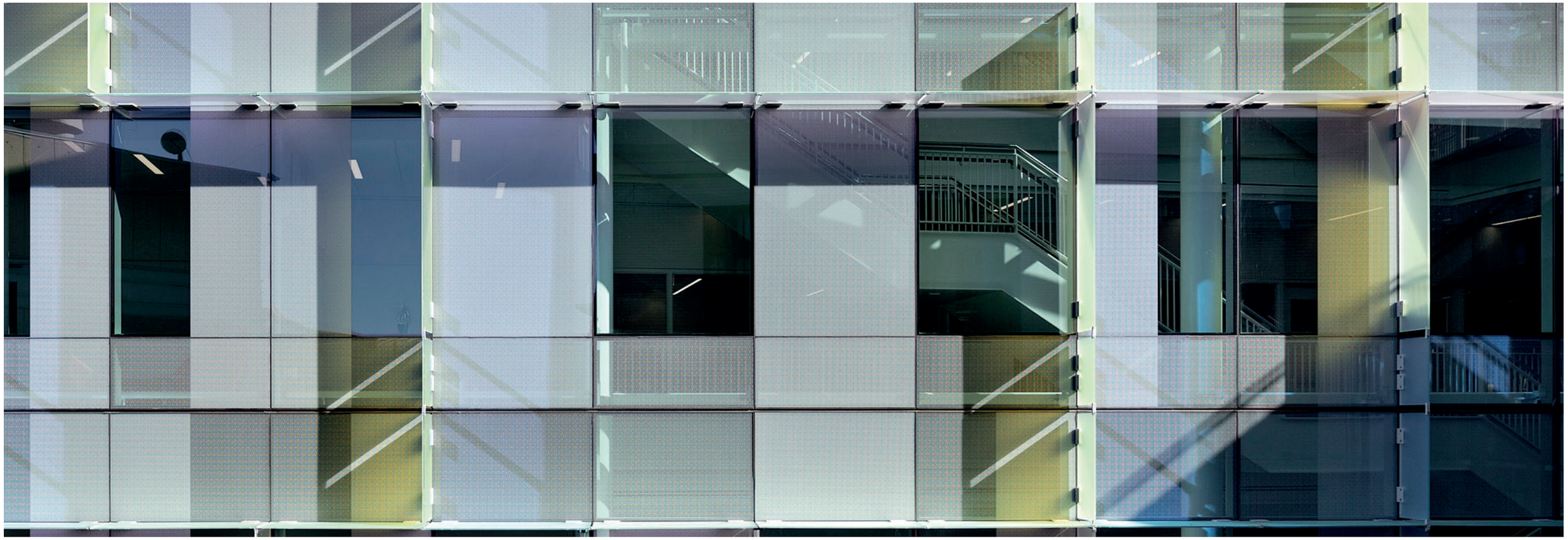
From Product to Product-Service System:

The demarcation of producer responsibilities
in the transition from linear to circular service system.



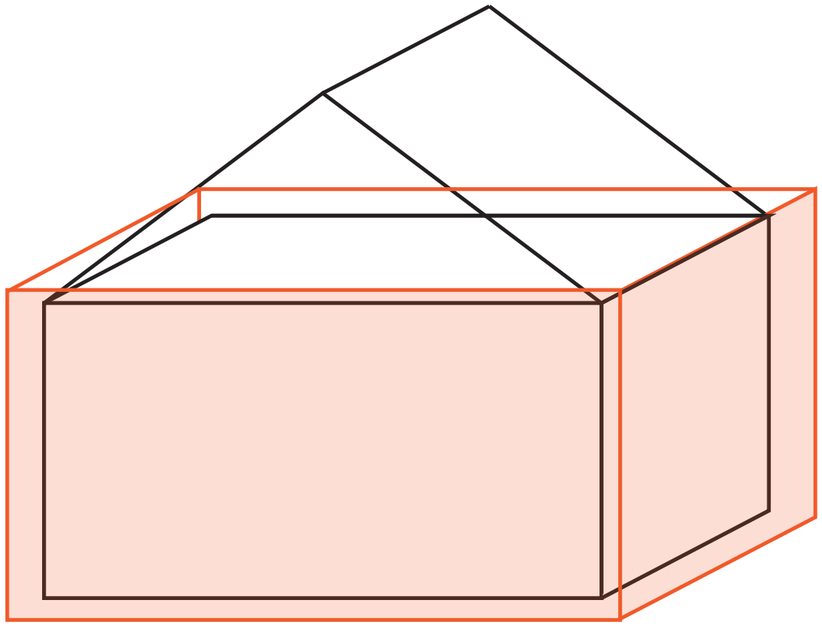
Challenges,
2050 NL

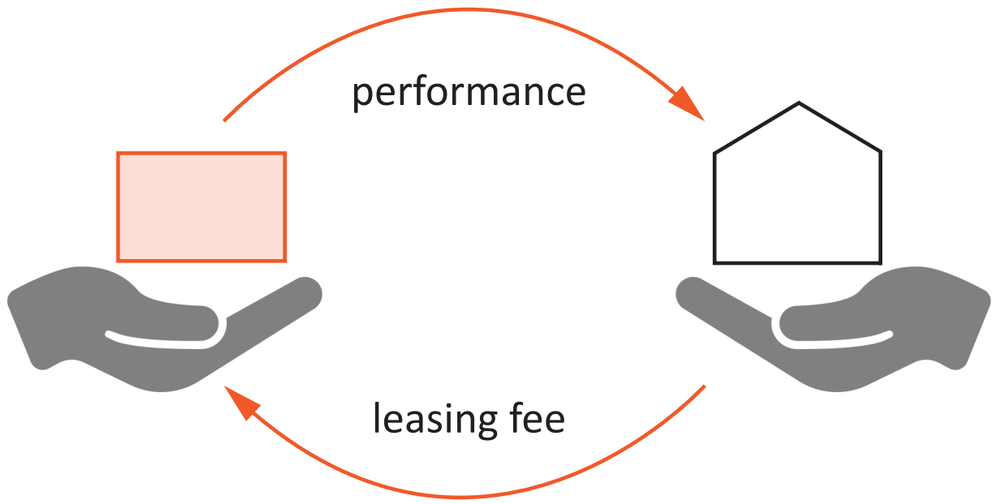
- eliminating Co2 emissions by 2050[1]

- no more > label C offices by 2023

- Dutch governmental aim of enforcing a circular economy[1]

1, The Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs, 2016
2, Azcarate Aguerre, Den Heijer, & Klein, 2017, p. 2





facade supplier
=
facade owner
and lessor

owner of building
=
facade user
and lessee

High innitial costs for investors

High innitial costs for investors

Regular payment for service

High innitial costs for investors

High risk for suppliers

Regular payment for service

High innitial costs for investors

High risk for suppliers

Regular payment for service

Continuous, steady earnings

High innitial costs for investors

High risk for suppliers

LC management unclear

Regular payment for service

Continuous, steady earnings

High innitial costs for investors

High risk for suppliers

LC management unclear

Regular payment for service

Continuous, steady earnings

One responsible party

Challenges,
2050 NL

Opportunities, Benefits

- eliminating Co2 emissions by 2050[1] → - accelerate building energy renovations[2]

- no more > label C offices by 2023 → - speed up innovation rate

→ - improving facade performance

- Dutch governmental aim of enforcing a circular economy[1] → - towards circular facade industry

1, The Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs, 2016
2, Azcarate Aguerre, Den Heijer, & Klein, 2017, p. 2

Facade Leasing

„circular business model, for facades as performance delivering tools”:

Facade Leasing

„circular business model, for facades as performance delivering tools”:

Product Service System


TEST
TUDelft
36
01
02
03
04

ALKONDOR

HENGELO

Main Research Question:

- **(Main RQ) What are the points of demarcation?**
- (SRQ1) What is the difference of PSS?
- (SRQ2) Which new tasks and responsibilities?

Chapter 2

- (SRQ3) Which critical factors guaranteeing energy performance?
- (SRQ4) What aspects can help the implementation?

Chapter 3

Main Design Question:

- **(Main DQ) What is the effect of the PSS on the design of facades?**
- (SDQ1) How does the PSS design compare to a standard construction?
- (SDQ2) What design criteria - facades as PSS?
- (SDQ3) Design of PSS facades - more circular construction?

Chapter 4

Ch. 1

Background Research
and Literature Review

+

Case Study and
Interviews with Alkondor

↓

Ch. 2

Defining the Points of Demarcation
of Producer Responsabilities
of the PSS model

↓

Asessing further,
where gaps in literature were found:

Ch. 3

- Facade Performance
- Asessing barriers
- Simulation:
  quantifying issues
- Discussion + Conclusion

Ch. 4

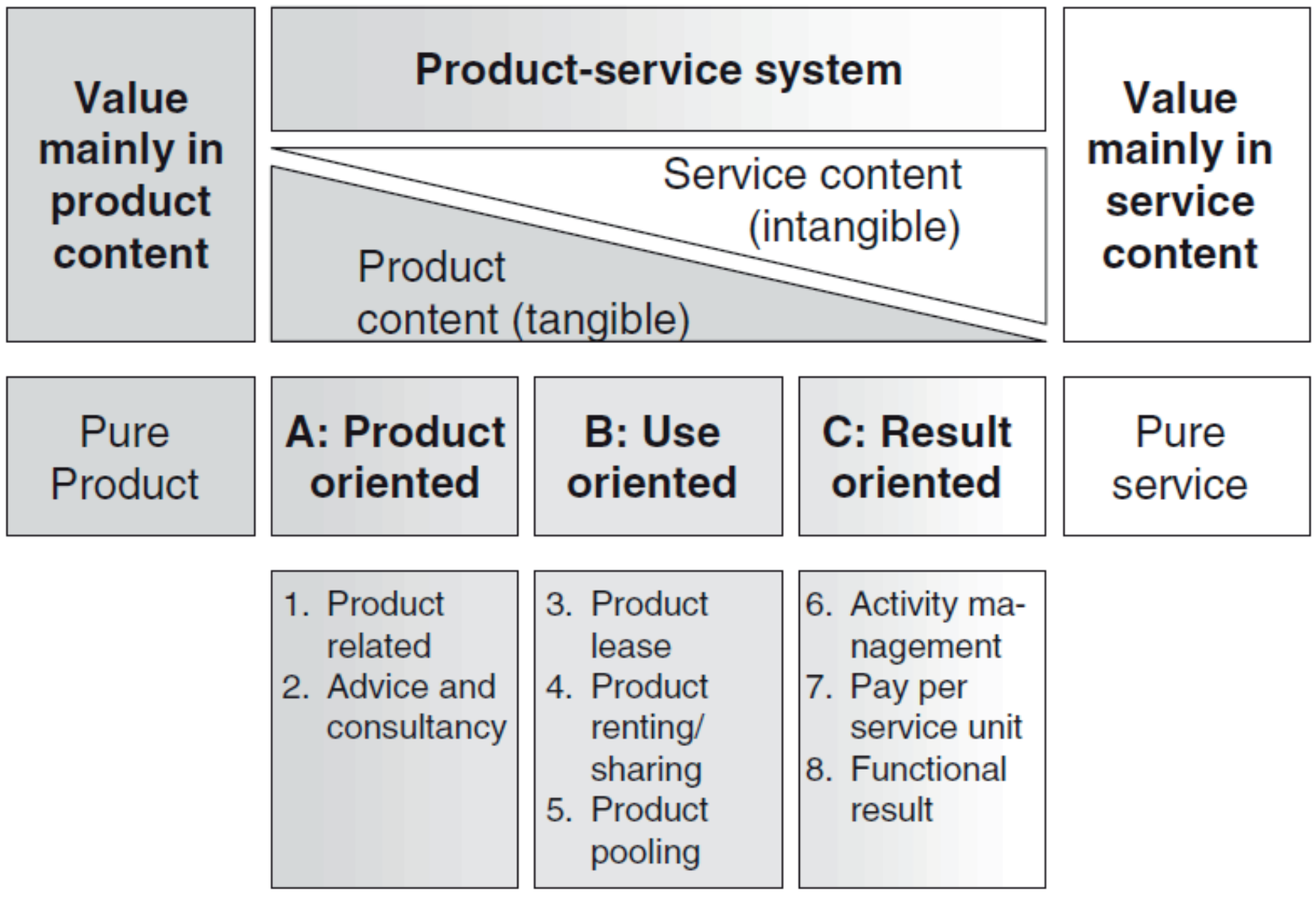
- Design
- Literature Research
- Research by Design
- Discussion + Conclusion

Main RQ

What are the points of demarcation related to energy perfomance and indoor comfort, along the pathway to facades as PSS, and how can they be specified?

Where does Service start?

How far does Service go?



Main and subcategories of PSS, Tukker (2004)

Value mainly in product content

Facades as product-service systems

service content (intangible)

product content (tangible)

Value mainly in service content

Pure Product	A:Product oriented	B: Use oriented	C: Result oriented	Pure service
	1. Product related → 1.1. Current practice	3. Product Lease → 3.1 Facade Lease	6. Activity Management → 6.1 Operation and/or Maintenance	
	2. Advice and consultancy → 2.1 Design consultancy	4. Product renting/ sharing -	7. Pay per service unit -	
		5. Product pooling -	8. Functional result → 8.1 Performance guarantee	

Adapted from Tukker (2004)


Start
Optimized
Perfomance

1. Design Consultancy

Start

Optimized Perfomance

1. Design
Consultancy

Start

deisign for performance

Optimized
Perfomance

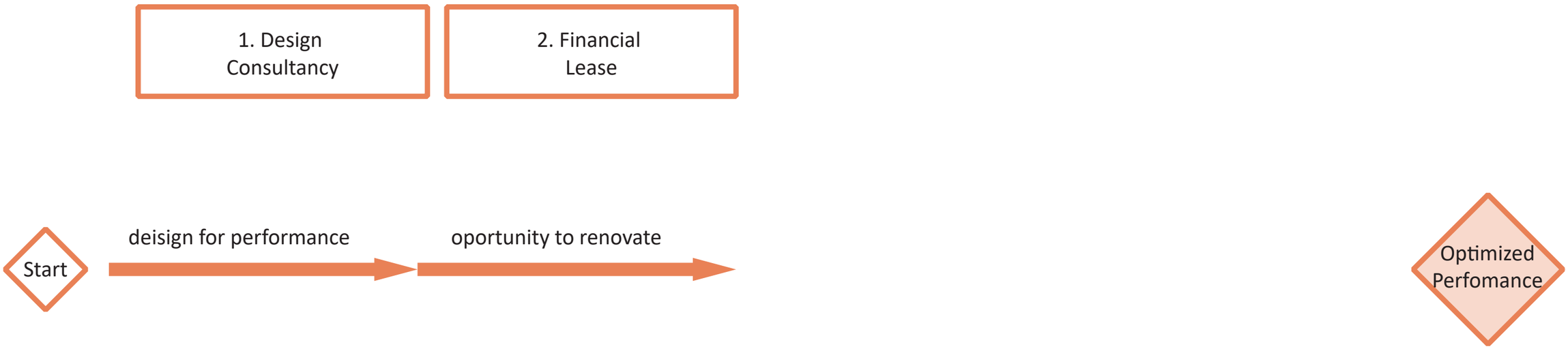
1. Design Consultancy

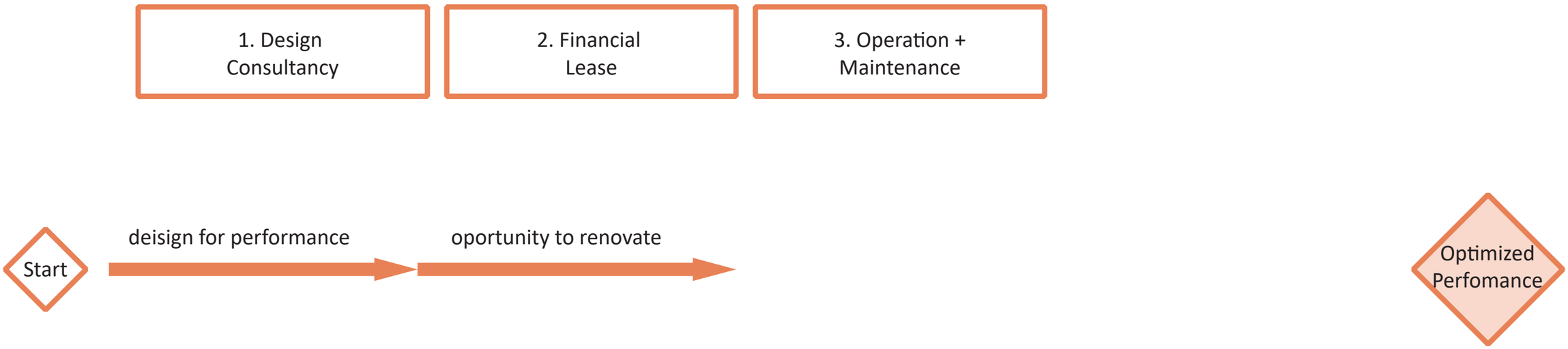
2. Financial Lease

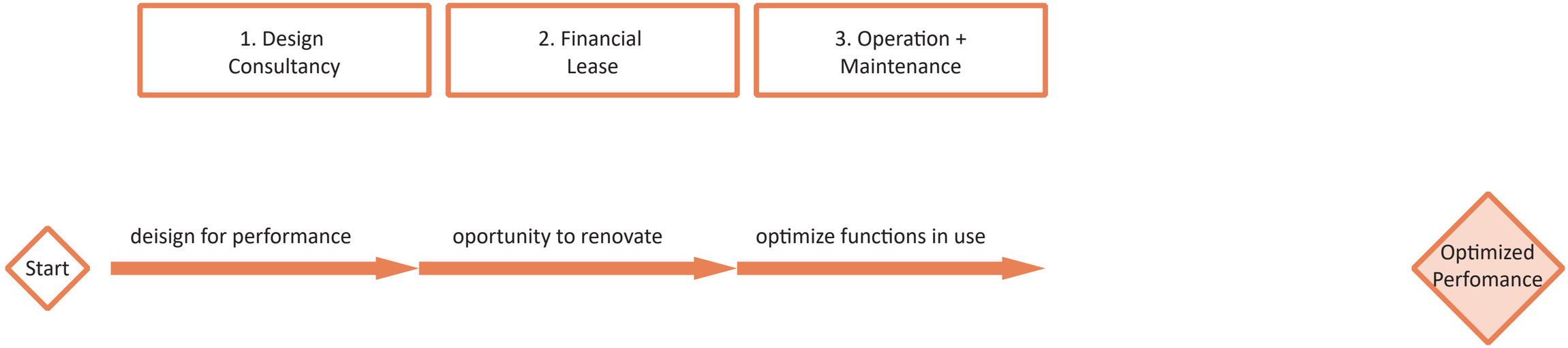
Start

deisign for performance

Optimized Perfomance


1. Design
Consultancy
2. Financial
Lease
Start
deisign for performance
oportunity to renovate
Optimized
Perfomance


1. Design Consultancy
2. Financial Lease
3. Operation + Maintenance
Start
deisign for performance
oportunity to renovate
Optimized Perfomance

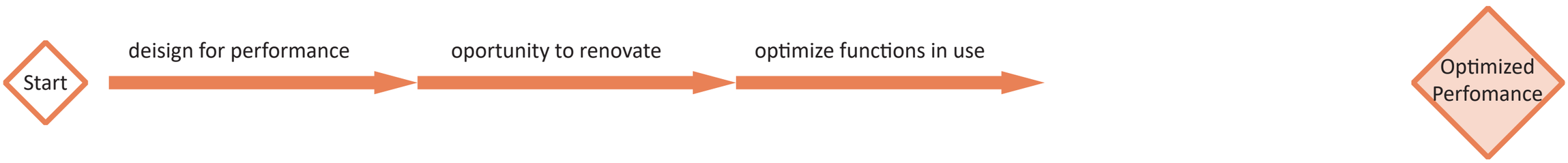

1. Design Consultancy
2. Financial Lease
3. Operation + Maintenance
Start
deisign for performance
oportunity to renovate
optimize functions in use
Optimized Perfomance

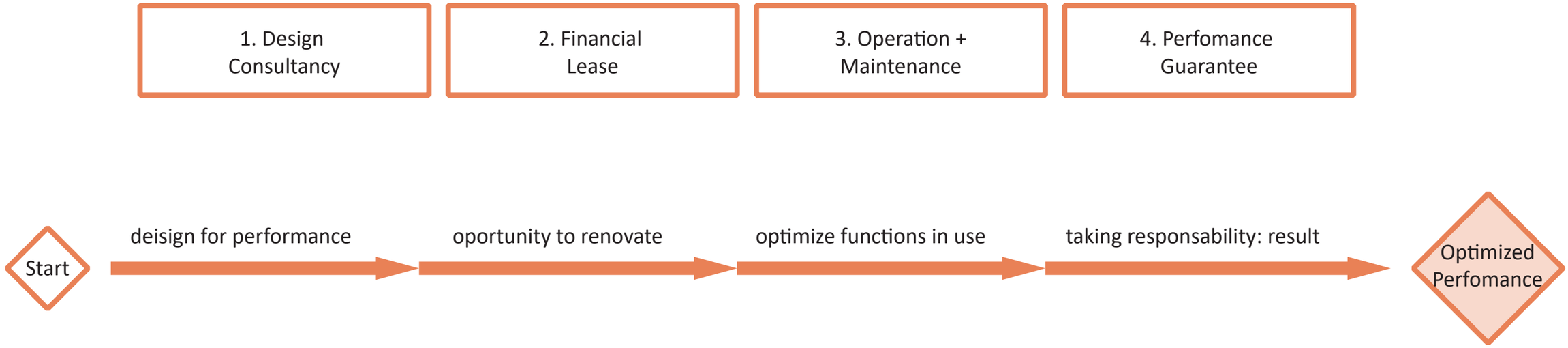
1. Design Consultancy

2. Financial Lease

3. Operation + Maintenance

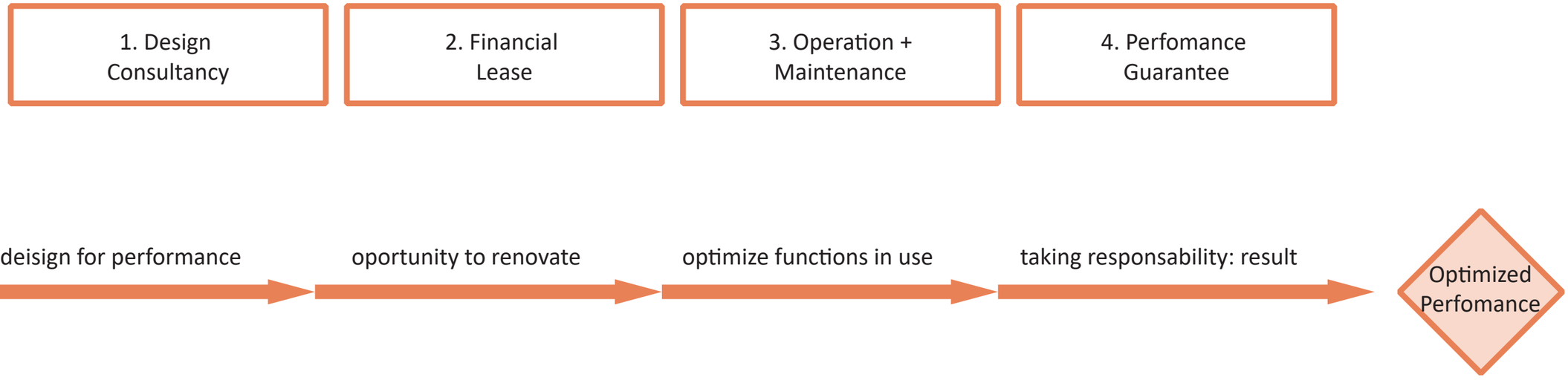
4. Perfomance Guarantee




1. Design Consultancy
2. Financial Lease
3. Operation + Maintenance
4. Perfomance Guarantee
Start
deisign for performance
oportunity to renovate
optimize functions in use
taking responsability: result
Optimized Perfomance

Conclusion of Main RQ:

Main RQ: What are the points of demarcation related to energy performance and indoor comfort, along the pathway to facades as PSS, and how can they be specified?



1. Design Consultancy

2. Financial Lease

3. Operation + Maintenance

4. Perfomance Guarantee

Start

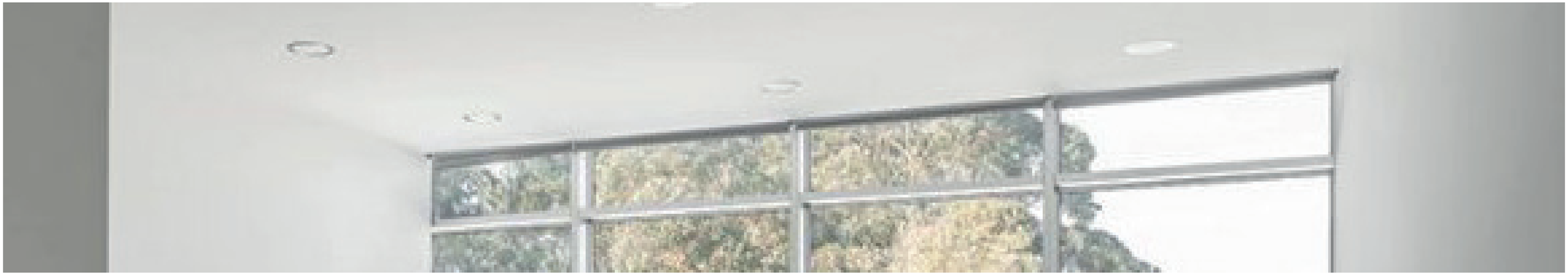
deisign for perfomance

oportunity to renovate

optimize functions in use

taking responsability: result

Optimized Perfomance



PERFORMANCE

performance = energy efficiency + indoor comfort

Barriers to guarantee Performance

Producer Risk and Consumer Risk

Limitation of this study

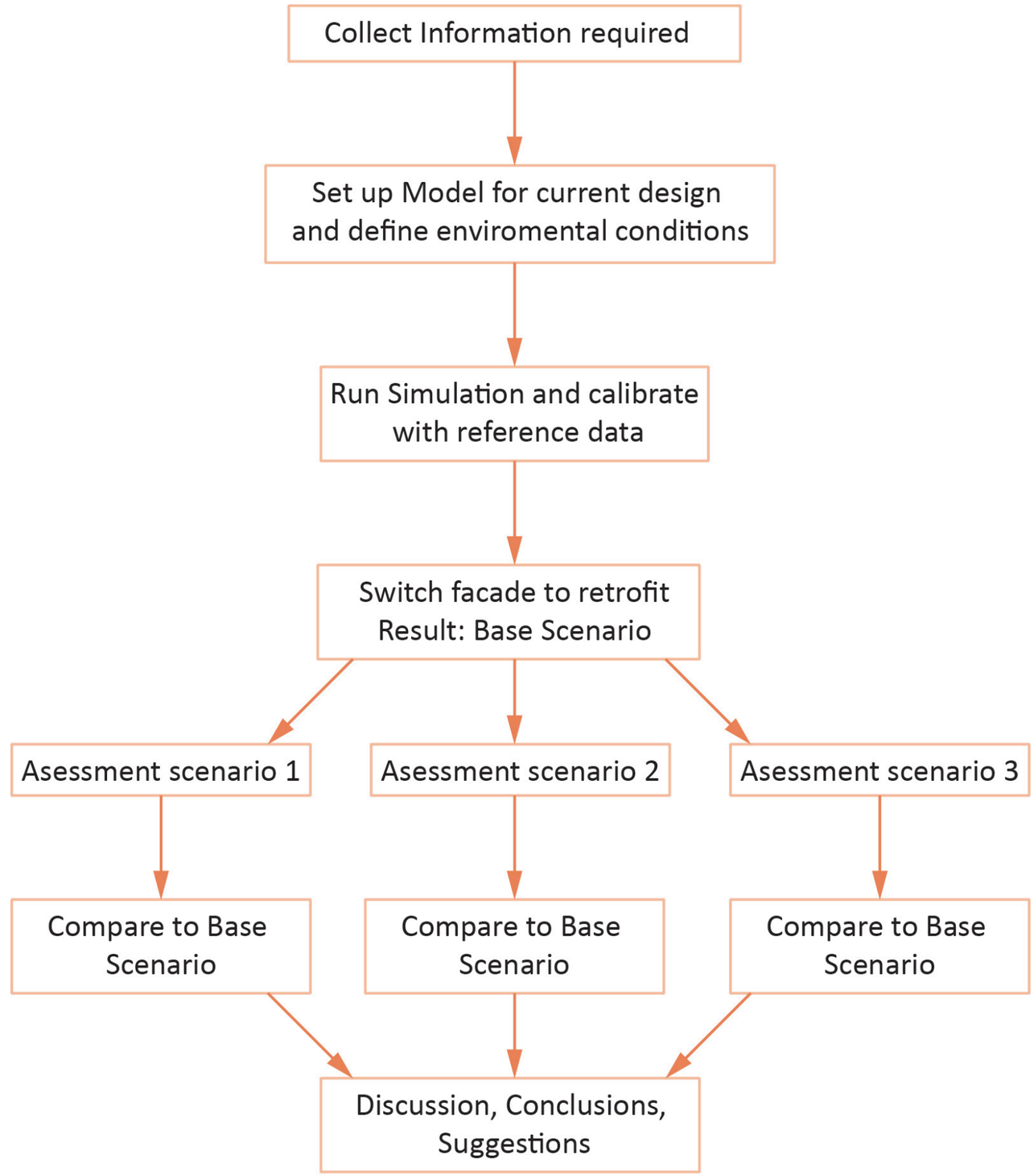
Multitude of factors that influence the IEQ

Research and Simulation

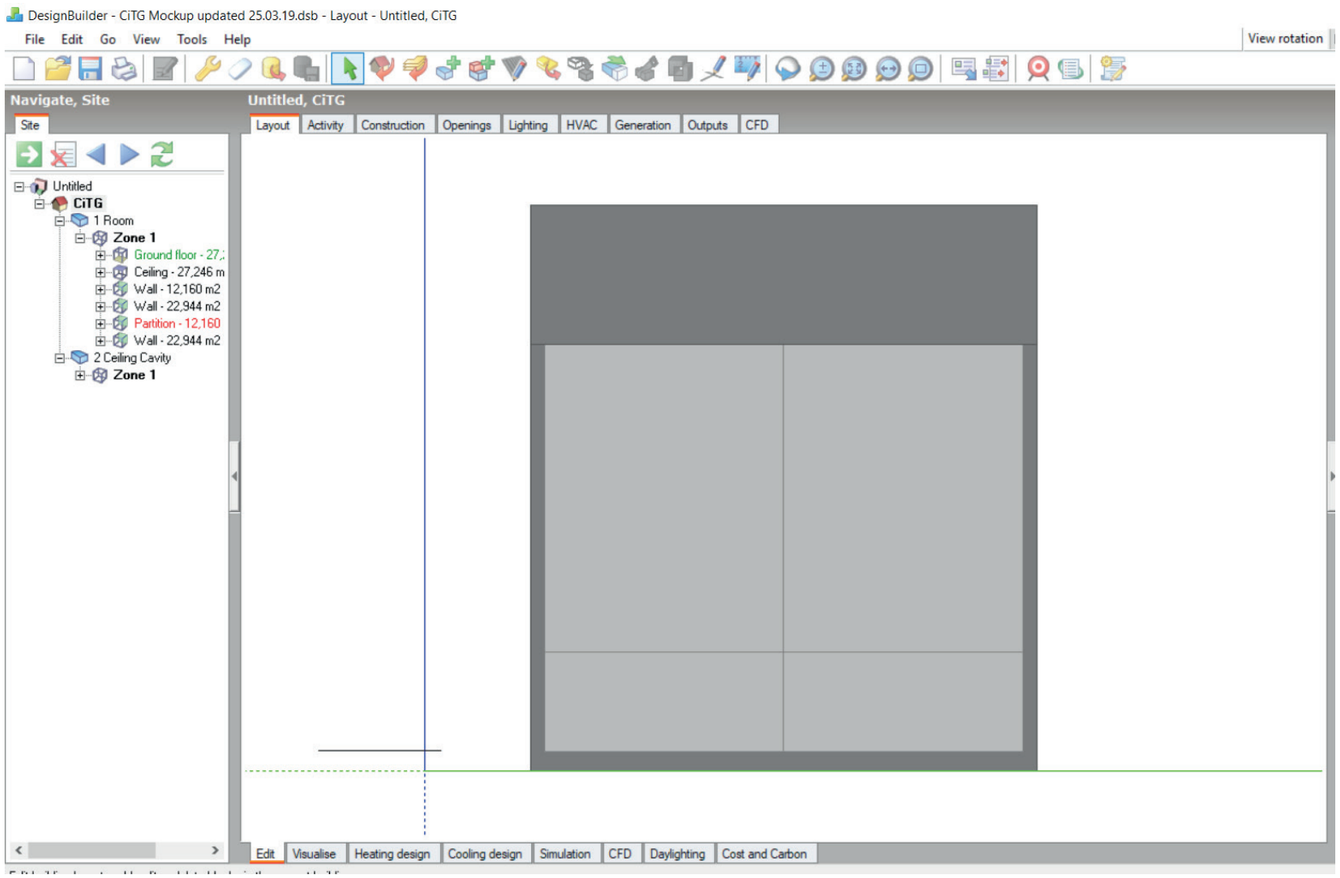
Sub Question (1.3)

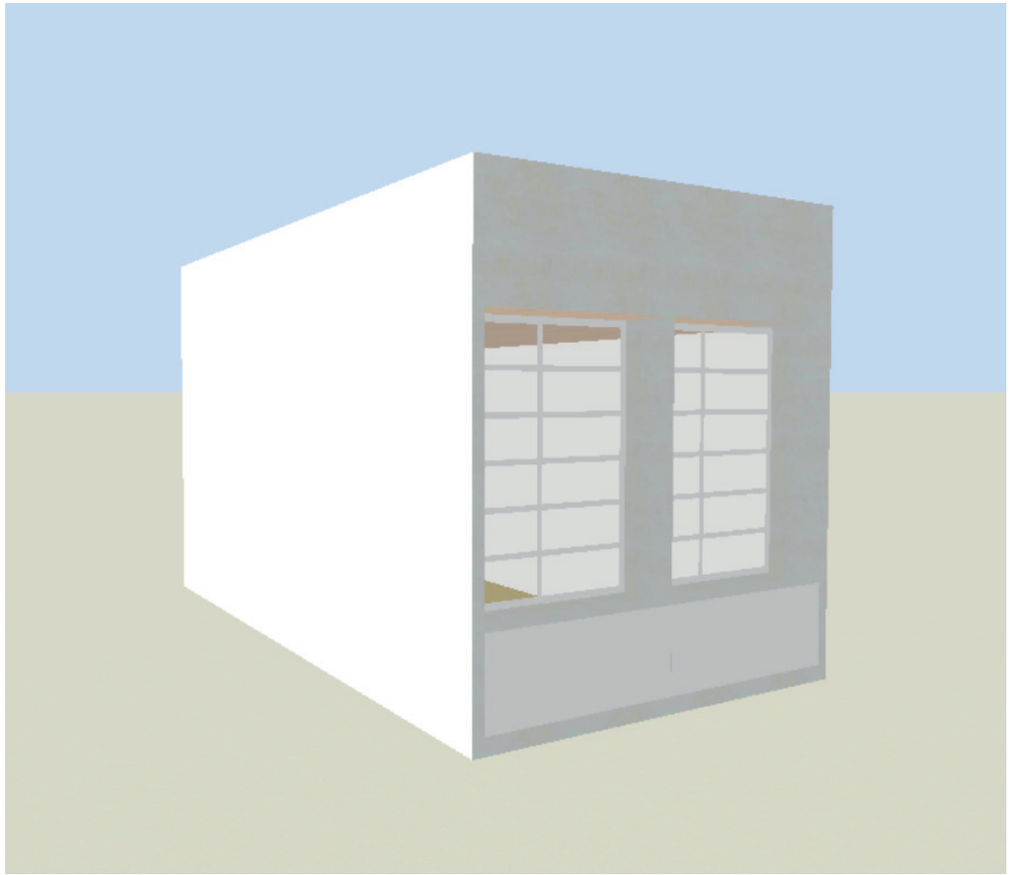
Which critical factors present an issue in guaranteeing a certain range of energy perfomance and indoor comfort of the CiTG east facade?

Design Builder Simulation



Design Builder Simulation





Design Builder Simulation

28. January, 10:00:

240 + 500 + 11	=	23,5 ΔT + 54,32 ΔT
751	=	77,82 * (Ti – 4)
9,65	=	Ti – 4
Ti (Jan.)	**=**	**13,65 °C**

27.September, 10:00:

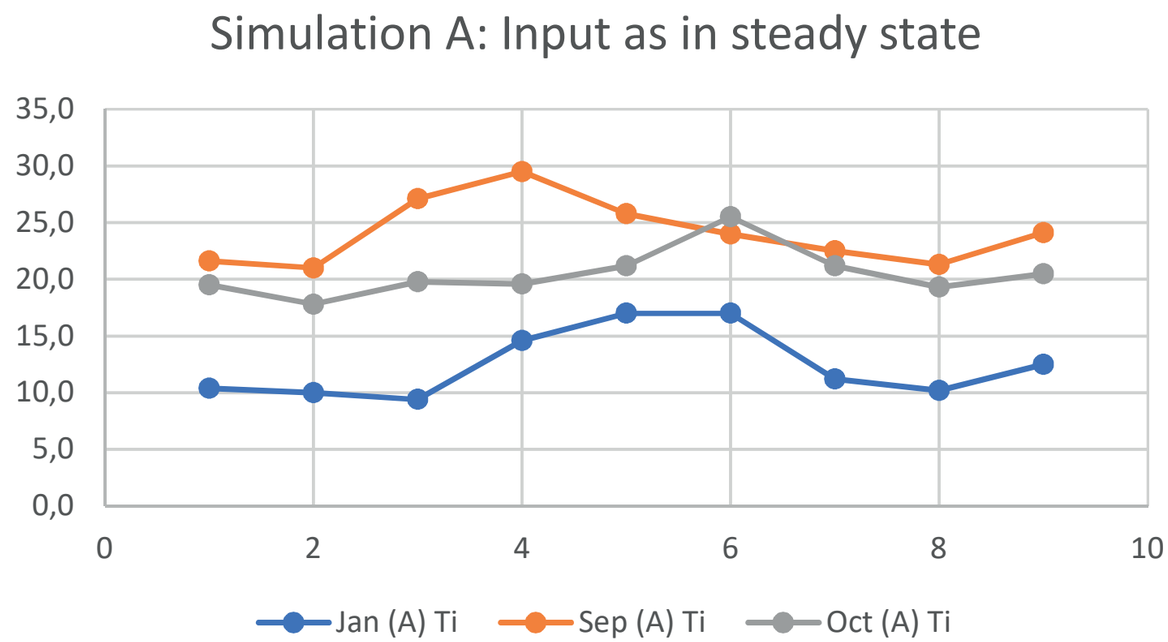
240 + 500 + 67,6	=	23,5 ΔT + 54,32 ΔT
807,6	=	77,82 * (Ti – 5,7)
10,3	=	Ti – 14
Ti (Sep.)	**=**	**24,37 °C**

18.October, 10:00:

240 + 500 + 0	=	23,5 ΔT + 54,32 ΔT
740	=	77,82 * (Ti – 15,2)
9,5	=	Ti – 12,4
Ti (Oct.)	**=**	**21,9 °C**

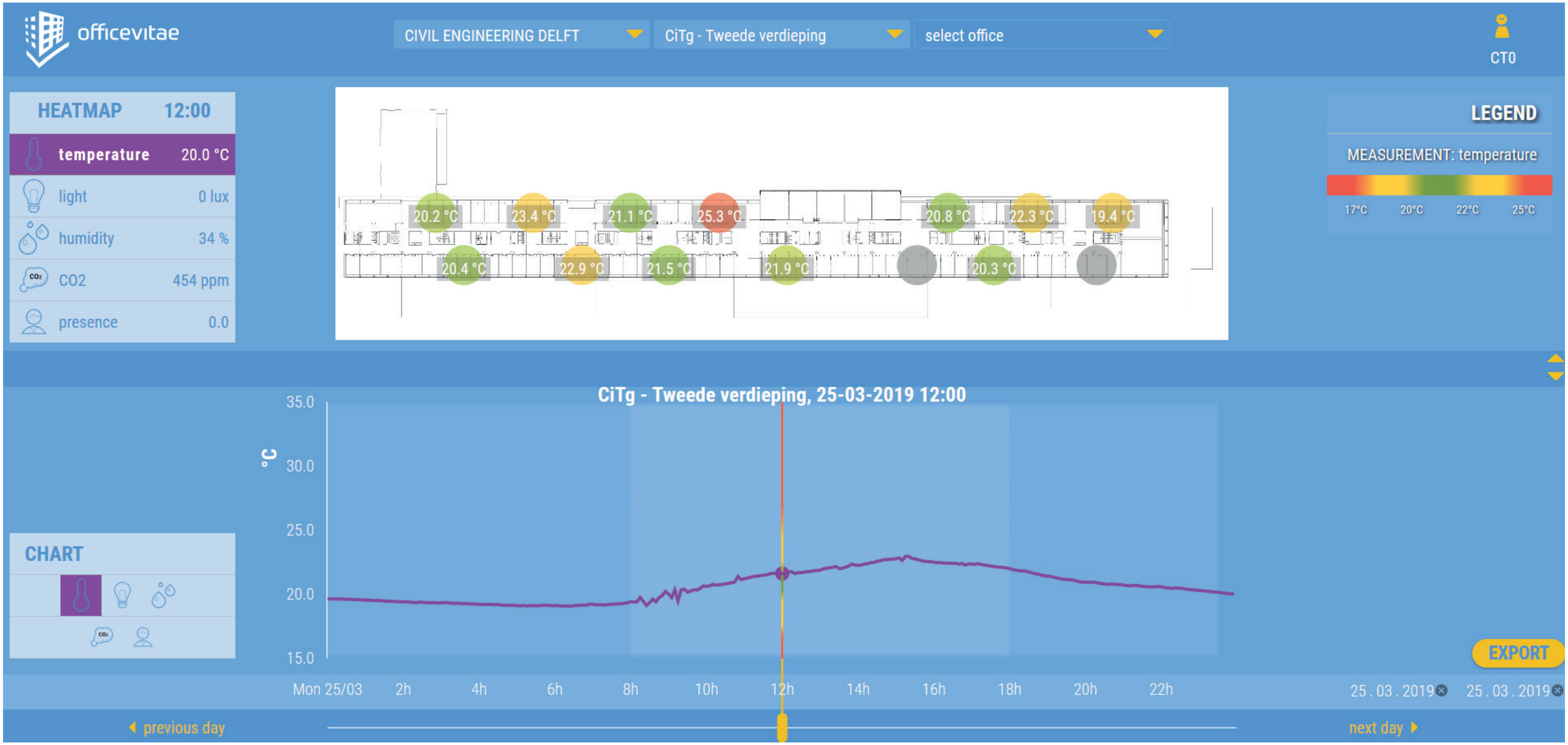
Design Builder Simulation

time	Jan (A)	Sep (A)	Oct (A)
	Ti	Ti	Ti
02:00	10,4	21,6	19,5
05:00	10,0	21,0	17,8
08:00	9,4	27,1	19,8
11:00	14,6	29,5	19,6
14:00	17,0	25,8	21,2
17:00	17,0	24,0	25,5
20:00	11,2	22,5	21,2
23:00	10,2	21,3	19,3
Average	12,5	24,1	20,5

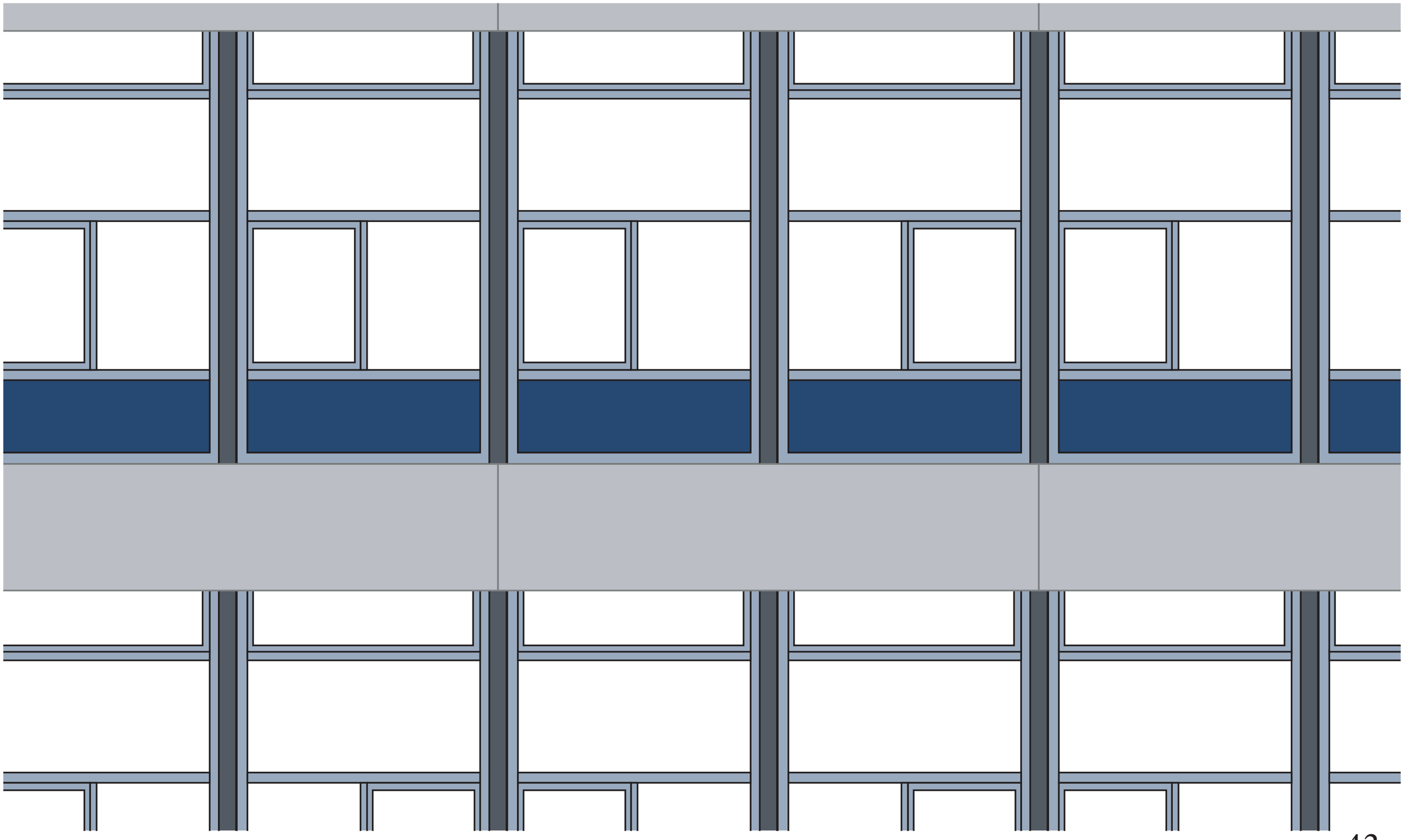


Design Builder Simulation with constant daily weather data

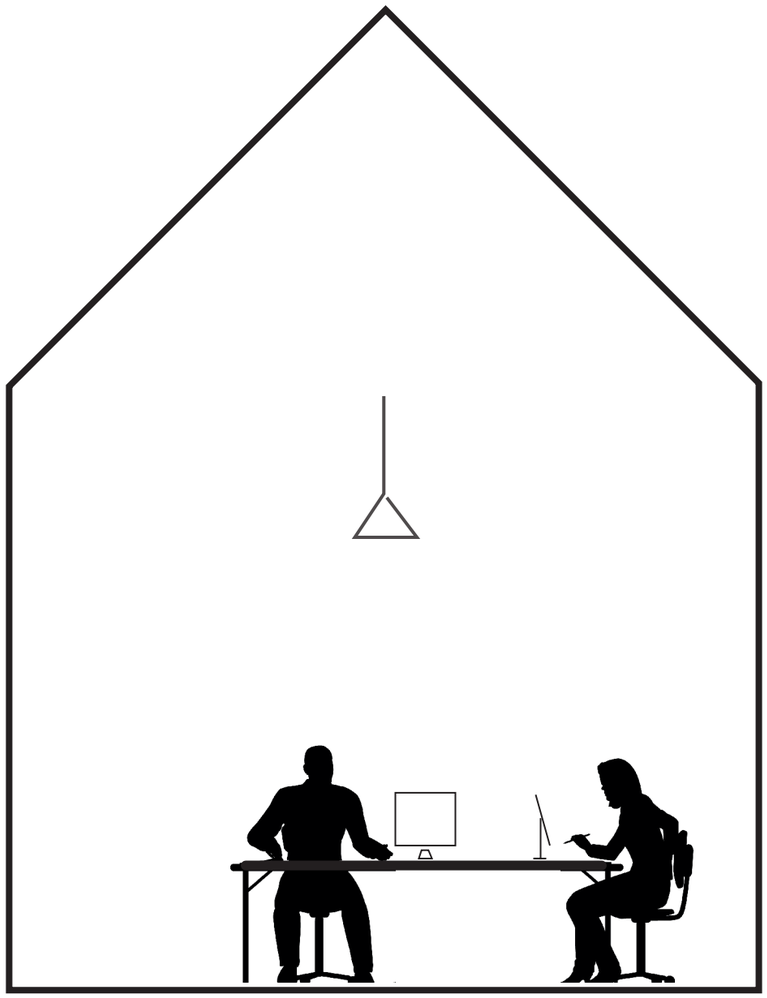
Calibrate Simulation



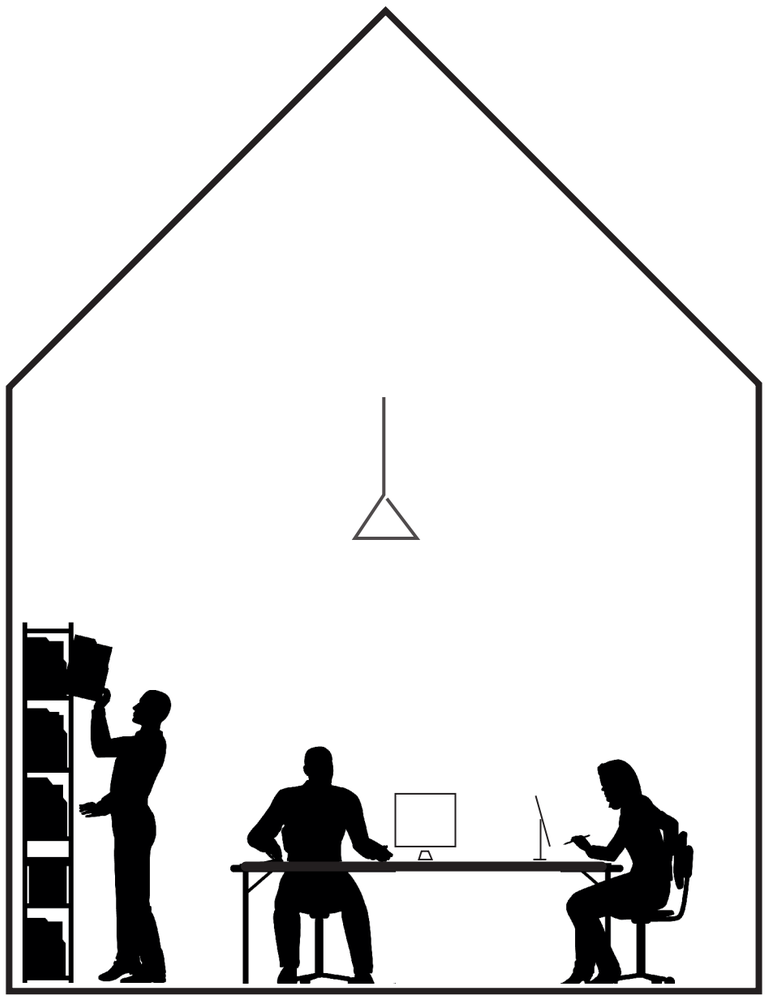
Simulation of Retrofit



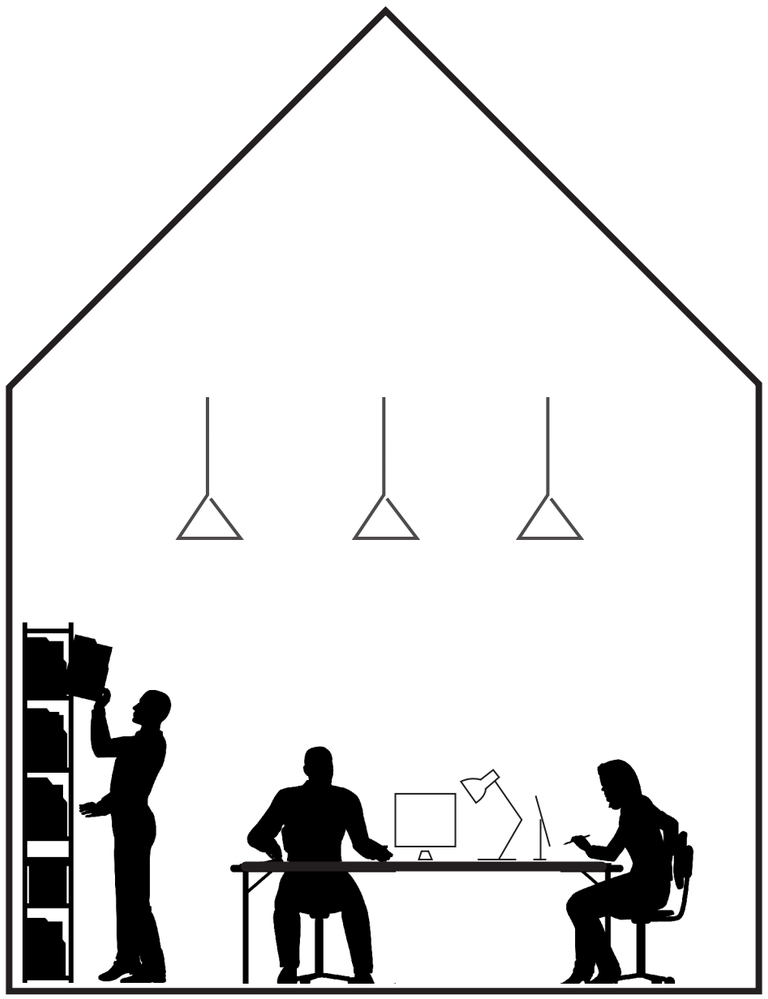
Changing Parameters



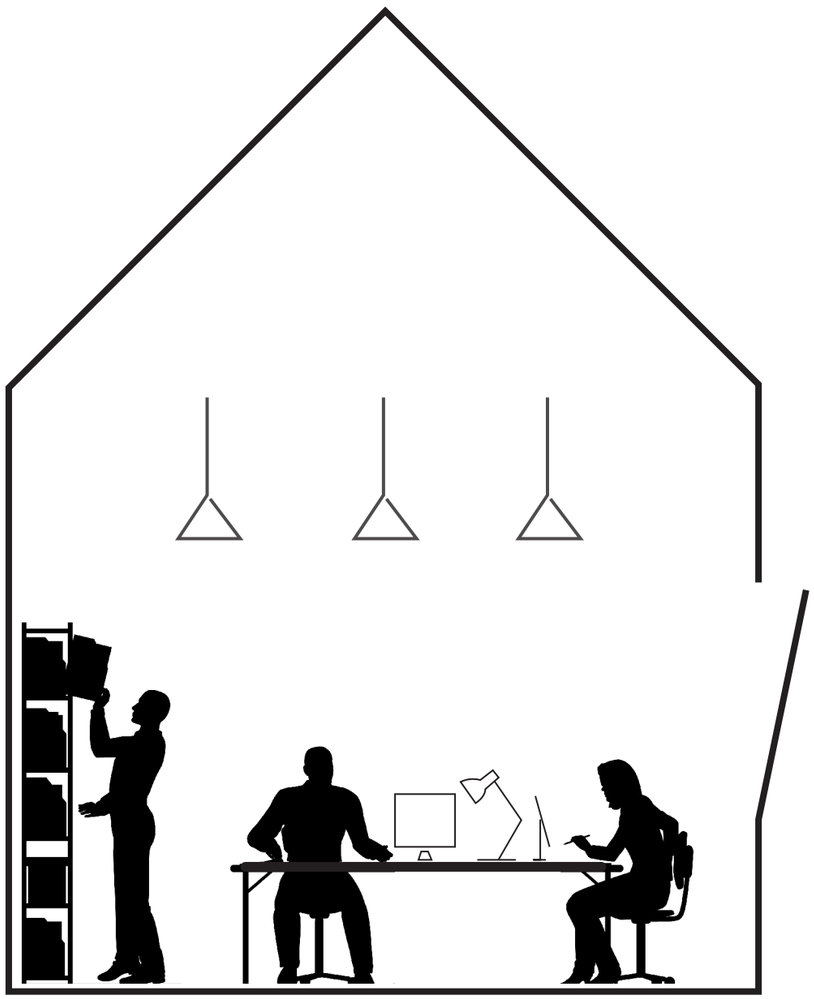
Changing Parameters



Changing Parameters

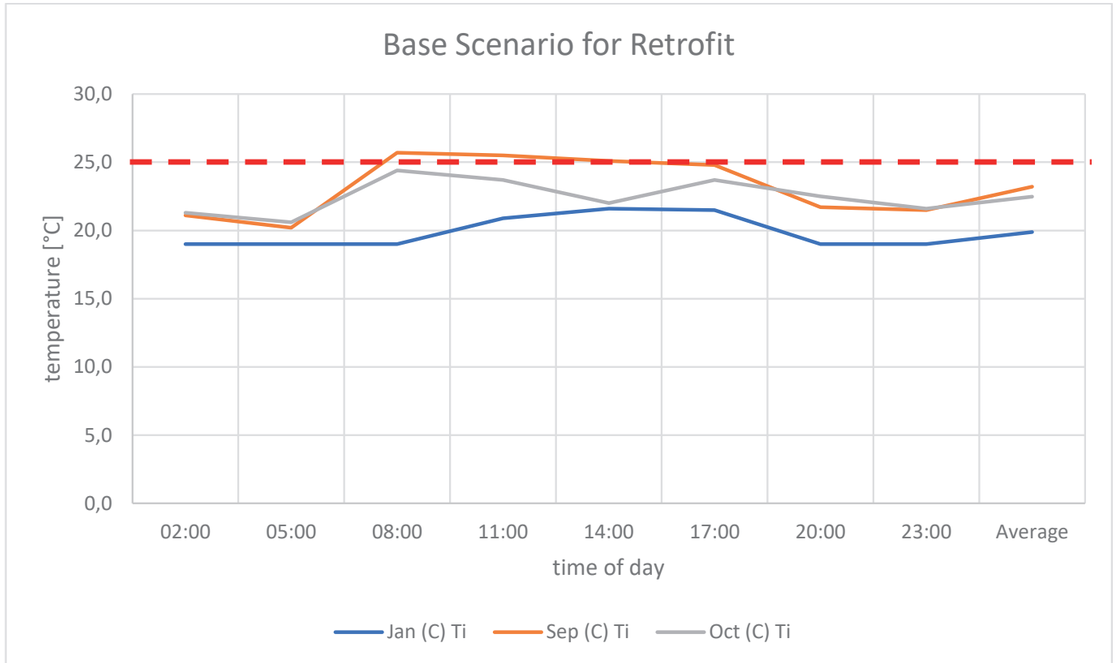


Changing Parameters



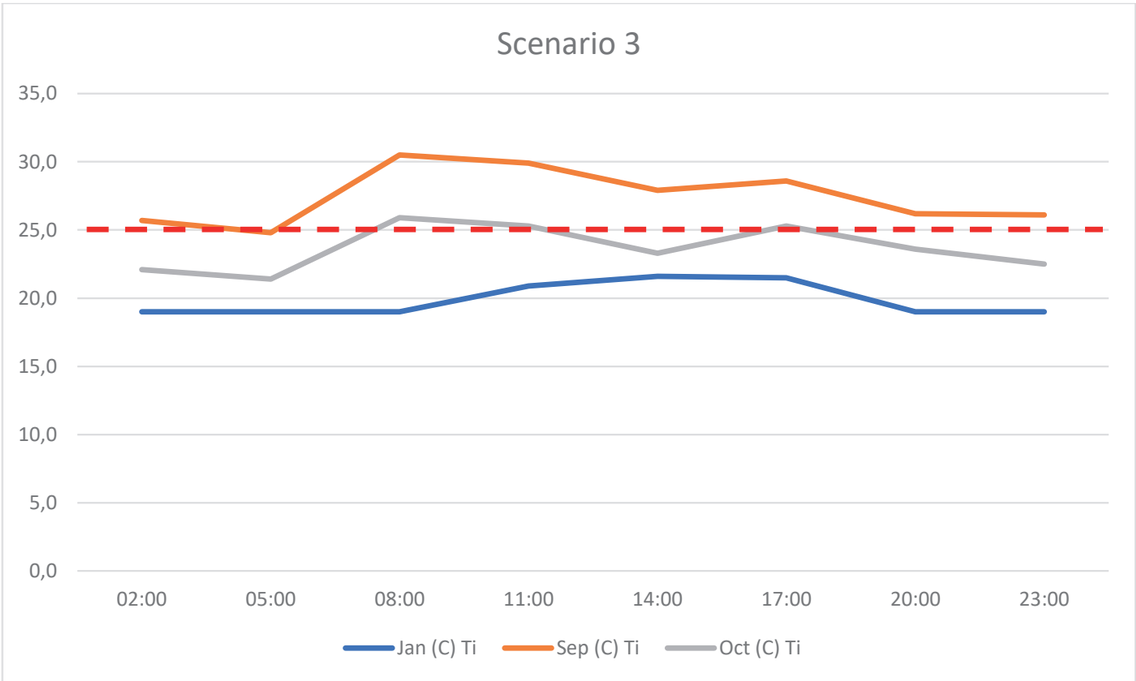
Base Scenario

Base	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	21,1	21,3
	05:00	19,0	20,2	20,6
	08:00	19,0	25,7	24,4
	11:00	20,9	25,5	23,7
	14:00	21,6	25,1	22,0
	17:00	21,5	24,8	23,7
	20:00	19,0	21,7	22,5
	23:00	19,0	21,5	21,6
	Average	19,9	23,2	22,5
Base	BASE SCENARIO RETROFIT: Input of retrofit characteristics as mentioned. Ventilation schedule adjusted for September: Natural night ventilation added.			



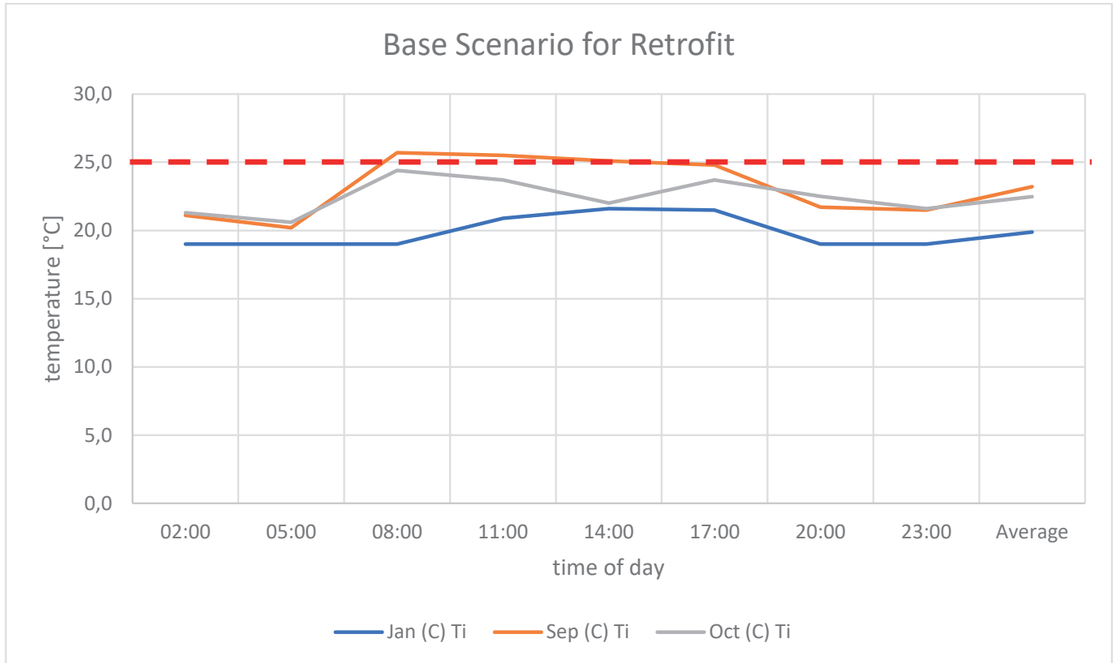
Scenario 3: Ventilation changed

S 3	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	25,7	22,1
	05:00	19,0	24,8	21,4
	08:00	19,0	**30,5**	25,9
	11:00	20,9	**29,9**	25,3
	14:00	21,6	**27,9**	23,3
	17:00	21,5	**28,6**	25,3
	20:00	19,0	26,2	23,6
	23:00	19,0	26,1	22,5
	Average	19,9	27,5	23,7
S 3	SCENARIO 3: **Ventilation** schedule changed: Only ventilated from around noon to the end of working day.			



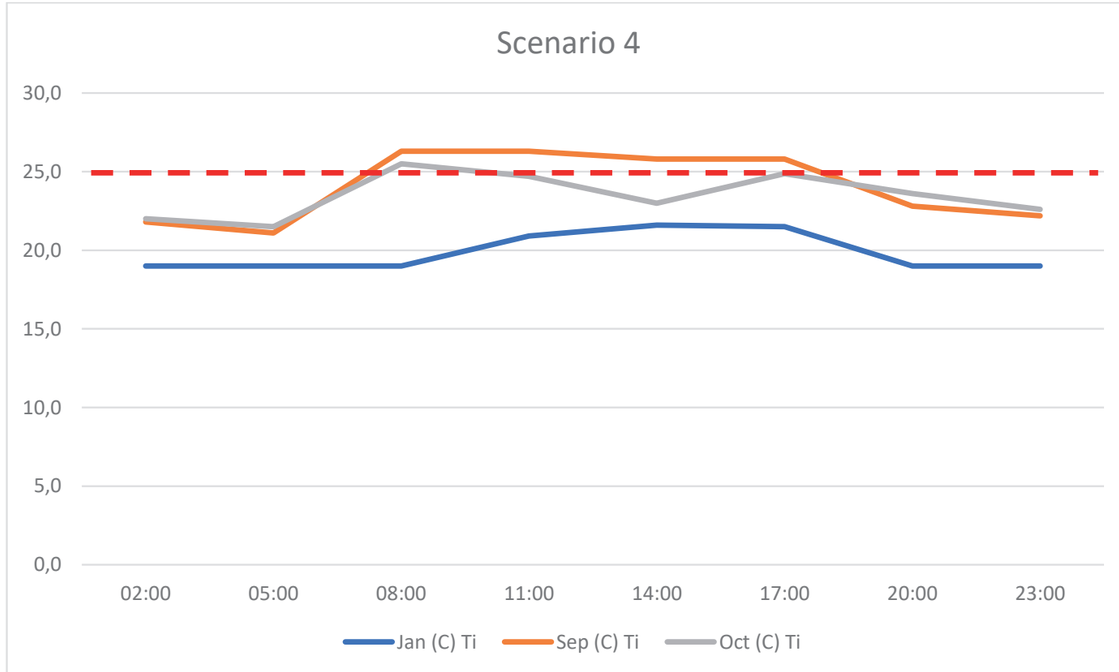
Base Scenario

Base	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	21,1	21,3
	05:00	19,0	20,2	20,6
	08:00	19,0	25,7	24,4
	11:00	20,9	25,5	23,7
	14:00	21,6	25,1	22,0
	17:00	21,5	24,8	23,7
	20:00	19,0	21,7	22,5
	23:00	19,0	21,5	21,6
	Average	19,9	23,2	22,5
Base	BASE SCENARIO RETROFIT: Input of retrofit characteristics as mentioned. Ventilation schedule adjusted for September: Natural night ventilation added.			



Scenario 4: Shading changed

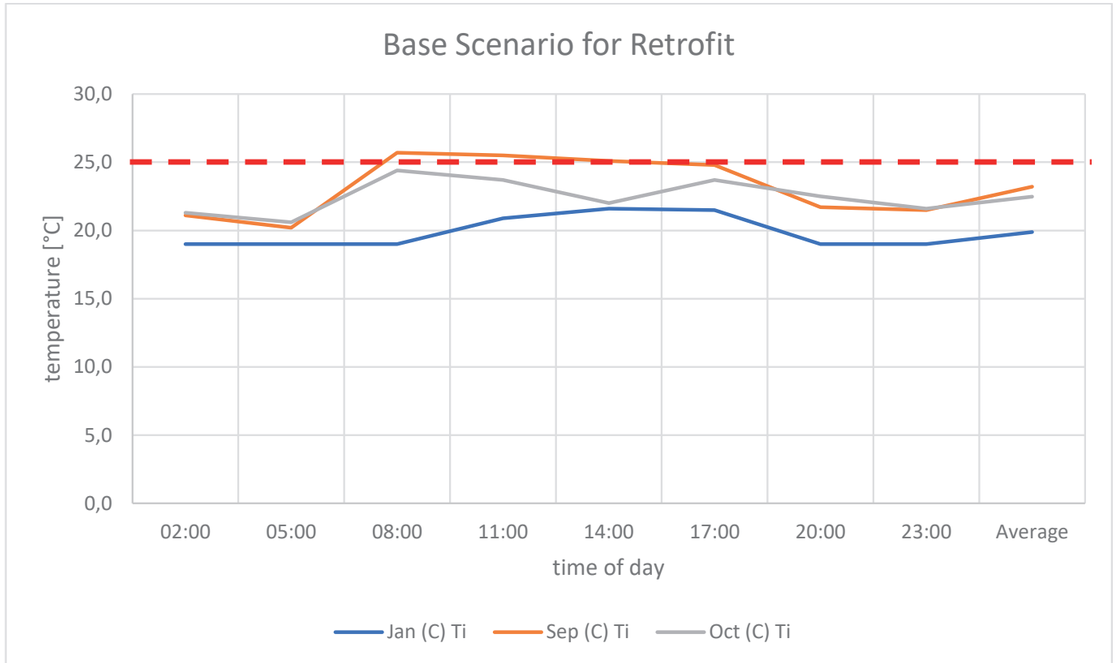
S 4	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	21,8	22,0
	05:00	19,0	21,1	21,5
	08:00	19,0	26,3	25,5
	11:00	20,9	26,3	24,7
	14:00	21,6	25,8	23,0
	17:00	21,5	25,8	24,9
	20:00	19,0	22,8	23,6
	23:00	19,0	22,2	22,6
	Average	19,9	24,0	23,5
S 4	SCENARIO 4: **Shading** schedule is changed. A situation is simulated, where shading is applied too late in the day.			



Base Scenario

Base	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	21,1	21,3
	05:00	19,0	20,2	20,6
	08:00	19,0	25,7	24,4
	11:00	20,9	25,5	23,7
	14:00	21,6	25,1	22,0
	17:00	21,5	24,8	23,7
	20:00	19,0	21,7	22,5
	23:00	19,0	21,5	21,6
	Average	19,9	23,2	22,5

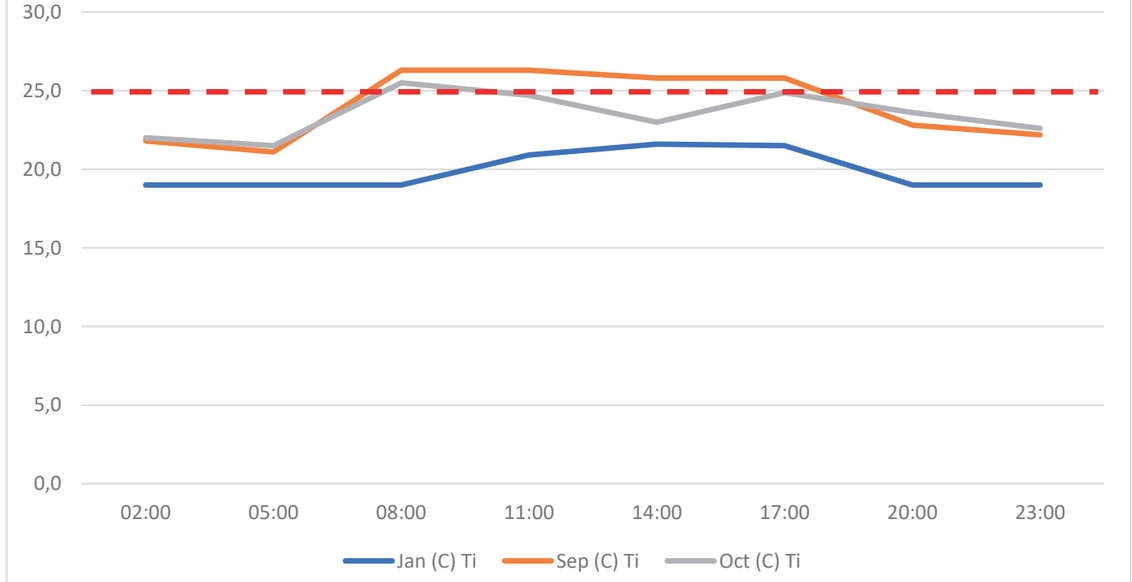
Base	BASE SCENARIO RETROFIT: Input of retrofit characteristics as mentioned. Ventilation schedule adjusted for September: Natural night ventilation added.



Scenario 4: Shading changed

S 4	time	Jan (C)	Sep (C)	Oct (C)
		Ti	Ti	Ti
	02:00	19,0	21,8	22,0
	05:00	19,0	21,1	21,5
	08:00	19,0	26,3	25,5
	11:00	20,9	26,3	24,7
	14:00	21,6	25,8	23,0
	17:00	21,5	25,8	24,9
	20:00	19,0	22,8	23,6
	23:00	19,0	22,2	22,6
	Average	19,9	24,0	23,5

S 4	SCENARIO 4: **Shading** schedule is changed. A situation is simulated, where shading is applied too late in the day.



Conclusion of RQ4:

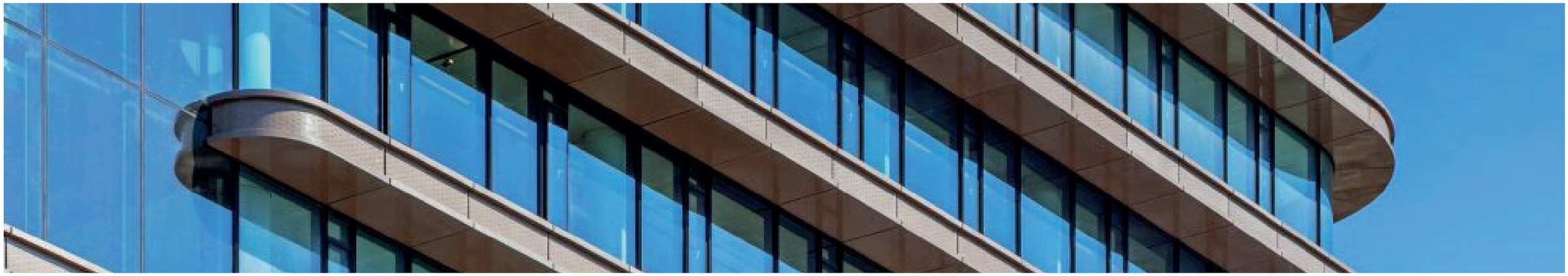
RQ4: What technical and managerial aspects can help the implementation of result-oriented PSS facades?

- Keeping in touch

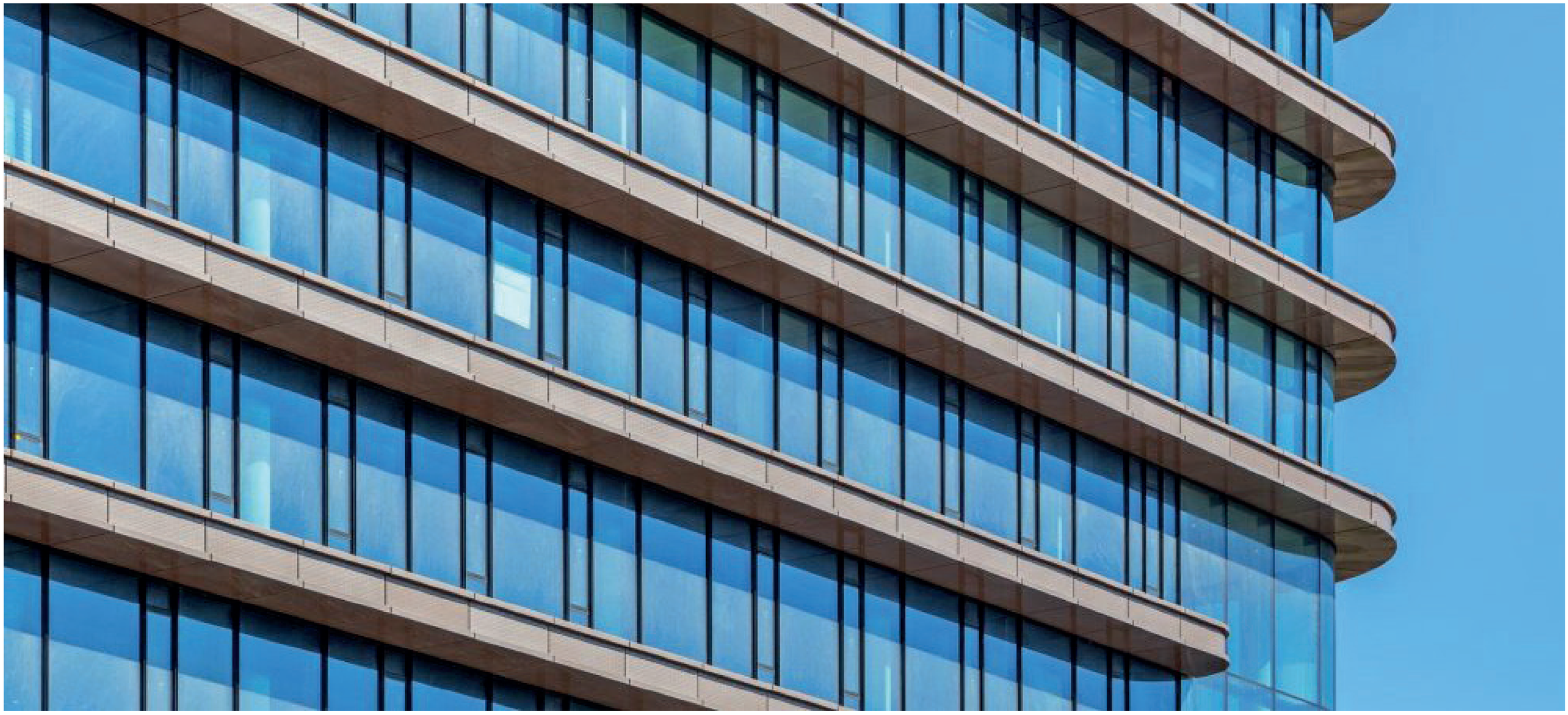
- Taking control

- Optimizing

- Collaborating



DESIGN



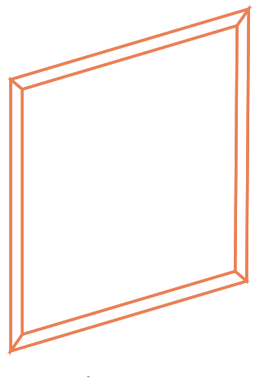
Facades as Circular PSS

Design for Performance
=
Operational Phase

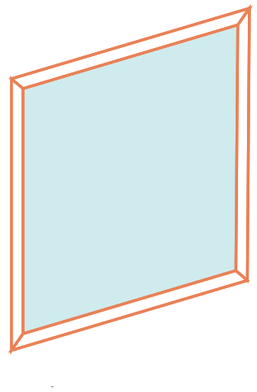
Design for Circularity
=
Beyond the Operational Phase

Residual Value of Facade Products

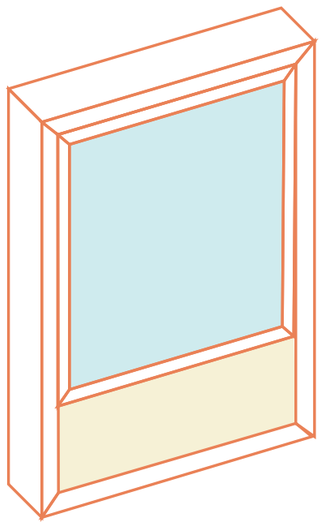
material:
extruded profile



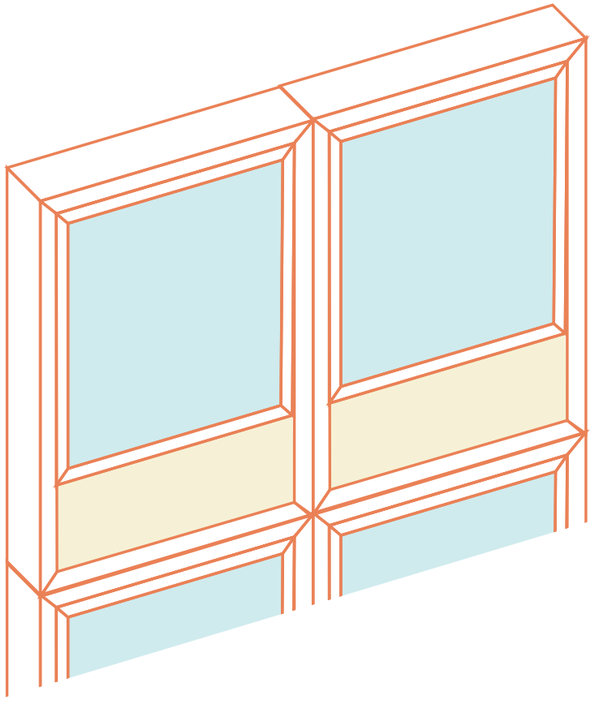
element:
window frame



sub-component:
window

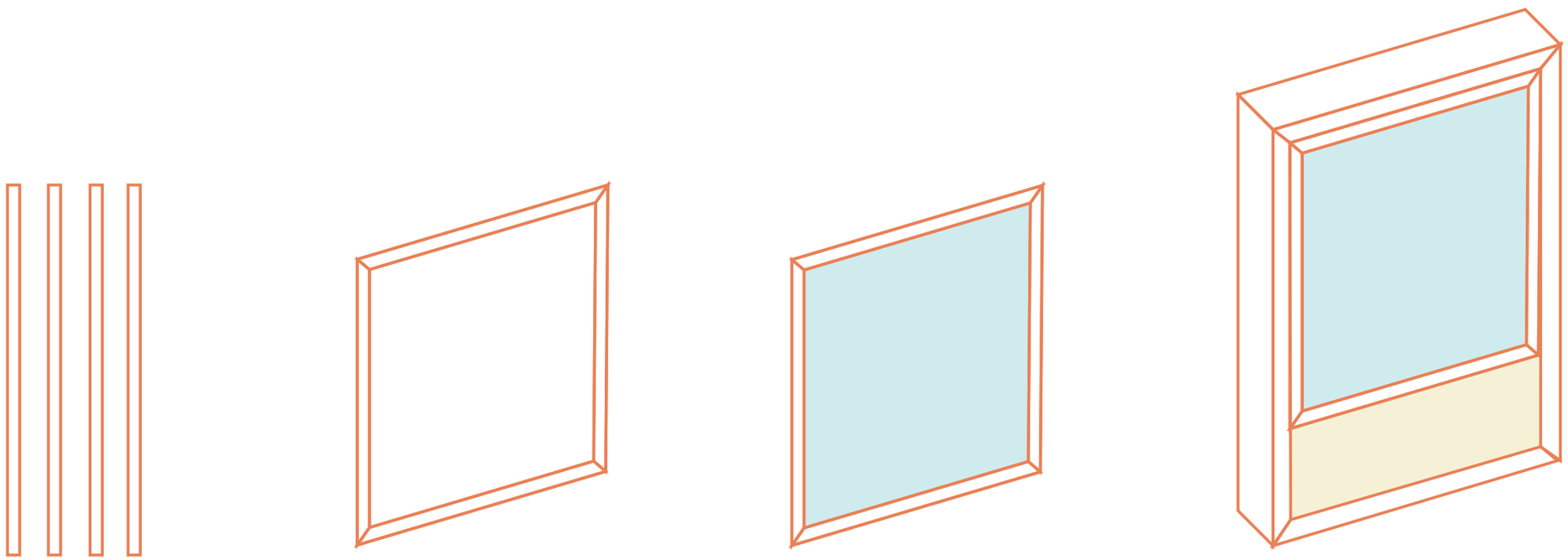


component:
unitized facade panel



building part:
curtain wall

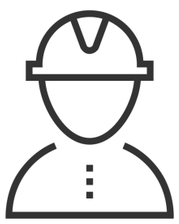
Residual Value of Facade Products



material → element → sub-component → component

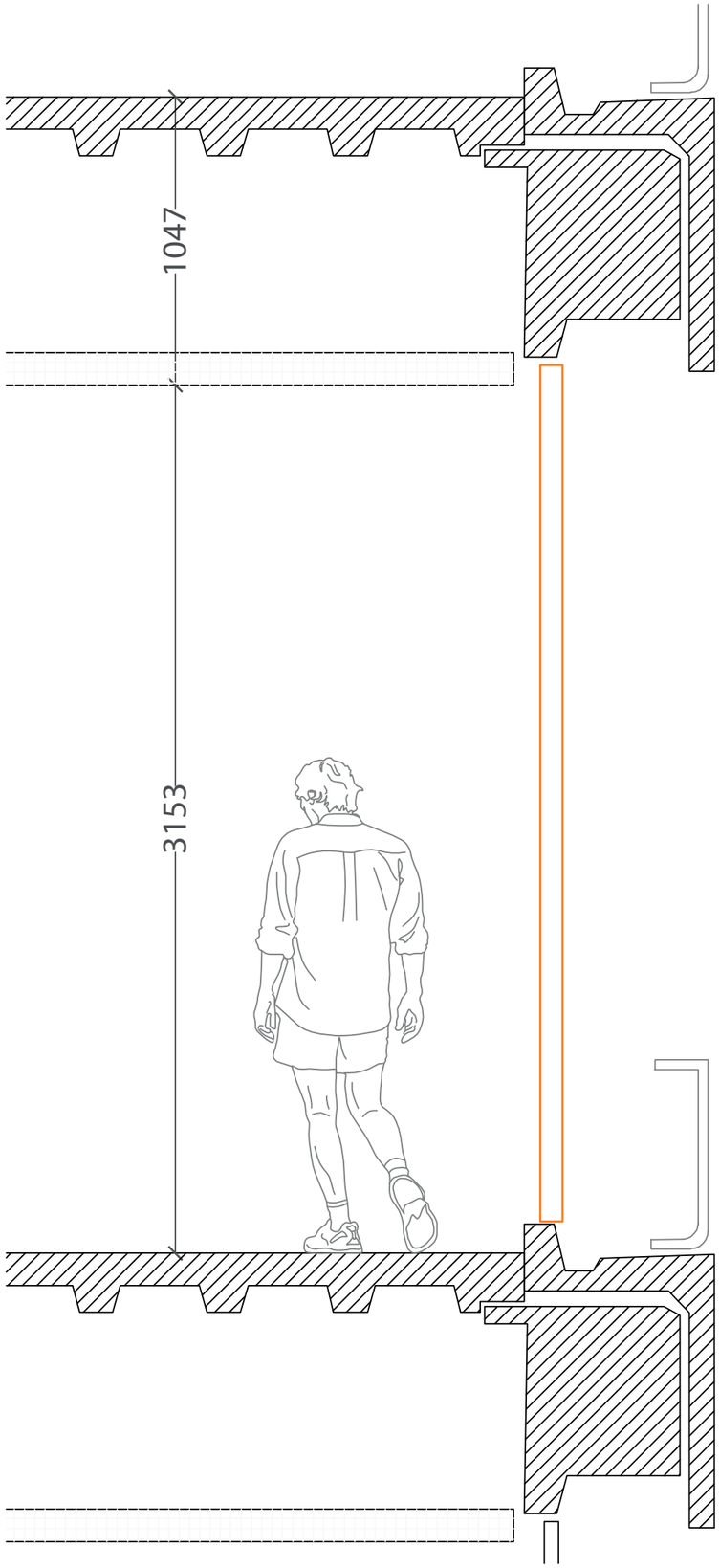
input for every step:

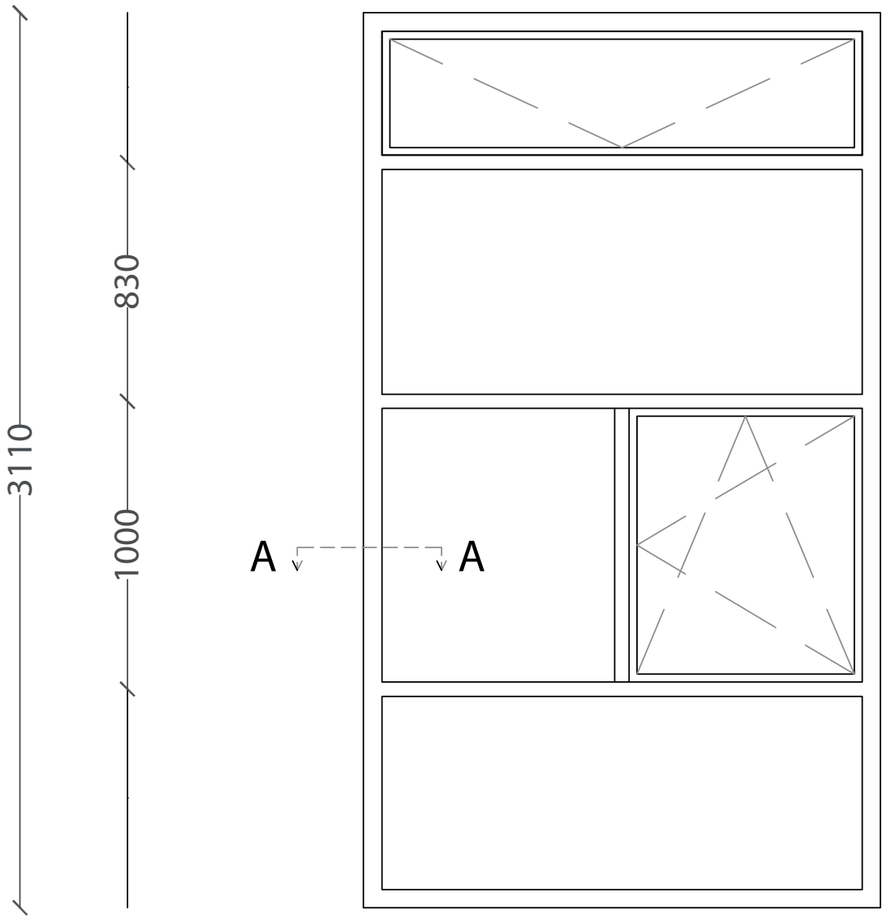
design and engineering hours

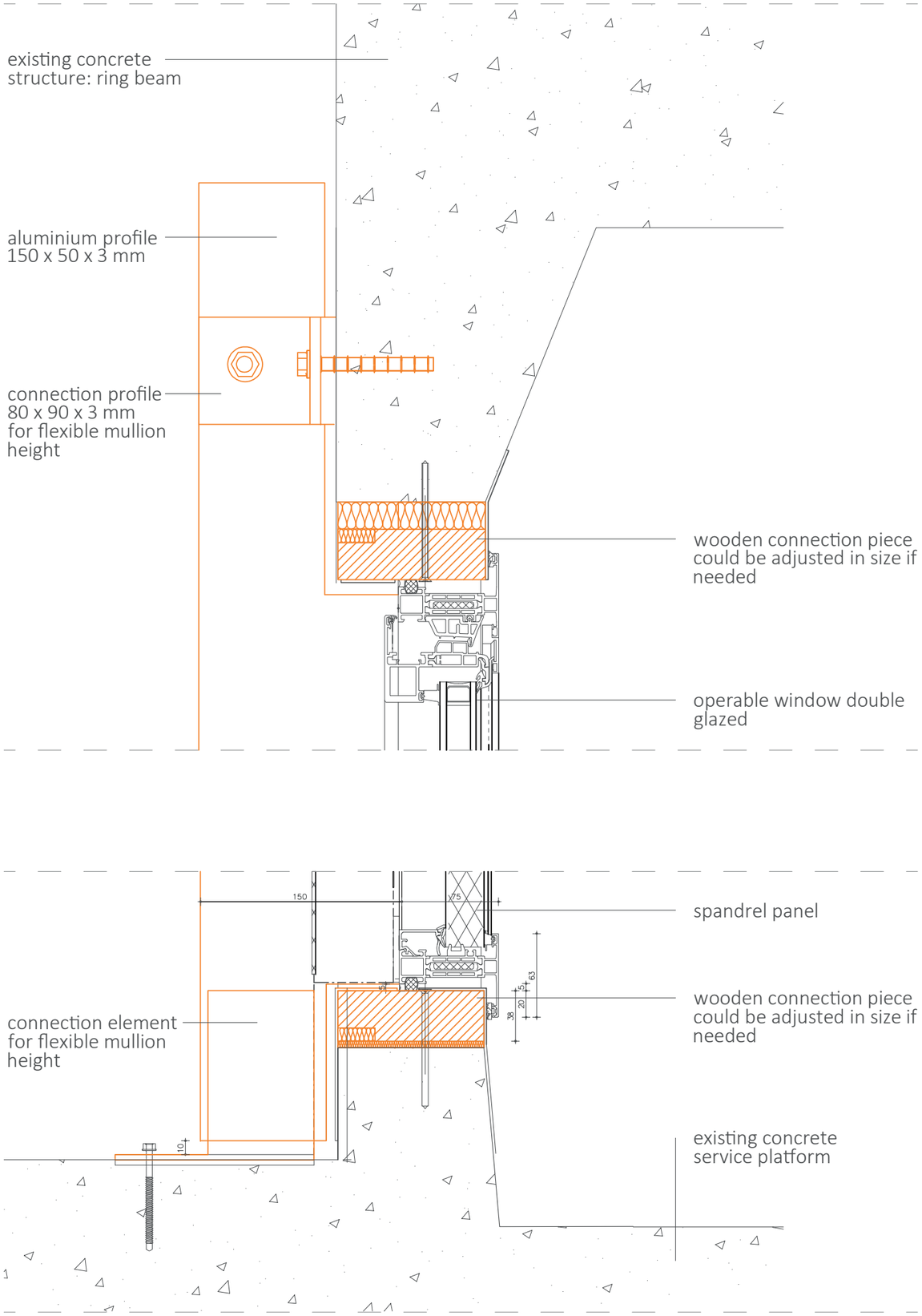


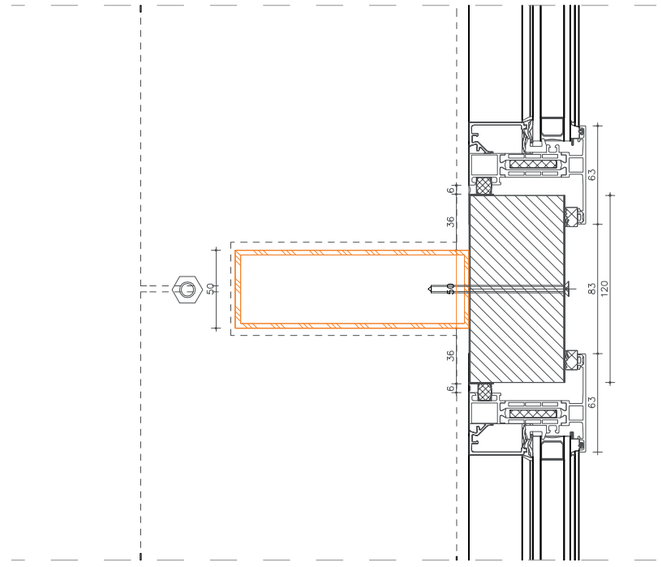
manufacturing hours

materials (connectors, sealants)

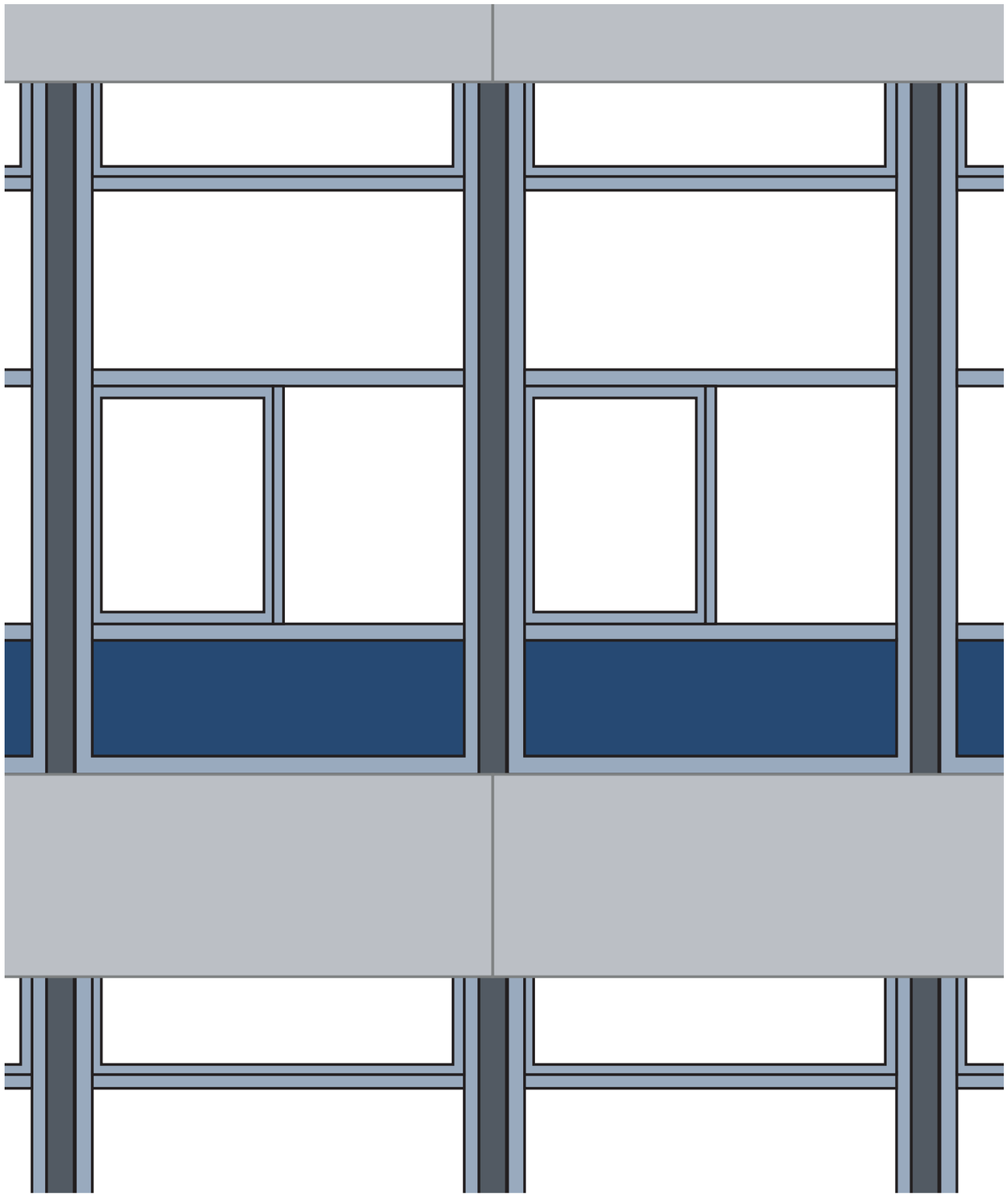

1047
3153
3110
4200

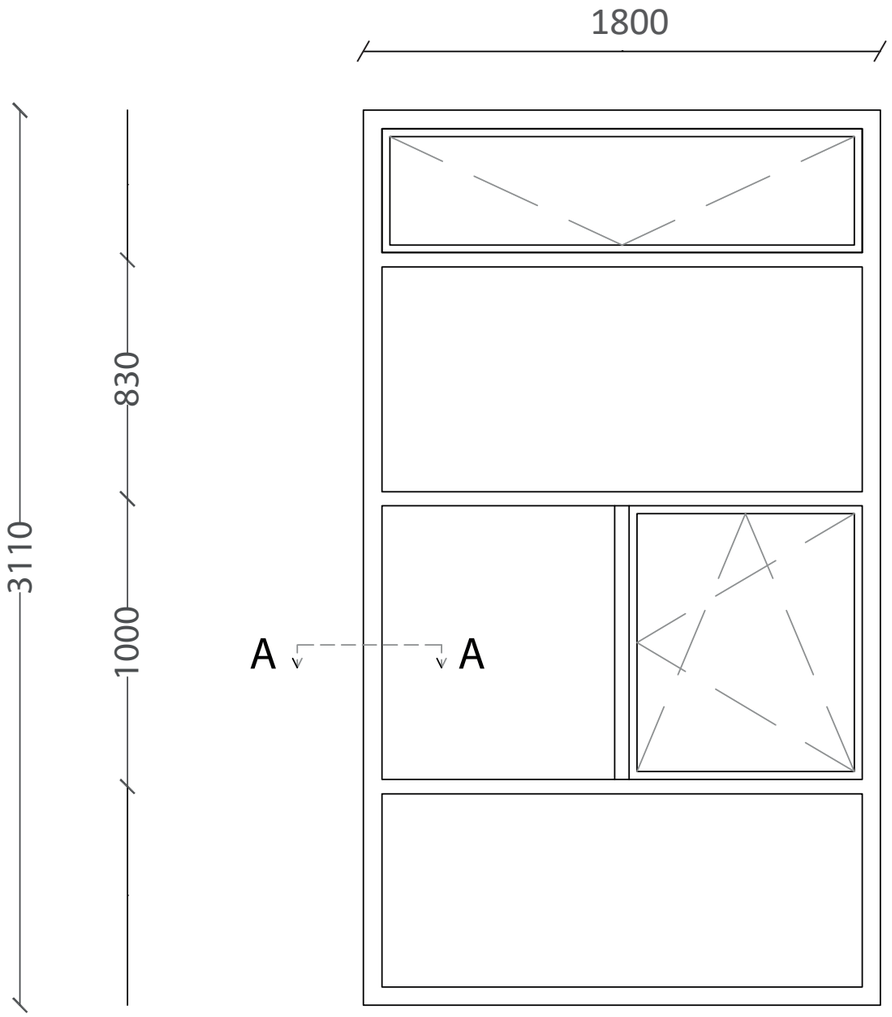

1800
3110
830
1000
A
A


existing concrete
structure: ring beam
aluminium profile
150 x 50 x 3 mm
connection profile
80 x 90 x 3 mm
for flexible mullion
height
wooden connection piece
could be adjusted in size if
needed
operable window double
glazed
spandrel panel
wooden connection piece
could be adjusted in size if
needed
connection element
for flexible mullion
height
existing concrete
service platform
150
75
63
5
20
38
19


63
6
36
50
83
120
36
6
63

Reuse of the CiTG East Facade Panels



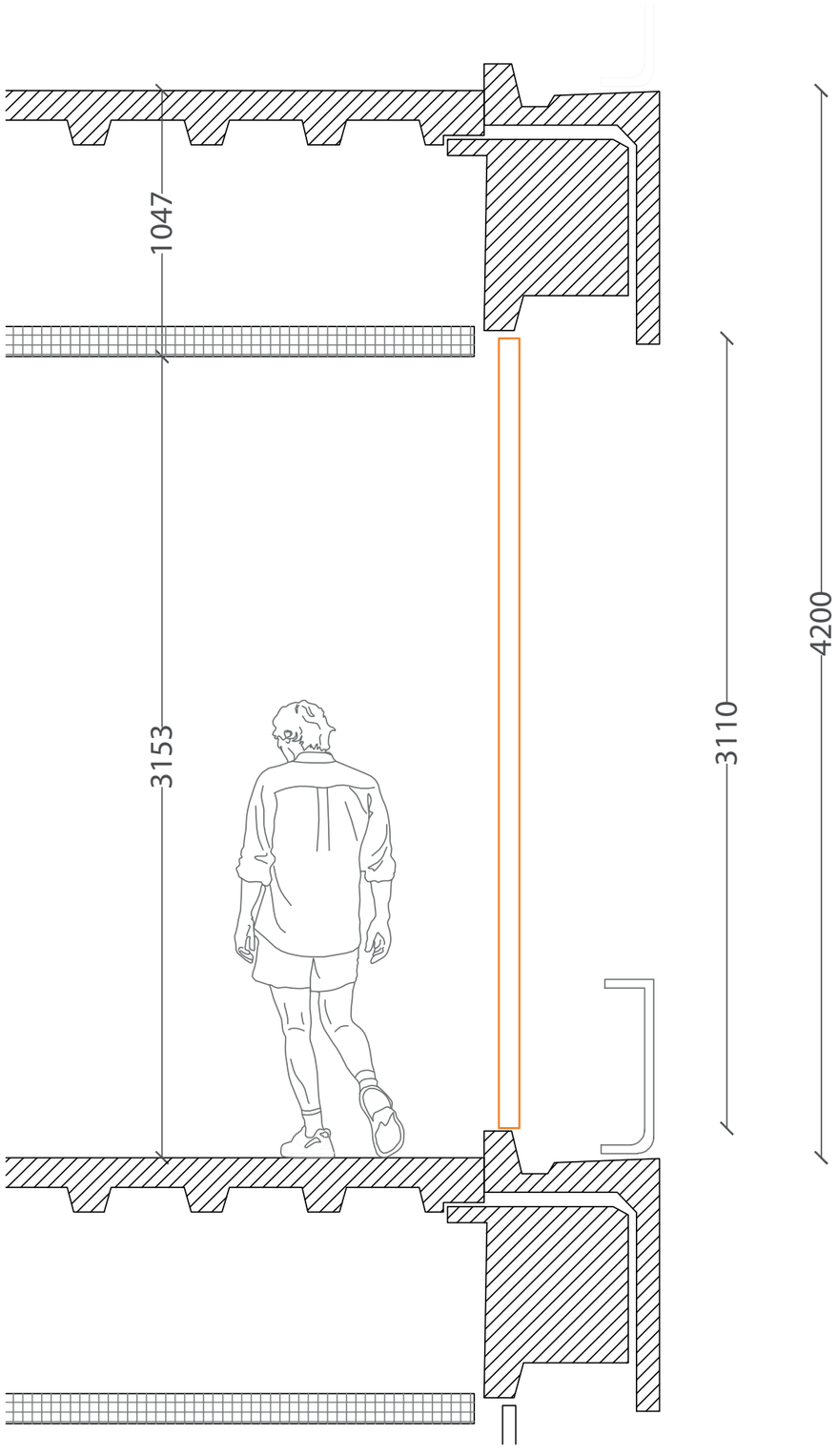


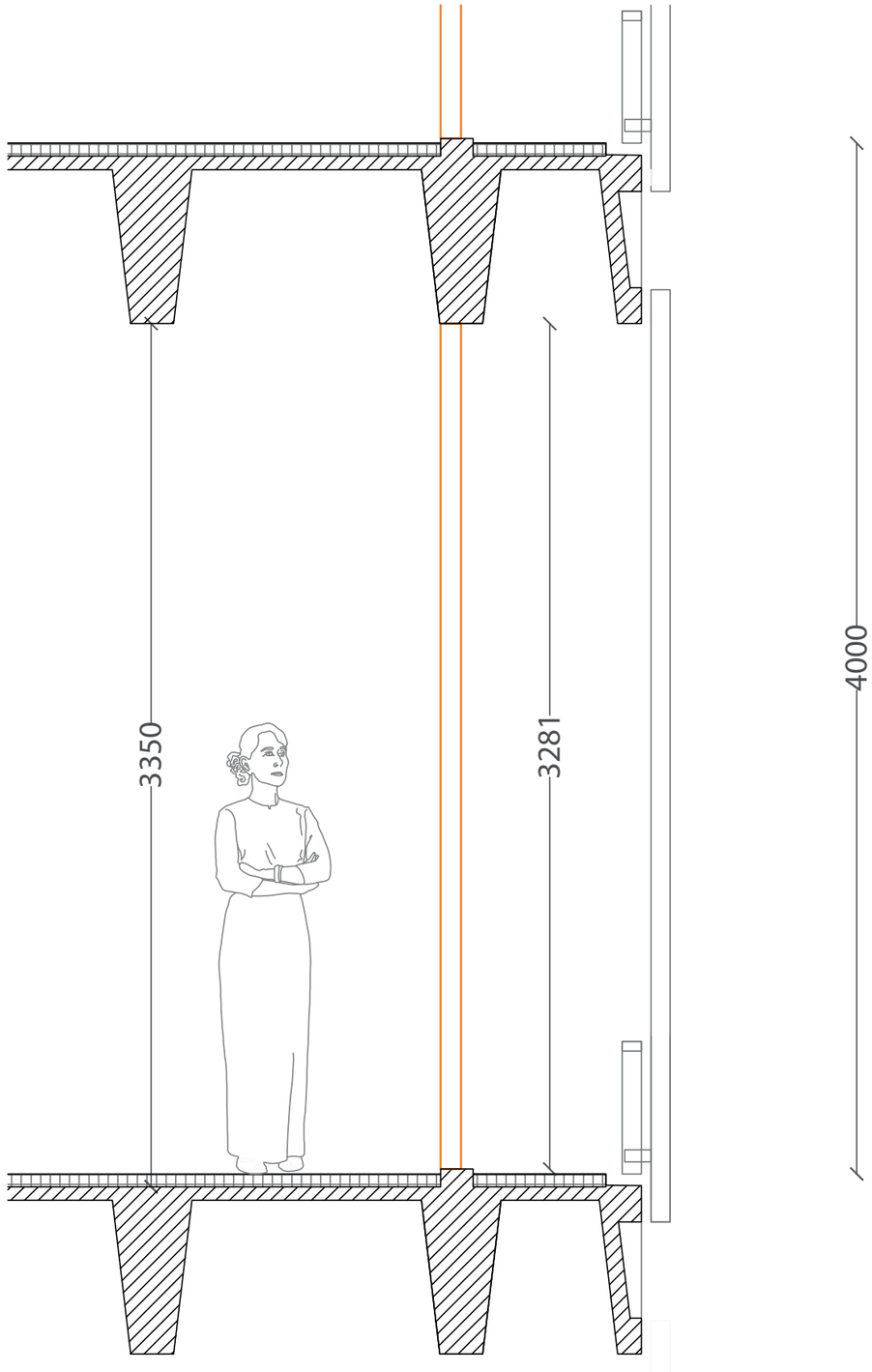
Reuse on TU Delft Campus

Critical difference in typology	**Applies to X amount of buildings**
Position of façade to structure different (curtain)	2
Clearance of openings less high than CiTG	3
Clearance of openings higher than CiTG	2
Clearance of openings less wide than CiTG	2
Clearance of openings wider than CiTG	2
Column obstructing clear opening width	2
Existing fixed parapet	4

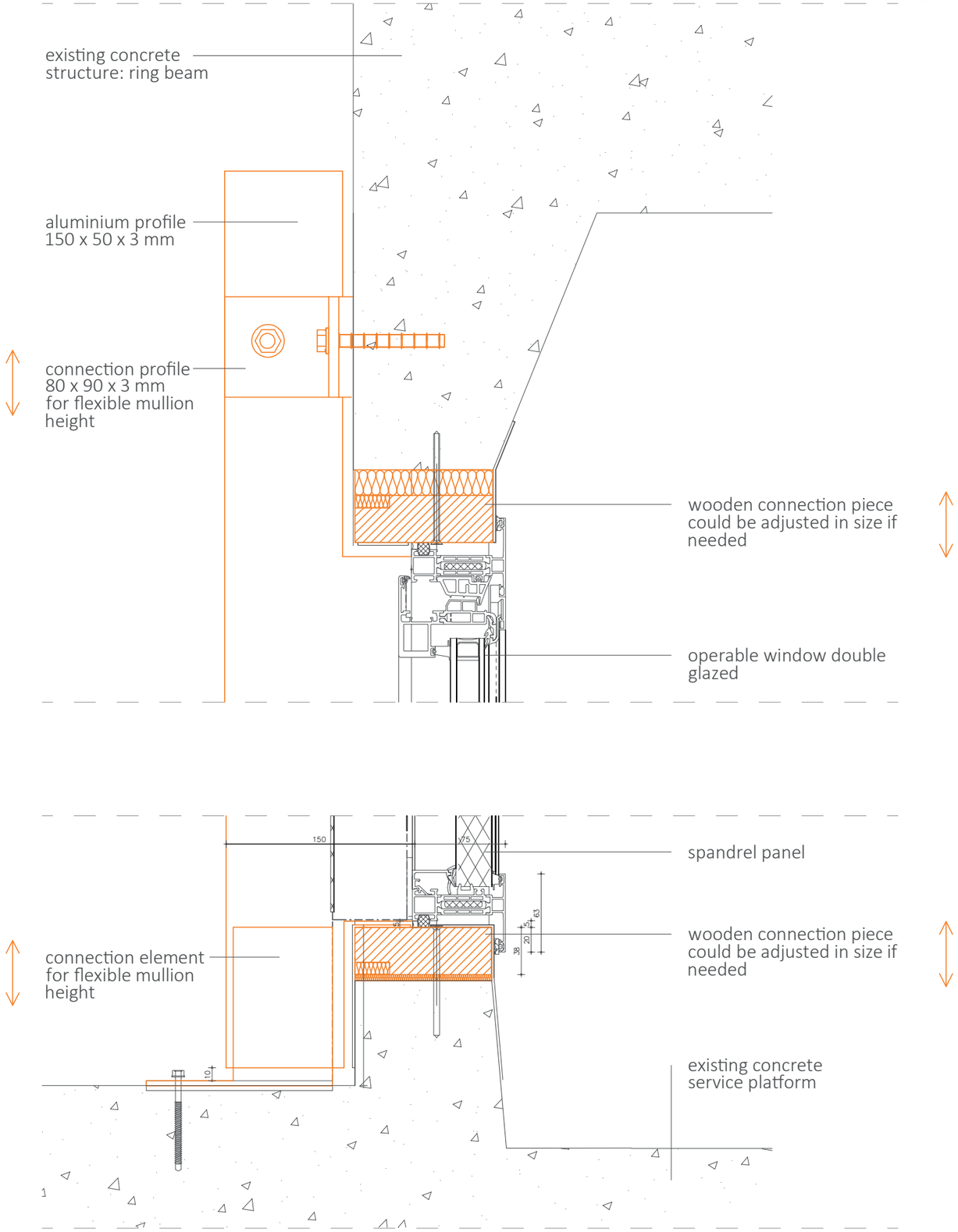
Reuse on Similar Building: Hogekamp UT Enschede

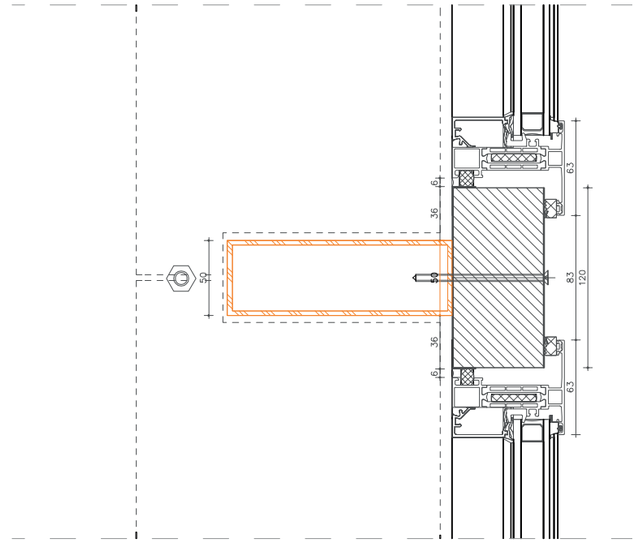
Reuse on Similar Building: Hogekamp UT Enschede



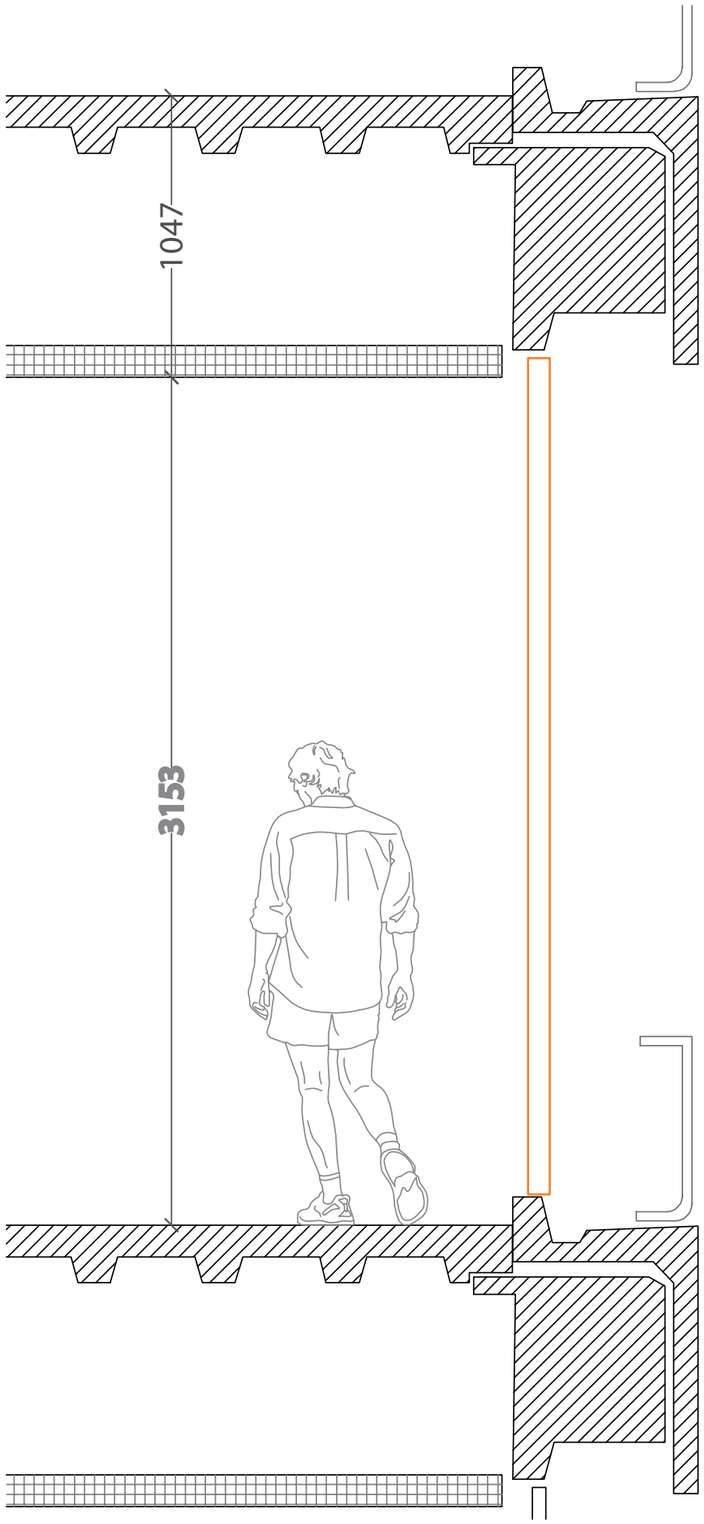


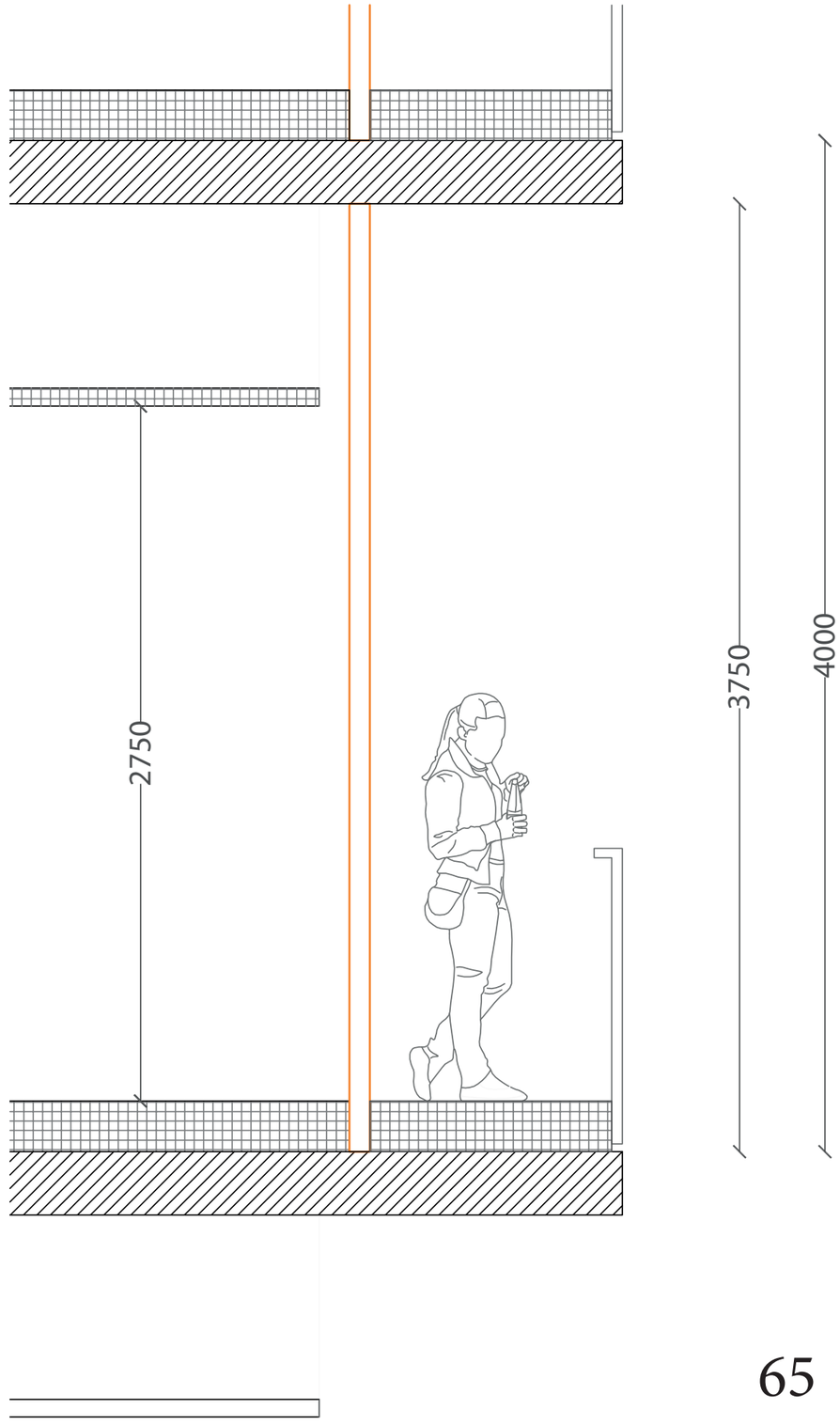
Reuse on Similar Building: Hogekamp UT Enschede



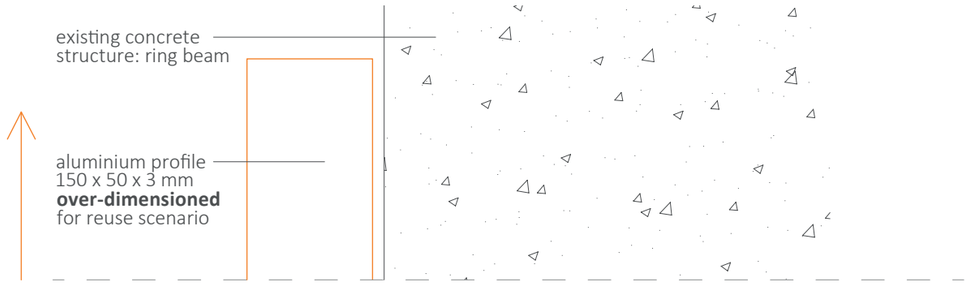


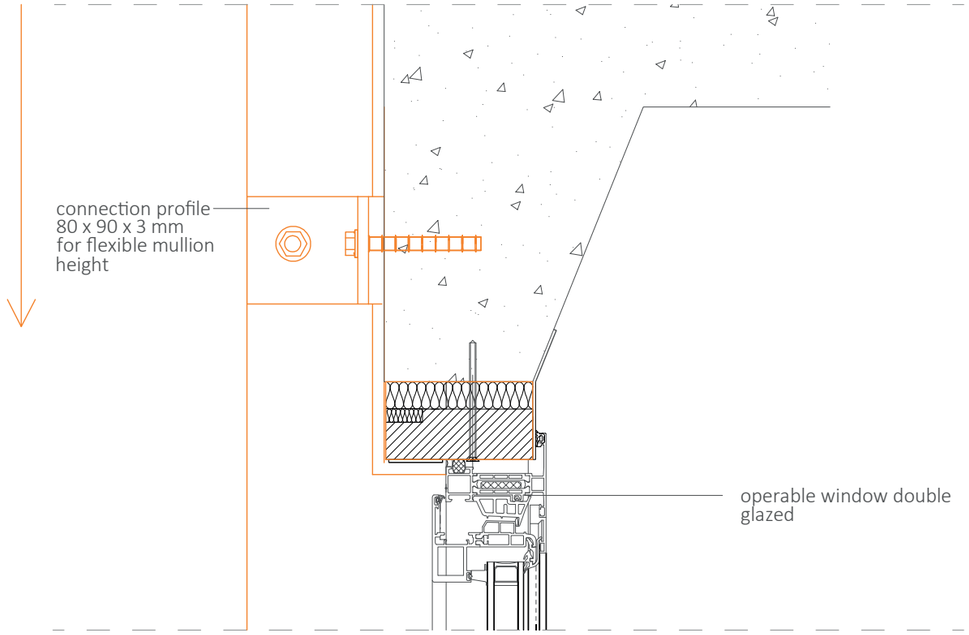
Reuse on a Standard Office Building

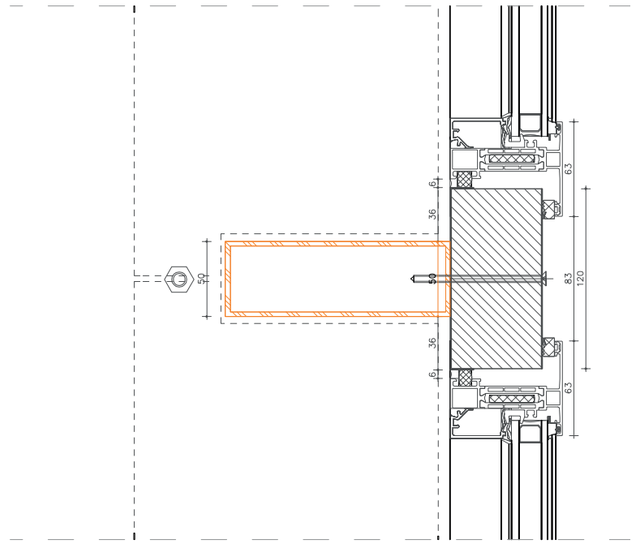


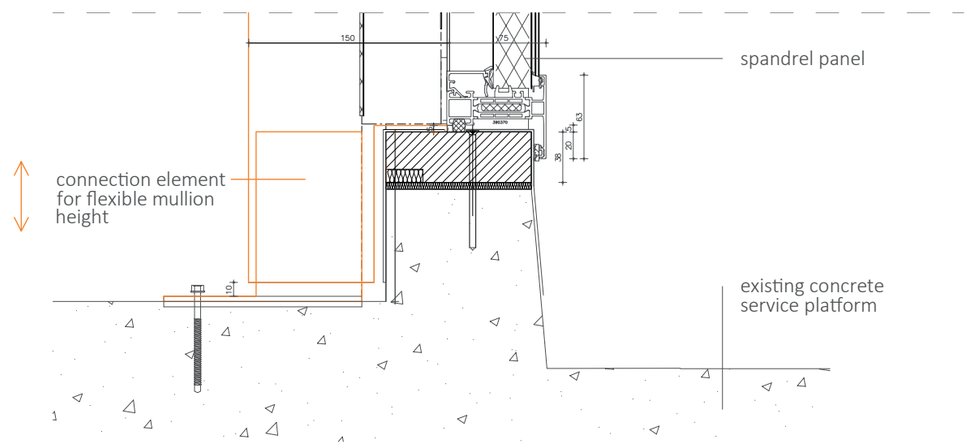


Detail of the CiTG facade, with overdimensioned mullion

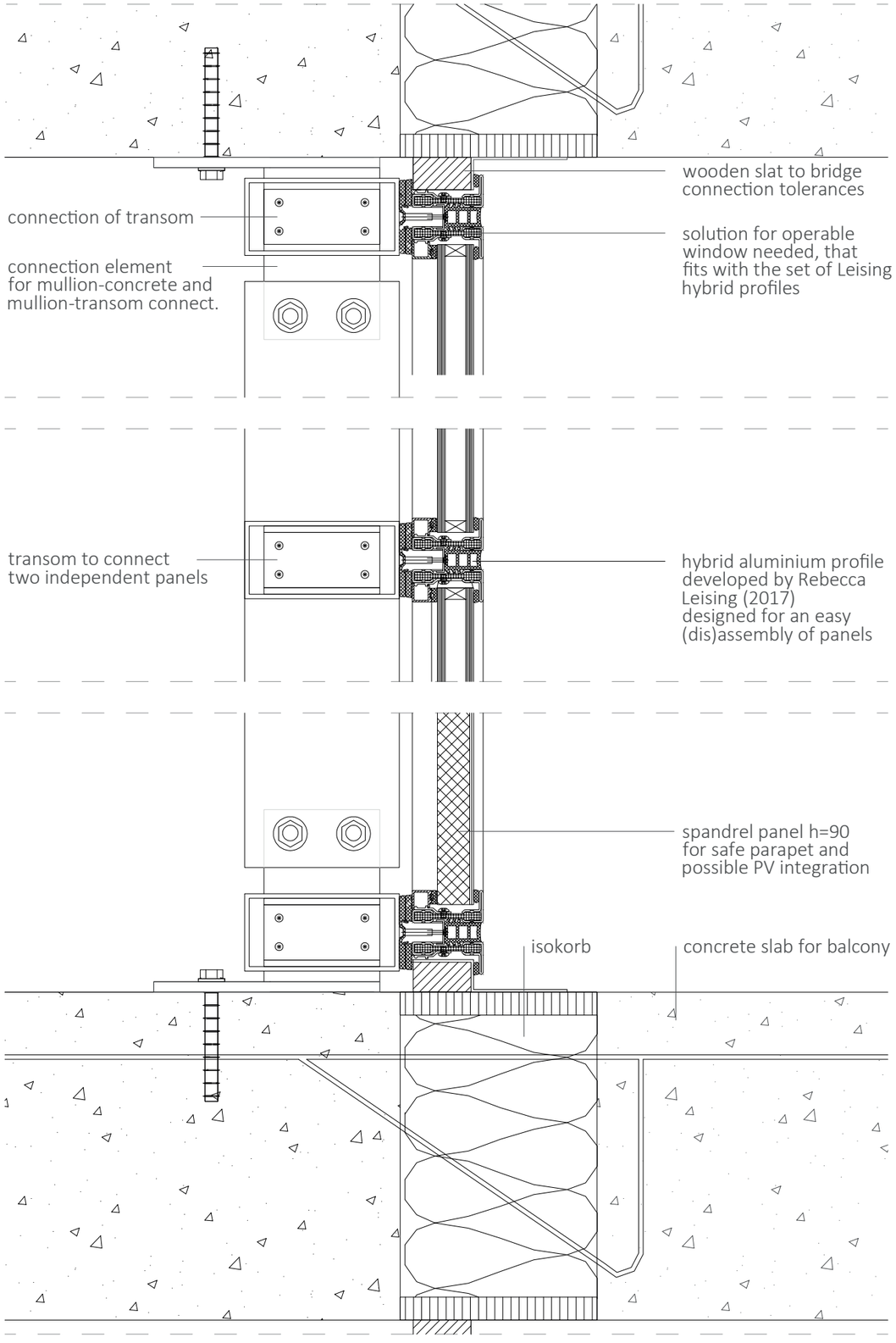


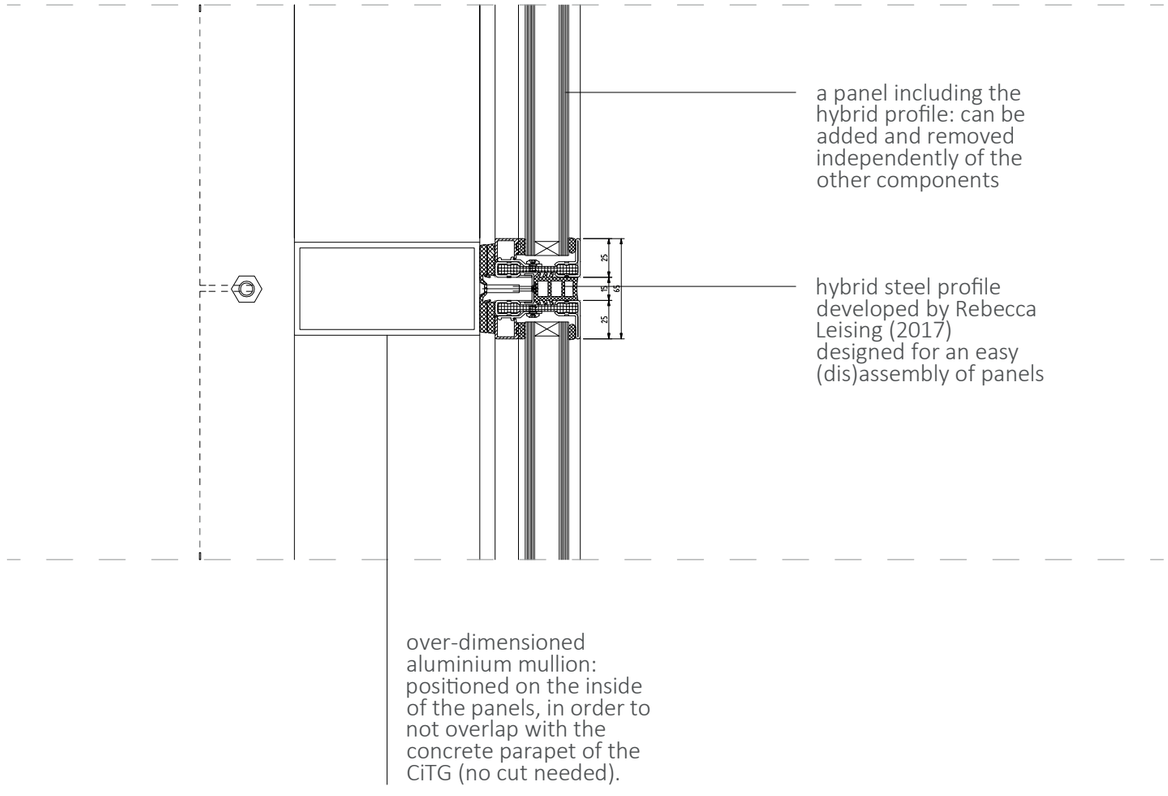




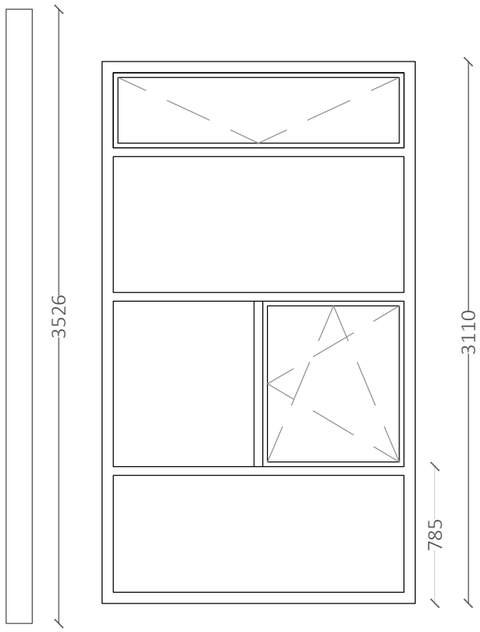


Detail: Reuse on a Standard Office Building

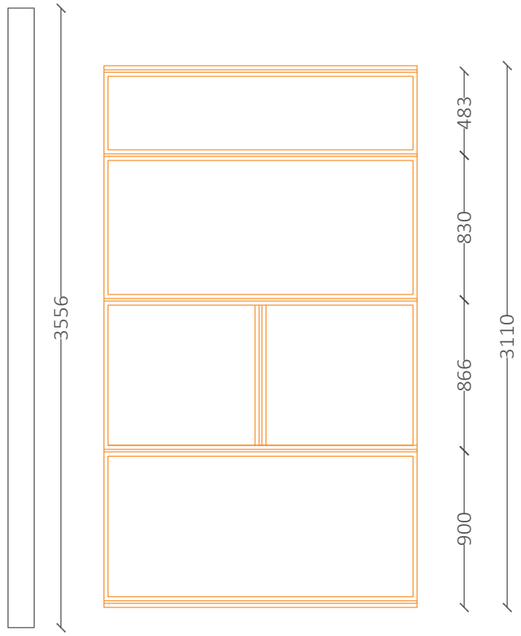




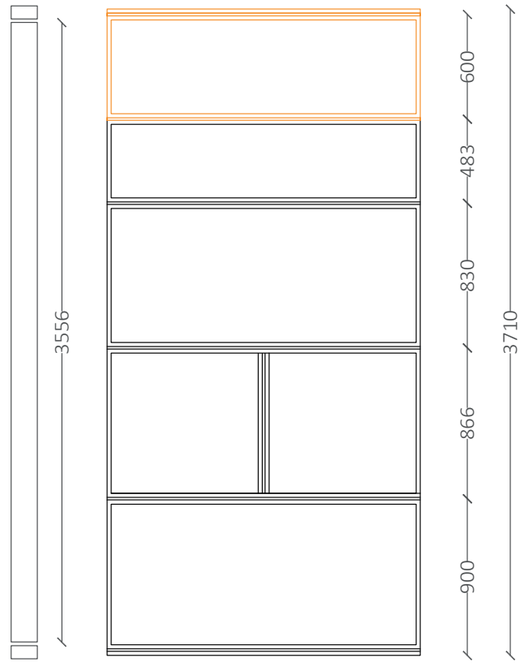
Proposed Solution: An Adaptable Modular System



Original design CiTG



Redesign on CiTG



Redesign on
Standard building

Summary

Supplying circular facades

- Think in systems:
- A PSS facade is **independent** from any single building:
  ownership; construction; market value; life cycle

Supplying facade performance

- The facade is a tool to supply performance.
- To guarantee performance, the gap needs to be closed:
- Increase the actual performance and close the gap
  between expectations and reality

What´s next?

Recommendations for further research:

1. Research through design:
Strandardized and adaptable
system of sub-components

2. Research on the producer-risk and
consumer-risk

3. Use the CiTG east side to simulate
a result-oriented service contract

thank you!

Image sources:

p. 1: Scott Hall Pittsburgh, by O52 architecture. https://www.office-52.com/work/custom-ceramic-frit/

p. 36: Office of PRF the Gás, Tecnologia e Construção, S.A in Portugal by Ivo Tavares Studio , https://www.archiscene.net/offices/impare-architects-portugal/.

p. 45: screenshot of the Office Vitae user platform: measurement data of the CiTG building, https://app.officevitae.com/timeline

p.58: New Atrium Amsterdam, http://www.alkondor.nl/projecten

p.70: Hogekamp UT Enschede, http://www.alkondor.nl/projecten

Proposed Solution: An Adaptable Modular System