Office-user oriented façade design

an interactive/adaptive design approach

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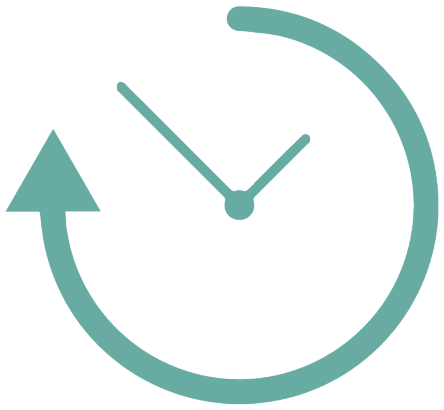
P5 Graduation Presentation
9th of July, 2020

Background & problem statement

90% indoors

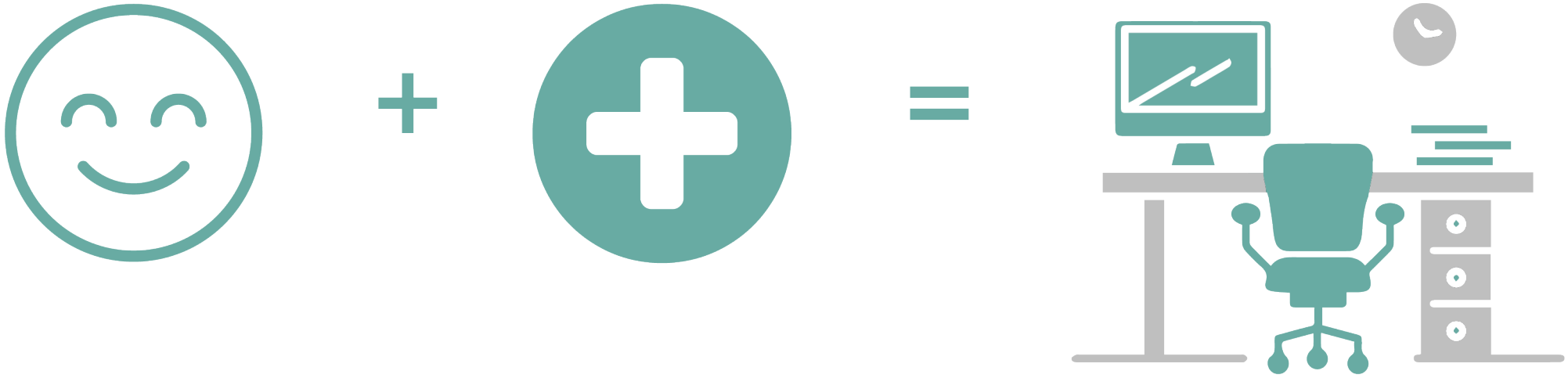
long process



frustrating

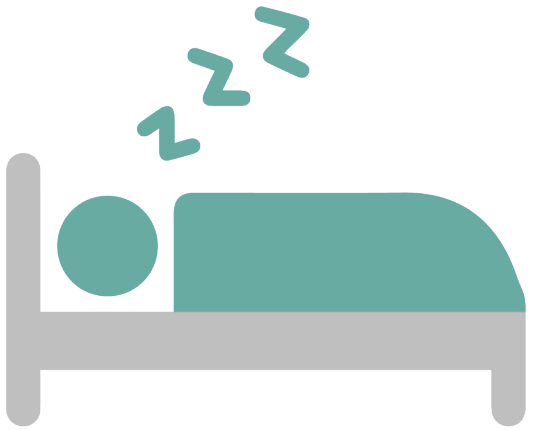
Background & problem statement

comfort + **health** = **work productivity**



Background & problem statement

miss work

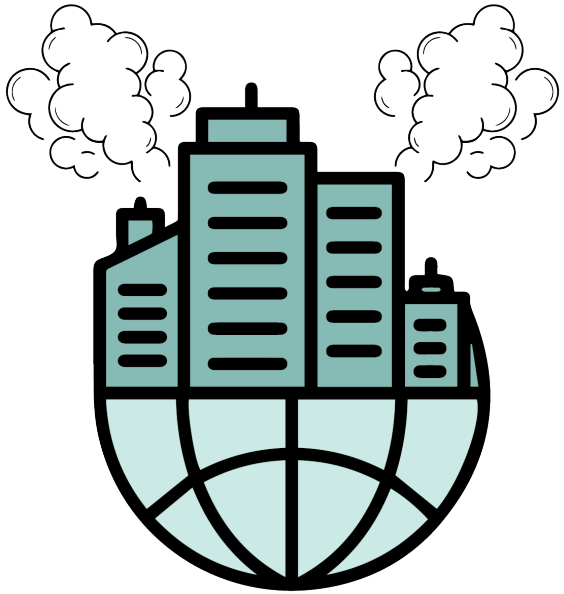


take longer

constantly complain

Background & problem statement

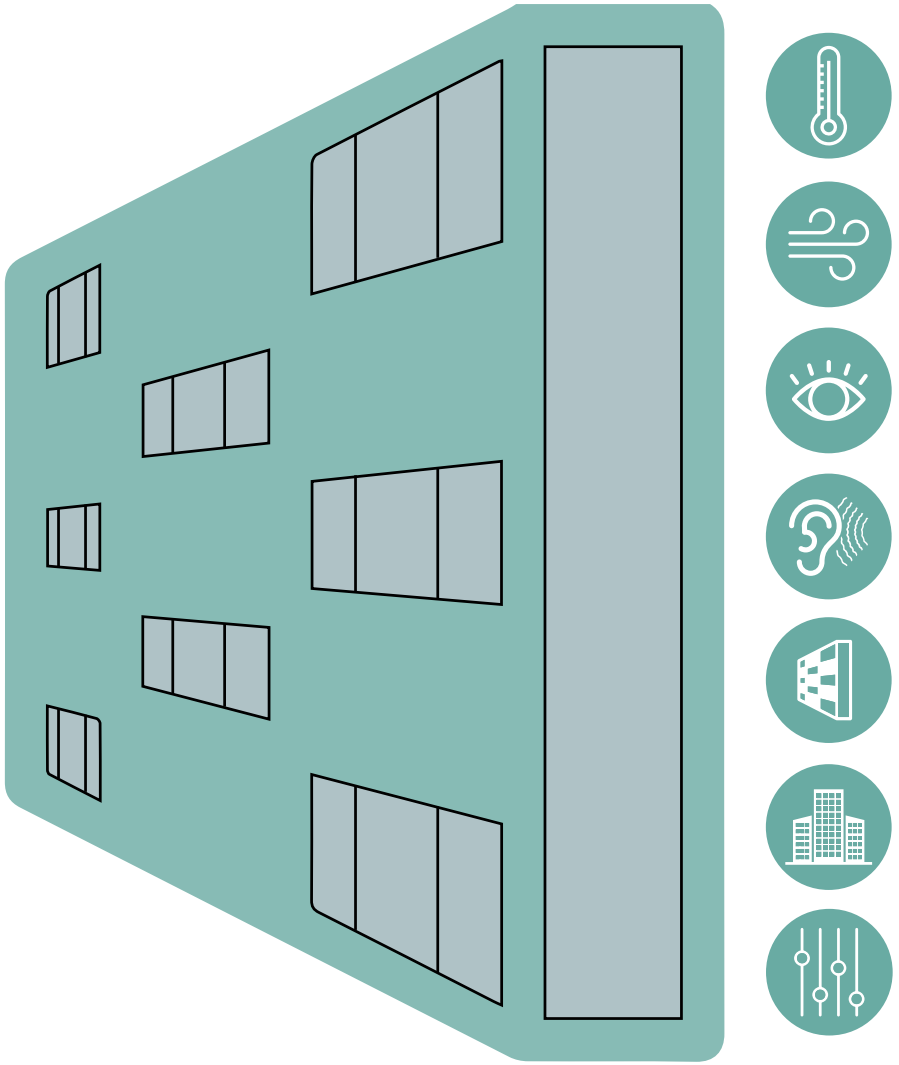
40% worlds' final energy use



Nearly zero energy buildings 2021

Background & problem statement

A+++

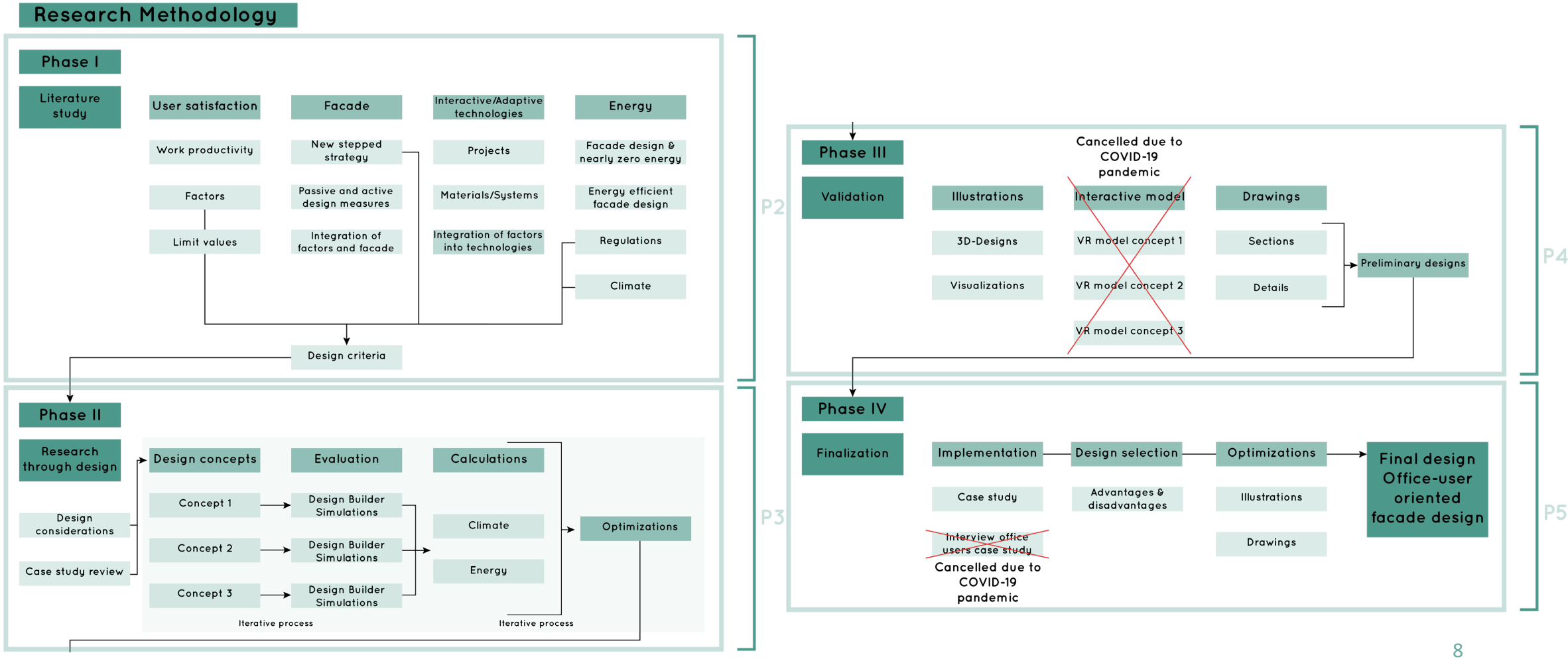


Research question

"How can an interactive/adaptive office building façade element be designed to optimally satisfy its users in order to increase work productivity and to support nearly energy neutrality of office buildings?"

interactive/adaptive	*= interaction between users and façade,*
	adapting according to users preferences & outdoor conditions
Optimally satisfy	*= users are comfortable*
Comfort	*= certain limit values are met*

Approach and methodology

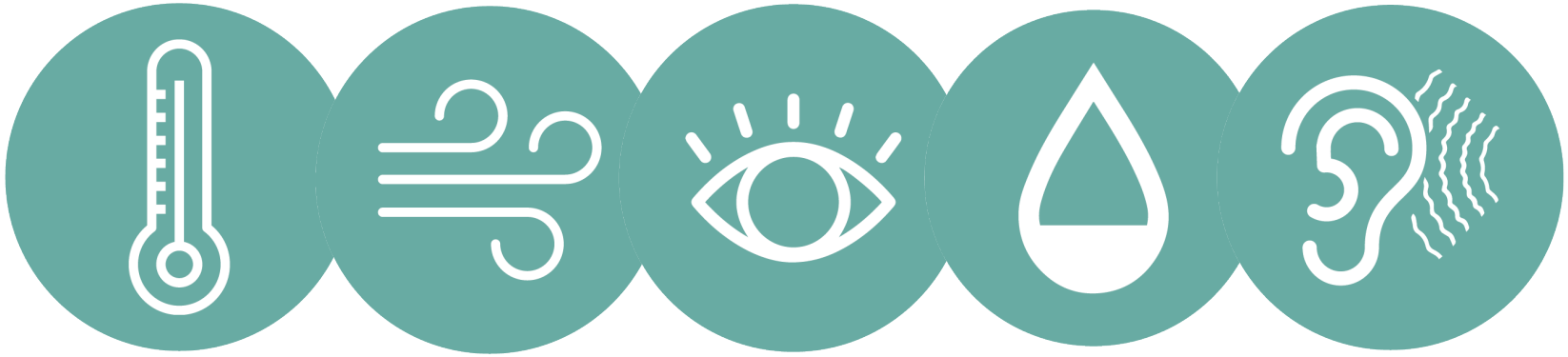


Literature study

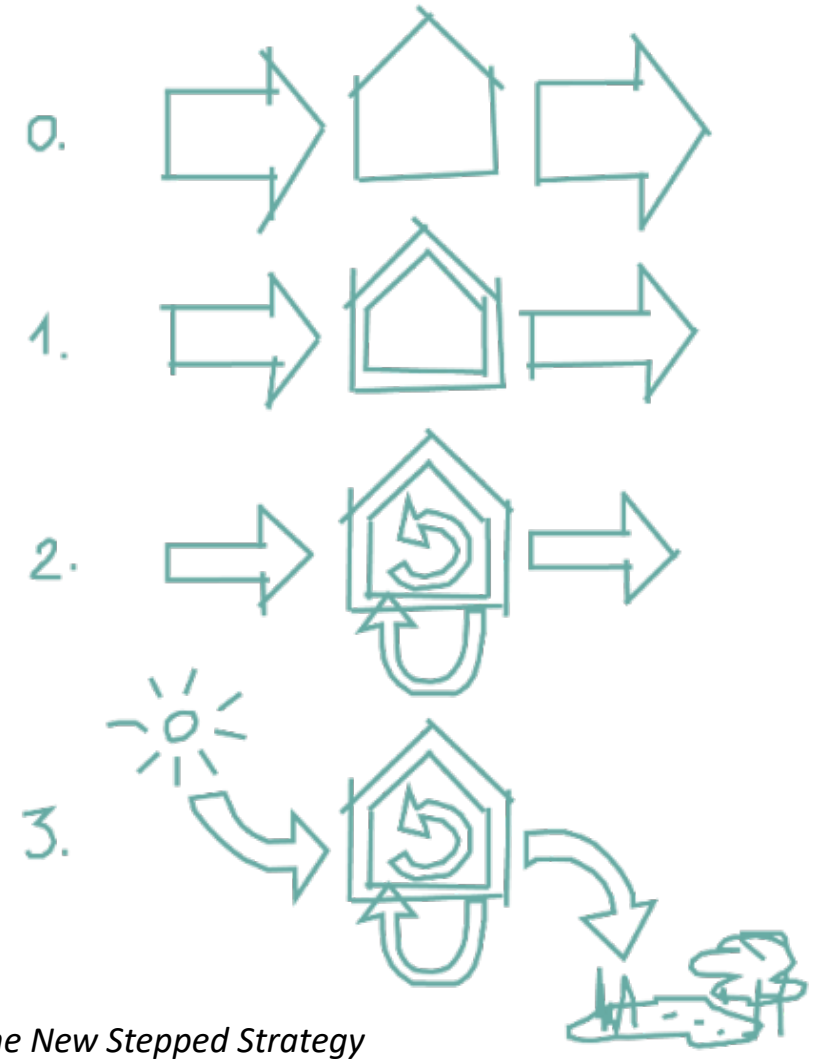
Literature study – user satisfaction

Work productivity

User satisfaction



Literature study – façade design

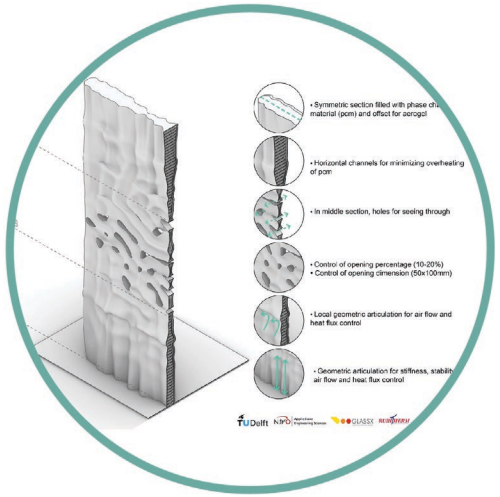


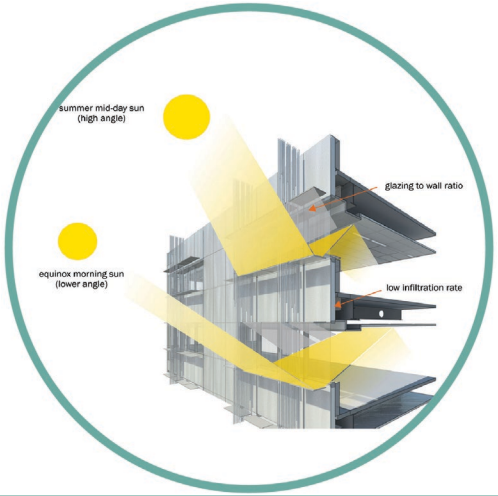
The New Stepped Strategy
(van den Dobbelsteen, 2008)

1. Reduce the demand
2. Reuse waste streams
3. Use renewable energy sources (a) and ensure that waste can be used as food (b)

Literature study – interactive/adaptive technologies

Concepts & Projects





Materials & Systems

Literature study - energy

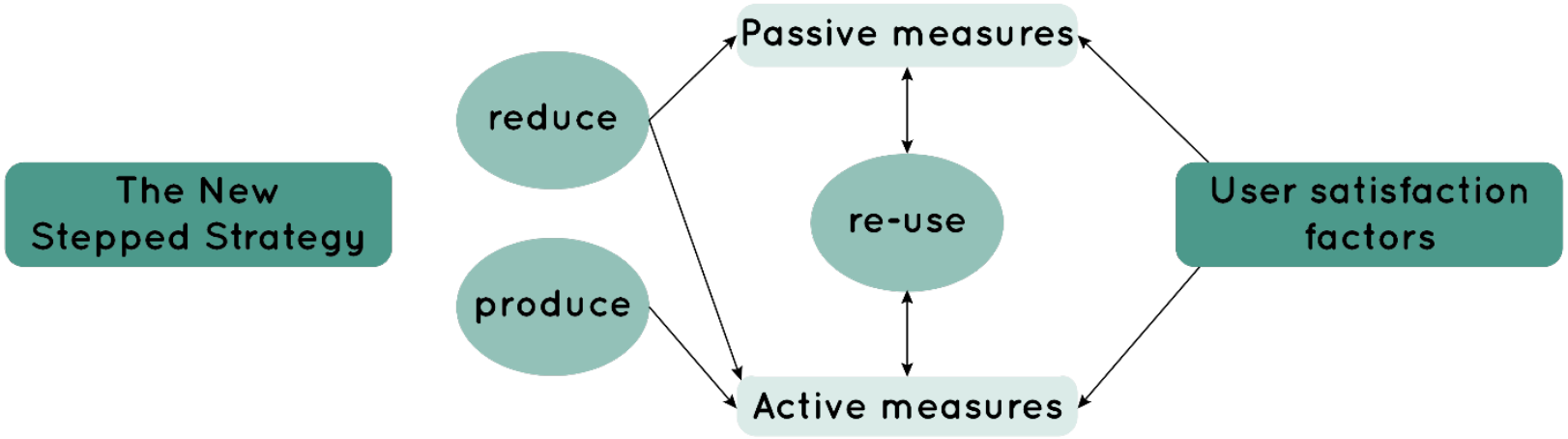
Energy efficient façade design principles

Local climate conditions

NZEB/BENG values (Nearly Zero Energy Buildings)

Literature study – integration

Façade design + user satisfaction factors:



Façade design + user satisfaction + interactive/adaptive technologies

Design considerations

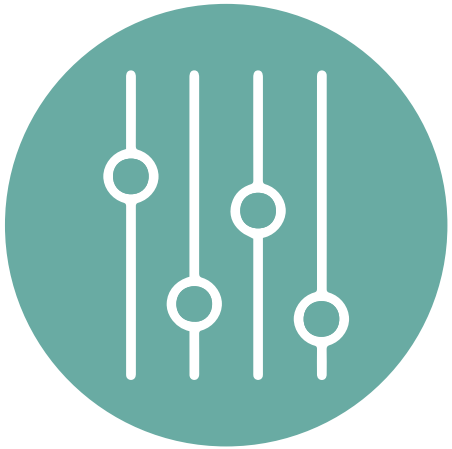
Design criteria

User comfort

Thermal comfort

Visual comfort

User control



Temperature

Air quality

Lighting

Aesthetics

Energy efficiency

Energy reduction

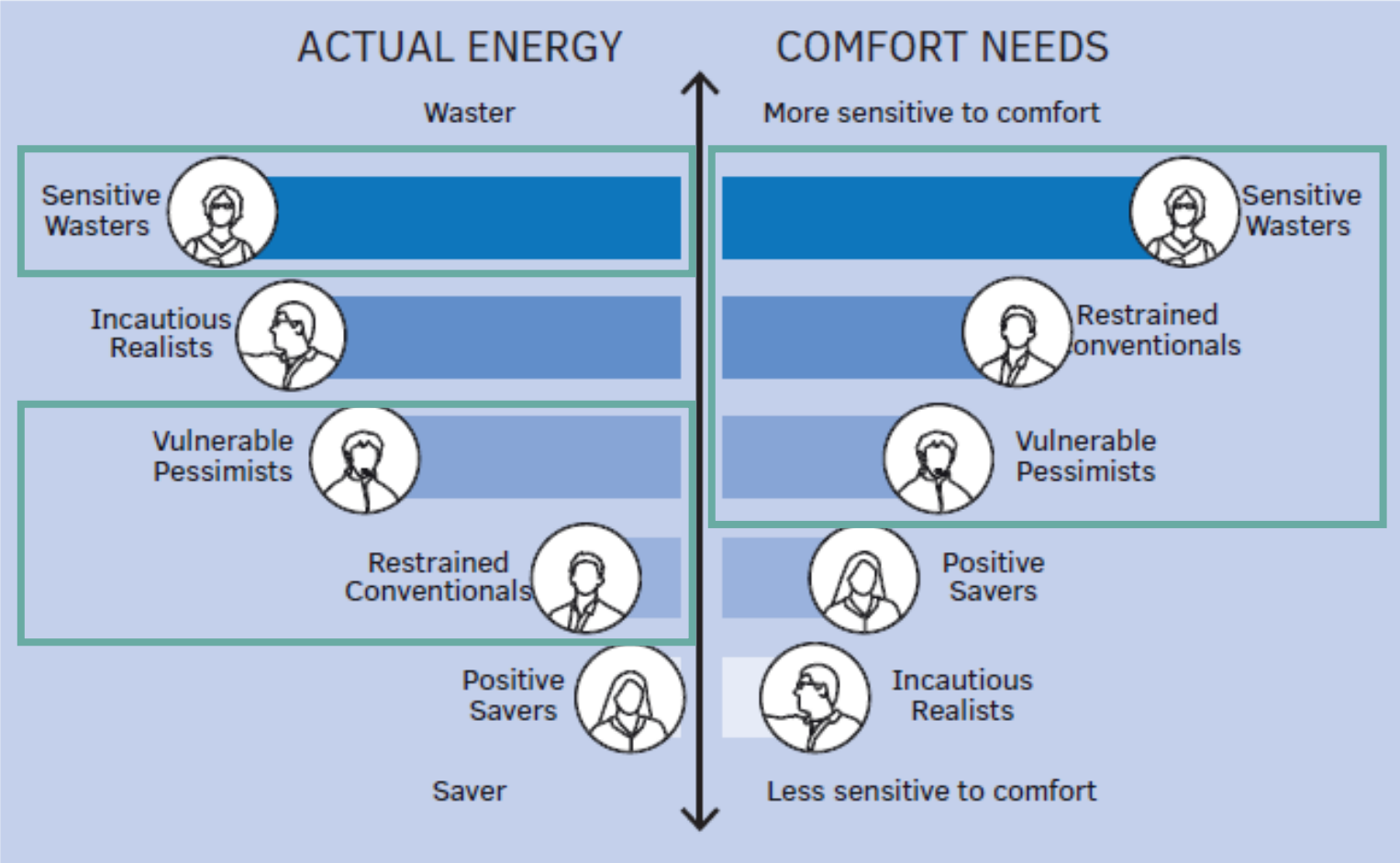
Energy production

Energy re-use

User preferences

Archetypes

Archetypes



Ranking of Archetypes for energy use and comfort affordance needs.
Image by Dr. M.A. Ortiz (2019)

Archetypes

Energy efficient

Self-Adaptive

Full Control

Archetypes

Energy efficient (EF)

Archetype energy efficient	Design principles
Outside view	Large window area for a view: maximum WWR according to Dr. M. Kwon's study or high performance functioning fully glazed façade (Kwon, Remøy, & van den Bogaard, 2019)
Contact with nature	Implementation of biomimicry/biophilic in design
Energy efficient	As much energy production as possible within the facades' components
High external control/low internal control	Façade components should go well together and complement each other so that the façade can function optimally according to the local climate conditions.

Archetypes

Self-Adaptive (SA)

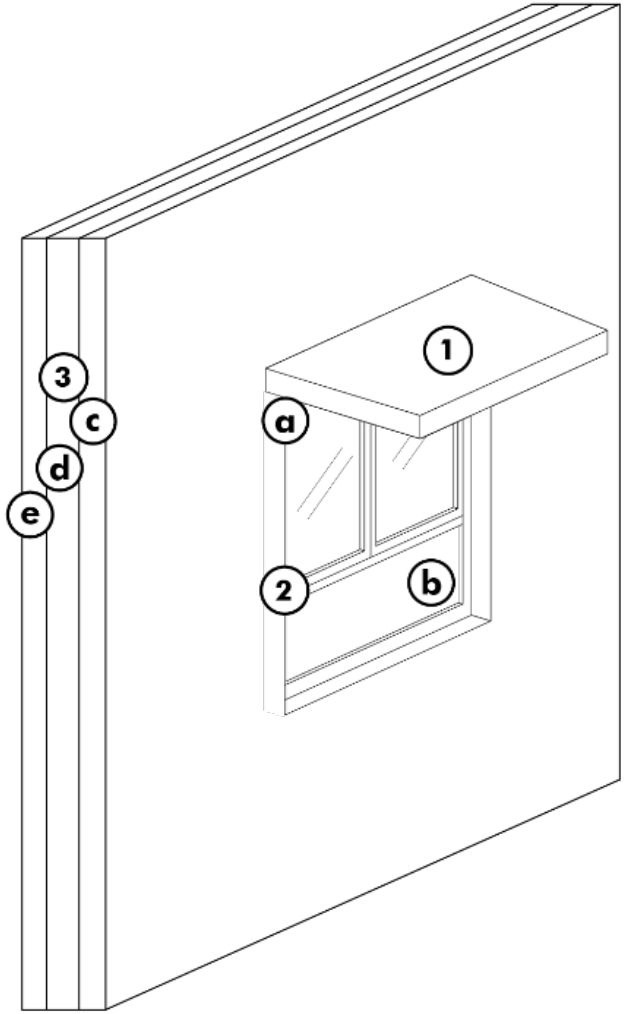
Archetype self–adaptive	Design principles
Technologies is main experience	Using or activating technologies for the enhancement of the user experience
Space matching lifestyle	Possibility to adapt the environment to the users' preferences
High external control/low internal control	Façade components should go well together and complement each other so that the façade can function optimally according to the local climate conditions

Archetypes

Full Control (FC)

Archetype full control	Design principles
Comfort above energy use	User needs to feel comfortable at all times, completely disregarding the energy this can cost. Smart features should be designed in order to help them save energy and make them aware of the ecological consequences
Own privacy and high freedom	The use of components which enhance the users' privacy and allows them to have freedom in their space
High internal control/low external control	Users have the possibility to control the components in order to adapt them according to their current comfort needs

Façade components

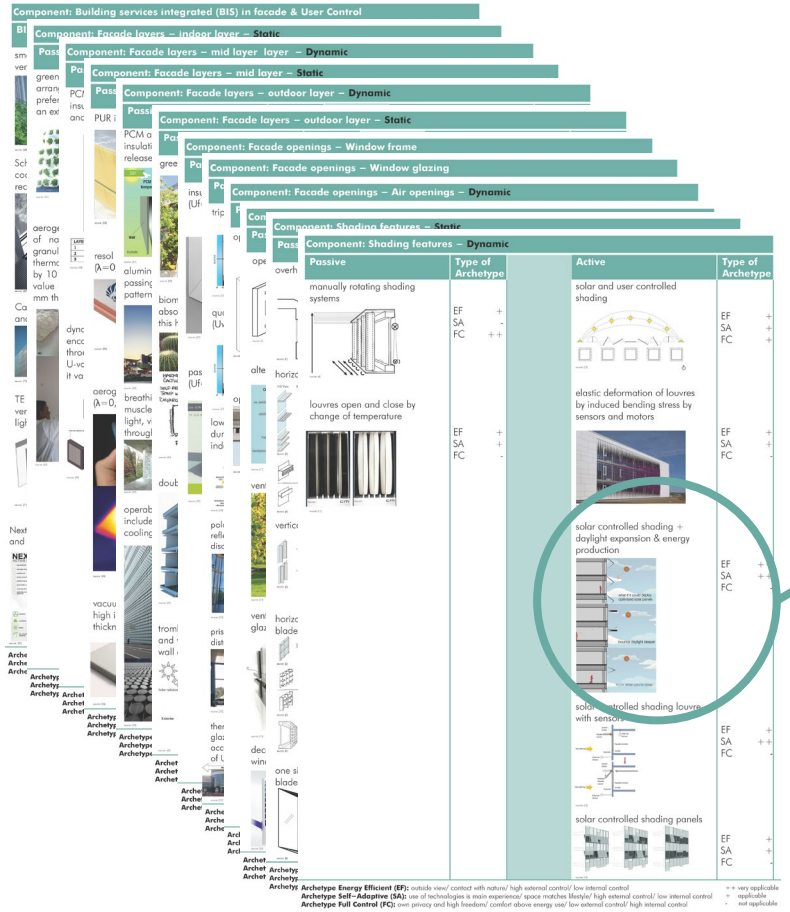


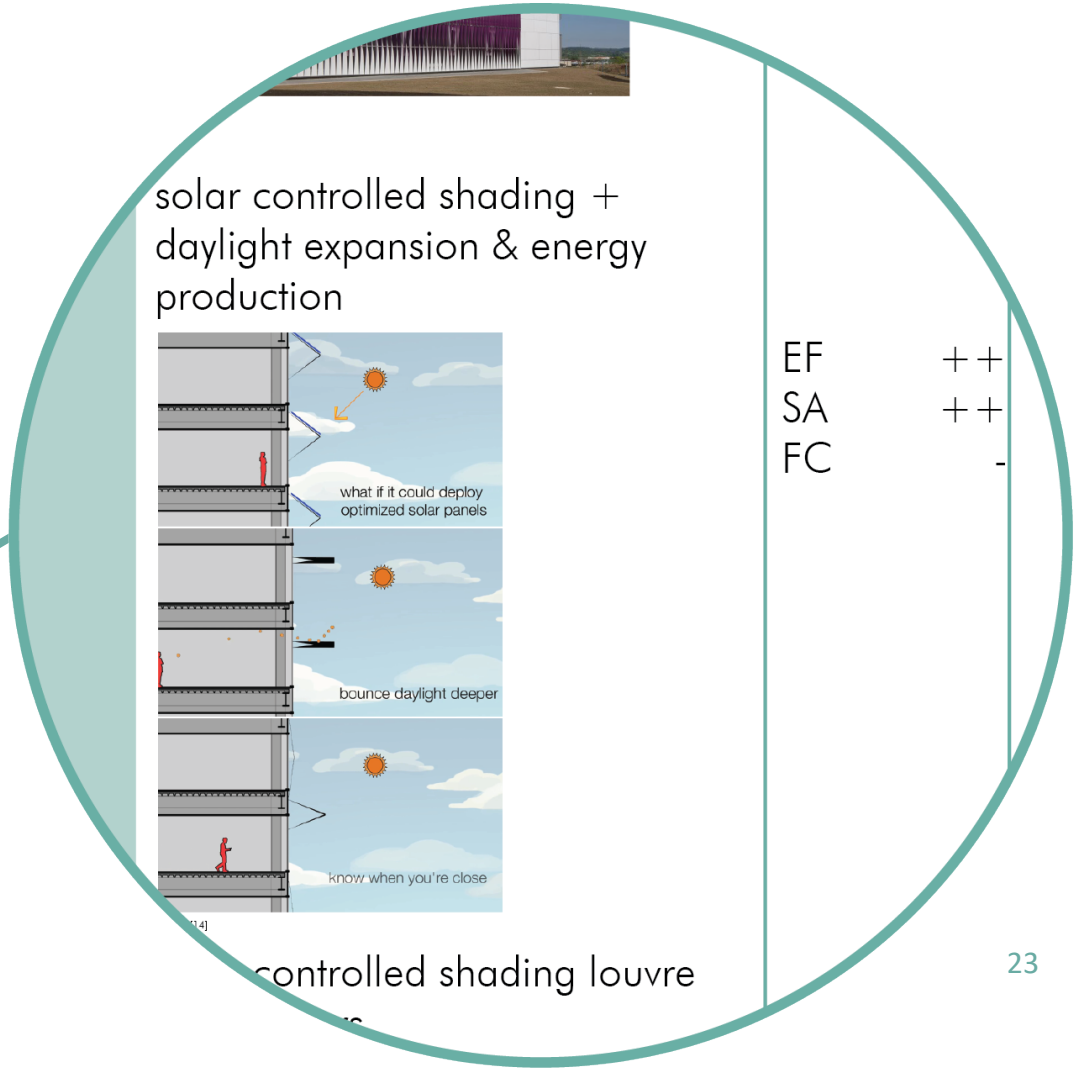
Facade components

1. Shading features
2. Facade openings:
   - a. Air openings:
     - i. ventilation;
     - ii. infilatration.
   - b. Window:
     - iii. window glazing
     - iv. window frame
3. Facade layers:
   - c. outdoor layer;
   - d. mid layer;
   - e. indoor layer.

Generic façade design guideline

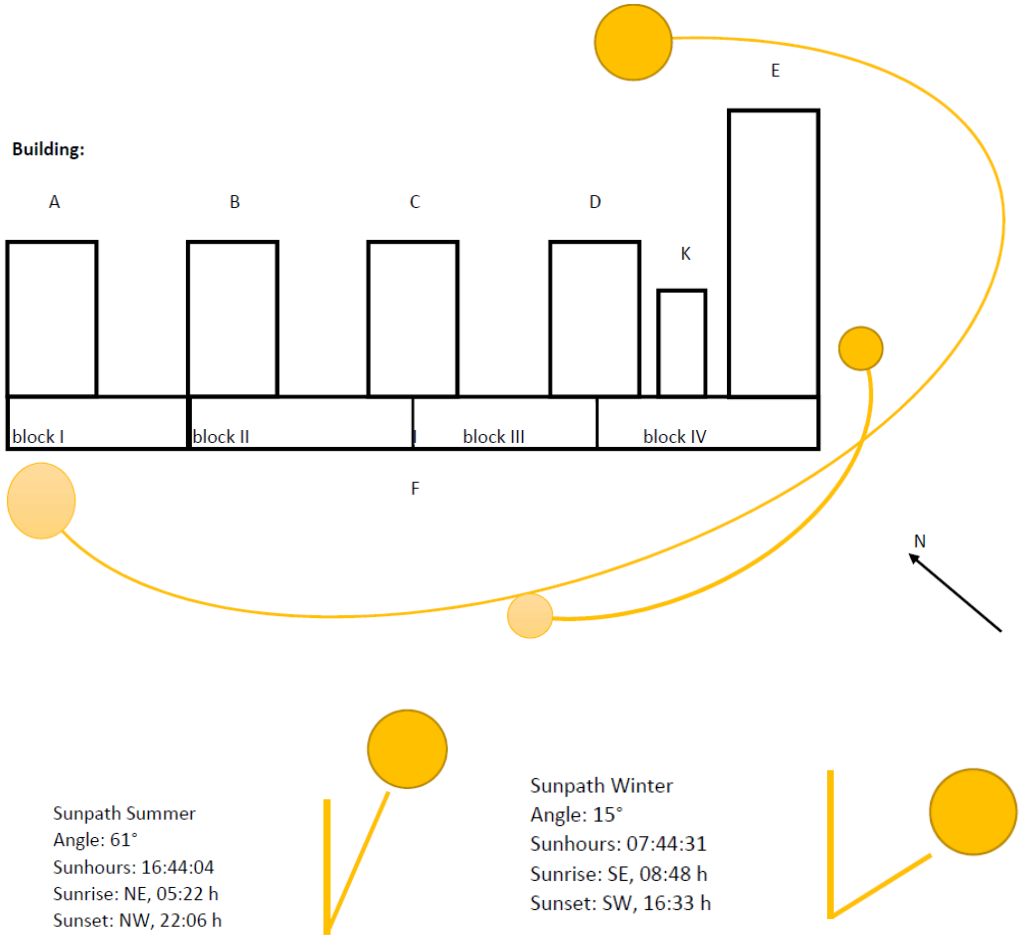
++ very applicable / + applicable / - not applicable





Case study review – Applied Physics building

Case study review – sun study

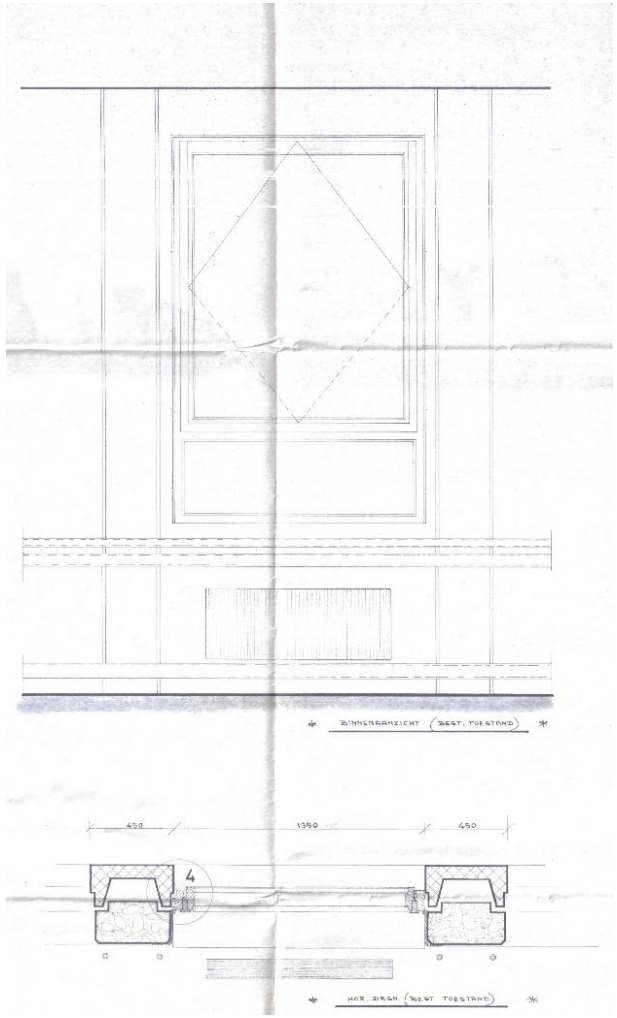


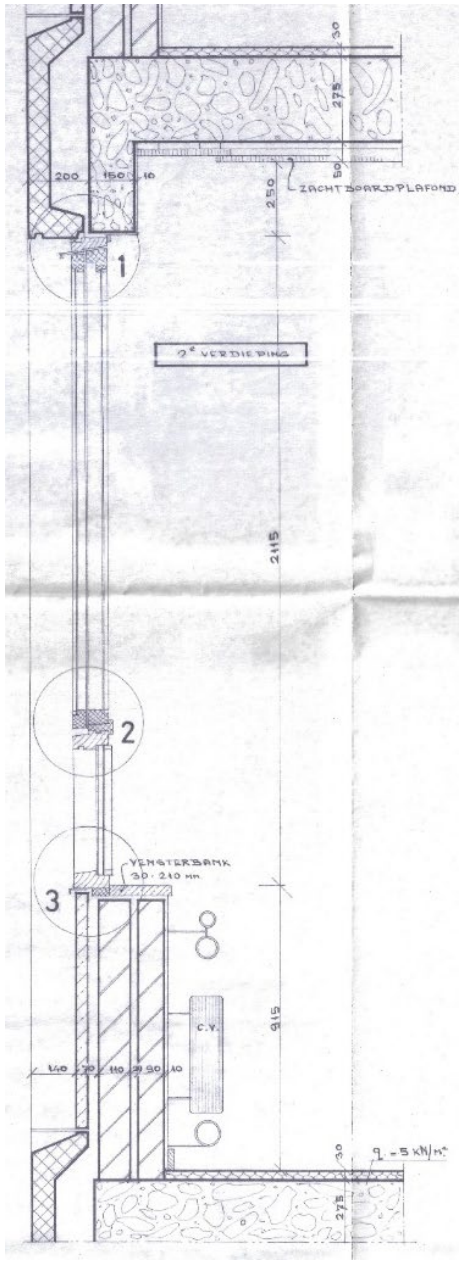
Sun study Applied Physics Building	
Orientation	West-southwest
Summer sun angle	61° – 7,5°
Sun hours exposure	8 hours (13:45-21:45)
Winter sun angle	14,6° – 0,50°
Sun hours exposure	4 hours (12:45-16:45)

Case study review – façade analysis

Technical aspects Applied Physics building	Dimension/type
Length	5,94 meter
Width	3,60 meter
Height	3,67 meter
Window	1 external window
Door	1 internal door

- Rc-value: 0,65 $m^2 \cdot K/W$



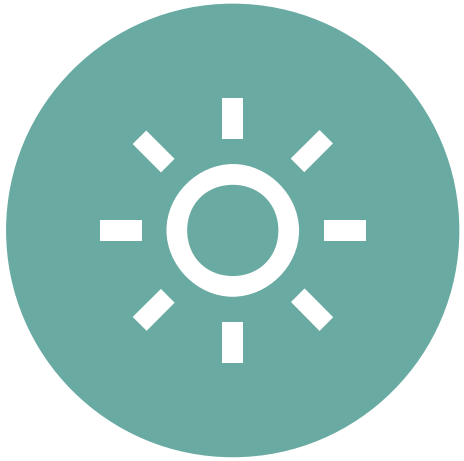


Case study review – user experience interview

Extremely dissatisfied

Too cold

Extremely dissatisfied



Too Hot

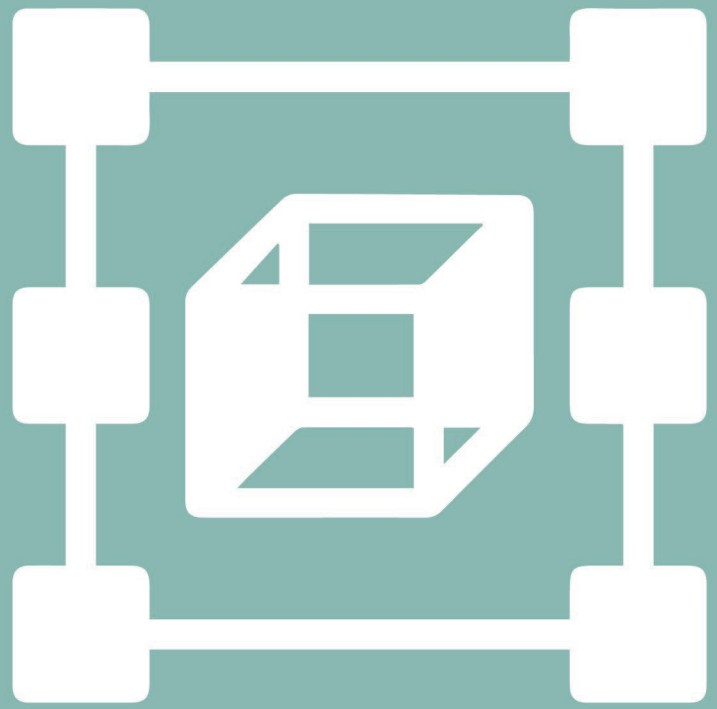
Somewhat dissatisfied

Neutral comfort

No control

Symptoms

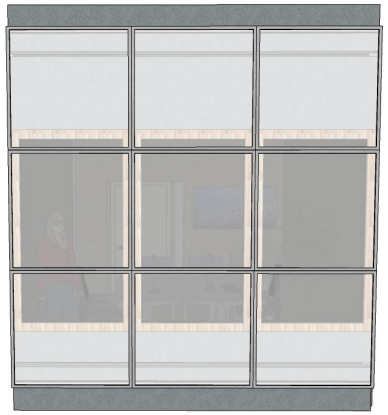
Sick Building Syndrome



Design exploration

Design configurations per Archetype

EF



PV-Trombe Wall

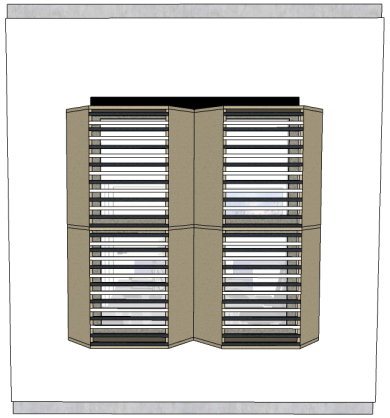
SolarWall PV/T

SA

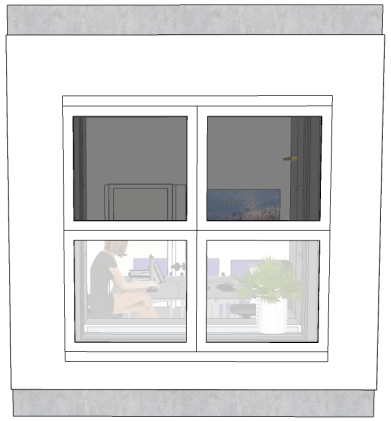
PCM Trombe Wall

PCM Living wall

FC



Interactive Wall++



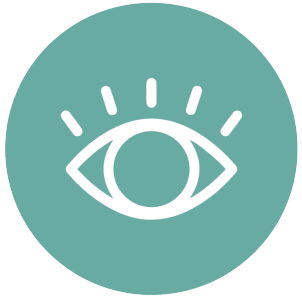
Controllable wall

Design performance evaluation

User satisfaction values:

20-24 C Winter (21 C)
23-26 C Summer (24 C)

7 l/s /pers or
25 m3/h/pers



2,5% or min. 0,5 m2
500 lux

Nearly energy neutral values:

BENG 1 ≤115
(Annual energy demand for heating & cooling)

BENG 2 ≤40
(Primary energy consumption heating, cooling, fans, lighting + office equipment)

BENG 3 ≥30
(Annual share of renewable energy)

Design performance evaluation – current situation

Simulated indoor environment and energy performance façade current situation:

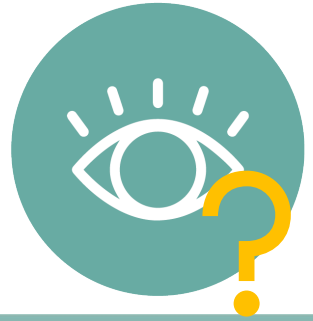
BENG 1
126>115

BENG 2
193>40

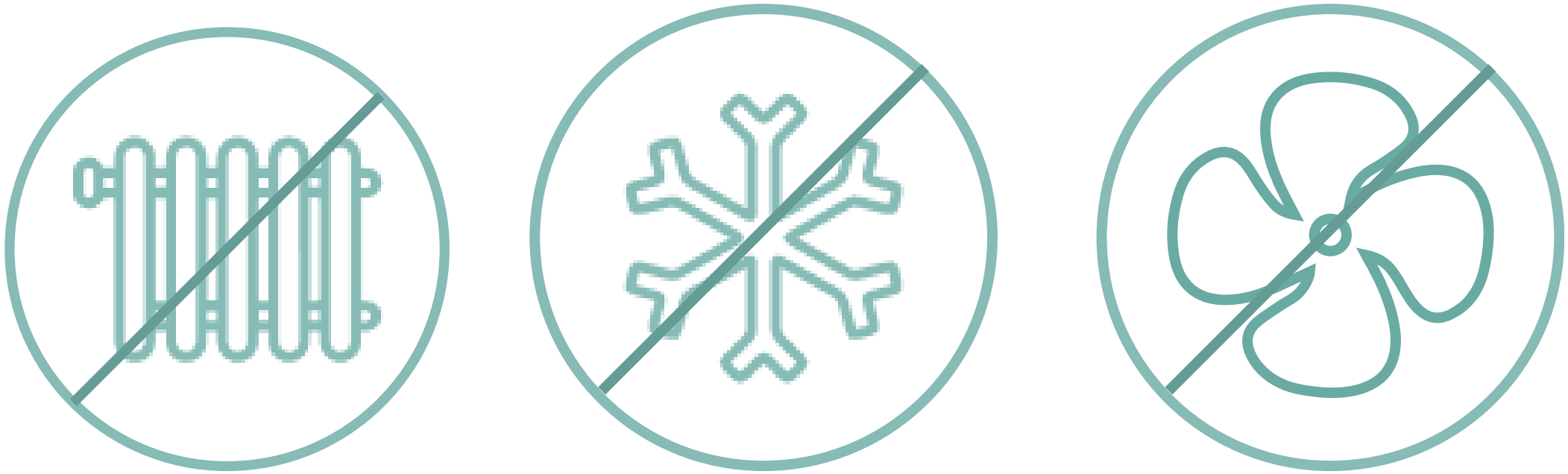
BENG 3
0<+30

19,7 C Winter < 21 C
25 C Summer > 24 C

2,5% or min. 0,5 m2
500 lux

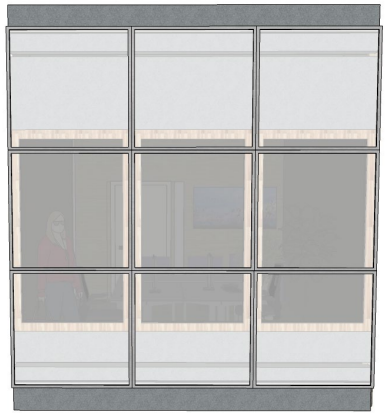


Design performance evaluation - simulations



Design configurations- evaluation

EF



PV-Trombe Wall

SolarWall PV/T

SA

PCM Trombe Wall

PCM Living wall

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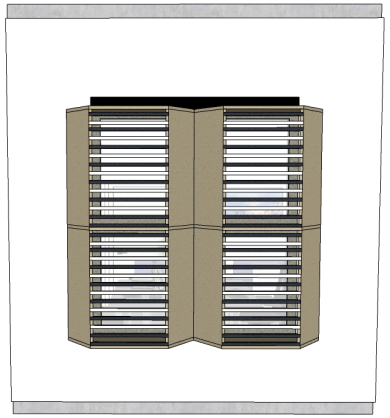
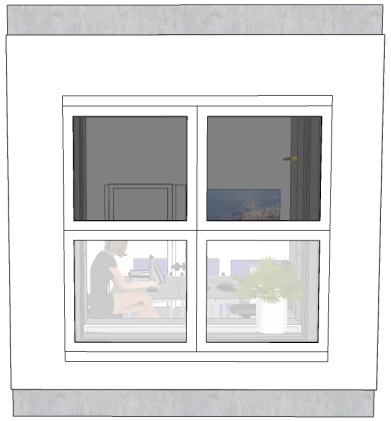


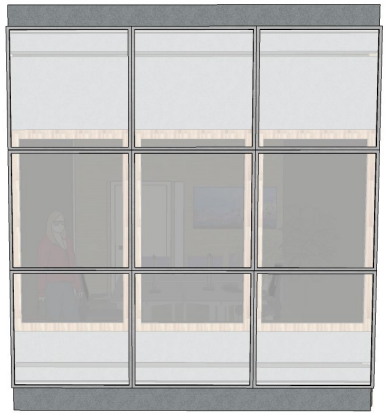
Interactive Wall++



Controllable wall

Design configurations- evaluation

EF



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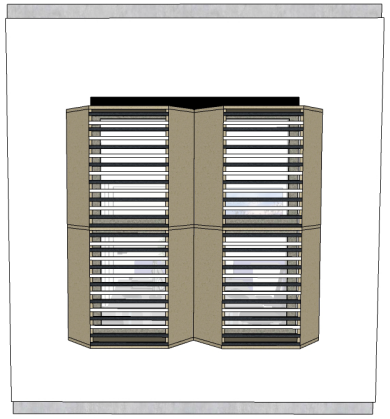


Interactive Wall++

Controllable wall

Final design

Energy Efficient Archetype

- Neutral comfort

- Outside view
- Contact with nature

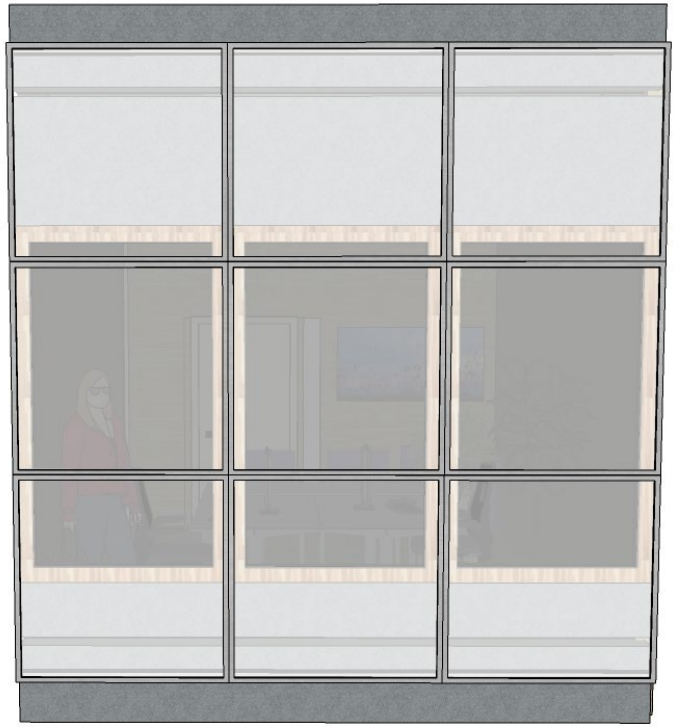
- High external control
- Low internal control

- Highly energy efficient

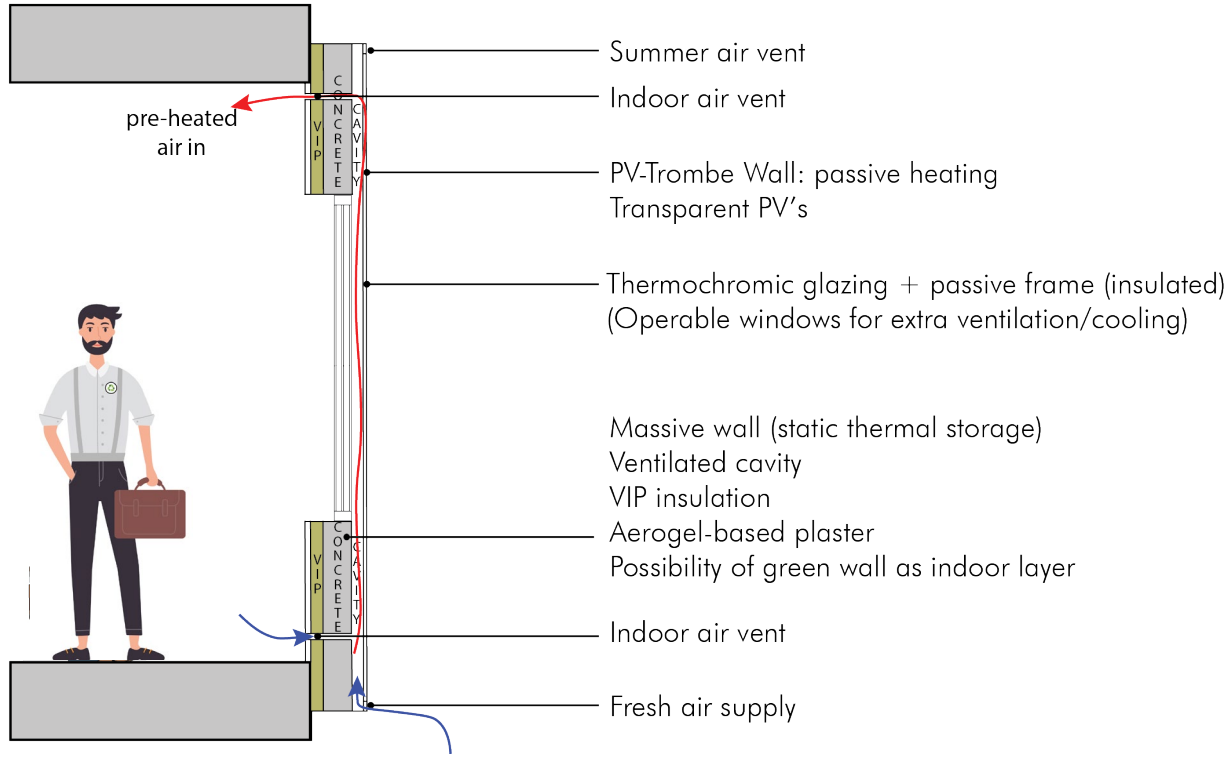
Energy efficient archetype - PV-Trombe Wall

WWR 50%

Static



Front facade



Section

- Neutral comfort

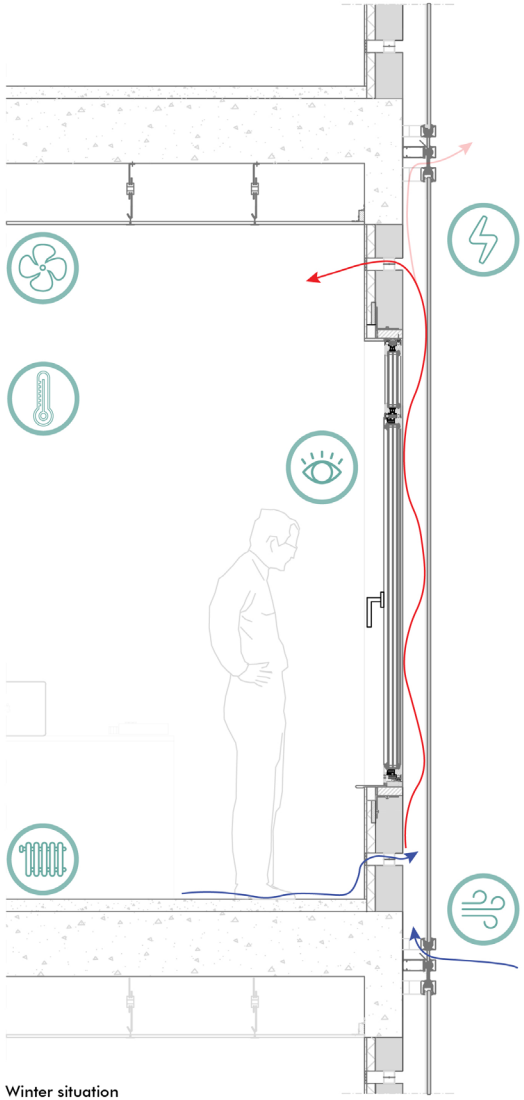
- Outside view
- Contact with nature

- High external control
- Low internal control

- Highly energy efficient

Seasonal performance

Winter:



Winter situation

Transparent PV-Trombe wall
Winter situation (Oct-April)

Fresh air supply through facade.
Supply: 80 m3/h (max. 3 people).

Air heating through facade.
Additional low temperature heating if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.
Summer air vent opens in case of overheating.

Mechanical ventilation exhaust if necessary.

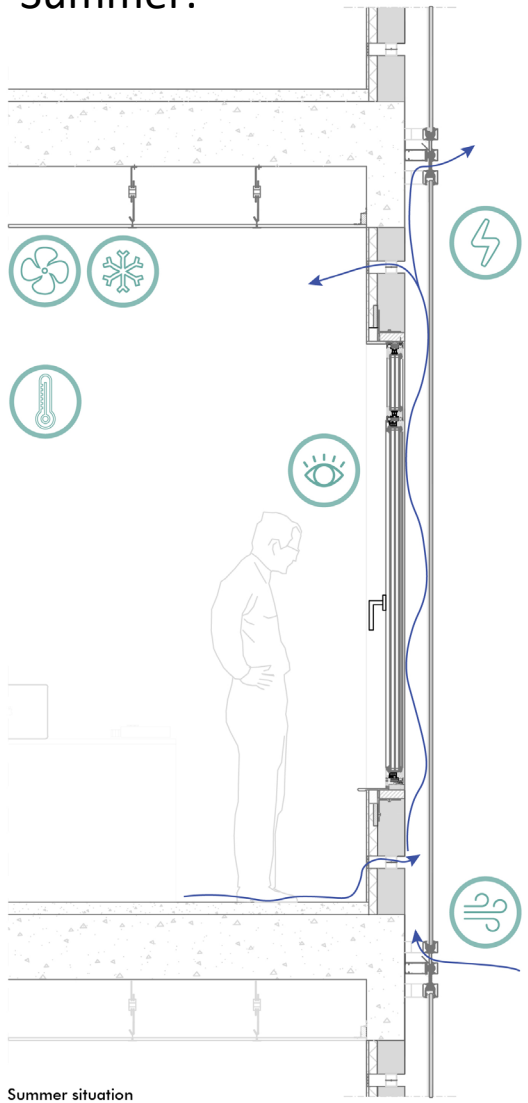
Average winter temperature 21,9°C (Oct-April).

50% window-to-wall-ratio.
10,1% daylight factor.
Thermochromic glazing in order to avoid glare.
500 lux LED lighting with occupancy sensors.

Onyx Solar transparent PV-panels.
Winter electricity production: 316 kWh (Oct-April).

PV-Trombe wall:
Rc-value: 8,15 m2·K/W opaque areas.
Thermochromic glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Summer:



Summer situation

Transparent PV-Trombe wall
Summer situation (May-Sept)

Fresh air supply through facade.
Supply: 80 m3/h (max. 3 people).

Air cooling through facade.
Operable windows for extra cooling/ventilation.
Additional low temperature cooling if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.
Summer air vent opens for continuous flow or air.

Mechanical ventilation exhaust if necessary.

Average summer temperature 24,0°C (May-Sept).

50% window-to-wall-ratio.
10,1% daylight factor.
Thermochromic glazing in order to avoid glare.
500 lux LED lighting with occupancy sensors.

Onyx Solar transparent PV-panels.
Summer electricity production: 497 kWh (May-Sept).

PV-Trombe wall:
Rc-value: 8,15 m2·K/W opaque areas.
Thermochromic glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Self-Adaptive Archetype

- Positive about comfort

- Use of technologies is main experience
- Technologies improves standard of living
- Space matches lifestyle

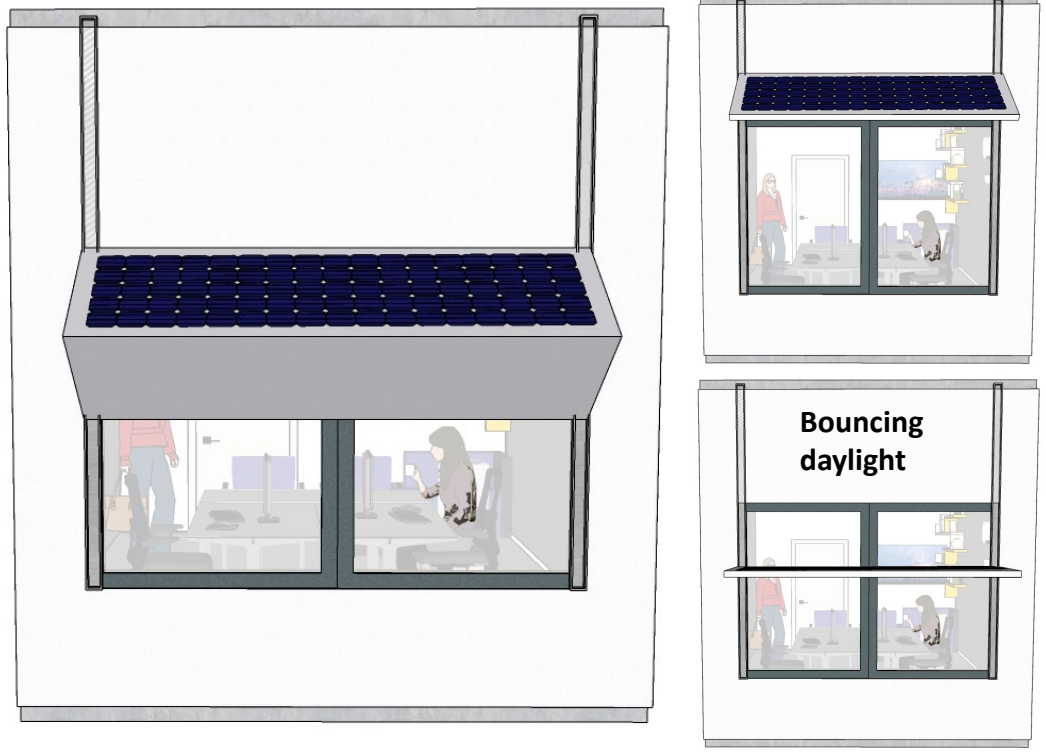
- High external control
- Low internal control

- Conflicted about energy use

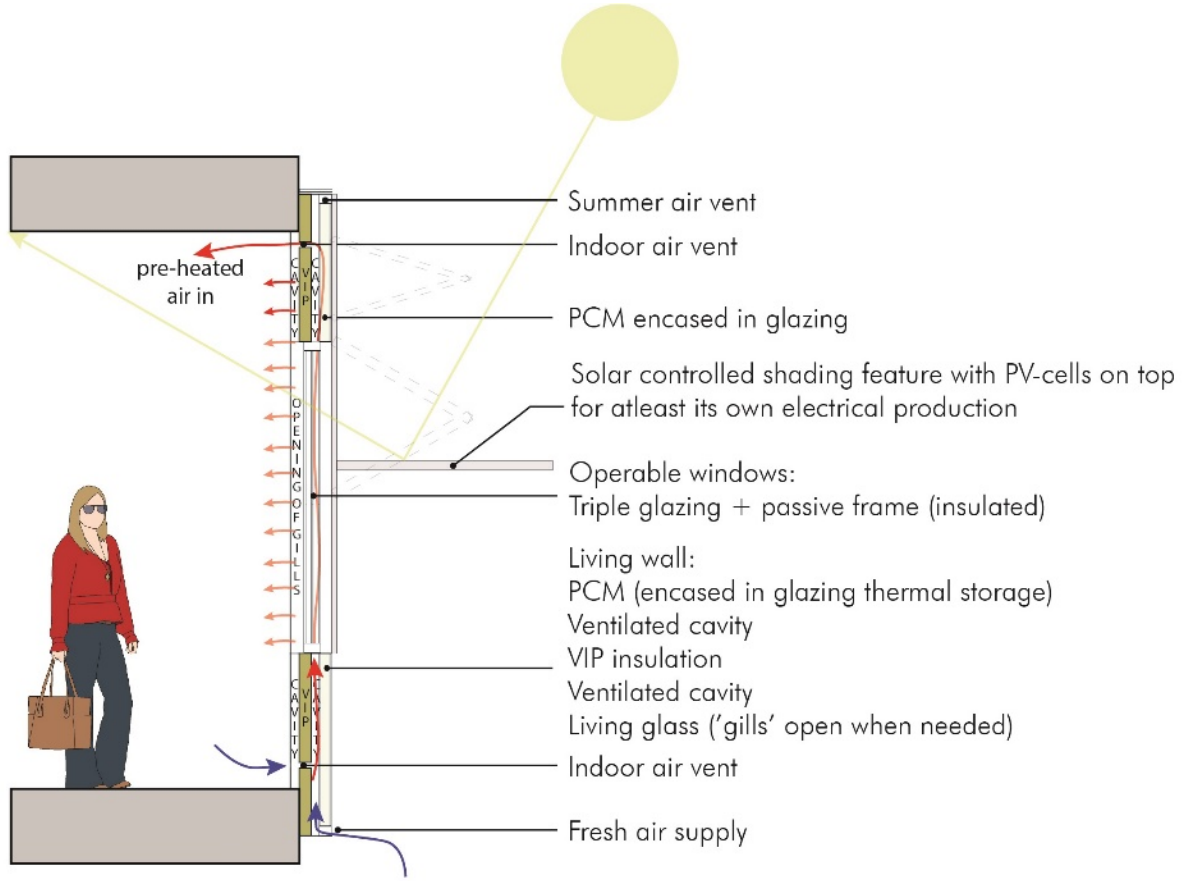
Self-Adaptive Archetype – Living wall

WWR 43%

Dynamic



Front facade



Section

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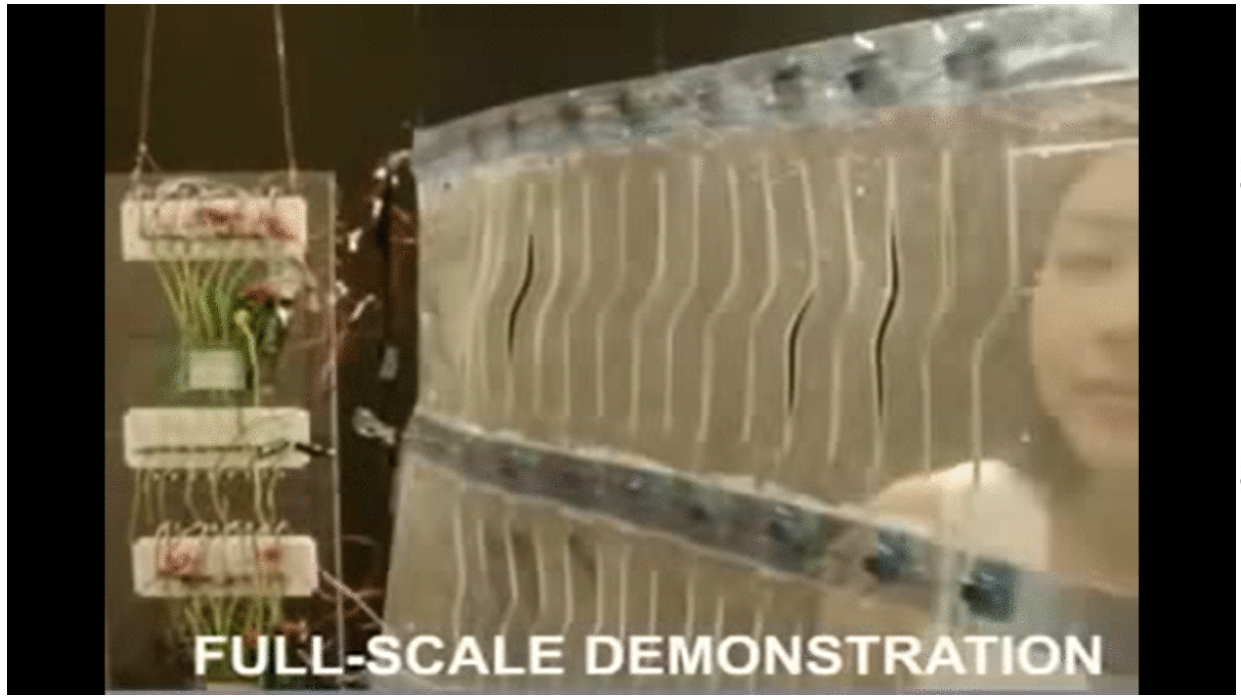
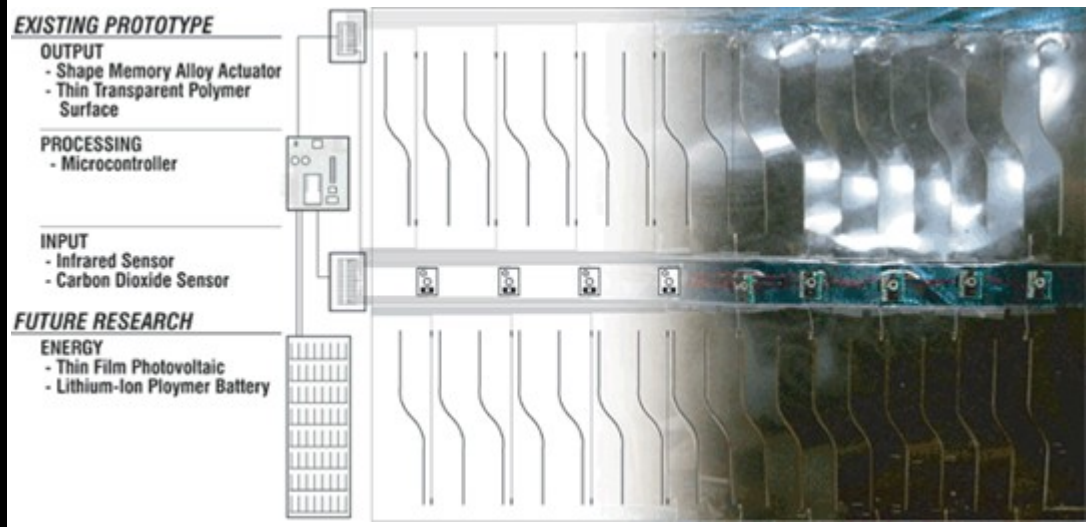
Self-Adaptive Archetype – Design configuration

Living wall – WWR 43%

Dynamic





Demonstration

- Positive about comfort

- Use of technologies is main experience
- Technologies improves standard of living
- Space matches lifestyle

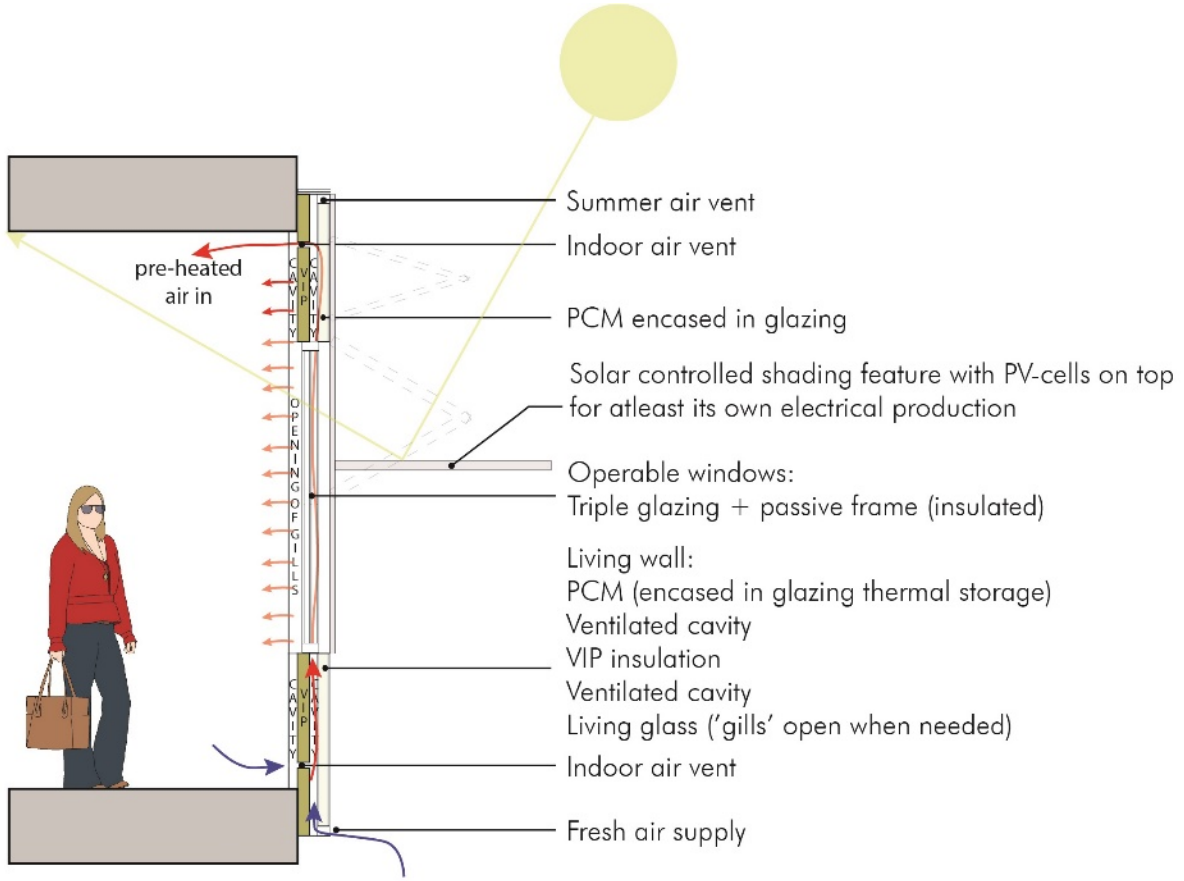
Components

- High external control
- Low internal control

- Conflicted about energy use

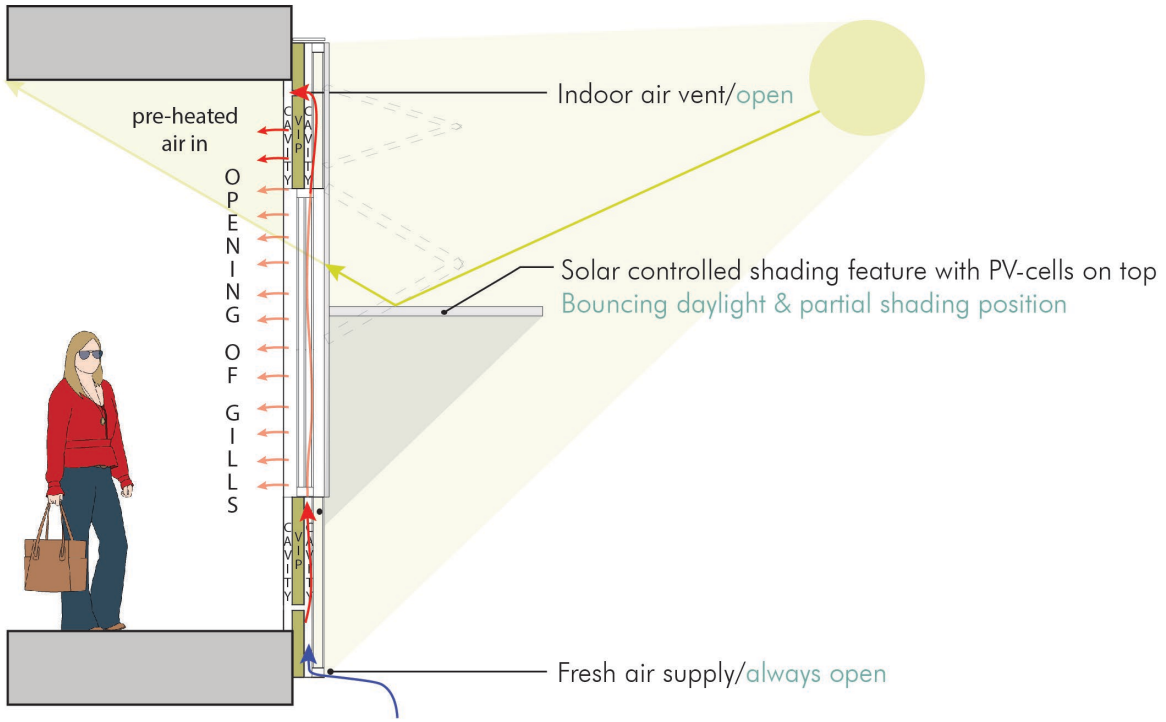
Self-Adaptive Archetype – Design configuration

Living wall – WWR 43%



Section

Winter performance



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Self-Adaptive Archetype – Design configuration

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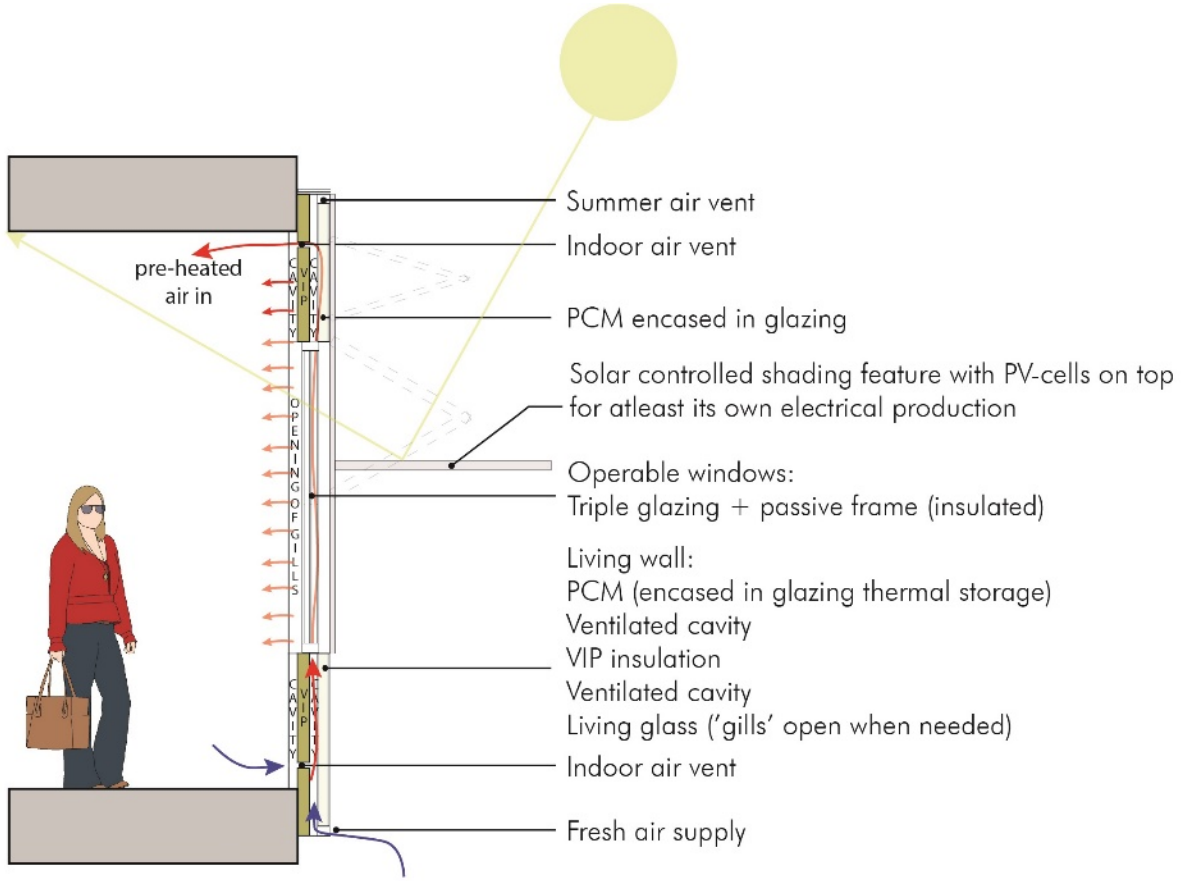
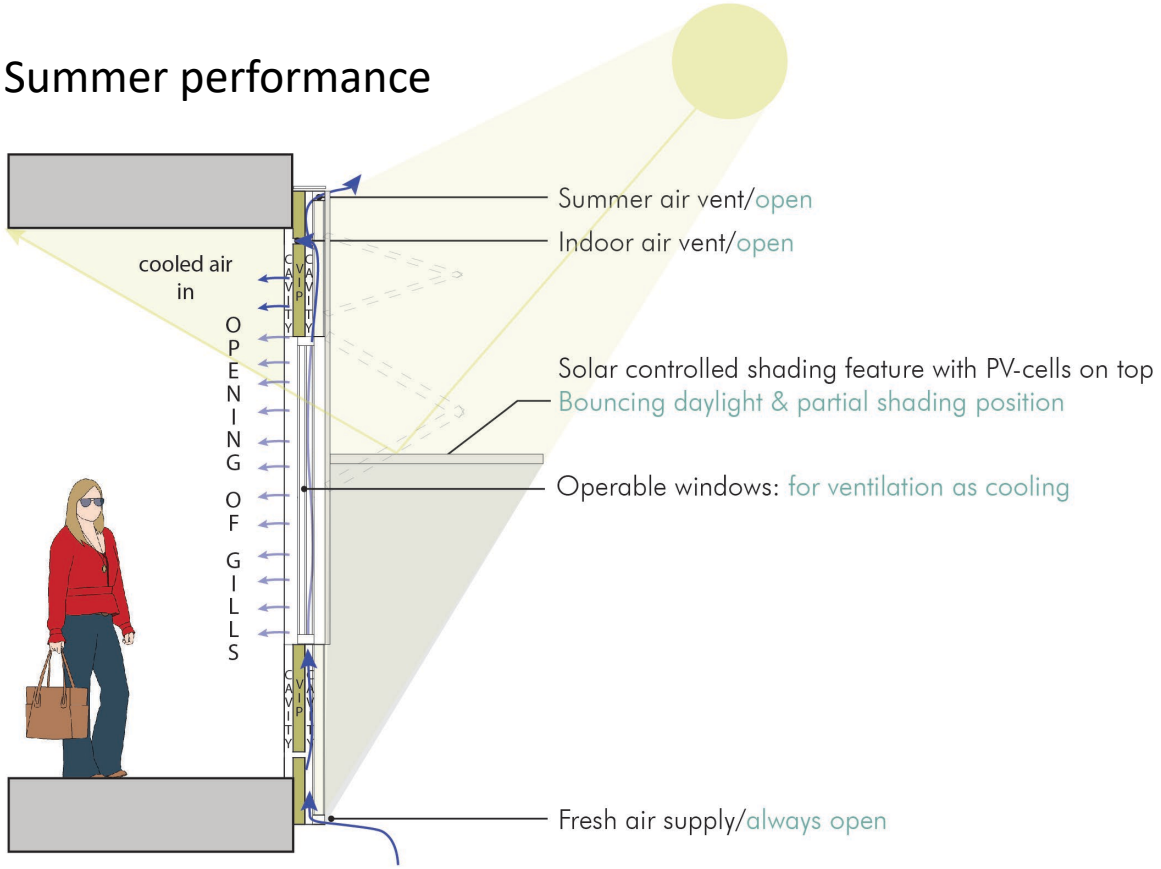


Section

Summer performance



- Positive about comfort

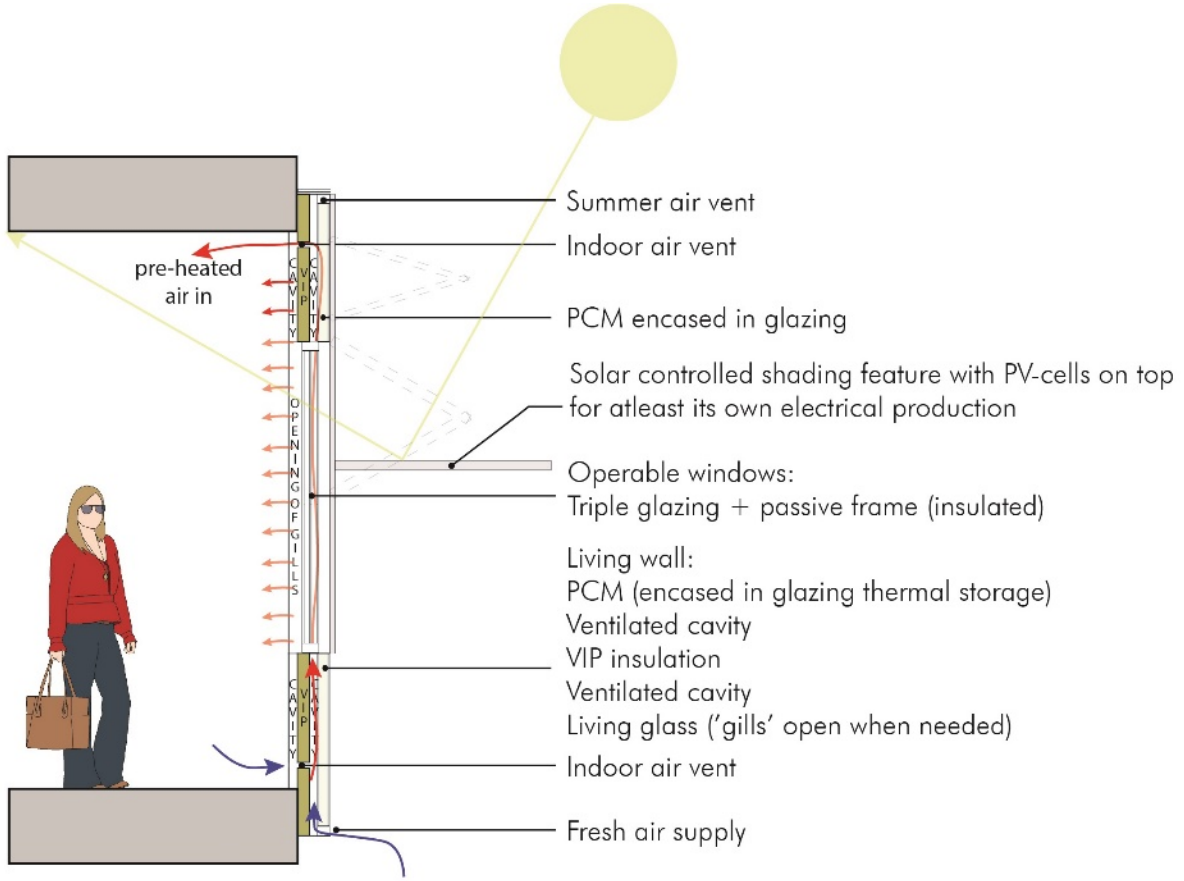
- Use of technologies is main experience
- Technologies improves standard of living
- Space matches lifestyle

- High external control
- Low internal control

- Conflicted about energy use

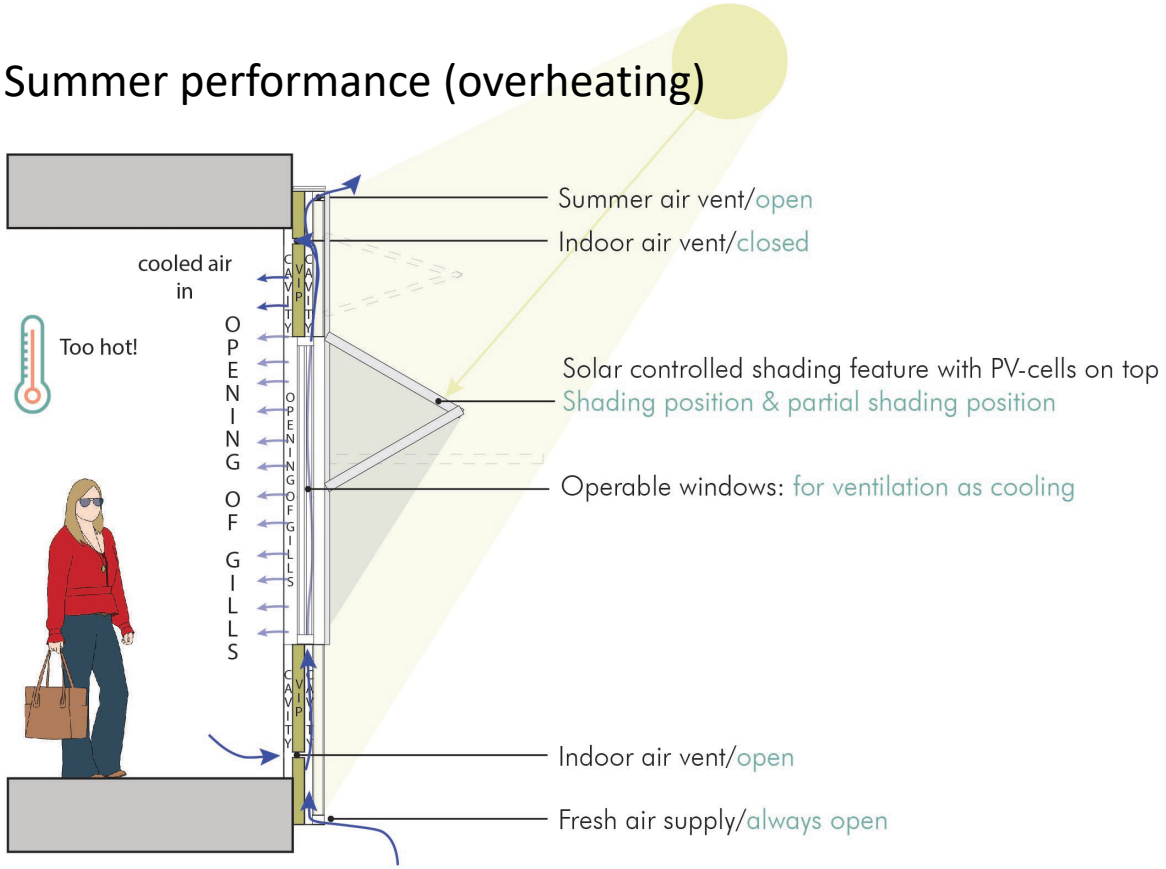
Self-Adaptive Archetype – Design configuration

Living wall – WWR 43%



Section

Summer performance (overheating)



- Positive about comfort

- Use of technologies is main experience
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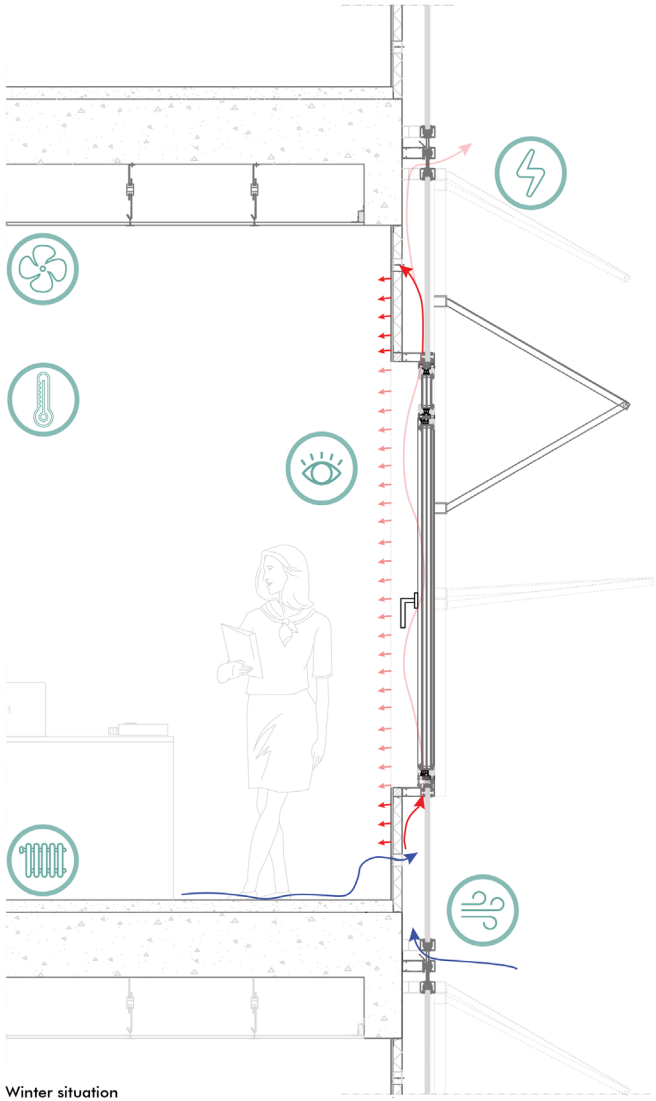
- High external control
- Low internal control

- Conflicted about energy use

Seasonal performance

Winter:



Winter situation

PCM living wall
Winter situation (Oct-April)

Fresh air supply through facade.
Supply: 80 m3/h (max. 3 people).

Air heating through facade by self-adaptive PCM thermal storage, supplied by opening of gills.
Additional low temperature heating if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.
Summer air vent opens in case of overheating.

Mechanical ventilation exhaust if necessary.

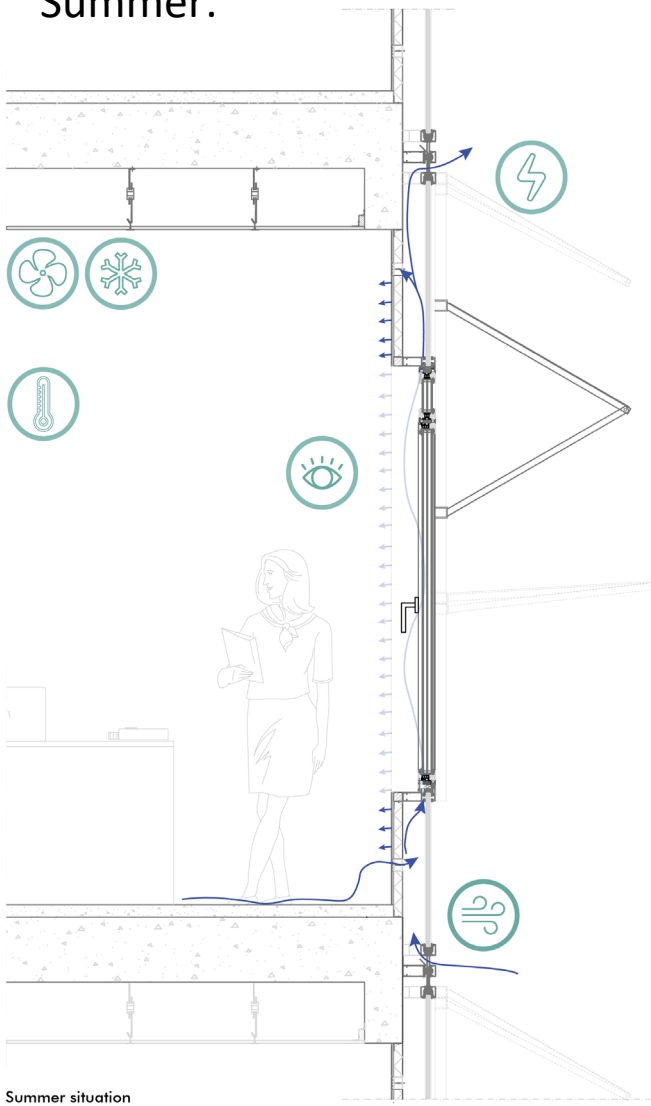
Average winter temperature 21,0°C (Oct-April).

43% window-to-wall-ratio.
9,3% daylight factor.
Bouncing of daylight by solar controlled shading feature.
500 lux LED lighting with occupancy sensors.

Solar controlled PV-panels on top of shading feature.
Winter electricity production: >110 kWh (Oct-April).

PCM living wall:
Rc-value: 7,85 m2·K/W opaque areas.
Triple glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Summer:



Summer situation

PCM living wall
Summer situation (May-Sept)

Fresh air supply through facade.
Supply: 80 m3/h (max. 3 people).

Air cooling through facade by self-adaptive PCM thermal storage, supplied by opening of gills.
Operable windows for extra cooling/ventilation.
Additional low temperature cooling if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.
Summer air vent opens for continuous flow or air.

Mechanical ventilation exhaust if necessary.

Average summer temperature 23,5°C (May-Sept).

43% window-to-wall-ratio.
9,3% daylight factor.
Bouncing of daylight by solar controlled shading feature.
500 lux LED lighting with occupancy sensors.

Solar controlled PV-panels on top of shading feature.
Summer electricity production: >199 kWh (May-Sept).

PCM living wall:
Rc-value: 7,85 m2·K/W opaque areas.
Triple glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Full Control Archetype

- High comfort

- Own privacy
- High freedom

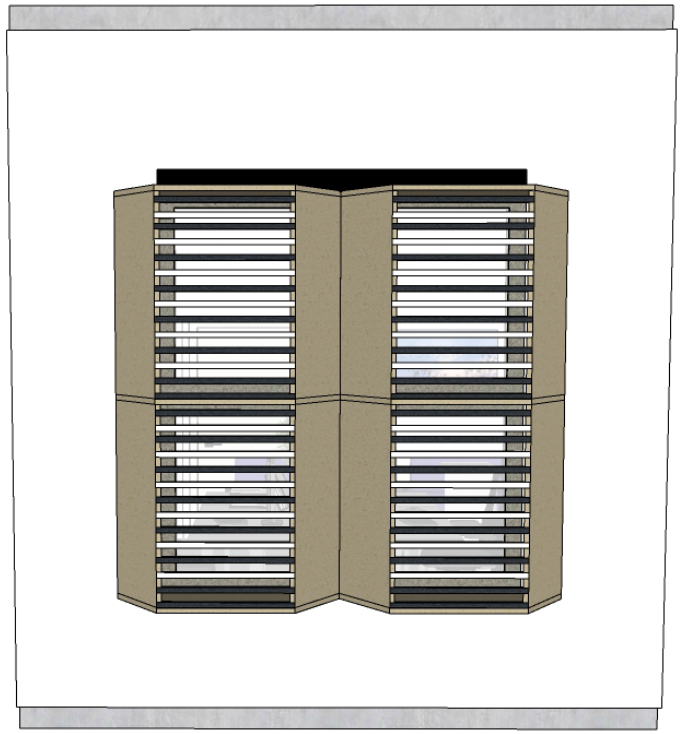
- Low external control
- High internal control

- Negative emotions about energy awareness

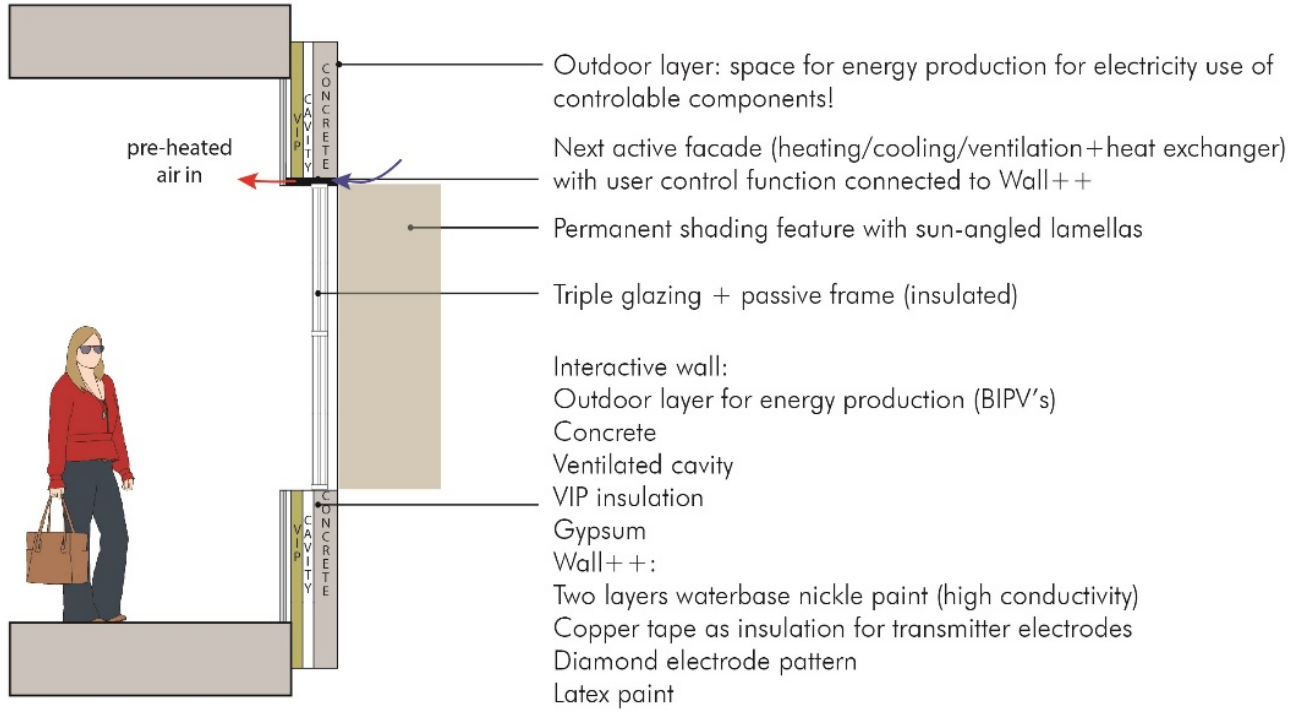
Full Control Archetype - Interactive Wall++

WWR 37%

Static



Front facade



Section

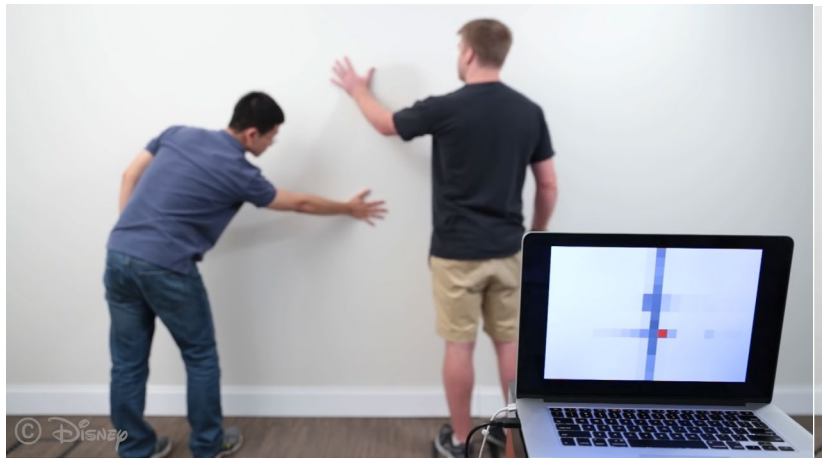
- High comfort
- Own privacy
- High freedom
- Low external control
- High internal control
- Negative emotions about energy awareness

Full Control Archetype – Interactive Wall++

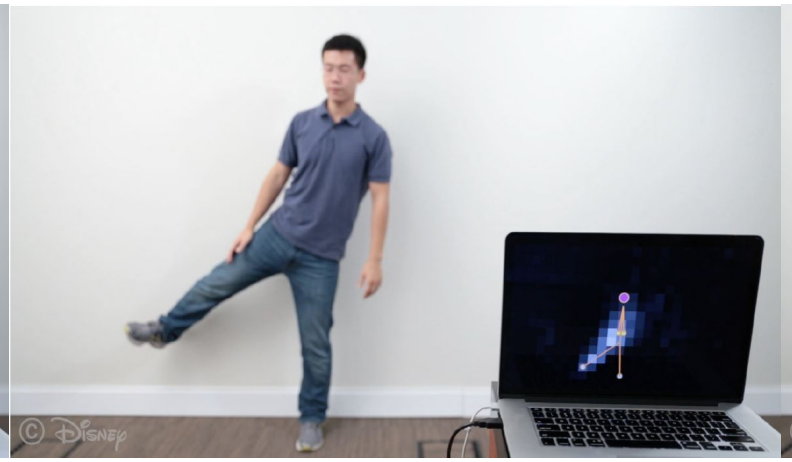
WWR 37%

Static

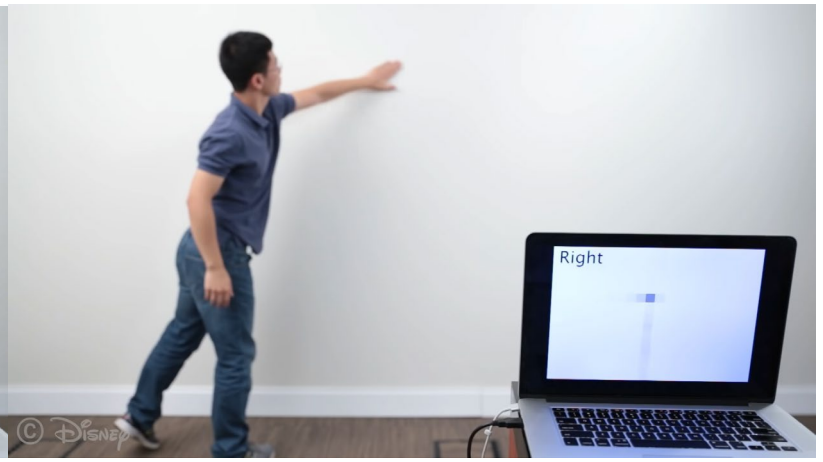
Demonstration



Touching



Human presence



Swiping

- High comfort

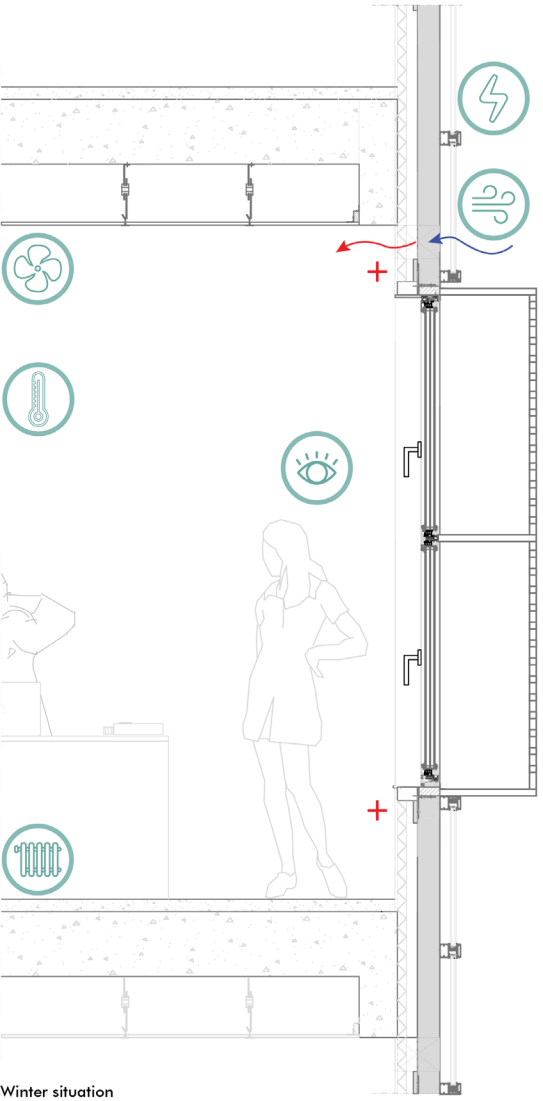
- Own privacy
- High freedom

- Low external control
- High internal control

- Negative emotions about energy awareness

Seasonal performance

Winter:



Winter situation

Interactive Wall++
Winter situation (Oct-April)

Fresh air supply by NEXT Active Facade Building Integrated System (BIS) and heat exchanger.
Supply: 80 m3/h (max. 3 people).

Air heating through NEXT Active Facade BIS with user control function connected to Wall++. Wall++ reacts to human presence, patterns, and signs.
Additional low temperature heating if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.

Air exhaust by NEXT Active Facade BIS.
Mechanical ventilation exhaust if necessary.

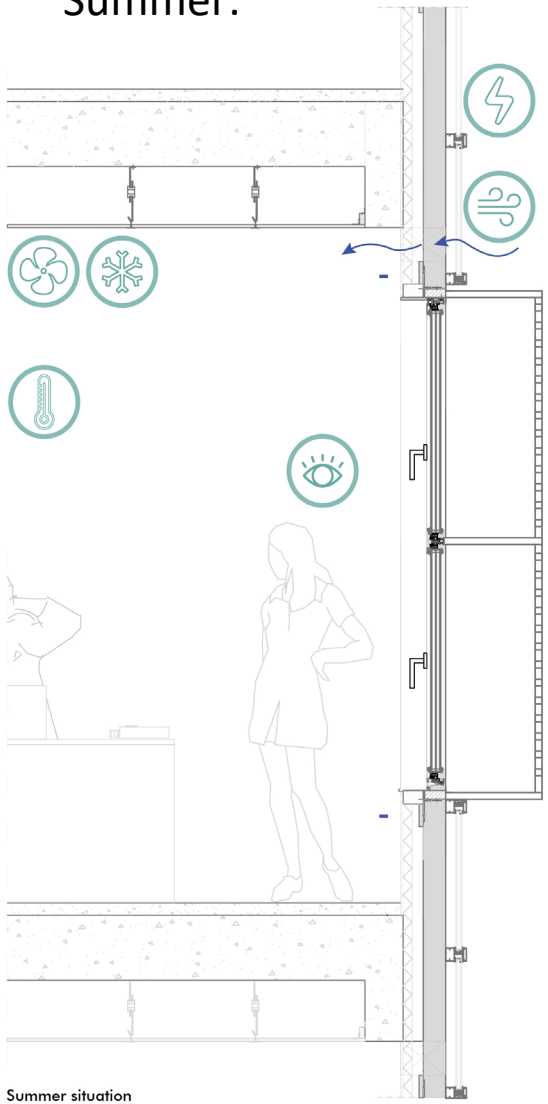
Average winter temperature 22,1°C (Oct-April).

37% window-to-wall-ratio.
2,8% daylight factor.
Sun-angled shading feature with sun-angled lamellas.
500 lux LED lighting with occupancy sensors.

Possibility to place Building Integrated PV-Panels (BIPV's) on outer facade without influencing the performance of the facade.
Possible winter electricity production: 235 kWh (Oct-April).

Interactive Wall++:
Rc-value: 7,15 m2·K/W opaque areas.
Triple glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Summer:



Summer situation

Interactive Wall++
Summer situation (May-Sept)

Fresh air supply by NEXT Active Facade Building Integrated System (BIS) and heat exchanger.
Supply: 80 m3/h (max. 3 people).

Air cooling through NEXT Active Facade BIS with user control function connected to Wall++. Wall++ reacts to human presence, patterns, and signs.
Operable windows for extra cooling/ventilation.
Additional low temperature cooling if necessary with heat pump (COP=5) with supply from aquifer thermal energy storage.

Air exhaust by NEXT Active Facade BIS.
Mechanical ventilation exhaust if necessary.

Average summer temperature 23,4°C (May-Sept).

37% window-to-wall-ratio.
2,8% daylight factor.
Sun-angled shading feature with sun-angled lamellas.
500 lux LED lighting with occupancy sensors.

Possibility to place Building Integrated PV-Panels (BIPV's) on outer facade without influencing the performance of the facade.
Possible summer electricity production: 371 kWh (May-Sept).

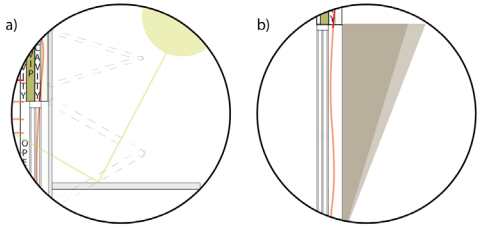
Interactive Wall++:
Rc-value: 7,15 m2·K/W opaque areas.
Triple glazing + passive frames:
U-value: 0,75 W/m2·K translucent areas.

Interpretations Guidelines

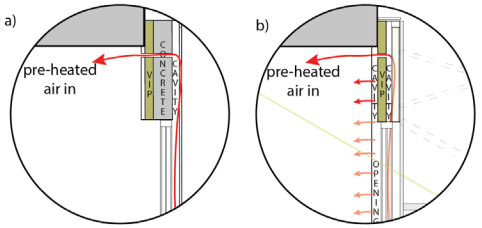
Optimal “all users” design guideline

Optimal "all users" facade design guideline

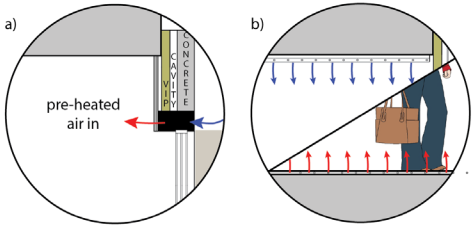
Shading feature:
Heat protection by solar controlled (a) or sun angled shading feature(s).



Ventilation through facade:
Supply of natural ventilation through facade to the indoor space by one opening (a) or by multiple openings (b).

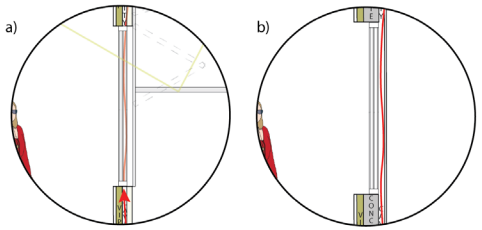


Additional ventilation + heating/cooling:
Supply of additional ventilation + heating/cooling, in case needed, by using the user controlled Next Active Facade system integrated in the facade (a) or by using low temperature heating/cooling systems (b) integrated in the floor and ceiling.



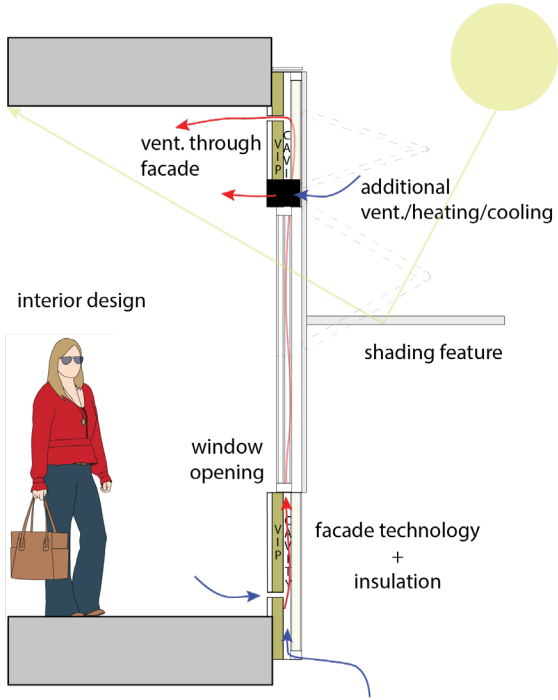
Interior design:
User freedom on adapting the indoor space to user's preference and taste, because of the different interior design preferences of every type of user (a/b/c).

WWR:
WWR percentage depending on orientation (a), taking into consideration most of the users preferences linked to WWR (b), such as outside view, privacy, and so on, and finding the right balance between the preferable amount of WWR per orientation and the user preferences linked to WWR.

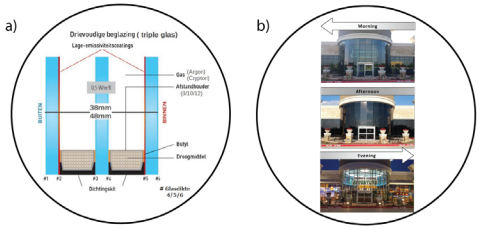


e.g.
West 37-43%

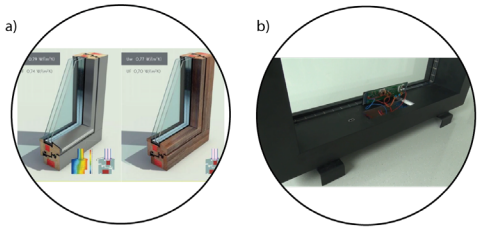
e.g.
West >43%
due to user preferences



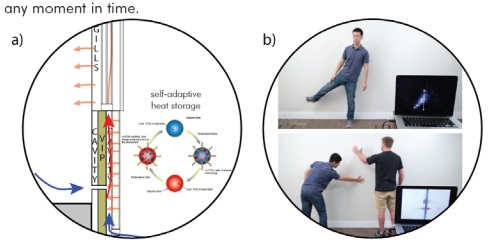
Window glazing:
For heat gain/heat loss through window openings, triple glazing (a) can be used when the window has a solar controlled or sun angled shading feature. If this is not the case, then a thermochromic triple glazing (b) window is the best option or the user controlled option of electrochromic glazing.



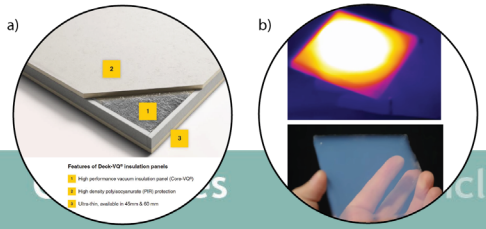
Window frame:
For window frame, passive (insulative) window frames (a) can be used or the option of electricity producing window frames (e.g. Physee SmartWindow) (b).



Facade technology:
For the optimal "all users" design, the Trombe wall method of the SA design with adaptive heat storage (a) can be used together with the user control technologies of the FC design (b). In this way the indoor environment would self-adapt according to the outdoor conditions and to the users' preferences at any moment in time.



Facade insulation:
For facade thermal insulation, the Vacuum Insulated Panel (VIP) is a high performing thermal insulation (a) (λ=0,006 W/m·K) with slim thickness giving the users more office area. Another very good thermal insulation is the Aerogel (silica) nano-insulation (b) (λ=0,013 W/m·K).



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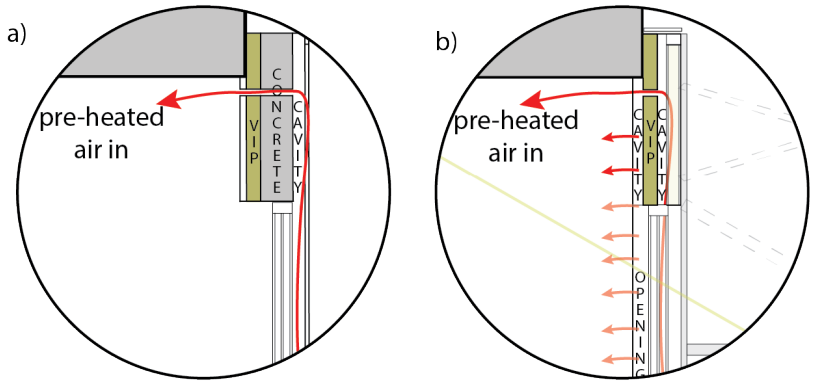

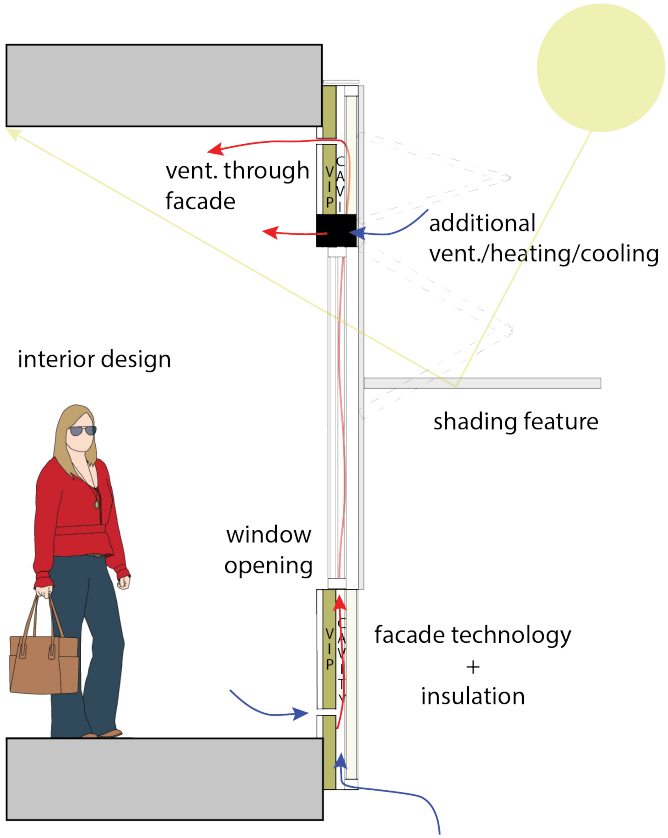

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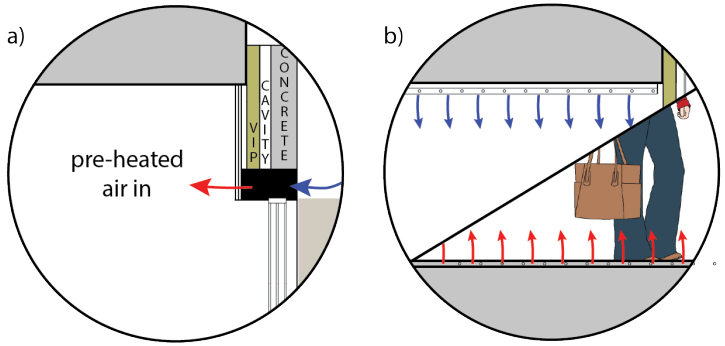

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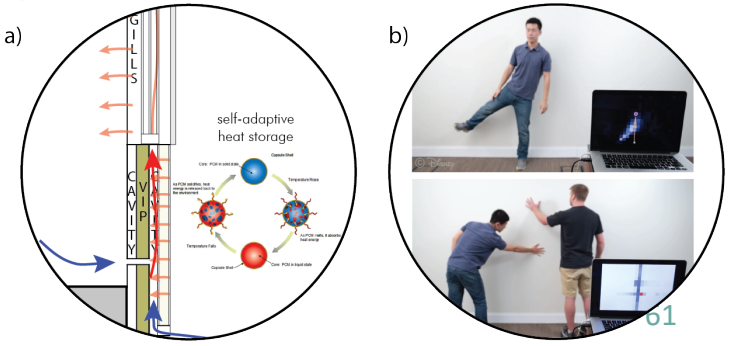


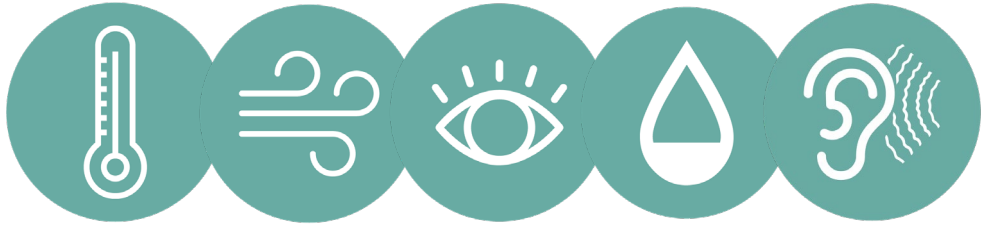
Conclusions

Conclusions

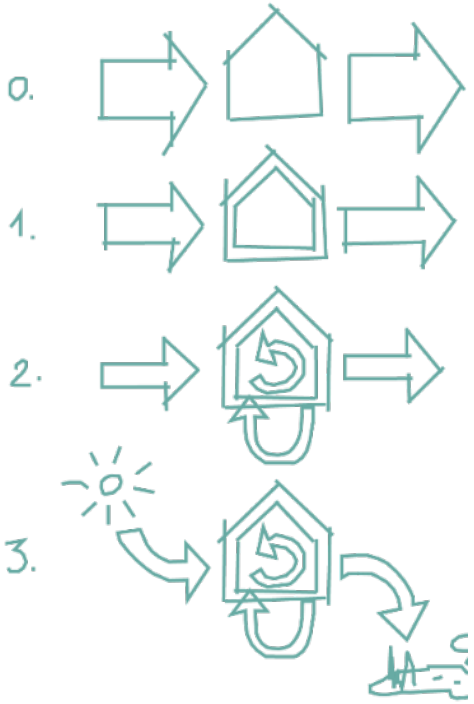
"How can an interactive/adaptive office building façade element be designed to optimally satisfy its users in order to increase work productivity and to support nearly energy neutrality of office buildings?"

Work productivity

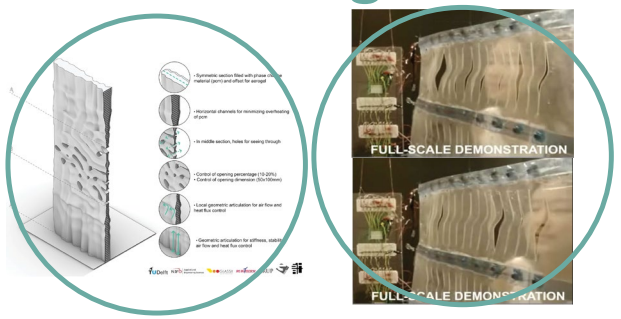
User satisfaction

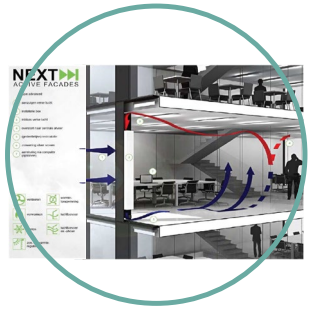


Façade design



Interactive/adaptive technologies





Conclusions

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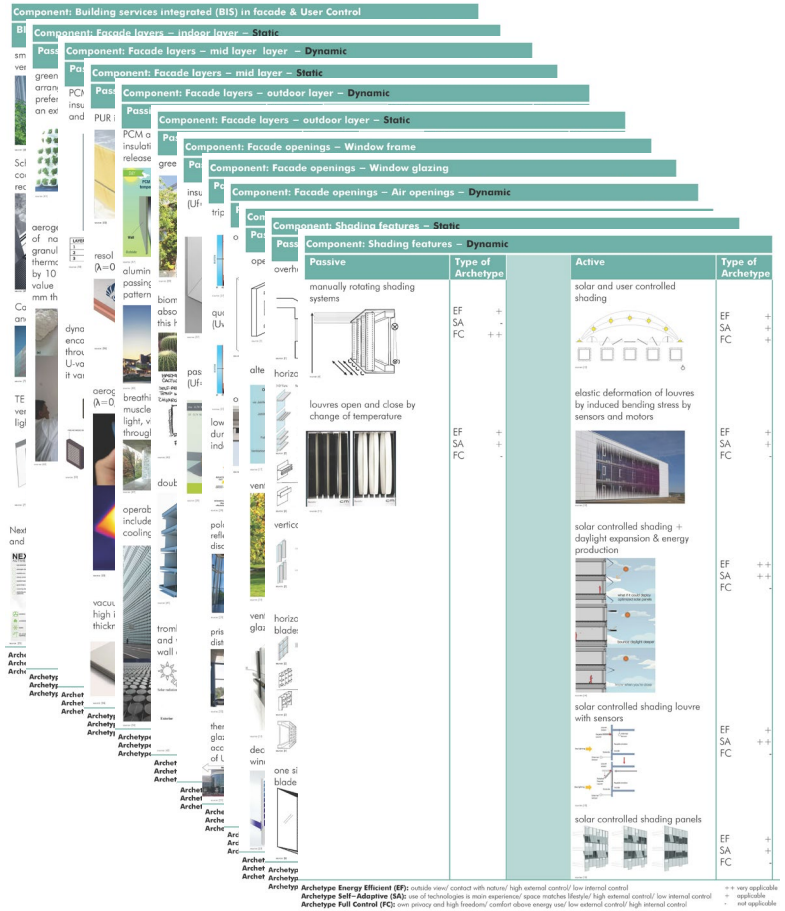


Conclusions

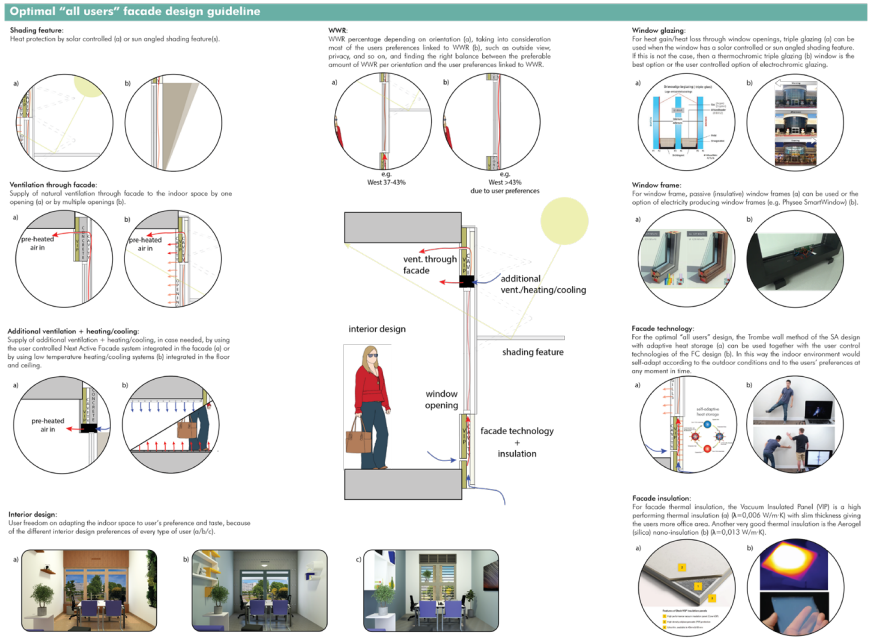
"How can an interactive/adaptive office building façade element be designed to optimally satisfy its users in order to increase work productivity and to support nearly energy neutrality of office buildings?"

Review of possible Archetypes per building

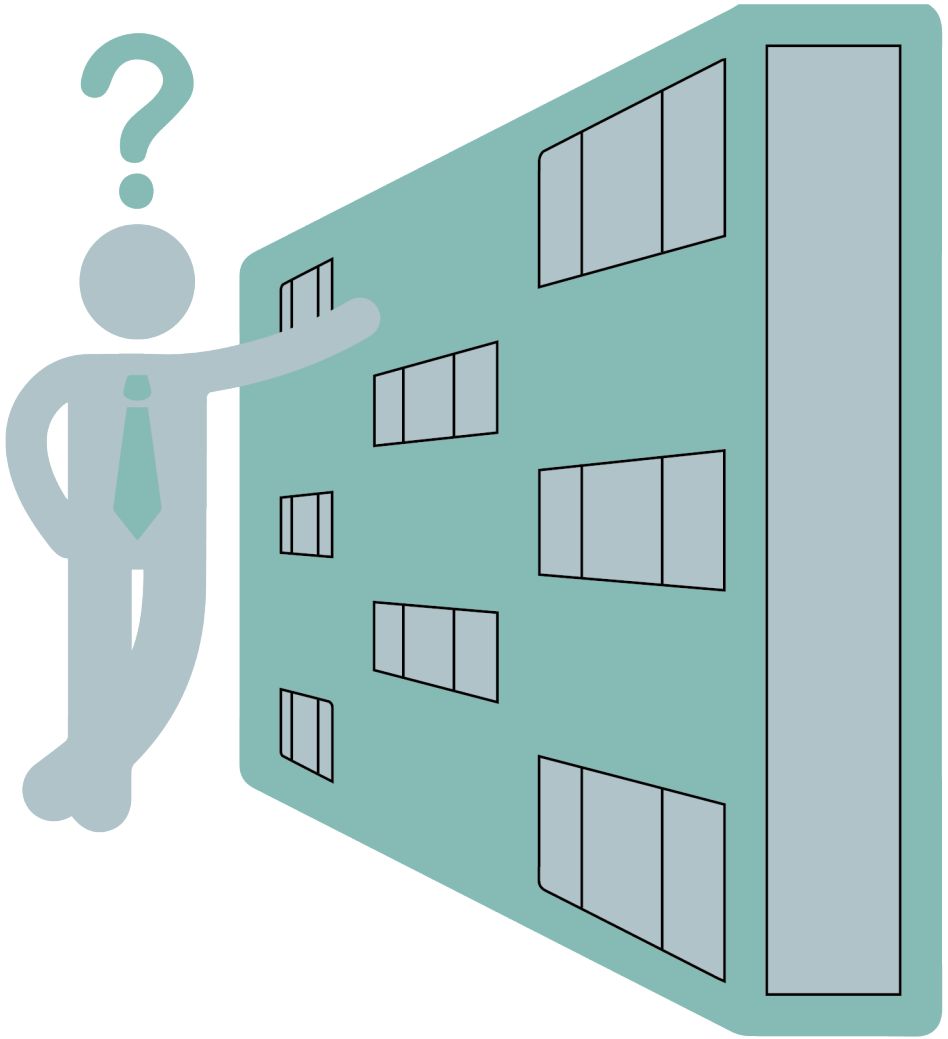
Conclusions

"How can an interactive/adaptive office building façade element be designed to optimally satisfy its users in order to increase work productivity and to support nearly energy neutrality of office buildings?"

Optimal "all users" design guideline



Any questions?



Thank you for your attention!