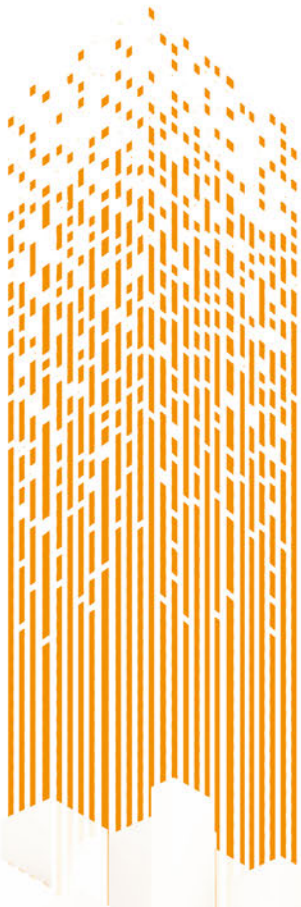


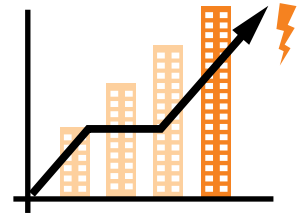
COMPUTATIONAL DESIGN ANALYSIS OF HEIGHT SCENARIOS IN RESIDENTIAL HIGH-RISE UNDER BENG 2020

Stephanie Moumdjian | 4907663
P5 Presentation

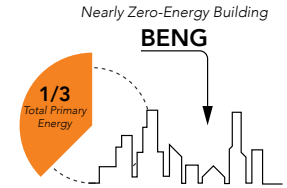
Introduction

Research Problem

Housing shortage
demand > supply

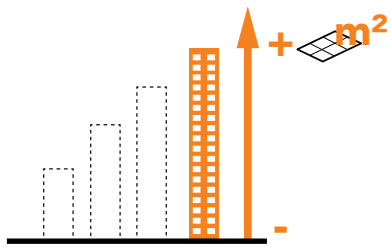


High-rise
high-energy consumption

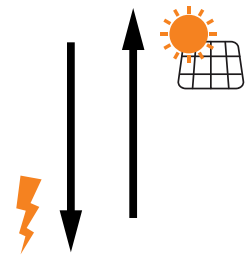


BENG
Constraint High-Rise Typology
> 5 floors

Solutions



High-Rise Typology
Building Vertically > Horizontally



Energy Efficient Design
Reduce Energy Demand
Maximize Energy Generation

BENG High-Rise Typology
Performance Gap ?

Main Research Question

Based on **computational optimization**, to which extent are **BENG regulations a constraint** to the construction of a **residential high-rise** in the Netherlands, and eventually what **amendments** can be proposed to **adapt the desired height to the performance** ?

Sub-Research Question

- Where does the limit in height increment of a residential high-rise stand until the BENG regulations are no longer satisfied?
- Then, which of the 3 BENG regulations is responsible for this limitation in the height increment?
- How does the energy performance of the residential high-rise vary in relation to addition of floors, and how does it affect the BENG indicators?
- What amendments can be proposed to improve the BENG regulations to achieve the desired high-rise height?

Objectives

- Design guidelines of the early design geometry and façade parameters derived from the optimization results of a conceptual study of a residential high-rise in the Netherlands, under the BENG 2020 regulations.

- Integrated workflow of the parametric design variables, the height increment and the energy performance for a nearly Zero Energy (nZEB) residential high-rise in the Netherlands.

- Assessment of the maximum height of a residential high-rise, in the temperate climate of the Netherlands that can satisfy the BENG 2020.

- Establish the relation between the 3 BENG indicators and the energy performance in parallel to the height increment of the residential high-rise and the design parameters.

Boundary Conditions

The research focuses on
a residential high-rise building,
with a repetitive floor plan,
in the temperate climate
of the Netherlands.

Methodology

Methodology

Research for Design

Research through Design

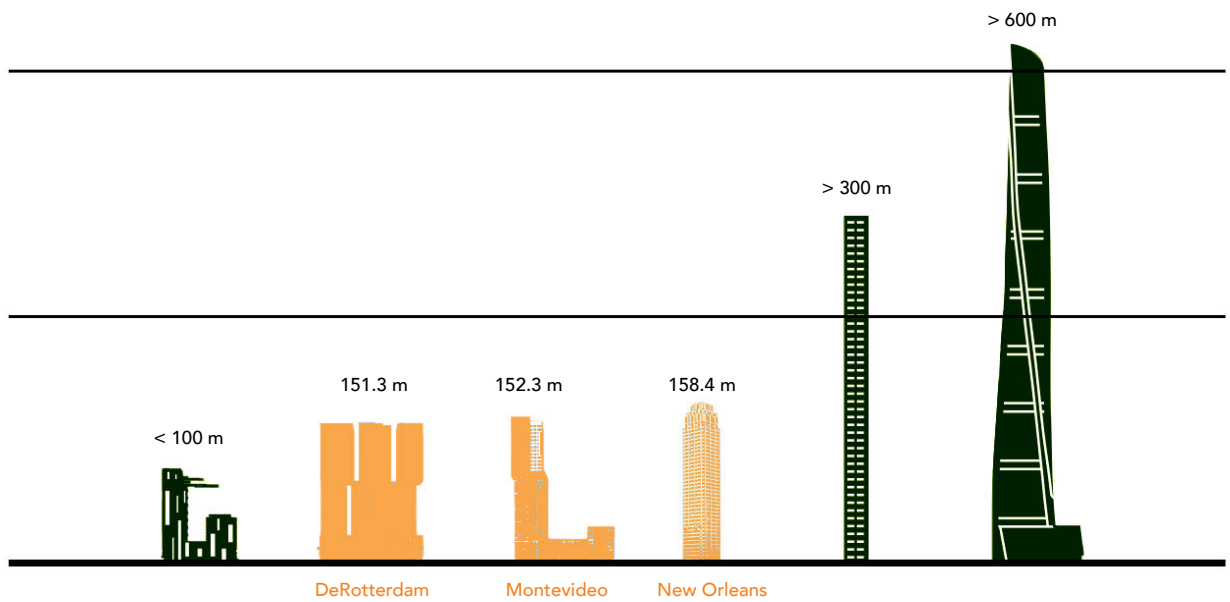
BENG 2020

			Residential Function	
	**BENG 1** *Reduce Energy Demand*	**≤ 65** *kWh/m².yr*	*≤ 55 + 30 * (A_{ls}/A_g - 1.5)* *kWh/m².yr*	*≤ 100 + 50 * (A_{ls}/A_g - 3.0)* *kWh/m².yr*
	**BENG 2** *Use Primary Fossil Energy*	**≤ 50** *kWh/m².yr*	–	–
	**BENG 3** *Share of Renewable Energy*	**≥ 40** *%*	–	–

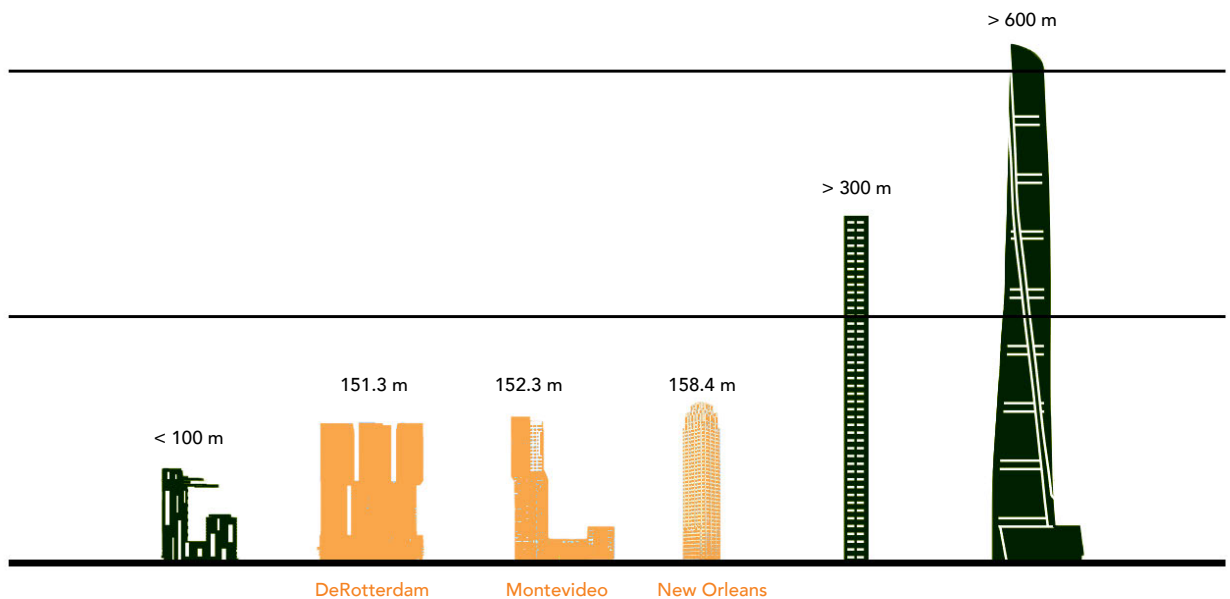
BENG 2020

		Residential Function		
		Related to Geometry & Envelope *Ratio of the Loss Surface Area (A_{ls}) / Usable Floor Area (A_g)*		
	**BENG 1** *Reduce Energy Demand*	**≤ 65** *kWh/m².yr*	*≤ 55 + 30 * (A_{ls}/A_g - 1.5)* *kWh/m².yr*	*≤ 100 + 50 * (A_{ls}/A_g - 3.0)* *kWh/m².yr*
	**BENG 2** *Use Primary Fossil Energy*	**≤ 50** *kWh/m².yr*	–	–
	**BENG 3** *Share of Renewable Energy*	**≥ 40** *%*	–	–

High-Rises

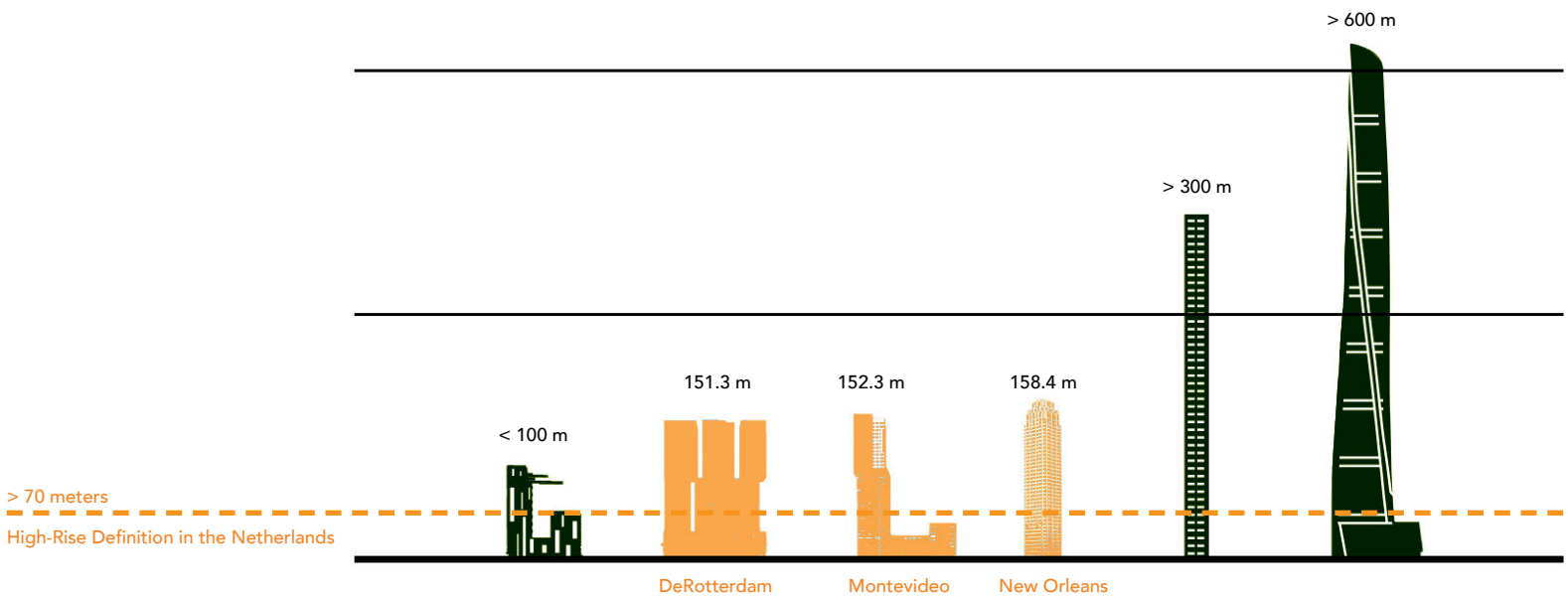

> 600 m
> 300 m
151.3 m
152.3 m
158.4 m
< 100 m
DeRotterdam
Montevideo
New Orleans

High-Rises

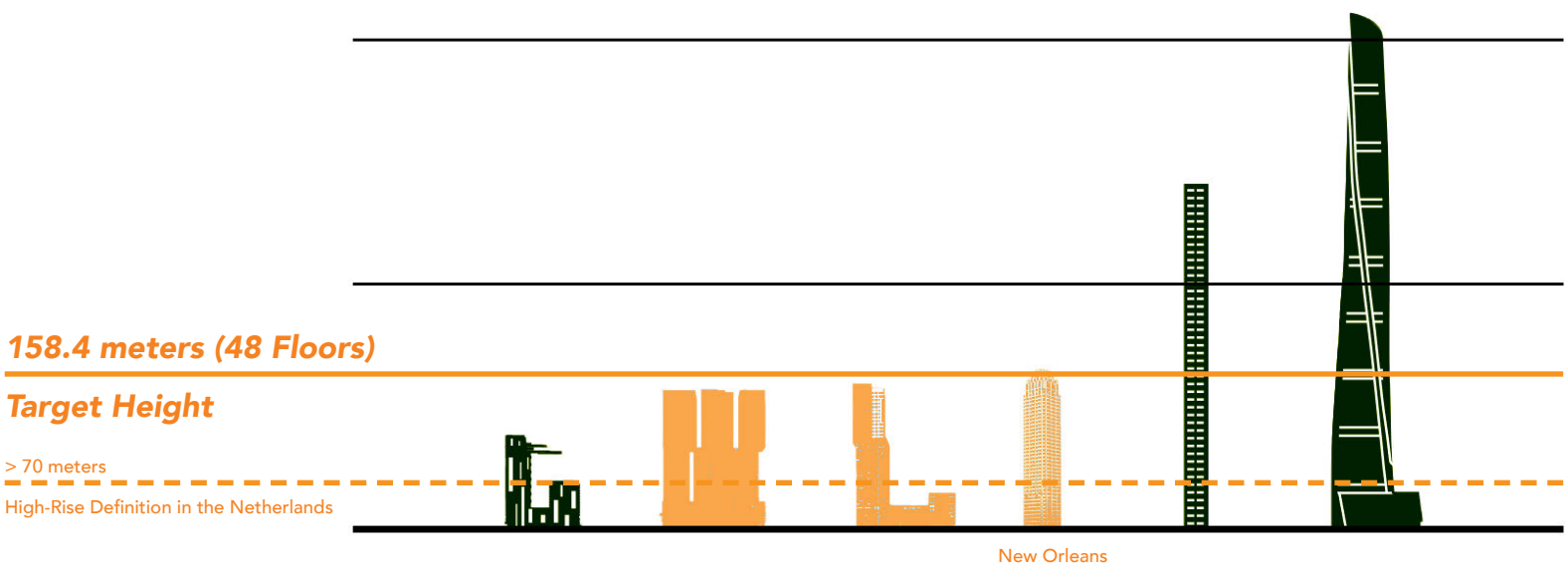


Tallest Dutch Residential High-rises

High-Rises

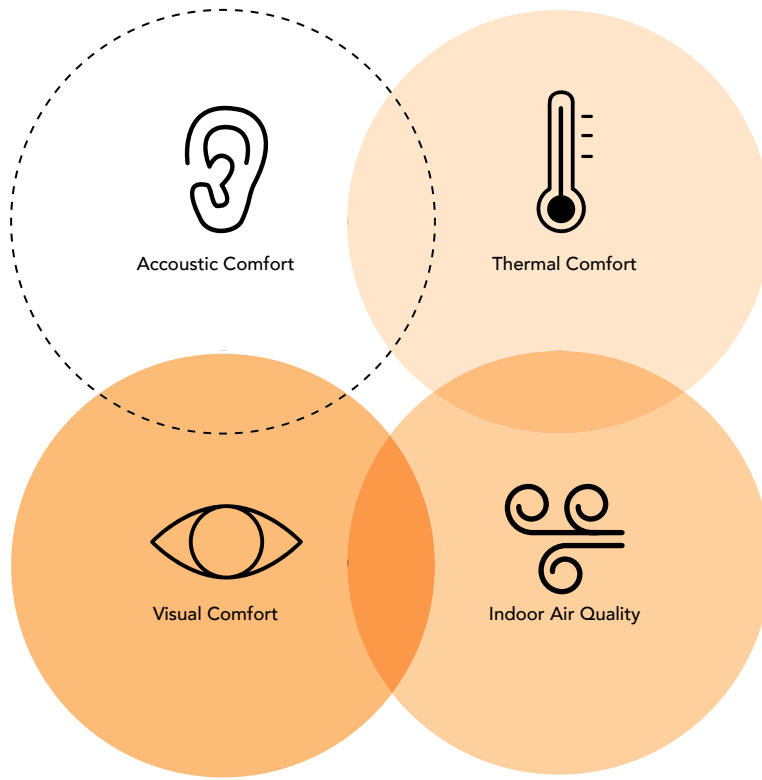

> 600 m
> 300 m
151.3 m
152.3 m
158.4 m
< 100 m
> 70 meters
High-Rise Definition in the Netherlands
DeRotterdam
Montevideo
New Orleans

High-Rises


158.4 meters (48 Floors)
Target Height
> 70 meters
High-Rise Definition in the Netherlands
New Orleans

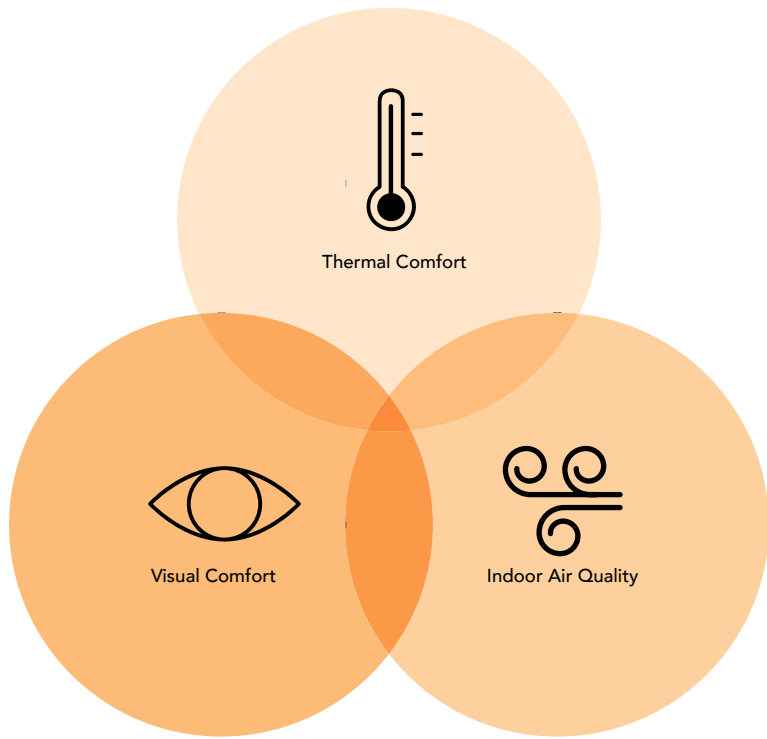
User's Requirement

User's Requirement



Indoor Environment Quality
IEQ

User's Requirement

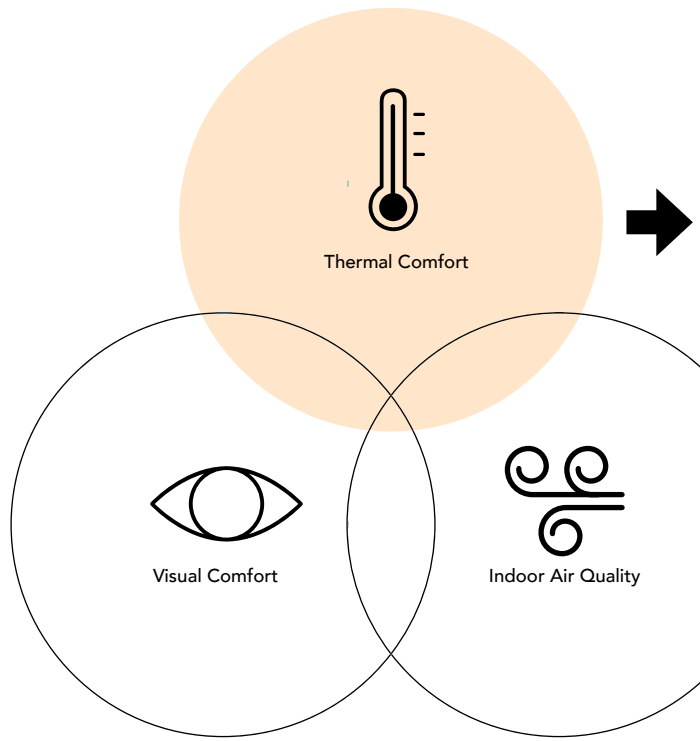


Indoor Environment Quality
IEQ

User's Requirement

Thermal Comfort

New Building Category
Total Thermal Comfort **> 90%**



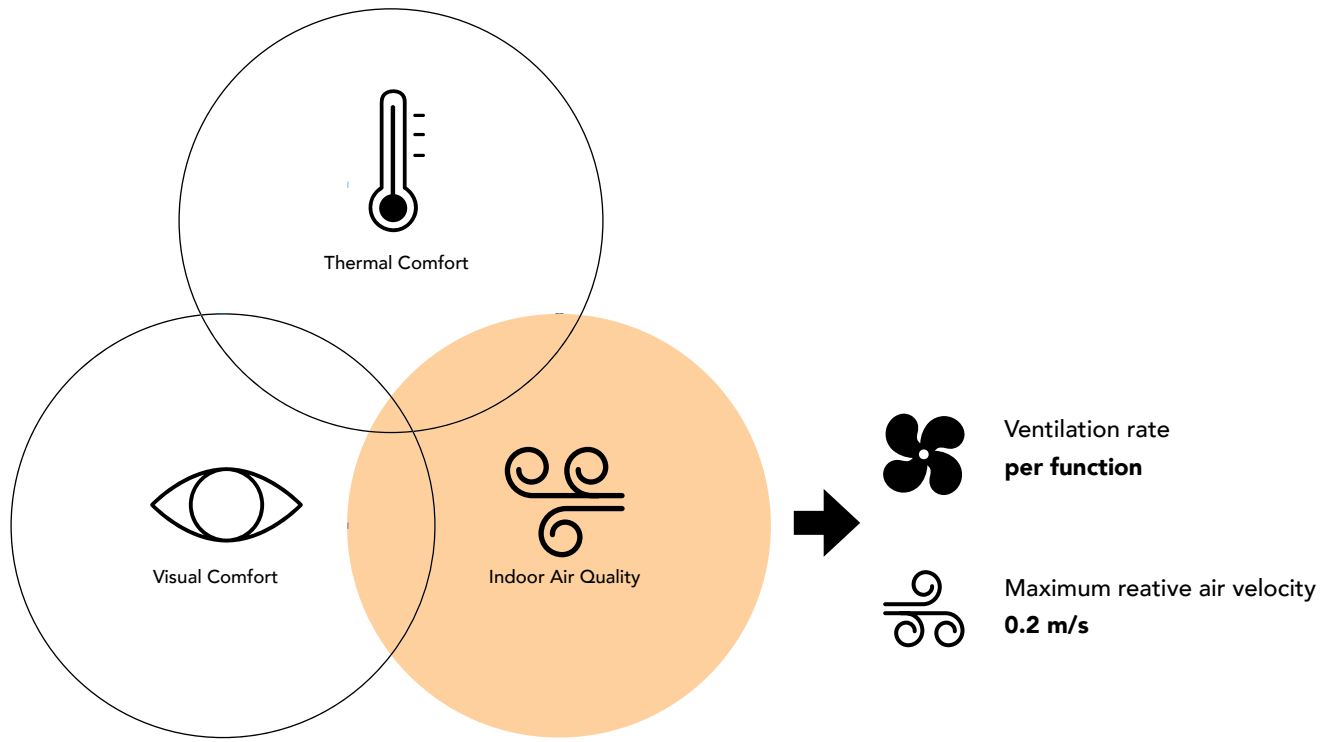
Temperature Range Winter
20°C - 25°C
Heating set point: 20 °C

Temperature Range Summer
23°C - 26°C
Cooling set point: **26 °C (TOjuli)**

User's Requirement

Thermal Comfort

Indoor Air Quality



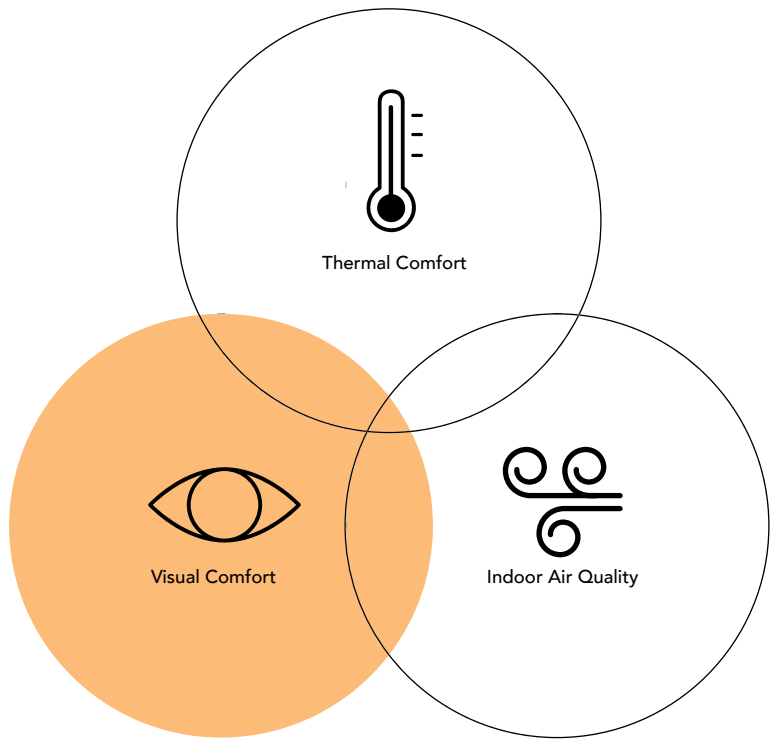
User's Requirement

Thermal Comfort

Indoor Air Quality

Visual Comfort

Daylight Threshold
> 300 lux
> 10 % space area
> 50 % occupancy time



User's Requirement

Thermal Comfort

Indoor Air Quality

Visual Comfort

Schedule of Occupancy

Research for Design

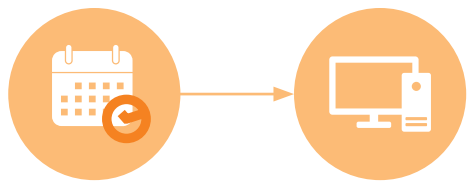
User's Requirement

Thermal Comfort

Indoor Air Quality

Visual Comfort

Schedule of Occupancy



Simulation

User's Requirement

Thermal Comfort

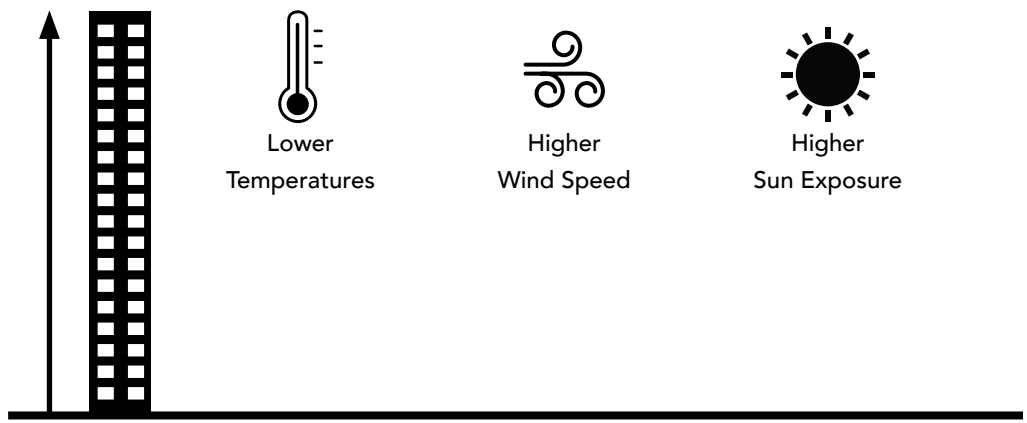
Indoor Air Quality

Visual Comfort

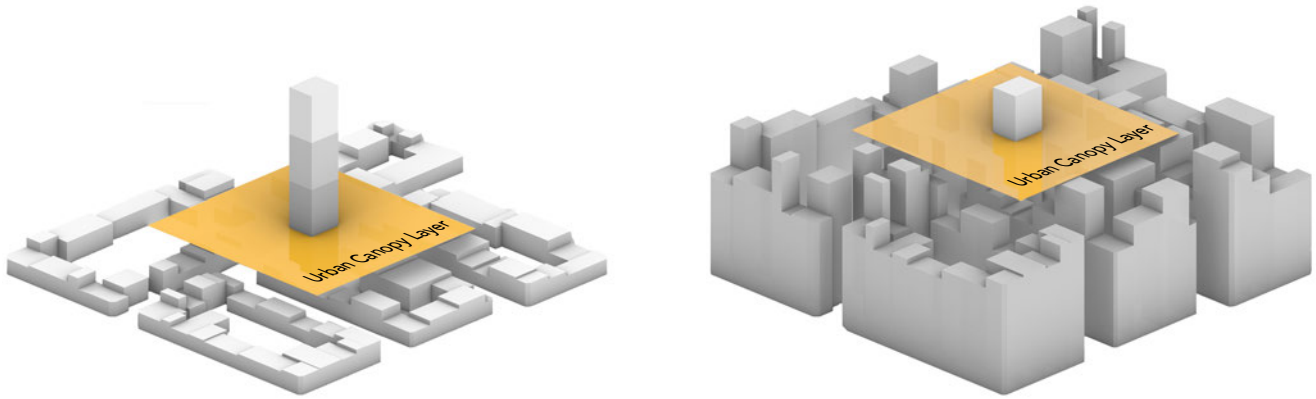
Schedule of Occupancy

Measure

Micro-Climates



Context



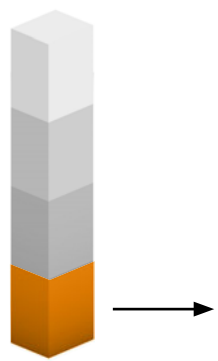
Low-Rise Context → High-Rise Context

Context

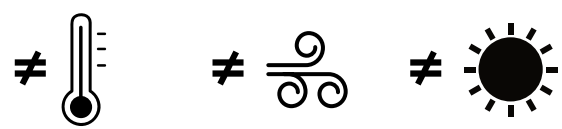
Low-Rise Context → High-Rise Context

Context

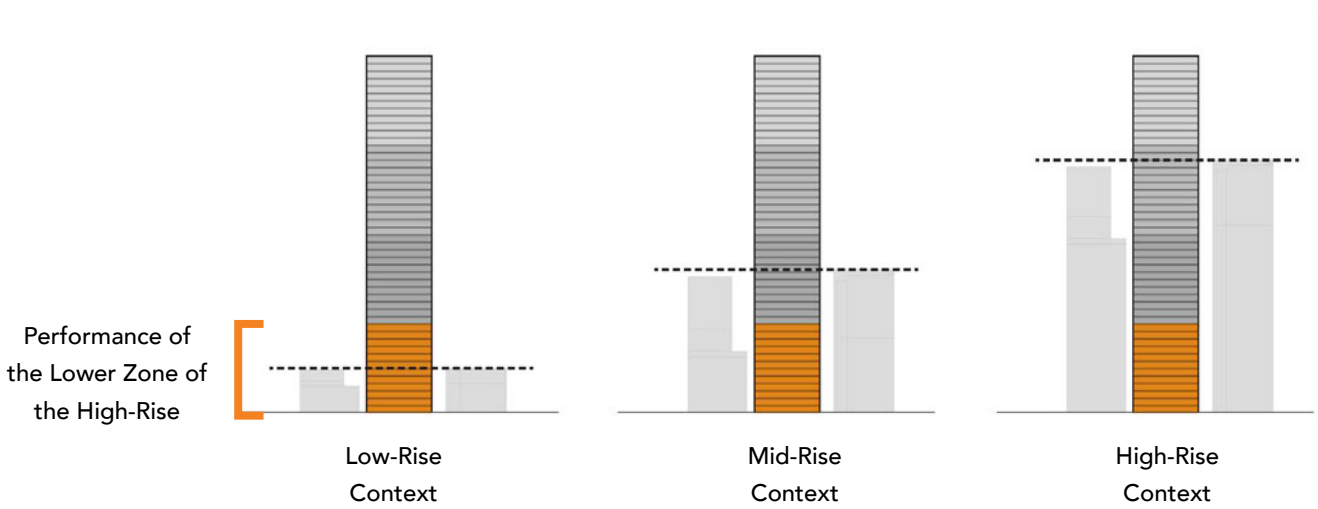
Performance of
the Lower Zone of
the High-Rise



≠ Exposure to Environmental Factors



Context

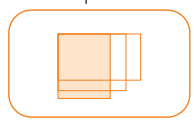

Performance of
the Lower Zone of
the High-Rise
Low-Rise
Context
Mid-Rise
Context
High-Rise
Context

Research for Design

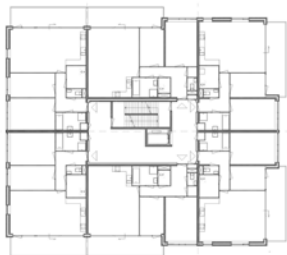
Design Parameters

Early Stage Geometry Parameters

Compactness

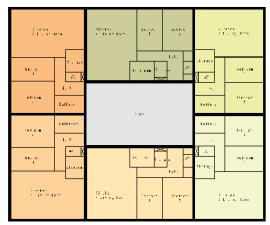


x 3

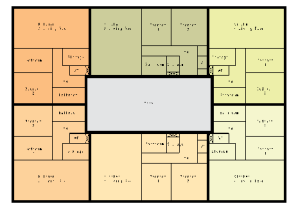


Referential Apartment Plan Layout in the Netherlands (RVO)

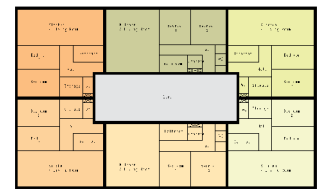
Plan Type 1



Plan Type 2



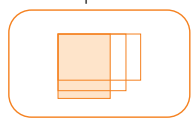
Plan Type 3



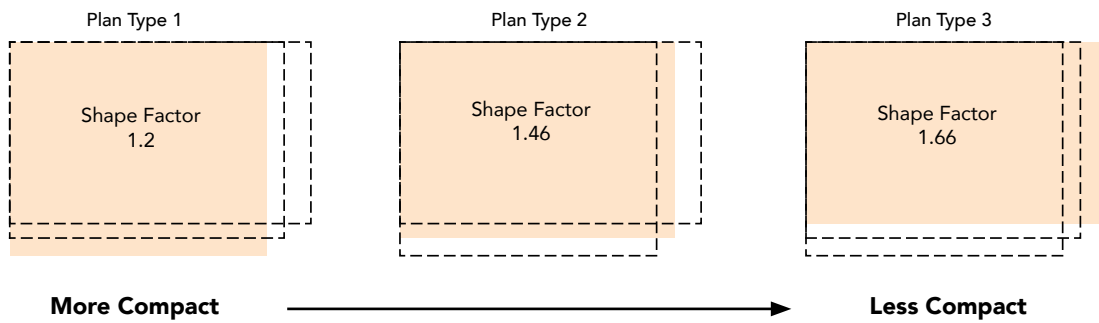
Design Parameters

Early Stage Geometry Parameters

Compactness



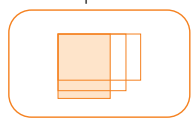
x 3



Design Parameters

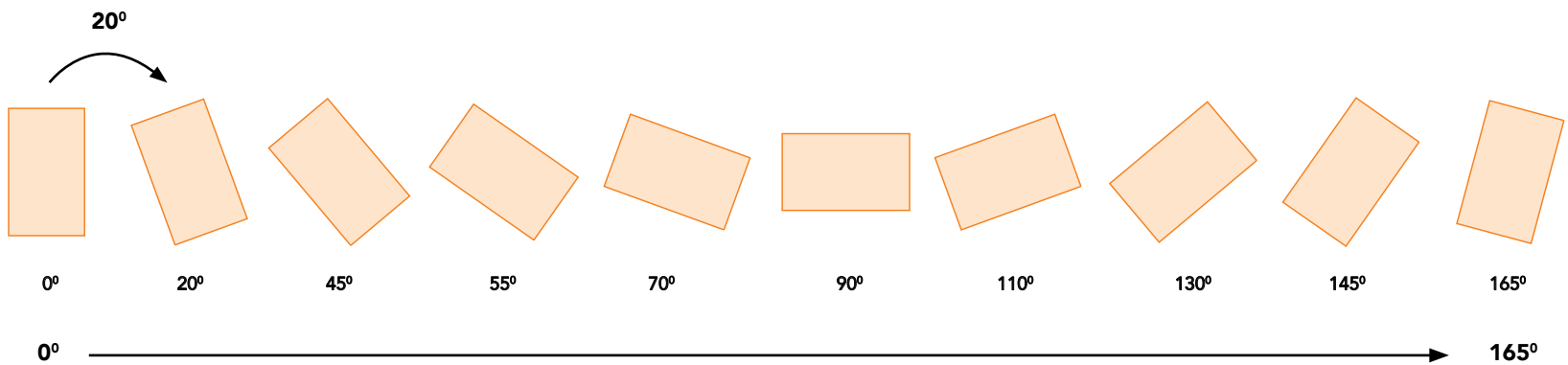
Early Stage Geometry Parameters

Compactness



Orientation

x 10

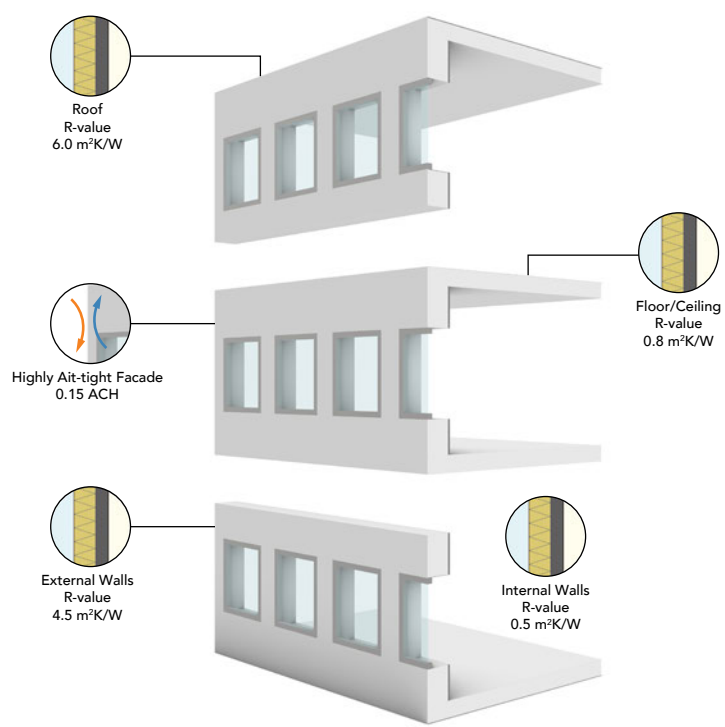


Design Parameters

Facade Parameters

Thermal Insulation

Fixed



Research for Design

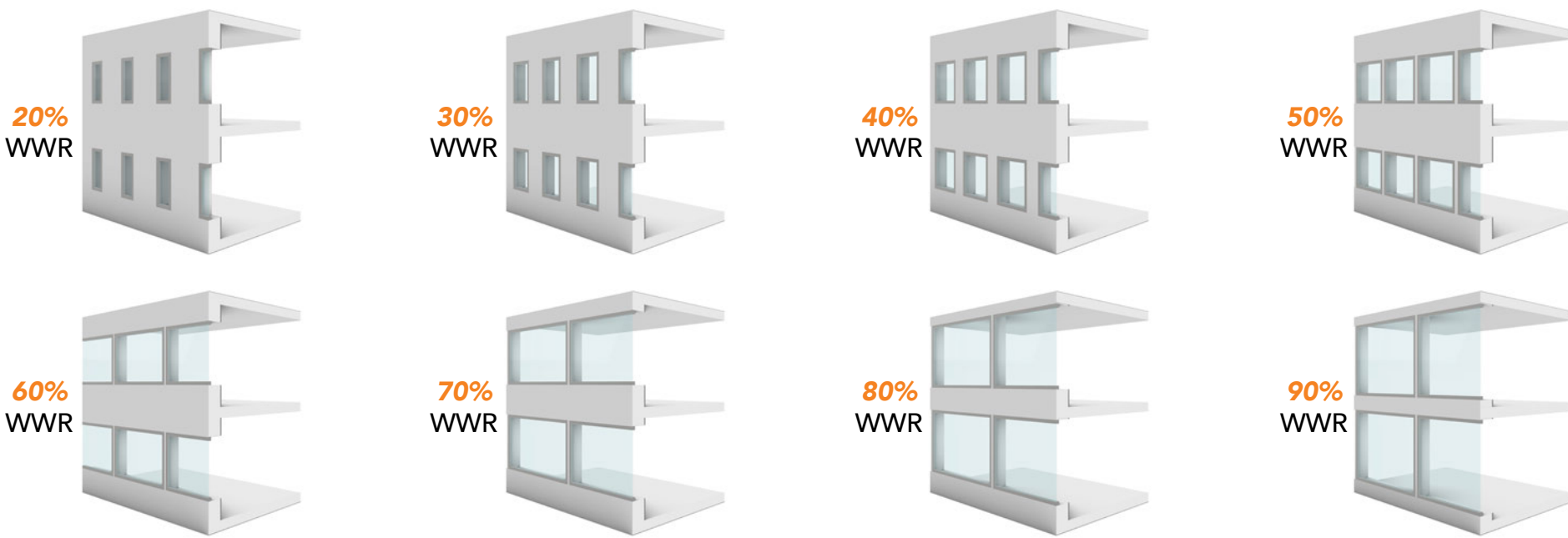
Design Parameters

Facade Parameters

Thermal Insulation

Glazing Ratio

x 9



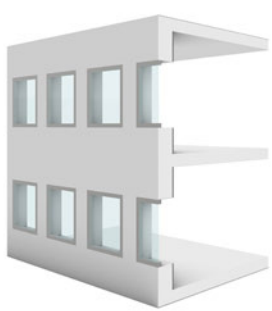
Research for Design

Design Parameters

Facade Parameters

Thermal Insulation | Glazing Ratio | Glazing Types

x 5



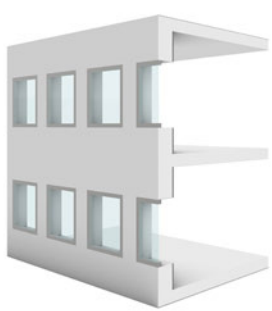
	Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***

Design Parameters

Facade Parameters

Thermal Insulation | Glazing Ratio | Glazing Types

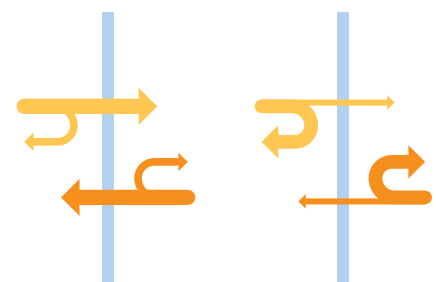
x 5



Glazing Type	1	2	3	4	5
	Double Glazing			*Triple Glazing*	
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5

high U-value

low U-value



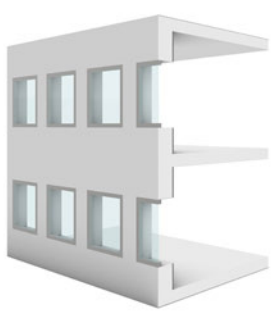
Research for Design

Design Parameters

Facade Parameters

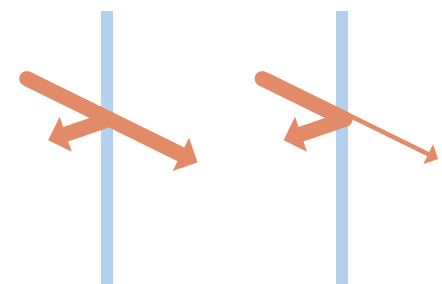
Thermal Insulation | Glazing Ratio | Glazing Types

x 5



		Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5
g-value [-]	0.62	0.47	0.5	0.5	0.7

high g-value | low g-value



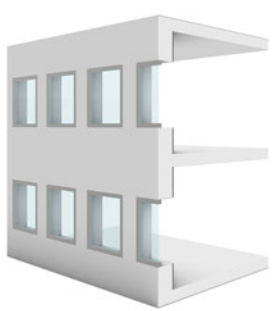
Research for Design

Design Parameters

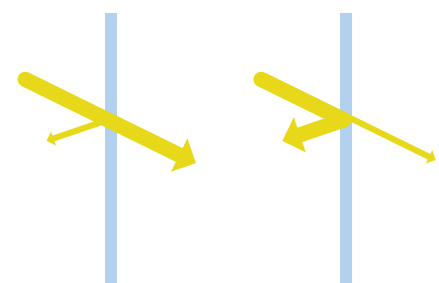
Facade Parameters

Thermal Insulation | Glazing Ratio | Glazing Types

x 5

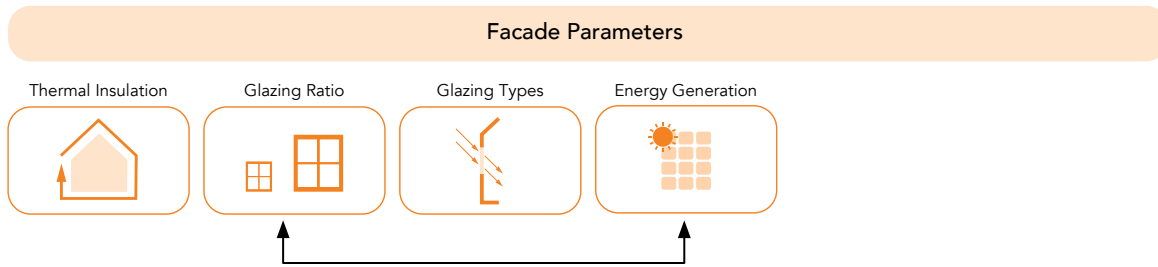


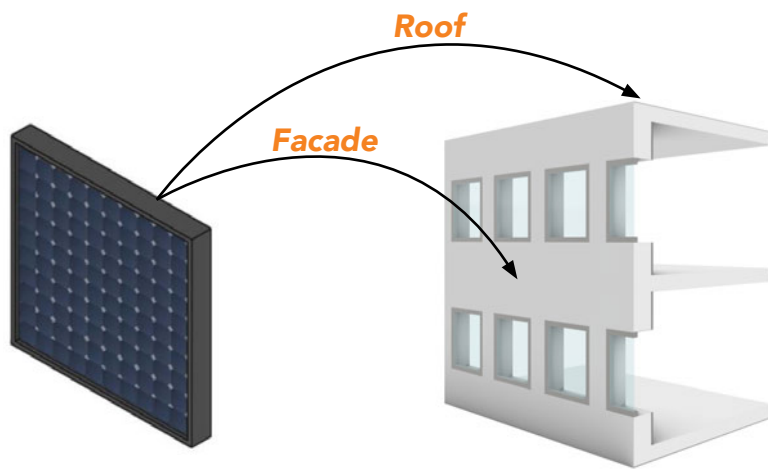
	Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5
g-value [-]	0.62	0.47	0.5	0.5	0.7
VLT [%]	80	75	69	75	72



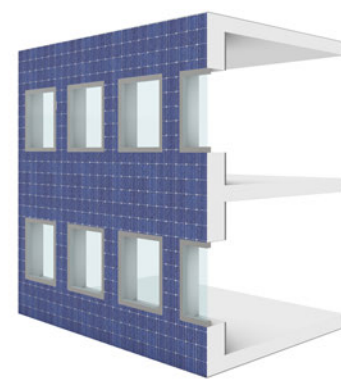
Research for Design

Design Parameters





20% Efficiency PV
moncrystalline silicon cells



Remaining Facade Area from WWR for PV

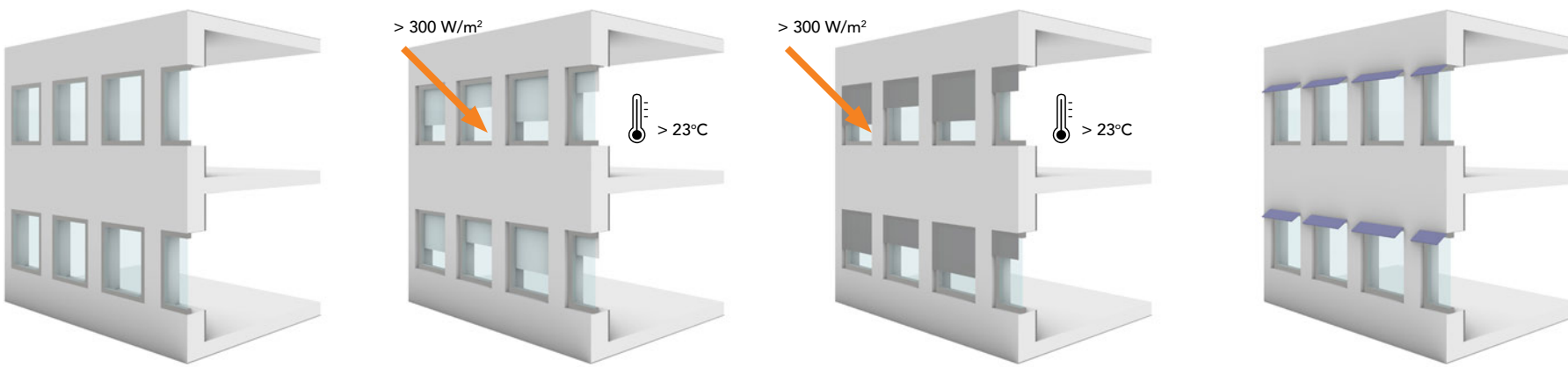
Research for Design

Design Parameters

Facade Parameters

Thermal Insulation | Glazing Ratio | Glazing Types | Energy Generation | Shading Systems

x 4

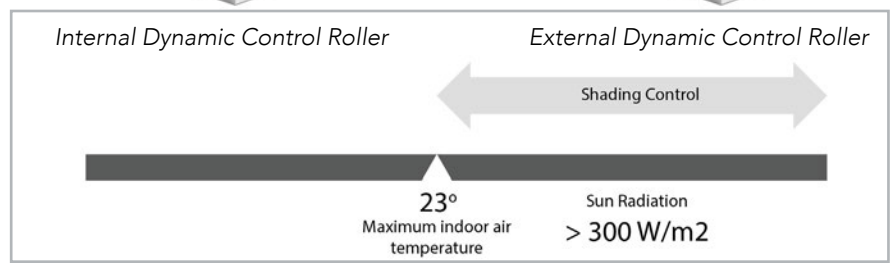


No Shading System

Internal Dynamic Control Roller

External Dynamic Control Roller

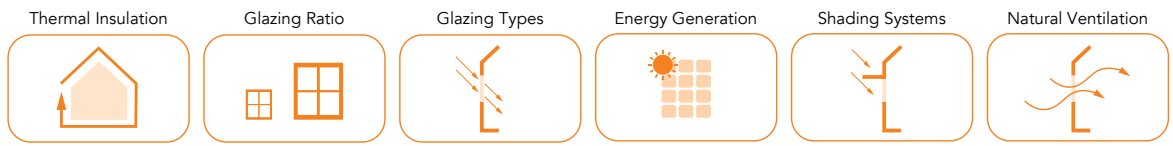
Fixed Fins & PV mounted

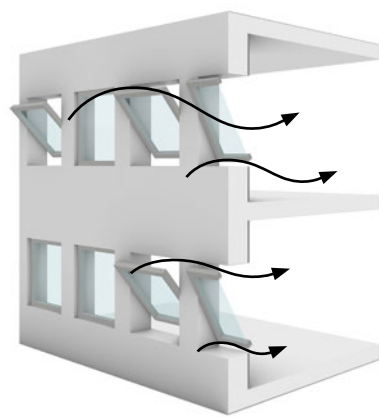


Research for Design

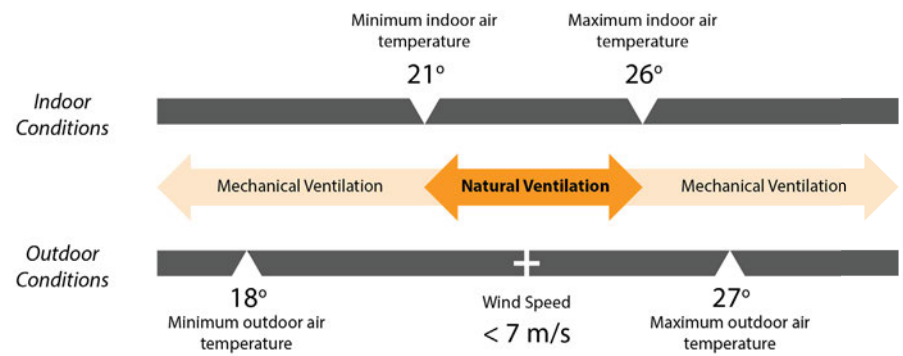
Design Parameters

Facade Parameters





30% Ratio Rotating Window Opening



Research for Design

Active Systems

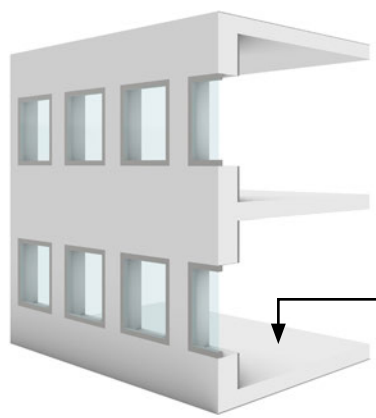
System D
Mechanical Ventilation

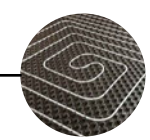
MVHR
95% Heat Recovery

Heating
COP 3.6
Radiant Floor

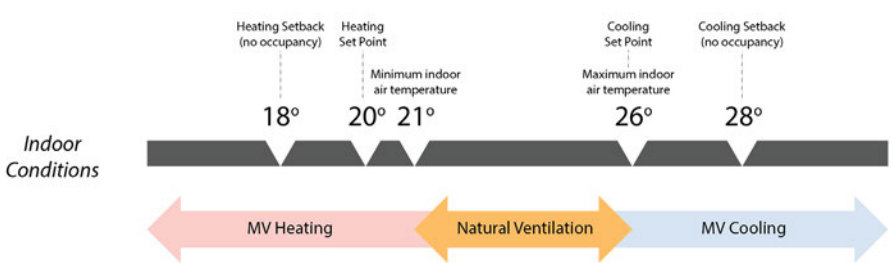
Cooling
EER 15
Radiant Floor

Domestic Hot Water
COP 3.6
61 l/day/pers



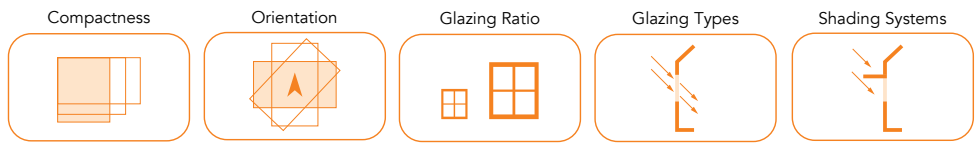


Radiant Floor



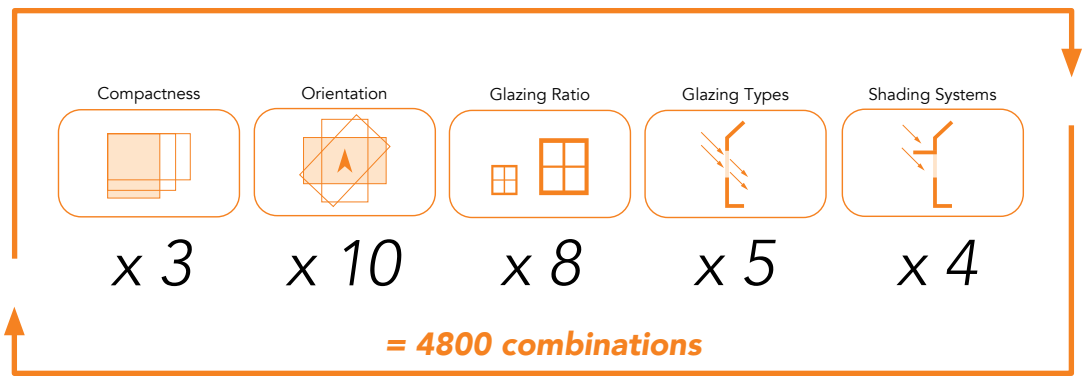
Based on **computational optimization**, to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands, and eventually what amendments can be proposed to adapt the desired height to the performance ?

Research for Design

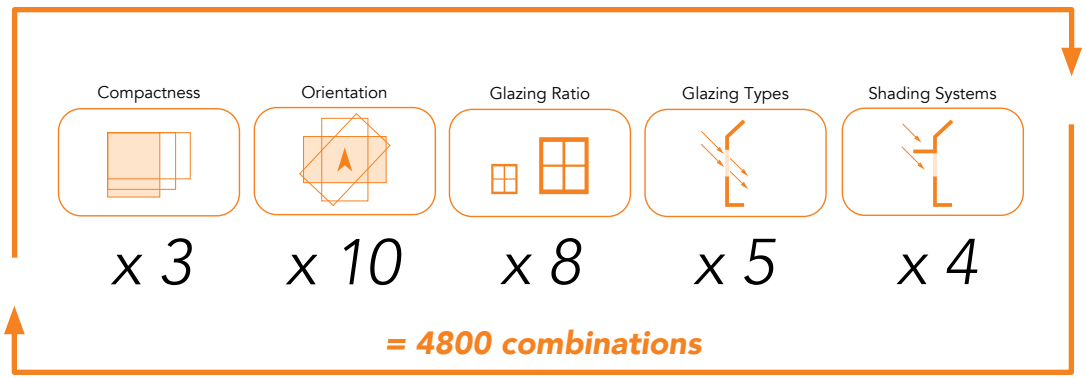


x 3 x 10 x 8 x 5 x 4

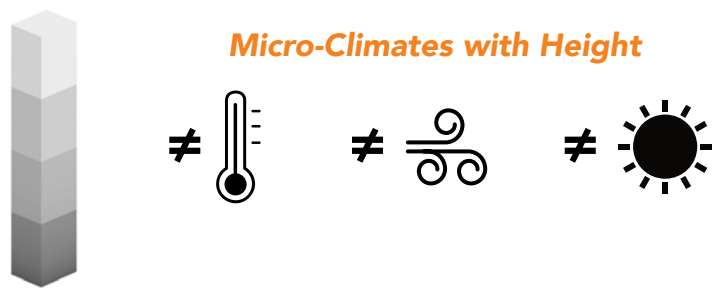
Interrelated Parameters



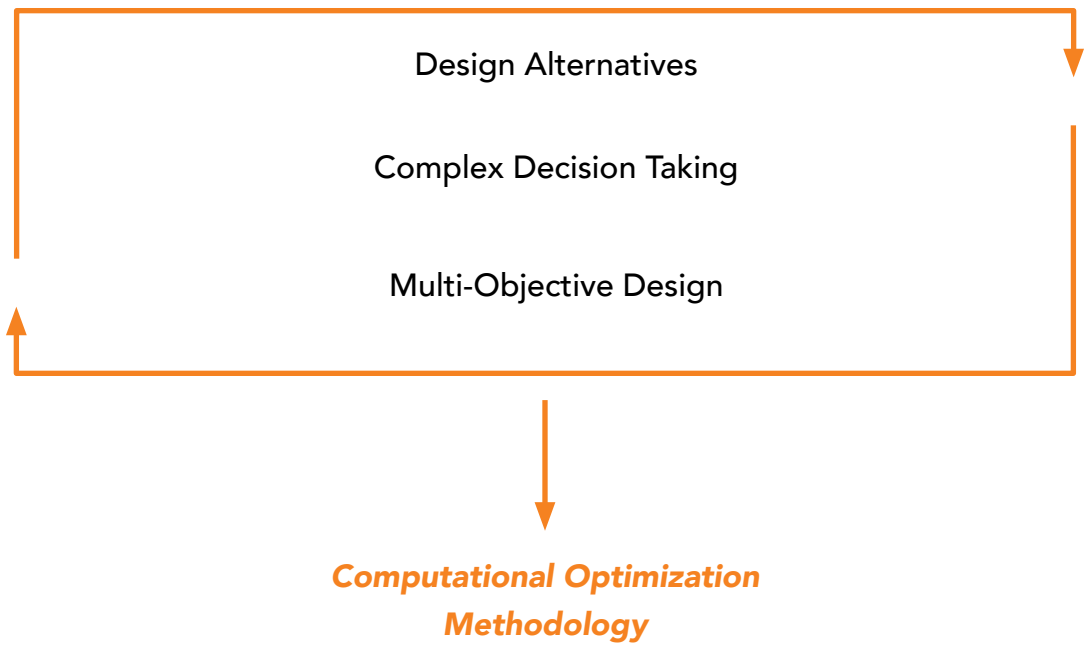
Interrelated Parameters



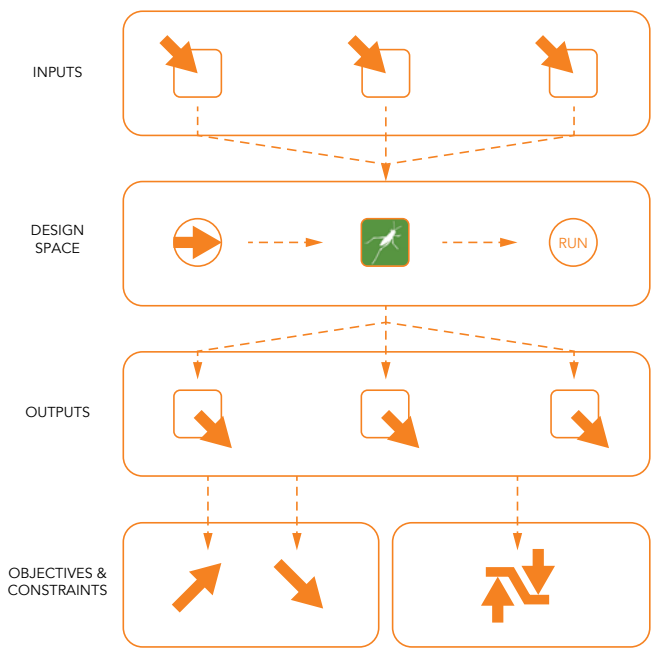
+



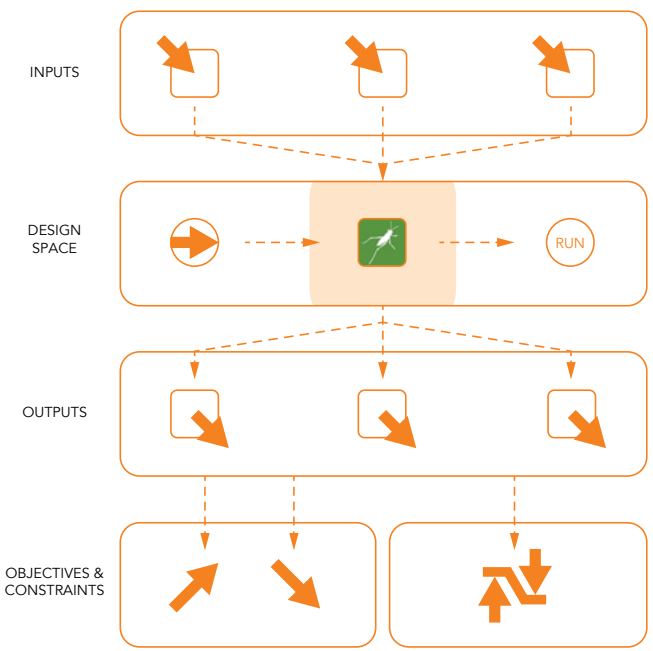
Research for Design



Intergrated Workflow

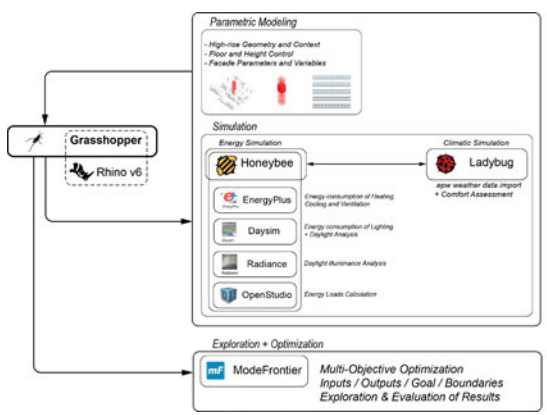


Intergrated Workflow

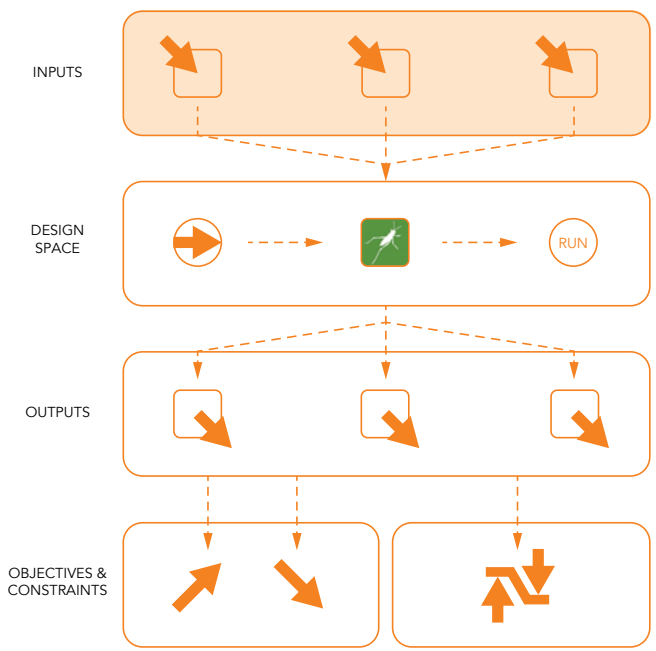


Grasshopper + Plug-ins

- Parametric Modeling
- Climatic Simulation
  (.epw Weather Data)
- Energy Simulation
- Daylight Simulation
- Outputs Loads
- Outputs Comfort



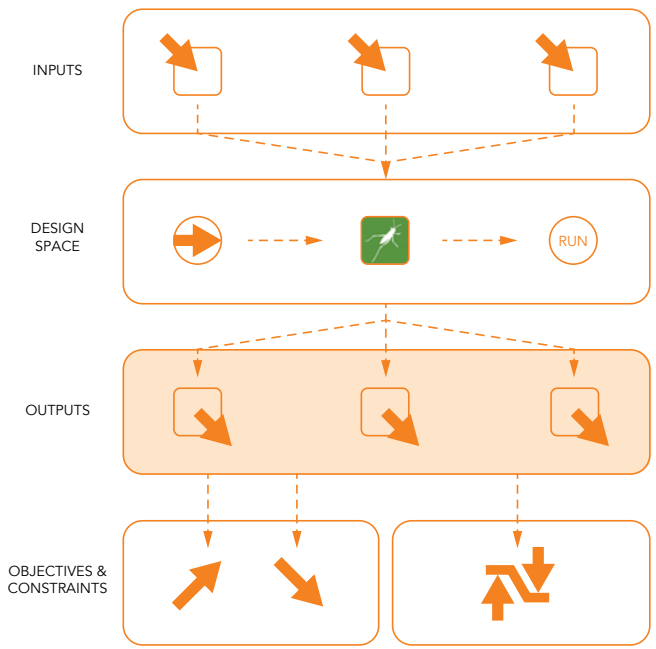
Intergrated Workflow



Inputs & Variables

x 3 x 10 x 8 x 5 x 4

Intergrated Workflow



Outputs

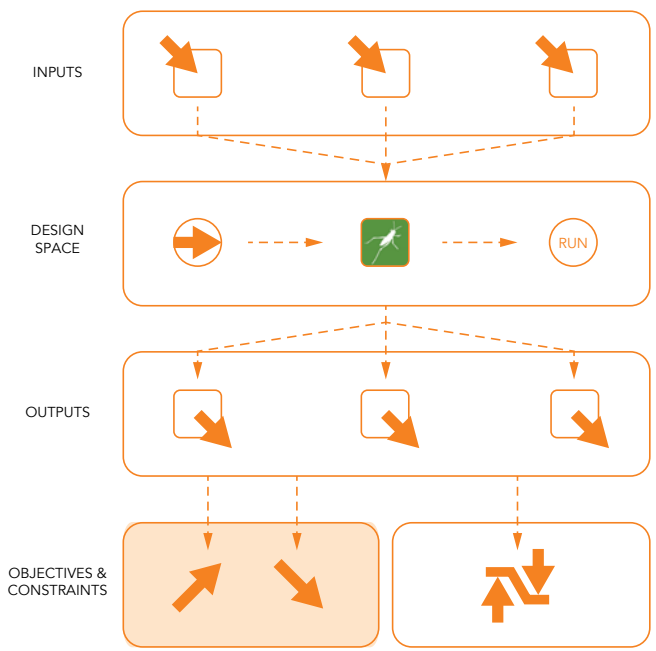
- **BENG 1** *Energy Demand*
- **BENG 2** *Primary Fossil Usage*
- **BENG 3** *Energy Generated*

- **Comfort Level**

- **sDA** *Spatial Daylight Autonomy*

- **Cooling Loads**
- **Heating Loads**
- **Lighting Loads**

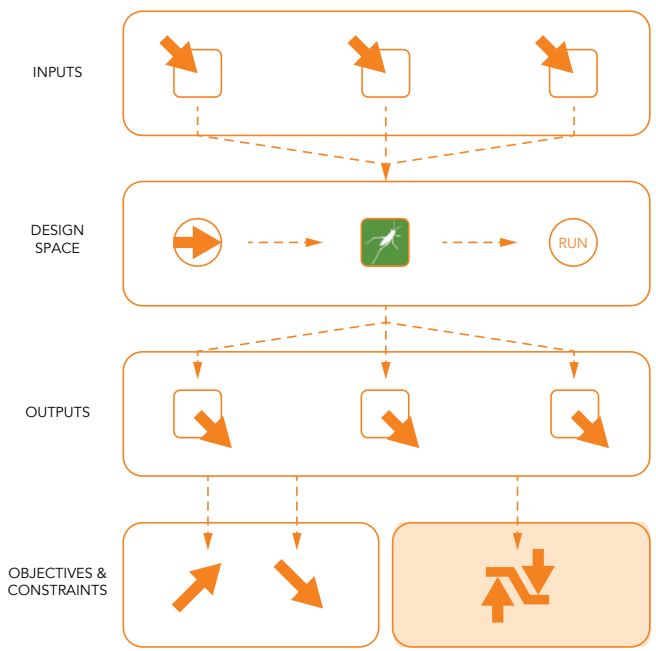
Intergrated Workflow



Objectives

Minimize	*Minimize*	*Maximize*
BENG 1	**BENG 2**	**BENG 3**

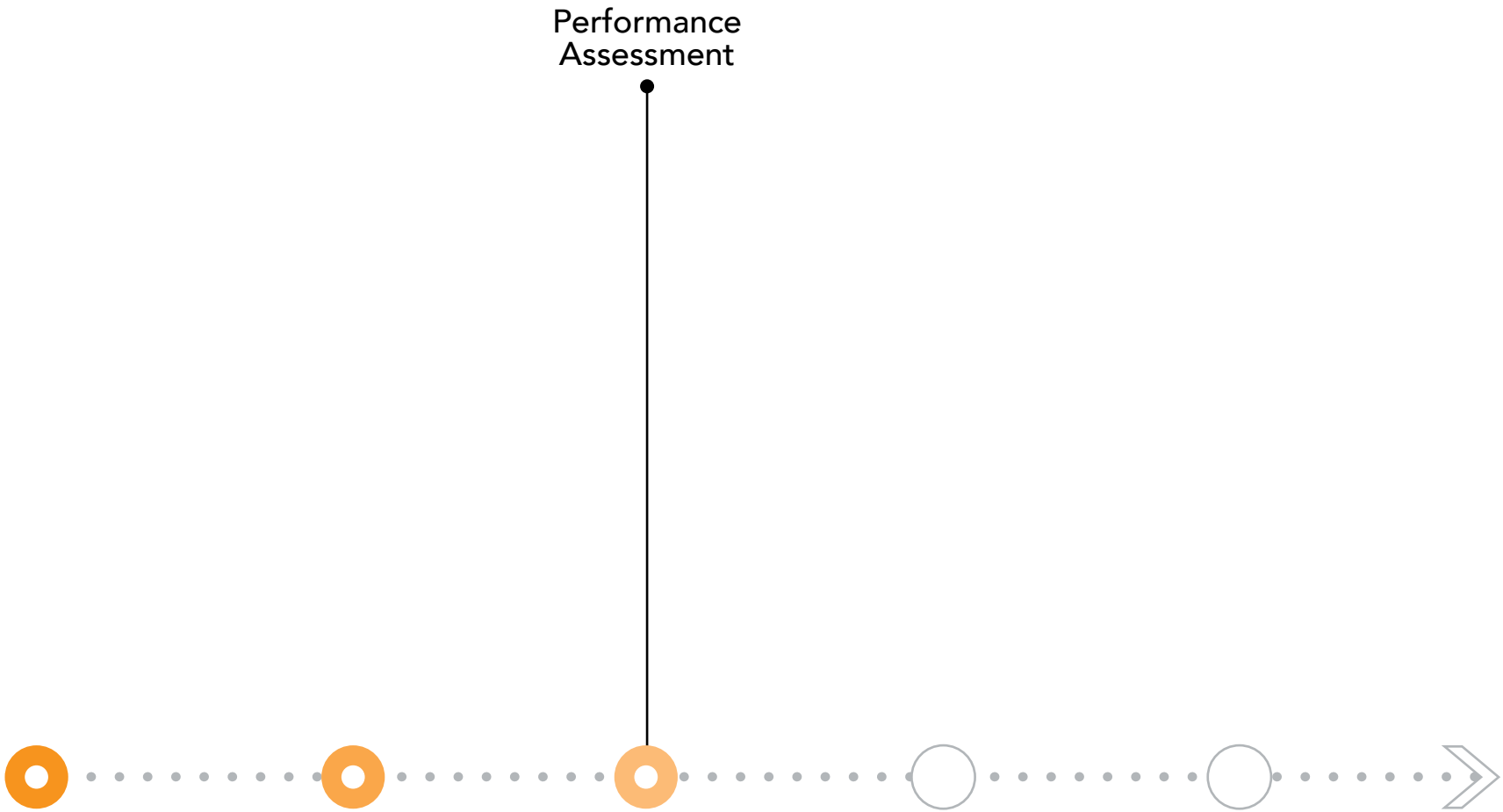
Intergrated Workflow



Constraint

Comfort Level

> 89 %


Performance
Assessment

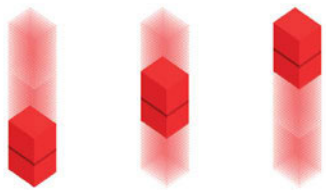
Zone Divisions Validation
based on:

Accuracy of Results

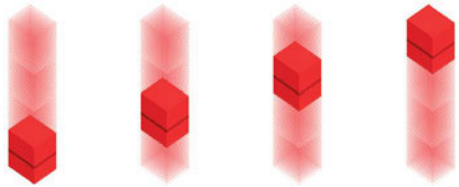
Time for Simulation

Zone Divisions

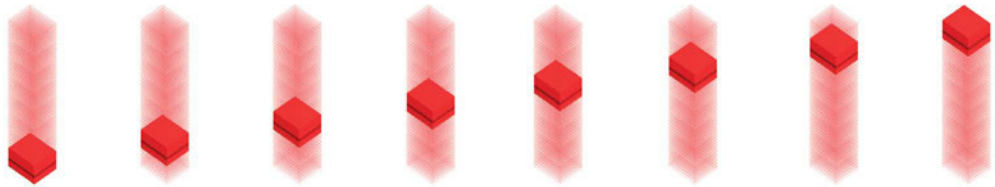
3 Zones



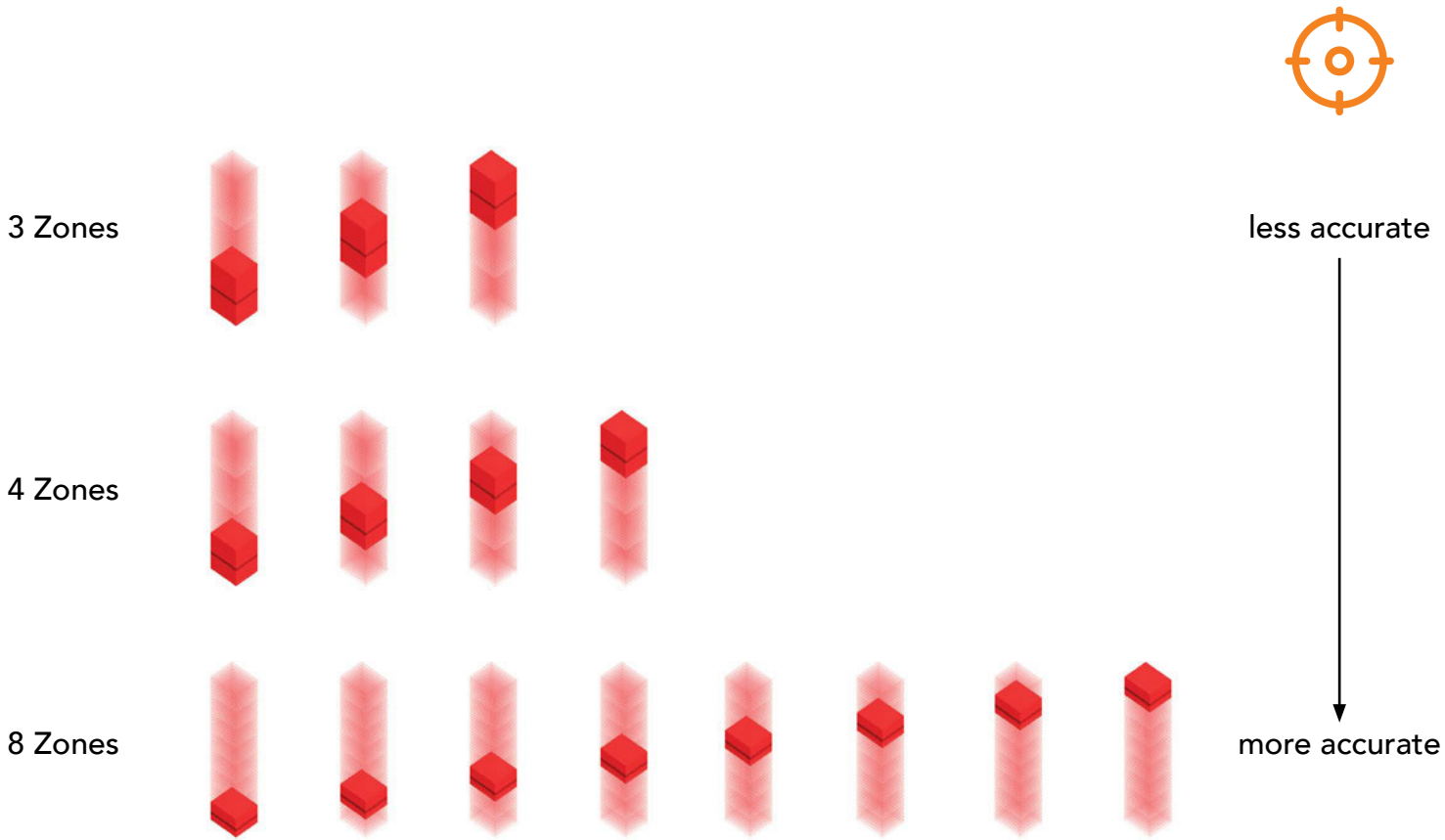
4 Zones



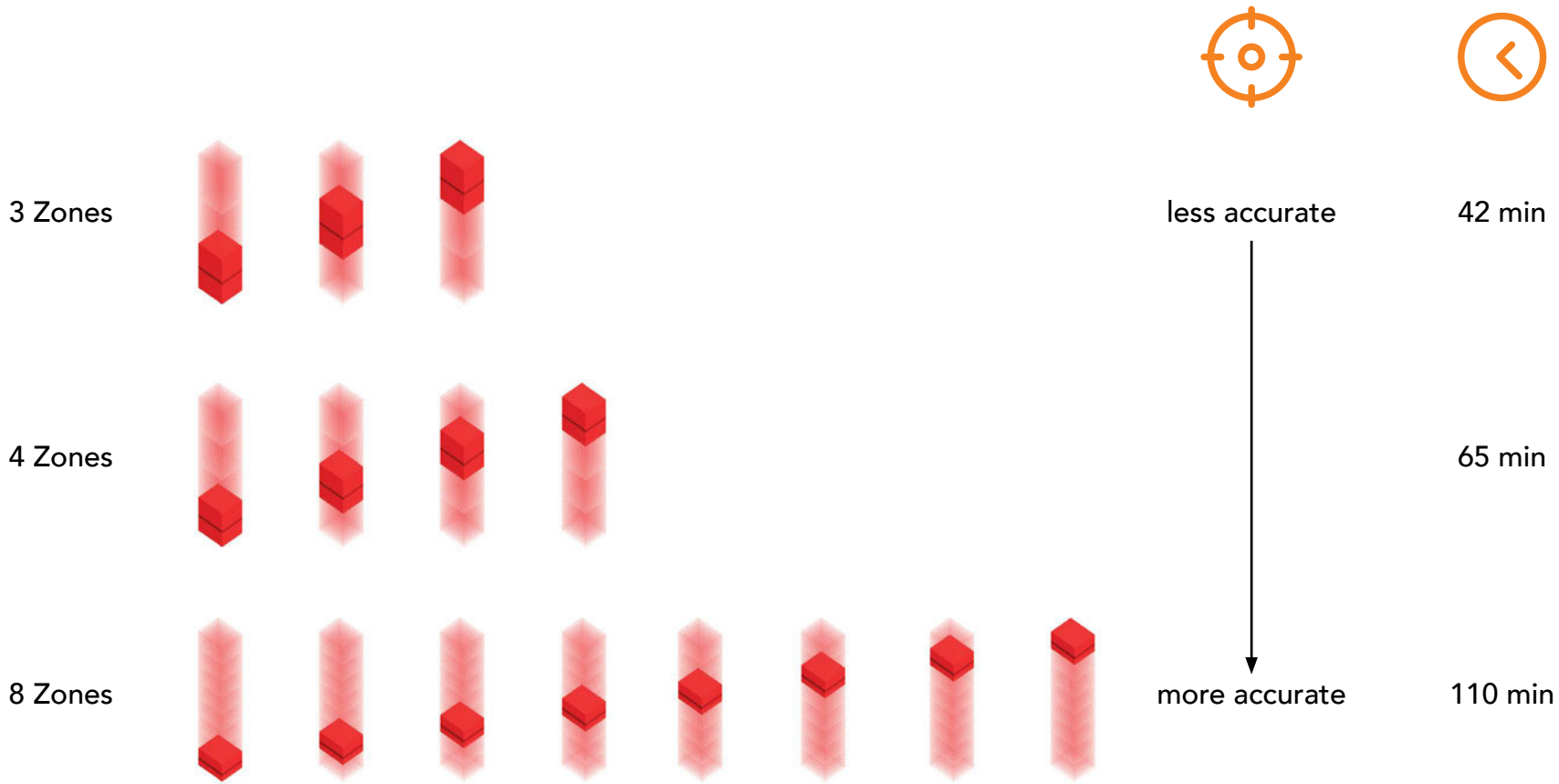
8 Zones



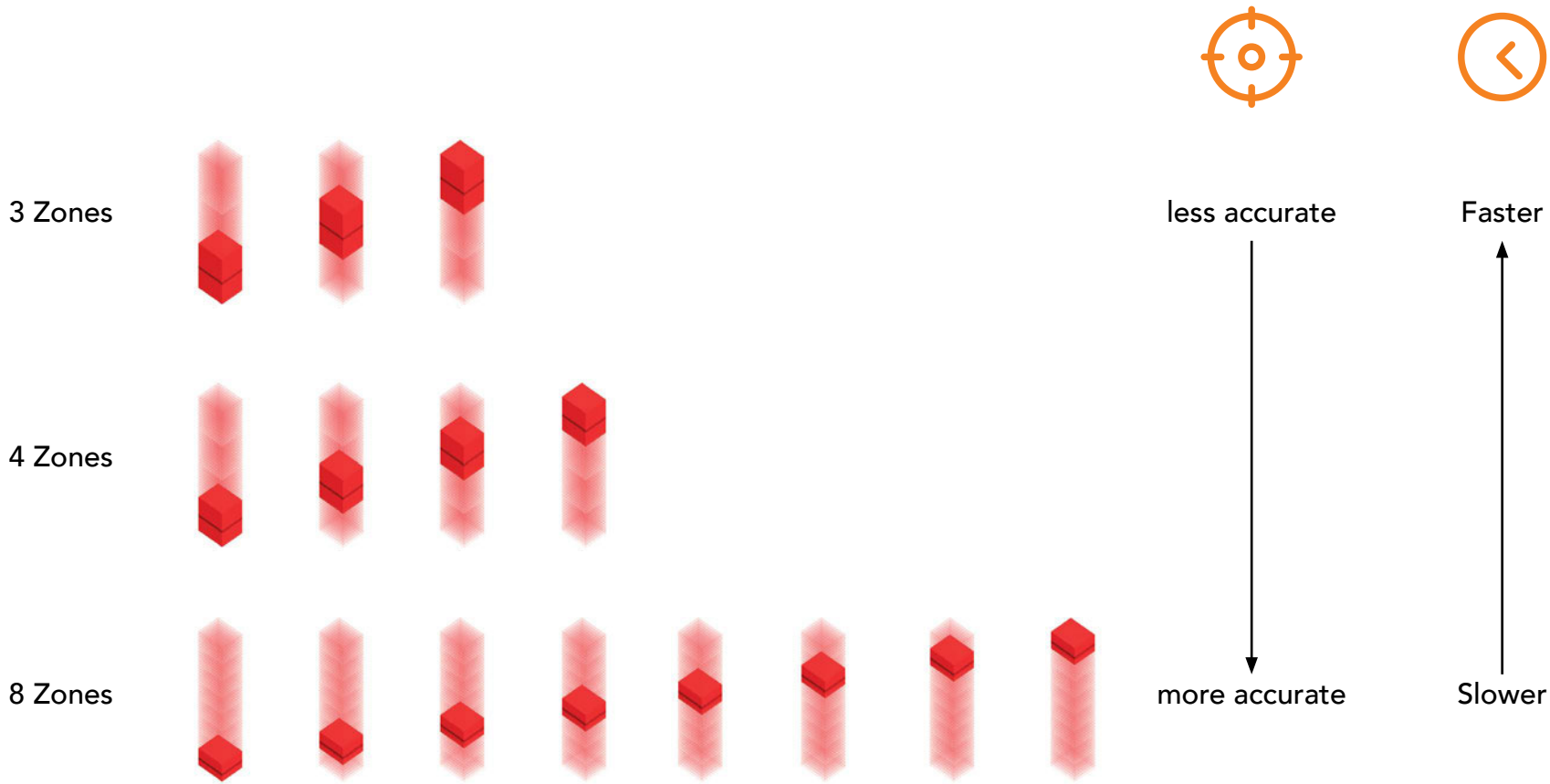
Zone Divisions



Zone Divisions

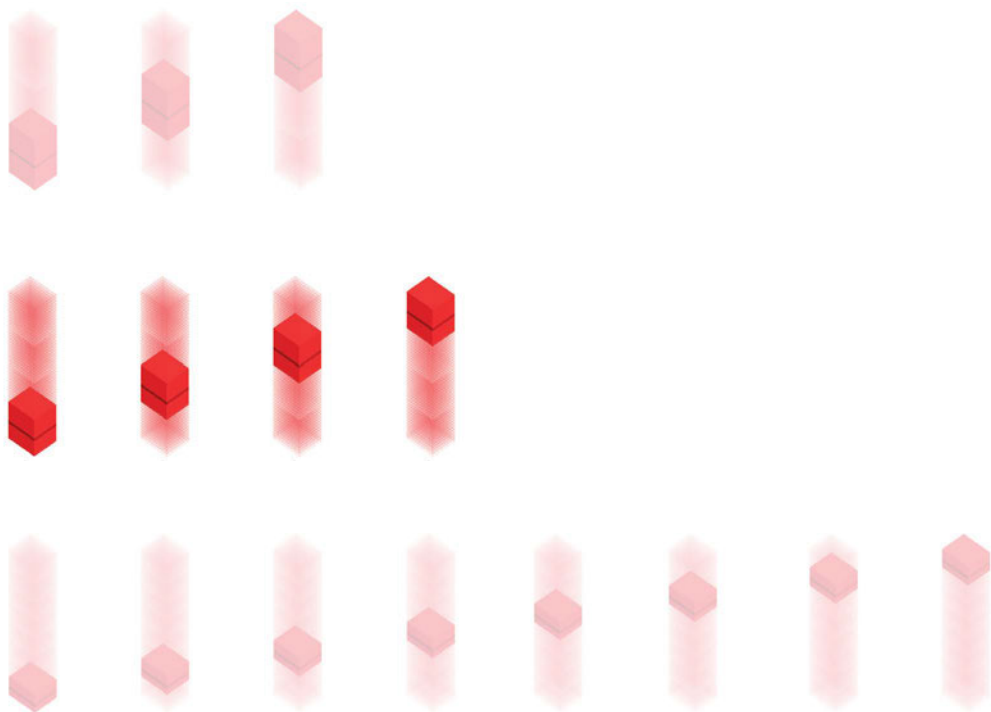


Zone Divisions

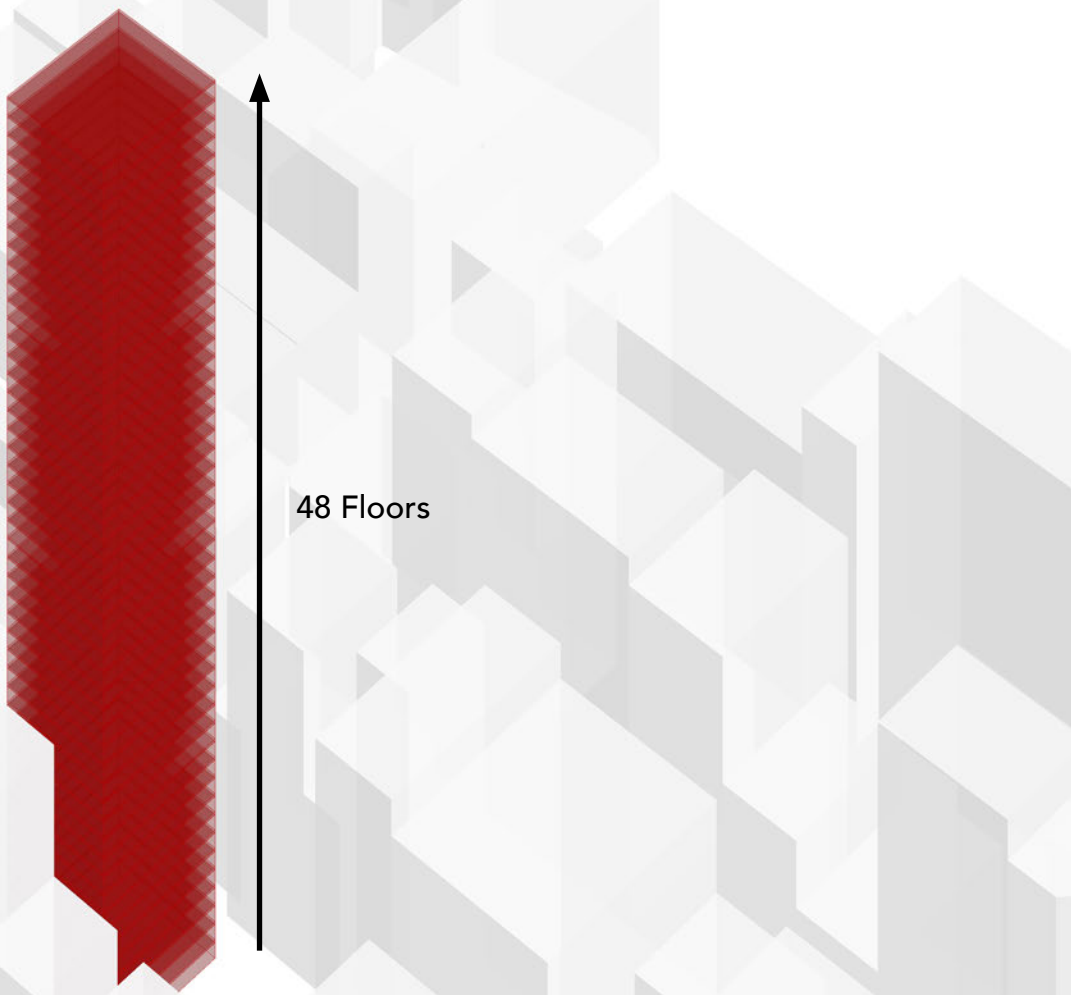


Zone Divisions

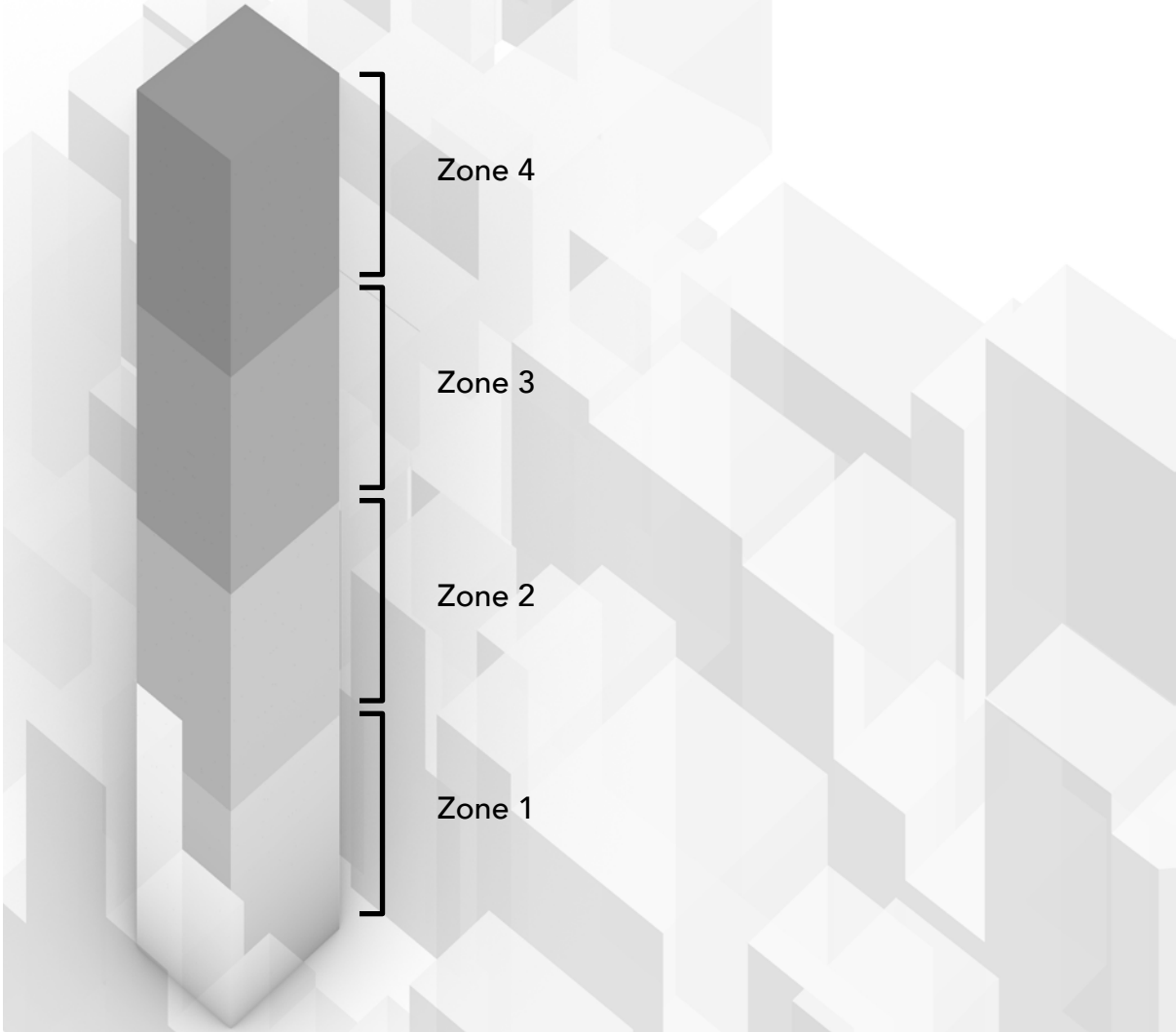
4 Zones



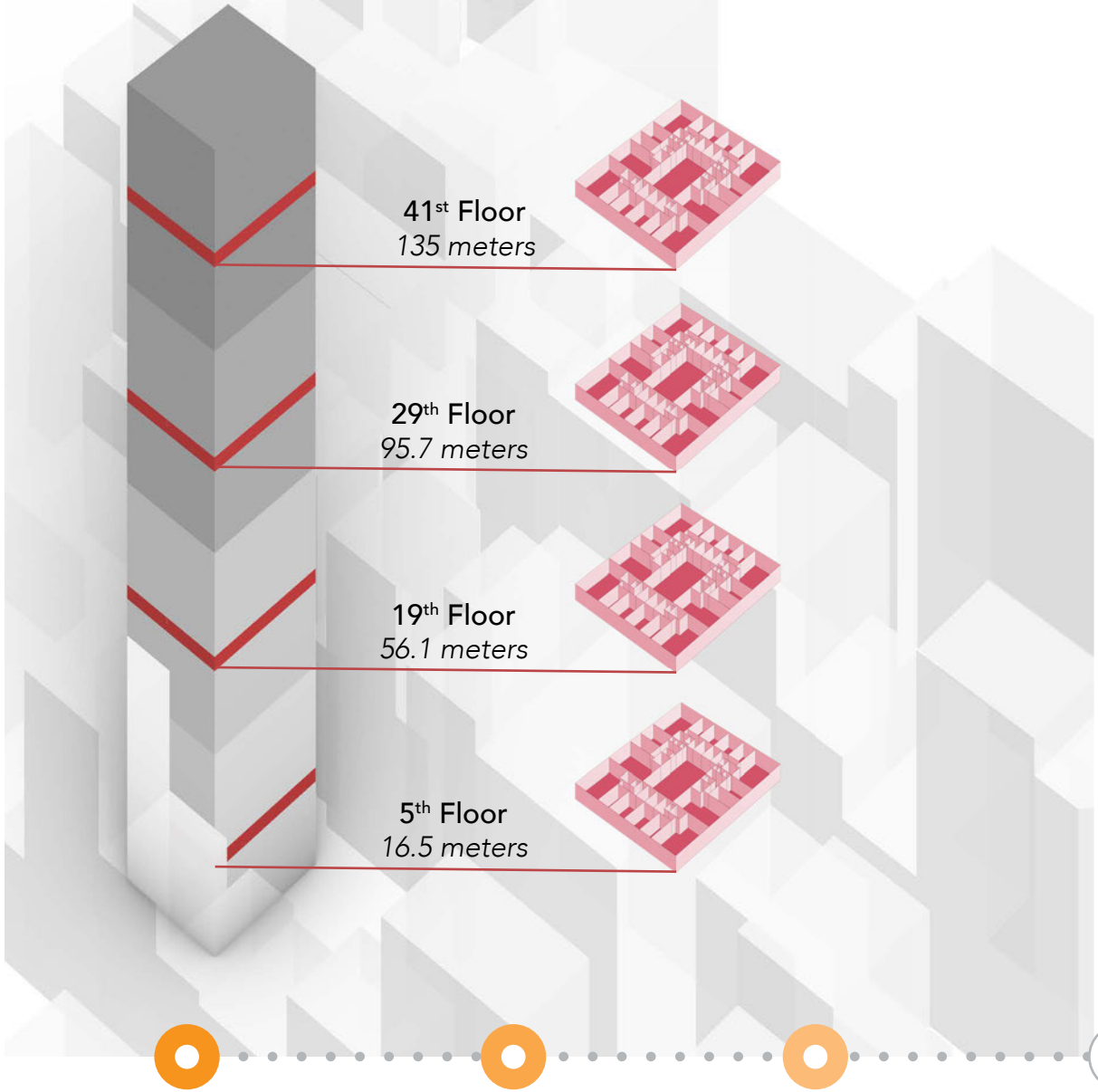
Zone Divisions



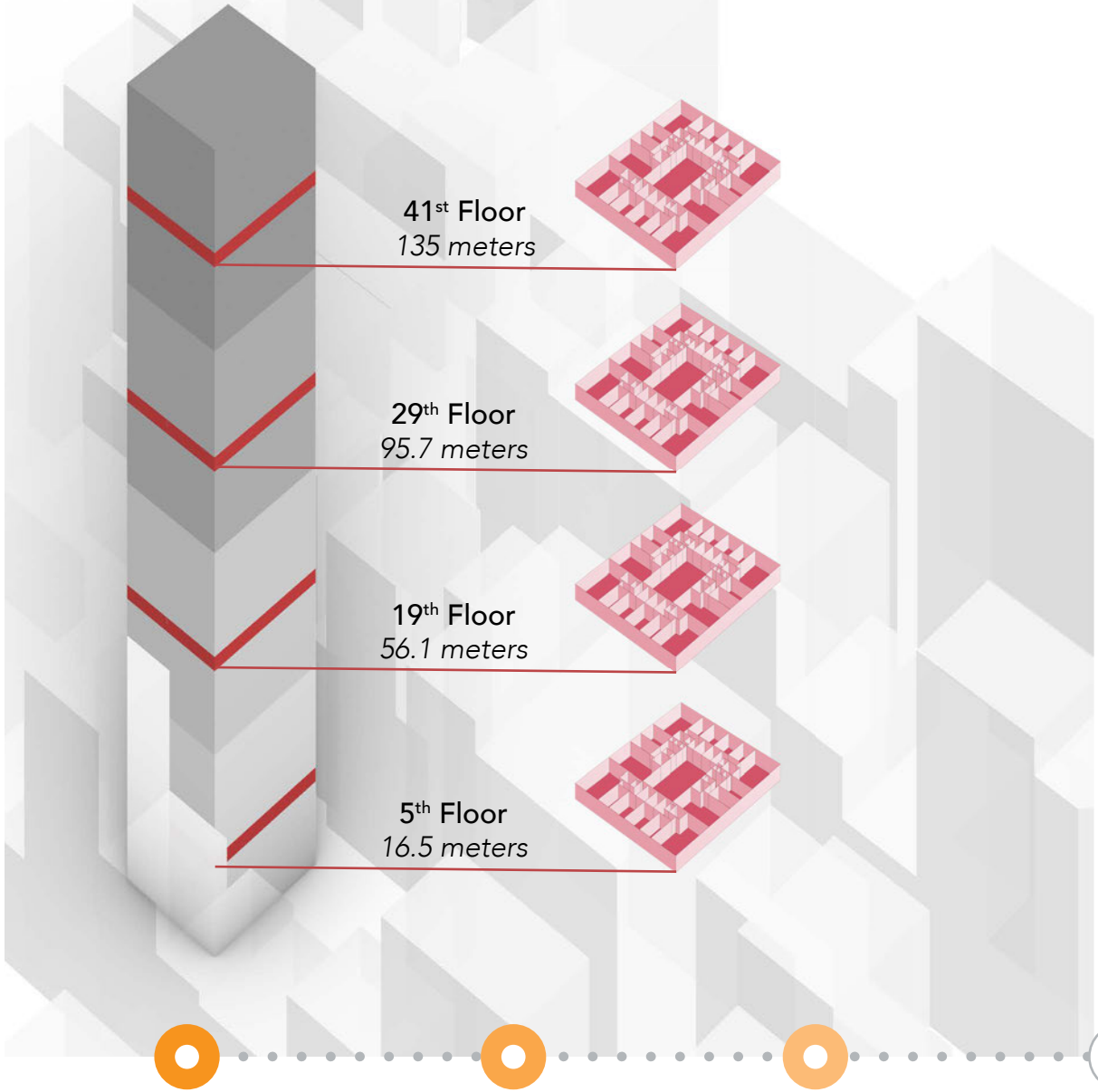
Zone Divisions

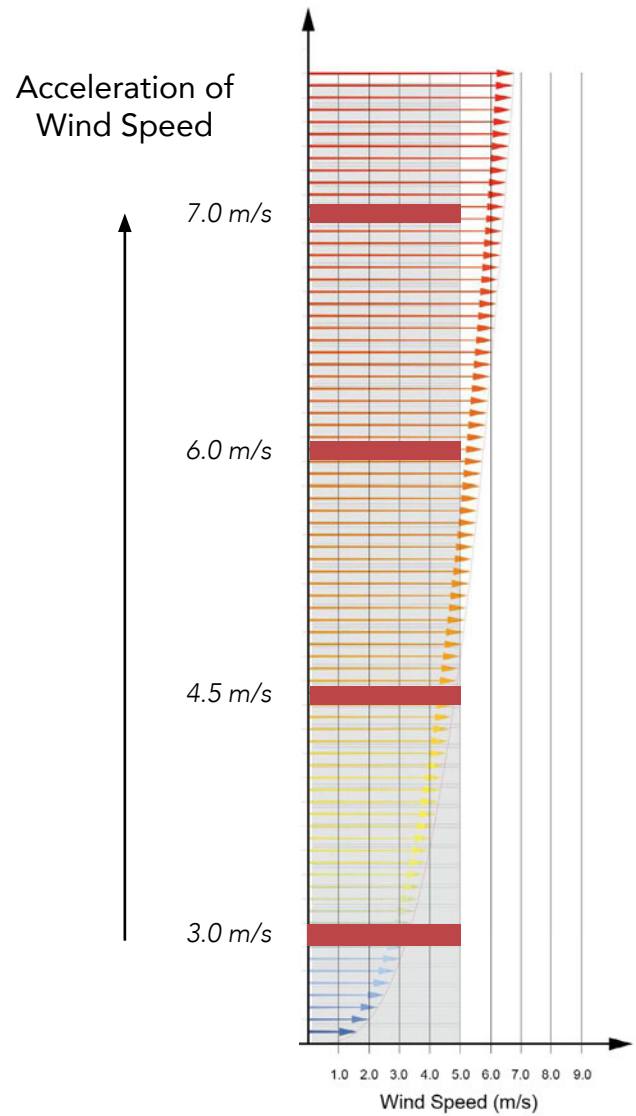


Zone Divisions

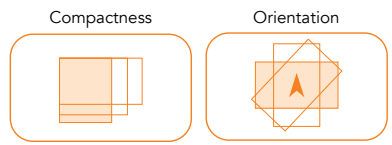


Zone Divisions

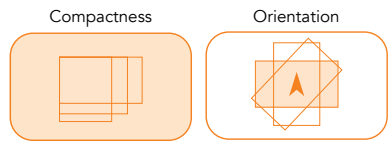




Early Design Stage
Orientation & Compactness

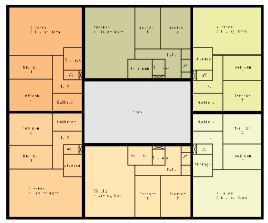


Early Design Stage



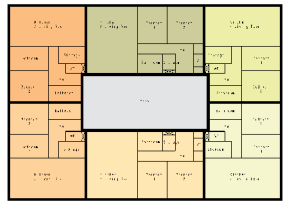
Plan Type 1

SF 1.2



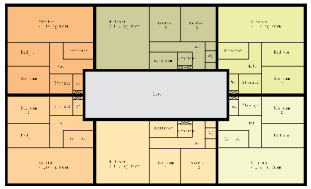
Plan Type 2

SF 1.46

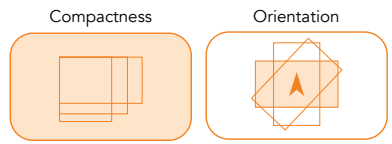


Plan Type 3

SF 1.66

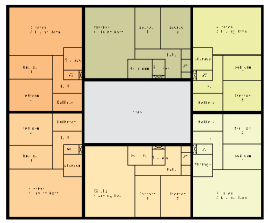


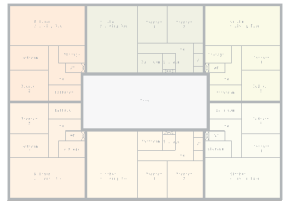
Early Design Stage



Plan Type 1

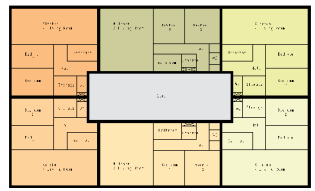
SF 1.2

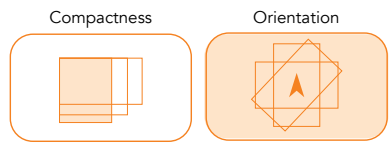




Plan Type 3

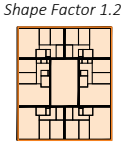
SF 1.66

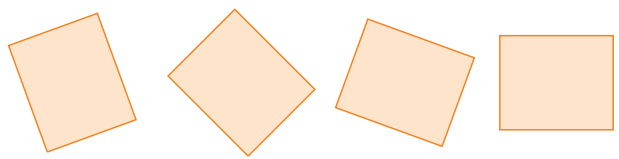




Plan Type 1

Shape Factor 1.2



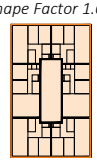


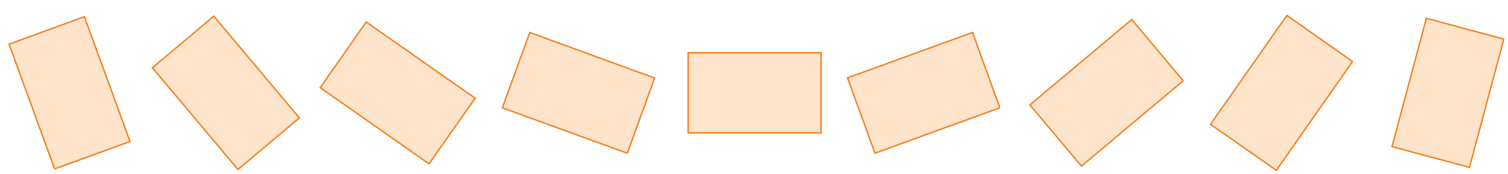
0⁰ 20⁰ 45⁰ 70⁰ 90⁰

N

Plan Type 3

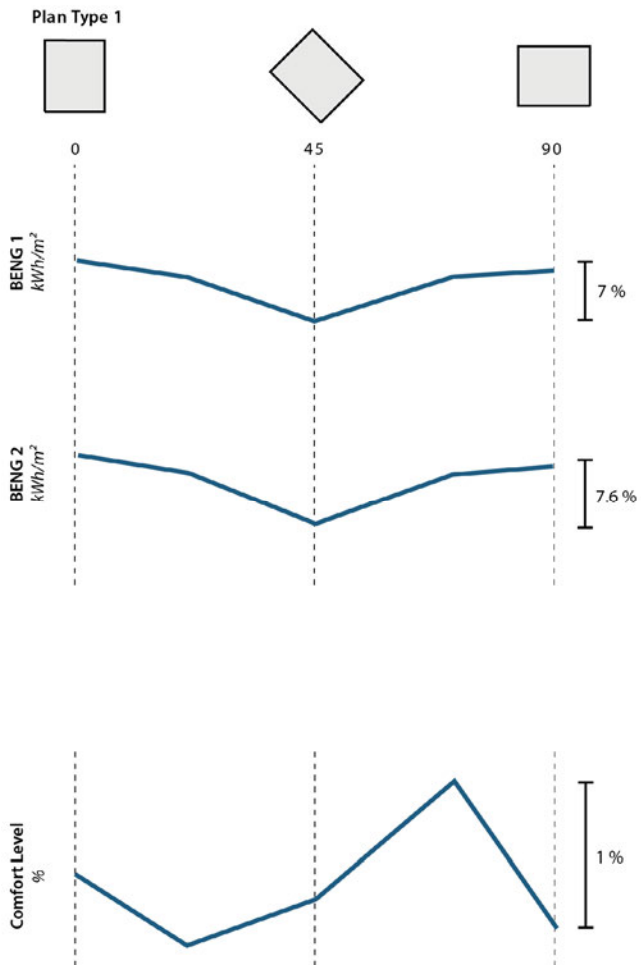
Shape Factor 1.66

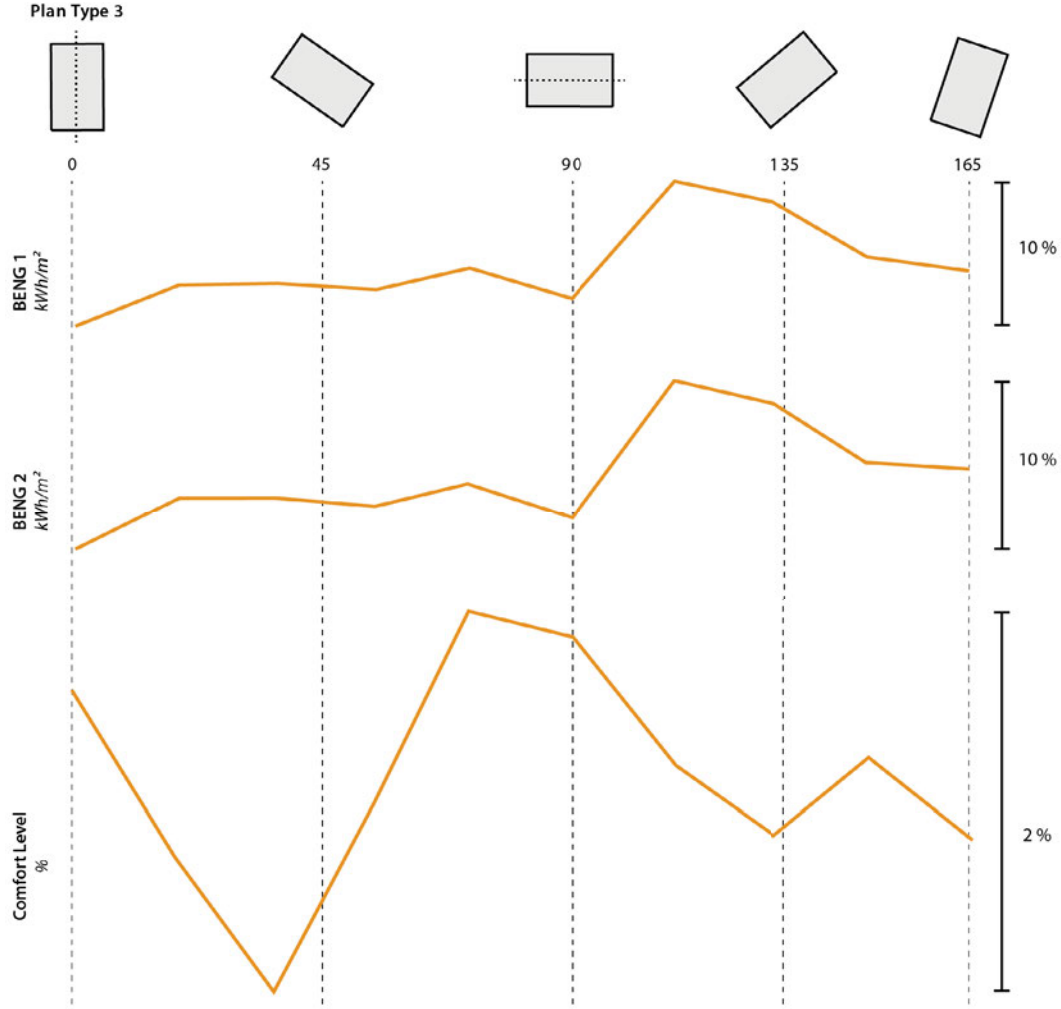




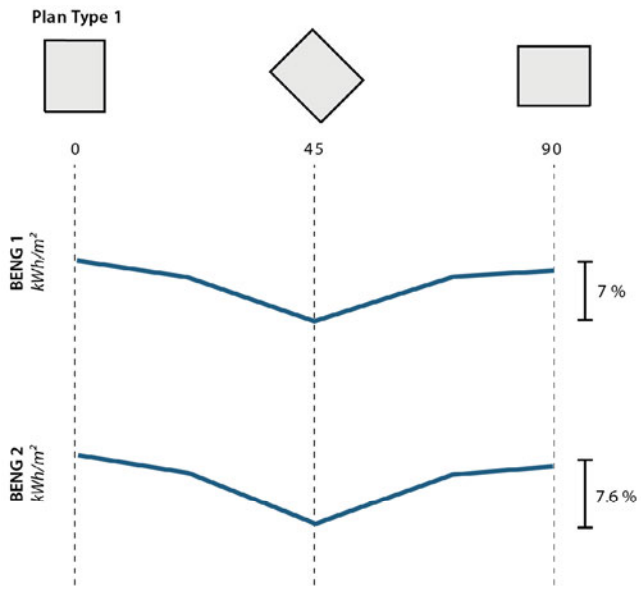
0⁰ 20⁰ 45⁰ 55⁰ 70⁰ 90⁰ 110⁰ 130⁰ 145⁰ 165⁰

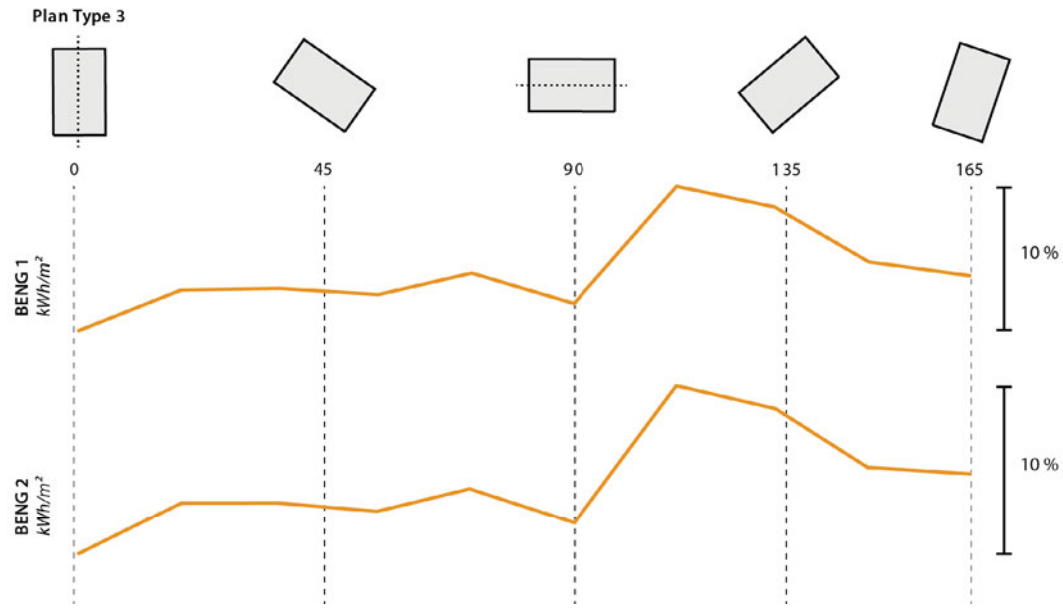
Early Design Stage

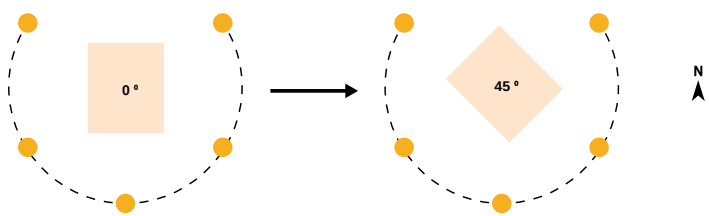




Early Design Stage





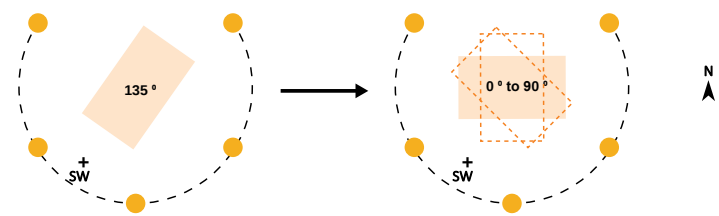


Heat gains mainly **W / S / E**
Heating Loads ↑
Comfort Level ↓

BENG 1 ↑
BENG 2 ↑

Heat gains = **W / S / E / S**
Heating Loads ↓
Comfort Level ↑

BENG 1 ↓
BENG 2 ↓



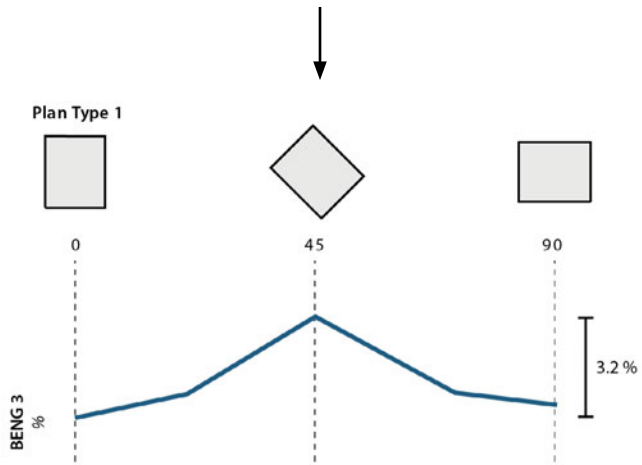
Heat gains on Shortest Side
Heating Loads ↑
Comfort Level ↓

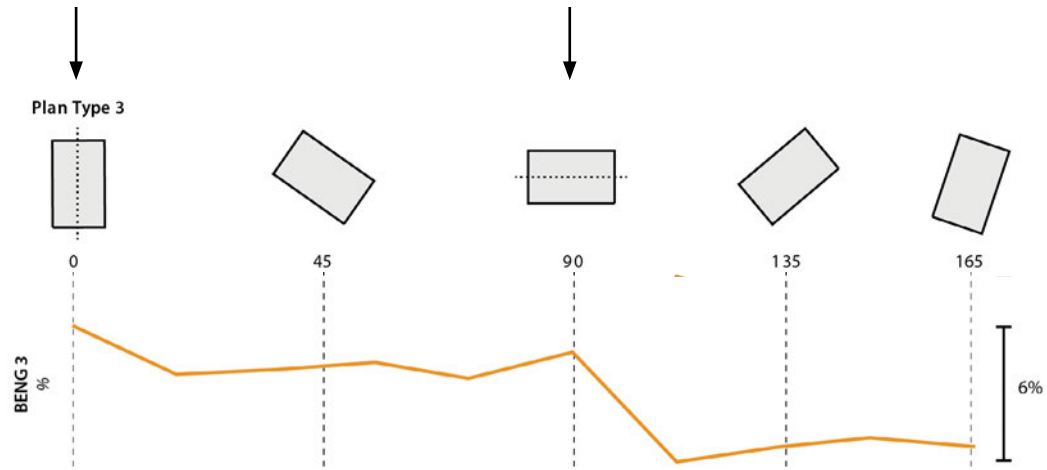
BENG 1 ↑
BENG 2 ↑

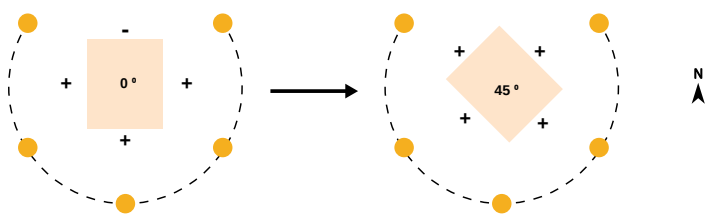
Heat gains Longest Side
Heating Loads ↓
Comfort Level ↑

BENG 1 ↓
BENG 2 ↓

Early Design Stage





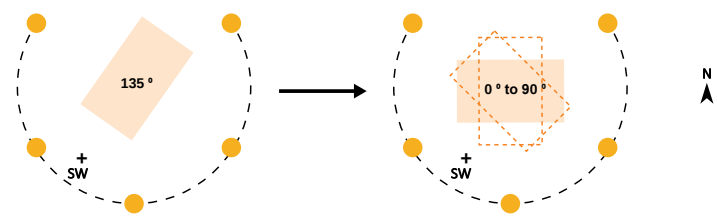


Facade PV panels
W / S / E

BENG 3

Facade PV panels
W / S / E / N

BENG 3

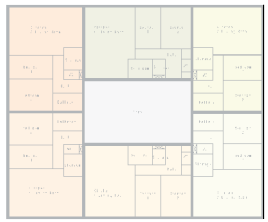


Highest Radiation on
Shortest Side

BENG 3

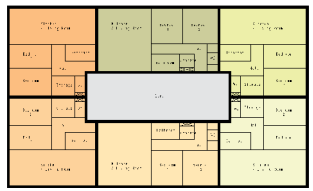
Highest Radiation on
Longest Side

BENG 3



Plan Type 3

SF 1.66

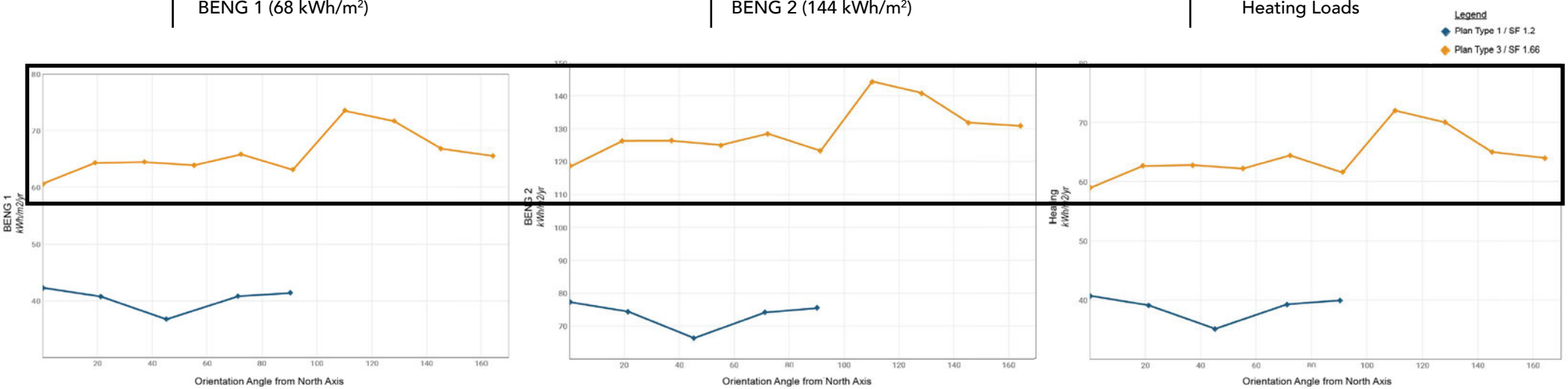


Less Compact

BENG 1 (68 kWh/m²)

BENG 2 (144 kWh/m²)

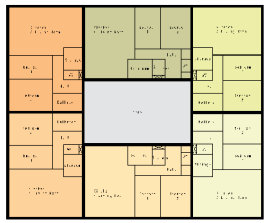
Heating Loads



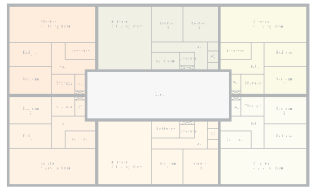
Early Design Stage

Plan Type 1

SF 1.2



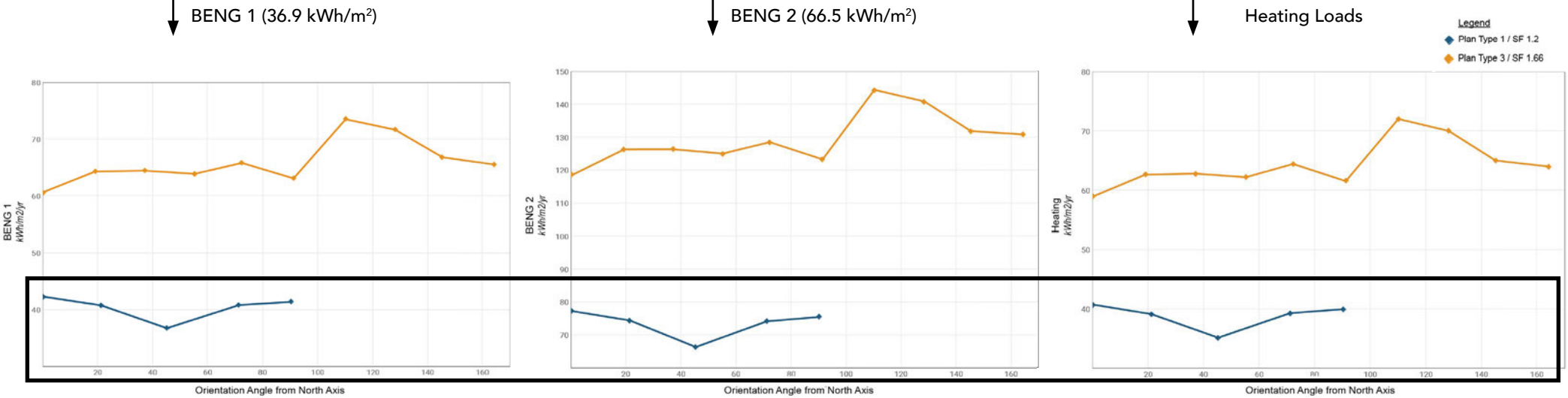
More Compact



BENG 1 (36.9 kWh/m²)

BENG 2 (66.5 kWh/m²)

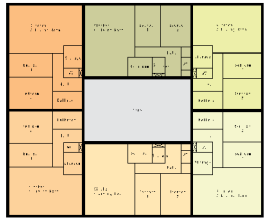
Heating Loads



Early Design Stage

Plan Type 1

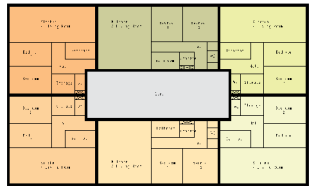
SF 1.2



More Compact

Plan Type 3

SF 1.66

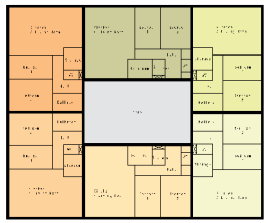


Less Compact

Early Design Stage

Plan Type 1

SF 1.2



More Compact

= floor surface area (698 m2)

= space/function area

= Identical layout

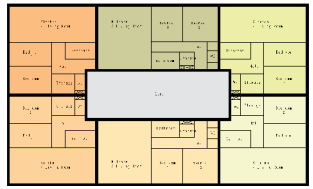
= Identical distribution of the rooms

= WWR 40%

≠ Compactness

Plan Type 3

SF 1.66

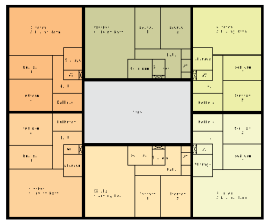


Less Compact

Early Design Stage

Plan Type 1

SF 1.2



More Compact

= *floor surface area (698 m2)*

= *space/function area*

= *Identical layout*

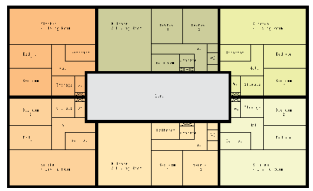
= *Identical distribution of the rooms*

= *WWR 40%*

≠ Compactness

Plan Type 3

SF 1.66



Less Compact

↓ Envelope Area (16752 m²)

↓ Glazing Area (6701 m²)

↓ Heat Transfer

↓ Cooling / Heating

↑ Envelope Area (17280 m²)

↑ Glazing Area (6912 m²)

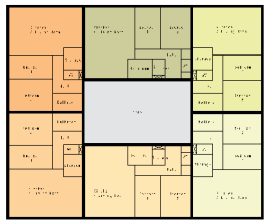
↑ Heat Transfer

↑ Cooling / Heating

Early Design Stage

Plan Type 1

SF 1.2



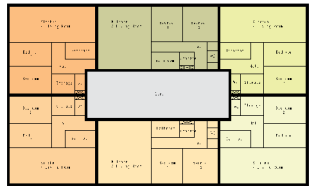
More Compact

≠ Compactness

3.2 %

Plan Type 3

SF 1.66

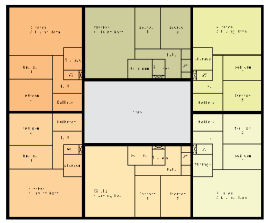


Less Compact

Early Design Stage

Plan Type 1

SF 1.2



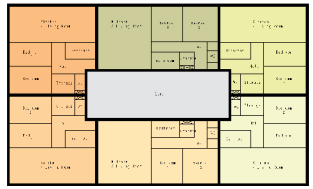
More Compact

≠ *Compactness*

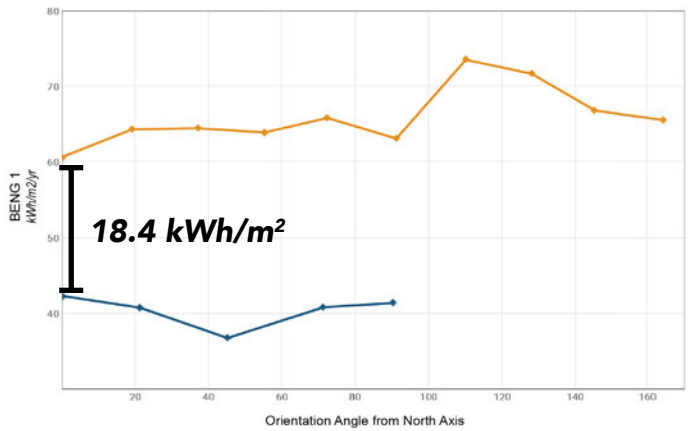
3.2 %

Plan Type 3

SF 1.66



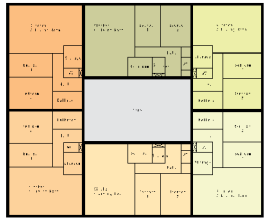
Less Compact



Early Design Stage

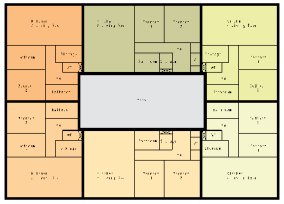
Plan Type 1

SF 1.2



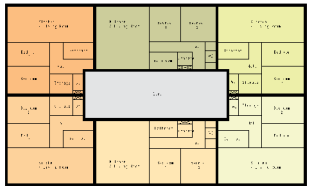
Plan Type 2

SF 1.46



Plan Type 3

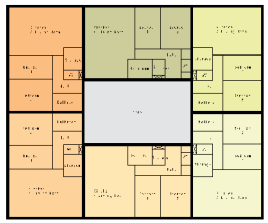
SF 1.66



Early Design Stage

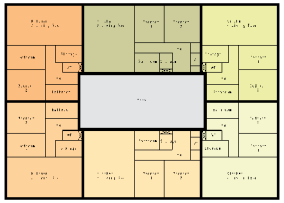
Plan Type 1

SF 1.2



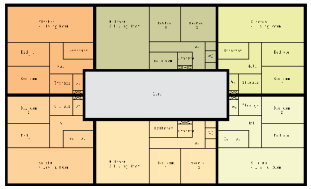
Plan Type 2

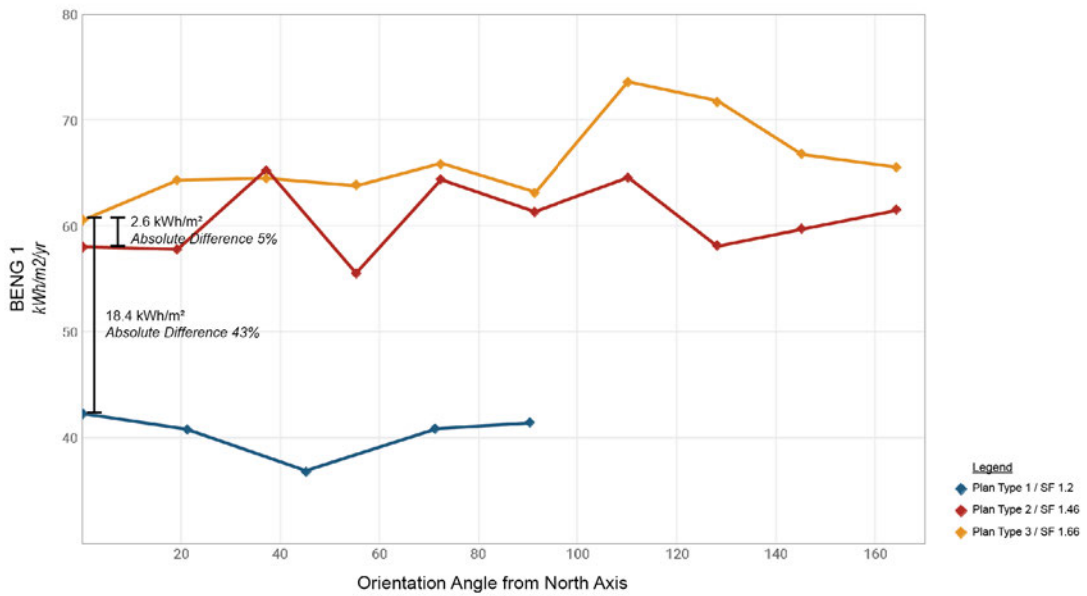
SF 1.46



Plan Type 3

SF 1.66

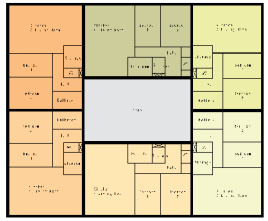


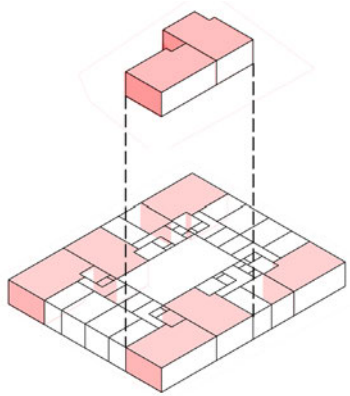


Early Design Stage

Plan Type 1

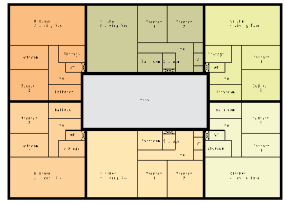
SF 1.2

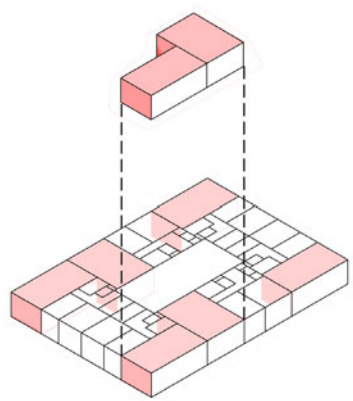




Plan Type 2

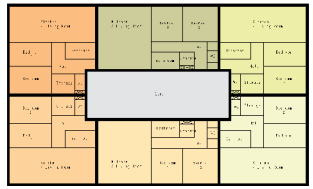
SF 1.46

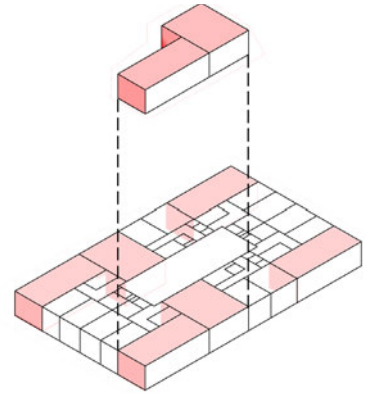




Plan Type 3

SF 1.66



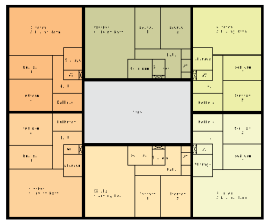


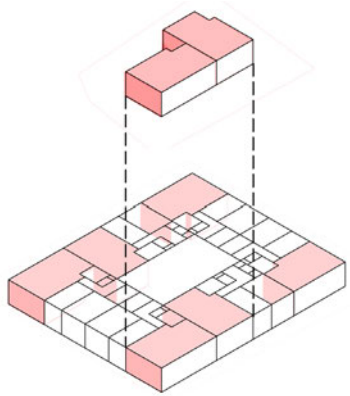
Honeybee Plug-in Modeling

Early Design Stage

Plan Type 1

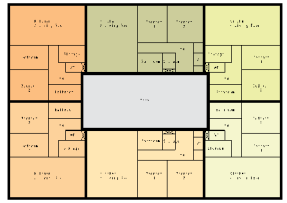
SF 1.2

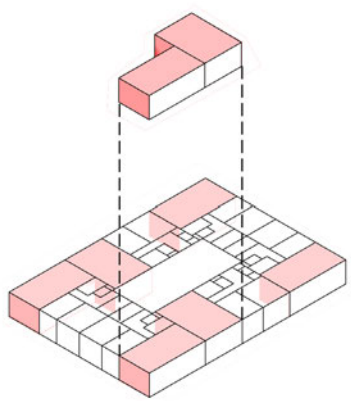




Plan Type 2

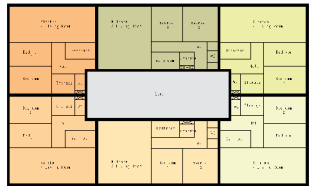
SF 1.46

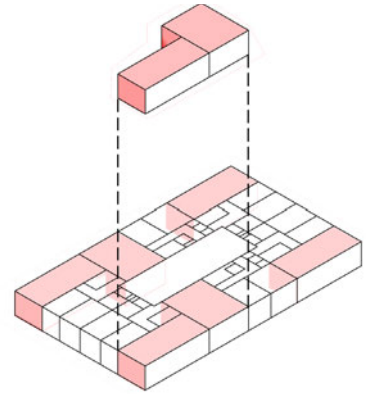


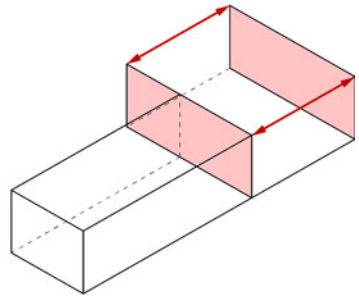


Plan Type 3

SF 1.66





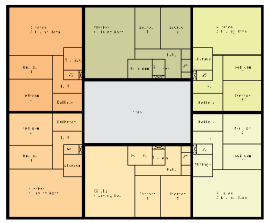


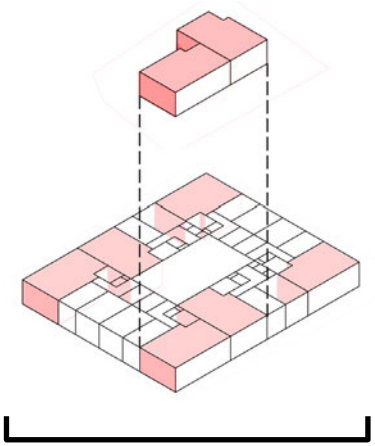
same division between surfaces
of adjacent zones

Early Design Stage

Plan Type 1

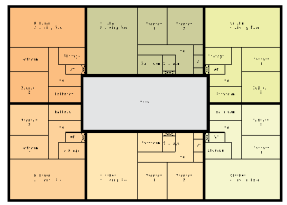
SF 1.2

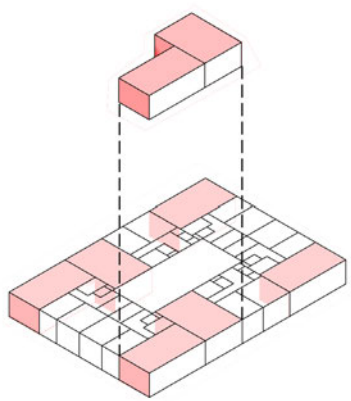




Plan Type 2

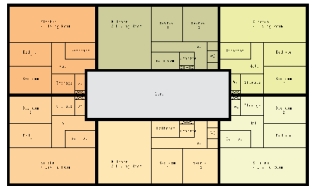
SF 1.46

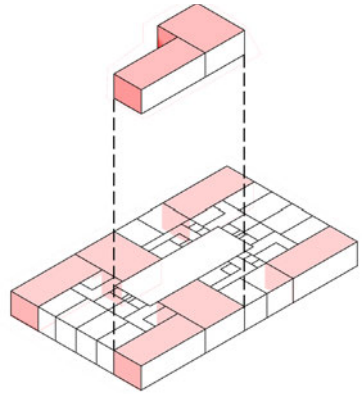


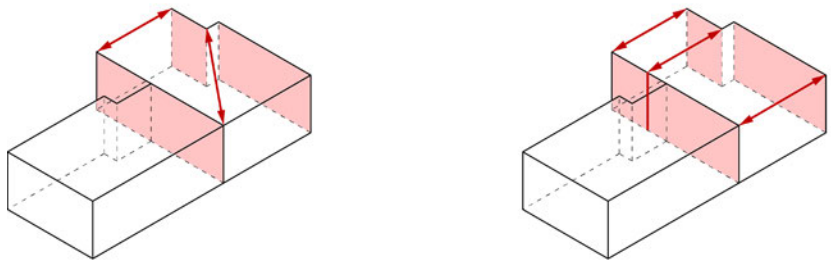


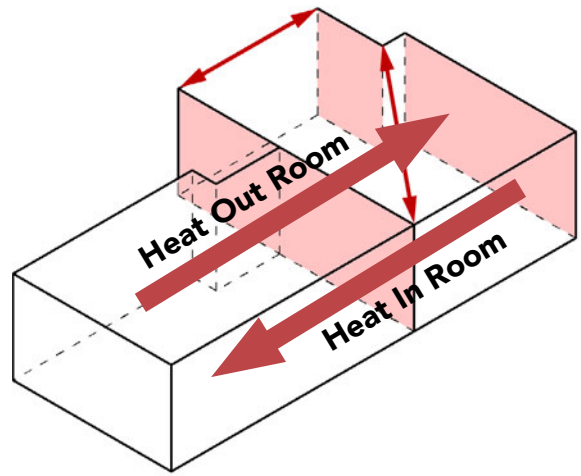
Plan Type 3

SF 1.66



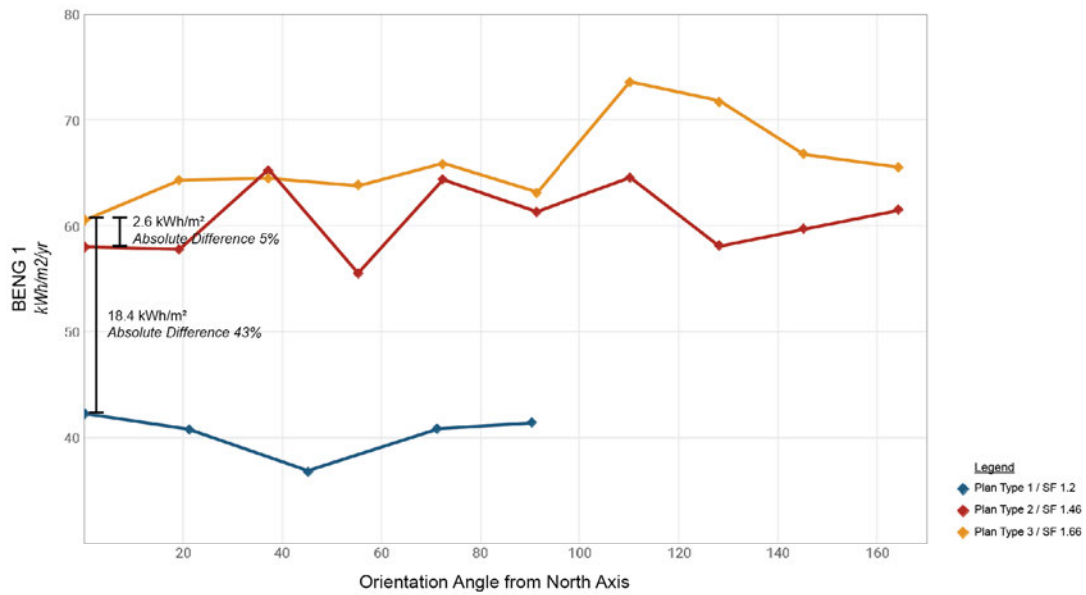


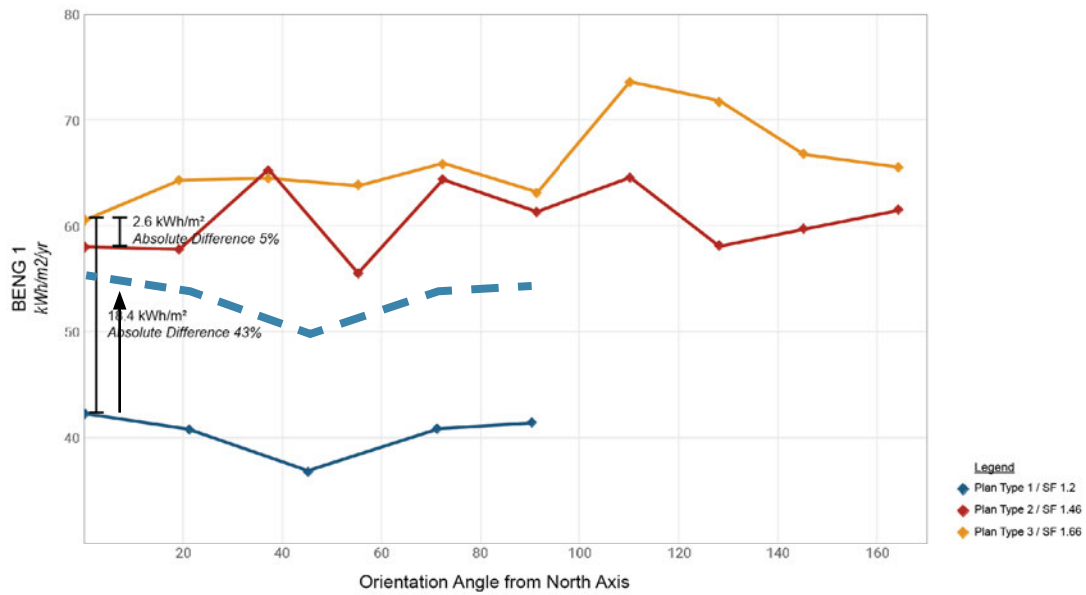




Heat Leaving Room ≠ Heat Entering Room

Imbalanced Heat Flux

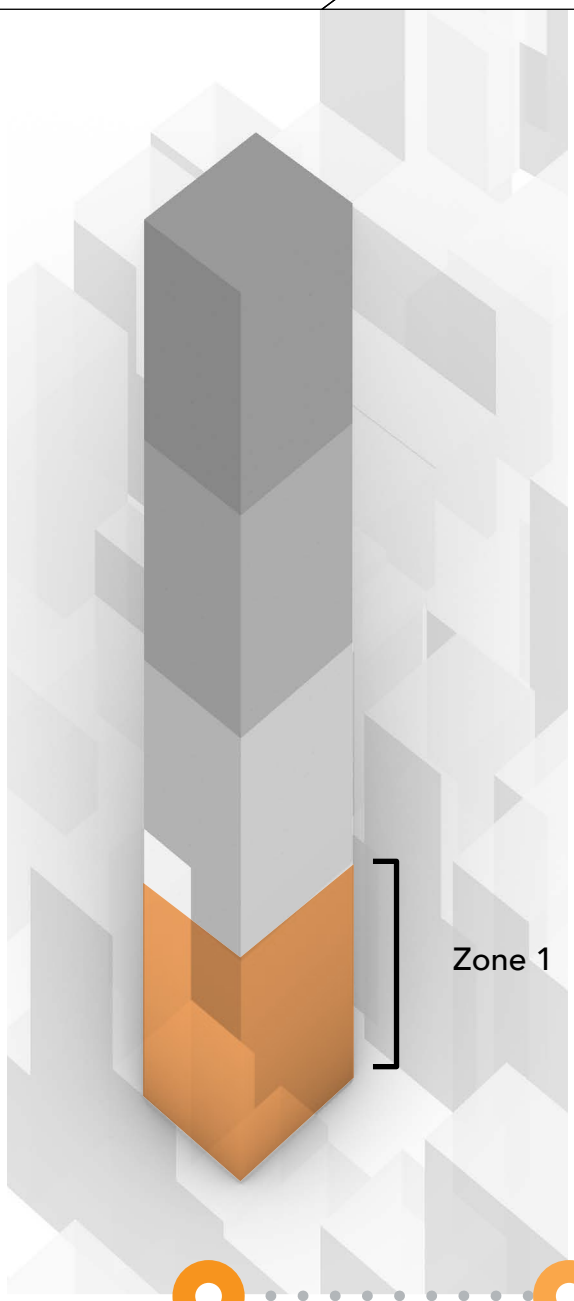

80
70
60
50
40
BENG 1
kWh/m2/yr
2.6 kWh/m²
Absolute Difference 5%
18.4 kWh/m²
Absolute Difference 43%
20
40
60
80
100
120
140
160
Orientation Angle from North Axis
Legend
Plan Type 1 / SF 1.2
Plan Type 2 / SF 1.46
Plan Type 3 / SF 1.66

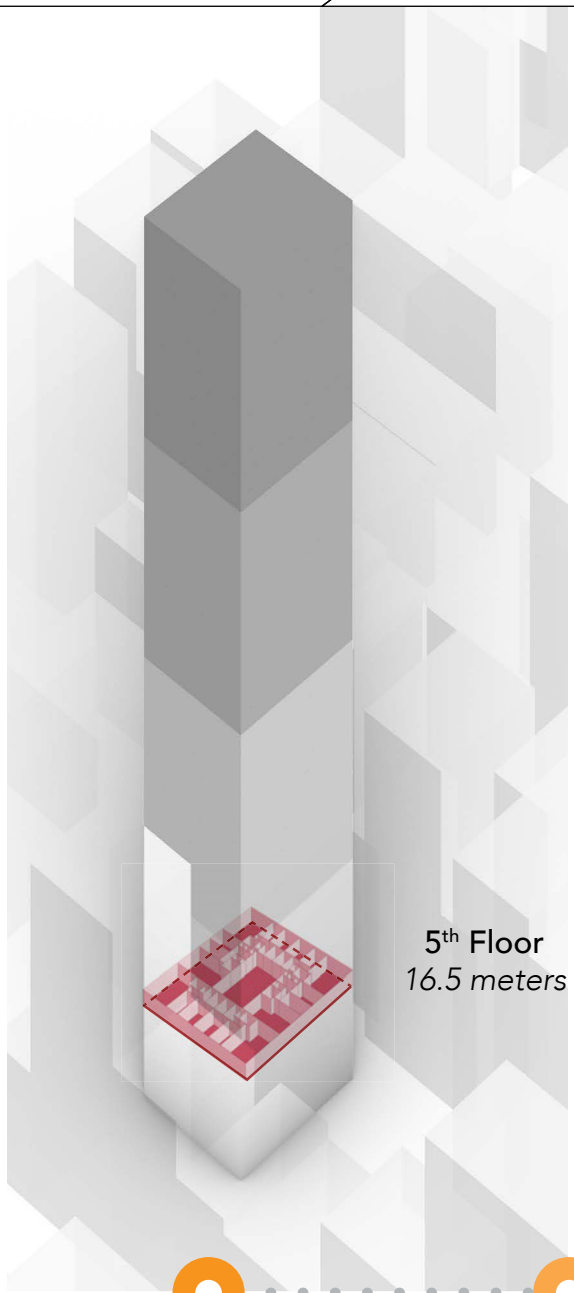

80
70
60
50
40
BENG 1
kWh/m2/yr
2.6 kWh/m²
Absolute Difference 5%
14.4 kWh/m²
Absolute Difference 43%
20
40
60
80
100
120
140
160
Orientation Angle from North Axis
Legend
Plan Type 1 / SF 1.2
Plan Type 2 / SF 1.46
Plan Type 3 / SF 1.66

Facade Performance under Different Surrounding Height

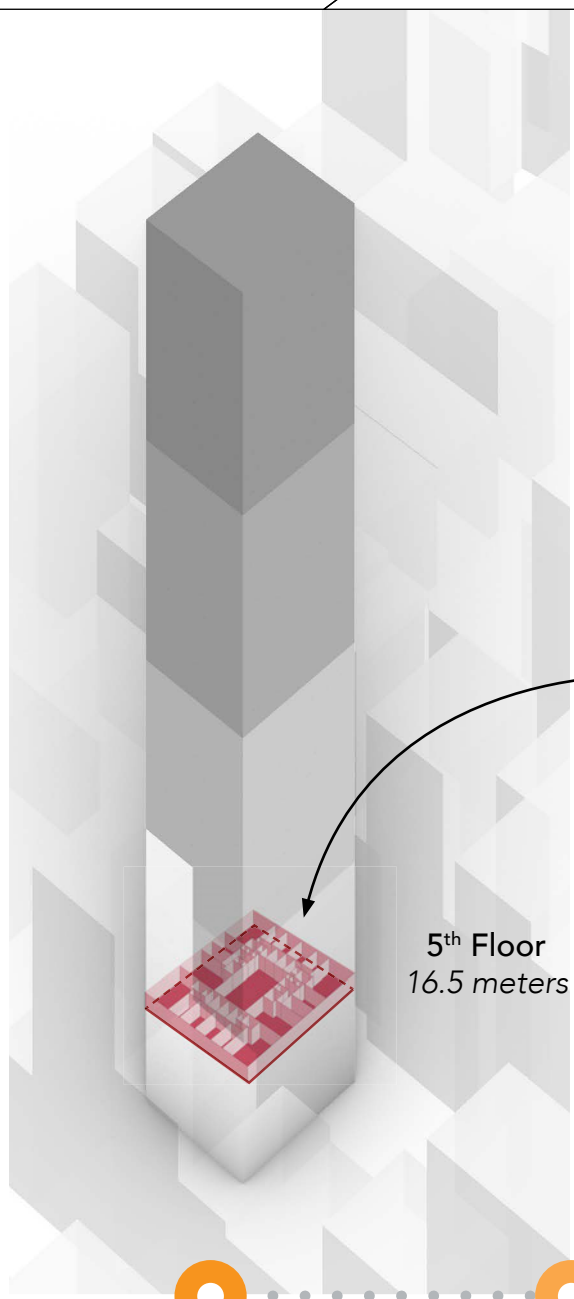
Facade Performance under Different Surrounding Height

Low-Rise Context → *Mid-Rise Context* → *High-Rise Context*

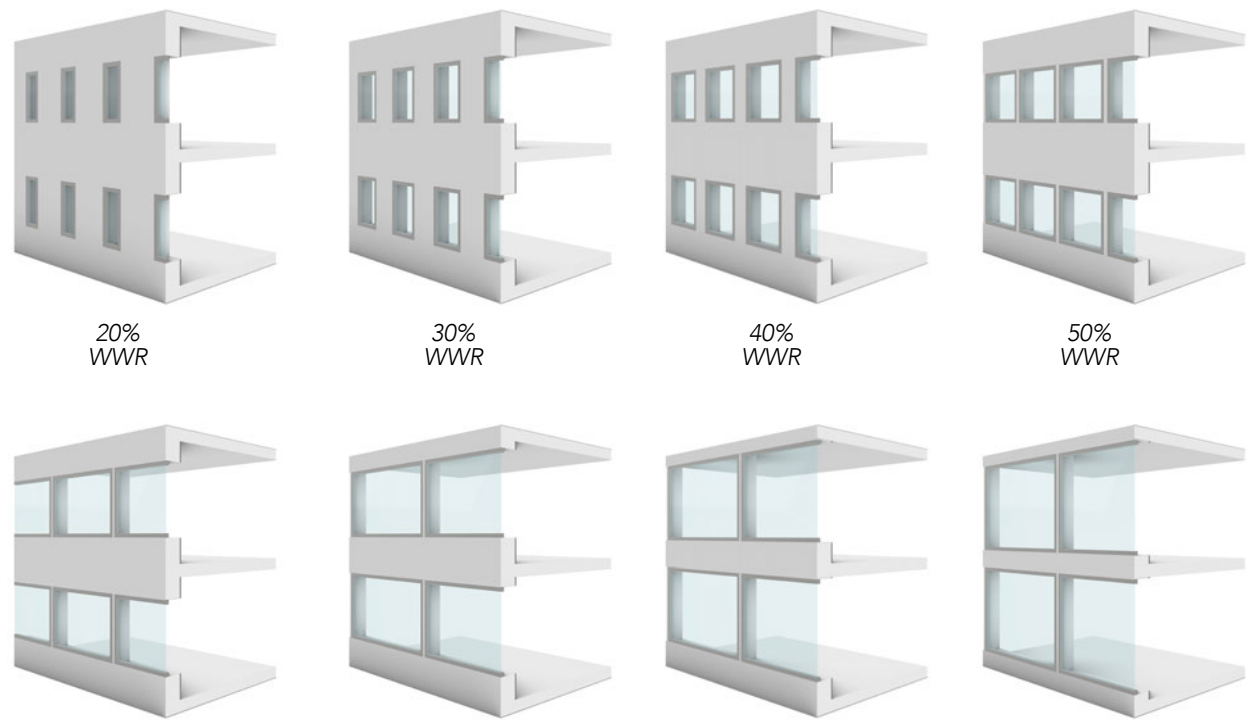

Zone 1



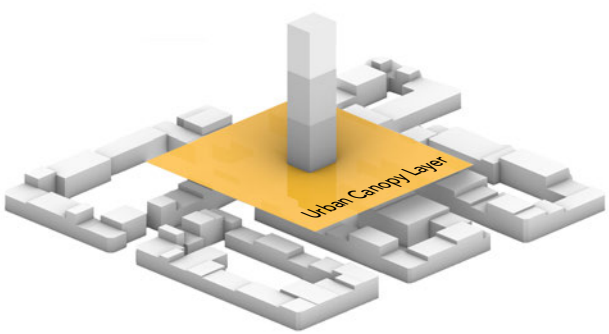
5th Floor
16.5 meters



Window-to-Wall Ratio

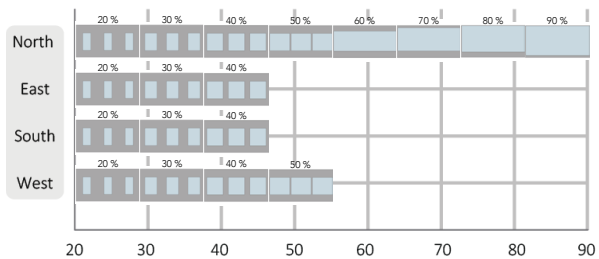


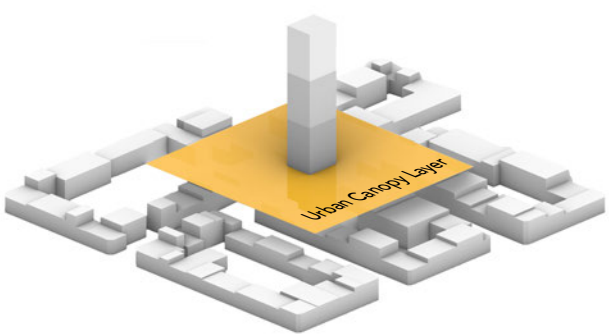
Optimal Variable Ranges of WWR



Low-Rise Context

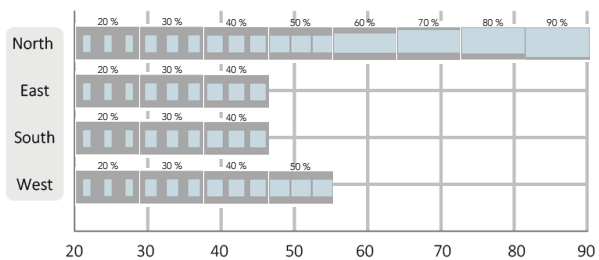
Optimal Variable Ranges of WWR

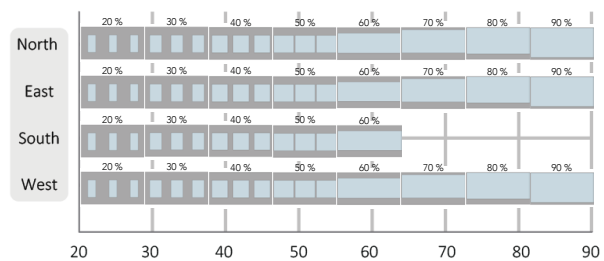


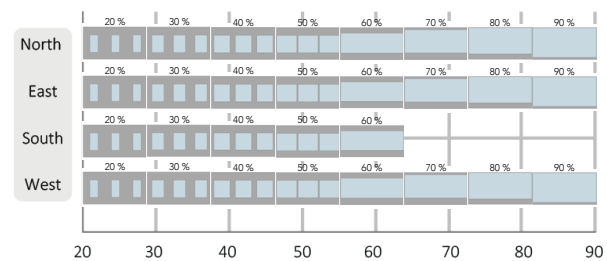


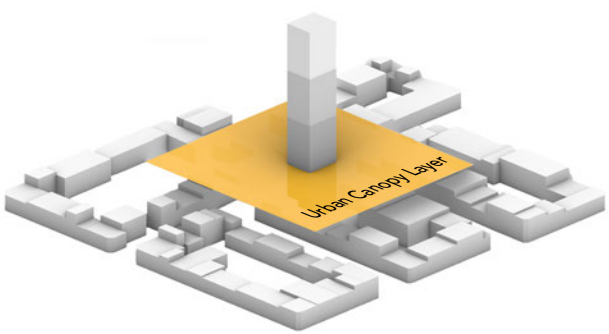
Low-Rise Context

Optimal Variable Ranges of WWR

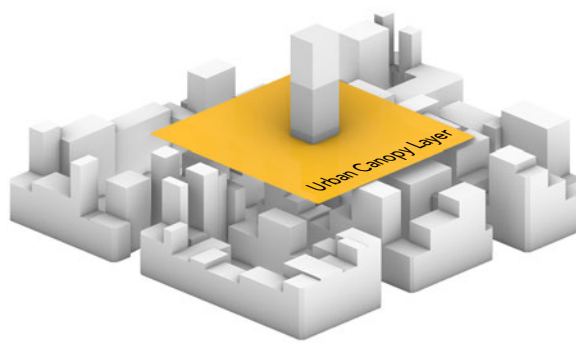




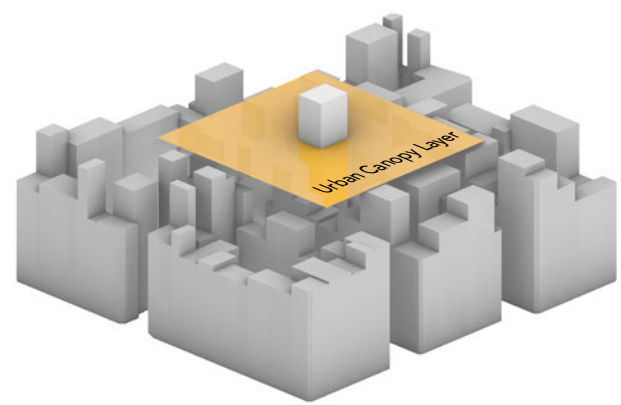




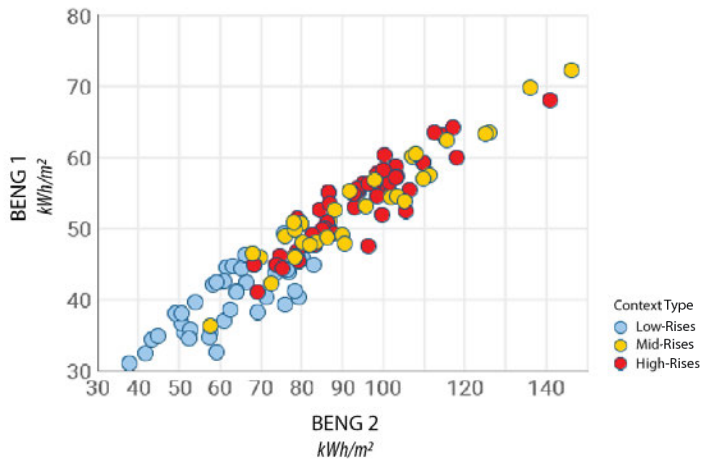
Low-Rise Context

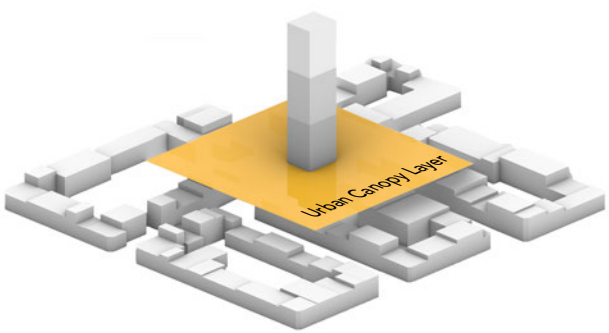


Mid-Rise Context

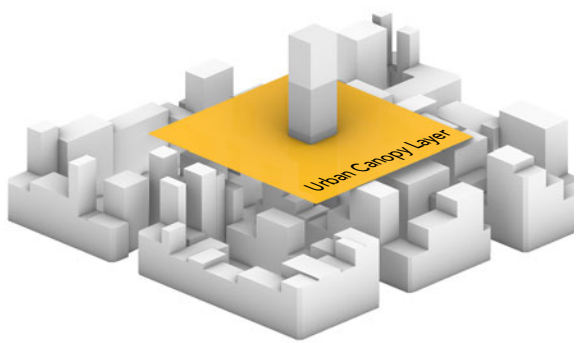


High-Rise Context





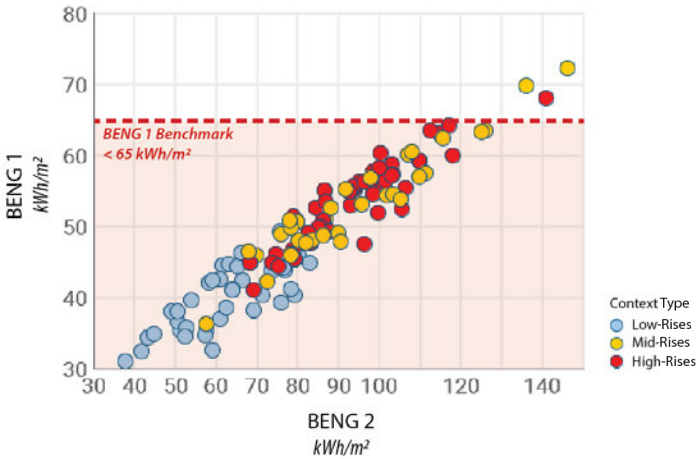
Low-Rise Context

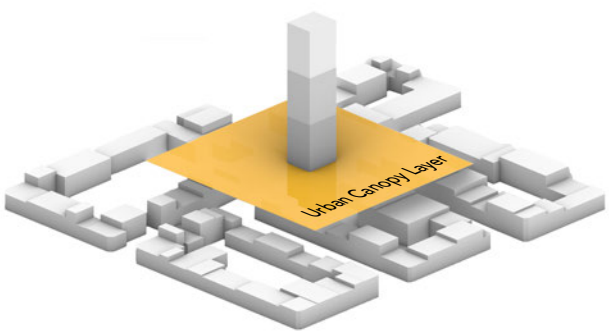


Mid-Rise Context

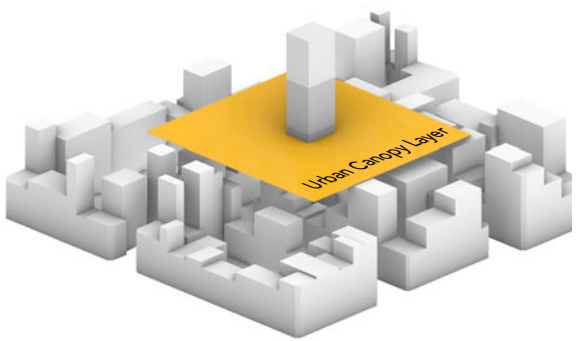
High-Rise Context

BENG 1 Energy Demand

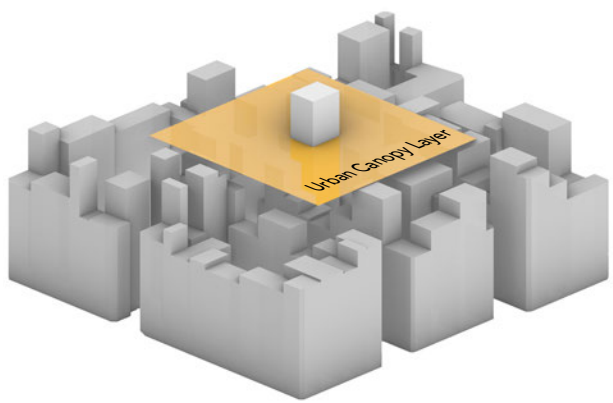




Low-Rise Context

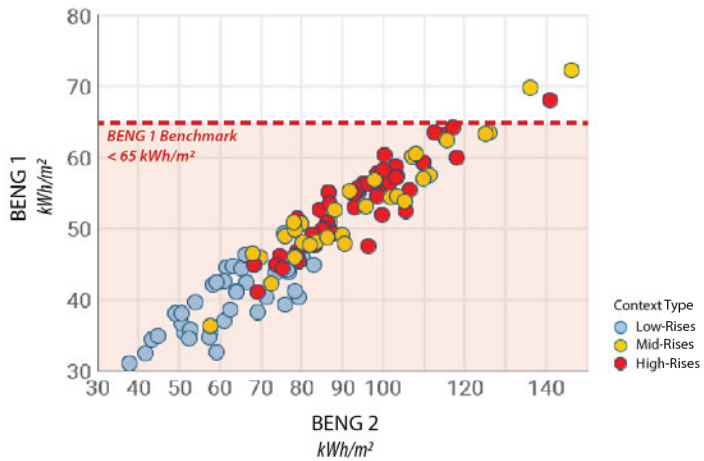


Mid-Rise Context

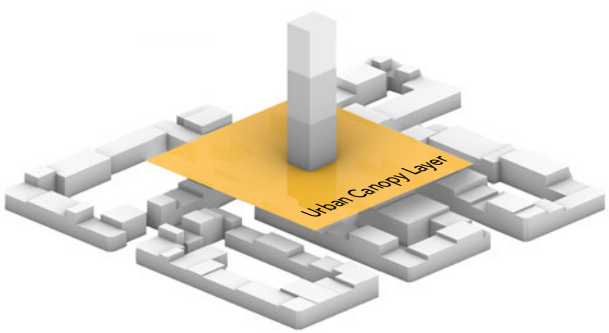


High-Rise Context

BENG 1 Energy Demand

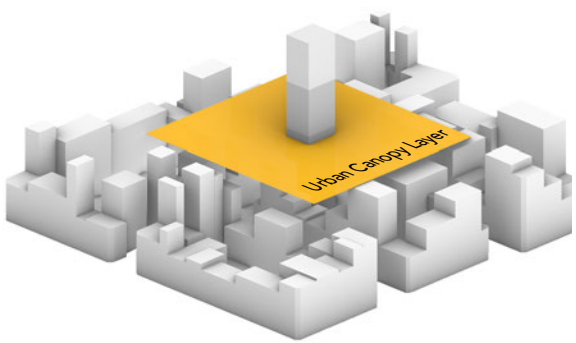


BENG 1 ✓



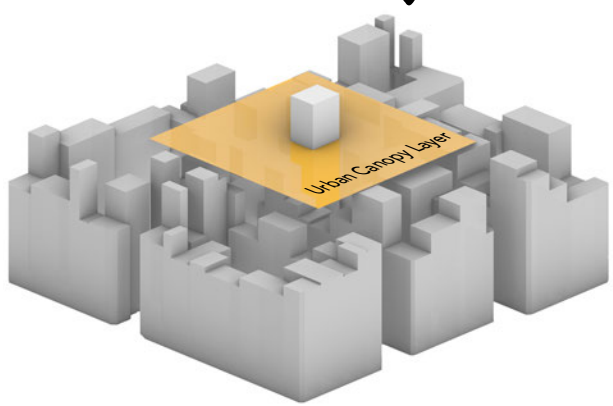
Low-Rise Context

BENG 1 ✓



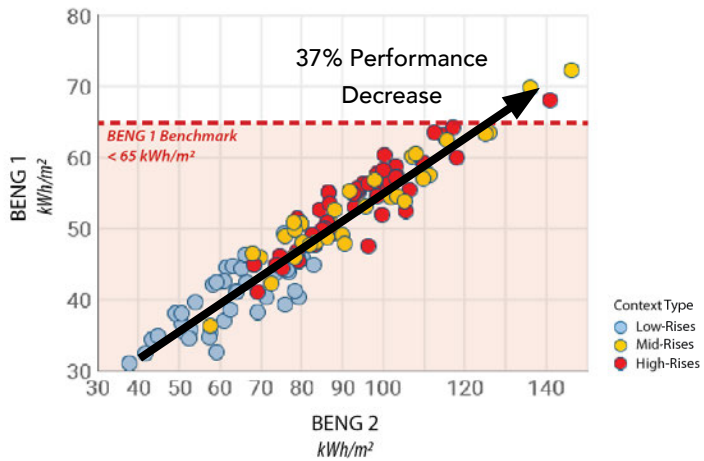
Mid-Rise Context

BENG 1 ✓

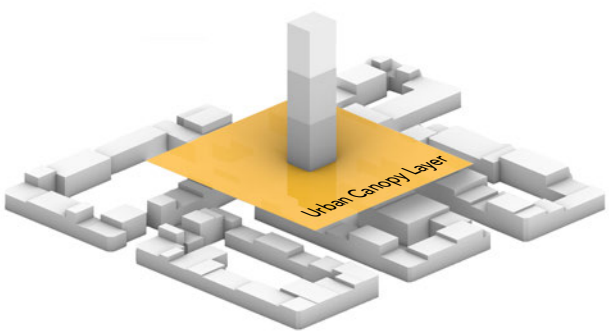


High-Rise Context

BENG 1 Energy Demand

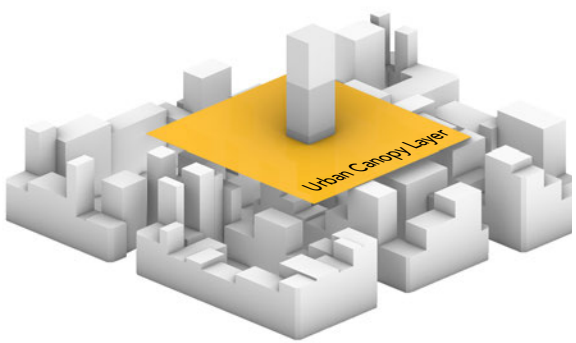


BENG 1 ✓



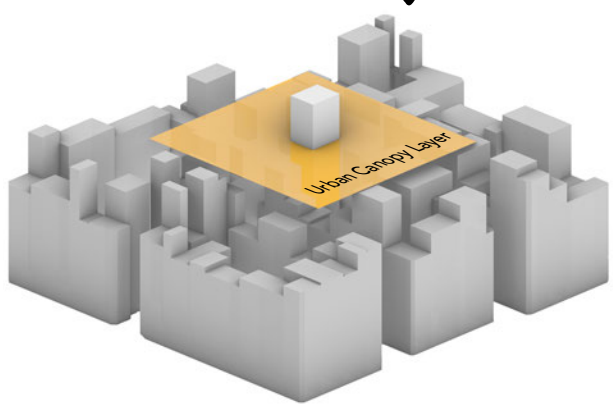
Low-Rise Context

BENG 1 ✓



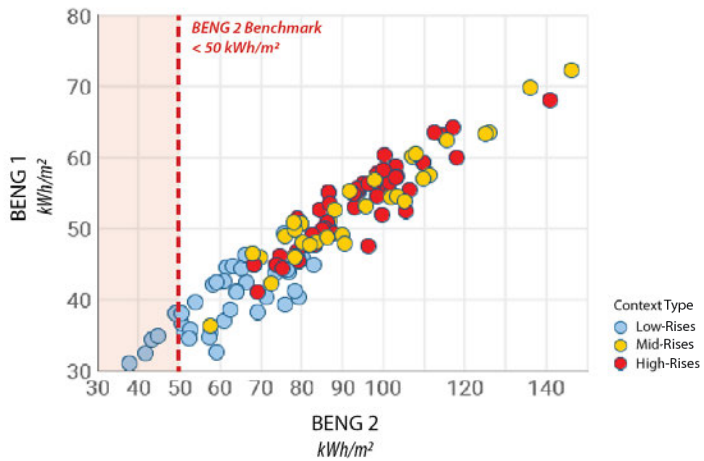
Mid-Rise Context

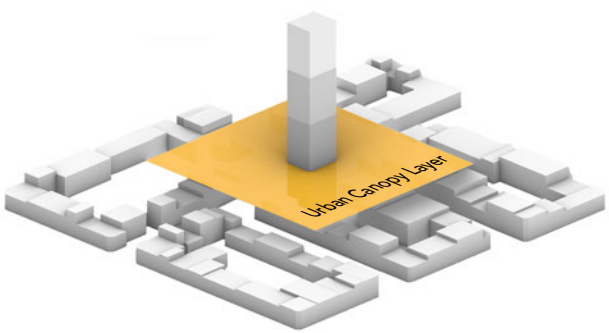
BENG 1 ✓



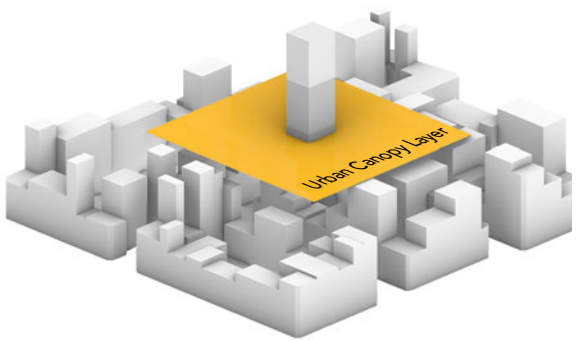
High-Rise Context

BENG 2 Primary Fossil Usage

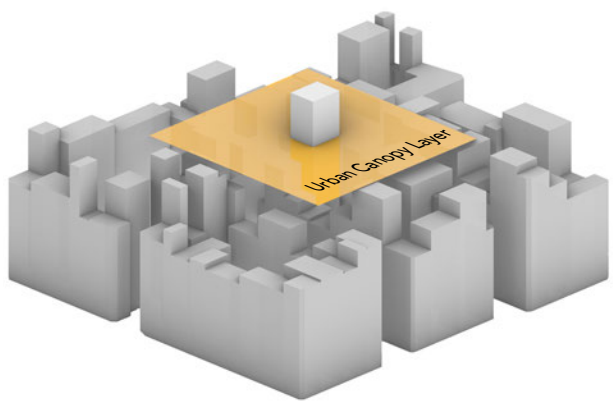




Low-Rise Context

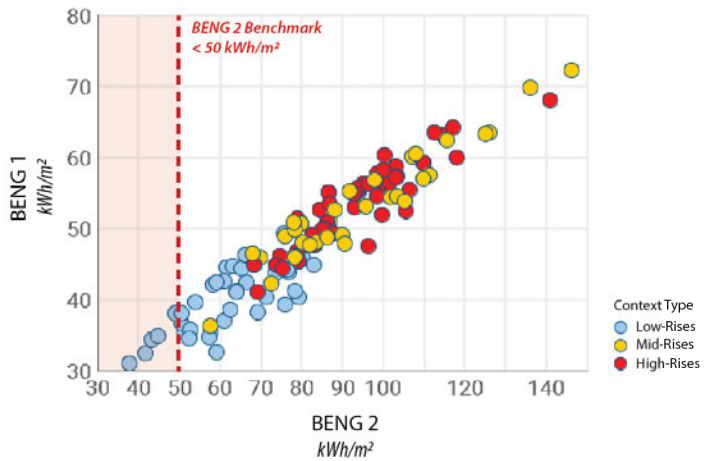


Mid-Rise Context

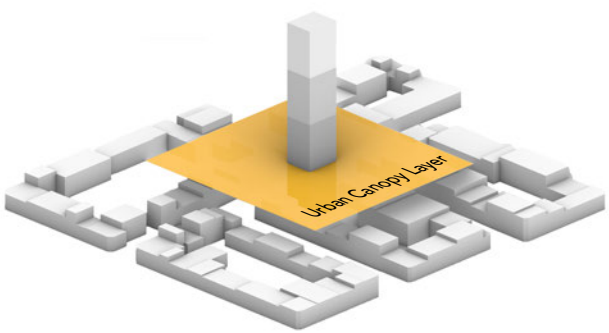


High-Rise Context

BENG 2 Primary Fossil Usage

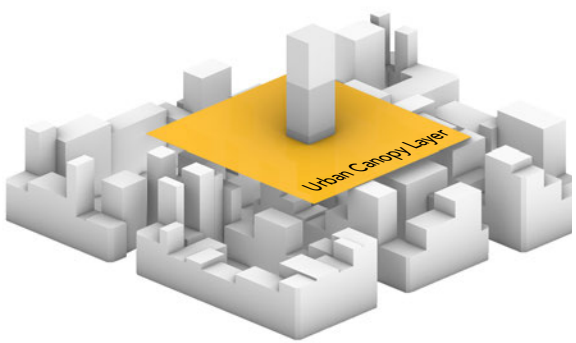


BENG 2 ✓



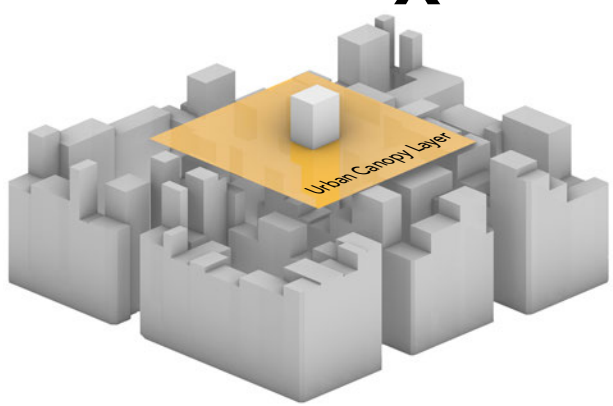
Low-Rise Context

BENG 2 X



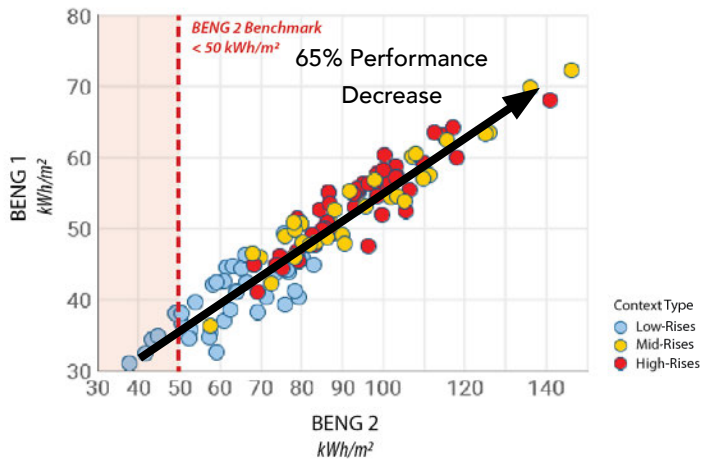
Mid-Rise Context

BENG 2 X



High-Rise Context

BENG 2 Primary Fossil Usage

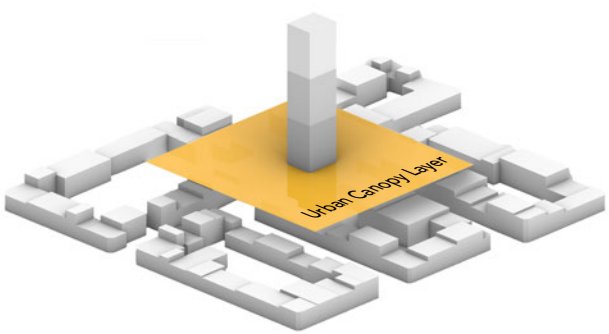


Performance Decrease of BENG 1 & BENG 2

Related to the households demand

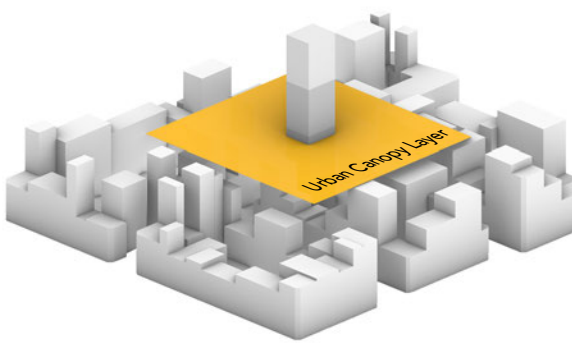
***Cooling, Heating, Lighting** Loads*

BENG 2 ✓



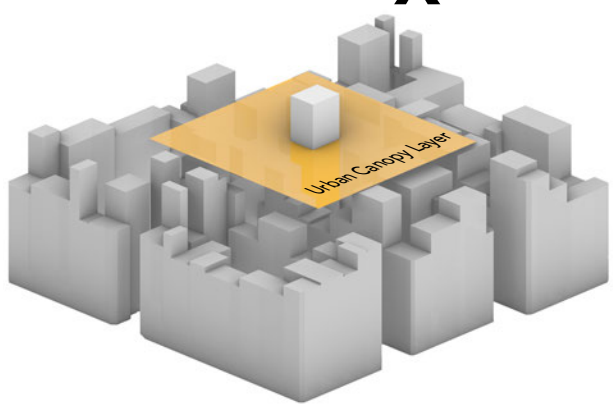
Low-Rise Context

BENG 2 X



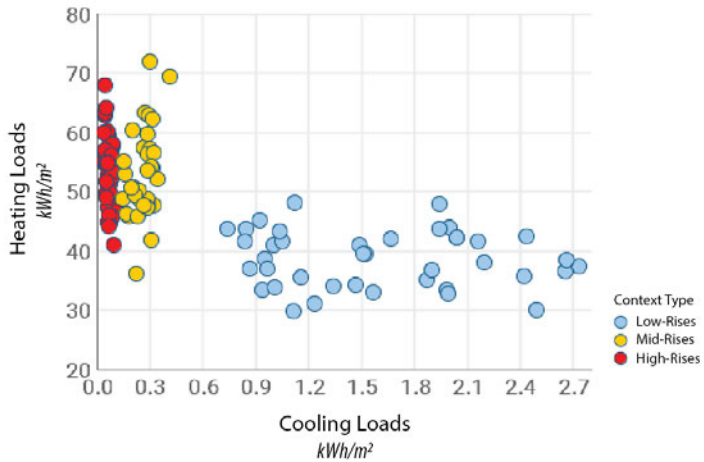
Mid-Rise Context

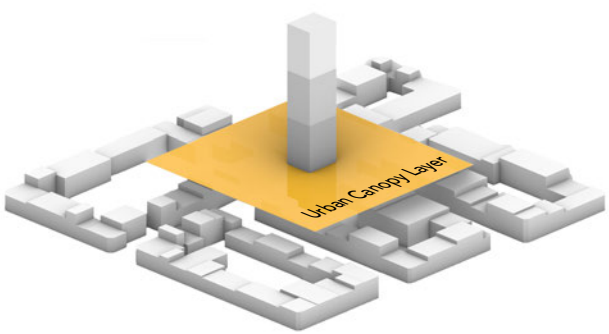
BENG 2 X



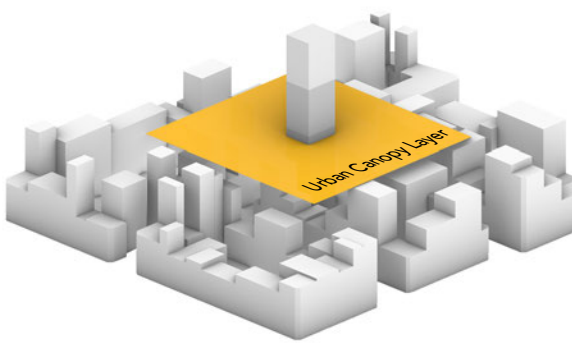
High-Rise Context

Energy Loads

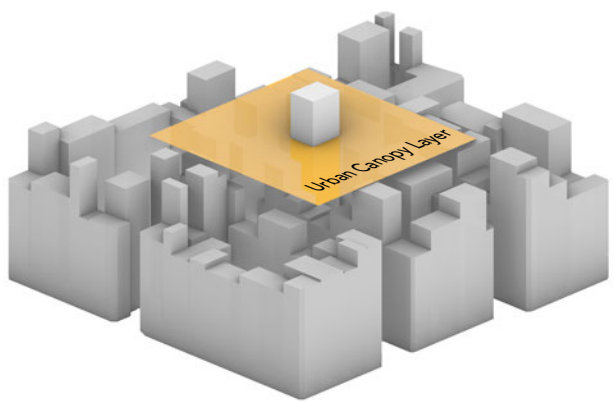




Low-Rise Context

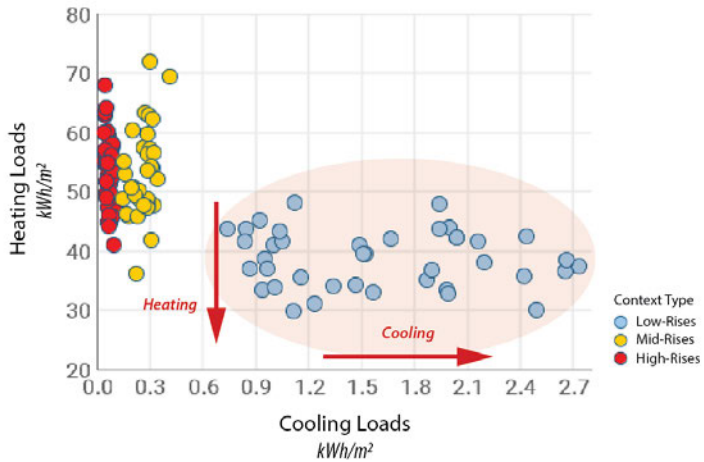


Mid-Rise Context

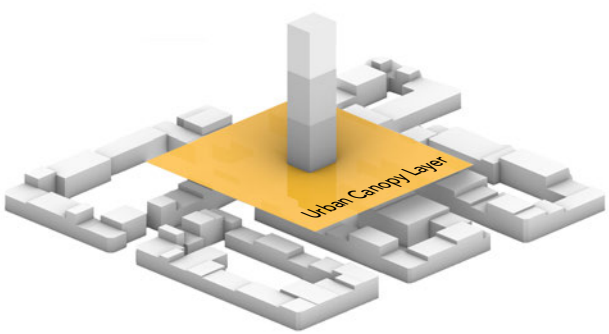


High-Rise Context

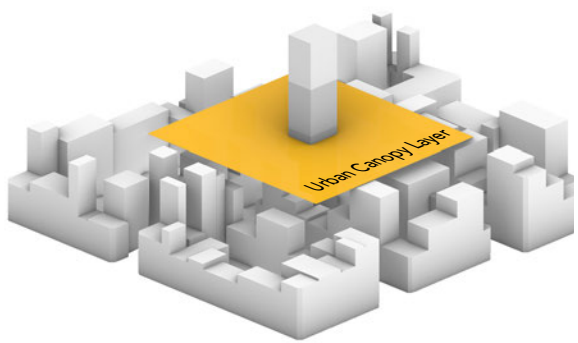
Energy Loads



Heating Loads Cooling Loads



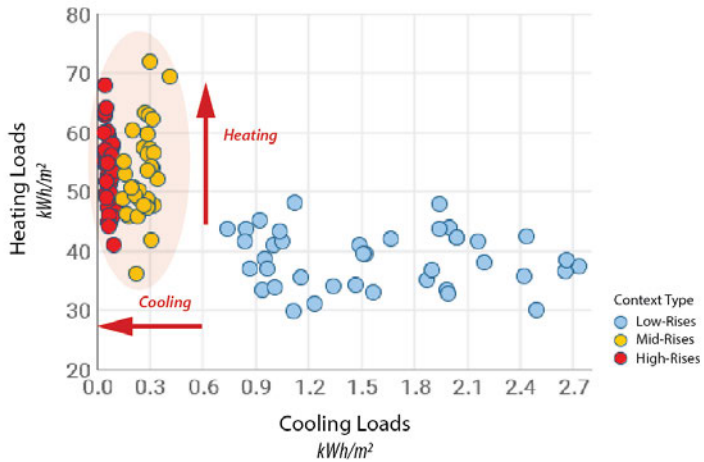
Low-Rise Context

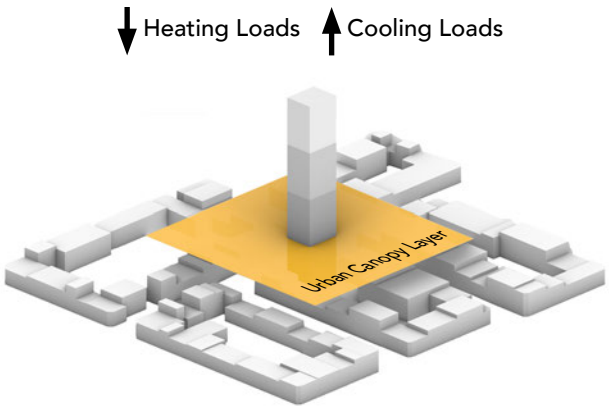


Mid-Rise Context

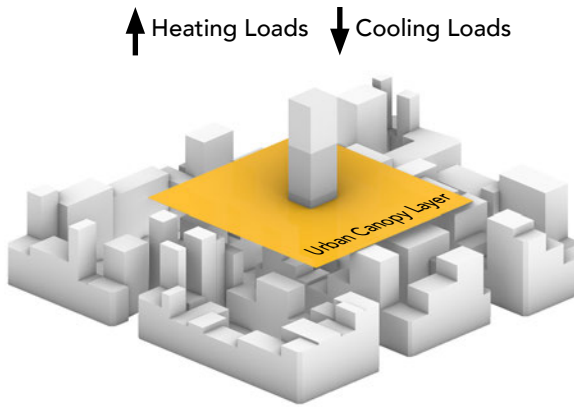
High-Rise Context

Energy Loads

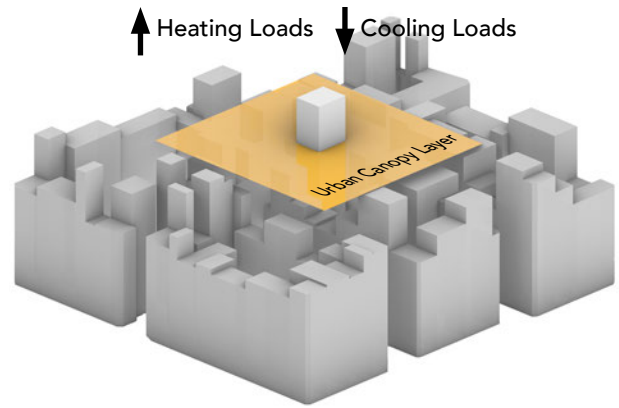




Low-Rise Context

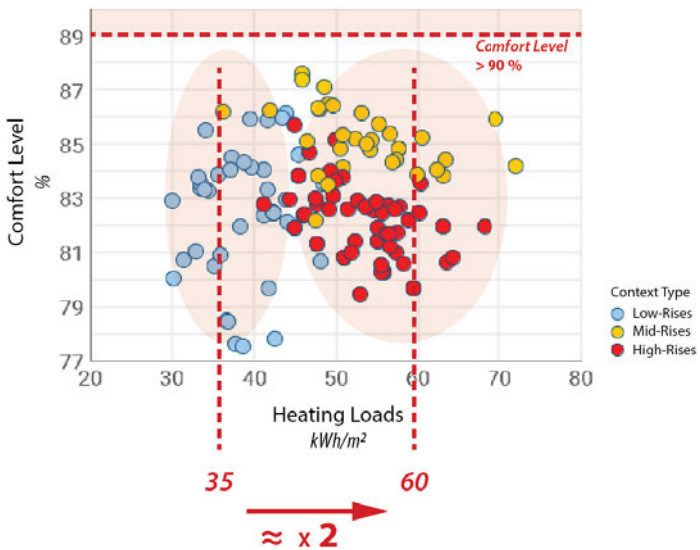


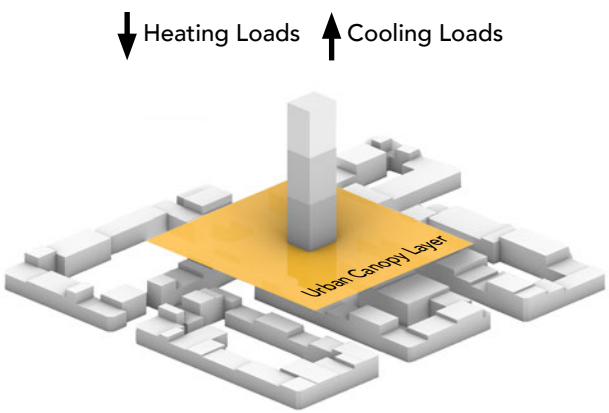
Mid-Rise Context



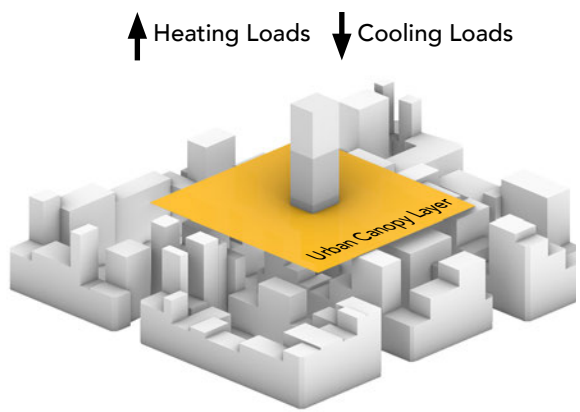
High-Rise Context

Energy Loads

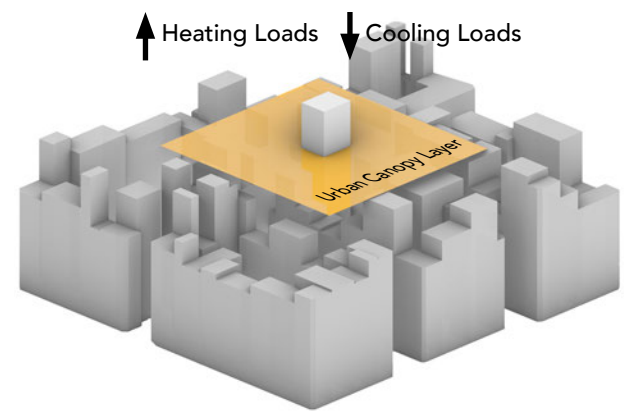




Low-Rise Context

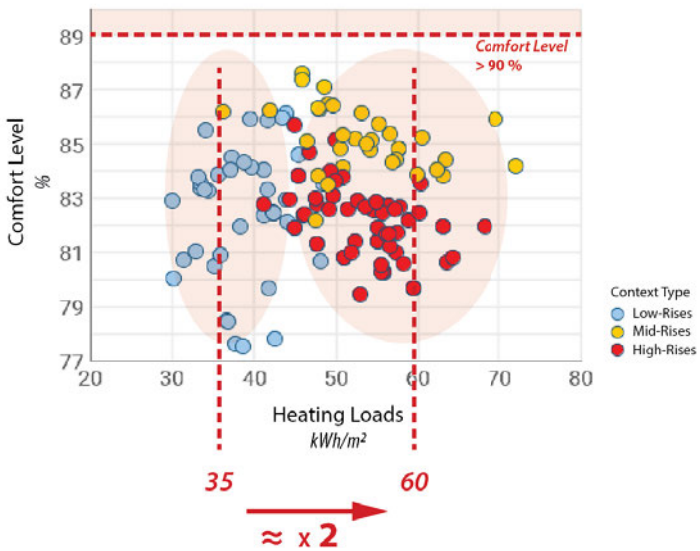


Mid-Rise Context



High-Rise Context

Energy Loads

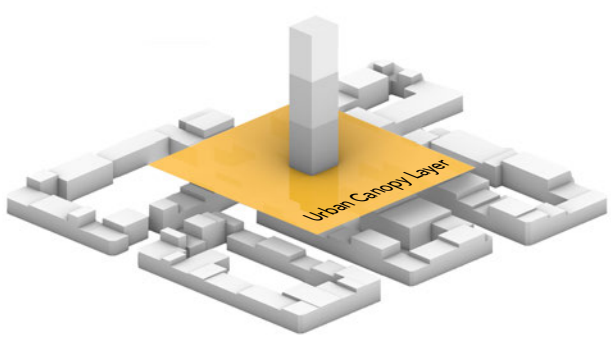


BENG 1

BENG 2

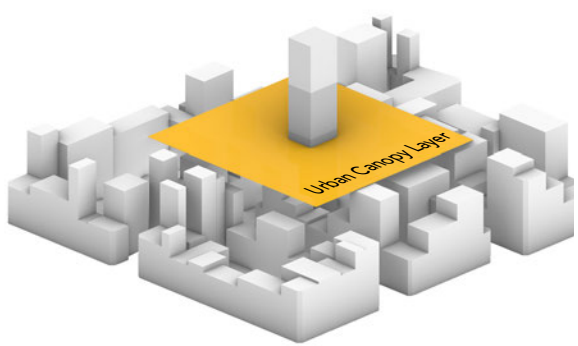
Heating Dominant

Heating Loads Cooling Loads



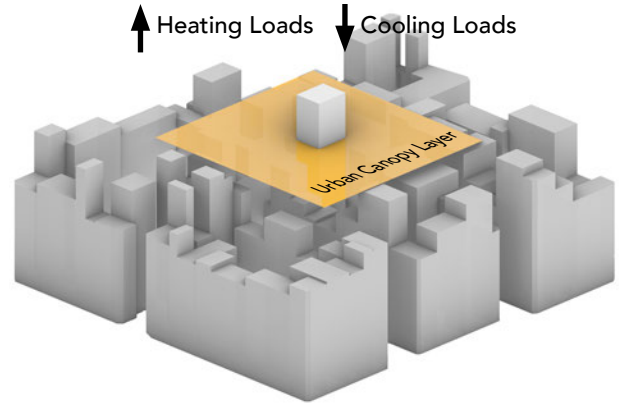
Low-Rise Context

Heating Loads Cooling Loads



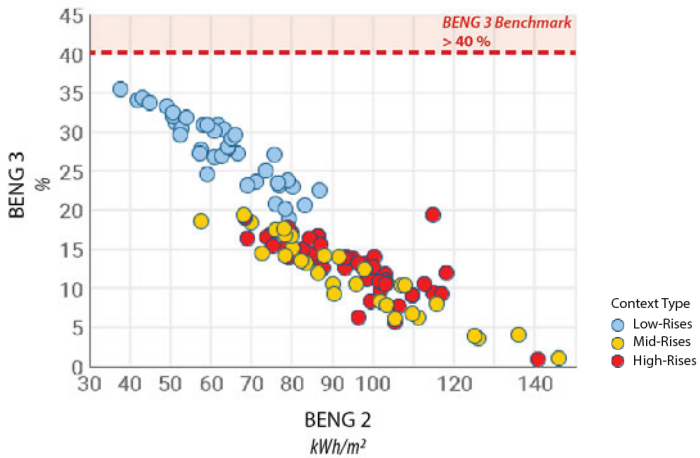
Mid-Rise Context

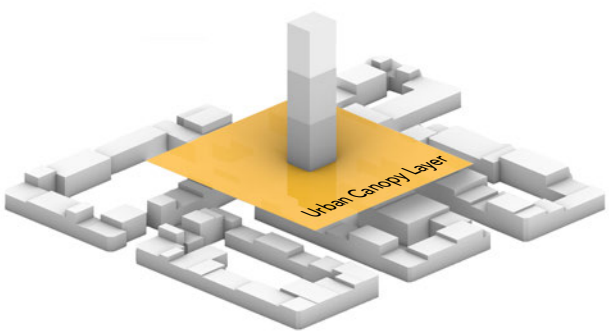
Heating Loads Cooling Loads



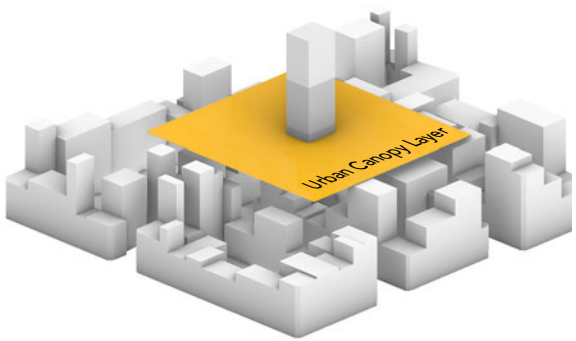
High-Rise Context

BENG 3 Renewable Energy

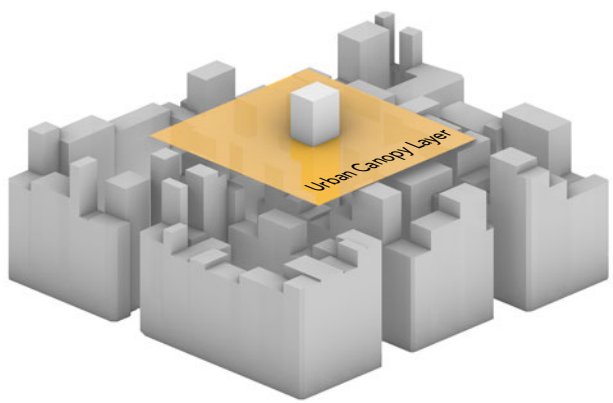




Low-Rise Context

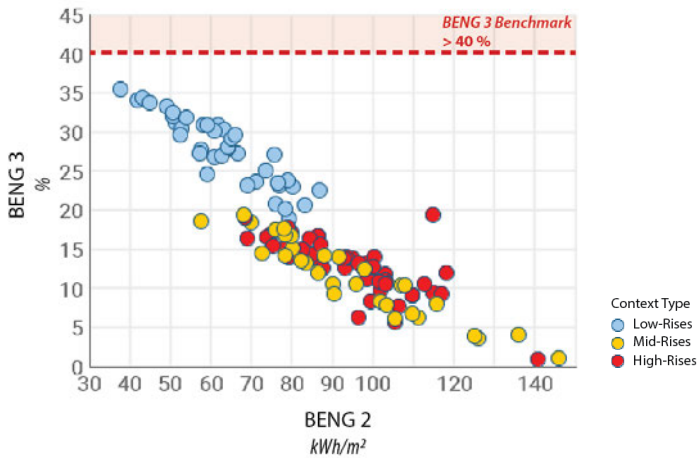


Mid-Rise Context

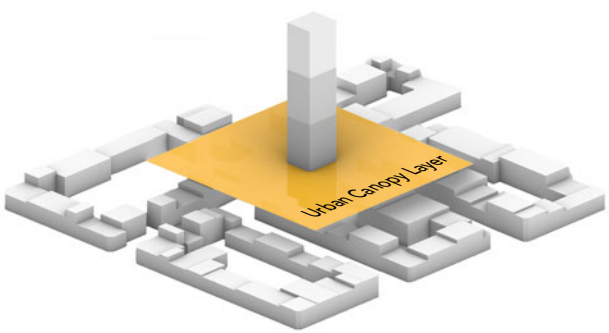


High-Rise Context

BENG 3 Renewable Energy

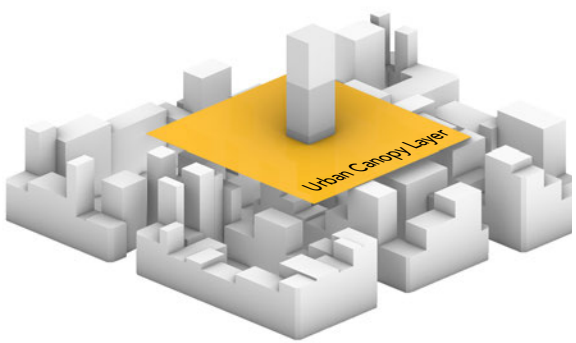


BENG 3 X



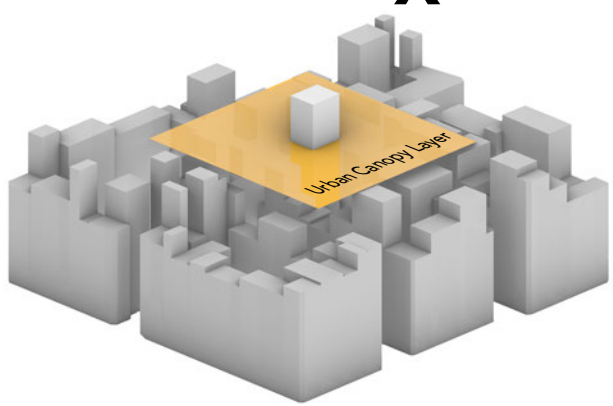
Low-Rise Context

BENG 3 X



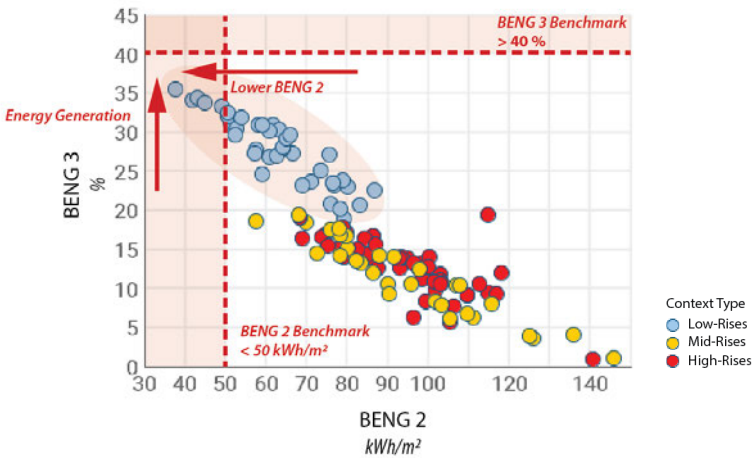
Mid-Rise Context

BENG 3 X

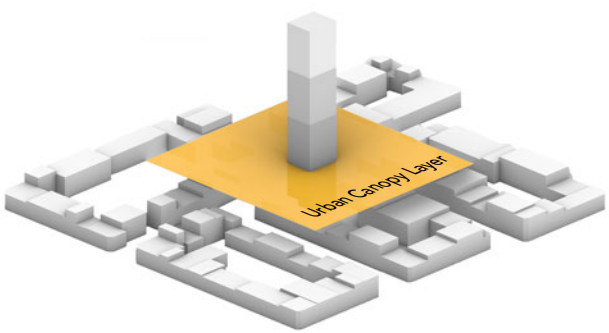


High-Rise Context

BENG 3 Renewable Energy

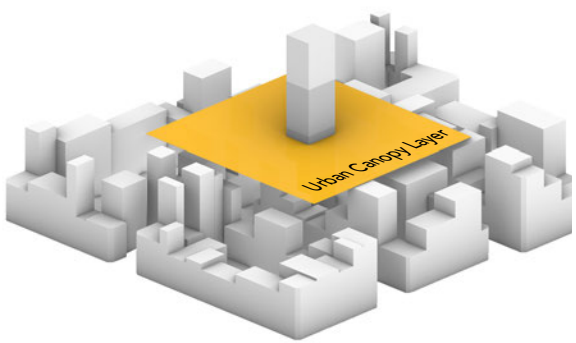


BENG 3 **X**



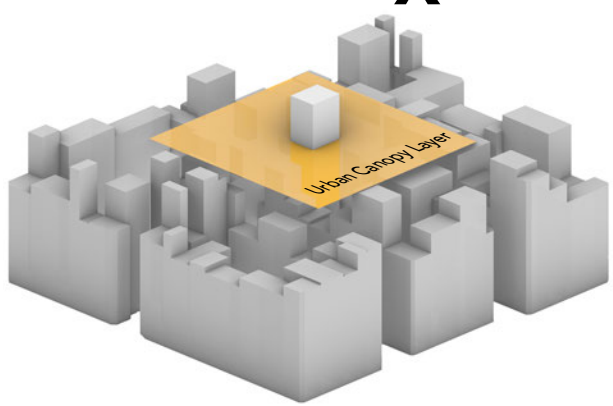
Low-Rise Context

BENG 3 **X**



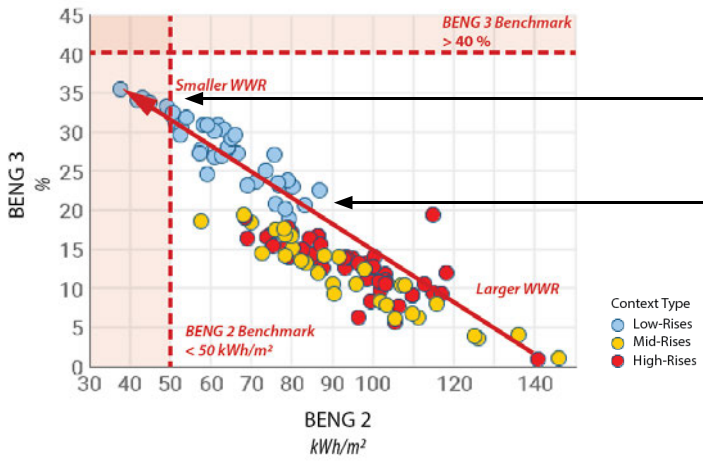
Mid-Rise Context

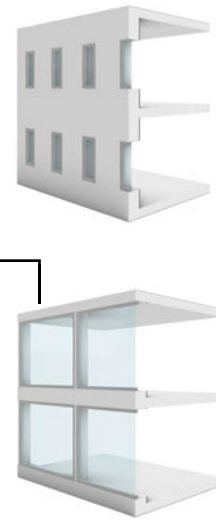
BENG 3 **X**



High-Rise Context

BENG 3 Renewable Energy

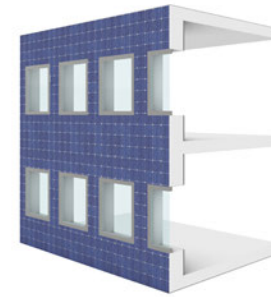




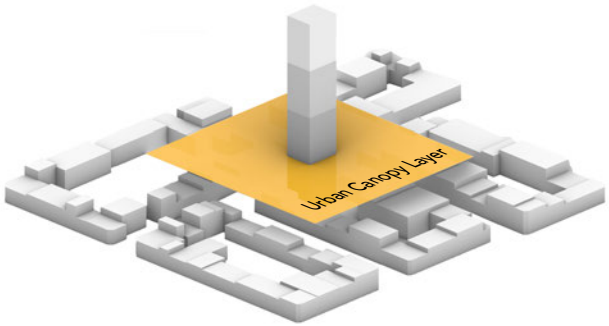
20% WWR

90% WWR

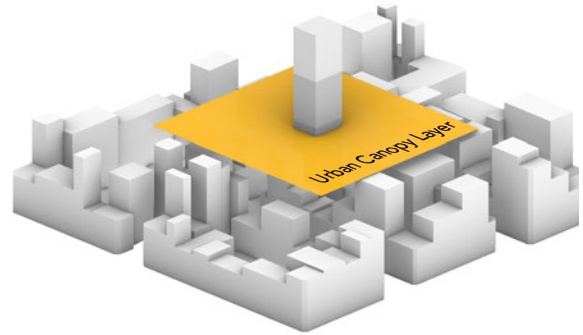
+



PV mounted on Facade



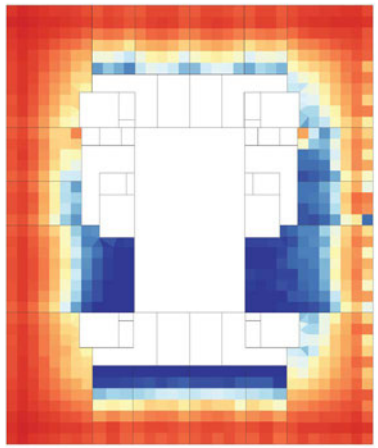
Low-Rise Context



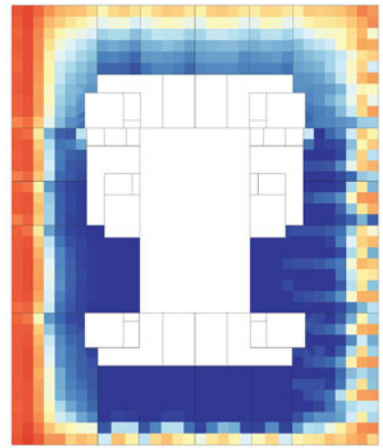
Mid-Rise Context

High-Rise Context

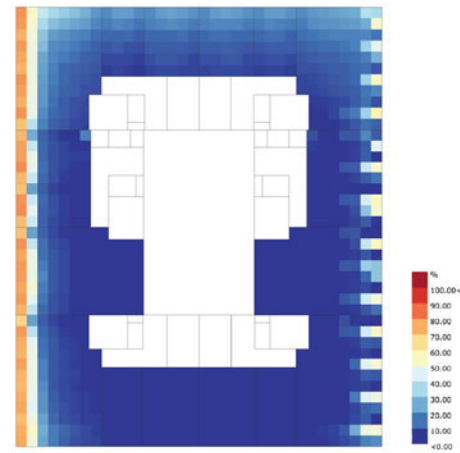
Surrounding Context



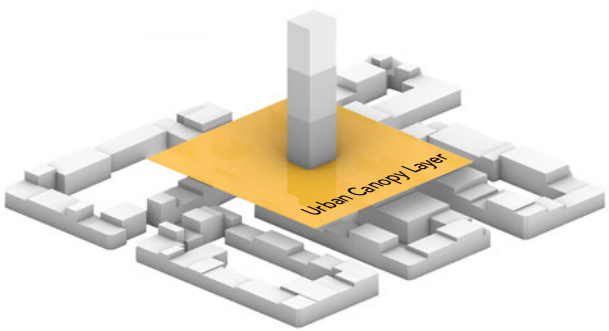
Daylight Autonomy
Under a Low-Rise Context



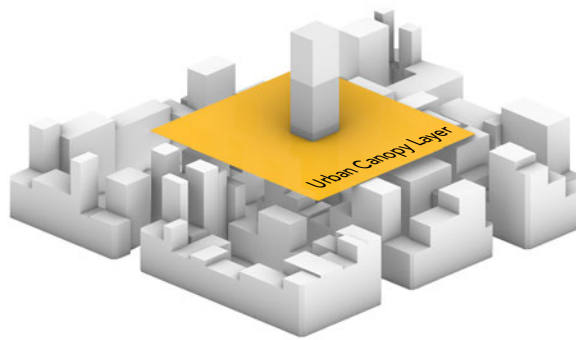
Daylight Autonomy
Under a Mid-Rise Context



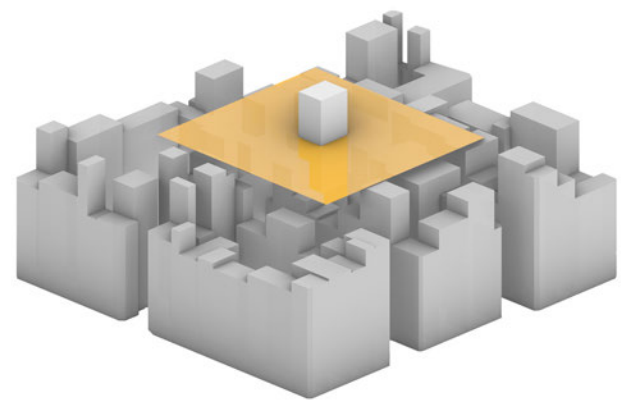
Daylight Autonomy
Under a High-Rise Context



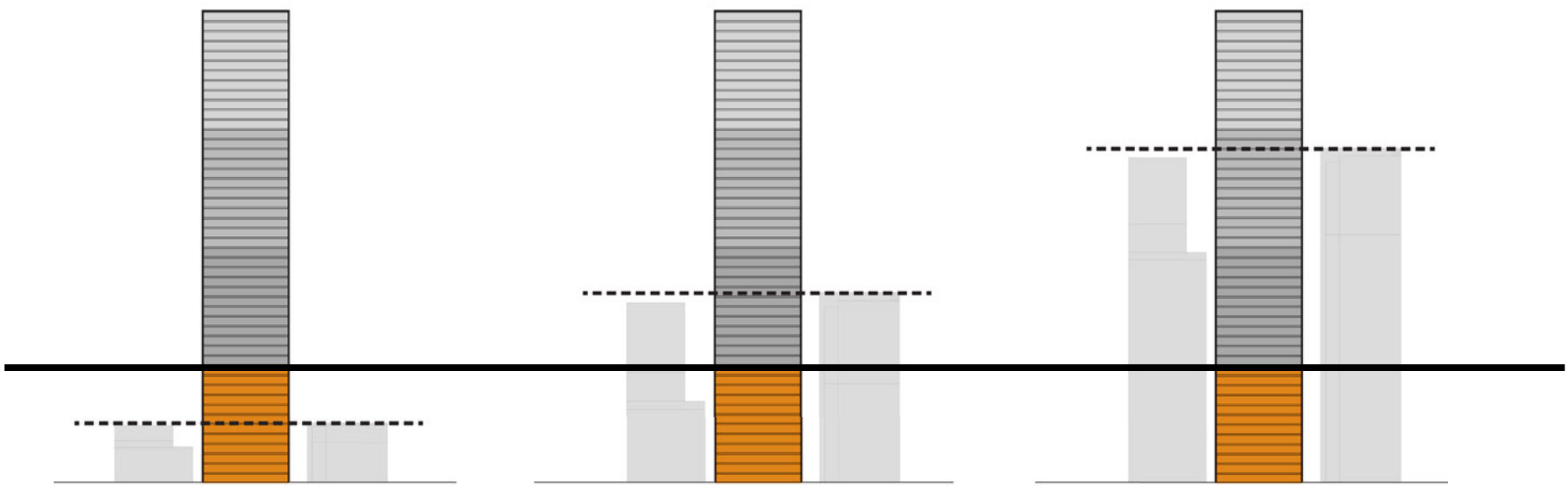
Low-Rise
Context



Mid-Rise
Context



High-Rise
Context

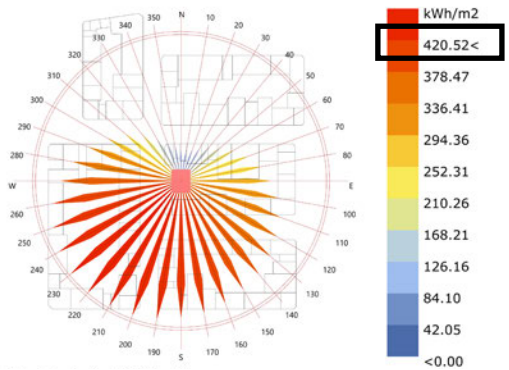


Low-Rise Context

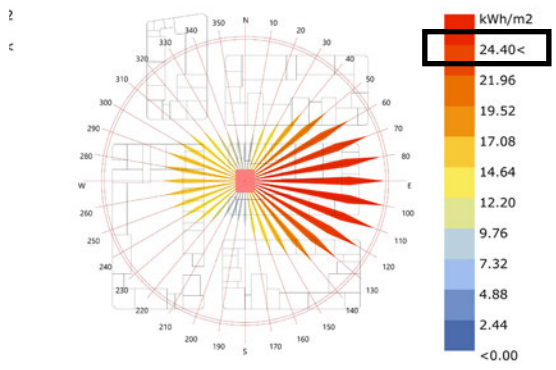
Mid-Rise Context

High-Rise Context

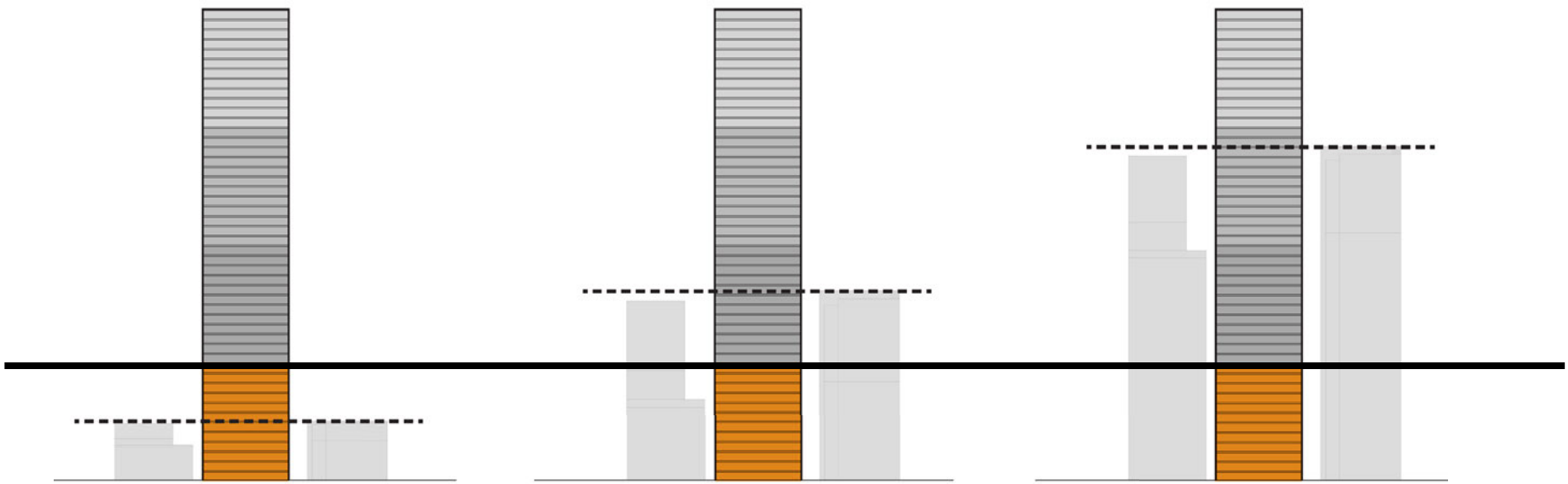
Surrounding Context



420 kWh/m²



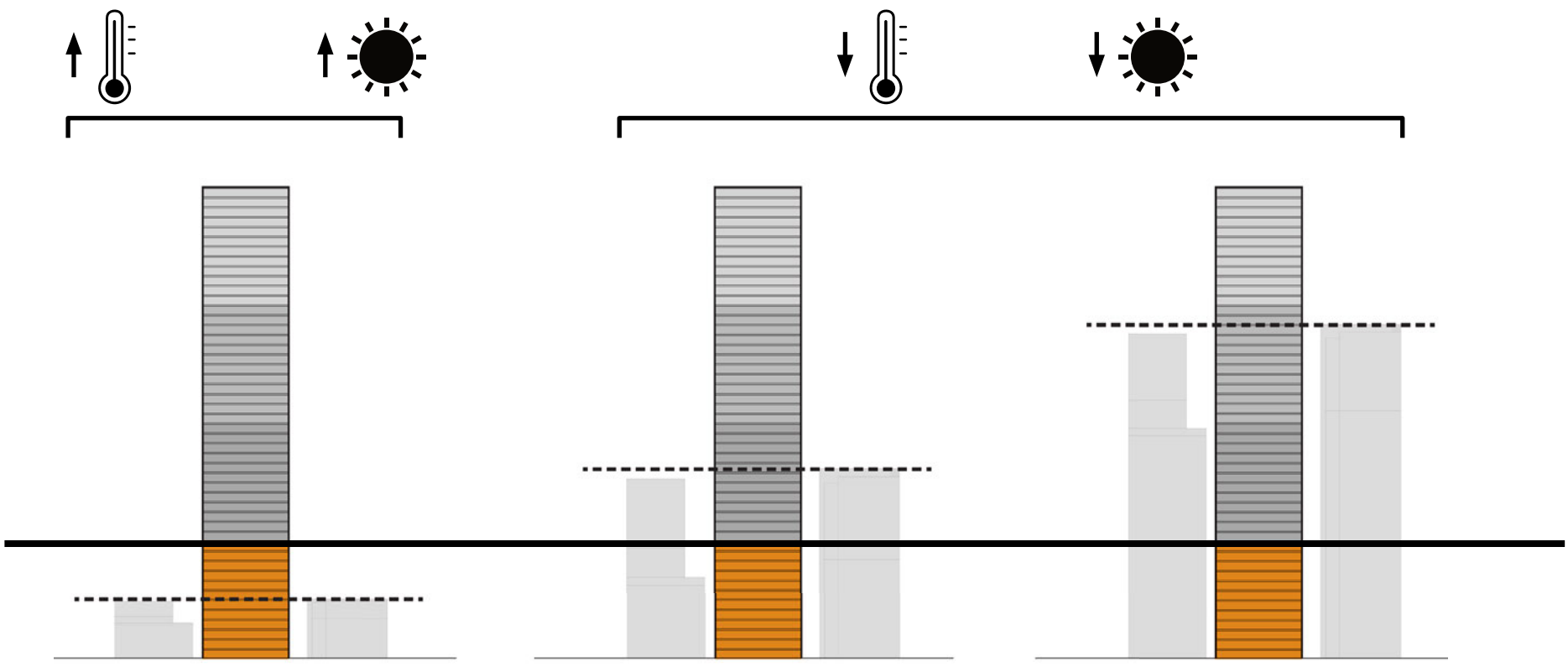
24.4 kWh/m²



Low-Rise Context

Mid-Rise Context

High-Rise Context

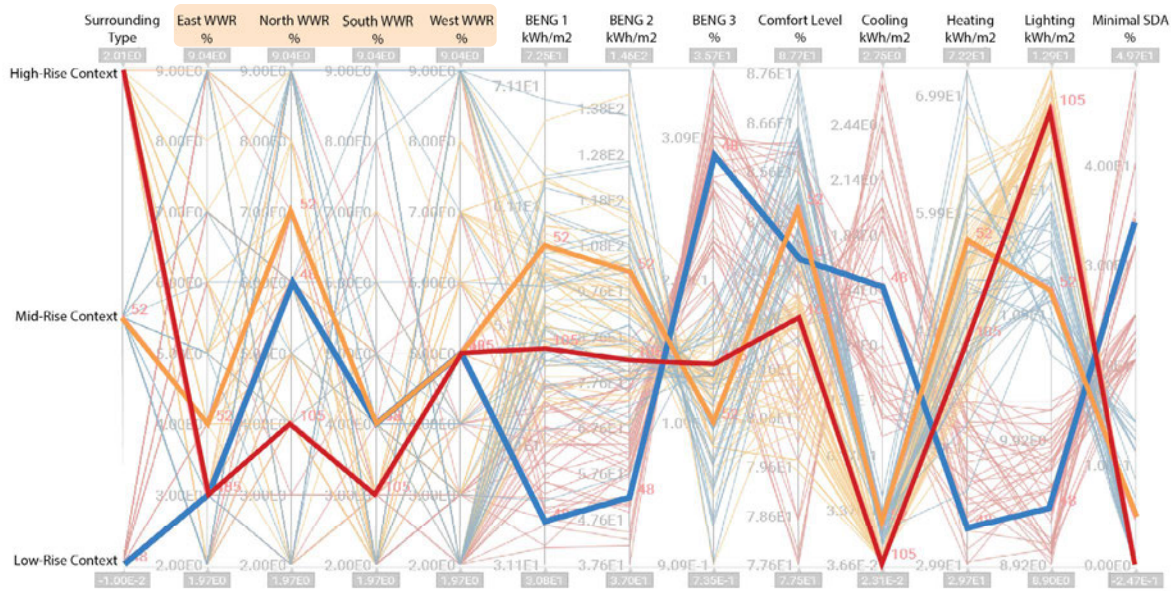


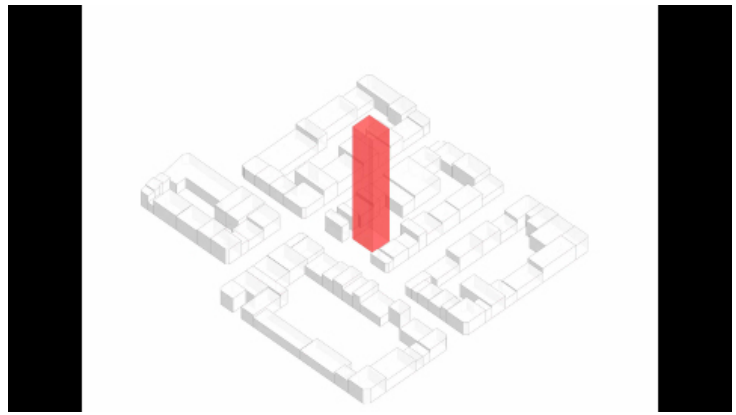
Low-Rise Context

Mid-Rise Context

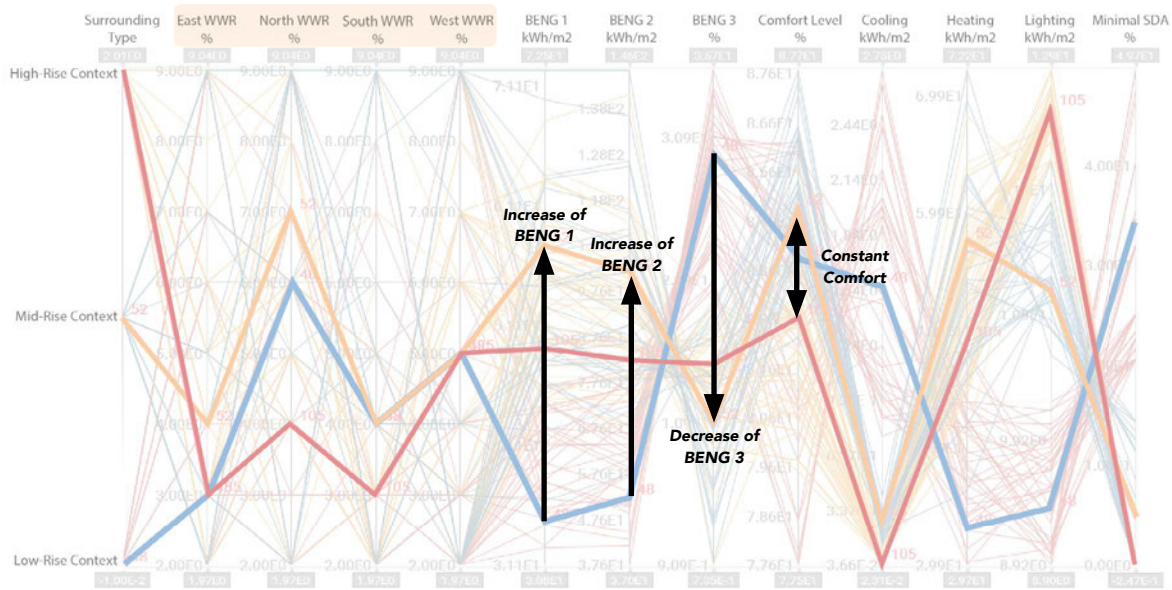
High-Rise Context

Design for Future Urban Change

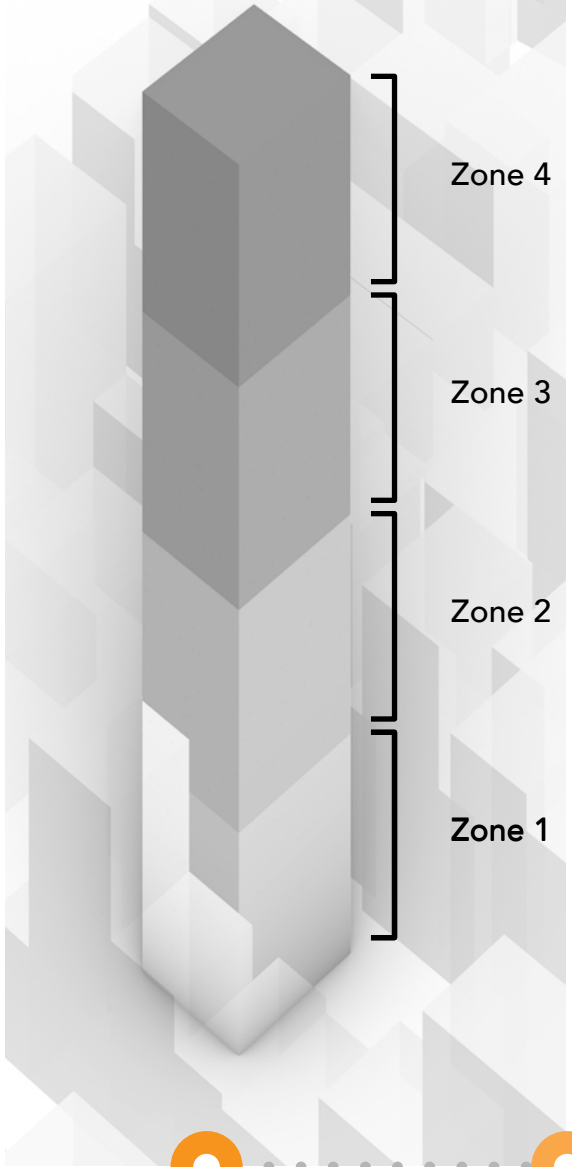


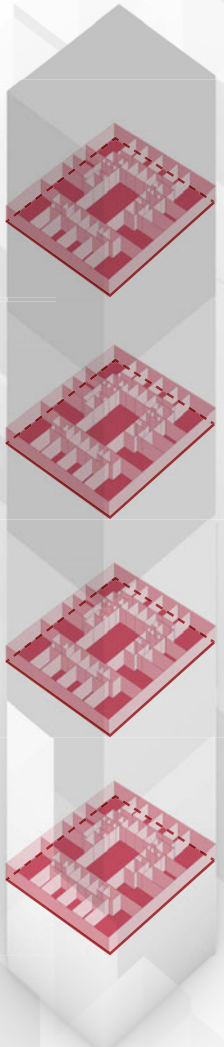


Design for Future Urban Change



Optimal Ranges of WWR per Zone & per Facade


Zone 4
Zone 3
Zone 2
Zone 1

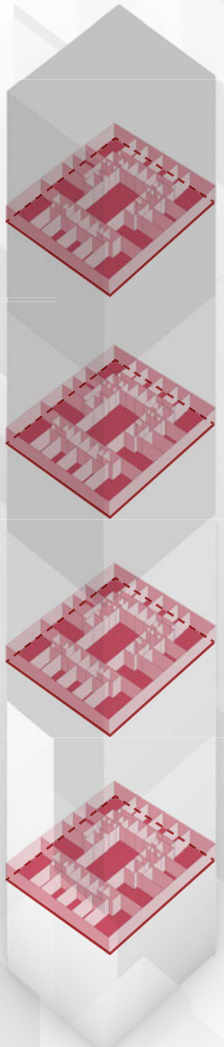


41st Floor
135 meters

29th Floor
95.7 meters

19th Floor
56.1 meters

5th Floor
16.5 meters



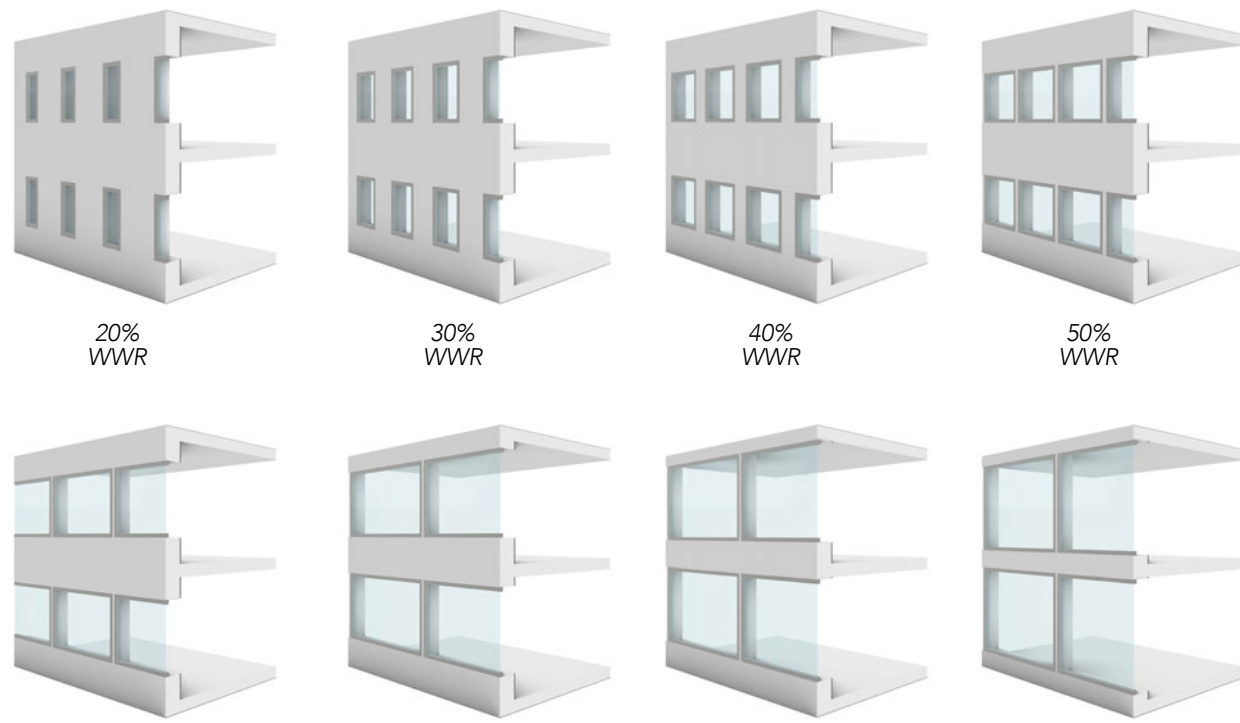
41st Floor
135 meters

29th Floor
95.7 meters

19th Floor
56.1 meters

5th Floor
16.5 meters

Window-to-Wall Ratio



20% WWR

30% WWR

40% WWR

50% WWR

60% WWR

70% WWR

80% WWR

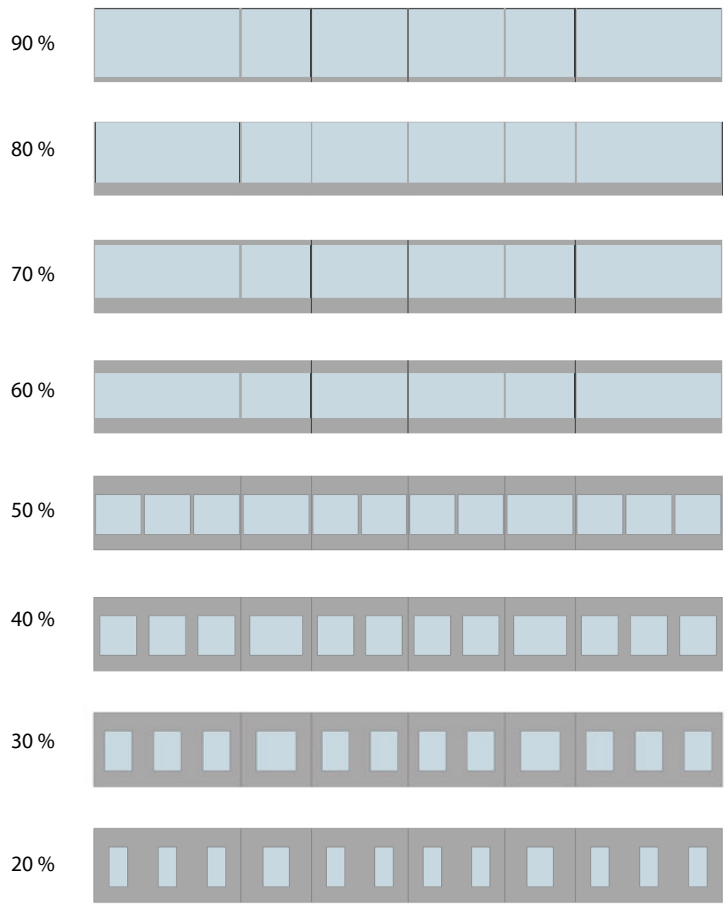
90% WWR

Reassessment of Objectives

Initial Optimization Objectives

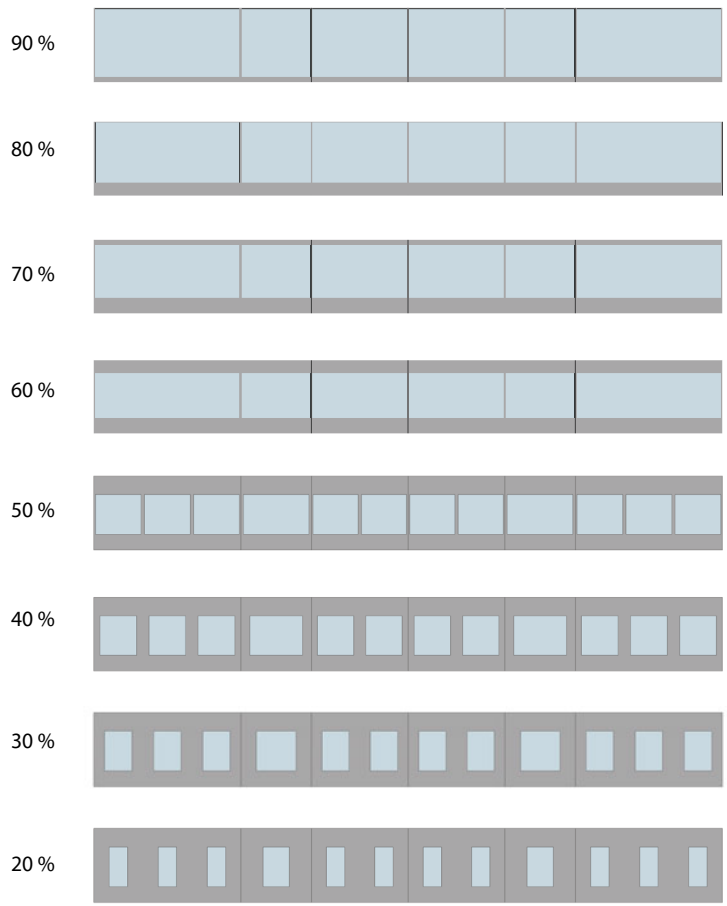
- ↘ BENG 1
- ↘ BENG 2
- ↗ BENG 3

Constant Window-to-Wall Ratio

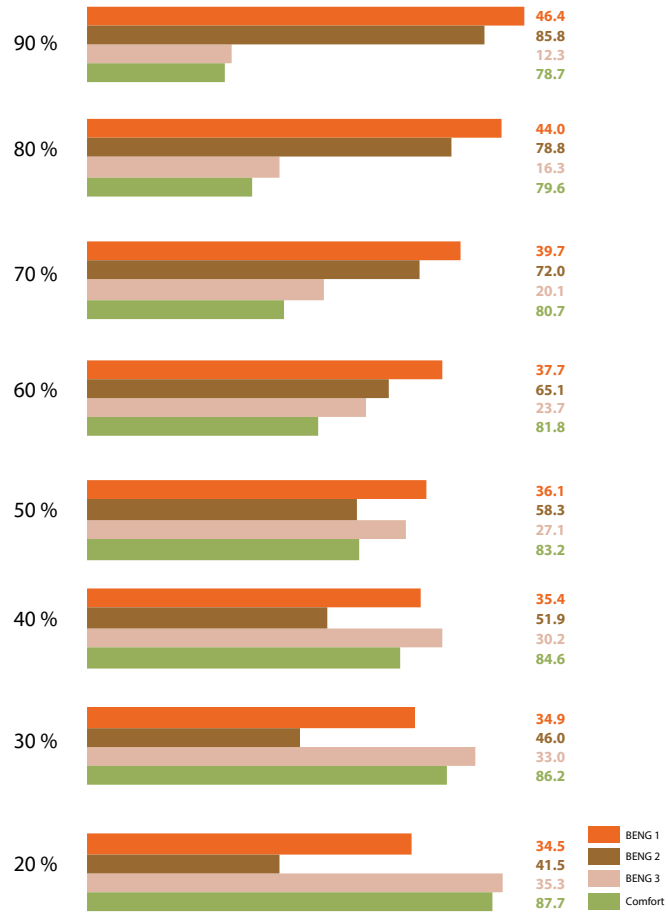


Optimal WWR

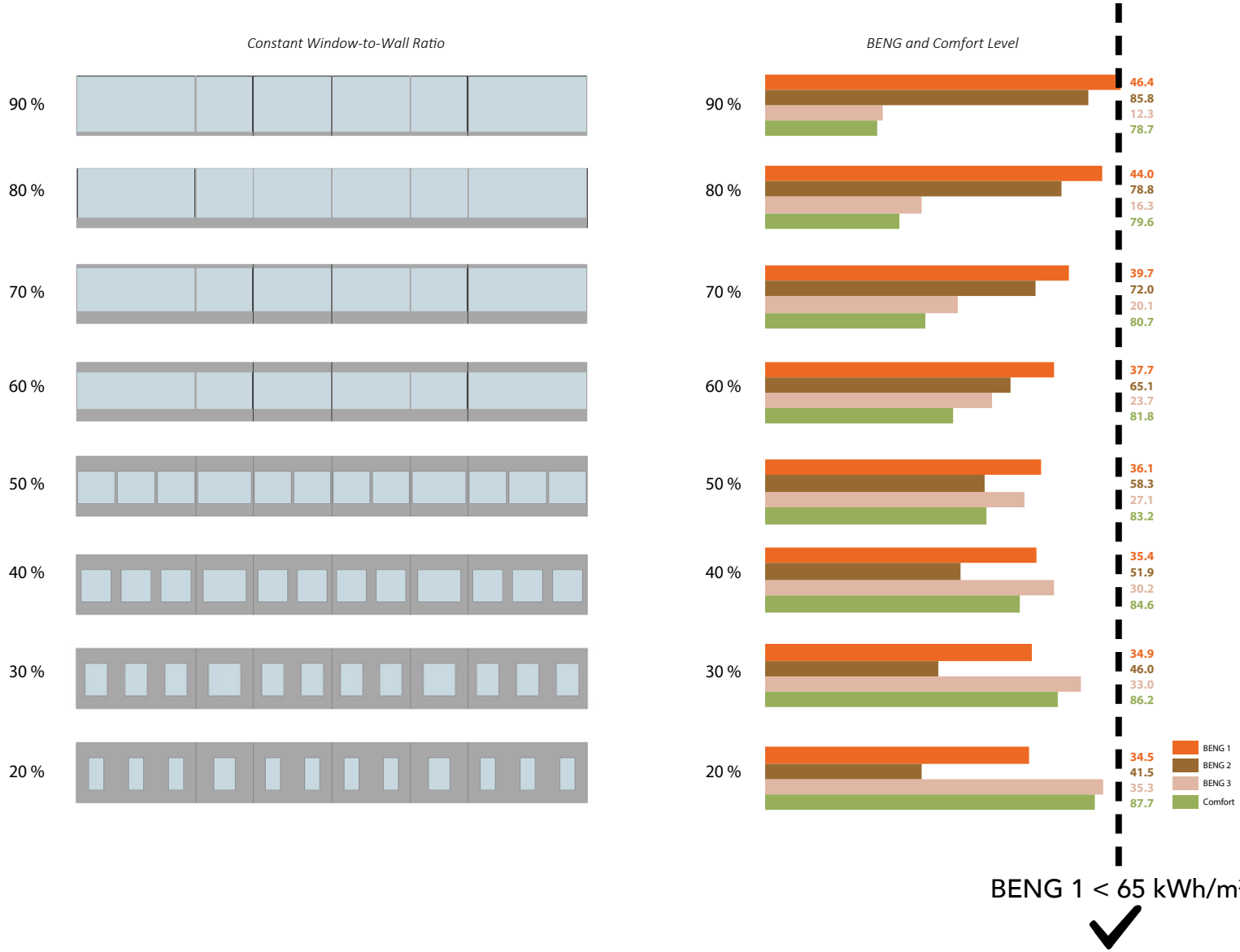
Constant Window-to-Wall Ratio



BENG and Comfort Level

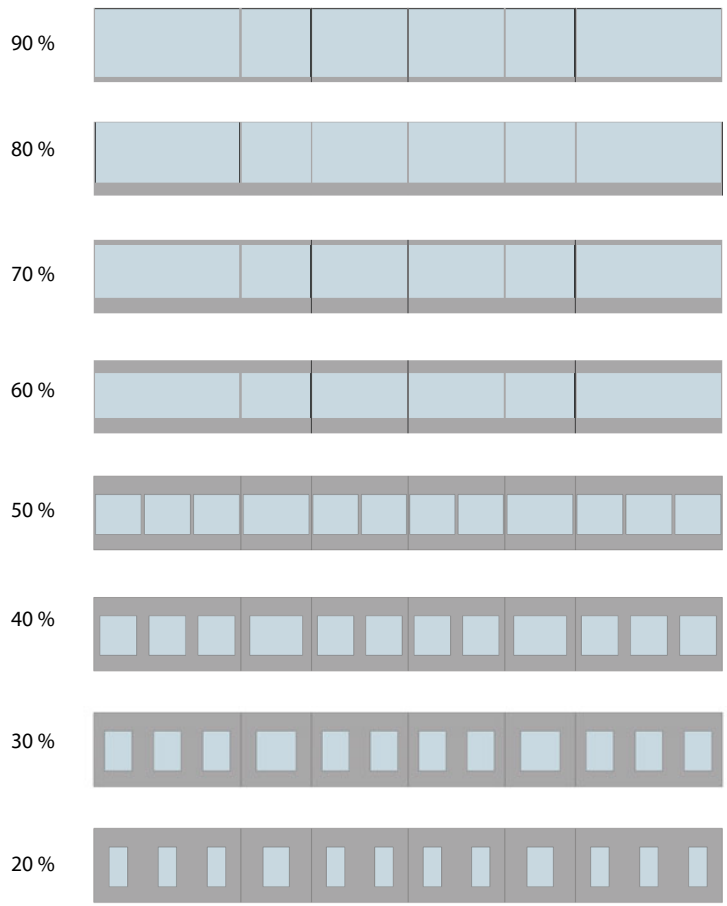


Optimal WWR


Constant Window-to-Wall Ratio
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
BENG and Comfort Level
90 %
46.4
85.8
12.3
78.7
80 %
44.0
78.8
16.3
79.6
70 %
39.7
72.0
20.1
80.7
60 %
37.7
65.1
23.7
81.8
50 %
36.1
58.3
27.1
83.2
40 %
35.4
51.9
30.2
84.6
30 %
34.9
46.0
33.0
86.2
20 %
34.5
41.5
35.3
87.7
BENG 1
BENG 2
BENG 3
Comfort
BENG 1 < 65 kWh/m²

Optimal WWR

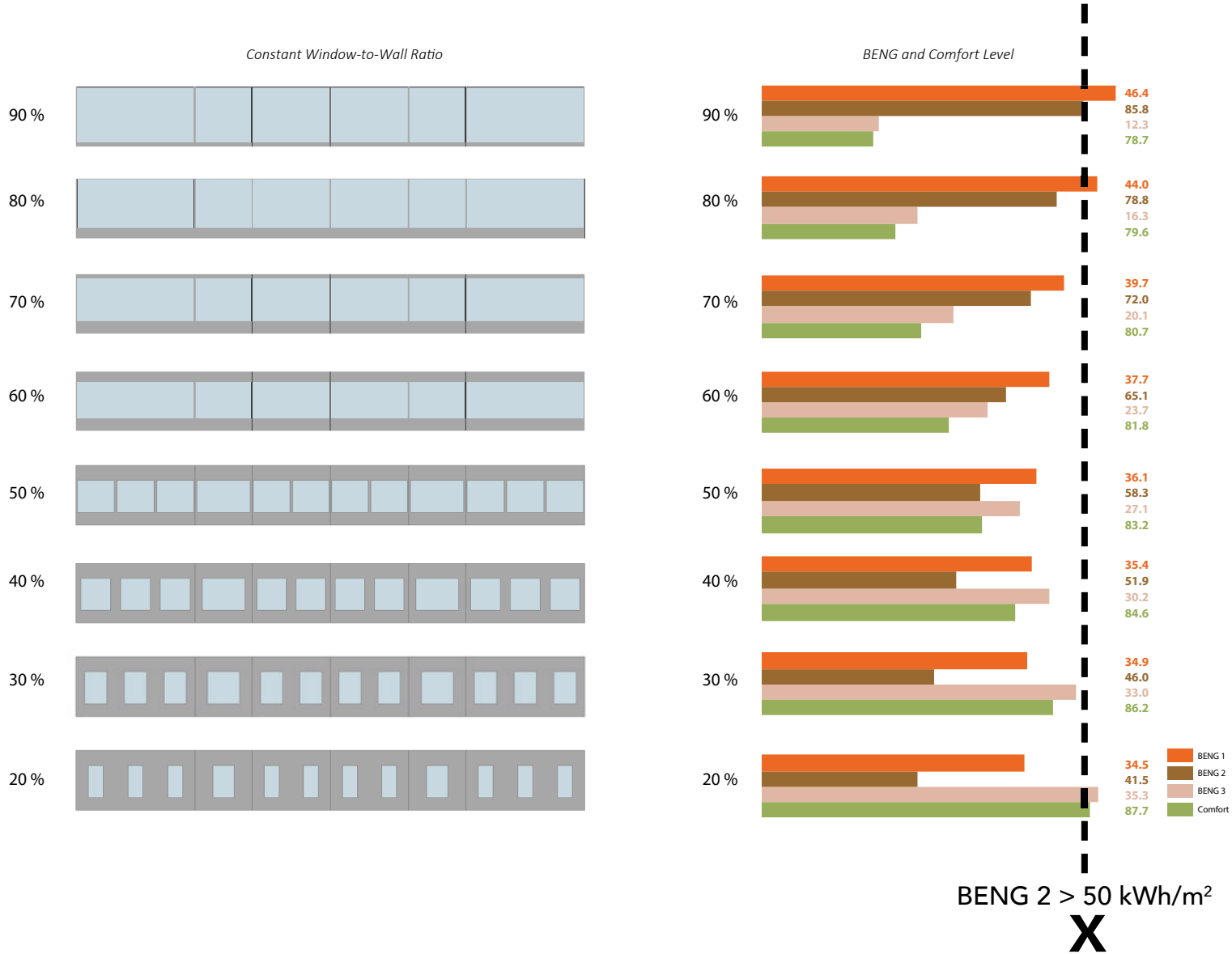
Constant Window-to-Wall Ratio



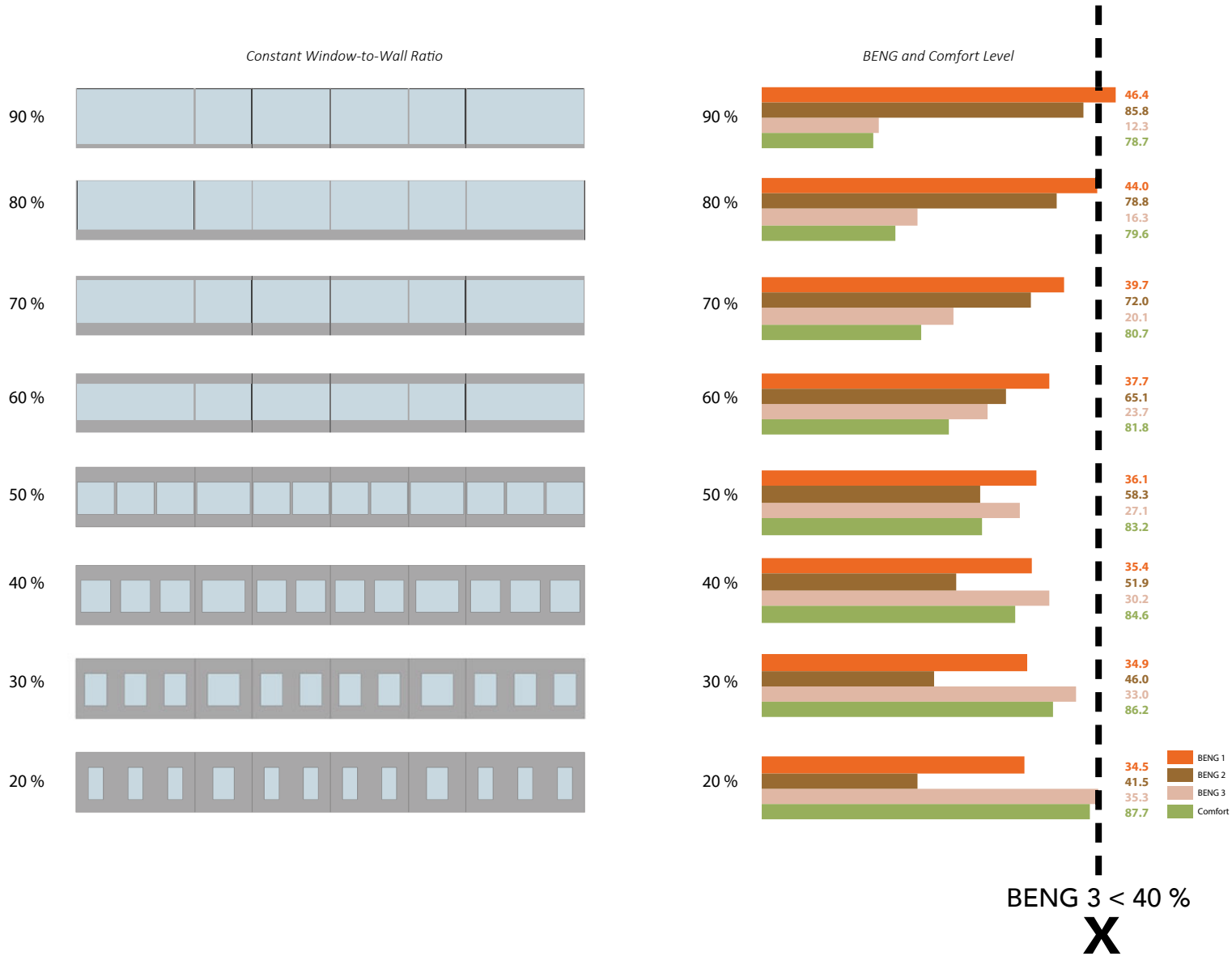
BENG and Comfort Level

BENG 2 < 50 kWh/m²

Optimal WWR


Constant Window-to-Wall Ratio
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
BENG and Comfort Level
90 %
46.4
85.8
12.3
78.7
80 %
44.0
78.8
16.3
79.6
70 %
39.7
72.0
20.1
80.7
60 %
37.7
65.1
23.7
81.8
50 %
36.1
58.3
27.1
83.2
40 %
35.4
51.9
30.2
84.6
30 %
34.9
46.0
33.0
86.2
20 %
34.5
41.5
35.3
87.7
BENG 1
BENG 2
BENG 3
Comfort
BENG 2 > 50 kWh/m²
X

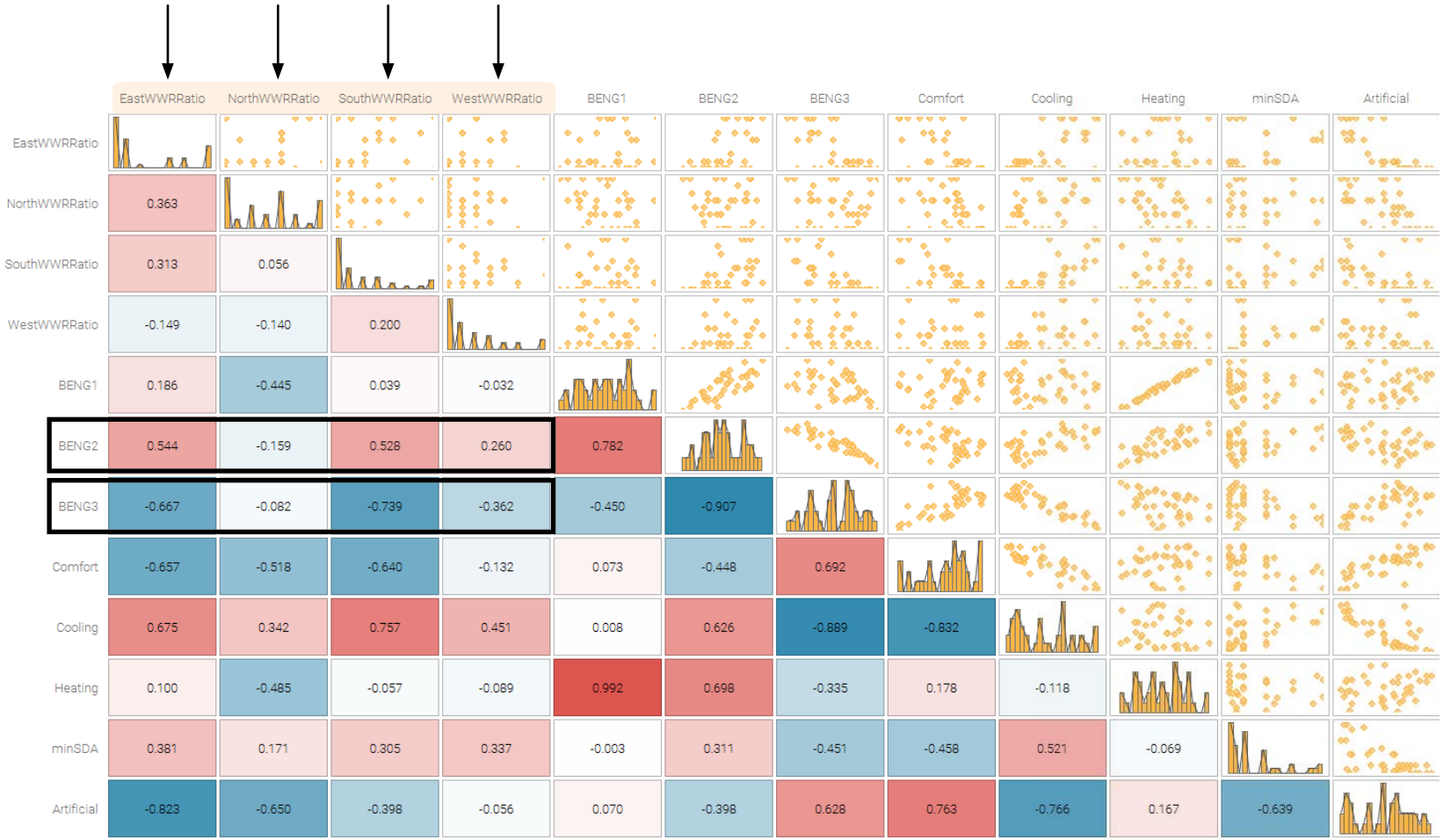
Optimal WWR

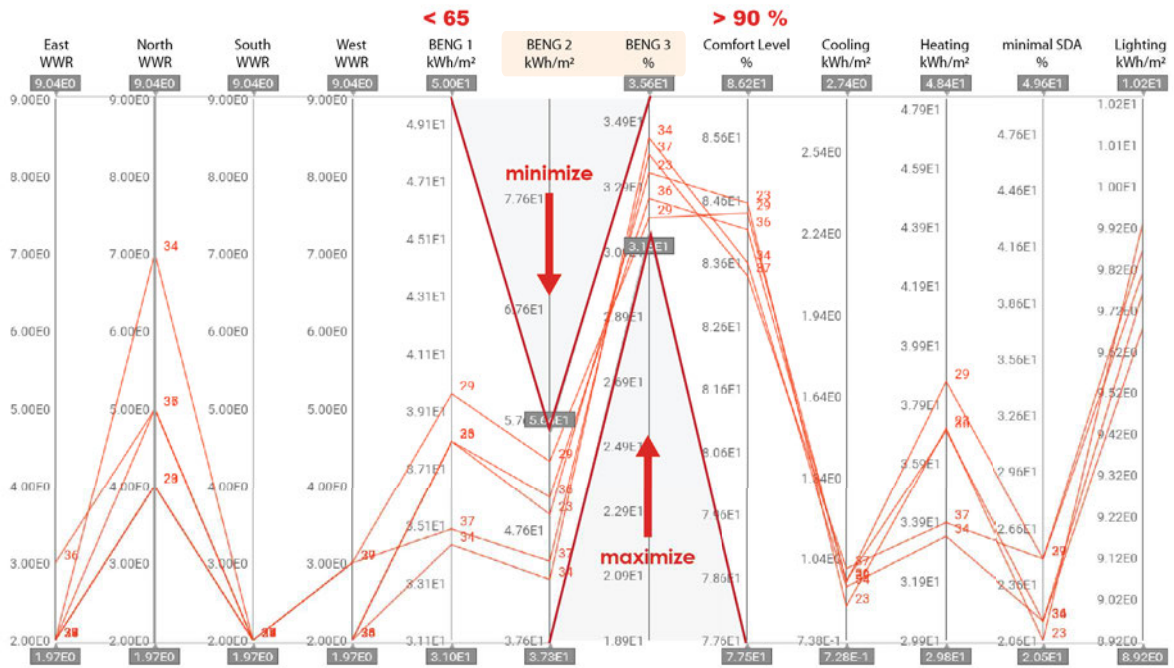

Constant Window-to-Wall Ratio
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
BENG and Comfort Level
90 %
46.4
85.8
12.3
78.7
80 %
44.0
78.8
16.3
79.6
70 %
39.7
72.0
20.1
80.7
60 %
37.7
65.1
23.7
81.8
50 %
36.1
58.3
27.1
83.2
40 %
35.4
51.9
30.2
84.6
30 %
34.9
46.0
33.0
86.2
20 %
34.5
41.5
35.3
87.7
BENG 1
BENG 2
BENG 3
Comfort
BENG 3 < 40 %
X

Reassessed Optimization Objectives

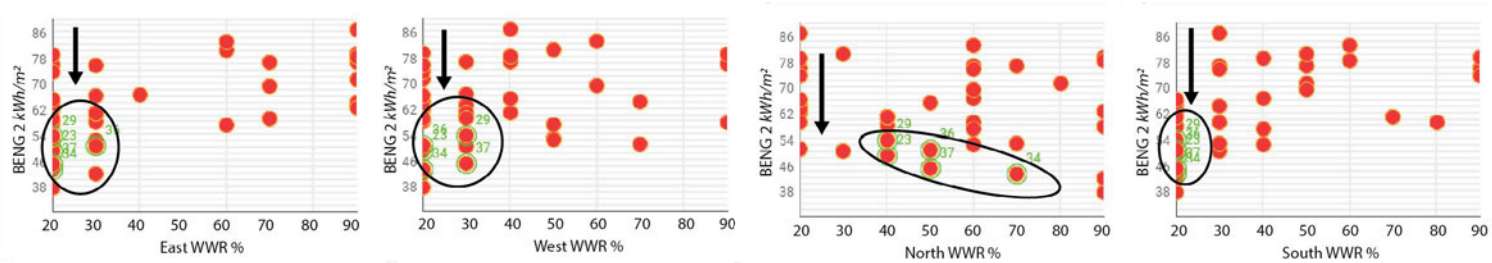
BENG 2

BENG 3

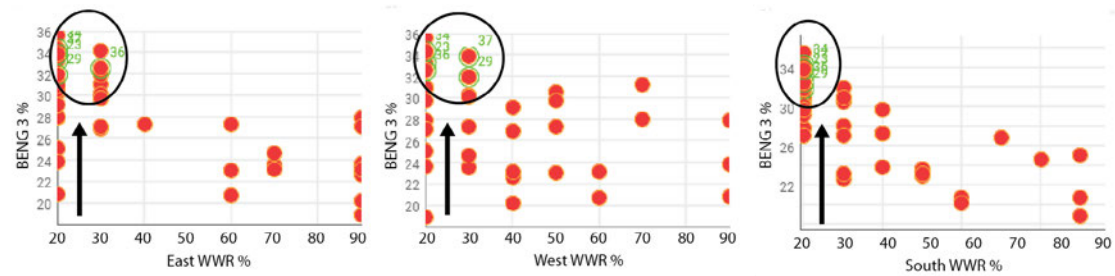

EastWWRRatio
NorthWWRRatio
SouthWWRRatio
WestWWRRatio
BENG1
BENG2
BENG3
Comfort
Cooling
Heating
minSDA
Artificial
EastWWRRatio
NorthWWRRatio 0.363
SouthWWRRatio 0.313 0.056
WestWWRRatio -0.149 -0.140 0.200
BENG1 0.186 -0.445 0.039 -0.032
BENG2 0.544 -0.159 0.528 0.260 0.782
BENG3 -0.667 -0.082 -0.739 -0.362 -0.450 -0.907
Comfort -0.657 -0.518 -0.640 -0.132 0.073 -0.448 0.692
Cooling 0.675 0.342 0.757 0.451 0.008 0.626 -0.889 -0.832
Heating 0.100 -0.485 -0.057 -0.089 0.992 0.698 -0.335 0.178 -0.118
minSDA 0.381 0.171 0.305 0.337 -0.003 0.311 -0.451 -0.458 0.521 -0.069
Artificial -0.823 -0.650 -0.398 -0.056 0.070 -0.398 0.628 0.763 -0.766 0.167 -0.639


< 65
> 90 %
East WWR
North WWR
South WWR
West WWR
BENG 1 kWh/m²
BENG 2 kWh/m²
BENG 3 %
Comfort Level %
Cooling kWh/m²
Heating kWh/m²
minimal SDA %
Lighting kWh/m²
minimize
maximize

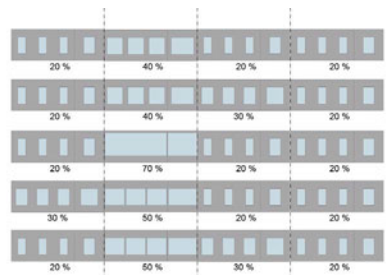
BENG 2

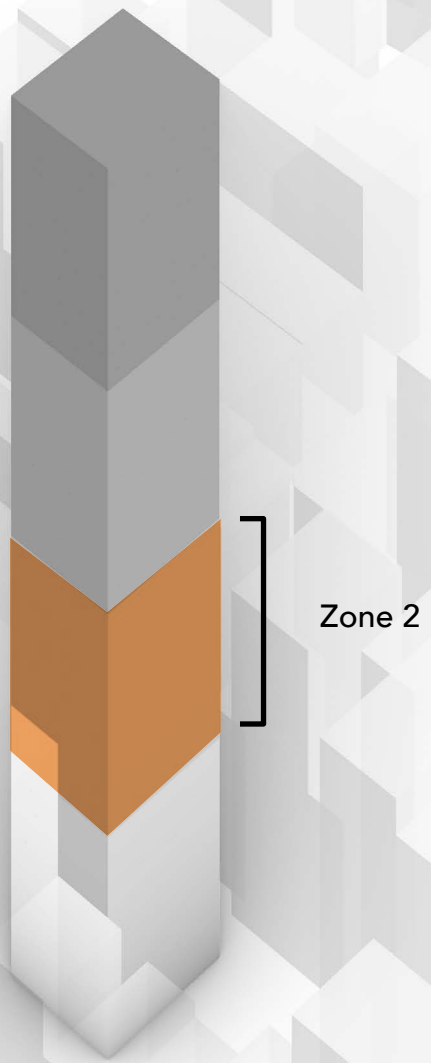

BENG 2 kWh/m²
East WWR %
West WWR %
North WWR %
South WWR %

BENG 3


BENG 3 %
East WWR %
West WWR %
South WWR %

Zone 1




Zone 2


20 %
60 %
20 %
20 %
20 %
50 %
20 %
20 %
30 %
40 %
20 %
20 %
20 %
50 %
20 %
30 %
20 %
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70 %
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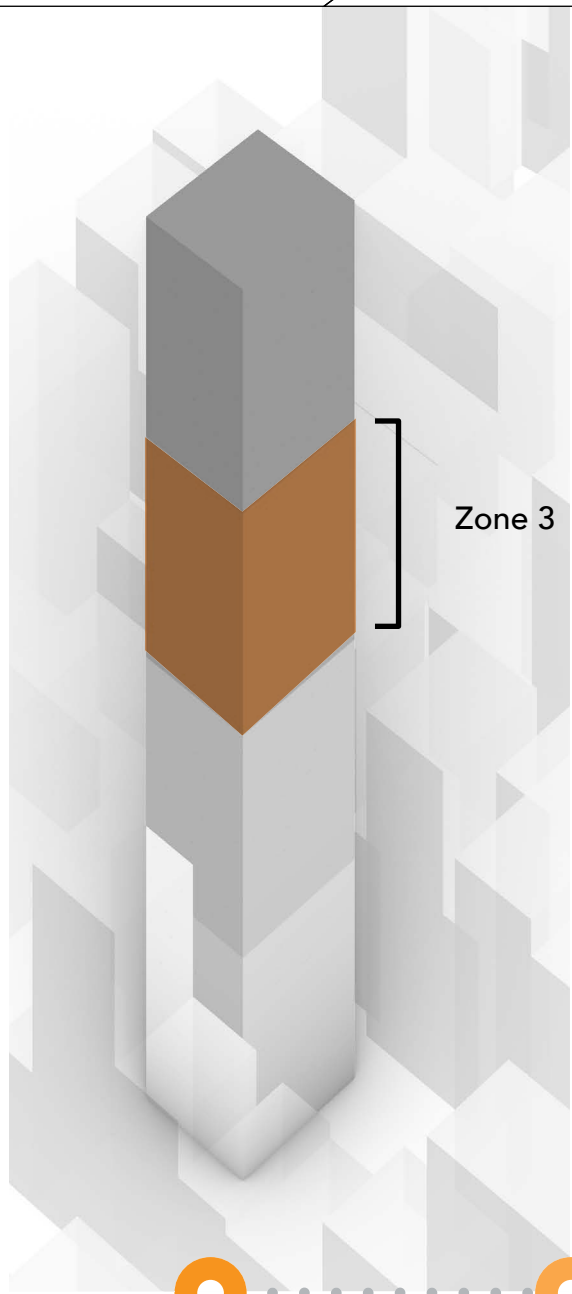
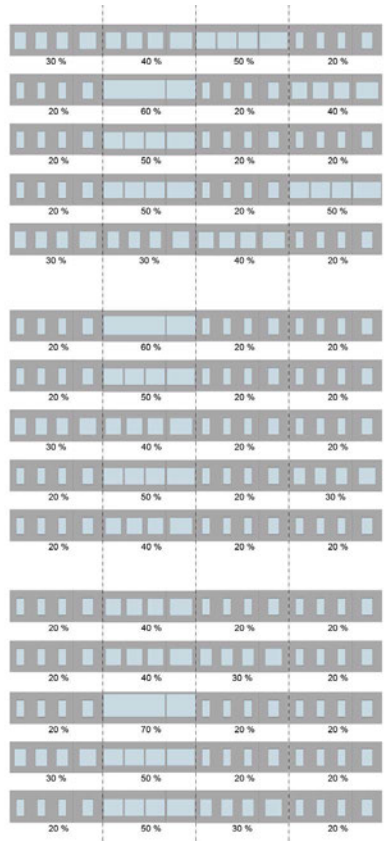
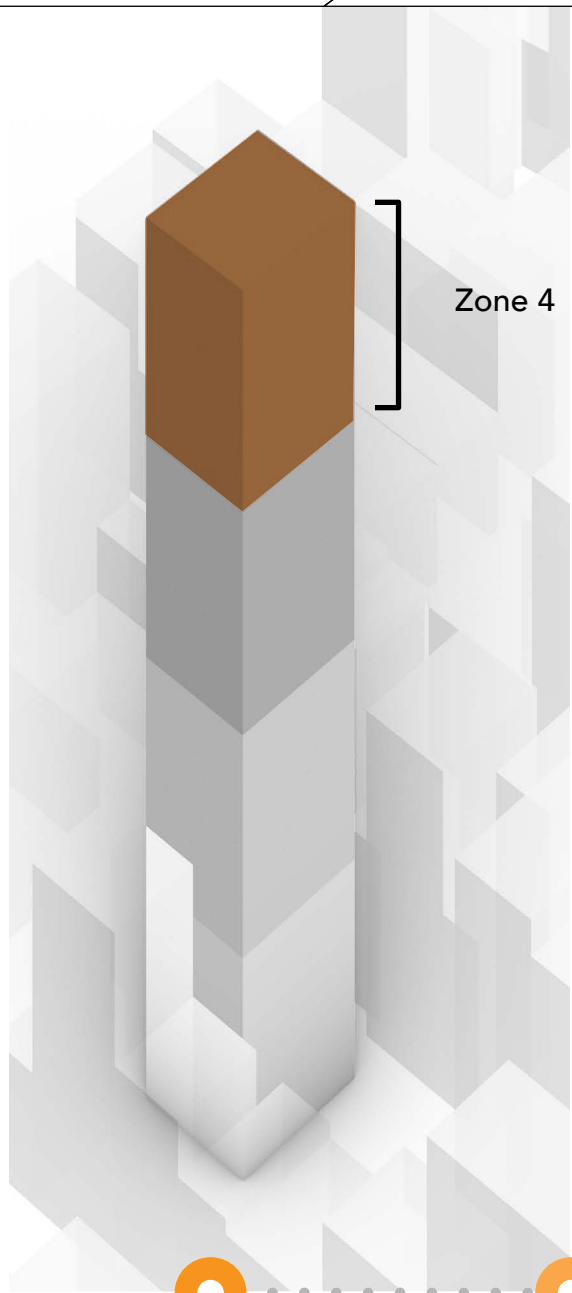
30 %
20 %

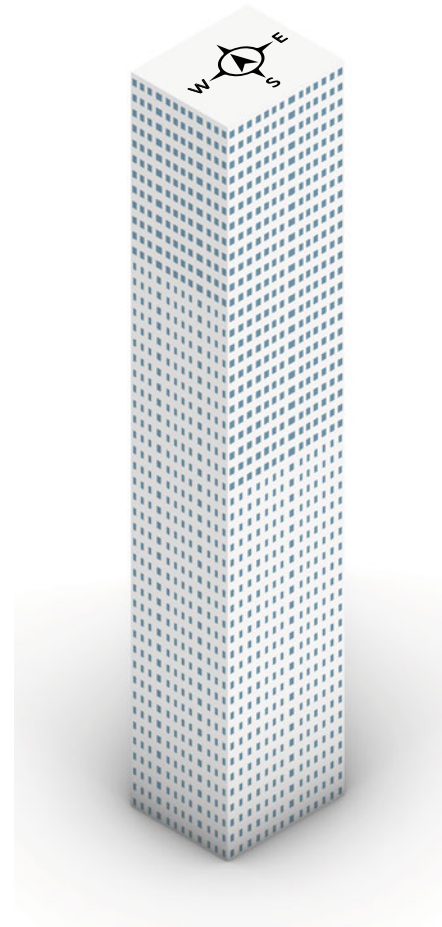

Zone 3


30 % 40 % 50 % 20 %
20 % 60 % 20 % 40 %
20 % 50 % 20 % 20 %
20 % 50 % 20 % 50 %
30 % 30 % 40 % 20 %
20 % 60 % 20 % 20 %
20 % 50 % 20 % 20 %
30 % 40 % 20 % 20 %
20 % 50 % 20 % 30 %
20 % 40 % 20 % 20 %
20 % 40 % 20 % 20 %
20 % 40 % 30 % 20 %
20 % 70 % 20 % 20 %
30 % 50 % 20 % 20 %
20 % 50 % 30 % 20 %


Zone 4


East
North
West
South
30 % 60 % 20 % 30 %
20 % 60 % 20 % 30 %
50 % 80 % 20 % 20 %
20 % 80 % 20 % 20 %
30 % 50 % 30 % 40 %
30 % 40 % 50 % 20 %
20 % 60 % 20 % 40 %
20 % 50 % 20 % 20 %
20 % 50 % 20 % 50 %
30 % 30 % 40 % 20 %
20 % 60 % 20 % 20 %
20 % 50 % 20 % 20 %
30 % 40 % 20 % 20 %
20 % 50 % 20 % 30 %
20 % 40 % 20 % 20 %
20 % 40 % 20 % 20 %
20 % 40 % 30 % 20 %
20 % 70 % 20 % 20 %
30 % 50 % 20 % 20 %
20 % 50 % 30 % 20 %

Scheme of Facade



WWR

East / South / West

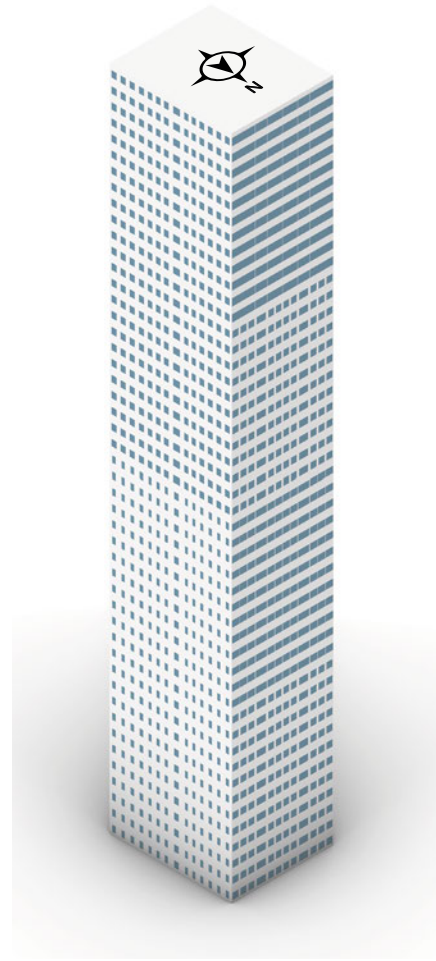
20%** to **30%
(Smaller Ratios)

Solar Gains

Heat Loss

Energy Generation

Scheme of Facade



WWR

North

30%** to **80%
(Larger Ratios)

Larger Ratio

Daylight

Smaller Ratio

Heat Loss

Facade Parameters Optimization

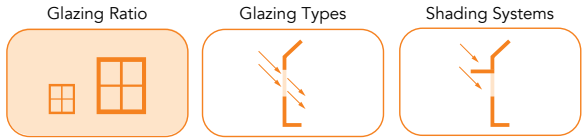
Facade Parameters Optimization

Glazing Ratio

Glazing Types

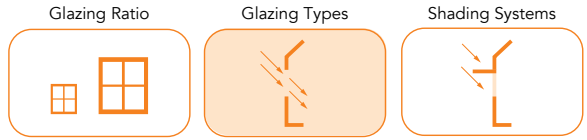
Shading Systems

Facade Parameters Optimization



x 8

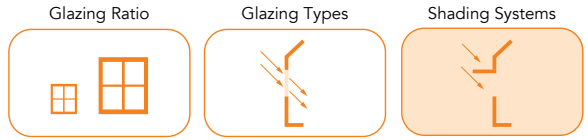
Facade Parameters Optimization



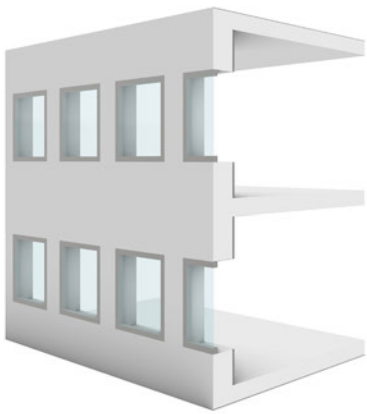
x 5

	Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5
g-value [-]	0.62	0.47	0.5	0.5	0.7
VLT [%]	80	75	69	75	72

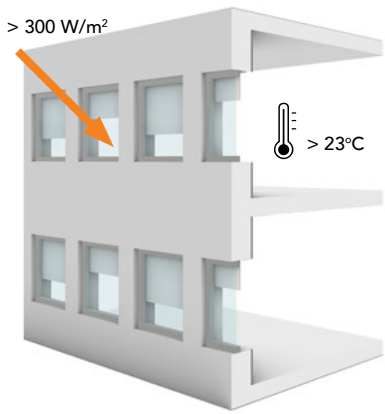
Facade Parameters Optimization

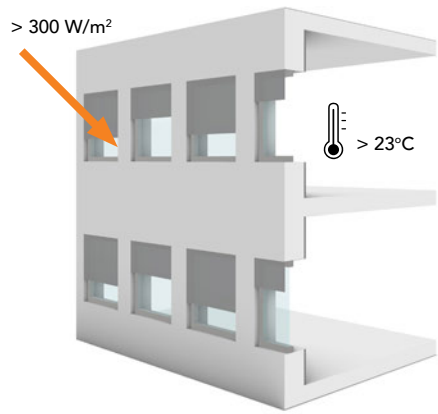


x 4

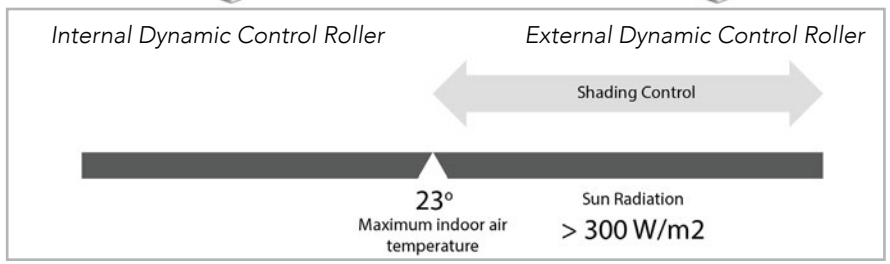


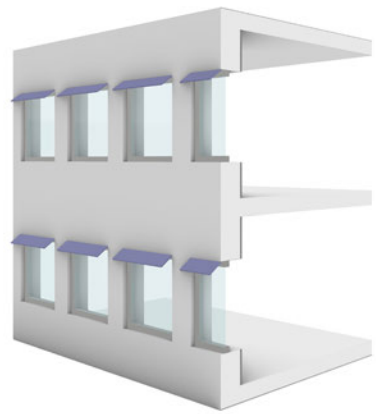
No Shading System





Internal Dynamic Control Roller *External Dynamic Control Roller*





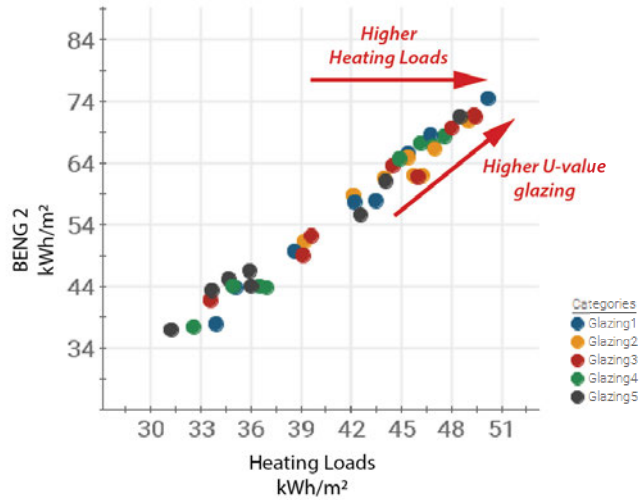
Fixed Fins & PV mounted

Glazing Properties Performance

Glazing Properties Performance

	Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5
g-value [-]	0.62	0.47	0.5	0.5	0.7
VLT [%]	80	75	69	75	72

Glazing Properties Performance



	Double Glazing			*Triple Glazing*	
Glazing Type	***1***	***2***	***3***	***4***	***5***
U-value [W/m^2K]	1.1	0.9	0.7	0.6	0.5
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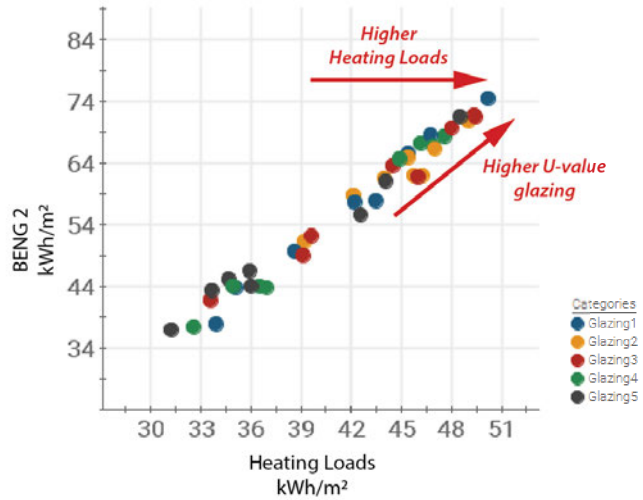
Glazing Properties Performance



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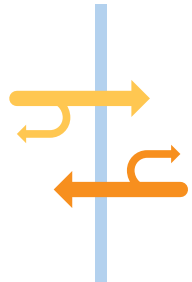
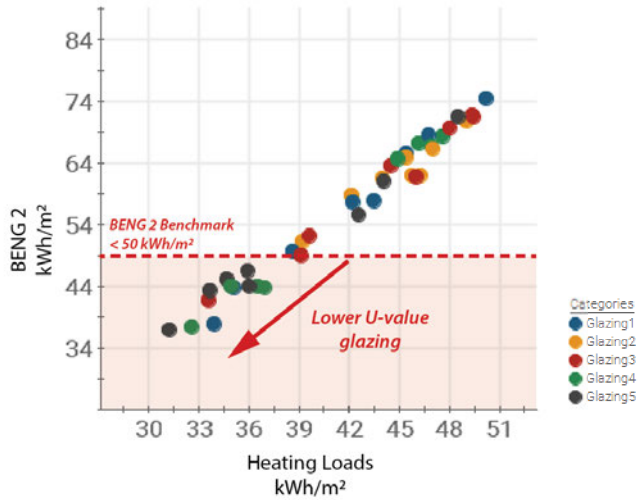
U -value

Heat Transfer



Glazing Properties Performance



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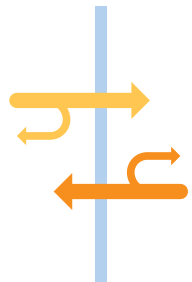
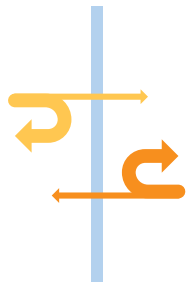
VLT [%]	80	75	69	75	72

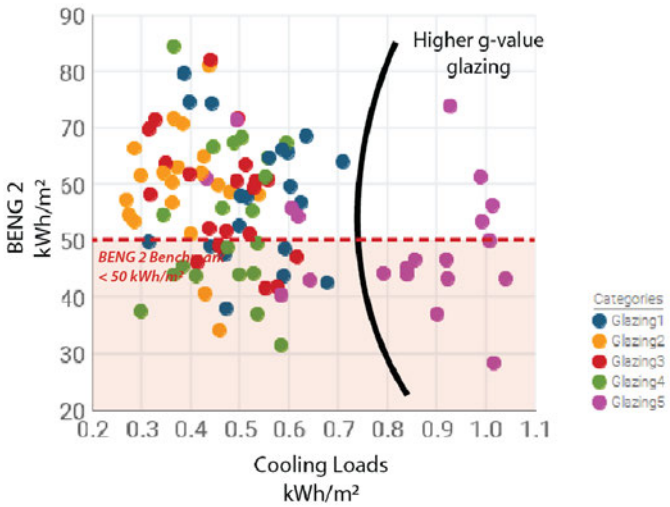
↑ *U -value*
↑ *Heat Transfer*



↓ *U -value*
↓ *Heat Transfer*



Glazing Properties Performance



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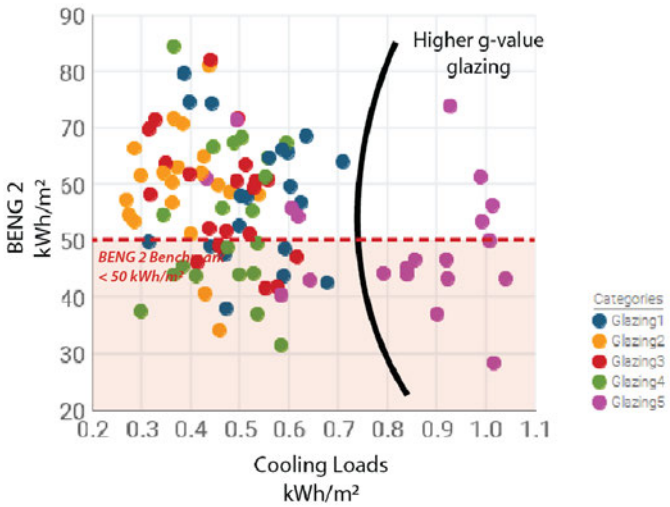
Glazing Properties Performance



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g-value [-]	0.62	0.47	0.5	0.5	0.7
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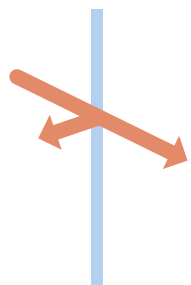
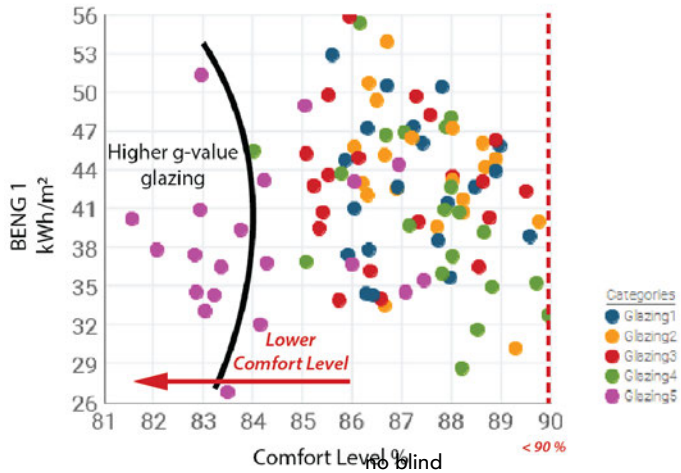
g -value

Solar Gains



Glazing Properties Performance



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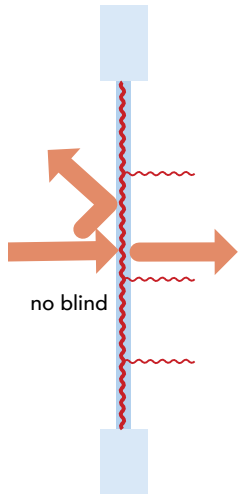
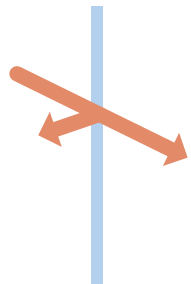


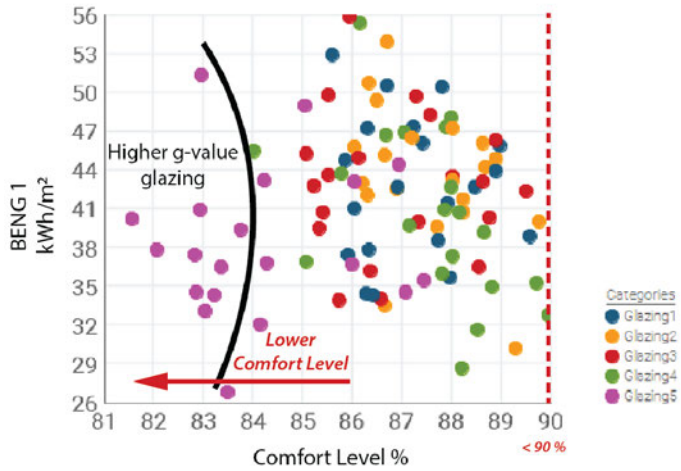
High g-value
Glazing = thermal mass
(radiating heat on long term)

g -value

Solar Gains



Glazing Properties Performance



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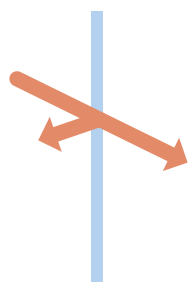
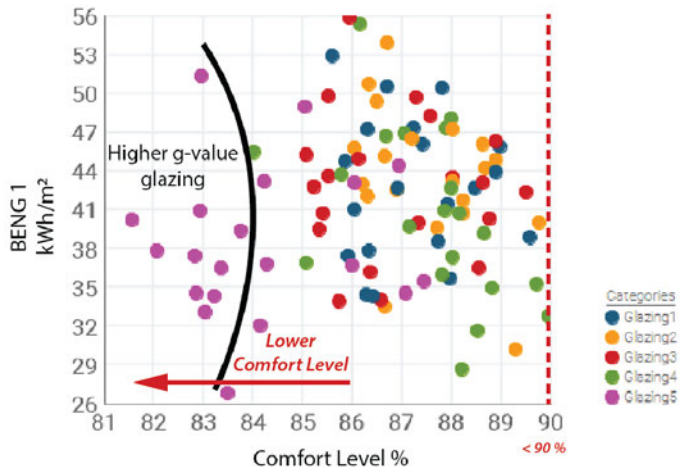
g -value

Solar Gains



Glazing Properties Performance



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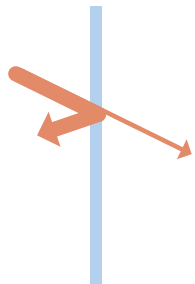
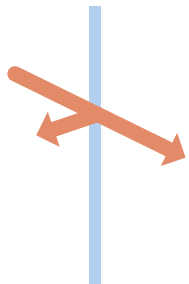
g -value
Solar Gains



g -value
Solar Gains



Glazing Properties Performance

	Double Glazing			*Triple Glazing*	
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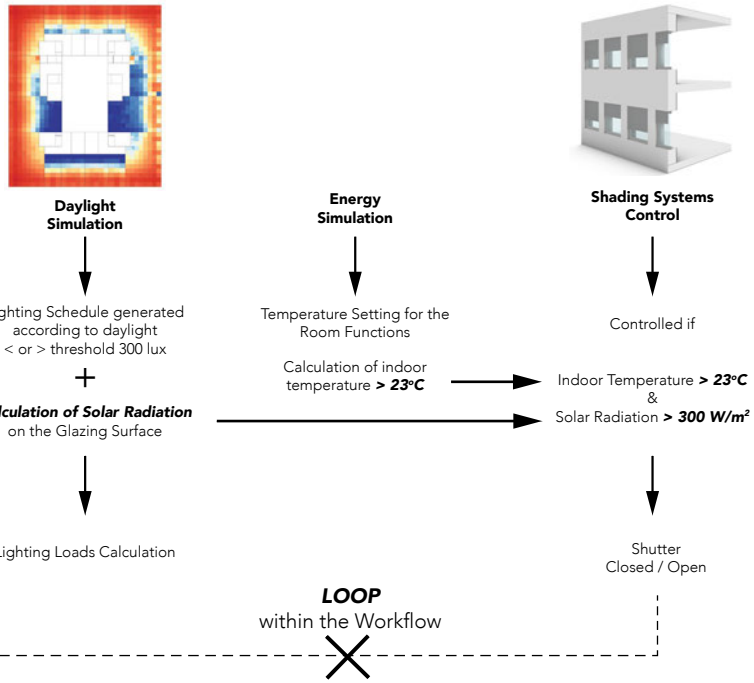
Glazing Properties Performance



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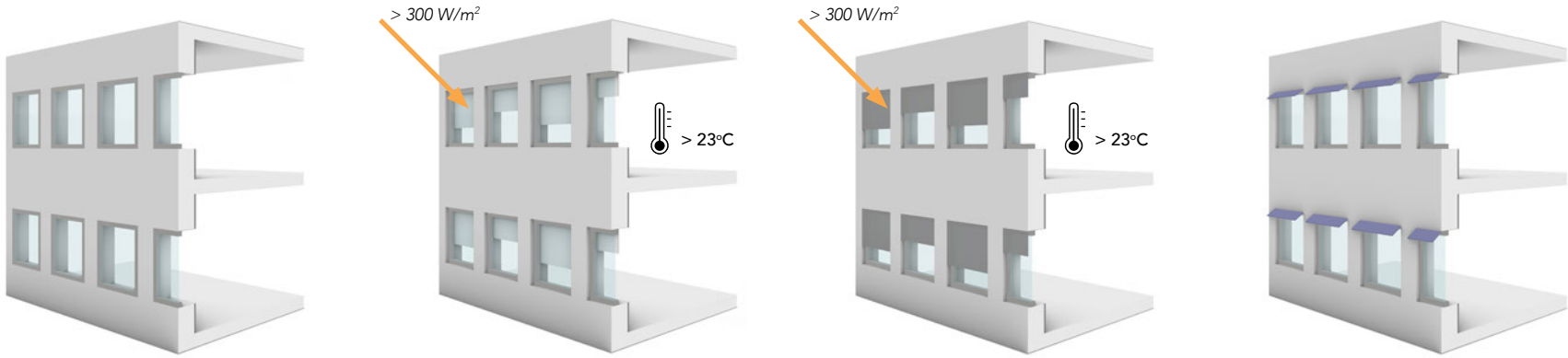
Shading Systems Performance



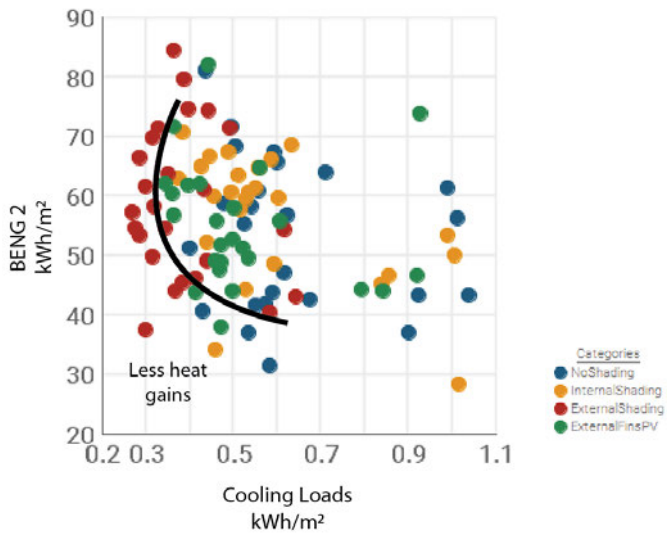
No Shading System

Internal Dynamic Control Roller

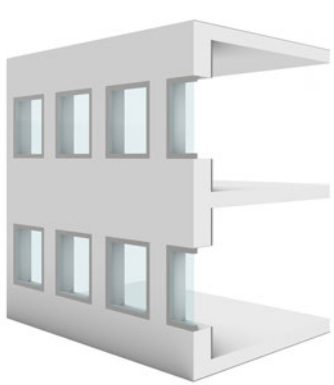
External Dynamic Control Roller

Fixed Fins & PV mounted

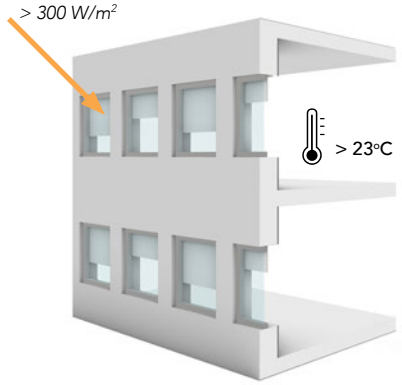
Shading Systems Performance



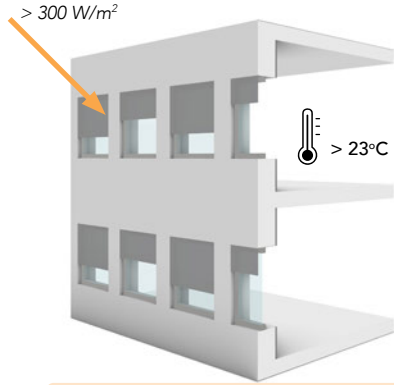
Externally Controlled Shutter



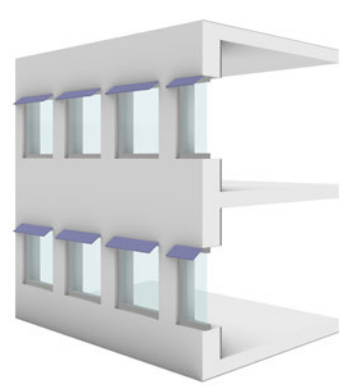
No Shading System



Internal Dynamic Control Roller

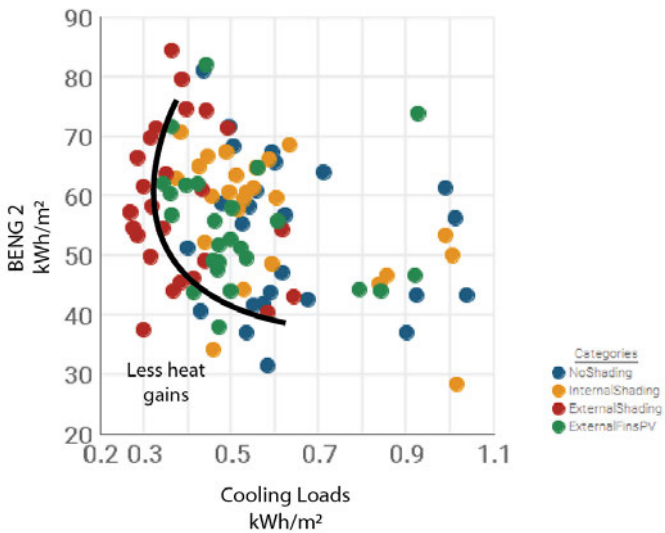


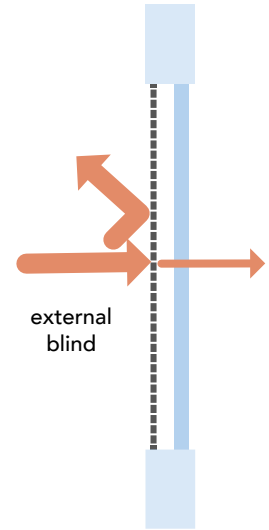
External Dynamic Control Roller



Fixed Fins & PV mounted

Shading Systems Performance



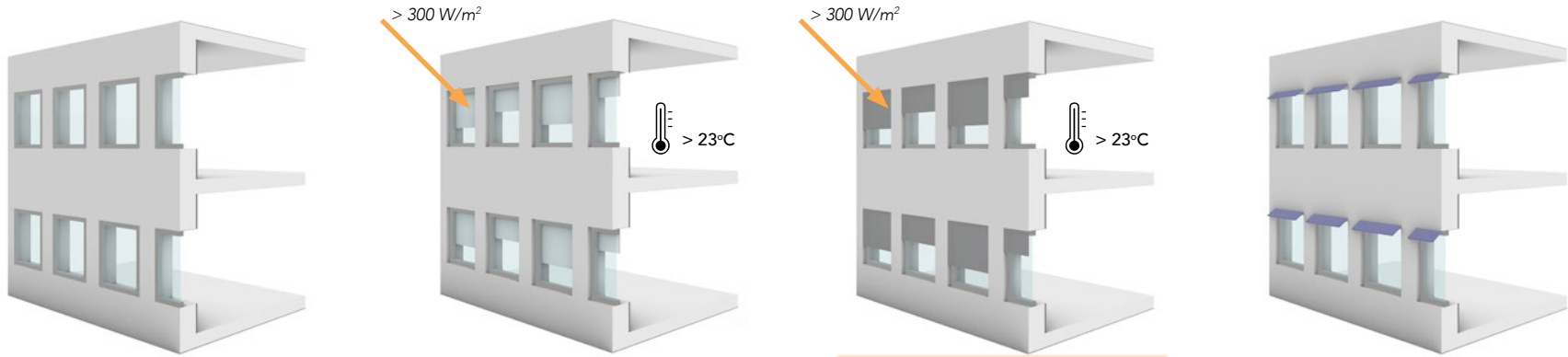


Externally Controlled Shutter

*Stops solar gains at **early layer outside***

↓ *Heat Gains*

↓ *Cooling Loads*



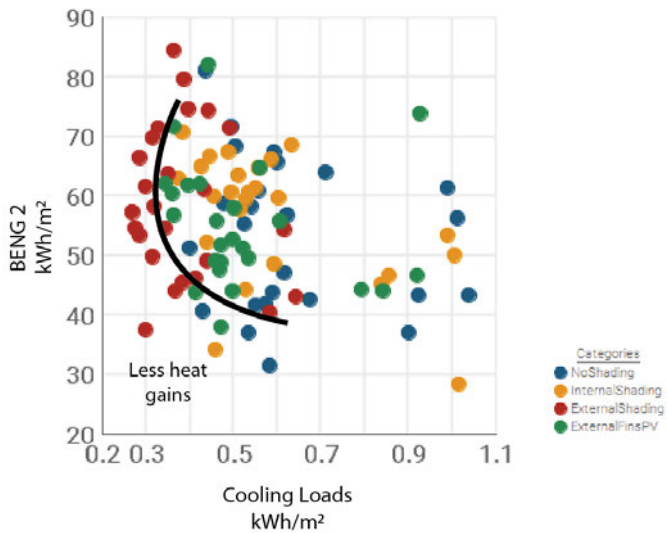
No Shading System

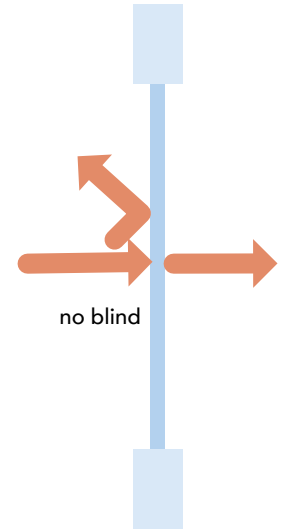
Internal Dynamic Control Roller

External Dynamic Control Roller

Fixed Fins & PV mounted

Shading Systems Performance

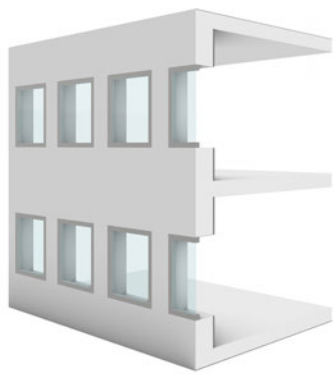




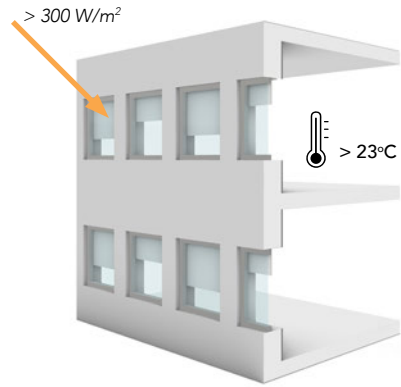
No Shading

Heat Gains

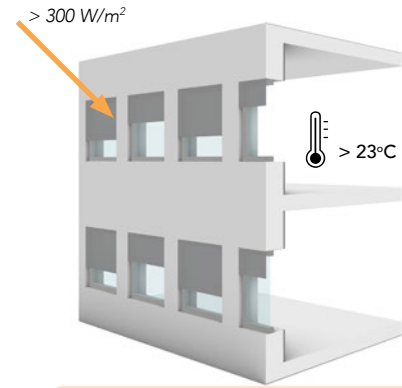
Cooling Loads



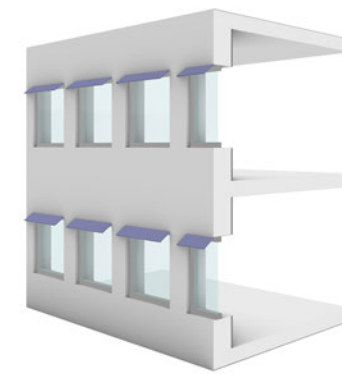
No Shading System



Internal Dynamic Control Roller

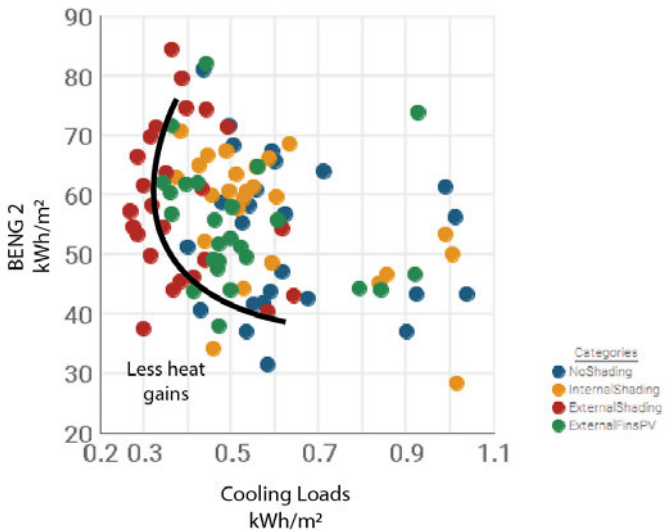


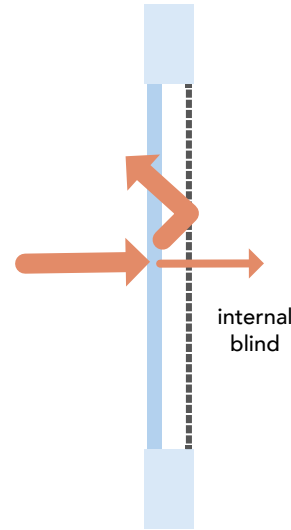
External Dynamic Control Roller



Fixed Fins & PV mounted

Shading Systems Performance



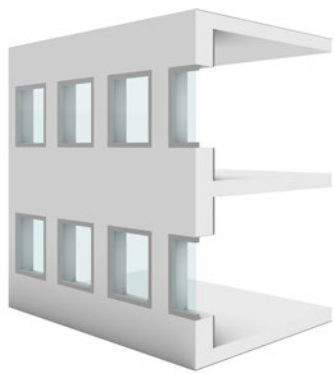


Internally Controlled Shutter

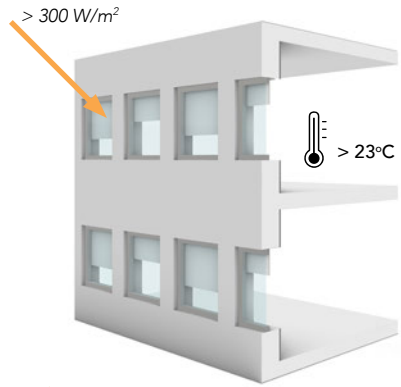
Solar gains reach indoor ***layer***

Heat Gains

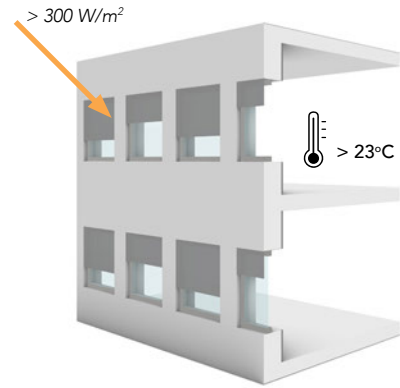
Cooling Loads



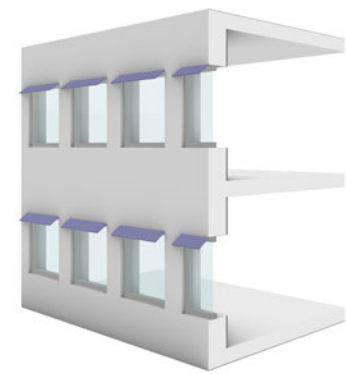
No Shading System



Internal Dynamic Control Roller

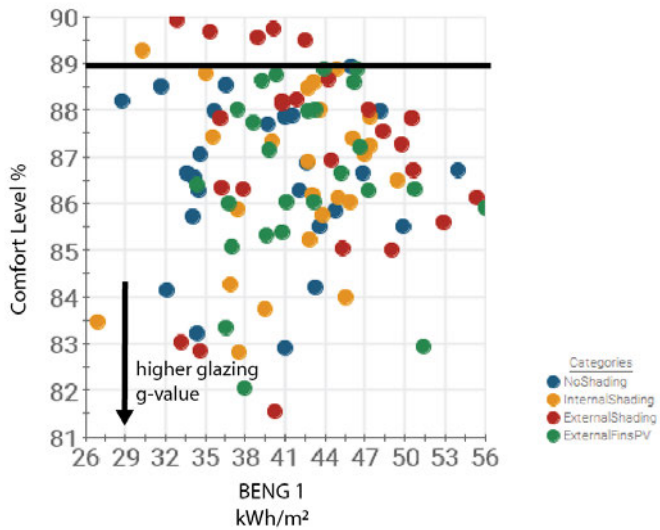


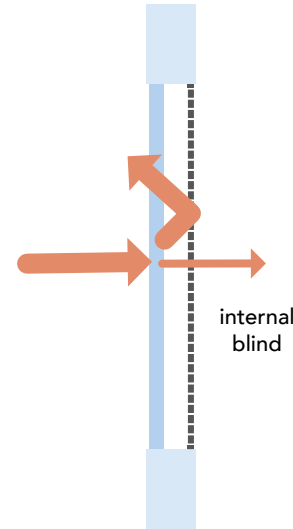
External Dynamic Control Roller



Fixed Fins & PV mounted

Shading Systems Performance

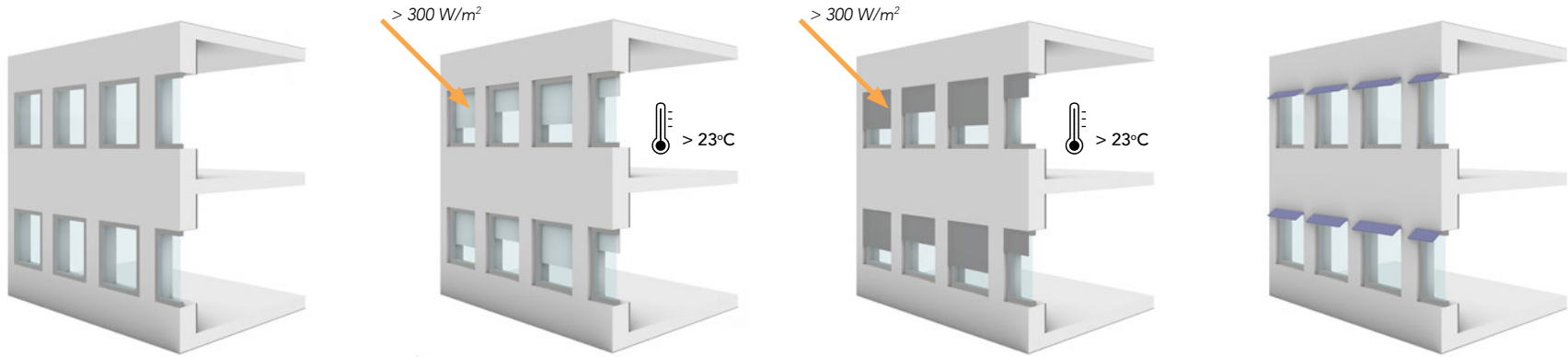




Internally Controlled Shutter

Solar gains reach indoor ***layer***

- ***Heat Gains***
- ***Cooling Loads***
- ***Comfort Level***



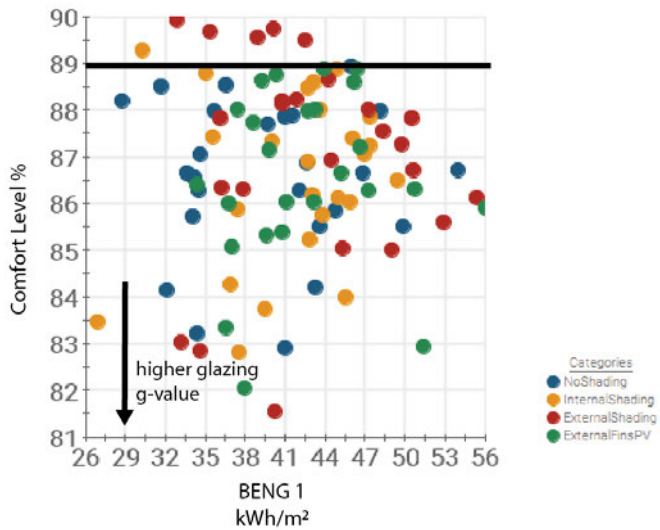
No Shading System

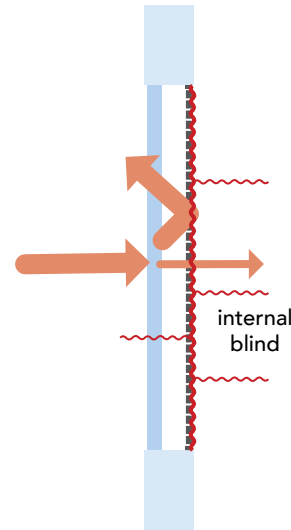
Internal Dynamic Control Roller

External Dynamic Control Roller

Fixed Fins & PV mounted

Shading Systems Performance





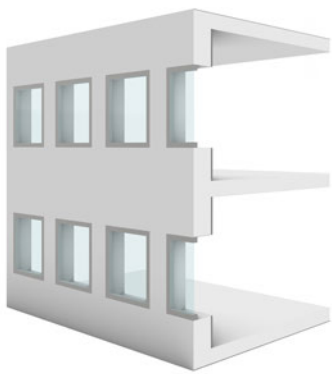
Internally Controlled Shutter

Solar gains reach indoor ***layer***

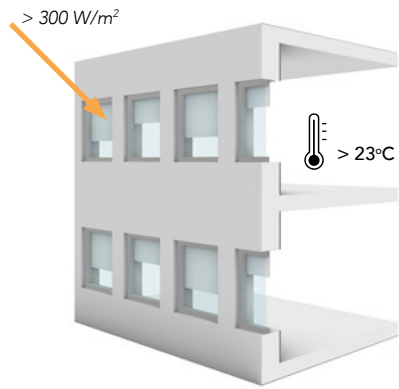
Heat Gains

Cooling Loads

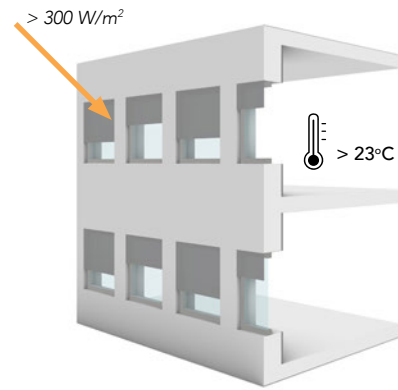
Comfort Level
shading acts as thermal mass



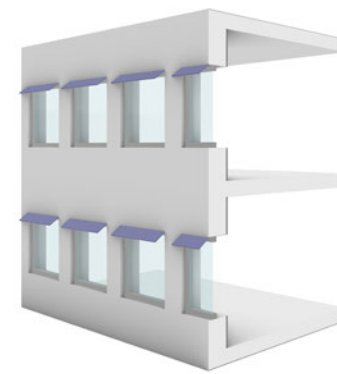
No Shading System



Internal Dynamic Control Roller

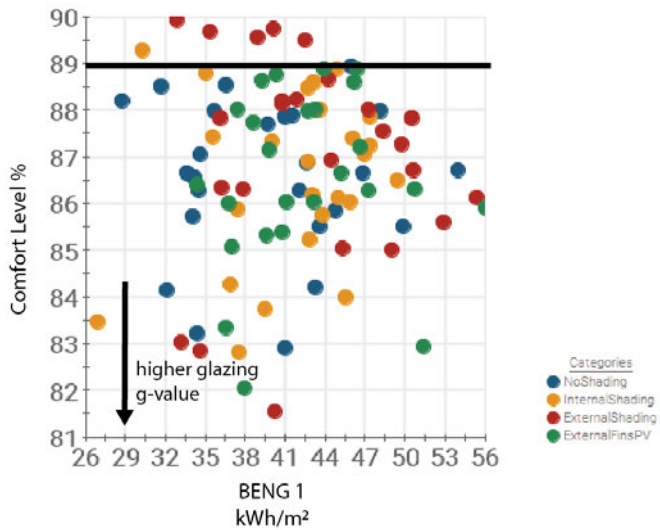


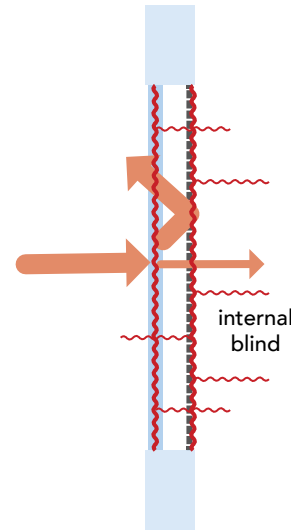
External Dynamic Control Roller



Fixed Fins & PV mounted

Shading Systems Performance





Internally Controlled Shutter

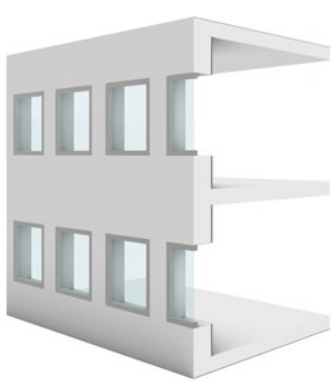
Solar gains reach indoor ***layer***

Heat Gains

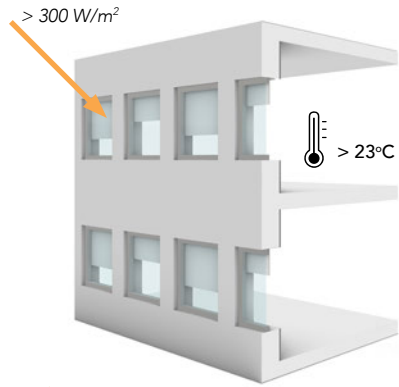
Cooling Loads

Comfort Level
shading acts as thermal mass

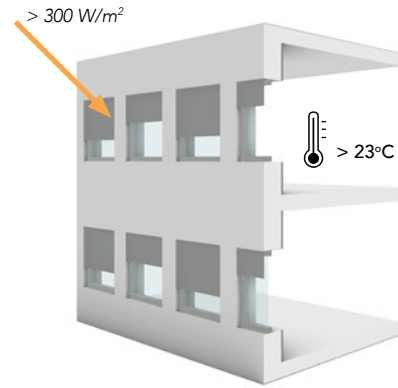
+ intensify by glazing of high g-value



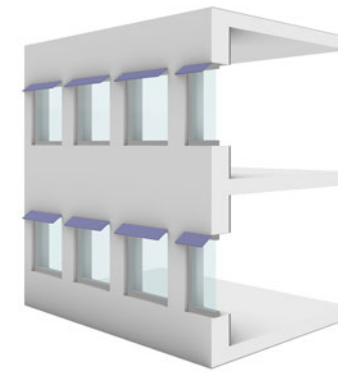
No Shading System



Internal Dynamic Control Roller

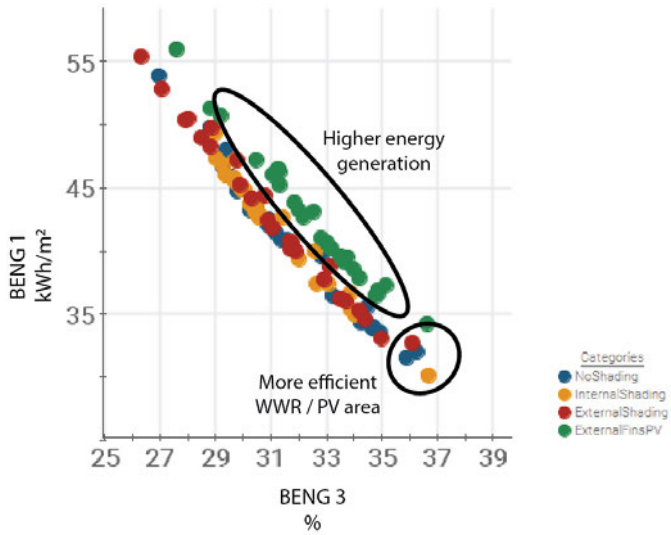


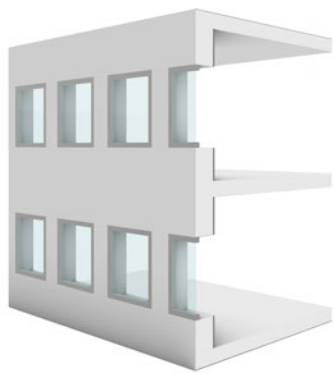
External Dynamic Control Roller



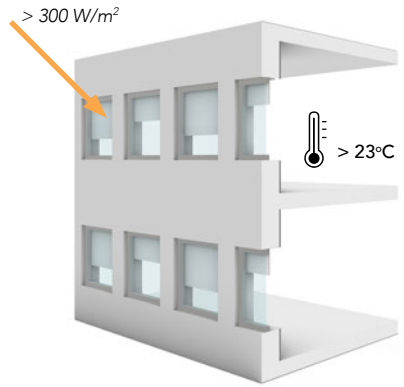
Fixed Fins & PV mounted

Shading Systems Performance

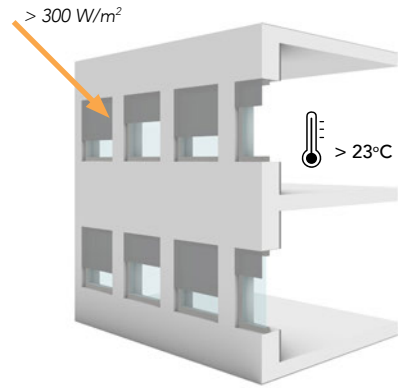




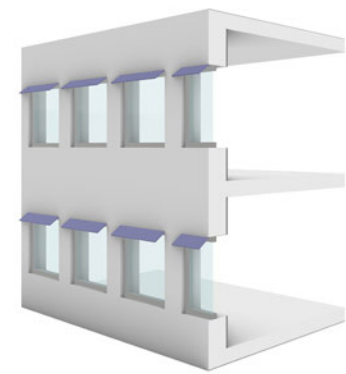
No Shading System



Internal Dynamic Control Roller

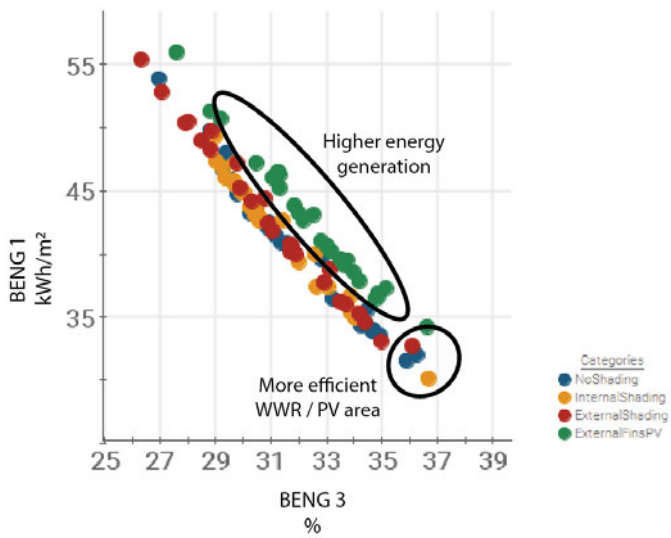


External Dynamic Control Roller



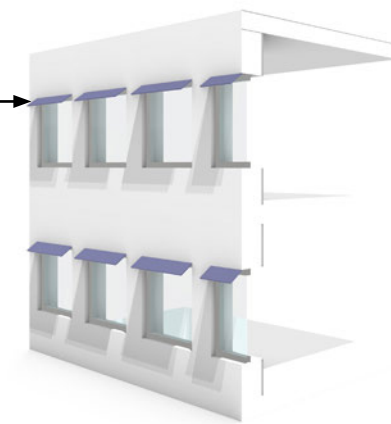
Fixed Fins & PV mounted

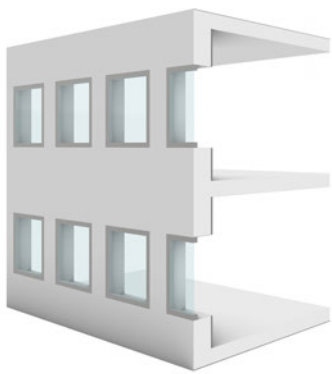
Shading Systems Performance



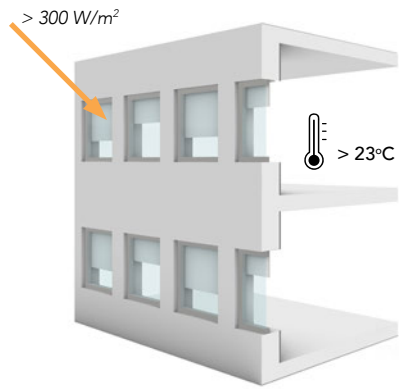
External Fixed Fins + PV

Energy Generation

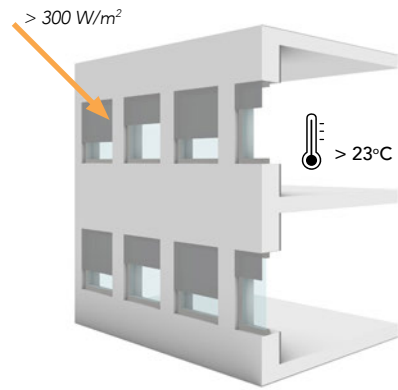




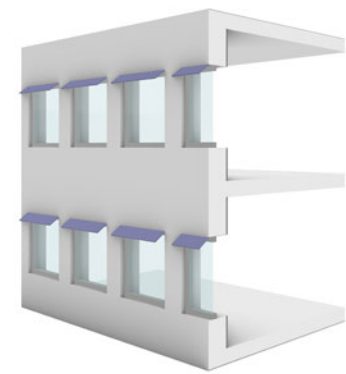
No Shading System



Internal Dynamic Control Roller

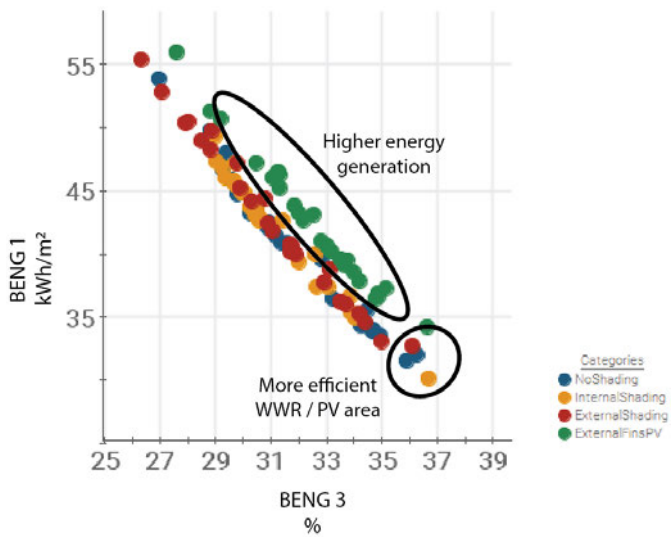


External Dynamic Control Roller



Fixed Fins & PV mounted

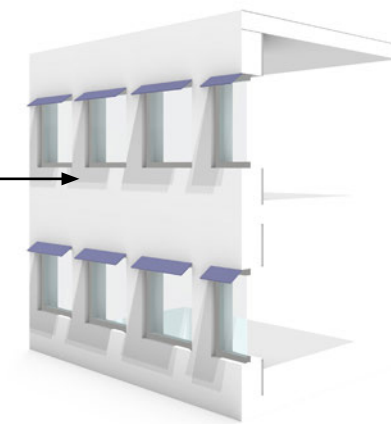
Shading Systems Performance

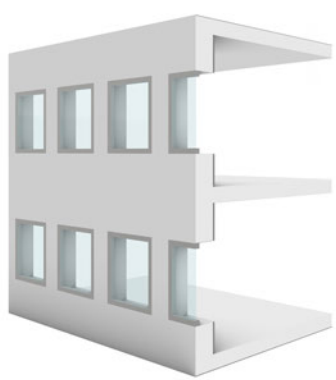


Self-Shadowing →

↓ *Energy Generation*

External Fixed Fins + PV





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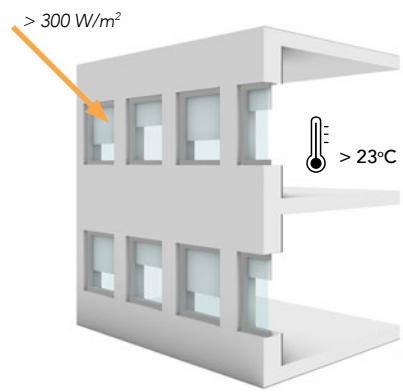
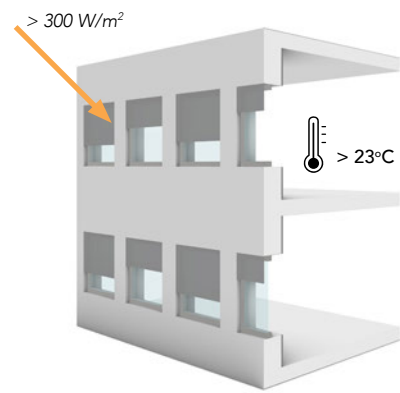
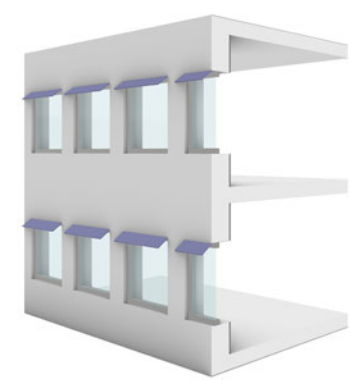


Internal Dynamic Control Roller

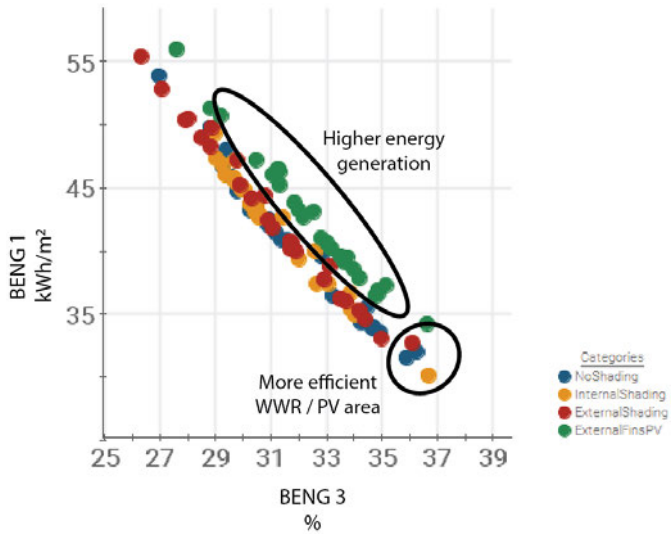


External Dynamic Control Roller



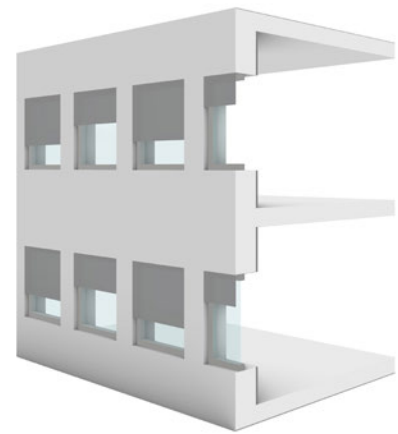
Fixed Fins & PV mounted

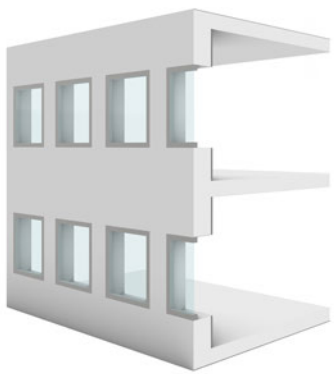
Shading Systems Performance



More Efficient WWR / PV %

Energy Generation





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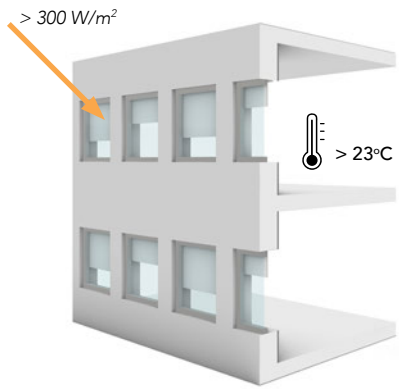
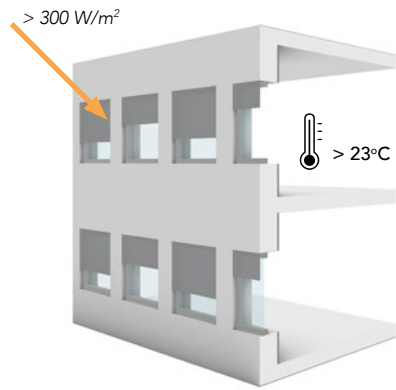
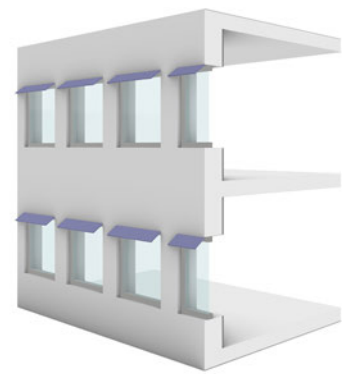


Internal Dynamic Control Roller

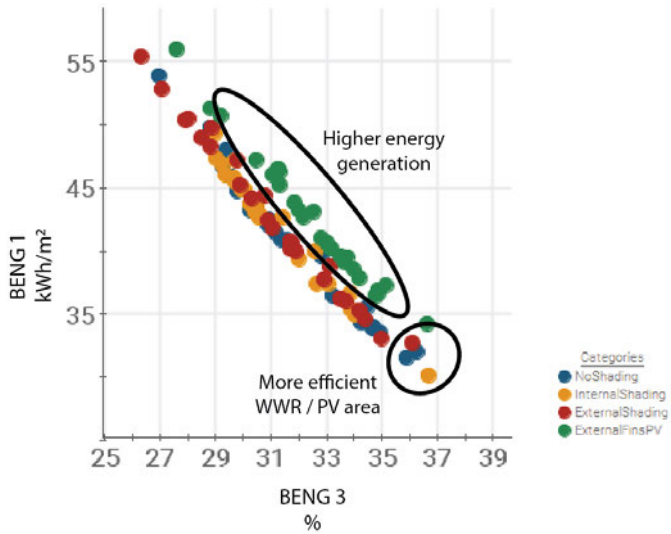


External Dynamic Control Roller



Fixed Fins & PV mounted

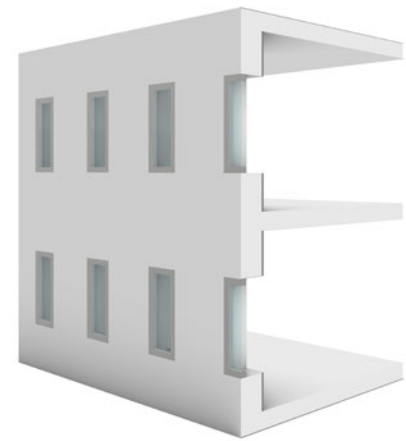
Shading Systems Performance

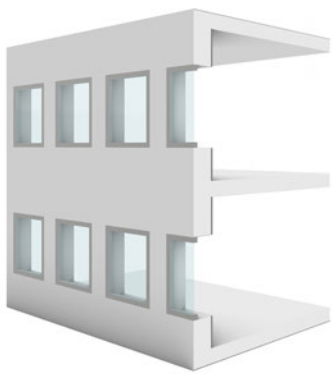


More Efficient WWR / PV %

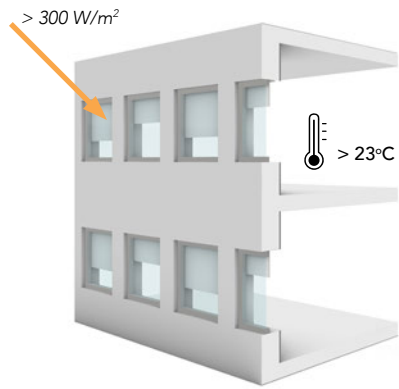
Energy Generation

Smaller WWR Ratios

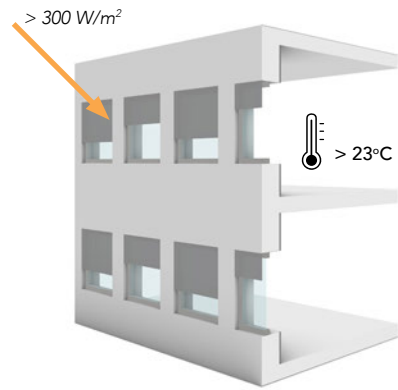




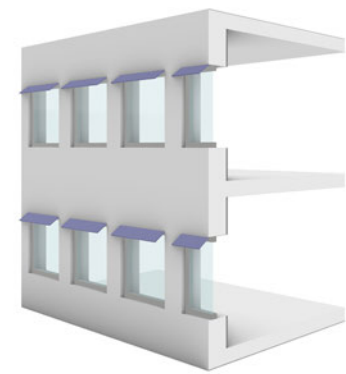
No Shading System



Internal Dynamic Control Roller



External Dynamic Control Roller



Fixed Fins & PV mounted

Facade Optimization

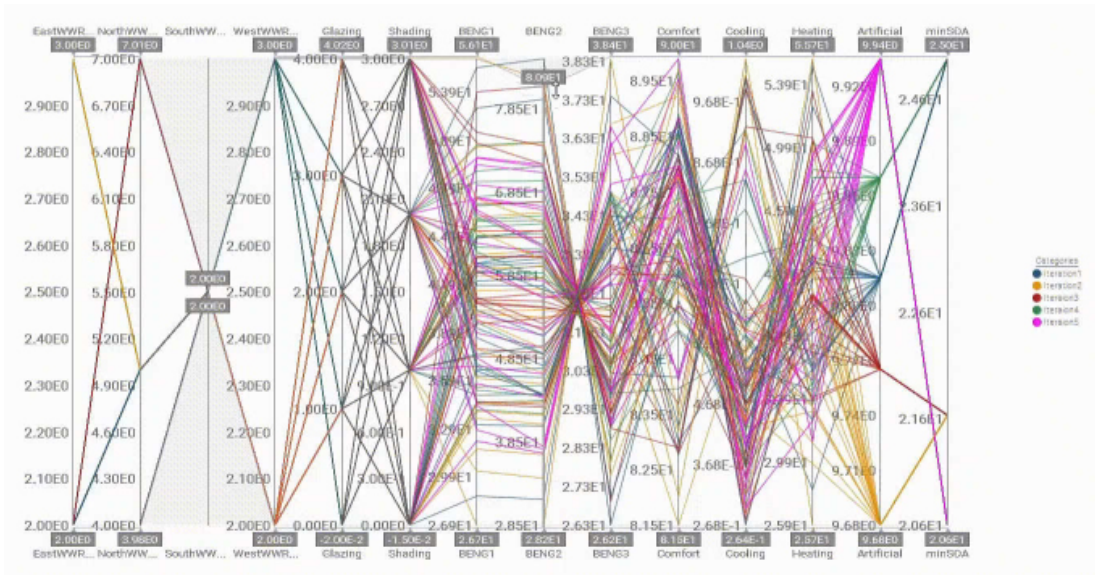
Facade Optimization

Glazing Ratio | Glazing Types | Shading Systems

Objectives

BENG 2

BENG 3

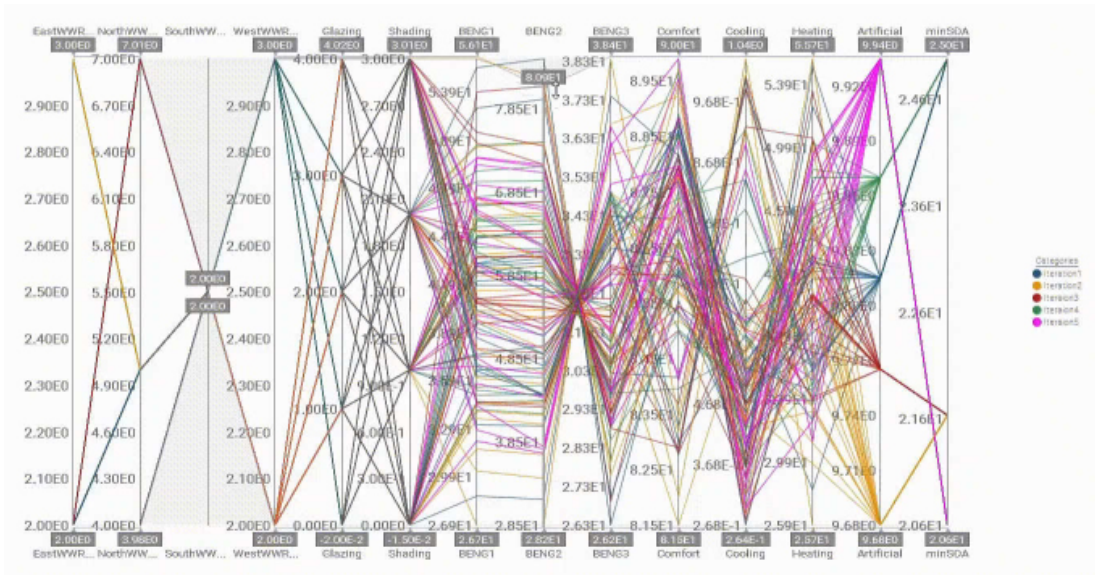


Facade Optimization

Glazing Ratio | Glazing Types | Shading Systems → *Glazing Type 4*

Objectives

- BENG 2
- BENG 3



Facade Optimization

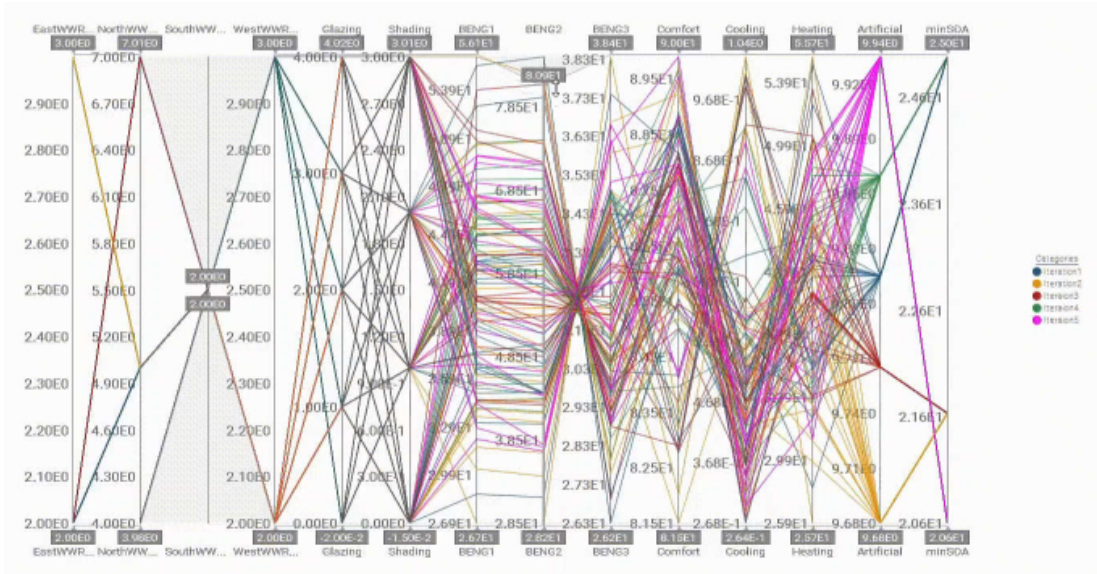
Glazing Ratio | Glazing Types | Shading Systems

→ *Shading Type 2*
Externally Controlled Roller

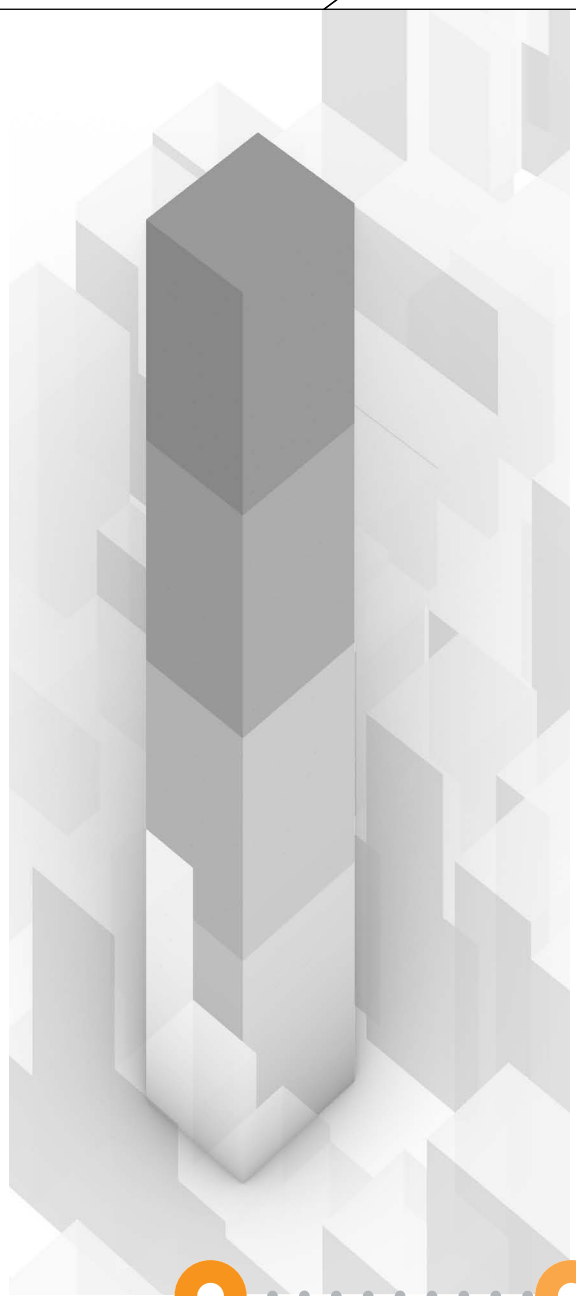
Objectives

BENG 2

BENG 3

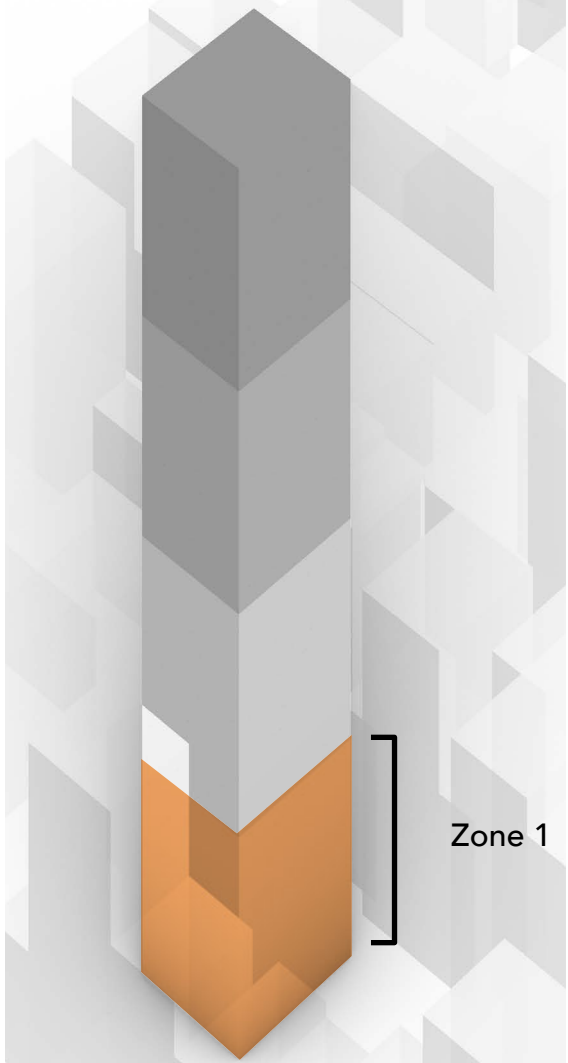


Facade Optimization

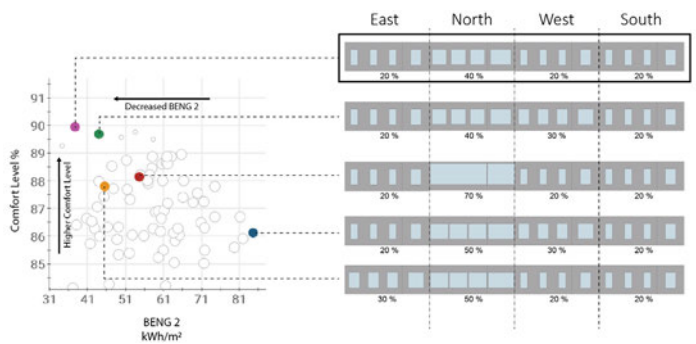


East North West South

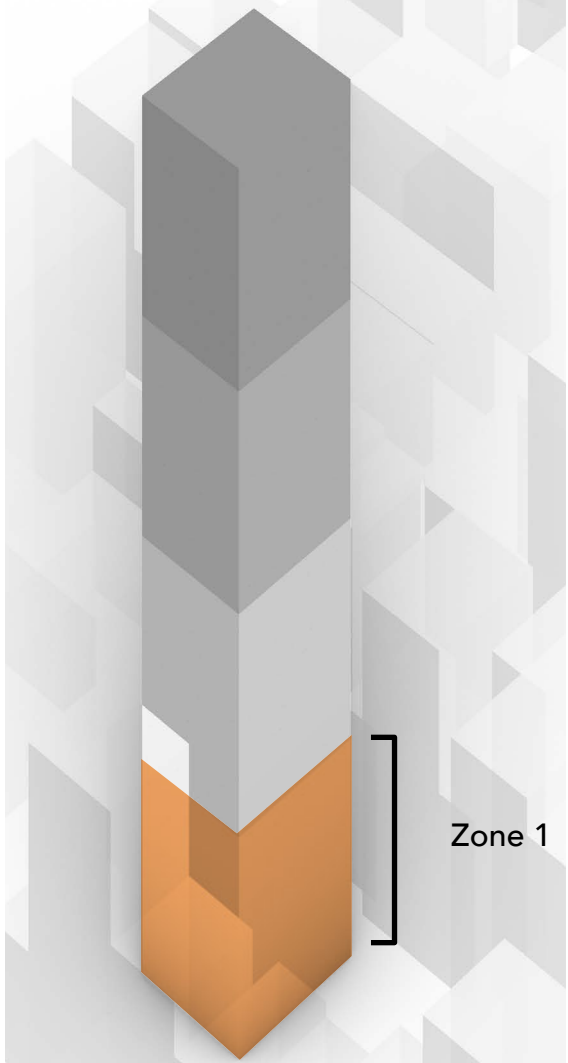
Facade Optimization

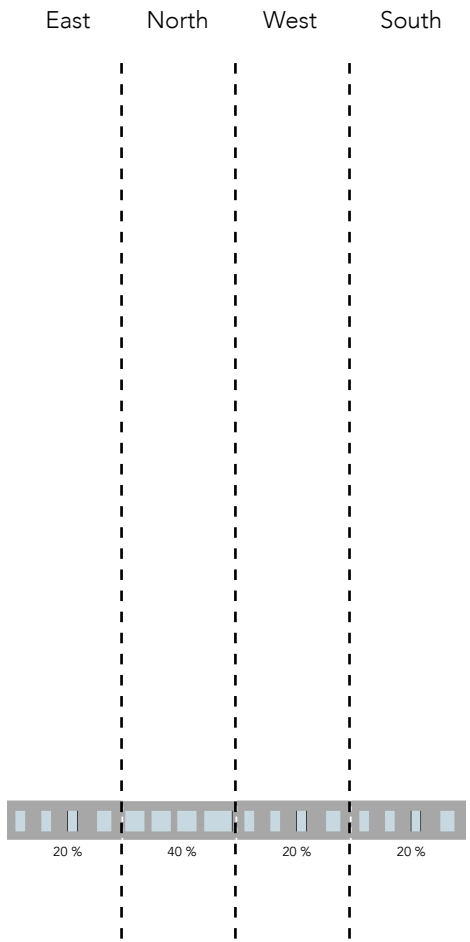


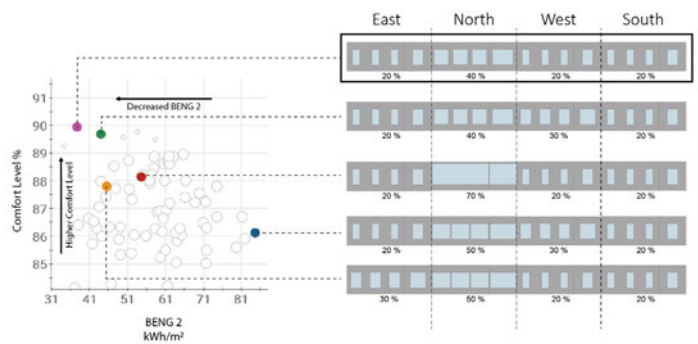
East North West South



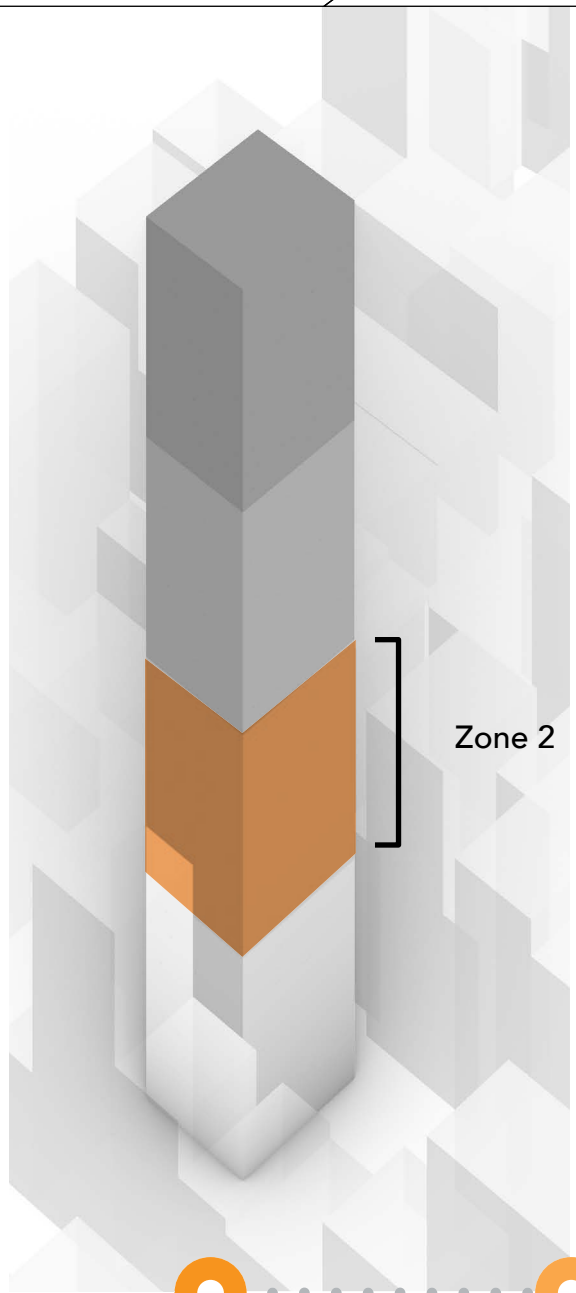
Facade Optimization

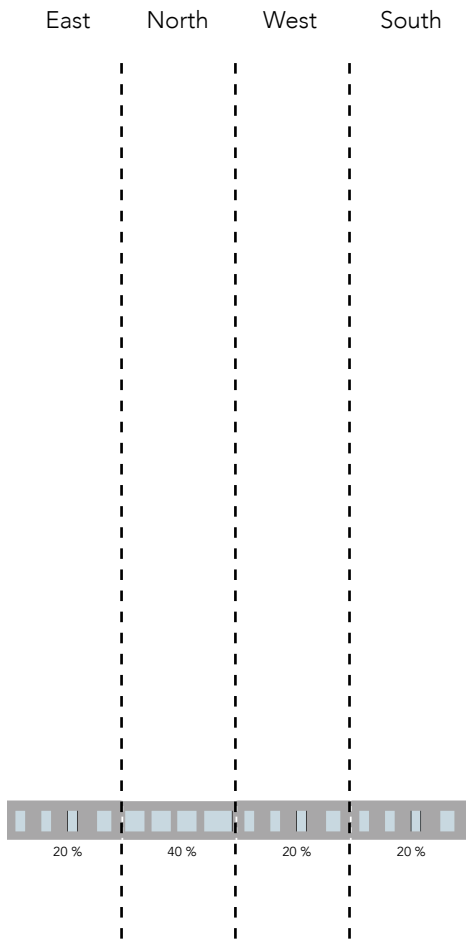


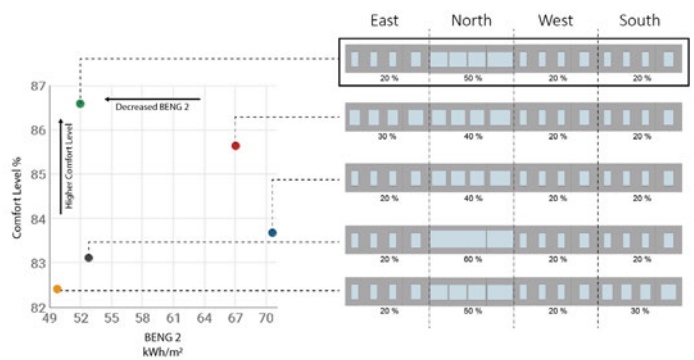


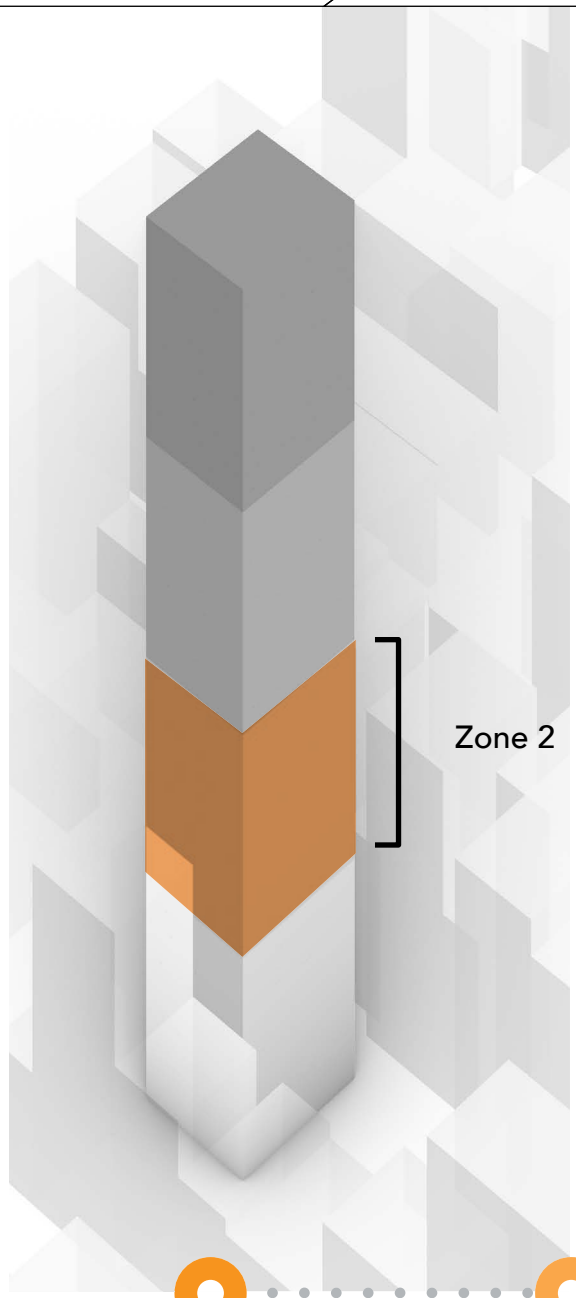


Facade Optimization

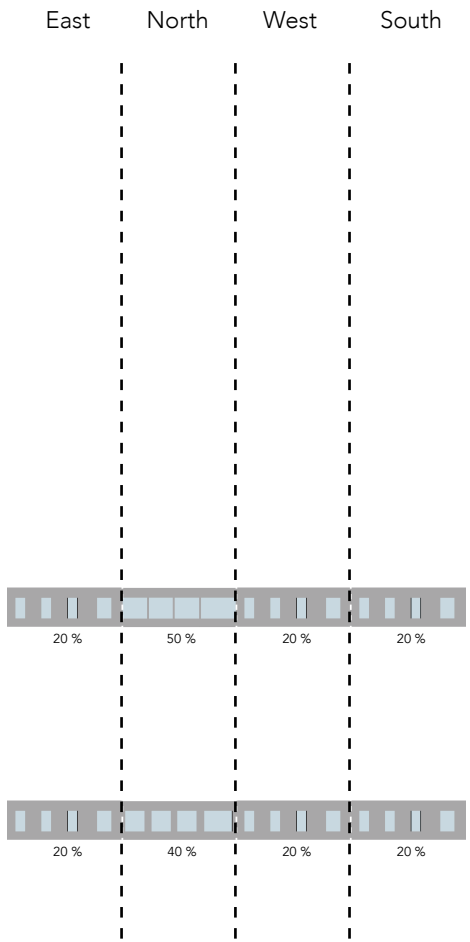


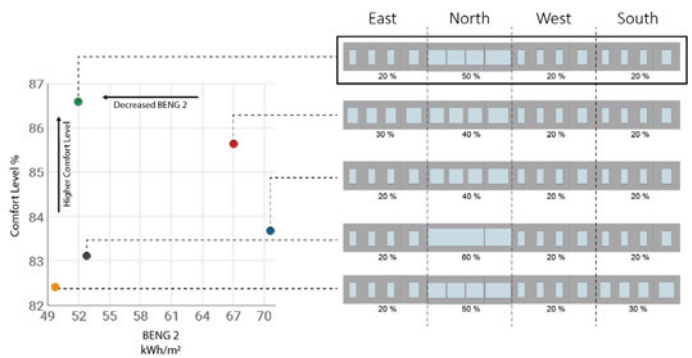




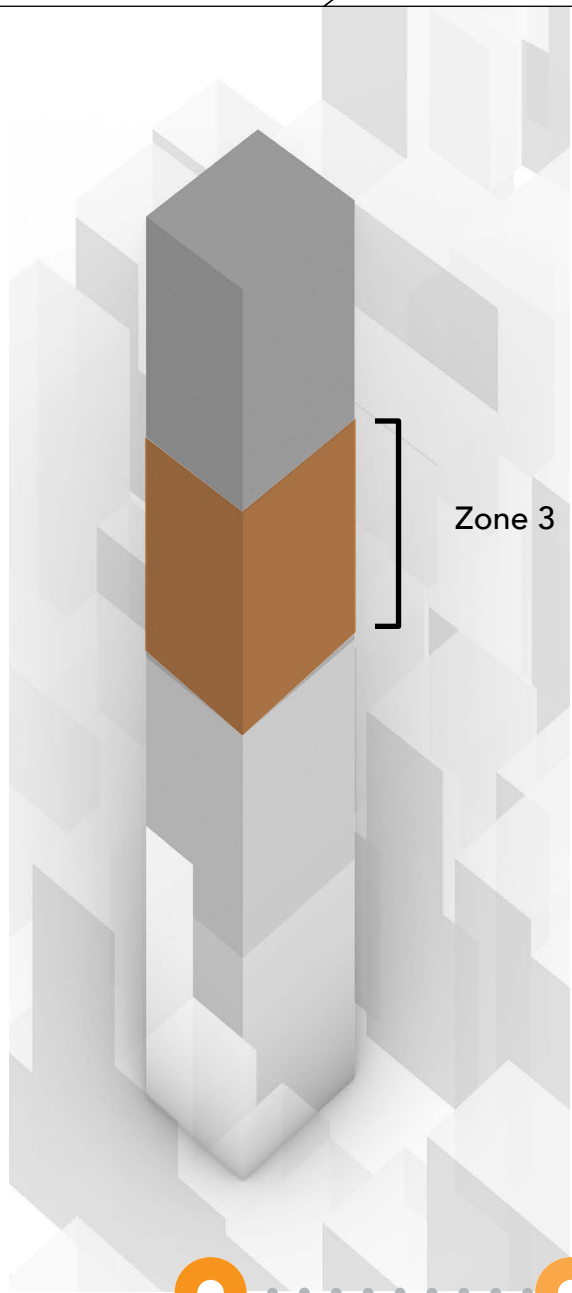


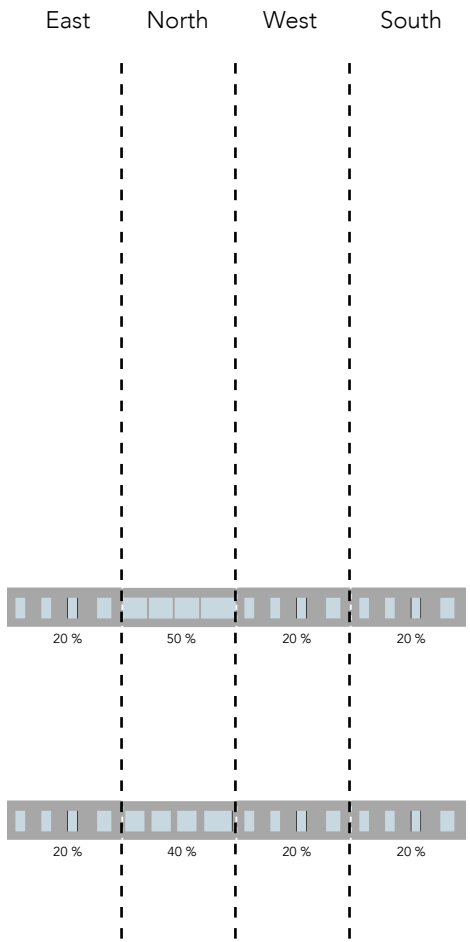
Facade Optimization

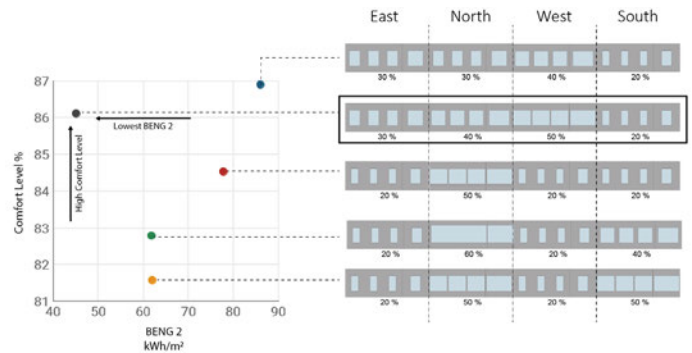




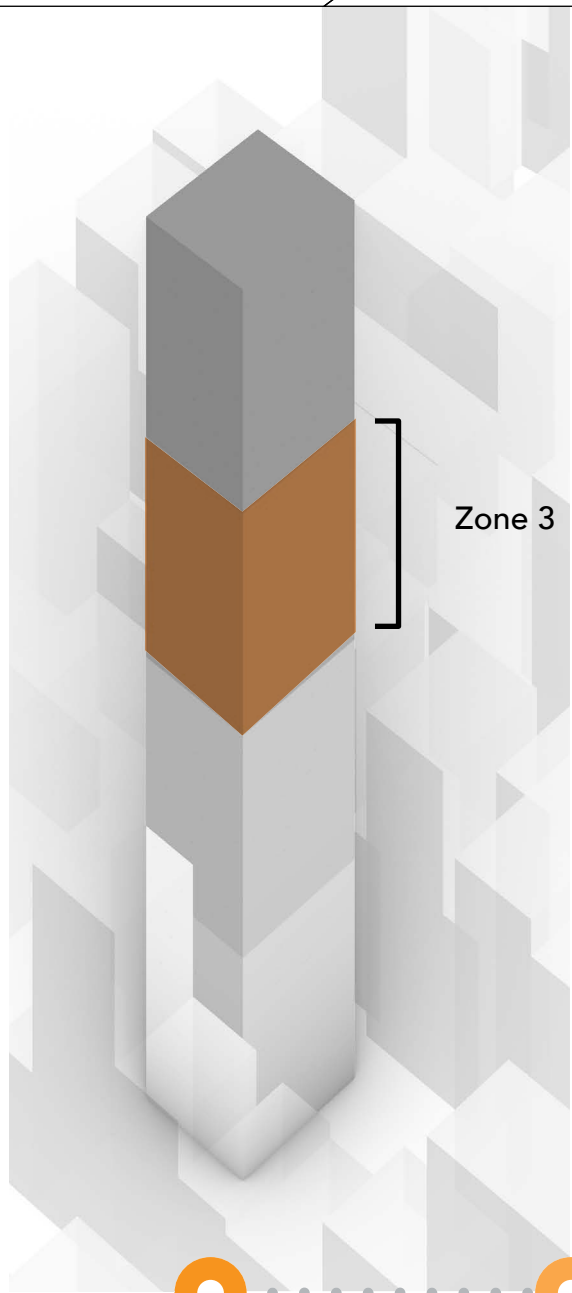
Facade Optimization

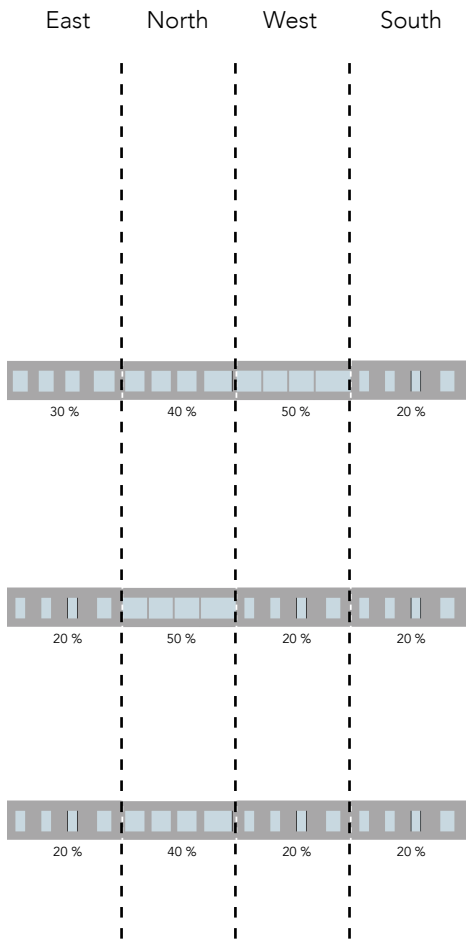


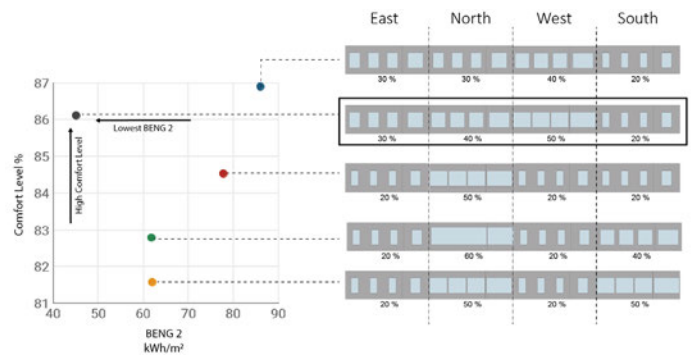




Facade Optimization







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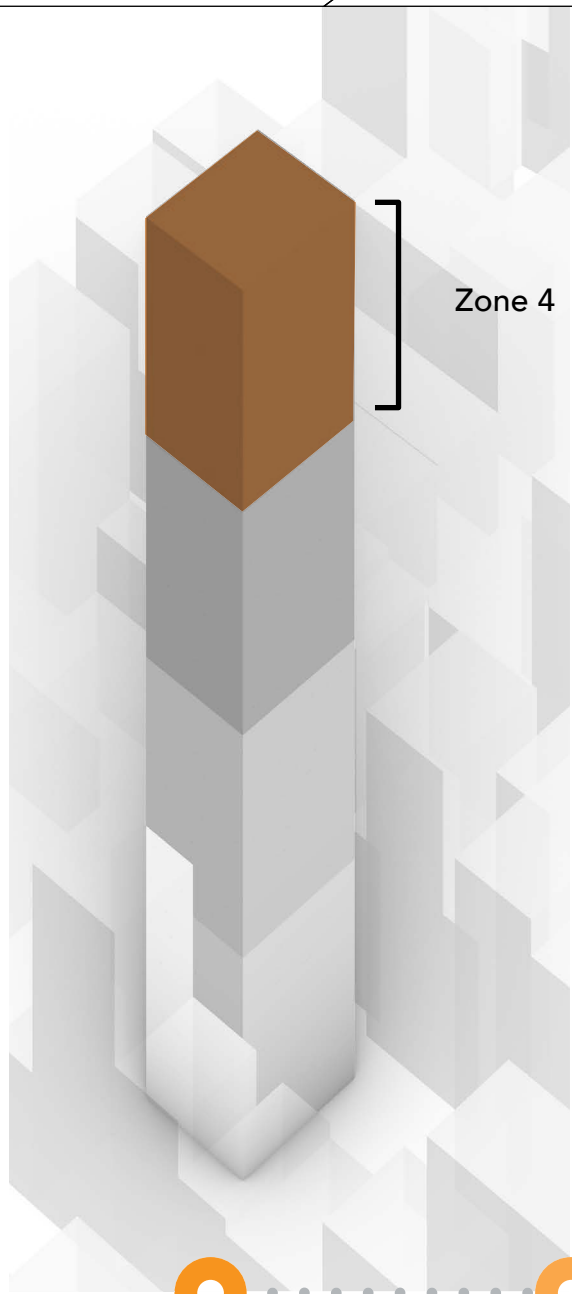
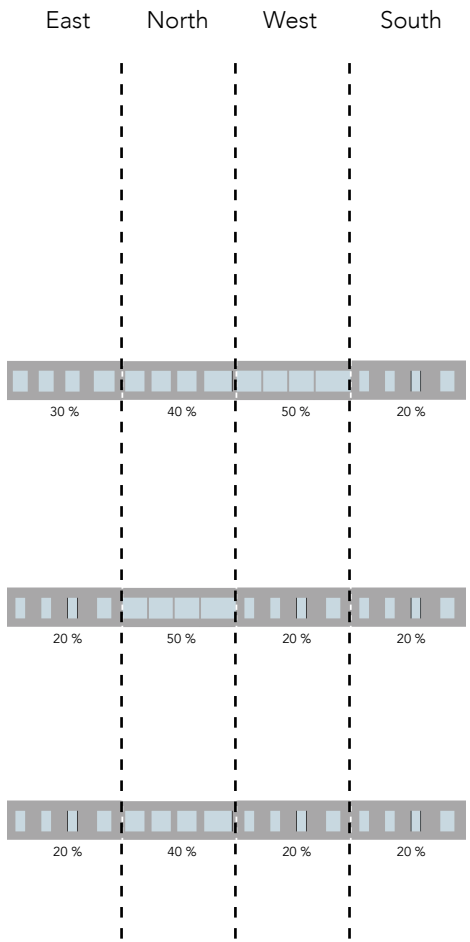
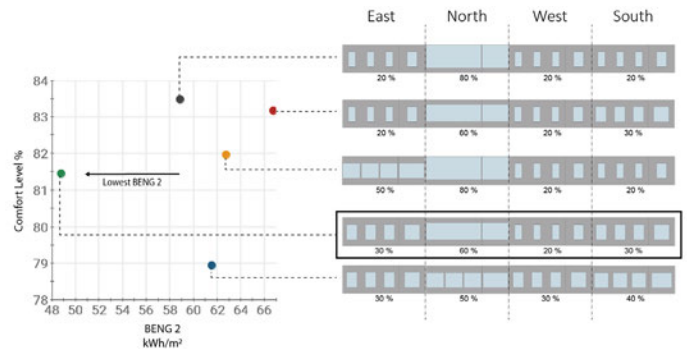
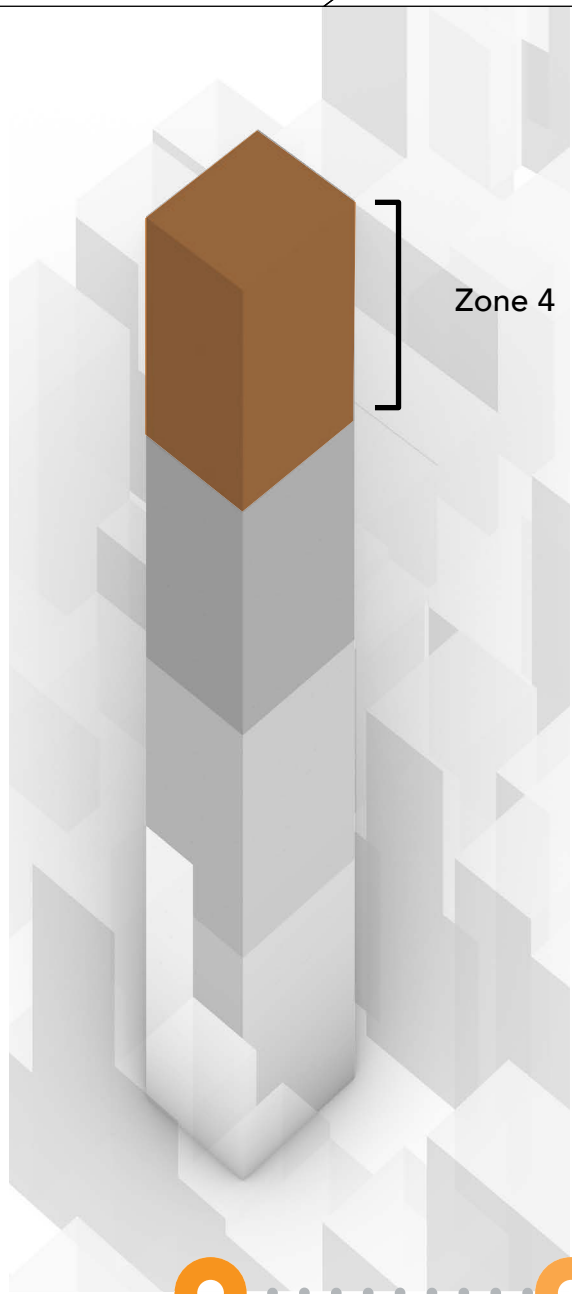
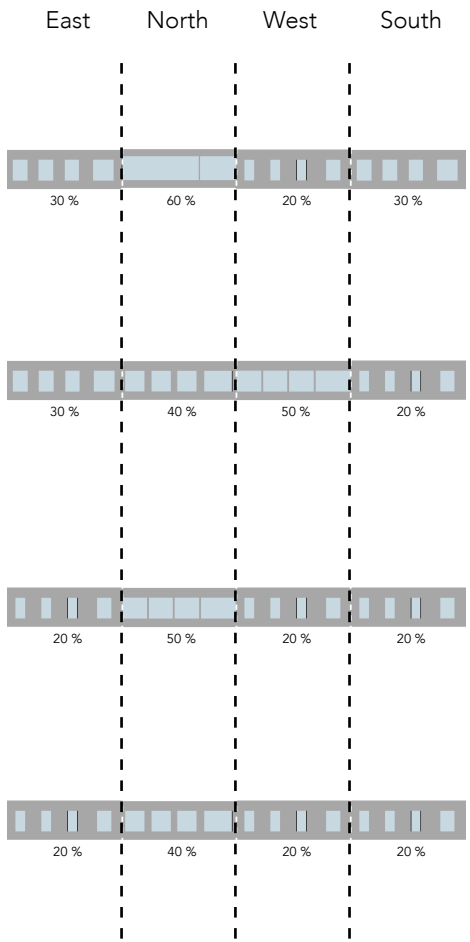


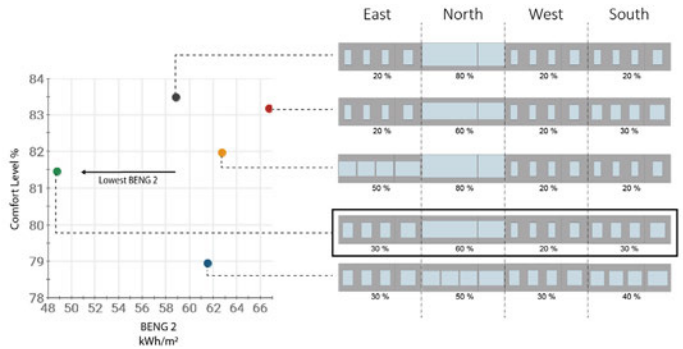


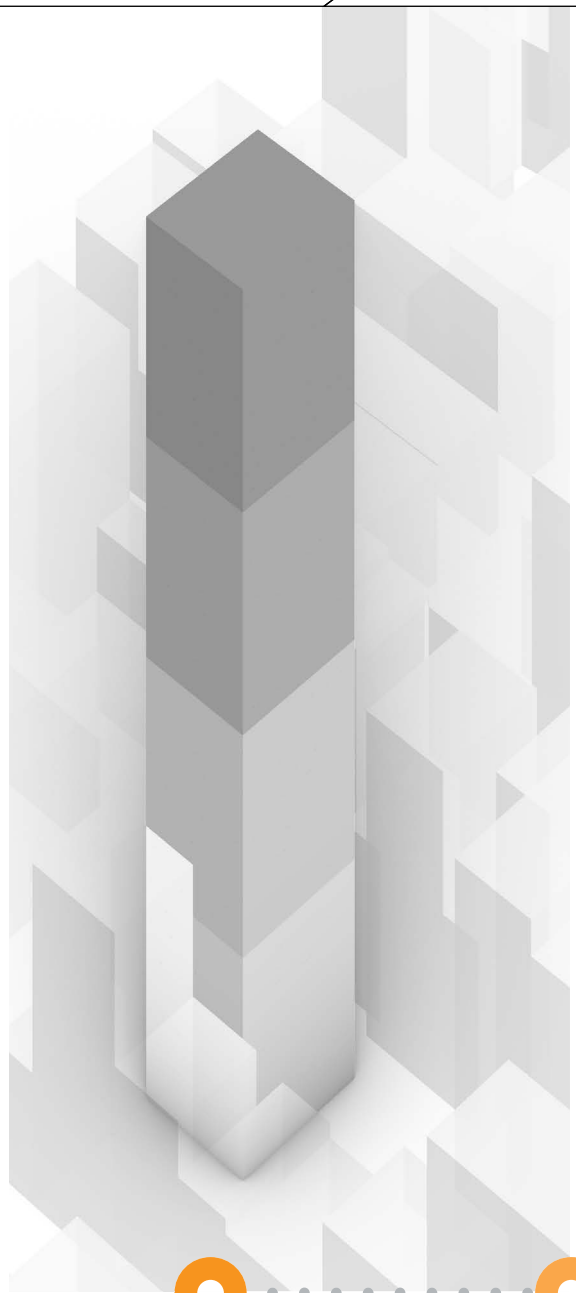




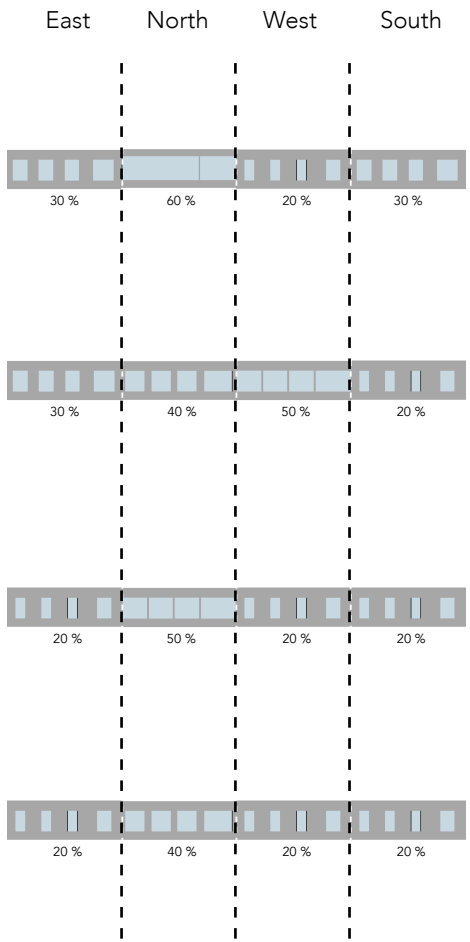
Facade Optimization







Facade Optimization



Scheme of Facade

Adaptation of the WWR

per Orientation

East
20% to 30%

North
40% to 60%

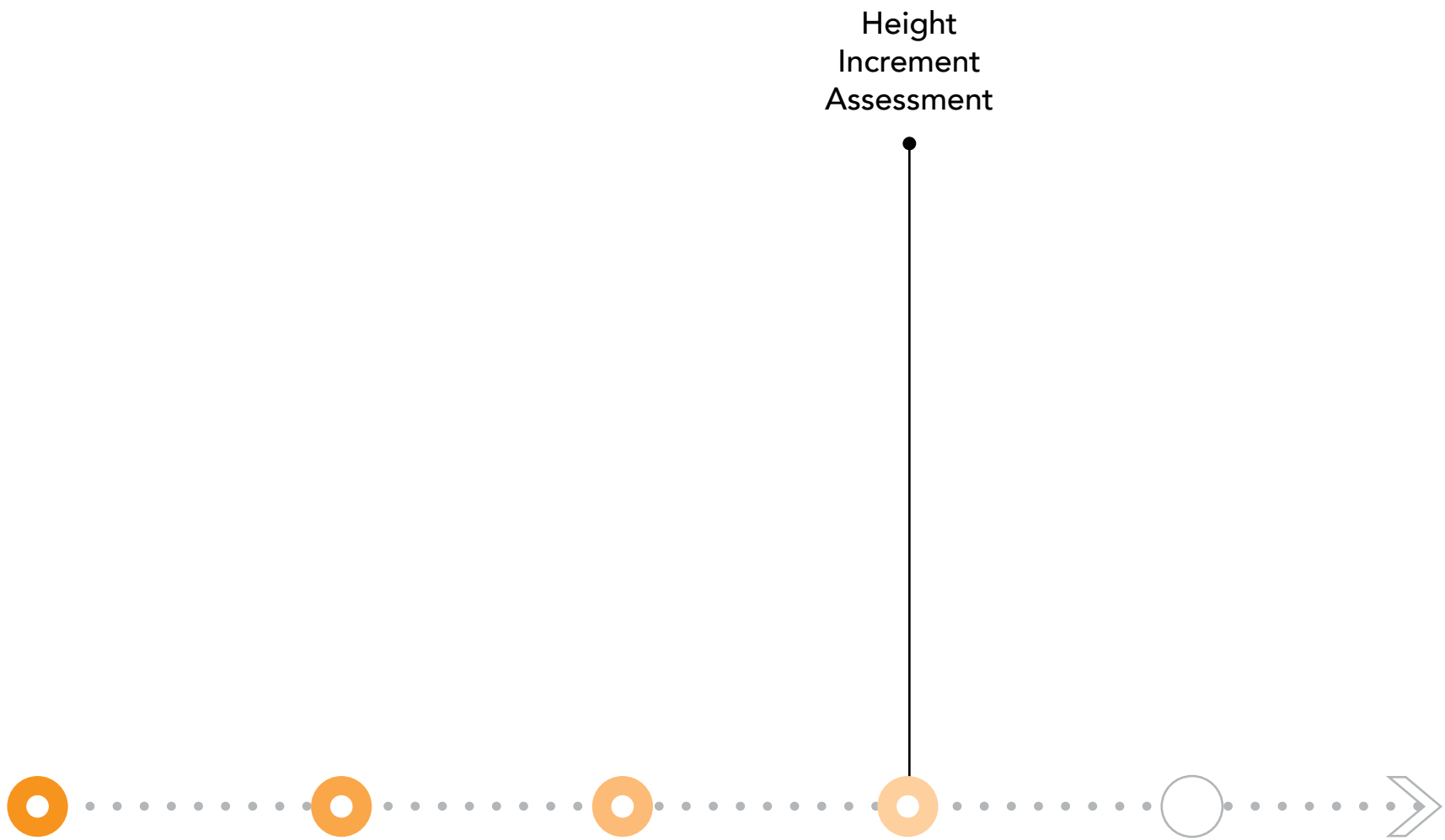
West
20% to 30% + 50%

South
20% to 30%

in parallel to the Height

No pattern of adaptation

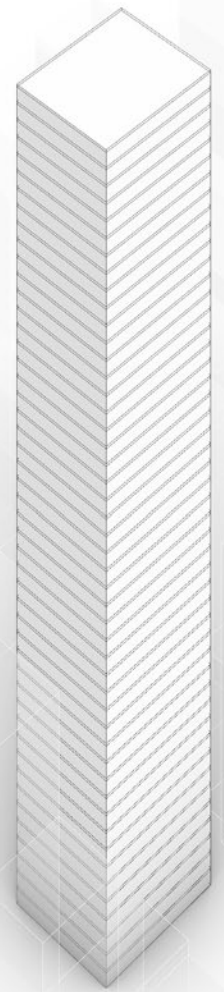
Based on computational optimization, **to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands**, and eventually what amendments can be proposed to adapt the desired height to the performance ?


Height
Increment
Assessment

Energy Performance per Height Increment (Floor Addition)

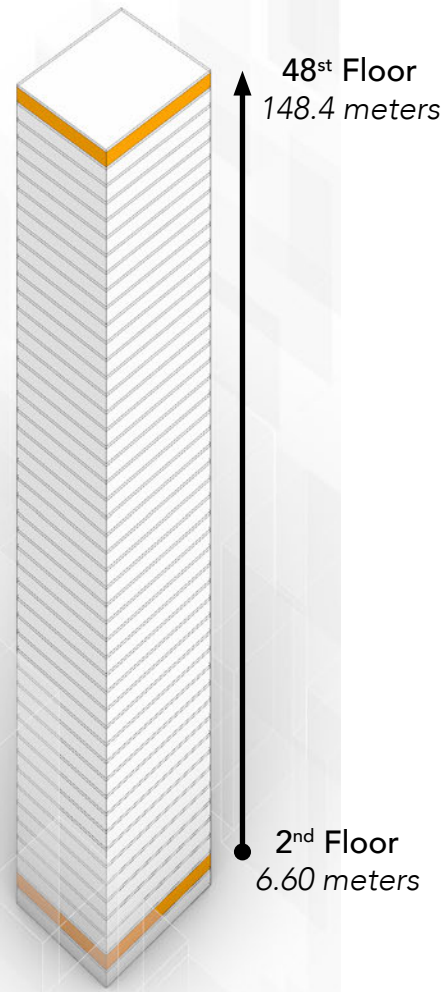
Height Increment Performance

Floor Addition



Height Increment Performance

Floor Addition



Height Increment Performance

Floor Addition

48st Floor
148.4 meters

2 Floors
Intervals

2nd Floor
6.60 meters

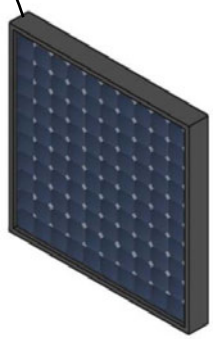
Height Increment Performance

Floor Addition + *Roof Parameters*

Height Increment Performance

Floor Addition + *Roof Parameters*

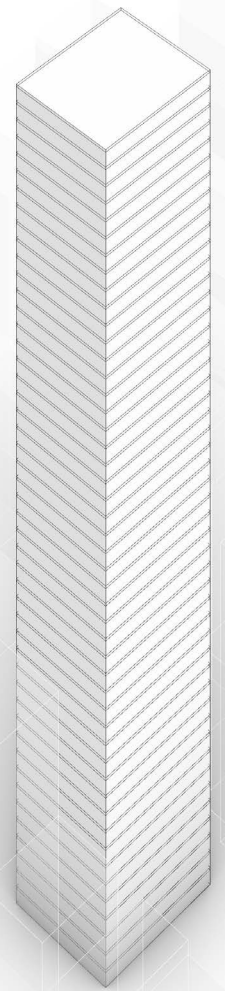
Energy Generation

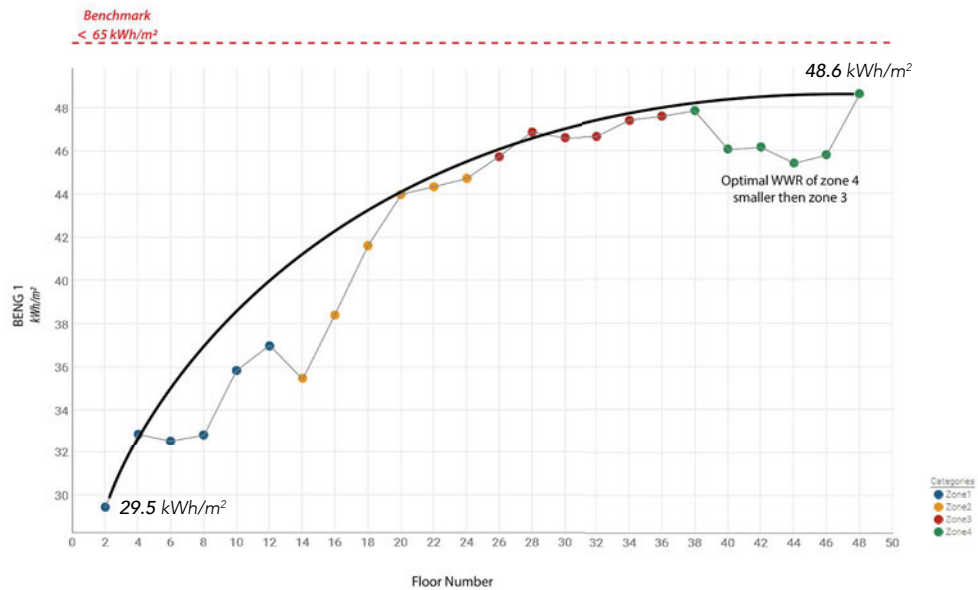


75% Covered Roof Area
with
PV of 20% Efficiency

Height Increment Performance

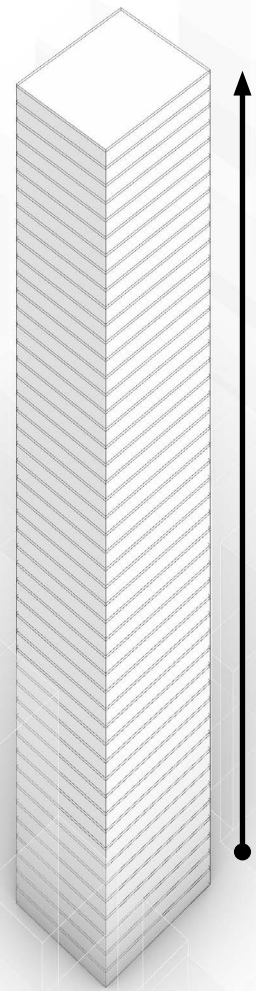
BENG 1 Energy Demand



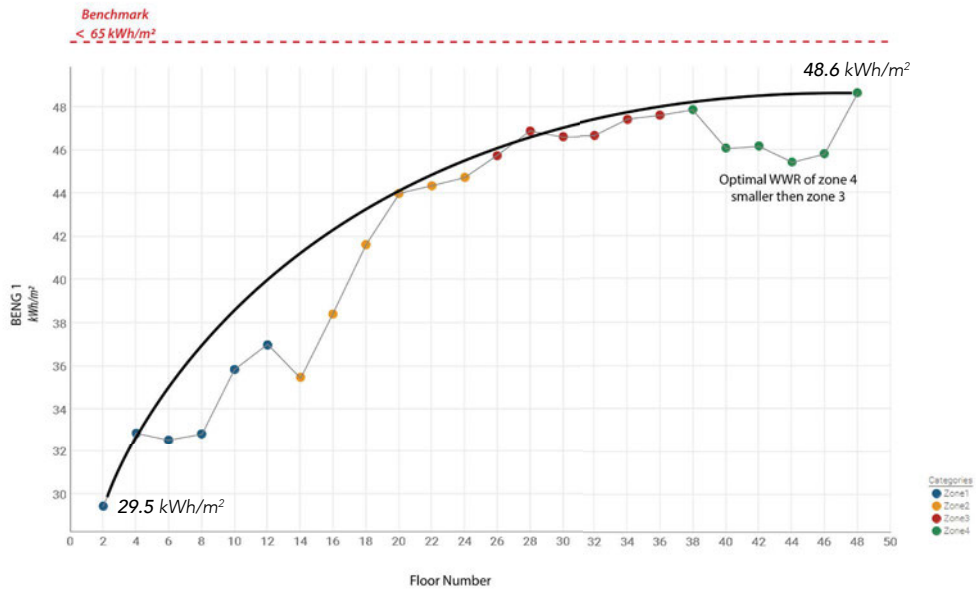


Height Increment Performance

BENG 1 Energy Demand

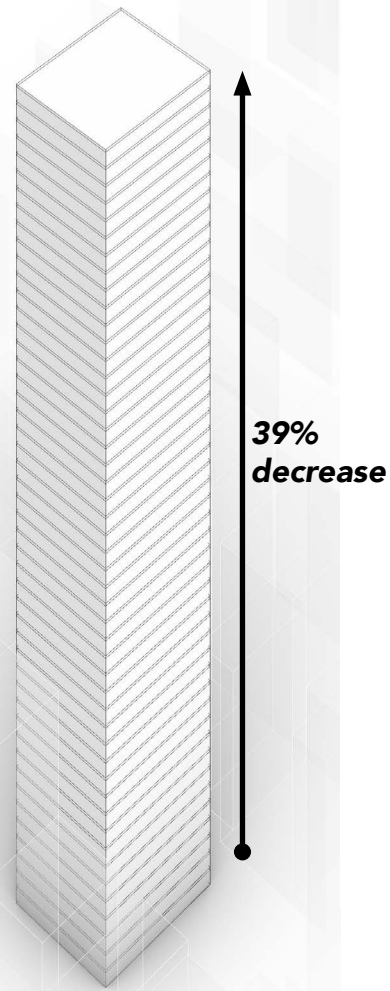


Increase of BENG 1

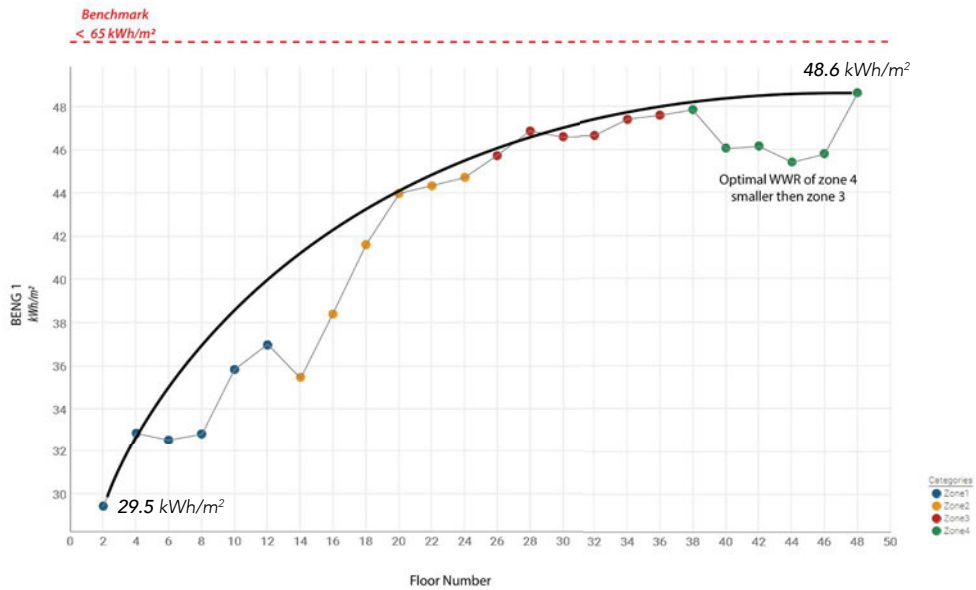


Increase of BENG 1

Height Increment Performance



BENG 1 Energy Demand



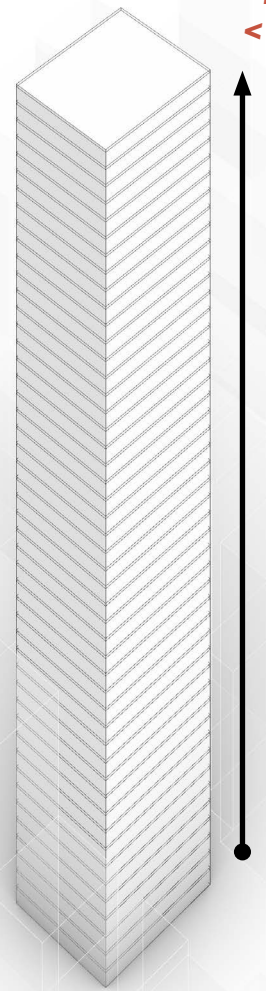
Increase of BENG 1

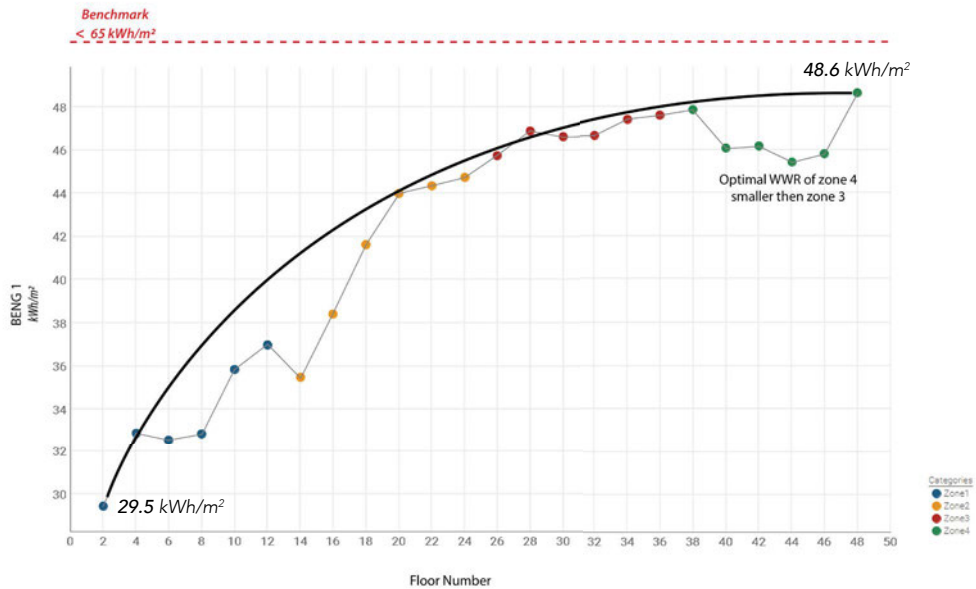
39%
Performance Decrease

Height Increment Performance

BENG 1 Energy Demand

Benchmark
< 65 kWh/m²



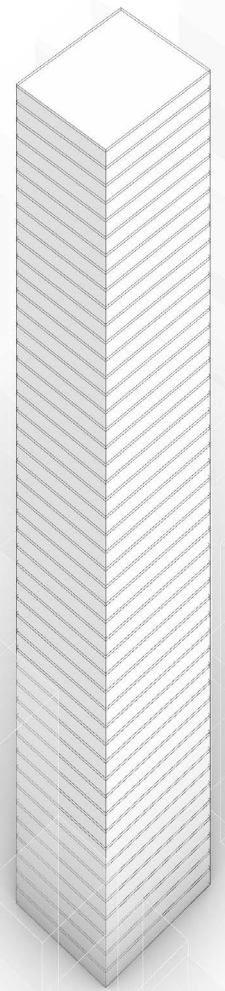


Increase of BENG 1

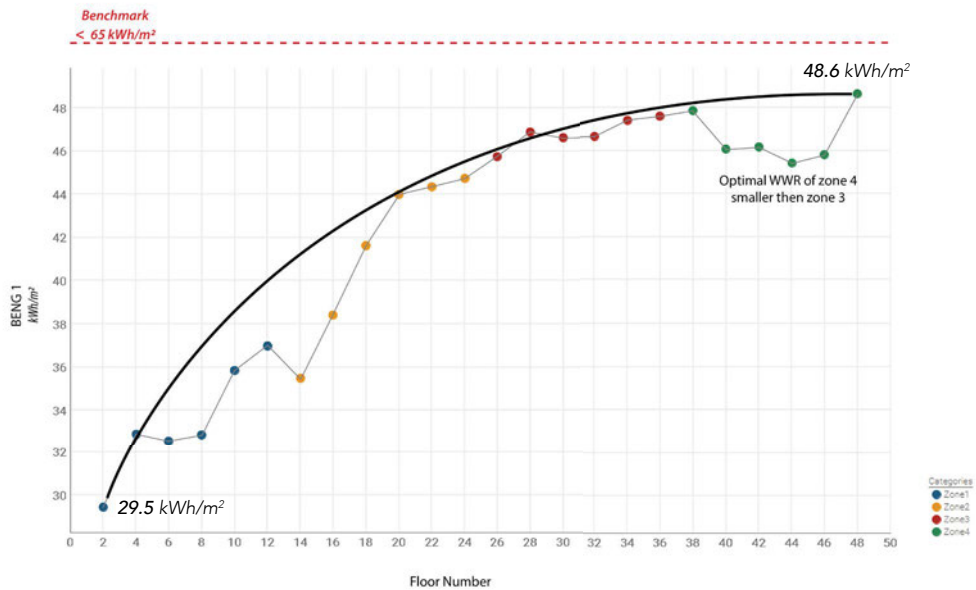
39%
Performance Decrease

Benchmark
< 65 kWh/m²

Height Increment Performance



BENG 1 Energy Demand



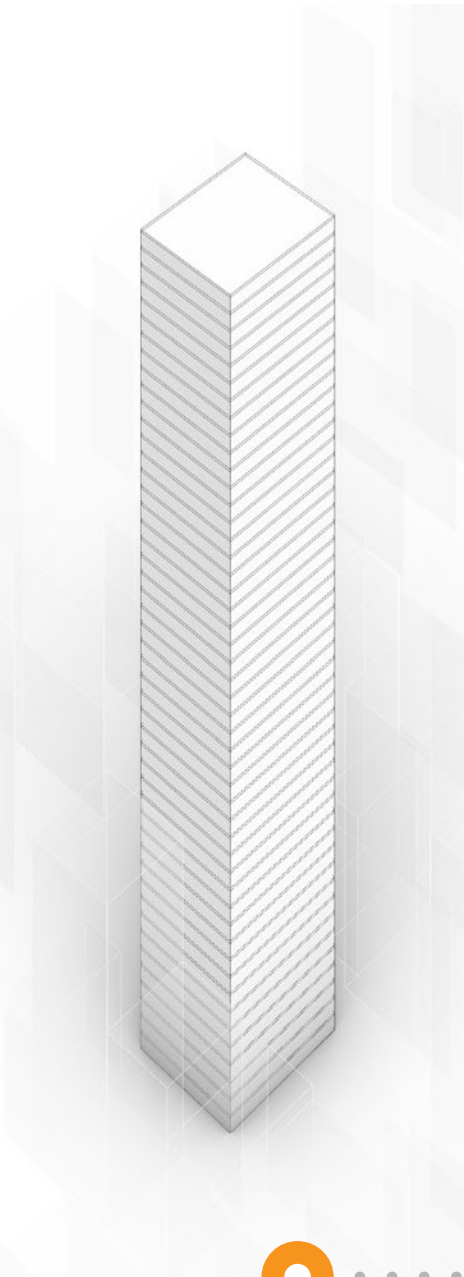
Increase of BENG 1

39%
Performance Decrease

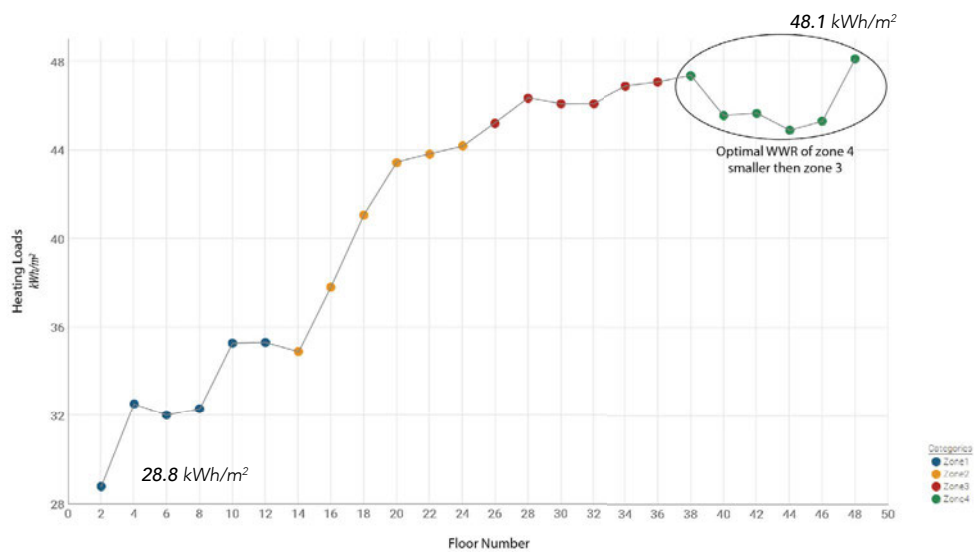
Benchmark
< 65 kWh/m²

BENG 1 = Heating + Cooling

Height Increment Performance

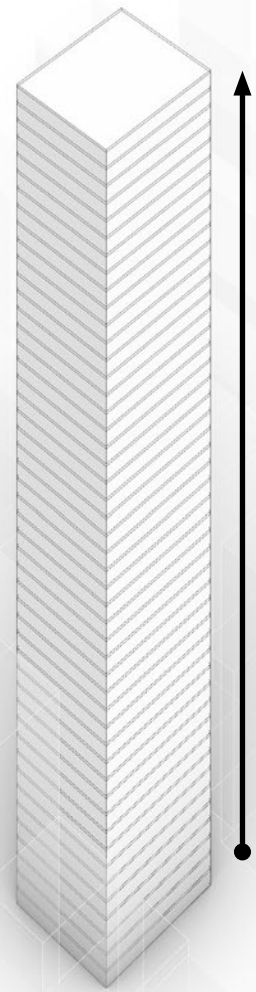


Heating Loads

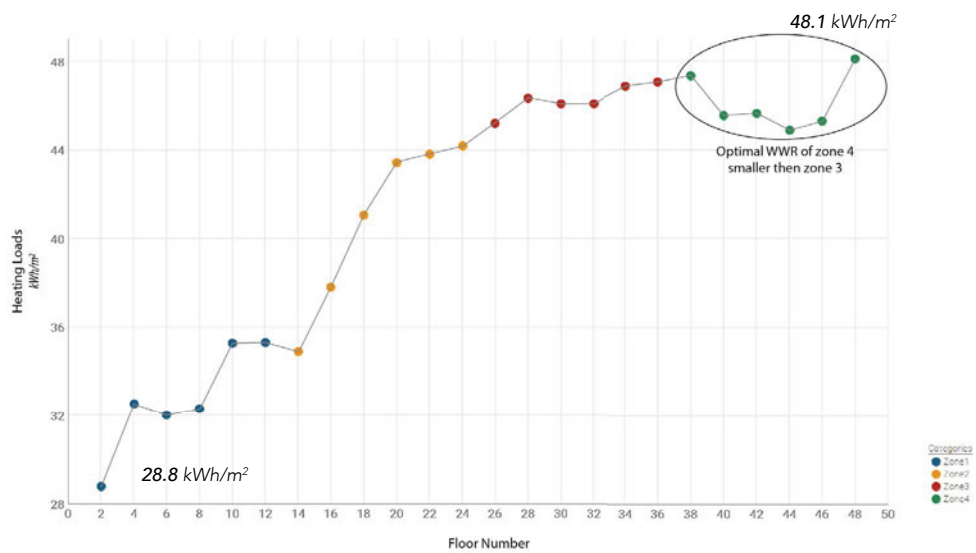


Height Increment Performance

Heating Loads

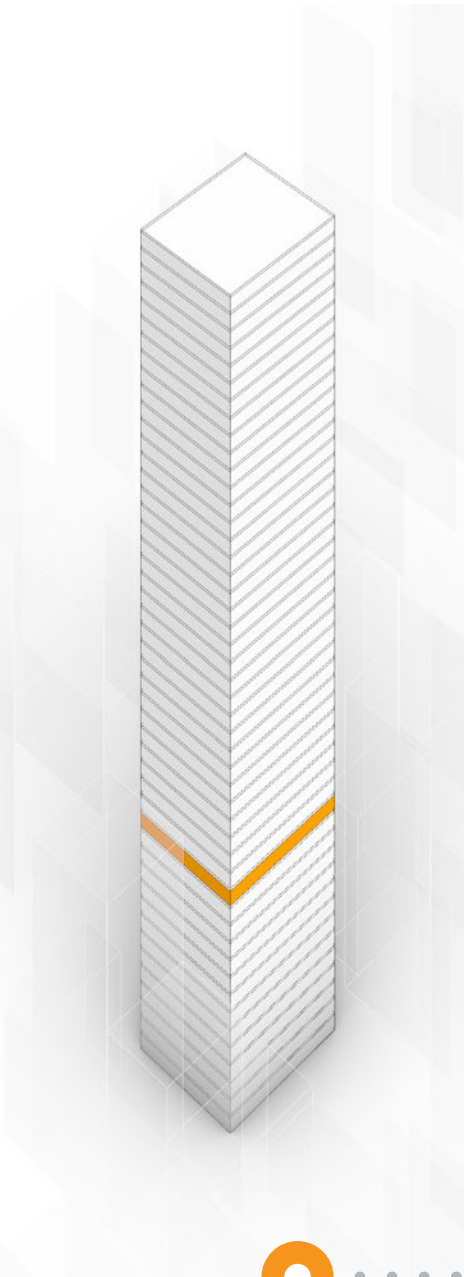


Increase of heating demand

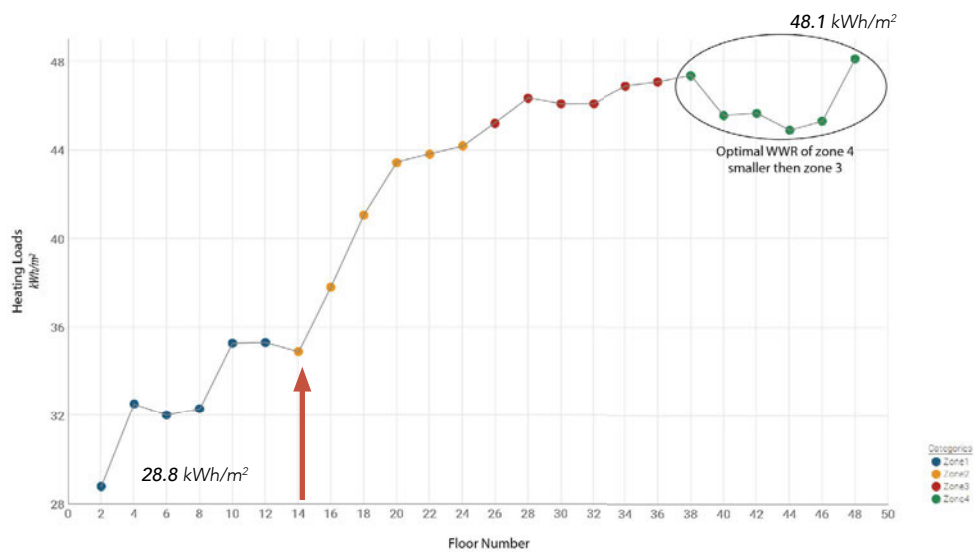


Increase of heating demand

Height Increment Performance



Heating Loads

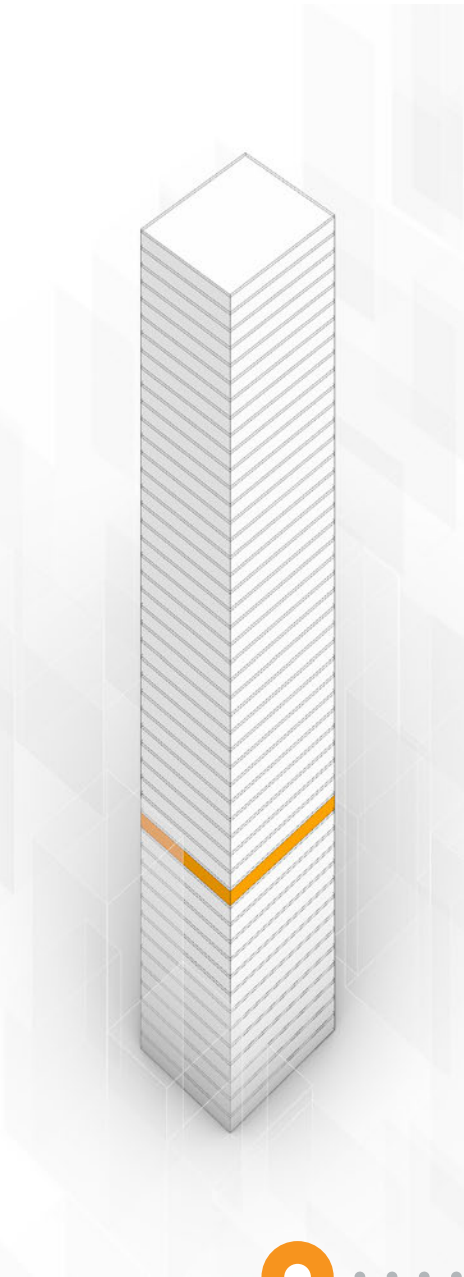


Increase of heating demand

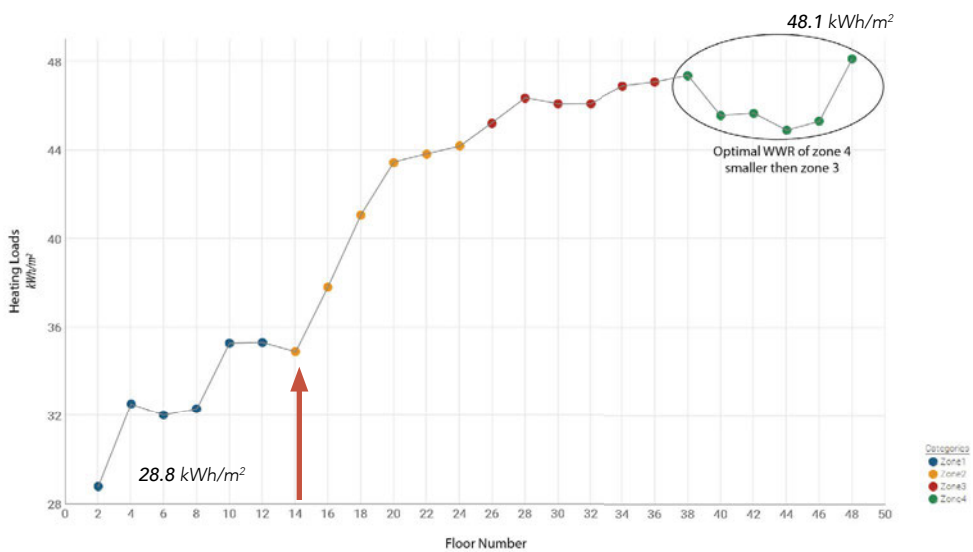
Amplification

at the 14th Floor (46.5 meters)

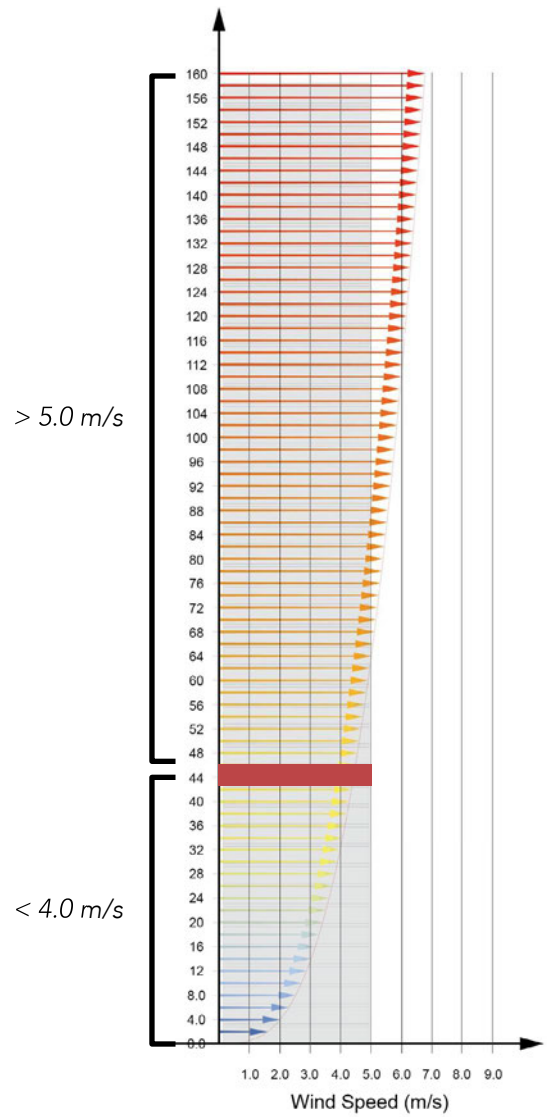
Height Increment Performance



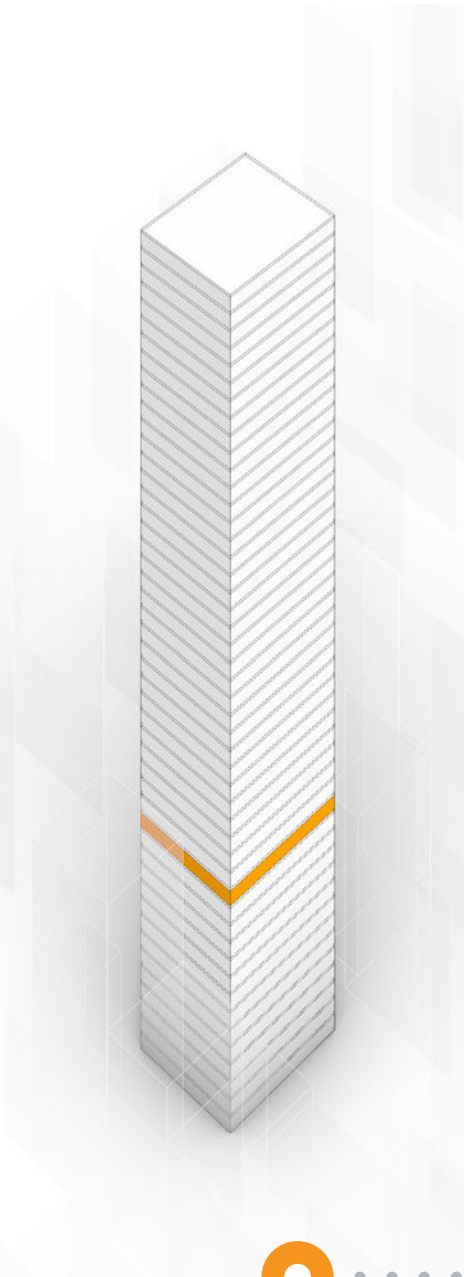
Heating Loads



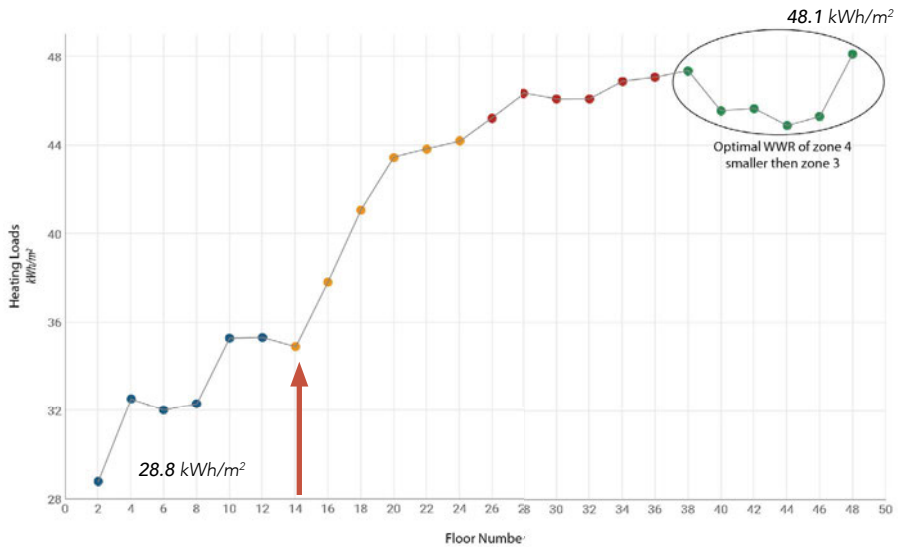
Acceleration of Wind Speed



Height Increment Performance

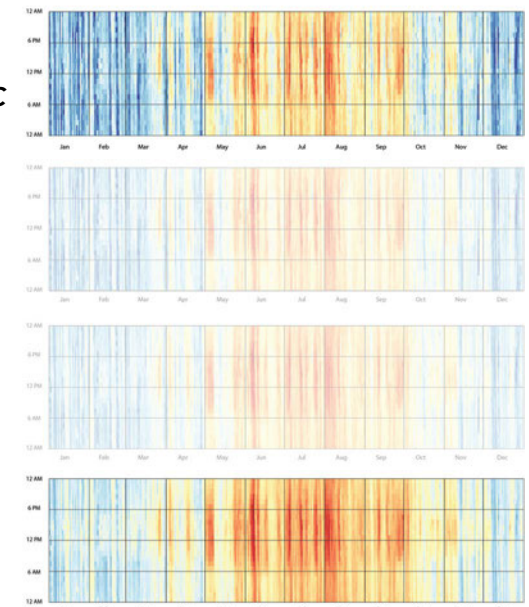


Heating Loads



Drop of Temperature

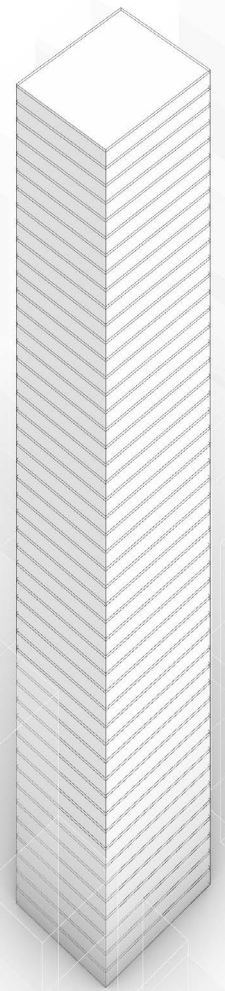
min T °
-11.9 °C

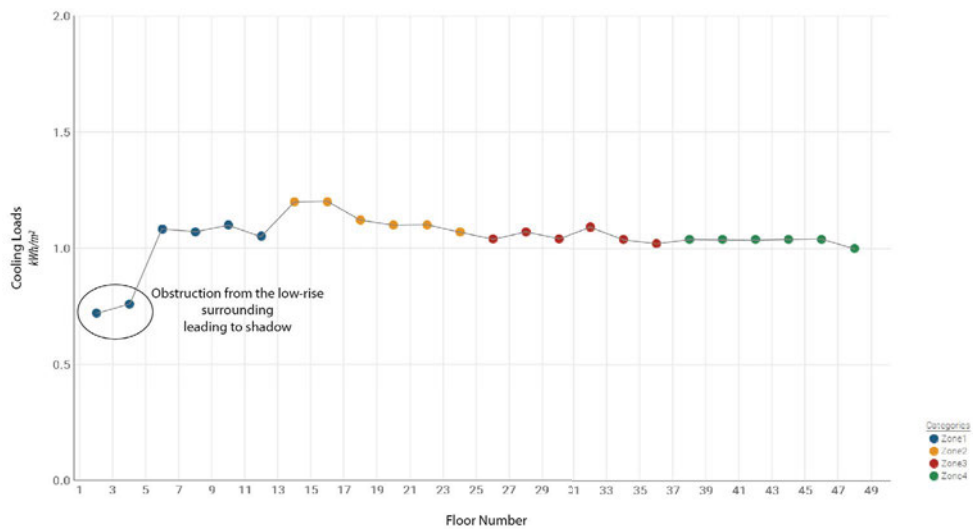


min T °
-5.2 °C

Height Increment Performance

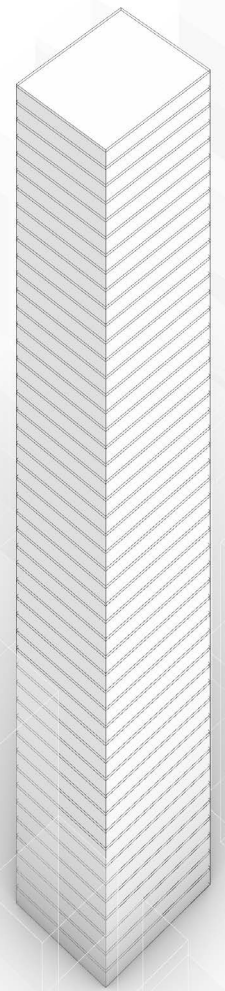
Cooling Loads

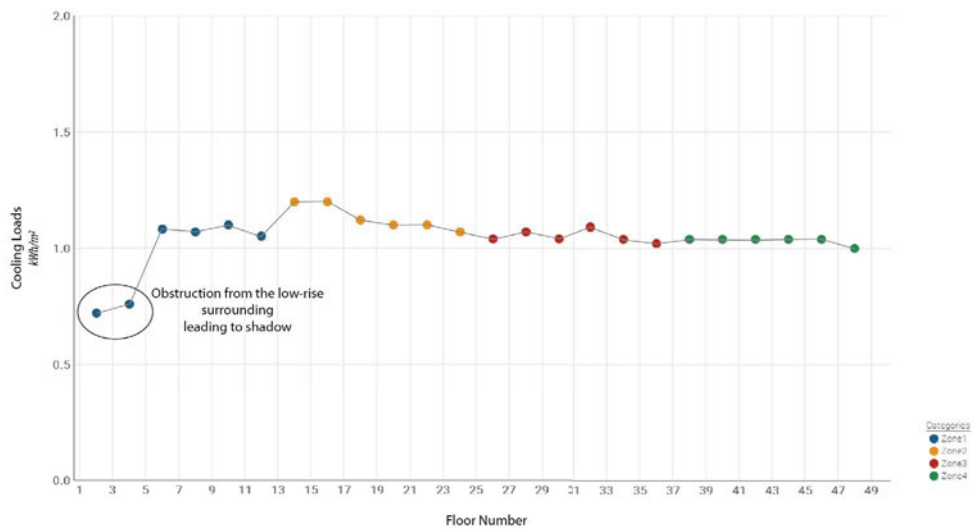




Height Increment Performance

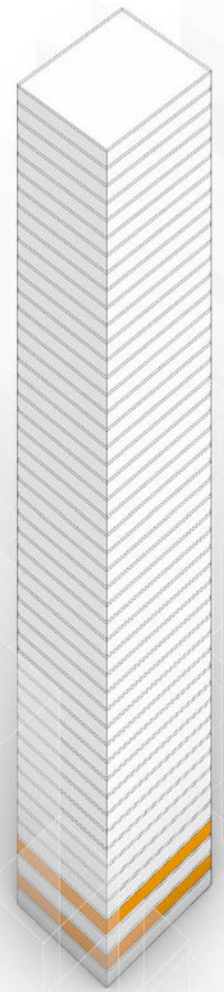
Cooling Loads



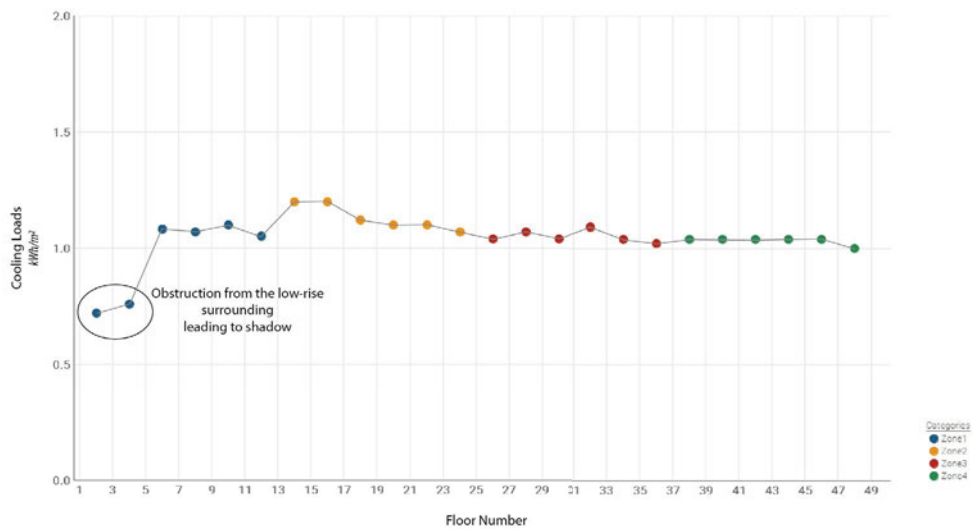


Constant cooling demand above the 4th floor (20 meters)

Height Increment Performance

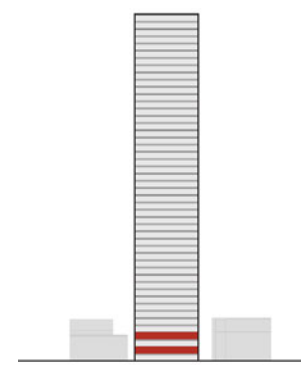


Cooling Loads



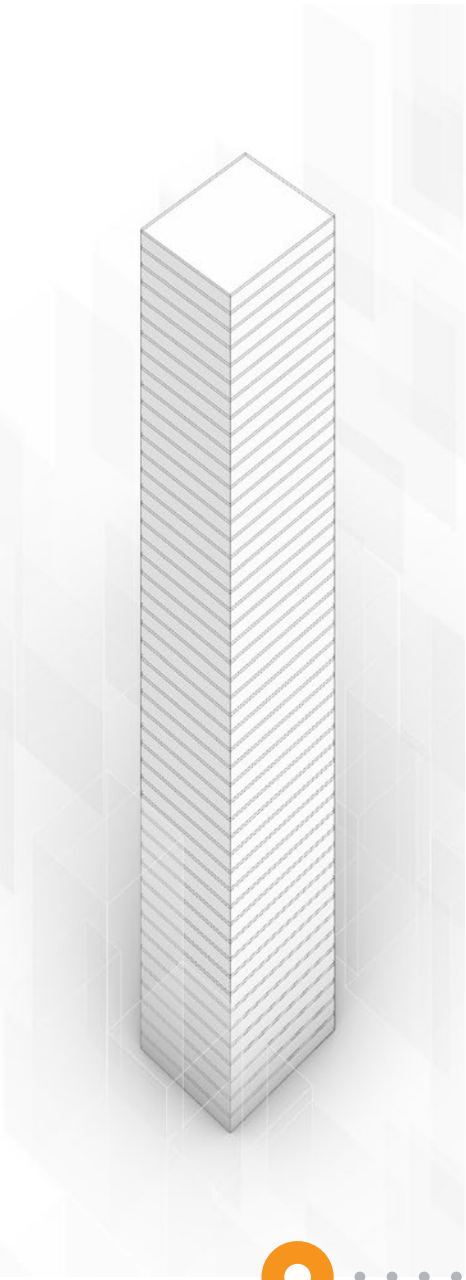
Constant cooling demand above the 4th floor (20 meters)

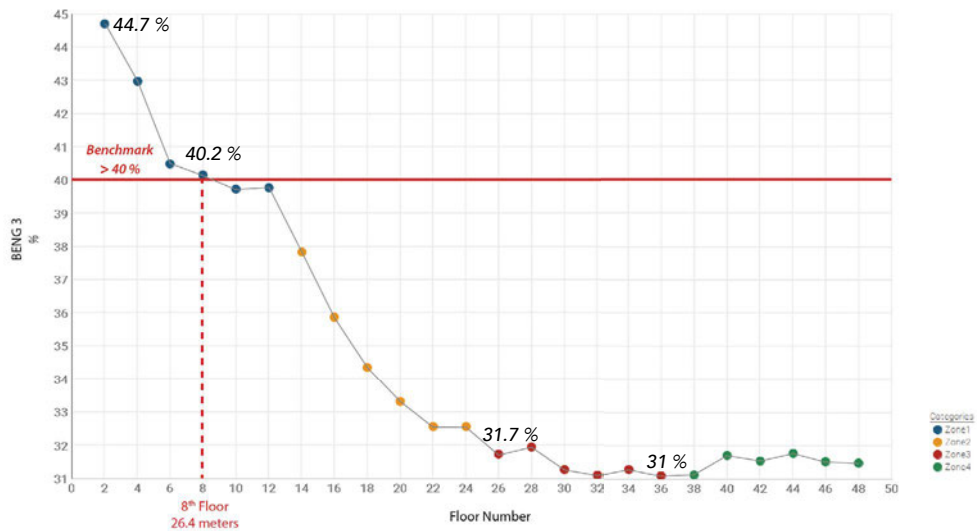
Surrounding Buildings Overshadowing
of lower floors



Height Increment Performance

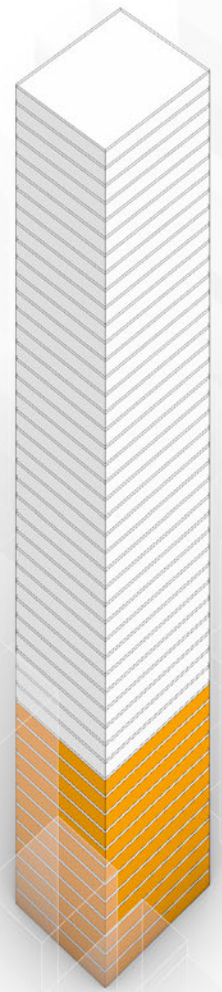
BENG 3 Renewable Energy

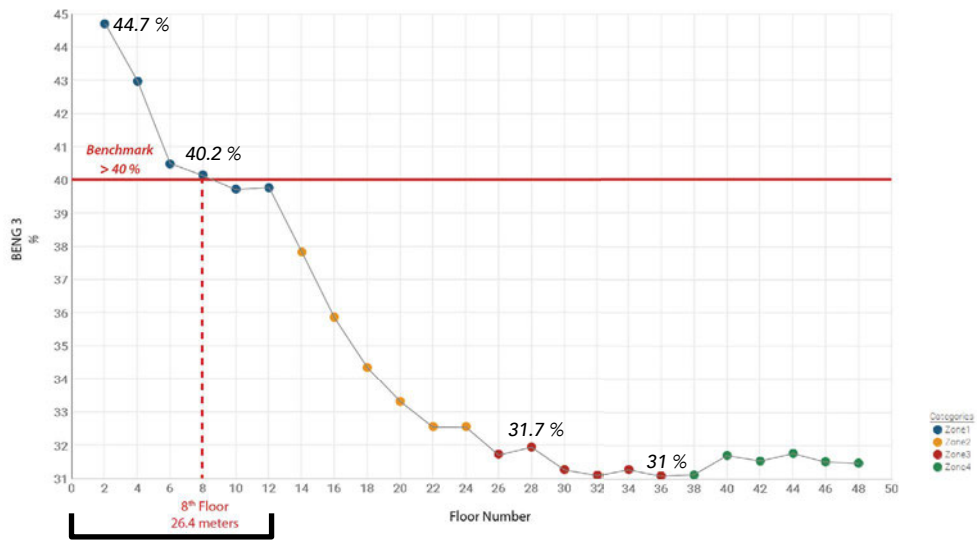




Height Increment Performance

BENG 3 Renewable Energy

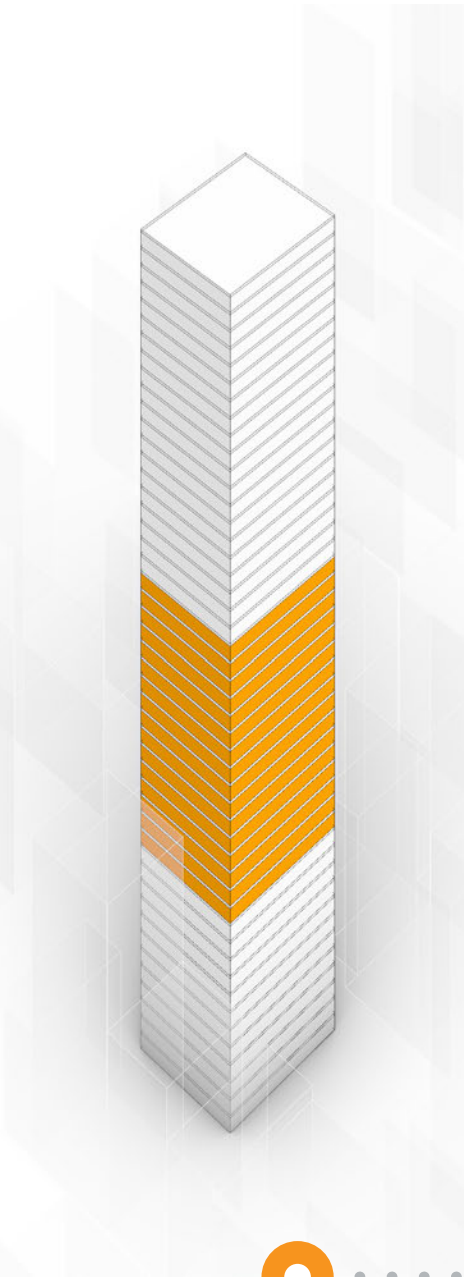


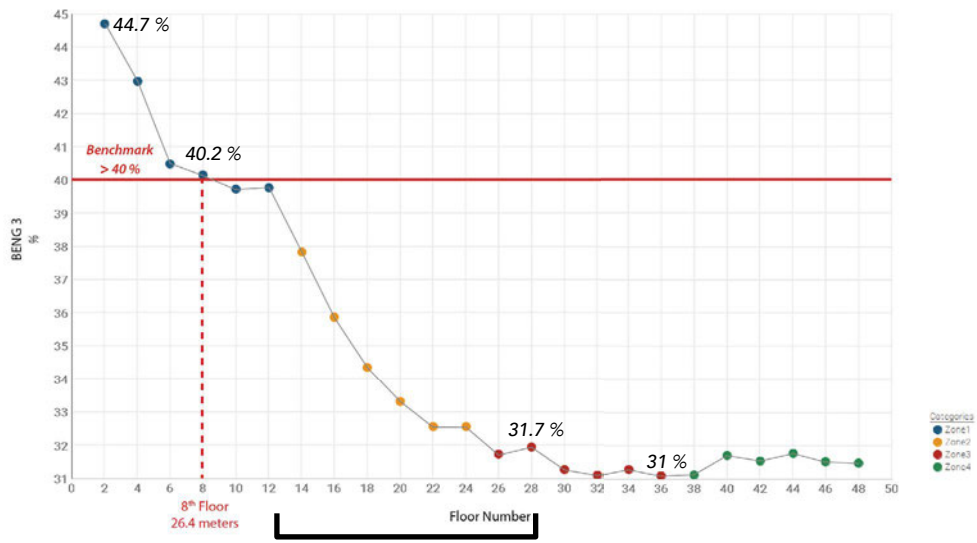


Gradual decrease
between 2nd and 12th floor

Height Increment Performance

BENG 3 Renewable Energy



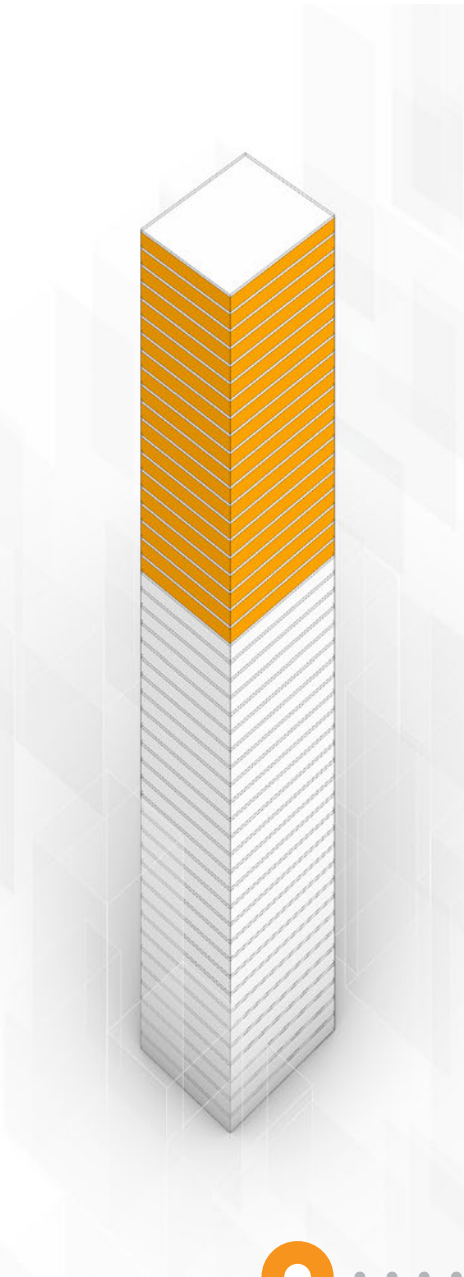


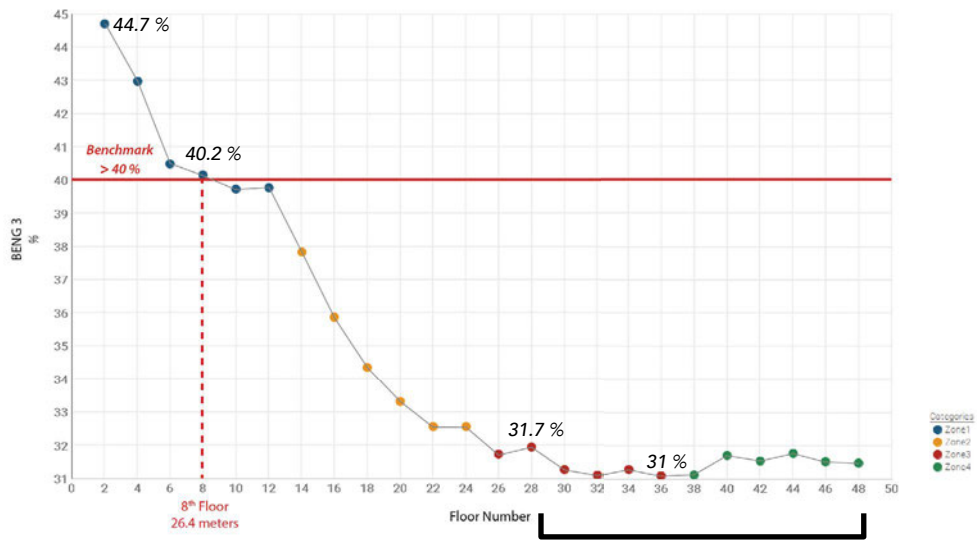
Gradual decrease
between 2nd and 12th floor

Fast rate decrease
between 12th and 28th floor

Height Increment Performance

BENG 3 Renewable Energy





Gradual decrease
between 2nd and 12th floor

Fast rate decrease
between 12th and 28th floor

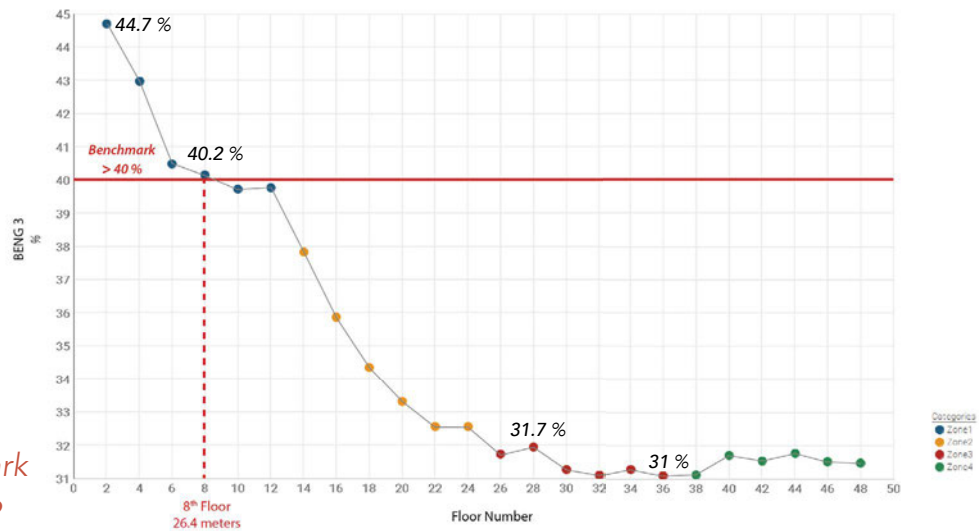
Constant trend
between 28th and 48th floor

30%
Performance Decrease

Height Increment Performance

BENG 3 Renewable Energy

Benchmark
> 40 %



Gradual decrease
between 2nd and 12th floor

Fast rate decrease
between 12th and 28th floor

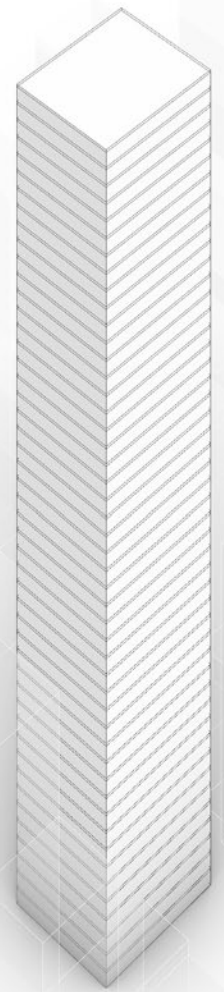
Constant trend
between 28th and 48th floor

30%
Performance Decrease

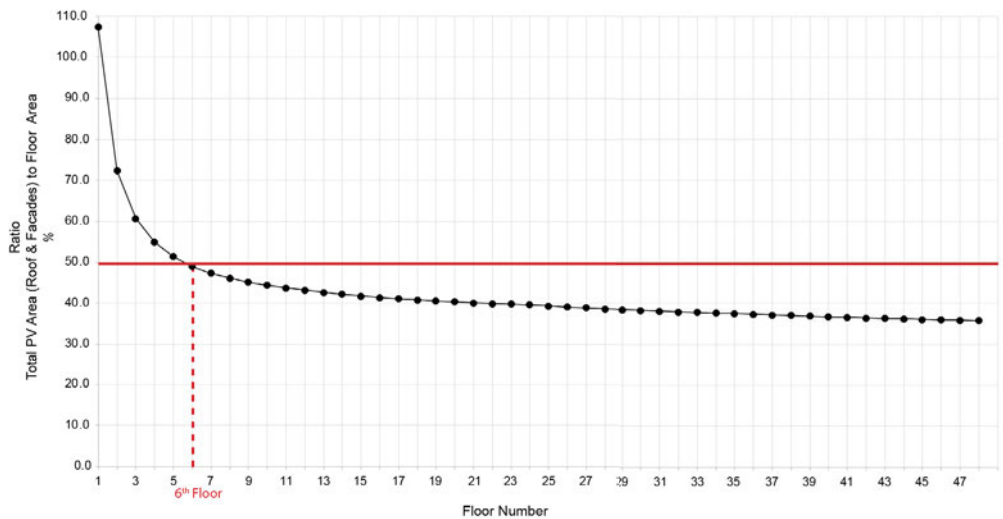
Benchmark
> 40 %

with 40.2%
until the 8th floor (26.4 meters)

Height Increment Performance



Total PV area

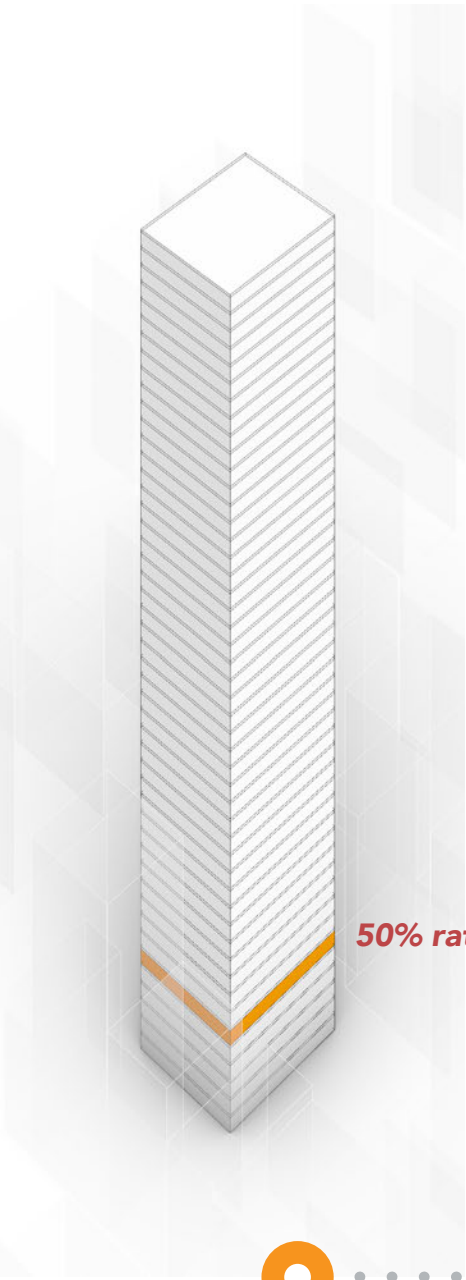


Ratio of
Total PV area
(Roof + Facade)

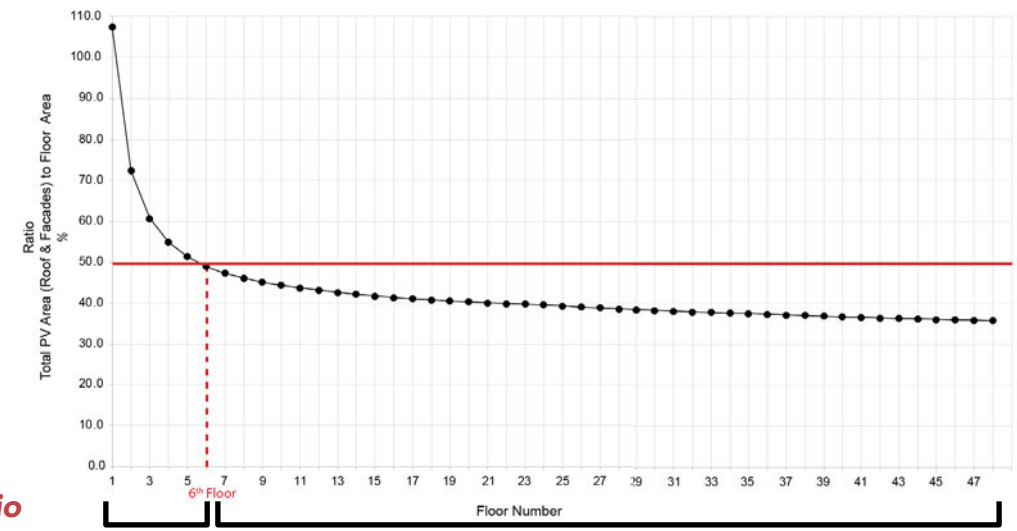
to
Total Usable Area
m²

Height Increment Performance

Total PV area



50% ratio



Ratio of
Total PV area
(Roof + Facade)

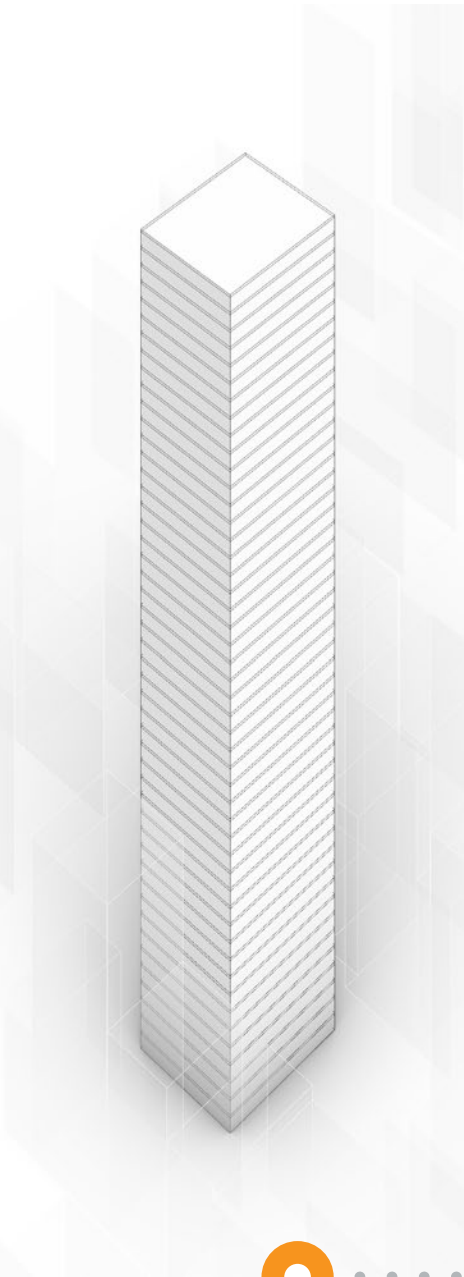
to
Total Usable Area
m²

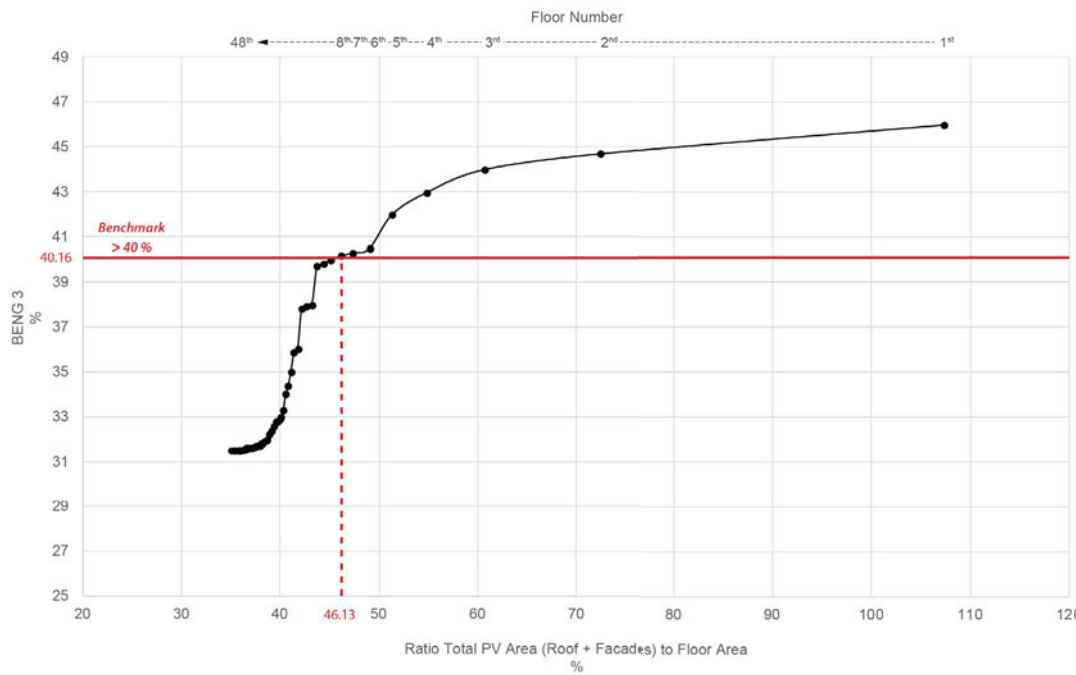
Gradual decrease
between 2nd and 6th Floor
from 110% to 50%
(half the total area)

Constant trend (40%)
between 6th and 48th Floor

Height Increment Performance

BENG 3 Renewable Energy

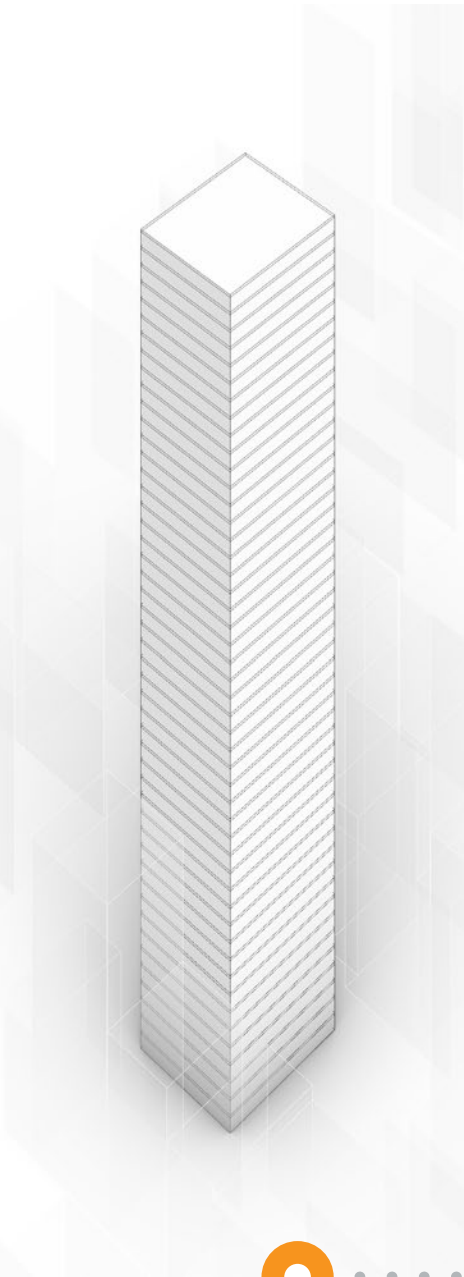


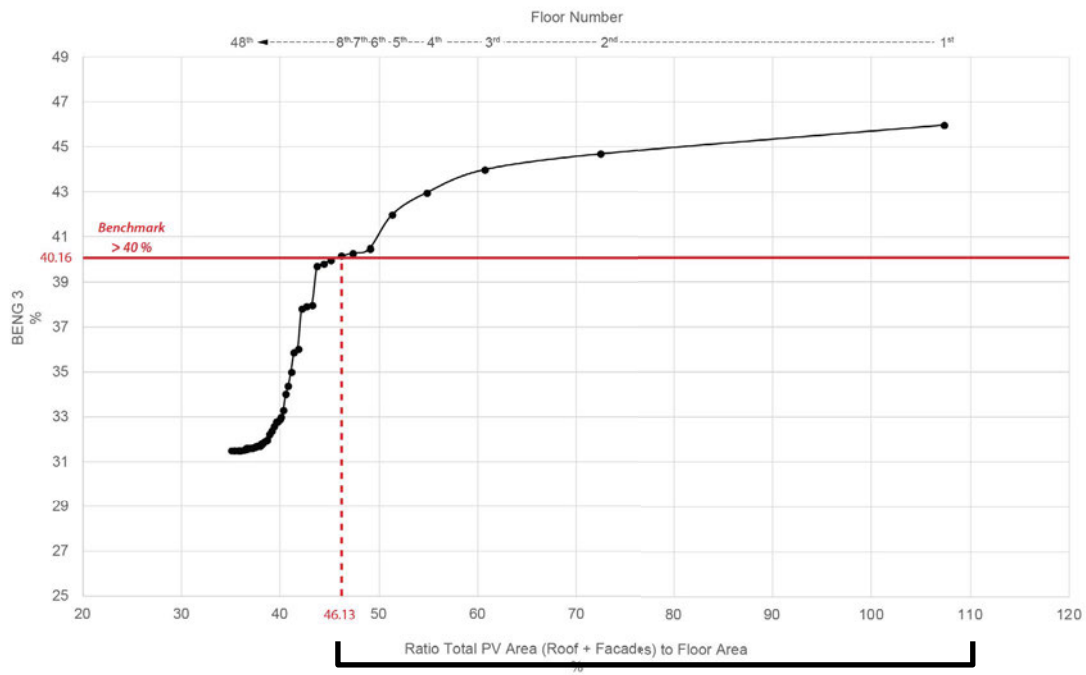


Similar trands in PV ratio & BENG 3 in parallel to height

Height Increment Performance

BENG 3 Renewable Energy



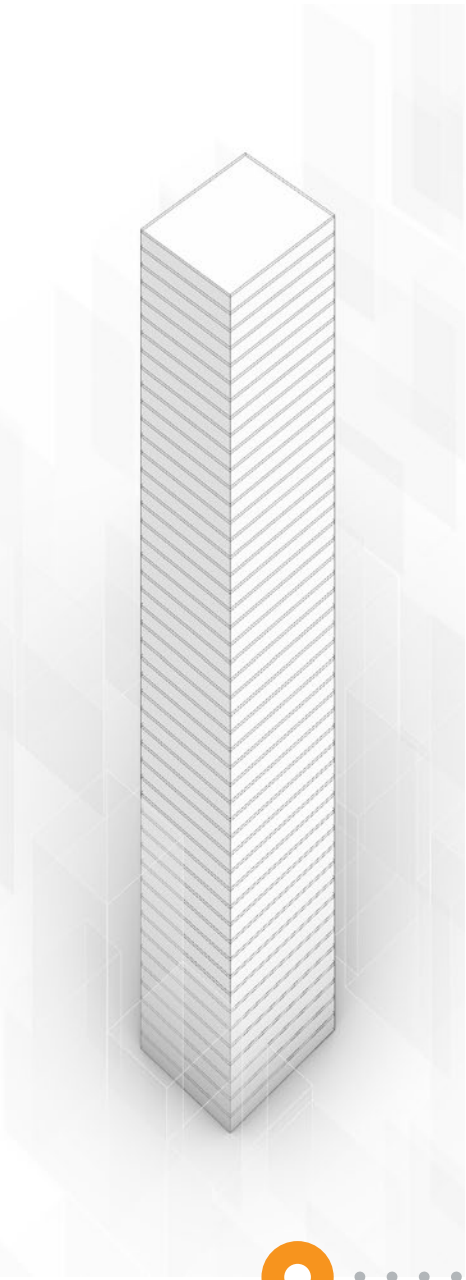


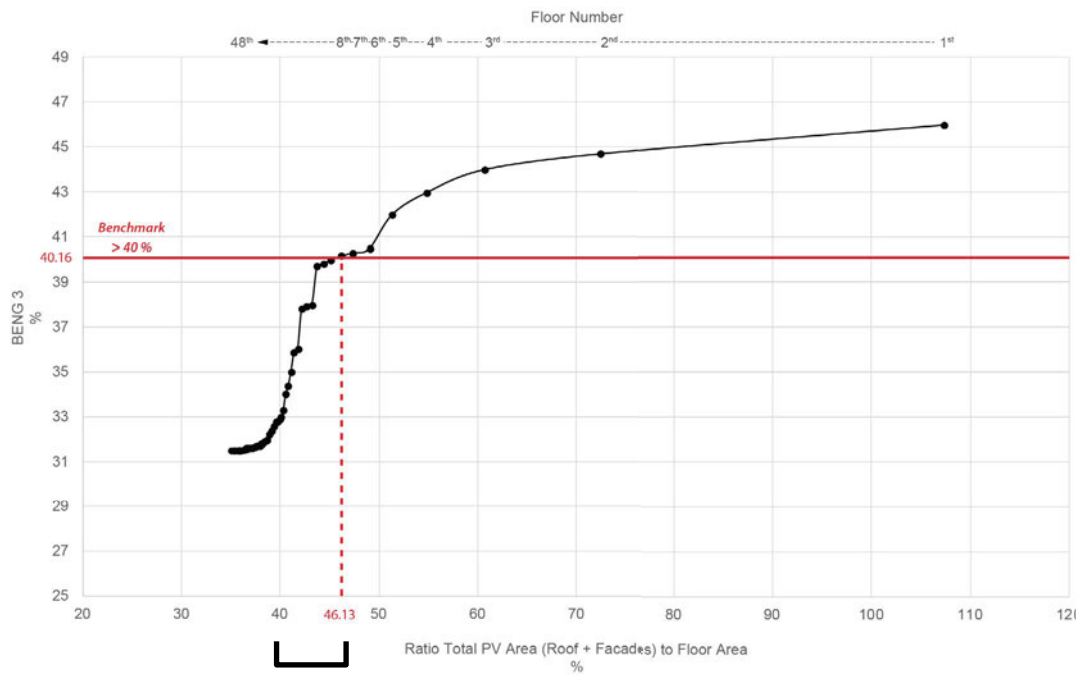
Similar trands in PV ratio & BENG 3 in parallel to height

Gradual decrease of BENG 3 *from 44.7% to* ***40.2%*** *(Above benchmark)*

Height Increment Performance

BENG 3 Renewable Energy





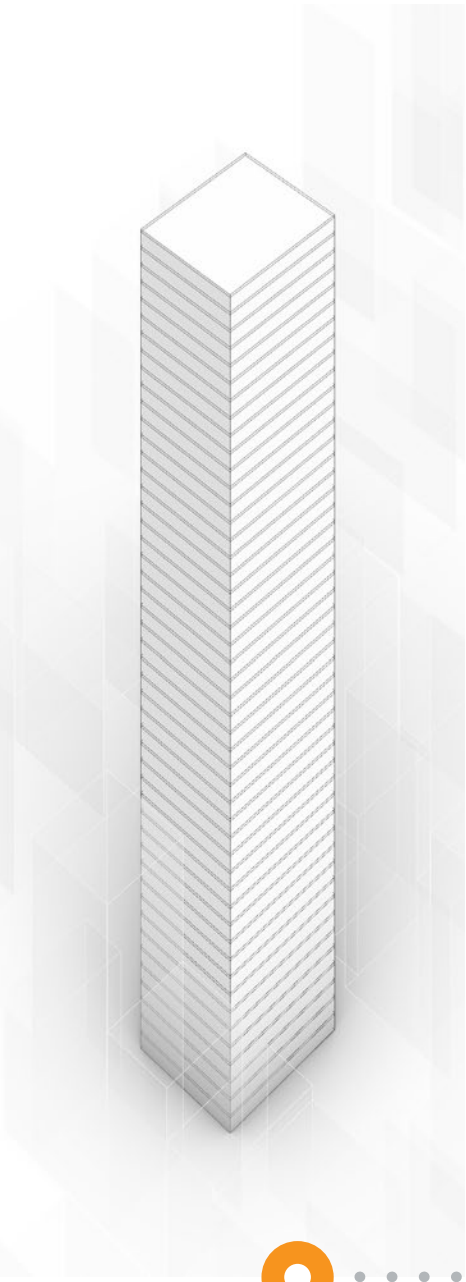
Similar trands in PV ratio & BENG 3 in parallel to height

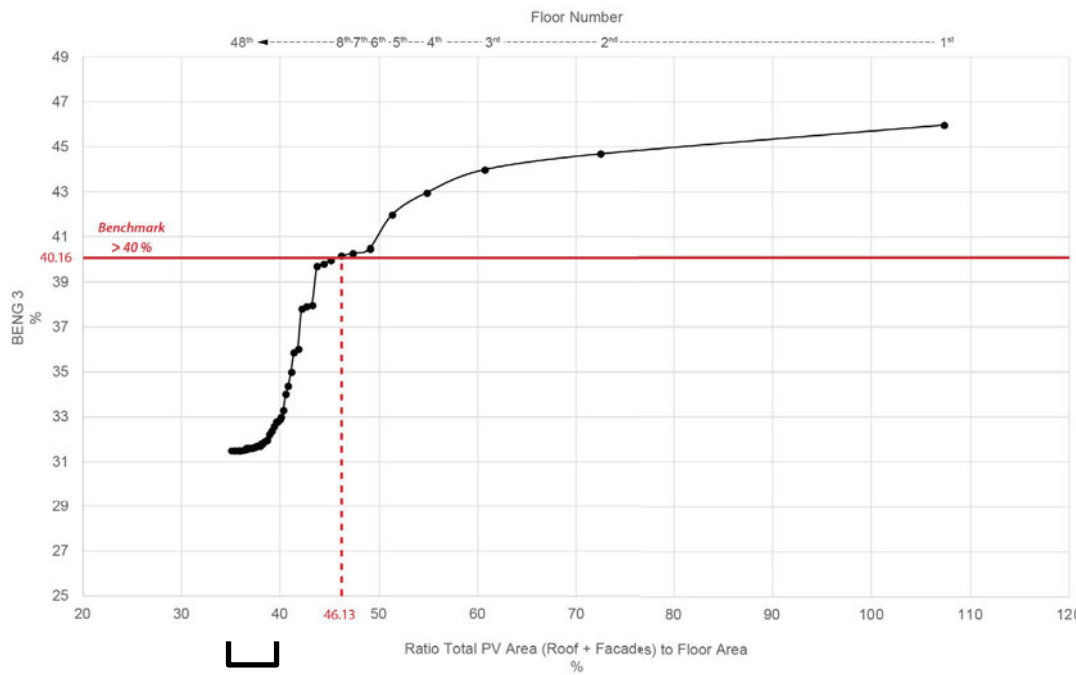
Gradual decrease of BENG 3
from 44.7% to ***40.2%***
(Above benchmark)

Fast rate decrease
from 40.2% down to 31.7%

Height Increment Performance

BENG 3 Renewable Energy





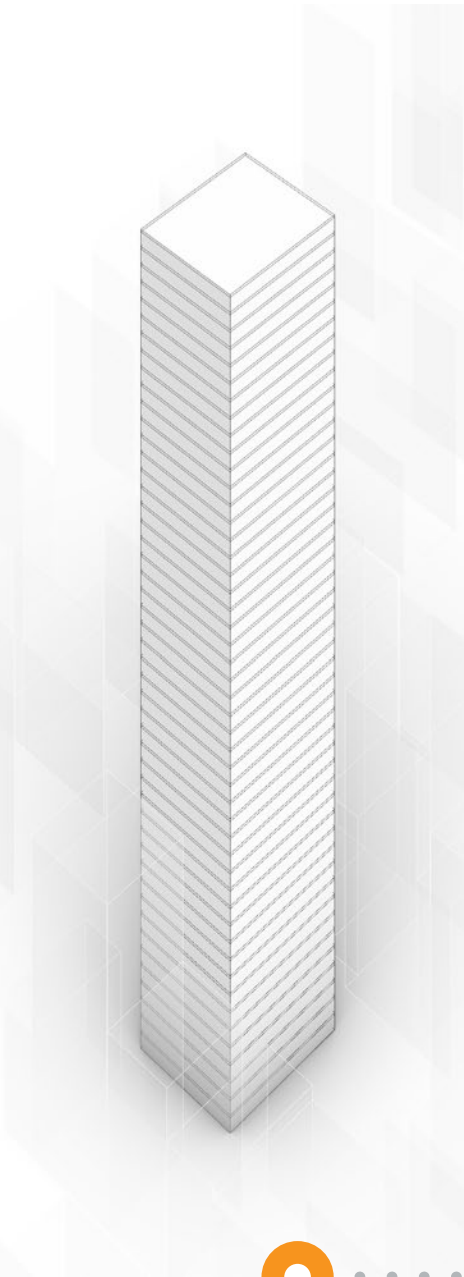
Similar trands in PV ratio & BENG 3 in parallel to height

Gradual decrease of BENG 3
from 44.7% to ***40.2%***
(Above benchmark)

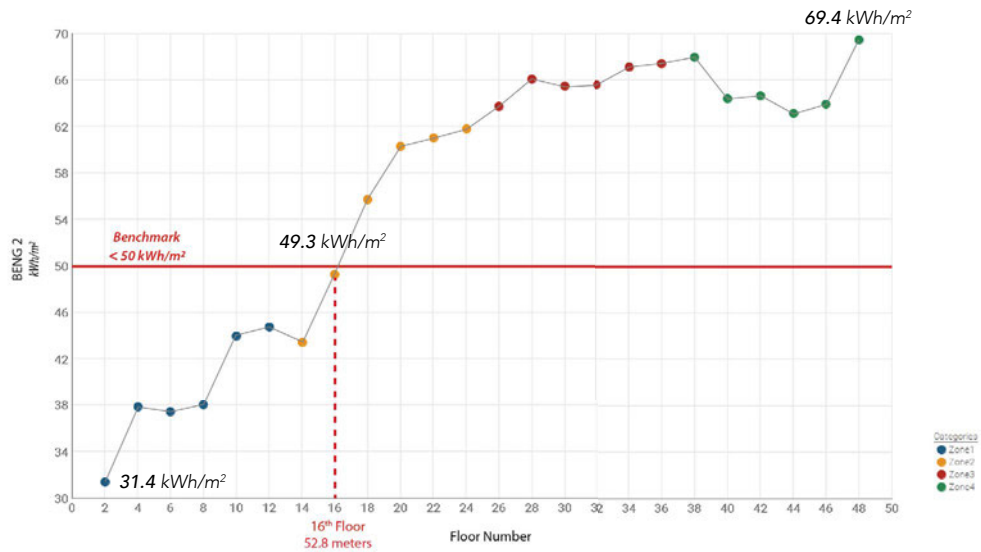
Fast rate decrease
from 40.2% down to 31.7%

Constant trend
around 31%

Height Increment Performance

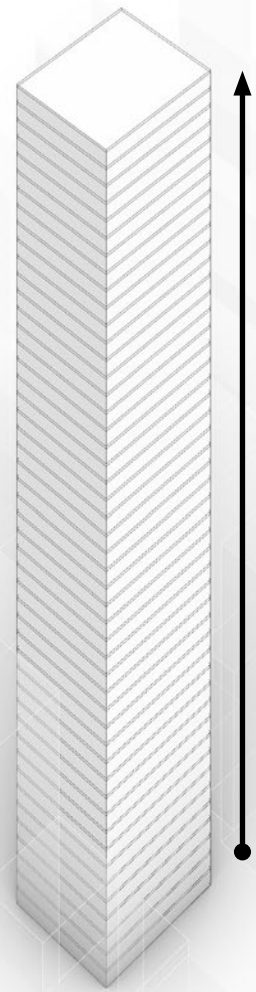


BENG 2 Primary Fossil Usage

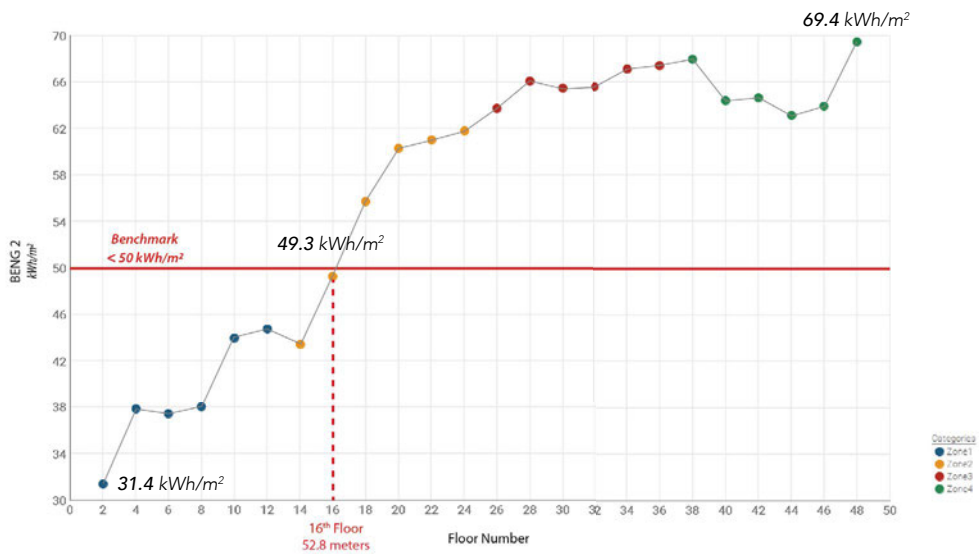


Height Increment Performance

BENG 2 Primary Fossil Usage

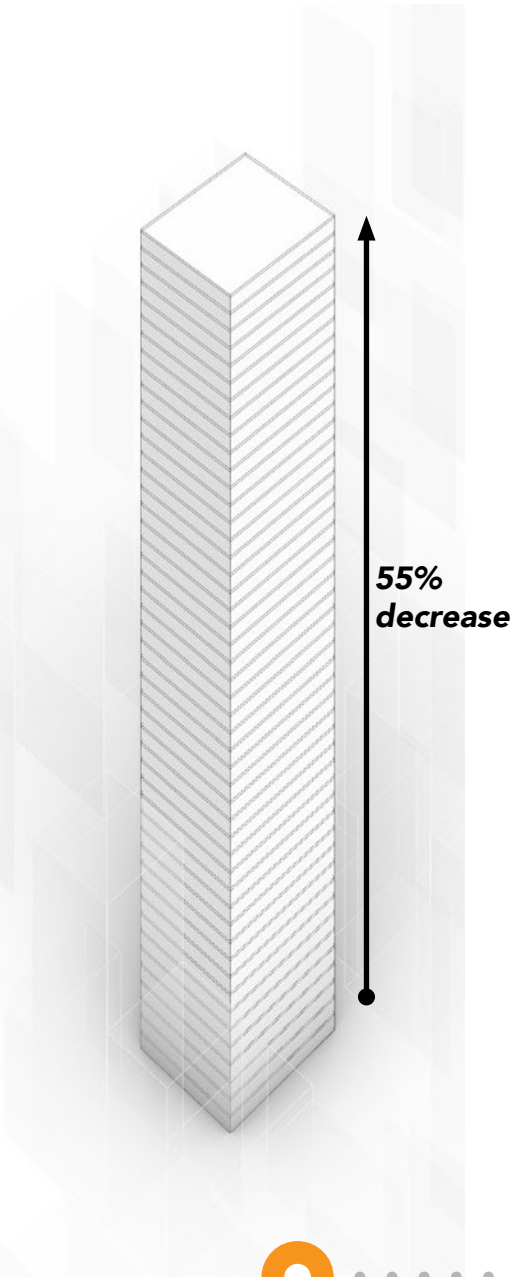


Increase of BENG 2

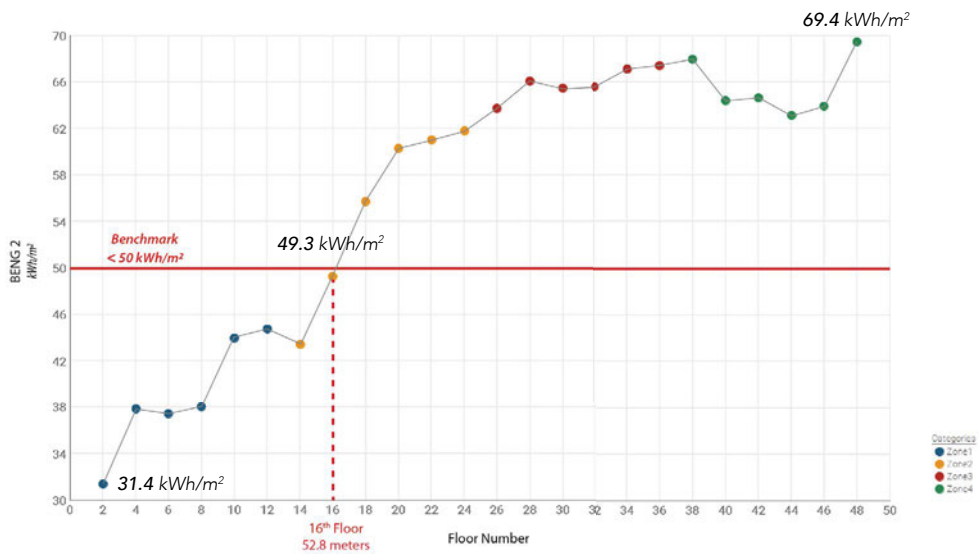


Increase of BENG 2

Height Increment Performance



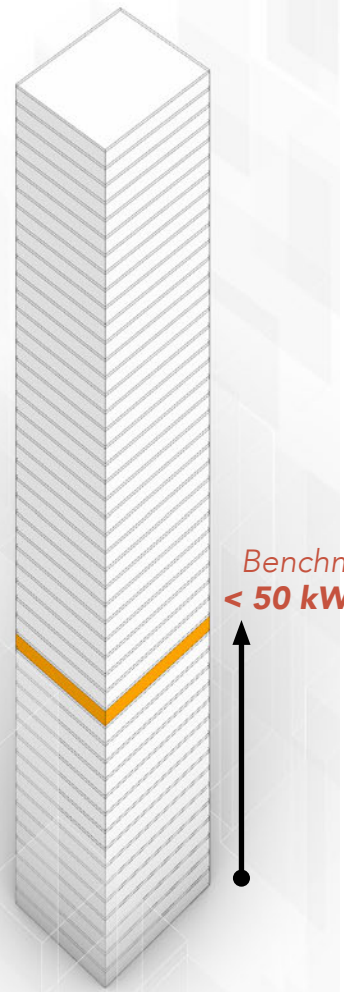
BENG 2 Primary Fossil Usage



Increase of BENG 2

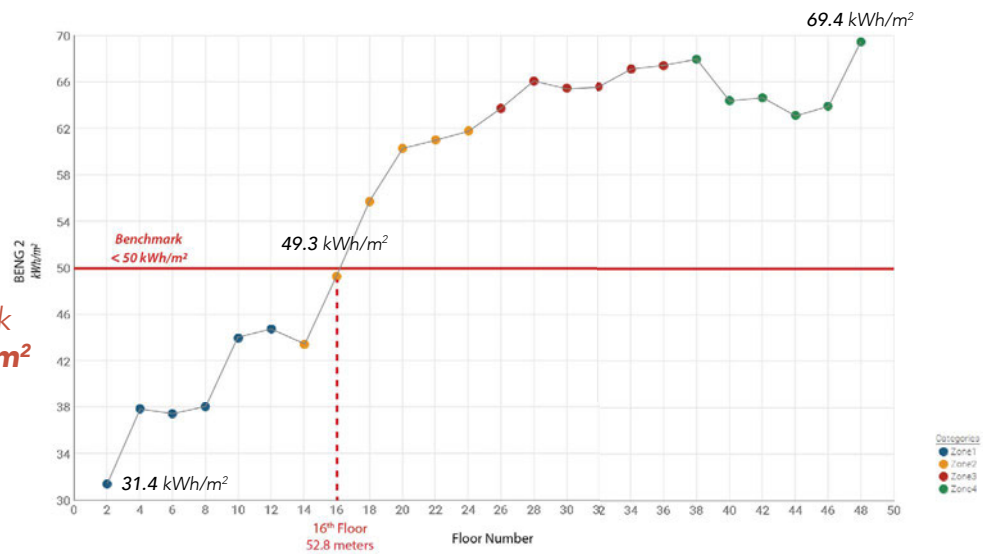
55%
Performance Decrease

Height Increment Performance



Benchmark
< 50 kWh/m²

BENG 2 Primary Fossil Usage



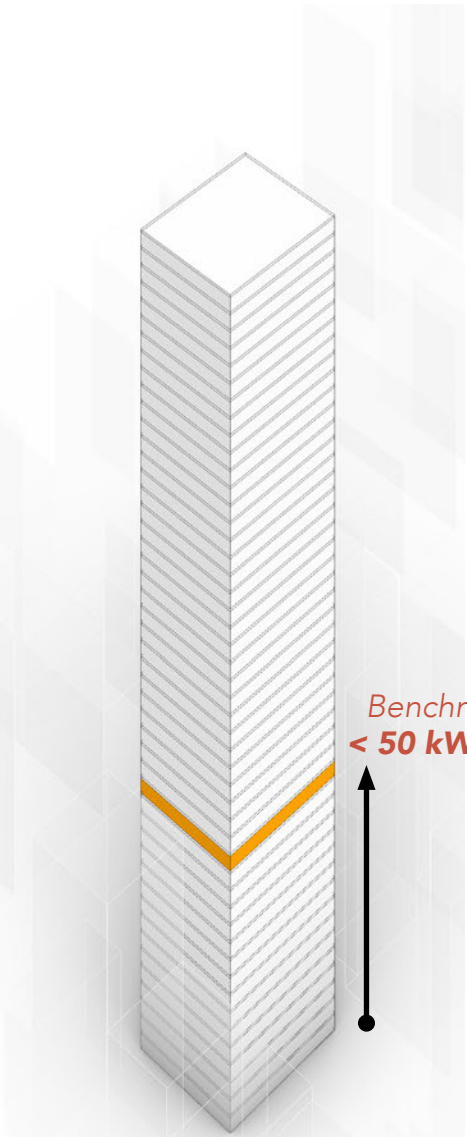
Increase of BENG 2

55%
Performance Decrease

Benchmark
< 50 kWh/m²

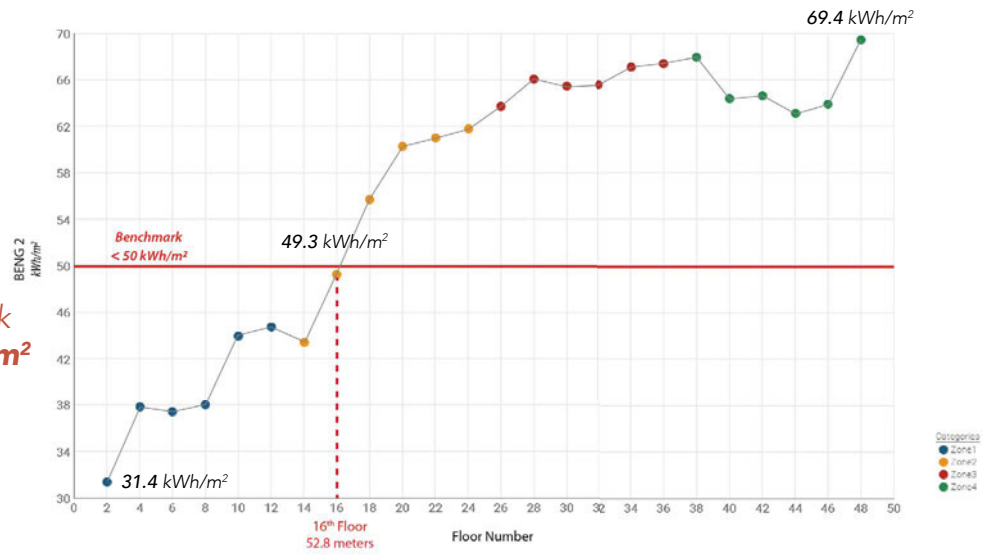
with 49.3 kWhm/m²
until the 16th floor (52.8 meters)

Height Increment Performance



Benchmark
< 50 kWh/m²

BENG 2 Primary Fossil Usage



Increase of BENG 2

55%
Performance Decrease

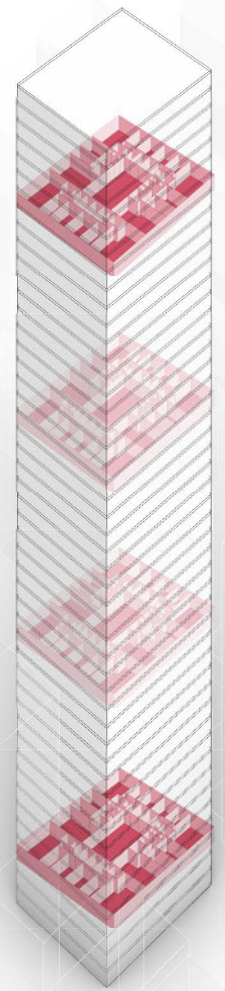
Benchmark
< 50 kWh/m²

with 49.3 kWhm/m² until the 16th floor (52.8 meters)

BENG 2
=
Heating + Cooling + Lighting + Ventilation

Height Increment Performance

Ventilation MV / NV schedules

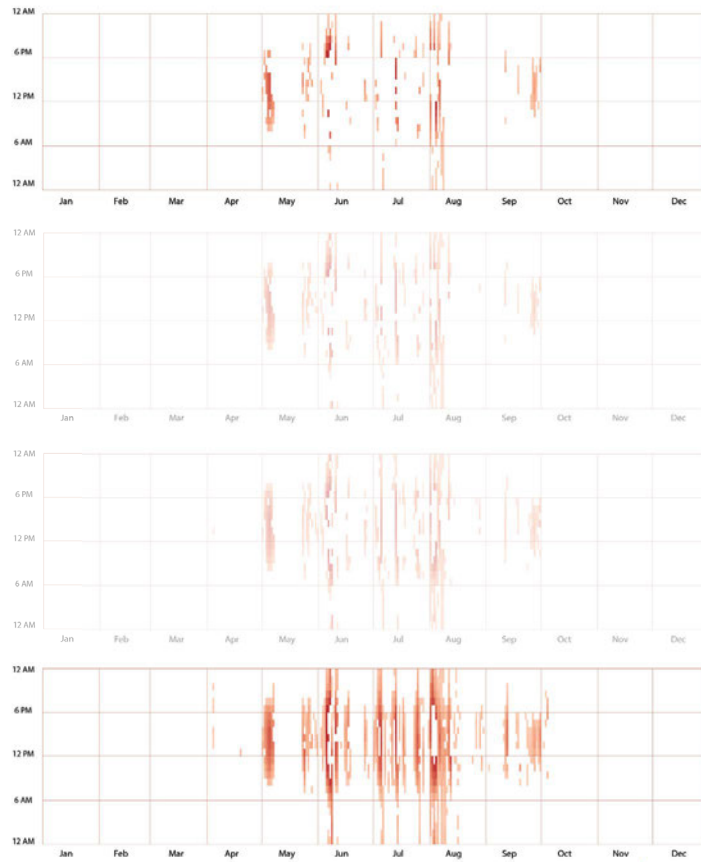


41st Floor
135 meters

29th Floor
95.7 meters

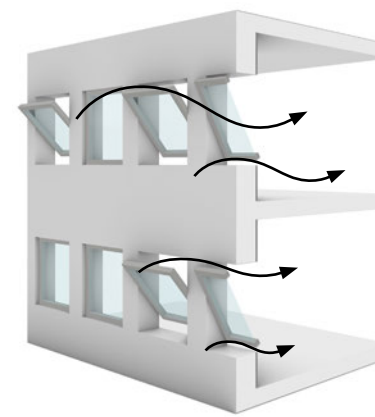
19th Floor
56.1 meters

5th Floor
16.5 meters



NV 186 hours

MV 9574 hours

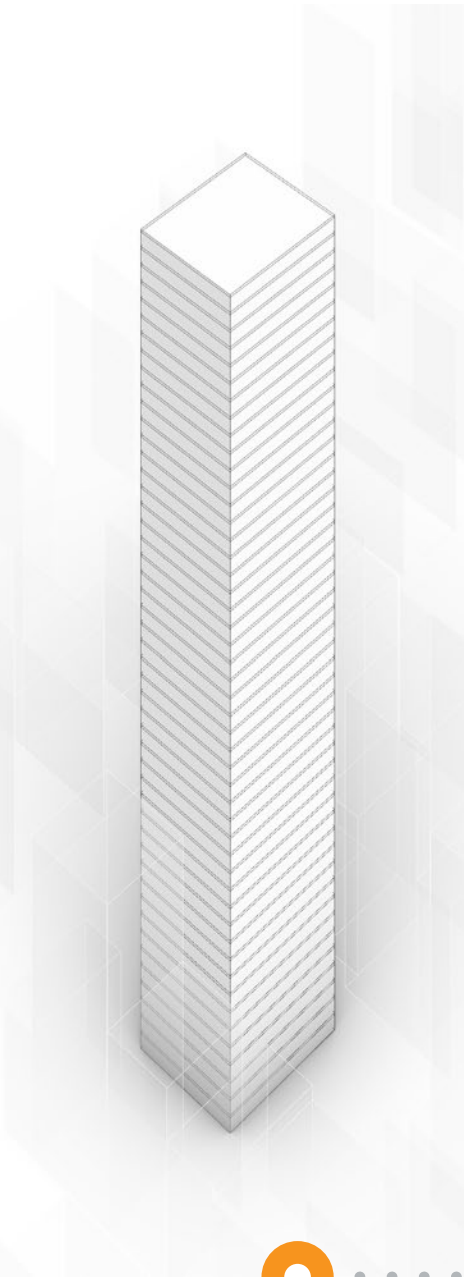


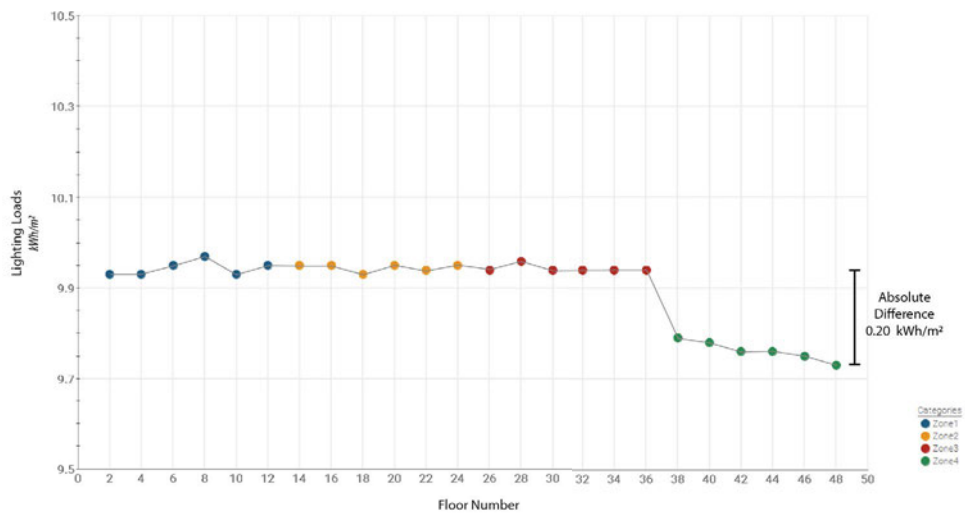
NV 645 hours

MV 8115 hours

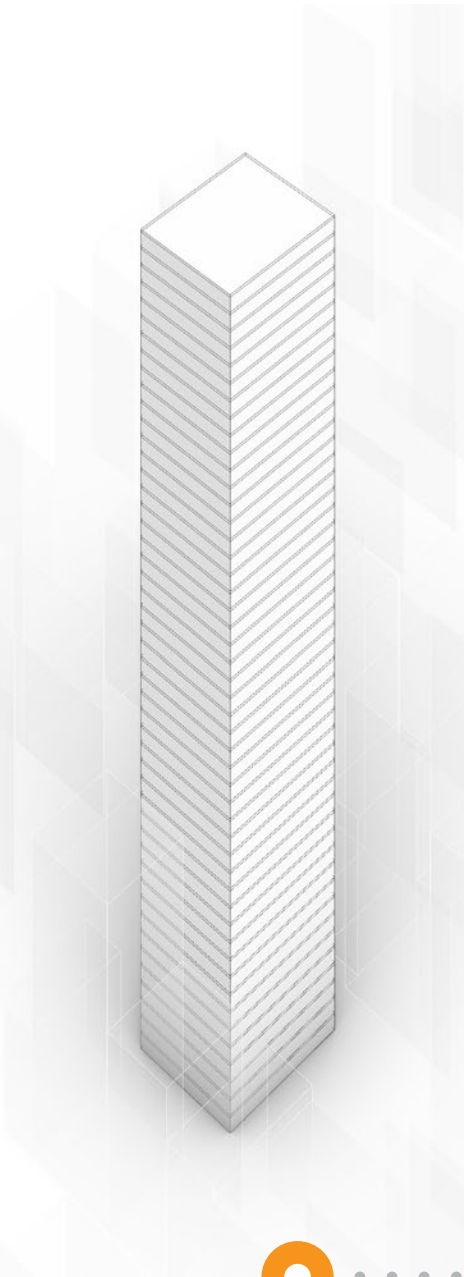
Height Increment Performance

Lighting Loads

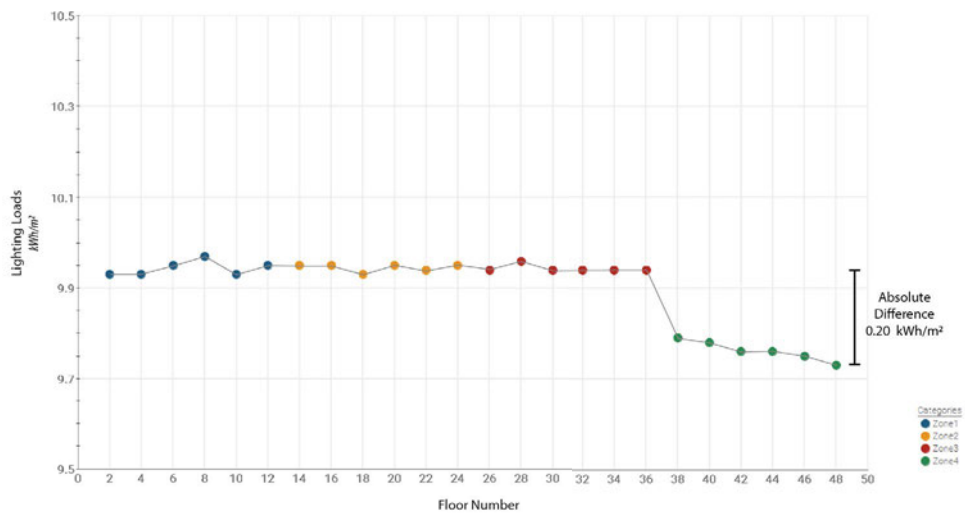




Height Increment Performance



Lighting Loads



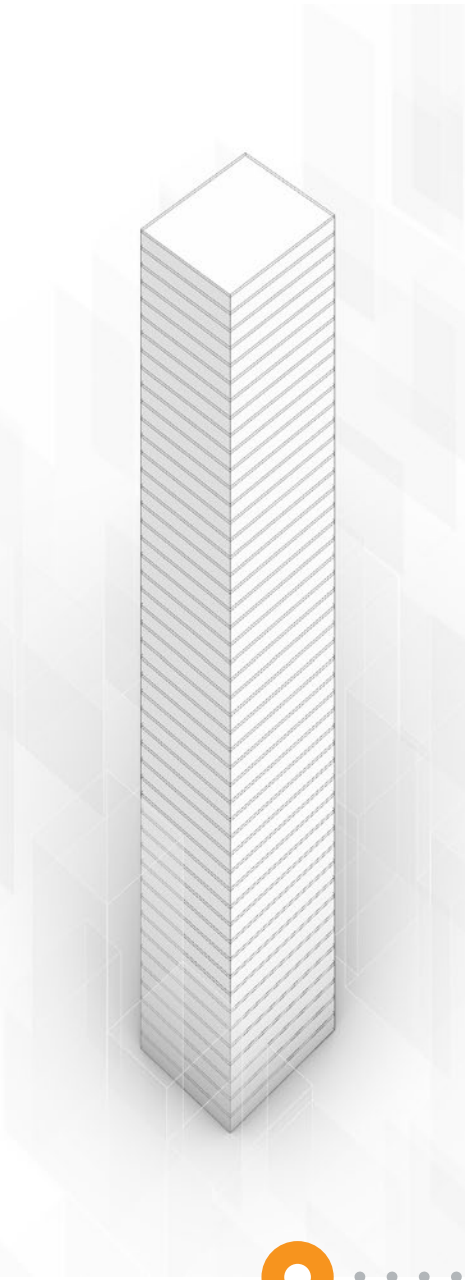
Constant Lighting Loads

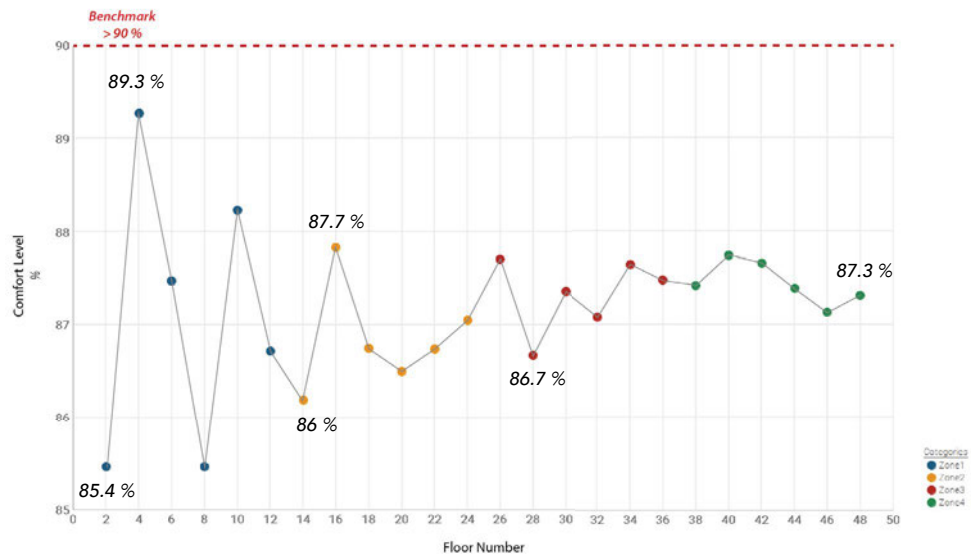
Constraint of Plug-in with Dynamic Shading

(results expected to be higher under the usage of the dynamic controlled roller)

Height Increment Performance

Comfort Level

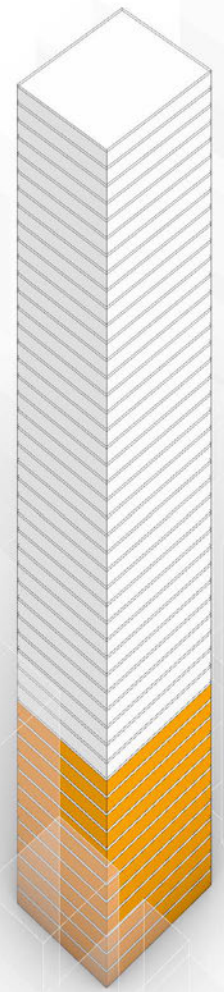




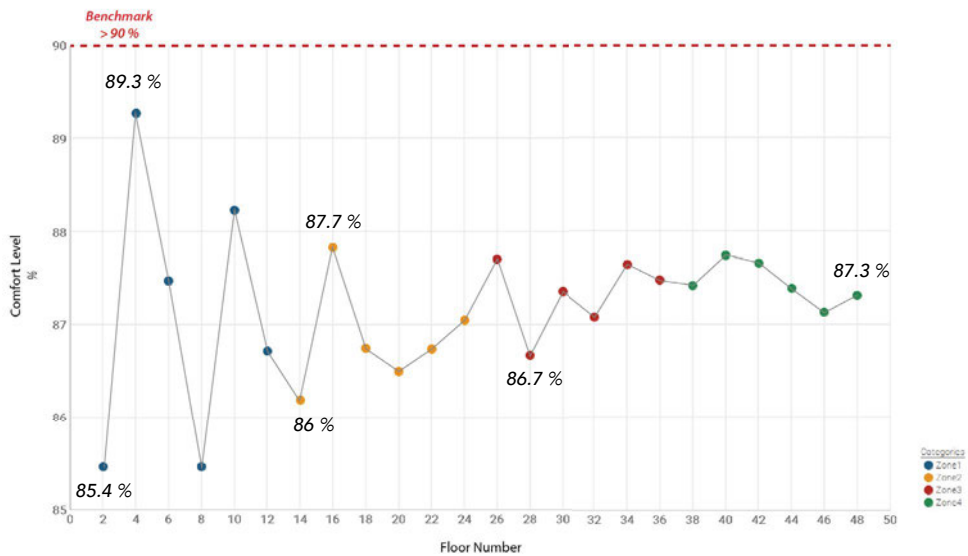
Fluctuation of Comfort Level

Height Increment Performance

Comfort Level



28.2 °C

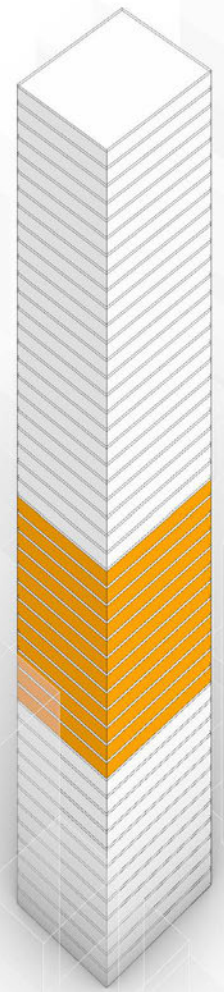


Fluctuation of Comfort Level

Zone 1
85.5% to 89.3%
Max T° = ***28.2°C > 26°C***

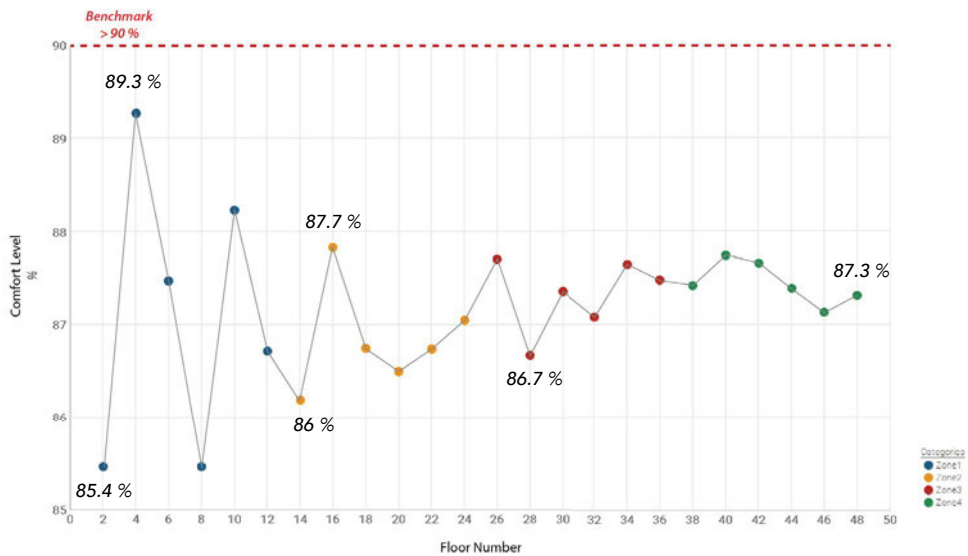
Height Increment Performance

Comfort Level



26.7 °C

28.2 °C



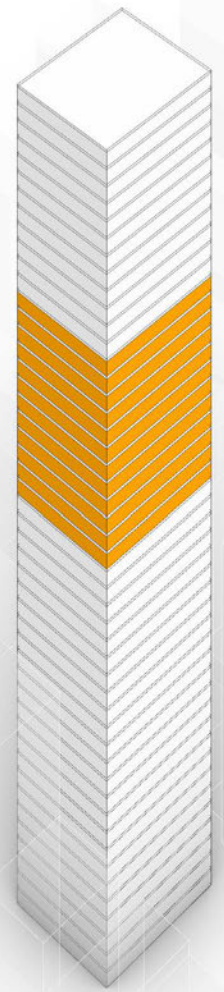
Fluctuation of Comfort Level

Zone 1
85.5% to 89.3%
Max T° = ***28.2°C > 26°C***

Zone 2
86% to 87%
Max T° = ***26.7°C > 26°C***

Height Increment Performance

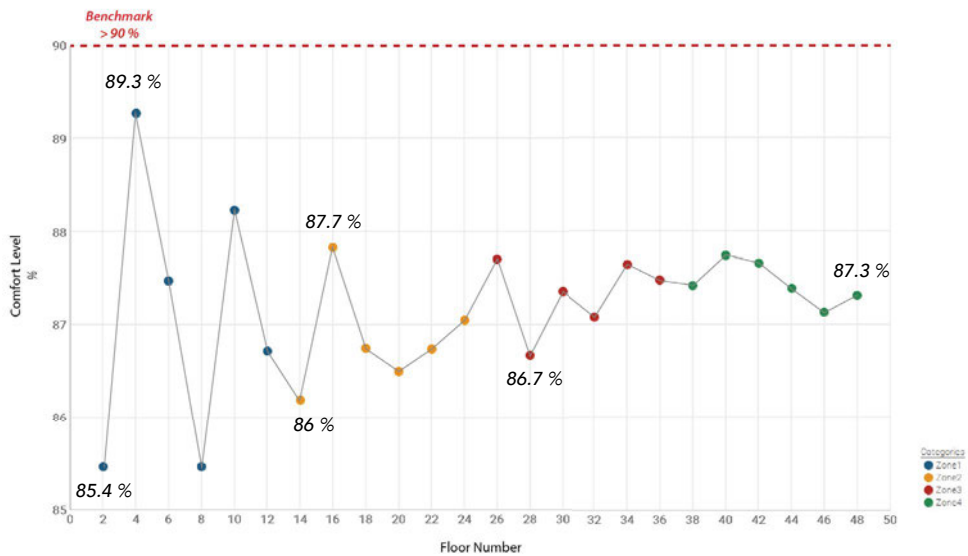
Comfort Level



26.2 °C

26.7 °C

28.2 °C



Fluctuation of Comfort Level

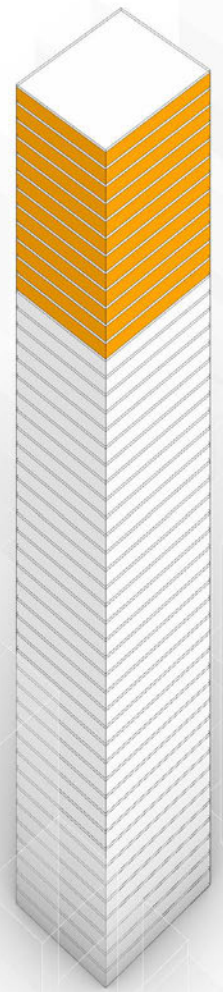
Zone 1
85.5% to 89.3%
Max T° = ***28.2°C > 26°C***

Zone 2
86% to 87%
Max T° = ***26.7°C > 26°C***

Zone 3
86.7% to 87.7%
Max T° = ***26.2°C > 26°C***

Height Increment Performance

Comfort Level

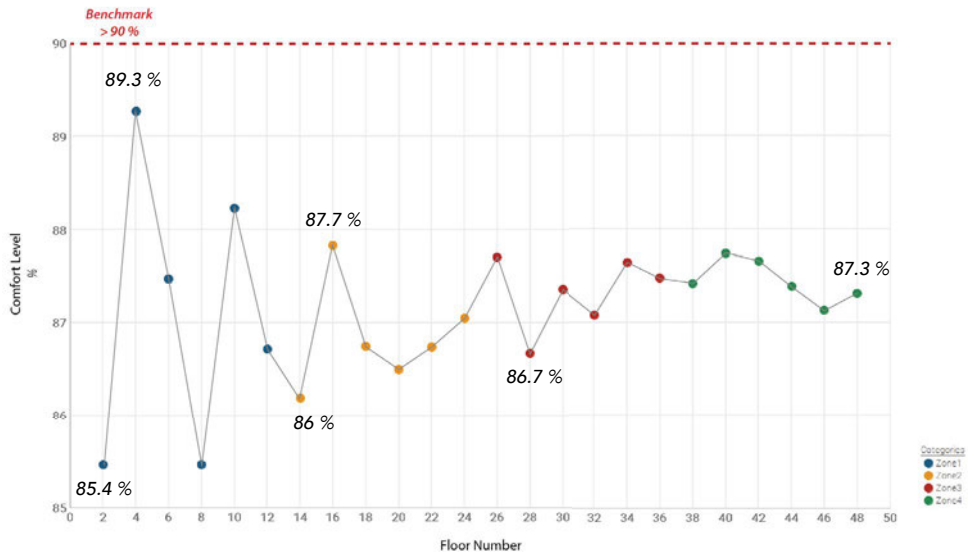


25.5 °C

26.2 °C

26.7 °C

28.2 °C



Fluctuation of Comfort Level

Zone 1
85.5% to 89.3%
Max T° = ***28.2°C*** ***> 26°C***

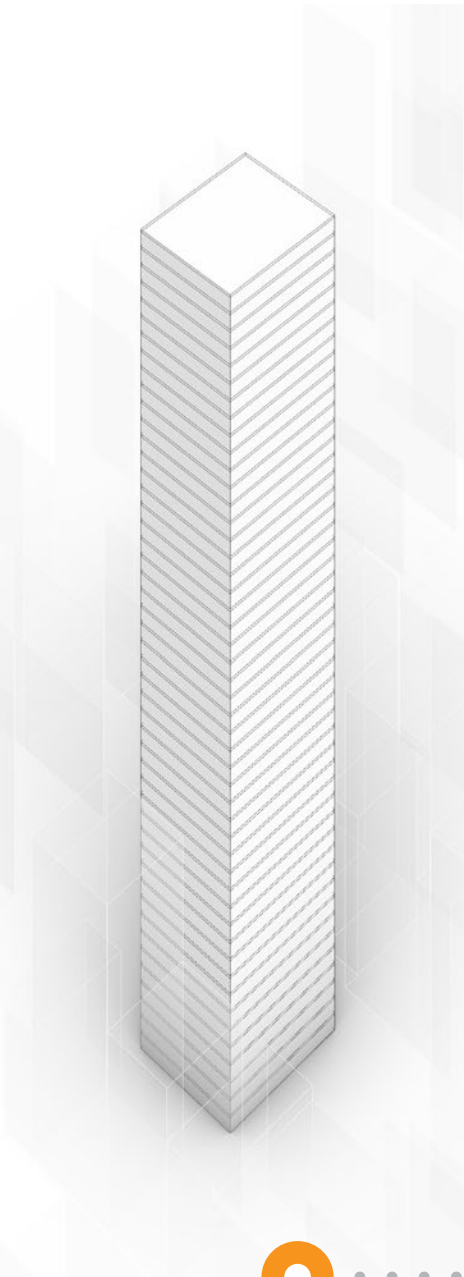
Zone 2
86% to 87%
Max T° = ***26.7°C*** ***> 26°C***

Zone 3
86.7% to 87.7%
Max T° = ***26.2°C*** ***> 26°C***

Zone 4
87% to 87.7%
Max T° = ***25.5°C*** *< 26°C*

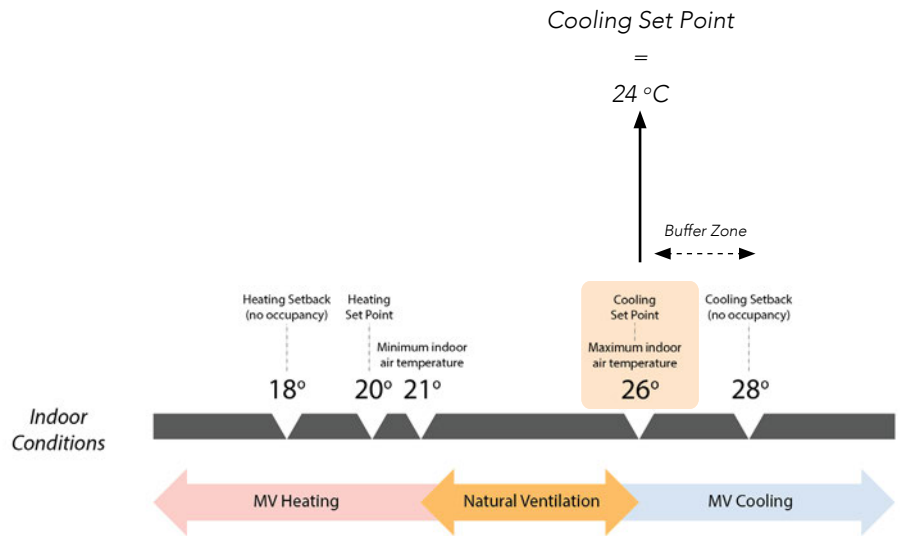
Below required Benchmark 90 %

Height Increment Performance



Comfort Level

TOjuli 26°C Exceeded



+

similar cooling & heating
set points for all levels
(different micro-climates)

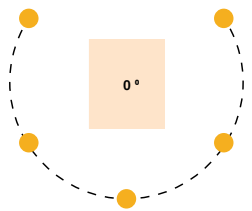
Guidelines

Design of a ***Residential High-Rise***

in the ***Temperate Climate***

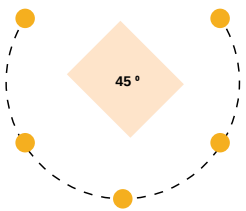
of the ***Netherlands***

Guidelines



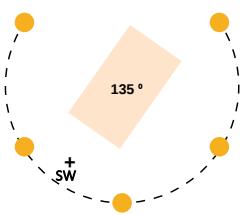
Heat gains mainly **W / S / E**
Heating Loads ↑
Comfort Level ↓

BENG 1
BENG 2



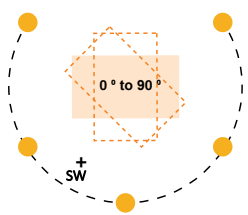
Heat gains = **W / S / E / S**
Heating Loads ↓
Comfort Level ↑

BENG 1
BENG 2



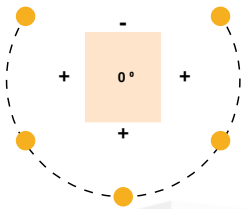
Heat gains on Shortest Side
Heating Loads ↑
Comfort Level ↓

BENG 1
BENG 2



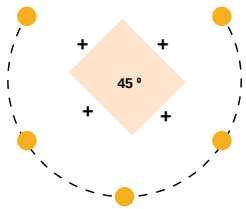
Heat gains Longest Side
Heating Loads ↓
Comfort Level ↑

BENG 1
BENG 2



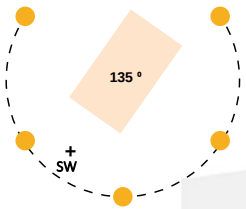
Facade PV panels
W / S / E

BENG 3



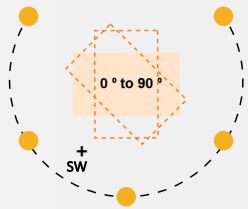
Facade PV panels
W / S / E / N

BENG 3



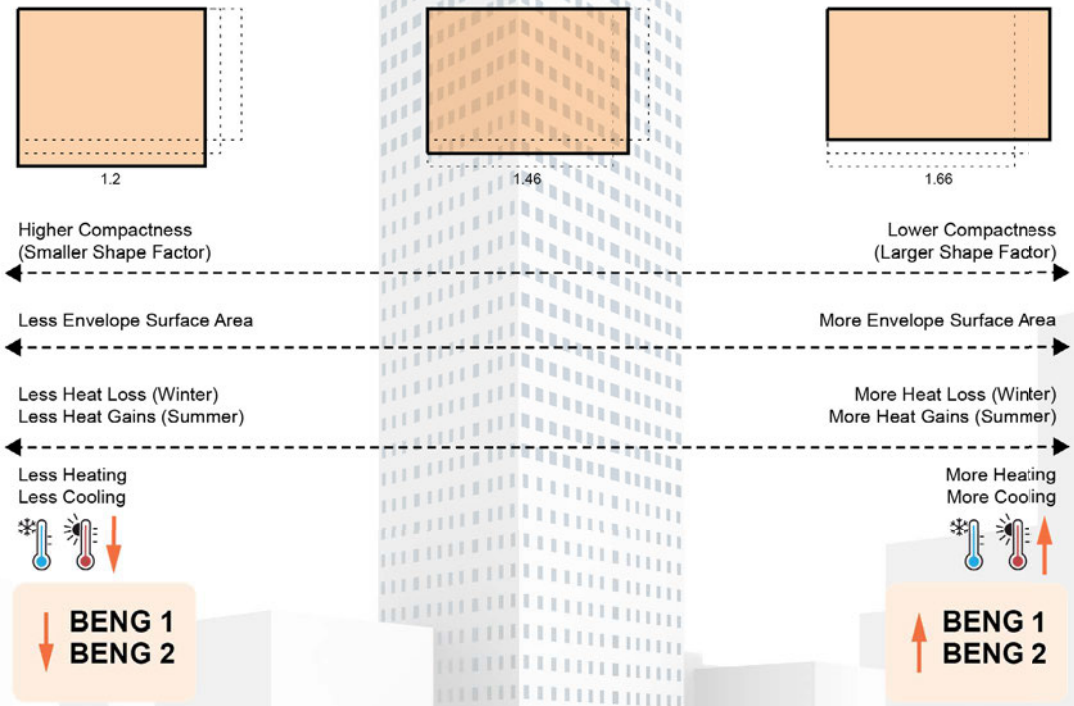
Highest Radiation on Shortest Side

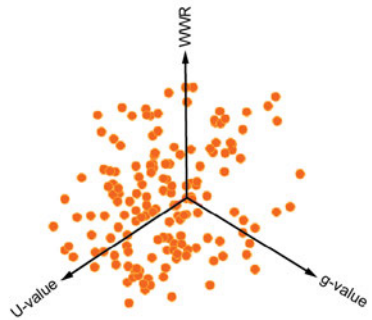
BENG 3



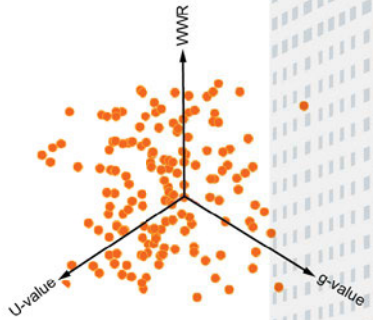
Highest Radiation on Longest Side

BENG 3

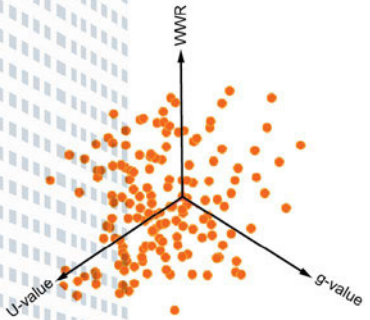

1.2
1.46
1.66
Higher Compactness
(Smaller Shape Factor)
Lower Compactness
(Larger Shape Factor)
Less Envelope Surface Area
More Envelope Surface Area
Less Heat Loss (Winter)
Less Heat Gains (Summer)
More Heat Loss (Winter)
More Heat Gains (Summer)
Less Heating
Less Cooling
More Heating
More Cooling
BENG 1
BENG 2
BENG 1
BENG 2



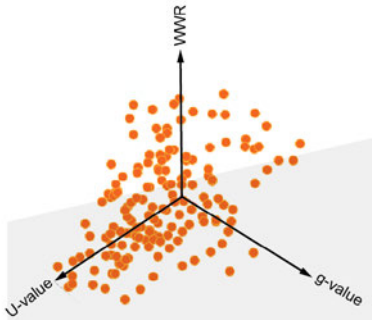
East Orientation



North Orientation

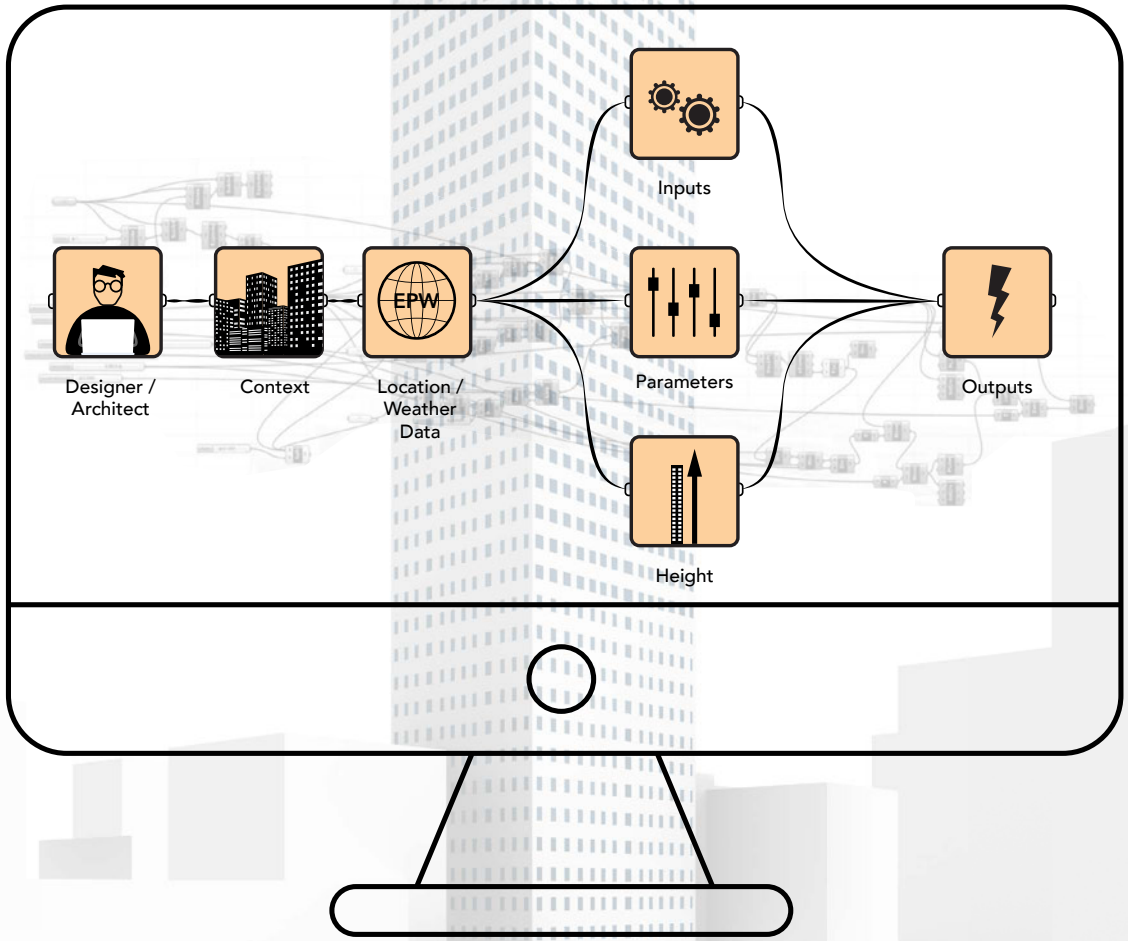


West Orientation



South Orientation

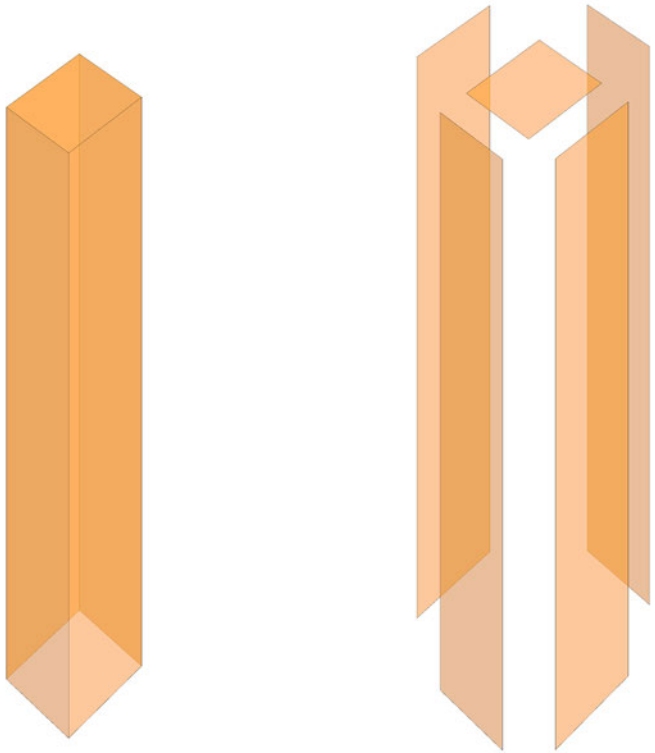
Integrated Workflow



Based on computational optimization, to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands, and eventually what **amendments can be proposed to adapt the desired height to the performance** ?

INDEX

Ratio Volume (V) / Loss Surface of Envelope (Als)



Volume (V)

Loss Surface of Envelope (Als)

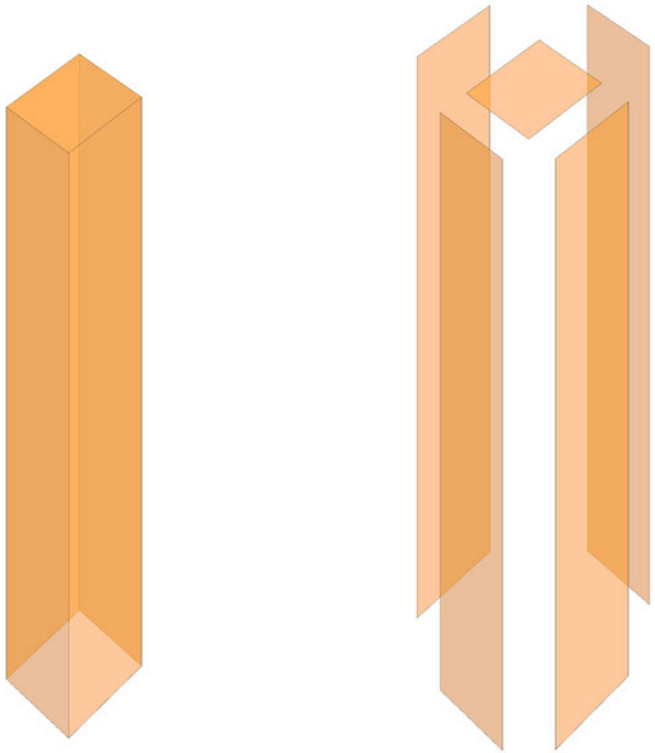
+

Geometry

Height

INDEX

Ratio Volume (V) / Loss Surface of Envelope (Als)

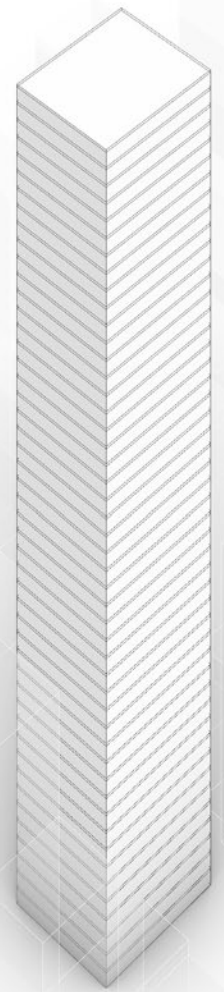


Volume (V) *Loss Surface of Envelope (Als)*

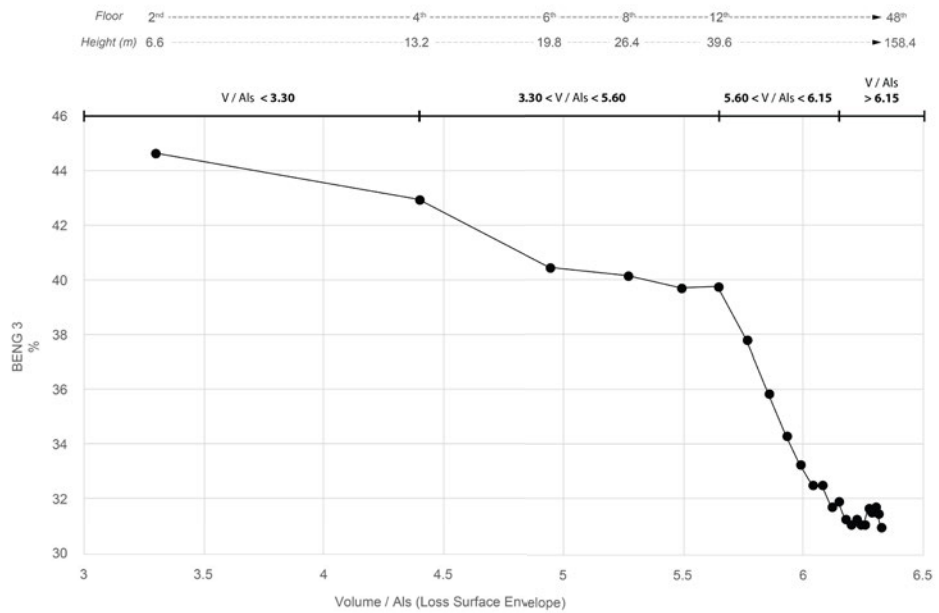
Geometry

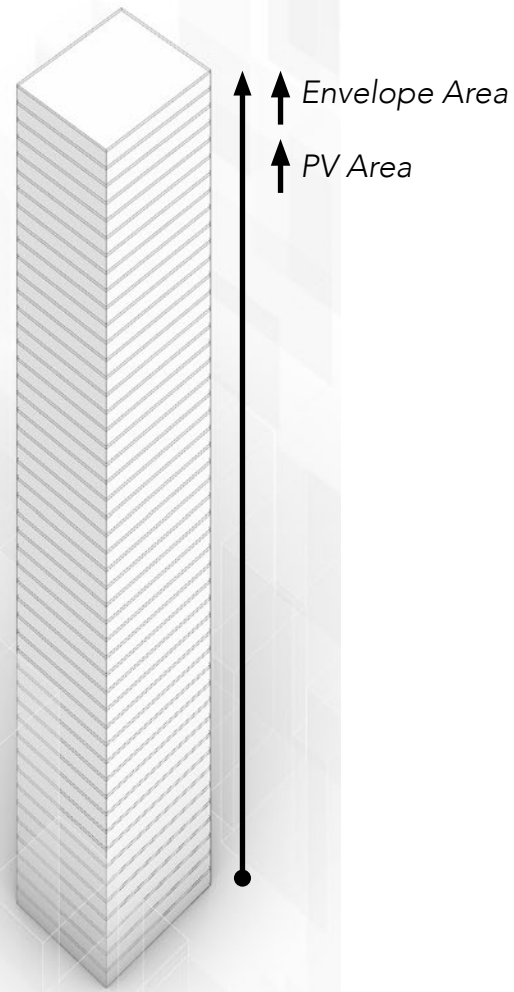
+

Height

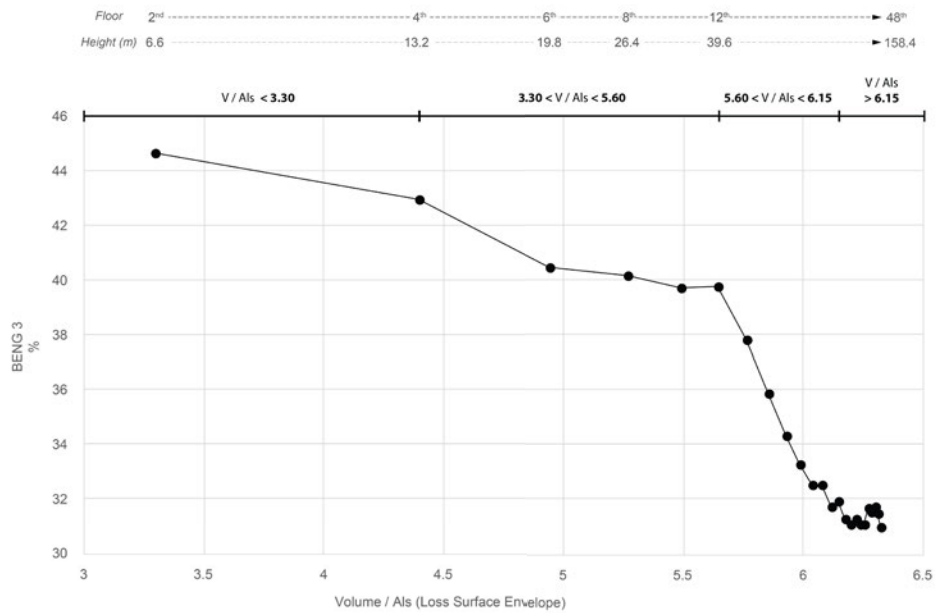


BENG 3


Floor
2nd
4th
6th
8th
12th
48th
Height (m)
6.6
13.2
19.8
26.4
39.6
158.4
V / Als < 3.30
3.30 < V / Als < 5.60
5.60 < V / Als < 6.15
V / Als > 6.15
BENG 3 %
46
44
42
40
38
36
34
32
30
3
3.5
4
4.5
5
5.5
6
6.5
Volume / Als (Loss Surface Envelope)


Envelope Area
PV Area

BENG 3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4.5
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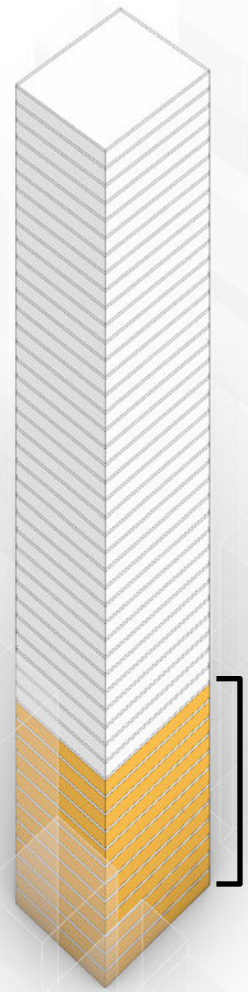
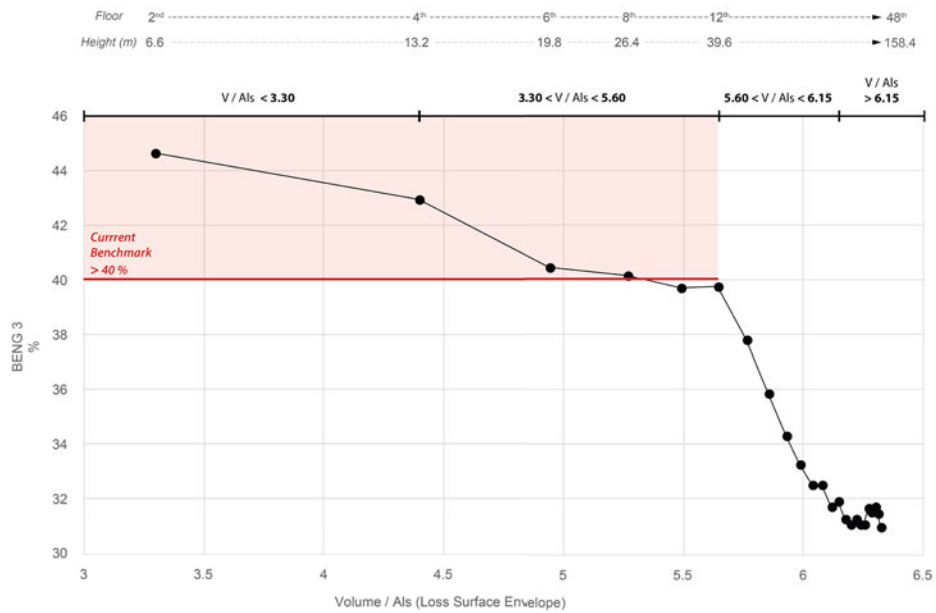
5.5
6
6.5
Volume / Als (Loss Surface Envelope)



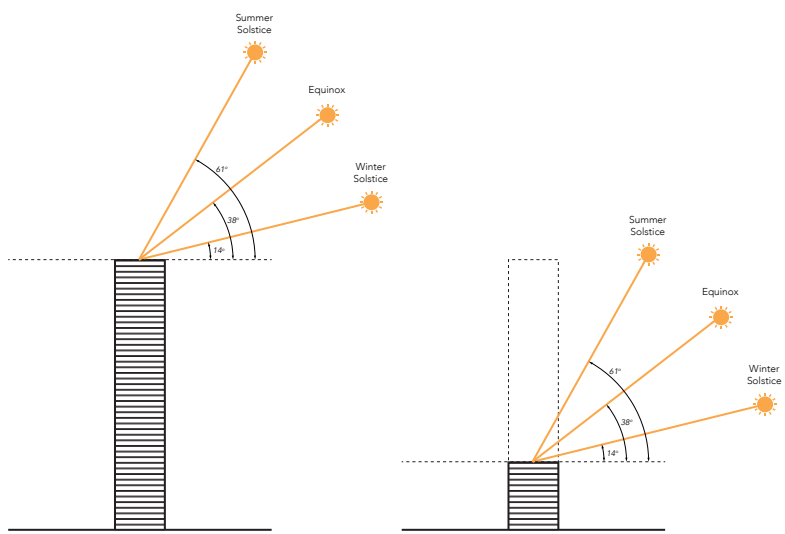
BENG 3

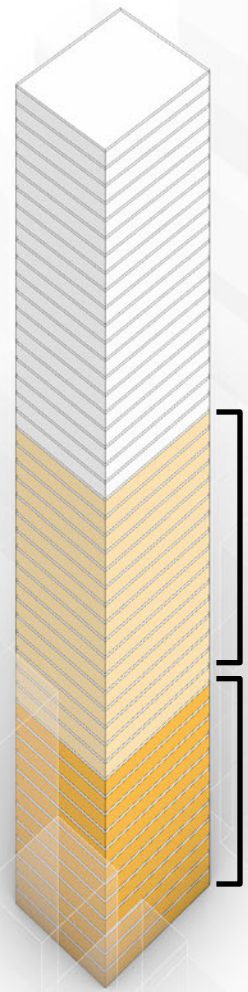


V/AIs < 5.60

Roof Efficiency > Facade Efficiency

BENG 3 > 40%





5.60 < V/AIs < 6.15

Maximal Roof Efficiency Reached

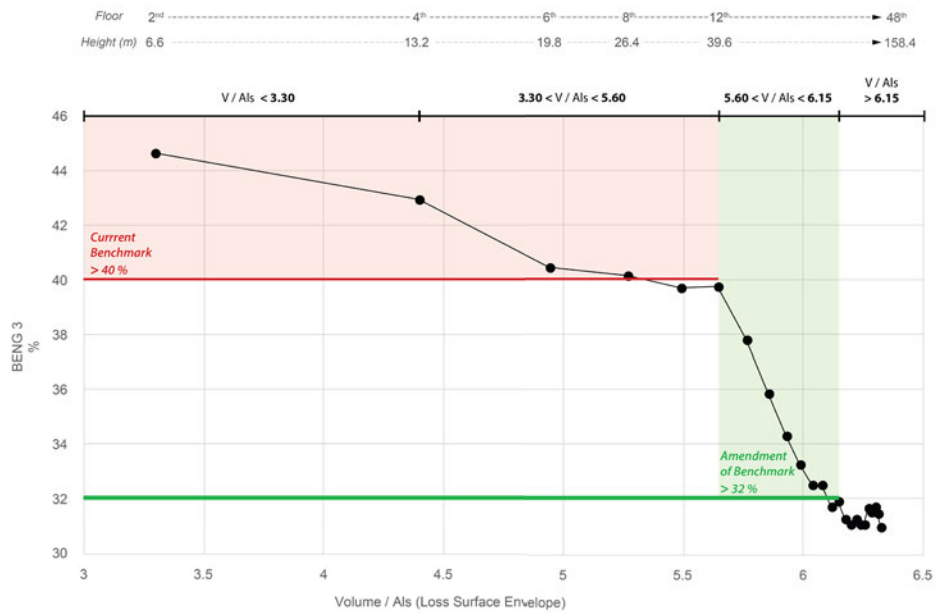
BENG 3 > 32%

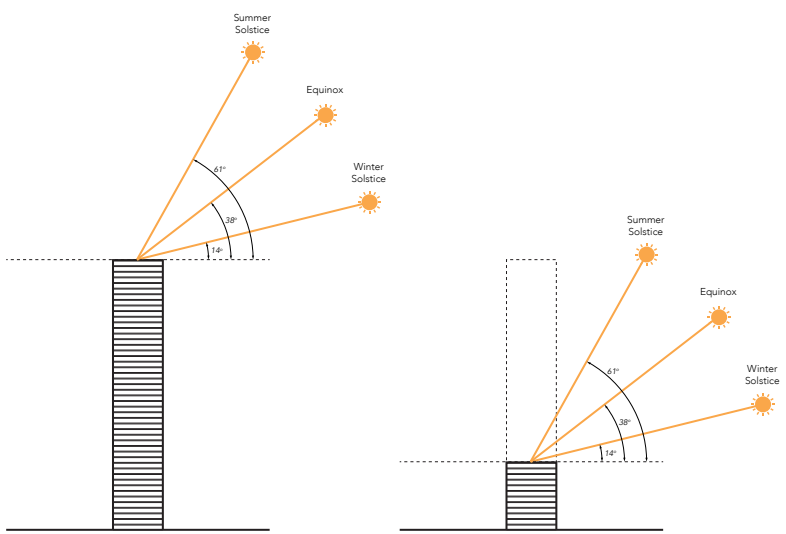
V/AIs < 5.60

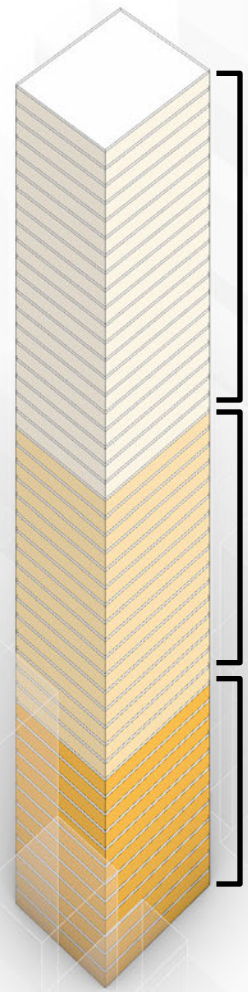
Roof Efficiency > Facade Efficiency

BENG 3 > 40%

BENG 3







V/Als > 6.15

Constant Energy Generation

Plateau Efficiency of PV

BENG 3 > 30%

5.60 < V/Als < 6.15

Maximal Roof Efficiency Reached

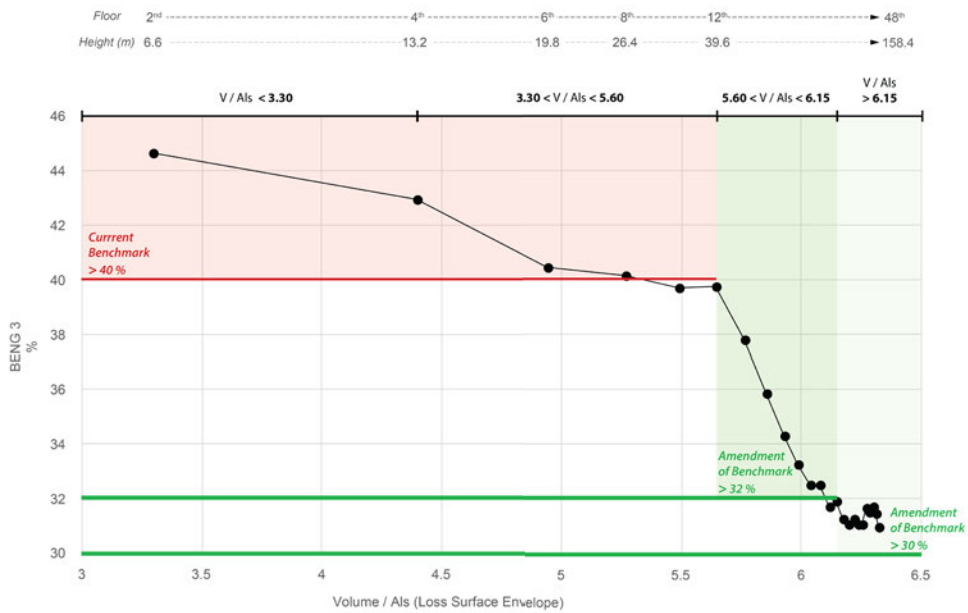
BENG 3 > 32%

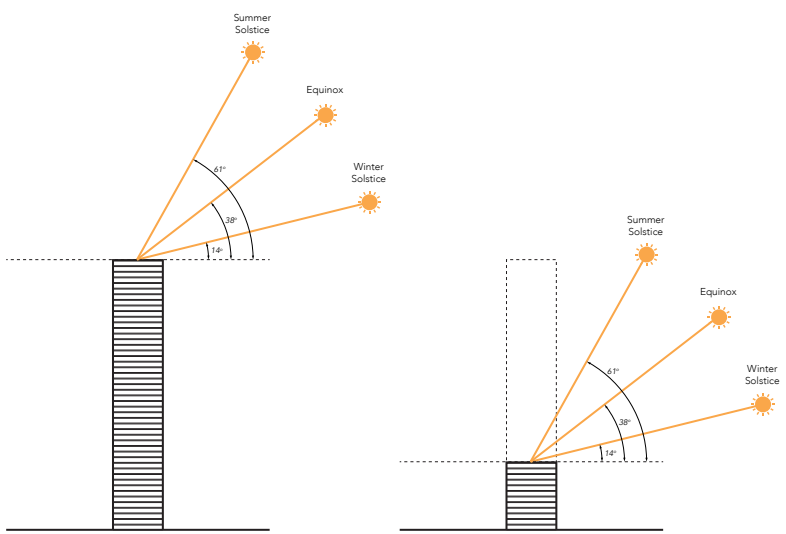
V/Als < 5.60

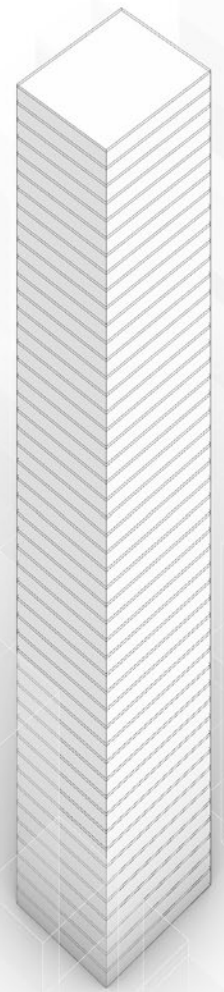
Roof Efficiency > Facade Efficiency

BENG 3 > 40%

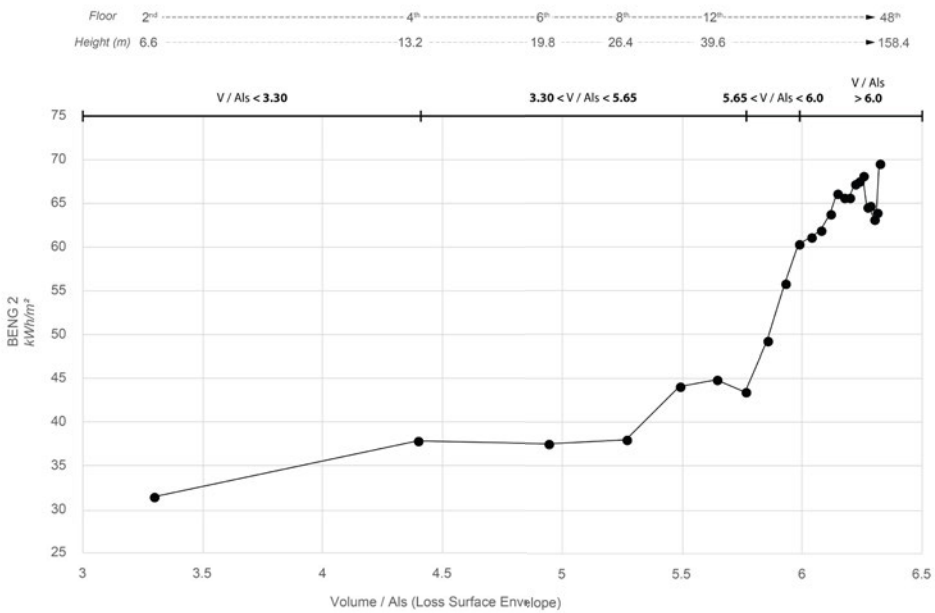
BENG 3

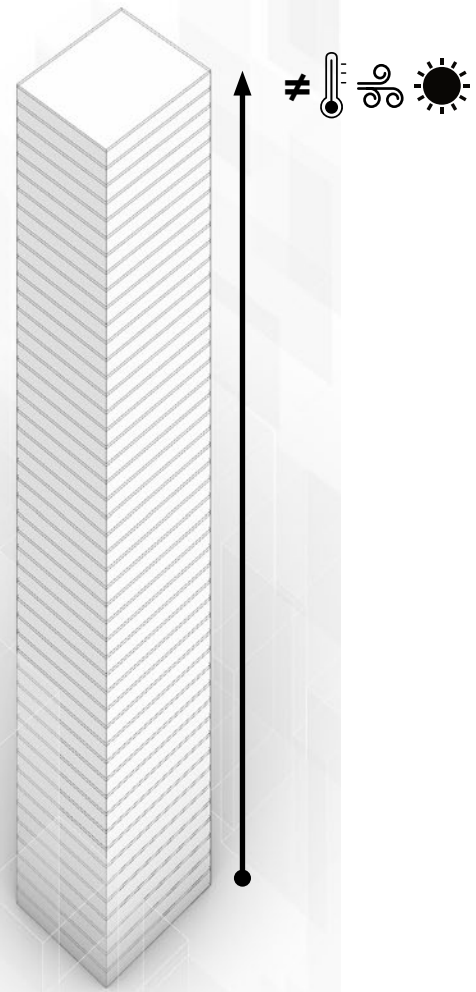




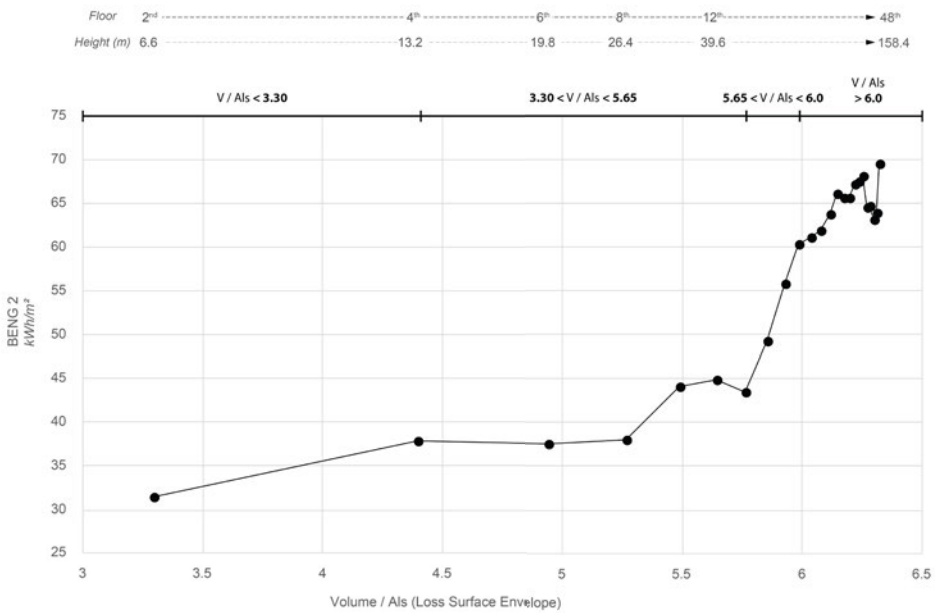


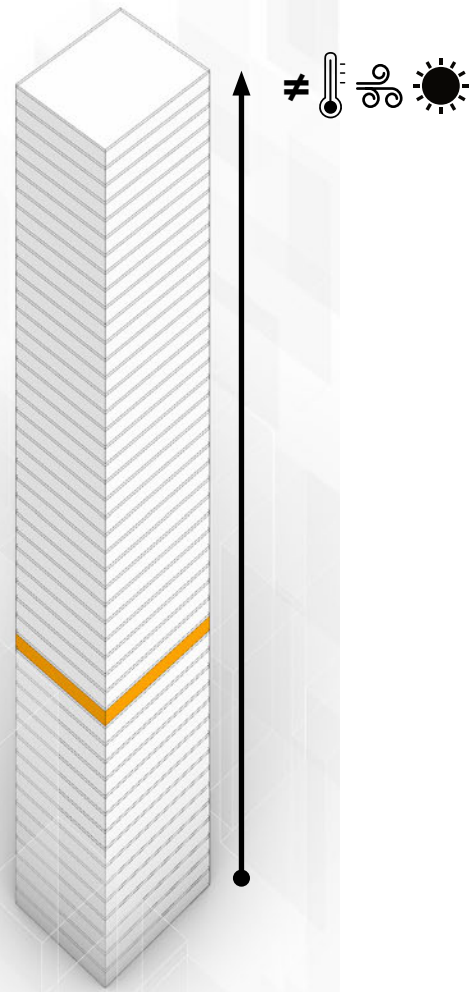
BENG 2


Floor
2nd
4th
6th
8th
12th
48th
Height (m)
6.6
13.2
19.8
26.4
39.6
158.4
V / Als < 3.30
3.30 < V / Als < 5.65
5.65 < V / Als < 6.0
V / Als > 6.0
BENG 2 kWh/m²
75
70
65
60
55
50
45
40
35
30
25
3
3.5
4
4.5
5
5.5
6
6.5
Volume / Als (Loss Surface Envelope)

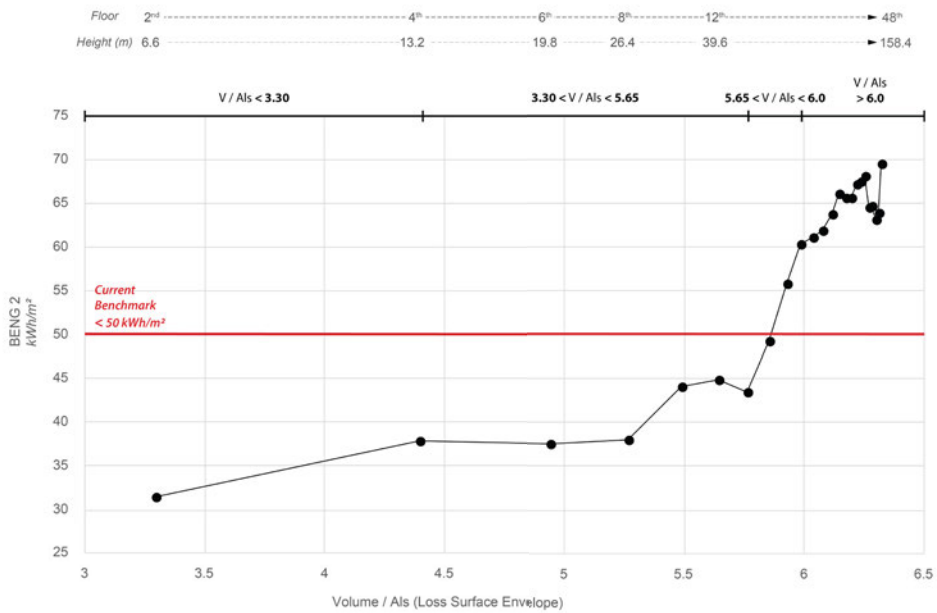


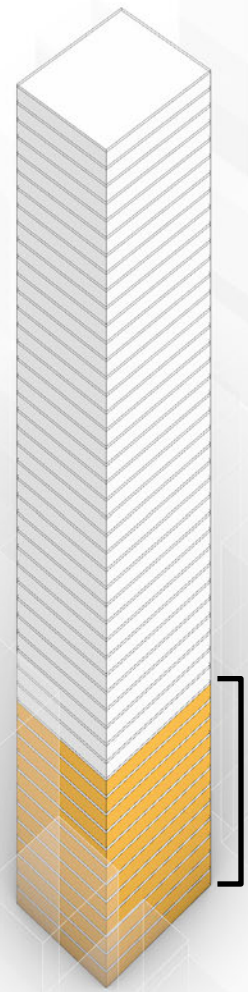
BENG 2


Floor
2nd
4th
6th
8th
12th
48th
Height (m)
6.6
13.2
19.8
26.4
39.6
158.4
V / Als < 3.30
3.30 < V / Als < 5.65
5.65 < V / Als < 6.0
V / Als > 6.0
BENG 2 kWh/m²
75
70
65
60
55
50
45
40
35
30
25
3
3.5
4
4.5
5
5.5
6
6.5
Volume / Als (Loss Surface Envelope)



BENG 2


Floor
2nd
4th
6th
8th
12th
48th
Height (m)
6.6
13.2
19.8
26.4
39.6
158.4
V / Als < 3.30
3.30 < V / Als < 5.65
5.65 < V / Als < 6.0
V / Als > 6.0
Current Benchmark < 50 kWh/m²
BENG 2 kWh/m²
75
70
65
60
55
50
45
40
35
30
25
3
3.5
4
4.5
5
5.5
6
6.5
Volume / Als (Loss Surface Envelope)



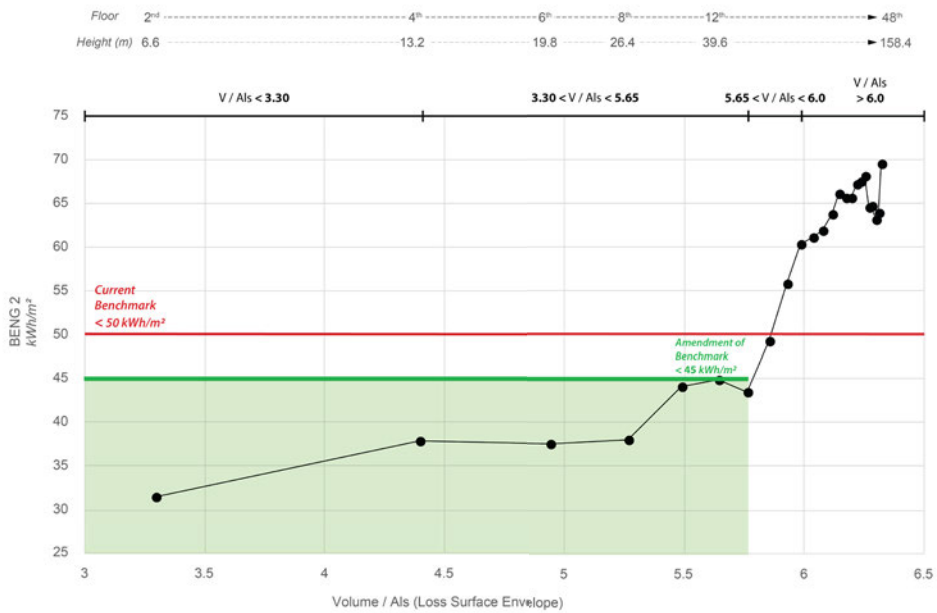
V/Als < 5.65

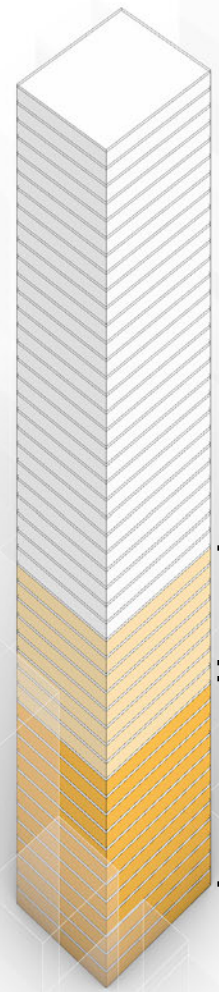
Constant Micro-Climates Conditions

(windspeed < 4.7 m/s)

BENG 2 < 45 kWh/m²

BENG 2





5.65 < V/Als < 6.0

Windspeed Acceleration < 6.7 m/s

Temperature Drop -6.0 °C

BENG 2 < 60 kWh/m²

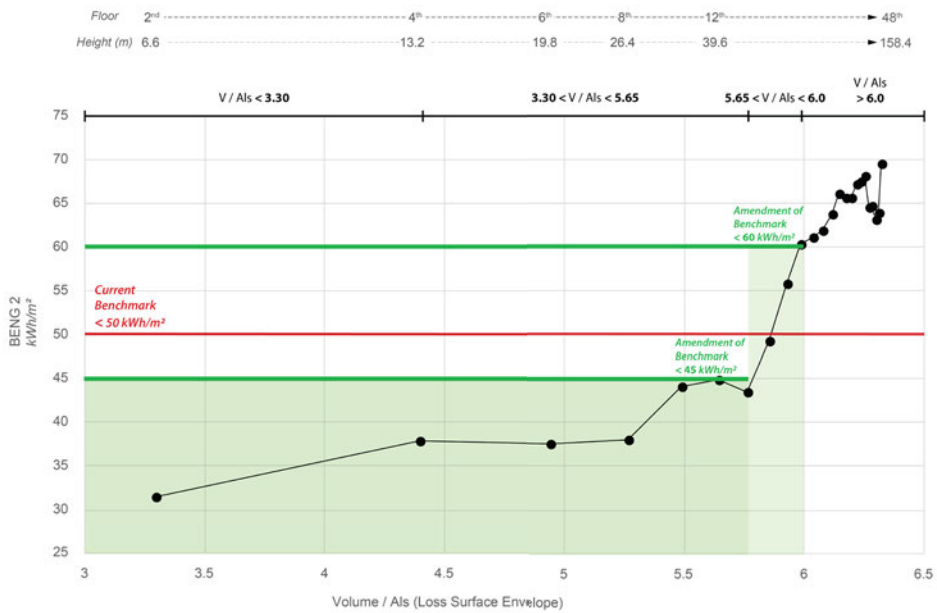
V/Als < 5.65

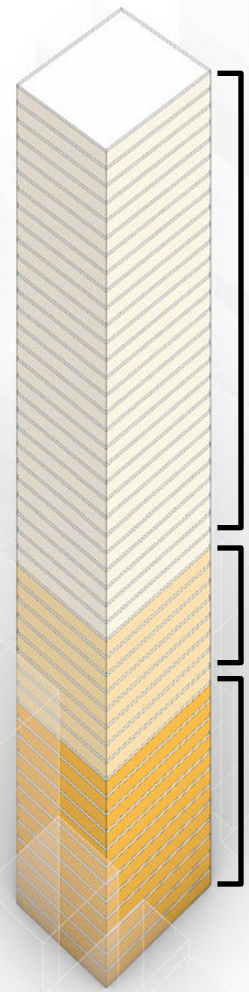
Constant Micro-Climates Conditions

(windspeed < 4.7 m/s)

BENG 2 < 45 kWh/m²

BENG 2





V/Als > 6.0

Windspeed Acceleration > 7.0 m/s

Temperature Drop -11.8 °C

More Volume & Envelope

More Heat Transfer

BENG 2 < 70 kWh/m²

5.65 < V/Als < 6.0

Windspeed Acceleration < 6.7 m/s

Temperature Drop -6.0 °C

BENG 2 < 60 kWh/m²

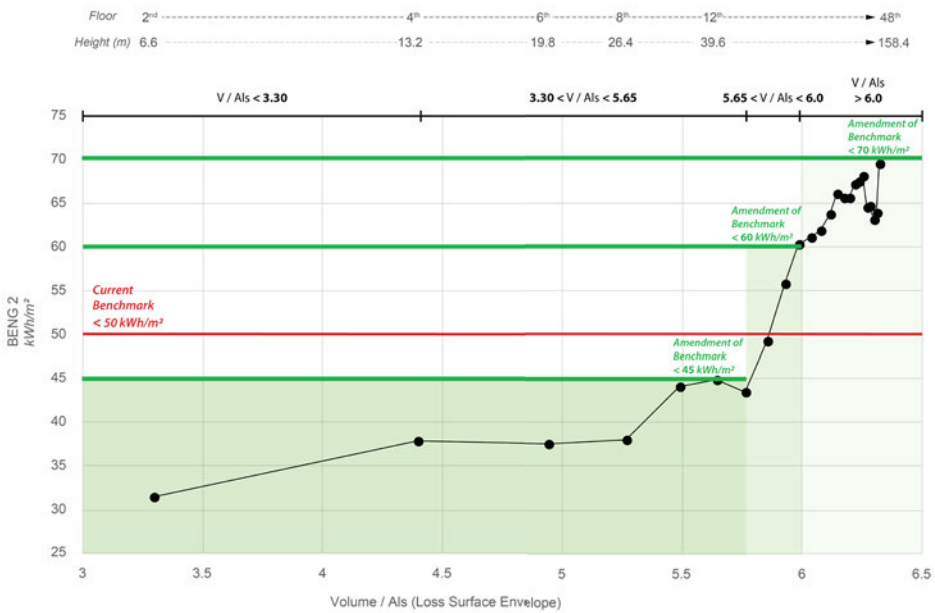
V/Als < 5.65

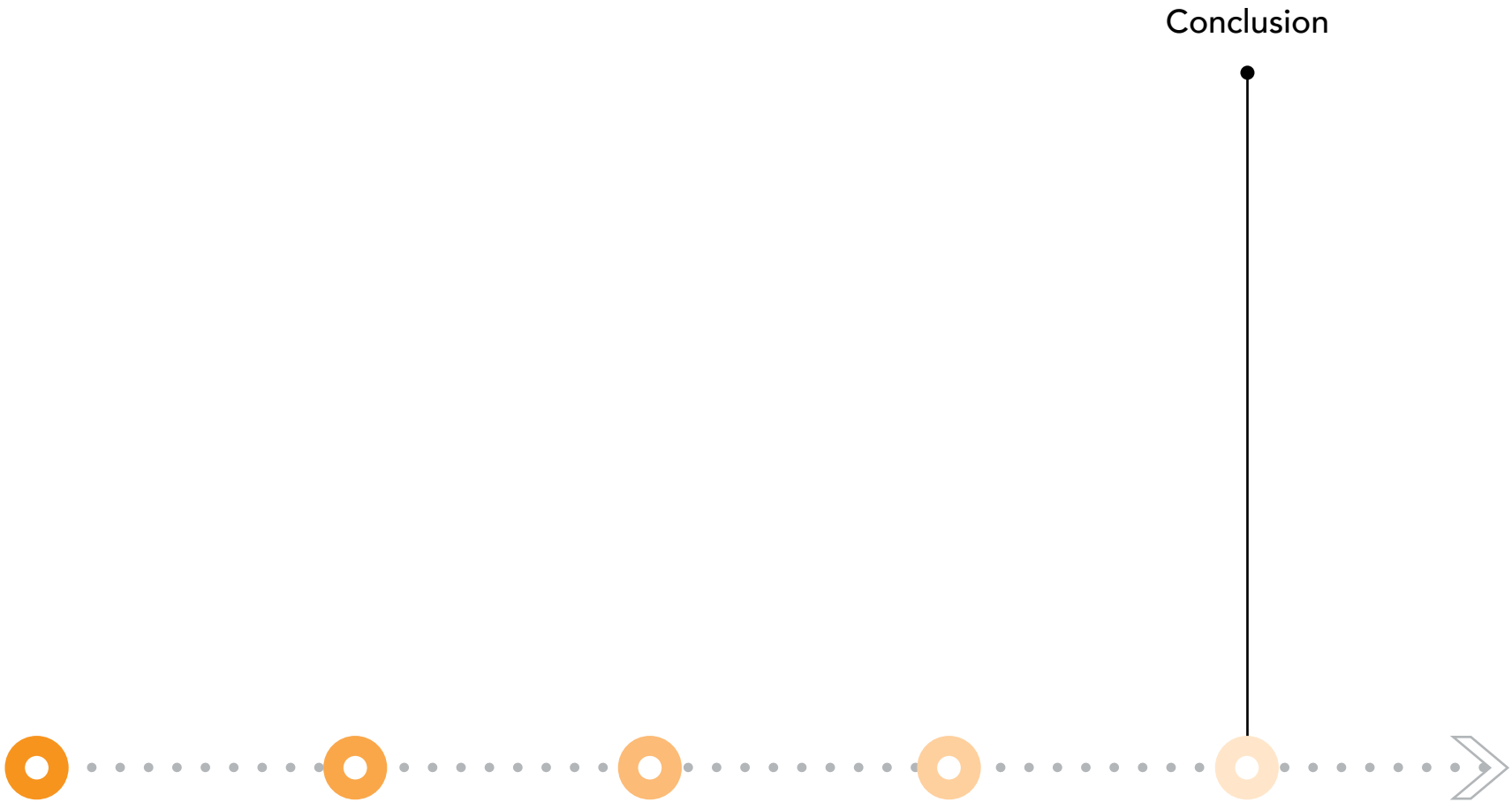
Constant Micro-Climates Conditions

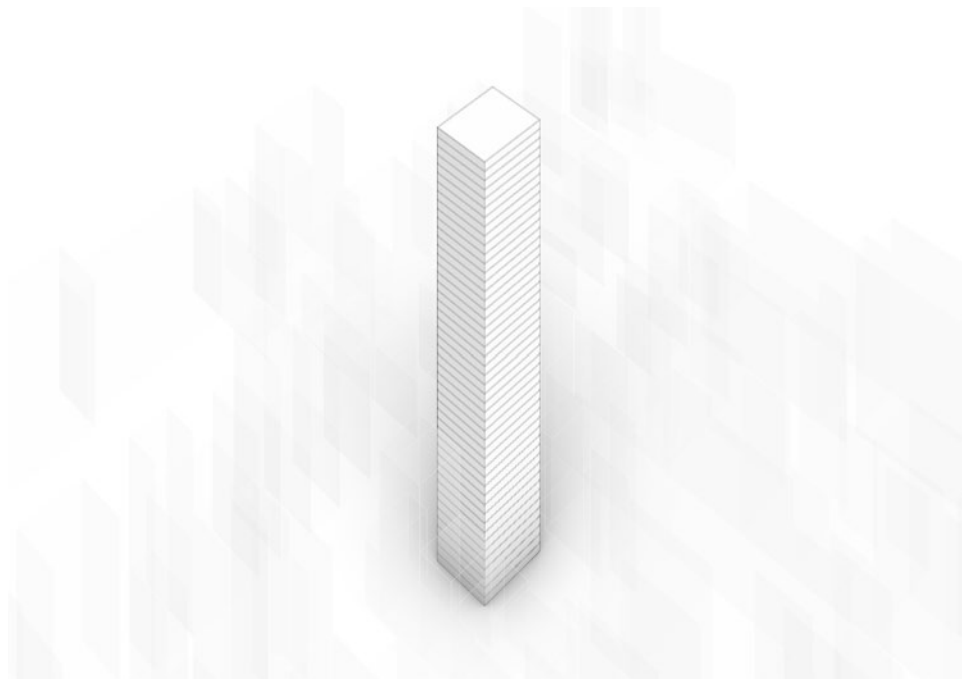
(windspeed < 4.7 m/s)

BENG 2 < 45 kWh/m²

BENG 2




Conclusion



Based on computational optimization,
to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands,
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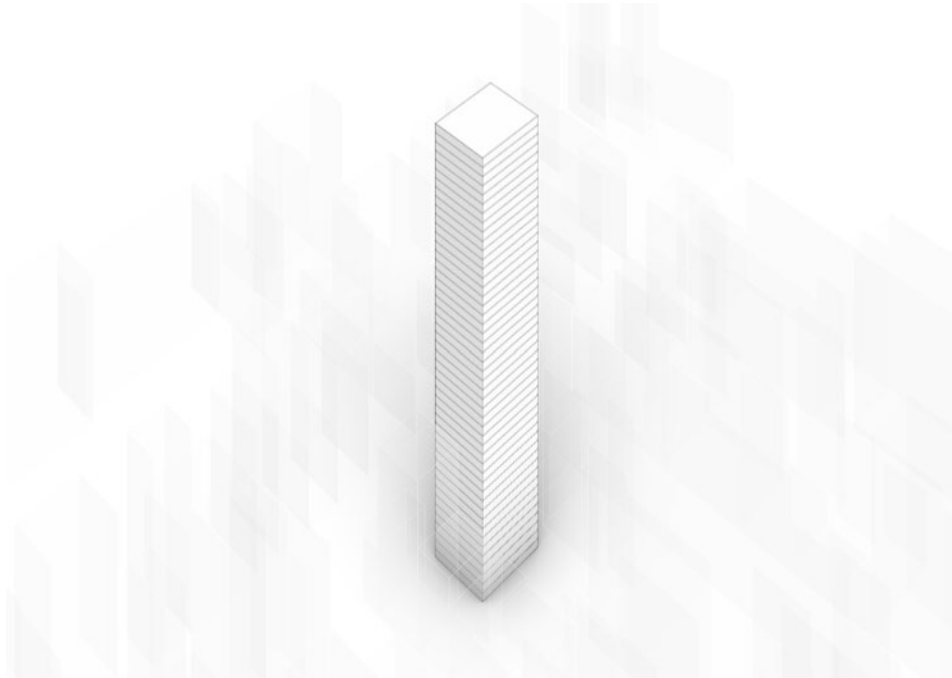

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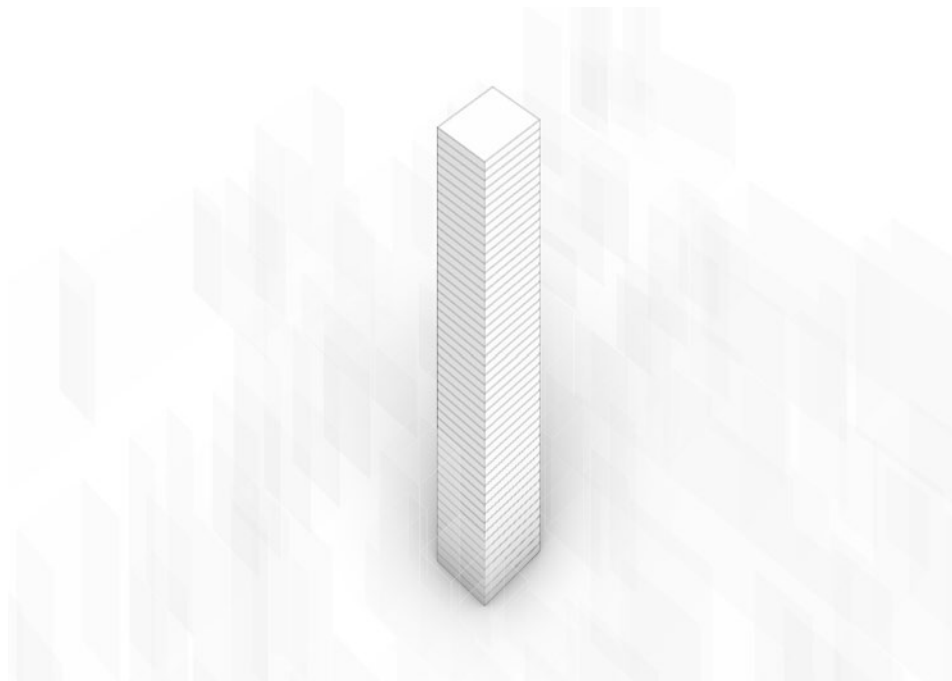
How does the energy performance of the residential high-rise vary
in relation to addition of floors,
and how does it affect the BENG indicators?



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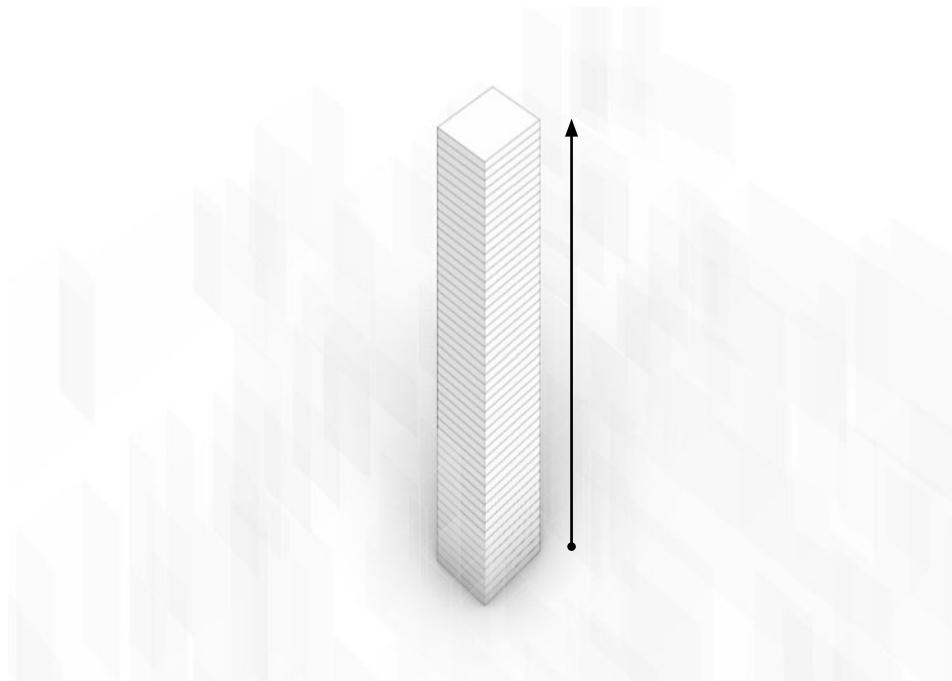
Along the floor addition,



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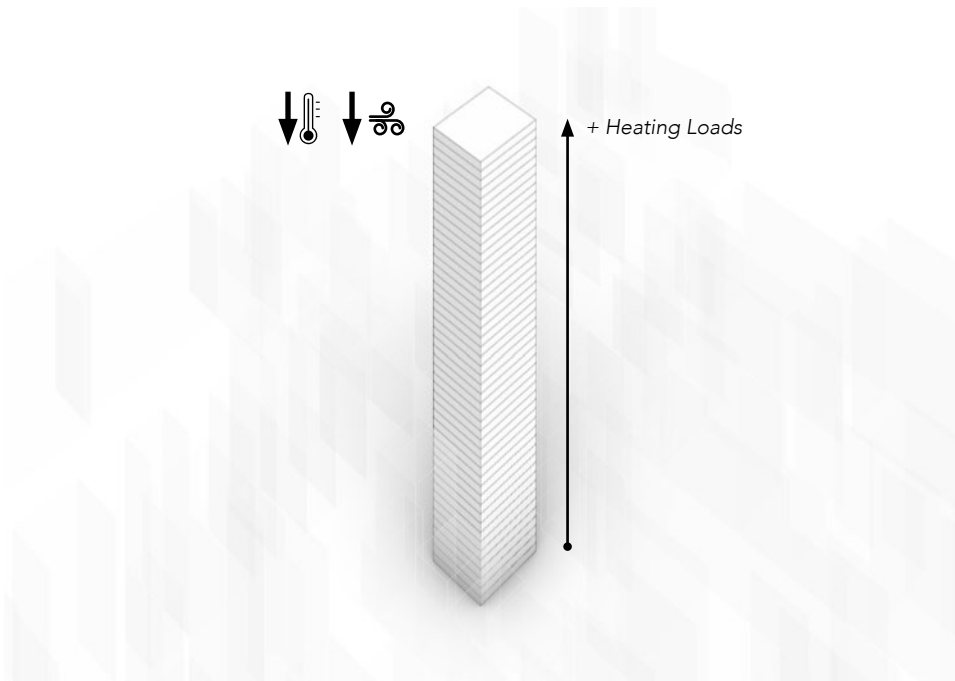

Along the floor addition,

40% Heating Demand
due to changing micro-climates

Based on computational optimization,
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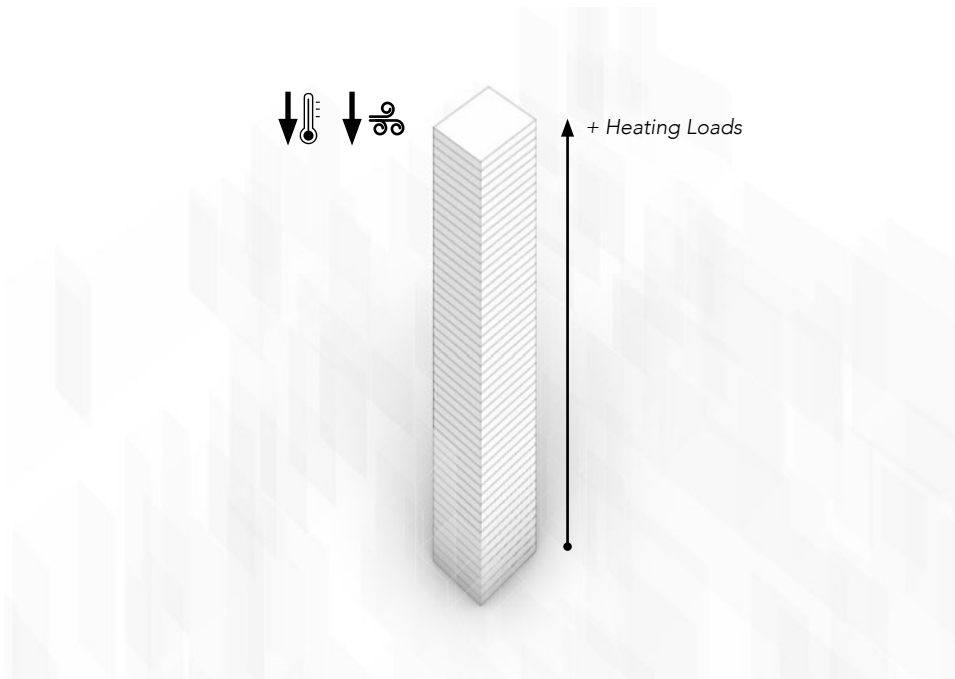

Along the floor addition,

40% Heating Demand
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PV
Roof Efficiency > Facade Efficiency

Based on computational optimization,
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How does the energy performance of the residential high-rise vary in relation to addition of floors, and how does it affect the BENG indicators?

Along the floor addition,

40% Heating Demand
due to changing micro-climates

PV
Roof Efficiency > Facade Efficiency

BENG 1 Increases
39% Decrease in Performance

BENG 2 Increases
55% Decrease in Performance

BENG 3 Decreases
30% Decrease in Performance

Based on computational optimization,
to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands,
and eventually what amendments can be proposed to adapt the desired height to the performance ?

Where does the limit in height increment of a residential high-rise stand until the BENG regulations are no longer satisfied?

Based on computational optimization,
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Where does the limit in height increment of a residential high-rise stand until the BENG regulations are no longer satisfied?

Then, which of the 3 BENG regulations is responsible for this limitation in the height increment?

Based on computational optimization,
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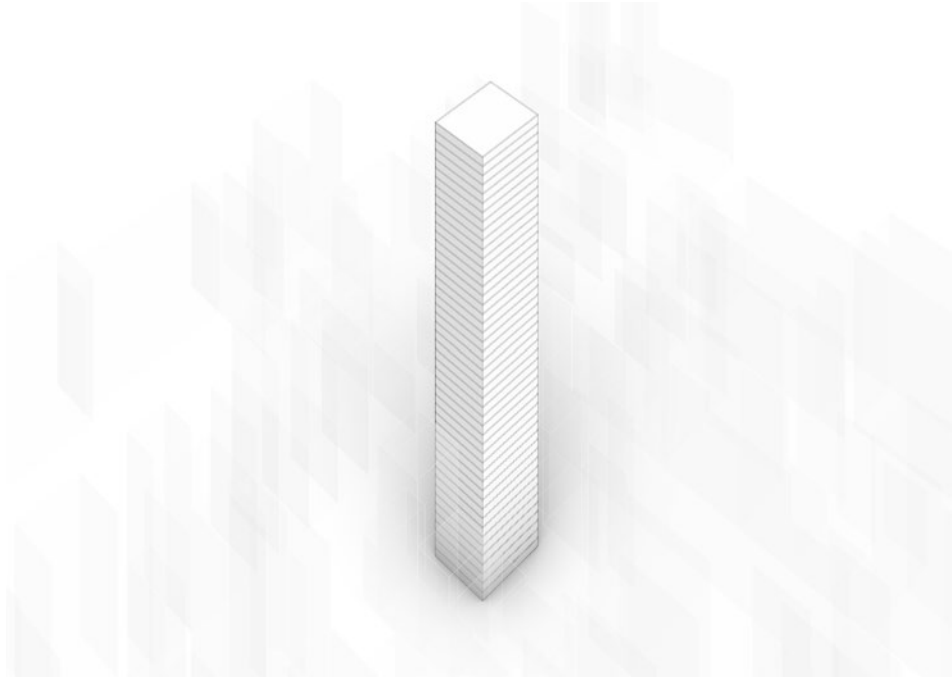

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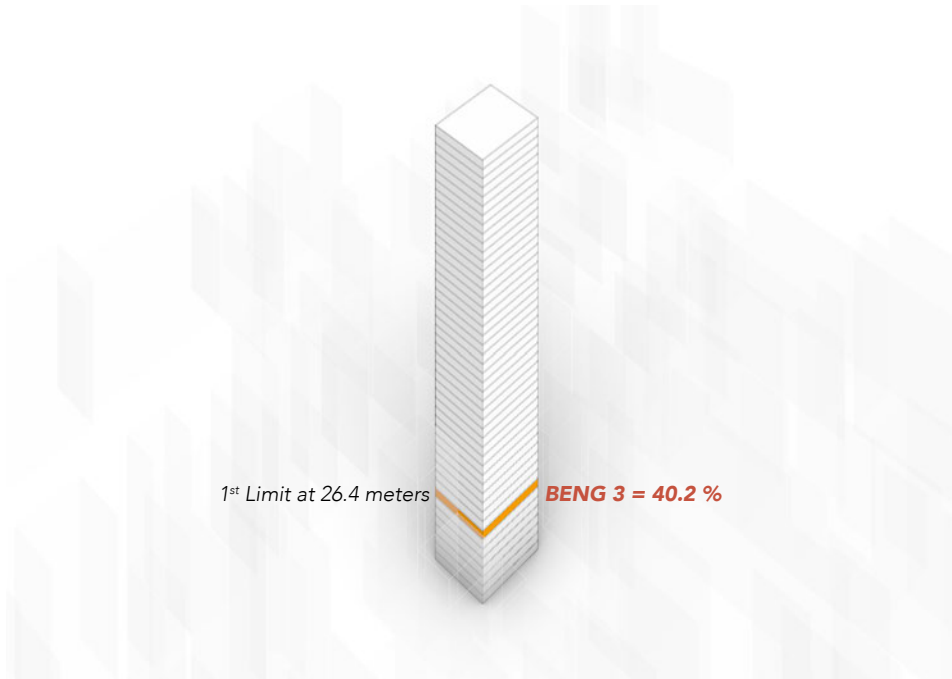
Where does the limit in height increment of a residential high-rise stand until the BENG regulations are no longer satisfied?

Then, which of the 3 BENG regulations is responsible for this limitation in the height increment?



1st Height Limit BENG 3

8th Floor / 26.4 meters
40.2%
(Benchmark > 40%)

Based on computational optimization,
to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands,
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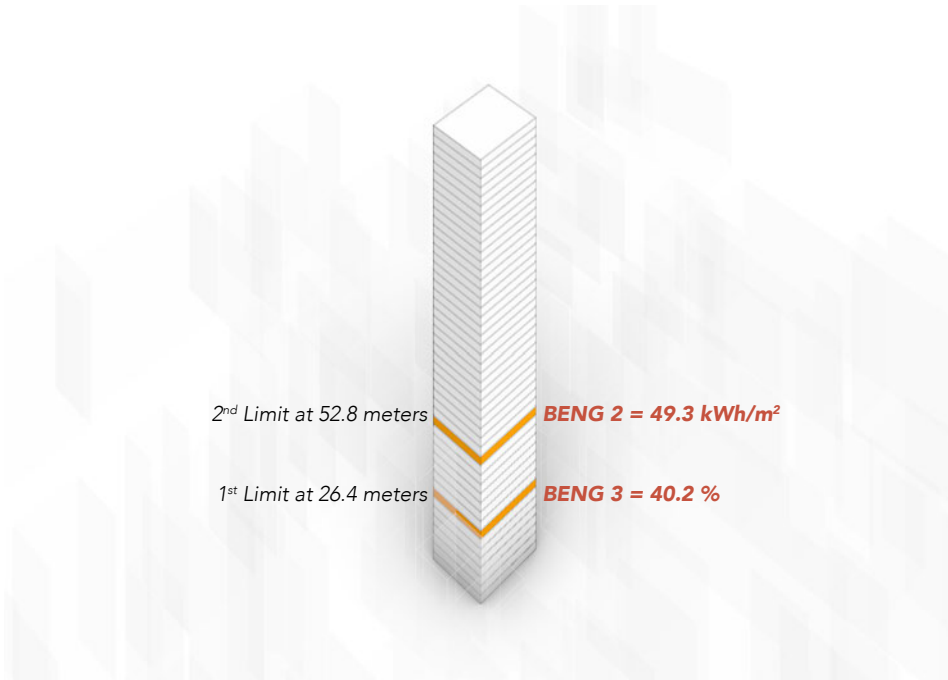

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40.2%
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2nd Height Limit BENG 2

16th Floor / 52.8 meters
49.3 kWh/m²
(Benchmark < 50 kWh/m²)

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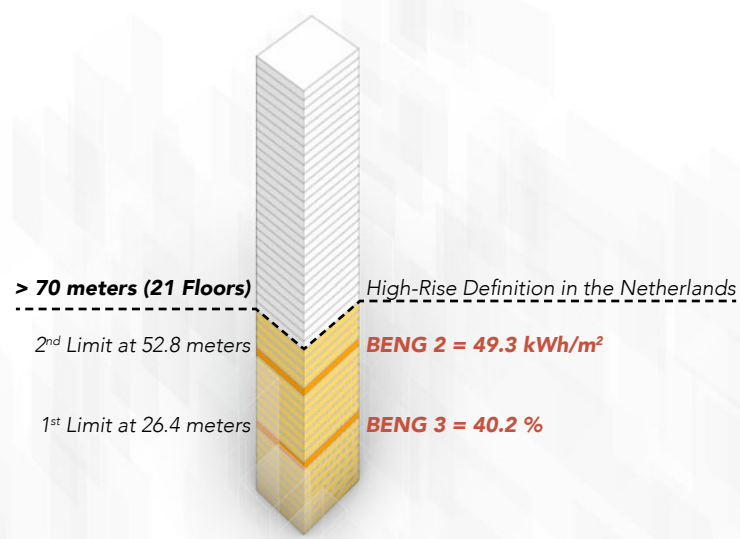

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		Related to Geometry & Envelope *Ratio of the Loss Surface Area (A_{ls}) / Usable Floor Area (A_g)*		
	**BENG 1** *Reduce Energy Demand*	**≤ 65** *kWh/m².yr*	*≤ 55 + 30 * (A_{ls}/A_g - 1.5)* *kWh/m².yr*	*≤ 100 + 50 * (A_{ls}/A_g - 3.0)* *kWh/m².yr*
	**BENG 2** *Use Primary Fossil Energy*	**≤ 50** *kWh/m².yr*	–	–
	**BENG 3** *Share of Renewable Energy*	**≥ 40** *%*	–	–

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BENG 3 *Share of Renewable Energy*	**≥ 40** *%*	–	–

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BENG 1 *Reduce Energy Demand*	**≤ 65** *kWh/m².yr*		
V/A_{ls}	$V/A_{ls} < 5.65$	$5.65 \leq V/A_{ls} \leq 6.0$	$V/A_{ls} > 6.0$
BENG 2 *Use Primary Fossil Energy*	**≤ 45** *kWh/m².yr*	**≤ 60** *kWh/m².yr*	**≤ 70** *kWh/m².yr*
V/A_{ls}	$V/A_{ls} < 5.60$	$5.60 \leq V/A_{ls} \leq 6.15$	$V/A_{ls} > 6.15$
BENG 3 *Share of Renewable Energy*	**≥ 40** *%*	**≥ 32** *%*	**≥ 30** *%*


Future
Research

Future Research

This study can serve as a starting point for further studies

Additional parameters and variables:

Evaluate several U-value for the insulation materials of the enclosed part of the envelope

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Investigate different cooling and heating temperature set points at different height

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Evaluate different occupancy and usage schedules to observe the relationship with user's behavior and the energy performance aside from the building design

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Implement the variation in the plan layout of upper floors in the high-rise where the usable space decreased due to structural principles


Thank You
Any Question ?