THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.

EARLY STAGE OPTIMIZATION WORKFLOW TOWARDS A CLIMATE RESPONSIVE DESIGN

P5 Presentation

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Serdar Asut
Martin Tenpierik

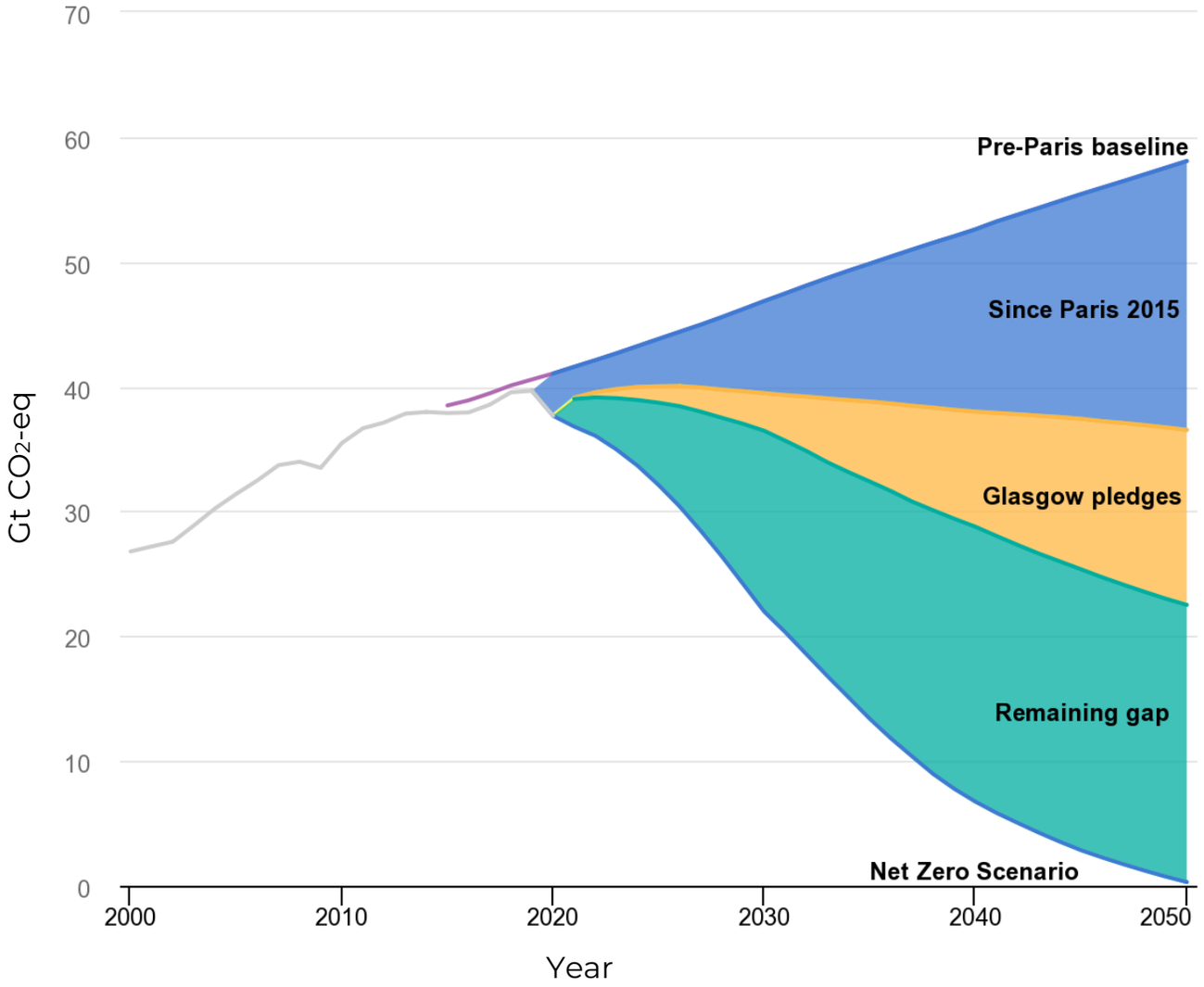
TU Delft



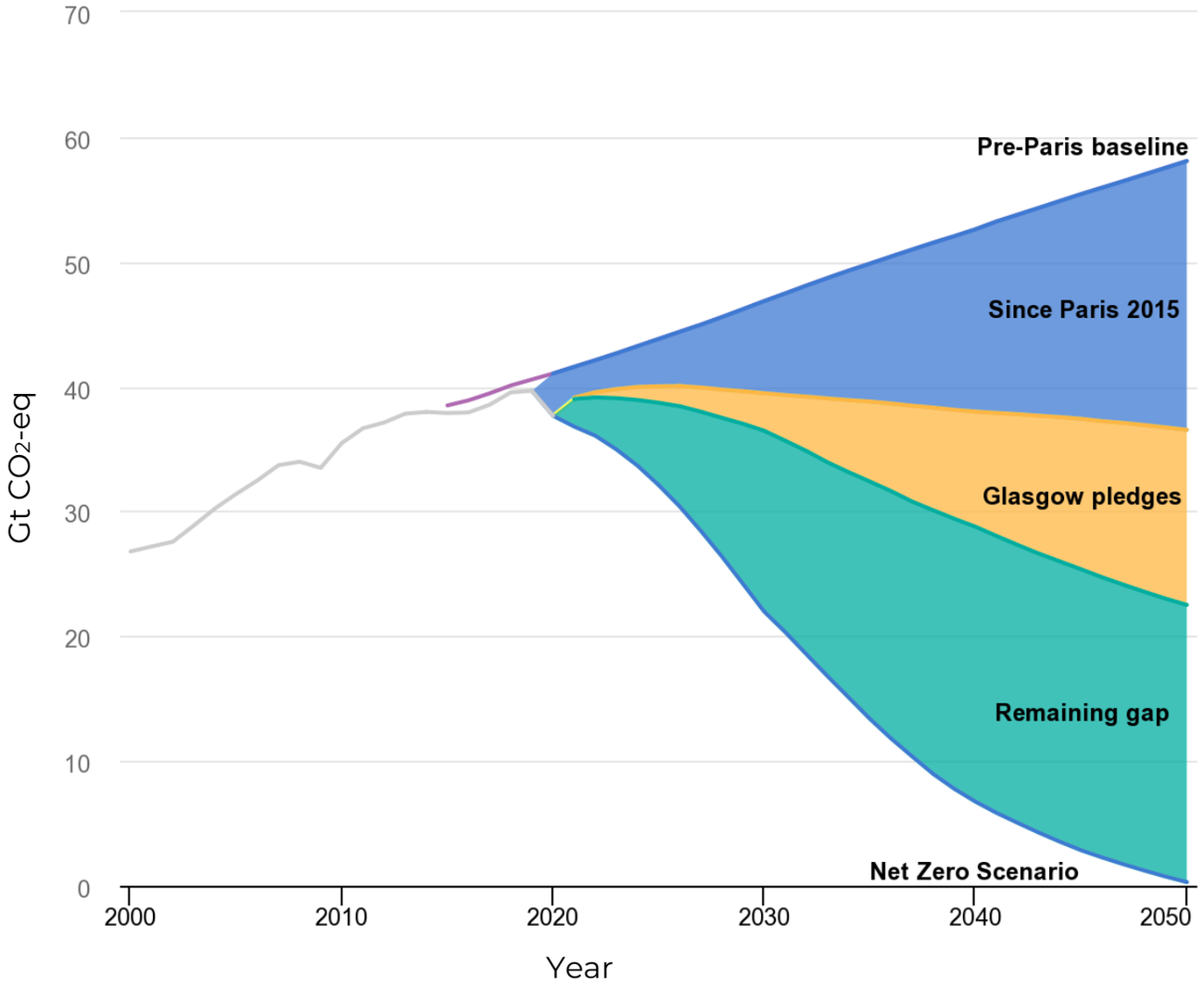


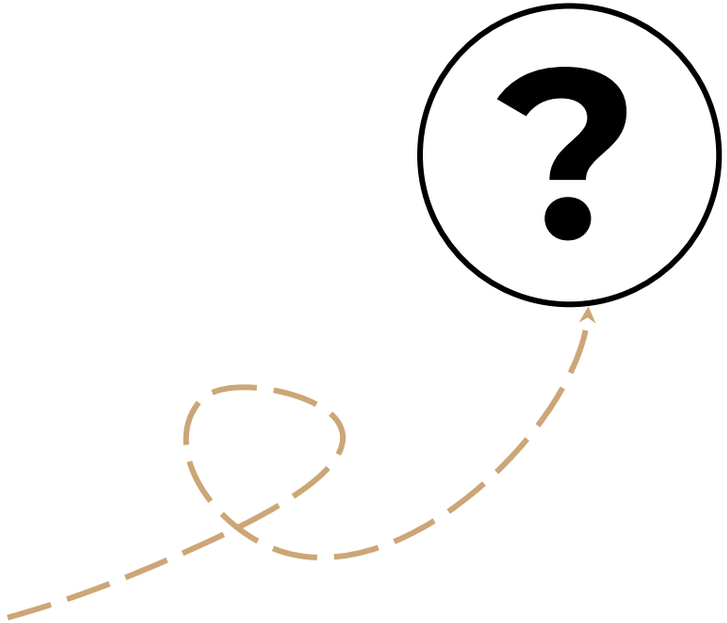
ONLY ≈ 5%
of world energy
produced by
Renewable Resources

CO_2 Global Emissions

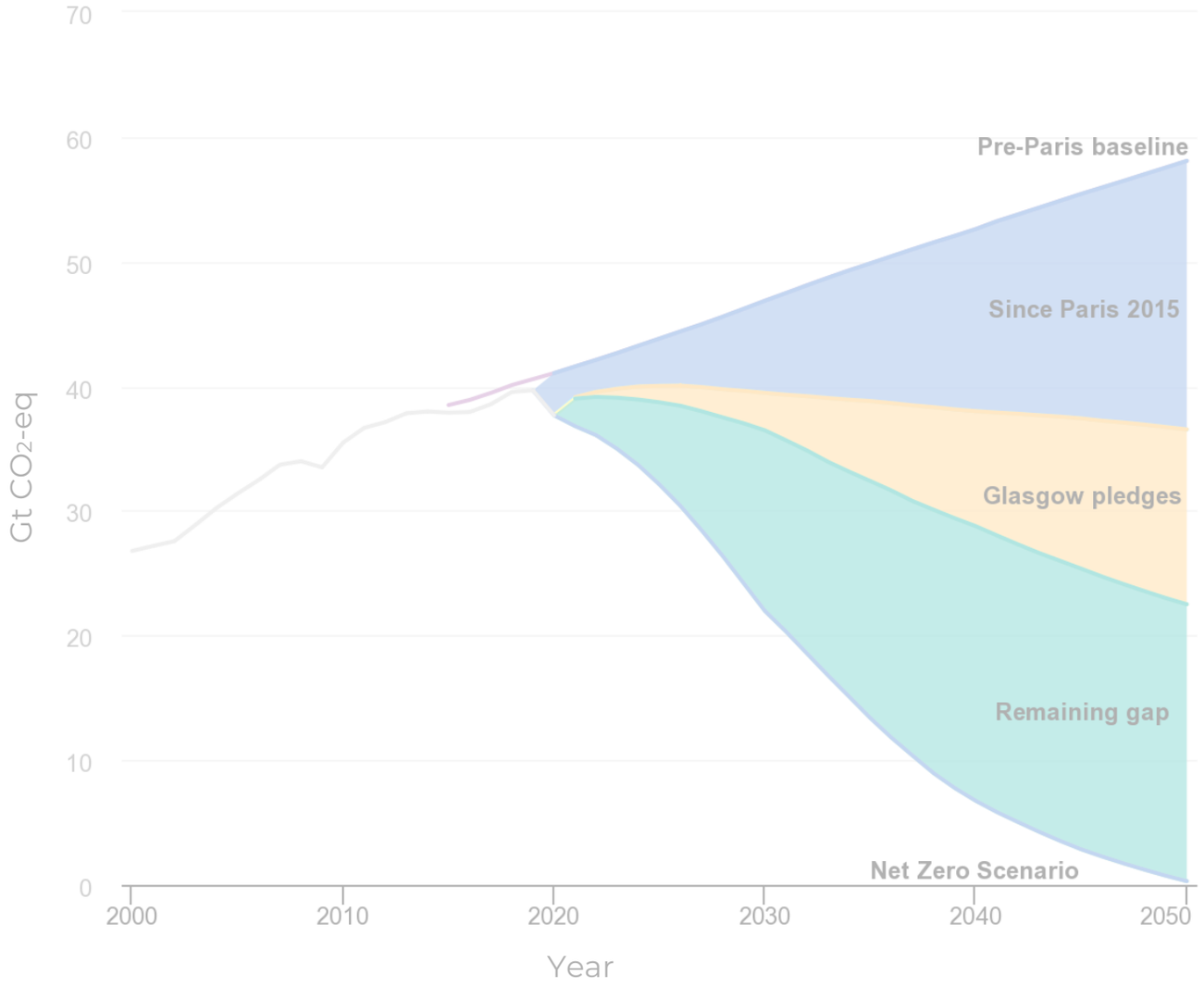


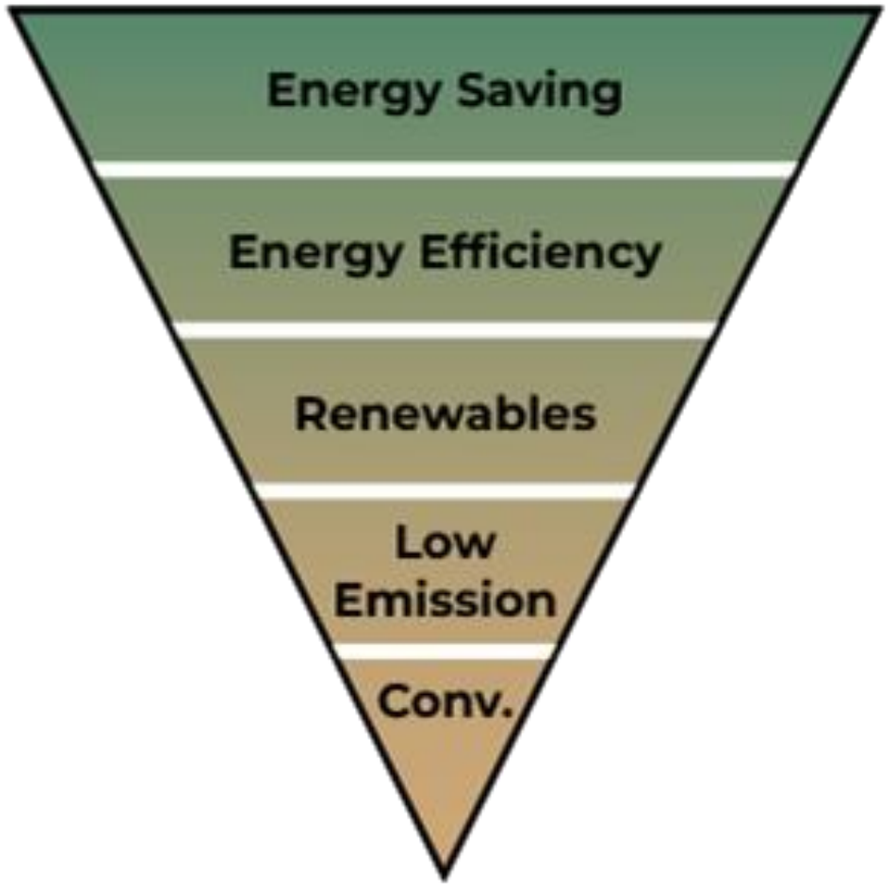
CO_2 Global Emissions





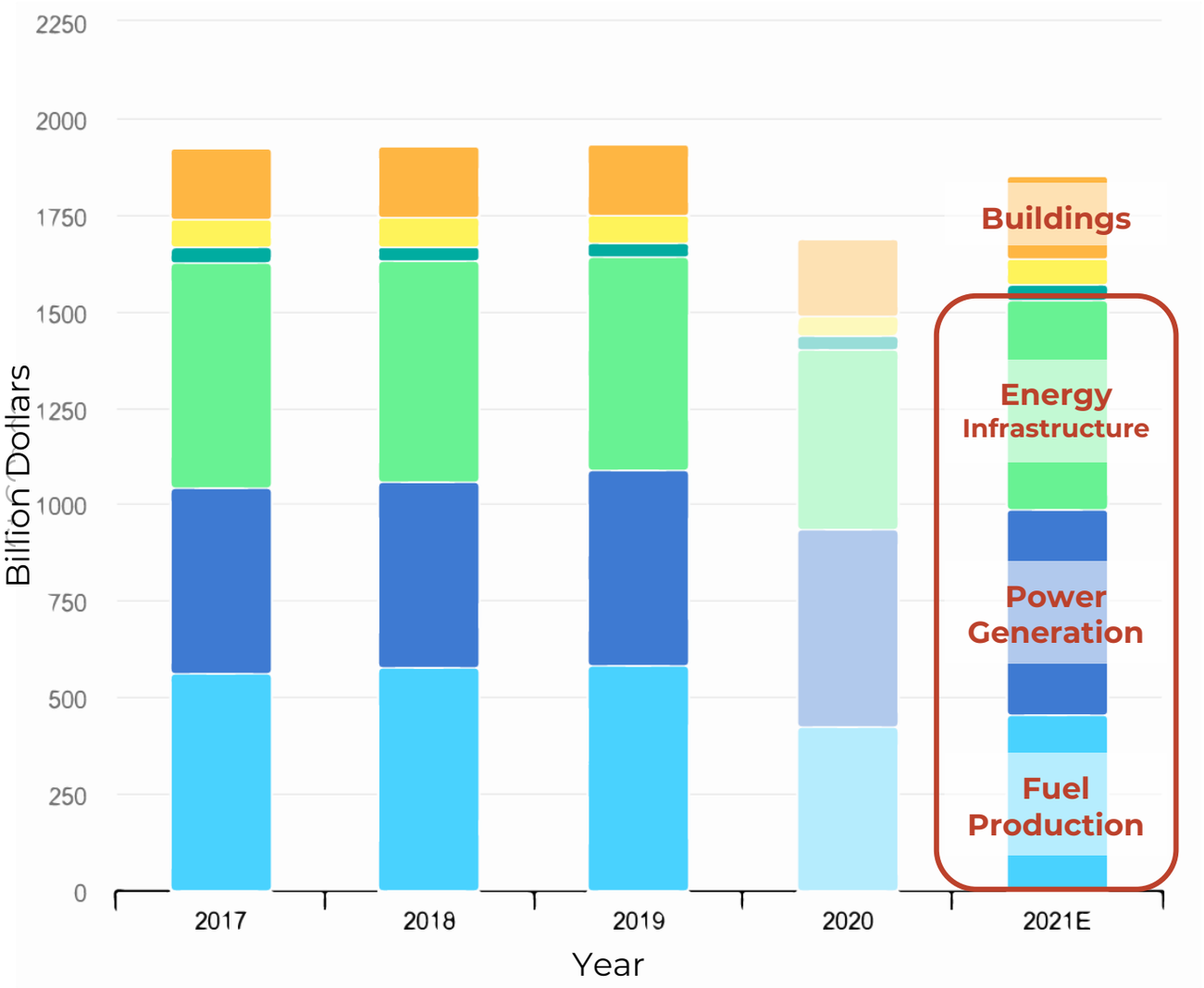
CO_2 Global Emissions

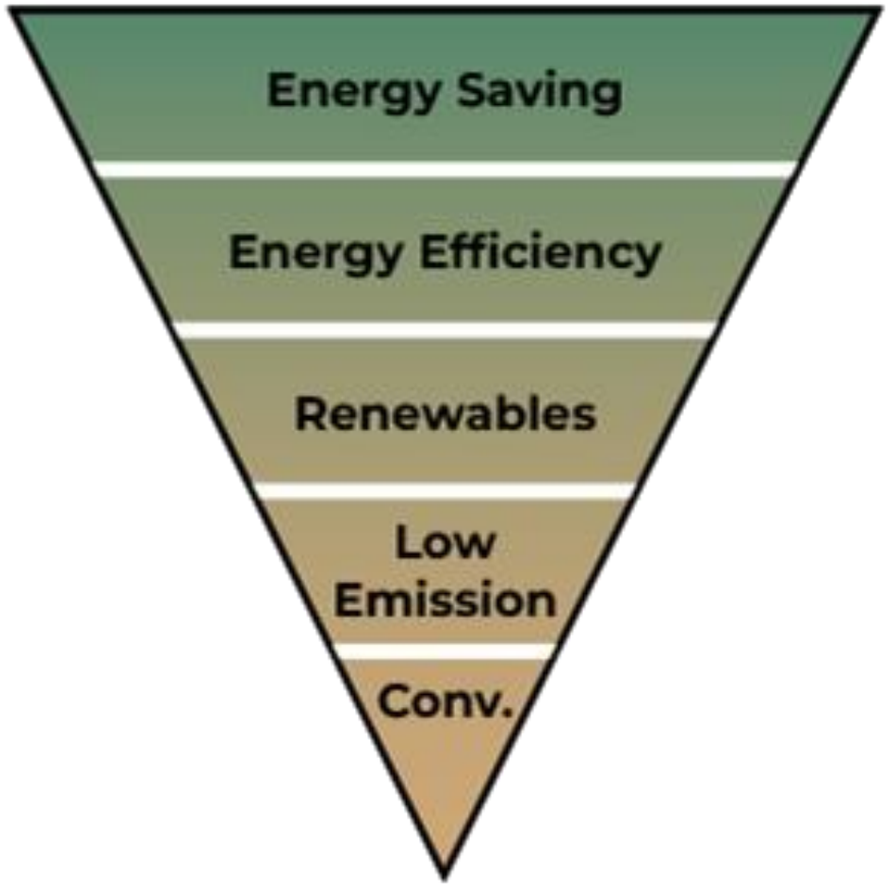




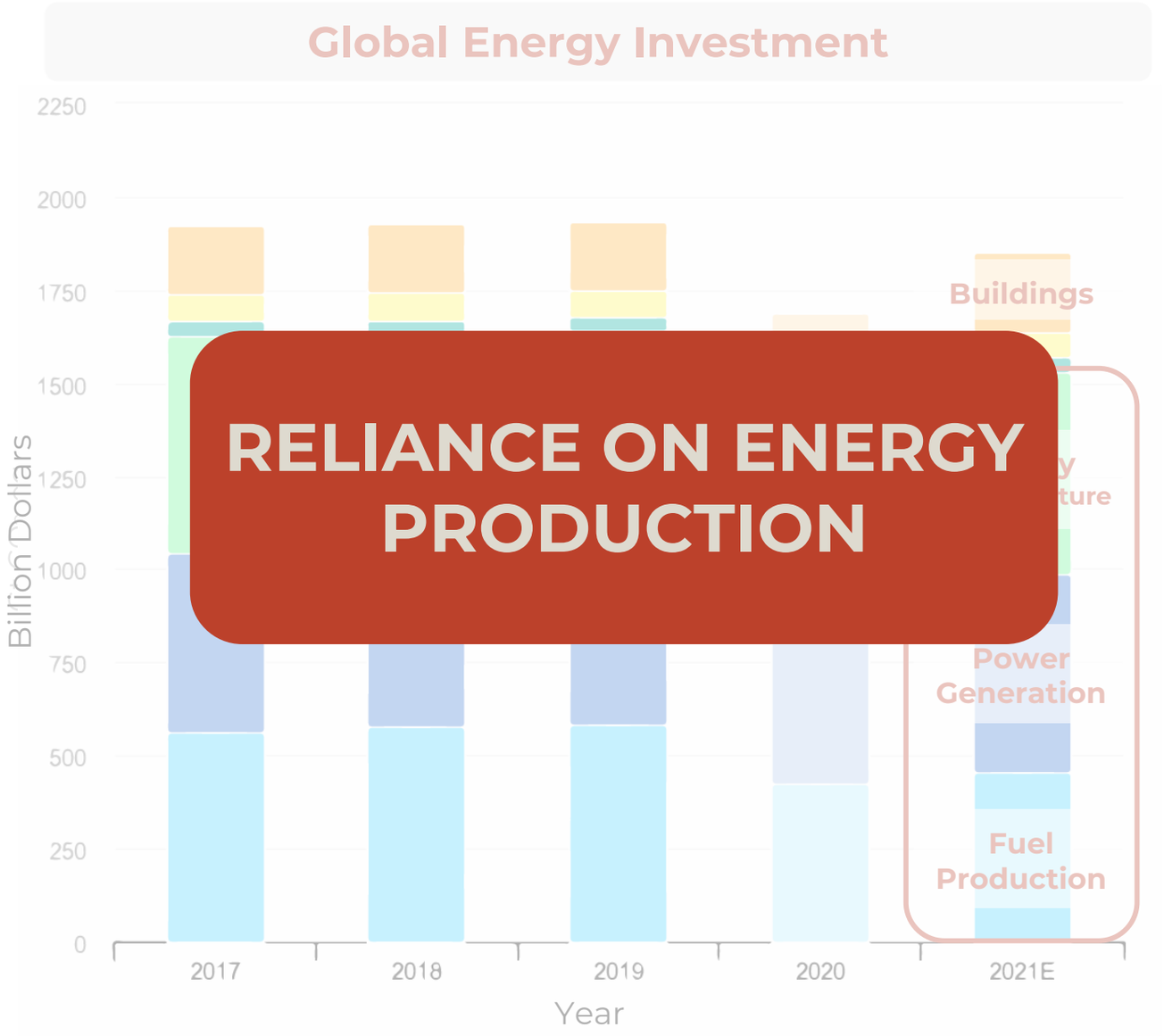
Institution of Mechanical Engineers, 2009

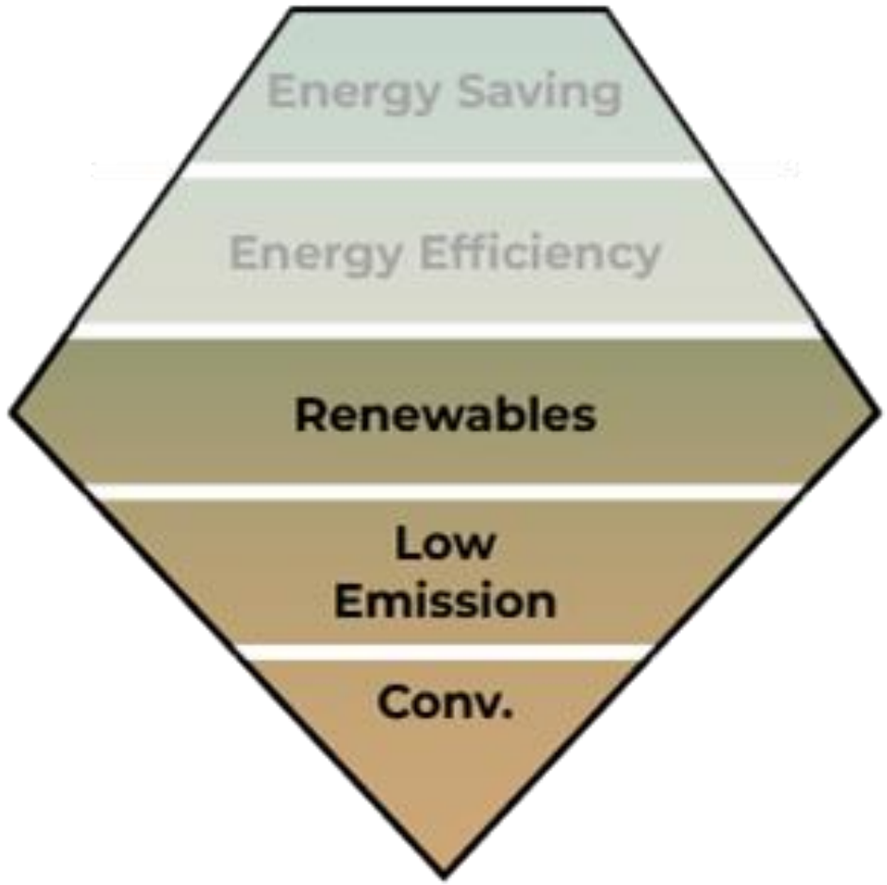
Global Energy Investment



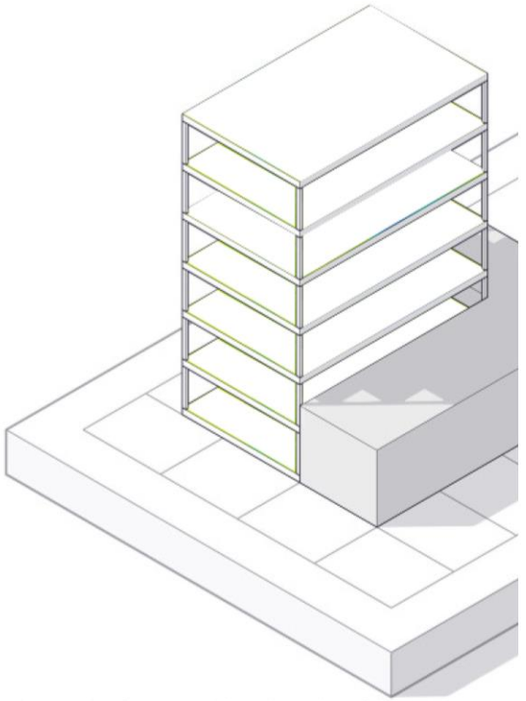


Institution of Mechanical Engineers, 2009


Global Energy Investment
2250
2000
1750
1500
1250
1000
750
500
250
0
Billion Dollars
2017
2018
2019
2020
2021E
Year
Buildings
Power Generation
Fuel Production
RELIANCE ON ENERGY PRODUCTION


Energy Saving
Energy Efficiency
Renewables
Low Emission
Conv.

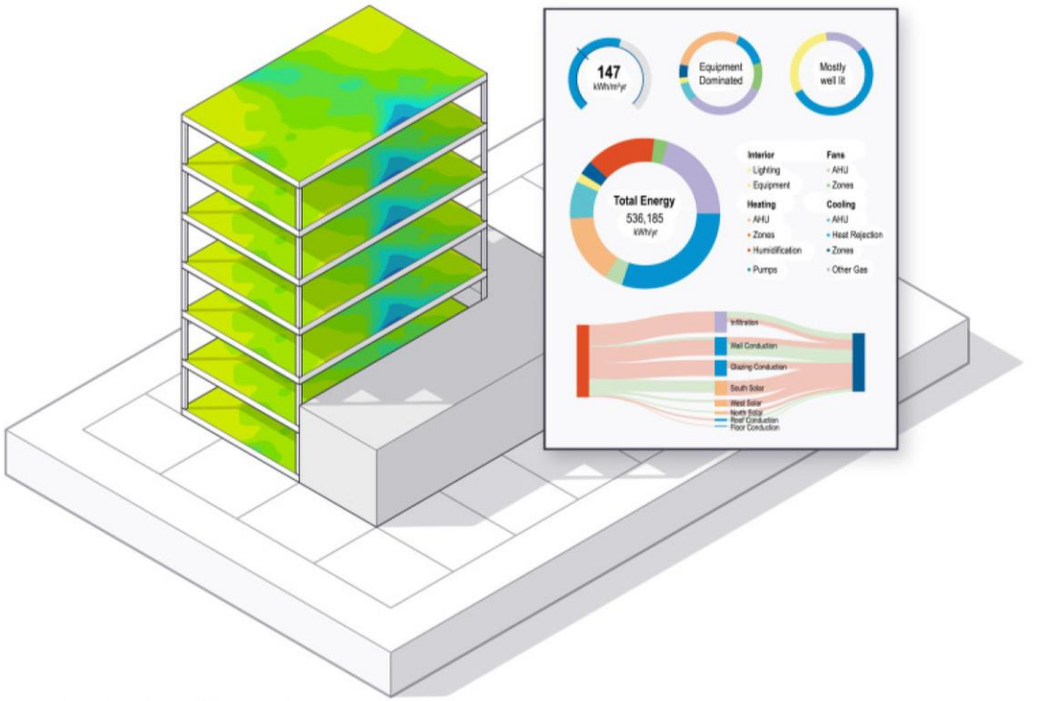
There are methods...



+

EnergyPlus

=

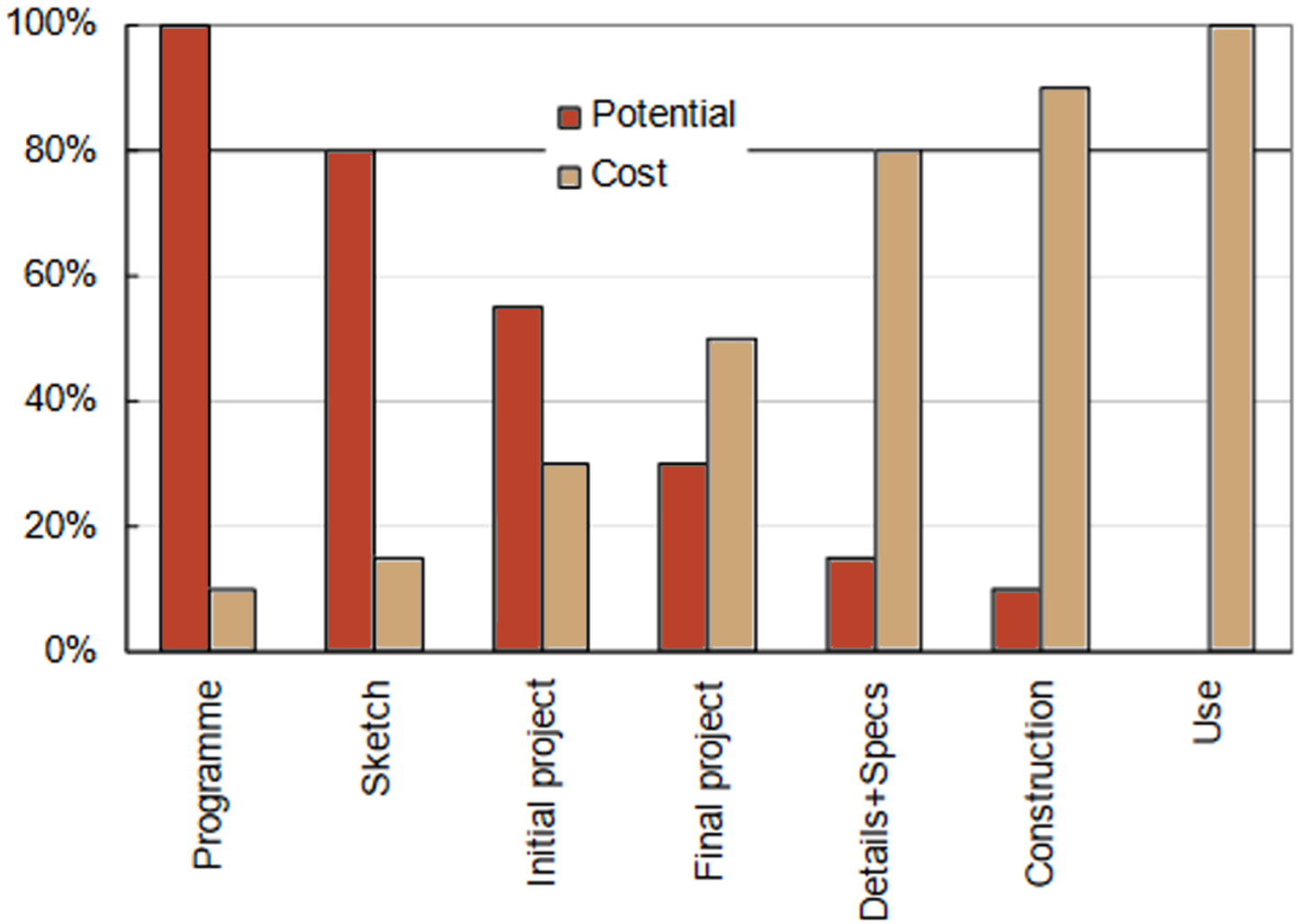


Adaptation from: Casini, M. (2022). Building Performance Simulation Tools

Casini, M. (2022). Building Performance Simulation Tools

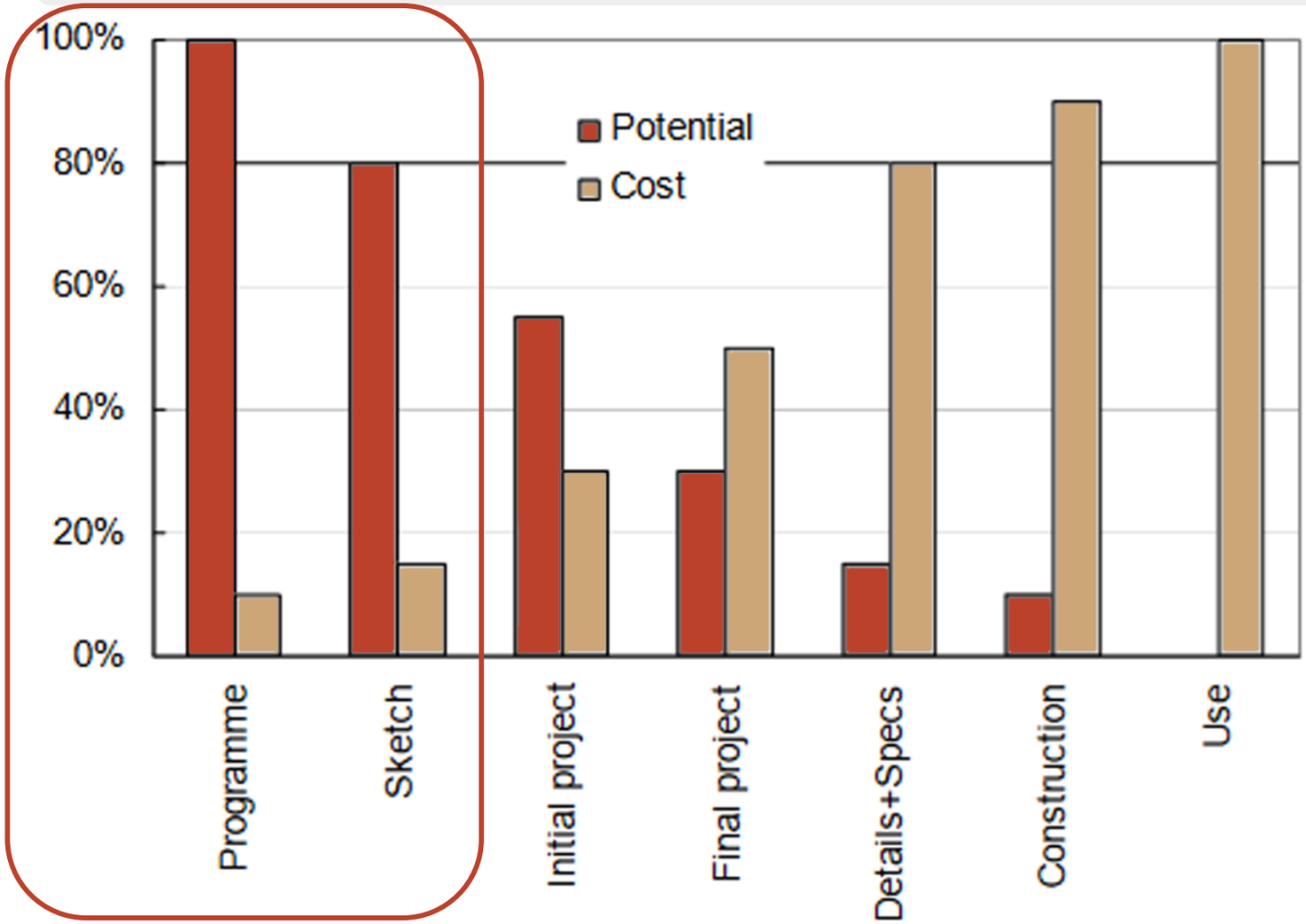

IT'S TOO LATE
FOR THAT, SAM...

Design Stage & Potential / Cost Impact



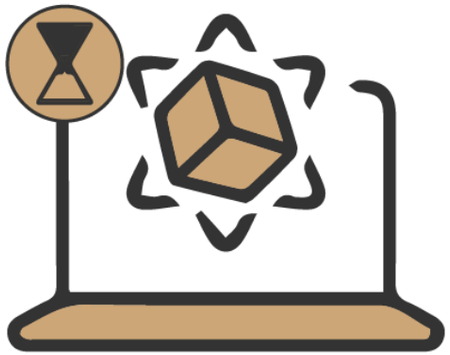
Evans, J.M. (2007). The Comfort Triangles: A New Tool For Bioclimatic Design

Design Stage & Potential / Cost Impact

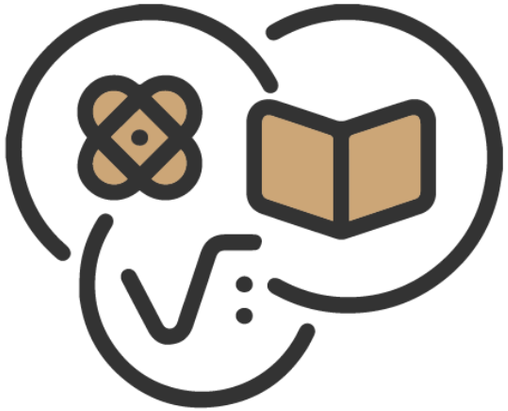


Evans, J.M. (2007). The Comfort Triangles: A New Tool For Bioclimatic Design

Energy consumption on the rise

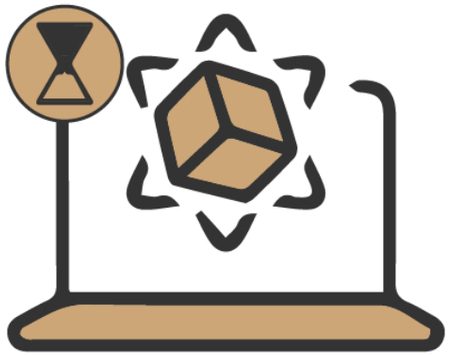


Simulations late in the design



Special knowledge is required

Energy consumption on the rise



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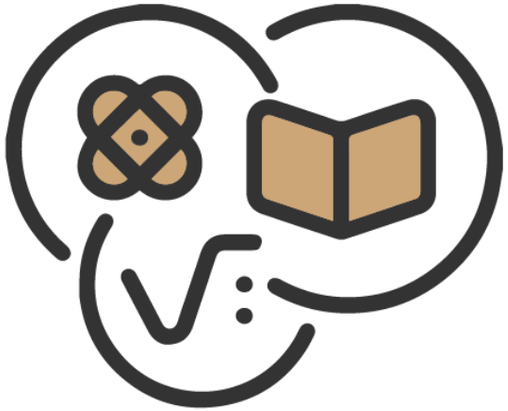


Special knowledge is required

How can
a multi-objective
optimization **workflow**
assist in **early design stages**
towards a **climate responsive design**?

Research Question

How can
a multi-objective
optimization **workflow**
assist in **early design stages**
towards a **climate responsive design**?

CLIMATE

Insensitive

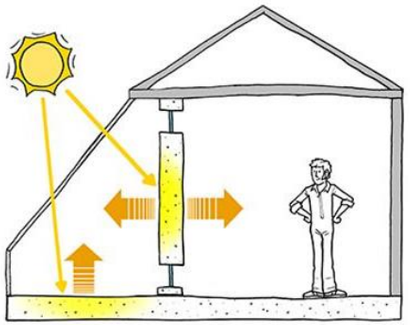
Combative

Responsive

Insensitive

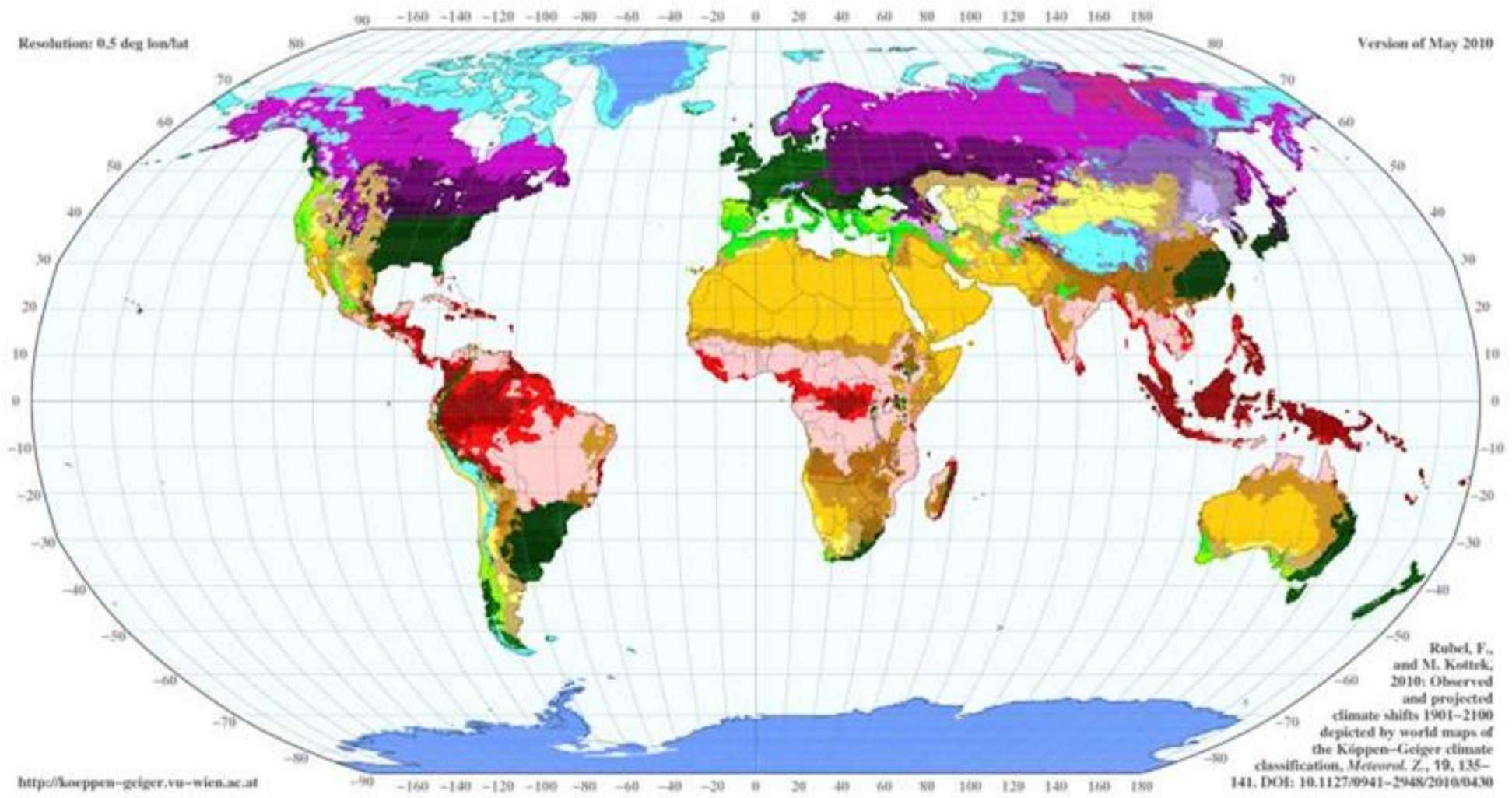
Combative

Responsive



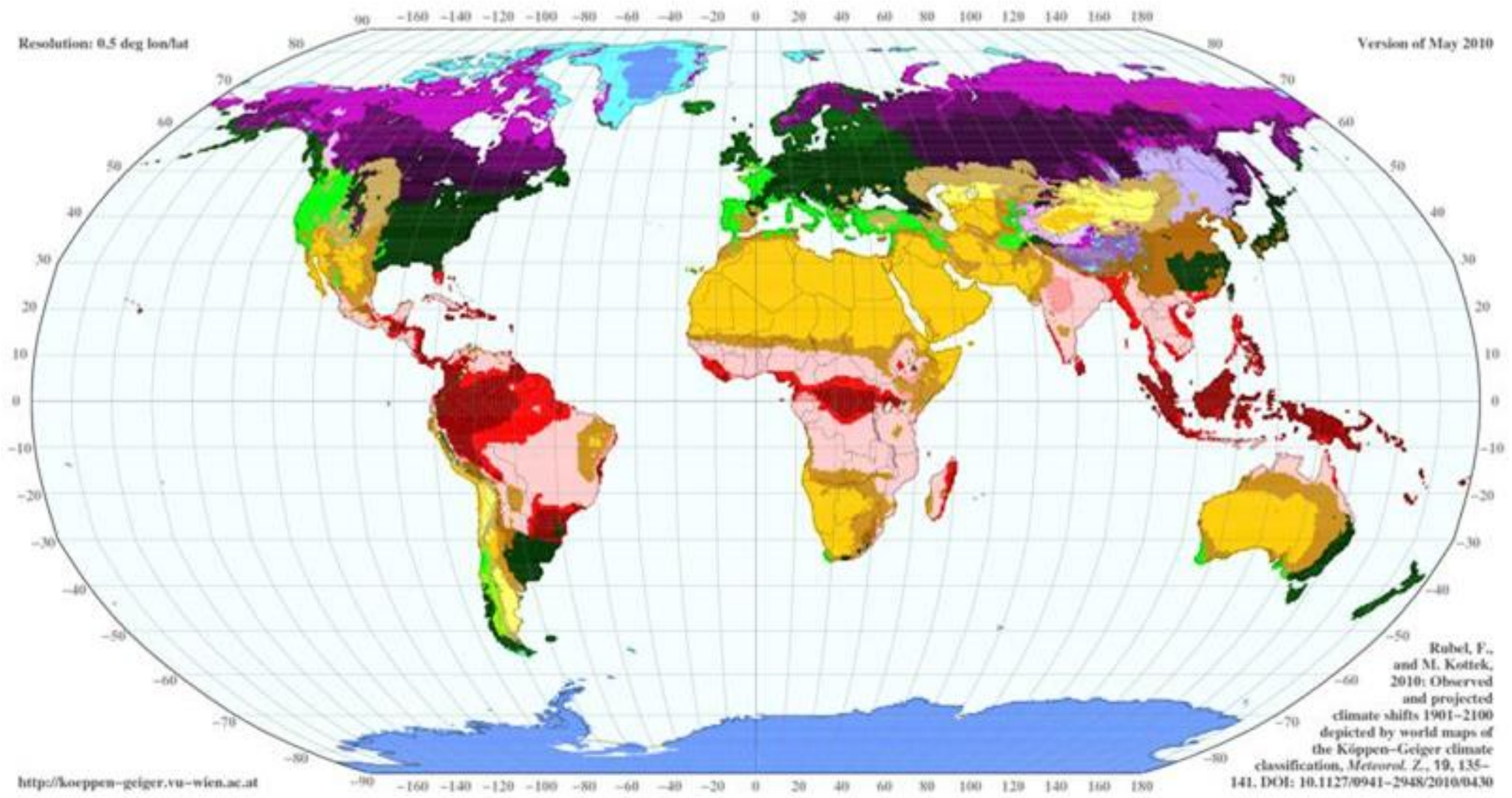
Köppen-Geiger Climate Classification

1901 - 1925



Köppen-Geiger Climate Classification

2076 - 2100



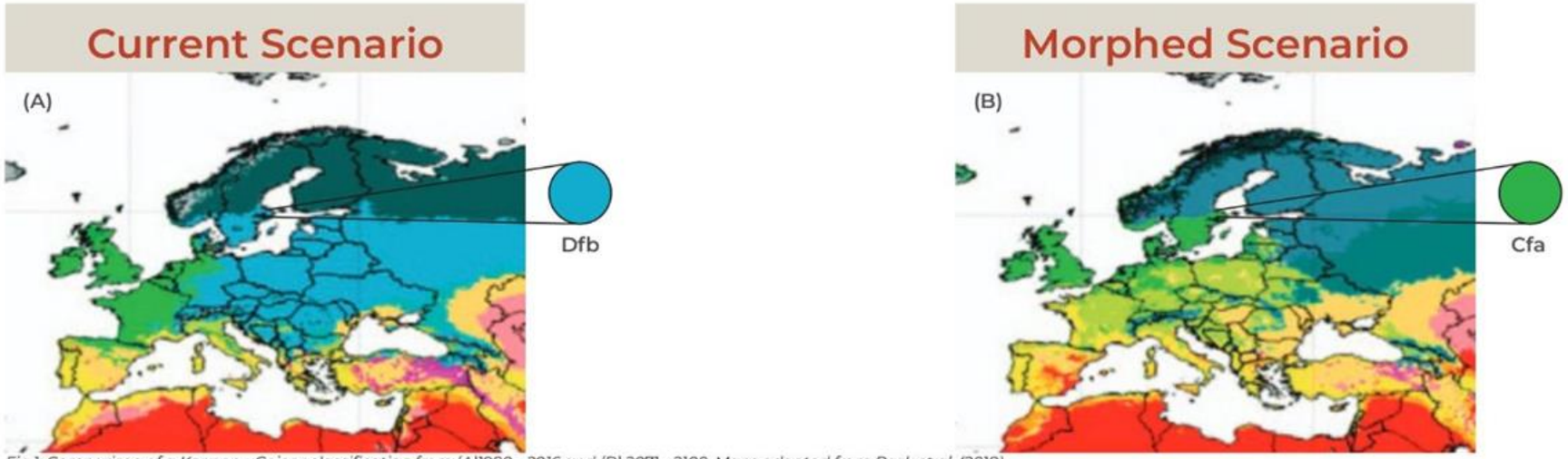
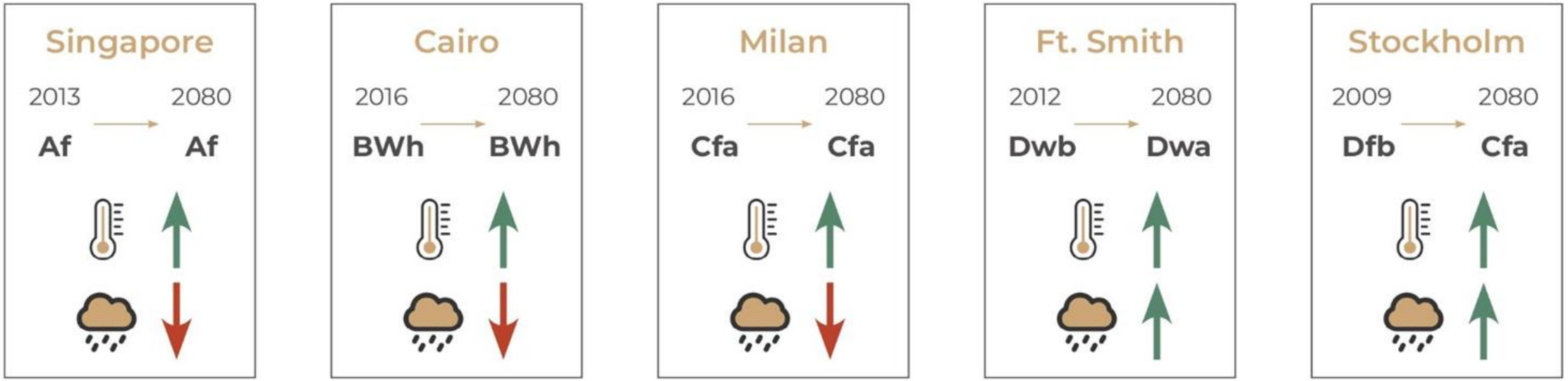
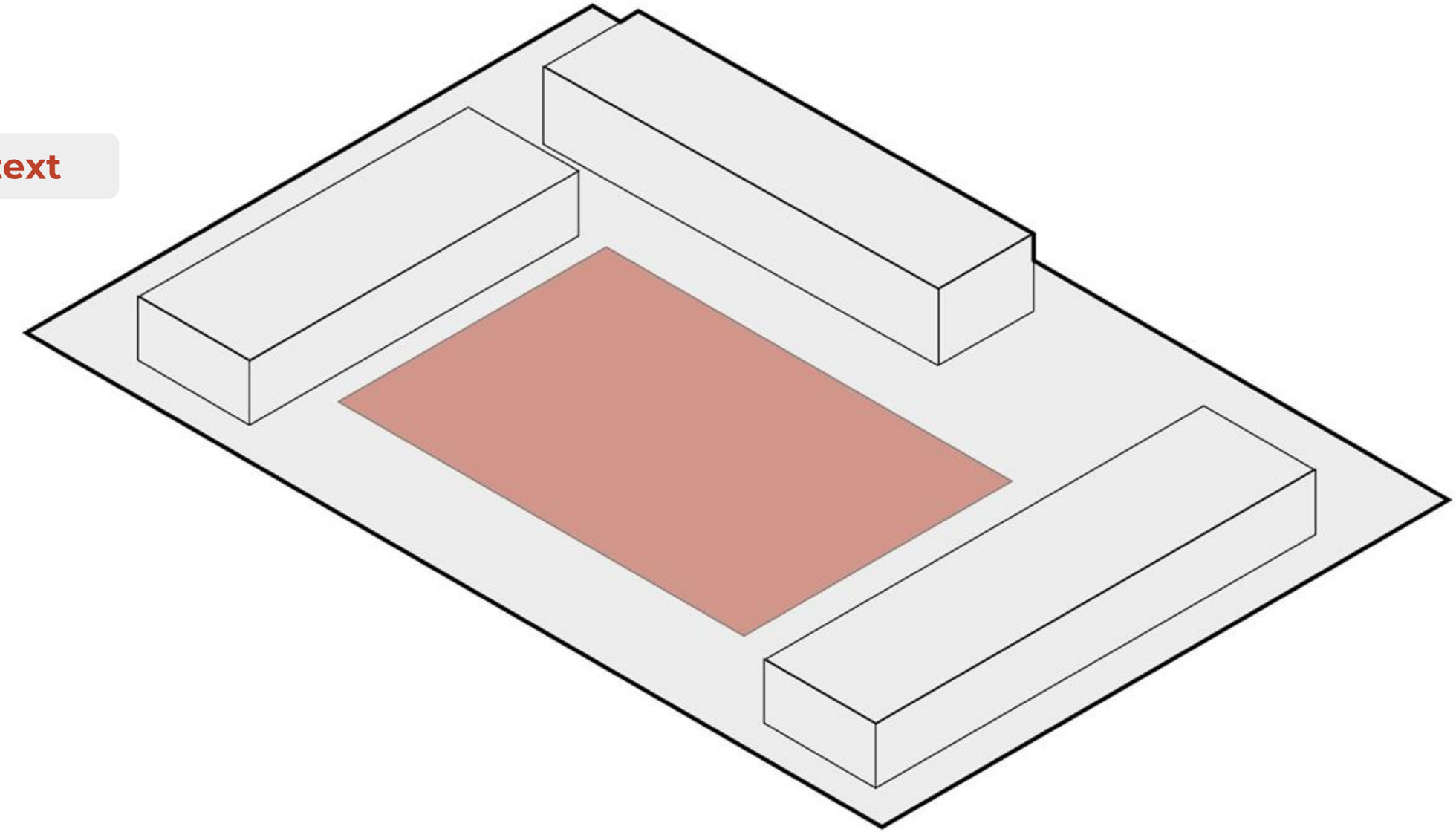


Fig 1: Comparison of a Koppen - Geiger classification from (A)1980 - 2016 and (B) 2071 - 2100. Maps adapted from Beck et al. (2018)

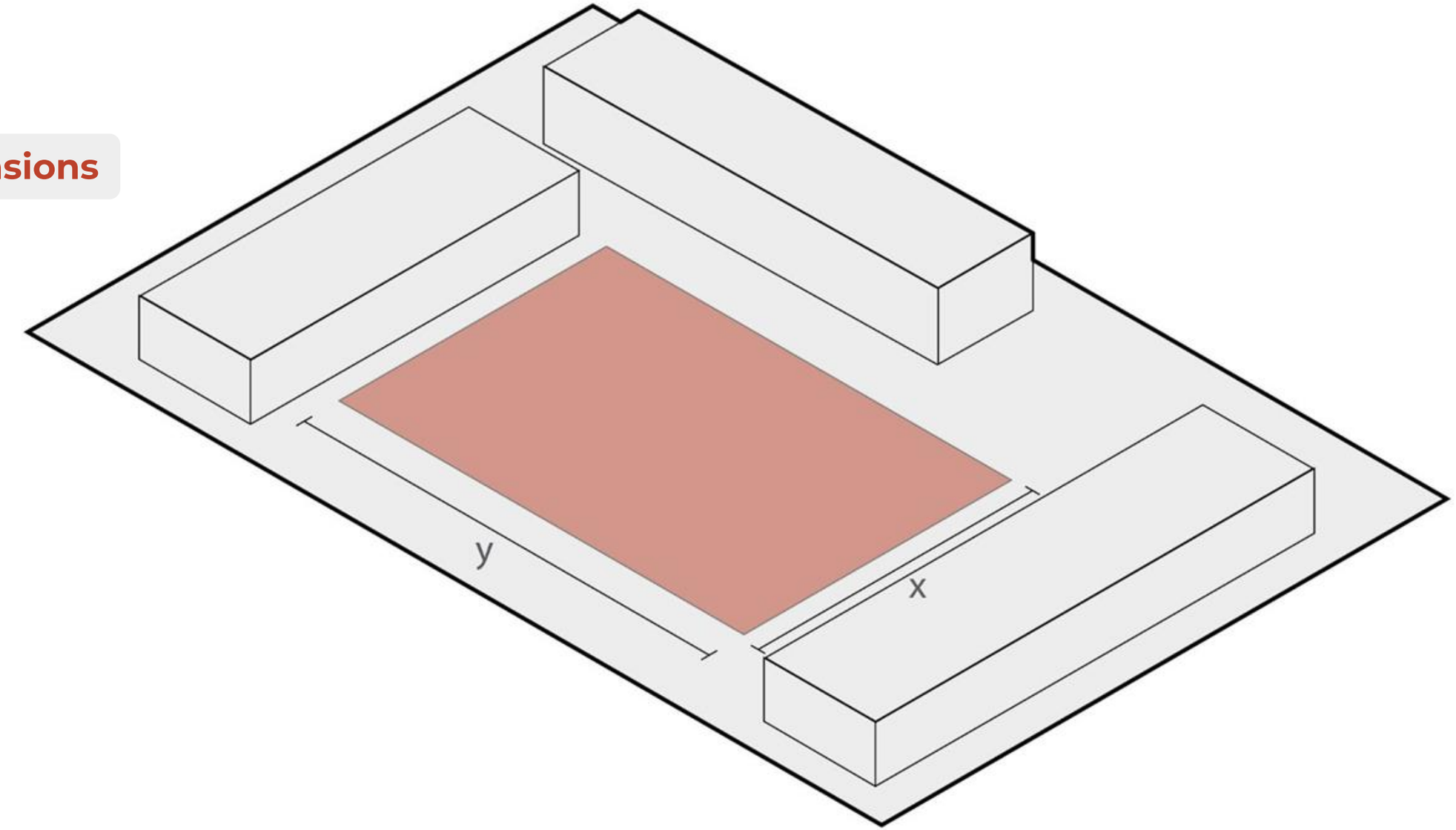


DESIGN INTEGRATION

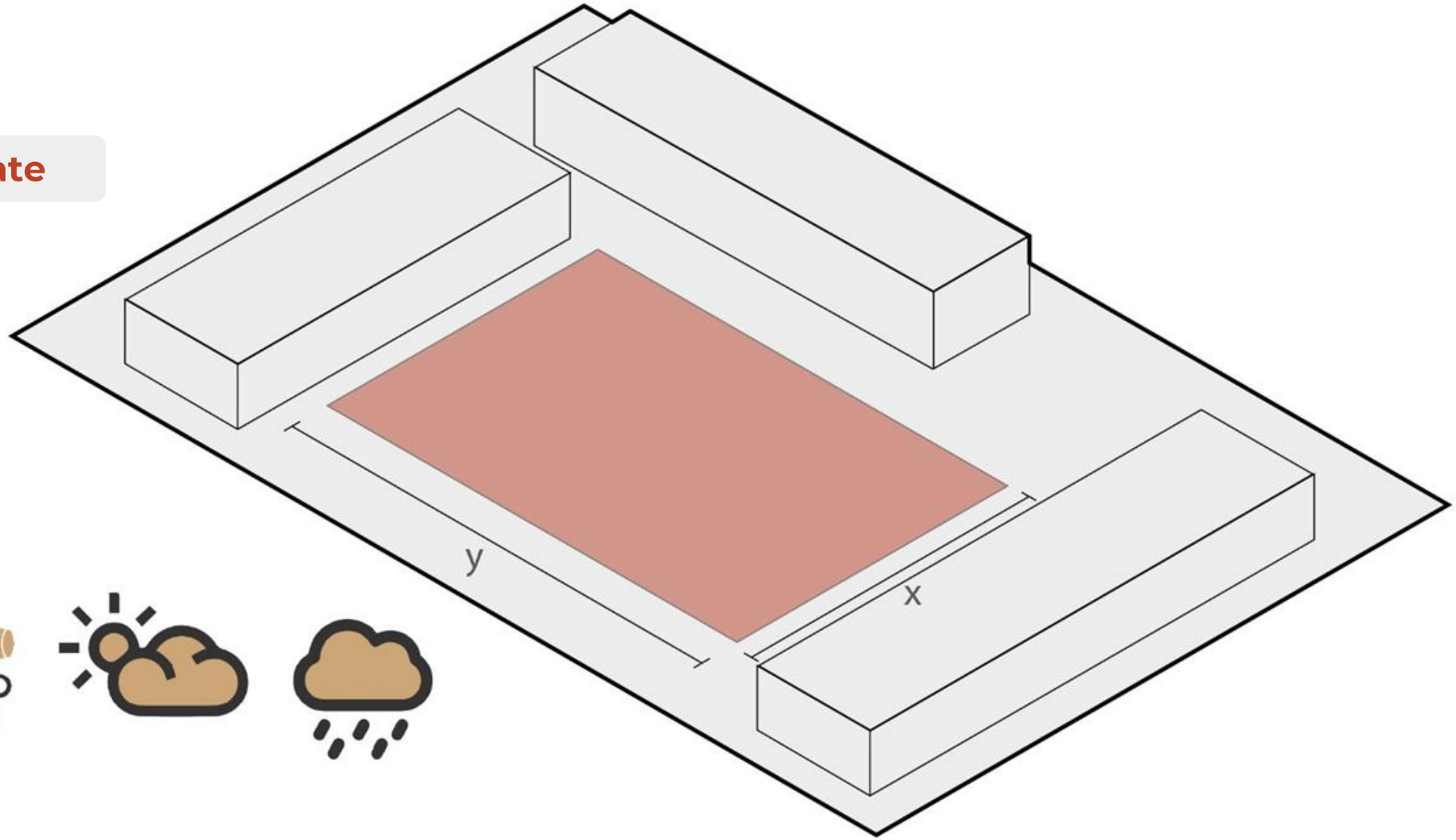
Context



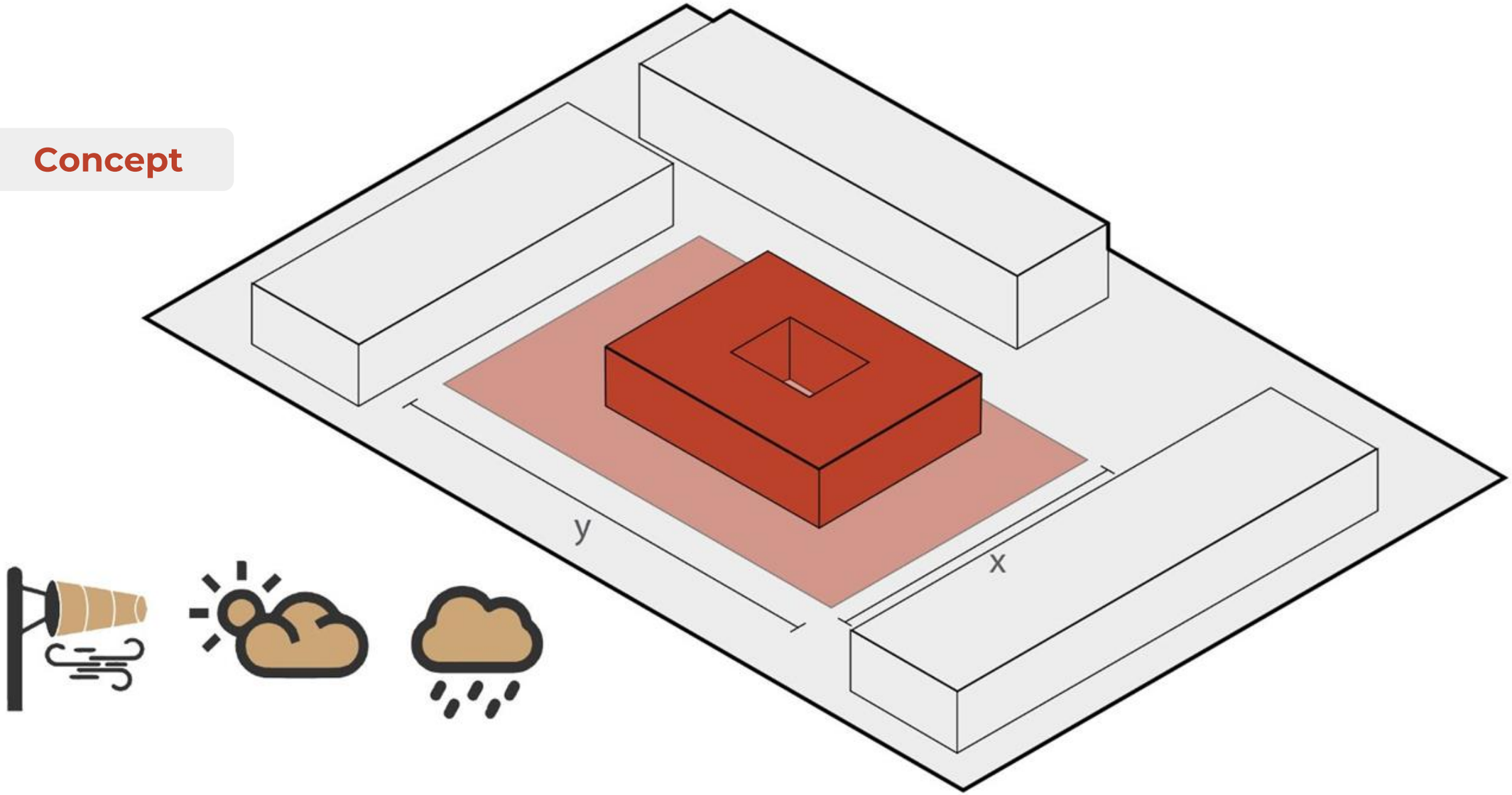
Dimensions



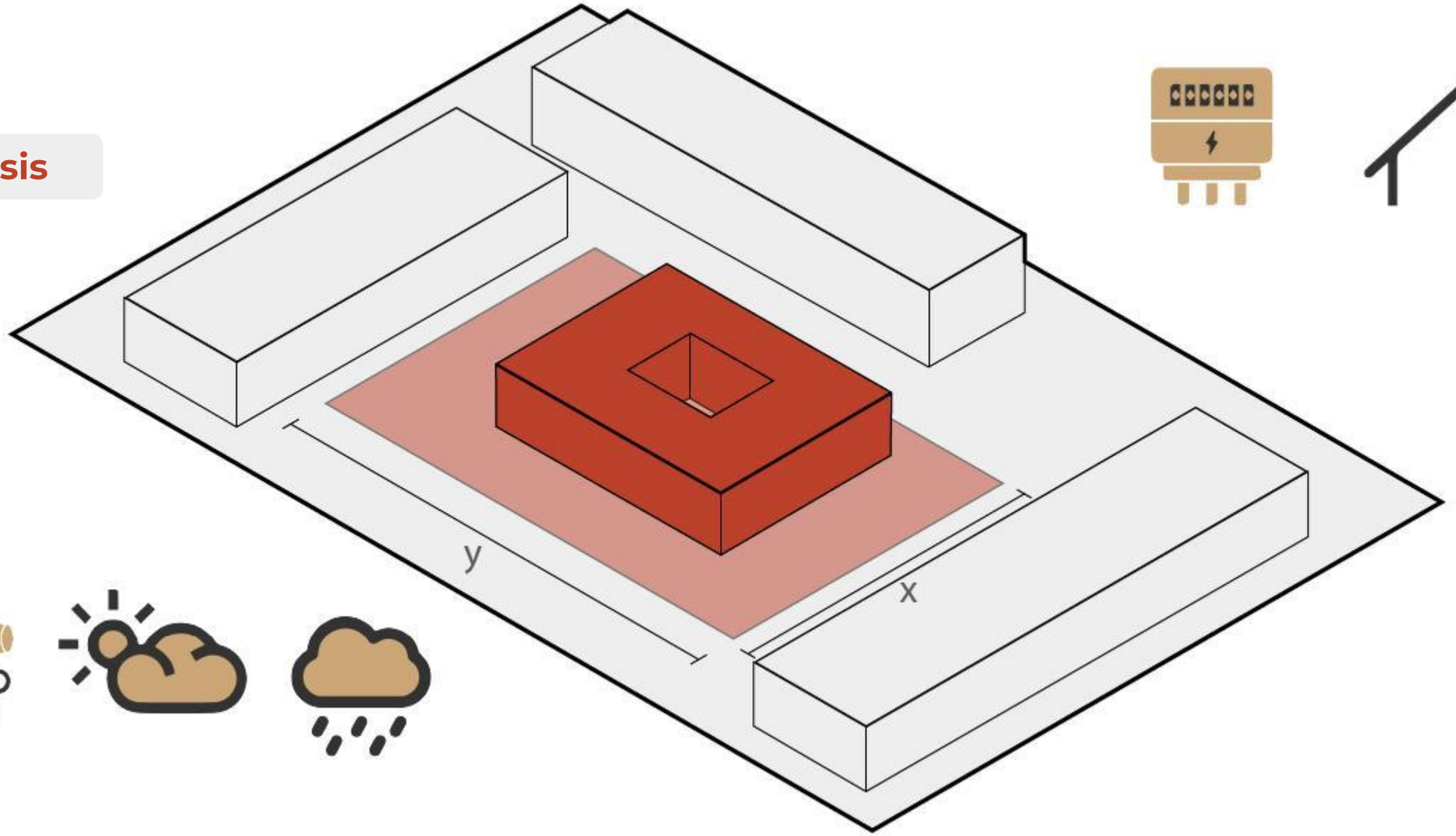
Climate

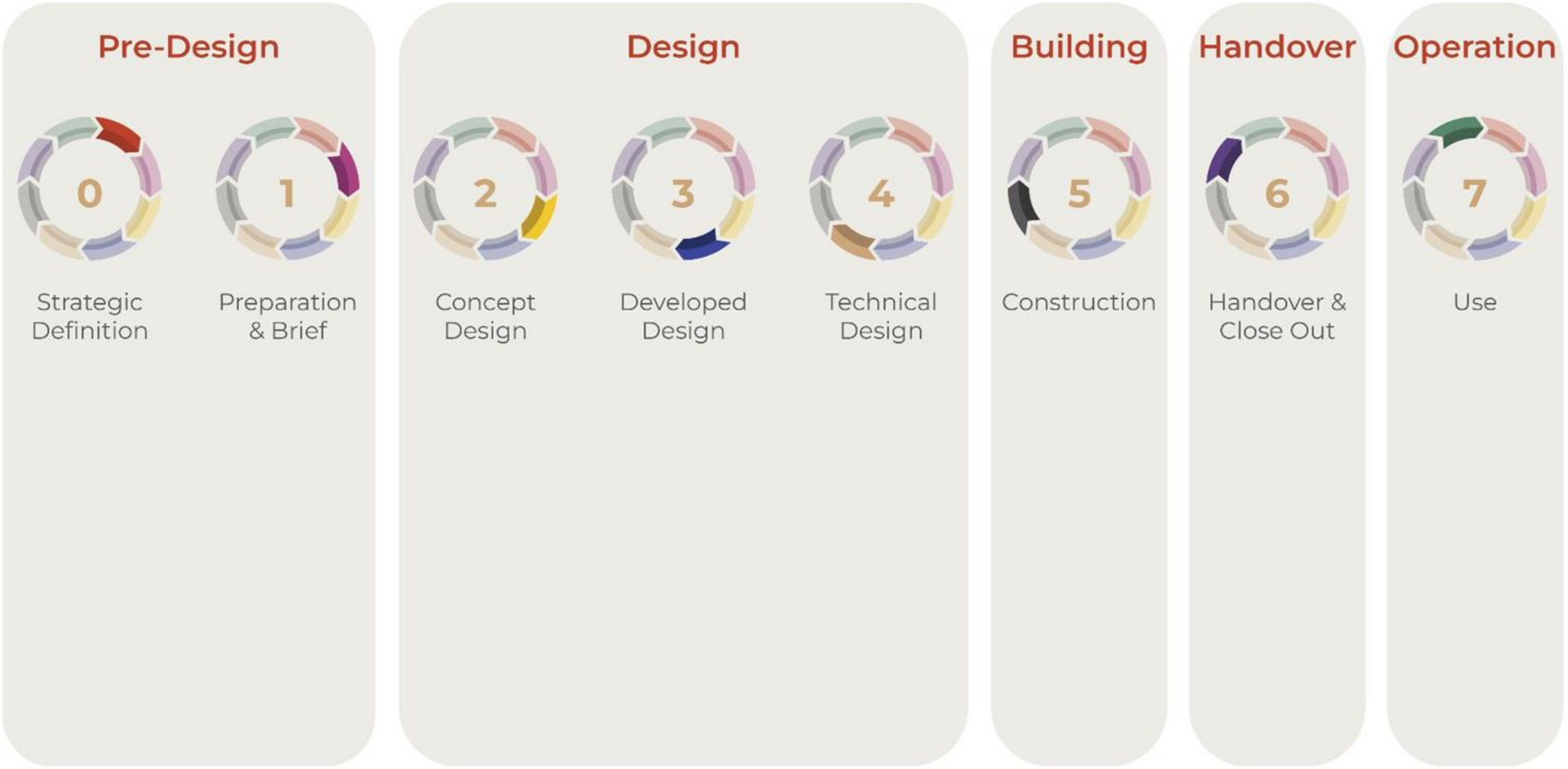


Concept



Analysis




Pre-Design
0
Strategic Definition
1
Preparation & Brief
Design
2
Concept Design
3
Developed Design
4
Technical Design
Building
5
Construction
Handover
6
Handover & Close Out
Operation
7
Use

Pre-Design

Strategic Definition

Preparation & Brief

Design

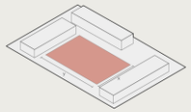
Concept Design

Developed Design

Technical Design

Pre-Design

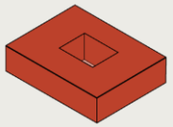
0 Strategic Definition



1 Preparation & Brief

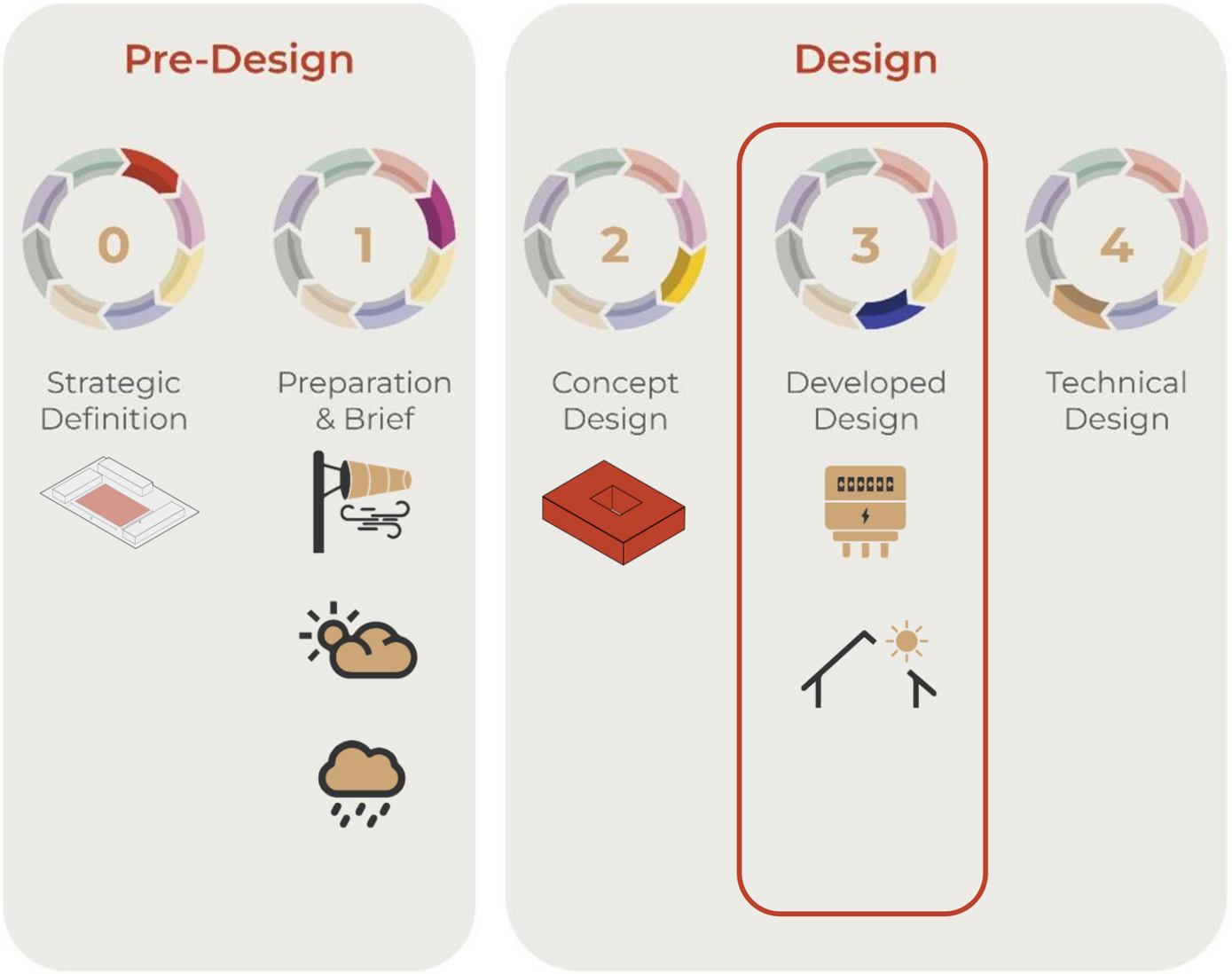
Design

2 Concept Design



3 Developed Design

4 Technical Design


Pre-Design
Design
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2
3
4
Strategic Definition
Preparation & Brief
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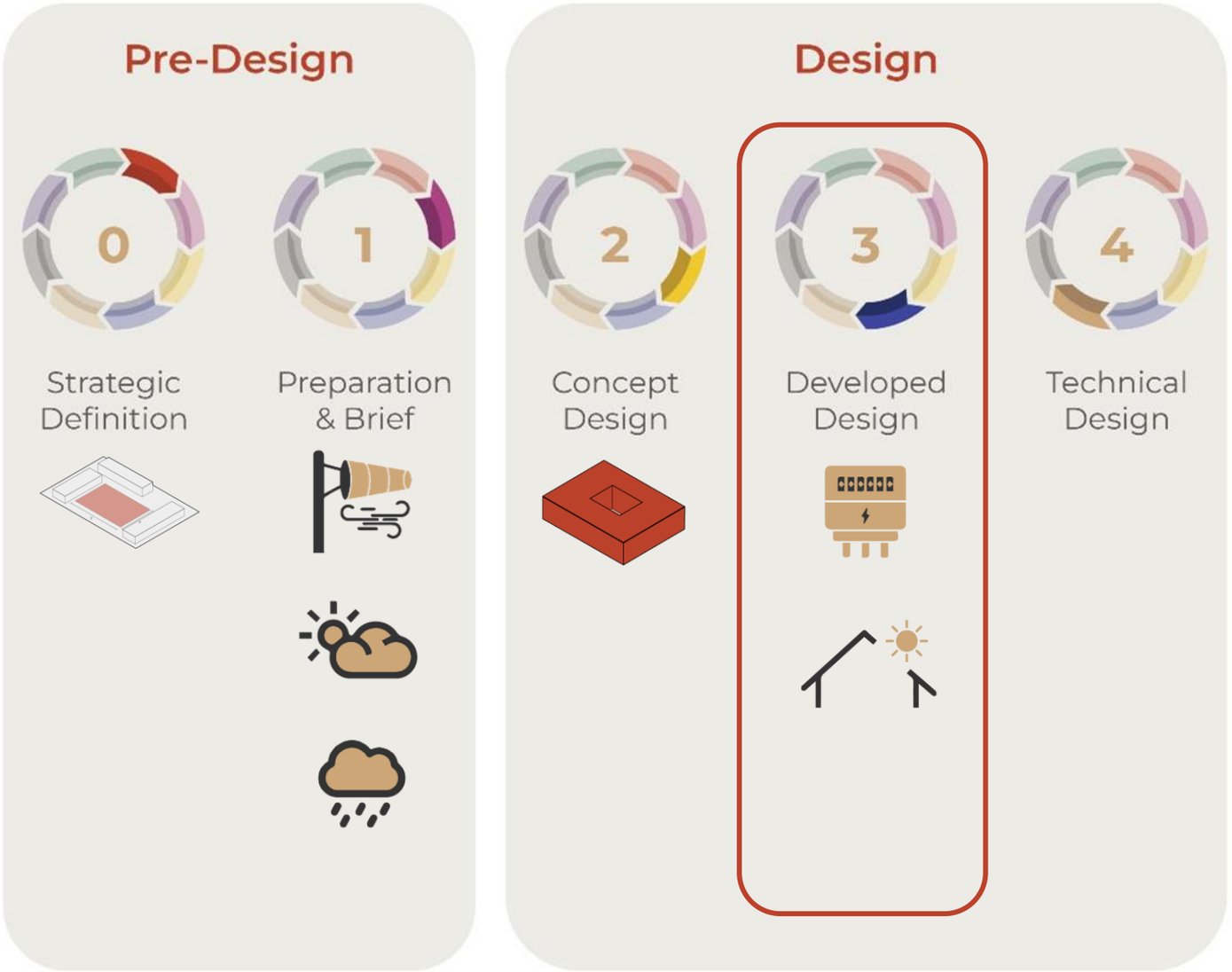
Technical Design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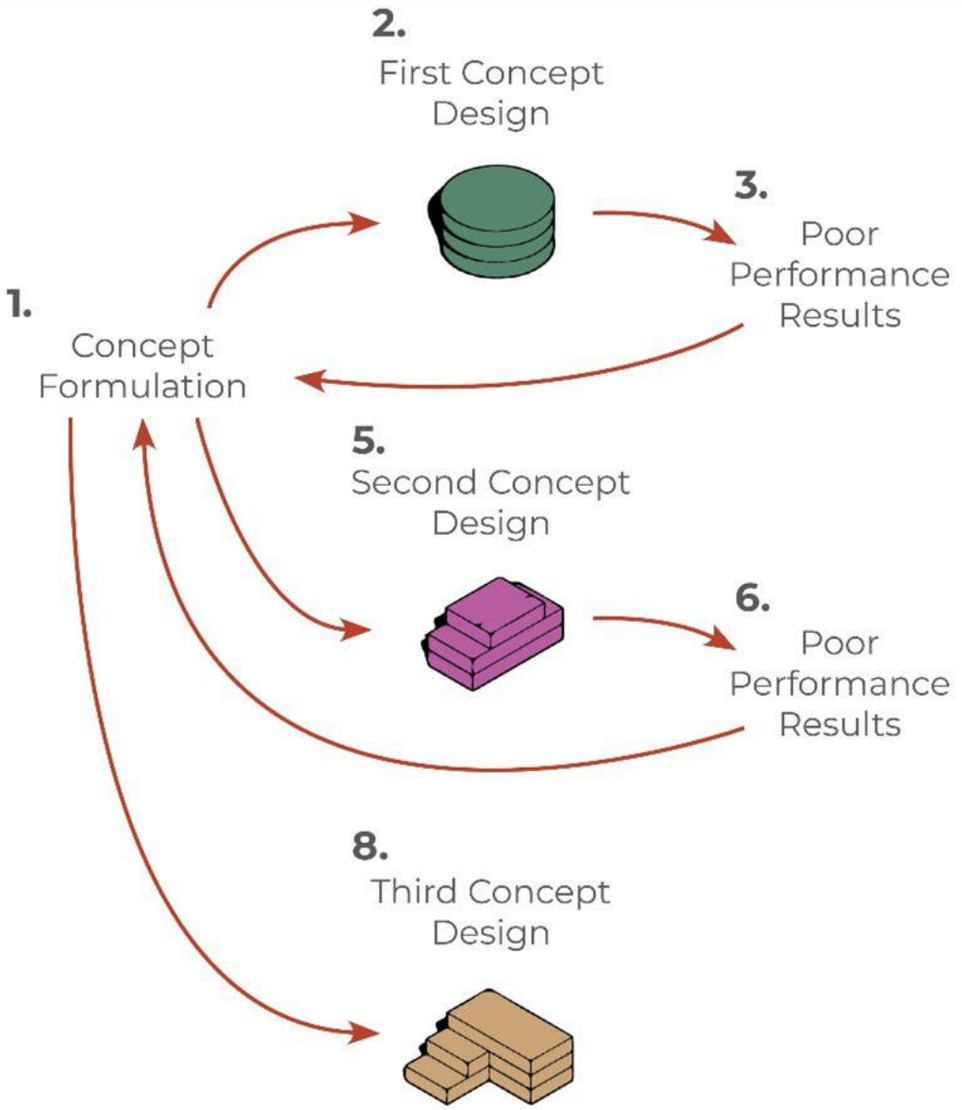
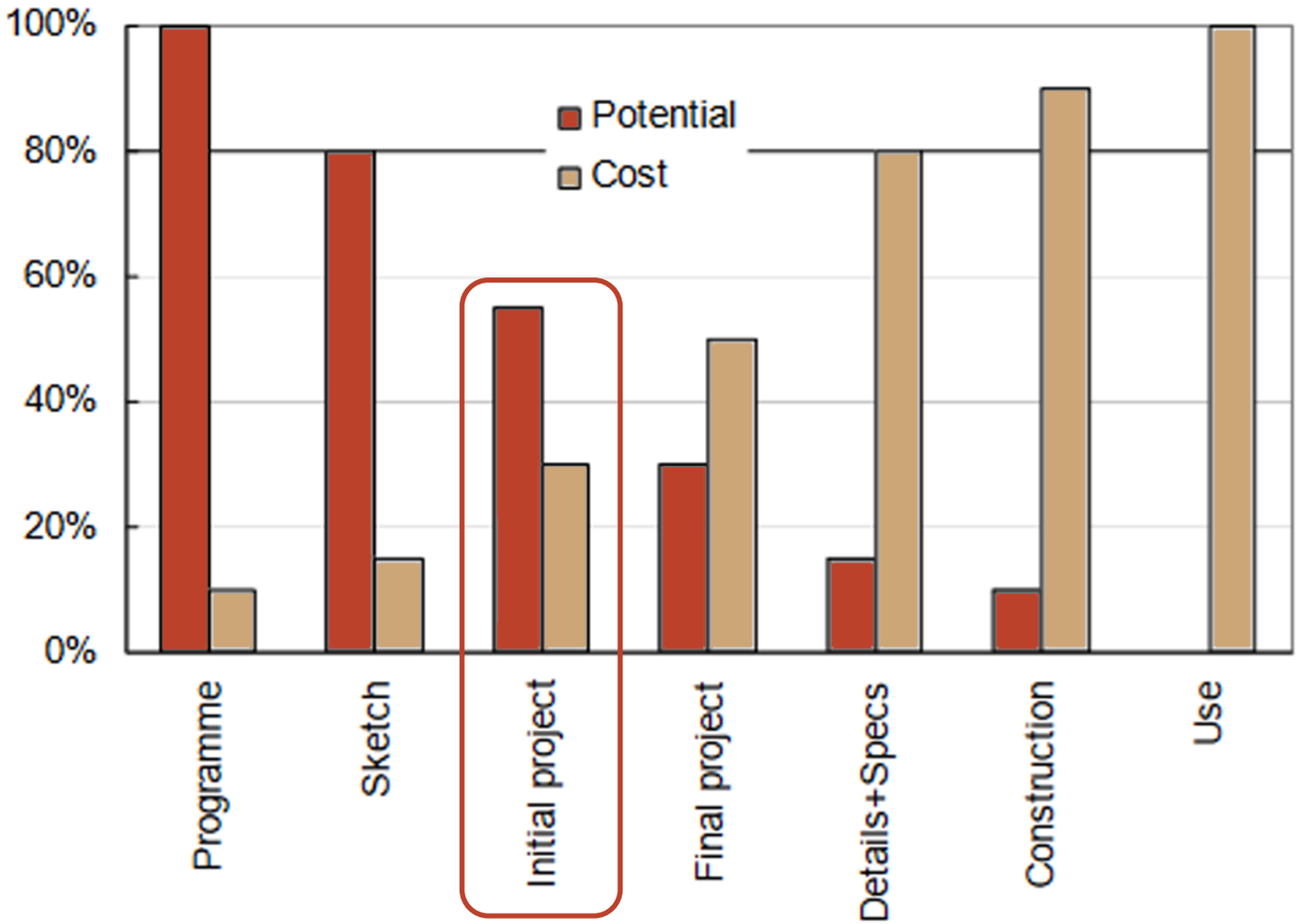
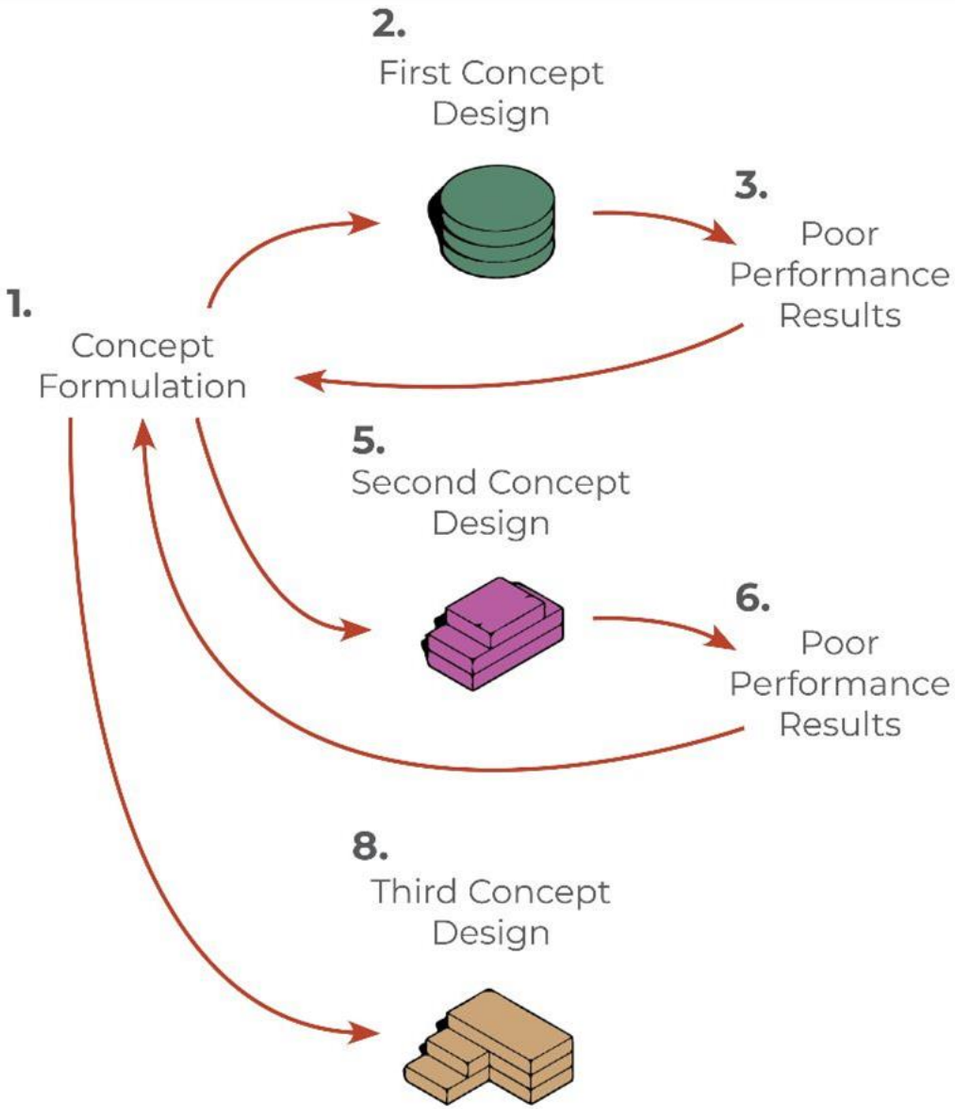
Technical Design


1.
Concept Formulation
2.
First Concept Design
3.
Poor Performance Results
5.
Second Concept Design
6.
Poor Performance Results
8.
Third Concept Design


100%
80%
60%
40%
20%
0%
Potential
Cost
Programme
Sketch
Initial project
Final project
Details+Specs
Construction
Use


1.
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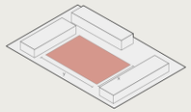
Pre-Design

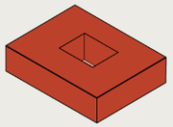
0 Strategic Definition



1 Preparation & Brief

Design

2 Concept Design

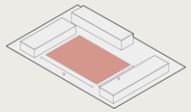


3 Developed Design

4 Technical Design

Pre-Design

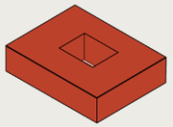
0 Strategic Definition



1 Preparation & Brief

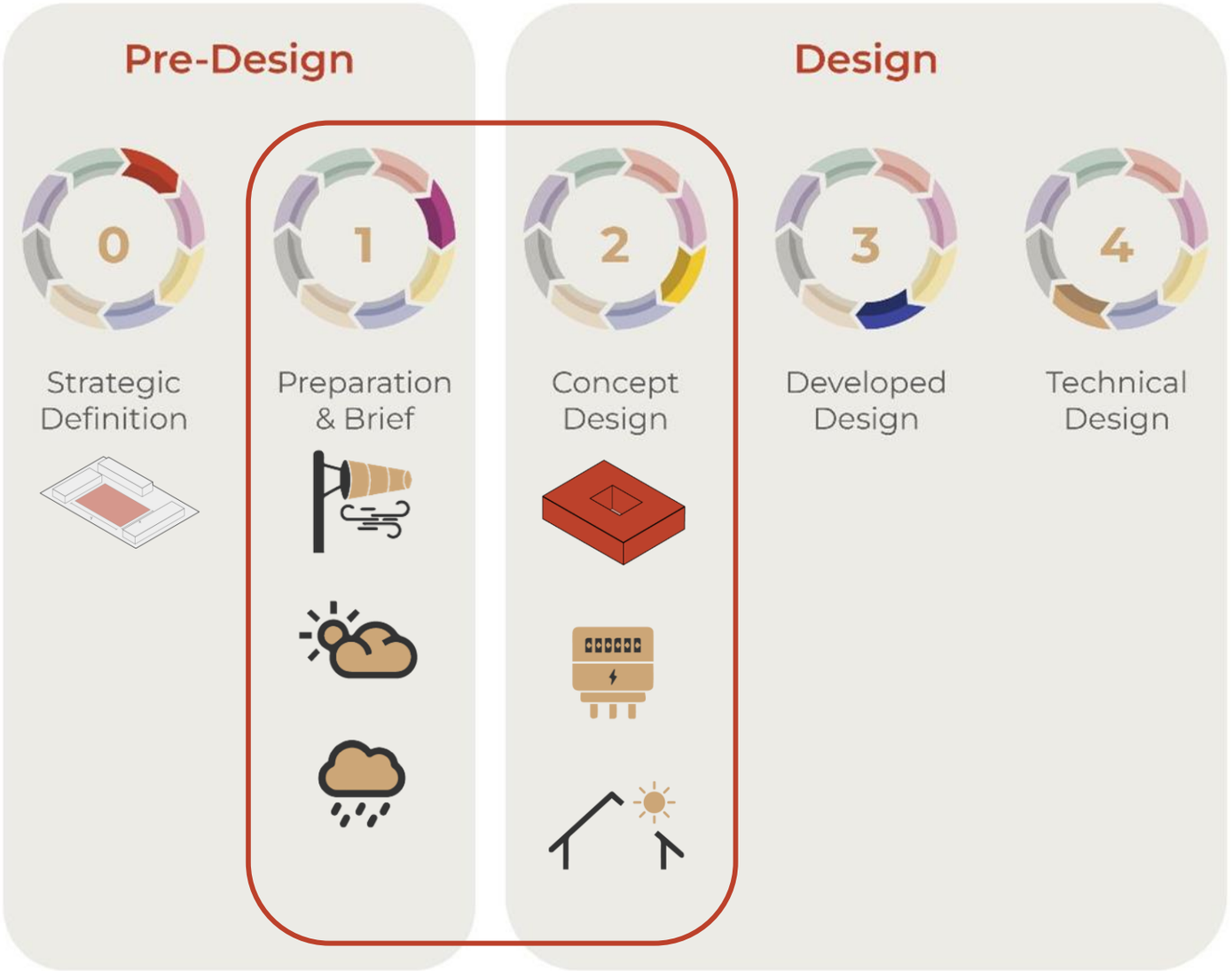
Design

2 Concept Design



3 Developed Design

4 Technical Design


Pre-Design
Design
0
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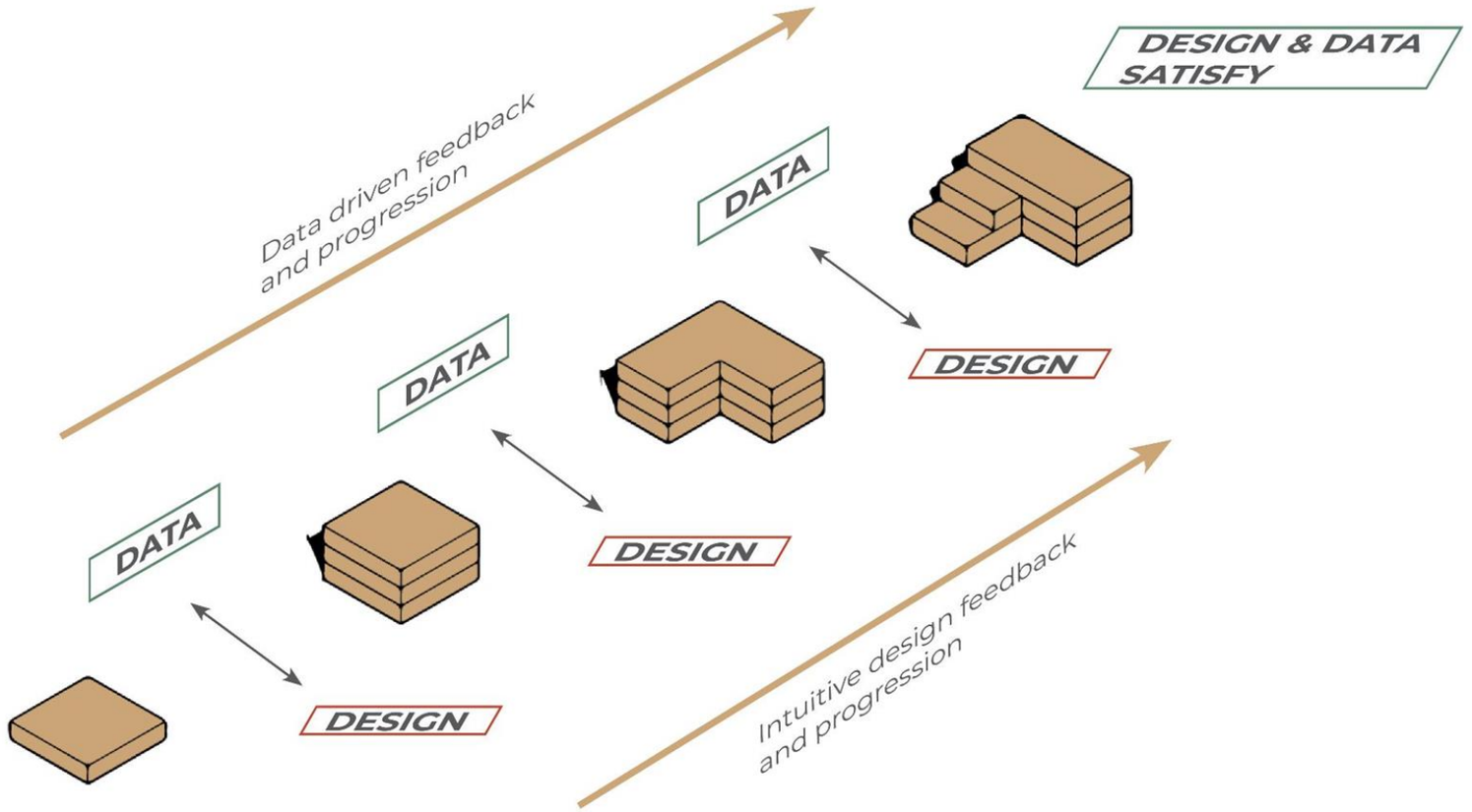
4
Strategic Definition
Preparation & Brief
Concept Design
Developed Design
Technical Design


Pre-Design
0
1
2
Strategic Definition
Preparation & Brief
Concept Design

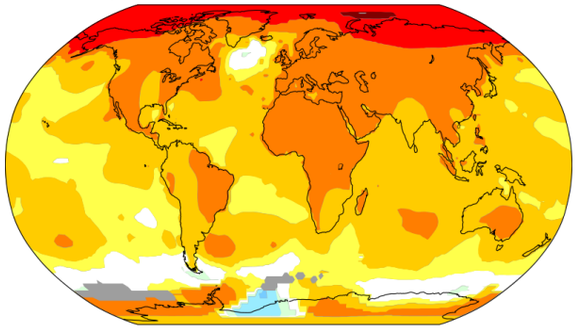
Data Driven Design



Let's Recap

Climate

Temperature change in the last 50 years

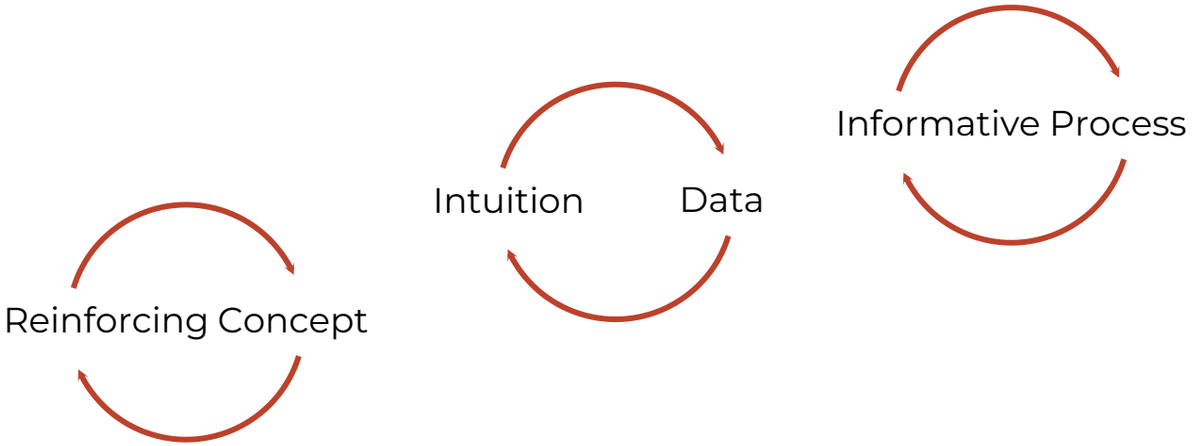


2011–2021 average vs 1956–1976 baseline

−1.0 −0.5 −0.2 +0.2 +0.5 +1.0 +2.0 +4.0 °C

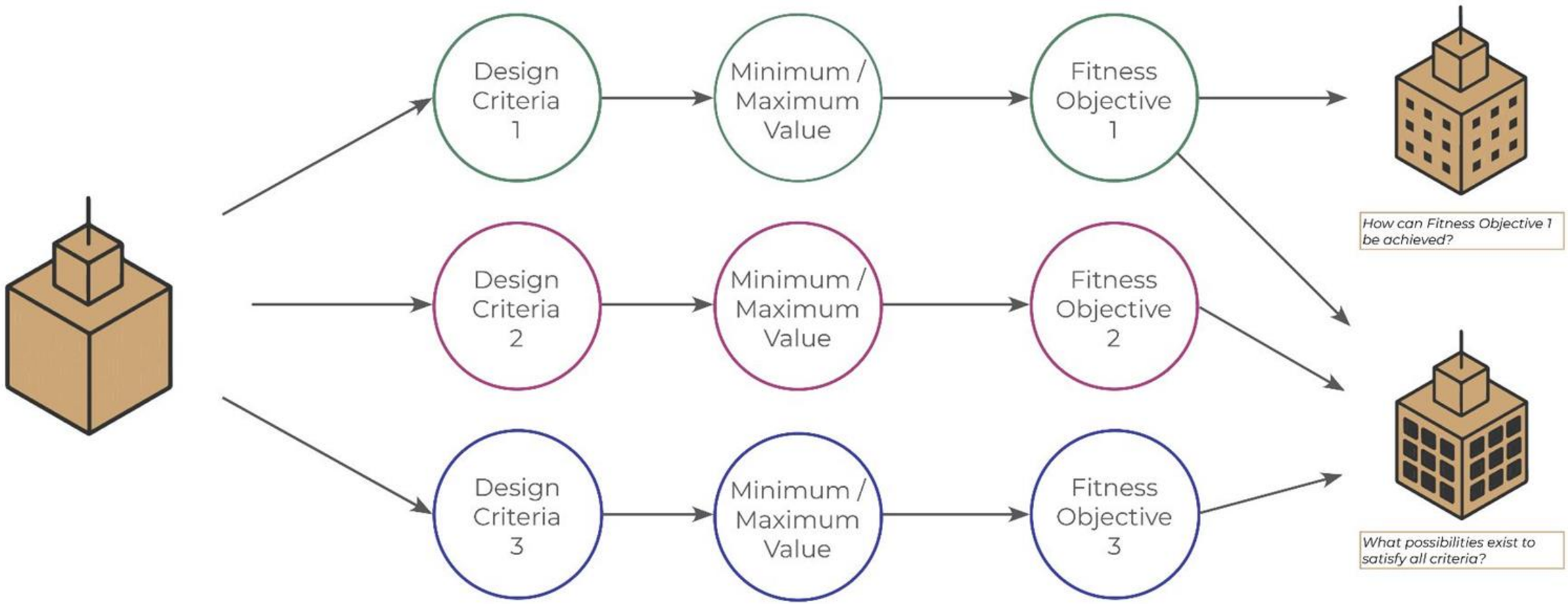
−1.8 −0.9 −0.4 +0.4 +0.9 +1.8 +3.6 +7.2 °F

Design Process

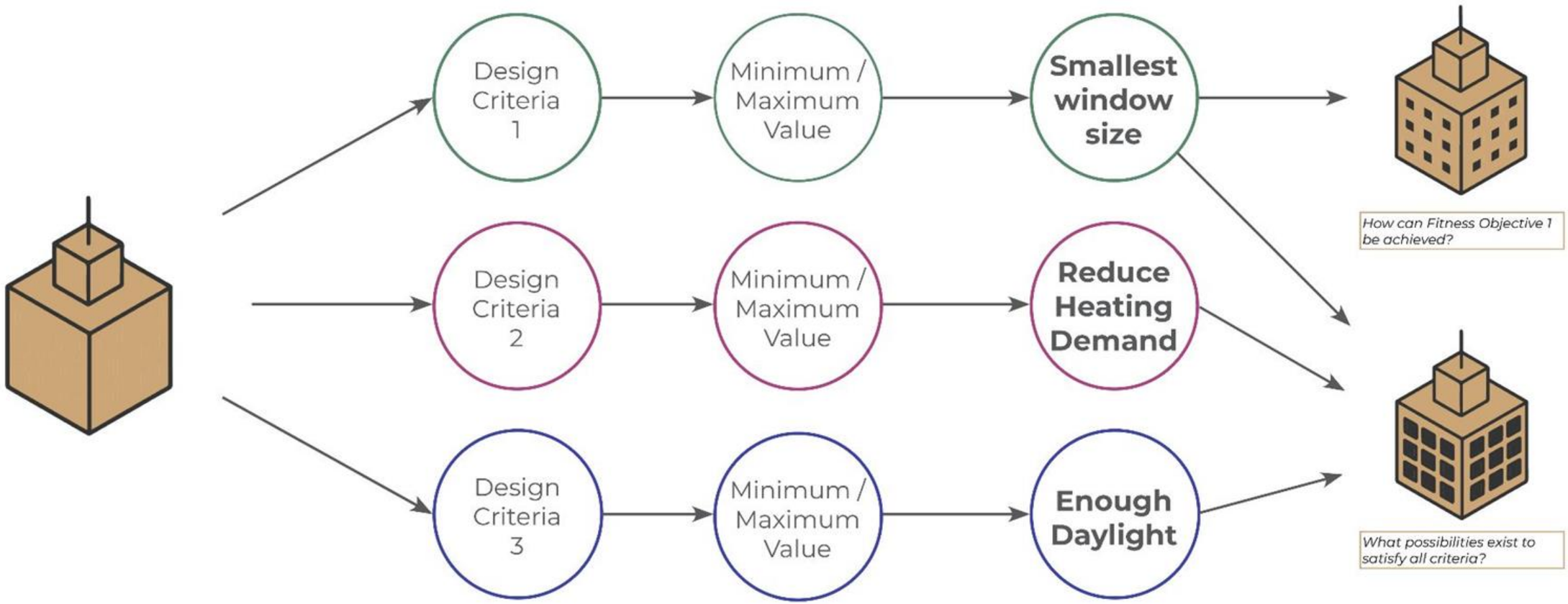


WORKFLOW

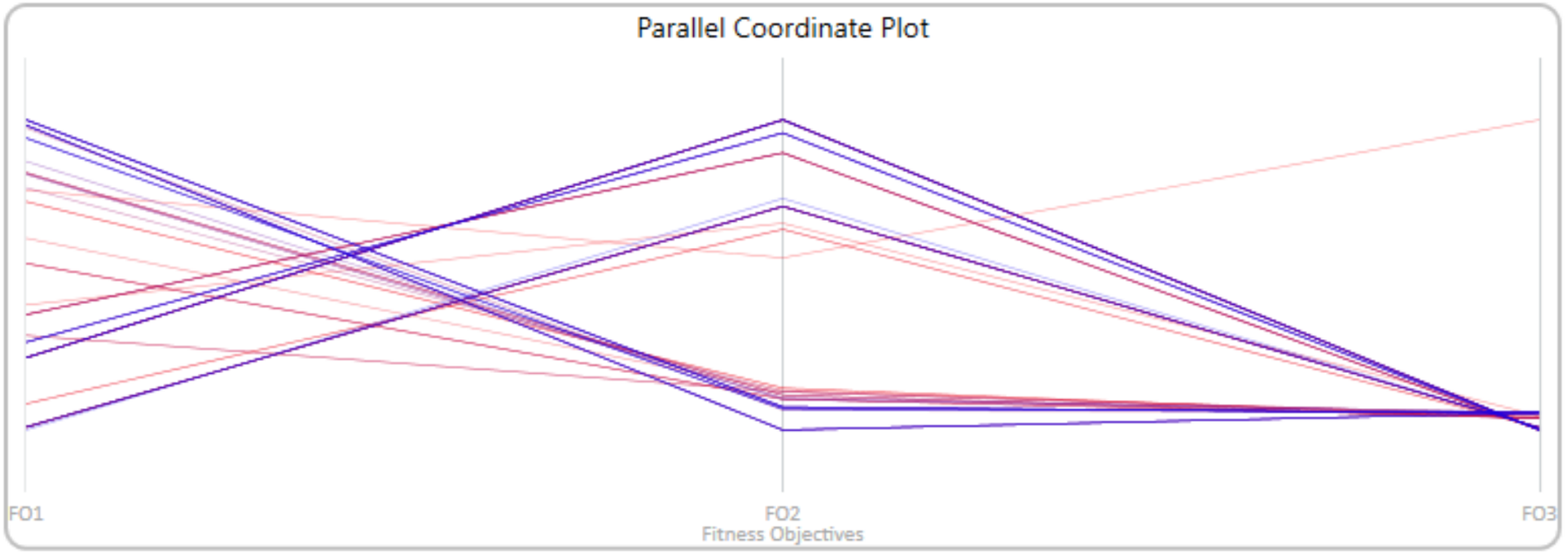
Multi-Objective Optimization



Multi-Objective Optimization

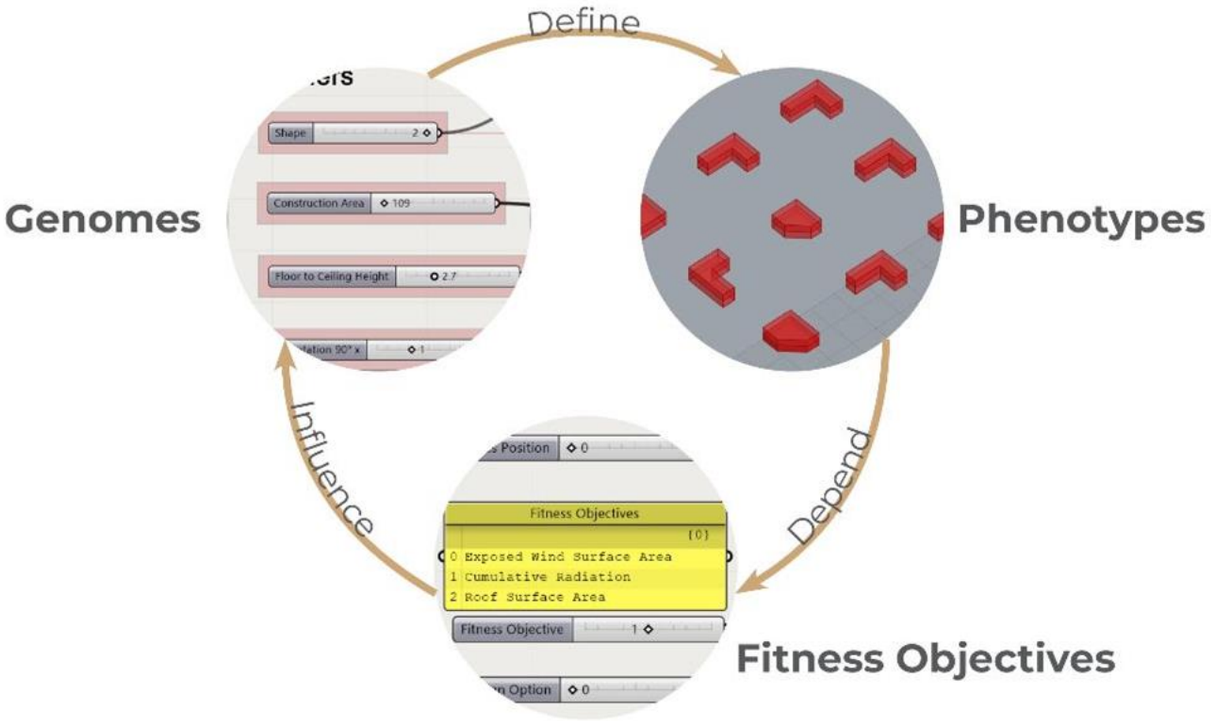


Multi-Objective Optimization



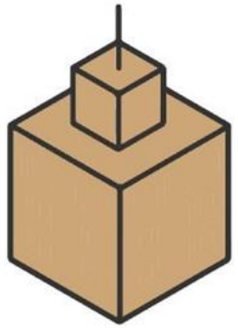
Understanding the trade-offs between chosen criteria

Multi-Objective Optimization

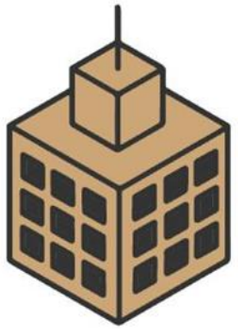


Developing
knowledge between
cause and effect

Stepped Approach

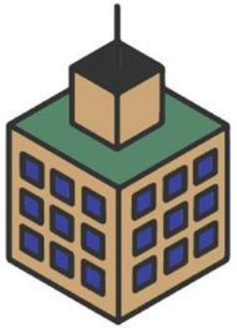


Volume



Fenestration

1. Genome Selection
2. Simulation
3. Results
4. Optimization
5. Phenotype Selection

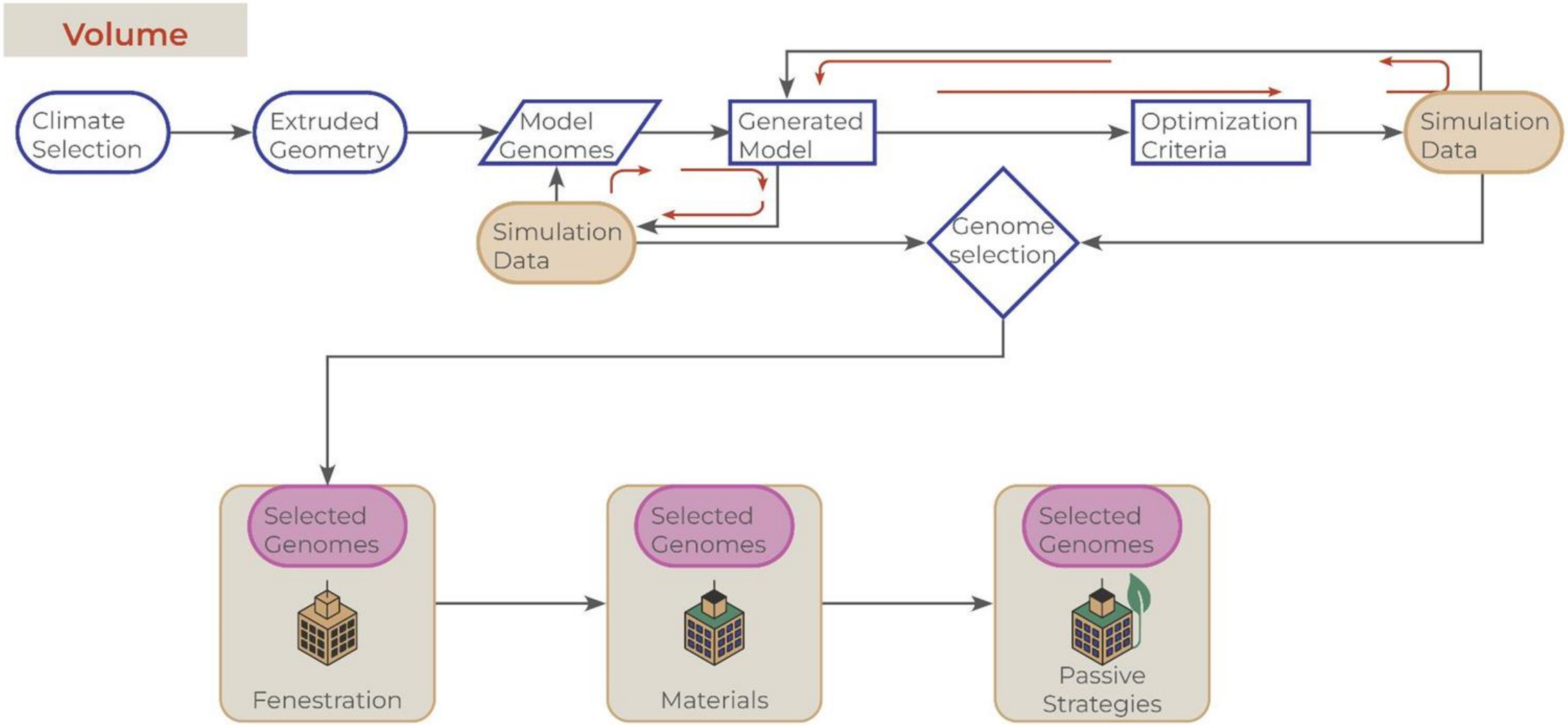


Materials

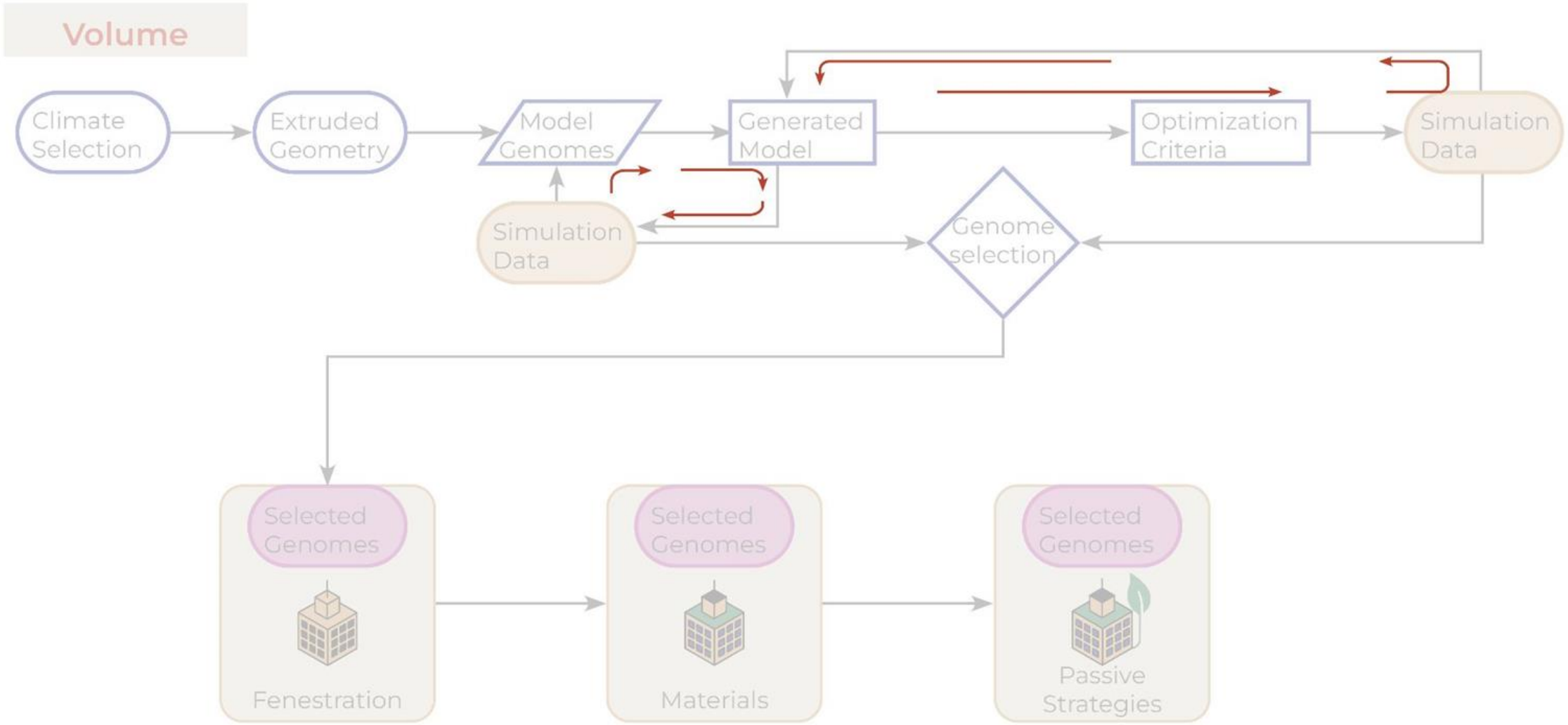
1. Genome Selection
2. Simulation
3. Results
4. Phenotype Selection

Passive Strategies

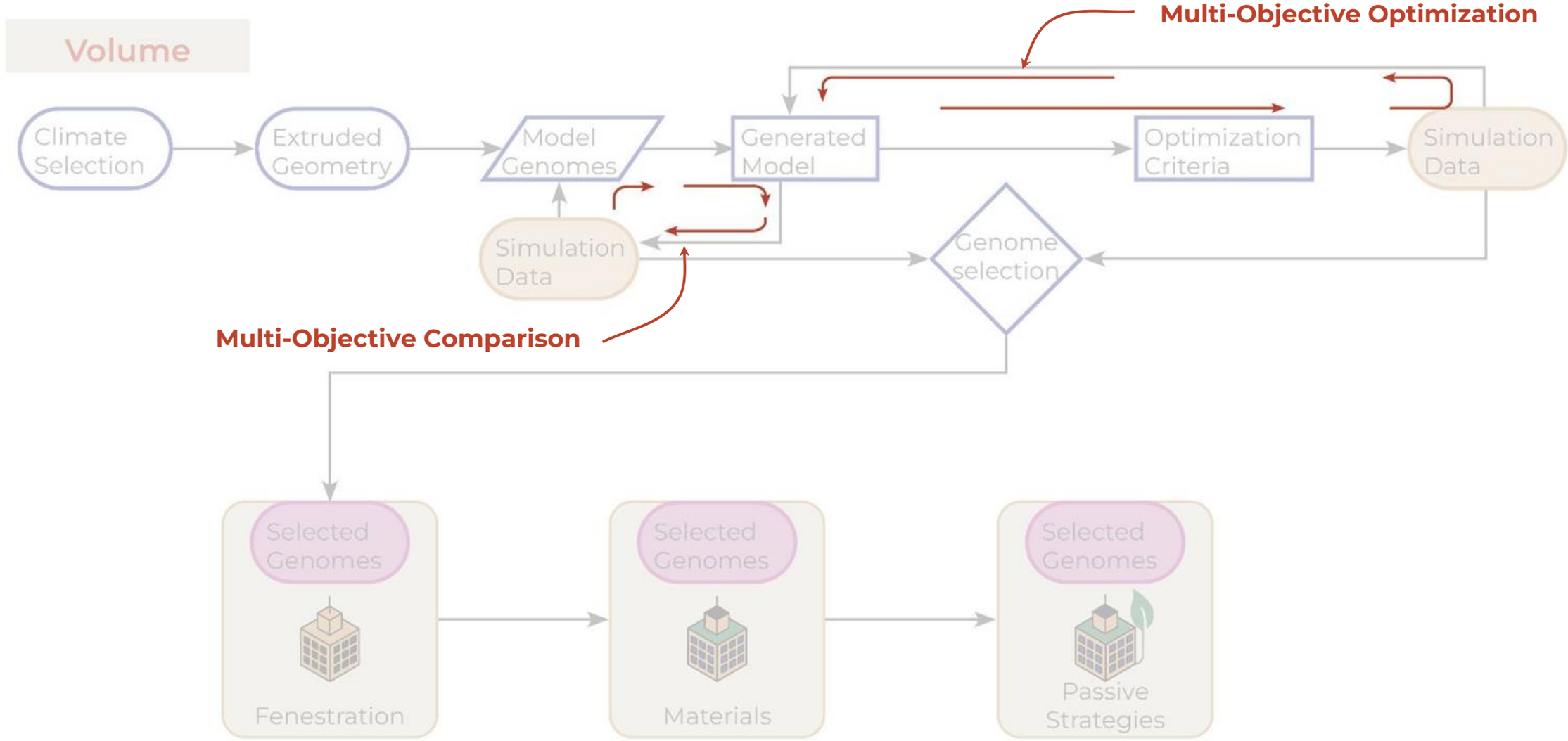
Stepped Approach

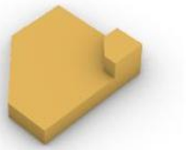
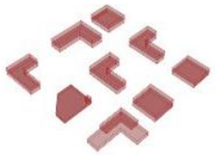
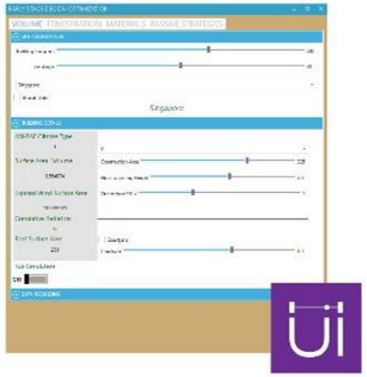
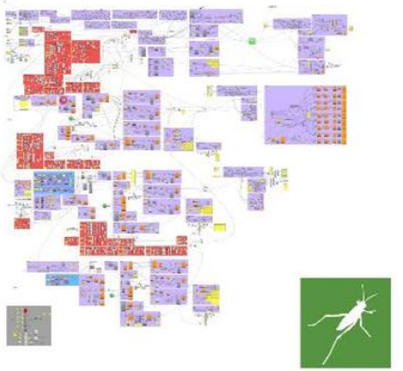
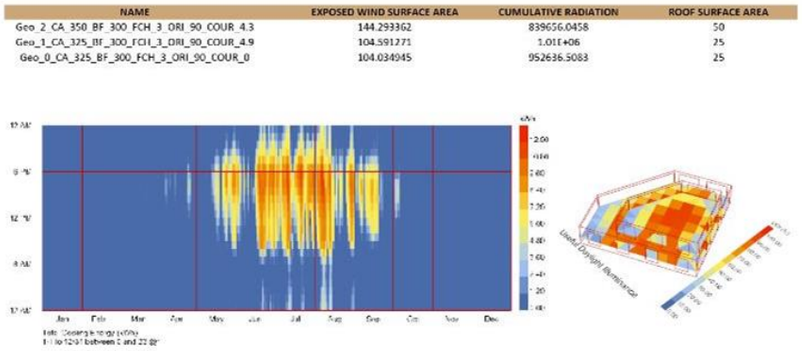
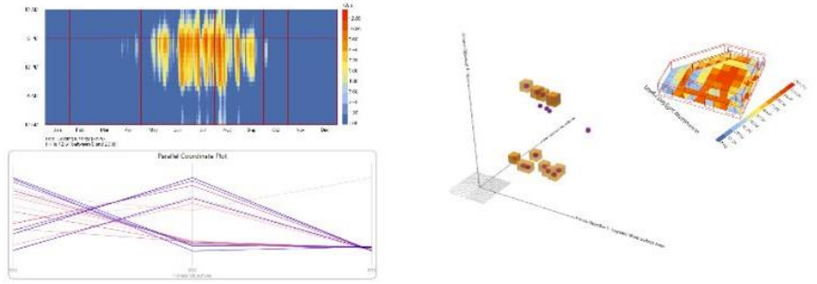


Stepped Approach



Stepped Approach



Criteria	Multi-Objective Comparison	Multi-Objective Optimization
Users	Clients / Design Team	Design Team / Engineers
Geometric Options Visualization		
Interface		
Data Obtained		

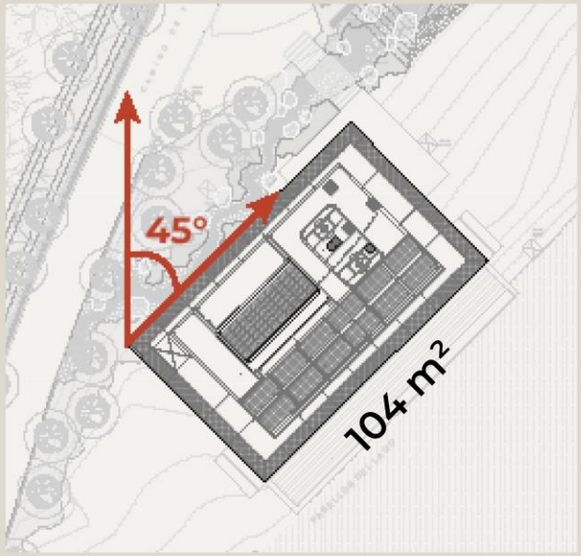
NAME	EXPOSED WIND SURFACE AREA	CUMULATIVE RADIATION	ROOF SURFACE AREA
Geo_2_CA_350_BF_300_FCH_3_ORI_90_COUR_4.3	144.293362	839656.0458	50
Geo_1_CA_325_BF_300_FCH_3_ORI_90_COUR_4.9	104.591271	1.01E+06	25
Geo_0_CA_325_BF_300_FCH_3_ORI_90_COUR_0	104.034945	952636.5083	25

NAME	EXPOSED WIND SURFACE AREA
Geo_0_CA_136_BF_2.9_FCH_2.9_ORI_2_COUR_0	104.25608
Geo_1_CA_241_BF_2.8_FCH_2.8_ORI_3_COUR_0	218.172986
Geo_0_CA_309_BF_2.4_FCH_2.4_ORI_1_COUR_0	175.06848

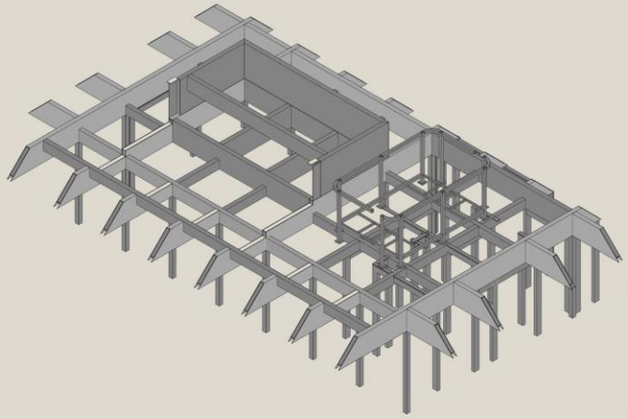
CASE STUDY

Case Study Details

Area & Plot Angle



Construction Type



Steel Framed

Wall R-Value
1.69 m² K/W

Roof R-Value
3.90 m² K/W

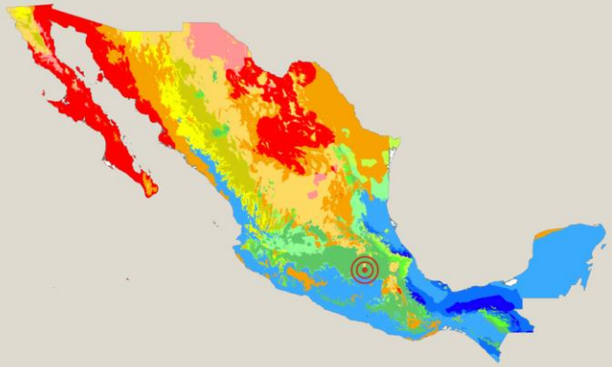
Floor R-Value
0.33 m² K/W

Window U-Value
1.65 W/m²·K

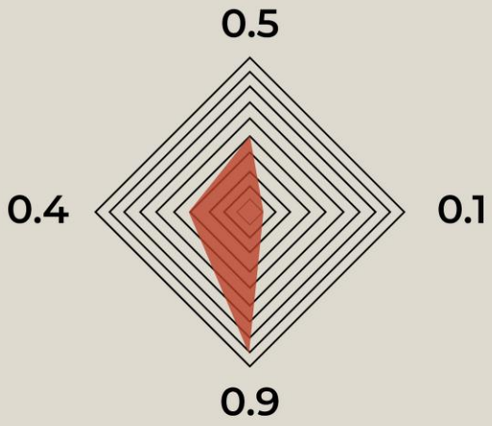
SHGC
0.39

Climate Type

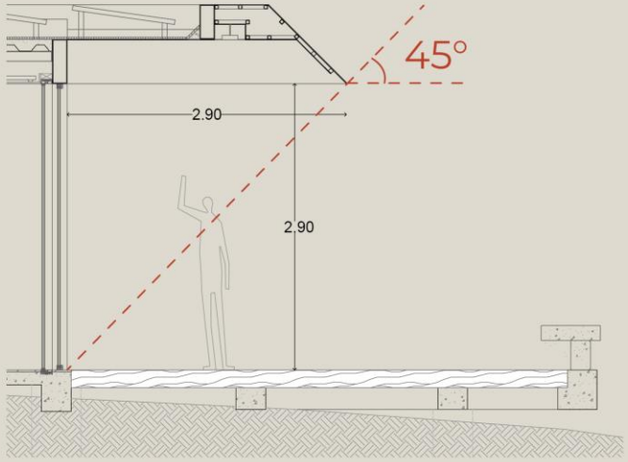
Köppen-Geiger: Cfb
ASHRAE: 3



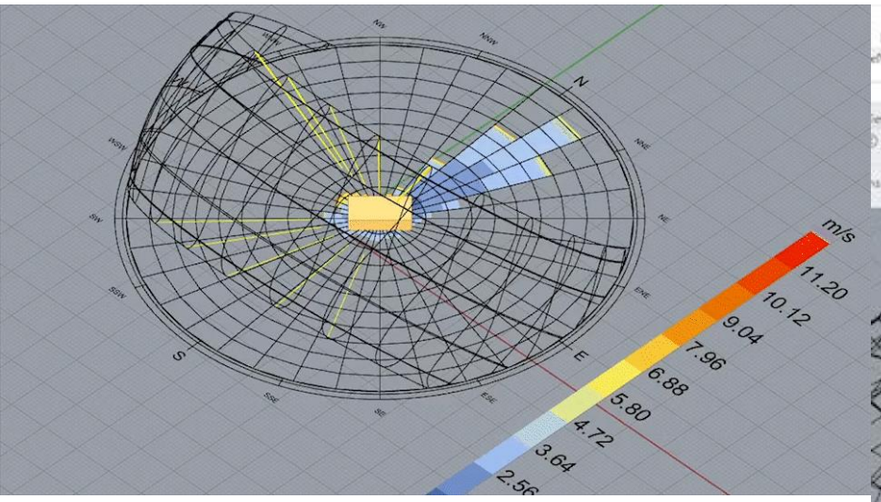
Window to Wall Ratio

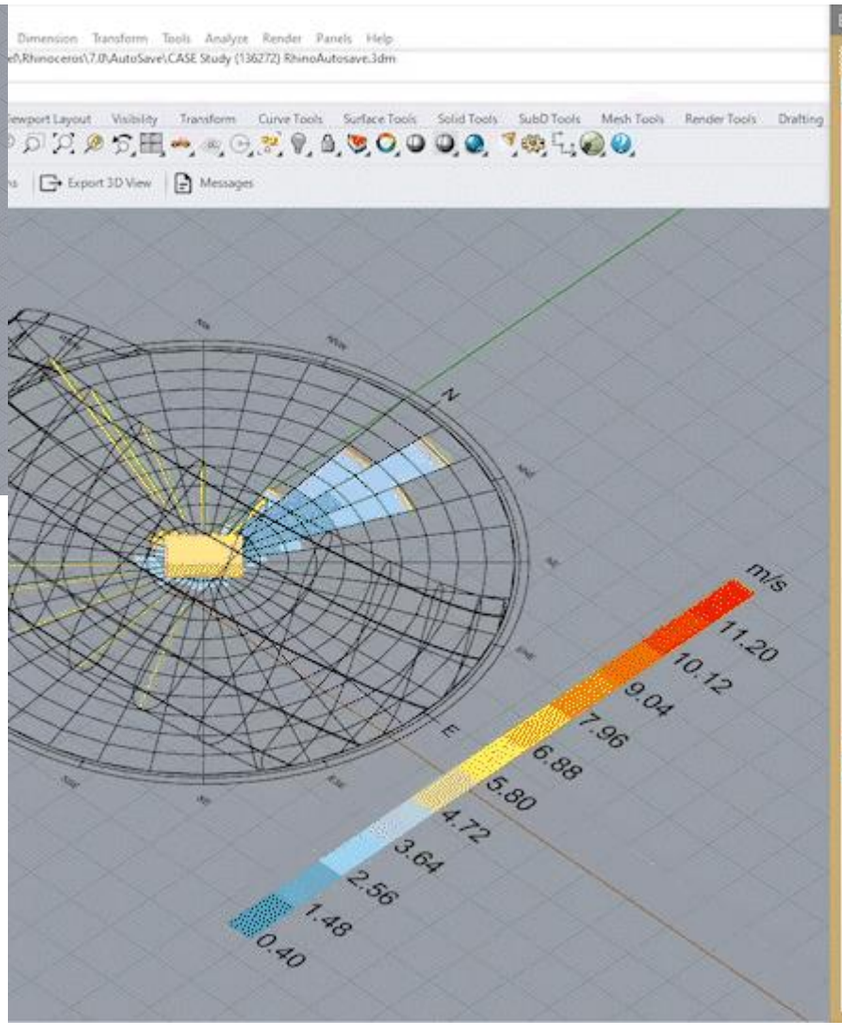


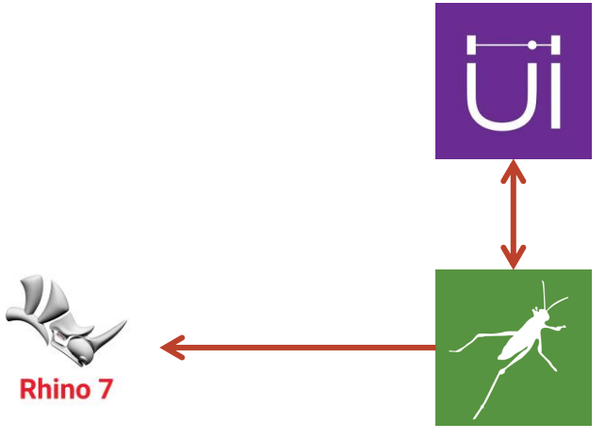
Passive Strategies



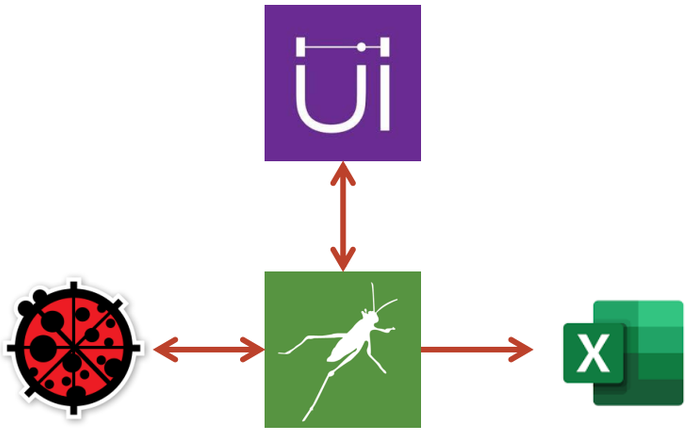
Geometry Selection



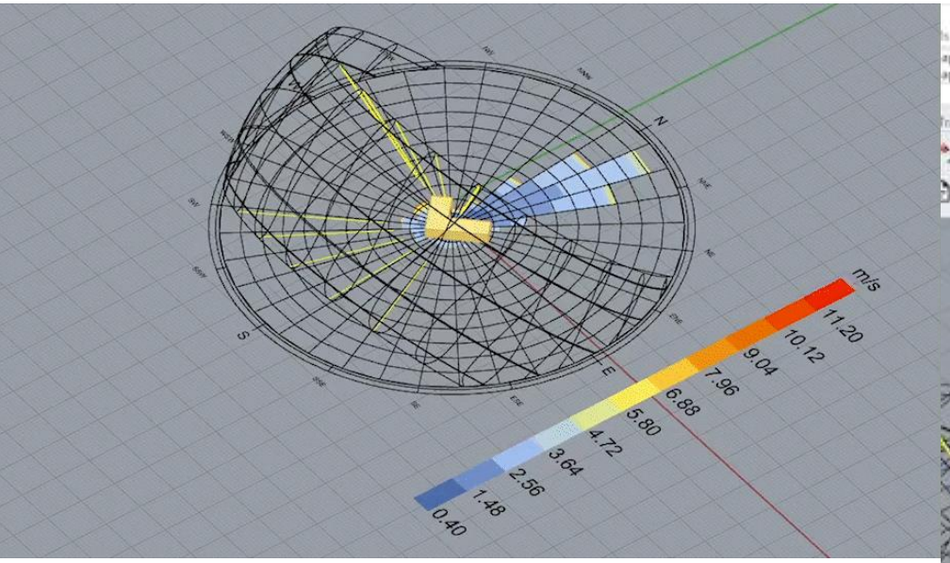


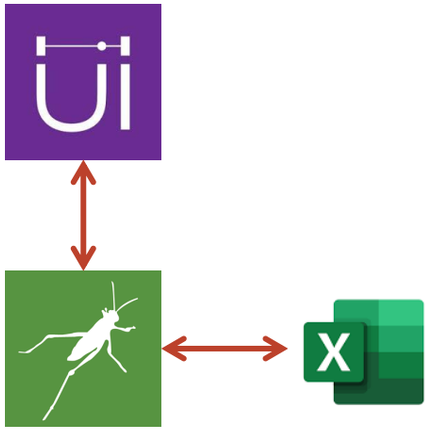


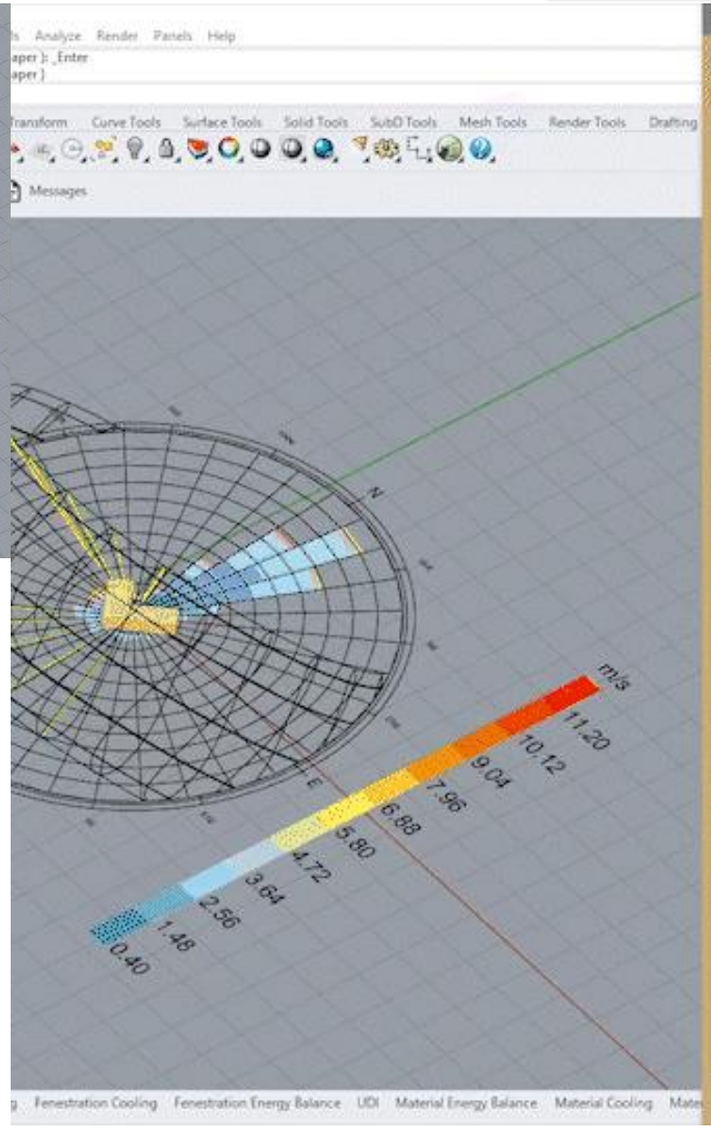
Restoring Saved Data



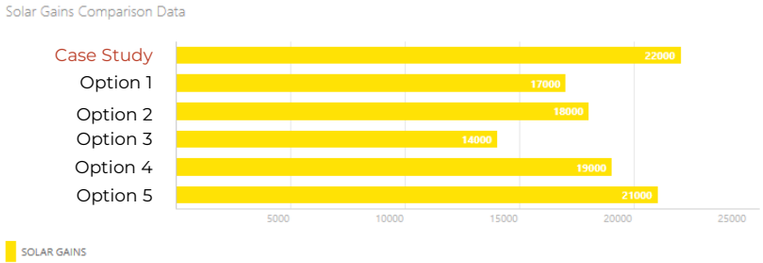
Fenestration Genome Selection

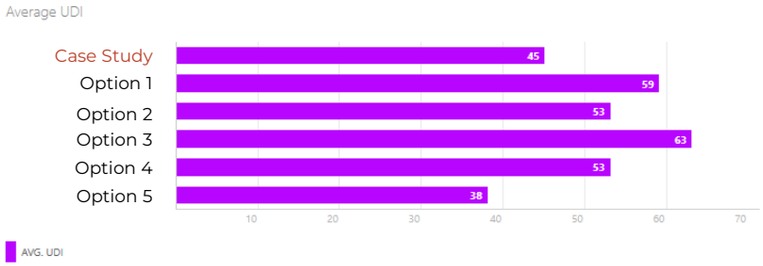


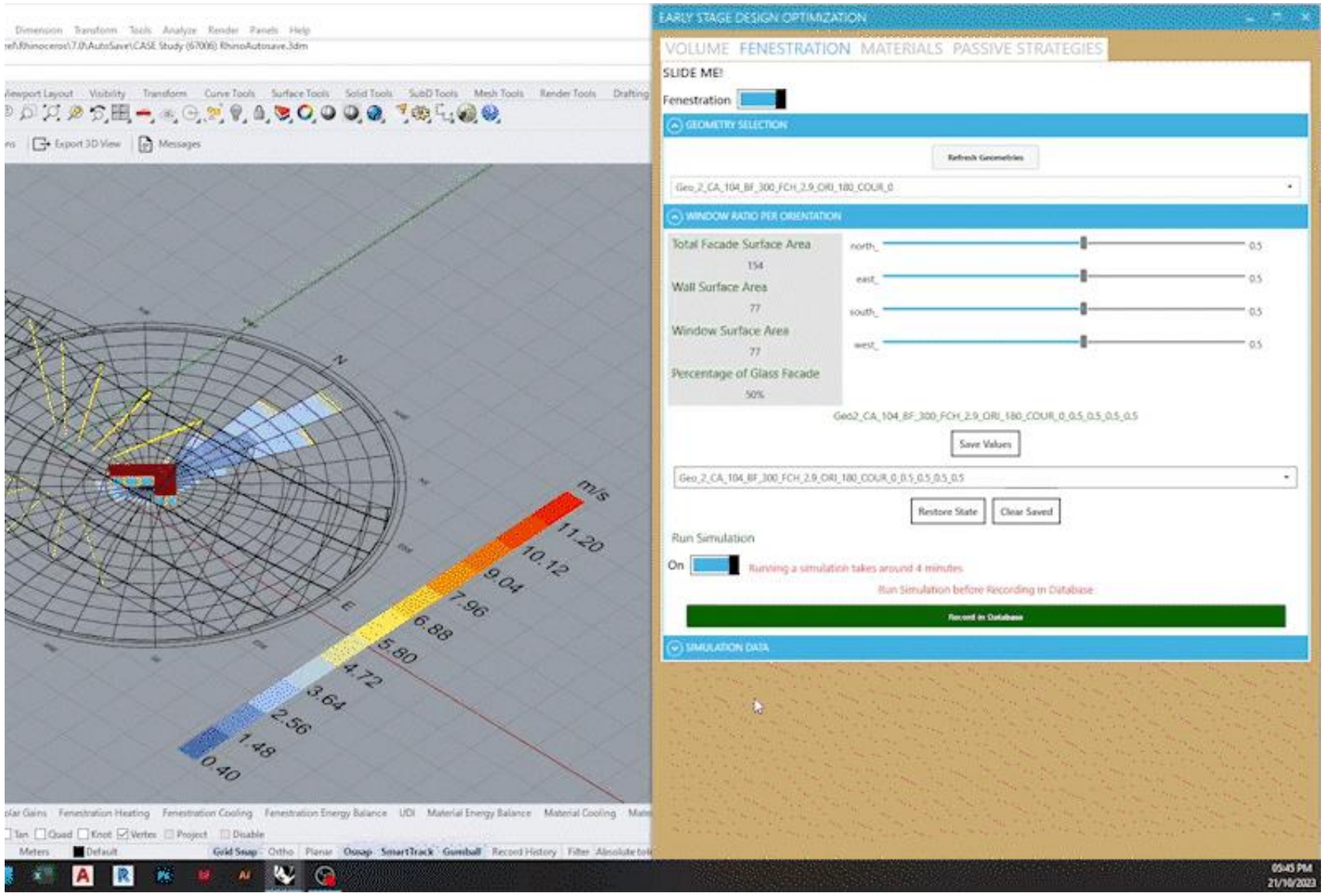




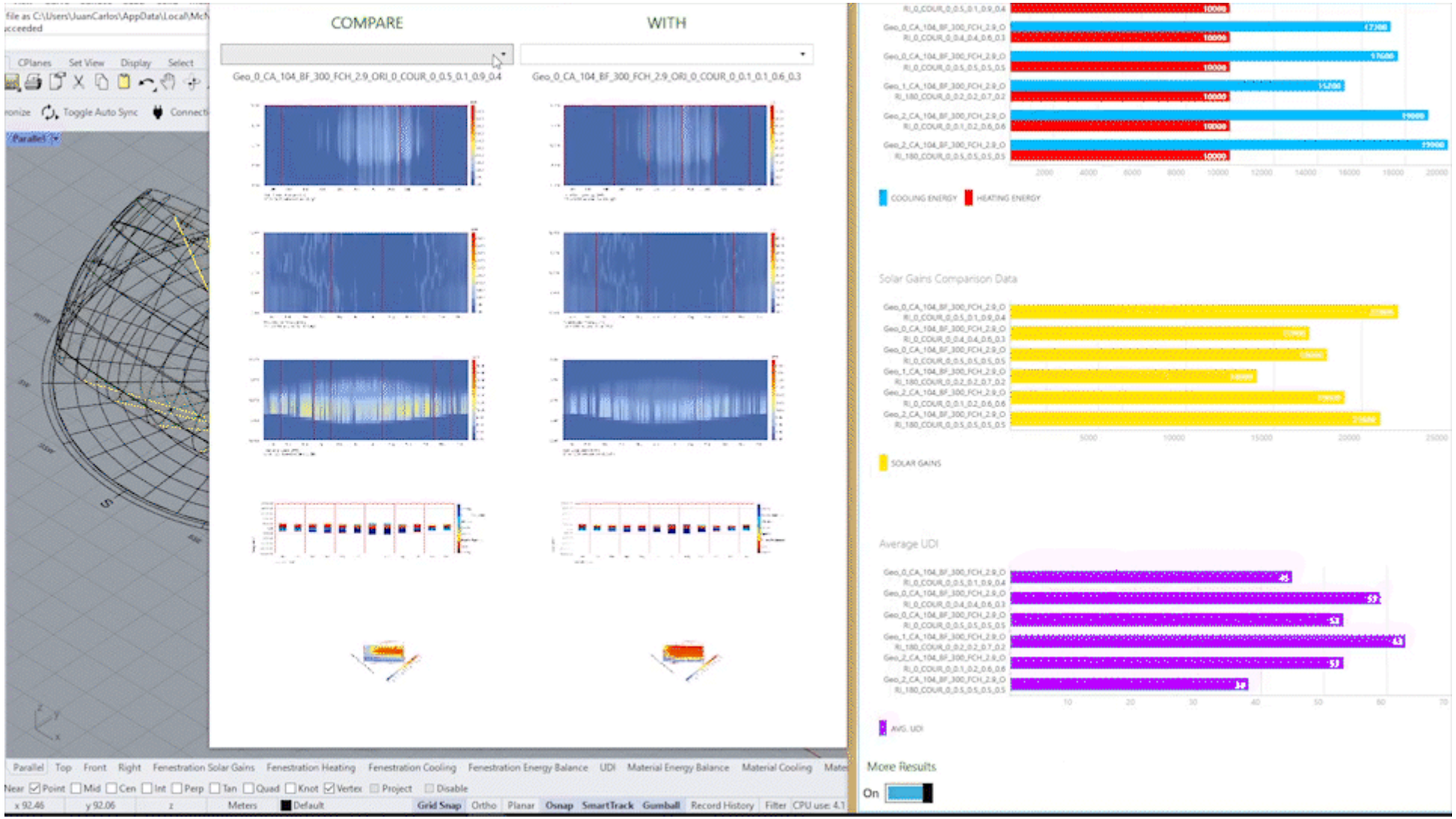
Fenestration Result Charts





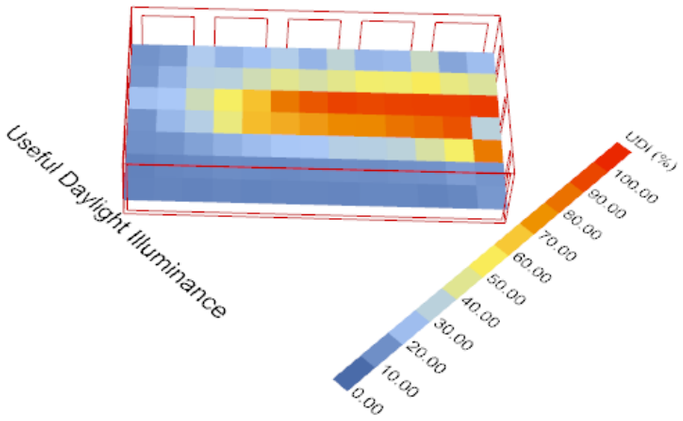


Fenestration Result Graphs

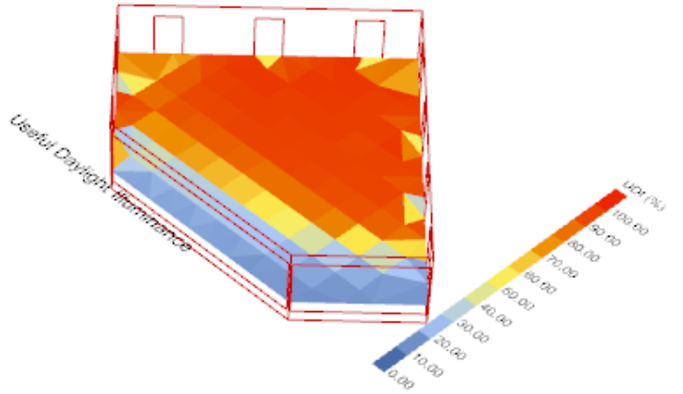


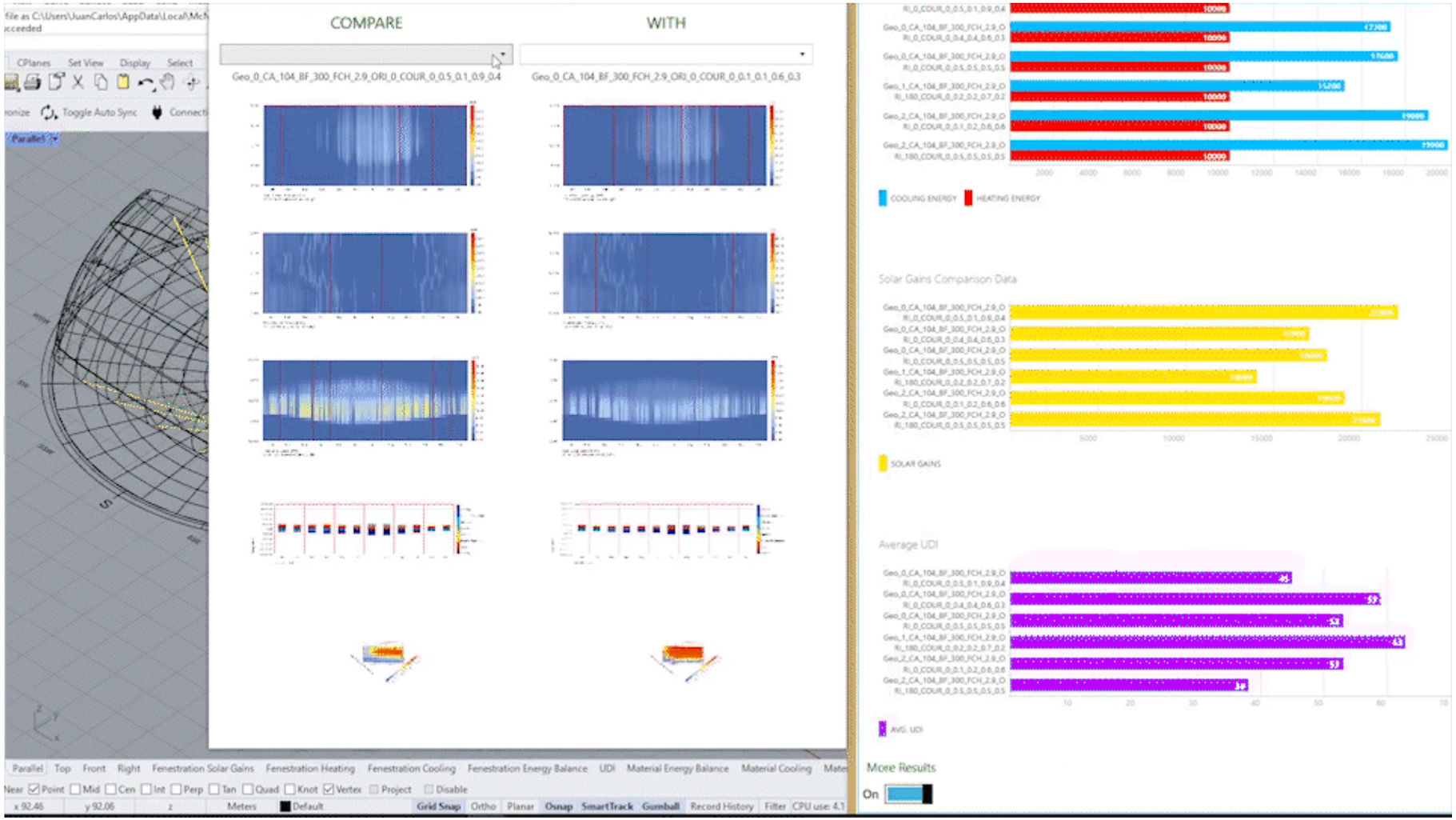
Fenestration Result Graphs

Case Study

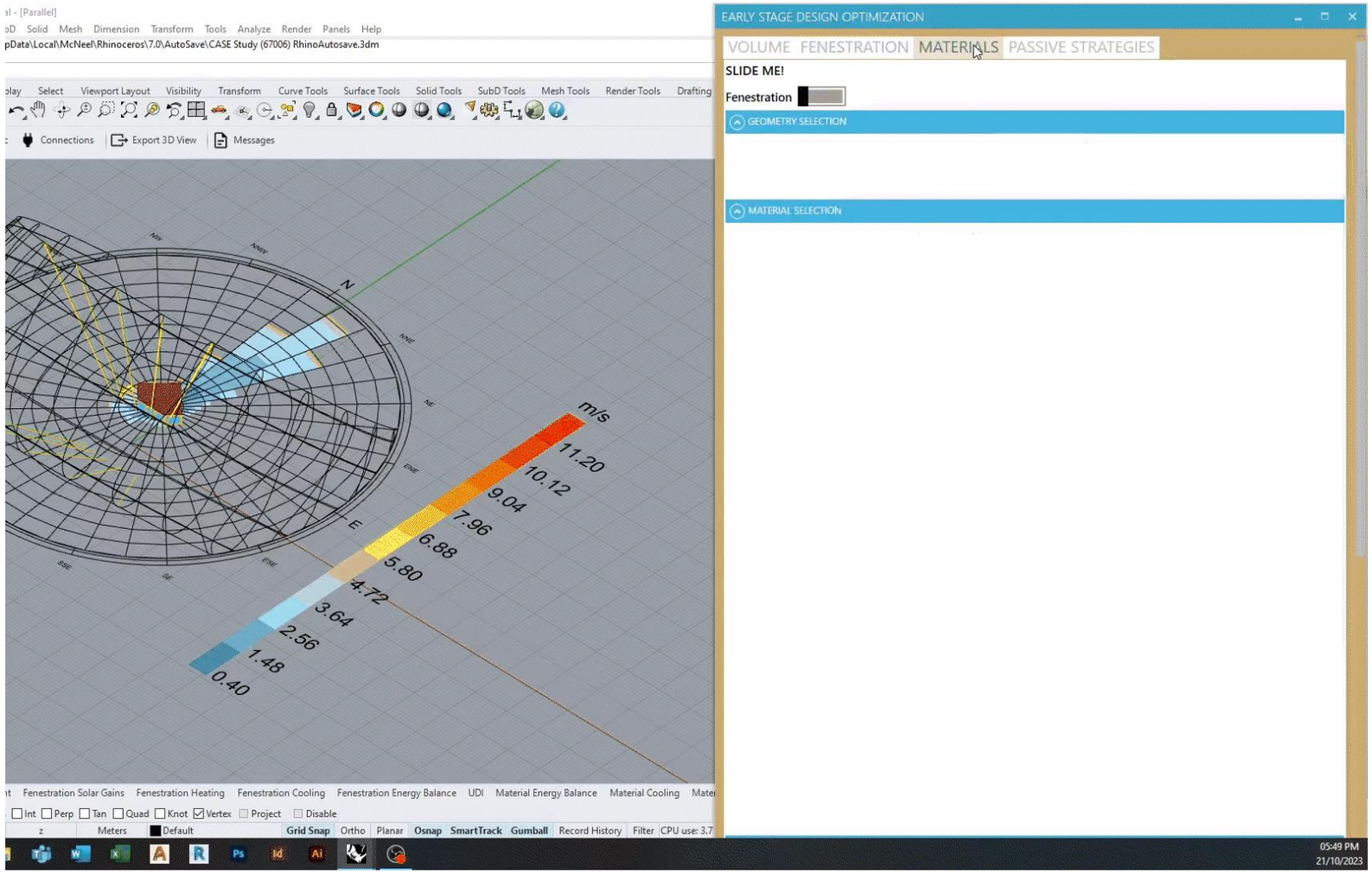


Highest Useful Daylight Illuminance





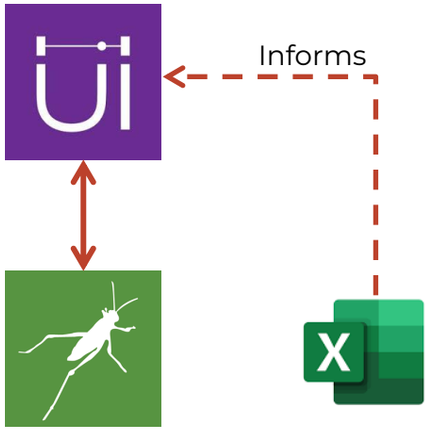
Material Genome Selection

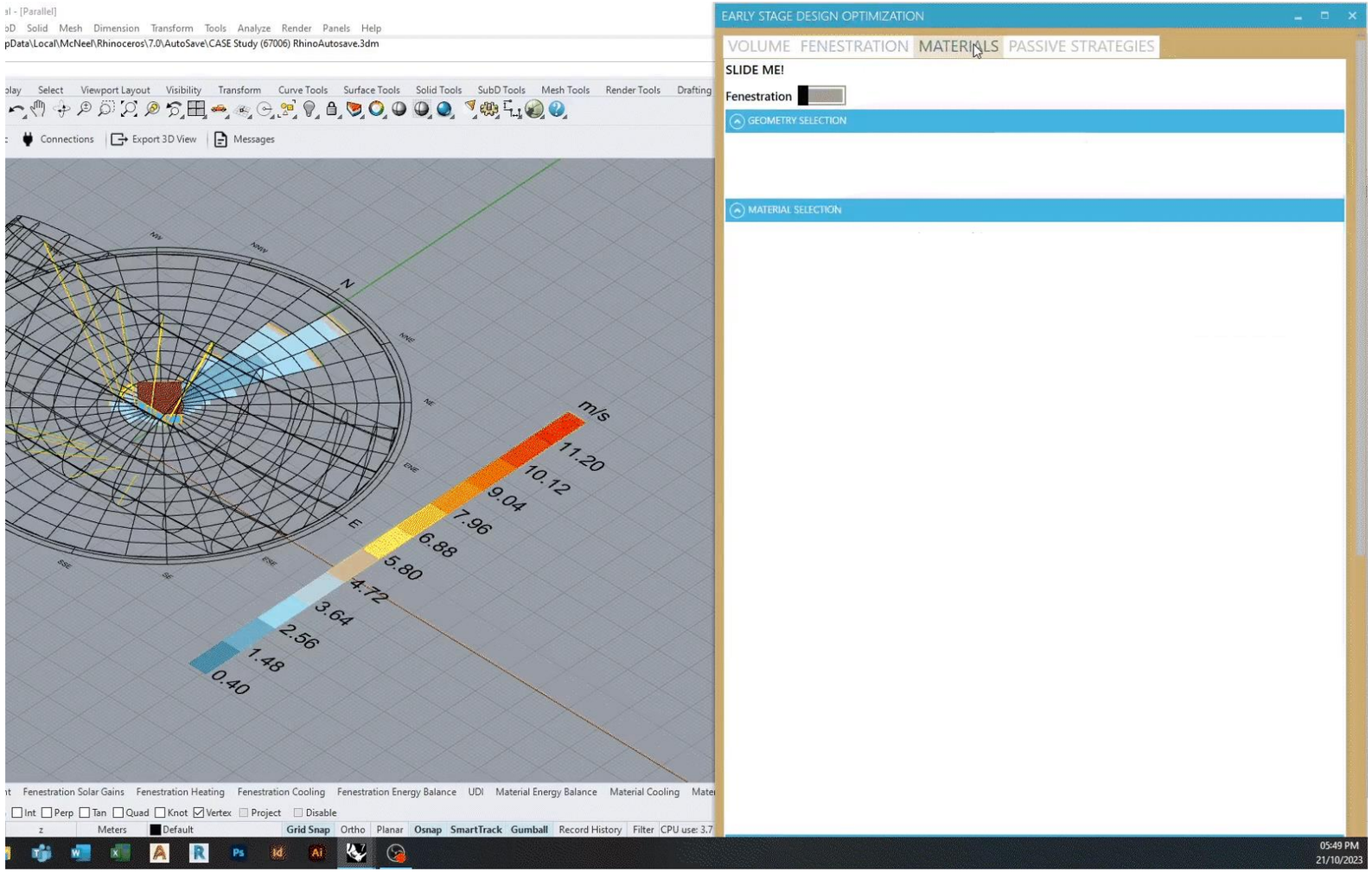


Material Genome Selection

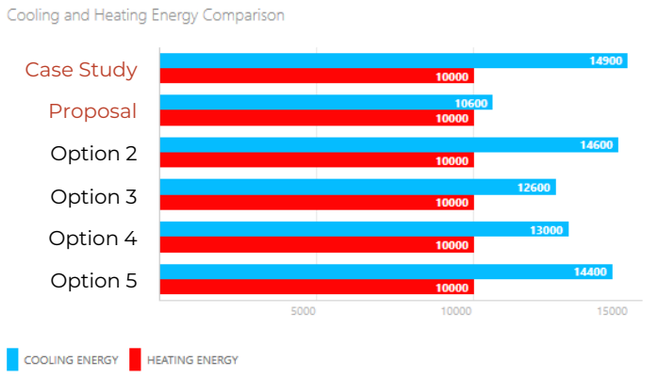
Material Assistance Table

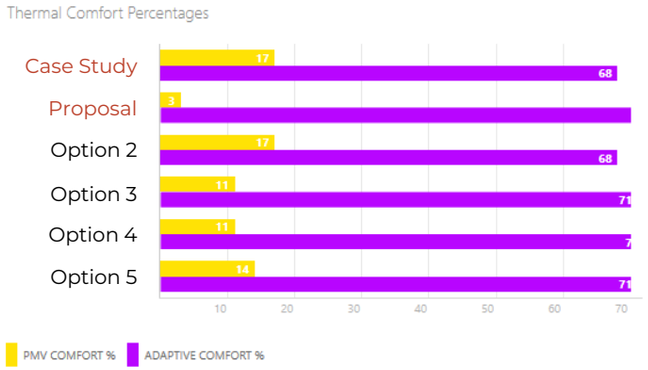
Material	Thermal Conductivity	Specific Heat Capacity	Density	Commercial Thicknesses (mm)							
	λ (W/m•K)	c (J/Kg•K)	p (Kg/m³)								
ABS Polymers	0.2	1470	1100	1	3	6					
Aluminium	200	880	2800	0.15	0.8	1	1.2	1.5	3	4	5
Air (Cavity)	0.026	1005	1225	5	10	15	20	25	30	35	40
Basalt	35	840	3000	0.55	2.5						
Brick 1	0.327	1000	850	140							
Brick 2	0.292	1000	930	120							
Brick 3	0.232	1000	800	180							
Brick 4	0.299	1000	910	120							
Brick 5	0.265	1000	920	120							
Brick 6	0.4	837	775	80							
Brick 7	0.19	837	1255	80							
Brick 8	0.187	1112	1171	100	140	290					
Brick Lightweight	0.3	840	1000	100							
Calcium Silicate Panel	0.045	1000	107.5	80	100	120	160	180	200	240	260
Cane Fiber Board	0.085	2100	300	8	10	12	16	18	21		
Cellular Glass	0.06	850	140	40	60	80	100	120			

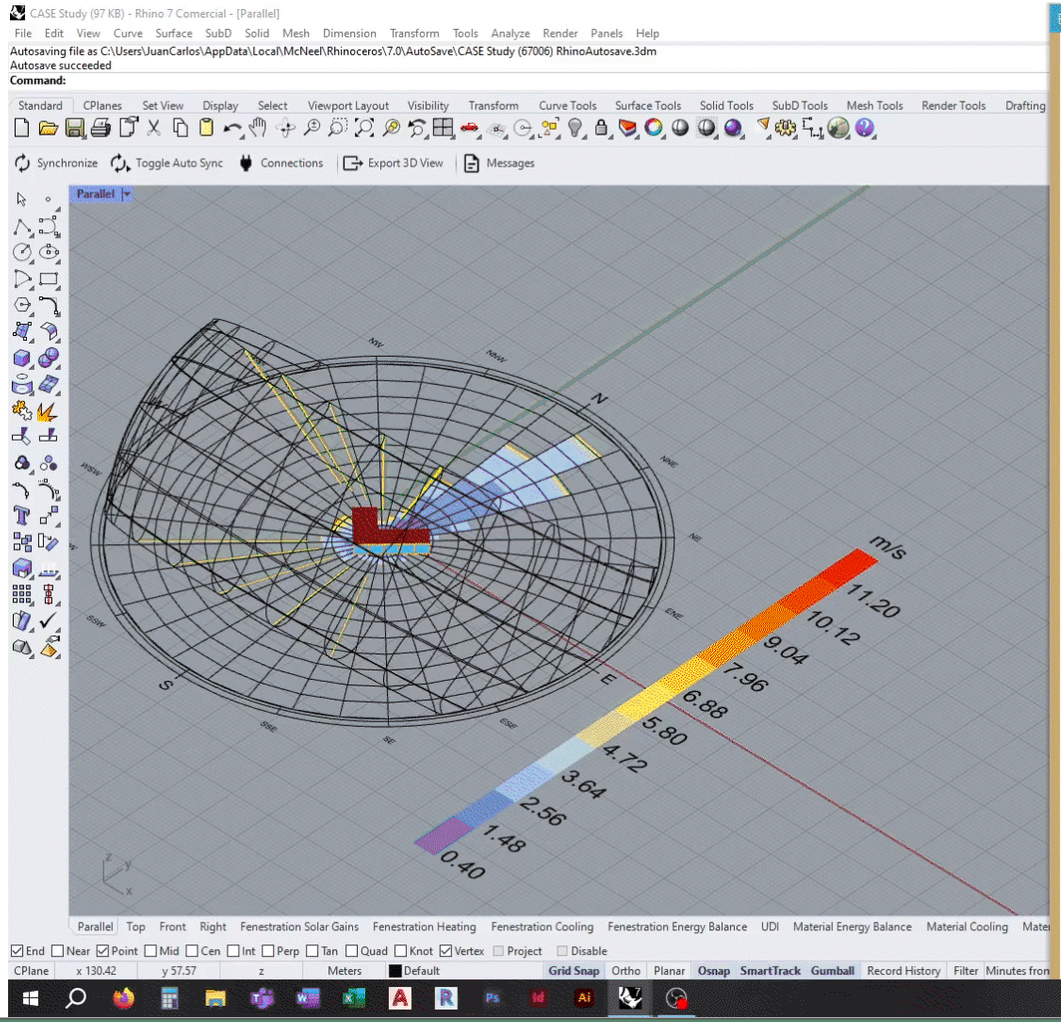


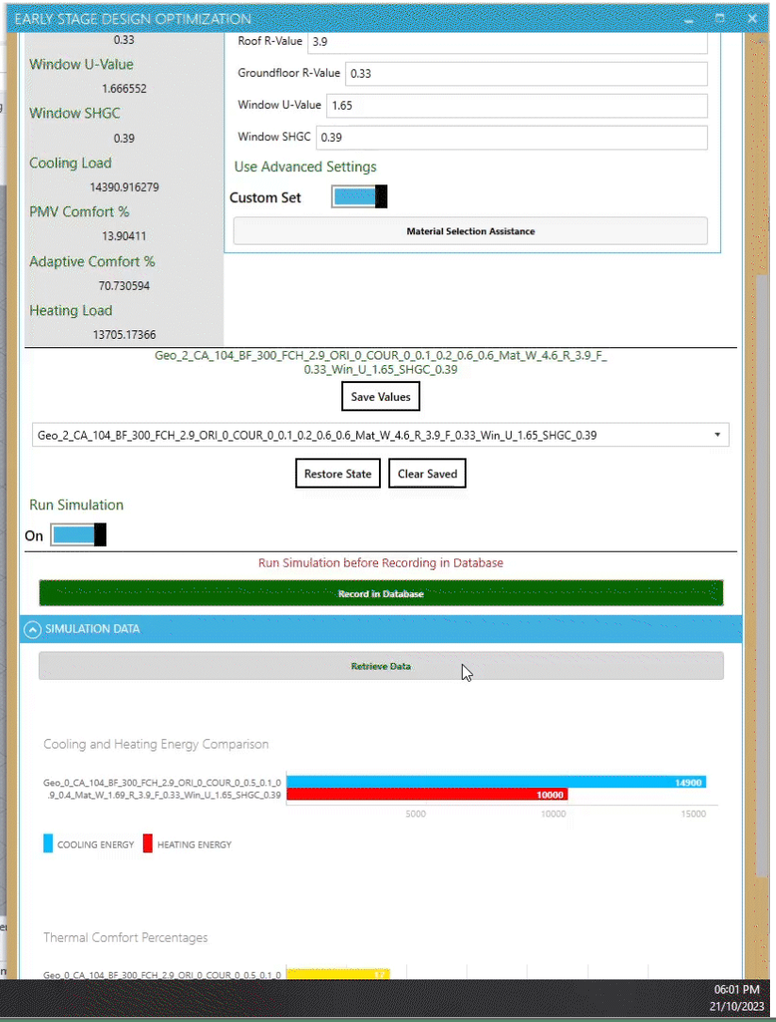


Material Result Charts





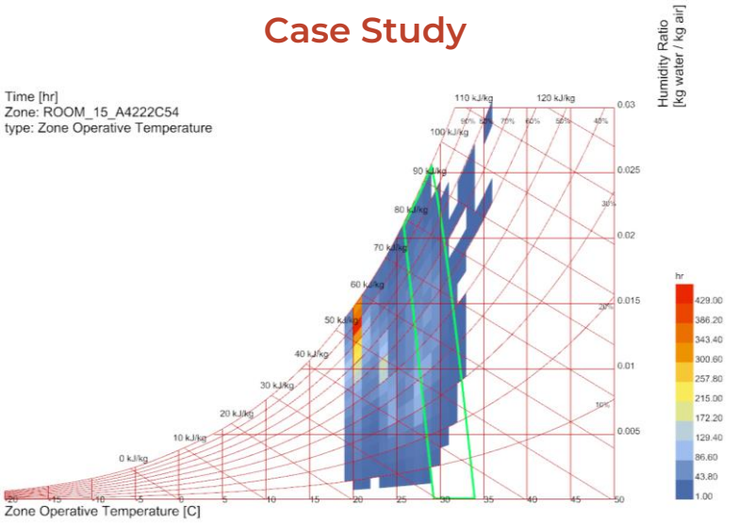




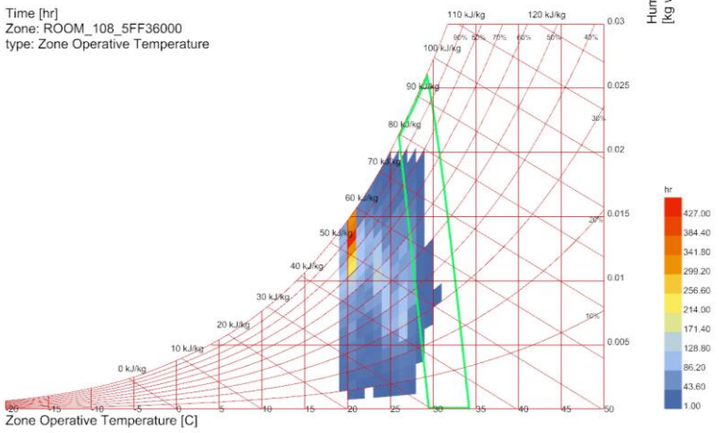
Material Result Graphs

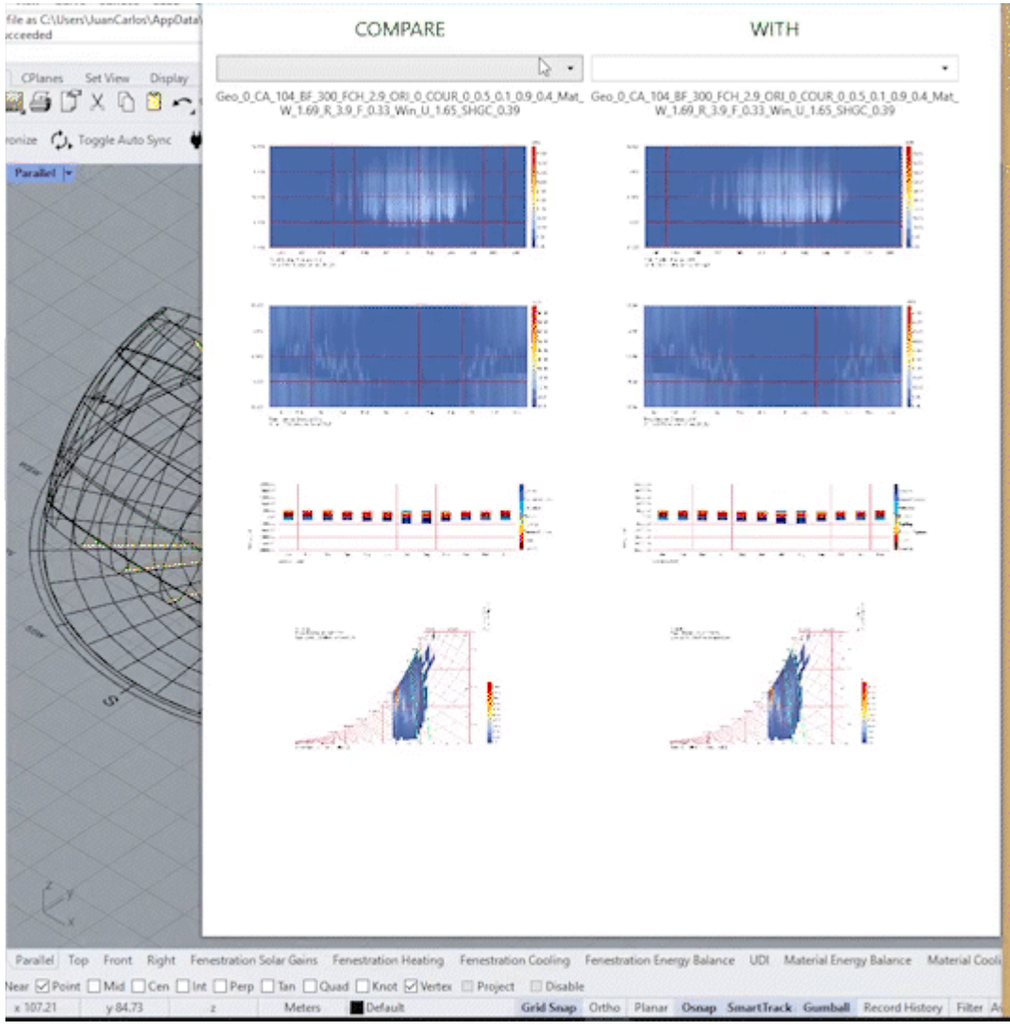
Material Result Graphs

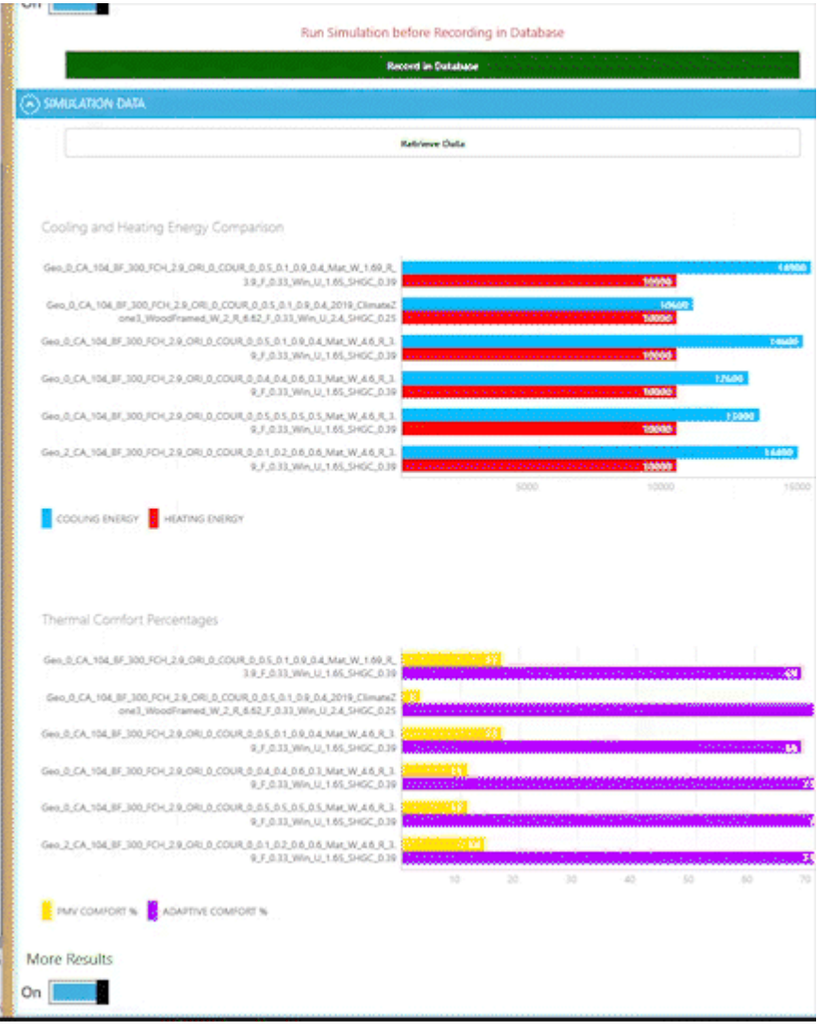
Case Study



Highest Adaptive Comfort
Lowest PMV

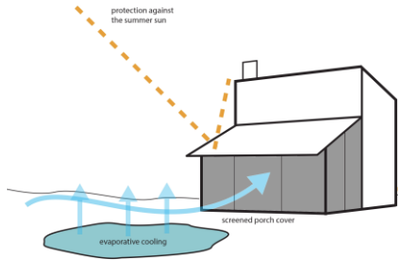




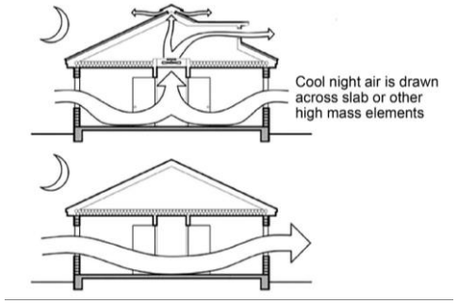


Passive Strategy Selection

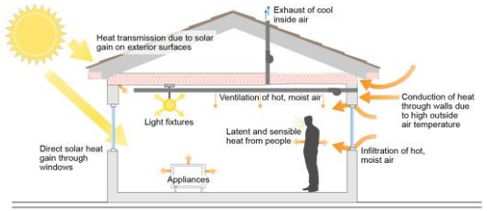
Evaporative Cooling



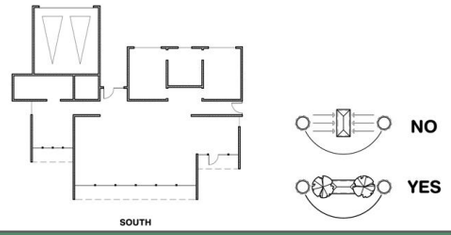
Mass + Night Ventilation

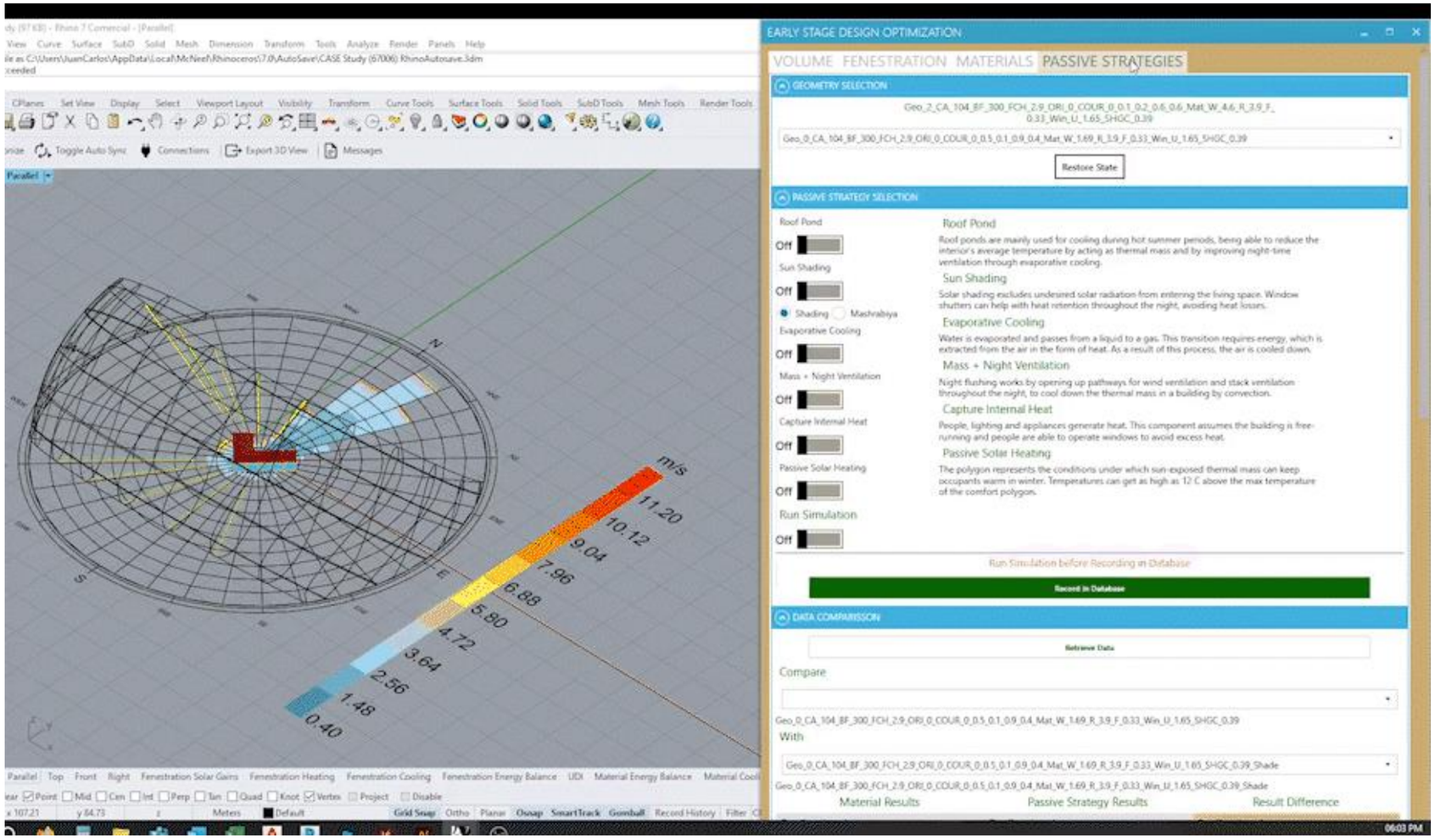


Capture Internal Heat



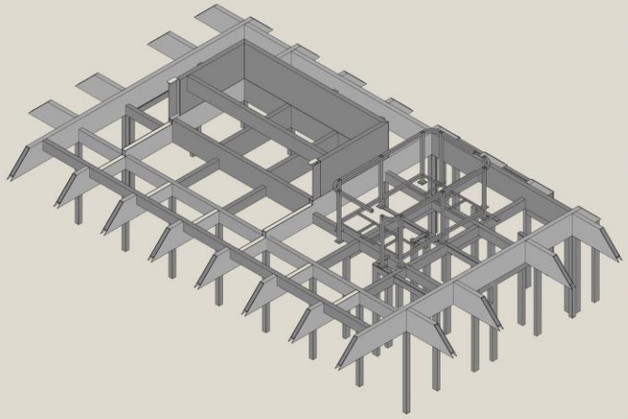
Passive Solar Heating





Case Study

Construction Type



Steel Framed

Wall R-Value
1.69 m² K/W

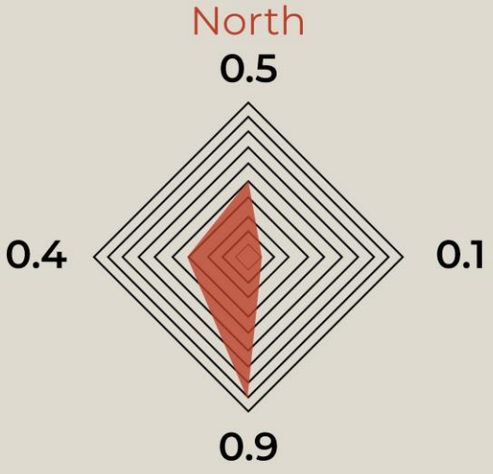
Roof R-Value
3.90 m² K/W

Floor R-Value
0.33 m² K/W

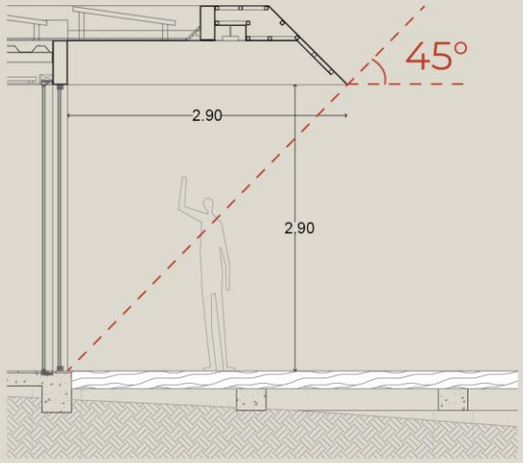
Window U-Value
1.65 W/m²·K

SHGC
0.39

Window to Wall Ratio

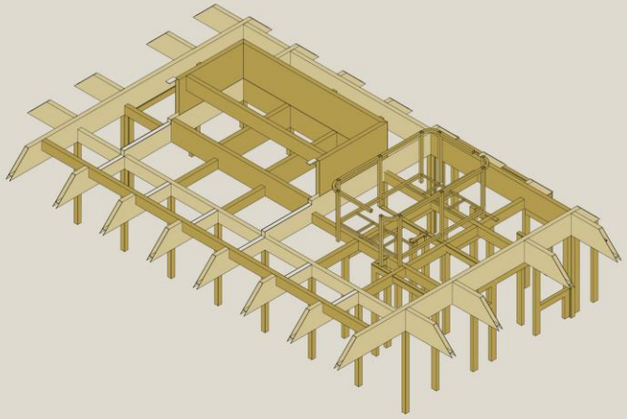


Passive Strategies



Proposal

Construction Type



Wood Framed

Wall R-Value
2.00 m² K/W

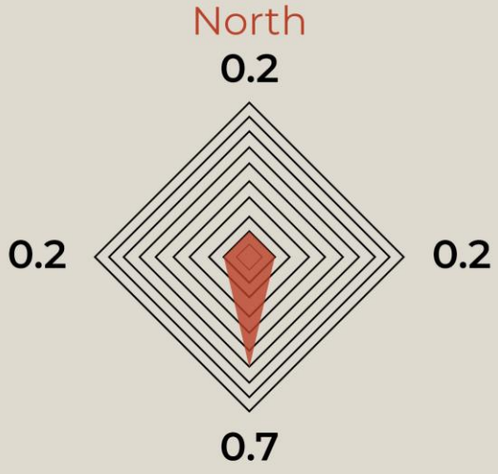
Roof R-Value
6.62 m² K/W

Floor R-Value
0.33 m² K/W

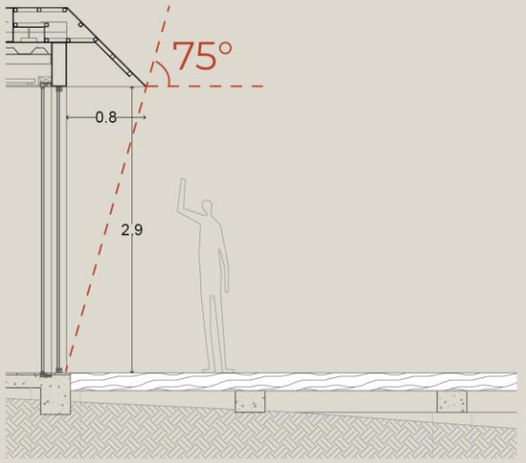
Window U-Value
2.40 W/m²·K

SHGC
0.25

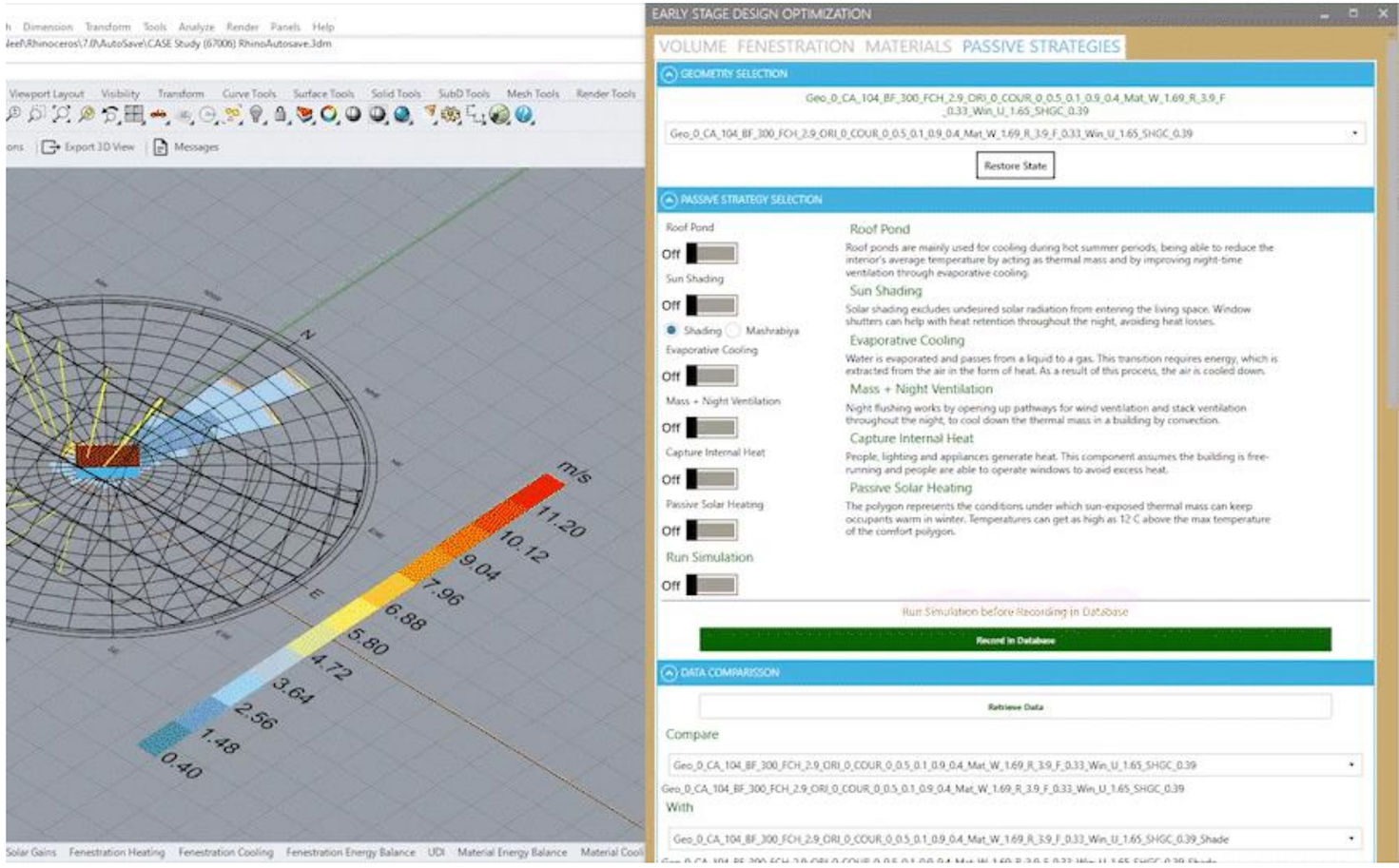
Window to Wall Ratio



Passive Strategies

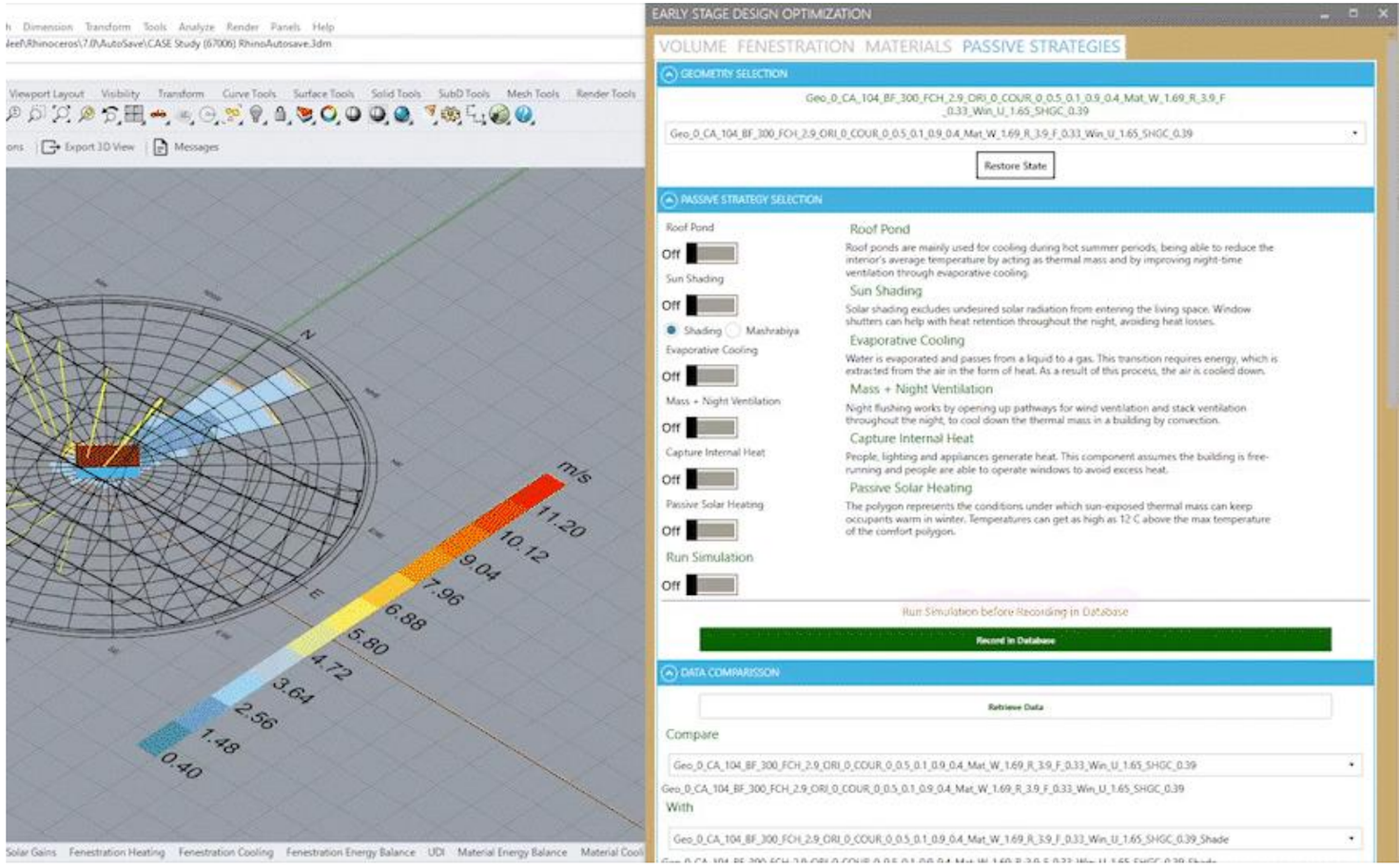


Result Comparison



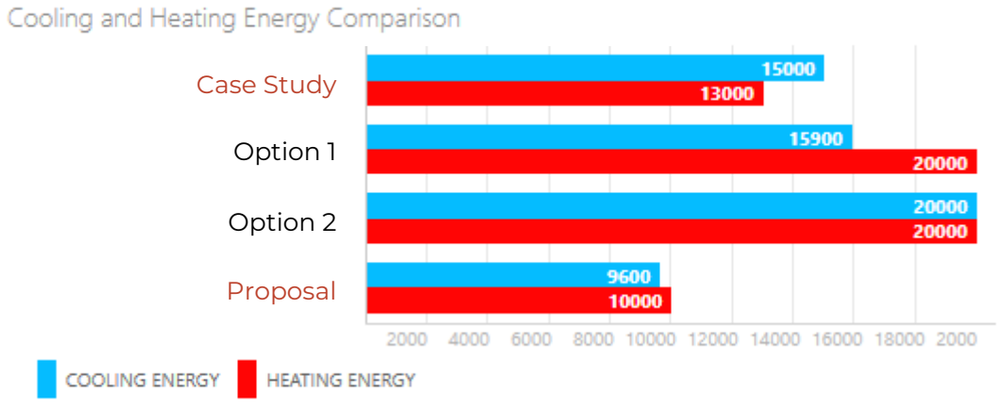
Result Comparison

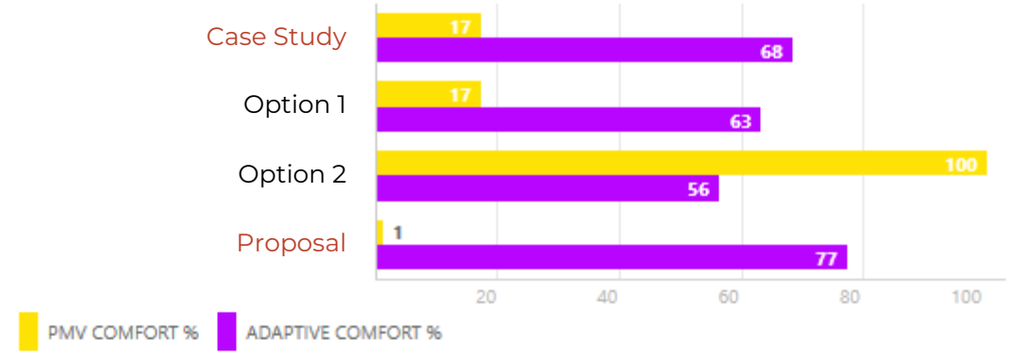
Case Study	Proposal	Differences
Cooling Load	Cooling Load	Cooling Load
15000	10000	-5000 (-40%)
PMV Comfort %	PMV Comfort %	PMV Comfort %
17	1	-16%
Adaptive Comfort %	Adaptive Comfort %	Adaptive Comfort %
68	77	9%
Heating Load	Heating Load	Heating Load
13000	14000	1000 (7%)

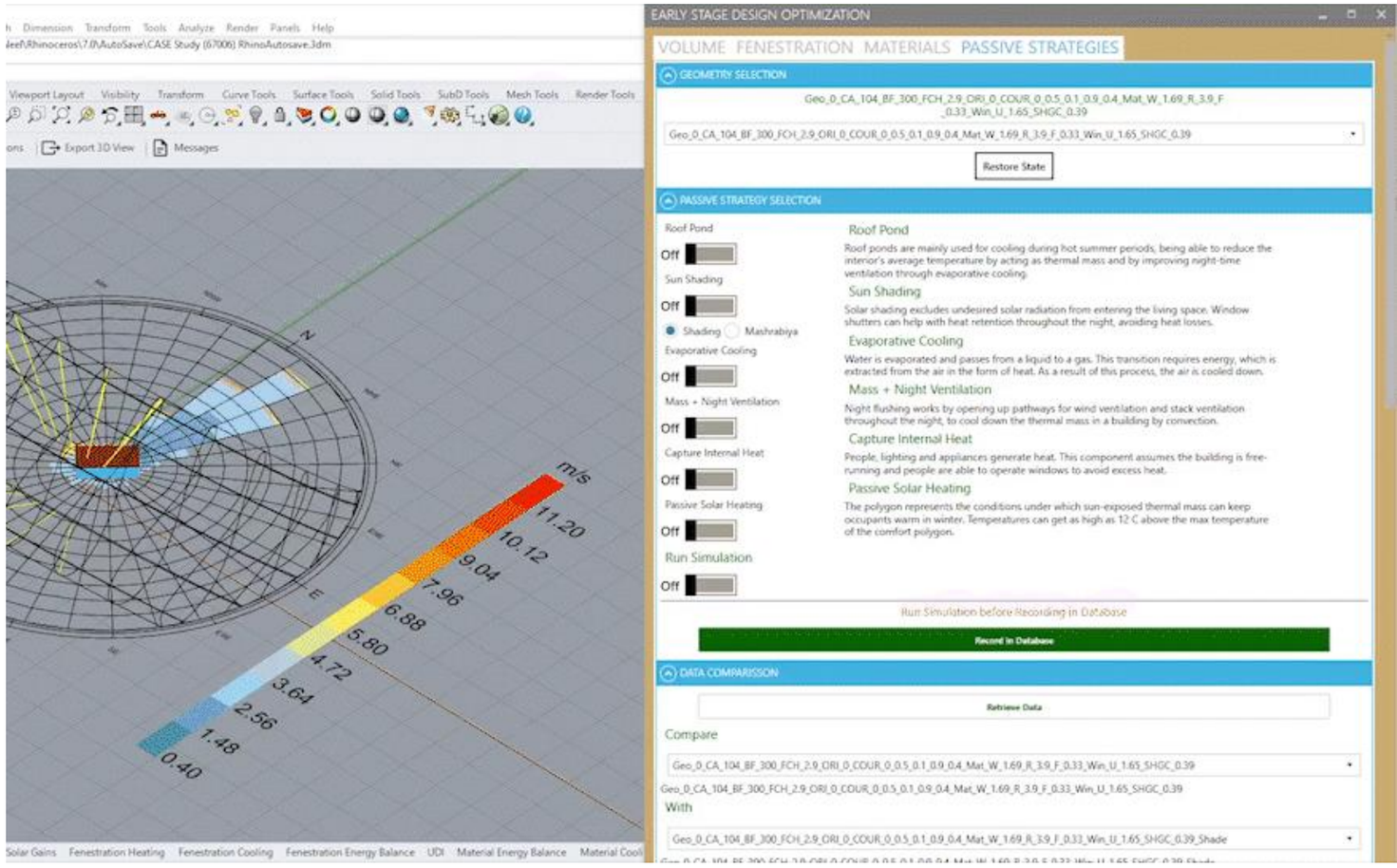


Result Comparison

Case Study	Proposal	Differences
Cooling Load	Cooling Load	Cooling Load
15000	10000	-5000 (-40%)
PMV Comfort %	PMV Comfort %	PMV Comfort %
17	1	-16%
Adaptive Comfort %	Adaptive Comfort %	Adaptive Comfort %
68	77	9%
Heating Load	Heating Load	Heating Load
13000	14000	1000 (7%)

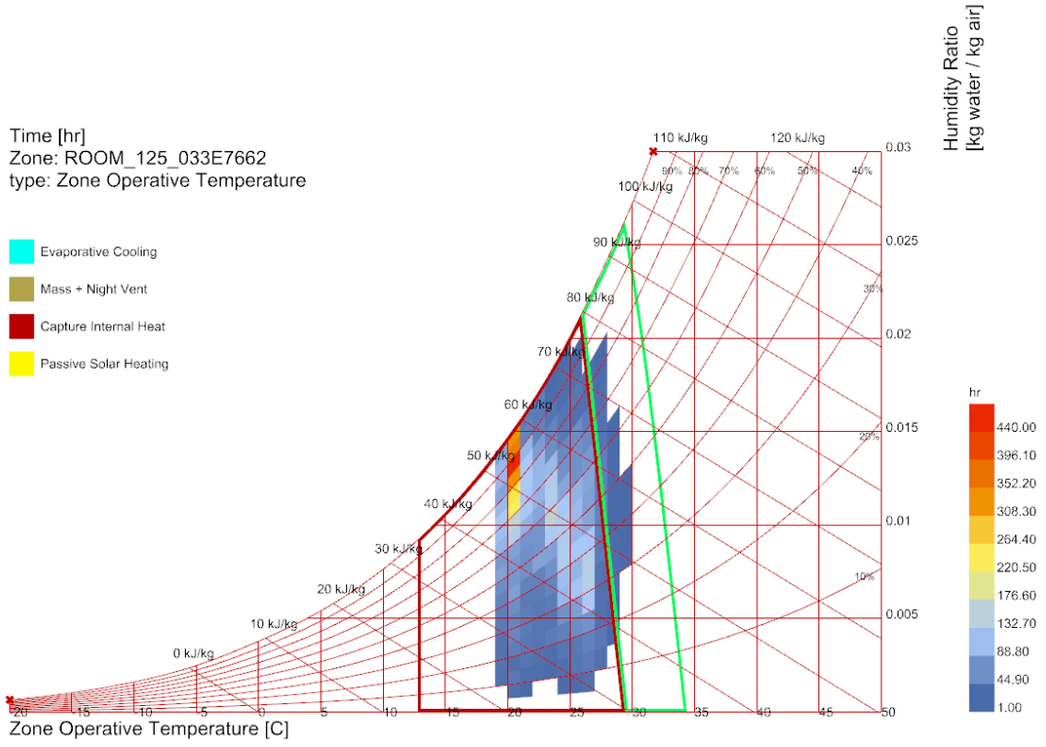


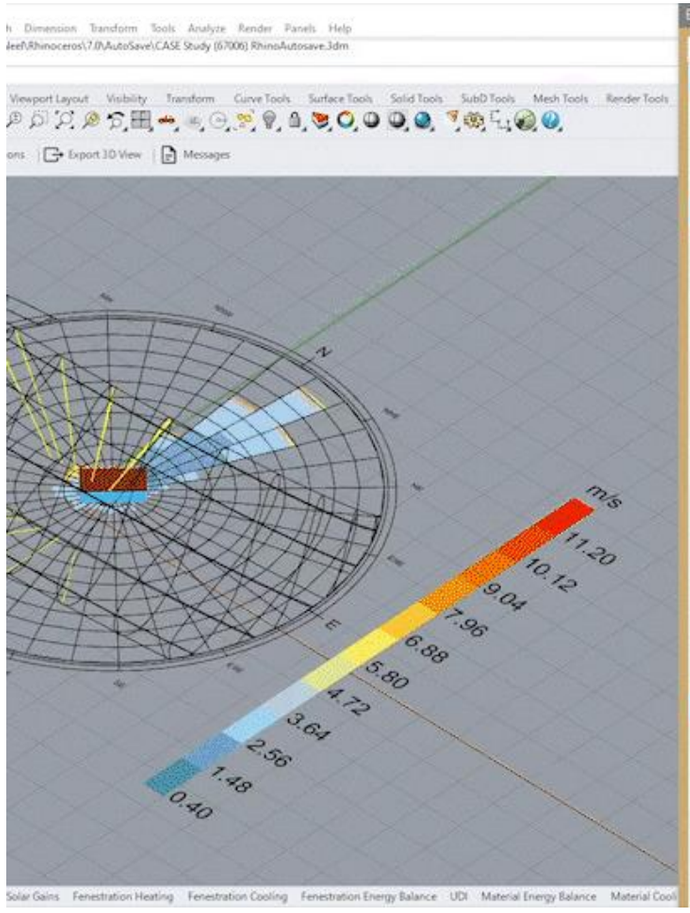


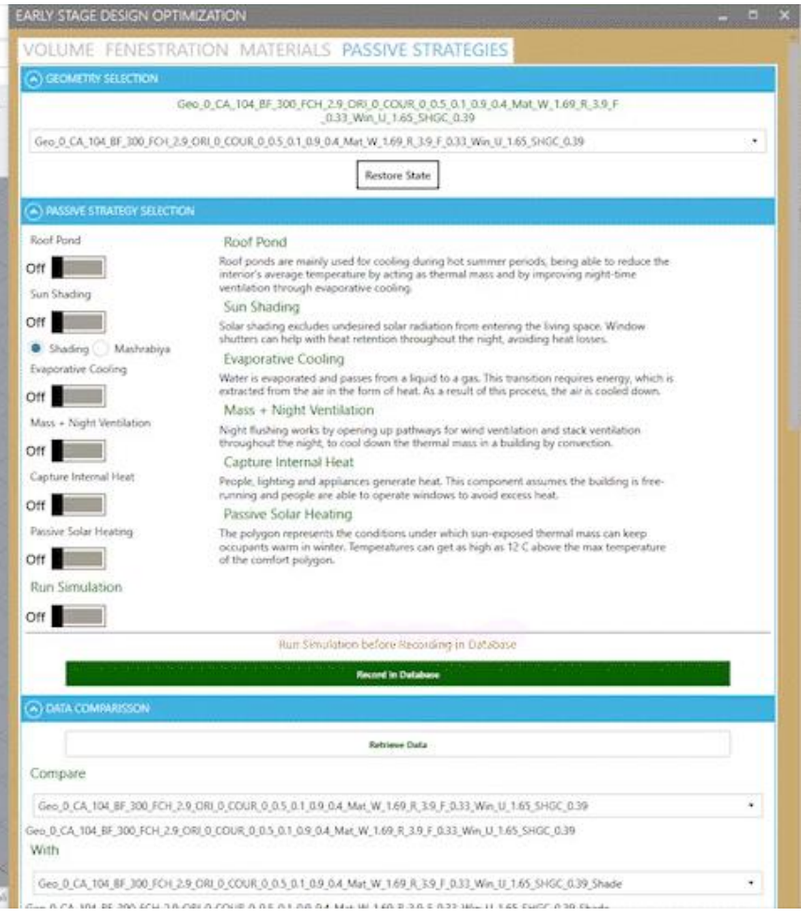


Result Comparison

Case Study	Proposal	Differences
Cooling Load	Cooling Load	Cooling Load
15000	10000	-5000 (-40%)
PMV Comfort %	PMV Comfort %	PMV Comfort %
17	1	-16%
Adaptive Comfort %	Adaptive Comfort %	Adaptive Comfort %
68	77	9%
Heating Load	Heating Load	Heating Load
13000	14000	1000 (7%)

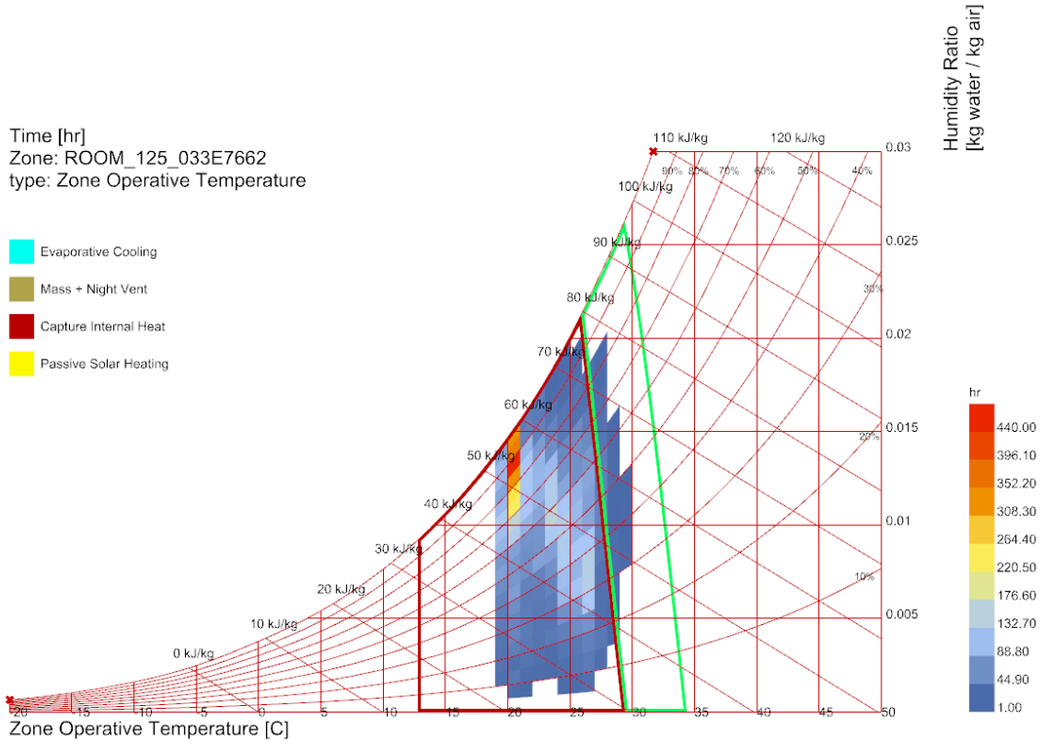


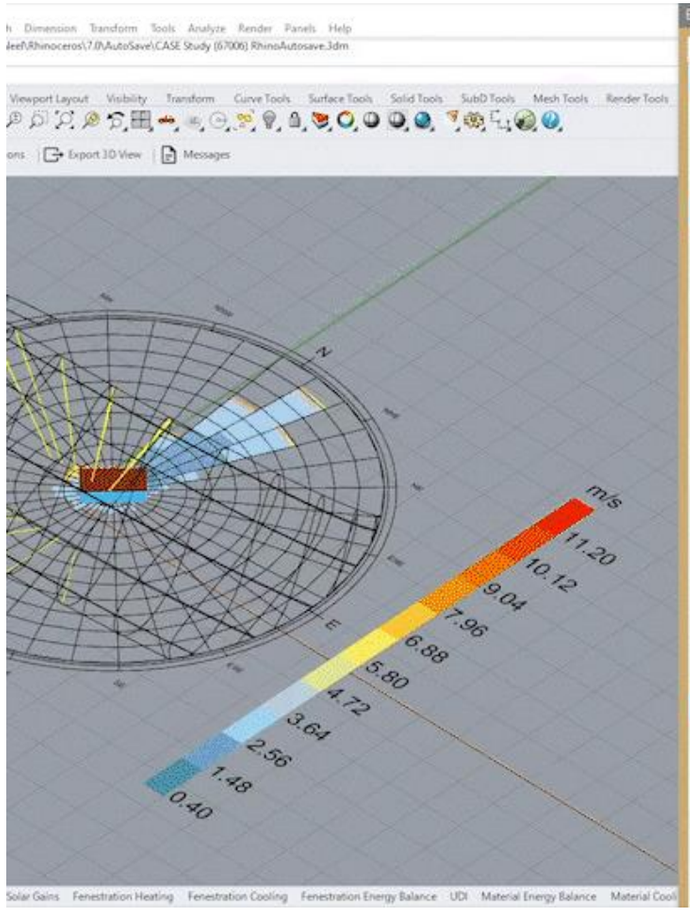


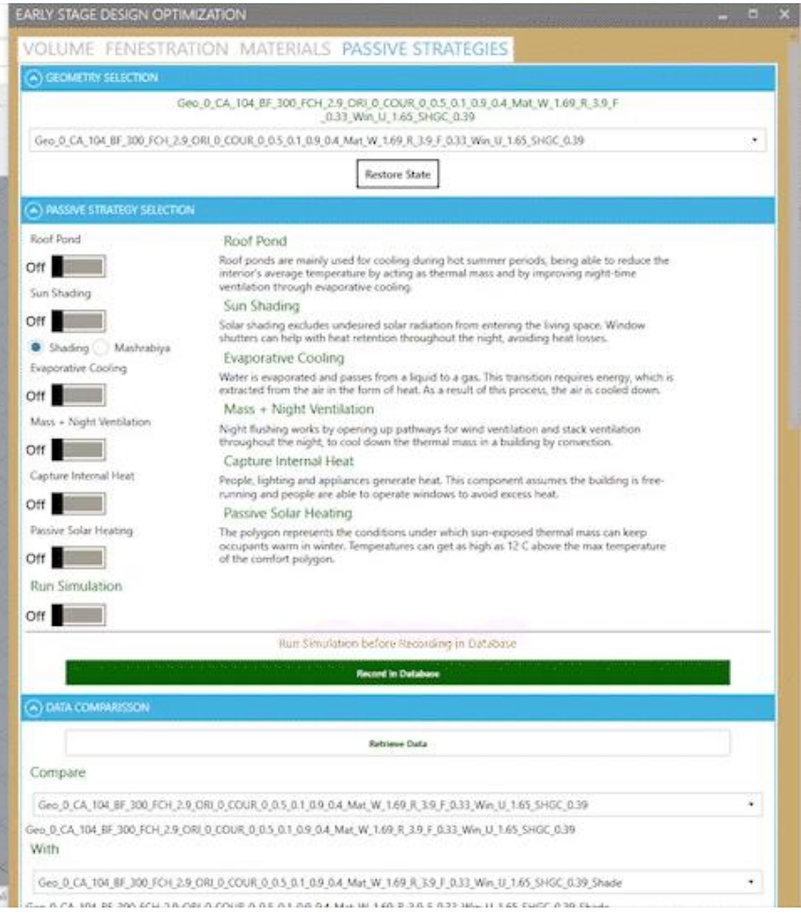


Result Comparison

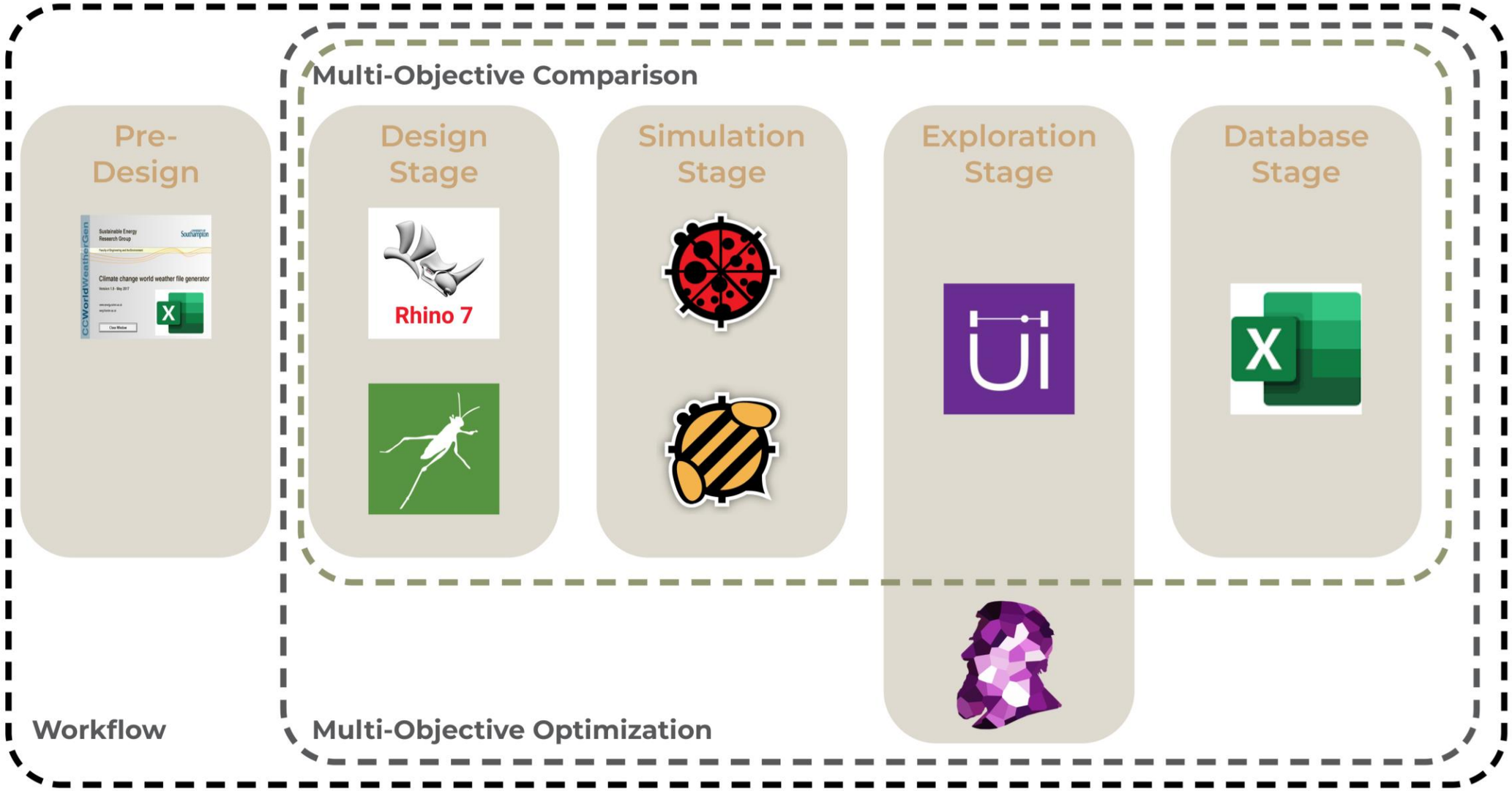
Case Study	Proposal	Differences
Cooling Load	Cooling Load	Cooling Load
15000	10000	-5000 (-40%)
PMV Comfort %	PMV Comfort %	PMV Comfort %
17	100	83%
Adaptive Comfort %	Adaptive Comfort %	Adaptive Comfort %
68	77	9%
Heating Load	Heating Load	Heating Load
13000	14000	1000 (7%)



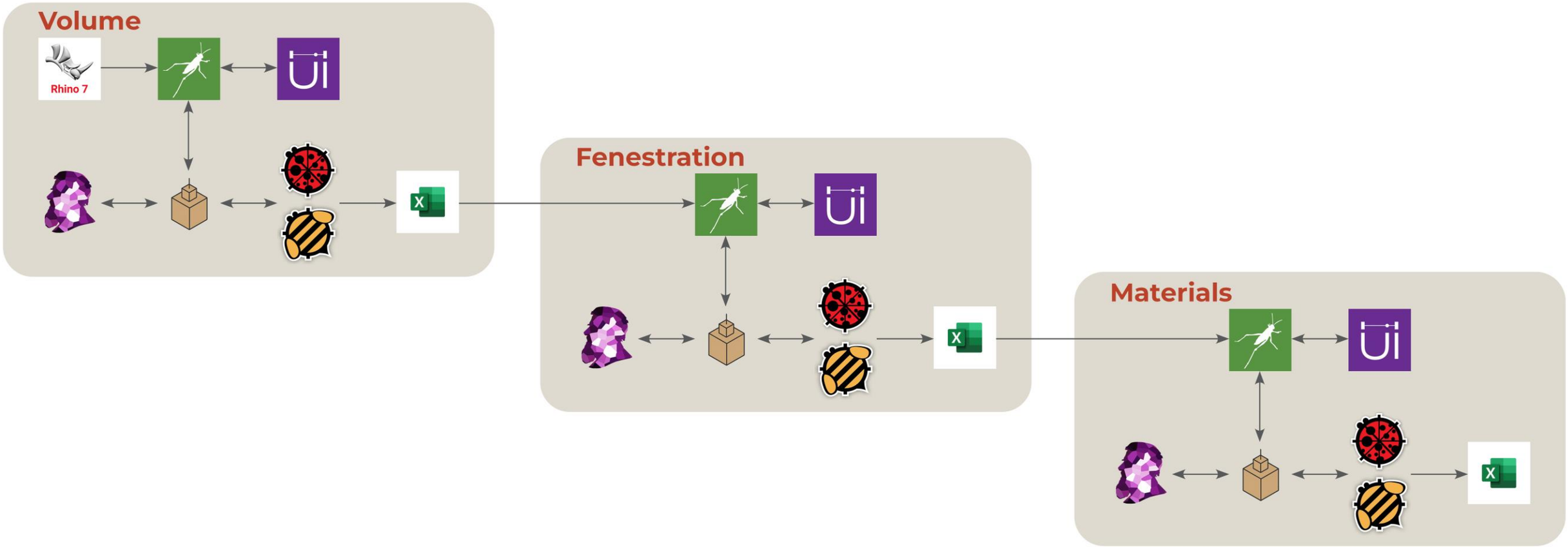




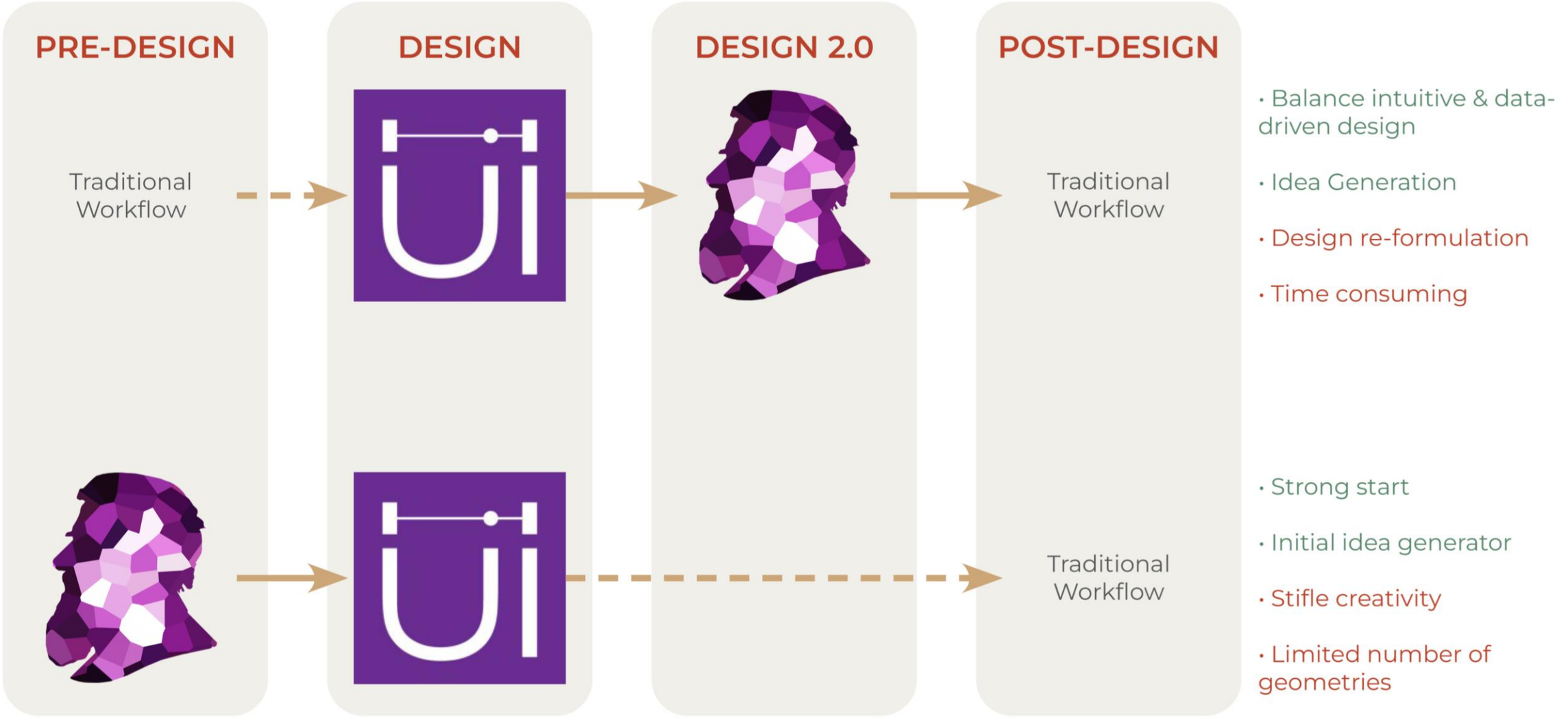
Existing Components → Innovative Process



Existing Components → Innovative Process

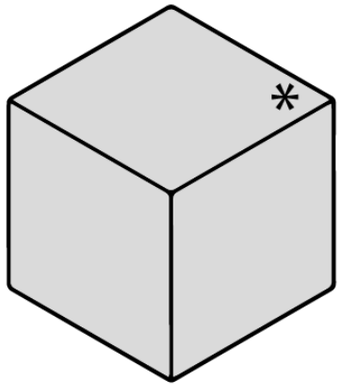


Optimization Workflow

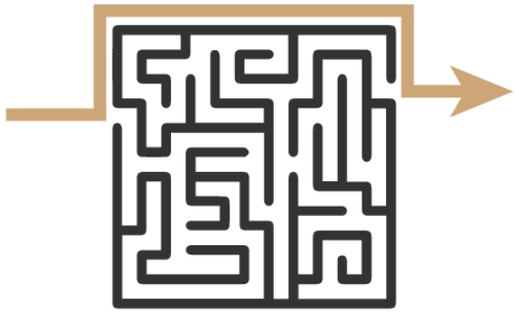


Limitations

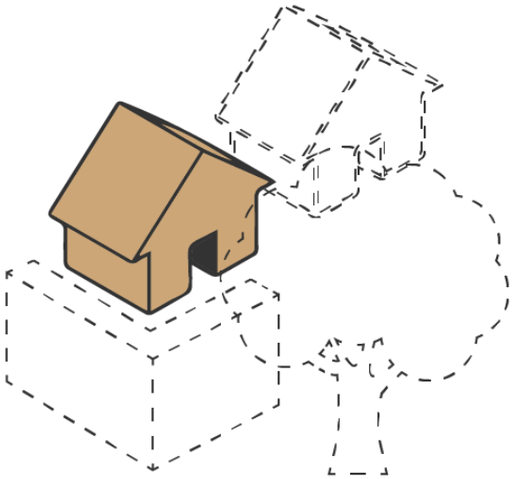
Limited Fitness Objectives



Material Simplification



Simple Passive Strategies



Omitting Context

Future Potential Integration