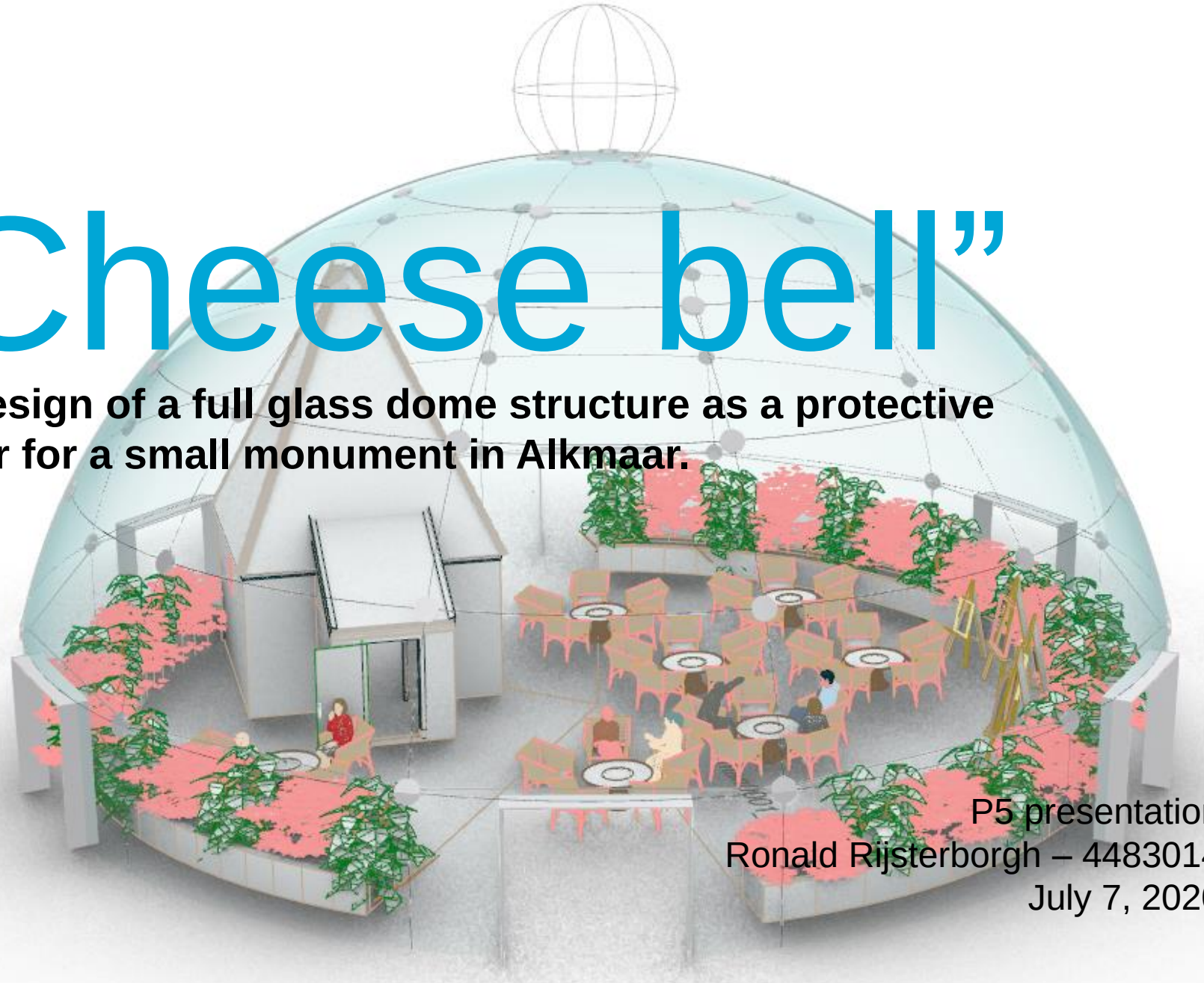
“Cheese bell”

The design of a full glass dome structure as a protective shelter for a small monument in Alkmaar.



P5 presentation
Ronald Rijsterborgh – 4483014
July 7, 2020

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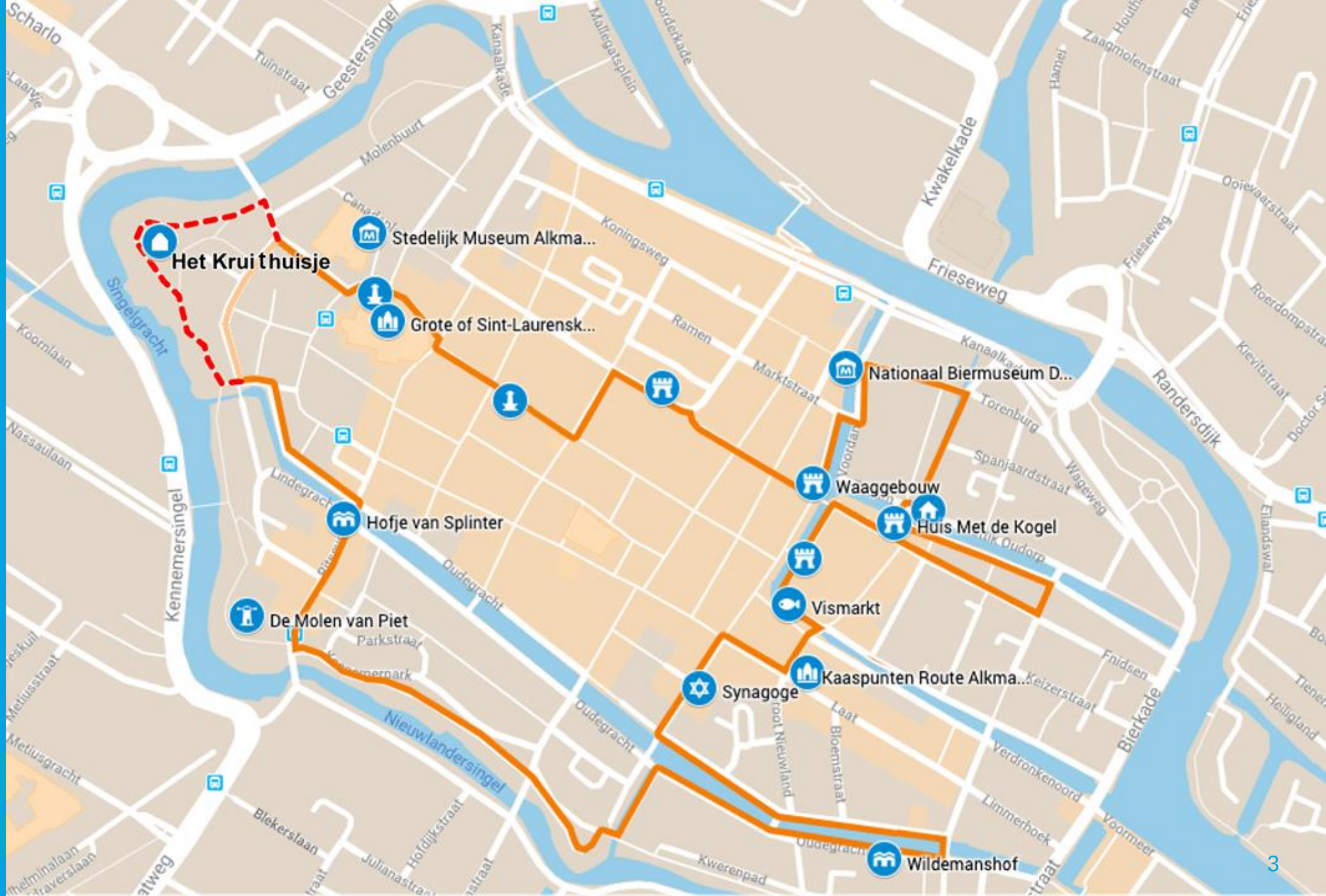
Het Kruithuisje
Stedelijk Museum Alkma...
Grote of Sint-Laurensk...
Nationaal Biermuseum D...
Waaggebouw
Huis Met de Kogel
Hofje van Splinter
De Molen van Piet
Vismarkt
Kaaspunten Route Alkma...
Synagoge
Wildemanshof
Singelgracht
Kennemersingel
Nieuwlandersingel
Oudegracht
Geestersingel
Kanaalkade
Kwakelkade
Frieseweg
Randersdijk
Koningsweg
Marktstraat
Lindegracht
Parkstraat
Bierkade
Molenbuurt
Tuinstraat
Koornlaan
Nassaulaan
Metiusgracht
Blekerslaan
Julianastraat
Hofdijkstraat
Kwerenpad
Verdronkenoord
Limmerhoek
Voormeer
Laat
Bloemstraat
Keizerstraat
Torenburg
Spanjaardstraat
Wageweg
Eilandswal
Zaagmolenstraat
Ooievaarstraat
Roerdompstraat
Krevitstraat
Fnidsen
Heiligland

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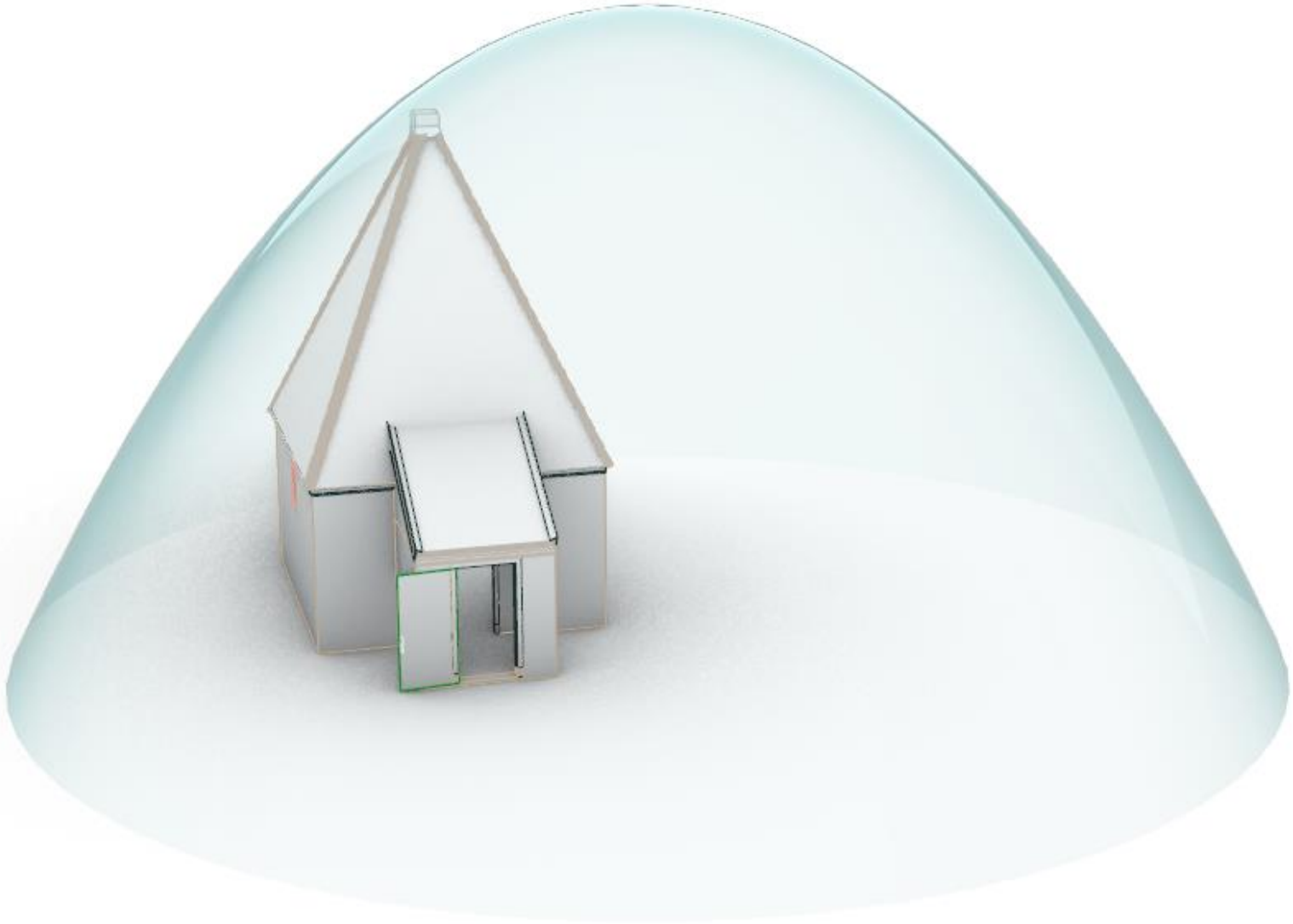
Main question

How can a full glass dome structure be built, to cover 'Het Kruithuisje' in Alkmaar, The Netherlands, in which the thermal comfort is maintained in the most passive manner, without impeding the visual benefits of glass?

General design

Paraboloid

- Max. defl.: 0.39 mm
- Max. stress (tension): 1.58 N/mm2
- Max. stress (compression): 2.16 N/mm2



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General design

Paraboloid
- Max. defl.: 0.39 mm
- Max. stress (tension): 1.58 N/mm2
- Max. stress (compression): 2.16 N/mm2

Hemisphere
- Max. defl.: 0.70 mm
- Max. stress (tension): 2.63 N/mm2
- Max. stress (compression): 3.37 N/mm2

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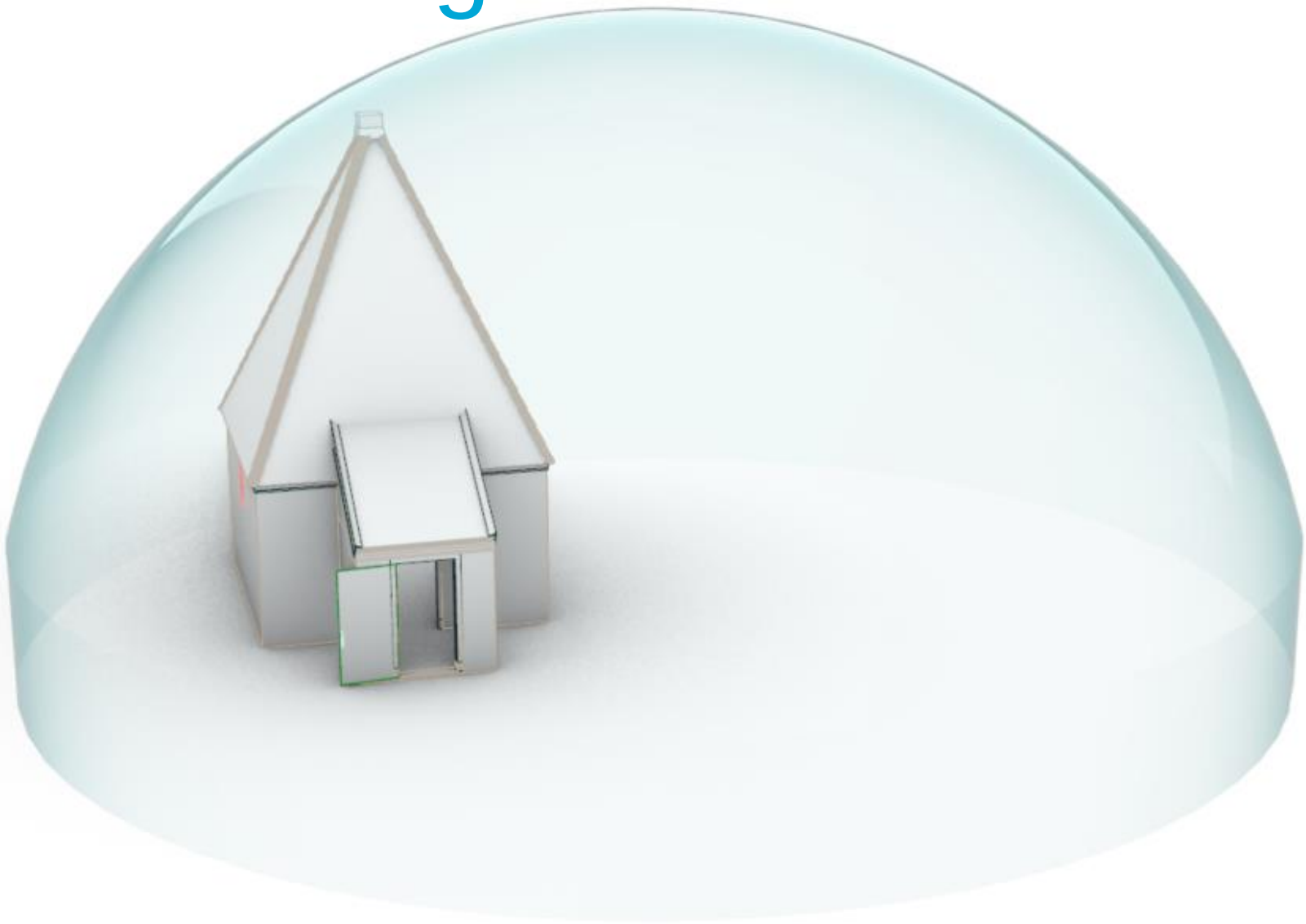
General design



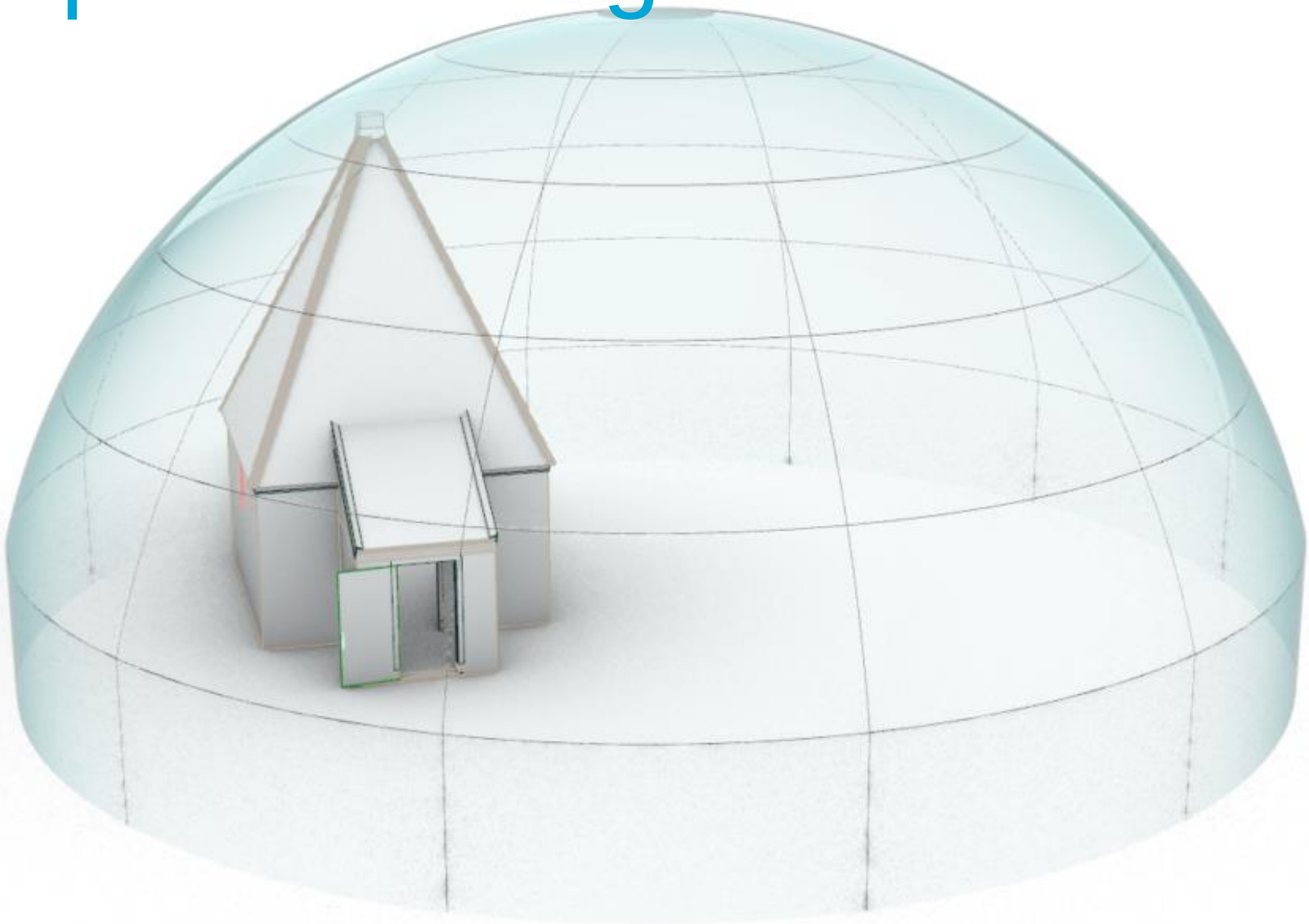
Component design

Different panels

- 12x 5550 x 2500 mm
- 12x 5550 x 2684 mm
- 12x 5201 x 2684 mm
- 12x 4194 x 2684 mm
- 6x 6220 x 2684 mm
- 6x 3707 x 2684 mm

Strengthening methods

- Thermal treatment
- Lamination of glass
    - SGP interlayer



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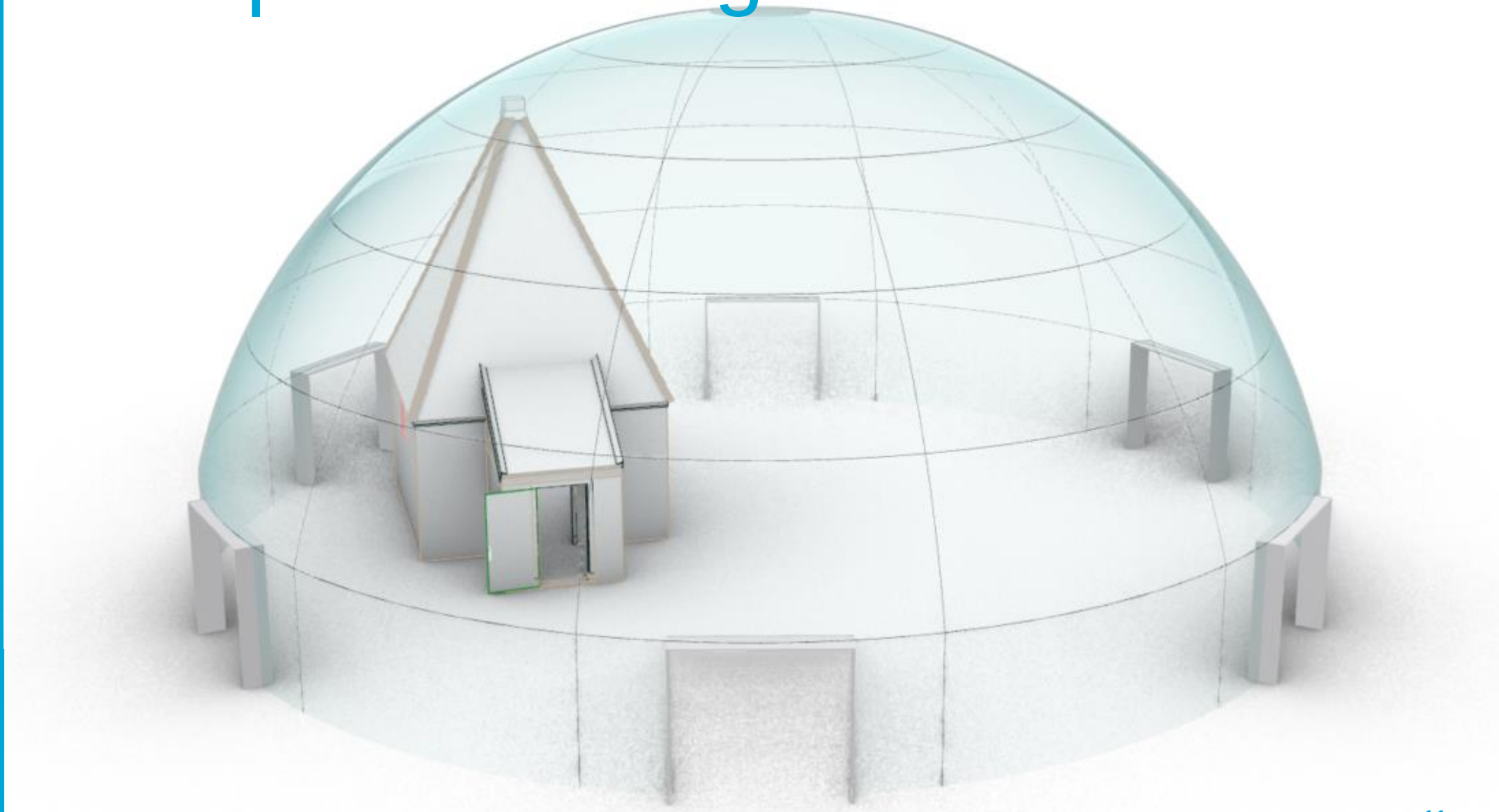
Component design

Portals

- Height: 2500 mm
- Width: 2750 mm
- Depth: 500 mm
- Thickness: 35 mm



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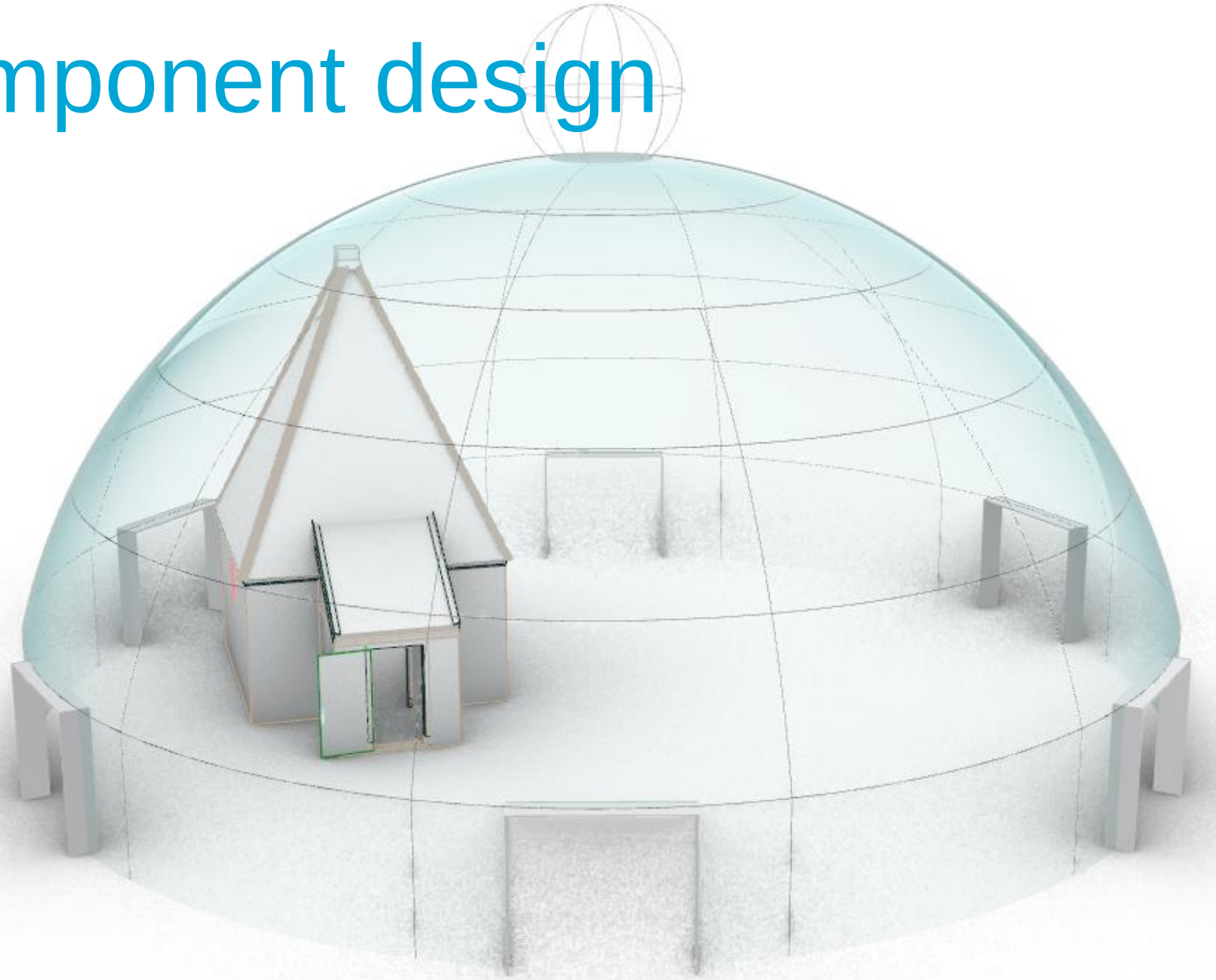
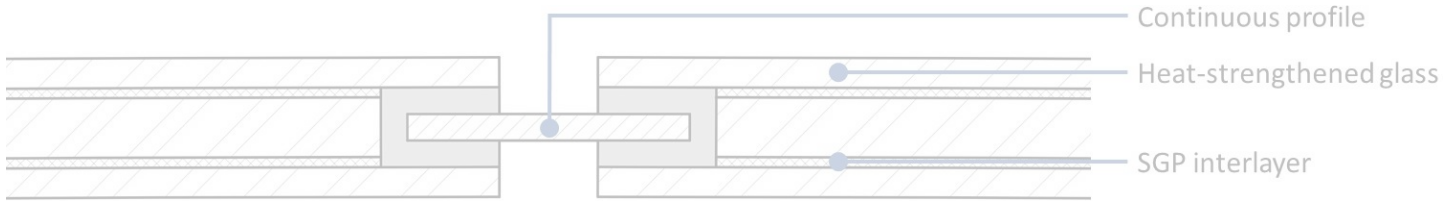
Component design

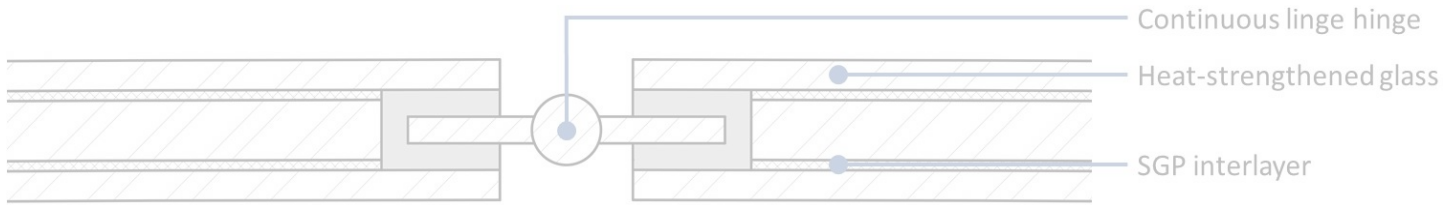


Connections

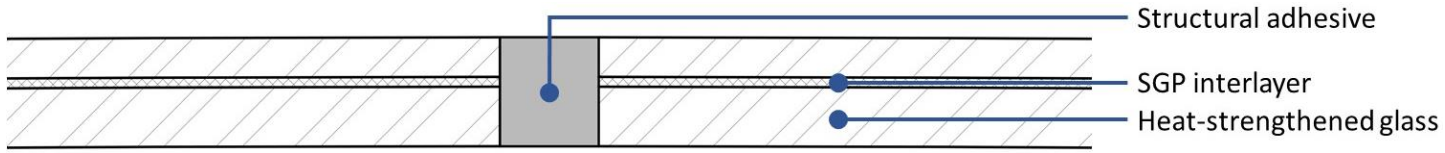
Glued-in plate connection



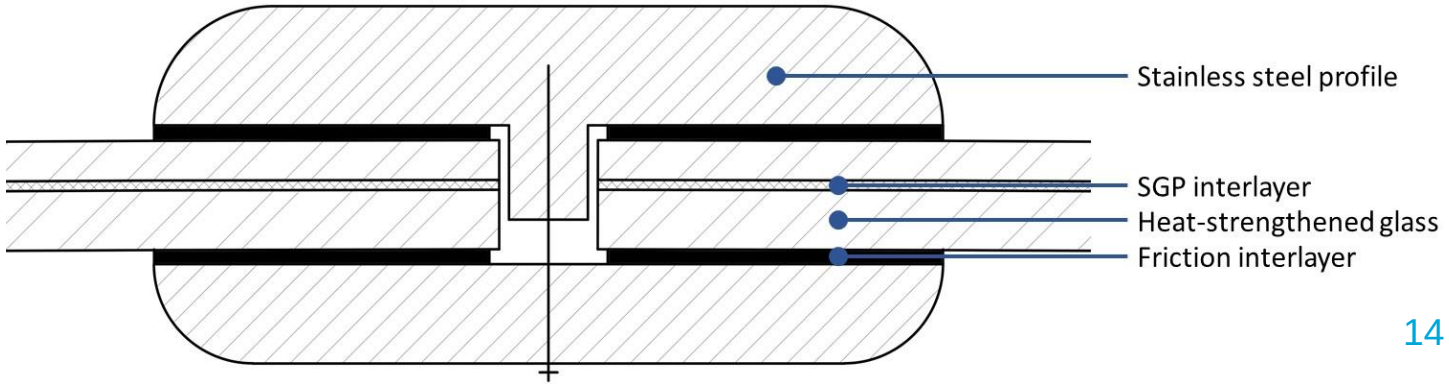
Glued-in hinge connection



Glued butt joint



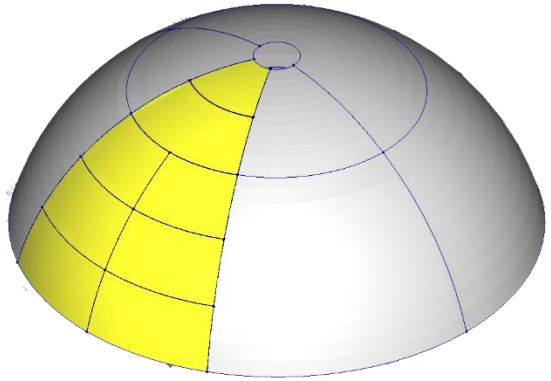
Clamp connection

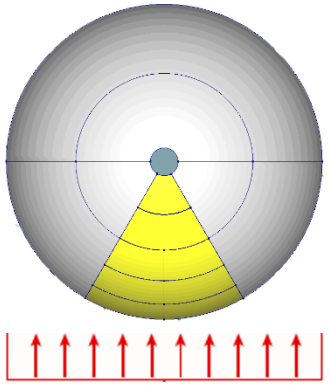


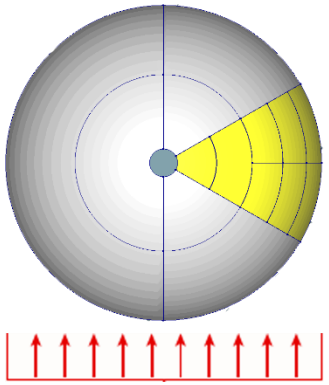
Connections

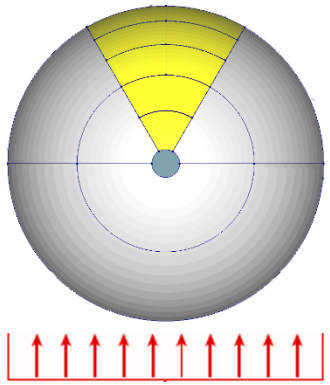
Validation settings:

- Thickness: 10mm (Soda lime)
- Applied loads: - Self-weight
  - Wind-load (1kN/m2)
  - Snow-load (1kN/m2) (≤30°)





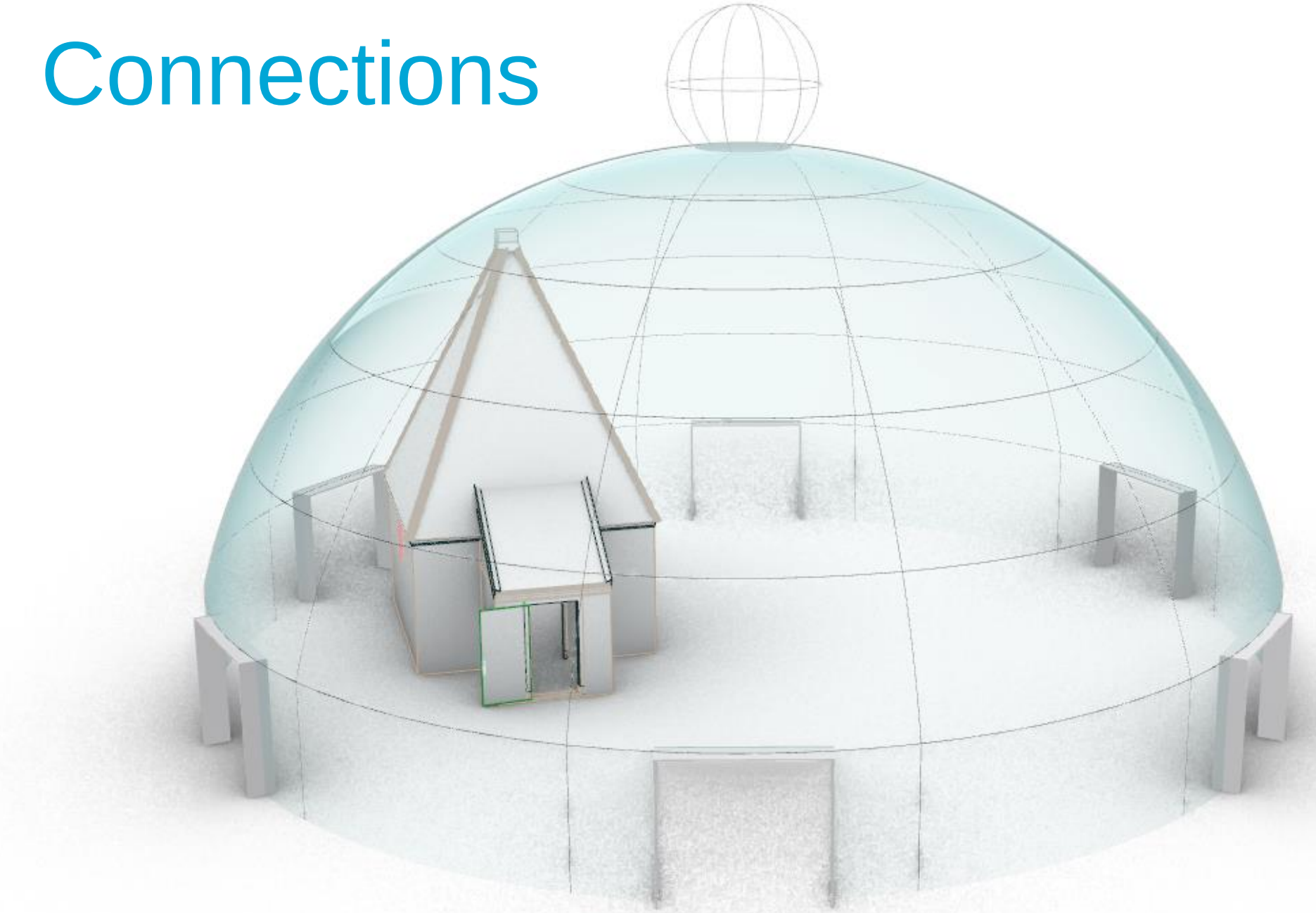




Connections

Glued butt joint

- Max. defl.: 0.76 mm
- Max. stress (tension): 2.53 N/mm2
- Max stress (compression): 3.25 N/mm2



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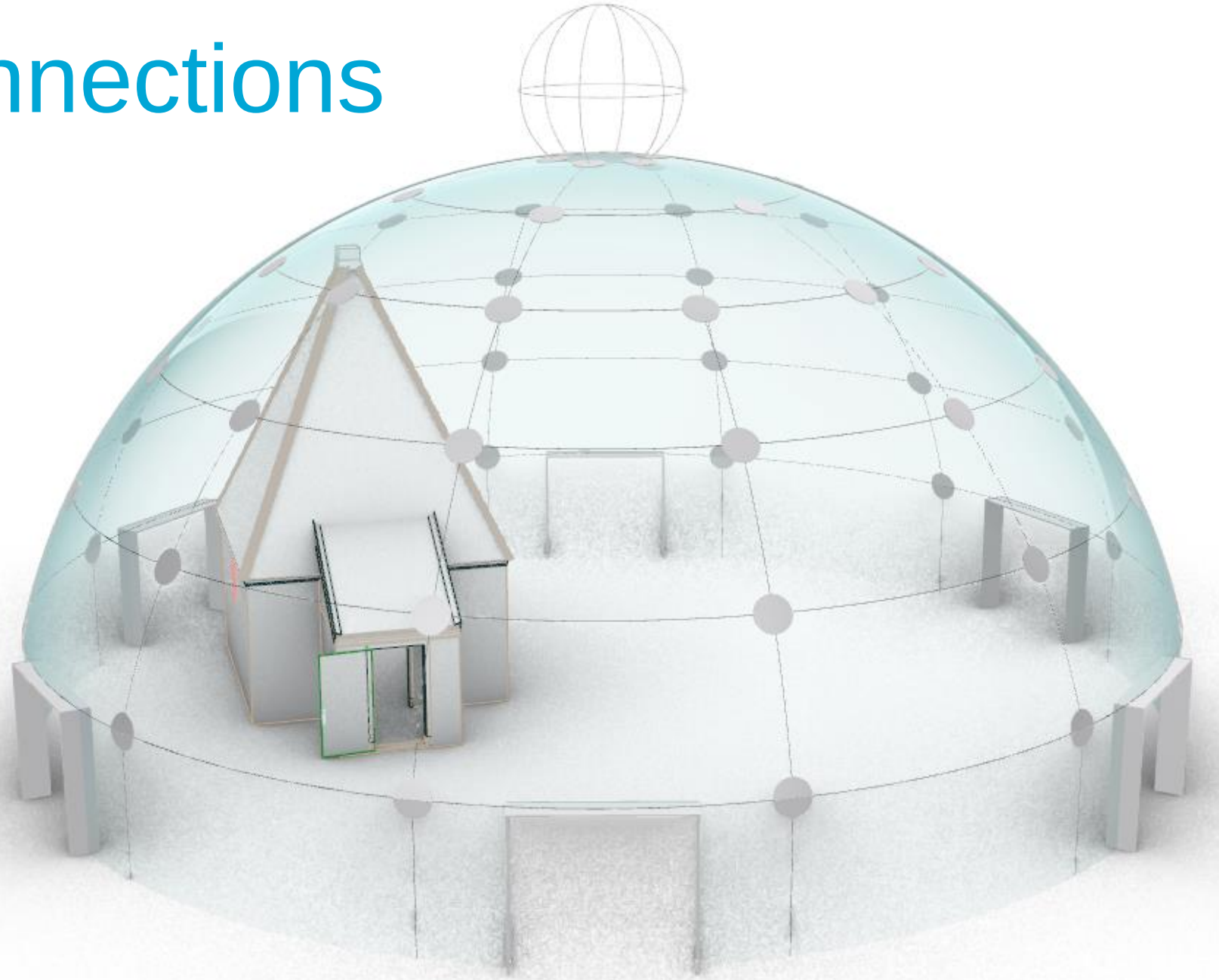
Connections

Clamp connenction (150mm)
- Max. defl.: 31.87 mm
- Max. stress (tension): 73.41 N/mm2
- Max stress (compression): 76.57 N/mm2

Clamp connenction (300mm)
- Max. defl.: 20.70 mm
- Max. stress (tension): 60.34 N/mm2
- Max stress (compression): 67.90 N/mm2

Clamp connenction (450mm)
- Max. defl.: 16.70 mm
- Max. stress (tension): 30.79 N/mm2
- Max stress (compression): 43.48 N/mm2

Clamp connenction (600mm)
- Max. defl.: 14.80 mm
- Max. stress (tension): 22.90 N/mm2
- Max stress (compression): 33.91 N/mm2



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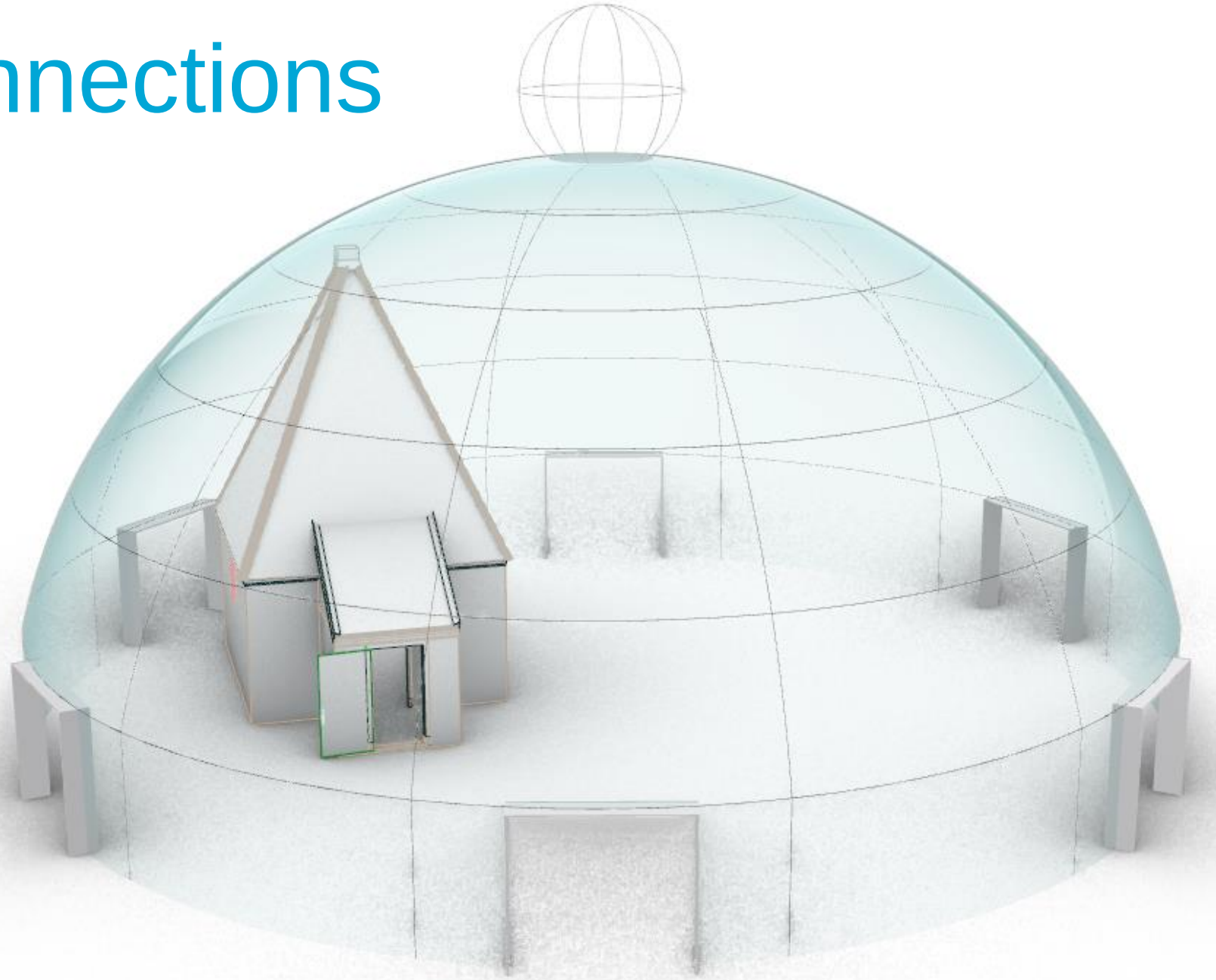
Connections

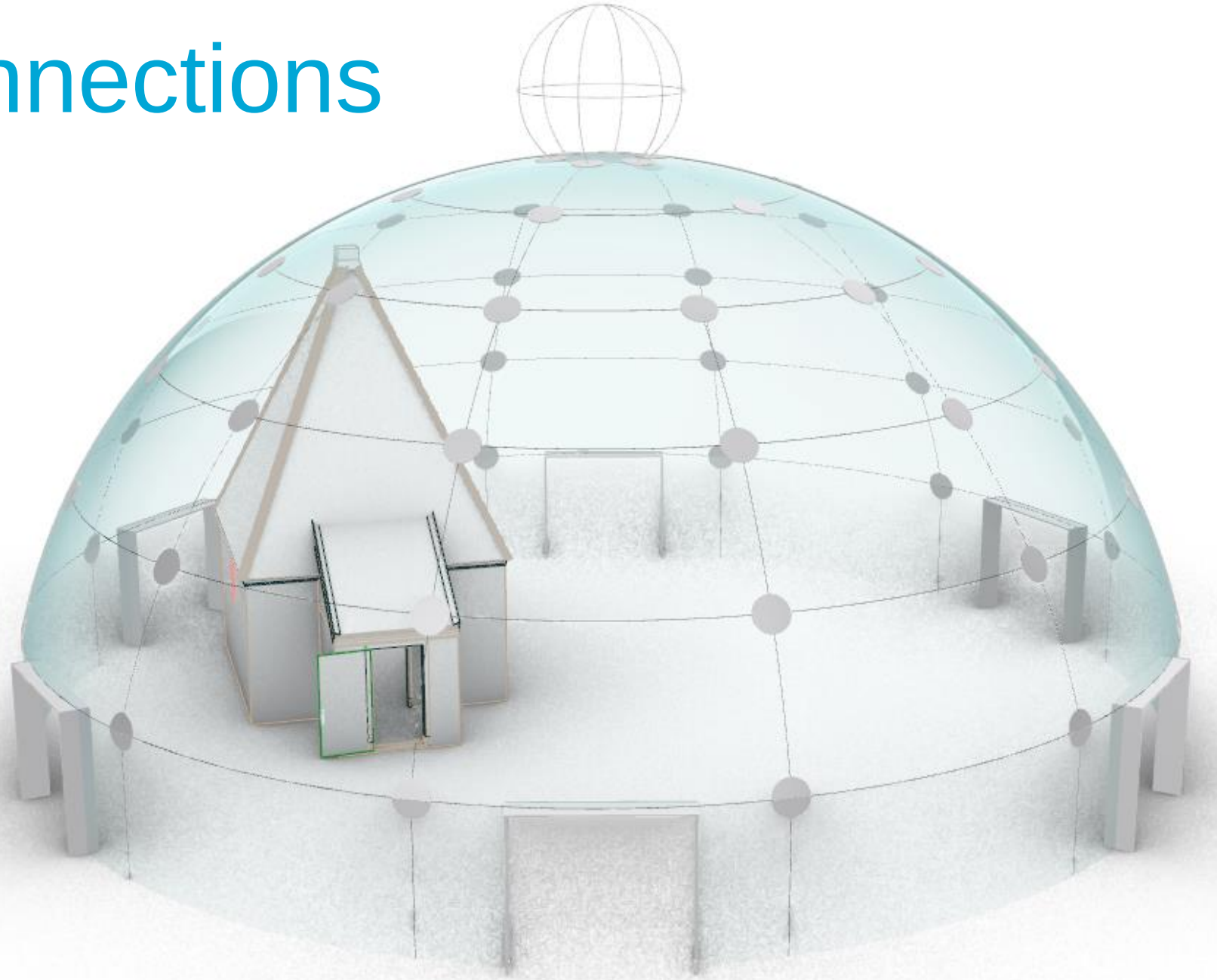


Safety analysis

Safety risk	Description	WS	BS	ES	RD	Explanation	Precaution to reduce risk
				Fault by people			
Vandalism on glass facade pane		10	0.5	7	35	Unlikely in the area of the dome (pedestrian area)	Create barrier around building
Error in construction	Contractor	10	1	40	400		Periodic inspection of constructive elements
Fire		3	0.5	3	4.5		
	element in the air						elements
Terror attack inside building	Bomb	0.5	0.5	100	25		
Bullet hits façade		0.5	0.5	1	0.25		Laminated glass is standard
Car crashes into façade	On purpose	0.2	0.5	100	10		
				Natural cause			
Bird	Bird crashes into façade	10	3	1	30		
Hail		10	1	1	10		
Snow on roof	More snow on the roof than expected/calculated	3	0.5	40	60		
Wind on façade	More snow on the facade than expected/calculated	3	0.5	40	60		
Meteorite		0.5	0.5	40	10		
Earthquake		0.2	0.5	40	60		

Error in construction	Contractor	10	1	40	400		Periodic inspection of constructive elements

Connections

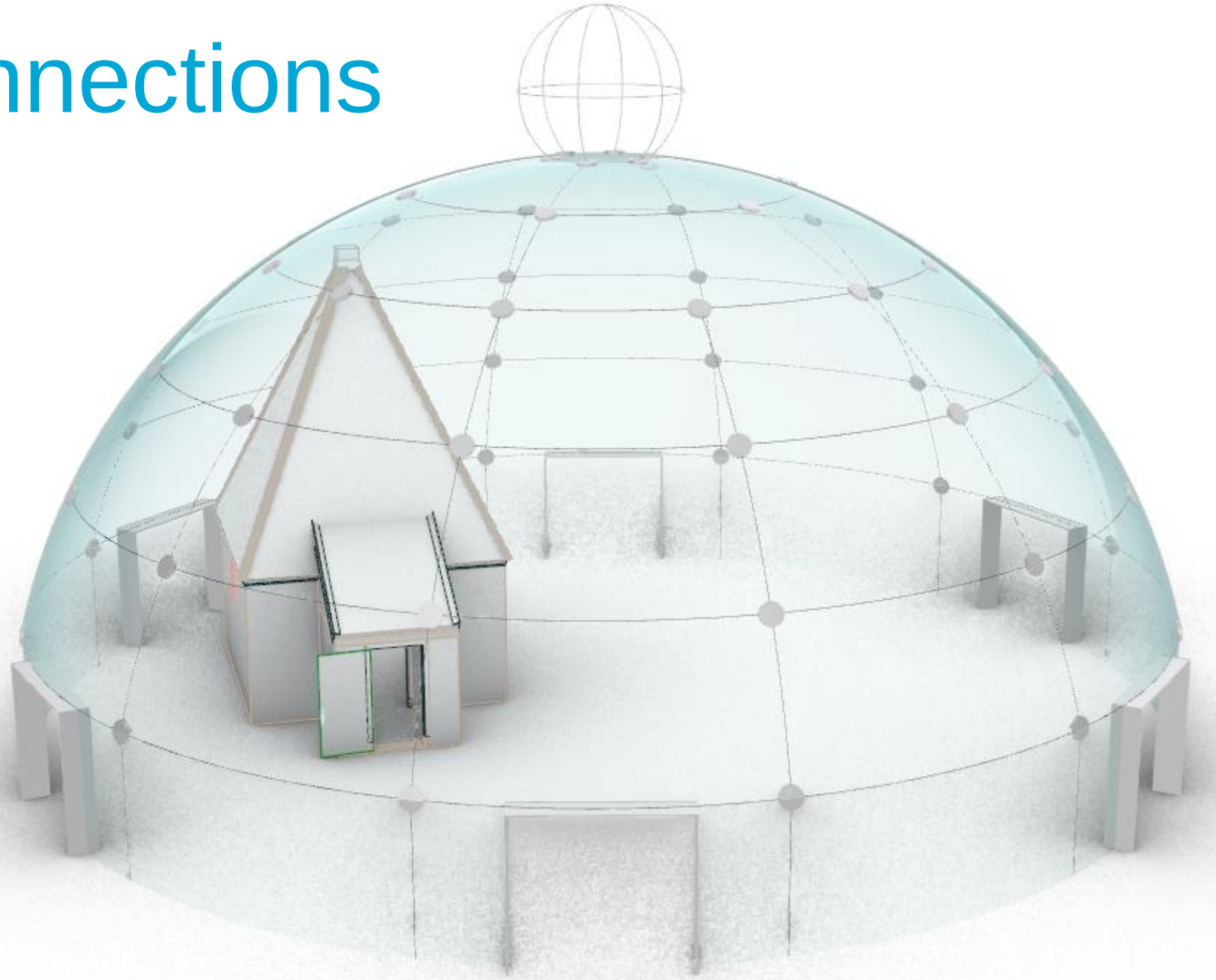


Connections

Glass thickness 10 mm
- Max. defl.: 31.87 mm
- Max. stress (tension): 73.41 N/mm2
- Max stress (compression): 76.57 N/mm2

Glass thickness 20 mm
- Max. defl.: 6.62 mm
- Max. stress (tension): 17.95 N/mm2
- Max stress (compression): 34.33 N/mm2

Glass thickness 30 mm
- Max. defl.: 2.76 mm
- Max. stress (tension): 9.79 N/mm2
- Max stress (compression): 26.34 N/mm2



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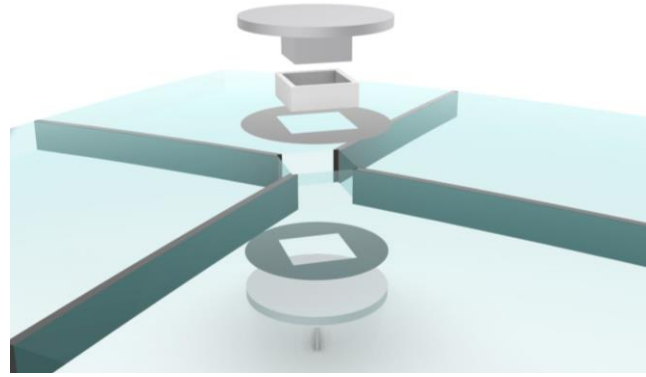
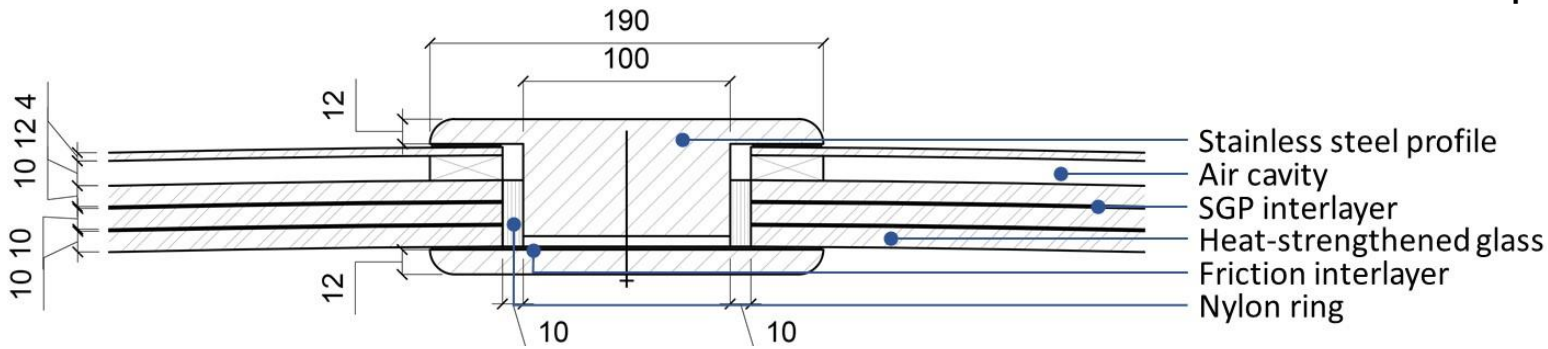
Connections dome

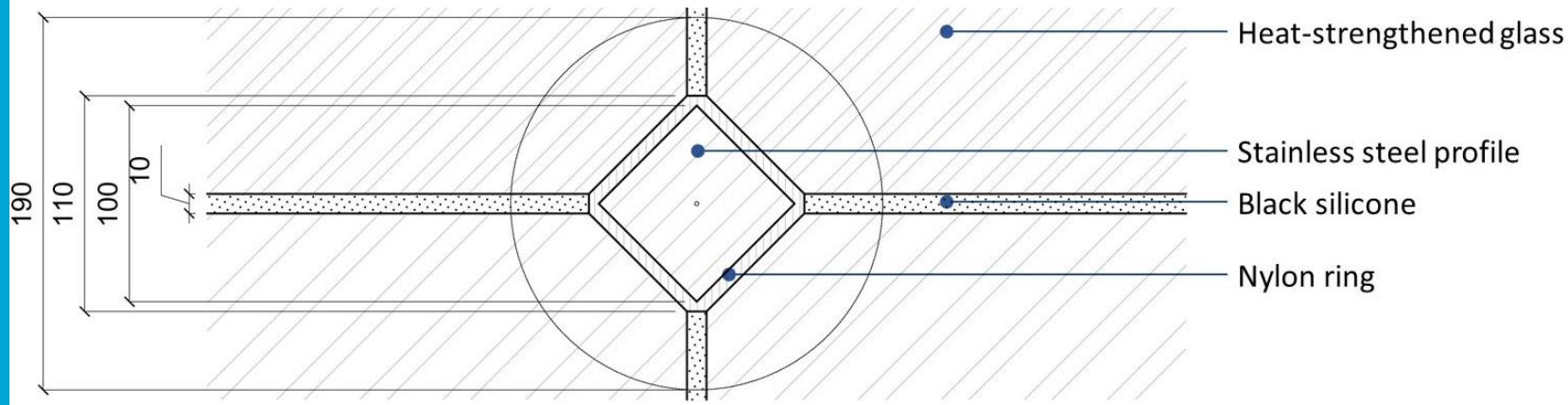


3D exploded view

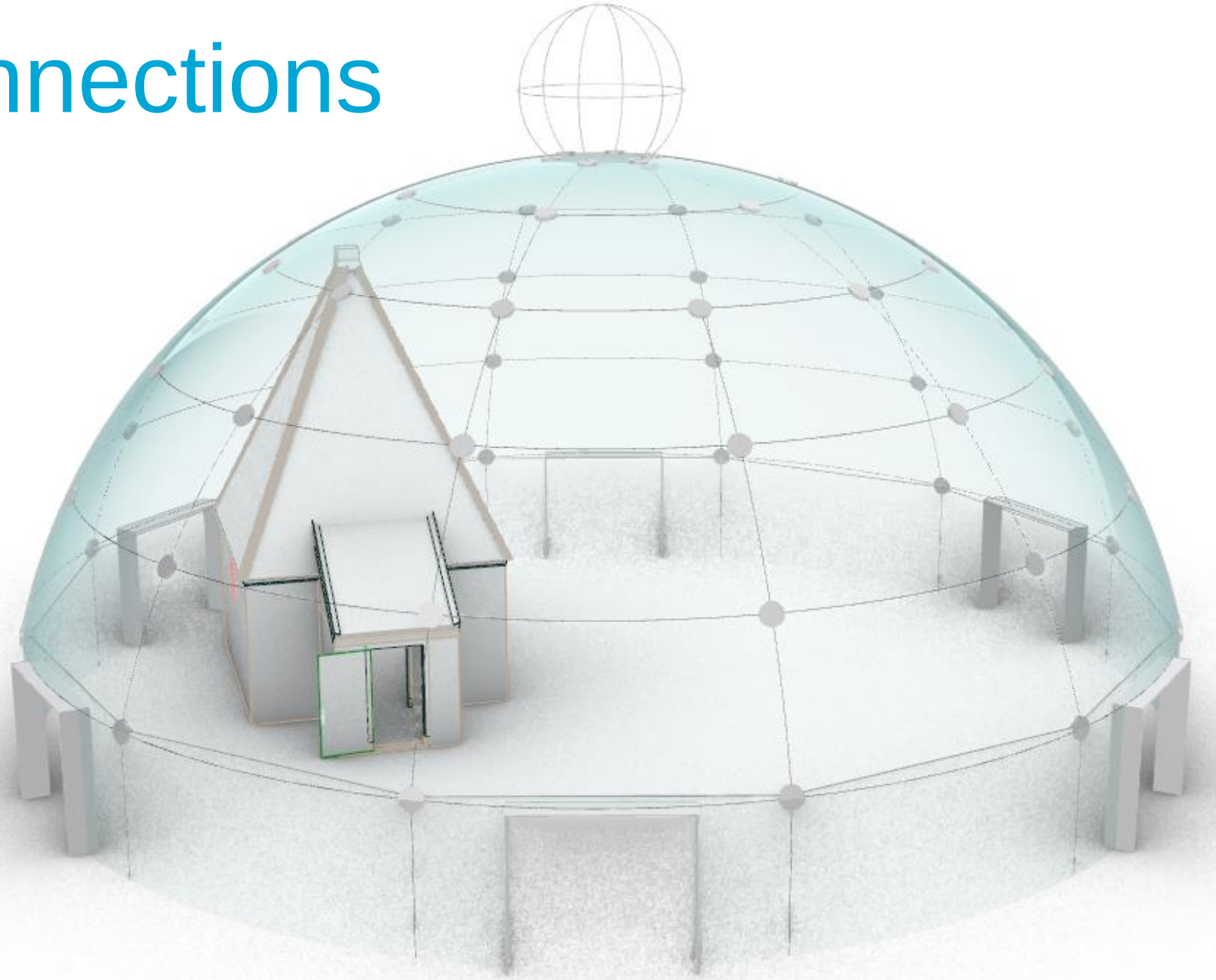
Vertical detail



Horizontal detail

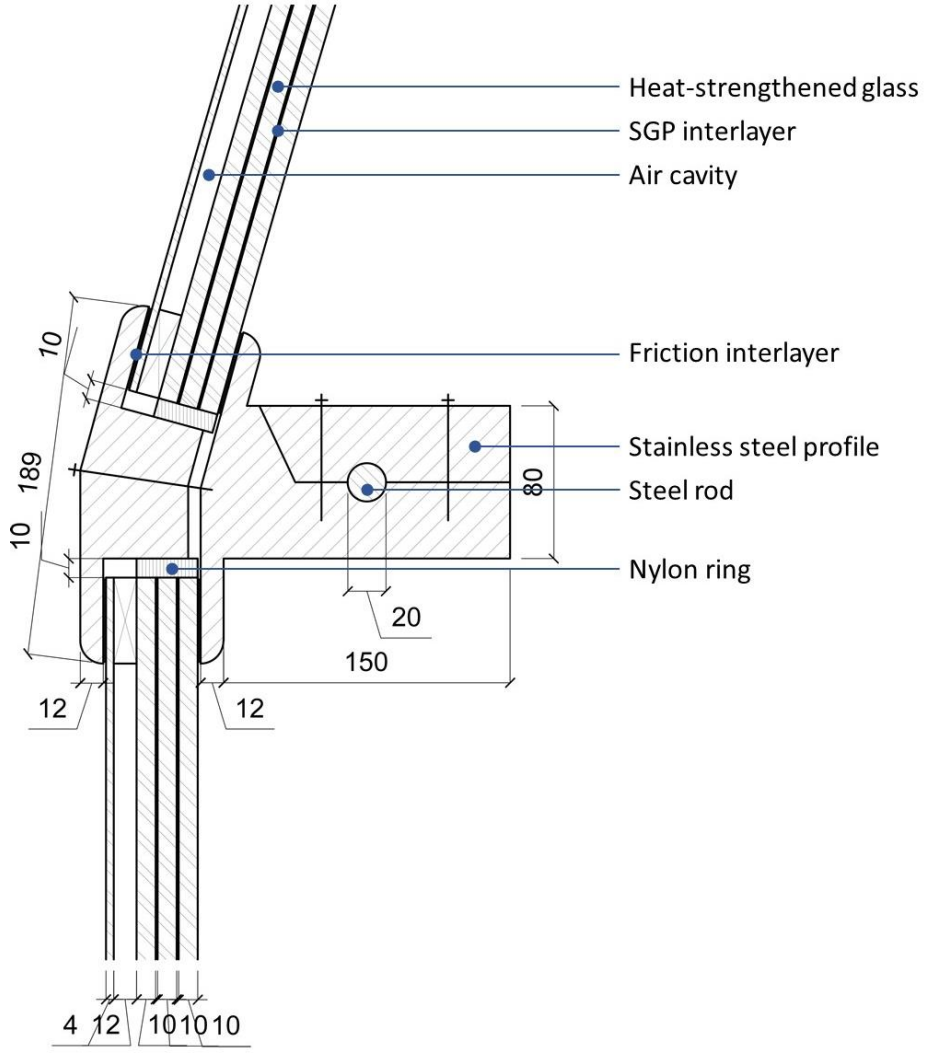


Connections

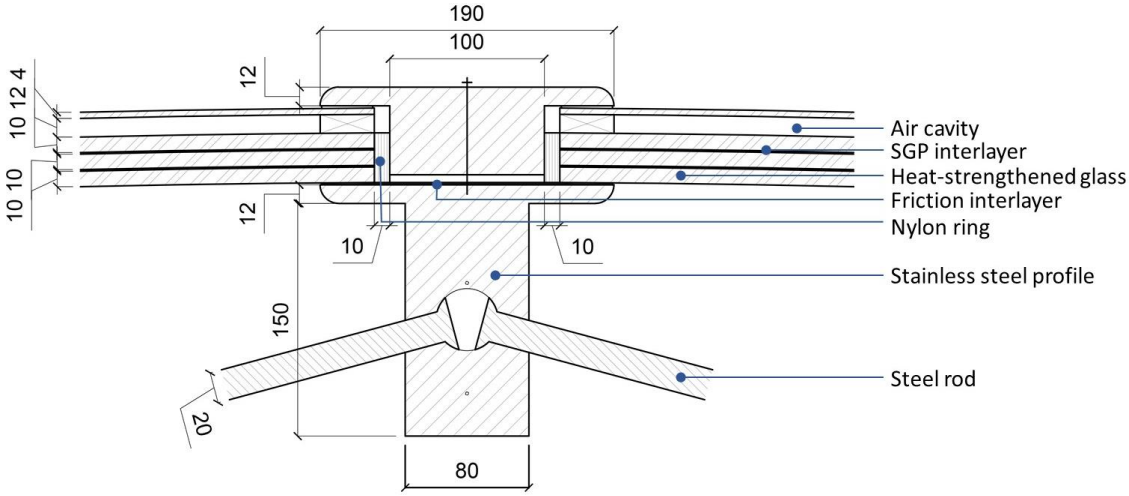


Connections between dome and base

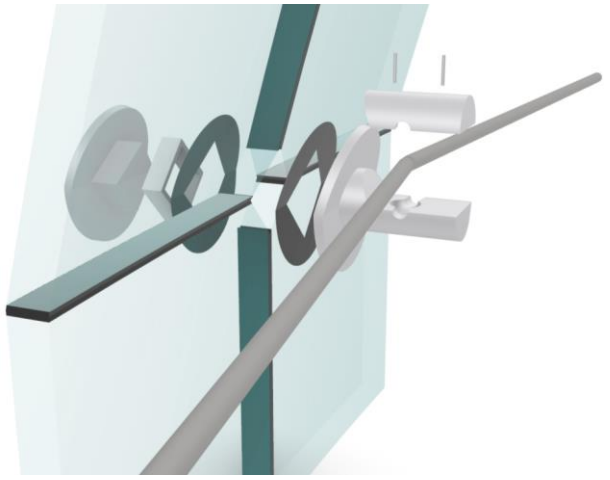
Vertical detail



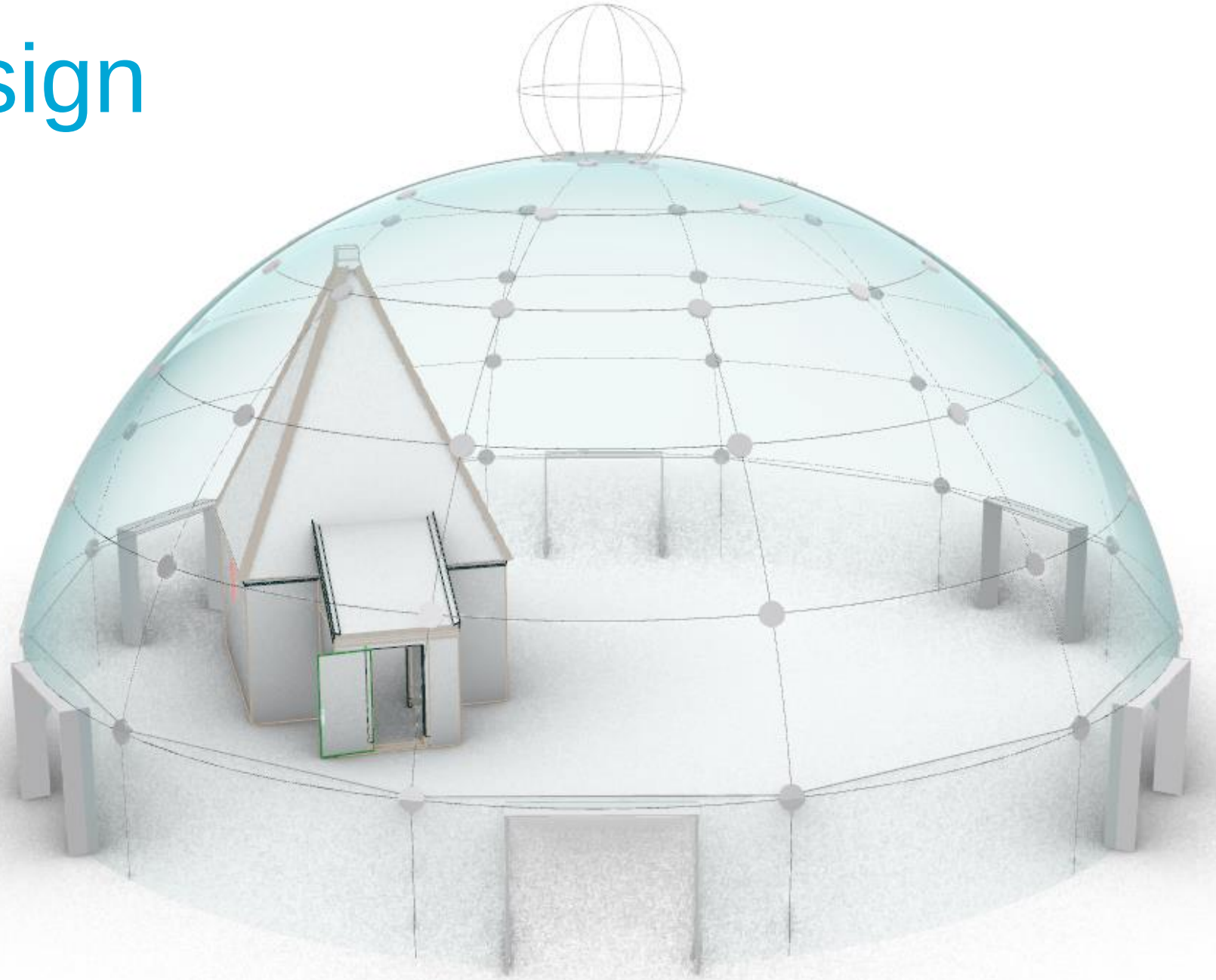
Horizontal detail



3D exploded view



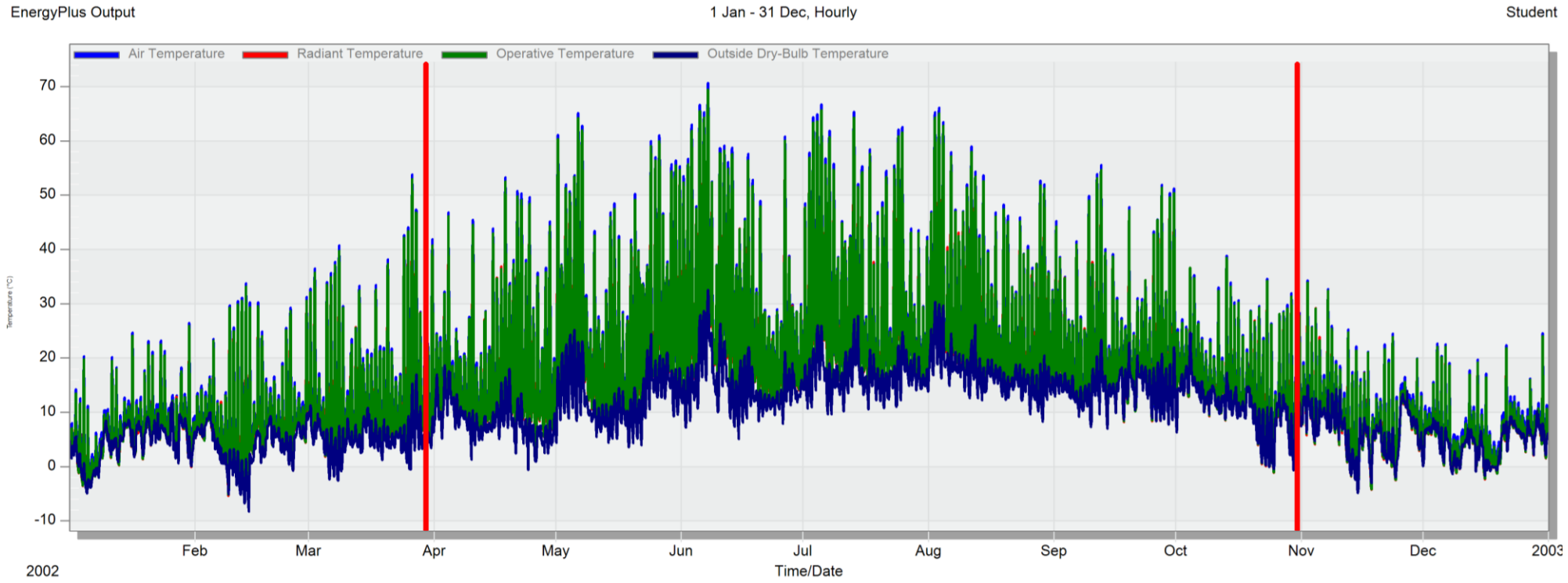
Design



Energy Plus analysis

Highest operative temperature: 70.35 °C June 7

Lowest operative temperature: -7.71 °C Februari 14



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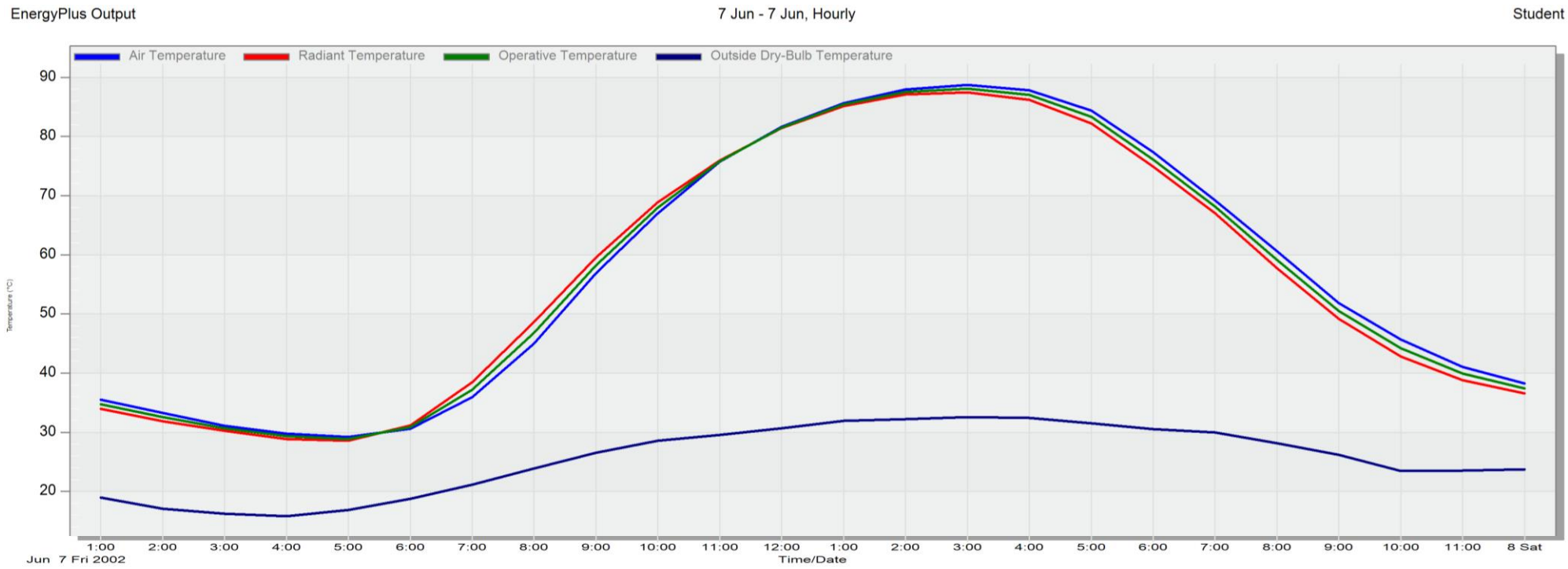
Energy Plus analysis

Highest operative temperature: 88.07 °C June 7



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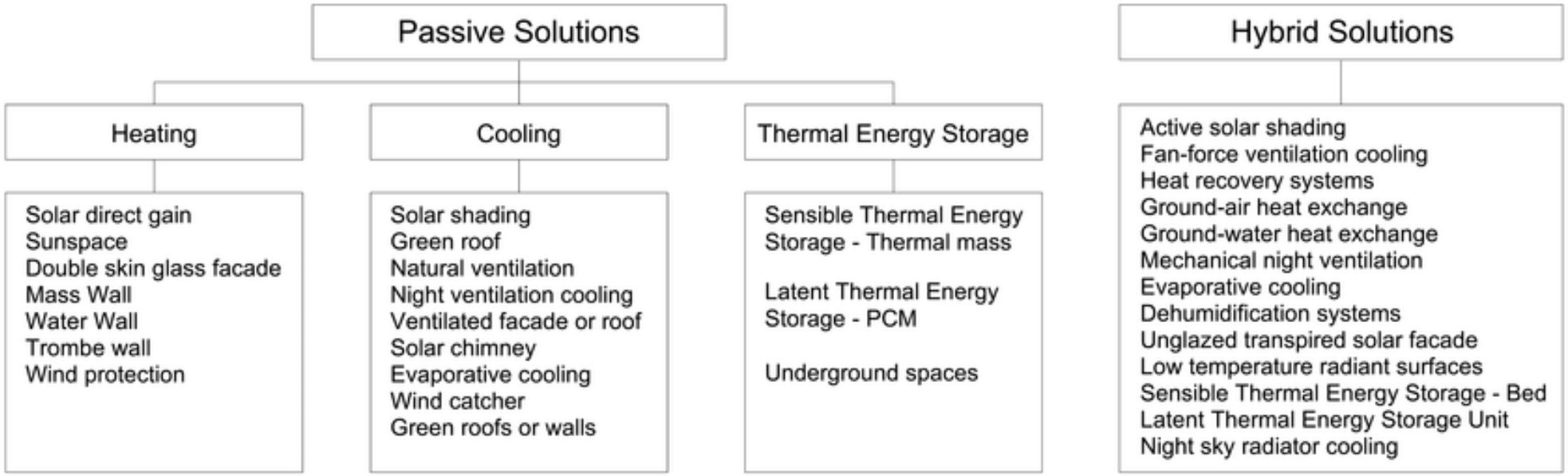
Thermal comfort design

NEN-EN-ISO 7730 (Class A: very good, score about 8.5)

- Operative temperature: Summer (0.5 clo): 23-26 °C
  Winter (1.0 clo): 20-24 °C
- Maximum number of exceedance hours: 100h
- Maximum air speed: Summer (0.5 clo): 0.12 m/s
  (The higher the temperature, the higher this value.)
  Winter (1.0 clo): 0.10 m/s
- Limits vertical difference air temperature (head and ankles): <2 °C
- Limits of radiation temperature asymmetry:
  - Warm ceiling: <2 °C
  - Cold wall (glass): <2 °C
  - Cold ceiling: <2 °C
  - Warm wall: <2 °C

  (Use common sense)
- Floor temperature limits: 19-26 °C

Passive strategies



Passive strategies

Outside temperature:
32.58°C

Baseline measurement
- Air temperature: 89.01 °C
- Radiant temperature: 87.48 °C
- Operative temperature: 88.07 °C
- Solar gains: 204.06 kW

Natural ventilation
(minimum requirements)**:**
- Air temperature: 66.56 °C
- Radiant temperature: 77.50 °C
- Operative temperature: 71.84 °C
- Solar gains: 204.06 kW

Adding natural ventilation
(ventilaton rate of 5)**:**
- Air temperature: 50.09 °C
- Radiant temperature: 69.73 °C
- Operative temperature: 59.84 °C
- Solar gains: 204.06 kW

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Outside temperature:
32.58°C

Baseline measurement
- Air temperature: 89,01 °C
- Radiant temperature: 87.48 °C
- Operative temperature: 88.07 °C
- Solar gains: 204.06 kW

Using Low-E coatings:
- Air temperature: 45.87 °C
- Radiant temperature: 62.11 °C
- Operative temperature: 53.95 °C
- Solar gains: 137.54 kW

Adding thermal mass:
- Air temperature: 45.11 °C
- Radiant temperature: 60.70 °C
- Operative temperature: 52.87 °C
- Solar gains: 137.54 kW

Passive strategies

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Outside temperature:
32.58°C

Baseline measurement
- Air temperature: 89,01 °C
- Radiant temperature: 87.48 °C
- Operative temperature: 88.07 °C
- Solar gains: 204.06 kW

Using fritted glass:
- Air temperature: 45.14 °C
- Radiant temperature: 61.69 °C
- Operative temperature: 53.35 °C
- Solar gains: 100.37 kW

Passive strategies

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Passive strategies

Outside temperature:
32.58°C

Baseline measurement
- Air temperature: 89,01 °C
- Radiant temperature: 87.48 °C
- Operative temperature: 88.07 °C
- Solar gains: 204.06 kW

Using switchable glass:
- Air temperature: 40.21 °C
- Radiant temperature: 52.10 °C
- Operative temperature: 46.14 °C
- Solar gains: 18.23 kW

Adding natural ventilation
(ventilation rate of 6.05)**:**
- Air temperature: 32.58 °C
- Radiant temperature: 51.61 °C
- Operative temperature: 45.39 °C
- Solar gains: 28.23 kW

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Outside temperature:
32.58°C

Baseline measurement:
88.07 °C

Natural ventilation (minimum requirements)**:**
71.84 °C

Adding natural ventilation (ventilaton rate of 5)**:**
59.84 °C

Using Low-E coatings:
53.95 °C

Adding thermal mass:
52.87 °C

Using fritted glass:
53.35 °C

Using switchable glass:
46.14 °C

Adding natural ventilation (ventilation rate of 6.05)**:**
45.39 °C

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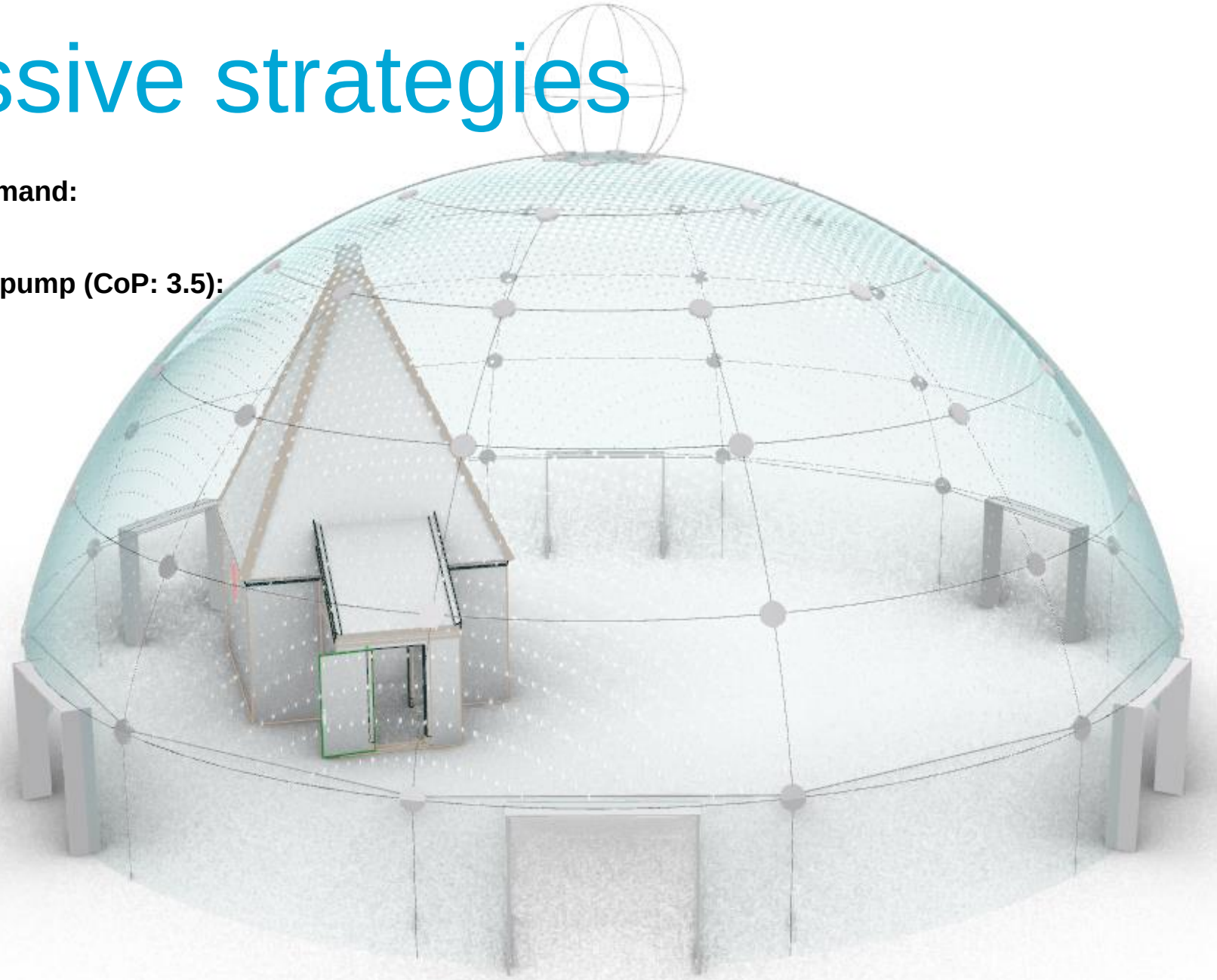
Passive strategies

Cooling demand:
352.44 kW

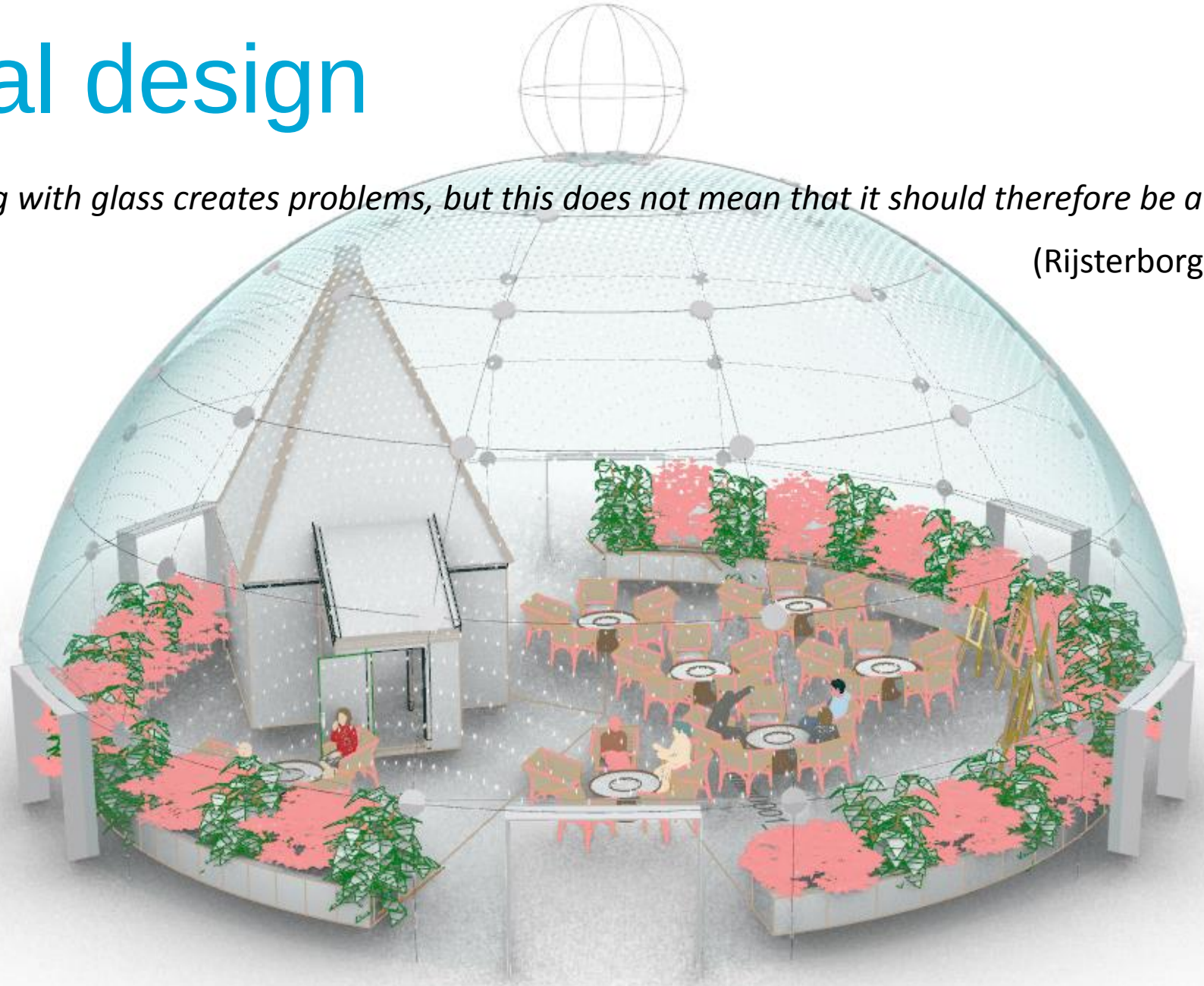
Using heat pump (CoP: 3.5):
100.70 kW



Final design

“Designing with glass creates problems, but this does not mean that it should therefore be avoided.”

(Rijsterborgh, 2020)



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