

# Green facade and photovoltaics on an existing building





FINA PARKHAUS  
Mannheim, Richard-Wagner Str.



STUDIARENDEWOHNHEIM  
Mannheim, Hafenstr a e



STUDIARENDEWOHNHEIM  
Mannheim, Carl-Zuckmayer Str.



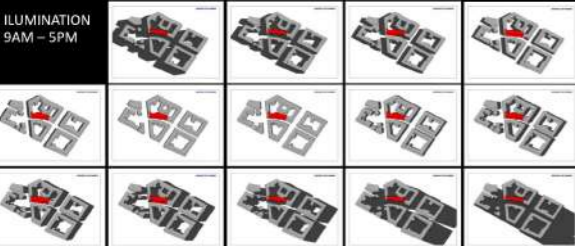
RADIO TOWER  
Bratislava, Slovakia



Seestern II  
D usseldorf



SUMMER SOLSTICE 7AM – 8PM



SUMMER SOLSTICE 5AM – 8PM



SUMMER SOLSTICE 5AM – 8PM



SUMMER SOLSTICE 4AM – 7PM



SUMMER SOLSTICE 5AM – 8PM



- S W O T
- function
  - two parts, two different GF systems
  - insufficient illumination
  - shading
  - design improvement
  - thermal improvement
  - longevity

- S W O T
- sufficient illumination
  - no shading
  - lately refurbished
  - enough greenery in proximity
  - no need for attraction
  - biodiversity
  - damage to former refurbishmet

- S W O T
- sufficient illumination
  - no need for attraction
  - design improvement
  - maintenance

- S W O T
- prominent building
  - urban centre
  - shading
  - monument protection
  - public dissatisfaction with the decling design
  - controversial entity

- S W O T
- prominent building
  - sufficient illumination
  - roof and facade size
  - parking situation
  - site revitalisation
  - space for employees
  - unused terraces, roofs, facades



# DÜSSELDORF

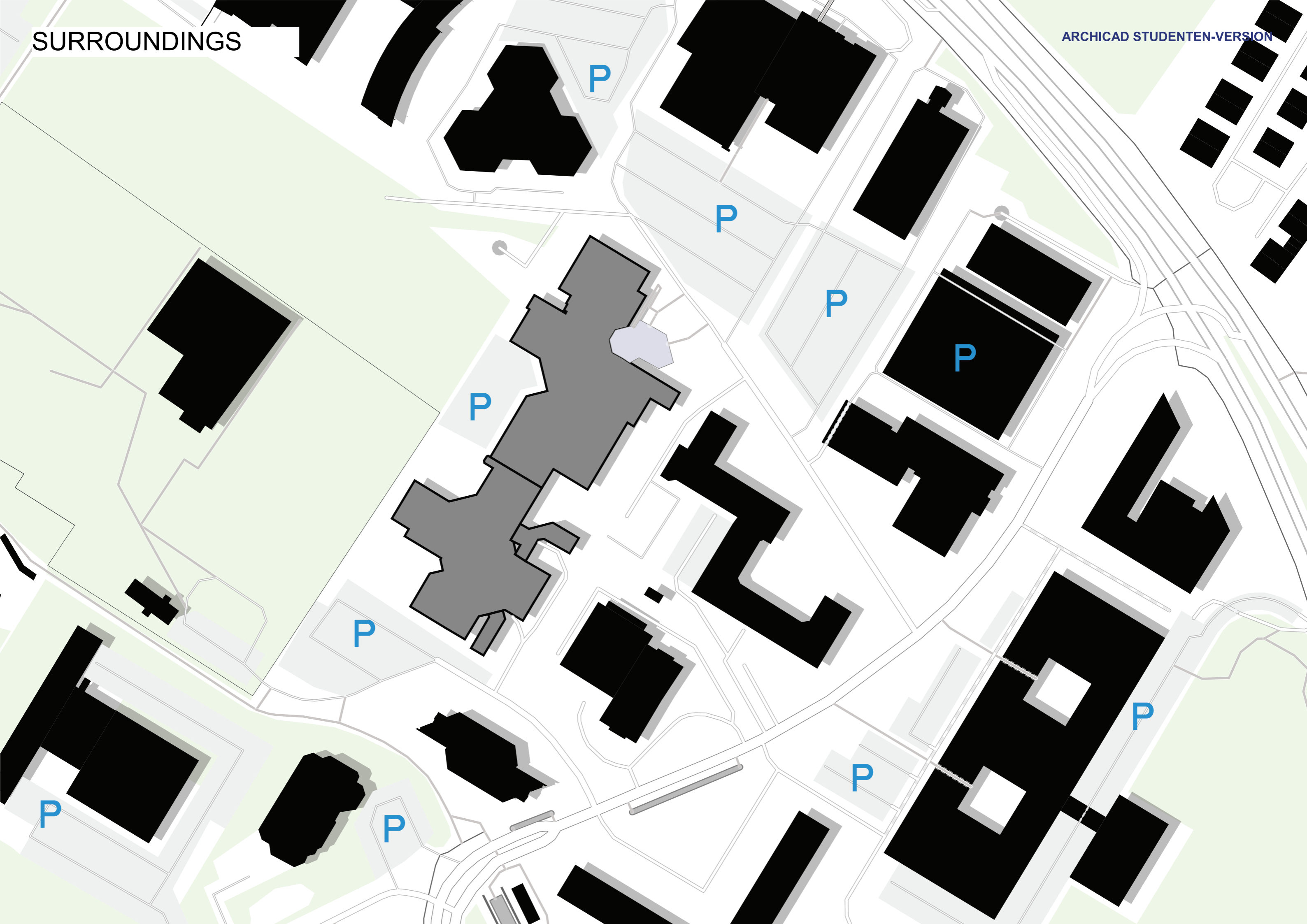
ARCHICAD STUDENTEN-VERSION













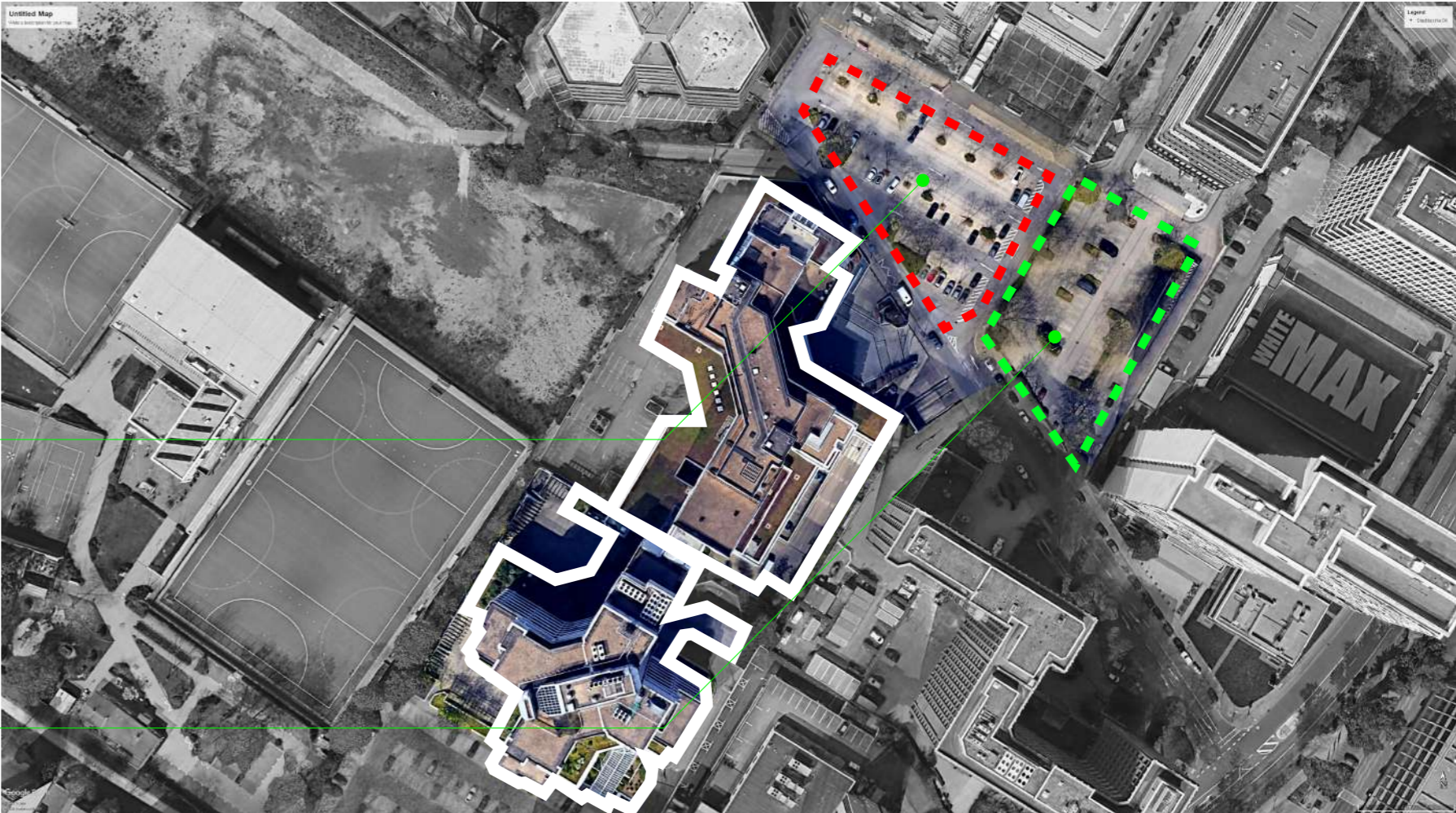




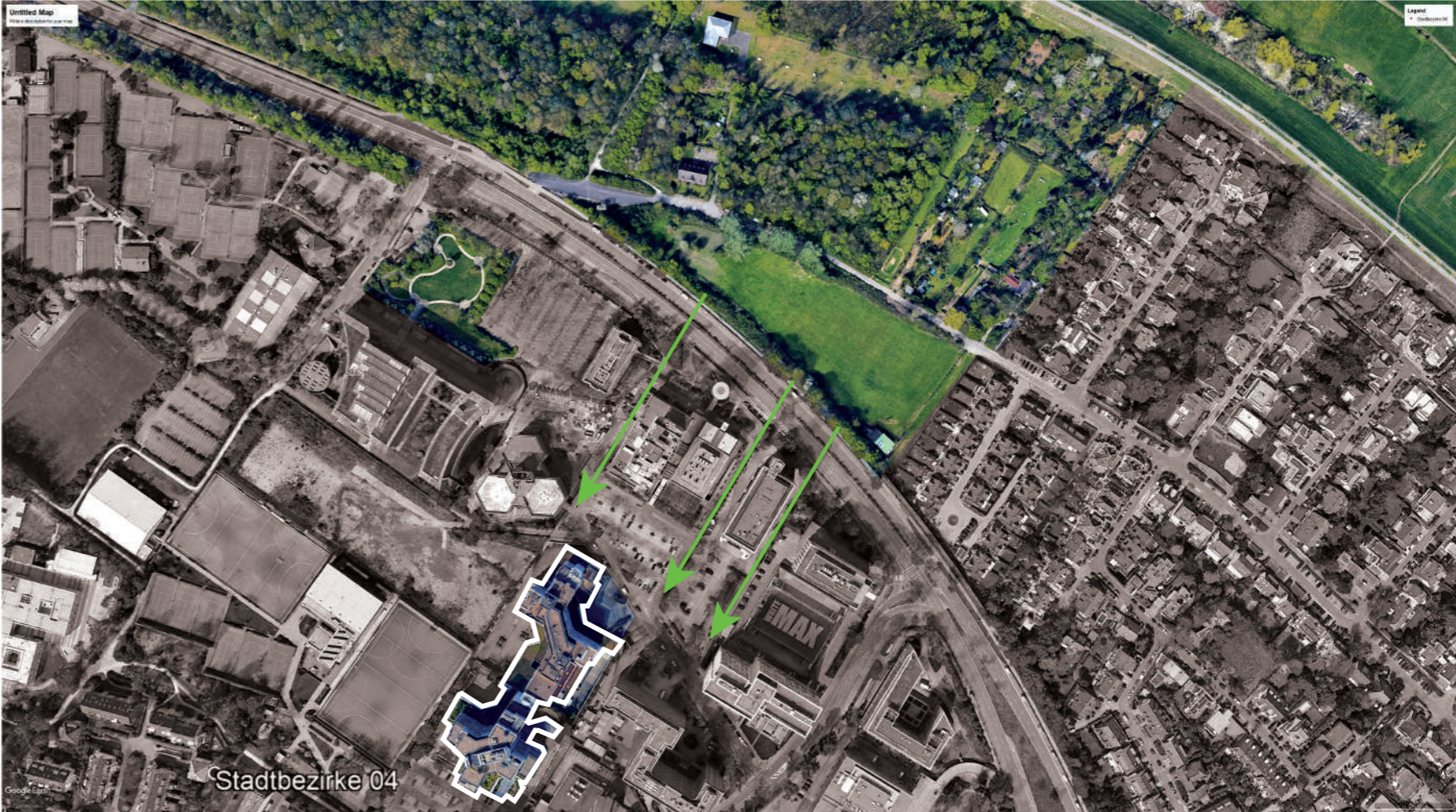
# SITE POTENTIAL

VEGETATION AREA  
instead of parking lots

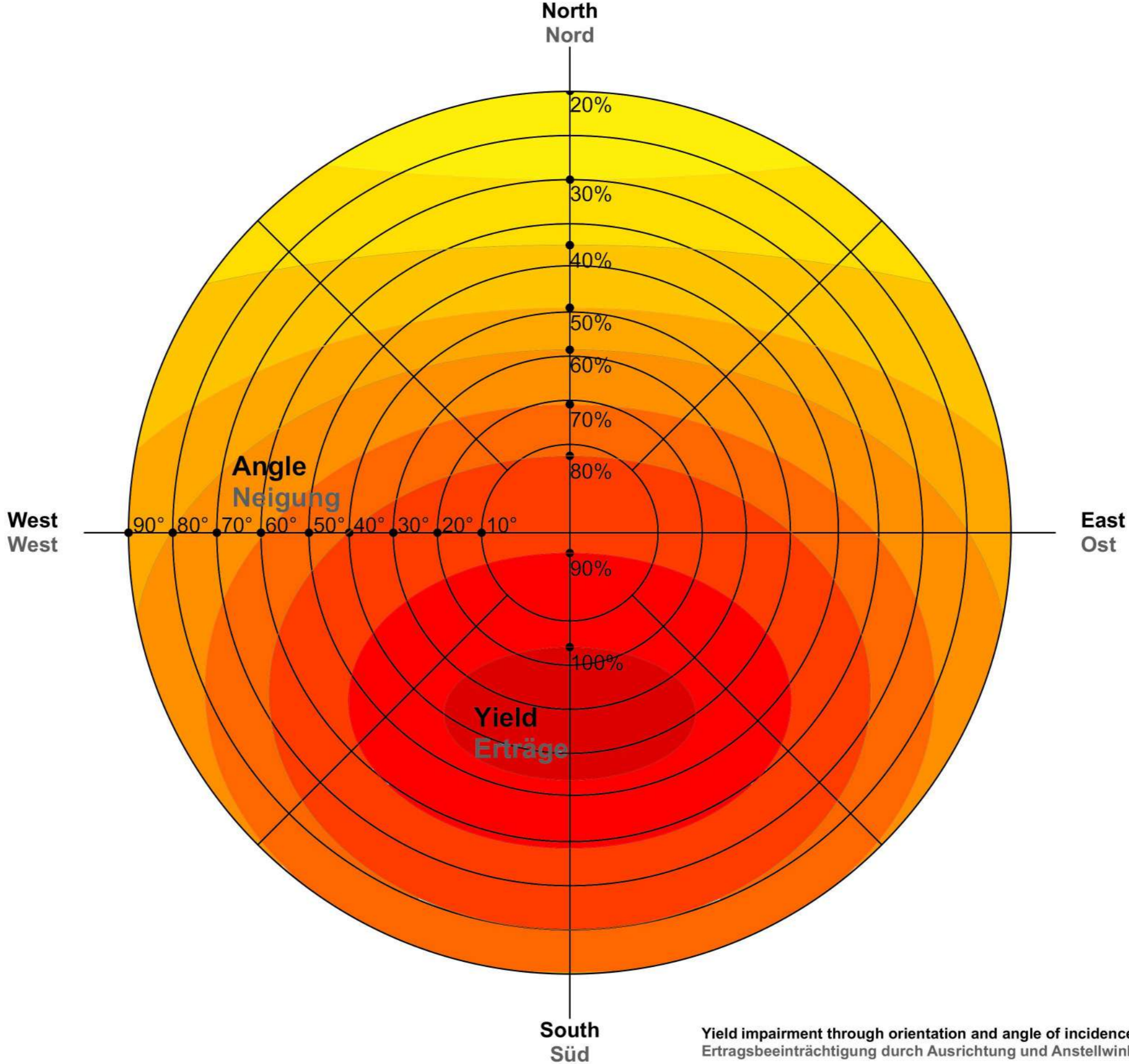
PARKING GARAGE  
instead of parking lots



BRINGING VEGETATION CLOSER TO THE  
BUILDING









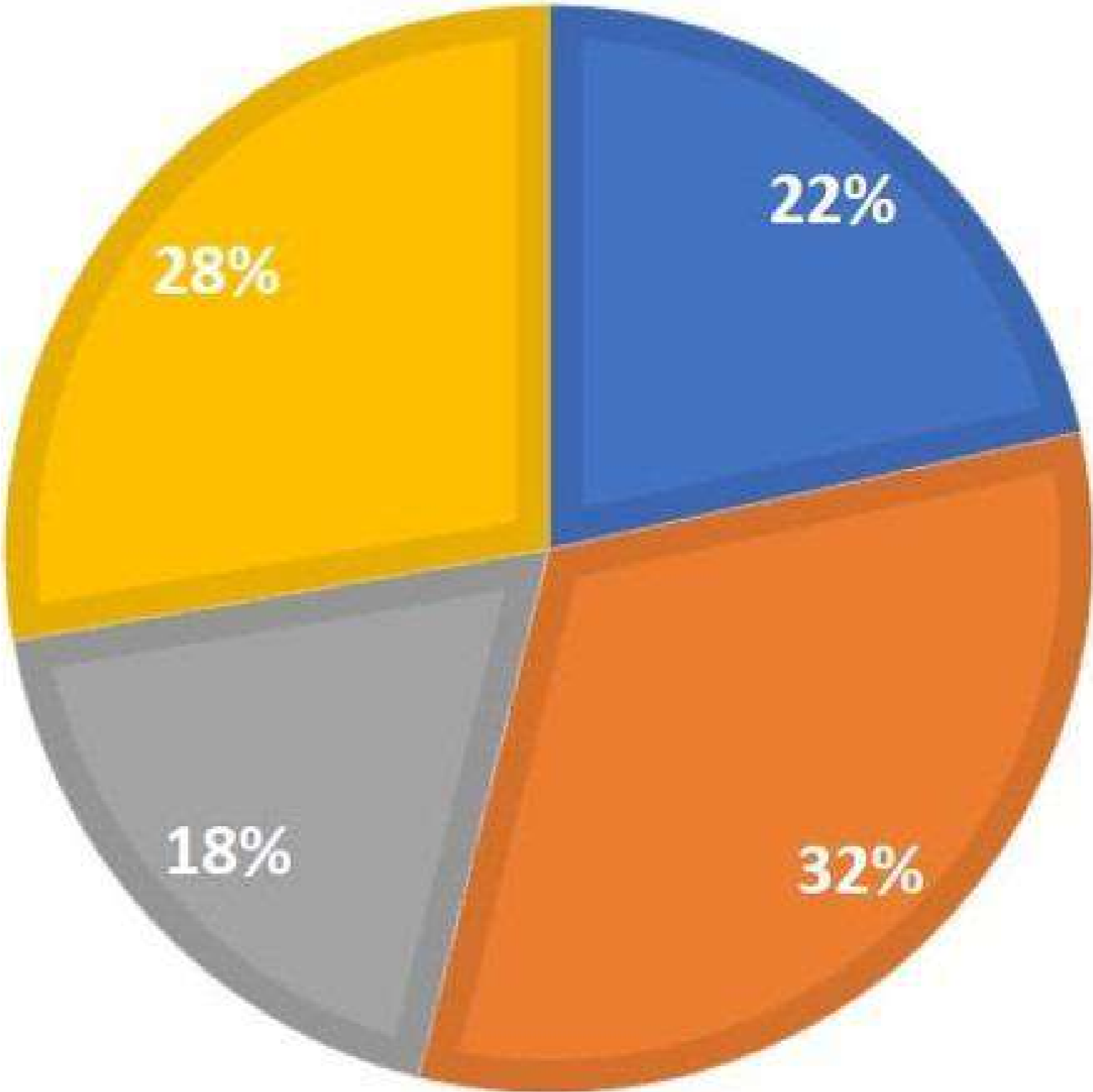
# GREEN FACADE ORIENTATION IN EUROPE

# ORIENTATION

Data collected throughout Spetialisation Project:

*Stanialav Rezucha*  
**Literature Study on Large Green Facades in Europe**  
Supervior: Prof. Dr.-Ing. Holger Techen  
(SS19/20)

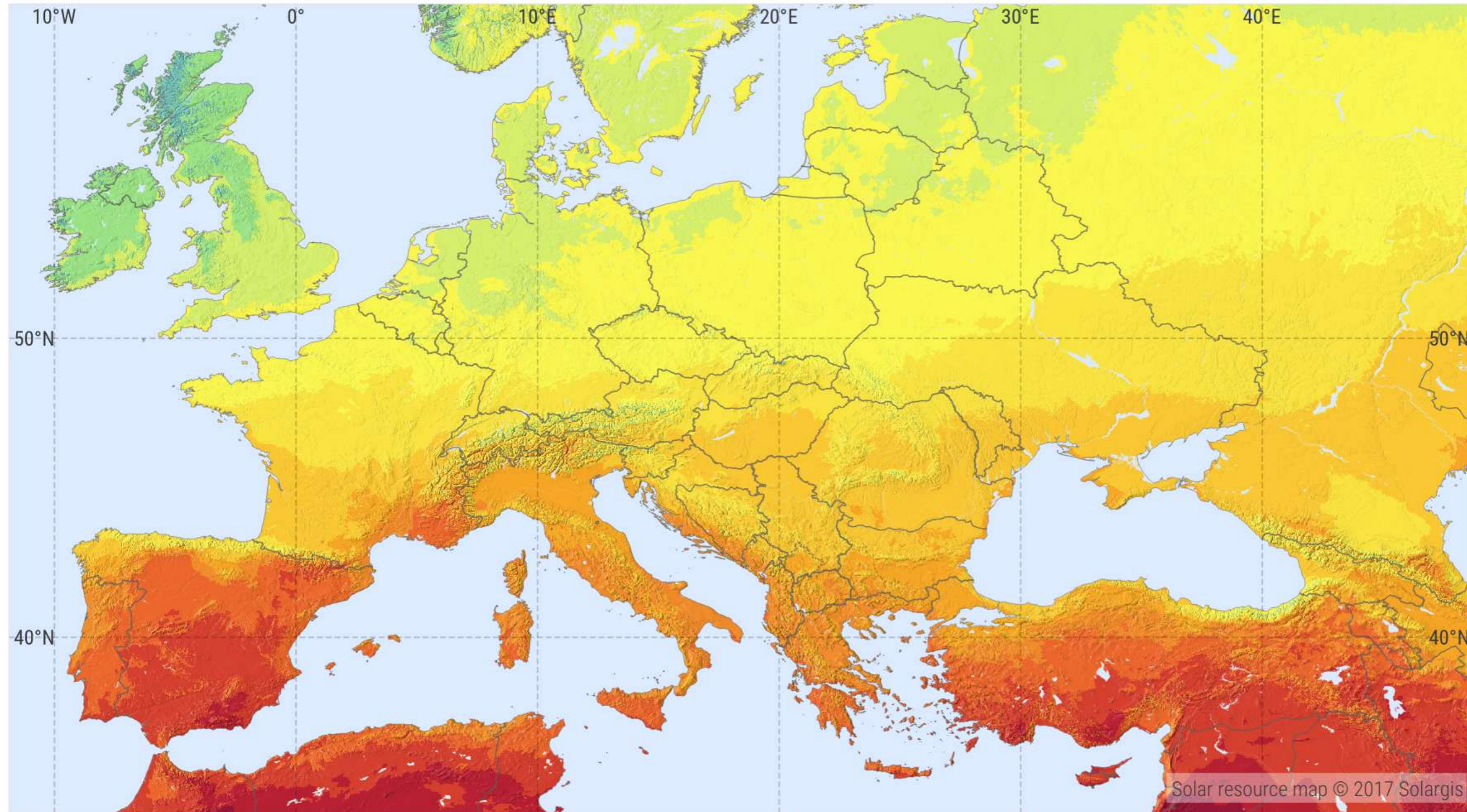
■ North ■ South ■ East ■ West





# PHOTOVOLTAIC POWER POTENTIAL

## EUROPE



Average annual sum of PVOUT, period 1994-2016



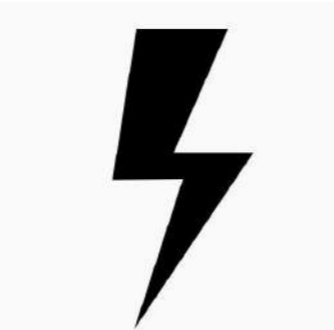


PRIMARY ENERGY  
Nature Energy



solar energy

SECONDARY ENERGY  
End Energy

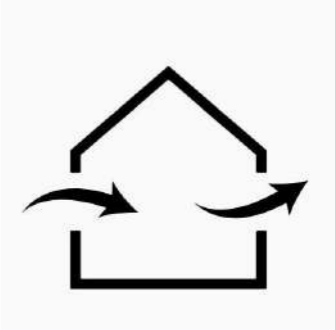


electricity

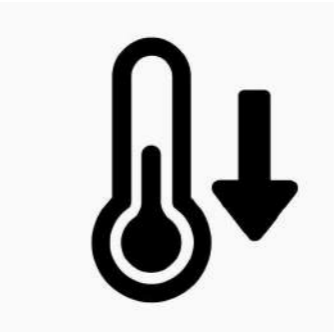
TERTIARY ENERGY  
Utility Energy



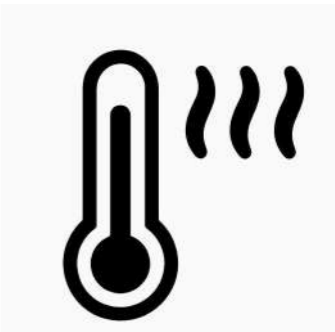
light



ventilation

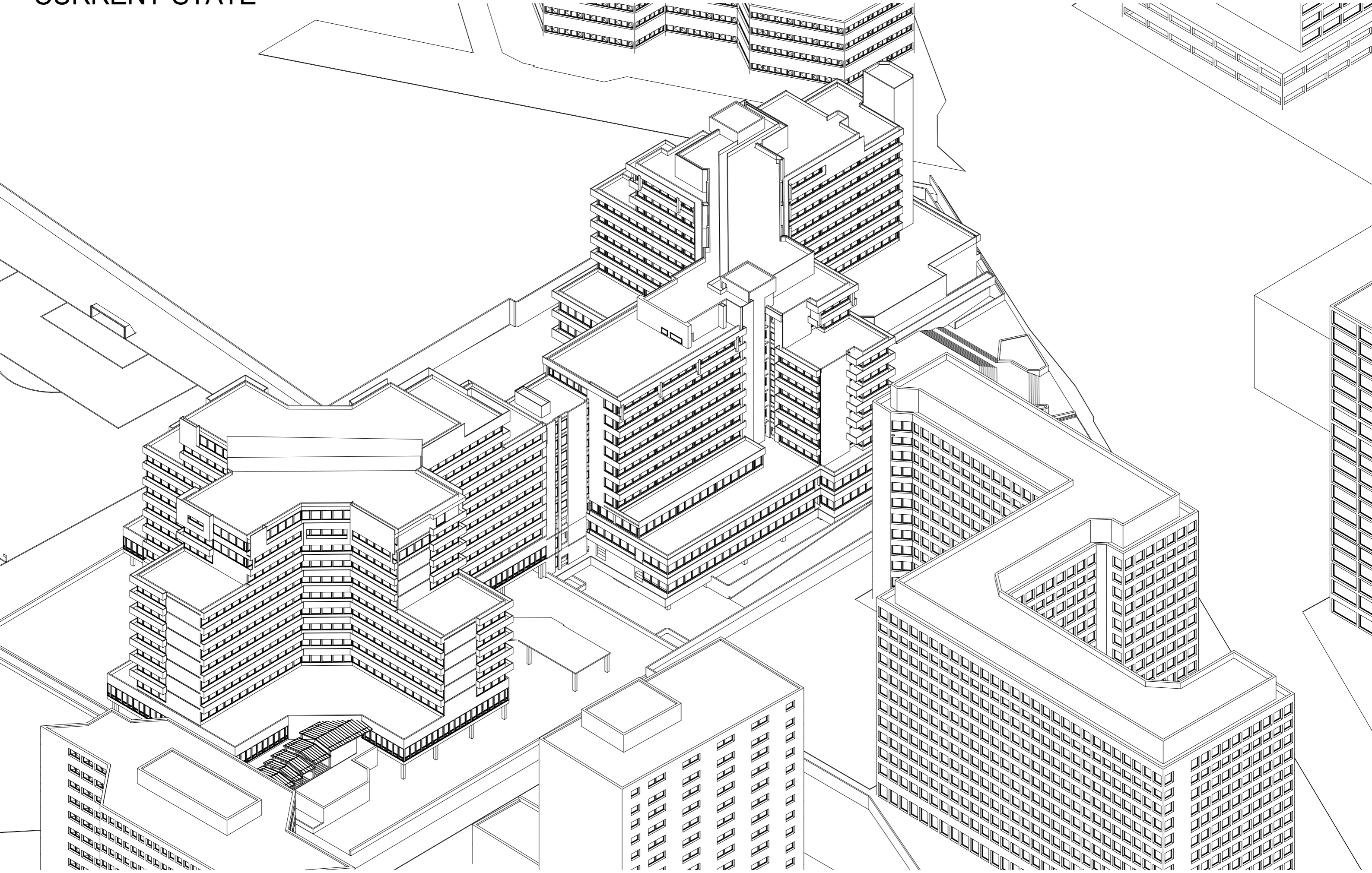


cooling



heating







# ACTIVATED SURFACE

ARCHICAD STUDENTEN-VERSION



- photovoltaics
- vegetation
- bee hotel
- terrace

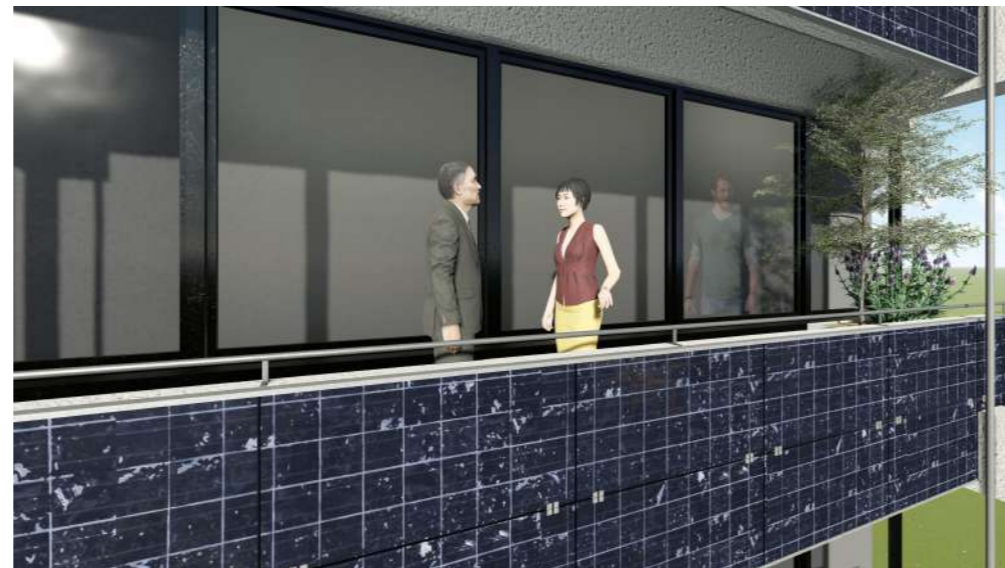






# VISUALIZATION MAIN ENTRANCE

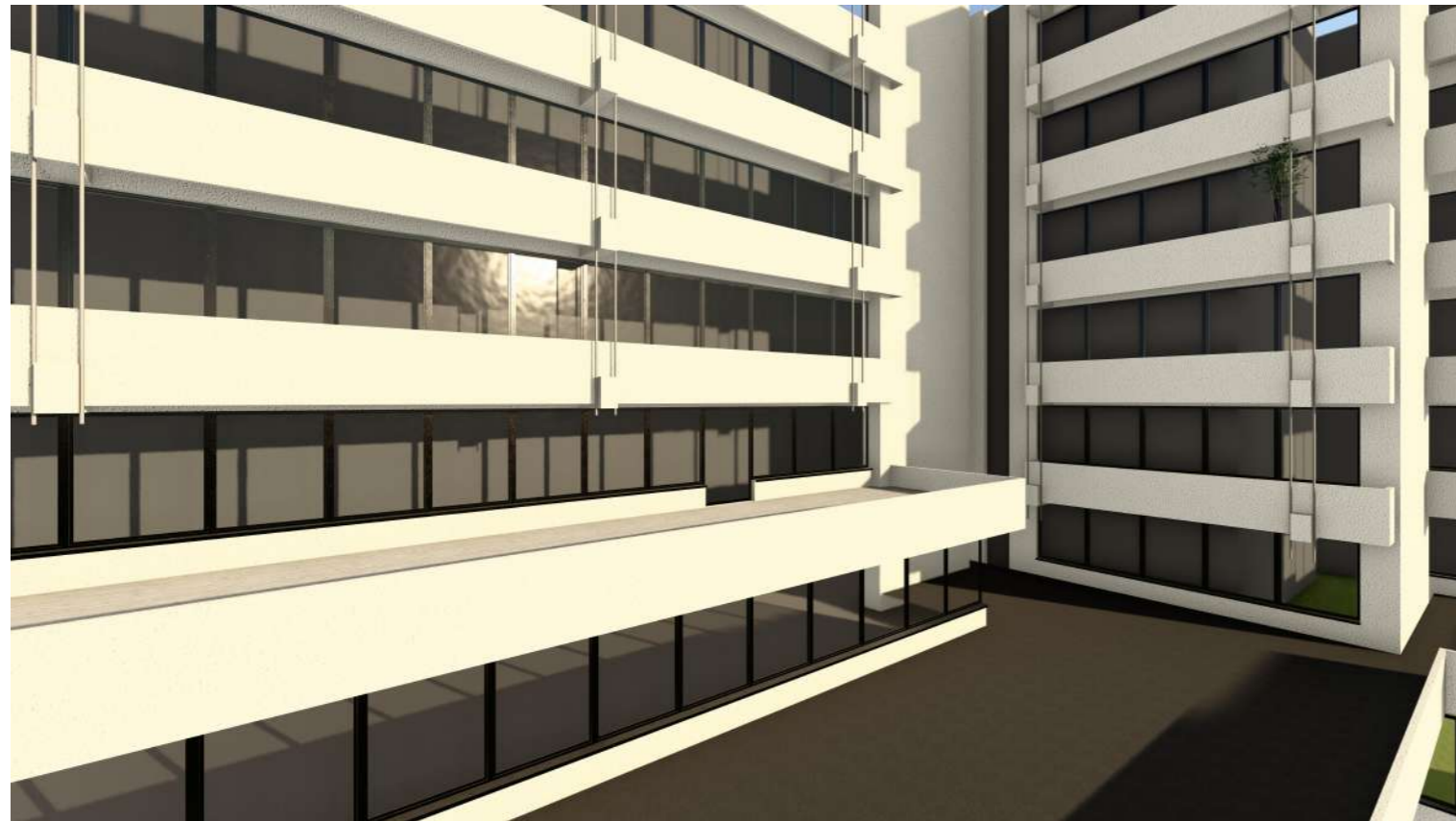
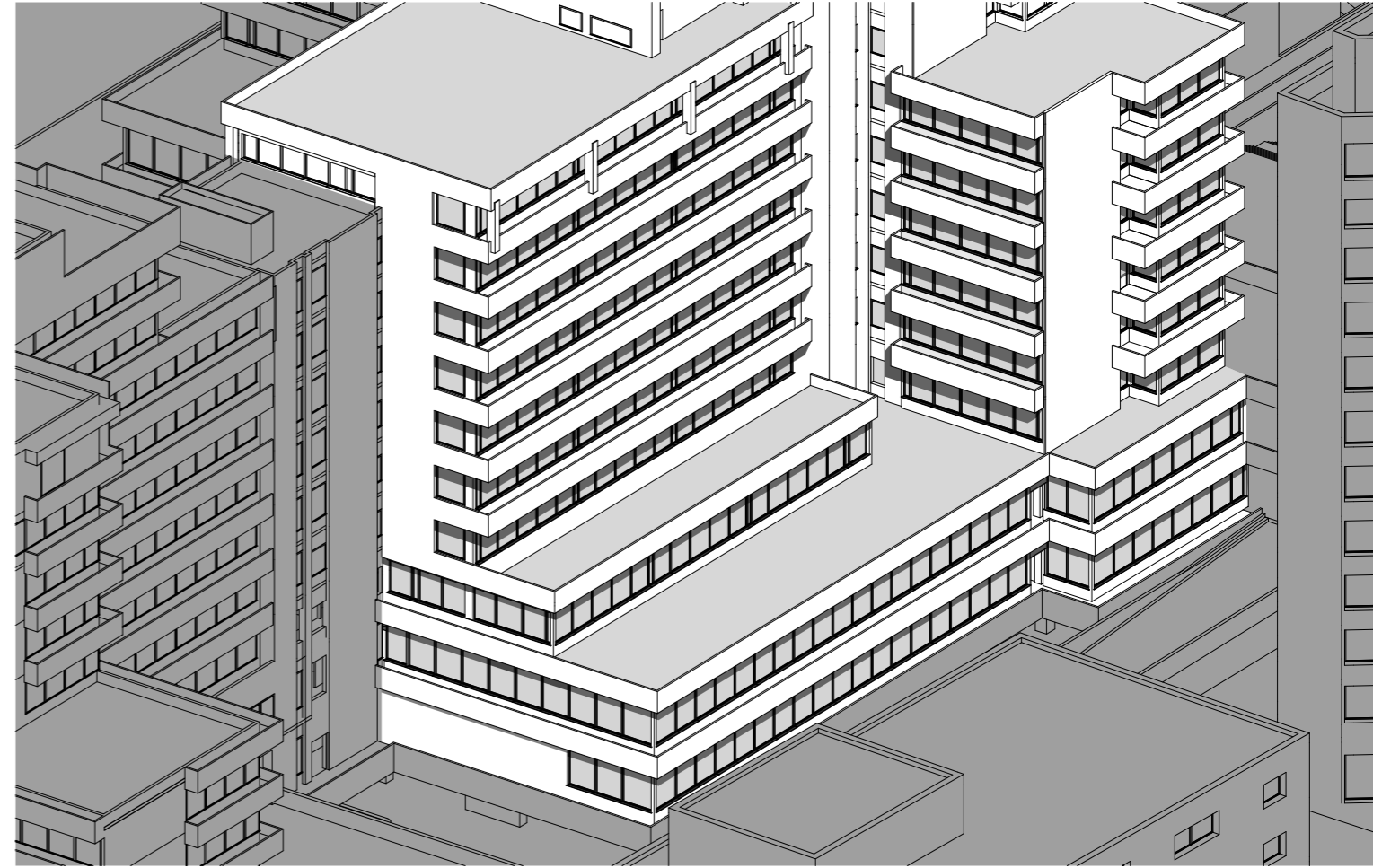
ARCHICAD STUDENTEN-VERSION





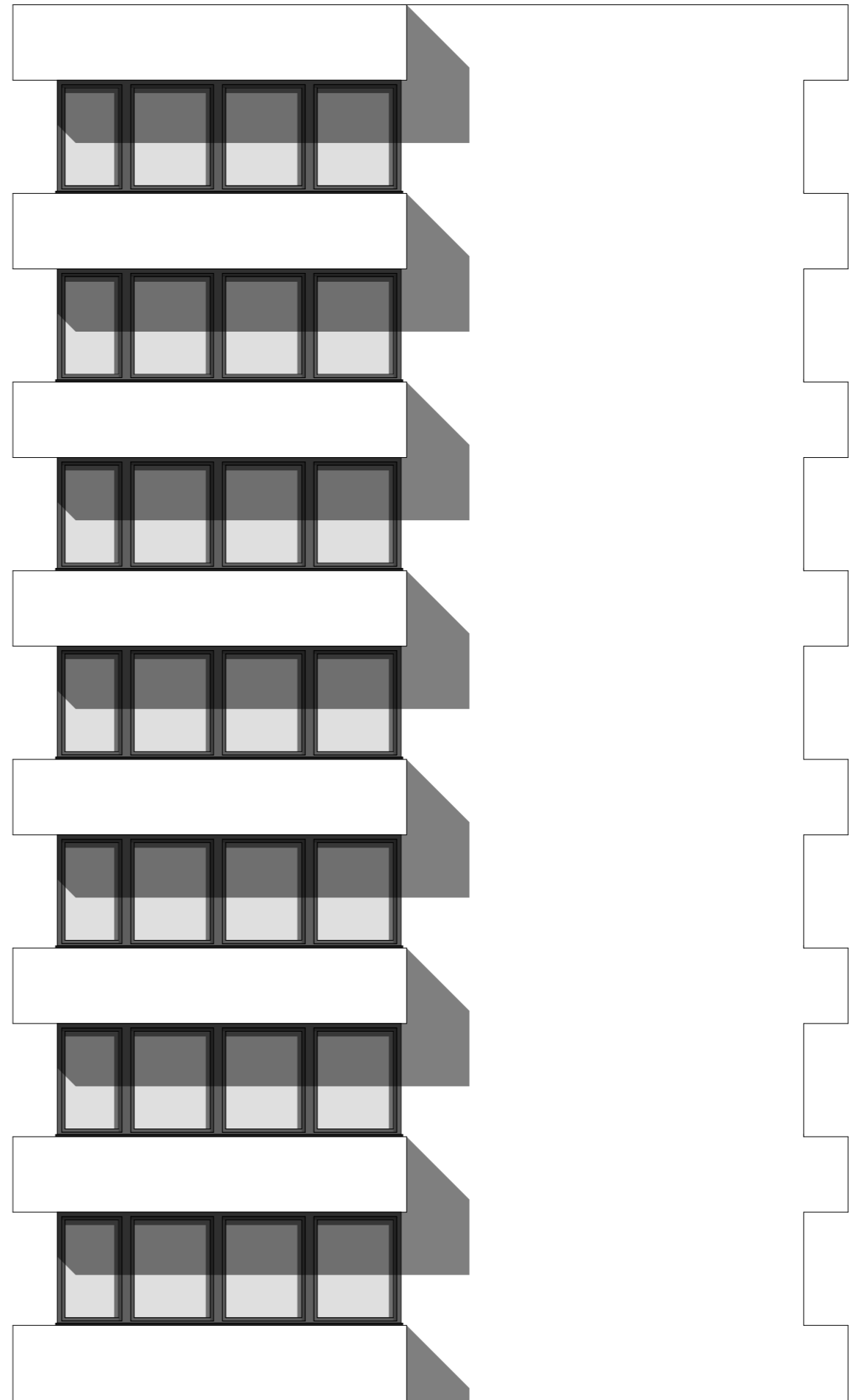
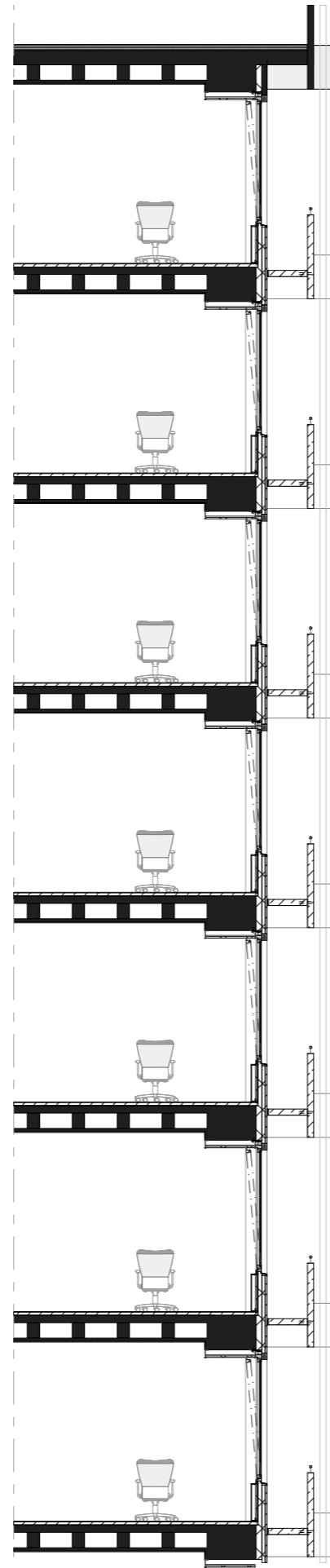
## TERRACE

- employee area
- illuminated mainly from morning to noon





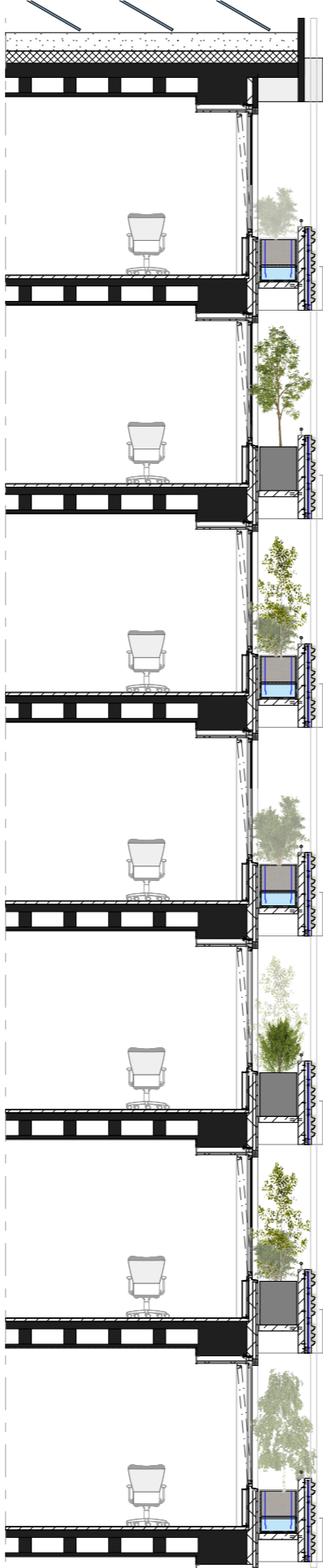
CURRENT STATE  
detail 1:100





# POT TREES AND MODULAR GREEN FACADE

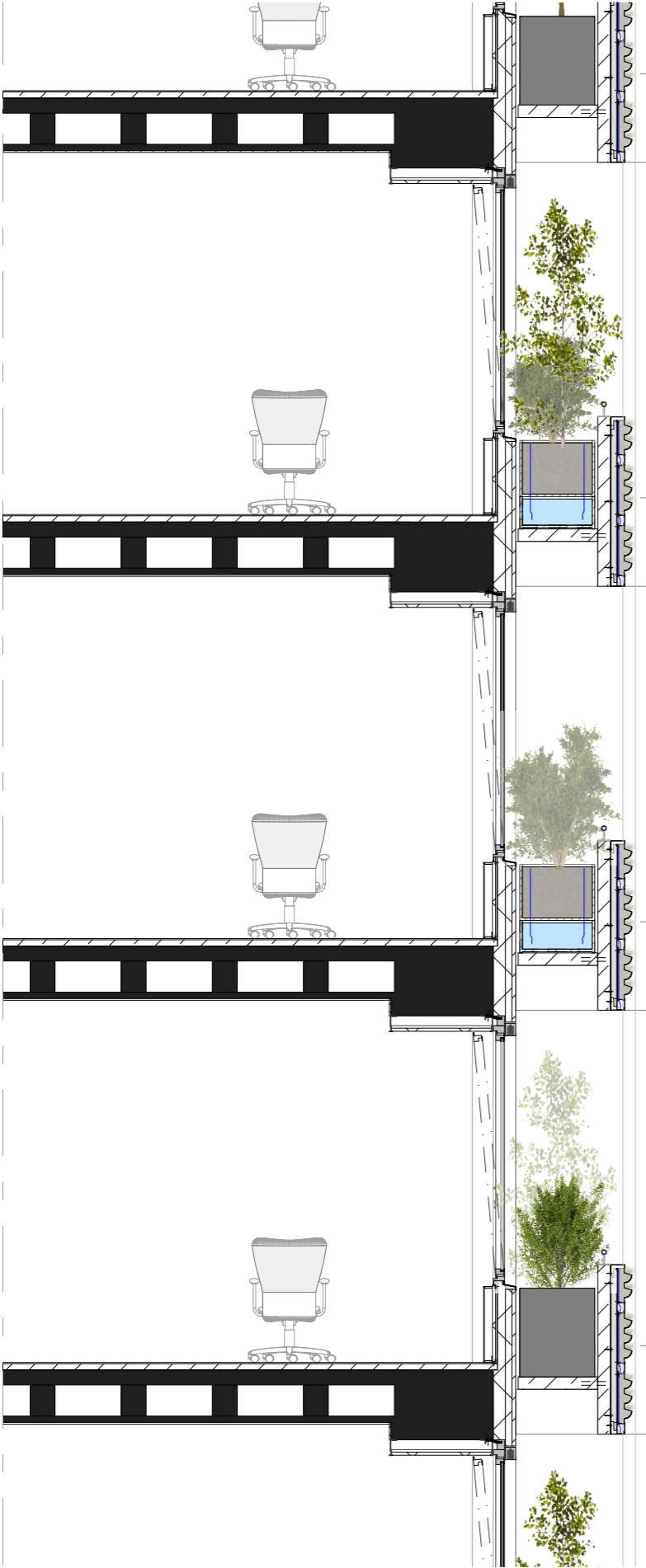
1:100





# POT TREES AND MODULAR GREEN FACADE

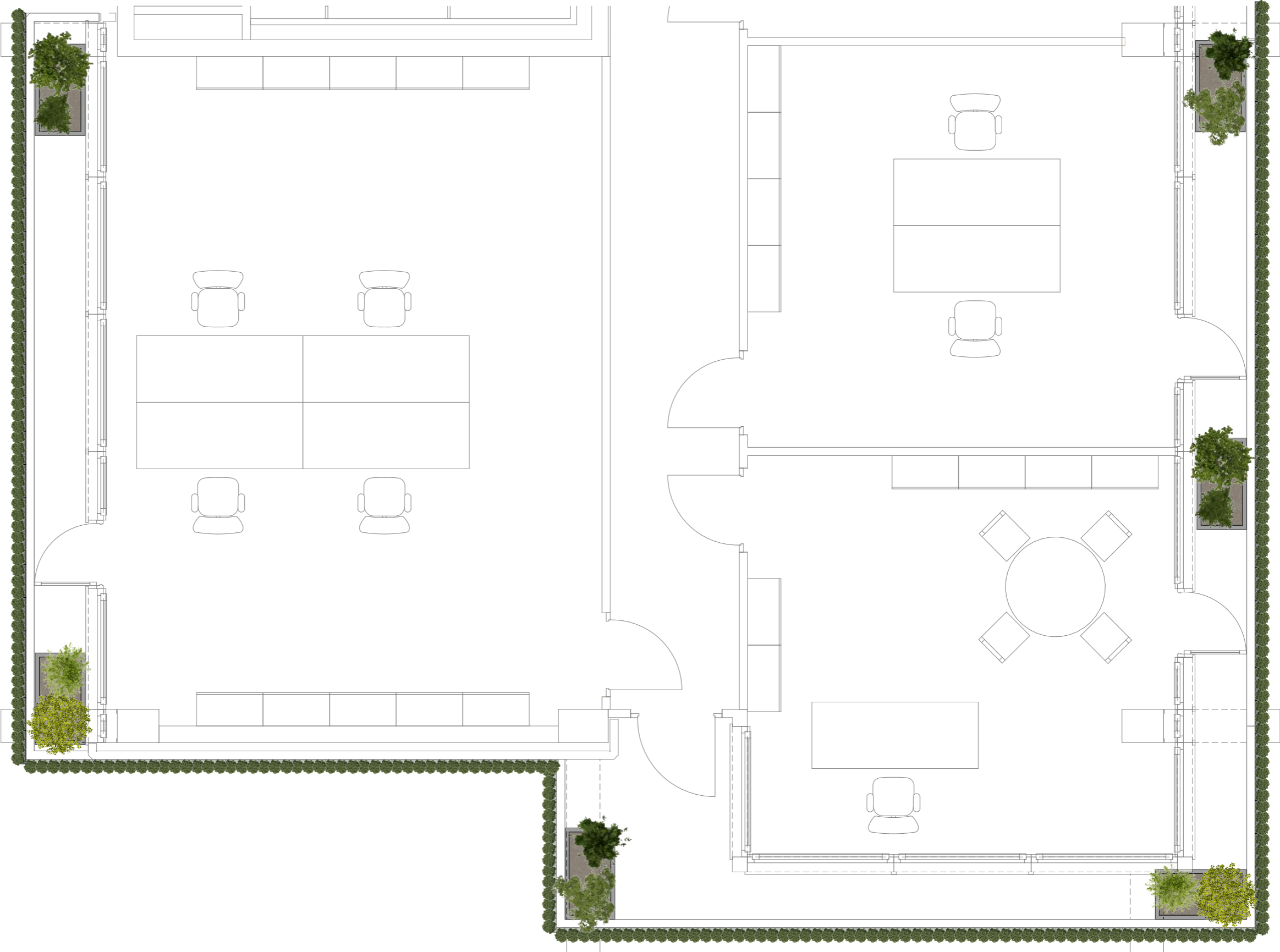
1:50





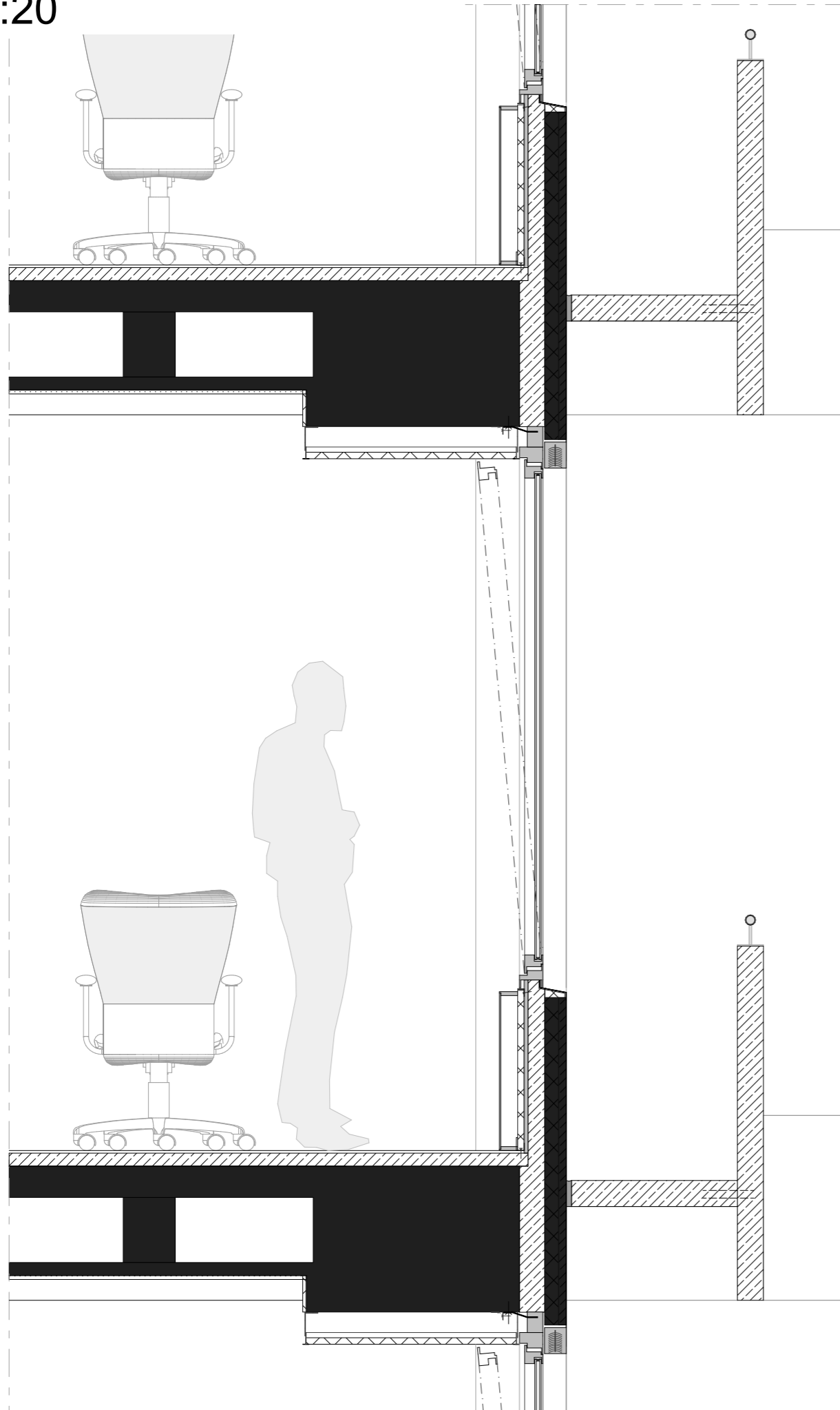
# POT TREES AND MODULAR GREEN FACADE

1:50

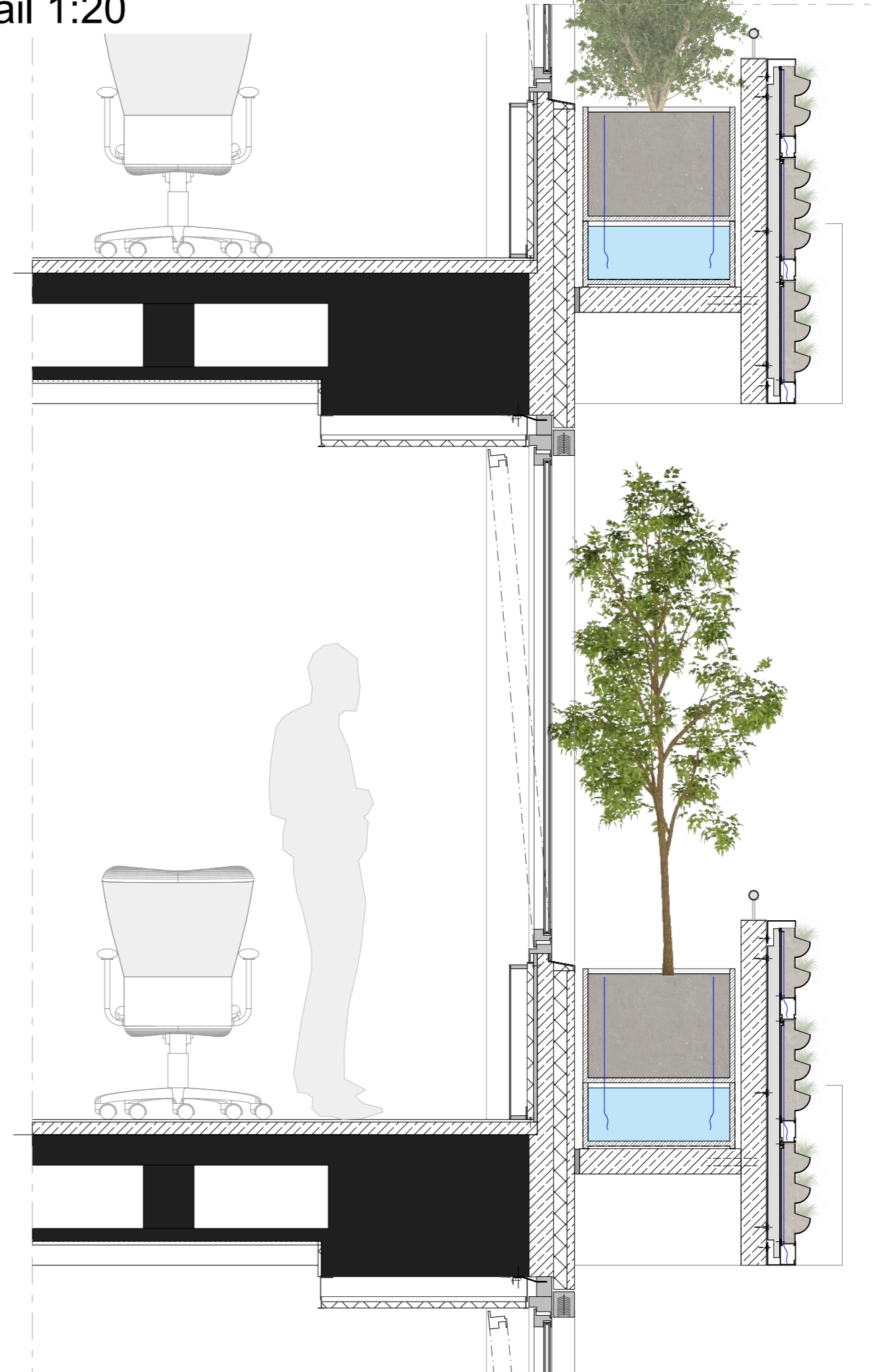




CURRENT STATE  
detail 1:20



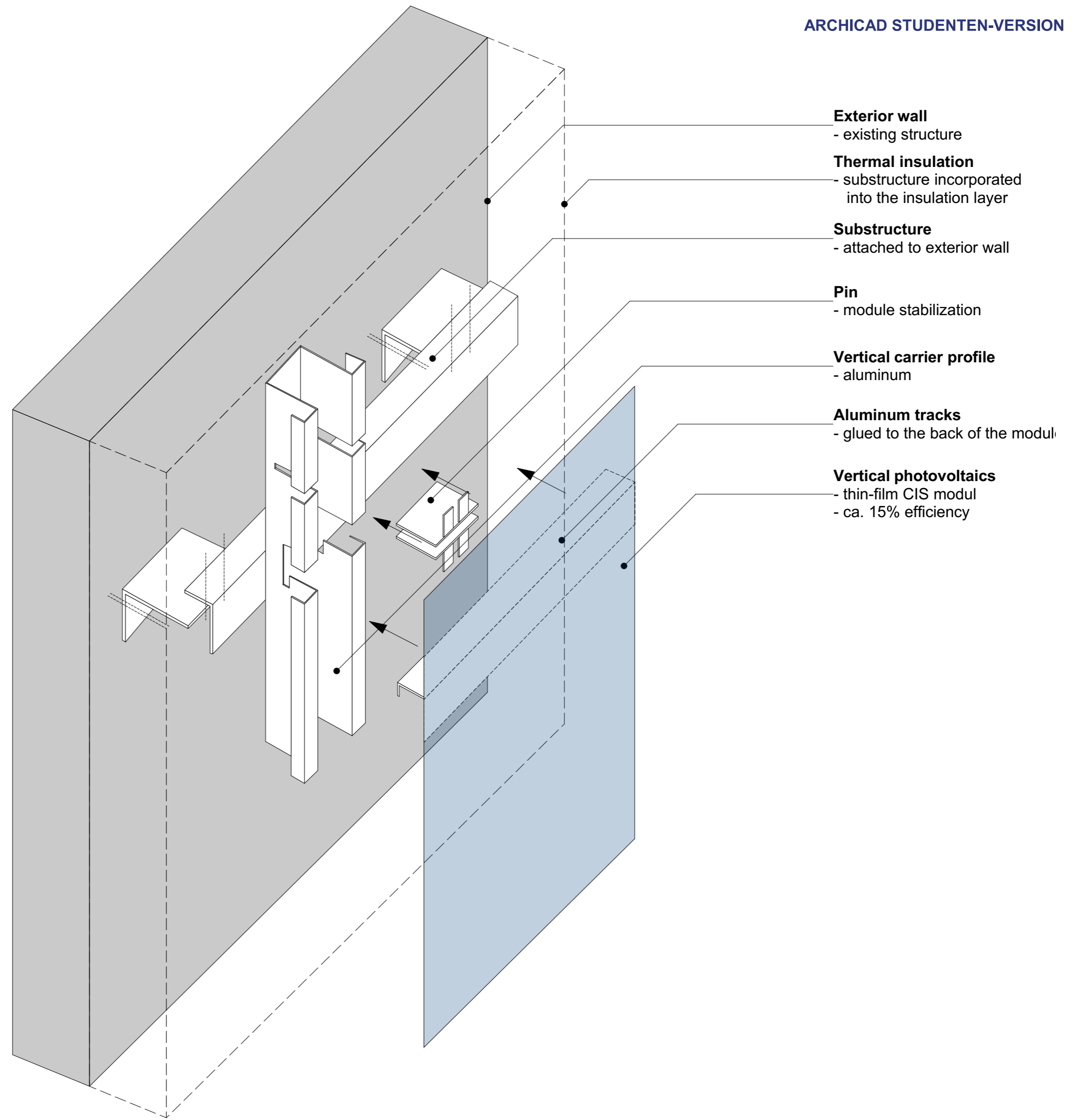
TREE CONCEPT  
detail 1:20





# BIPV - VERTICAL PV SYSTEM isometry

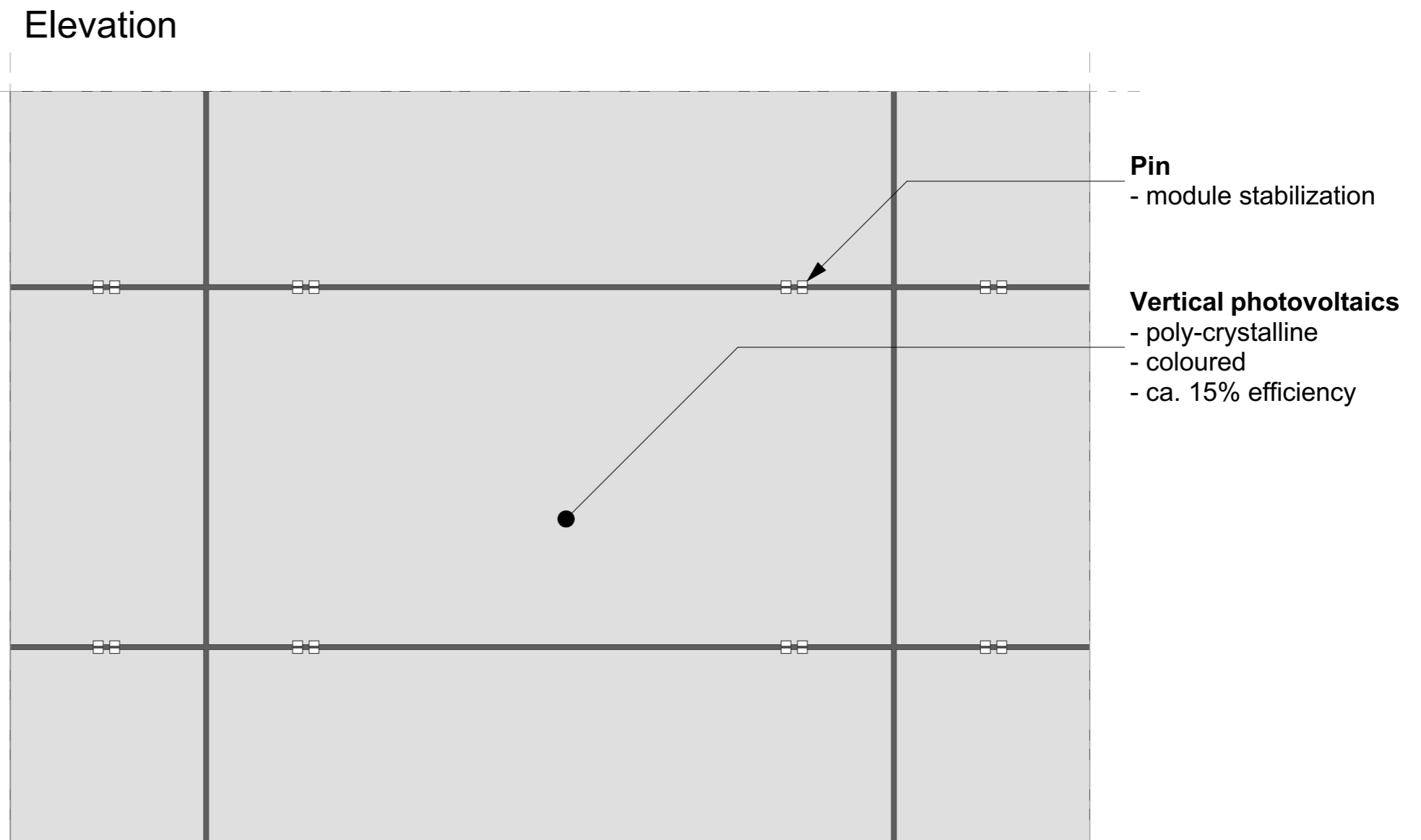
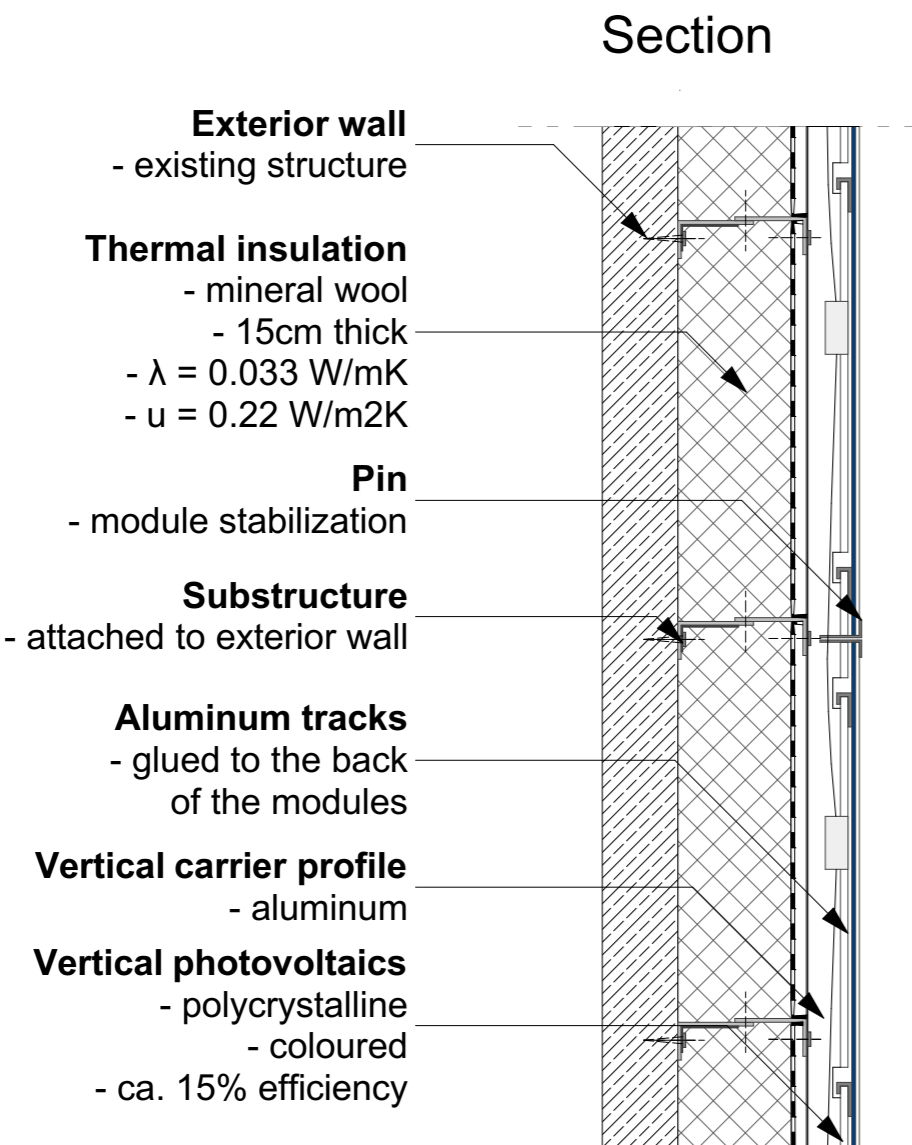
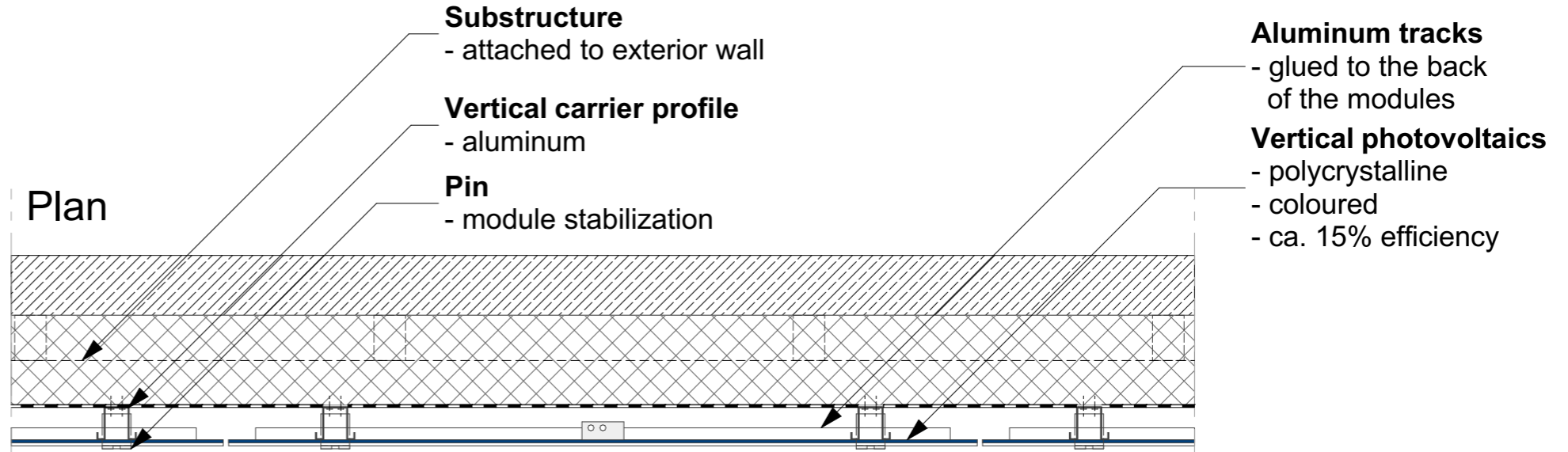
ARCHICAD STUDENTEN-VERSION





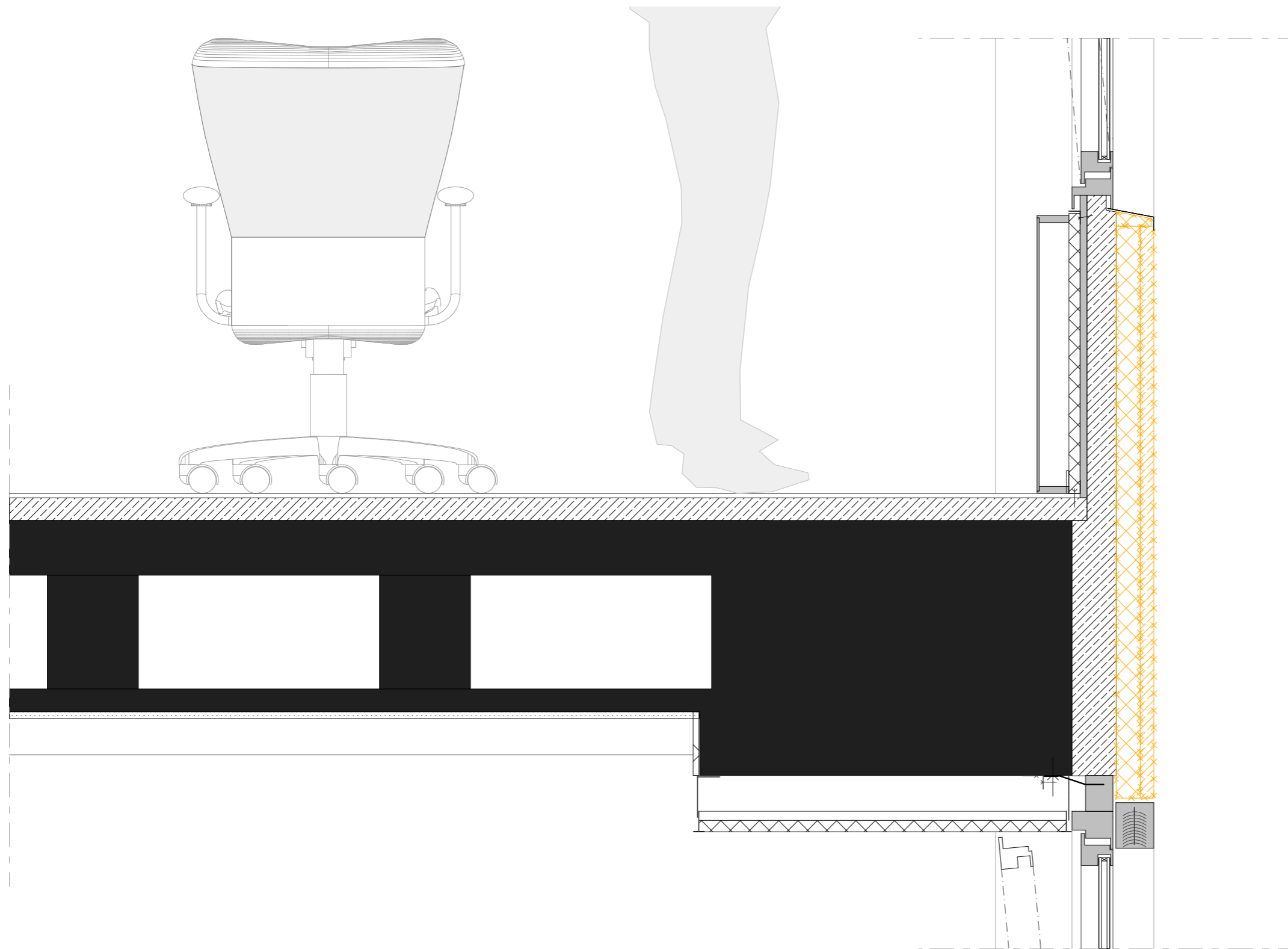
# BIPV - VERTICAL PV SYSTEM

## detail 1:10





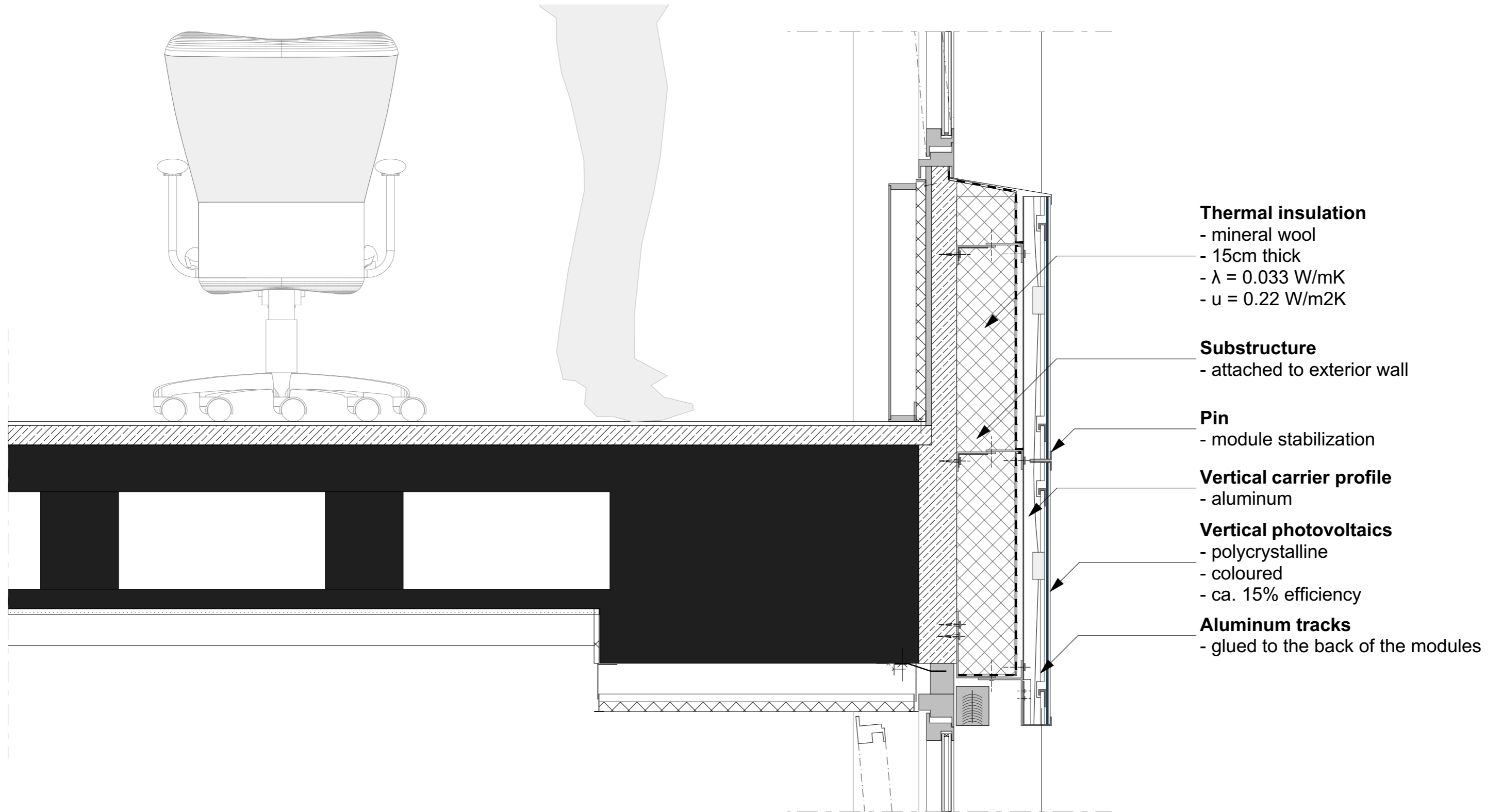
FACADE - CURRENT STATE  
detail 1:10





# BIPV - VERTICAL PV SYSTEM

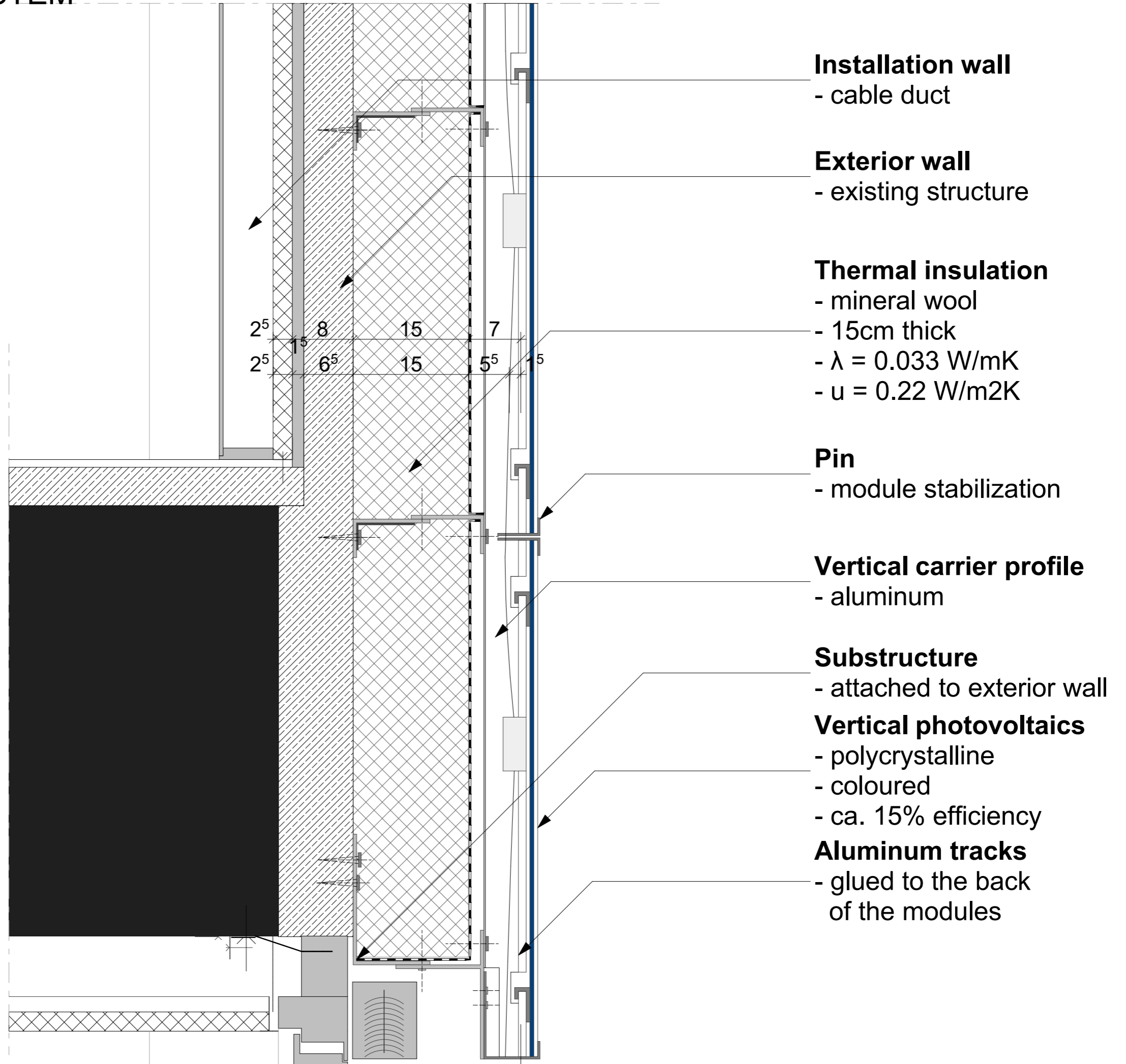
detail 1:10





# BIPV - VERTICAL PV SYSTEM

detail 1:5



**Installation wall**  
- cable duct

**Exterior wall**  
- existing structure

**Thermal insulation**  
- mineral wool  
- 15cm thick  
-  $\lambda = 0.033 \text{ W/mK}$   
-  $u = 0.22 \text{ W/m}^2\text{K}$

**Pin**  
- module stabilization

**Vertical carrier profile**  
- aluminum

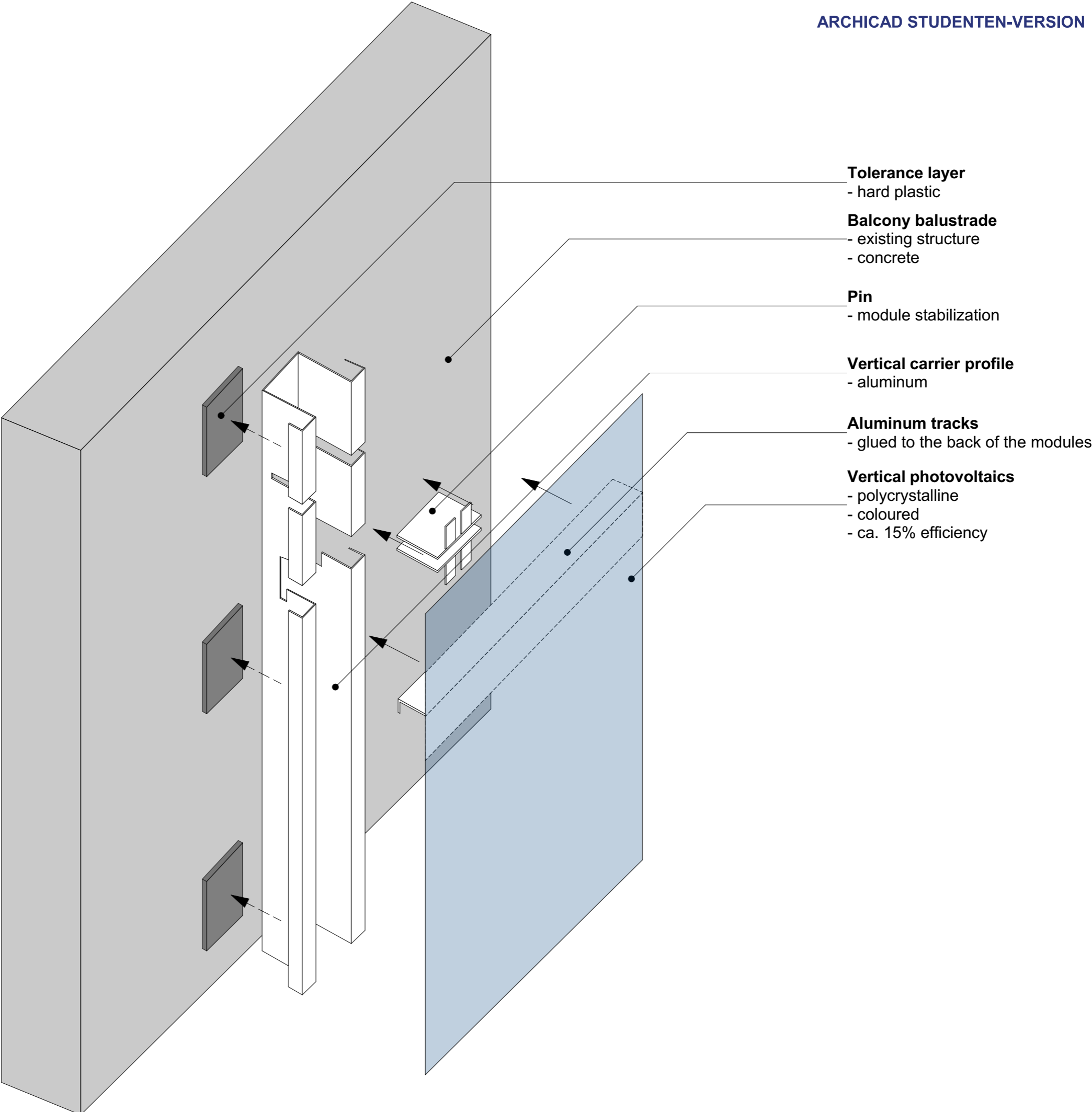
**Substructure**  
- attached to exterior wall

**Vertical photovoltaics**  
- polycrystalline  
- coloured  
- ca. 15% efficiency

**Aluminum tracks**  
- glued to the back  
of the modules



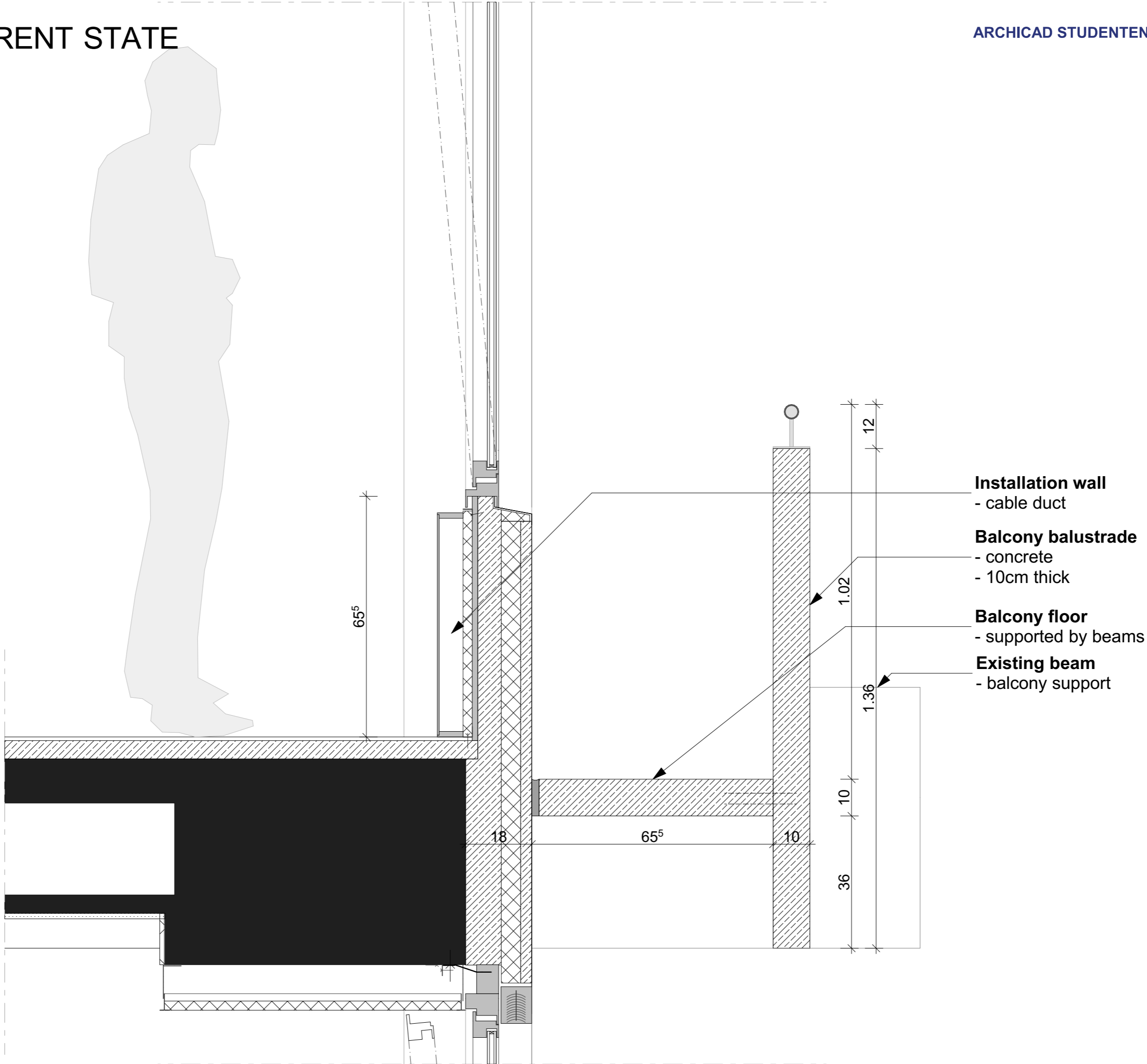
# BIPV - VERTICAL PV SYSTEM isometry





# BALCONY - CURRENT STATE

detail 1:10



**Installation wall**  
- cable duct

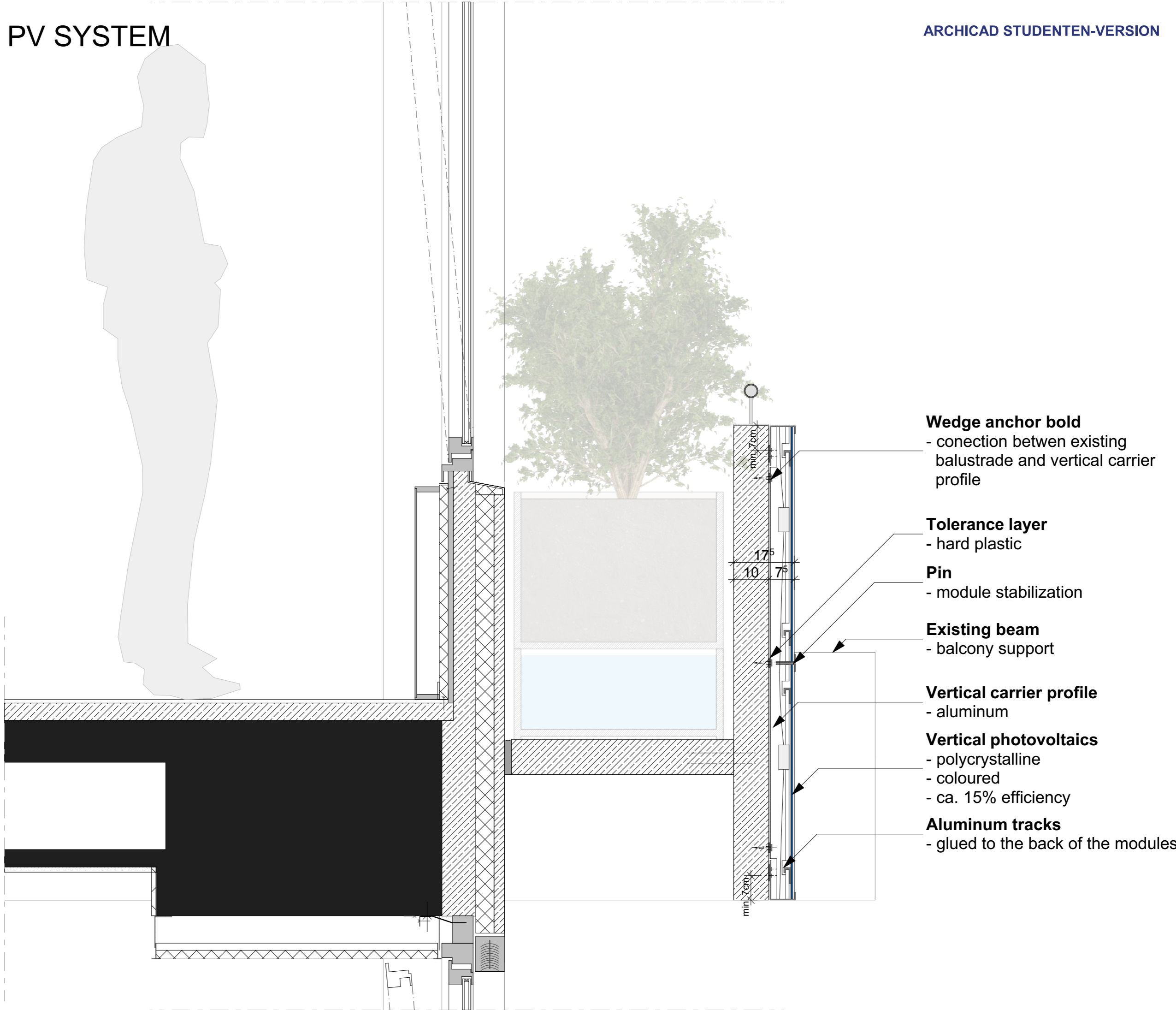
**Balcony balustrade**  
- concrete  
- 10cm thick

**Balcony floor**  
- supported by beams

**Existing beam**  
- balcony support



**BIPV - VERTICAL PV SYSTEM**  
detail 1:10



**Wedge anchor bolt**  
- conection between existing balustrade and vertical carrier profile

**Tolerance layer**  
- hard plastic

**Pin**  
- module stabilization

**Existing beam**  
- balcony support

**Vertical carrier profile**  
- aluminum

**Vertical photovoltaics**  
- polycrystalline  
- coloured  
- ca. 15% efficiency

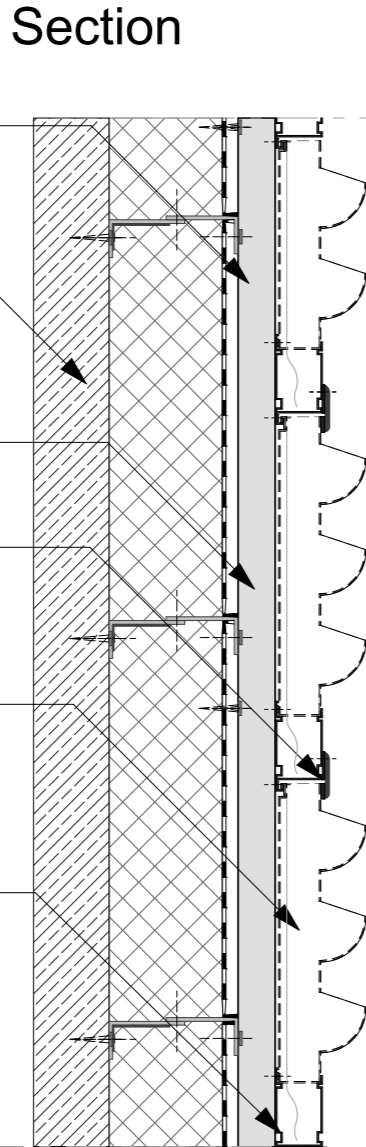
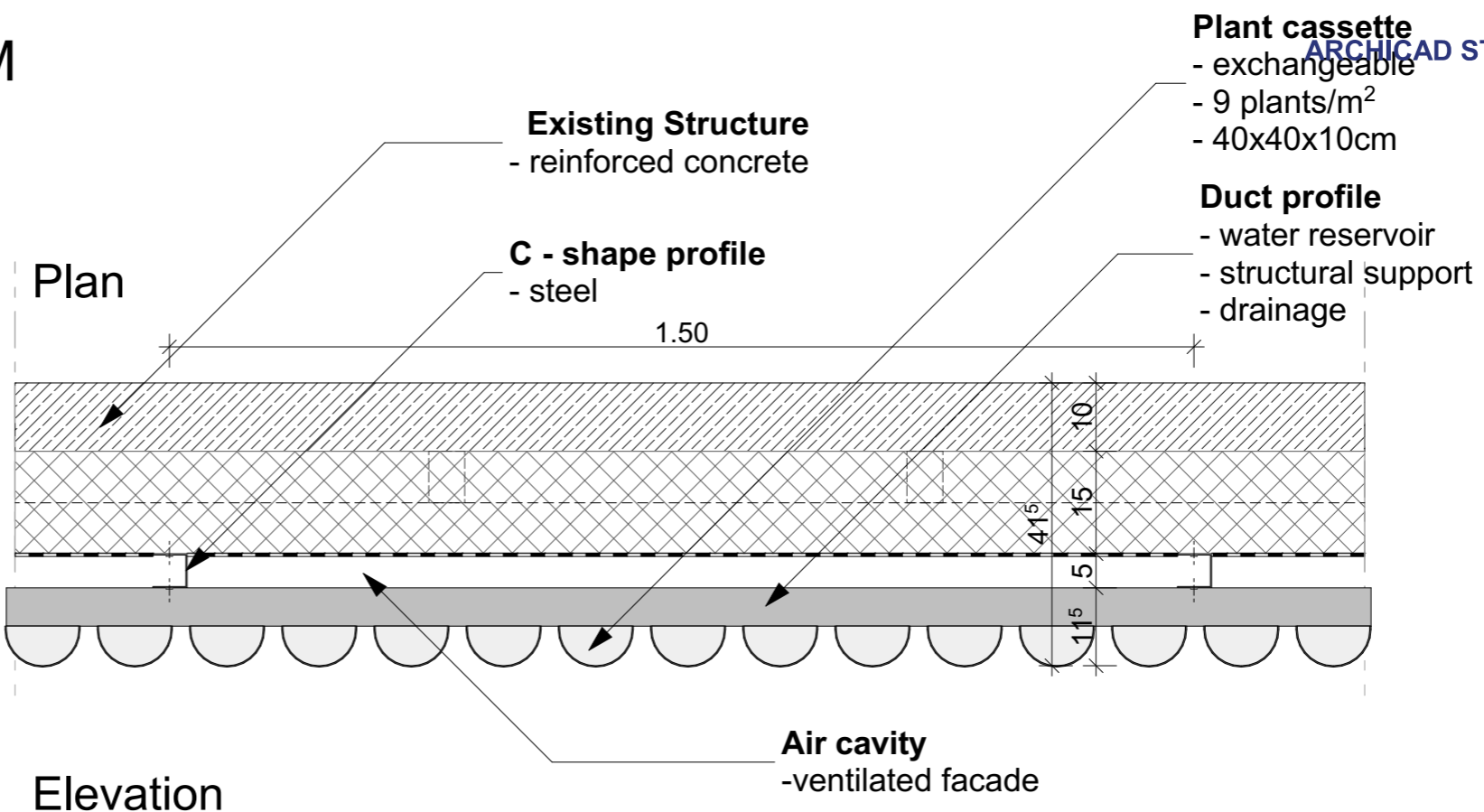
**Aluminum tracks**  
- glued to the back of the modules



# VERTICAL GREEN FACADE SYSTEM

detail 1:10

ARCHICAD STUDENTEN-VERSION

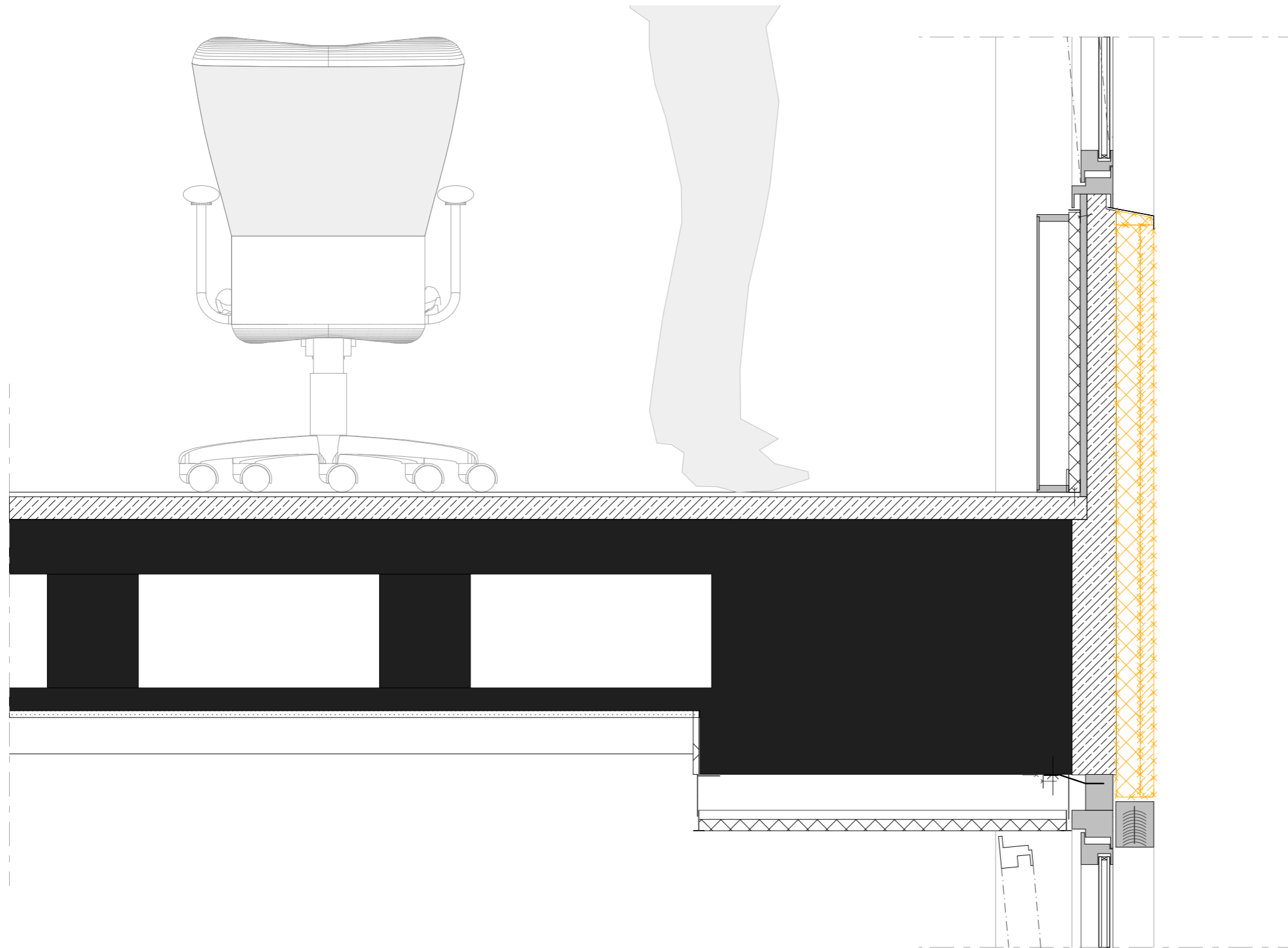


- Air cavity - ventilated facade
- Existing Structure - reinforced concrete
- C - shape profile - steel
- Pin - module stabilization
- Plant cassette
  - exchangeable
  - 9 plants/m<sup>2</sup>
  - 40x40x10cm
- Duct profile
  - water reservoir
  - structural support
  - drainage

- Pin - module stabilization
- Plant cassette
  - exchangeable
  - 9 plants/m<sup>2</sup>
  - 40x40x10cm
- Duct profile
  - water reservoir
  - structural support
  - drainage



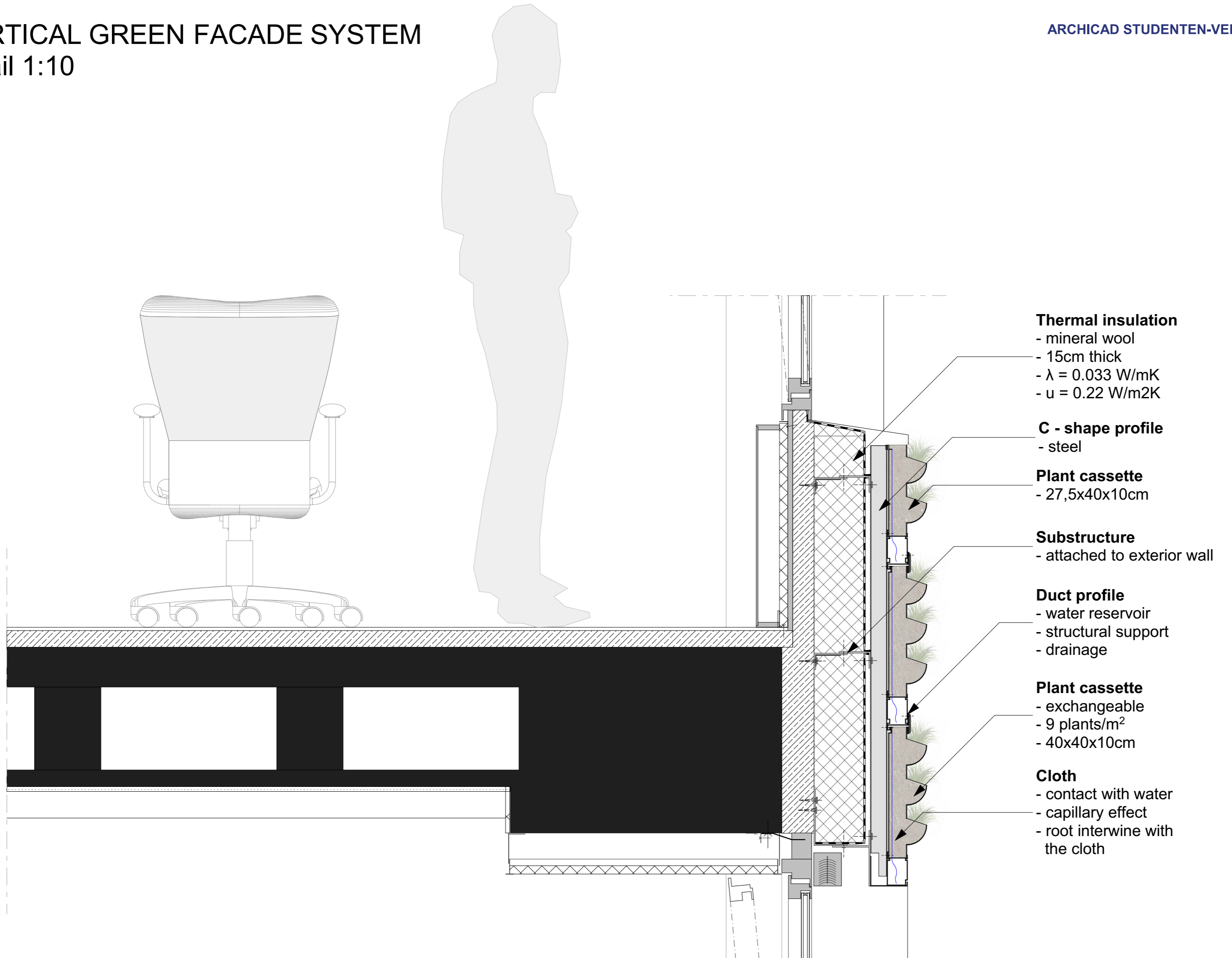
FACADE - CURRENT STATE  
detail 1:10





# VERTICAL GREEN FACADE SYSTEM

detail 1:10

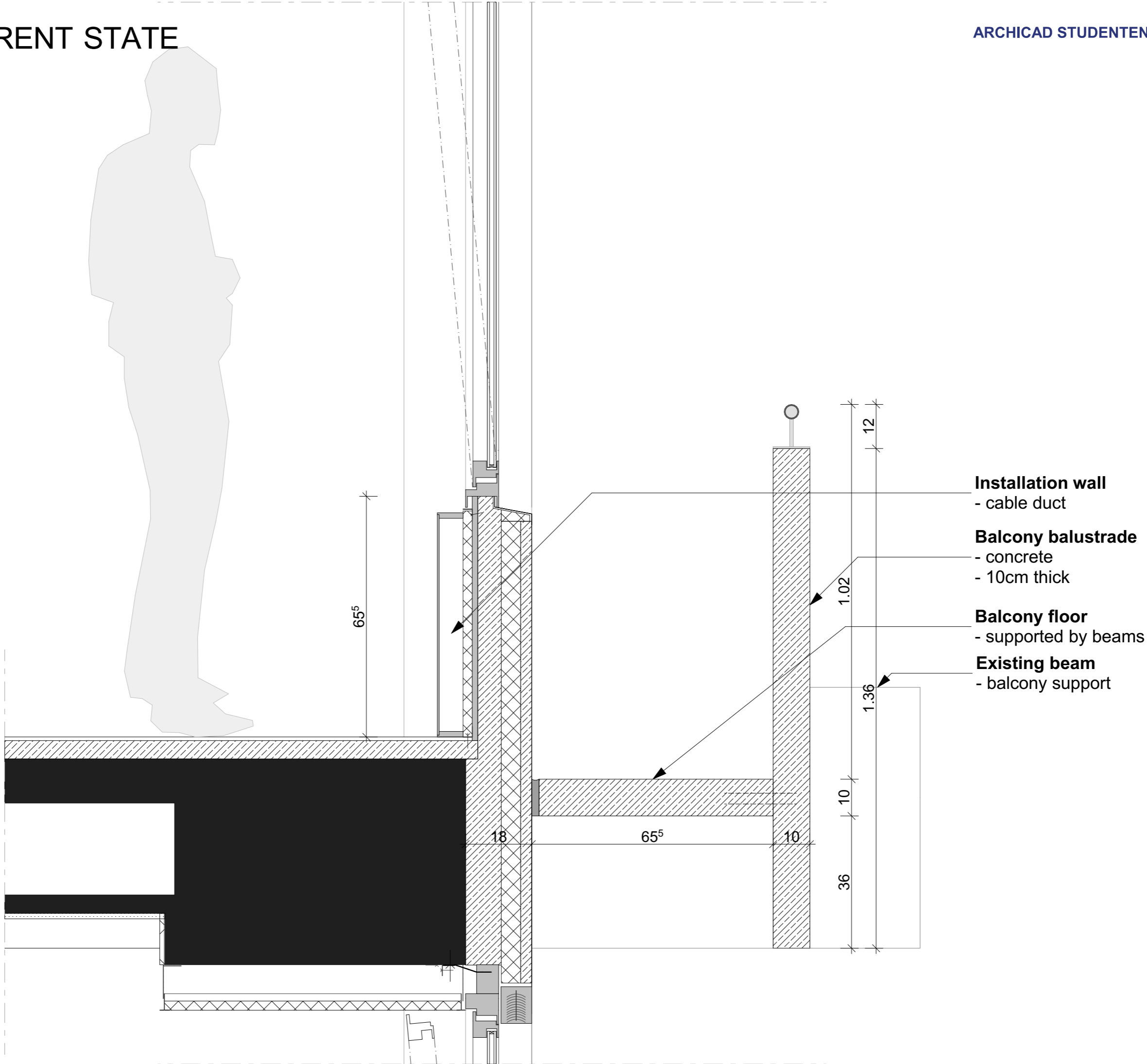








BALCONY - CURRENT STATE  
detail 1:10



**Installation wall**  
- cable duct

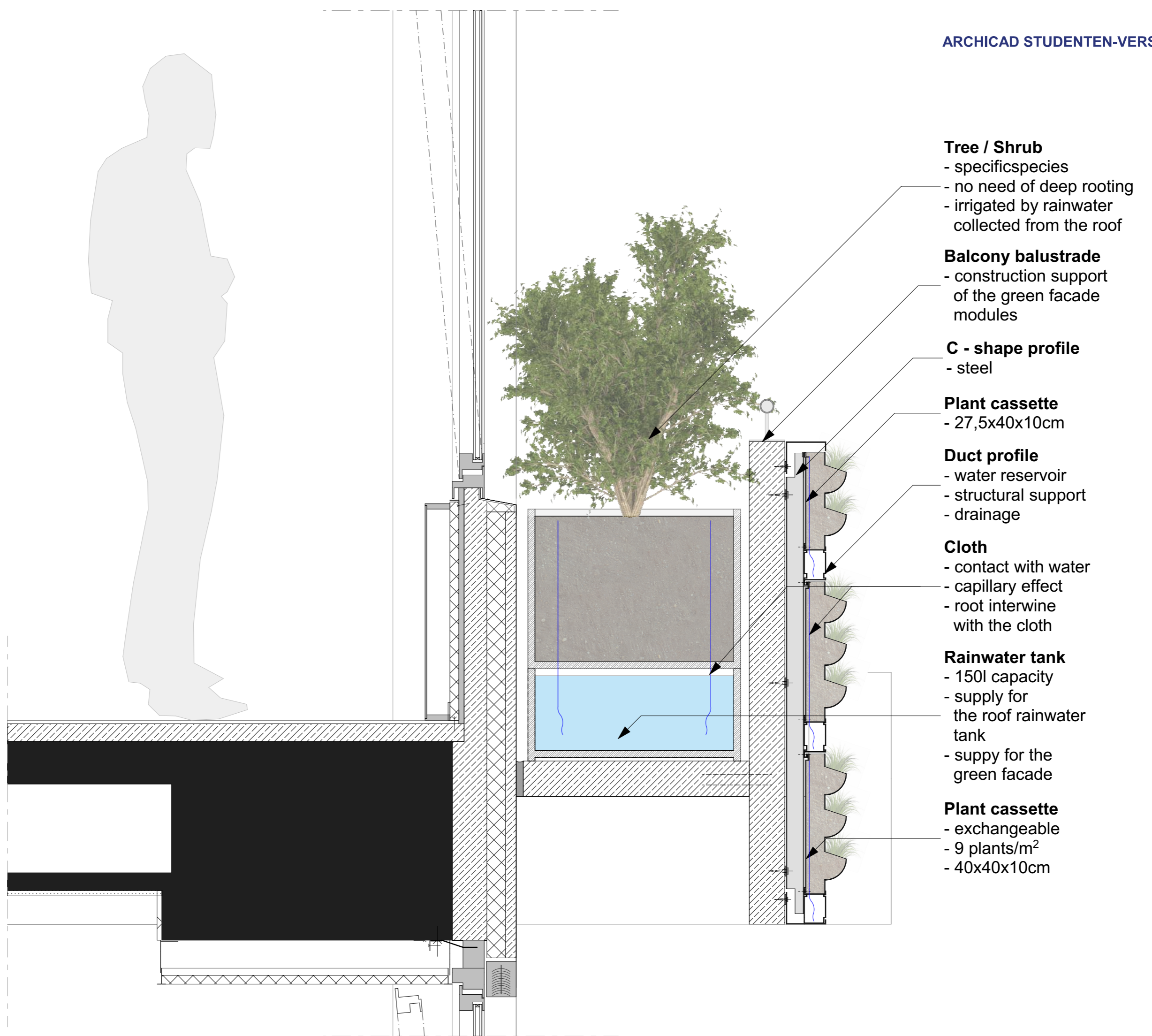
**Balcony balustrade**  
- concrete  
- 10cm thick

**Balcony floor**  
- supported by beams

**Existing beam**  
- balcony support



# BALCONY detail 1:10





# BALCONY detail 1:10

Inside

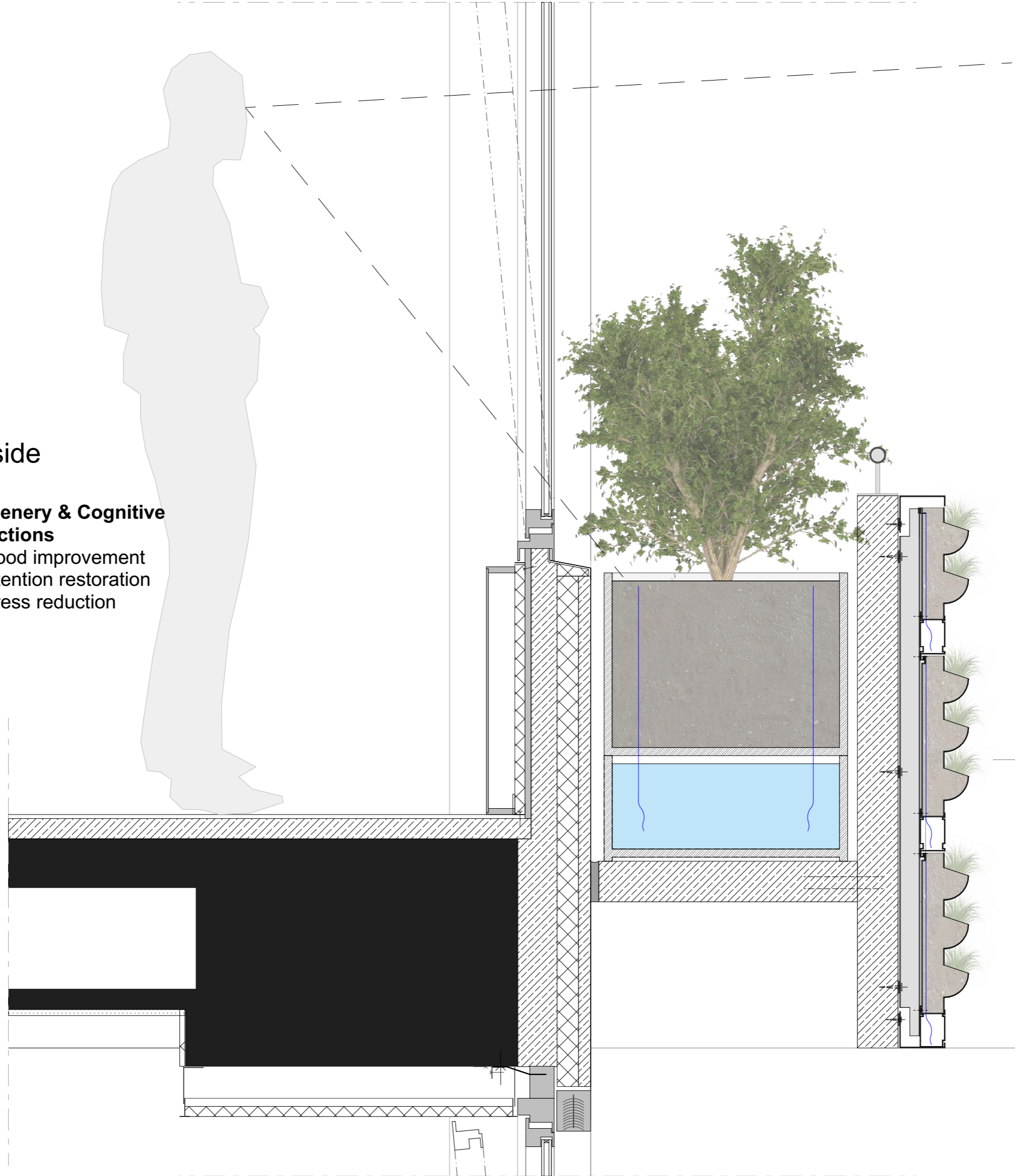
**Greenery & Cognitive functions**

- mood improvement
- attention restoration
- stress reduction

Outside

**Environmental effects**

- sound insulation
- support of biodiversity
- oxygen production
- fine dust capture



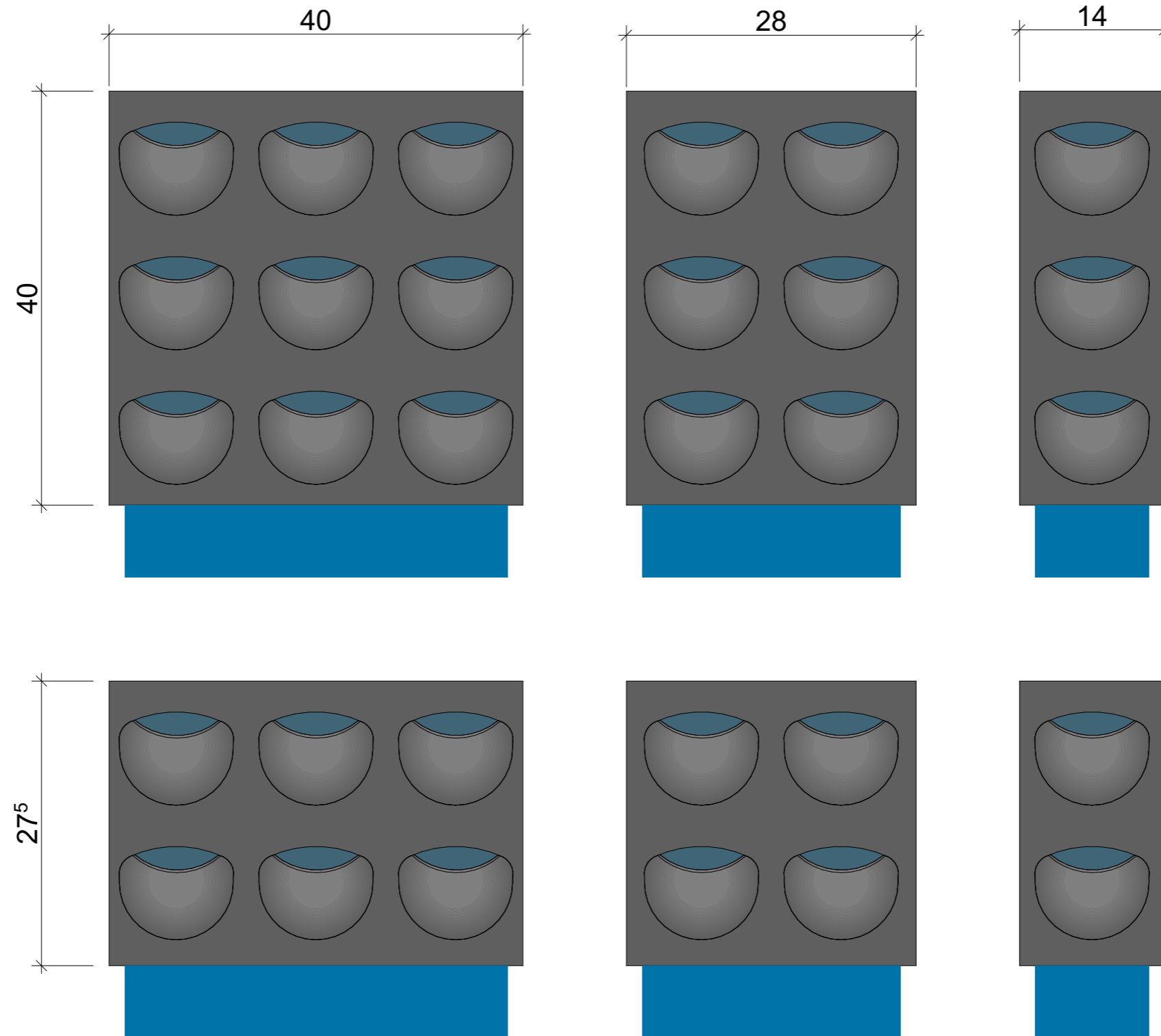






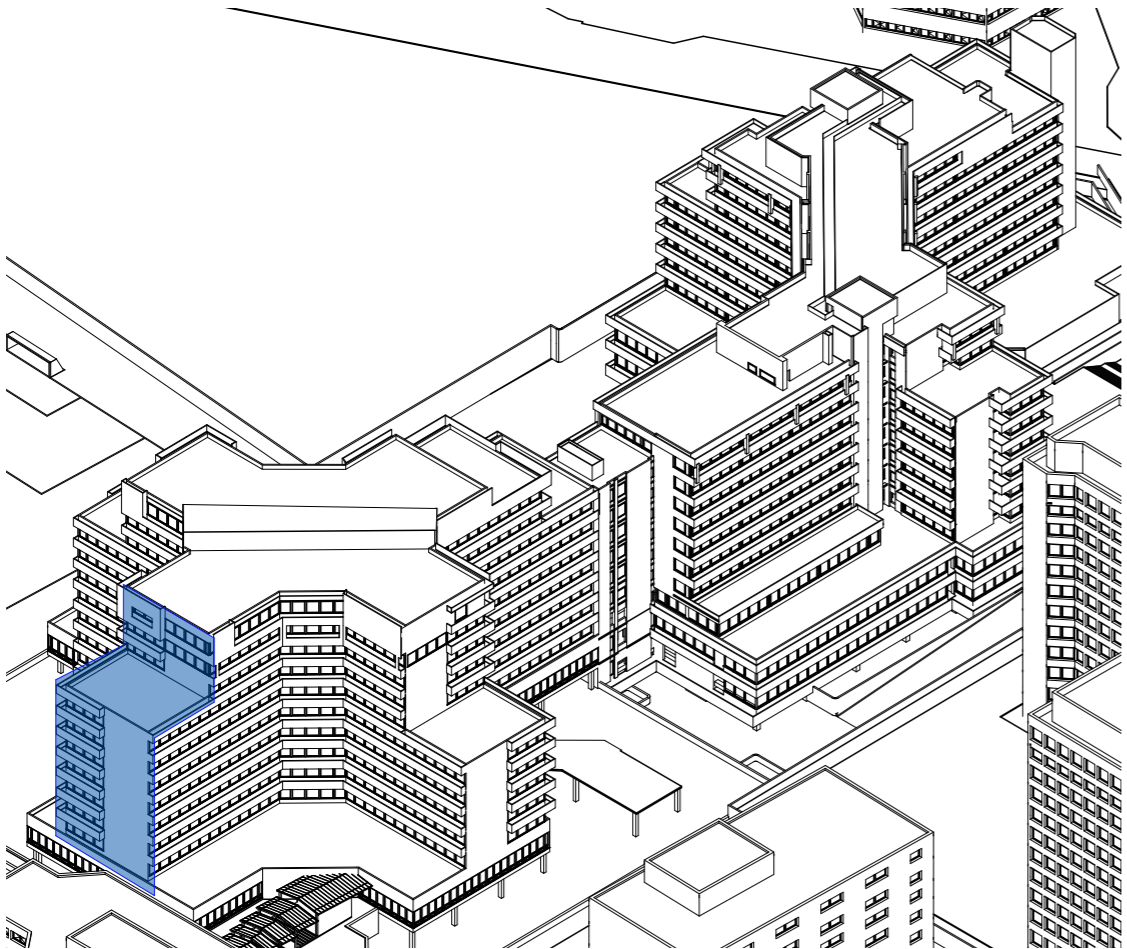
# VERTICAL GREEN FACADE MODULE

detail 1:5

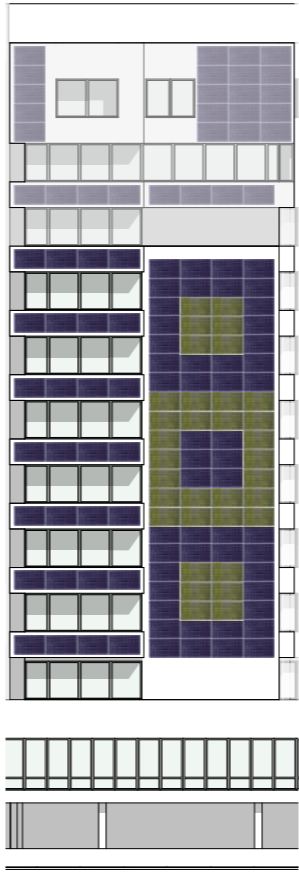




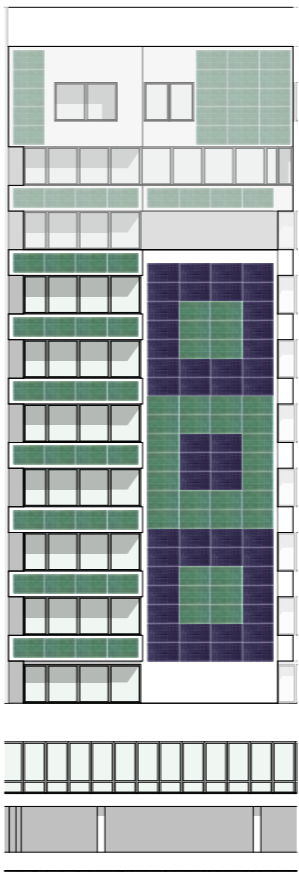
# PHOTOVOLTAICS FACADE DESIGN DEVELOPMENT



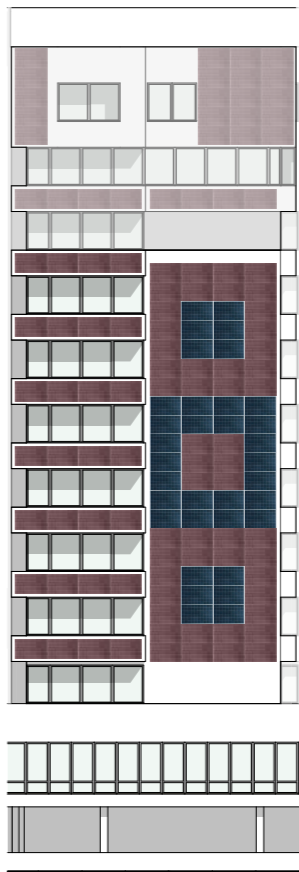
234 m2  
28 294kW/a



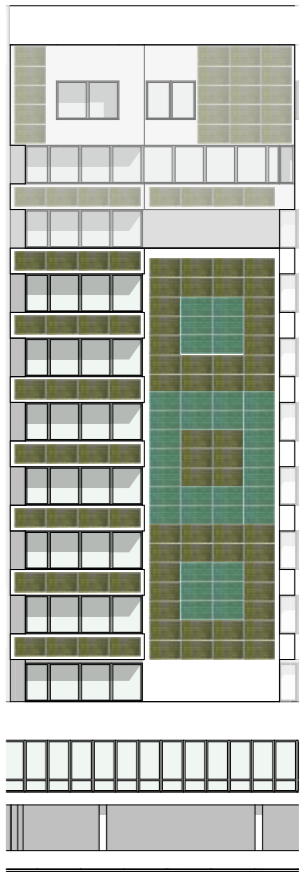
234 m2  
28 294kW/a



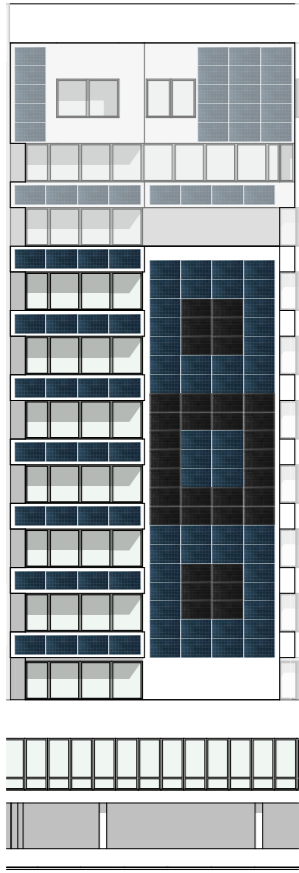
234 m2  
28 294kW/a



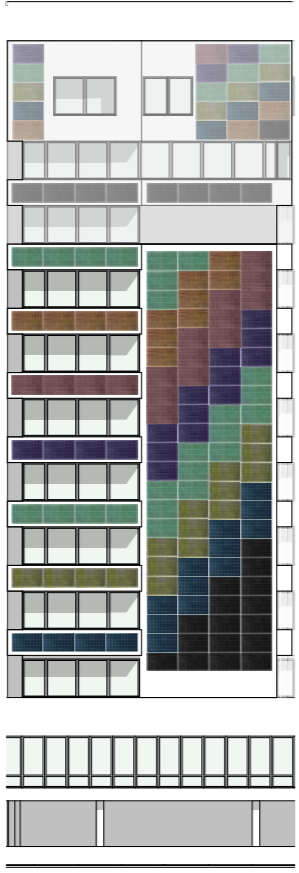
234 m2  
28 294kW/a



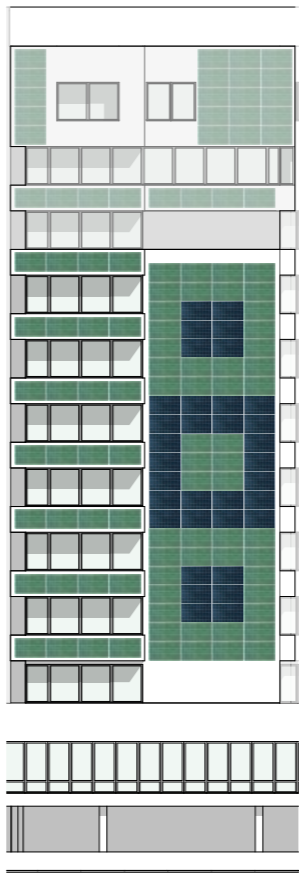
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34 970kW/a



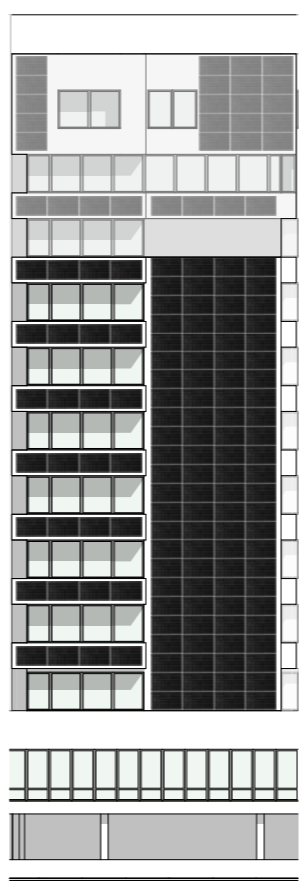
242 m2  
29 590kW/a



234 m2  
28 294kW/a



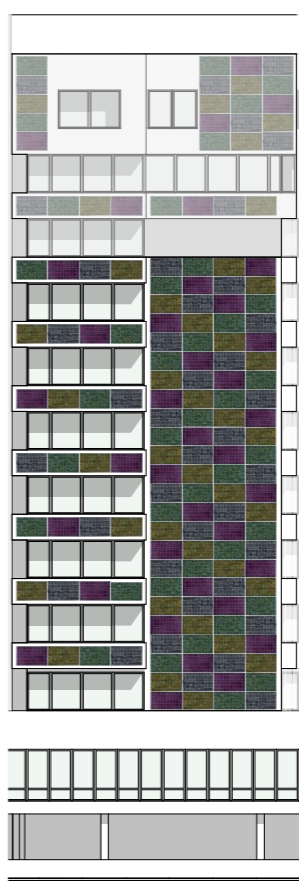
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42 795 kW/a



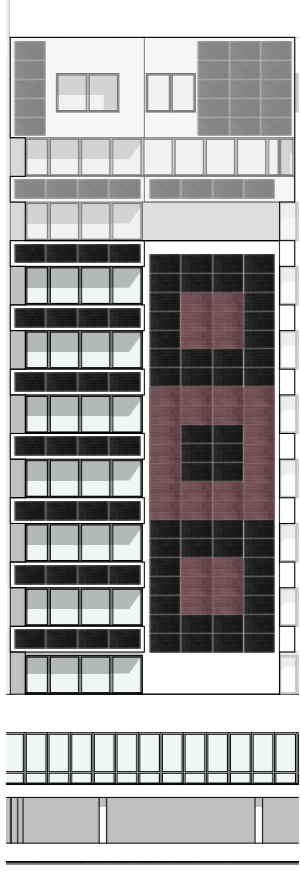
234 m2  
28 294kW/a



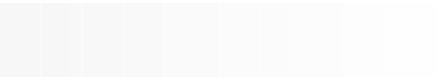
252 m2  
27 389 kW/a



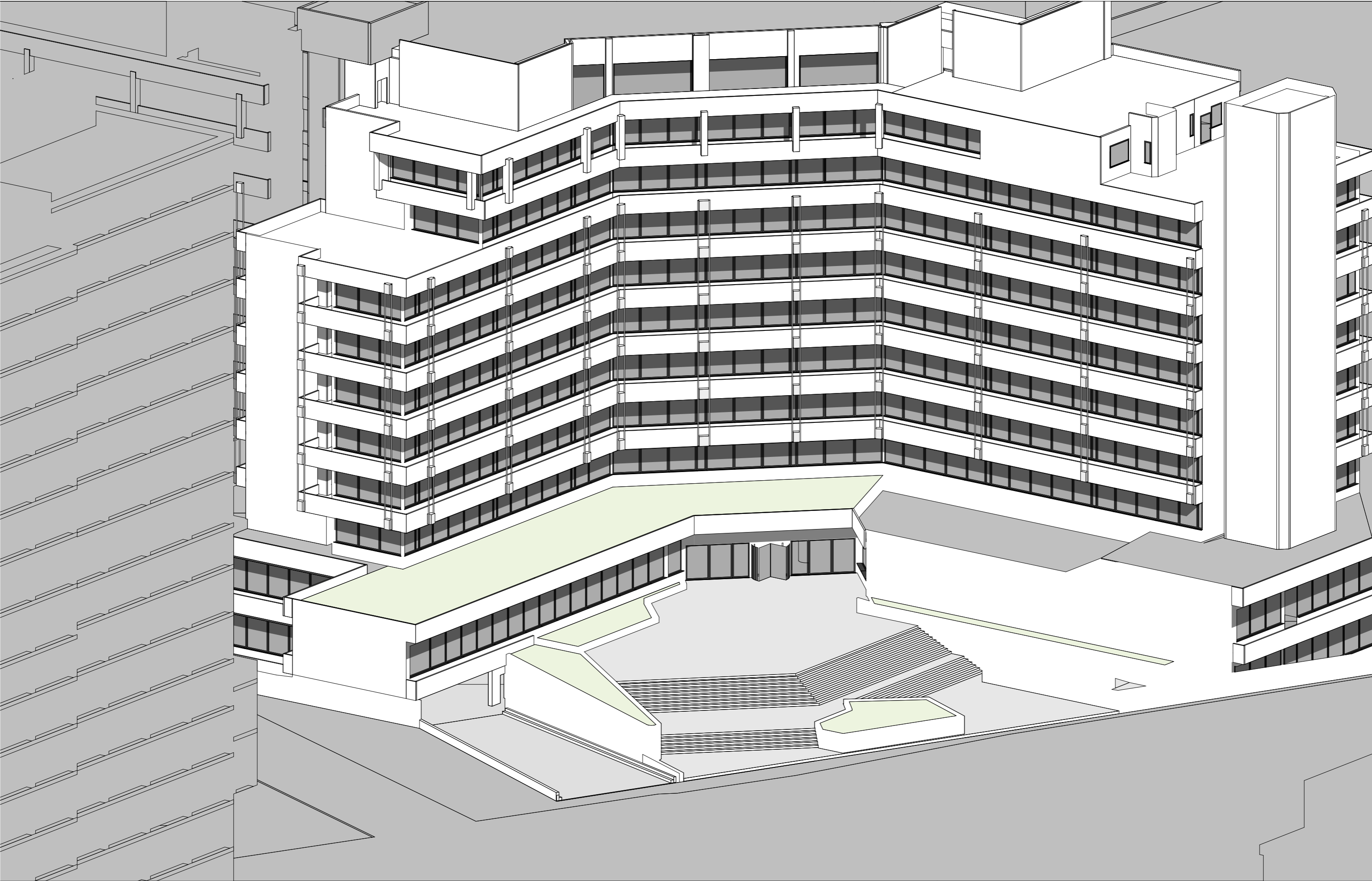
234 m2  
33 380kW/a



252 m2  
27 389 kW/a









# TREE SELECTION

ASH TREE



BEECH



OAK



MAPLE



YELLOW ACACIA





# PLANT SELECTION

ARCHICAD STUDENTEN-VERSION

VINCA MINOR



VINCA MAJOR



SEDUM SPURIUM



LONICERA PILEATA



HEUCHERA MICRANTHA



GERANIUM



CAMPANULA CARPATICA



CALAMINTHA NEPETA



BERGENIA CODIFOLIA



ALCHEMILLA MOLLIS



## BLOSSOM

	January	February	March	April	May	June	July	August	September	October	November	December
Allchemilla						Green	Green					
Bergania				Green	Green							
Calamintha							Green	Green	Green			
Campanula					Green	Green	Green	Green	Green			
Geranium					Green	Green	Green					
Heuchera						Green	Green	Green				
Lonicera					Green	Green	Green					
Sedum						Green	Green	Green				
Vinca Major				Green	Green							
Vinca Minor				Green	Green							

Allchemilla  
June - July



Bergania  
April - May



Calamintha  
July - September



Campanula  
May - September



Geranium  
May - July



Heuchera  
June - August



Lonicera  
May - July





# DESIGN - PLANT COLLAGE

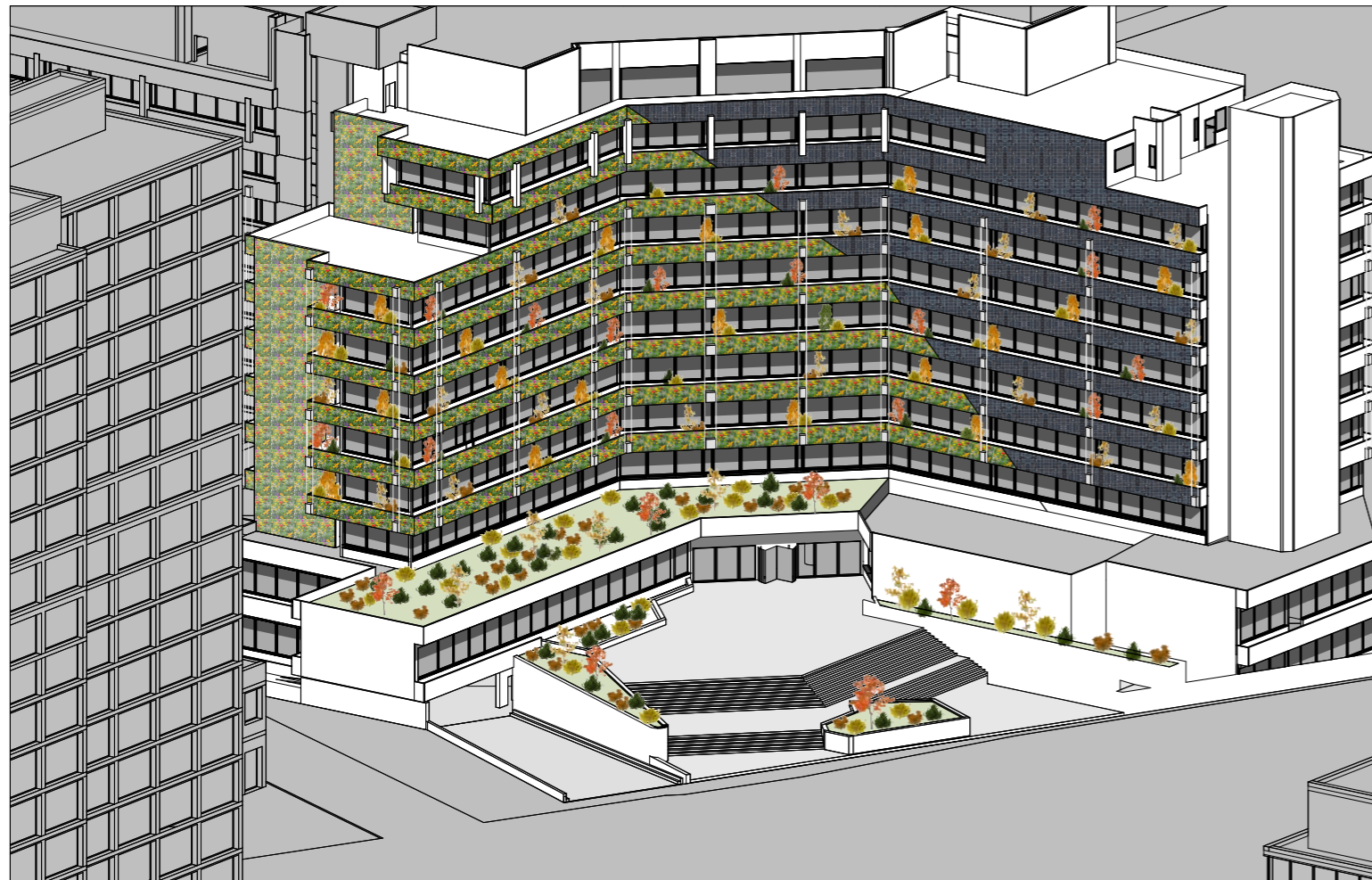
SPRING



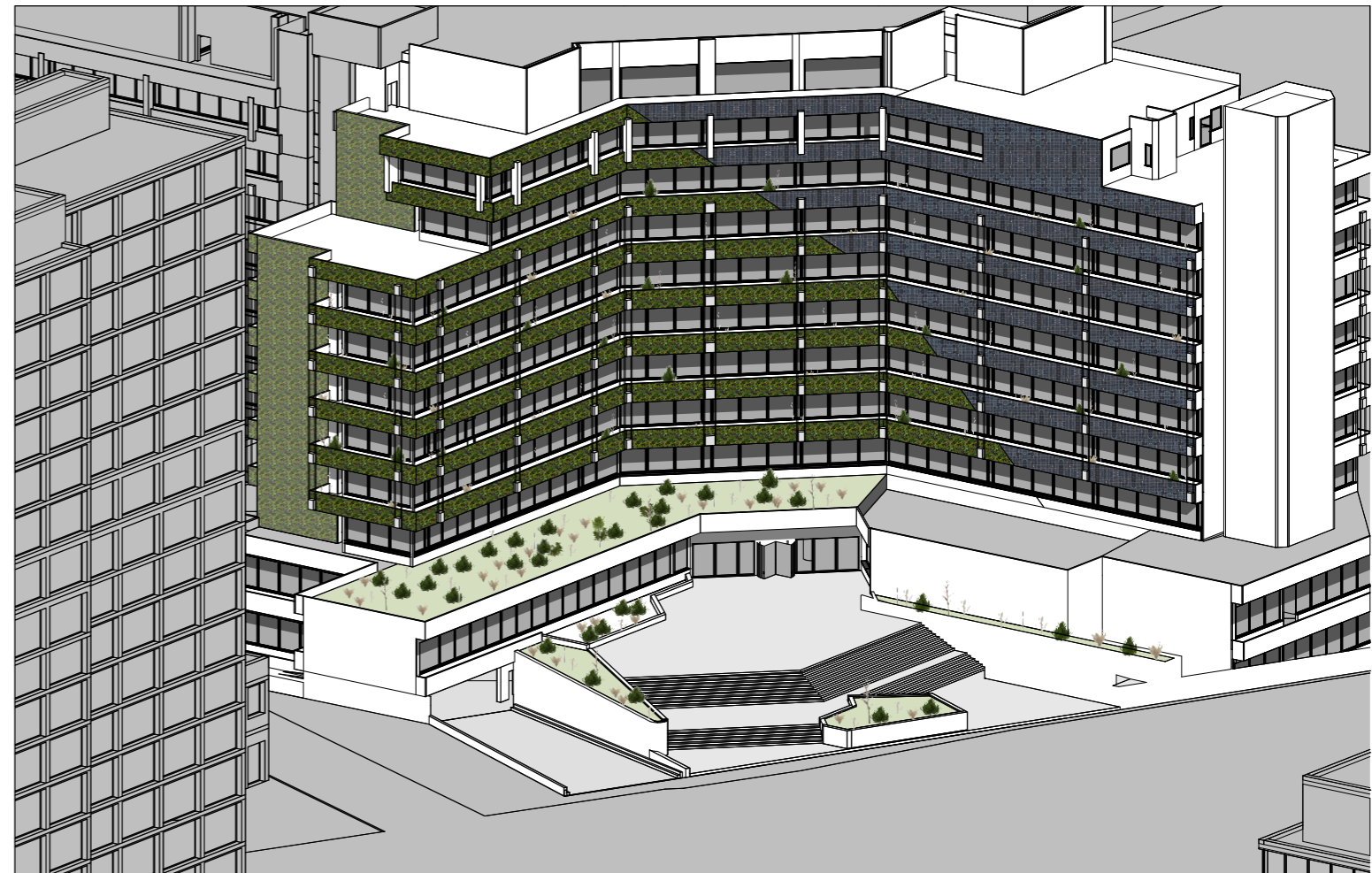
SUMMER



AUTUMN



WINTER





# DESIGN - PLANT SPECIES SEGREGATION

Allchemilla  
June - July

Bergania  
April - May

Calamintha  
July - September

Campanula  
May - September

Geranium  
May - July

Heuchera  
June - August

Lonicera  
May - July



Sedum  
June - August



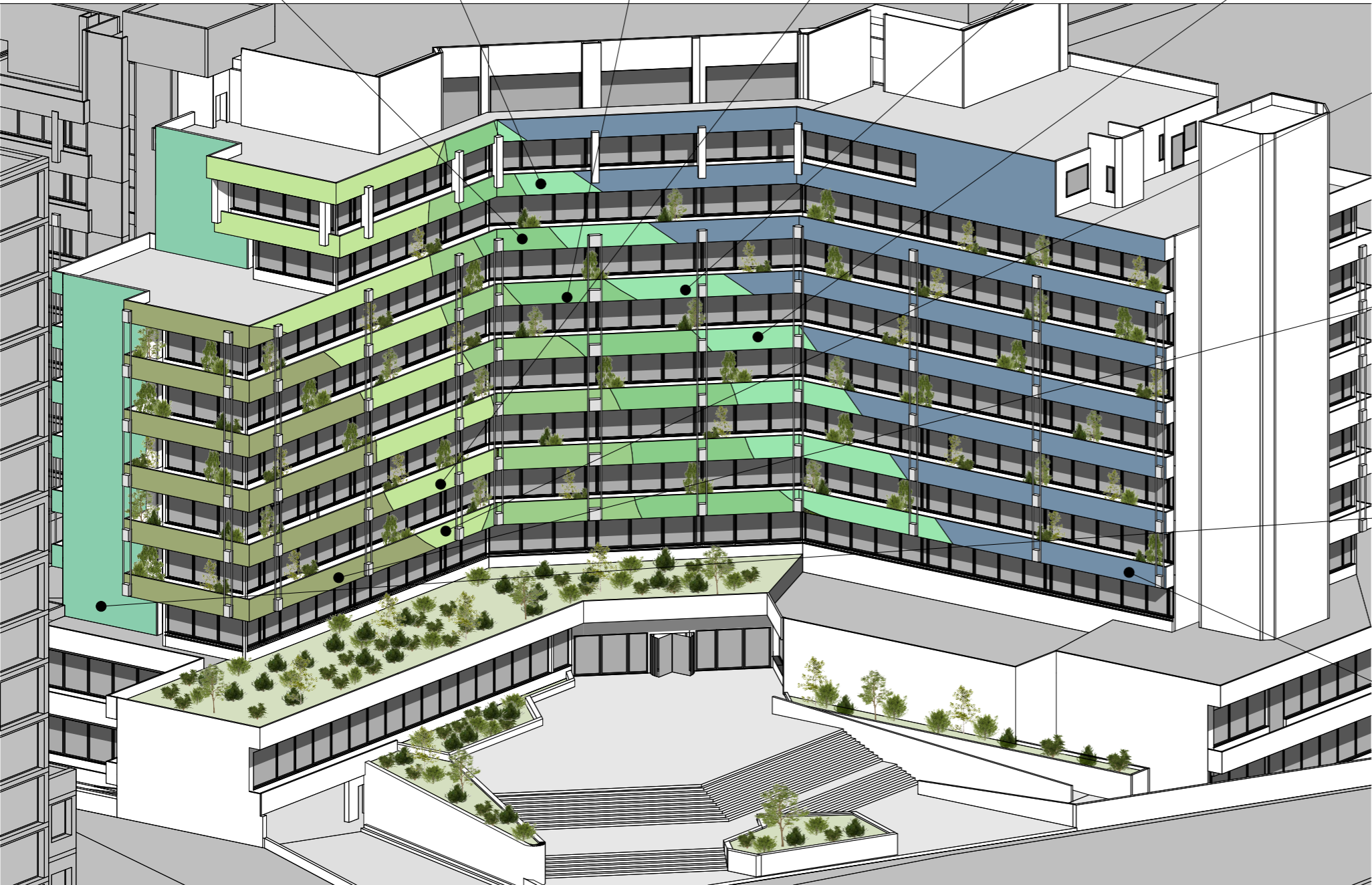
Vinica Major  
April - May



Vinica Minor  
April - May



Photovoltaics  
Mono-cristaline





# TREES AND SHRUBS SELECTION

Ash Tree



Beech



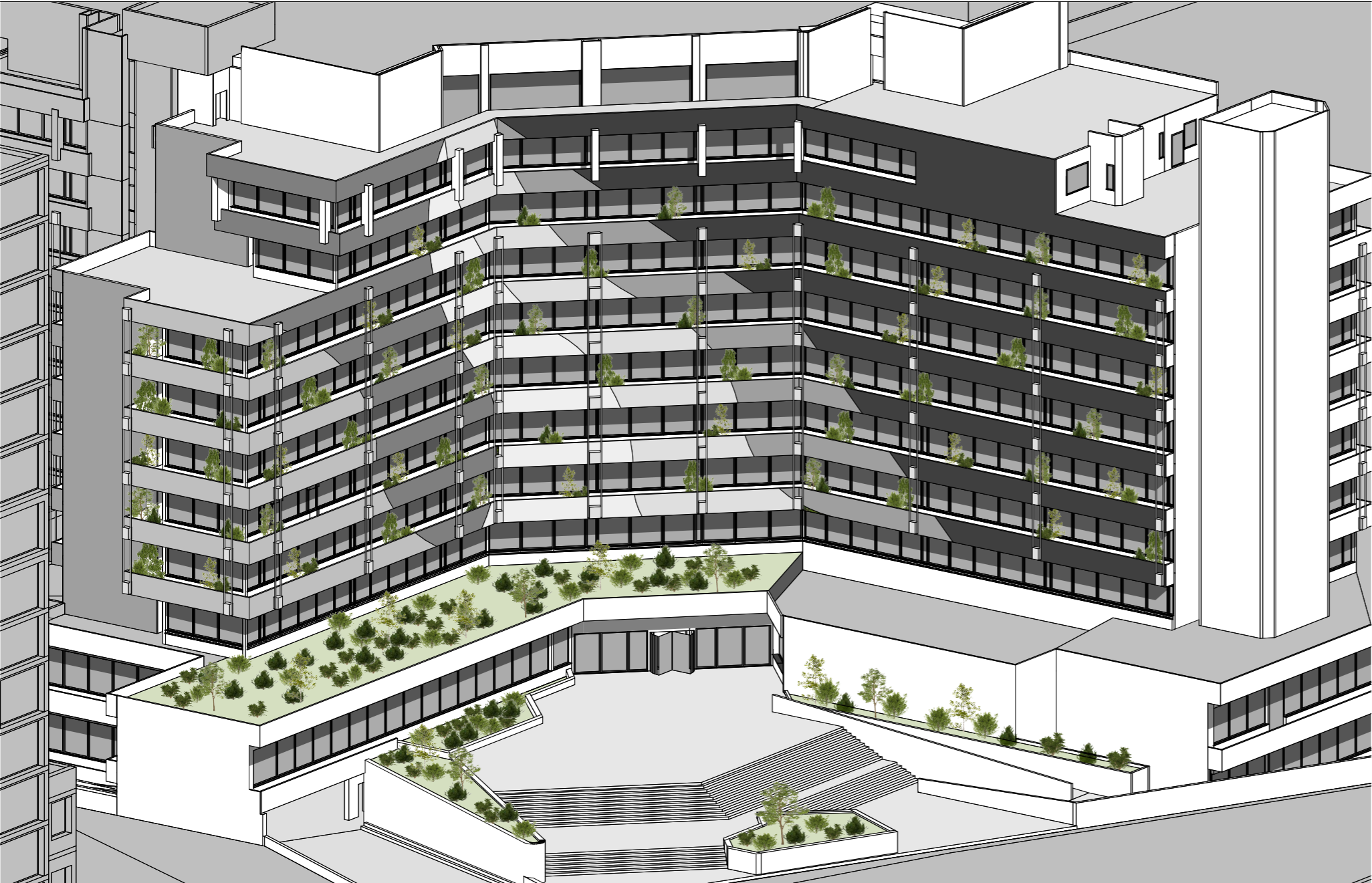
Maple



Oak



Yellow Acacia



Hazelnut Shrub



Elderberry Shrub



Juniper Shrub



# DESIGN - PLANT SPECIES SEGREGATION

SPRING



SUMMER



AUTUMN

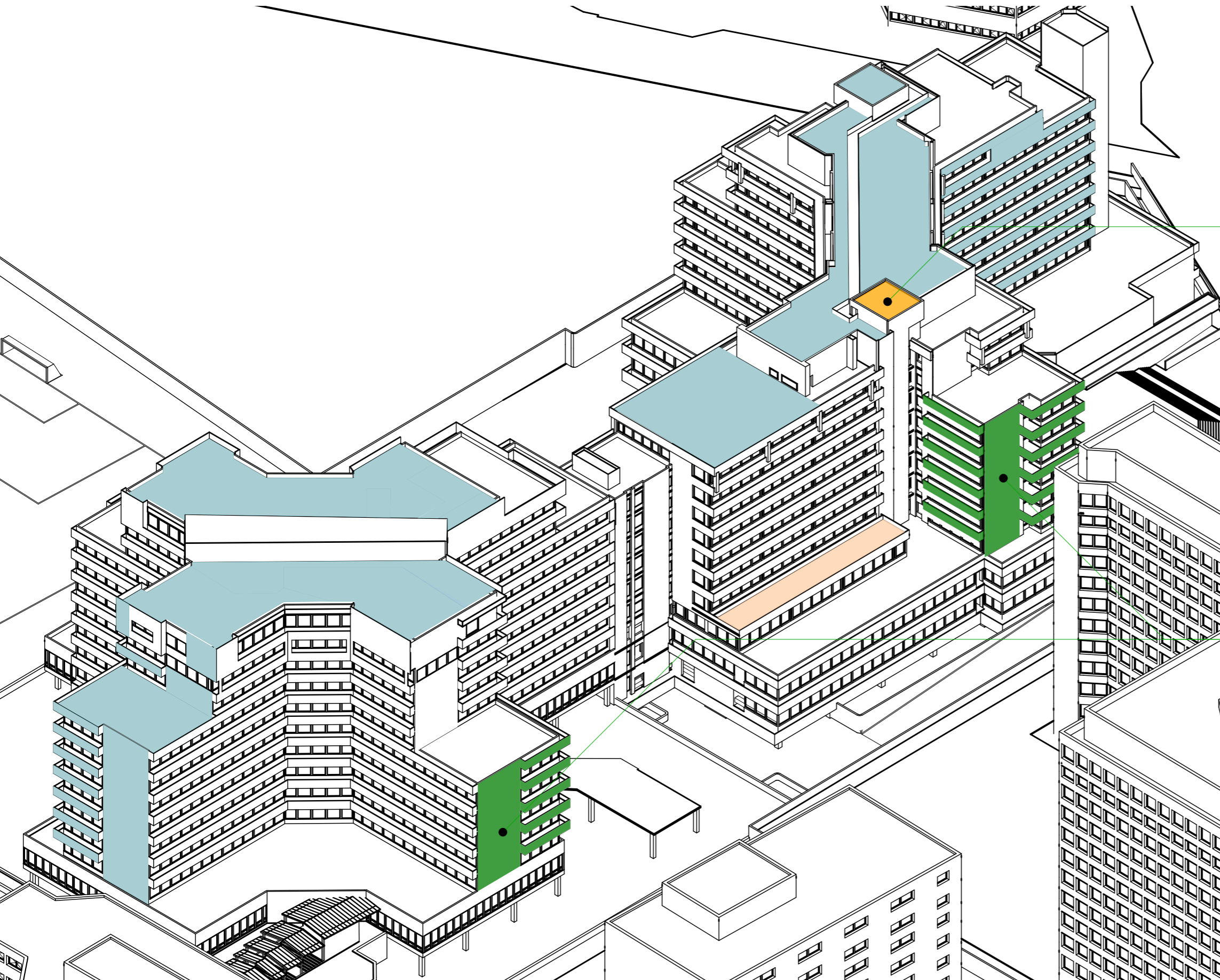


WINTER



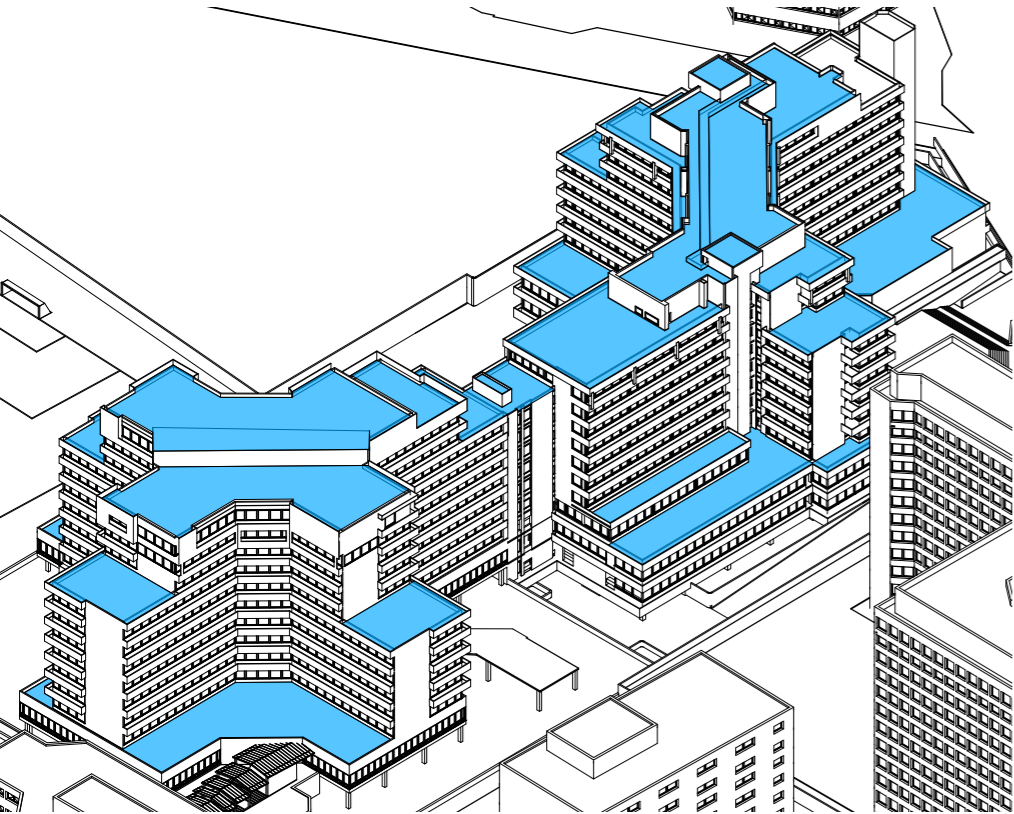


BIRD NESTS AND BEE HOTELS

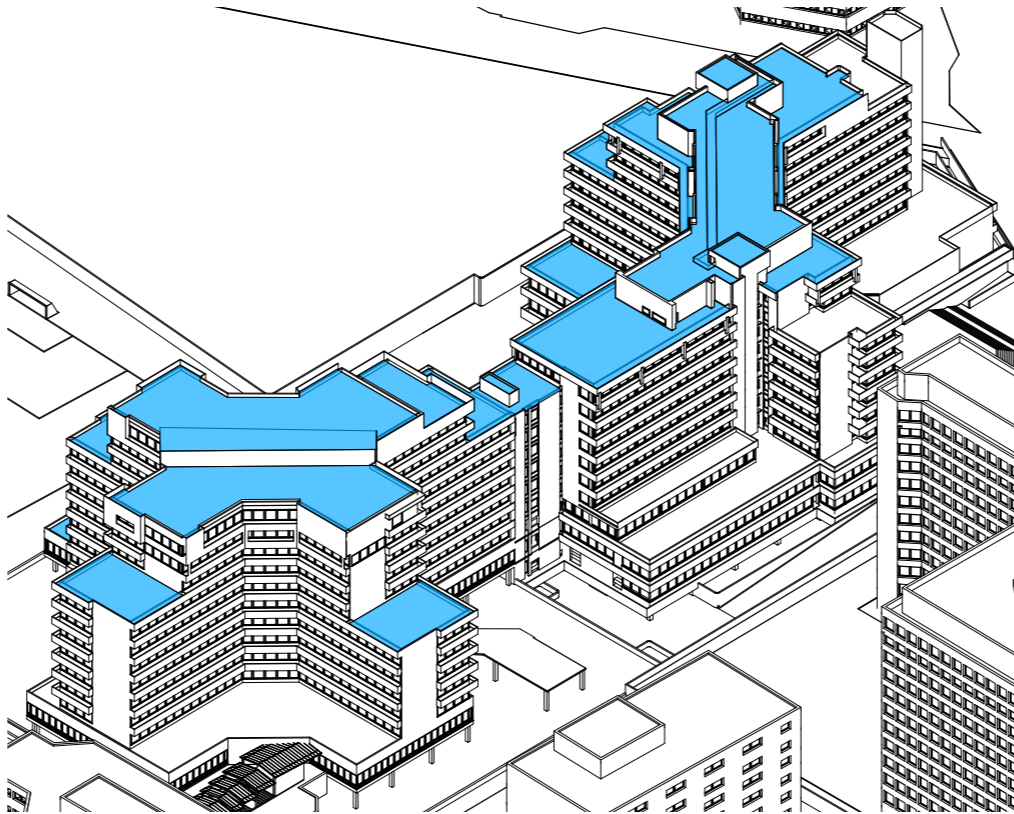




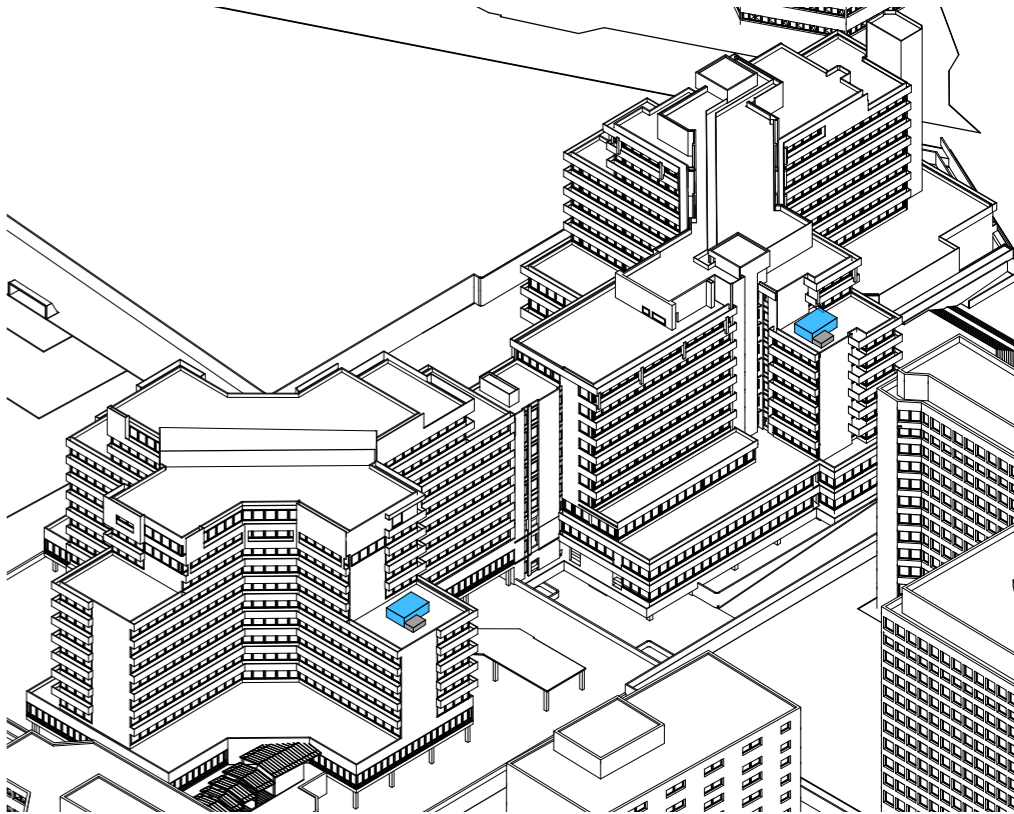
OVERALL COLLECTION



COLLECTED WATER USED FOR FACADE IRRIGATION



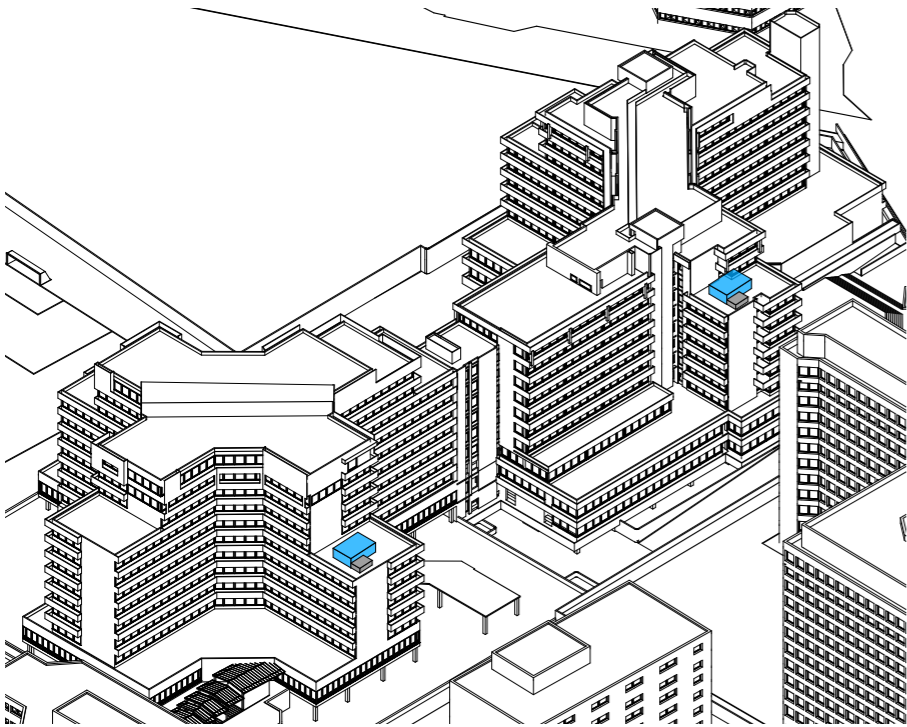
WATER TANKS AND FERTILISATION STATIONS



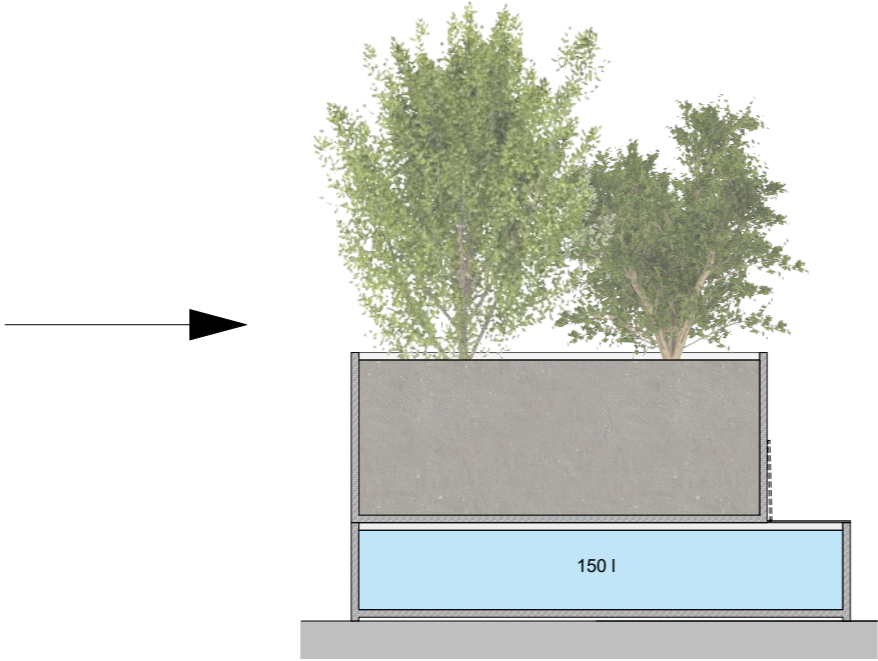


# IRRIGATION SEQUENCE

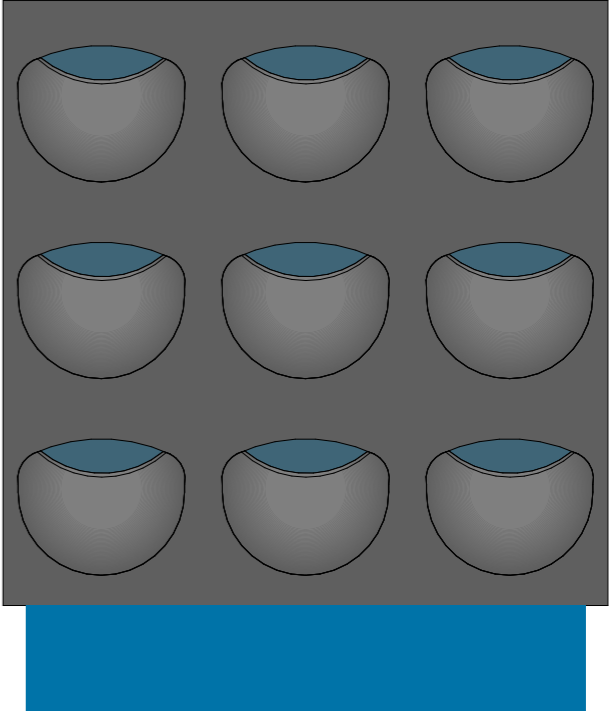
WATER TANKS



DECENTRALISED TANKS



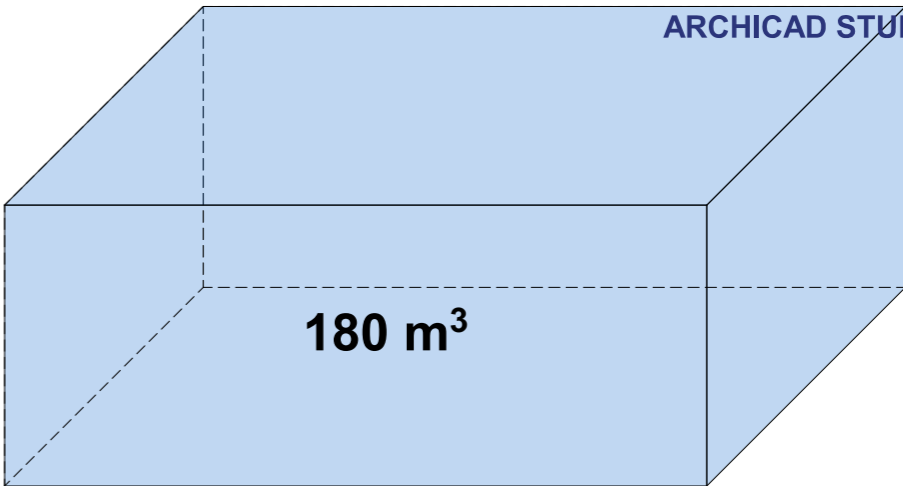
CASSETTES



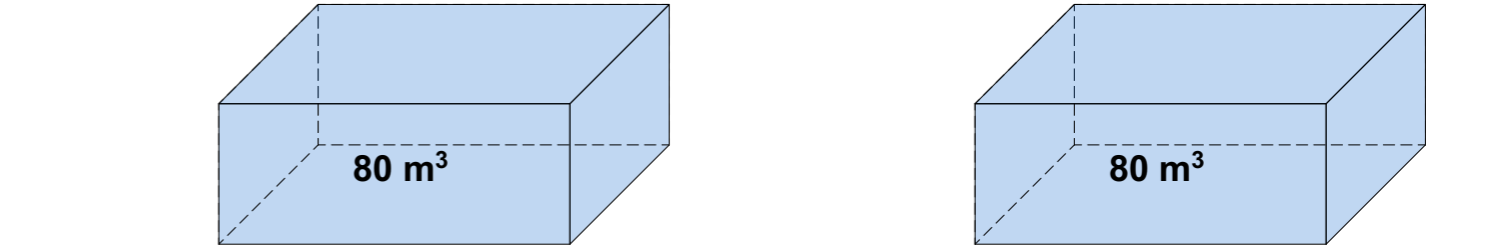


# RAINWATER TANKS scheme

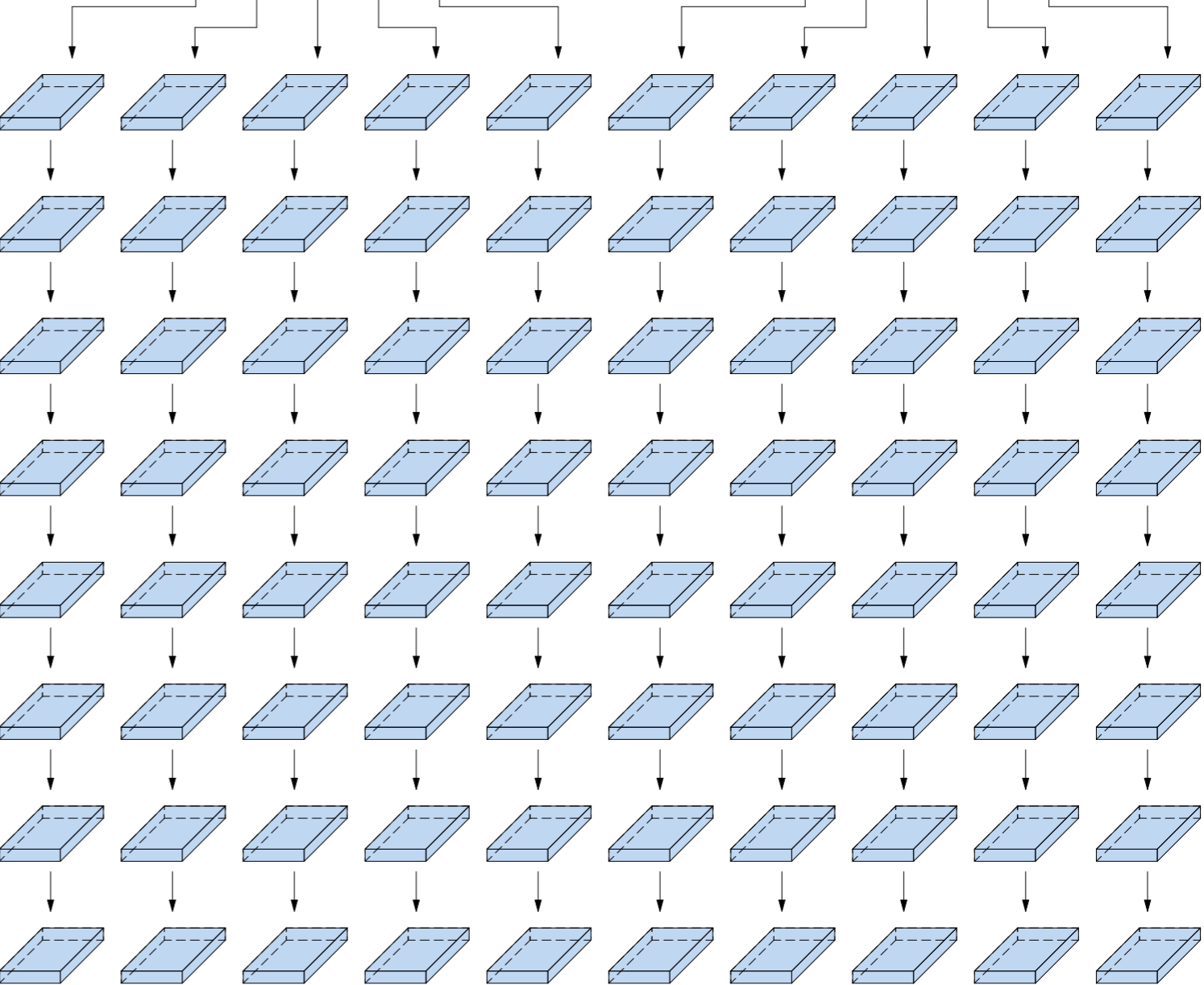
Collected rainwater  
**180 m<sup>3</sup>**



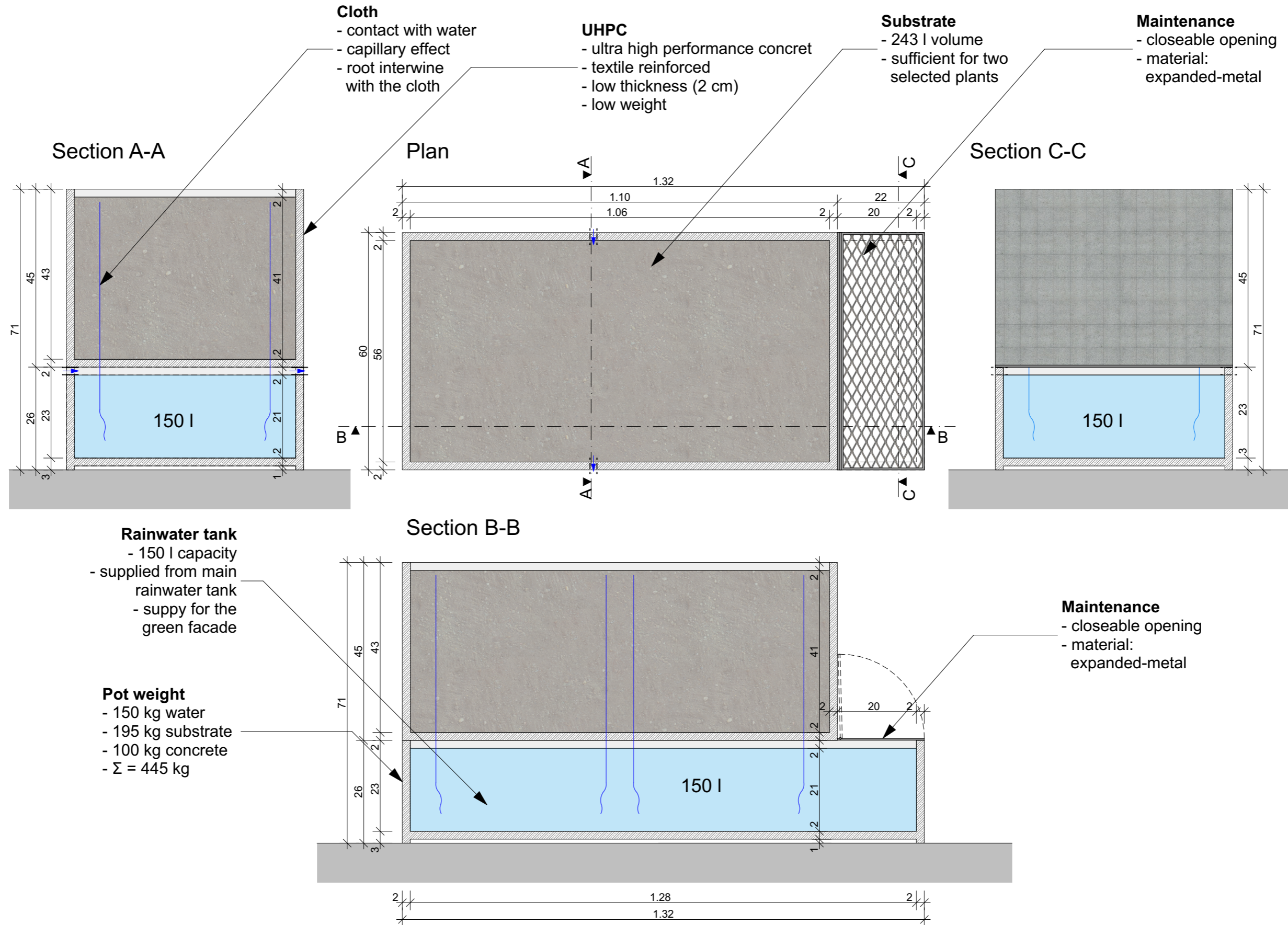
2 x tank 80 m<sup>3</sup>  
**160 m<sup>3</sup>**



150 x pot 0,15 m<sup>3</sup>  
**22,5 m<sup>3</sup>**



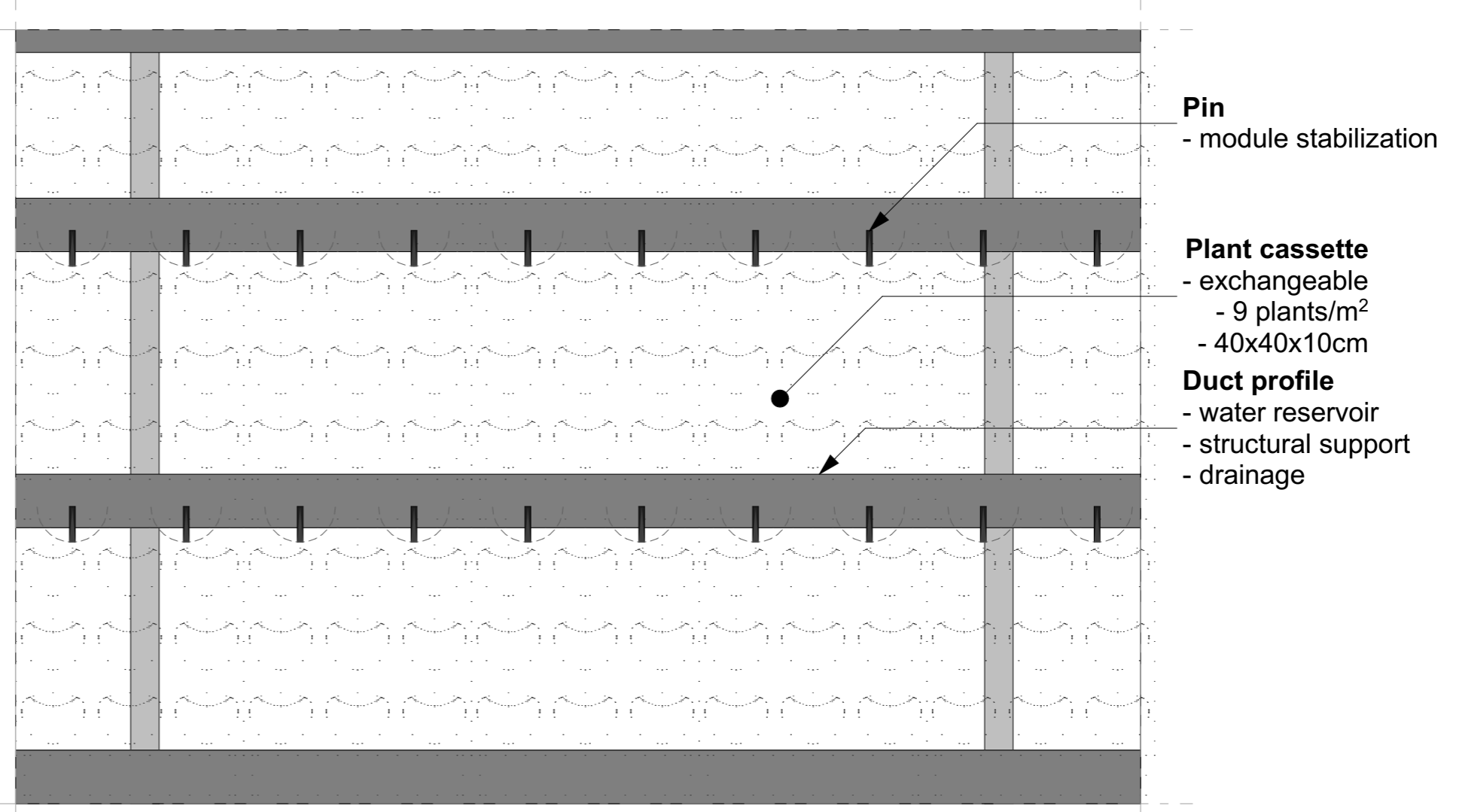
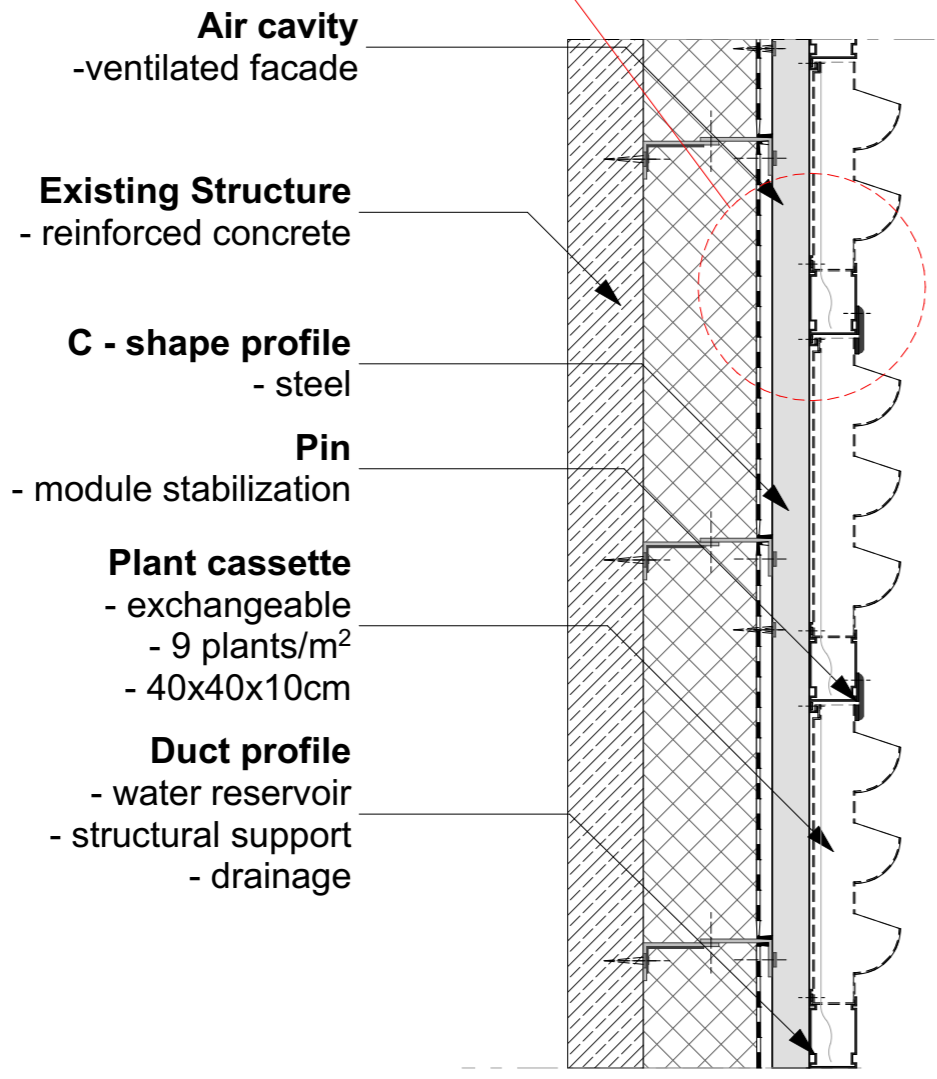
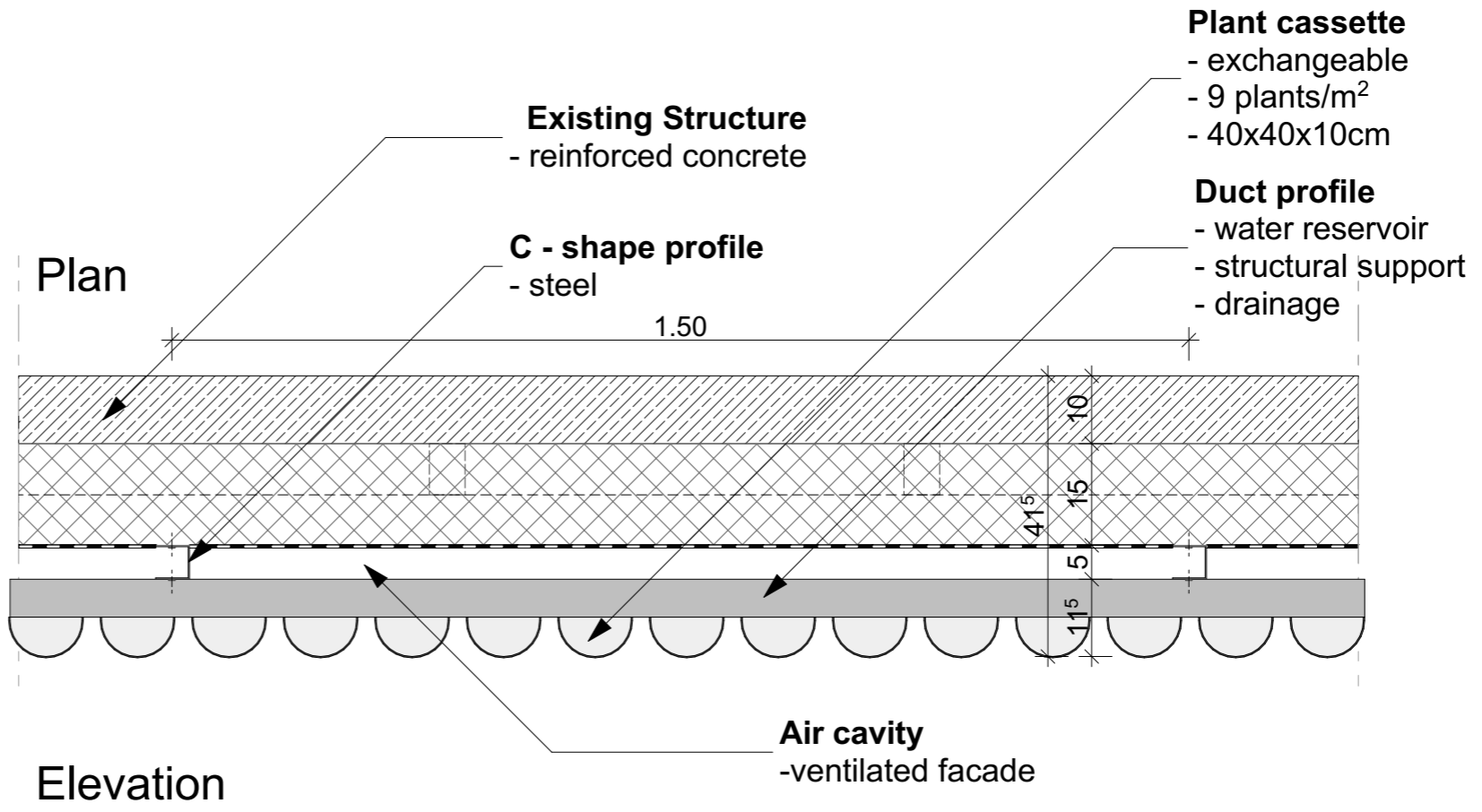
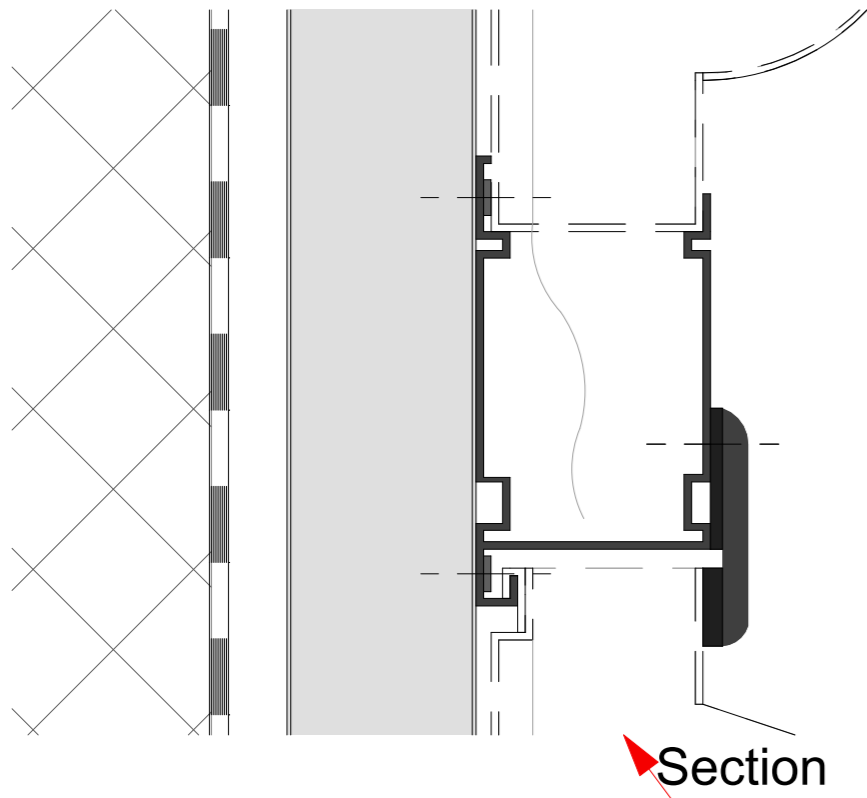






# GREEN FACADE STRUCTURE SYSTEM

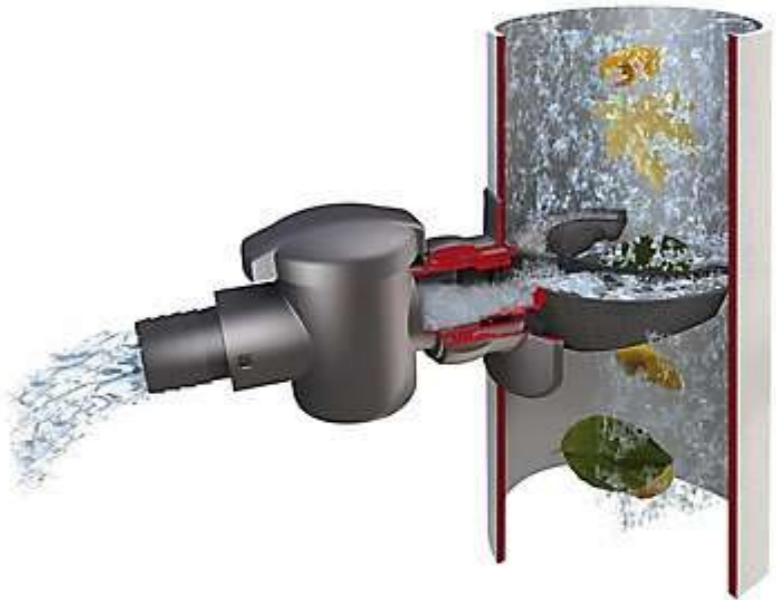
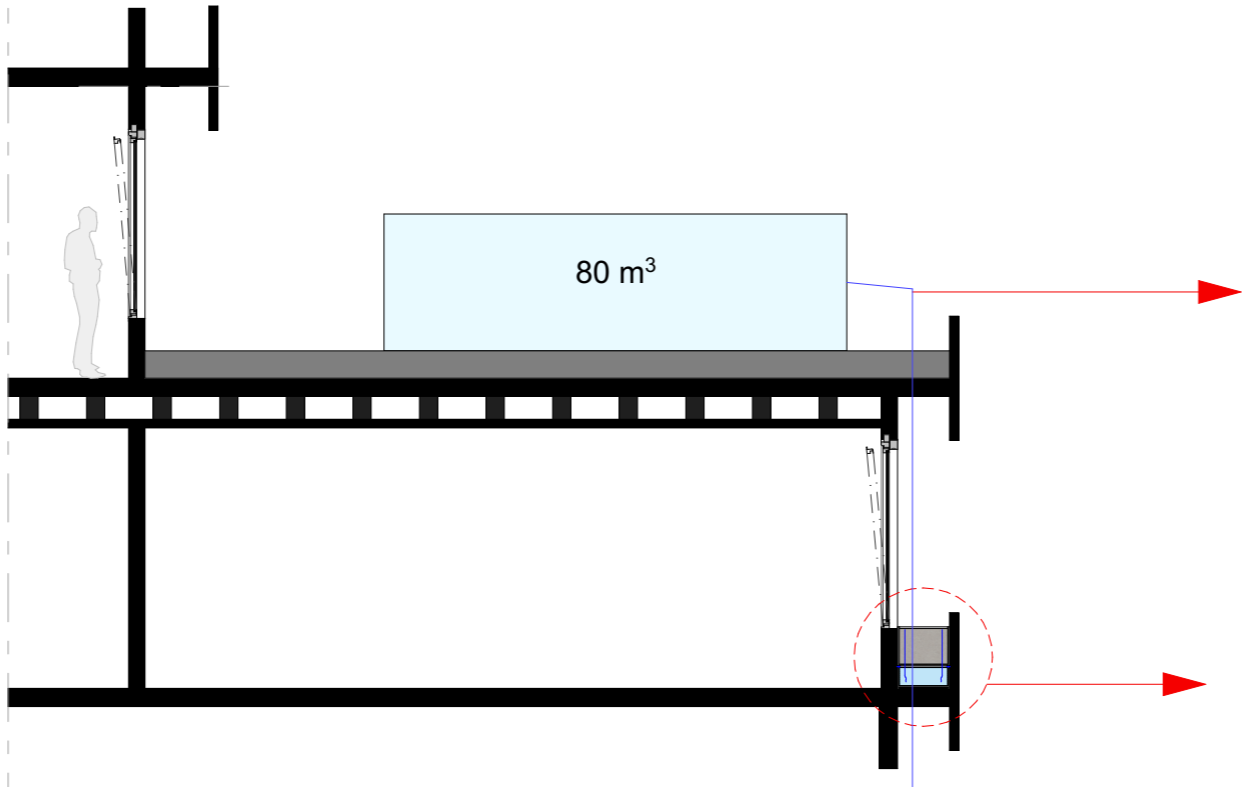
detail 1:2,1:10



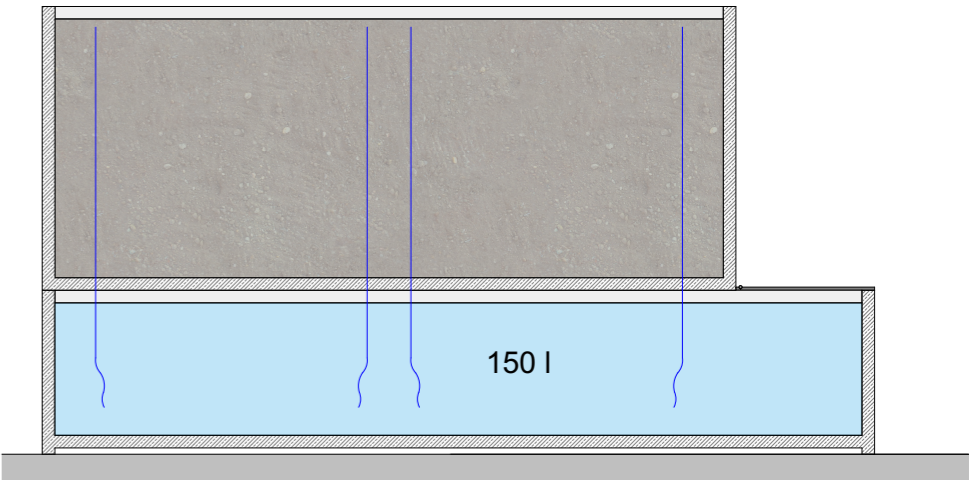


# IRRIGATION SEQUENCE

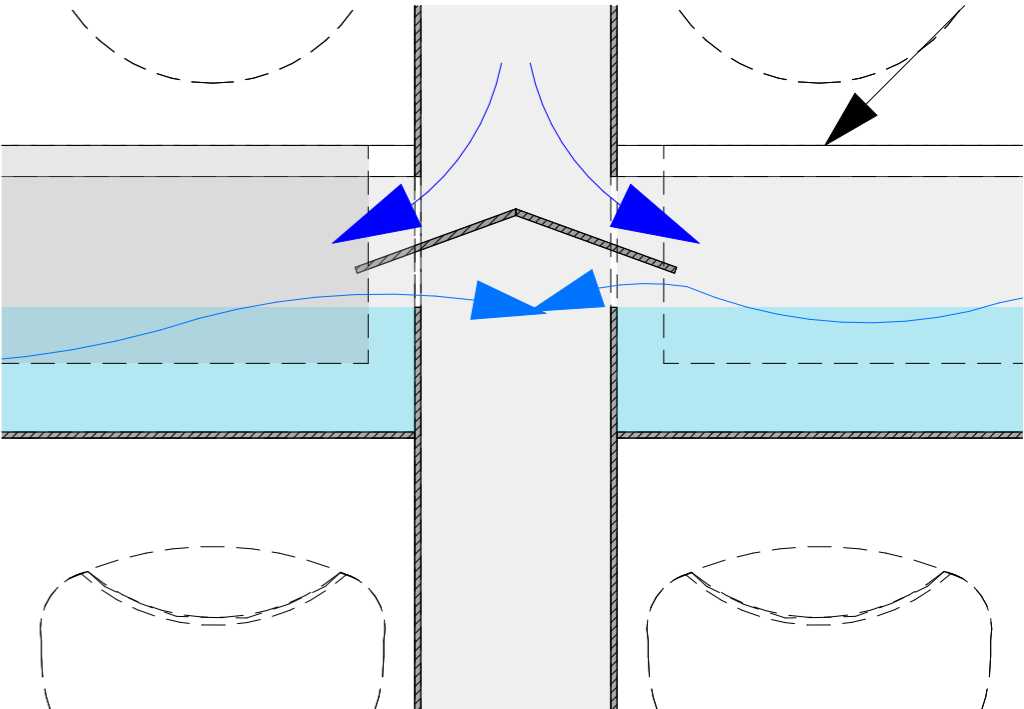
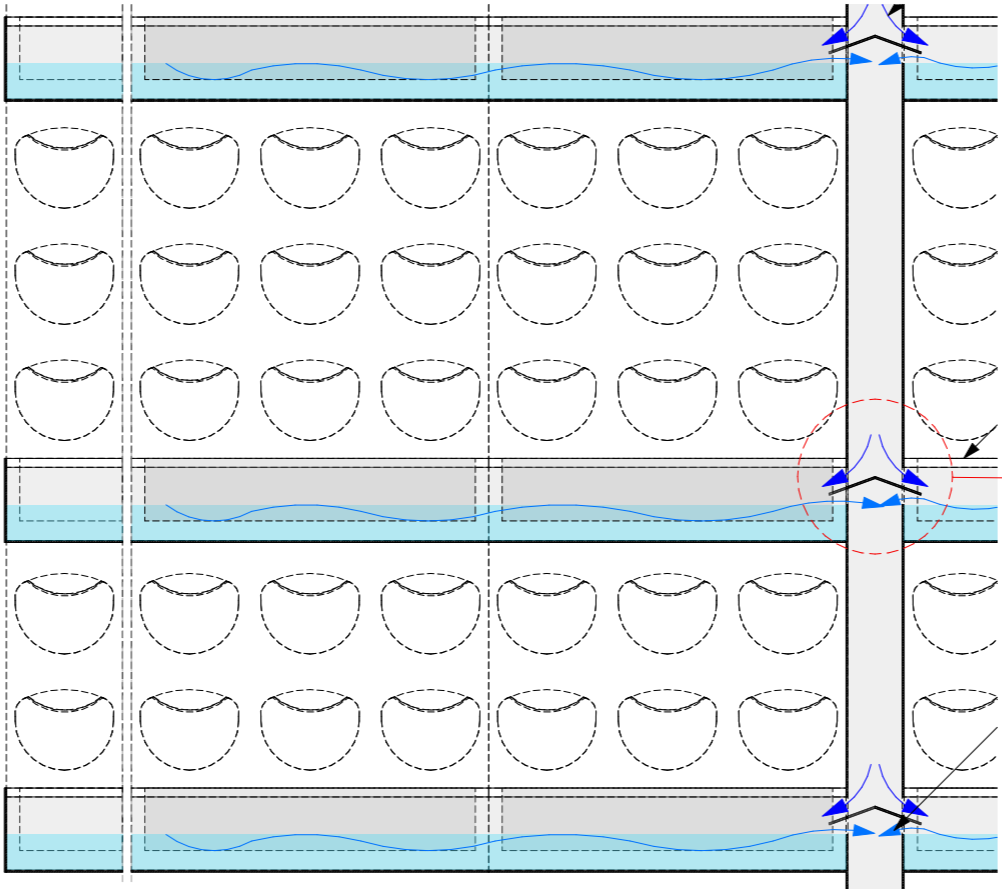
**WATER TANKS**



**DECENTRALISED TANKS  
POTS**



**CASSETTES**





# VERTICAL GREEN FACADE MODULE SYSTEM

detail 1:5



**Main supply duct**  
- water supplied from either water tank on the roof or from the tree pots on the balconies

**Water supply**  
- rainwater  
- gravity force

**Duct profile**  
- water reservoir  
- structural support  
- drainage

**Duct profile**  
- no opening in end  
- no slope

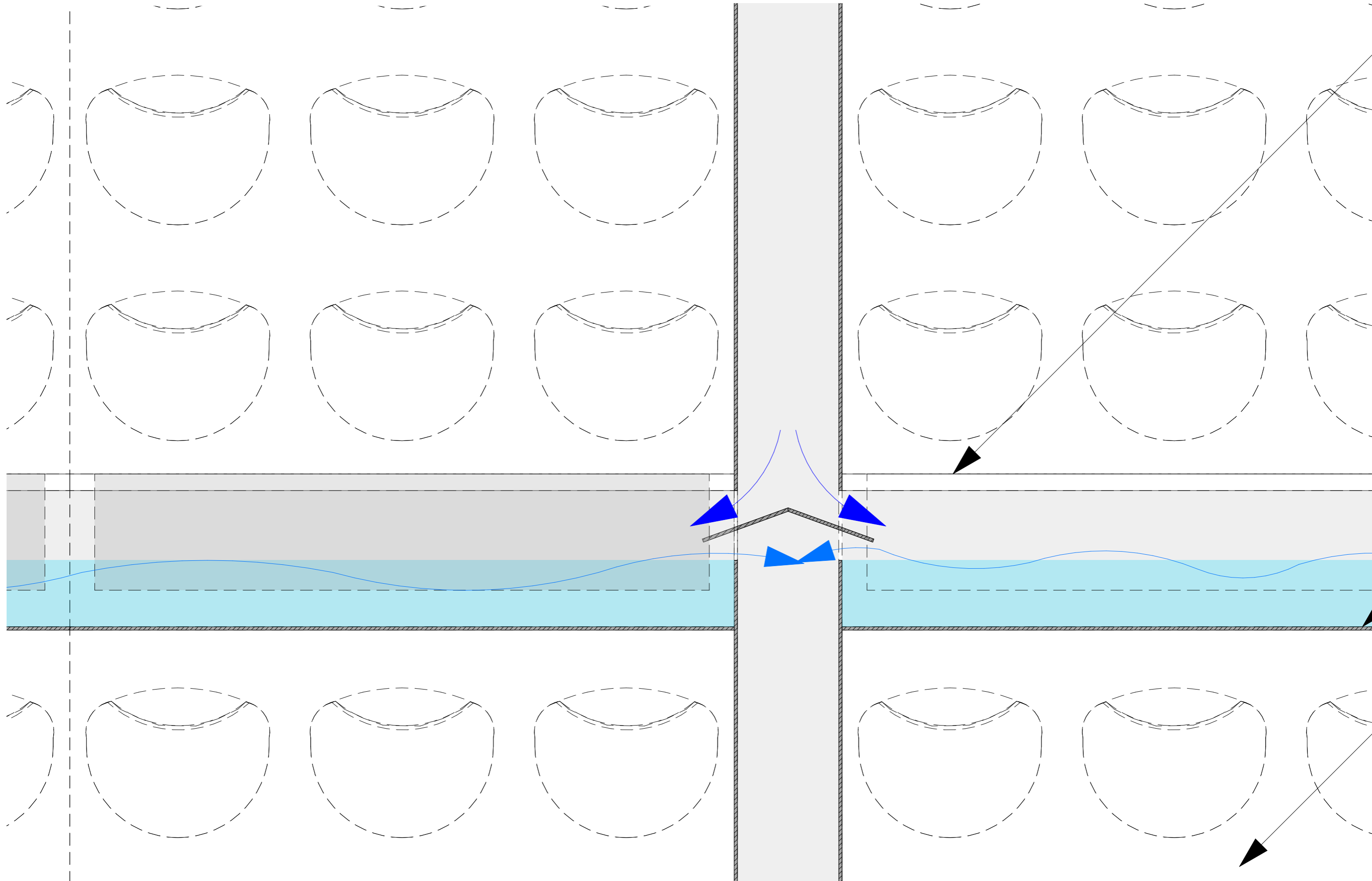
**Plant cassette**  
- exchangeable  
- 9 plants/m<sup>2</sup>  
- pre-planted plants prior to construction  
- 40x40x10cm

**Reuse water**  
- drained water reused for further irrigation



# VERTICAL GREEN FACADE MODULE SYSTEM

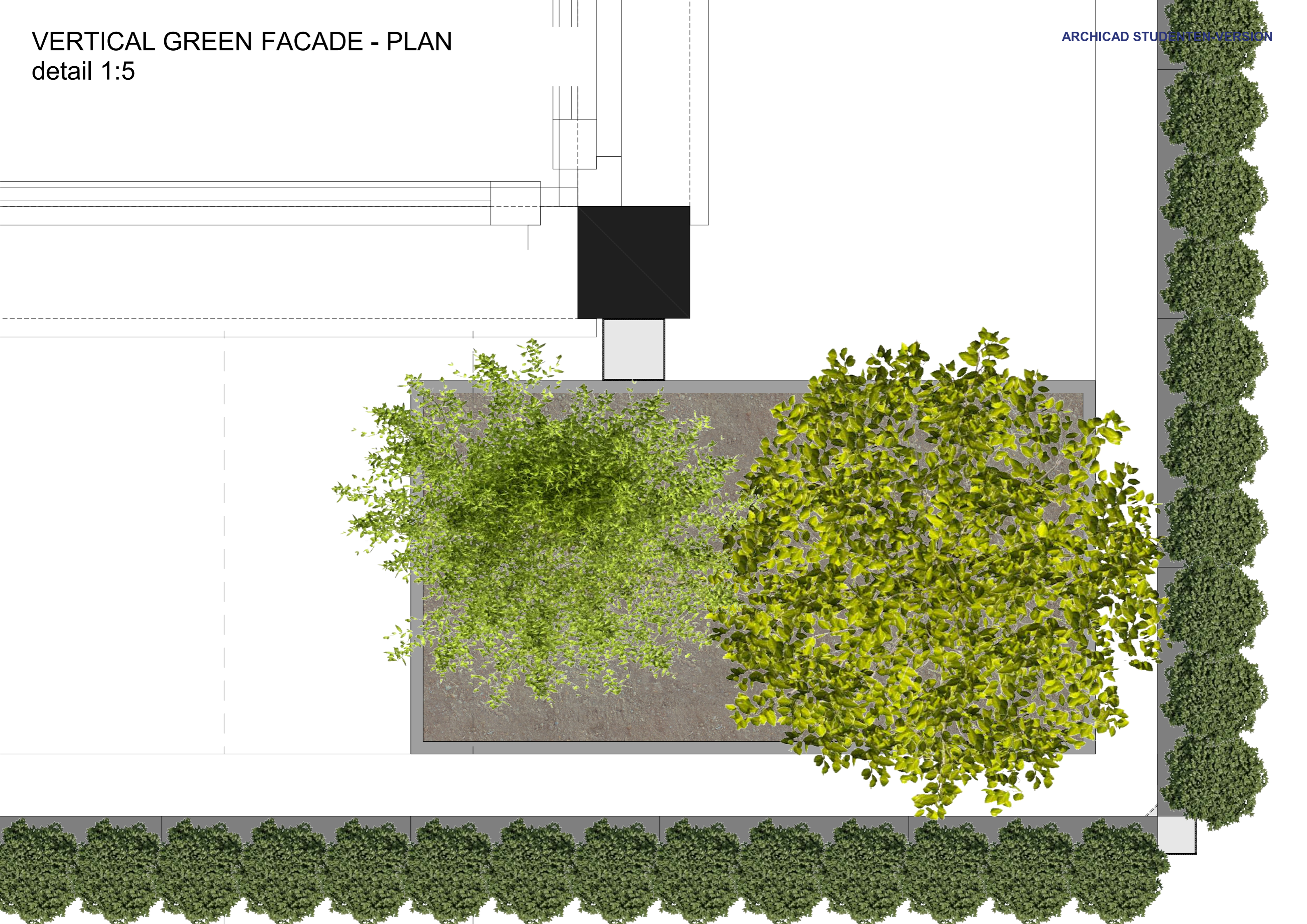
zoom-in 1:2





# VERTICAL GREEN FACADE - PLAN

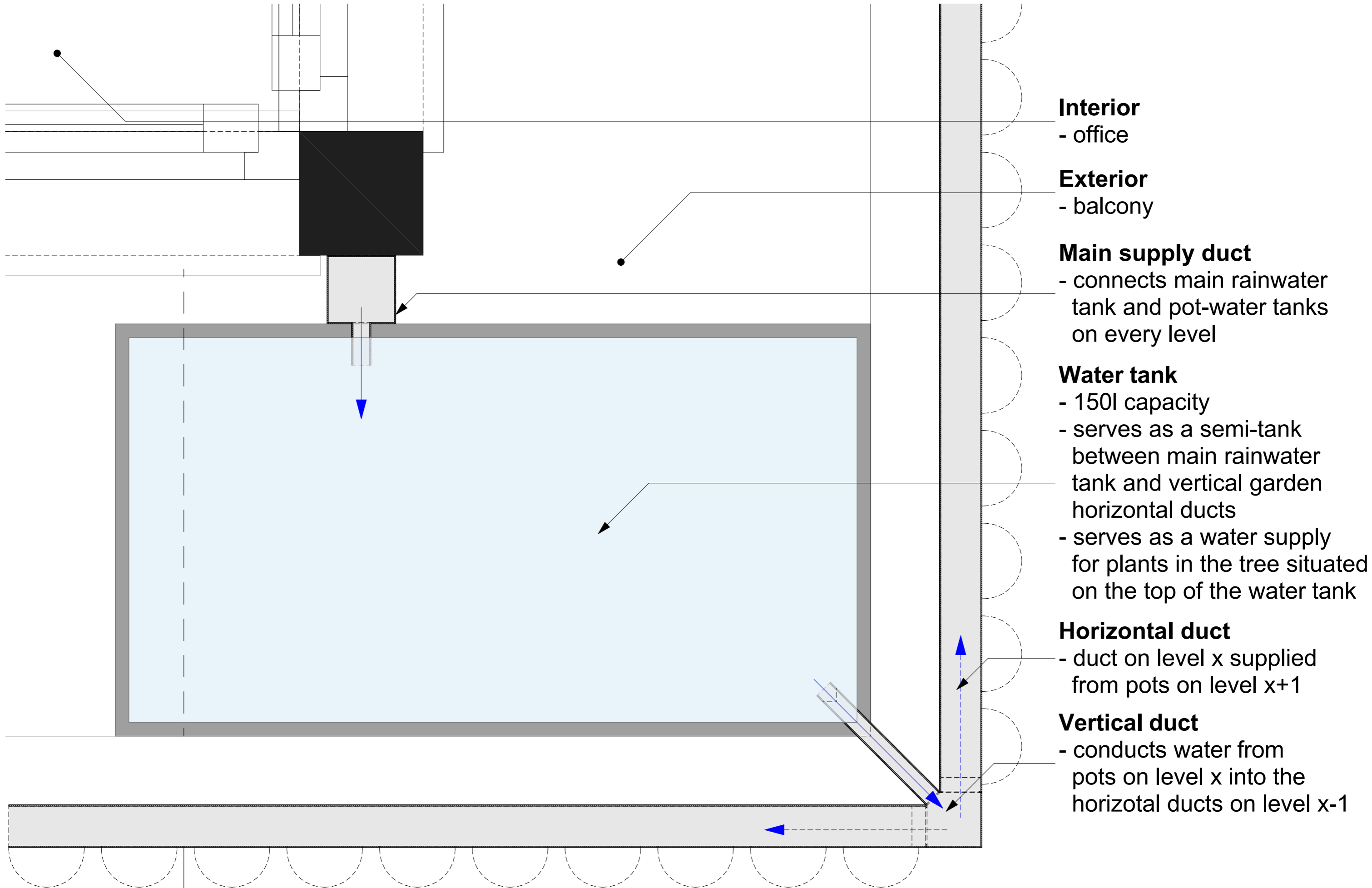
detail 1:5





# VERTICAL GREEN FACADE SYSTEM - PLAN

detail 1:5



## Interior

- office

## Exterior

- balcony

## Main supply duct

- connects main rainwater tank and pot-water tanks on every level

## Water tank

- 150l capacity  
- serves as a semi-tank between main rainwater tank and vertical garden horizontal ducts  
- serves as a water supply for plants in the tree situated on the top of the water tank

## Horizontal duct

- duct on level x supplied from pots on level x+1

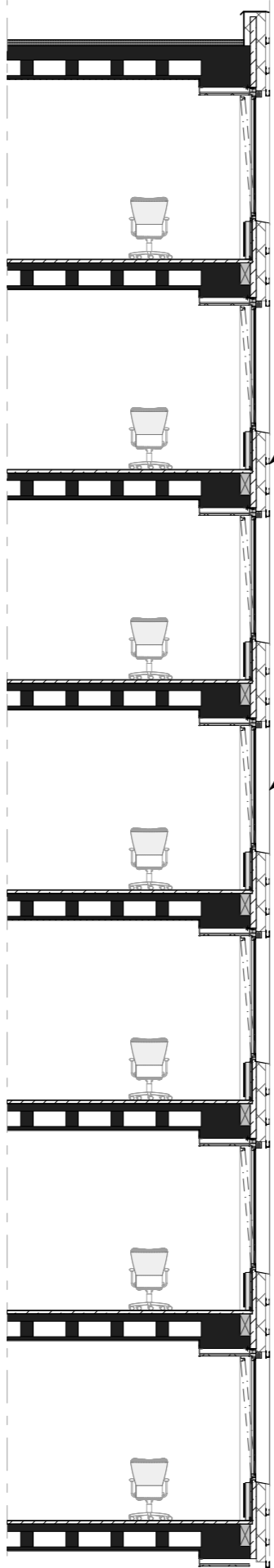
## Vertical duct

- conducts water from pots on level x into the horizontal ducts on level x-1



# VERTICAL GREEN FACADE SYSTEM

1:100



**Duct profile**  
- water reservoir  
- structural support  
- drainage

**Water supply**  
- supply pipes  
- drainage pipes



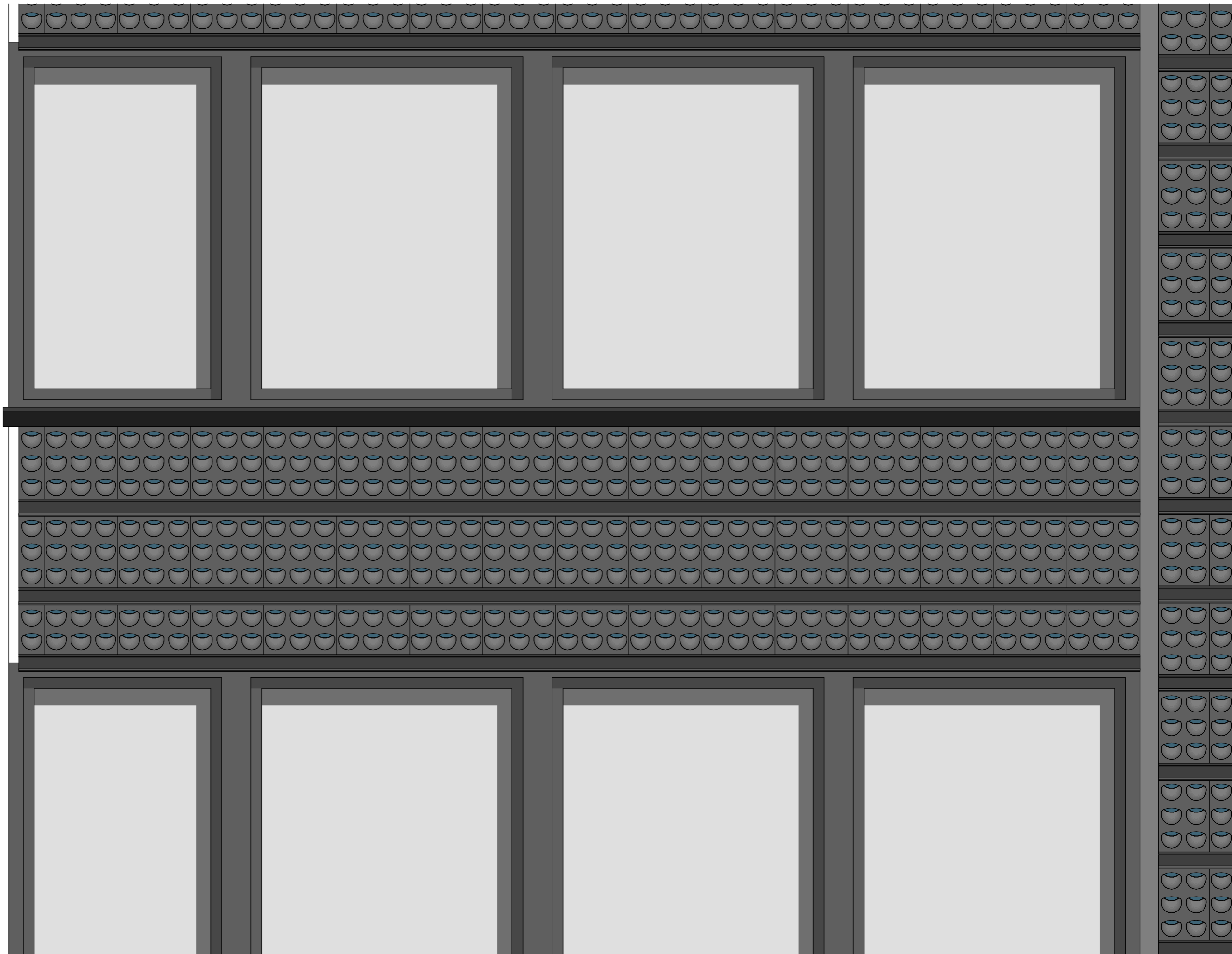
**Duct profile**  
- water reservoir  
- structural support  
- drainage

**Water supply**  
- supply pipes  
- drainage pipes



# VERTICAL GREEN FACADE SYSTEM

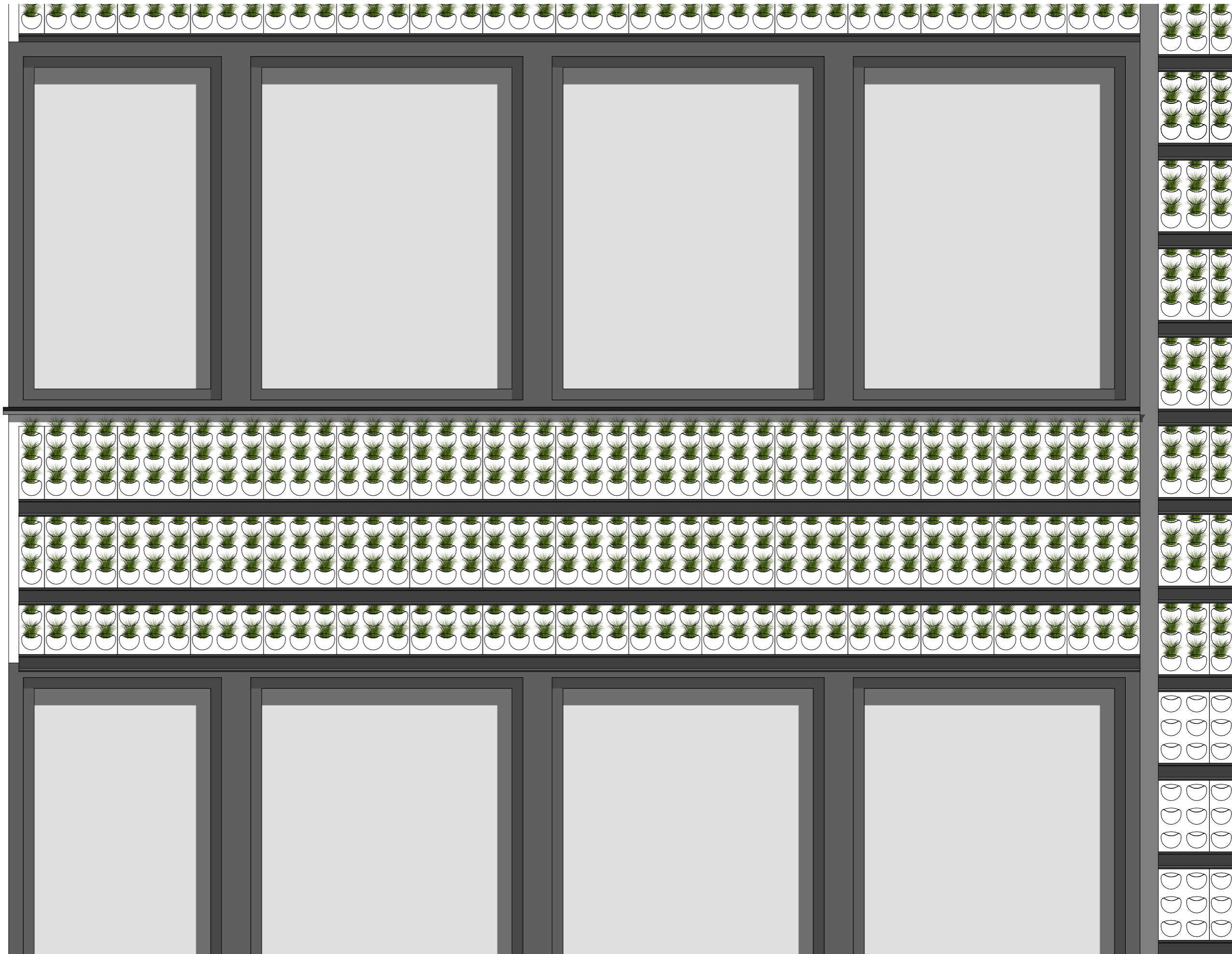
Detail 1:20





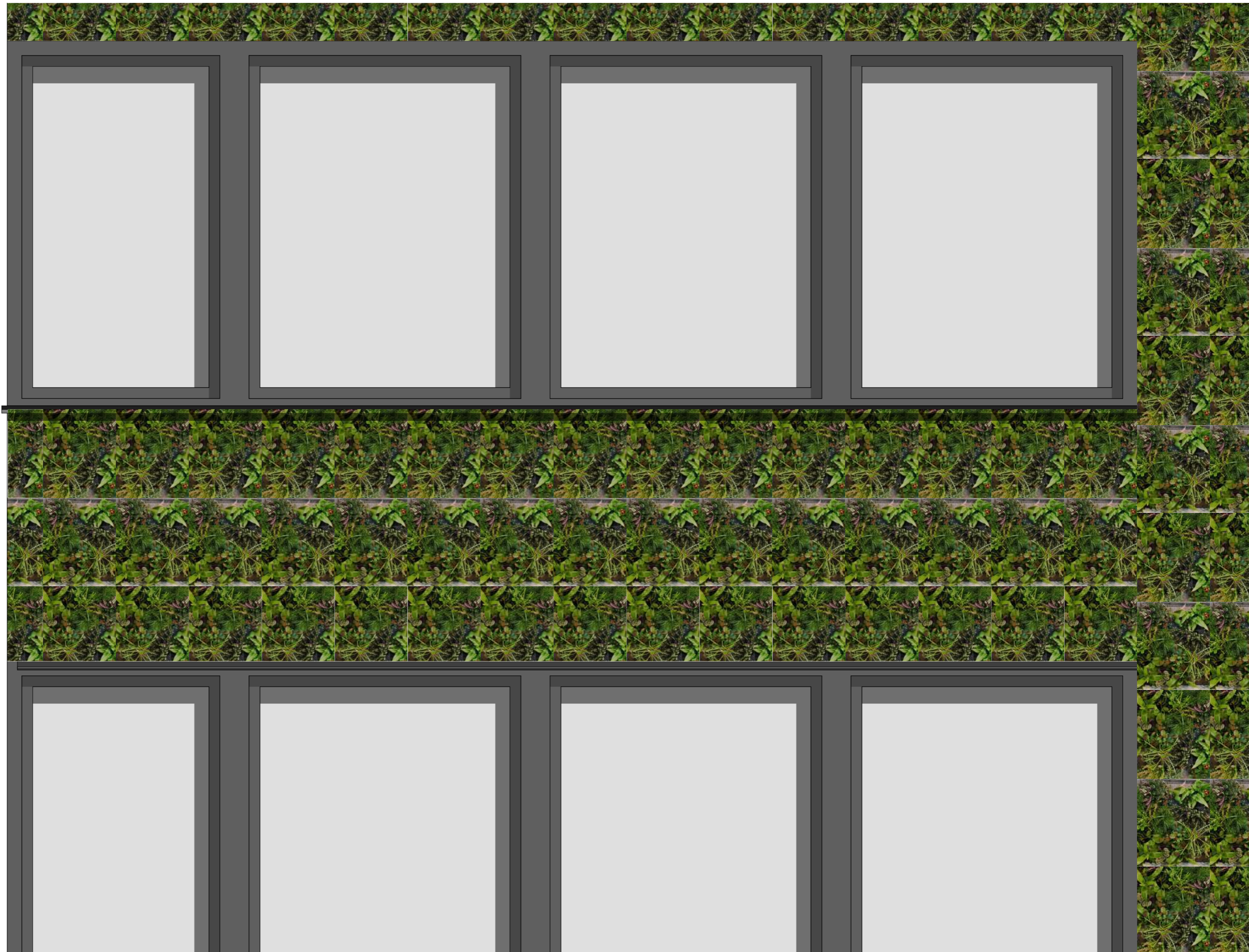
# VERTICAL GREEN FACADE SYSTEM

Detail 1:20



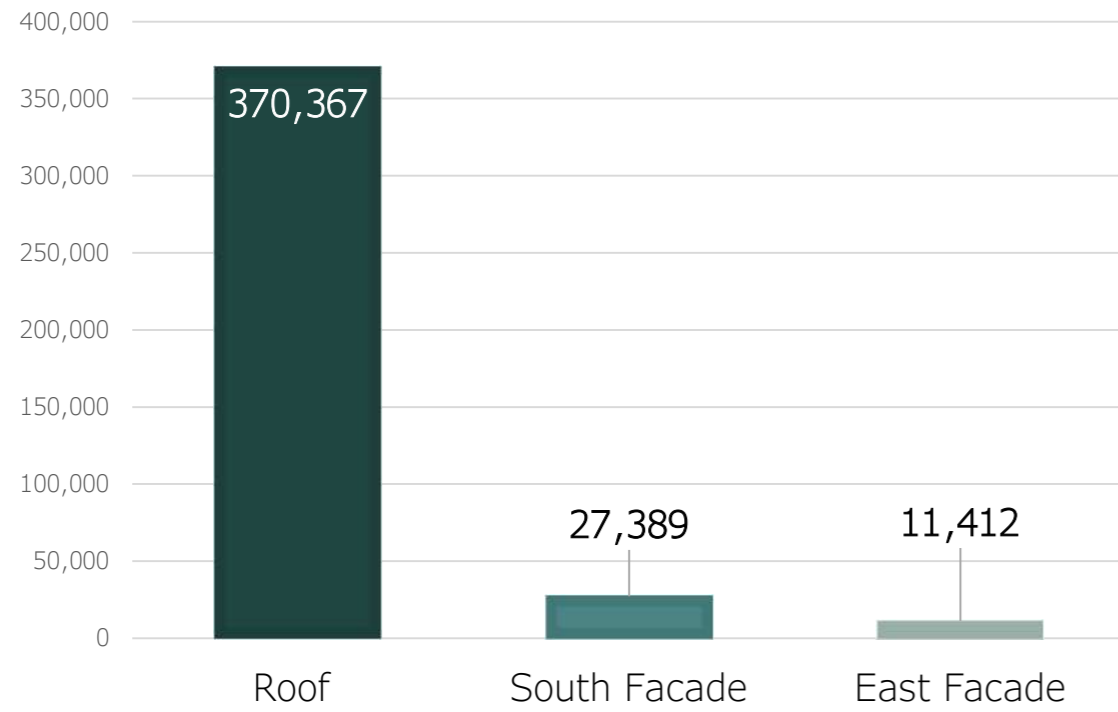
# VERTICAL GREEN FACADE SYSTEM

Detail 1:20



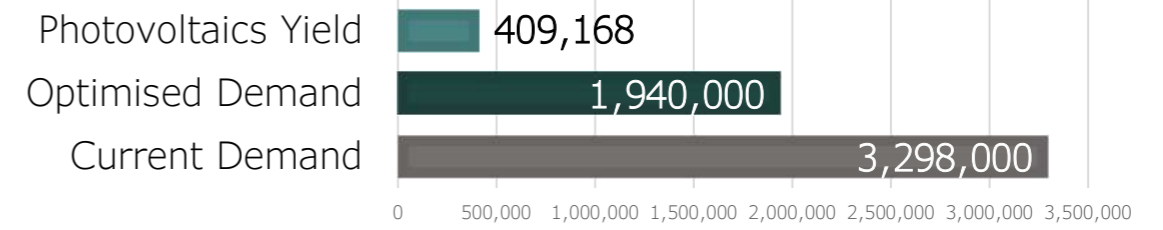


### Photovoltaics Yield [kW]



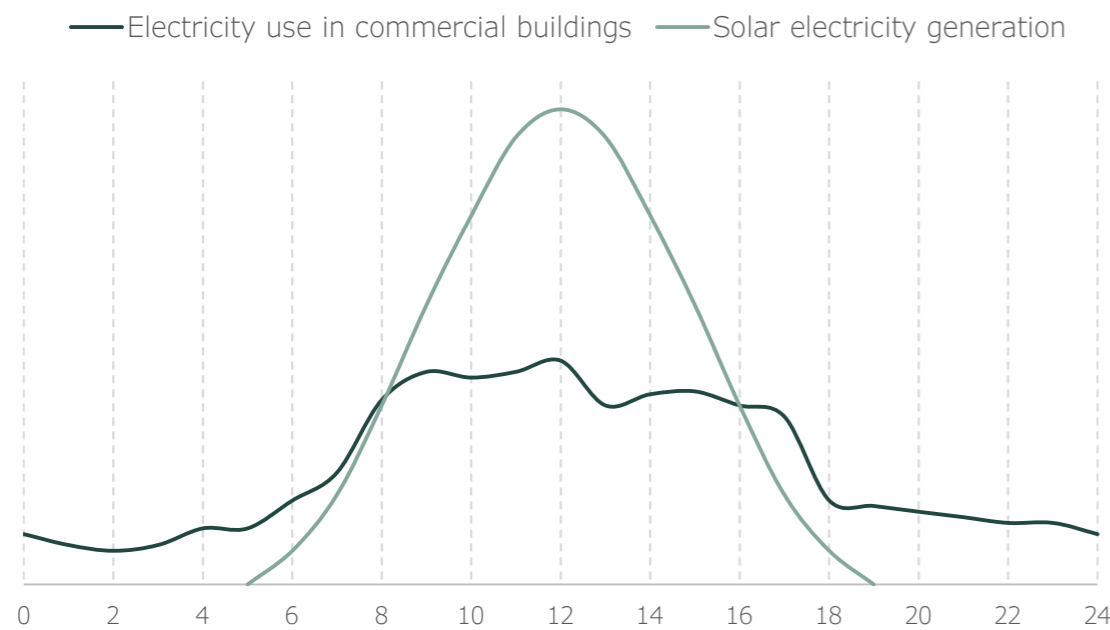
\*detailed calculation attached; PV Yield calculation method source: prof. Claudia Lüling, 2009, Energizing Architecture – Design and Photovoltaics, Berlin: TSB Technologiestiftung

### Energy Coverage [kW/a]



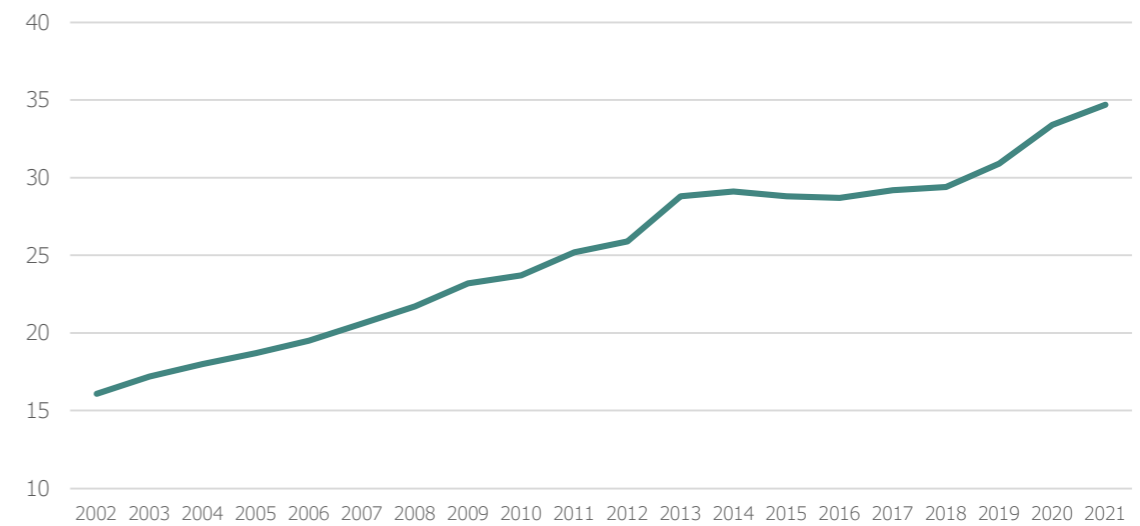
\*optimised demand: 100 kWh/m2.a, source: <https://standortportal.bayern.de/Anhaenge/bihkrepository/planungsleitfaden-effiziente-energienutzung-in-buerogebaeuden.pdf>  
 \*\*current demand: 170 kWh/m2.a, source: [https://effizienzgebaeude.dena.de/fileadmin/dena/Dokumente/Pdf/9143\\_dena-Analyse\\_Energieeffizienz\\_bei\\_Bueroimmobilien.pdf](https://effizienzgebaeude.dena.de/fileadmin/dena/Dokumente/Pdf/9143_dena-Analyse_Energieeffizienz_bei_Bueroimmobilien.pdf)  
 \*\*\*since the demand is far larger than yield, the generated energy is used directly and therefore there is no need for batteries

### Solar Generation and Use throughout a day



\*data source: Roland Krippner, 2017, Building-Integrated Solar Technology, Munich, Detail  
 \*\*since the demand is far larger than yield, the generated energy is used directly and therefore there is no need for batteries

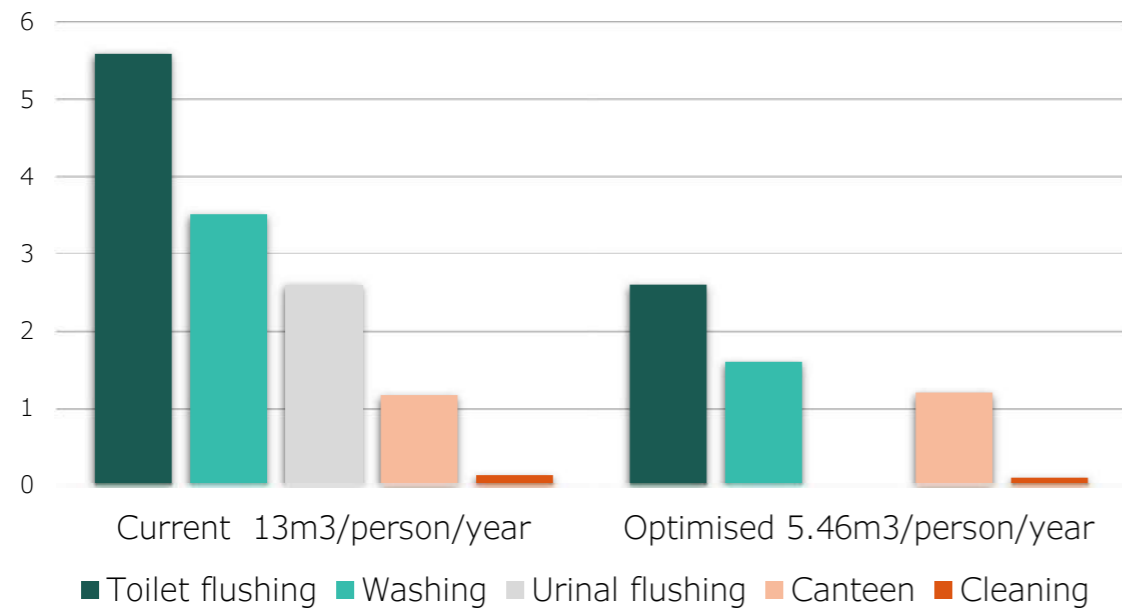
### Electricity Price Trend [ct/kWh]



\*data source: <https://www.stromauskunft.de/strompreise/was-kostet-strom/>  
 \*\* current price 34,7ct/kWh

v h YGgRce E  
 TGRh W19 E  
 y h RaVGTg E

### Water consumption - office building

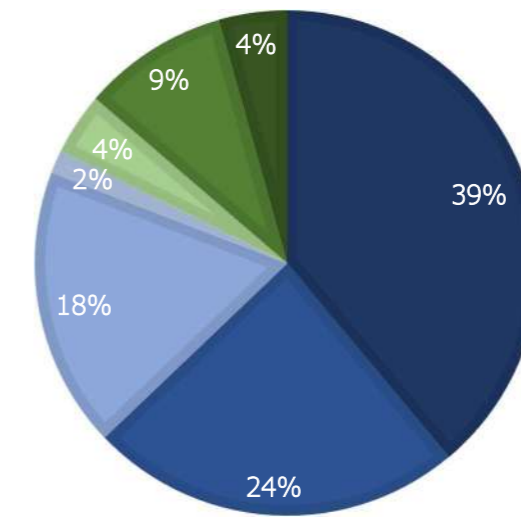


\*50/person/day - calculation method source: Österreichische Vereinigung für das Gas und Wasserfach  
 \*\*usage of water saving appliances

### Optimised Water Consumption

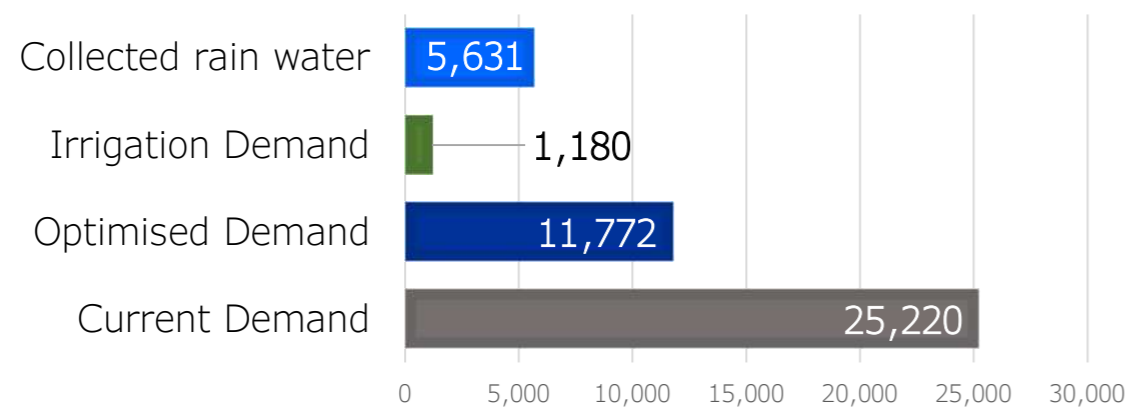
Building Operation      Greenery irrigation

■ Flushing ■ Washing ■ Canteen ■ Cleaning ■ Green facade ■ Trees ■ Shrubs



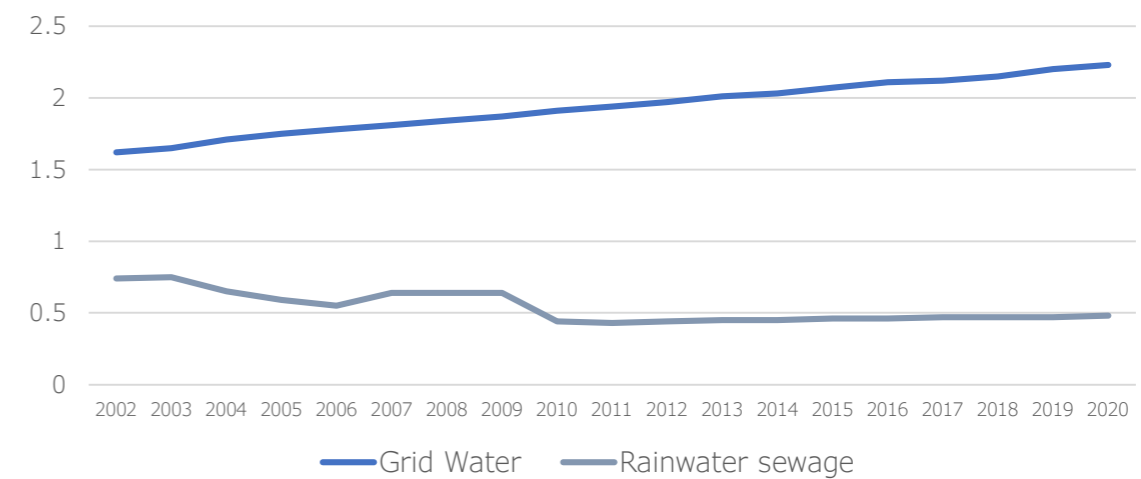
\*Optimised Overall Building Operation Calculation Method: occupancy x daily water demand/person (21l/day)  
 \*\*Green facade demand - 5l/m²/week - source: [www.mobilane.com](http://www.mobilane.com)  
 \*\*\* Tree Demand - 37l/2,5cm trunk/week - source: <https://www.deepproot.com/blog/blog-entries/how-much-should-you-water-your-tree>  
 \*\*\*\* Shrub Demand - 95l/150-180cm height source: <https://water.unl.edu/landscapewater/tree-watering>

### Rainwater Coverage [m³/year]



\*rainwater data source: <https://www.wetterkontor.de/de/wetter/deutschland/monatswerte-station.asp?id=10400>

### Water Price Trend [€/m³]



\*data source: <https://www.statistik-bw.de/Umwelt/Wasser/Trink-Abwasserpreise.jsp>  
 \*\* current price 2,23 €/m³

t h aWR VE  
 y TGTGh T9W E W  
 y h TGTGh G9e E W  
 Ra9cG E