MOBILE PLANT FACTORY

DESIGN PROPOSAL FOR PLANT FACTORY WITH HYBRID SYSTEM BY USING **CROSS-DISCIPLINARY** DESIGN STRATEGIES AND ASSISTED BY **COMPUTATIONAL WORKFLOW**

Prof.dr.ir. Andy A.J.F. van den Dobbelsteen
Dr. MScArch. Michela Turrin – PhD, Architect (SBA)
MSc. Luuk Graamans
Dr. I. (Ilir) Nase

2018| P5

Tarik Alboustani
4627709
T.alboustani-1@student.tudelft.nl

MOBILE PLANT FACTORY

DESIGN PROPOSAL FOR PLANT FACTORY WITH HYBRID SYSTEM BY USING CROSS-DISCIPLINARY DESIGN STRATEGIES AND ASSISTED BY COMPUTATIONAL WORKFLOW

Prof.dr.ir. A.A.J.F. van den Dobbelsteen
Dr. MScArch. Michela Turrin – PhD, Architect (SBA)
MSc. Luuk Graamans
Dr. I. (Ilir) Nase

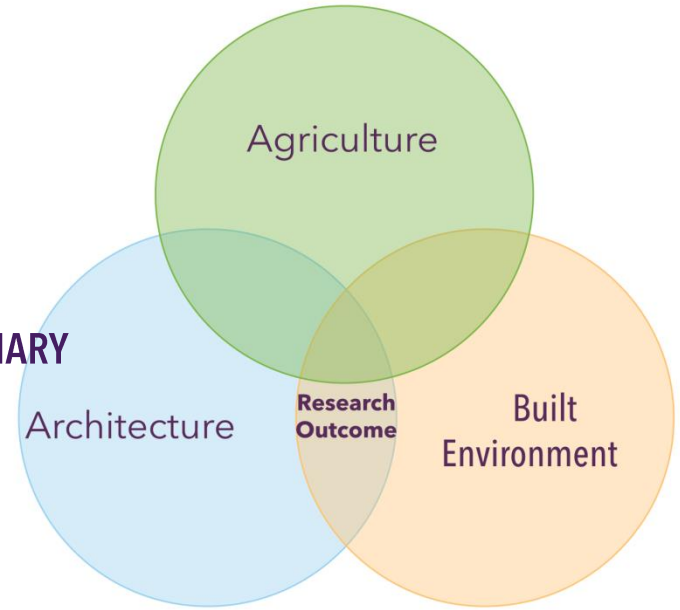
STRUCTURE

INTRODCTION

1. LITERATURE REVIEW
2. PRACTICAL PART
3. FINAL DESIGN

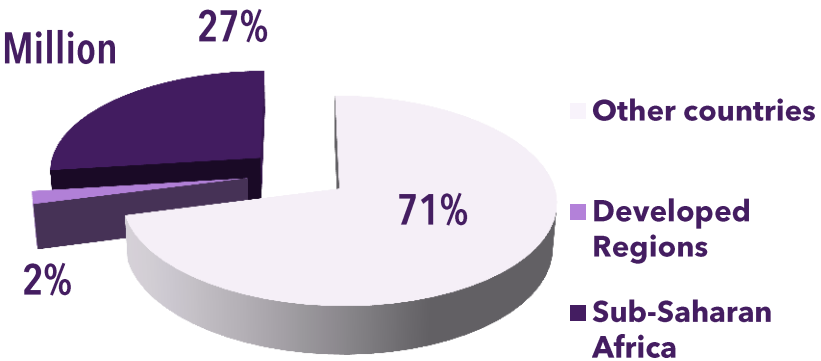
CONCLUSION

Tarik Alboustani
4627709
T.alboustani-1@student.tudelft.nl



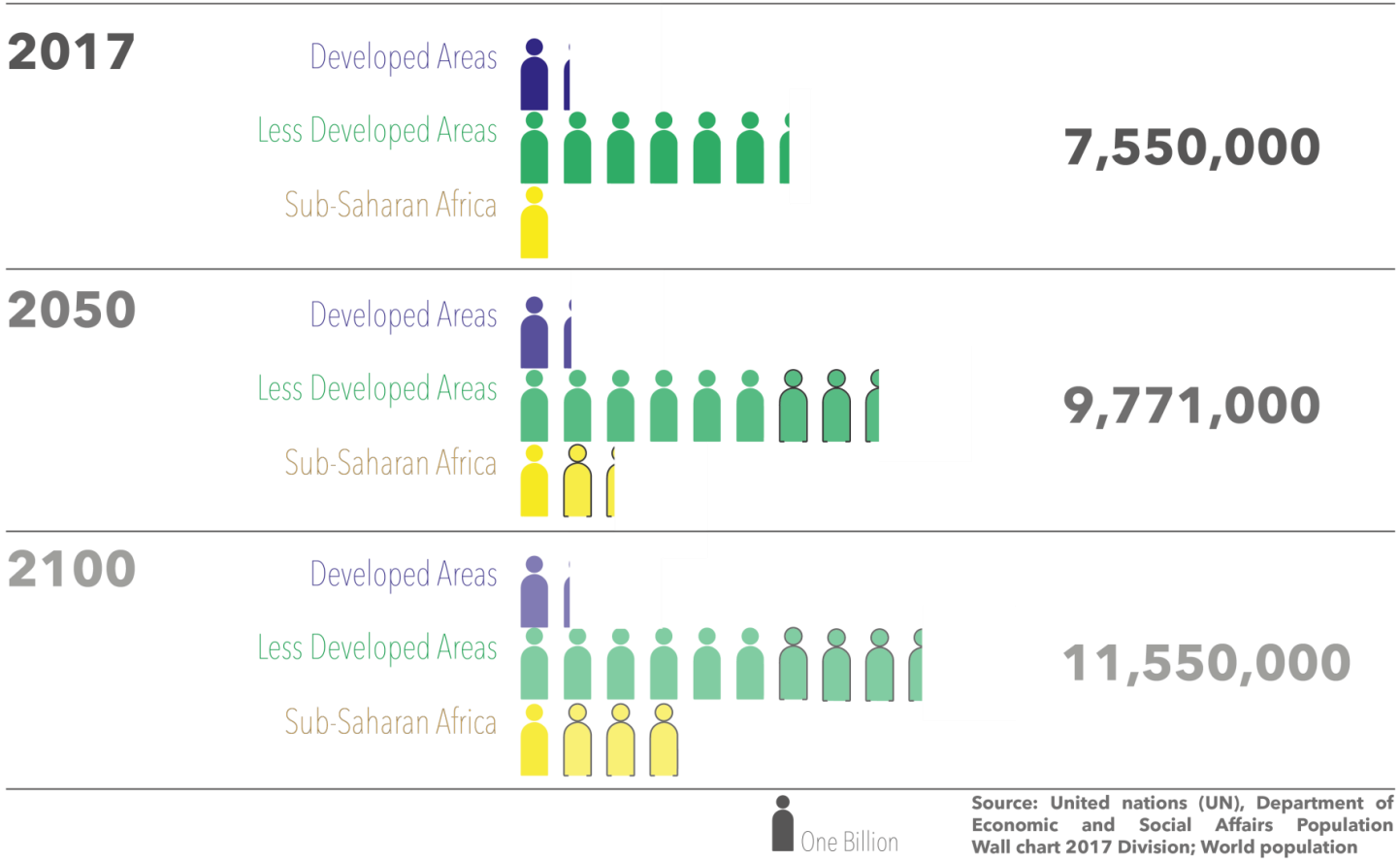
DISCIPLINARY

CROSS



Undernourished people

World Population

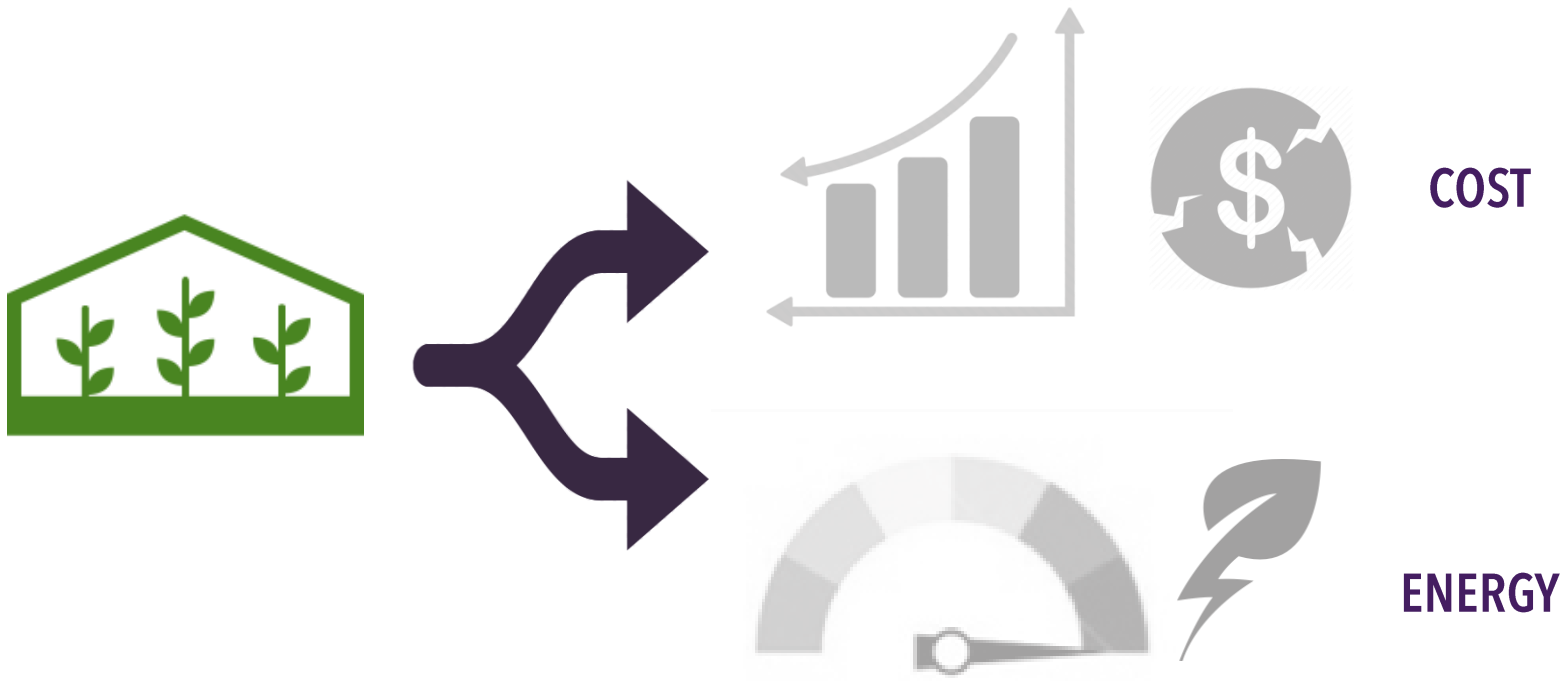


Source: United nations (UN), Department of Economic and Social Affairs Population Wall chart 2017 Division; World population

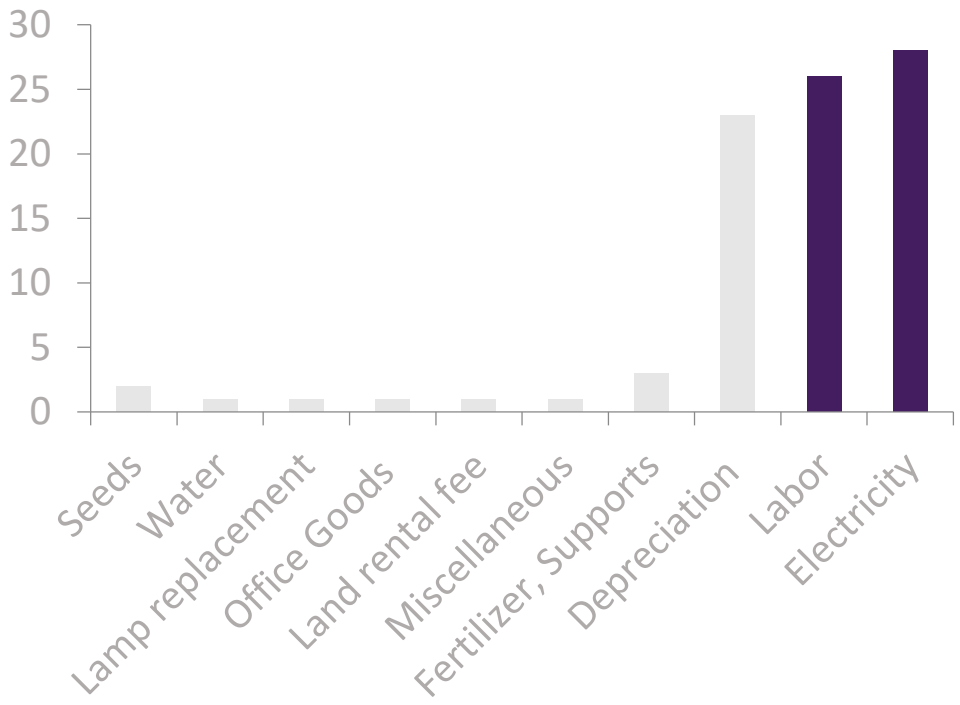
Urban Farmers, The Hague

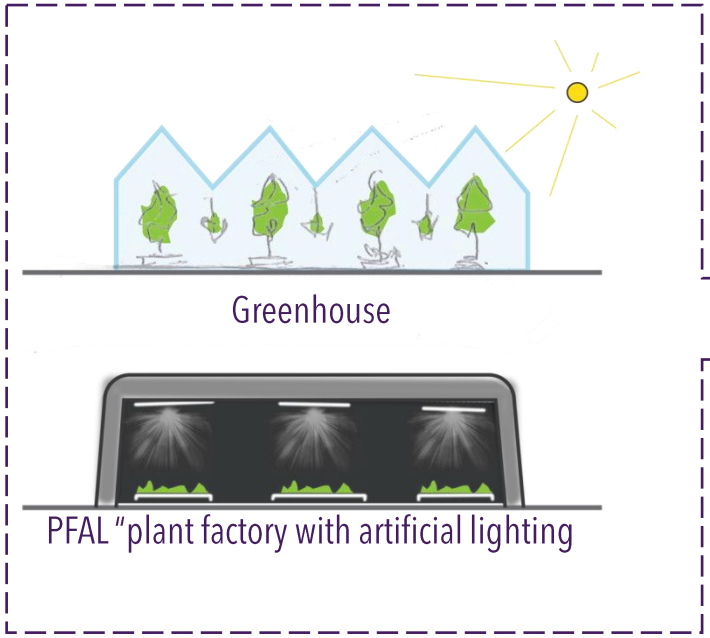
Technology

Agri-FoodTech 2017



High Cost for PFAL





PLANT FACTORY

HYBRID

RESEARCHQUESTIONS

Main questions

- What are the best strategies for designing a mobile plant factory to achieve a HIGH level of PRODUCTION at LOW ENERGY output based on different external climatic boundary conditions?

Sub Question

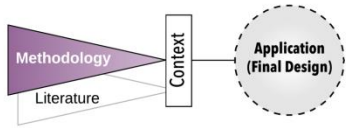
- To what extent the COMPUTATIONAL WORKFLOW process support the designers to achieve the optimum energy and production output in Plant Factory?

- What are the climate design potentials of using smart skin (BIOMIMICRY) inspired design on designing the facade SKIN of plant factory?

OBJECTIVES

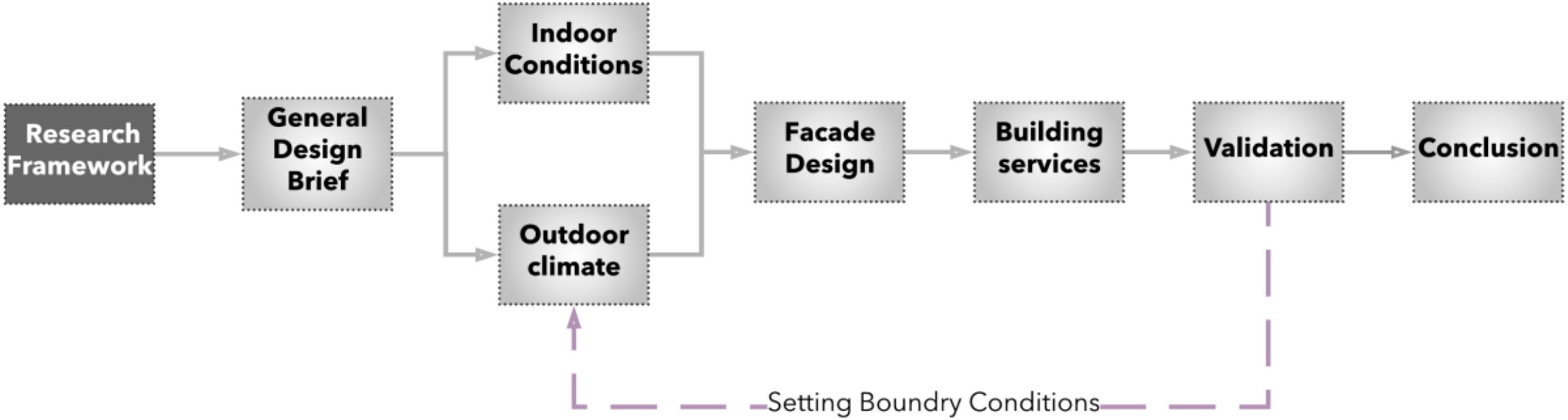
General objectives

- Create optimal Light and temperature conditions for food PRODUCTION inside plant factory.
- Study the OUTDOOR conditions Various CLIMATE.
- Design climate-responsive, intelligent SKIN that can intelligently deliver best light and temperature conditions – Hypothesis direction of a solution in biomimicry.



Sub-objectives

- Investigate the applicability for SELECTION of production types in the industry.


Research Framework
General Design Brief
Indoor Conditions
Outdoor climate
Facade Design
Building services
Validation
Conclusion
Setting Boundry Conditions

Literature Review (Guide)

Research Framework
Current Design Strategies
Site Visits
Literature
Prodction Types
Infill Requirments
Internal Climate Requirements
Skin
Structure - Mobility
Building Services

Facade Design

Facade Design
PLFA - Fully closed
Hybrid System
Biomimetic Facade
Case study
Case study 2

- Responsive to different Climate
- Mobility and minimal structure.
- Maximize the production area sunlight and reduce Heat lose

Building Services

Building Services
Integrated building services
Passive solar heating
Natural illumination
Ventilation

I II III

Research Framework
General Design Brief
Indoor Conditions
Outdoor climate
Facade Design
Building services
Validation
Conclusion
Setting Boundry Conditions

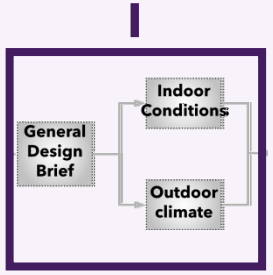
Design Proposal

Research Framework
Tools Examination
Computational Workflow
Baseline Design
Output Result
Location Climatic Zones
A Tropical
B Arid
C Temperature
D Snow
E Polar
Select Location
Constraints
Parameters
Design Proposal
Final Result
Valdiation & Conclusion

Literature Review (Guide)

1

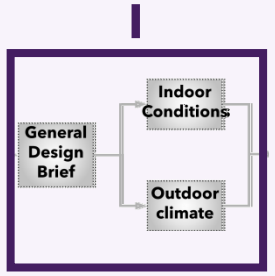
LITERATURE REVIEW



1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.3 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

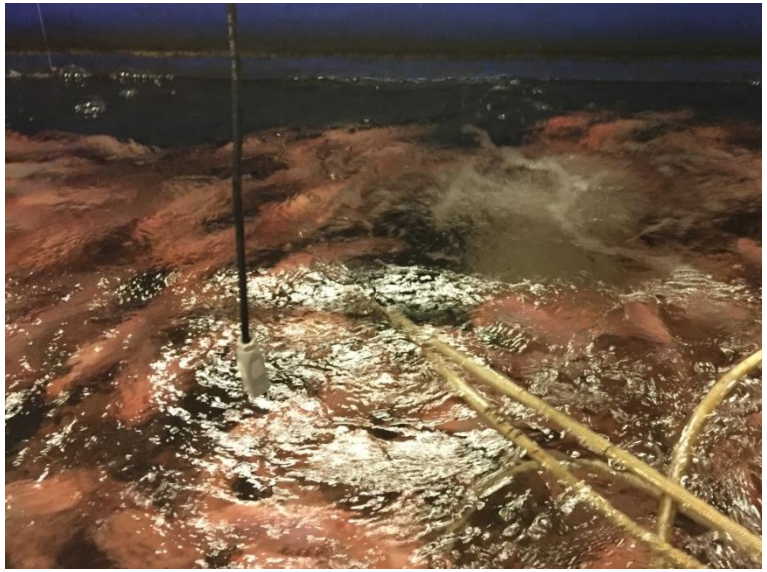
1

LITERATURE REVIEW



1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

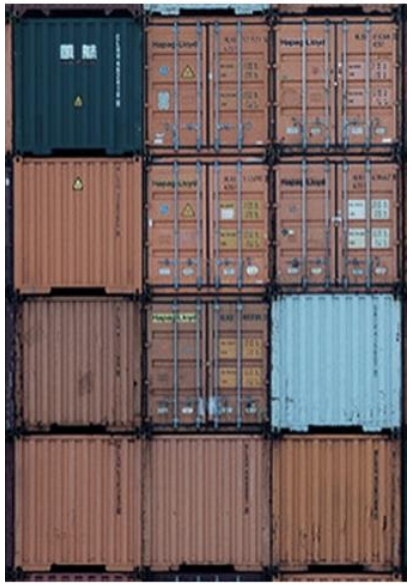
FISH FARM

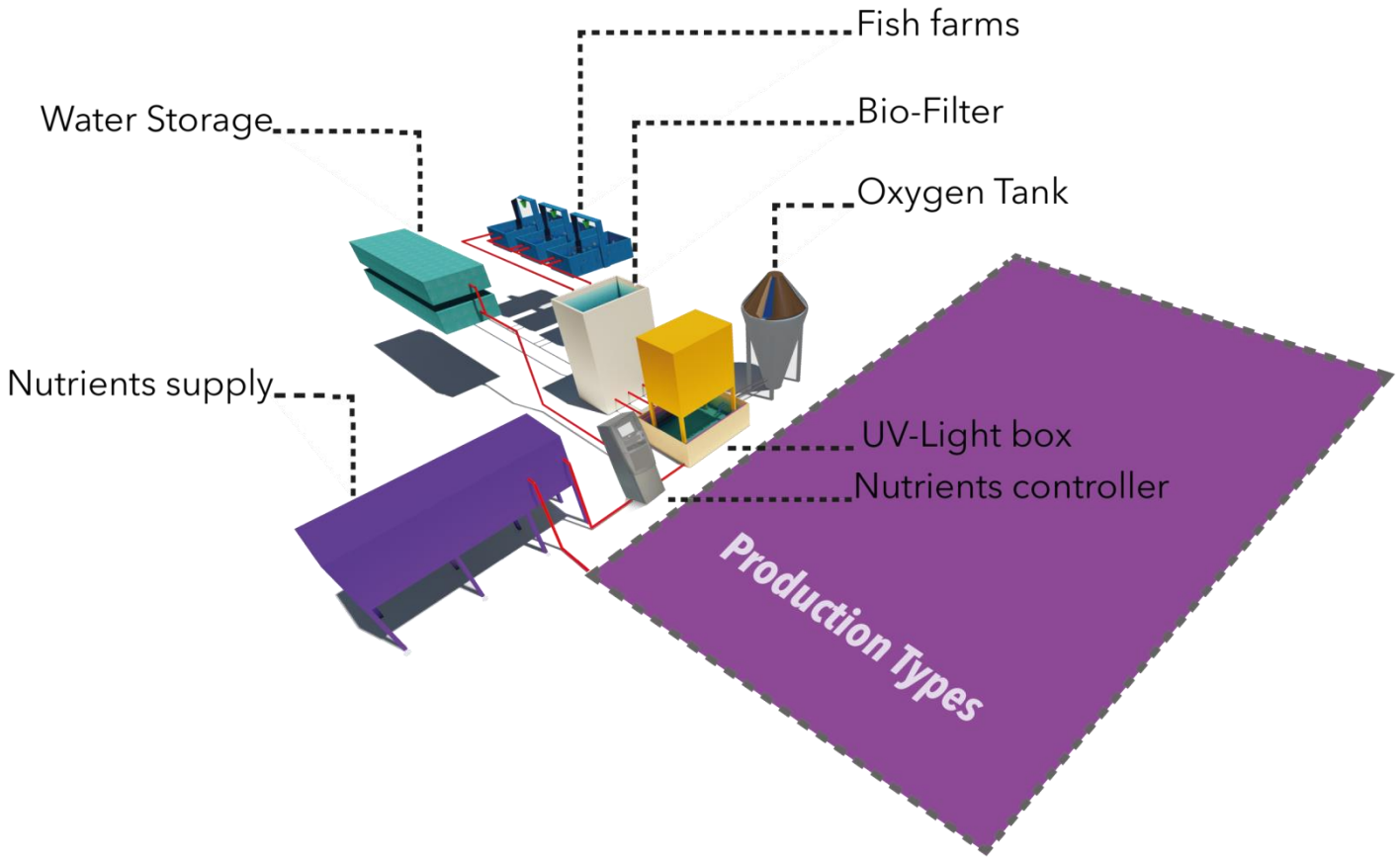


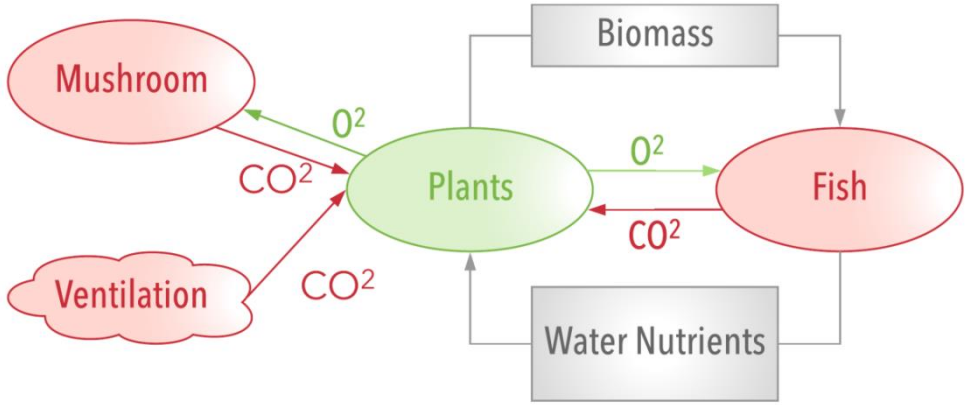
Urban Farmers, The Hague

P

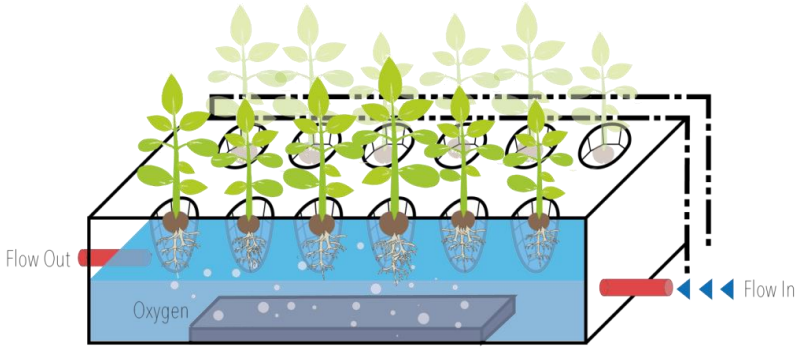
Urban Farmers, The Hague



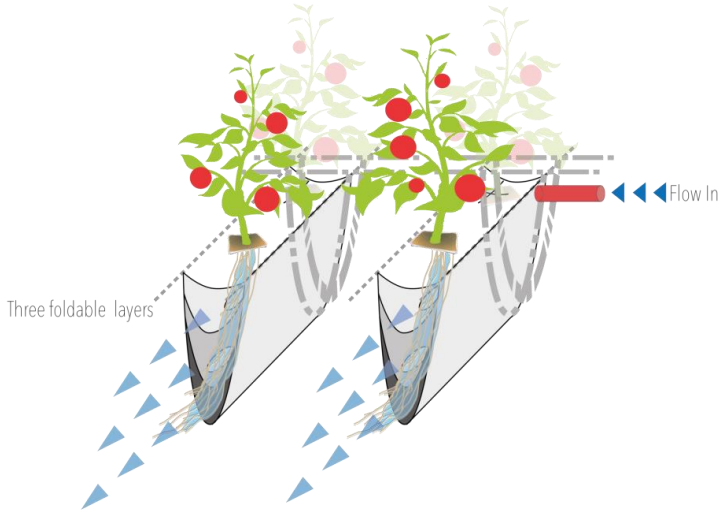

Fish farms
Water Storage
Bio-Filter
Oxygen Tank
Nutrients supply
UV-Light box
Nutrients controller
Production Types


Biomass
Mushroom
O2
CO2
Plants
O2
Fish
CO2
Ventilation
CO2
Water Nutrients

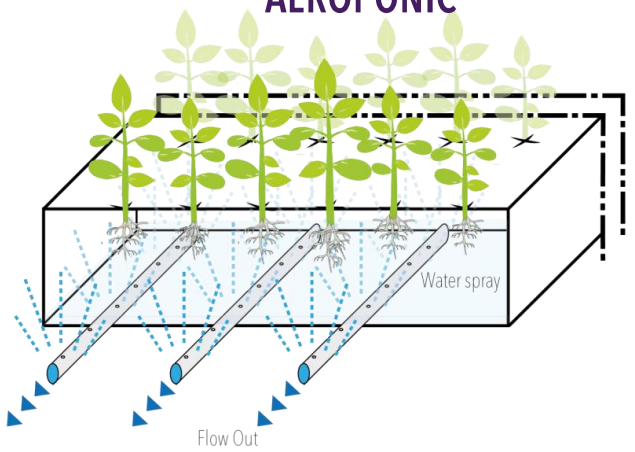
DEEP WATER CULTURE



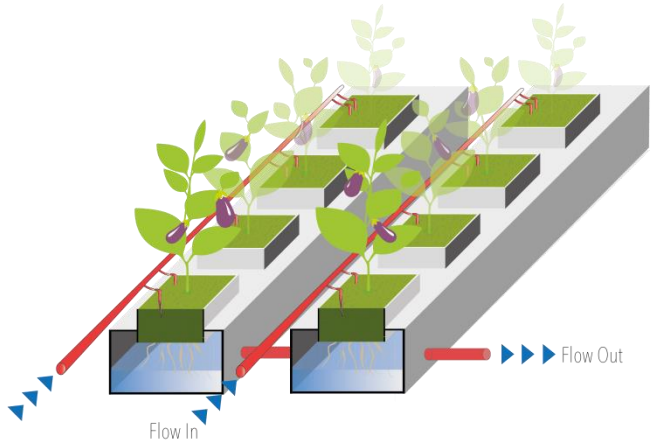
NUTRIENT FILM TECHNIQUE



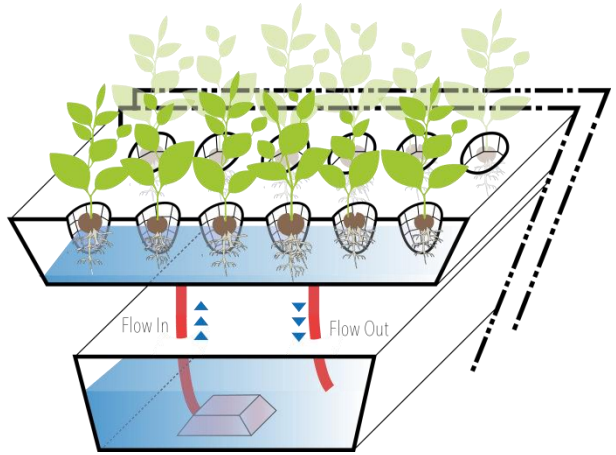
AEROPONIC



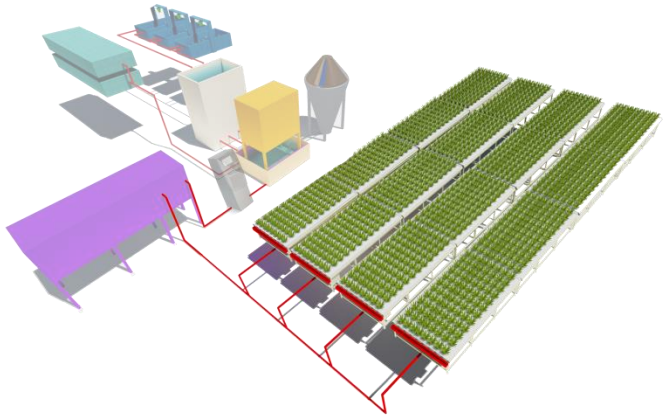
DRIP SYSTEM



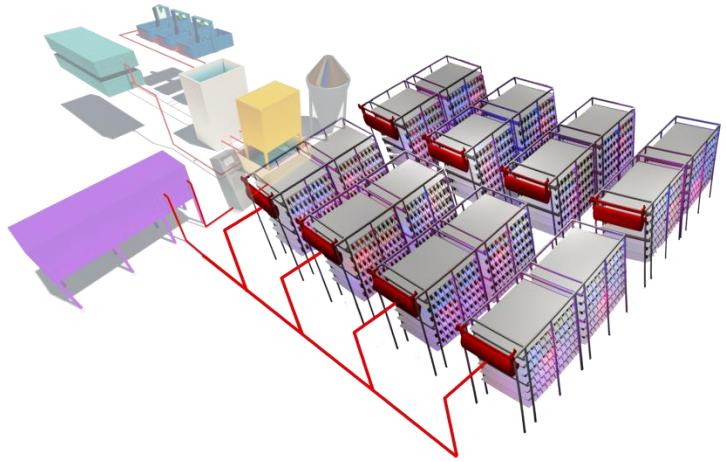
EBB & FLOW



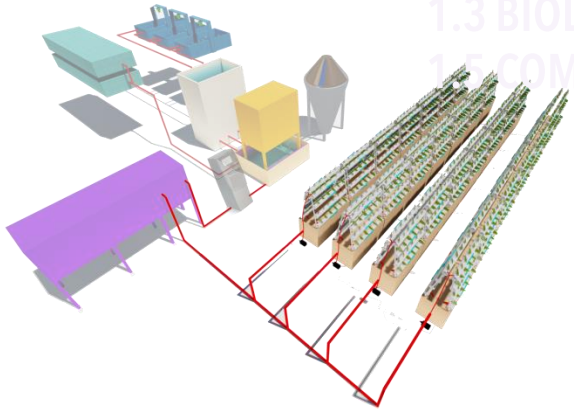
DWC SINGLE LAYER



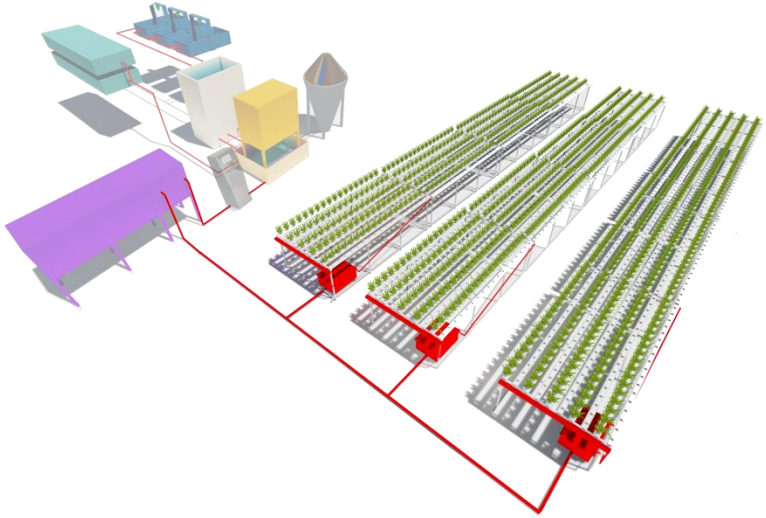
DWC – MULTI LAYERS



NFT SINGLE LAYER

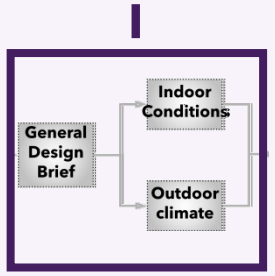


NFT A-FRAME



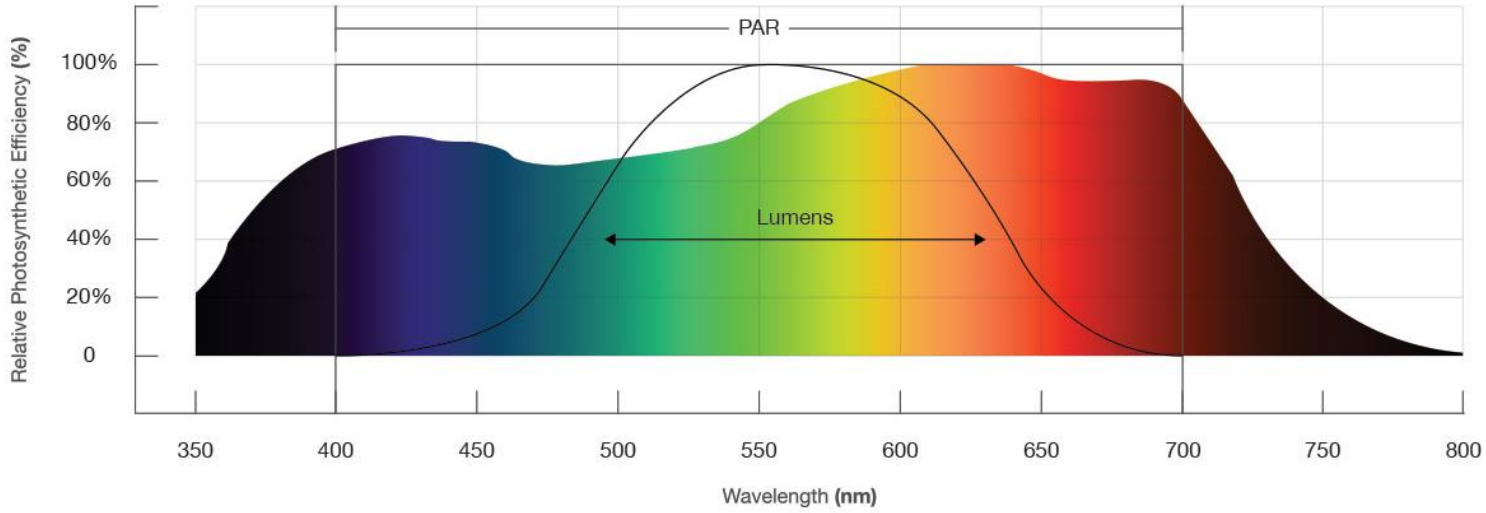
1

LITERATURE REVIEW

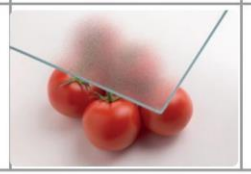


1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

Source : BBC Growing Plants

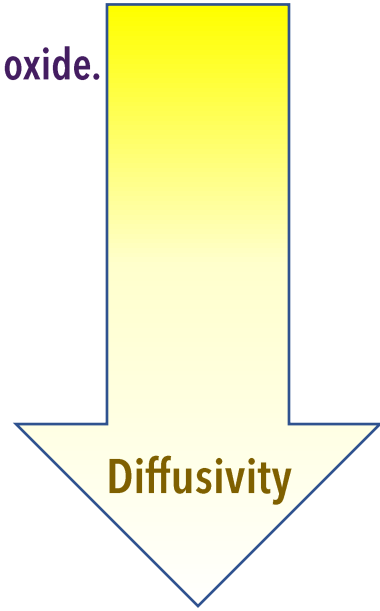


Source : source website: www.fluence.science.

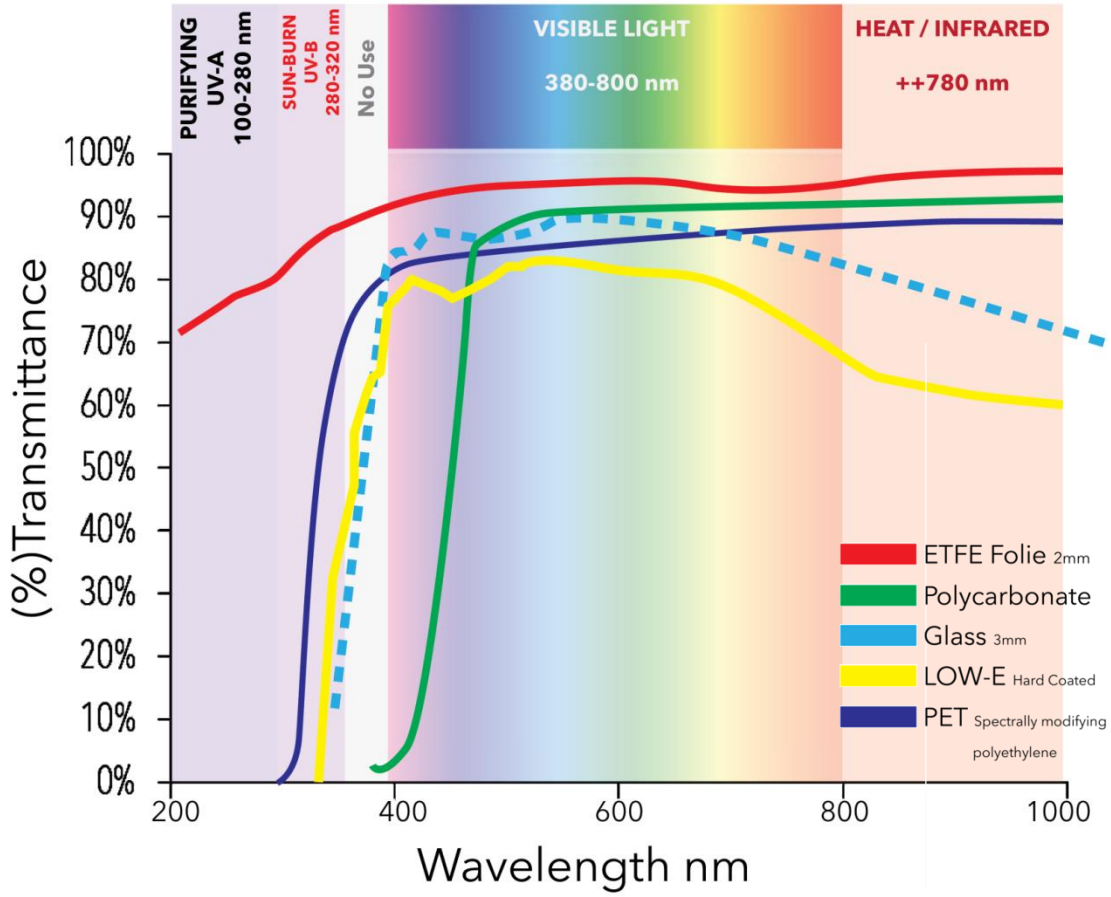
	Glazing Type	Example Albarino® products	Light transmission	Hemispherical (WUR method)	Compare production with using the material in Spring Autumn and Summer	Compare production with using the material in winter
1	Crystal Glass		90.5 - 96.8	90.0	-/0	+
2	Low Haze		91.5 - 96.5	89.0	++ 7% Kg/m2	-/0
3	High Haze		91.5 - 95.5	85.0	++ 9.4% Kg/m2	-/0

Source of the output by [Hemming & Reinders, 2007] Graph by author

- Crystal , Very low percentage of iron oxide.
- Ultra Low Haze
- Low Haze
- Mid Haze
- High Haze
- Very High Haze > 93%.

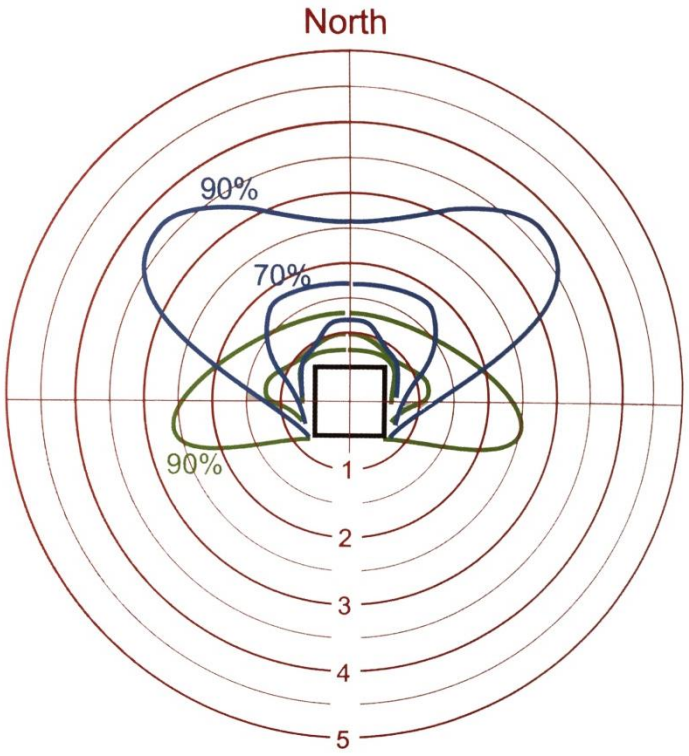


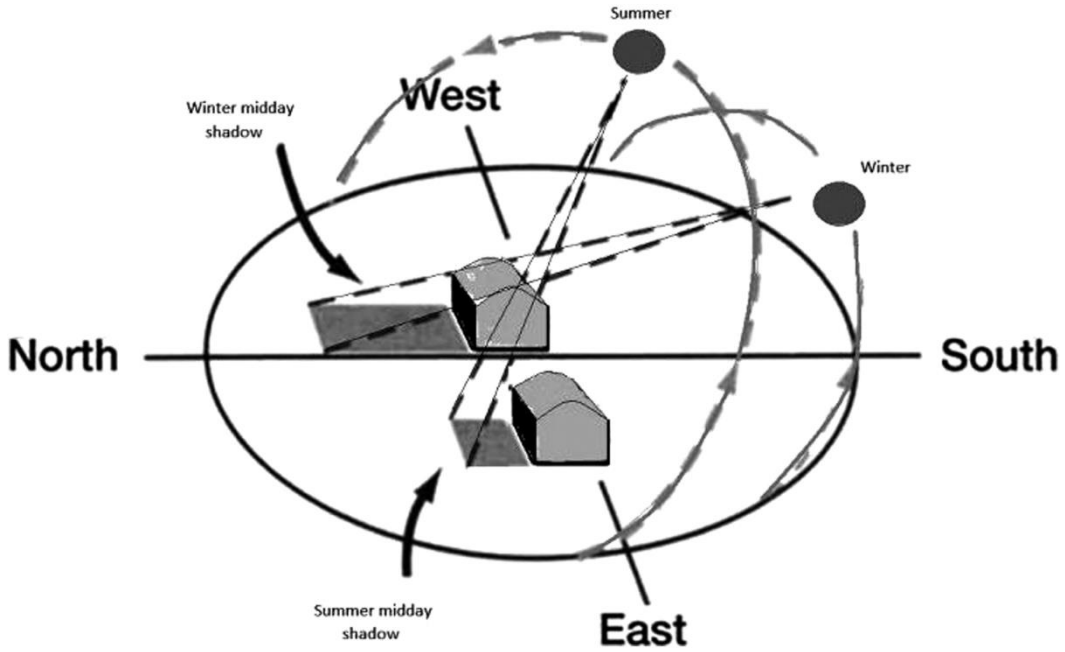
	Material Type	Application	Price	Weight	Refractive Index	UV resistance	Flamibility
1	ETFE		●●●	●	1.4	Good	Self extinguishing
2	Glass		●●	●●●	1.45	Excellent	Non flammable
3	Polyethylene PET		●	●	1.6	Fair	Highly flammable
4	Polycarbonate PC		●●	●●	1.56	Fair	Slow burning

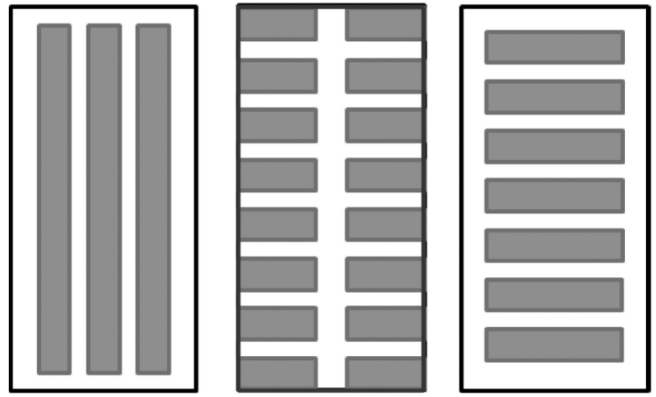


Sorce: Glass, PC, ETFE **[LeCuyer,2008]** - PET **[Abd El-Al,2008]**

Source : [Hemming&Reinders, 2007]







Longitudinal
Easy access mechanization but difficult access

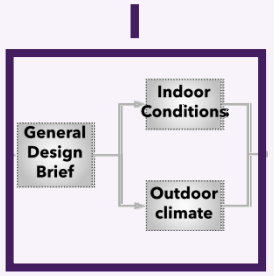
Peninsular
Easy access with maximum growing area

Cross Benching
Easy access but less growing area

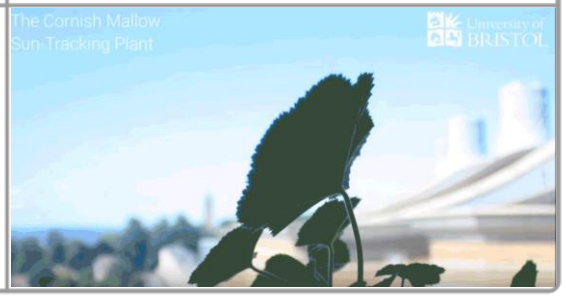
Source : [Tregenza,2011] & [Ponce,2015]

1

LITERATURE REVIEW



1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

	LIGHT PROPERTIES	NATURE	Feature	Graph
E.g 1	Transmission	Deep Sea Venus flower	Light distribution	
E.g 2	Reflection	Butterfly wing	Reflects certain wavelengths	
E.g .2	Harness	Cornish Mallow	perpendicular to solar radiation	

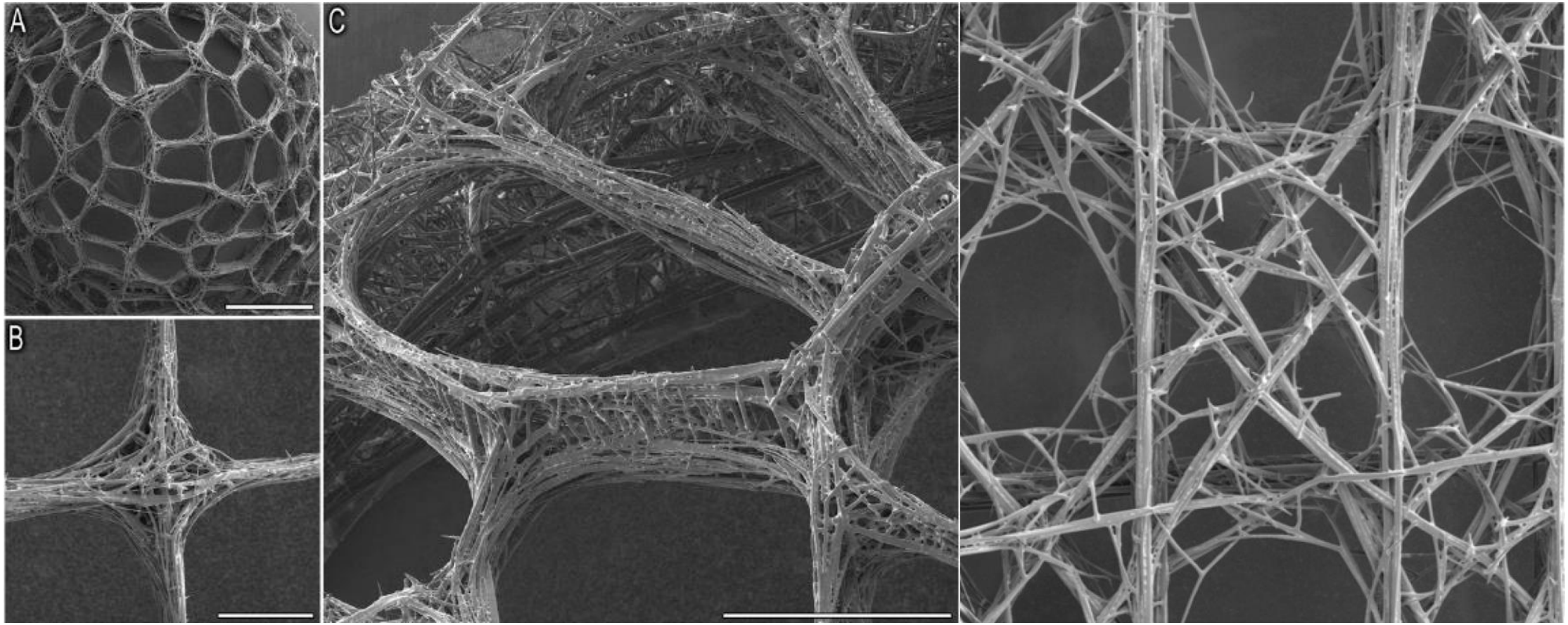
1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

Venus flower basket

hexactinellid sponge

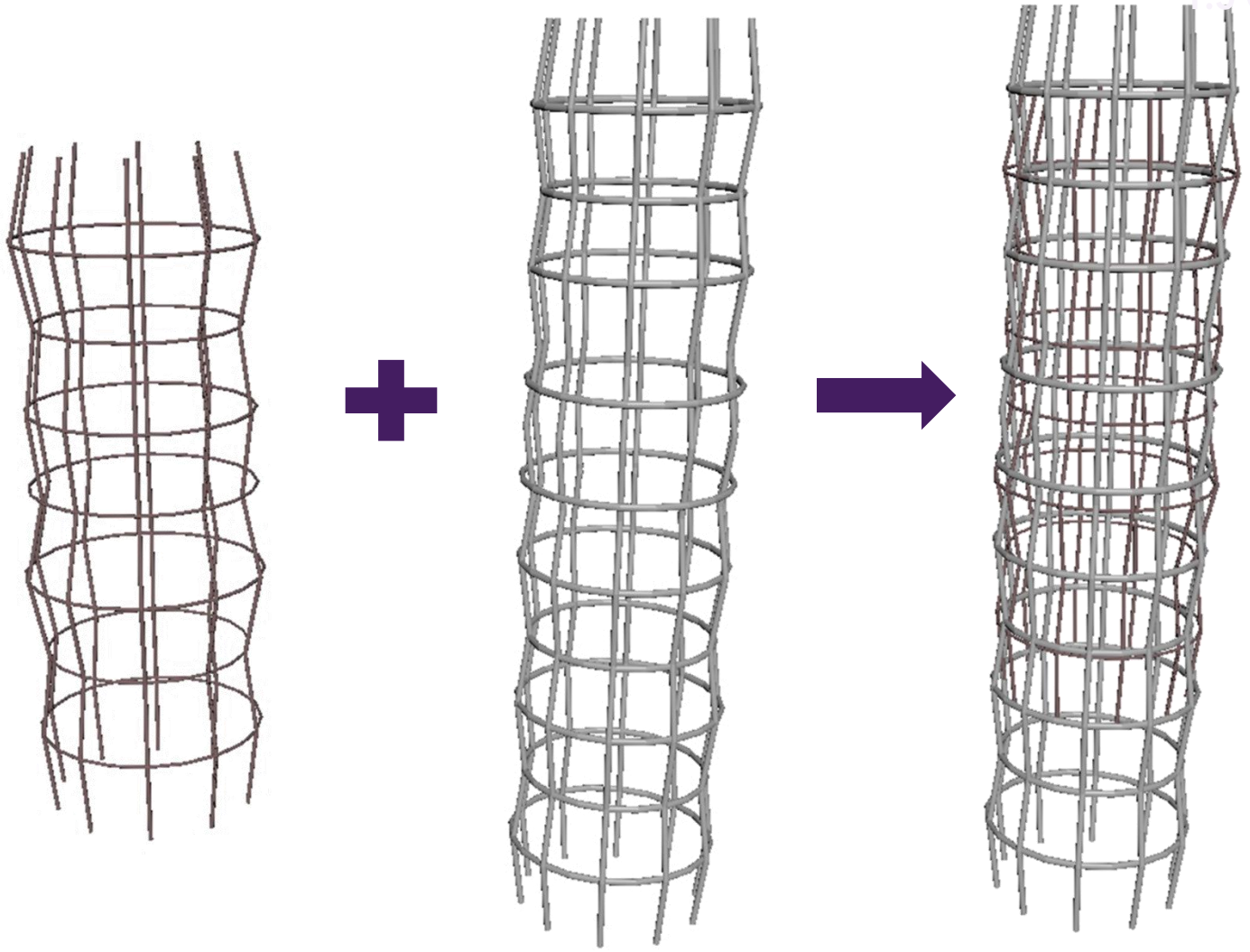
''Euplectella Aspergillum''

1.3 BIOLOGICAL MODEL

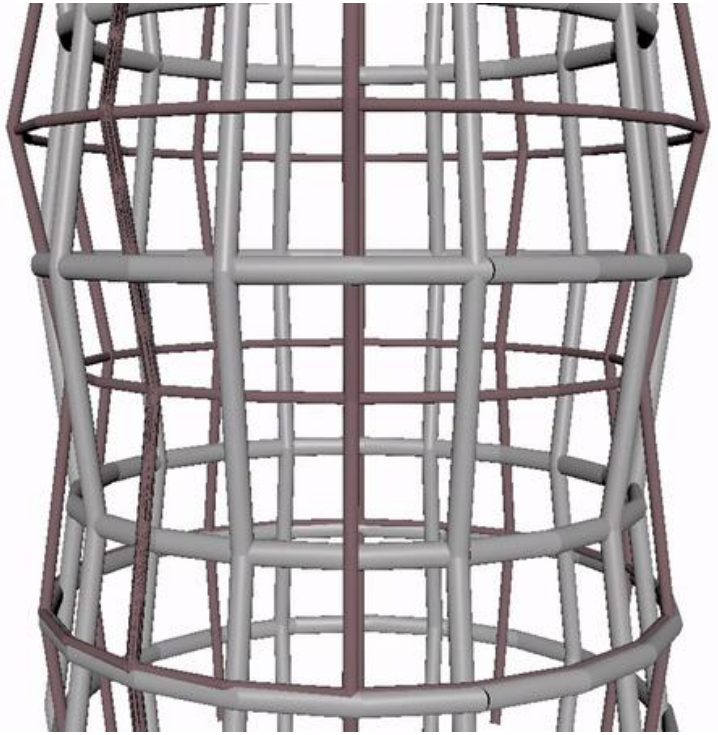


Source : [Weaver, 2006]

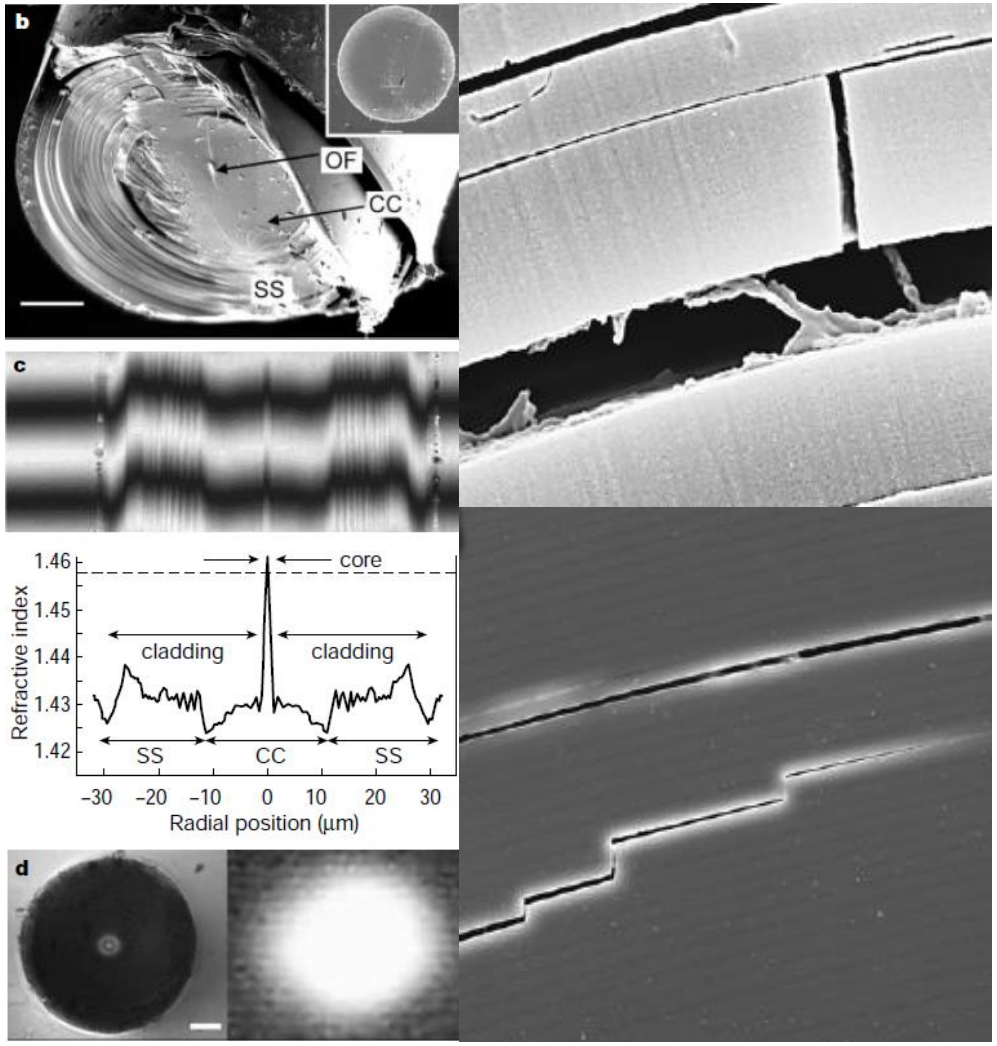
1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING



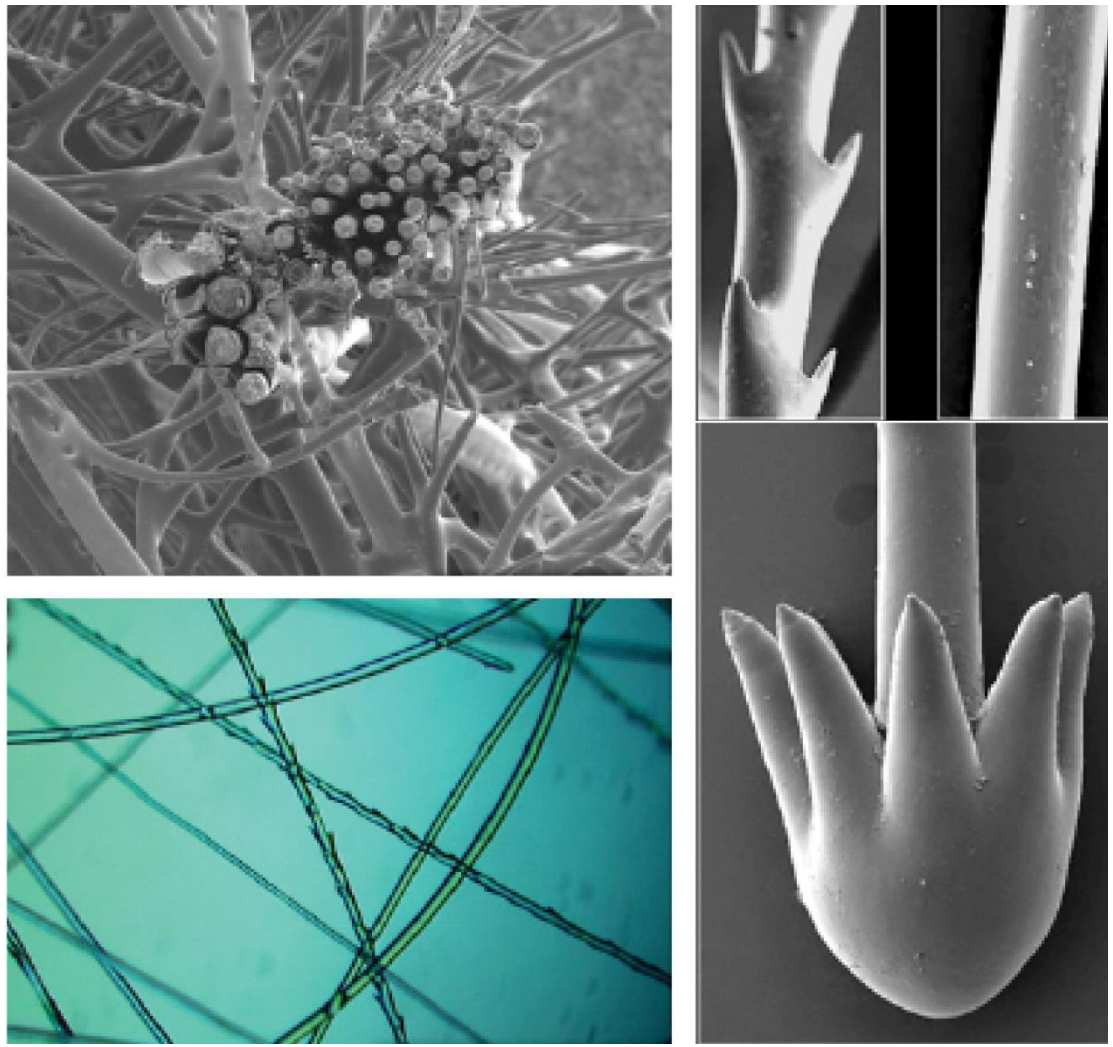
1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING



1.3 BIOLOGICAL MODEL



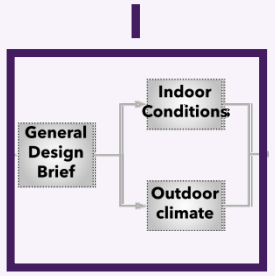
Source : [NATURE,2003]



Source ;[Weaver, 2006]

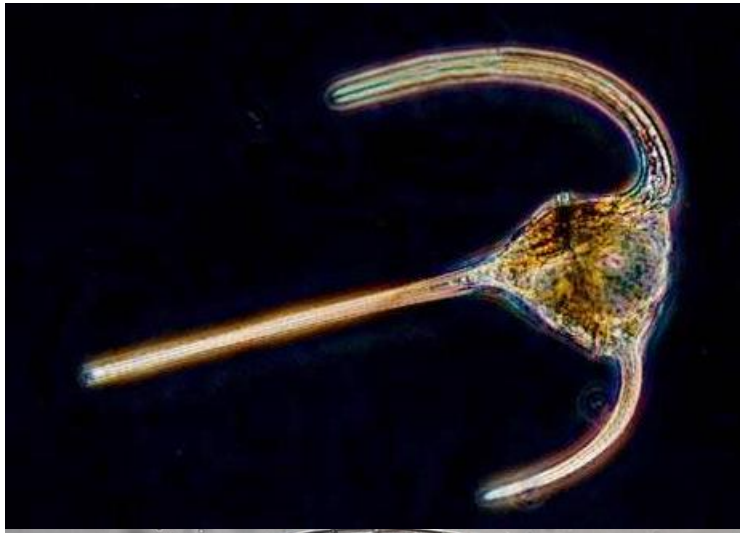
1

LITERATURE REVIEW

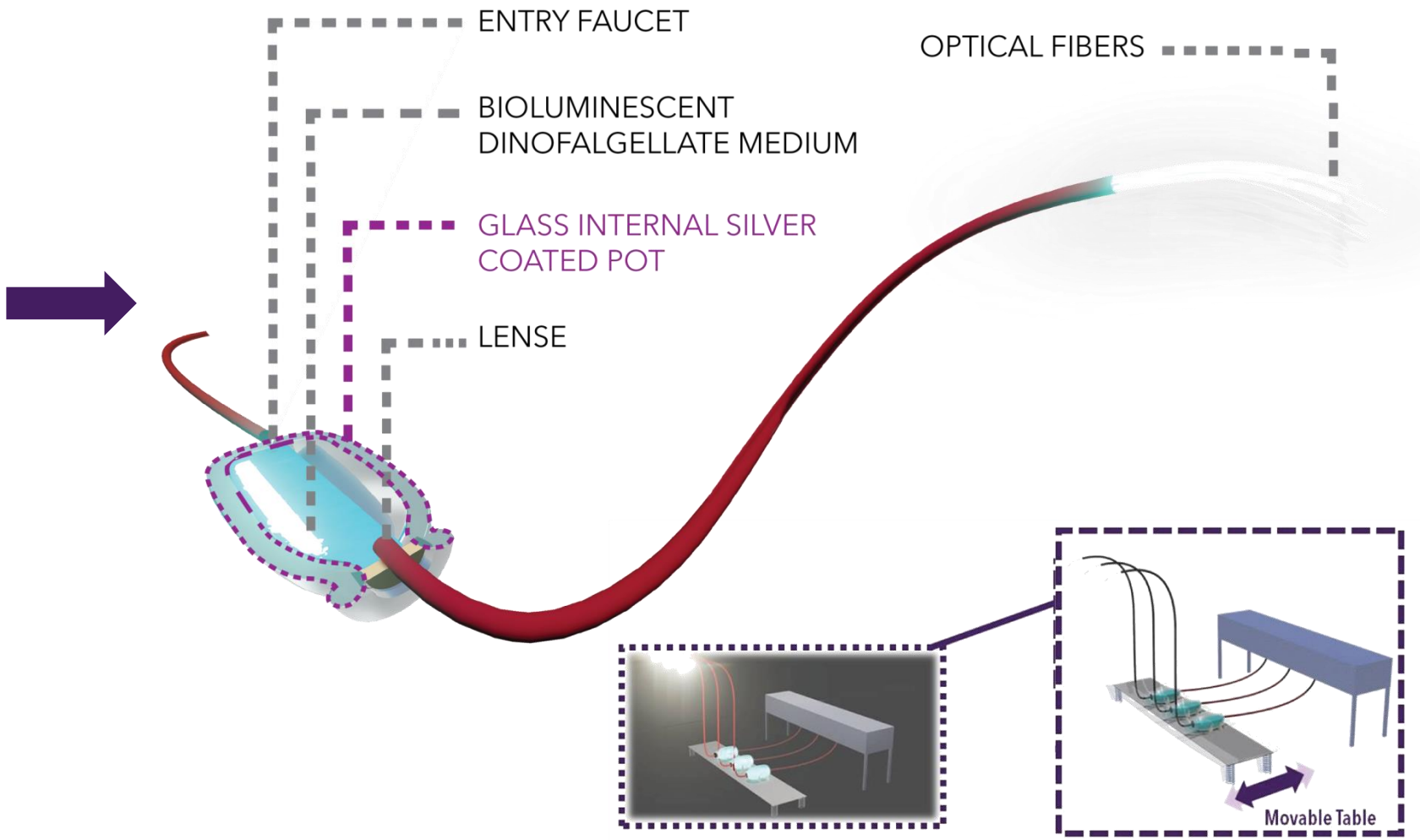


1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING

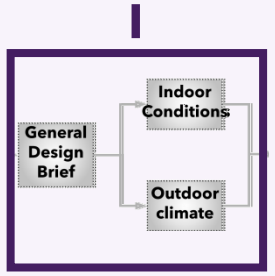


1.4 BIOLUMINESCENCE

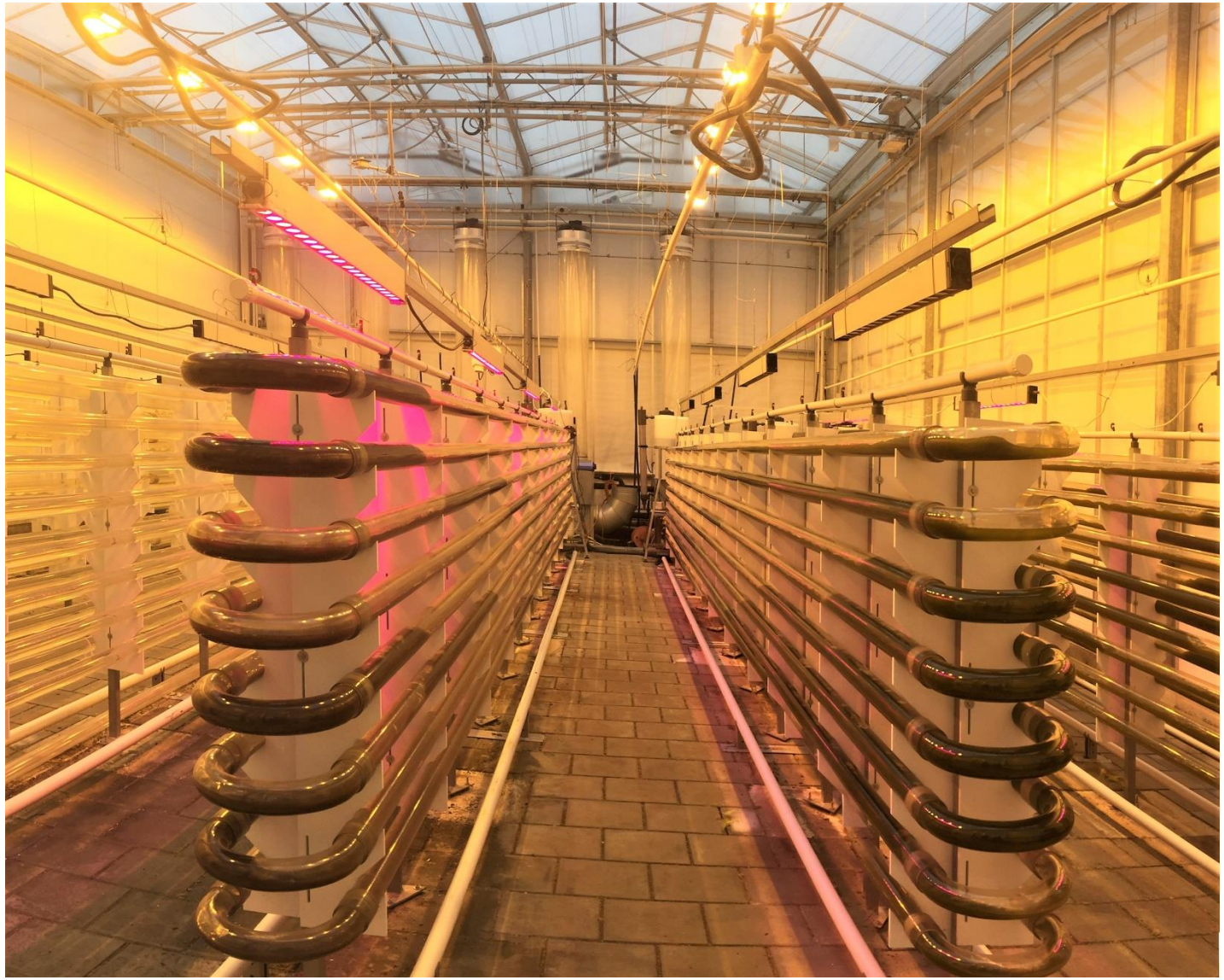


1

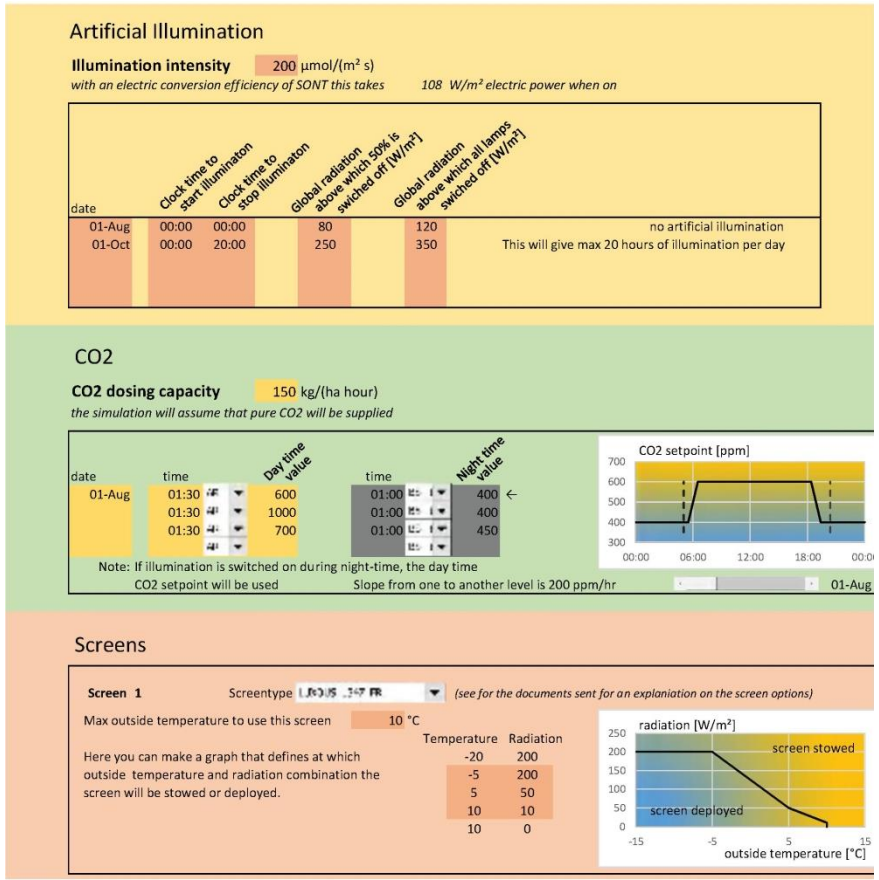
LITERATURE REVIEW



1.1 PRODCTION TECHNIQUE
1.2 LIGHT PROPERTIES
1.3 BIOLOGICAL MODEL
1.4 BIOLUMINESCENCE
1.5 COMPUTATIONAL IN FARMING



University
of Wageningen
Bleiswijk research
Center



Field Study / Lab Tests

plant growth model
Greenhouse light, CO2, Humidty parameters (Climate controller)

Simulation results / Profit, crops quality, quantity.

-Prepare xls files.

-Send the files to simulation software automatically.

-Gather the results automatically & process them.

-combine all results into one dataset.

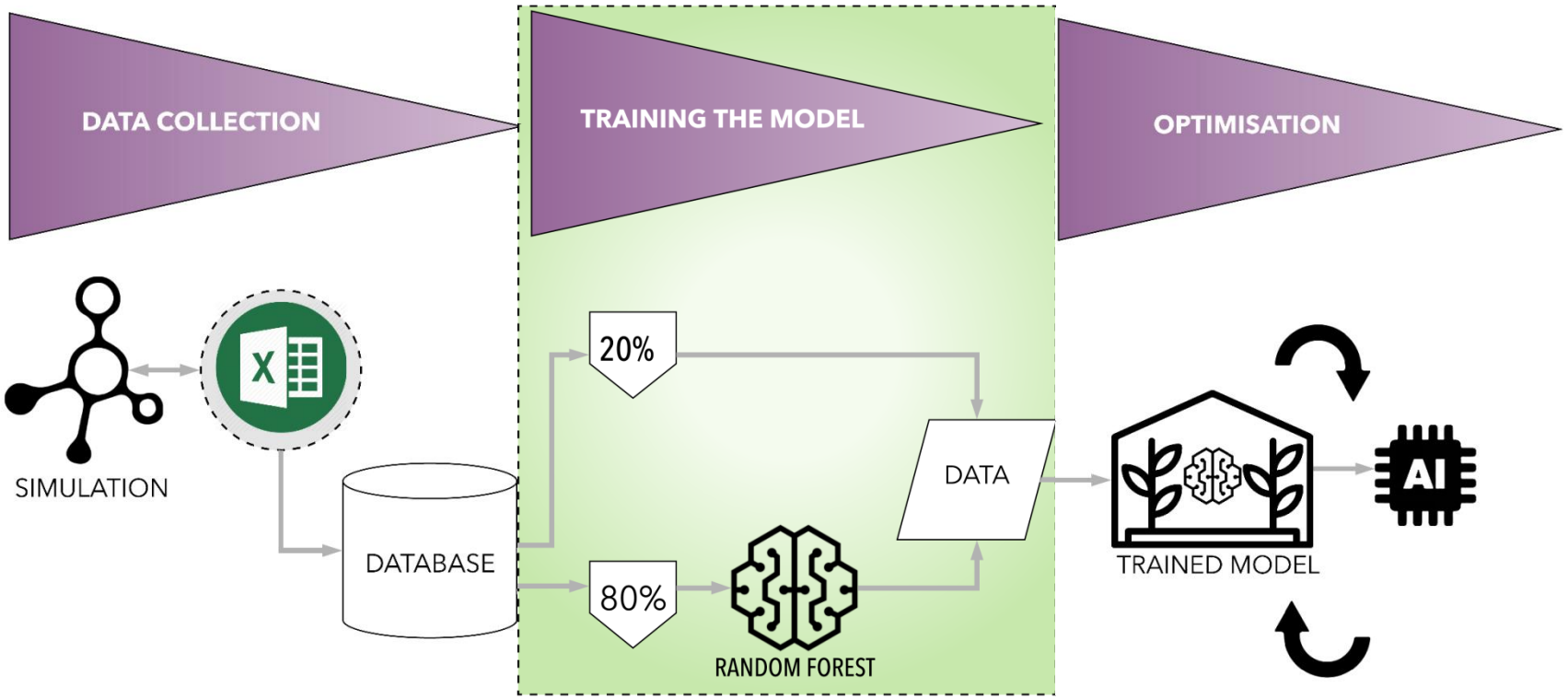
-Split the dataset into training & data validation 80%-20% Random Forest.

-Feed the dataset to different ML optimises

-Determine the best one.

Using the trained model, prediction can be made on simulation input.

Use genetic optimisation to find the best setting


DATA COLLECTION
TRAINING THE MODEL
OPTIMISATION
SIMULATION
DATABASE
20%
80%
RANDOM FOREST
DATA
TRAINED MODEL
AI

2

PRACTICAL PART

2.1 MATERIAL AND DESIGN
2.2 TRANSLATION OF BIOLOGICAL MODEL
2.3 COMPUTATIONAL WORKFLOW

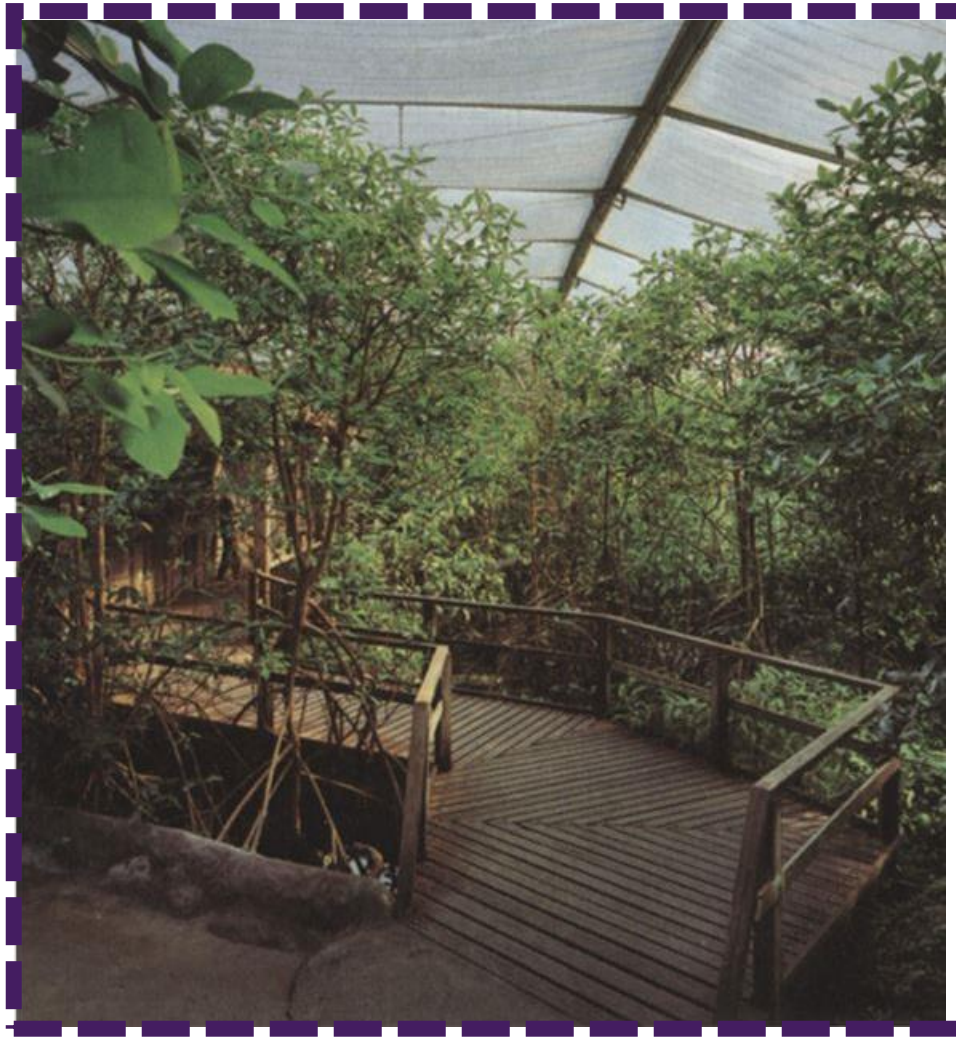
2

PRACTICAL PART

2.1 MATERIAL AND DESIGN

2.2 TRANSLATION OF BIOLOGICAL MODEL

2.3 COMPUTATIONAL WORKFLOW

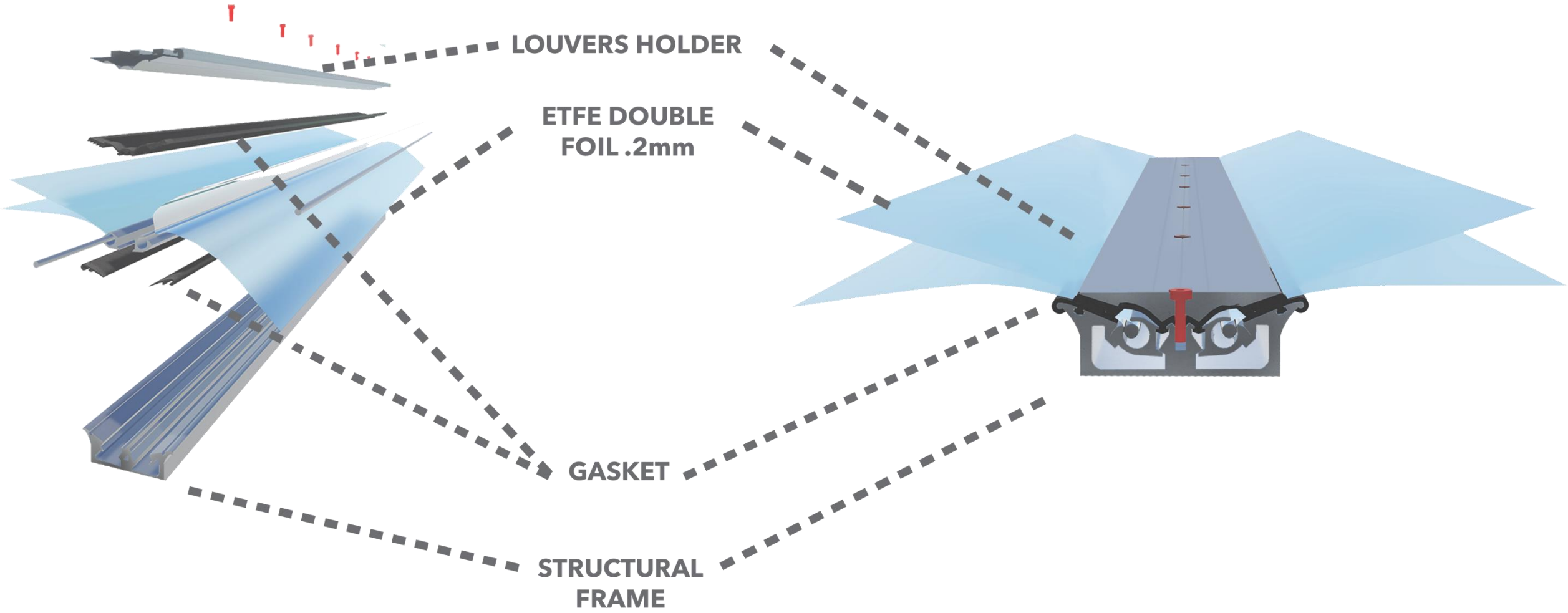


Source :Burgers' Zoo in Arnhem in the Netherland. Source ABT

Source : Eden project website

TROPICAL BIOME

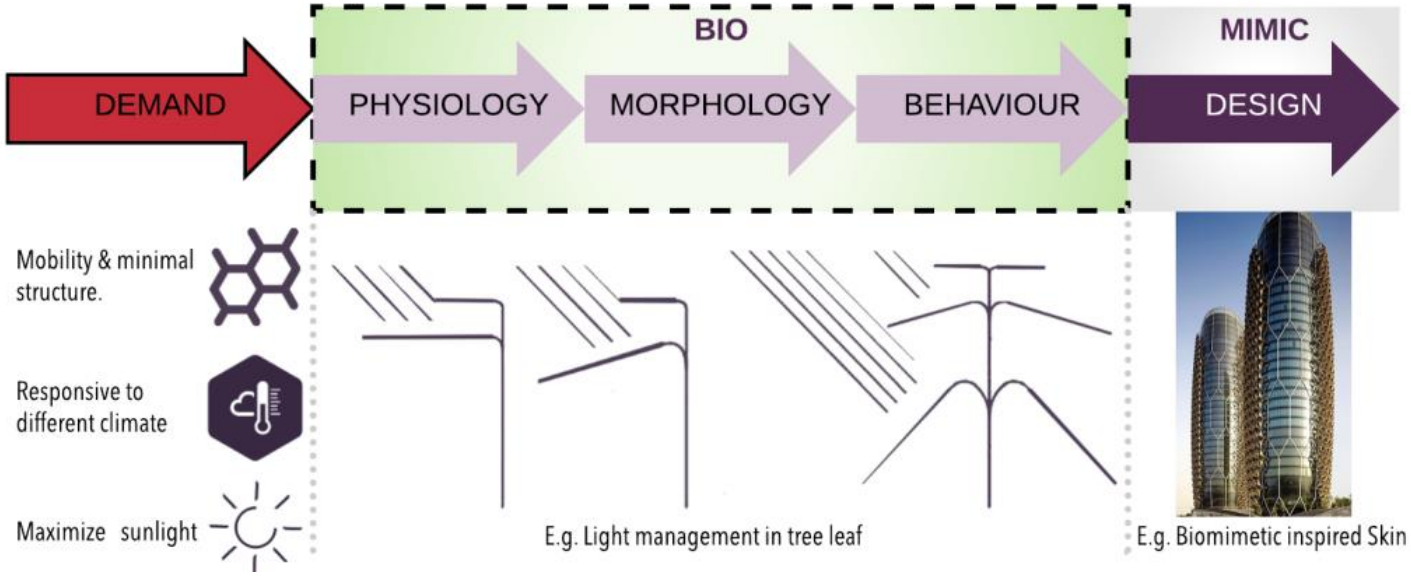
Material	Purifying UV-C 100-280nm	Sunburn UV-B 280-320nm	NO use UV-A 320 - 380nm	Photosy-nthesis 380-800nm	Heat 780nm ++
ETFE	70-78 %	78-83 %	-----	98 %	98 %
Glass	0	15 %	-----	95 %	79 %
Polyethylene PET	0	7 %	-----	85-90 %	90 %
Polycarbonate PC	0	0	-----	95 %	95 %

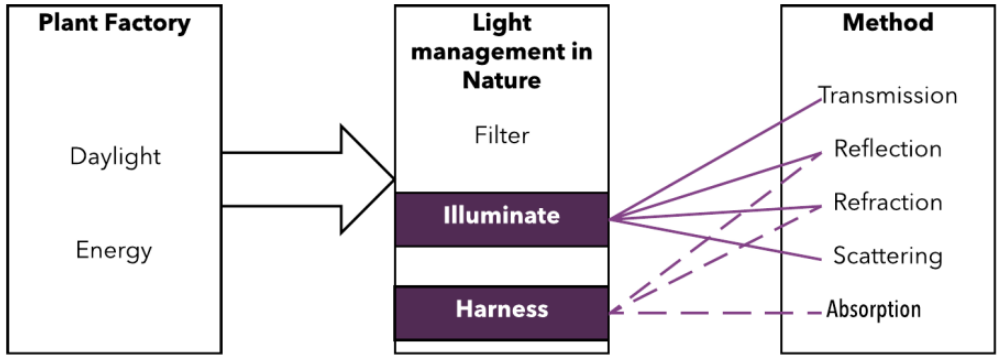

LOUVERS HOLDER
ETFE DOUBLE FOIL .2mm
GASKET
STRUCTURAL FRAME

2

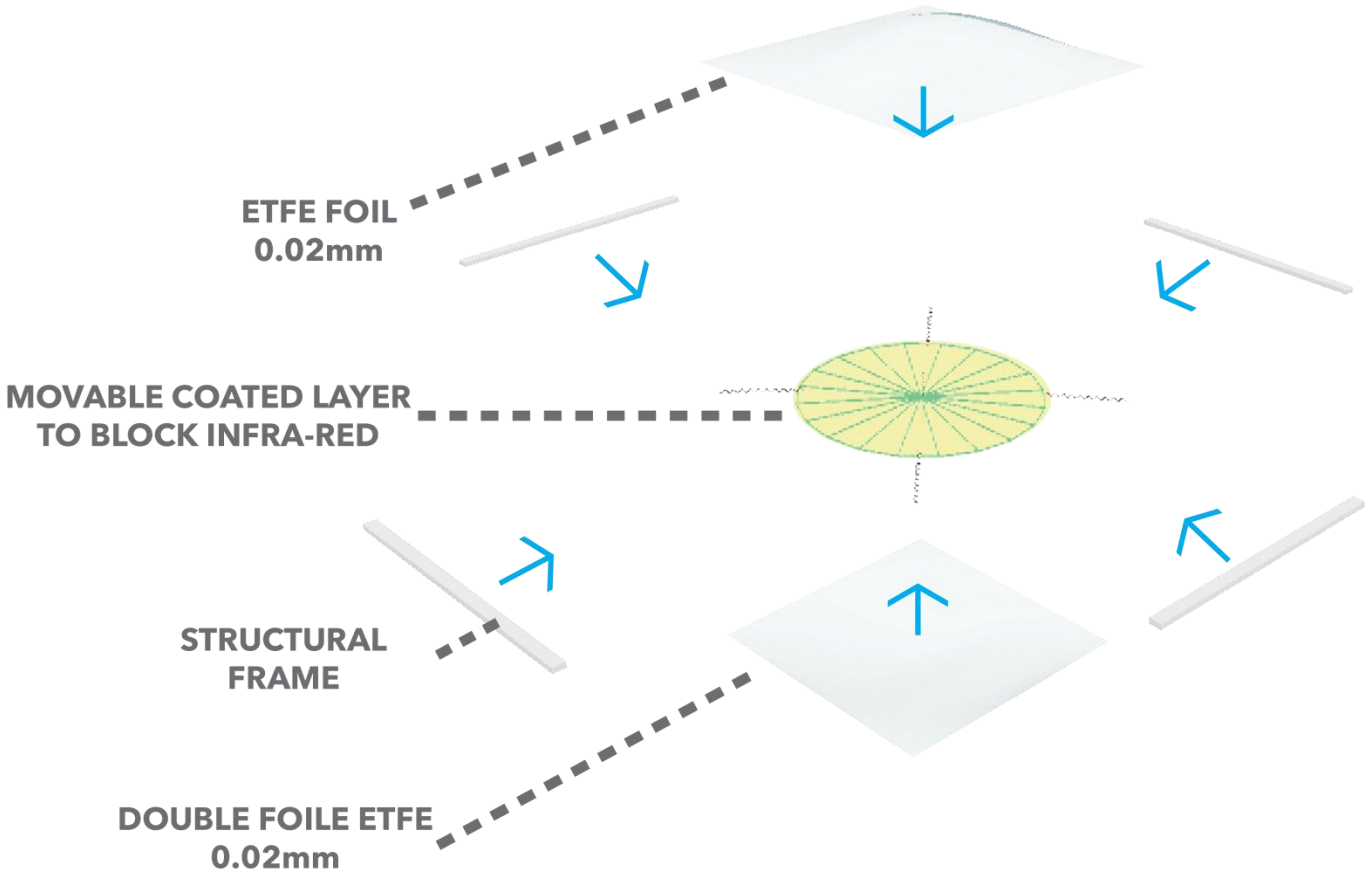
PRACTICAL PART

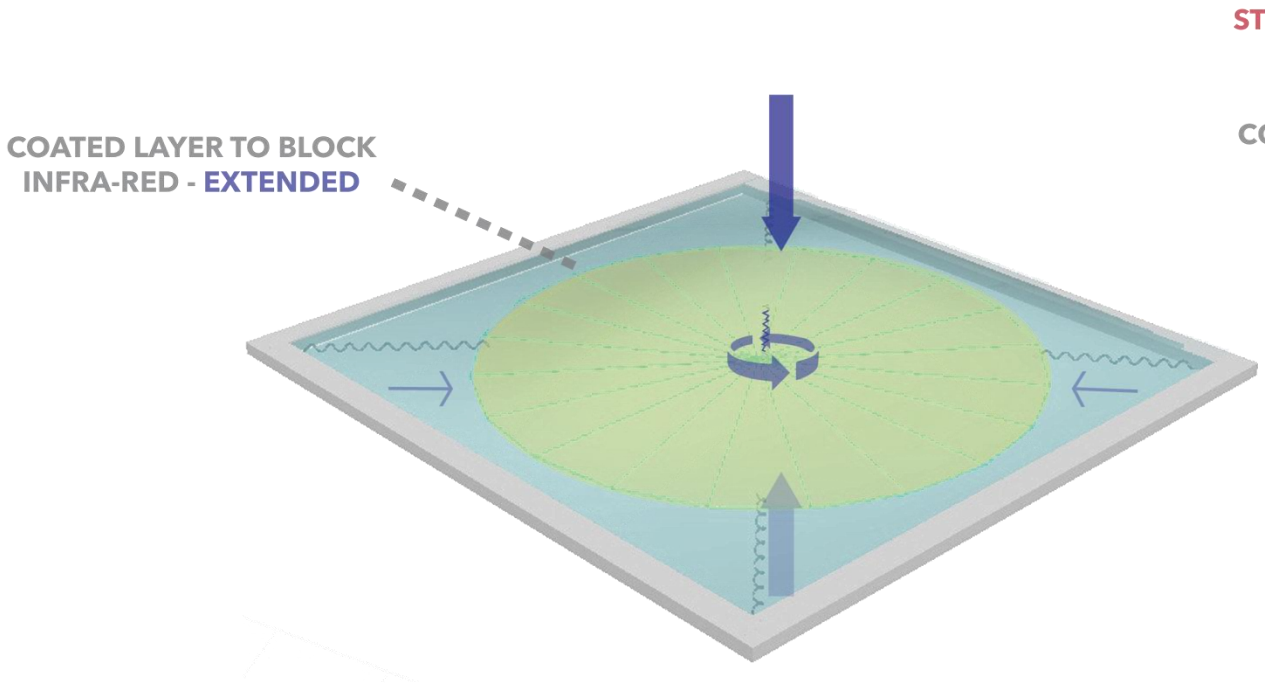
2.1 MATERIAL AND DESIGN
2.2 TRANSLATION OF BIOLOGICAL MODEL
2.3 COMPUTATIONAL WORKFLOW

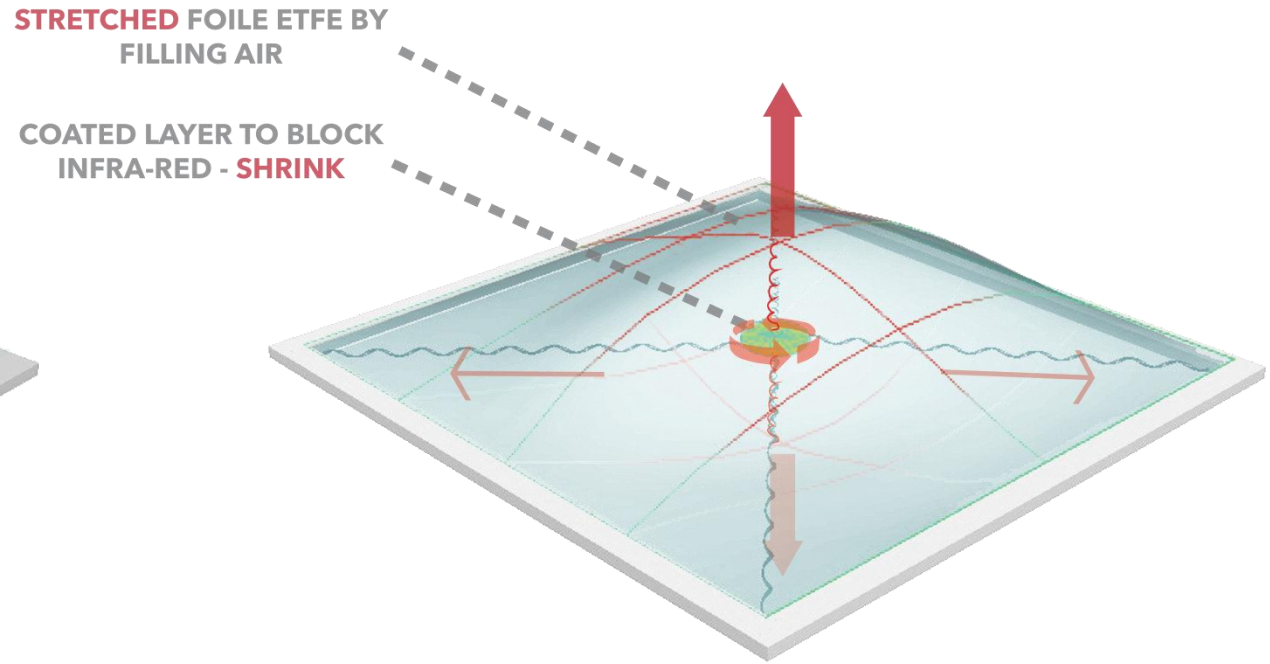

BIO
MIMIC
DEMAND
PHYSIOLOGY
MORPHOLOGY
BEHAVIOUR
DESIGN
Mobility & minimal structure.
Responsive to different climate
Maximize sunlight
E.g. Light management in tree leaf
E.g. Biomimetic inspired Skin

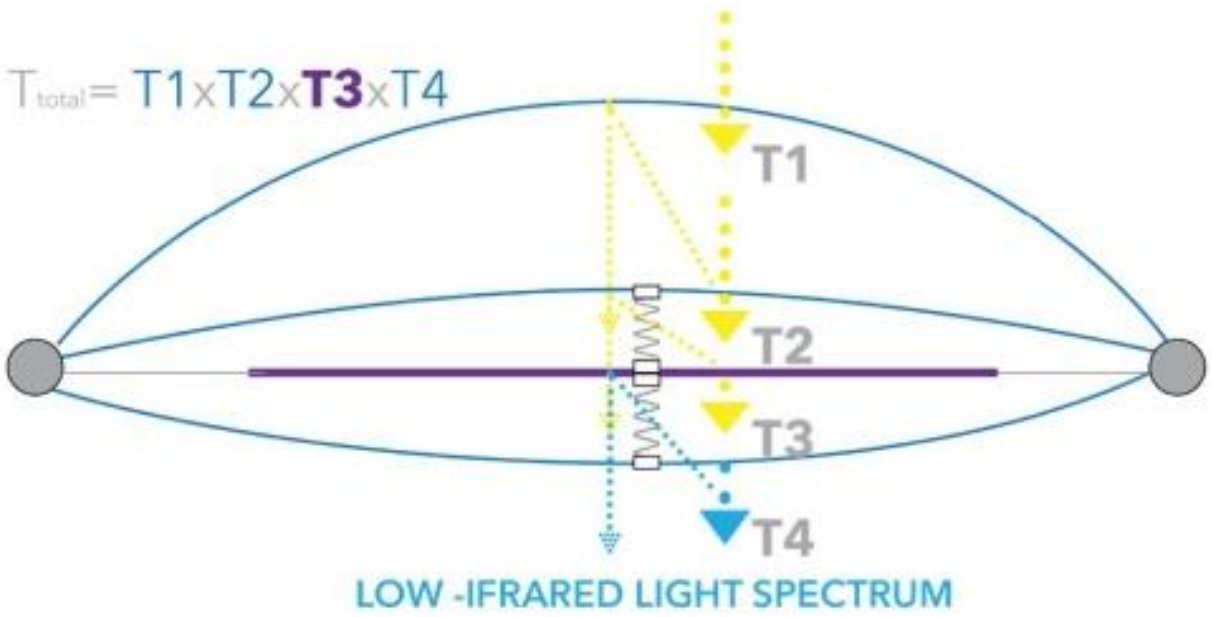

Plant Factory
Daylight
Energy
Light management in Nature
Filter
Illuminate
Harness
Method
Transmission
Reflection
Refraction
Scattering
Absorption

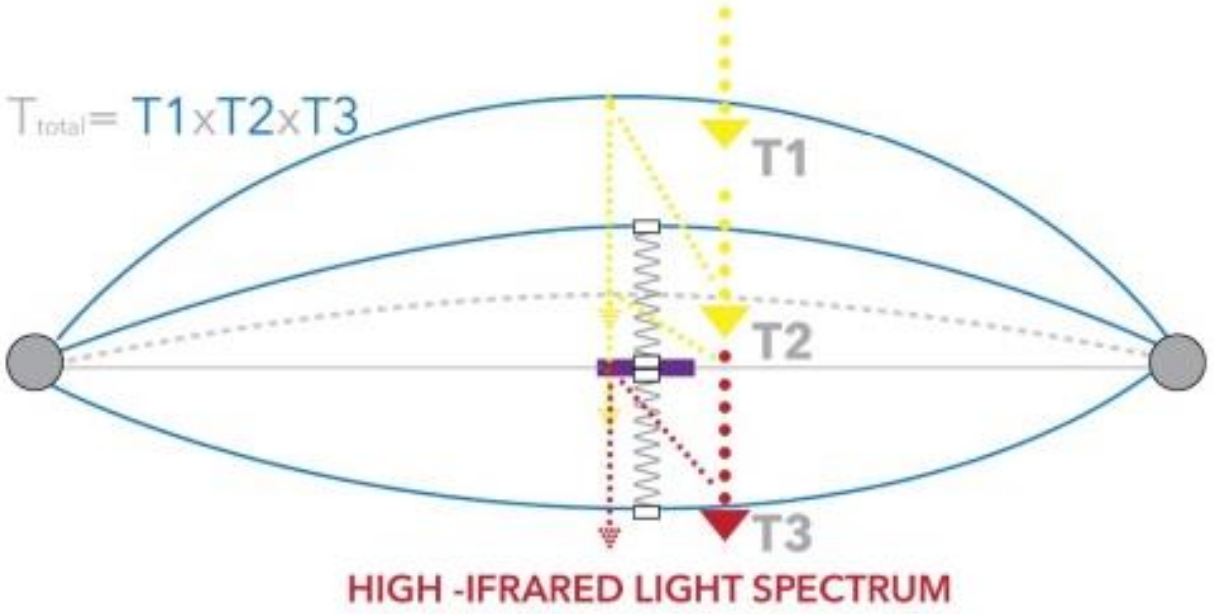
Deep Sea Venus flower	Area Of Study	Physiology (Structure)	Morphology (Pattern and Design)	Behaviour (Process)
E.g 1	**Light Management Transmission**	-The walls of the organism structure are cemented and strengthened by spicule bundles, oriented vertically, horizontally and diagonally concerning the cylindrical lattice. - The Fibres function as structural parts as well Divided into four main structural elements, anchoring apparatus, cap, spiral ridges and tubes horizontally and vertically where the last two skeletal parts are separated in form. That maintains the glass sponge stiffness.	- The top open skeletal lattice cylinder covered with an irregular network-like structure that constitutes the terminal sieve plate. Protect the sponge interior, and provide rigid capping structure has a mechanical role. By preventing lateral collapse. - beyond structural anchorage support, could also provide a highly effective fibre-optical network, which may be useful in distributing light in its deep-sea environment.	- Refractive indices for the high-index core and a low-index cladding. They also function as efficient single-mode, few-mode or multi-mode waveguides, depending on the optical launch conditions, the optic fibres have this friction index due to cracks whereas in the spicules due to organic lamination. - The transmittance occurs by very thin natural silica spicules - similar to human-made optic fibres alongside thin lamination layer of the proteinaceous filament. The optical fibres have this friction index due to cracks whereas in the spicules due to organic lamination. It has either superior feature as its formation under ambient temperature process.
Result	**Translation in Skin Design**	The Skin Material made of pneumatic ETFE cushions that are lightweight and can highly stiff to the outer dead and live loads. The shading is reacting independently inside the cushions in separate installation expand with the increase of air volume that based on solar analysis	- The Geometrical form that based on best orientation to capture solar light as well as well as using highly resistence materilas for harsh wether condtions (selection of ETFE).	- The Use of Optic fibres to transfer the light of the Dinoallge to the production source indirectly. -selecting the materials based on spectral wavelength and diffusivity '' haze materials effects.'' - implement internal selective spectral shading elements that manipulate the light to deliver the best light spectrum combination for production level.


ETFE FOIL
0.02mm
MOVABLE COATED LAYER
TO BLOCK INFRA-RED
STRUCTURAL
FRAME
DOUBLE FOILE ETFE
0.02mm


COATED LAYER TO BLOCK
INFRA-RED - EXTENDED


STRETCHED FOILE ETFE BY
FILLING AIR
COATED LAYER TO BLOCK
INFRA-RED - SHRINK


T_{total}= T1xT2x**T3**xT4
T1
T2
T3
T4
LOW -IFRARED LIGHT SPECTRUM

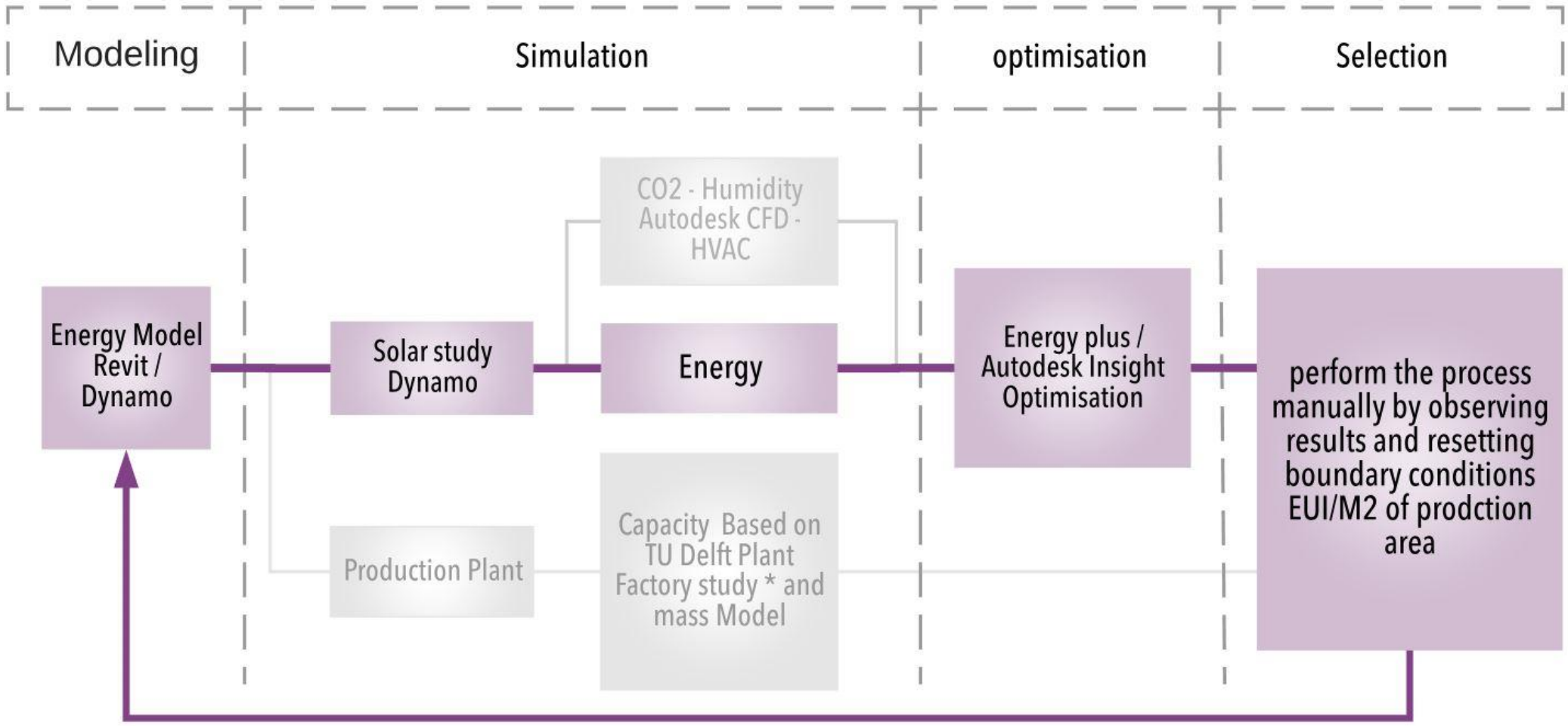

T_{total}= T1xT2xT3
T1
T2
T3
HIGH -IFRARED LIGHT SPECTRUM

2

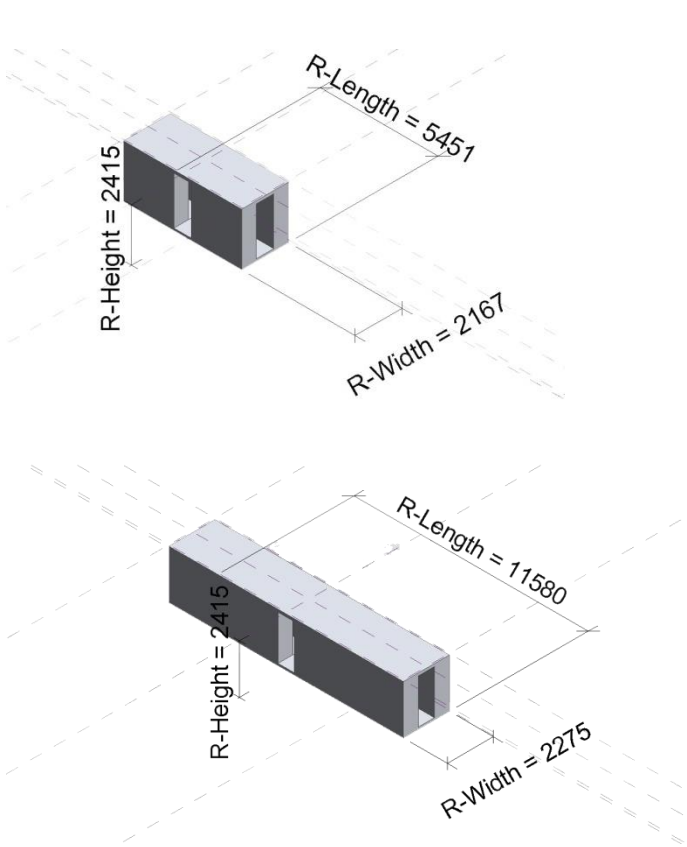
PRACTICAL PART

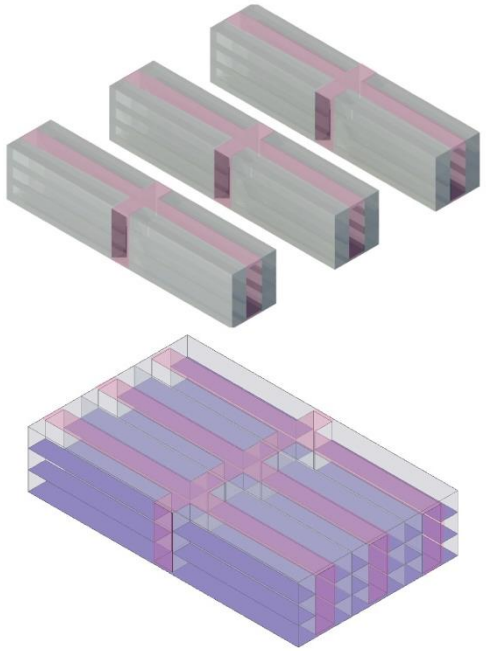
2.1 MATERIAL AND DESIGN
2.2 TRANSLATION OF BIOLOGICAL MODEL
2.3 COMPUTATIONAL WORKFLOW

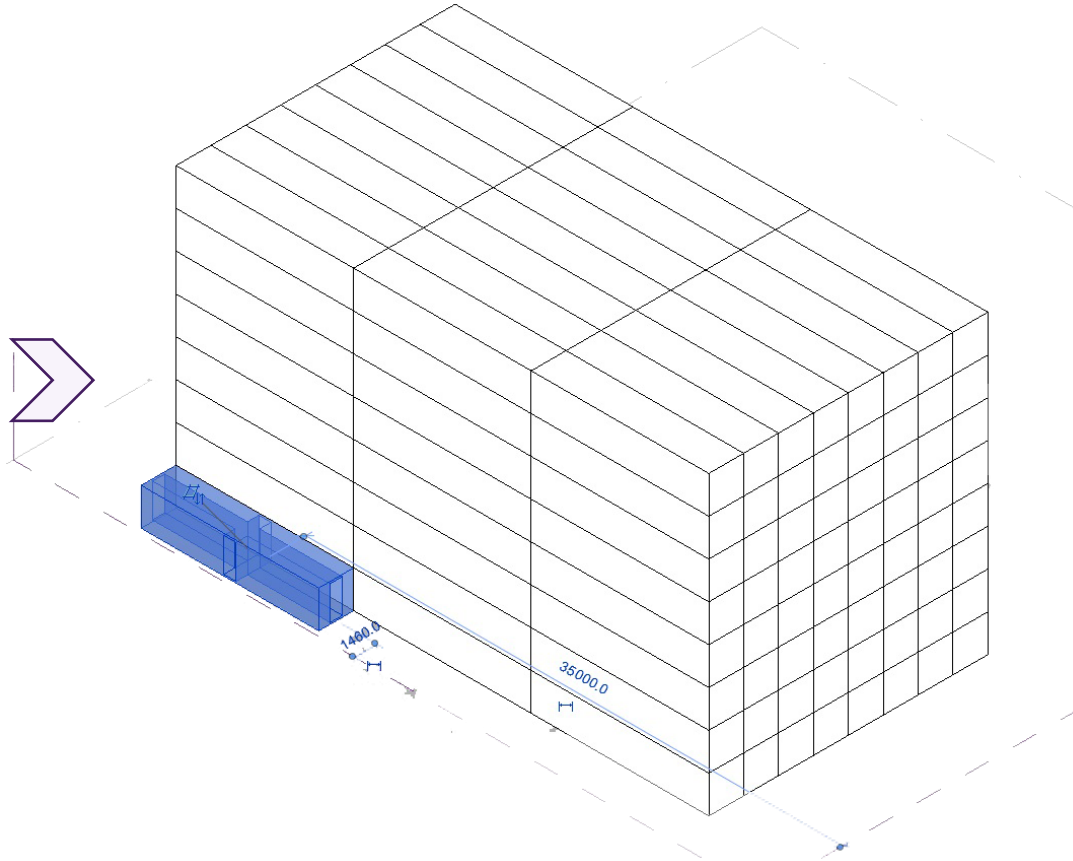
2.3 COMPUTATIONAL WORKFLOW



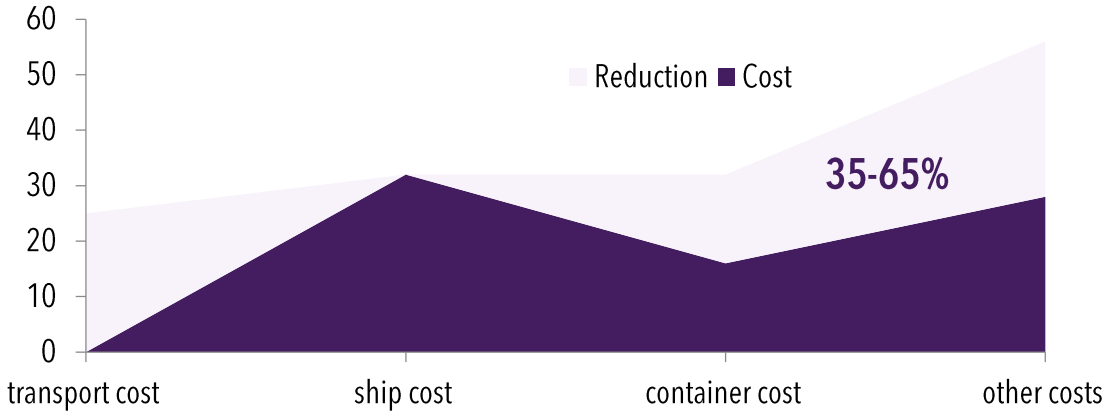
2.3 COMPUTATIONAL WORKFLOW

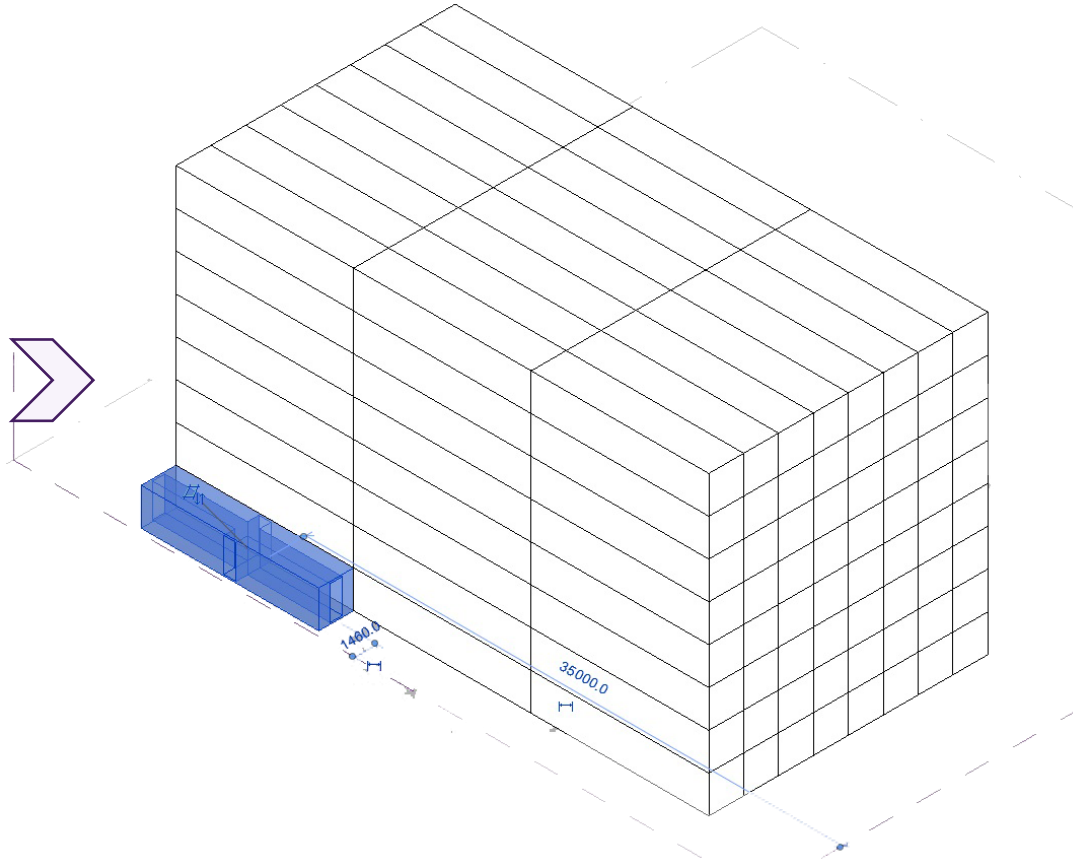




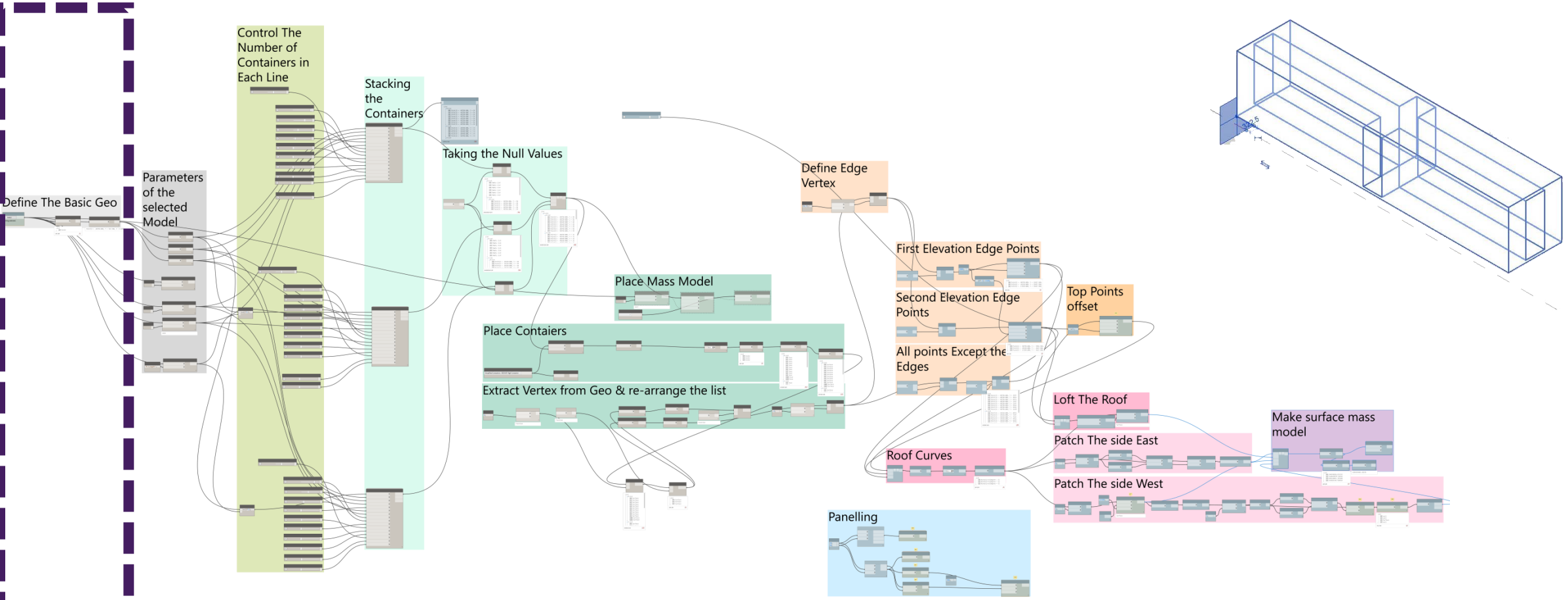


2.3 COMPUTATIONAL WORKFLOW

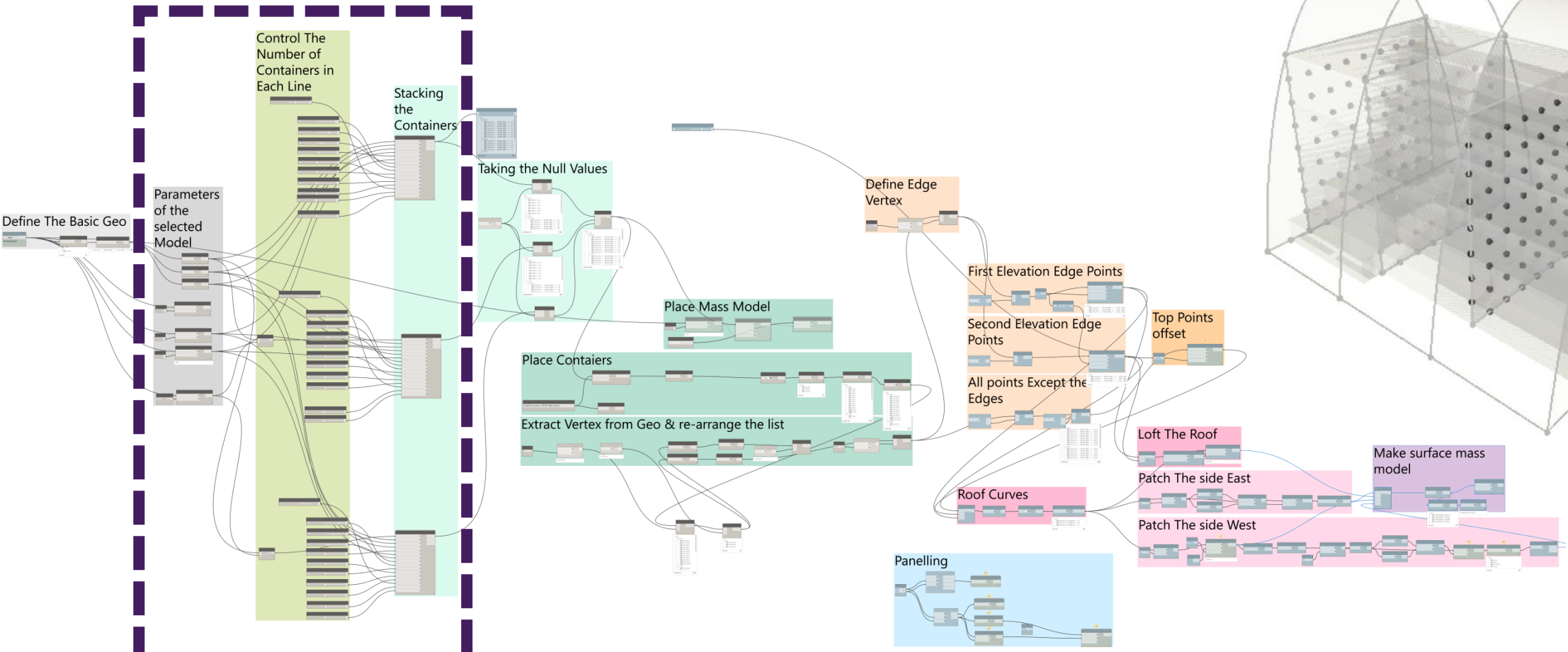


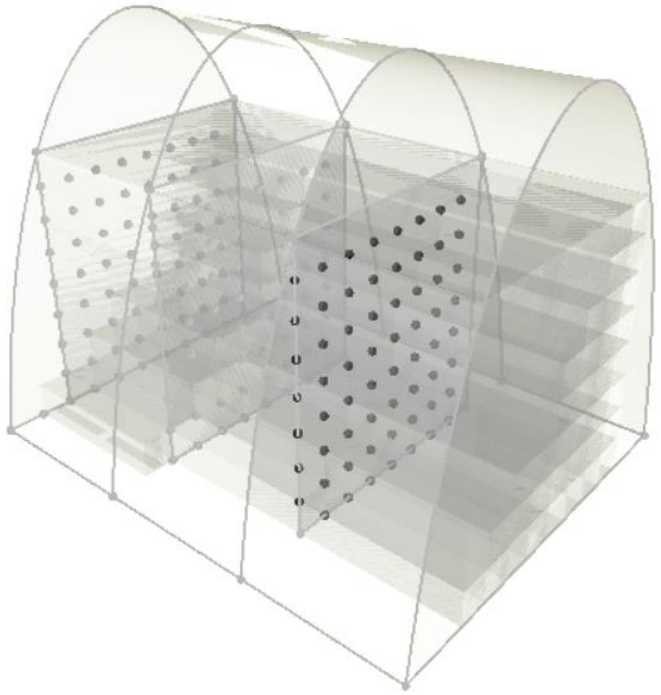


2.3 COMPUTATIONAL WORKFLOW

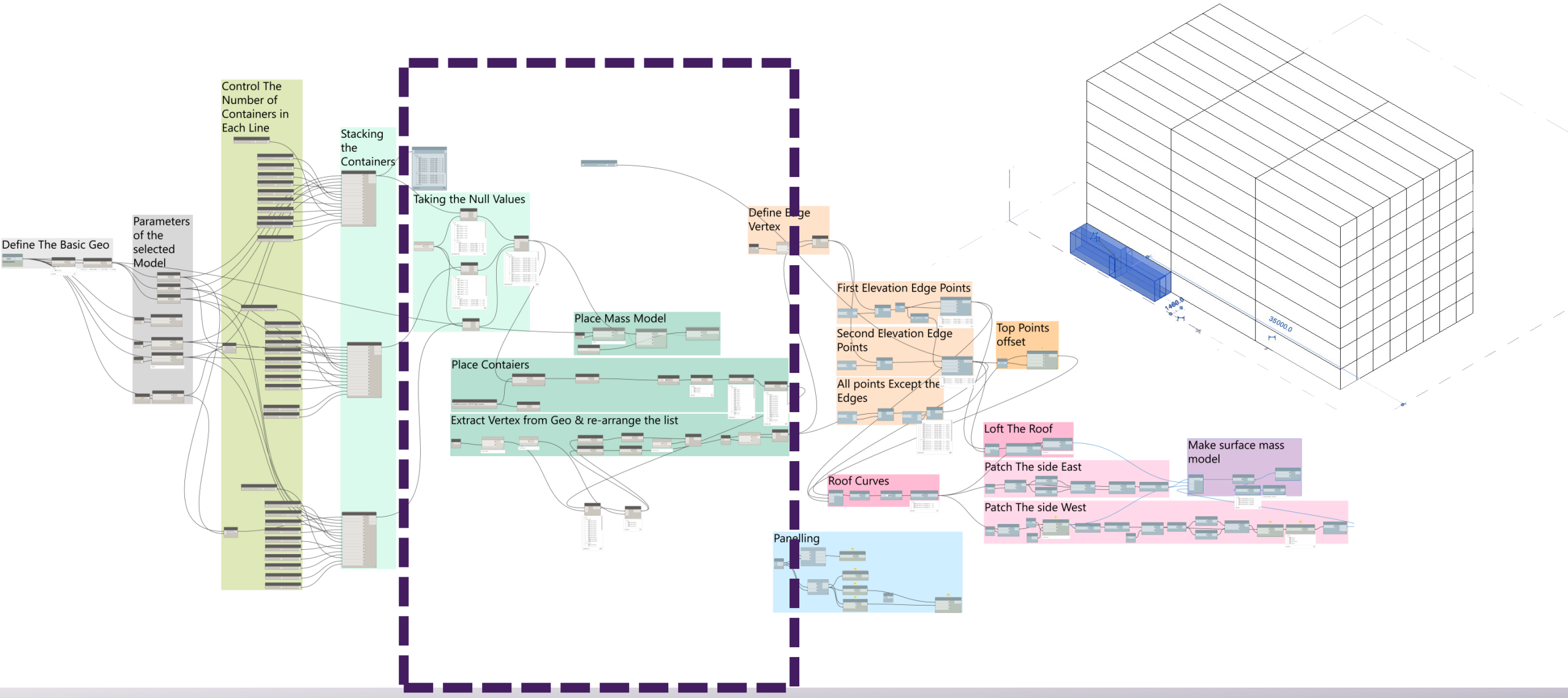


2.3 COMPUTATIONAL WORKFLOW

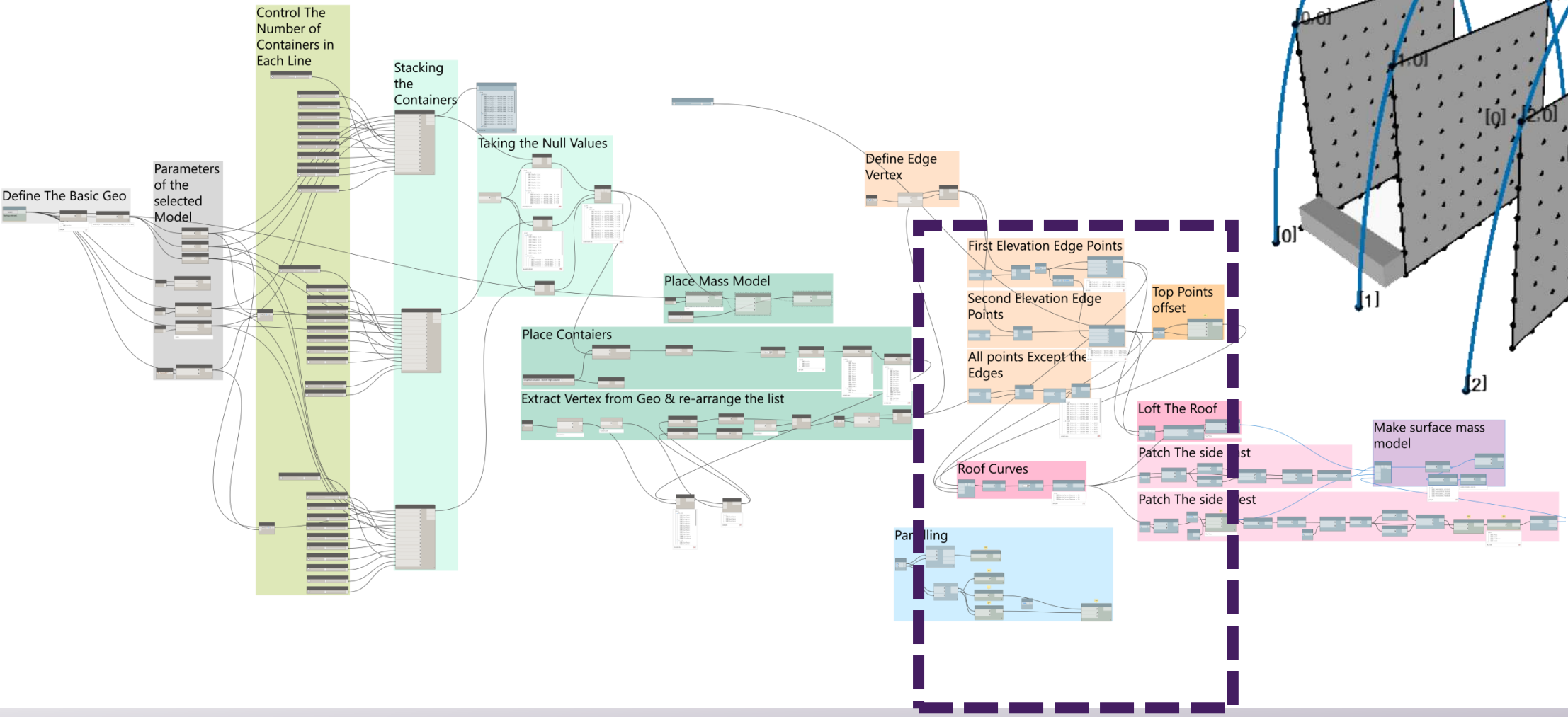


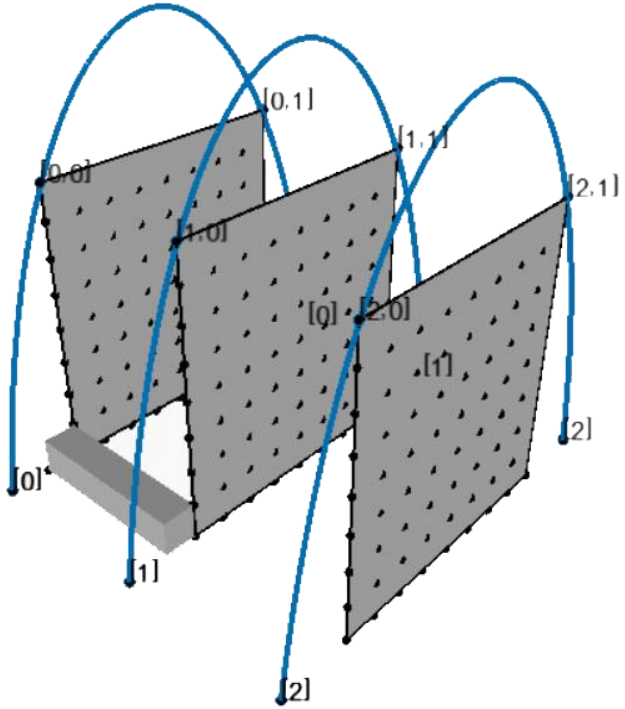


2.3 COMPUTATIONAL WORKFLOW

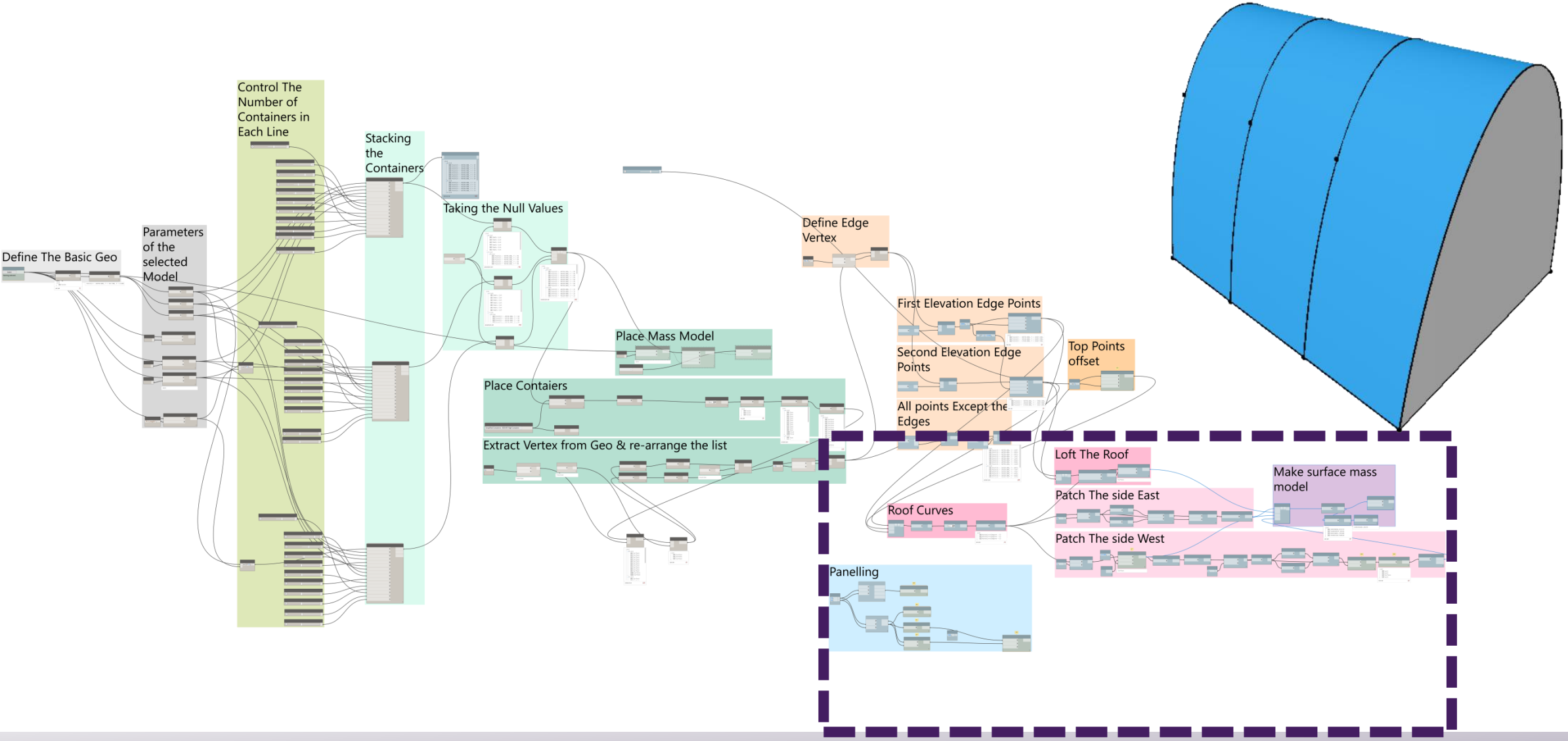


2.3 COMPUTATIONAL WORKFLOW

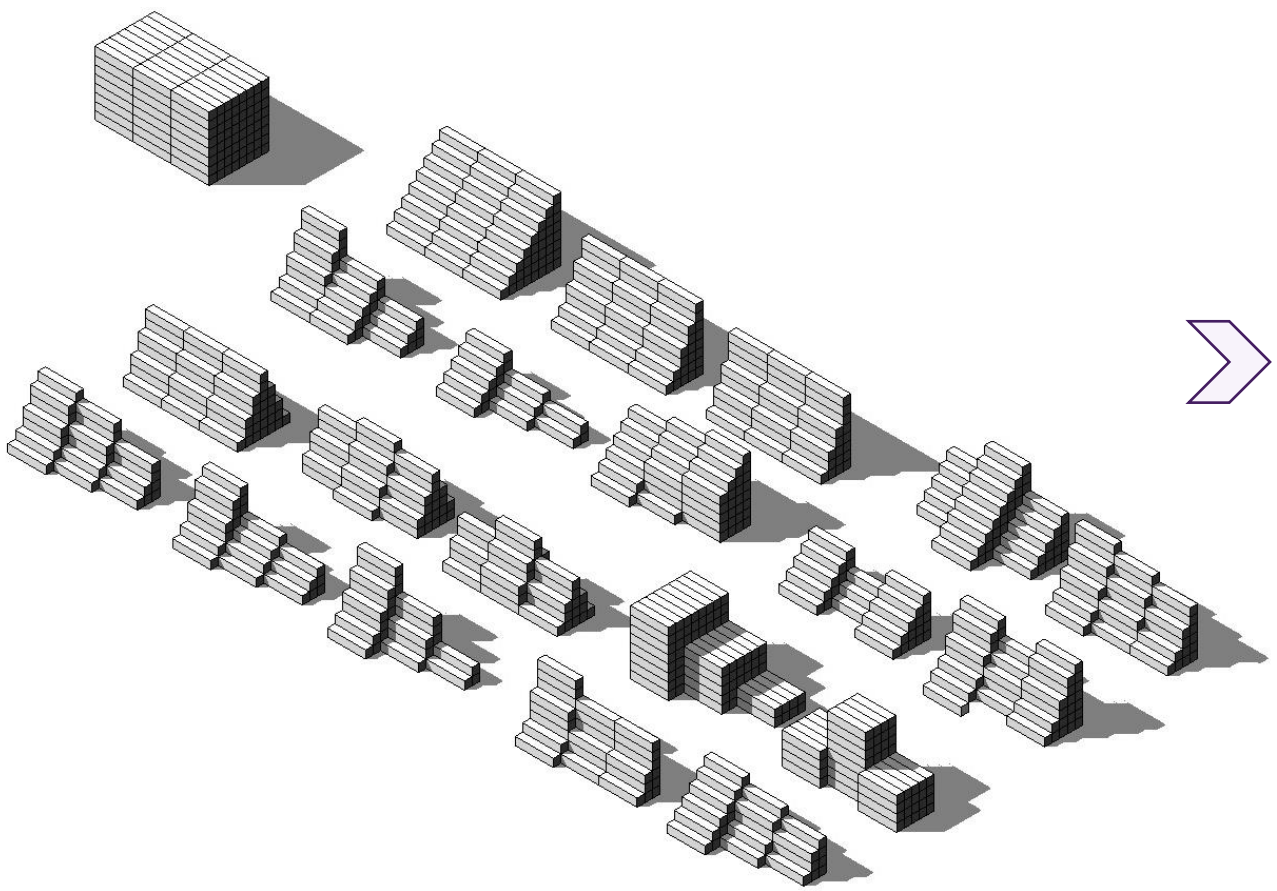


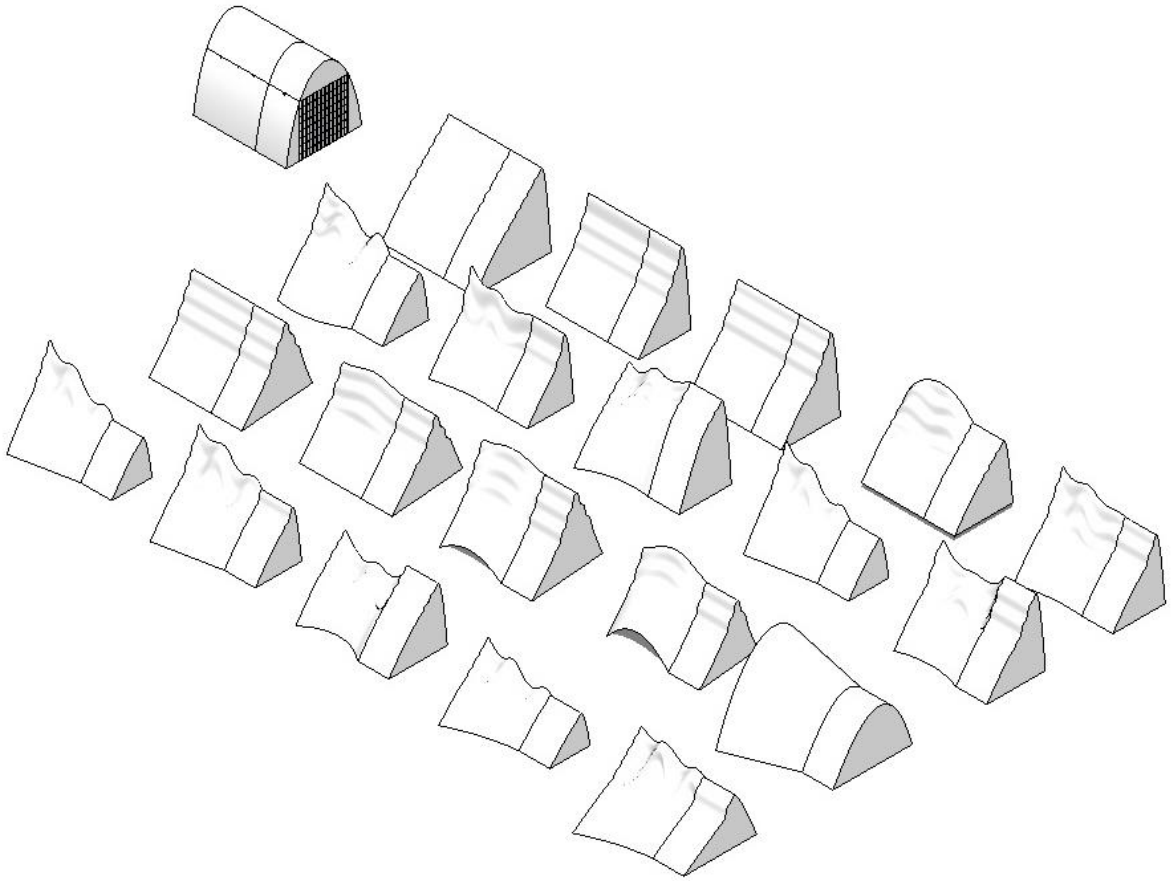


2.3 COMPUTATIONAL WORKFLOW

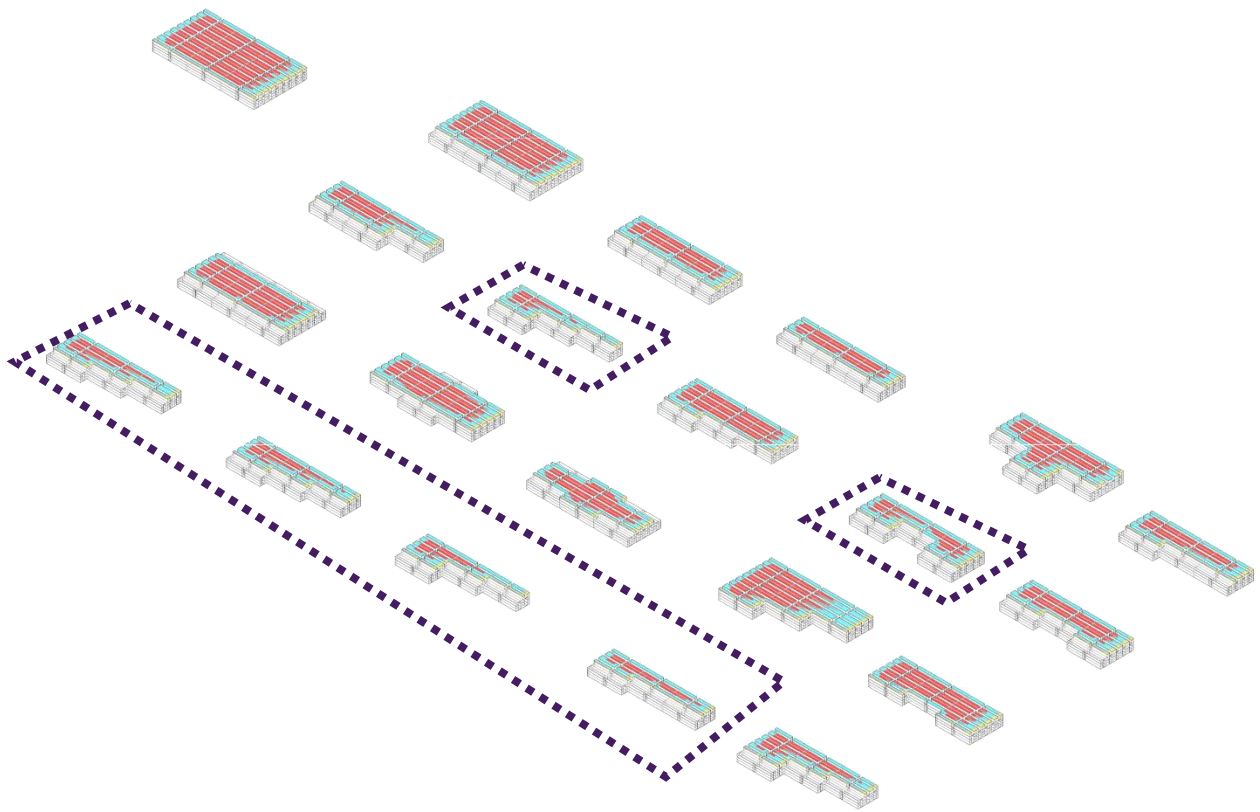


2.3 COMPUTATIONAL WORKFLOW

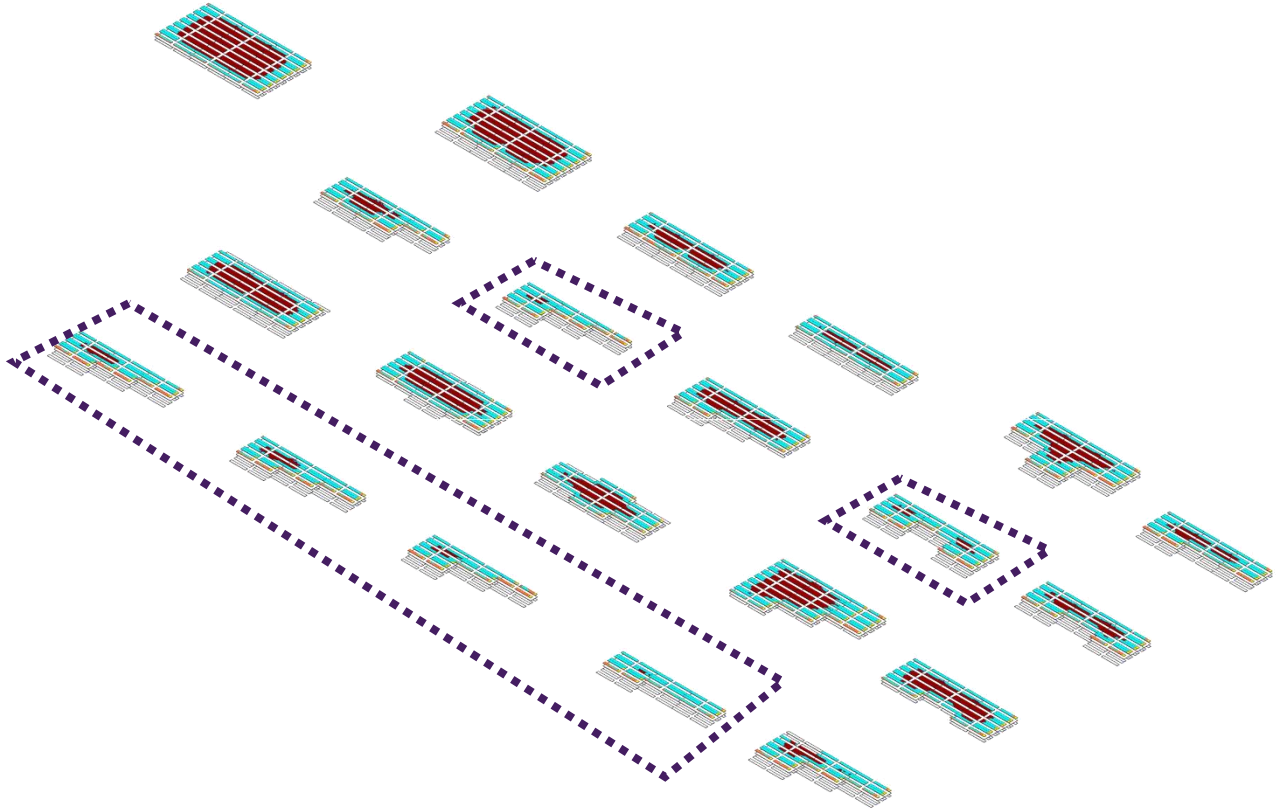




2.3 DAYLIGHT ANALYSIS PHASE ONE

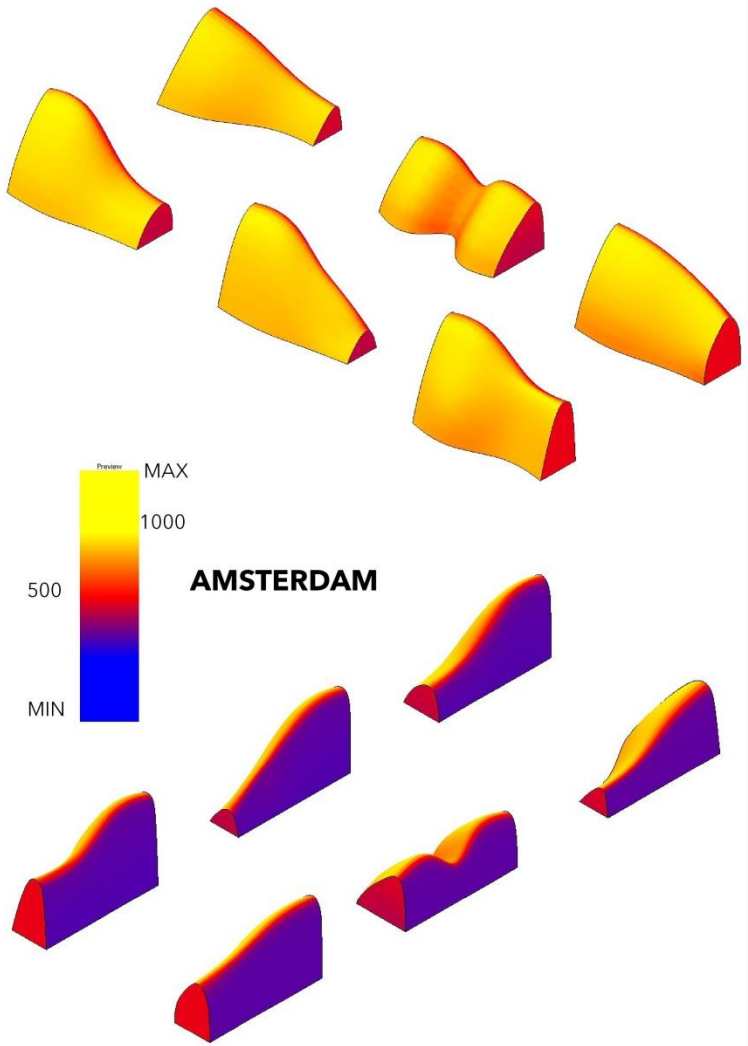


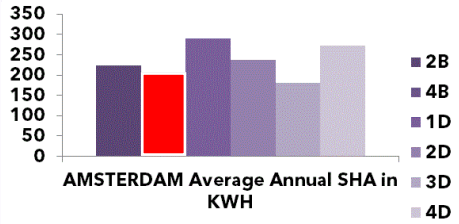
AMSTERDAM

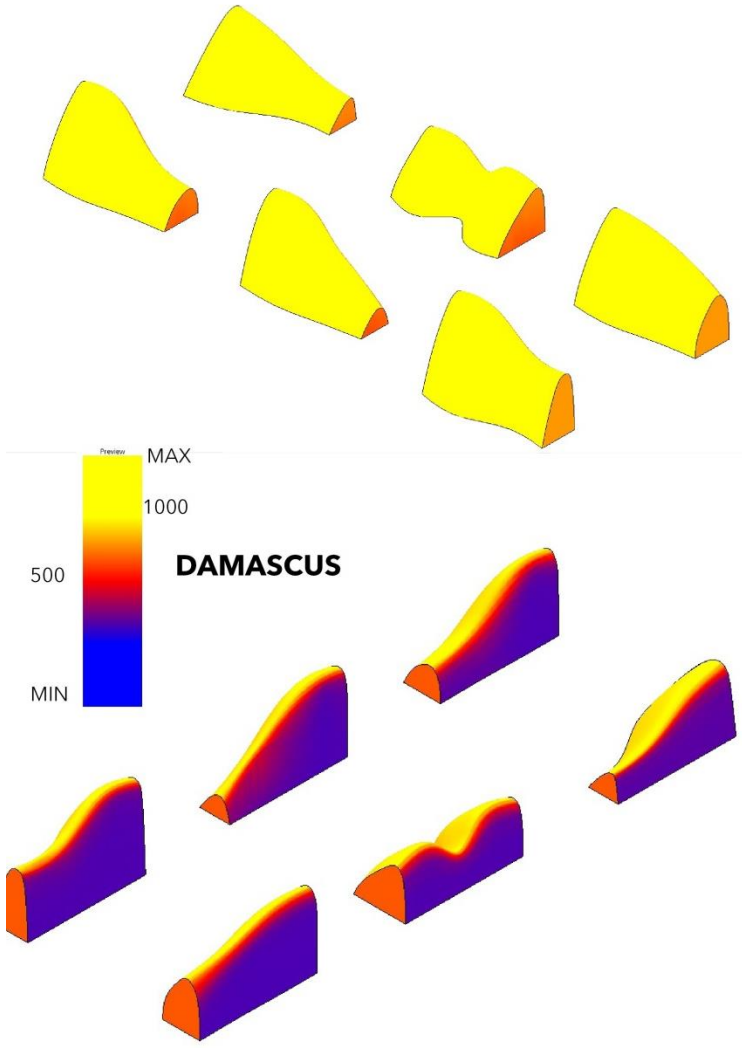


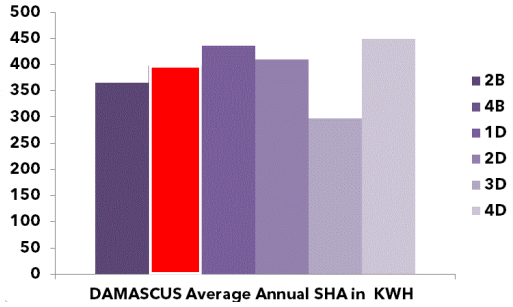
DAMASCUS

2.3 DAYLIGHT ANALYSIS PHASE ONE

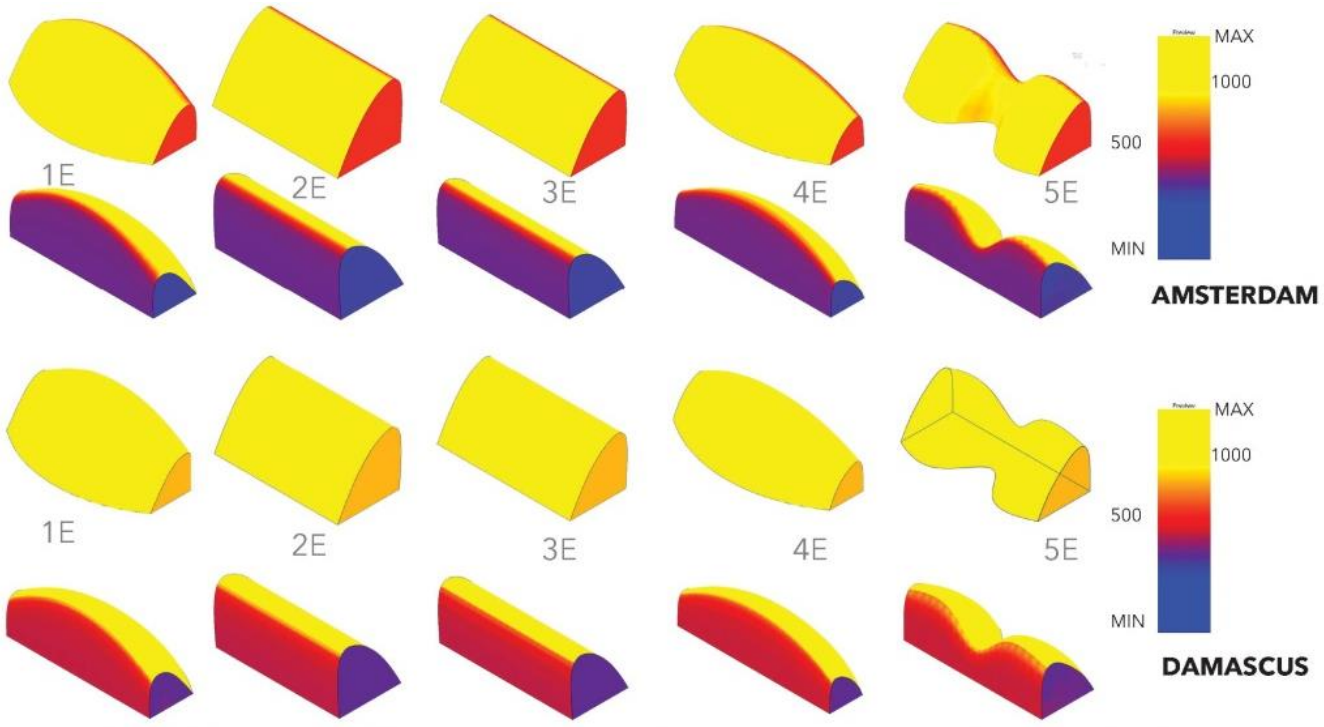


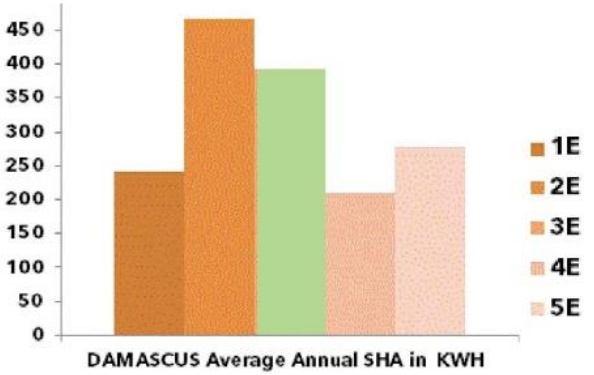




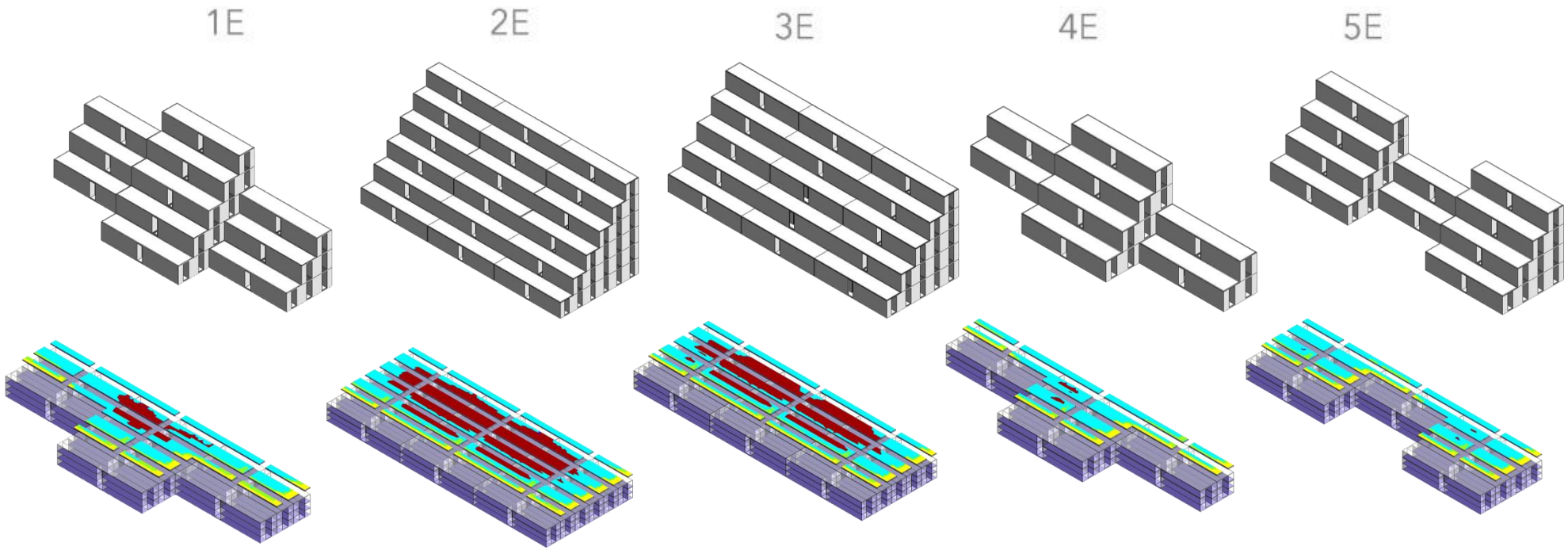


2.4 DAYLIGHT ANALYSIS PHASE TWO





2.4 DAYLIGHT ANALYSIS PHASE TWO

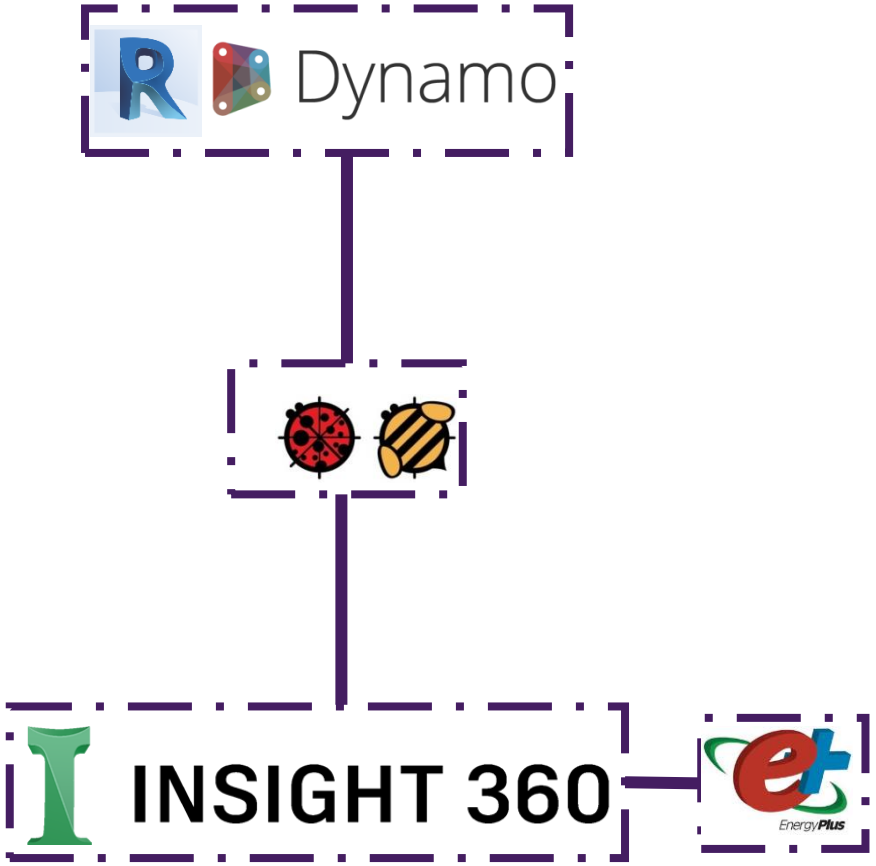


INDICATORS

-SOLAR GAIN (WH/M2)
-SUNLIGHT HOURS (HOURS)
-DAYLIGHT ILLUMINANCE

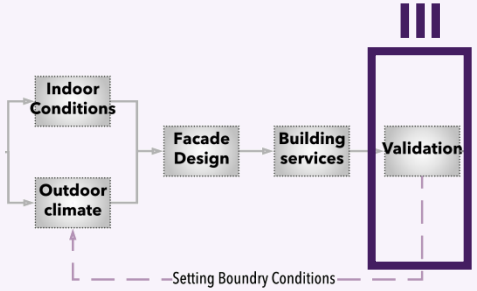
TARGET

- MINIMAL 85% LIGHTING
- INTERIOR TEMPERATURE 24-31
- 600 PPFD
- LOW EUI



3

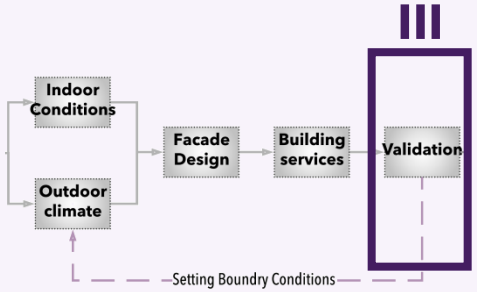
FINAL DESIGN



3.1 SELECTED CONFIGURATIONS
3.2 LOCATIONS
3.3 ENERGY OPTIMISATION
3.4 VISUALIZATION AMS

3

FINAL DESIGN

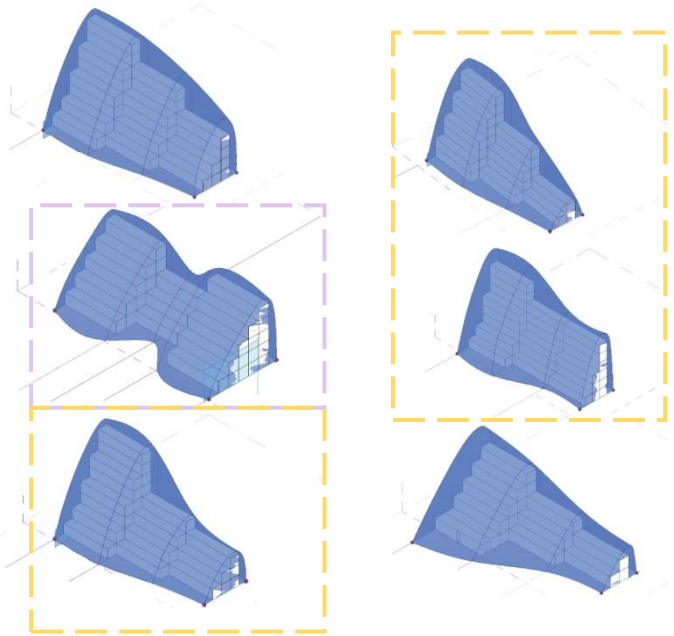


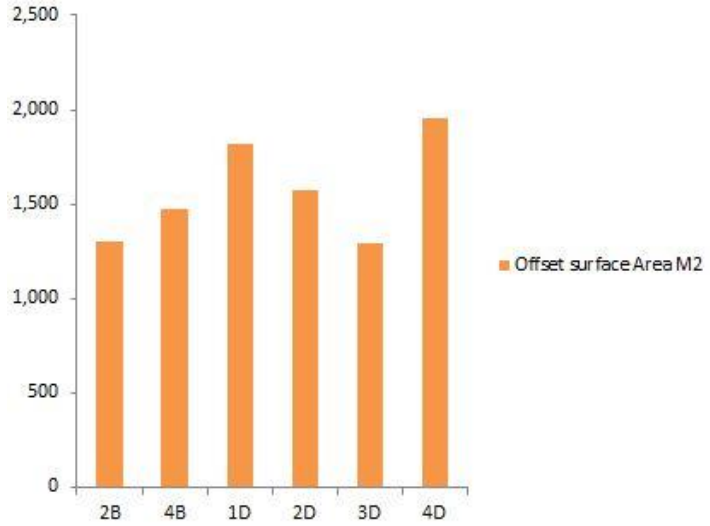
3.1 SELECTED CONFIGURATIONS

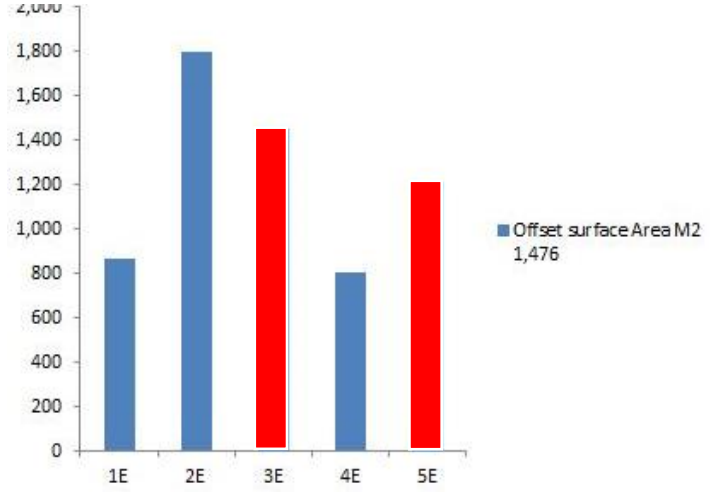
3.2 LOCATIONS

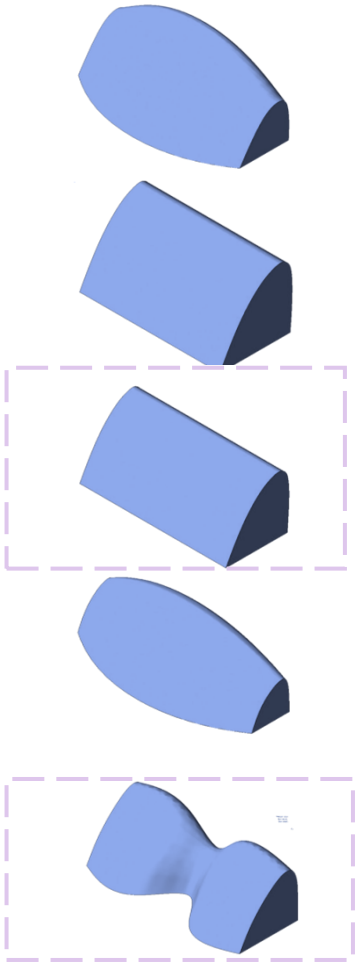
3.3 ENERGY OPTIMISATION

3.4 VISUALIZATION AMS



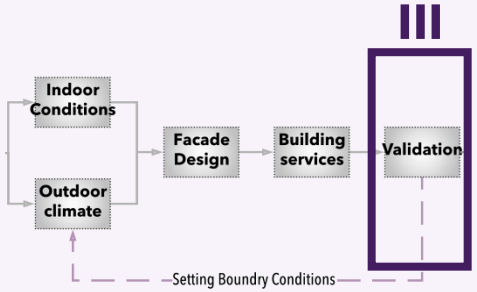

2,500
2,000
1,500
1,000
500
0
2B
4B
1D
2D
3D
4D
Offset surface Area M2


1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1E
2E
3E
4E
5E
Offset surface Area M2
1,476



3

FINAL DESIGN



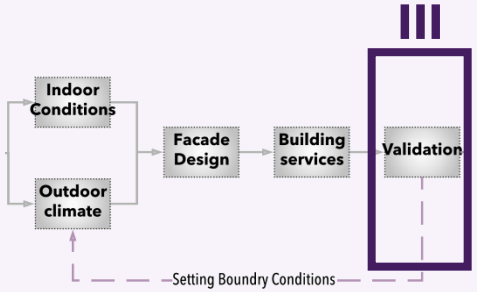
3.1 SELECTED CONFIGURATIONS
3.2 LOCATIONS
3.3 ENERGY OPTIMISATION
3.4 VISUALIZATION AMS

AMSTERDAM
AlMERE
THE SITE

THE SITE

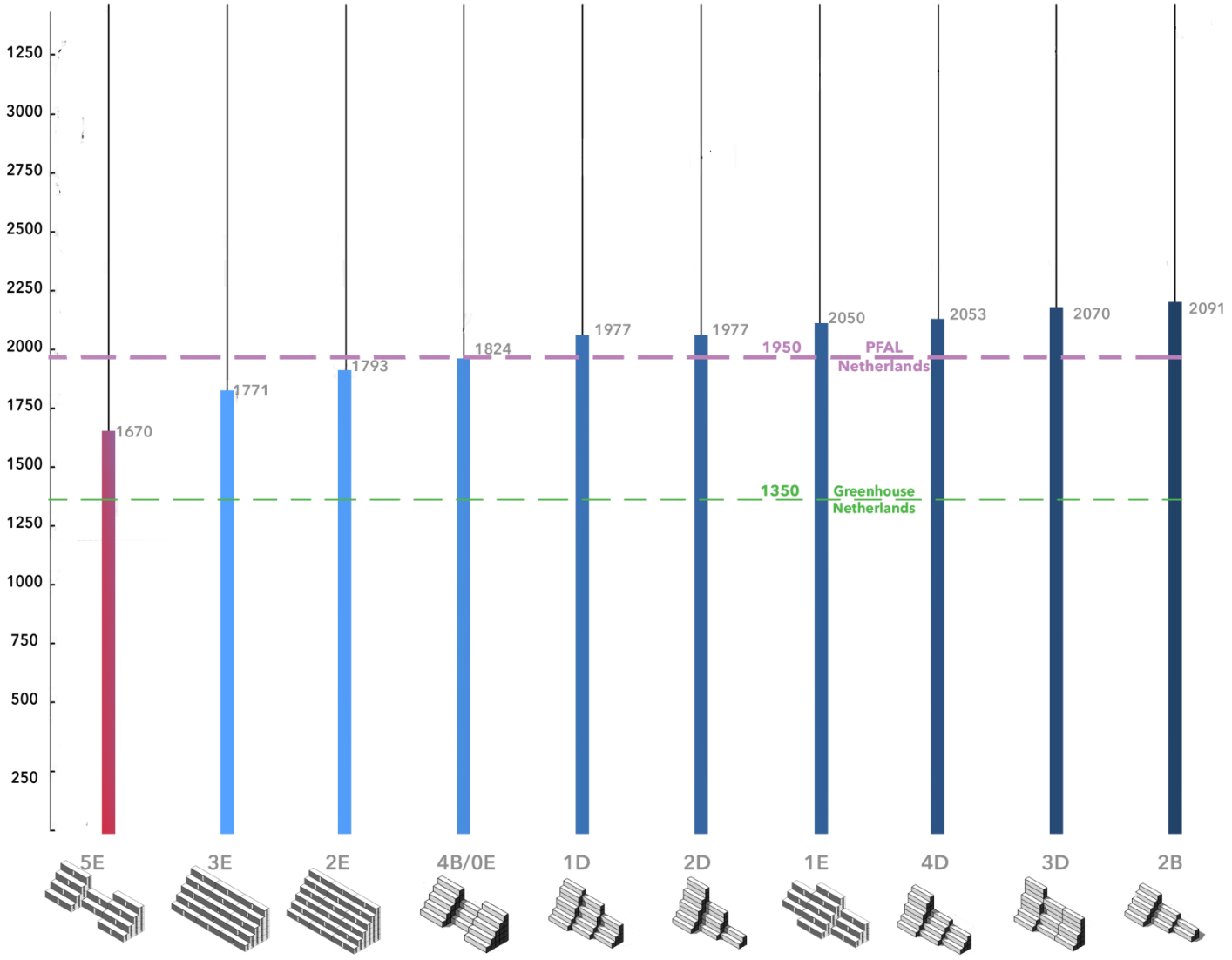
3

FINAL DESIGN



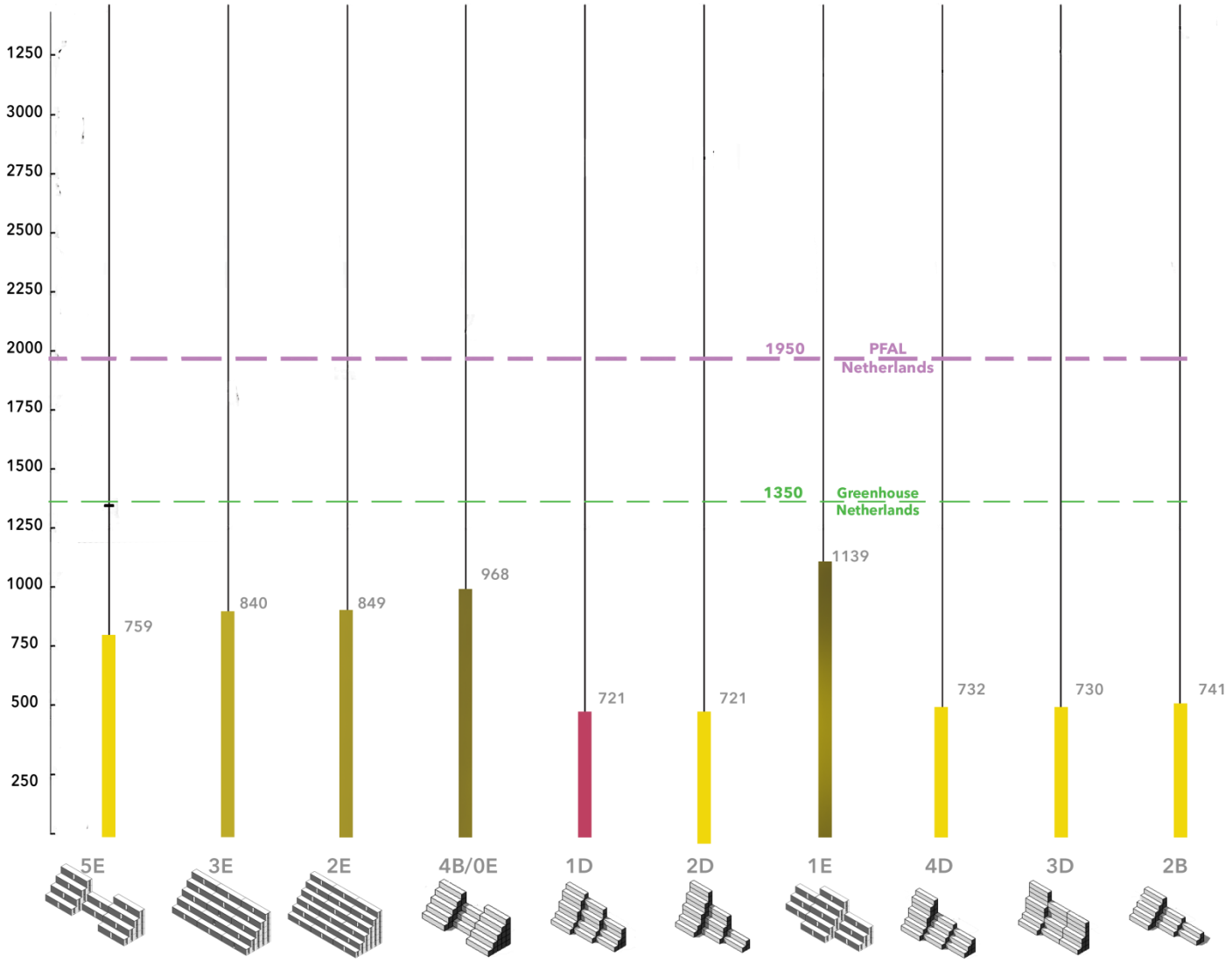
3.1 SELECTED CONFIGURATIONS
3.2 LOCATIONS
3.3 ENERGY OPTIMISATION
3.4 VISUALIZATION AMS

3.3 ENERGY OPTIMISATION



Model Comparison / AMS Selected Models

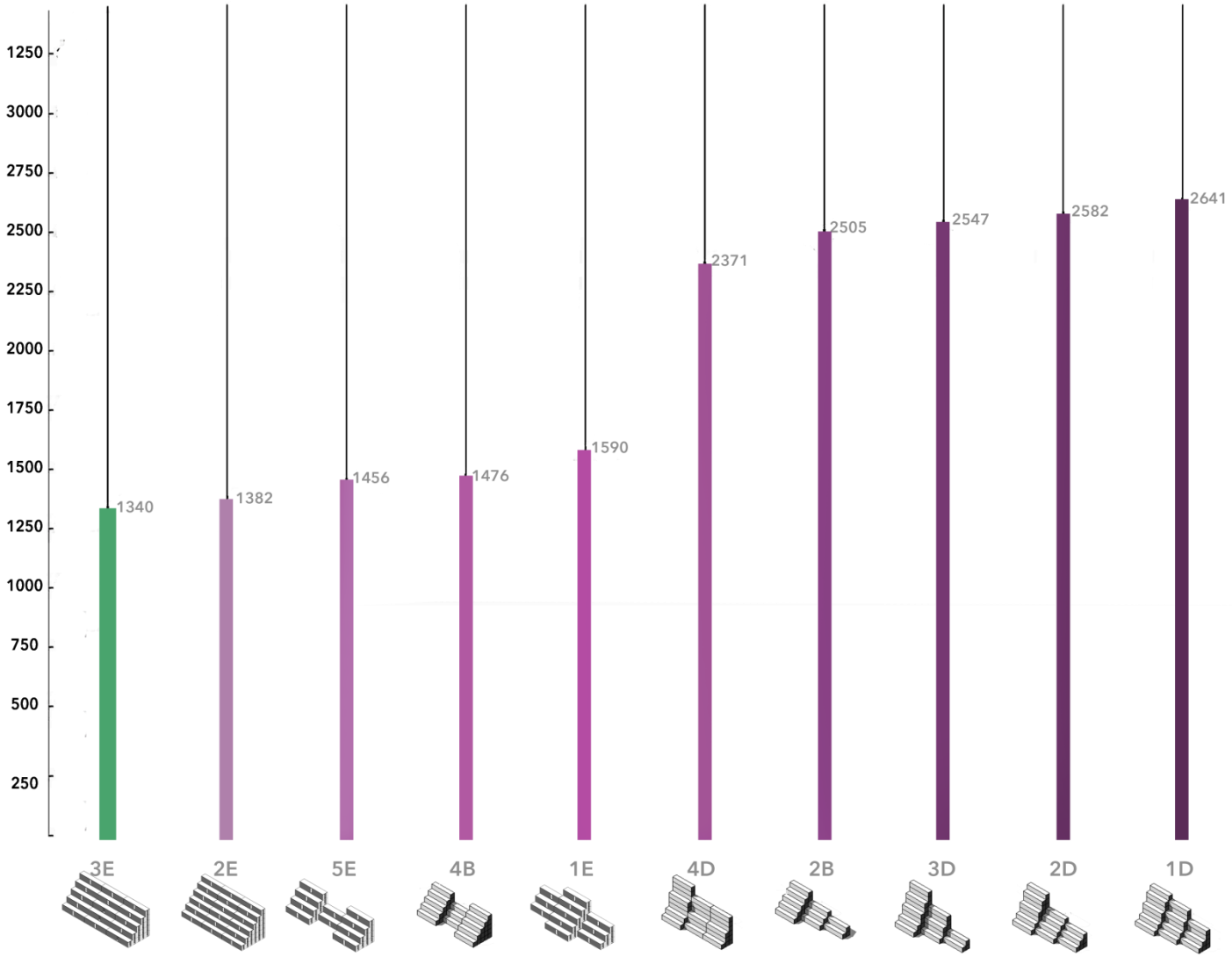
3.3 ENERGY OPTIMISATION



Model Comparison / AMS Selected Models

3.3 ENERGY OPTIMISATION

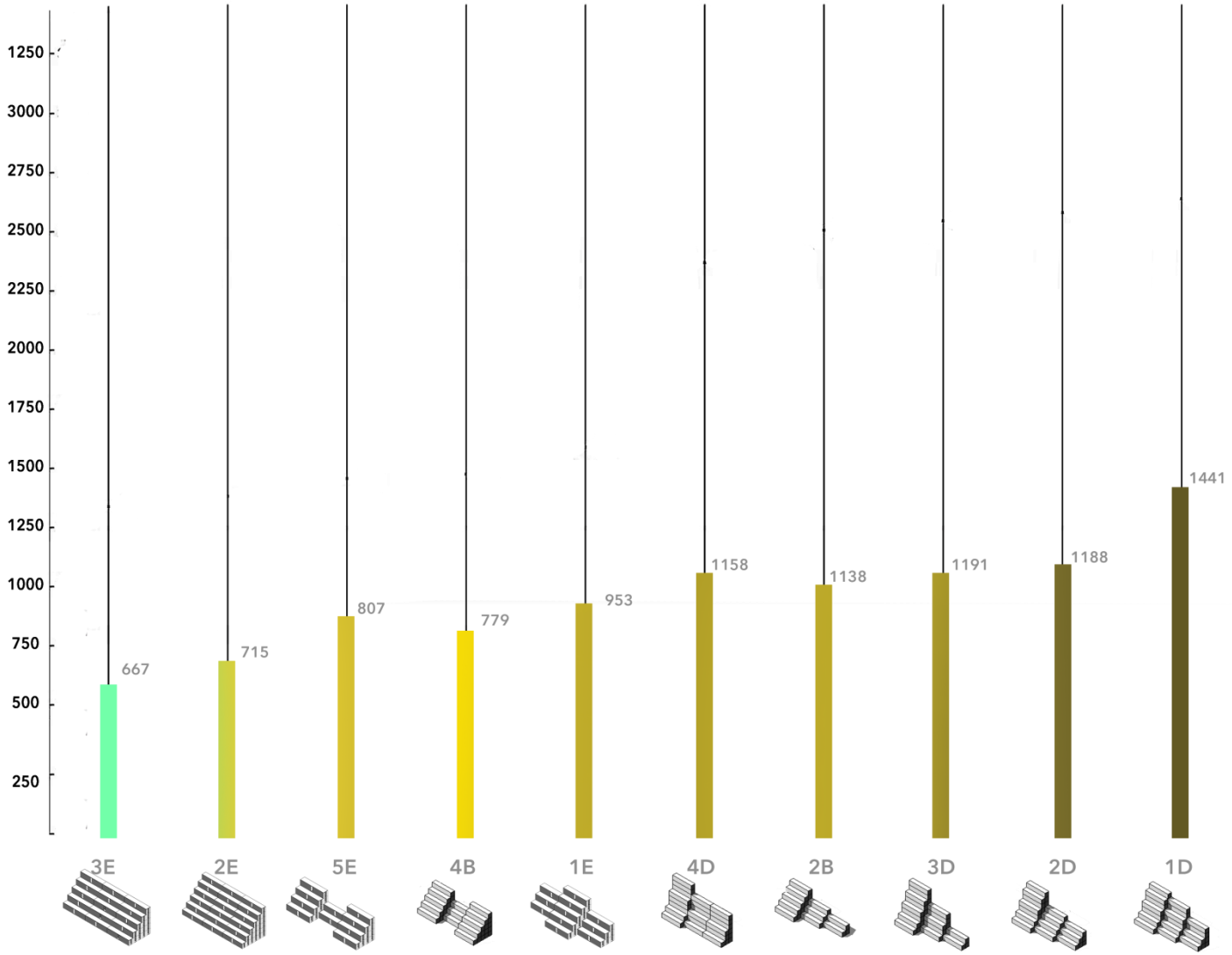
KWH/M2



Model Comparison / DAM Selected Model

3.3 ENERGY OPTIMISATION

KWH/M2

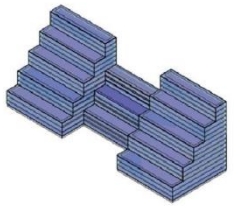


Model Comparison / DAM Selected Model

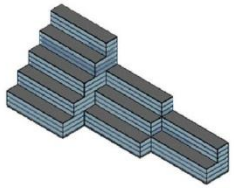
AMSTERDAM

Amsterdam

4B

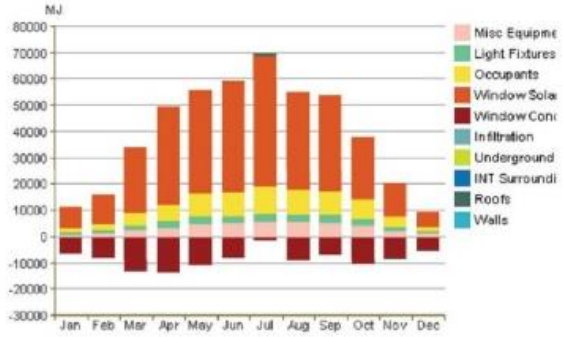


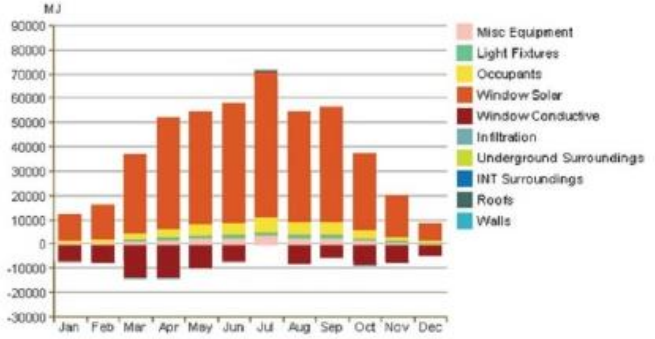
2B



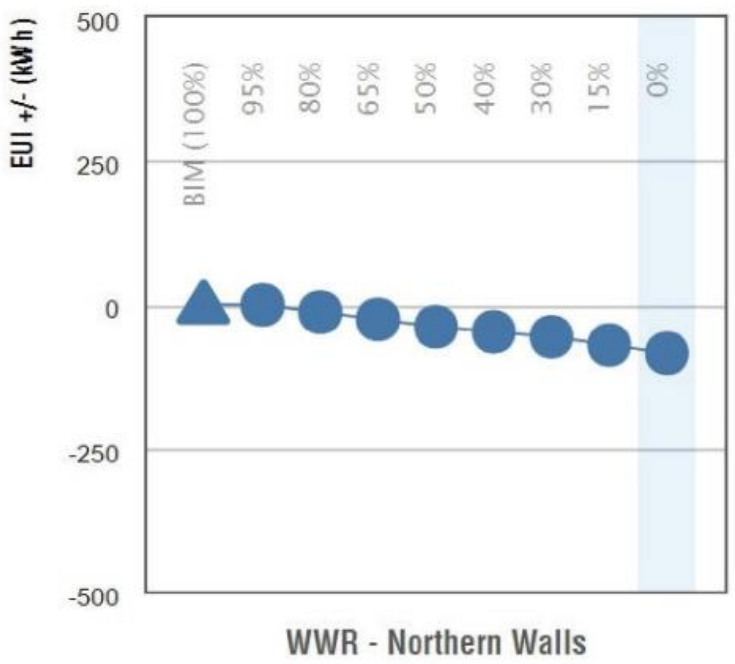
Monthly Heating Load

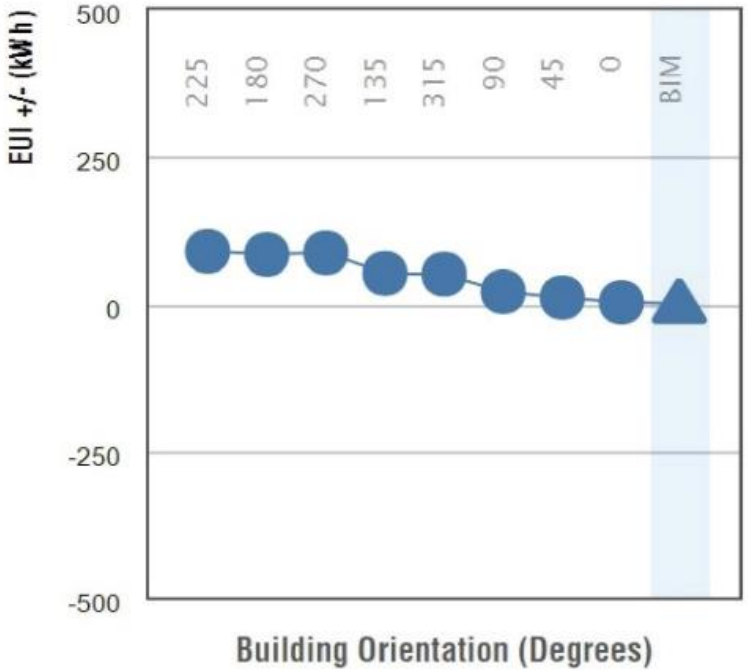
Monthly Cooling Load





AMSTERDAM

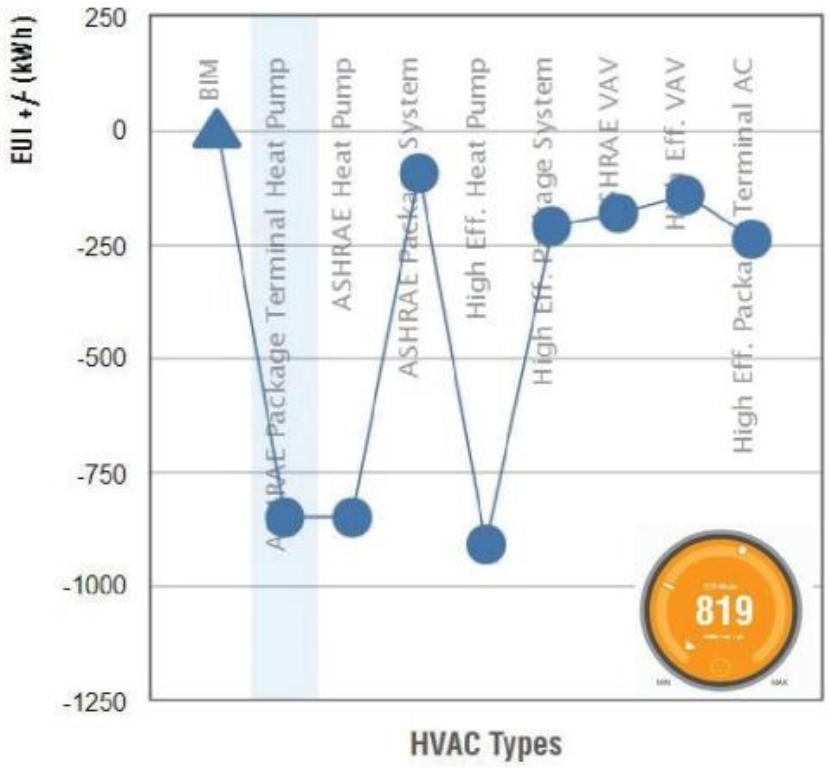

EUI +/- (kWh)
500
250
0
-250
-500
BIM (100%)
95%
80%
65%
50%
40%
30%
15%
0%
WWR - Northern Walls

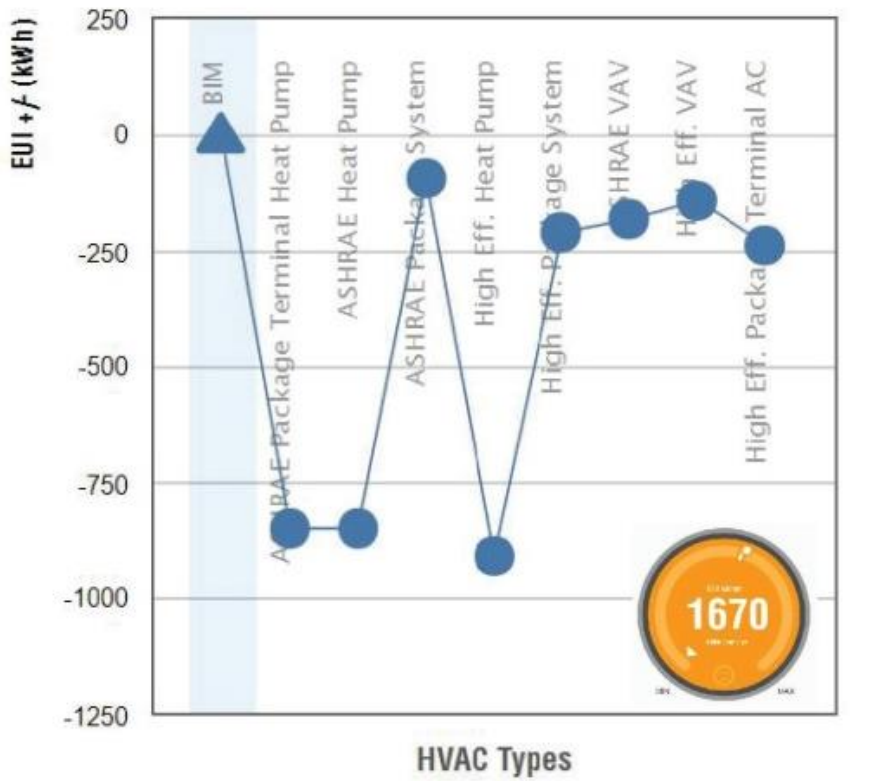

EUI +/- (kWh)
500
250
0
-250
-500
225
180
270
135
315
90
45
0
BIM
Building Orientation (Degrees)

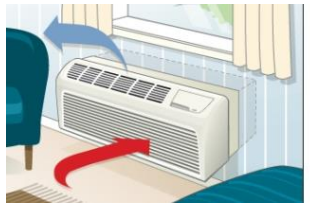
AMSTERDAM

Source: [De Zwart, Righini,2018]

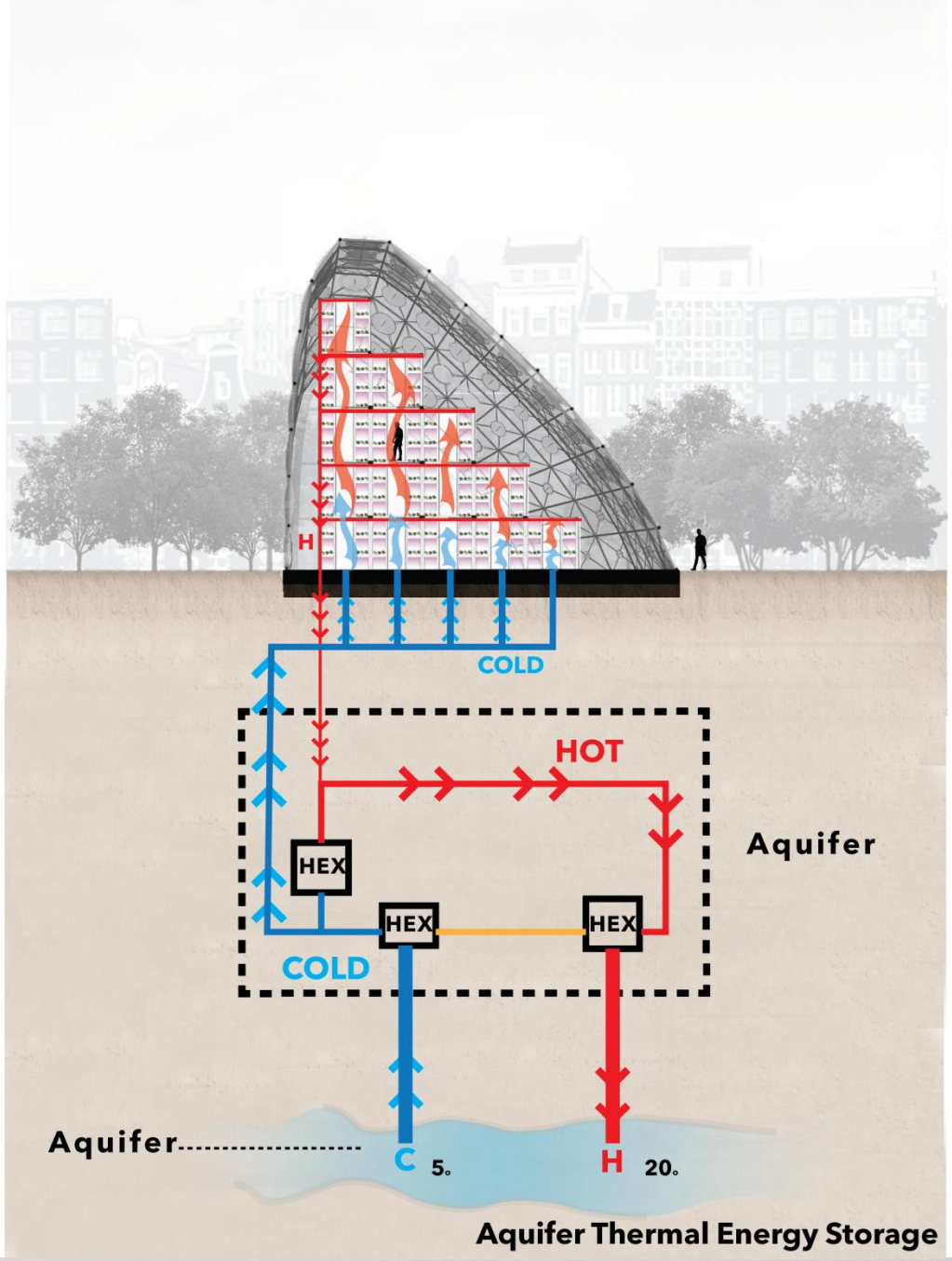
AMSTERDAM


EUI +/- (kWh)
250
0
-250
-500
-750
-1000
-1250
BIM
ASHRAE Package Terminal Heat Pump
ASHRAE Heat Pump
ASHRAE Packa System
High Eff. Heat Pump
High Eff. P age System
SHRAE VAV
H Eff. VAV
High Eff. Packa Terminal AC
819
HVAC Types


EUI +/- (kWh)
250
0
-250
-500
-750
-1000
-1250
BIM
RAE Package Terminal Heat Pump
ASHRAE Heat Pump
ASHRAE Packa System
High Eff. Heat Pump
High Eff. P age System
SHRAE VAV
H Eff. VAV
High Eff. Packa Terminal AC
1670
HVAC Types

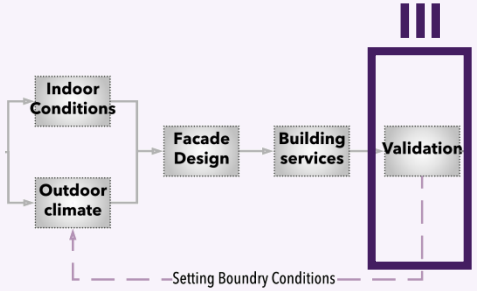


AMSTERDAM


H
COLD
HOT
HEX
HEX
HEX
COLD
Aquifer
Aquifer
C 5.
H 20.
Aquifer Thermal Energy Storage

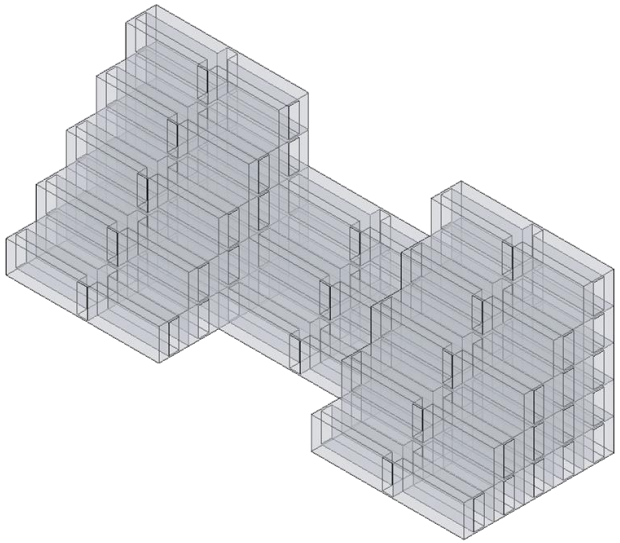
3

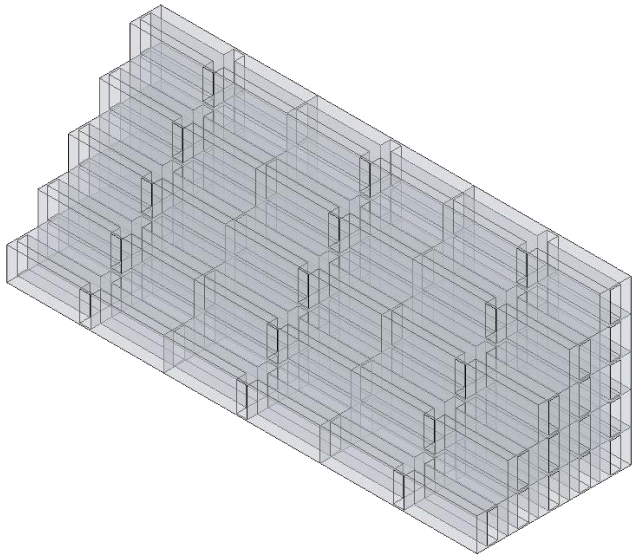
FINAL DESIGN



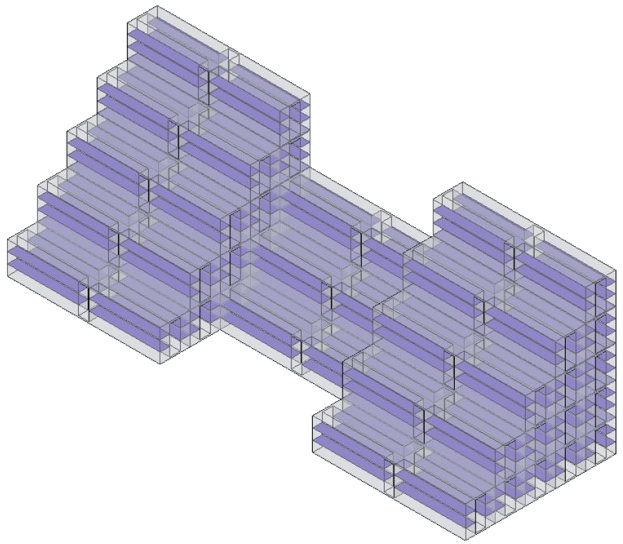
3.1 SELECTED CONFIGURATIONS
3.2 LOCATIONS
3.3 ENERGY OPTIMISATION
3.4 VISUALIZATION AMS

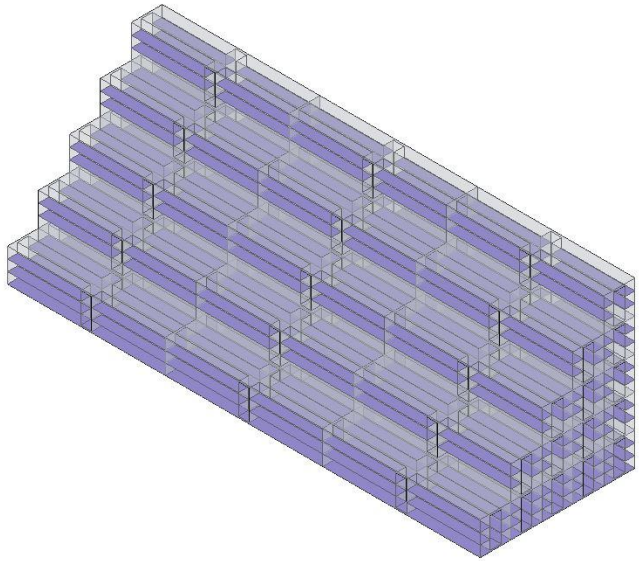
3.4 VISUALIZATION AMS



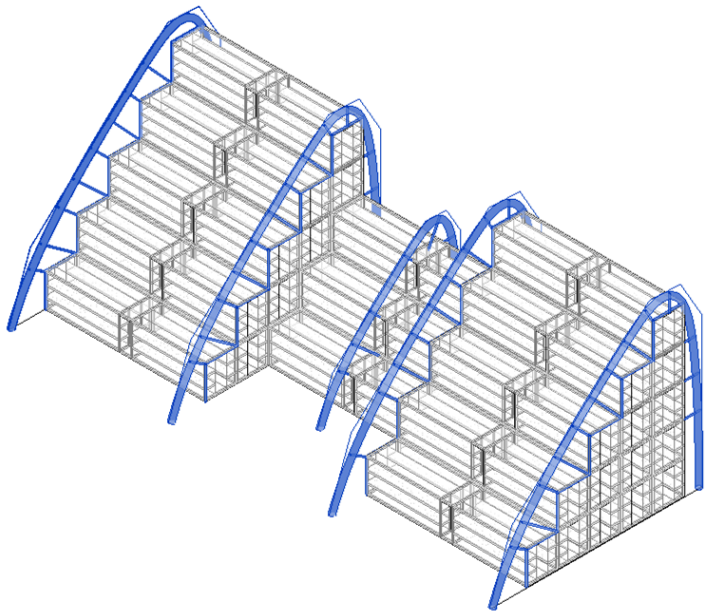


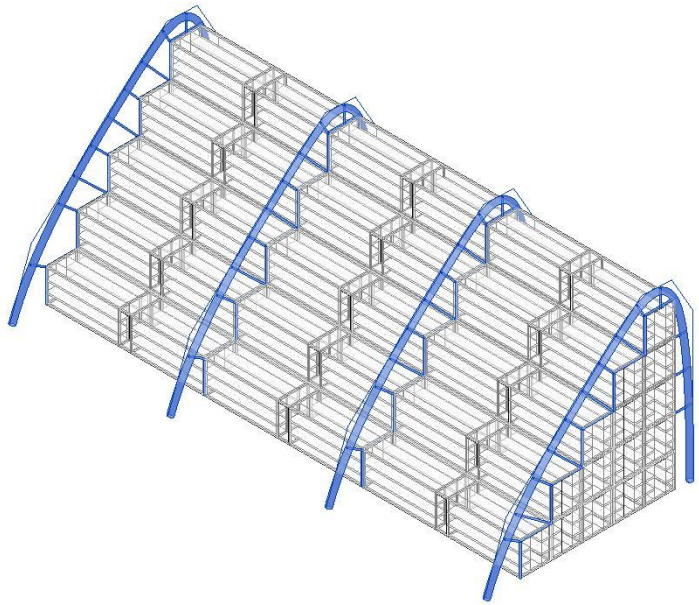
3.4 VISUALIZATION AMS



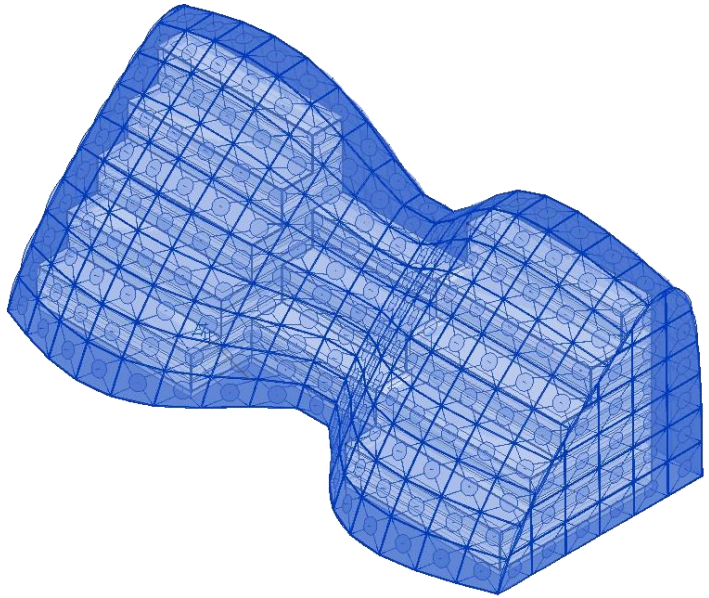


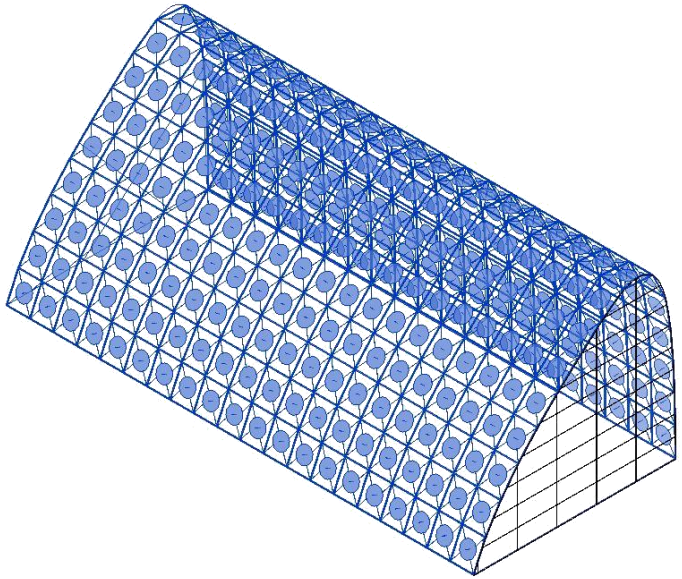
3.4 VISUALIZATION AMS



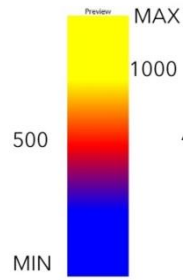


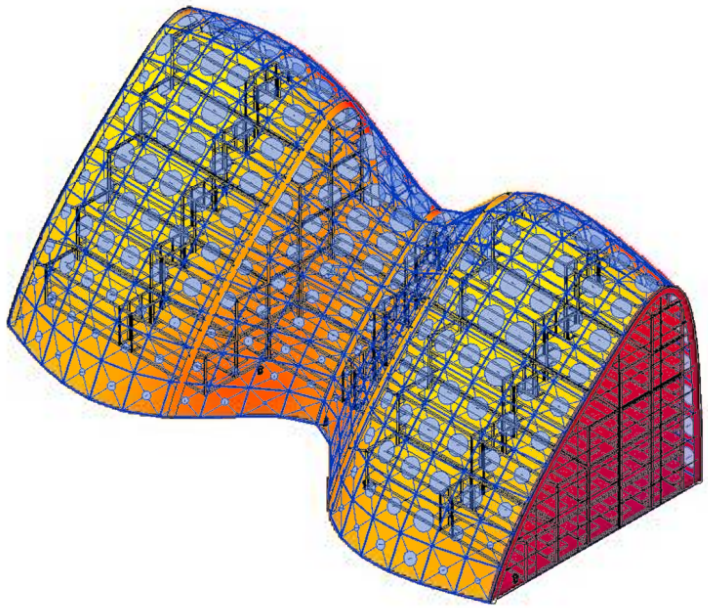
3.4 VISUALIZATION AMS

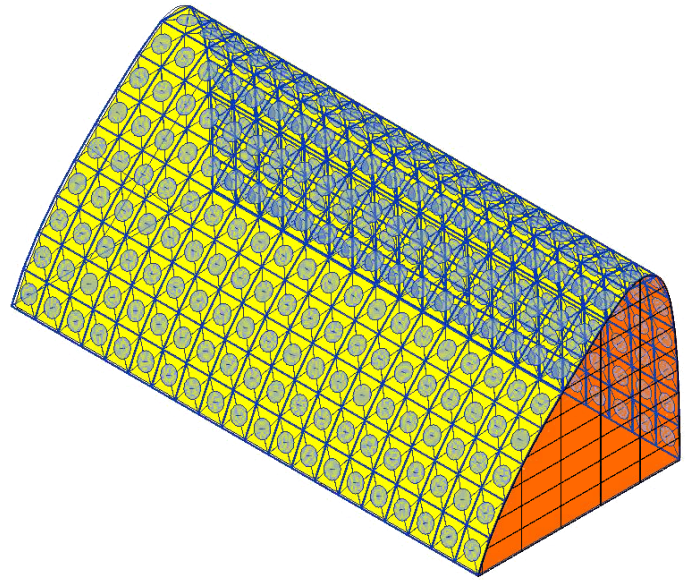


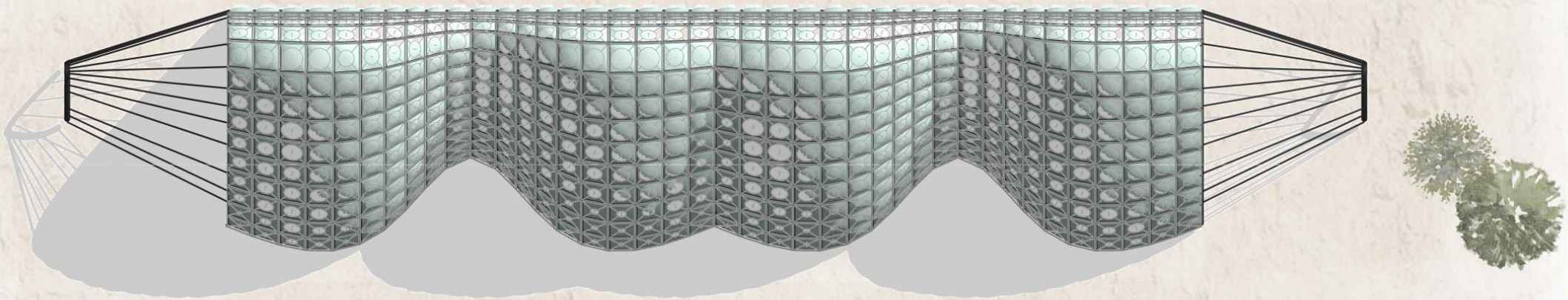


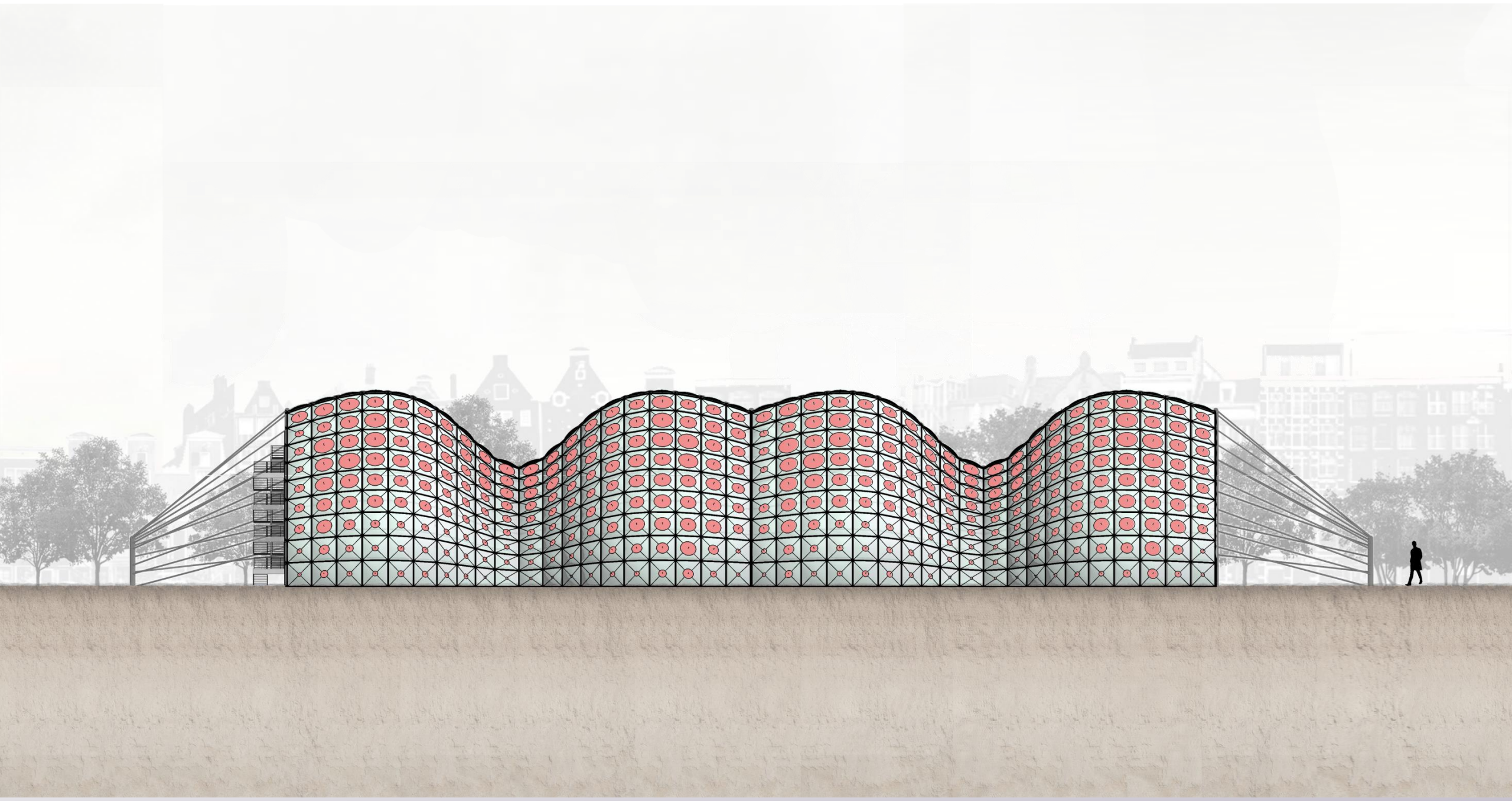
3.4 VISUALIZATION AMS

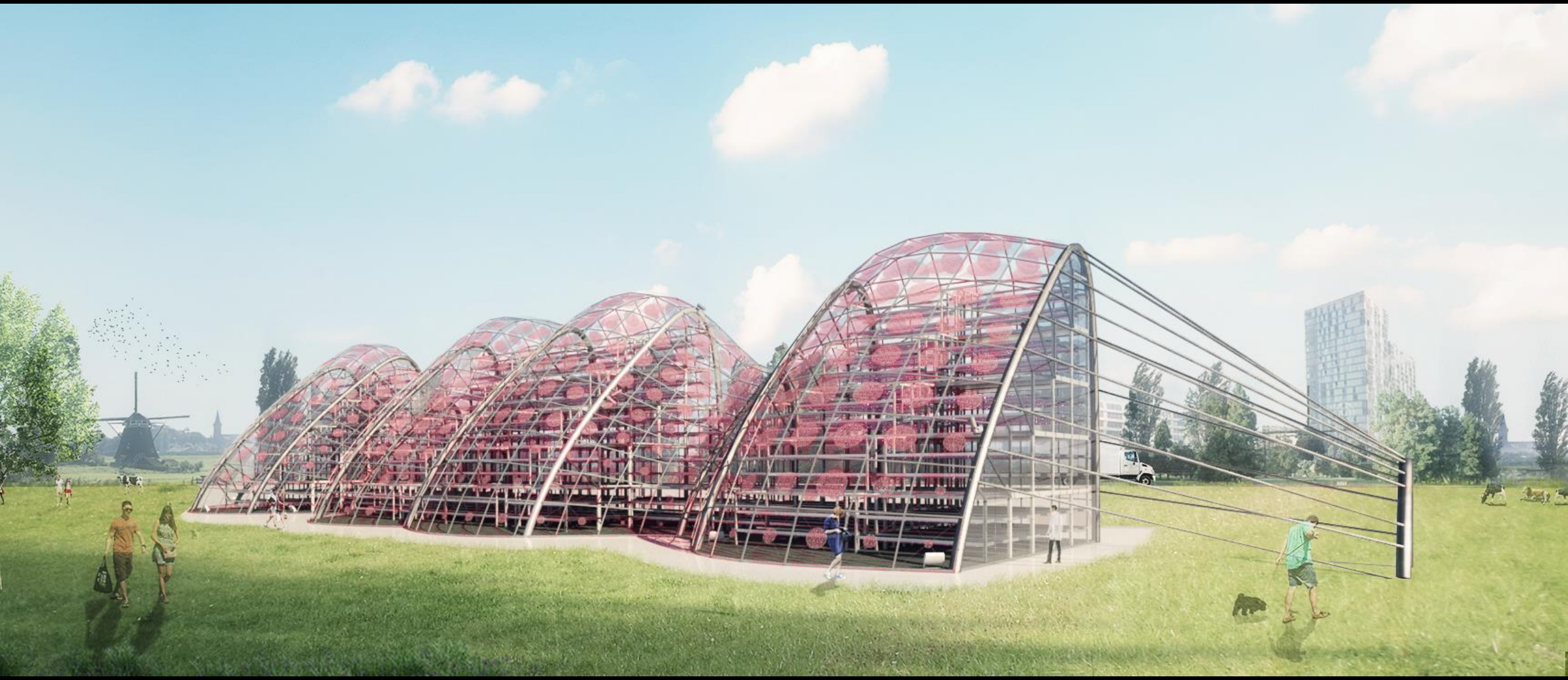




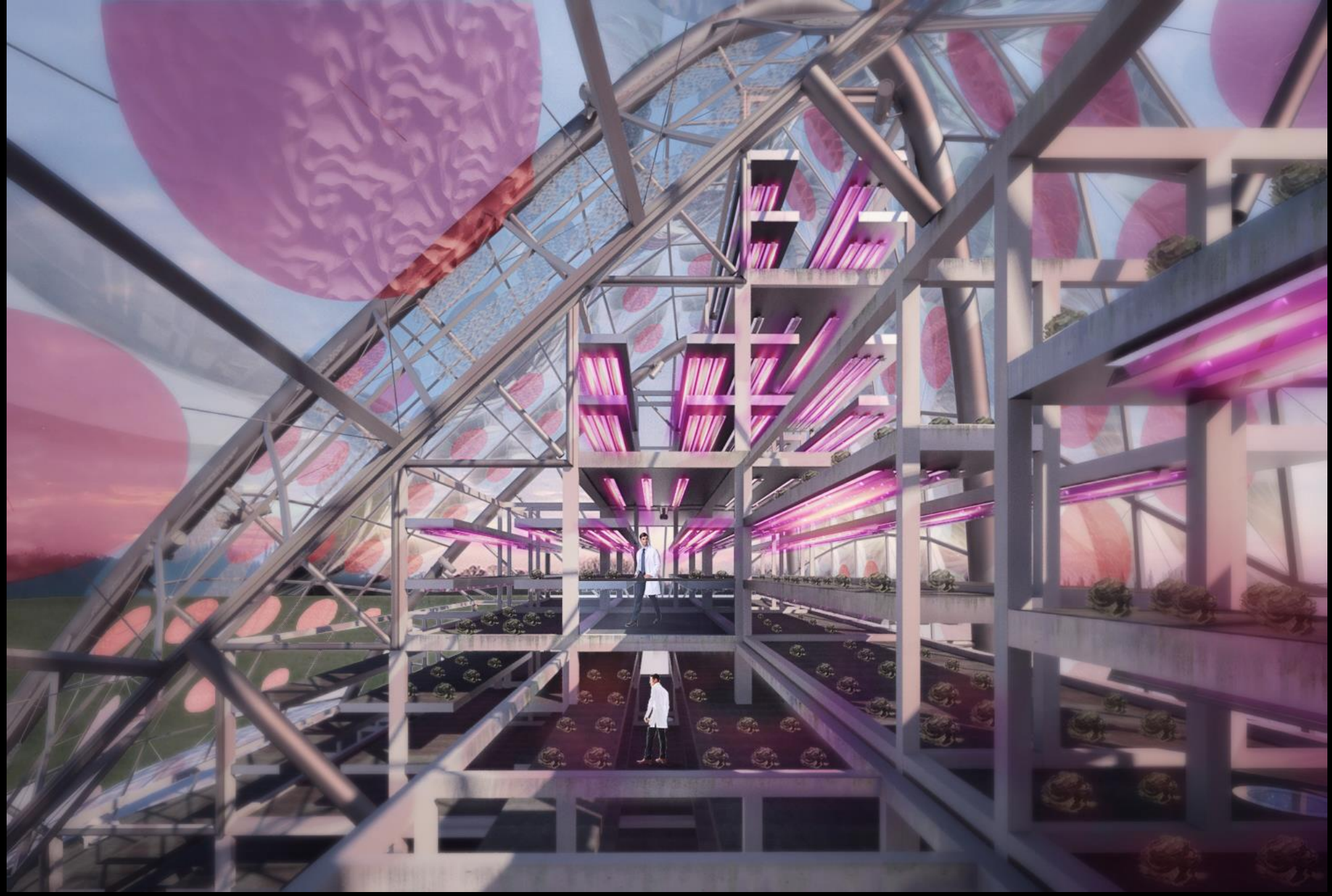








FINAL DESIGN-AMSTERDAM | MOBILE PLANT FACTORY| P5



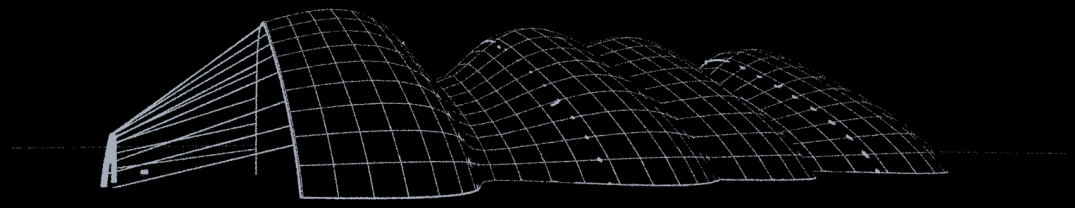
FINAL DESIGN-AMSTERDAM | MOBILE PLANT FACTORY| P5

FINAL DESIGN- DAMASCUS | MOBILE PLANT FACTORY| P5

FINAL DESIGN- DAMASCUS | MOBILE PLANT FACTORY| P5

“ The history of architecture is the history of the struggle for light ”

Le Corbusier



REFERENCES

NATURE ;Fibre-optical features of a glass sponge; Nature PublishingGroup; NATURE Vol 24; August 2003

Weaver James C. , Joanna Aizenberg, Georg E. Fantner. David Kisailus, Alexander Woesz d, Peter Allen a, Kirk Fields, Michael J. Porter, Frank W. Zok, Paul. Hansma, Peter Fratzl, Daniel E. Morse; Hierarchical assembly of the siliceous skeletal lattice of the hexactinellid sponge Euplectella aspergillum; Elsevier Inc. ; 2006

Hala A. Abd El-Aala, Amany M. Rizka, Ibrahim E. Mousab; Evaluation of new greenhouse covers with modified light regime to control cotton aphid and cucumber (Cucumis sativus L.) productivity; Elsevier; 2018

Annette LeCuyer; ETFE Building technology; Birkhauser; Germany; 2006

Hemming S. ; Wageningen UR Greenhouse Horticulture ; Use of Natural and Artificial Light in Horticulture - Interaction of Plant and Technology; Wageningen, The Netherlands; 2011