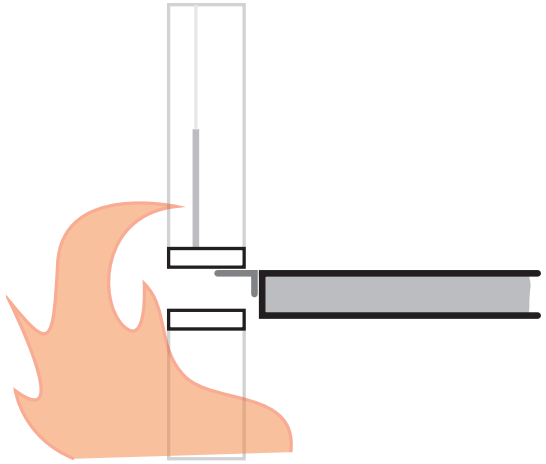
Mylar parapet
fire protection
puncture resistance



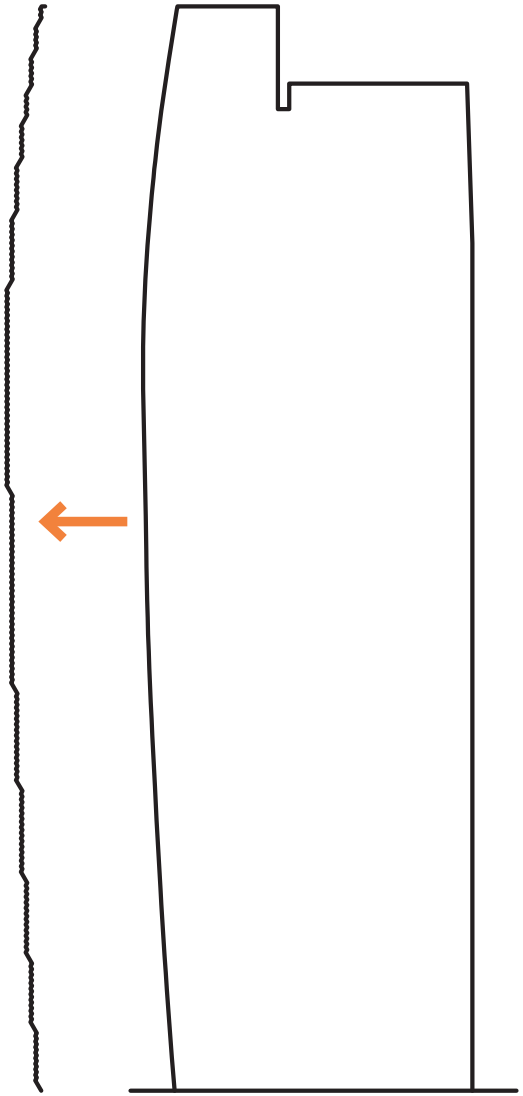
window placement in unitized facade

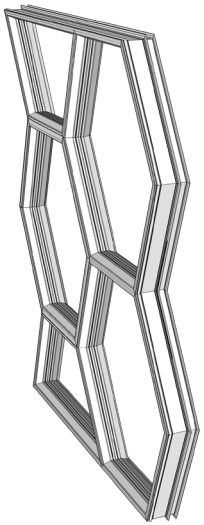

Air evactuation ducts and pump location

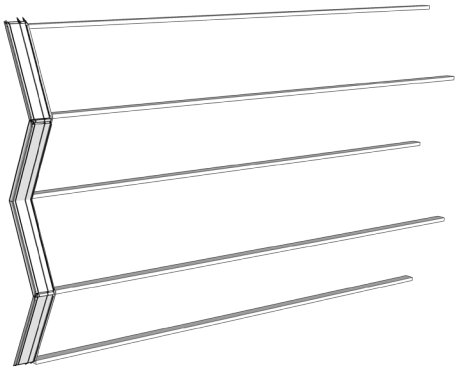

Mylar parapet

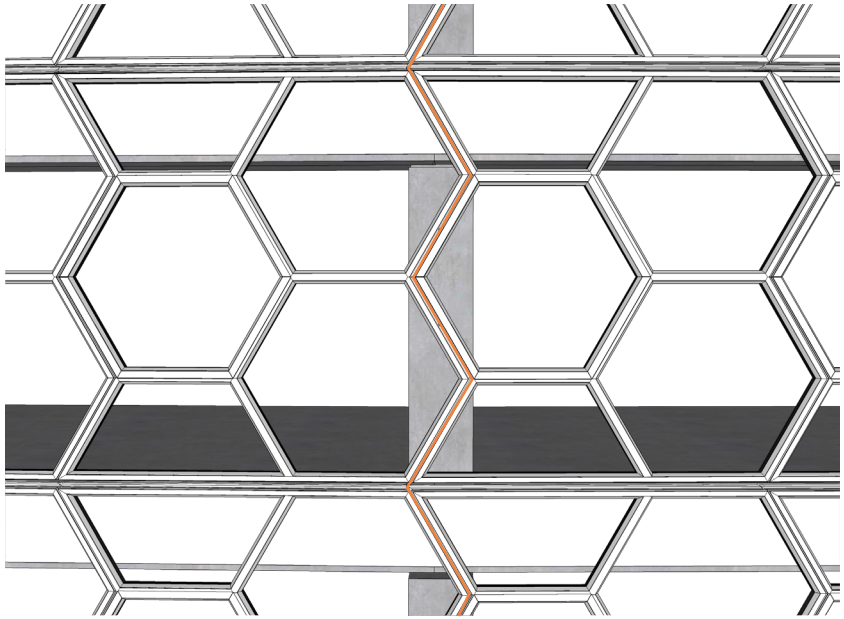

Fire transfer preventtion

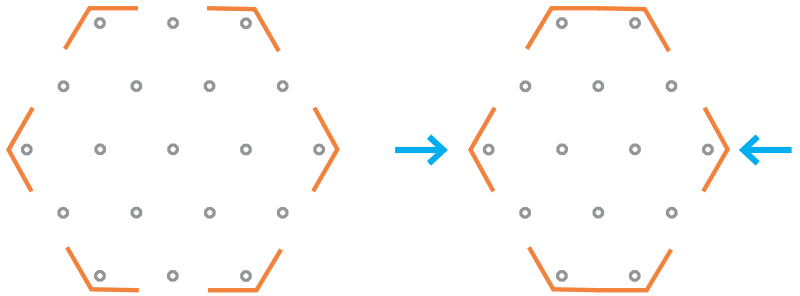
South-West facade









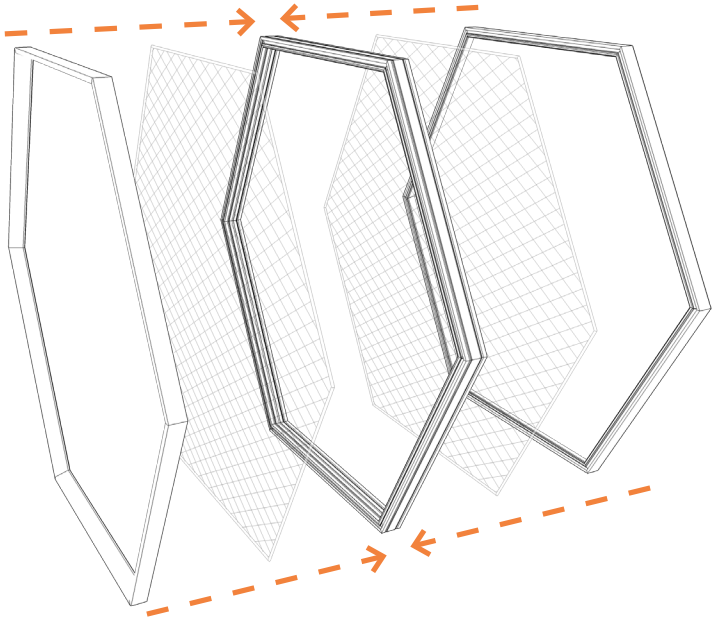


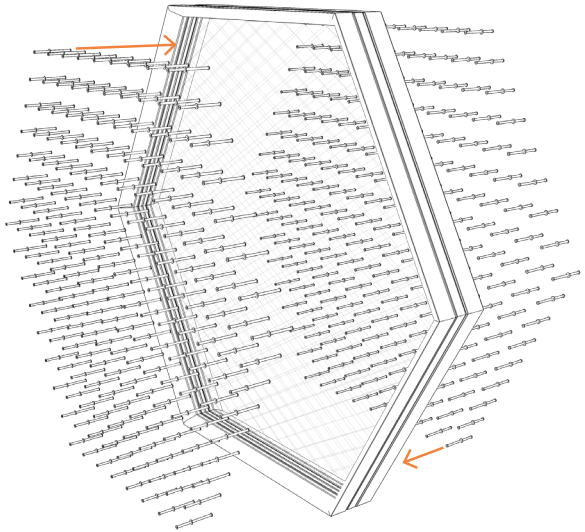
Building steps

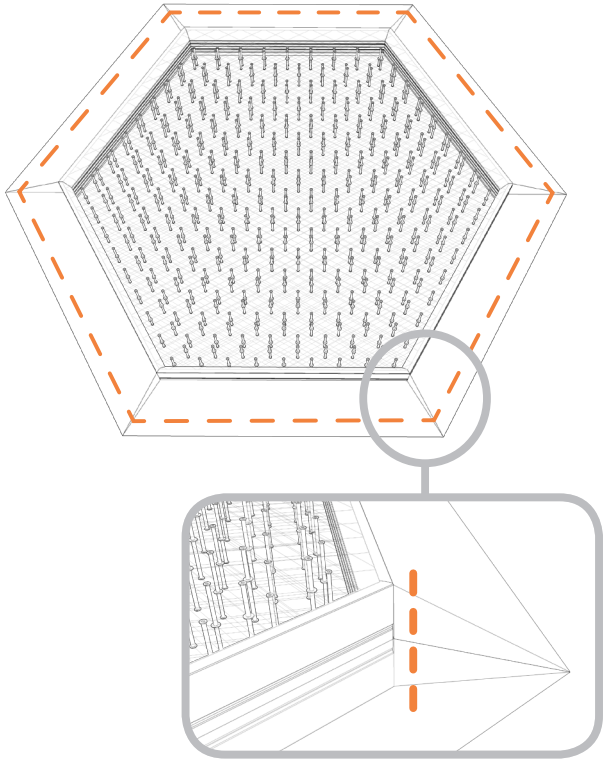
Step 1

Step 3

Step 2





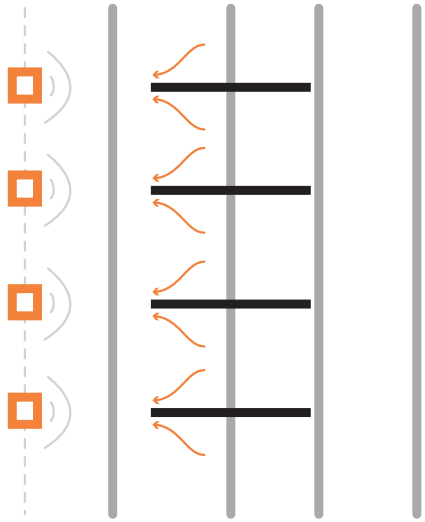


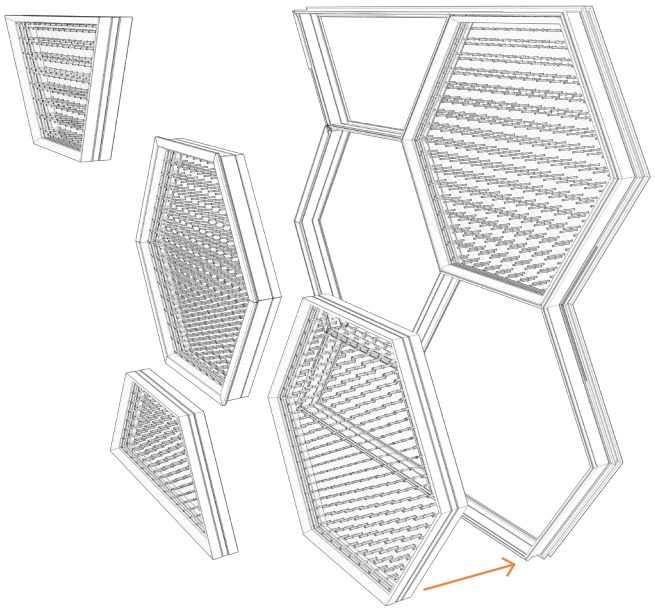
Building steps

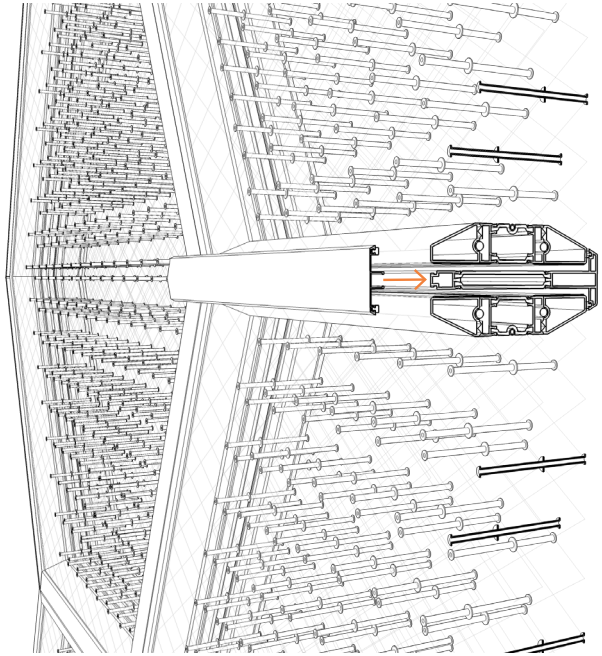
Step 4

Step 5

Step 6

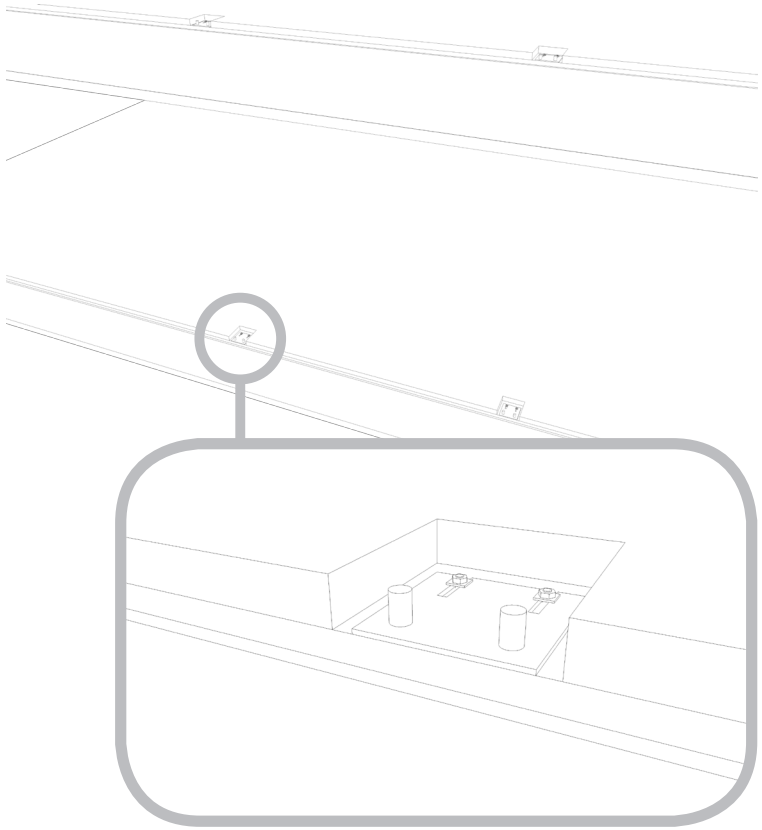




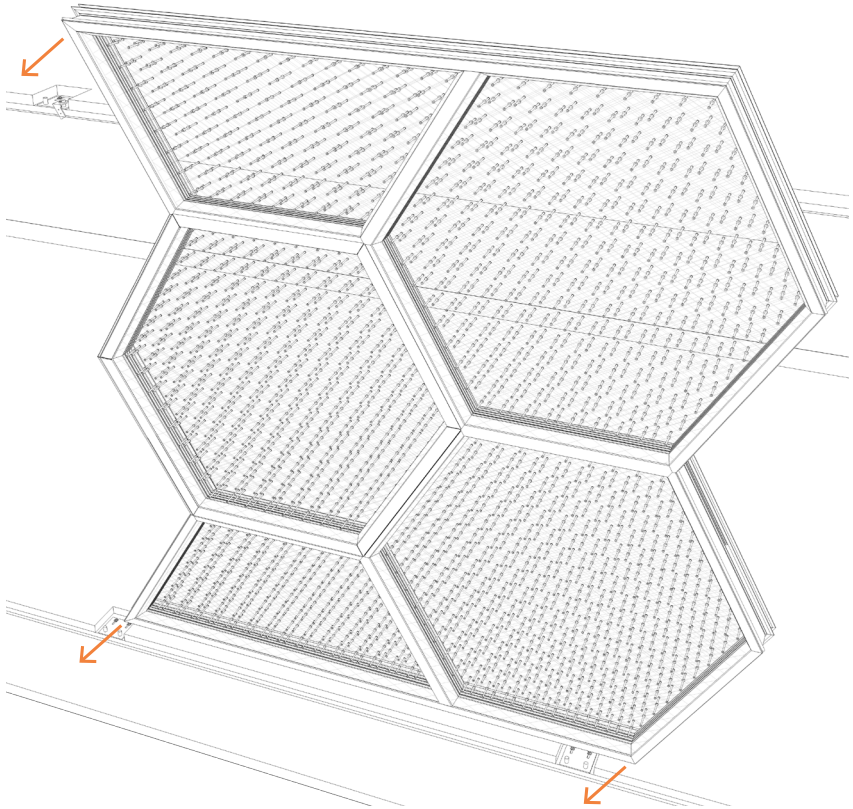


Building steps

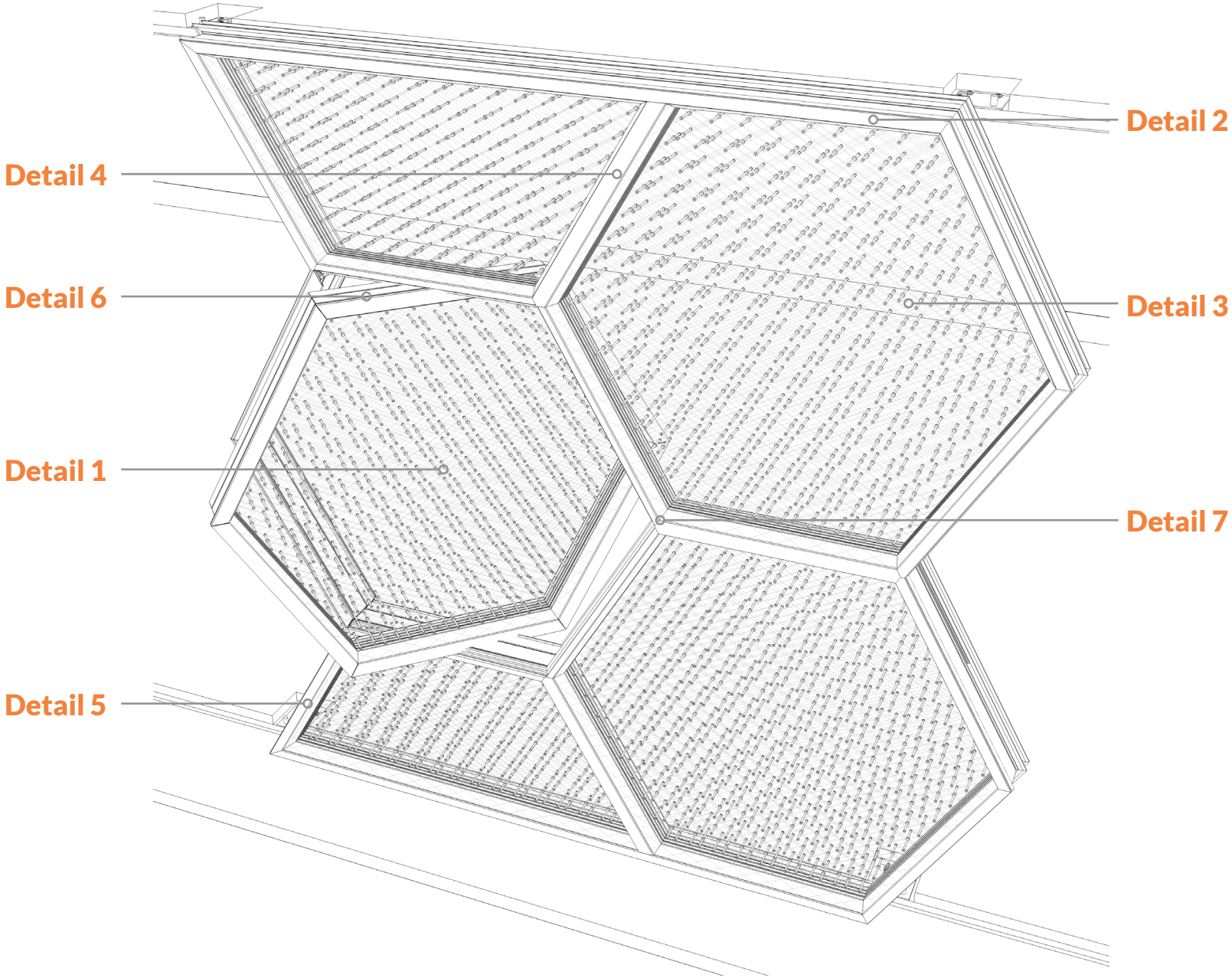
Step 7



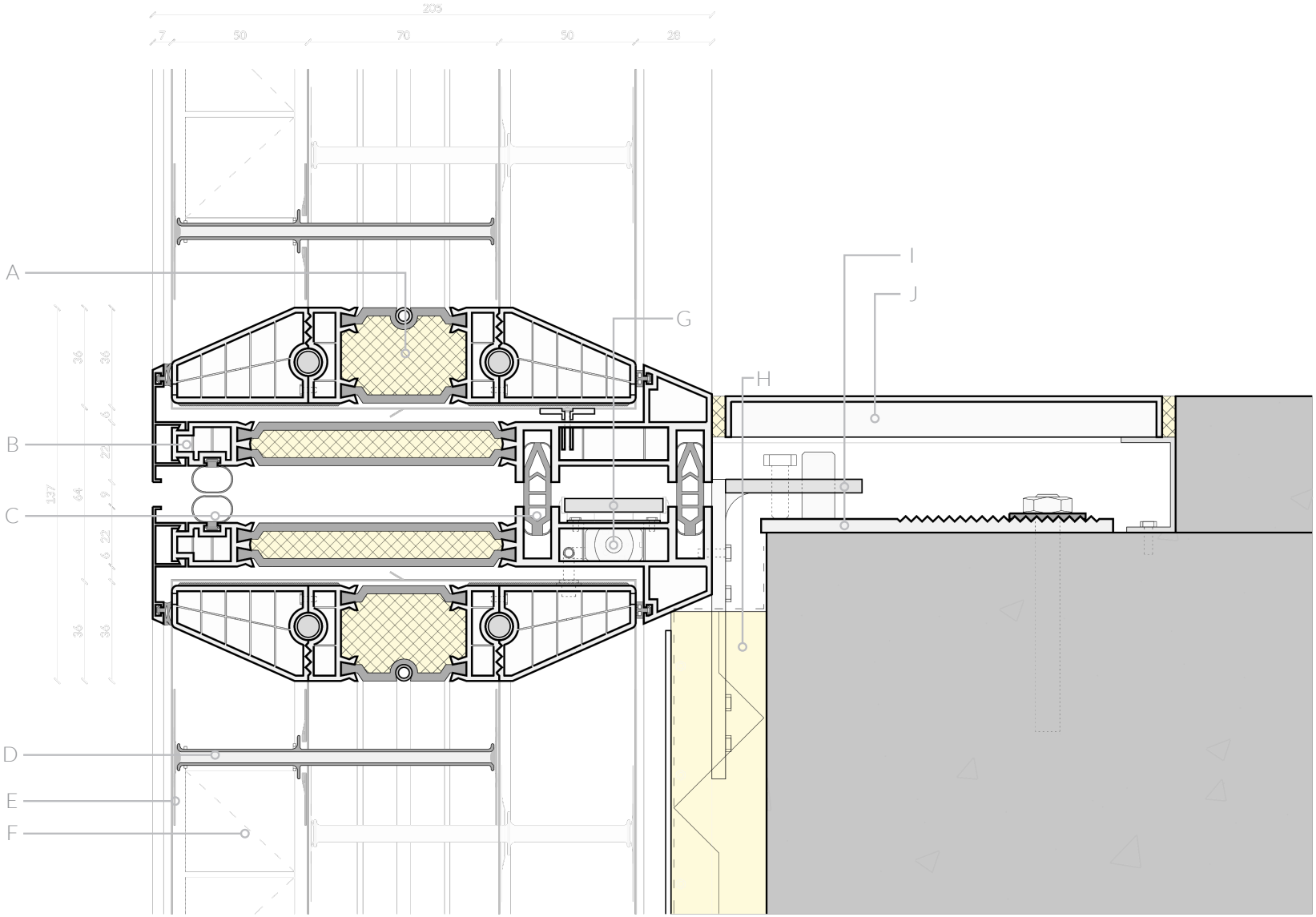
Step 8



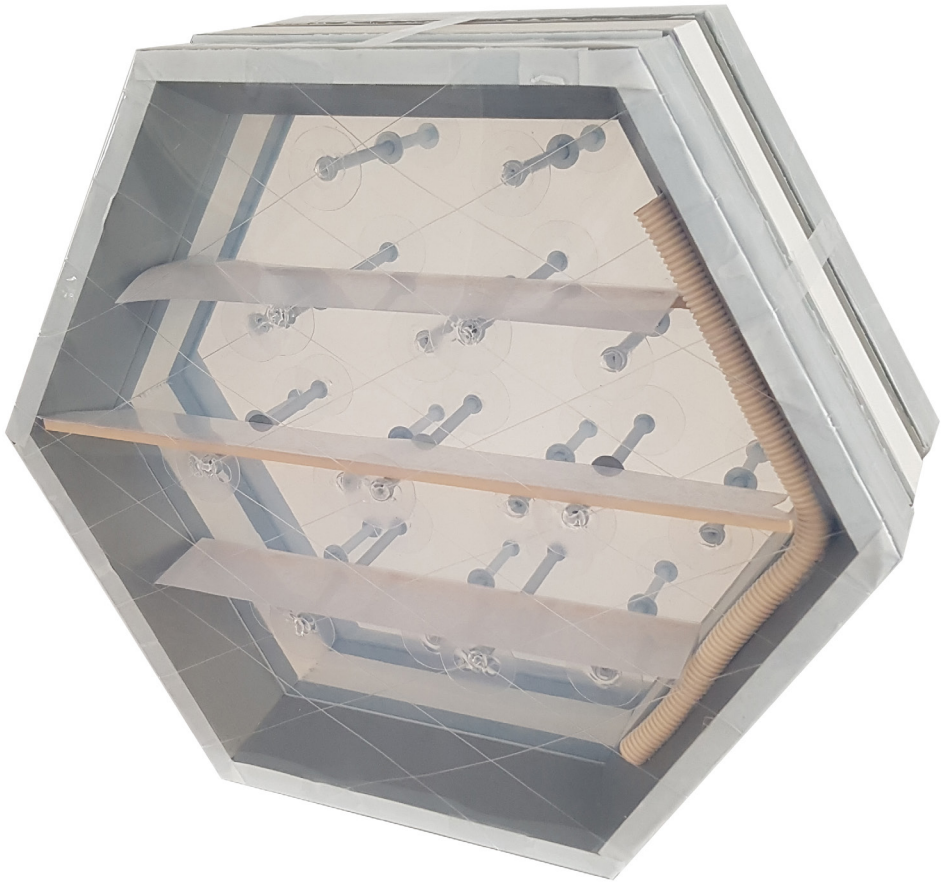
Detailing



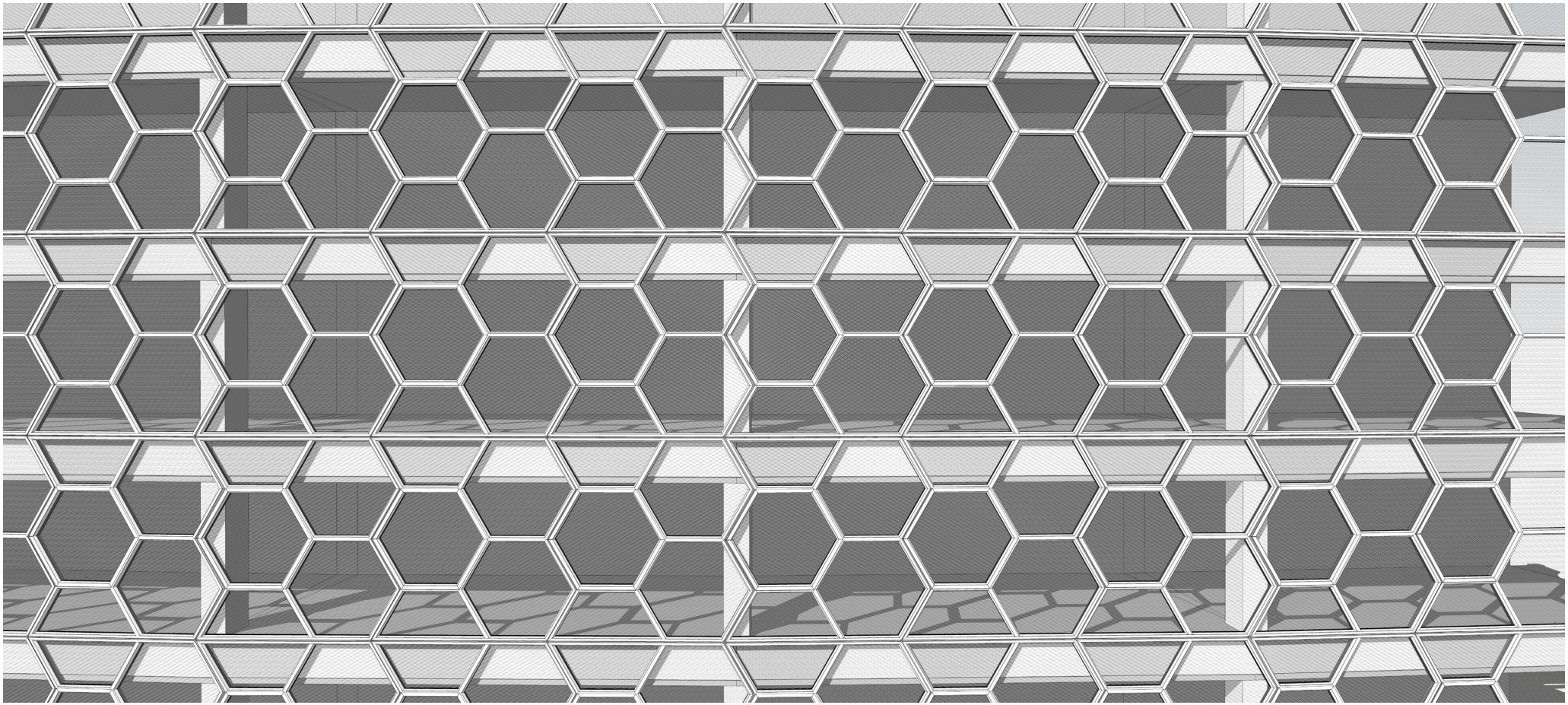
Detail 2



Visual comfort

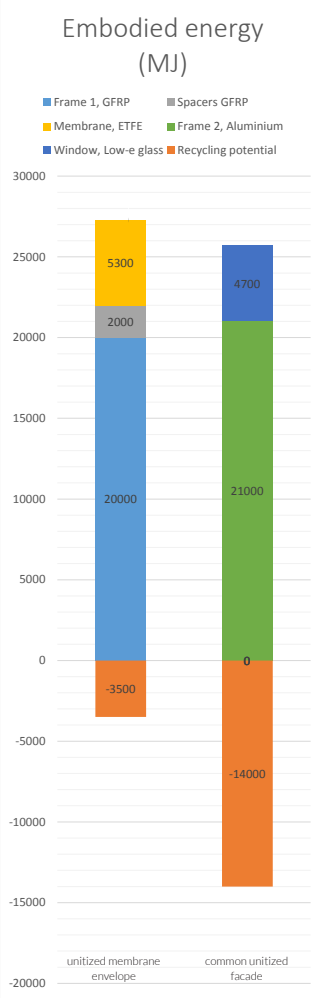


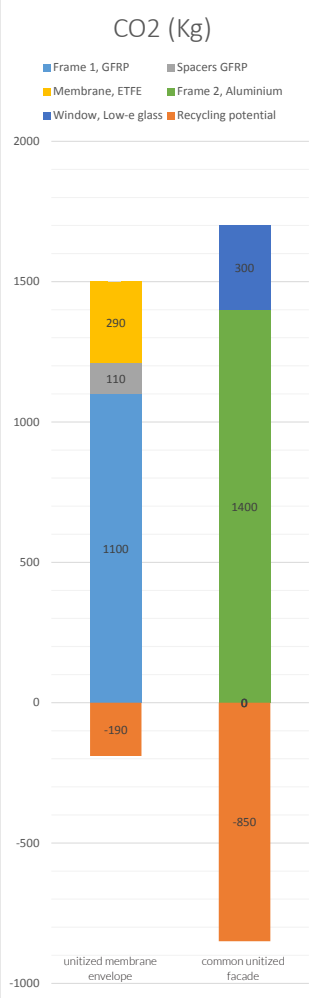
Appearance

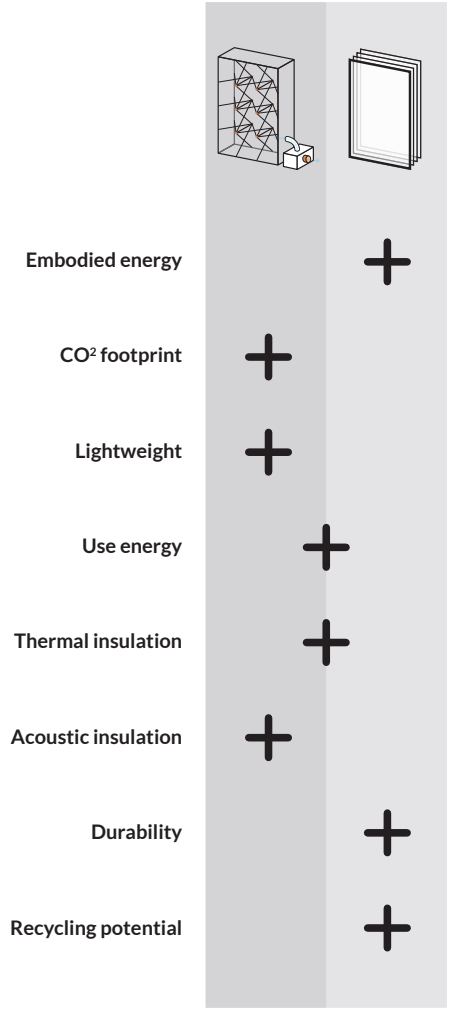


CONCLUSIONS

Sustainability review







Conclusion

Main research question

How can an adaptive unitized façade be designed by utilizing the advantages of membrane envelopes for residential high rise buildings in Singapore?

Sub-questions

What are the properties required of a façade for residential high rise buildings in Singapore?

Which types of membranes or membrane systems have the desired properties, as defined in the first sub-question?

What types of membrane envelopes have been built and how are they materialized, detailed and constructed?

What types of unitized façades are used on high rise buildings and how are they materialized, detailed and constructed?

What are the advantages of membrane envelopes compared to commonly used unitized façade systems?

Thank you!

for your attention